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ASTROS
Programmer's Manual
for Version 20

UNIVERSAL ANALYTICS, INC.

Publication AD-001

First Edition, March 1997
Second Edition, December 1997

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TABLE OF CONTENTS

ALPHABETICAL INDEX OF SOFTWARE MODULES

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Chapter 1.
INTRODUCTION

There are five manuals documenting ASTROS, the Automated Structural Optimization System:

- The User's Reference Manual
- The Theoretical Manual
- The Programmer's Manual
- The ASTROS eBASE Schemata Description
- The Installation and System Support Manual

This Programmer's Manual gives the detailed description of ASTROS software. It describes the system in terms of its software components, documents the procedure for installing ASTROS on different host machines and provides detailed documentation of the application and utility modules that comprise the procedure. In addition, the data structures of the database entities are presented in detail. This manual is intended to provide the system administrator with a guide to the existing software and the researcher with sufficient information to add application modules or otherwise manipulate the data generated by the ASTROS system. Using standard ASTROS features does not require a familiarity with the information contained in this manual except, perhaps, for the entity documentation, which is useful when additional database entities are to be viewed.

This document, while useful to the advanced engineering user, is directed toward the system administrator or code developer. This is the individual referred to by the term *user* unless otherwise indicated. The Programmer's Manual is structured in this way because all the information needed by the engineering user is contained as a subset of that needed by the system administrator. As a consequence, however, the manual is not as simple for the analyst as might be desired. It is anticipated that the advanced application user will need to sift through the module documentation and entity documentation to extract the information needed to modify the ASTROS execution path or to insert additional modules for performing

alternative computations, printing additional results, writing data in alternative formats or other advanced features that may be performed.

As an introduction to the ASTROS system, Chapter 2 contains a description of the software structure of ASTROS, both to provide a resource for the system administrator and to be a road map for the application user in identifying specific modules relevant to the task of interest. Chapter 2 attempts to introduce the user to the totality of ASTROS source code and their interrelationships so that subsequent reading will be more readily interpretable: in essence, Chapter 2 provides a nomenclature section enabling the reader to identify (with the inevitable exceptions) the major unit (module) or functional library to which a particular program belongs. This shapter provides a framework for subsequent shapters in the Programmer's Manual.

Chapter 3 is devoted to the installation of the ASTROS system on various host computers. The steps involved in installing the system are given, followed by detailed documentation of all the machine and installation dependent code. Sufficient detail is given to allow someone familiar with the target host system to write a set of machine-dependent code for that machine or site. This documentation is followed by the description of the System Generation Process (SYSGEN) and its inputs. These inputs, along with the SYSGEN program, define the system database which, in turn, defines system data to the ASTROS executive. It is these inputs which the researcher may wish to modify to define a new module, define a new set of inputs or make other advanced modifications of the system. A brief presentation of the order of the operations that follow preparation of the machine dependent library is given to complete an installation of the system.

Chapters 4 through 8 contain the formal documentation of the ASTROS modules. Chapter 4 documents those portions of the code that are considered to be at the system level. This means that the user need not be aware of their existence but they are important in the overall system architecture. Further, they perform many tasks of which the user may want to be aware if any system modifications are to be made. Chapters 6 through 8 document the utilities that are associated with the ASTROS application modules, matrix operations and the database. These shapters are the most important from the view of the advanced researcher/user in that these are the software tools from which additional capabilities can be put together with reasonable rapidity. In each case, the executive (MAPOL) and application interface is fully defined and the algorithm of the utility is outlined.

Chapter 9 contains the documentation of the data structures on the CADDB database that are used by the ASTROS system. The contents and structure of each database entity are given along with an indication of the module that generates the data and which modules use the data. For matrix entities, the relevant shapter of the Theoretical Manual is also referenced since the entity contents are more clearly understood in the content of the equations that are highlighted there.

Chapter 10 contains a presentation of notes for the ASTROS application programmer. It is felt that the ASTROS system has been designed with sufficient flexibility that the additional features or minor enhancements are desired. Chapter 10, therefore, attempts to address some issues involved in writing an ASTROS module. Rules and guidelines are given which will help the programmer avoid complications arising from the interface of the new module and application utilities are also given. Particular emphasis is placed on the memory management utilities and the database utilities since these require a more sophisticated interface than the simple application utilities.

< module type> Module: <name>

Entry Point: **<FORTRAN calling list for module>**

PURPOSE:

<one or two sentence description>

MAPOL Calling Sequence:

<Executive system access method>

Application Calling Sequence:

<FORTRAN call followed by input description>

Method:

<Description of the module's action>

Design Requirements:

<Indicates what the module expects to have completed in the context of the standard sequence>

Error Conditions:

<Brief description of major error conditions that are trapped by the module>

Figure 1-1. Module Documentation Format

A standard documentation format has been adopted for the modules that are described in Chapter 3 through 8. Figure 1 illustrates this format and provides a key for identifying the data that are given for each module. While this format is brief, enough information is given for the user to identify the principal action of the module and the role it plays in the standard ASTROS execution. The utility modules are documented to the extent necessary for an application programmer to use the utility in any new code to be inserted in the system.

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Chapter 2.

ASTROS SOFTWARE DESCRIPTION

ASTROS is a software system made up of two separate executable programs comprising over 1500 independently addressable code segments containing approximately 300,000 lines of FORTRAN. While this Programmer's manual is devoted primarily to the detailed documentation to the separate modules and subroutines of the ASTROS system, an overview of that system is necessary to understand how the individual pieces fit together. This section introduces the ASTROS system and describes the software structure of ASTROS in terms of its major code blocks. Both the system generation program, SYSGEN, and the main program, ASTROS, are described and their interrelationships are illustrated. This section provides a resource for the system administrator and a road map for the application programmer to identify the section documenting modules relevant to the task of interest. This section also provides a framework to direct the subsequent sections in the Programmer's Manual.

In the context of the Programmer's Manual, the structure of the ASTROS system refers to the interrelationships among the major code blocks. Typically, an analysis of the software associated with an individual code segment will indicate the nature of the task being performed and provide information on the mechanisms by which intramodular communication takes place. The larger picture, in which the intermodular requirements of a particular code segment becomes clear, is more difficult to grasp. It is that picture which this section attempts to provide.

The magnitude of the ASTROS system requires that the code segments be grouped into abstract collections of code such as utility modules and the database in order to be understood. While necessary, these abstract collections can also obscure the picture of the system since a great deal of the detail is necessarily lost. Nonetheless, since a discussion of each individual code segment is not possible, a set of code blocks has been defined for the purpose of writing the Programmer's Manual. Naturally, there are many ways in which the code segments could be grouped to aid the user in understanding the code segments and their interactions. For the Programmer's Manual, the code is grouped in a hierarchical manner by function: that is, code segments that perform similar tasks at a similar level (relative to the executive

system) are grouped together. Some segments of the code, of course, do not fit clearly into this sort of functional abstraction. Their role is such that they could lie in more than one group or really don't belong to any group that has been defined. These exceptions complicate the issue but do not destroy the utility of the functional breakdown of the code. When a module could be documented with more than one code group, this fact is noted in the appropriate manual sections.

2.1. THE ASTROS SYSTEM

The highest level of abstraction is illustrated in Figure 2, which presents the two executable images that comprise the ASTROS system, their inputs, outputs, and interrelationships. Referring to the figure, each of the illustrated components is briefly described in the following sections.

2.1.1. SYSGEN Components

The SYSGEN program is a stand-alone executable program that is used to define ASTROS system parameters. The use of an executable program that is directed by a set of inputs was adopted to provide a simple mechanism to expand the capabilities of the ASTROS procedure. The inputs, outputs, and use of this very important feature of the ASTROS architecture are fully documented in Section 3.2. The SYSGEN program consists of five items indicated by the numbered boxes in Figure 2. Each of these is briefly discussed below:

1. The SYSGEN INPUTS consist of a set of files that define certain system level data that is written by SYSGEN to the system database, SYSDB.

2. SYSGEN is an executable program that reads the SYSGEN INPUTS and creates a set of database entities on SYSDB that provide data to the ASTROS executive and high level engineering modules.

3. The SYSTEM DATABASE, SYSDB, consists of an index file, SYSDBIX, and (typically) a single data file, SYSDB01. The SYSGEN program creates and loads database entities onto the system database which defines:

   a. The set of modules which can be addressed through the MAPOL language

   b. The set of relational schemata for all relations declared in the MAPOL sequence

   c. The set of input Bulk Data entries

   d. The error message texts for most run time error messages

   e. The standard MAPOL sequence to direct the execution of the ASTROS

4. **XQDRIV** is a FORTRAN subroutine written by SYSGEN that must be compiled and linked into the ASTROS executable during the generation of the ASTROS executable image. It is the **XQDRIV** subroutine that forms the FORTRAN link between the MAPOL language and the application/utility modules.

5. The SYSGEN OUTPUT FILE is a listing generated by SYSGEN that echoes all the data stored on the system database. As such, it provides a resource for the application user and the system administrator documenting the current ASTROS system. Since this file represents what is, by

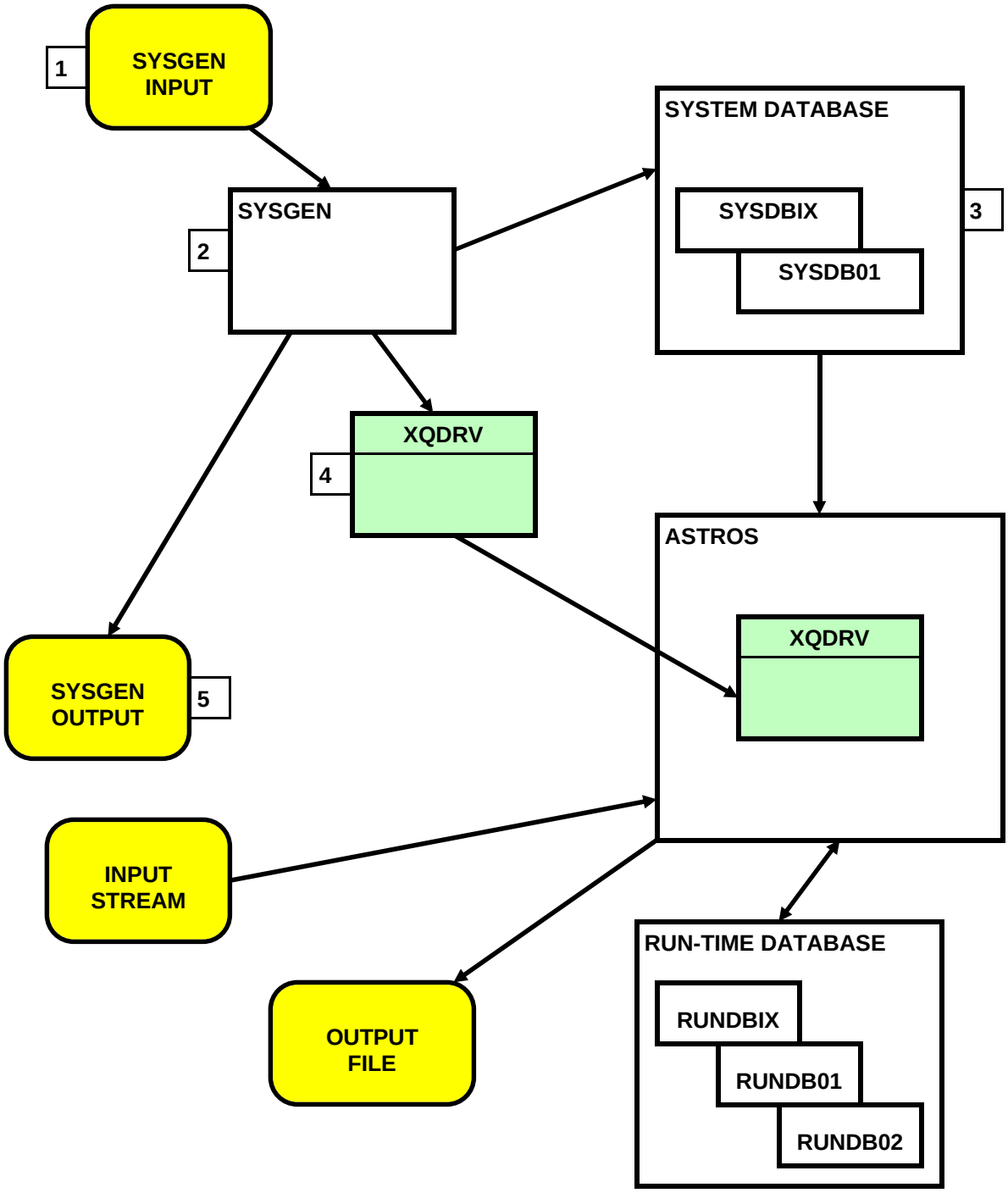

Figure 2-1. ASTROS System Overview

definition, the ASTROS program, any problems that arise or questions in the documentation should be checked against the data in this file. If any discrepancies exist, either the documentation is in error or the SYSGEN inputs are in error. In any case, the ASTROS program is directed by the SYSGEN data.

2.1.2. ASTROS Components

As illustrated in Figure 2, the **XQDRIV** subroutine and SYSDB are also part of the ASTROS program. The **XQDRIV** subroutine is needed to generate the executable image and the SYSDB files MUST be available on a read-only basis by the ASTROS program whenever an ASTROS job is run. The ASTROS program is comprised of the following:

1. **XQDRIV** is a FORTRAN subroutine written by SYSGEN that must be compiled and linked into the ASTROS executable during the generation of the ASTROS executable image. It is the **XQDRIV** subroutine that forms the FORTRAN link between the MAPOL language and the application/utility modules.

2. The SYSTEM DATABASE, SYSDB, contains database entities which define sets of data establishing the extent of some of the capabilities of the ASTROS program. ASTROS requires these files on a read-only basis for every execution of the system.

3. The ASTROS program is the main executable image associated with the ASTROS procedure. It is comprised of all the executive, database, utility, and engineering application modules that are needed to perform the automated multidisciplinary optimization tasks.

4. The INPUT STREAM is the user's input file containing the directives to execute the ASTROS program. The User's Manual is devoted to its documentation.

5. The OUTPUT FILE contains the data written to the user's output file containing those results of the ASTROS execution that were requested to be printed or that are printed by default.

6. The RUN-TIME DATABASE consists of one index file and one or more data files (called, respectively, RUNDBIX, and RUNDB01, 02, etc., in Figure 2) that contain the database generated at run time by ASTROS. Assuming an execution based on the standard MAPOL sequence, the run-time database will contain some or all of the entities that are documented in Section 9 of this manual. The application user can direct whether this database is to be saved or deleted on termination of the execution. The Interactive CADDB Environment (ICE) (AFWAL-TR-88-3060, August 1988) can be used to view these data, prepare reports or port the data into other applications.

2.2. MAJOR FUNCTIONAL CODE BLOCKS

Figure 3 presents a grouping of source code blocks within the ASTROS system. This grouping is functional in that code related to the performance of one task or a series of tasks at the same level relative to the executive system are grouped together. According to this breakdown, there are seven major blocks of code within ASTROS executable programs. The SYSGEN program has no executive system and is directed by a simple FORTRAN driver called SYSGEN. The ASTROS system, on the other hand, has a

highly developed executive system that comprises this major ASTROS code block. Also shown are the five groups of routines which are used by the SYSGEN and ASTROS programs.

The naming conventions used within each code block are worthy of some discussion since they are useful in identifying an unknown routine in a piece of ASTROS software. Whenever possible, a set of consistent, meaningful mnemonics was adopted to identify groups of code that belong together, either functionally or logically. Where such conventions have been adopted, they are indicated in the discussion of the code block. One complication to such conventions is the use of existing source code as a resource for the ASTROS program. When major code units were used from existing software, the convention was not typically enforced. As a result, there are exceptions to the nomenclatures adopted in some of the source code blocks presented in this section.

Each of the source code blocks is now briefly discussed by reference to the name assigned to it in Figure 3 and its related Programmer's Manual section is indicated.

1. SYSGEN is a very small code block containing the SYSGEN driver (SYSGEN), a set of four output routines (**xxxOUT**) to print the SYSGEN output file and five routine (**TIMxxx**) that compute the timing constants for the large matrix utilities. The SYSGEN program has a single execution path which is documented in Section 3.2.

2. The ASTROS executive is the code block containing the ASTROS main driver program, ASTROS, and the ASTROS executive system software. The executive system is embodied in the routines beginning with the mnemonics **XQxxxx**. In addition to the pure executive system routines, the executive initialization routines for the database (**DBINIT**) and the memory manager (**MMINIT**) are also located in this code block. Finally, the general initialization routine **PREPAS** and the MAPOL compiler software are considered, for the purposes of the Programmer's Manual, to be part of the executive system. These routines are documented in Section 5.

3. The DATABASE code block contains all the software related to the application interface to the database and memory management systems for the ASTROS procedure. This software is further subdivided into five groups of code that represent the application interface to the database and memory manager. These groups are:

    a. The General Utilities that comprise the database application interface applicable to all database entity types. These routines are denoted by the mnemonics **DBxxxx** and are documented in Section 8.2.

    b. The Memory Management Utilities that comprise the application interface to the ASTROS dynamic memory manager. These routines are denoted by the mnemonics **MMxxxx** and are documented in Section 8.3.

    c. The Matrix Utilities that comprise the database application interface applicable to matrix entities. These routines are denoted by the mnemonics **MXxxxx** and are documented in Section 8.4.

    d. The Relation Utilities that comprise the database application interface applicable to relational entities. These routines are denoted by the mnemonics **RExxxx** and are documented in Section 8.5.

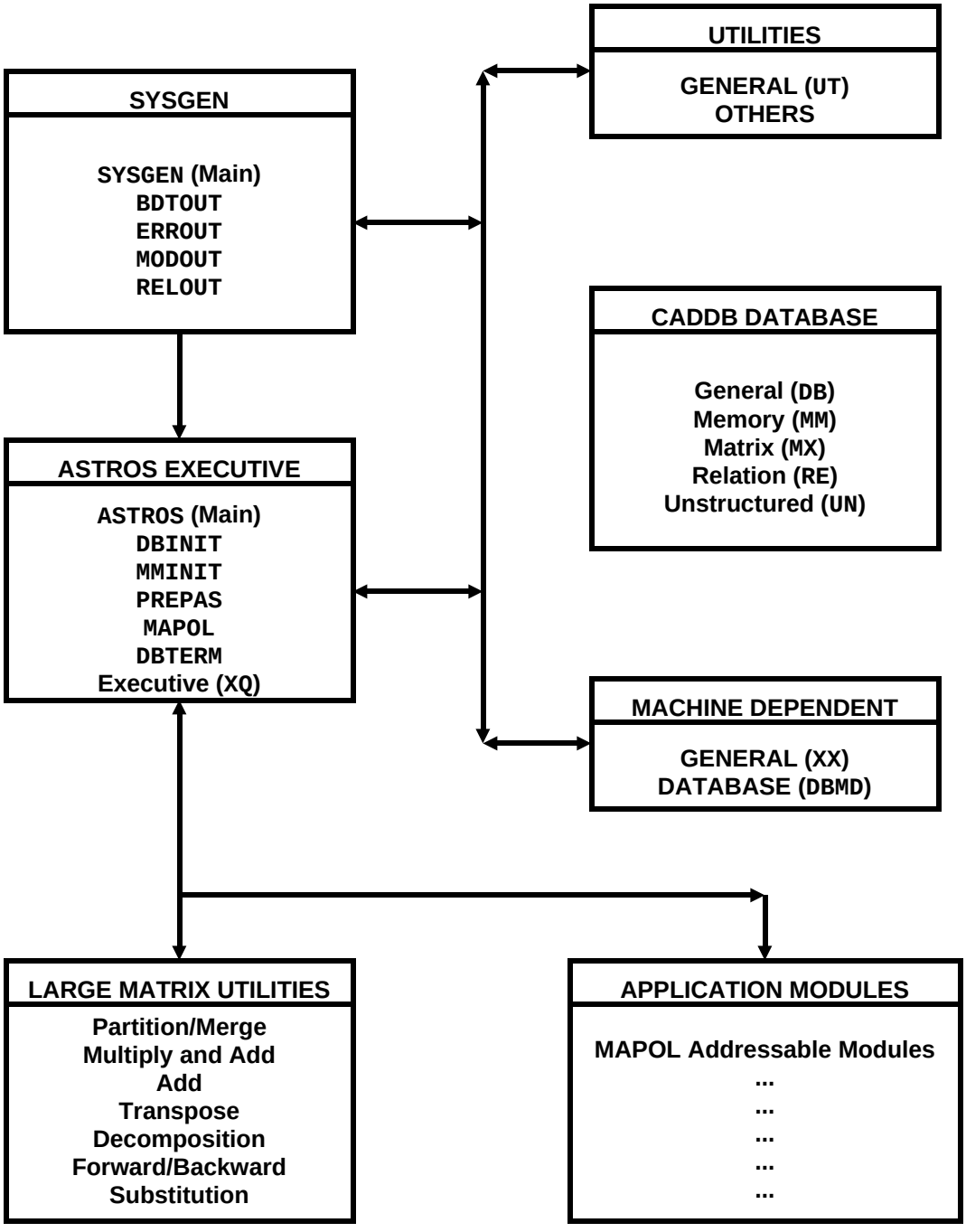

Figure 2-2. ASTROS Code Blocks

e. The Unstructured Utilities that comprise the database application interface applicable to unstructured entities. These routines are denoted by the mnemonics **UNxxxx** and are documented in Section 8.6.

4. The MACHINE DEPENDENT code block contains all the software in the ASTROS system that has been designated machine dependent. This software supplies the interface between the host computer and the ASTROS system. It is further subdivided into two groups of code:

   a. The General Utilities, comprising the machine dependent code used throughout the ASTROS system. These routines are denoted by the mnemonics **XXxxxx** and are documented in Section 3.1.1.

   b. The Database Utilities, comprising the database machine dependent code used primarily by the database software. These routines are denoted by the mnemonics **DBMDxx** and are documented in Section 3.1.2.

5. The UTILITIES code block contains all the machine independent application utilities developed for the ASTROS system. This software is a suite of functions that are useful in many places in the code. They have therefore been formalized to the extent that they may be used by any ASTROS application routine. The majority of these routines are denoted by the mnemonics **UTxxxx** with exceptions corresponding to those in-core utilities that came from COSMIC/NASTRAN. These are documented in Section 6.

6. The LARGE MATRIX UTILITIES code block contains the utilities developed for the ASTROS system to operate on large matrices stored on the ASTROS database (rather than matrices stored in memory). This software comprises a suite of matrix operations that have been formalized to the extent that they may be used by any ASTROS application routine and by the ASTROS executive system. There is no consistent naming convention for these routines since they have been derived from their COSMIC/NASTRAN counterparts. The utilities are documented in Section 7.

7. The APPLICATION MODULES code block is the largest code block within ASTROS. It contains the engineering and application modules that support the analysis and optimization features of the ASTROS system. Each of these modules has been designed to be independent of the other application modules to the maximum extent possible. Typically, consistent naming conventions have been used for routines within each module. Because of the disparate code resources that were used in the development of ASTROS, however, no globally consistent naming convention was adopted. Section 5 documents each of the modules in the application library.

2.3. CODE COMMON TO ASTROS AND SYSGEN

Since some machines require or can take advantage of an explicit knowledge of which routines are needed to create an executable image, this section attempts to indicate which portions of the source code blocks (as grouped in Figure 3) are utilized within the SYSGEN program. With the exception of the SYSGEN code block, all the illustrated code blocks are used by the ASTROS program. The source code blocks that are needed, in whole, or in part, by SYSGEN are (1) the SYSGEN code, (2) the DATABASE code, (3) parts of the MACHINE DEPENDENT code, (4) some of the UTILITIES and (5) parts of the ASTROS EXECUTIVE.

Rather than write and maintain separate code blocks to perform similar functions, SYSGEN makes use of the suite of general utilities in the UTILITIES CODE BLOCK. The machine dependent code block is also shared between ASTROS and SYSGEN.

One of the tasks of SYSGEN is to compile and store the standard executive sequence (written in the MAPOL language) onto the system database. Therefore, the SYSGEN program makes use of the ASTROS EXECUTIVE code block to supply the MAPOL compiler. In addition, the SYSGEN driver must perform the executive functions to initialize the memory manager and the database. Therefore, the **MMINIT** and **DBINIT** routines from the ASTROS EXECUTIVE code block are also used by SYSGEN.

Chapter 3.

SYSTEM INSTALLATION

A software system of the magnitude of ASTROS requires a formal installation of the system on each host computer. For ASTROS, the installation process can be broken into three distinct phases. In the first phase, the ASTROS/host interface is defined and the proper machine dependent code is written to create that interface. The second phase involves the generation of the executable image of the SYSGEN program and its execution. Finally, the ASTROS executable image is generated using the outputs from the SYSGEN program. The purpose of this section is to document all the machine dependent code in a generic manner and to indicate which parameters and routines are most likely to be site dependent and which are truly machine dependent. In the typical case, the system manager at each facility will be given the machine dependent library for the host system that is to be used. For completeness, however, sufficient detail is presented to allow someone familiar with the host system to write a new set of machine dependent code.

Following the formal documentation of the machine dependent interface is a discussion of the SYSGEN program and its inputs. The SYSGEN program is important in that it provides the advanced analyst/user with a mechanism to add features to the system. It is also important for system installation in that part of its output is required before the executable image of the ASTROS procedure can be generated. Again, in the typical case the user will be given a proper set of SYSGEN outputs but the utility of SYSGEN in increasing the capabilities of the system makes its complete documentation very useful to the majority of ASTROS users. Finally, a brief section is included to present the total ASTROS installation in a step by step manner to give an overall view of the process.

The information presented in these sections serves as a guide to the installation of ASTROS on alternative host machines, but the nature of the machine dependencies make it impossible to anticipate all contingencies that may arise. The installation of the ASTROS procedure on a new host computer can therefore be a complex task despite the relatively small number of machine dependent routines.

3.1. MACHINE DEPENDENT CODE

The machine dependent interface has been designed to minimize the number of routines needed to complete the connection between ASTROS and the host system. The development of the machine dependent interfaces can be done in a straightforward manner on most machines with more complexity required for sophisticated interfaces or for alternative host architectures. The typical ASTROS user will not be willing to perform any but the most rudimentary duplication of the standard, supported installation dependent interface, although anyone familiar with the host computer system could accomplish the task. Installation at sites using machines that are much like the ones already supported is fairly simple, although even the installation of ASTROS on identical host machines can require some modification to the machine dependent code since some parameters and code are site dependent as well as machine dependent.

The machine dependent code is separated into two libraries: the general library, denoted by names starting with **XX**, and the database machine dependent library, denoted by names starting with **DBMD**. The general library consists of timing routines, bit manipulation routines, some character string manipulation routines, a random number generator and a **BLOCK DATA** subroutine containing a number of machine and installation dependent parameters. The timing routines and the random number generator are site dependent in that each facility typically has a library of such routines. The **BLOCK DATA** contains such parameters as the open core size, the definition of logical units, output paging parameters and other site dependent parameters. The remainder of the routines are very simple and typically do not vary substantially from site to site, although they are different between machines. In some cases, the **XX**-routines are written in standard FORTRAN and are in the machine dependent library only because some host systems provide special routines to perform these tasks.

The database machine dependent library (**DBMD**) is much more complex than the general machine dependent library. The complication arises because of the flexibility of the machine dependent interface and because of the nature of the interface. Unlike the **XX** library, the **DBMD** library deals with file structures and I/O to the host system and with memory management. These issues are highly machine dependent and are further complicated because the translation of machine independent parameters like file names to the actual host system file name may need to be very flexible depending on the nature of the local host system. The **ASSIGN DATABASE** entry in ASTROS allows the user to enter machine dependent parameters associated with the data base file attachment. A major task in writing the **DBMD** library is the definition of these parameters and the rules for their use: in general they are used to enable the user to modify the default file attributes. For example, block sizes; or their location on a physical device, such as disk volume. The flexibility inherent in the machine dependent interface can cause difficulties in writing the **DBMD** code, however, in that the code developer may find it hard to differentiate those aspects of the interface that are free to be redefined from those that are required by ASTROS. In the authors' experience, however, the task has proven to be tractable for all host systems used thus far by using the existing routines as a model. The reader should be under no illusion, however, that the task of writing the **DBMD** machine dependent library is simple.

The following sections document the **XX** and **DBMD** machine dependent libraries in a machine independent manner. Each routine that is essential to the ASTROS interface, its calling sequence and its design requirements is listed. It is very important to appreciate that the actual machine dependent interface may require additional routines that are not documented in these sections. The only routines that are

shown here are those that are referenced by the machine independent portions of ASTROS. By definition, it is these routines that constitute the machine dependent interface. It is often desirable and sometimes necessary for the machine dependent code to call other machine dependent routines. These internal interfaces are not documented in this report because of their high degree of dependence on particular host machines and/or site configurations. It is completely up to the discretion of the code developer to decide whether such routines are desirable and what tasks they should perform. In fact, there are no requirements of any kind for the machine dependent code ***except*** those imposed by the definition of the interface (calling sequence and design assumptions). It is that very flexibility that makes the machine dependent code generation difficult.

3.1.1. General Dependent Code

The following sections document each of the general machine dependent routines contained in the **XX** library. These routines tend to be highly site dependent as well as machine dependent, but are relatively straightforward to develop. Their functions are simple and do not deal with the major machine dependencies like I/O and word sizes.

Machine Dependent Utility Module: DOUBLE

Entry Point: DOUBLE

Purpose:

Machine dependent logical function to determine the machine precision as one of single or double precision.

MAPOL Calling Sequence:

None

Application Calling Sequence:

DOUBLE ( )

Method:

DOUBLE returns a **.TRUE.** if the machine precision is double or a **.FALSE.** if it is single. ASTROS then produces ***all*** matrix entities and ***assumes*** that ***all*** matrix entities are of the machine precision. Mixing single and double precision matrices is ***not*** supported by ASTROS code. **DOUBLE** should be used by ***all*** application modules that use matrix entities.

Design Requirements:

1. All matrix operations must be either single or double, not mixed.

Error Conditions:

None

Machine Dependent Utility Module: XXBCLR

Entry Point: XXBCLR

Purpose:

Machine dependent integer function to clear a bit in an array.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
XXBCLR ( ARRAY, BIT )
```

Method:

The bit manipulation routines all assume that the **BIT** identifier can vary from 1 to any positive integer. A consistent set of assumptions on the correspondence of **BIT** to a word/bit combination in **ARRAY** must be made for all bit routines.

Design Requirements:

1. For machine independent use, application program units should size **ARRAY** based on 32 or fewer bits per word.

Error Conditions:

None

Machine Dependent Utility Module: XXBD

Entry Point: XXBD

Purpose:

A block data subroutine to initialize machine or installation dependent parameters.

MAPOL Calling Sequence:

None

Application Calling Sequence:

None

Method:

The **XXBD** block data establishes the values of machine dependent constants. These parameters include any constant that may be needed for the machine dependent library as well as the following installation or machine dependent values required by the ASTROS machine independent routines:

1. The size of the open core common block **/MEMORY/** in single precision words.
2. System dependent precision terms for the large matrix utilities and memory management
3. The parameters identifying the name and password of the ASTROS system database. These must correspond to those used in the SYSGEN program.
4. The number of bytes and bits in a single precision word, the number of characters that will be stored in a hollerith word and the FORTRAN format statement to read or write one hollerith word.
5. The set of "large" and "small" numbers for the machine, including a large real number, a small real number, the square root of a small real number and the largest integer value supported by the host system.
6. The installation dependent number of lines per page and the maximum number of output lines that will be used by the ASTROS page utility, **UTPAGE**.
7. The ASTROS and SYSGEN version and release identifiers.
8. The installation dependent set of logical unit numbers identifying the read/write/punch units and the unit to be used for the include files, intermediate storage of the executive timing summary and the queued storage of the error messages.
9. System dependent null values for relational entity attribute types

Design Requirements:

1. The logical units specified in the **XXBD** block data must not conflict with those identified in the database machine dependent block data **DBBD** for the database files.

Error Conditions:

None

Machine Dependent Utility Module: XXBSET

Entry Point: XXBSET

Purpose:

Machine dependent routine to set a bit in an array.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XXBSET ( ARRAY, BIT )
```

Method:

The bit manipulation routines all assume that the **BIT** identifier can vary from 1 to any positive integer. A consistent set of assumptions on the correspondence of **BIT** to a word/bit combination in **ARRAY** must be made for all bit routines.

Design Requirements:

1. For machine independent use, application program units should size **ARRAY** based on 32 or fewer bits per word.

Error Conditions:

None

Machine Dependent Utility Module: XXBTST

Entry Point: XXBTST

Purpose:

Machine dependent logical function to test a bit in an array.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
XXBTST ( ARRAY, BIT )
```

Method:

The bit manipulation routines all assume that the **BIT** identifier can vary from 1 to any positive integer. A consistent set of assumptions on the correspondence of **BIT** to a word/bit combination in **ARRAY** must be made for all bit routines.

Design Requirements:

1. For machine independent use, application program units should size **ARRAY** based on 32 or fewer bits per word.

Error Conditions:

None

Machine Dependent Utility Module: XXCLOK

Entry Point: XXCLOK

Purpose:

Machine dependent routine to return the time of day as a character string and as a number of seconds past midnight.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XXCLOK ( TIME, ISEC )
```

TIME	Character string containing the time of day as **HH:MM:SS** (Character, Output)
ISEC	Integer number of seconds since midnight. (Integer, Output)

Method:

None

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: XXCPU

Entry Point: XXCPU

Purpose:

Machine dependent routine to return the elapsed CPU time in seconds.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XXCPU ( CPU )
```

CPU	Number of seconds of CPU time used since the job started. (Real, Output)

Method:

On the first call to **XXCPU**, the utility must initialize the system CPU timer and return 0.0 elapsed seconds. On subsequent calls, the elapsed CPU time in seconds is returned.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: XXDATE

Entry Point: XXDATE

Purpose:

Machine dependent routine to return the date as a character string **MM/DD/YY**.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XXDATE ( TODAY )
```

TODAY	Character string containing the date as **MM/DD/YY**. (Character, Output)

Method:

None

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: XXFLSH

Entry Point: XXFLSH

Purpose:

Machine dependent routine to flush any data in the buffer for a given logical unit.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XXFLSH ( LU )
```

LU	The logical unit number of the file whose buffer is to be flushed. (Integer, Input)

Method:

The **XXFLSH** routine will typically be a return. On machines that support the ability to flush the I/O buffer for a file, however, the **XXFLSH** routine should call that routine to flush the buffer to the file.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: XXINIT

Entry Point: XXINIT

Purpose:

Machine dependent routine to perform general machine dependent initialization tasks.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XXINIT
```

Method:

The **XXINIT** routine is typically used to enter machine dependent parameters relating to error handling by the host machine, the initialization of the machine dependent parameters that must be done at run time on certain machines and performing any other machine or installation dependent actions that may be useful. The **XXINIT** routine is called by the ASTROS main driver as the first executable statement of the ASTROS.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: XXITOS

Entry Point: XXITOS

Purpose:

Machine dependent routine to return the character representation of an integer.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XXITOS ( N, V )
```

N	Input integer
V	Output character string

Method:

This routine may be written in standard FORTRAN 77 using the internal file feature to write the integer onto the character string. It is often more efficient to crack the integer into its constituent digits. Some machines have local utilities that may be used.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: XXLSFT

Entry Point: XXLSFT

Purpose:

Machine dependent integer function to shift bits to the left in an integer word.

Function Arguments:

```
XXLSFT ( INT, NBIT )
```

INT	Input integer
NBIT	Integer number of bits to shift left

Method:

The machine independent use of this function requires that **NBIT** be less than the smallest number of bits in a word for any target machine (typically 32).

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: XXNOT

Entry Point: XXNOT

Purpose:

Machine dependent integer function that returns the complement of **INT**.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
XXNOT ( INT )
```

INT	Input integer

Method:

None

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: XX0VFL

Entry Point: XX0VFL

Purpose:

Machine dependent routine to test for floating point overflow or underflow and return a flag denoting which has occurred.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XX0VFL ( J )
```

J	Integer value returned based on the over/underflow condition: **= 1** floating point overflow exists **= 2** no error condition **= 3** floating point underflow exists

Method:

In the case of this special routine, if the host system does not have an **XX0VFL** type of routine, it is necessary to return a **J=2** value for all calls to **XX0VFL**. In this case, the host system will be relied upon to indicate the occurrence of a floating point error.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: XXRAND

Entry Point: XXRAND

Purpose:

Machine dependent function that returns a random single precision number between 0.0 and 1.0.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
XXRAND ( )
```

Method:

Returns uniformly distributed random numbers.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: XXRSFT

Entry Point: XXRSFT

Purpose:

Machine dependent integer function to shift bits to the right in an integer word.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
XXRSFT ( INT, NBIT )
```

INT	Input integer
NBIT	Integer number of bits to shift right

Method:

The machine independent use of this function requires that **NBIT** be less than the smallest number of bits in a word for any target machine (typically 32).

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: XXRT0S

Entry Point: XXRT0S

Purpose:

Machine dependent routine to return the character representation of a real number.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XXRT0S ( REL, STR )
```

REL	Input real number
STR	Output character string

Method:

This routine may be written in standard FORTRAN 77 using the internal file feature to write the real onto the character string. It is often more efficient to crack the real into its constituent digits. Some machines have local utilities that may be used.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: XXULNS

Entry Point: XXULNS

Purpose:

Machine dependent routine to return the used length of a character string.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XXULNS ( STR, ULEN )
```

STR	Character string (Character, Input)
ULEN	The position of the last nonblank character (the first character in the string is character 1). (Integer, Output)

Method:

The **XXULNS** routine may be written in standard FORTRAN 77 using the **LEN** function to return the total length and then looking backwards for the first nonblank character. Certain hosts may benefit from a machine dependent approach when byte operations are expensive.

Design Requirements:

None

Error Conditions:

None

3.1.2. Database Dependent Code

The following sections document each of the database machine dependent routines contained in the **DBMD** library. These routines tend to be site independent, but are highly machine dependent. Their development on a new host system can become quite complex depending on the desired sophistication of the interface. These routines deal with file structures I/O and memory management as well as certain CPU critical string manipulation functions.

Machine Dependent Utility Module: DBMDAB

Entry Point: DBMDAB

Purpose:

To abort the execution of ASTROS due to a database or memory management fatal error.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDAB    ( FLAG )
```

FLAG	An integer input denoting whether the executive termination utility **XQENDS** is to be called or not. **= 0**, call **XQENDS**, otherwise stop

Method:

The **DBMDAB** routine is set up to avoid the recursion that can occur due to the termination actions taken by the **XQENDS** termination utility. Since the database and memory manager are calling for the abort, the **XQENDS** routine's attempts to close the database files often cause the **DBMDAB** routine to be called again. Hence, the flag argument is input to denote that the abort condition is such that any attempts to close the database will cause recursion.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDAN

Entry Point: DBMDAN

Purpose:

Machine dependent integer function that returns the logical **AND** of **INT1** and **INT2**.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
DBMDAN ( INT1, INT2 )
```

INT1	Input integer
INT2	Input integer

Method:

None

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDCH

Entry Point: DBMDCH

Purpose:

To convert a character variable of arbitrary length into an integer array with four hollerith characters per word.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDCH ( CVAR, IVAR, LEN )
```

CVAR	An input character variable of arbitrary length
IVAR	The output integer array containing the hollerith equivalent of **CVAR**
LEN	An input integer denoting the number of characters to be placed in **IVAR**. **LEN** should always be a multiple of four, this routine pads with blanks as needed.

Method:

The **DBMDCH** routine is used extensively by the database routines to convert user supplied character variables into hollerith integers for subsequent processing. It is critical for performance that this routine be efficient. For implementation purposes, it must be assumed that the input character string can be of any length, but the output hollerith variable must always have four characters per word. Any extra bytes left unused are filled with blanks.

The only way standard FORTRAN provides to convert character data to hollerith data is with an incore file operation using the FORTRAN read. While this method works on all machines, it is typically very slow and causes severe performance penalties. This method can be avoided in most cases since compilers typically pass two arguments for every character variable with the virtual argument containing the character length. The virtual argument either follows the character argument directly or is passed at the end of the list of actual arguments. Knowing this, this routine can usually be written using all integer data thereby producing much faster code.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDCX

Entry Point: DBMDC1

Purpose:

To perform phase 1 of database configuration initialization.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDC1 ( NWORD )
```

NWORD Number of words required in **DBNT** (Integer, Output)

Method:

Phase 1 of the database configuration normally involves the determination of default values for the database. The values that can be changed are defined in the **/DBCONS/** common block. These values can be hard coded in this routine, hard coded in the **DBBD** block data routine or read from a configuration file.

The only required function of the routine is to return the number of words in the system dependent portion of the **DBNT**.

Design Requirements:

None

Error Conditions:

None

Entry Point: DBMDC2

Purpose:

To perform phase 2 of database configuration initialization.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDC2 ( DBNT )
```

DBNT Database name table (Integer, Input)

Method:

When phase 2 of the database configuration is performed, the **DBNT** table has been allocated and partially initialized. This routine must initialize the system dependent portion of the table. The location of this data can be found as follows.

```
DBENTSD          = Z (DBNT + DBNSD)
Z(DBENTSD + xx) = machine dependent data
```

It is also the responsibility of this routine to make sure that all of the following variables in **/DBCONS/** have legal values.

DBDFIL	default number of data files
DBMFIL	maximum number of data files
DBDEFD	default data file block size
DBDEFI	default index file block size
DBMAXE	maximum number of **ENT** entries
DBMAXD	maximum number of **DBNT** entries
DBMAXN	maximum number of **NST** entries
DBALGN	required buffer alignment

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDDT

Entry Point: DBMDDT

Purpose:

To return the time and date in hollerith formats.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDDT ( DATE, TIME )
```

DATE	Date in form **MM/DD/YY** (2 integer words, output)
TIME	Time in form **HH:MM:SS** (2 integer words, output)

Method:

This subroutine should return the current date and time in the appropriate locations. Each value returned should be stored in two integer words with four hollerith characters per word.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDER

Entry Point: DBMDER

Purpose:

To handle machine and installation dependent error conditions for the database and memory manager.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDER ( ERROR )
```

ERROR	A character argument containing an error message identifier.

Method:

The **DBMDER** routine is intended to be used in two ways. The first, denoted by a blank character string on input, is to activate any machine dependent error handling. This is the interface to the **DBMDER** routine from the machine independent library. For example, the **DBMDER** routine typically invokes the host dependent mechanism to obtain a traceback to assist in locating the source of an error. The second interface, using nonblank character strings on input, is intended for use by the machine dependent (**DBMD**) library. In this function, the **DBMDER** routine typically writes out error messages identifying the nature of the (machine dependent) error condition. This is useful for error checking the file naming conventions, host I/O limitations, and other host dependent user interfaces to the ASTROS system.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDFP

Entry Point: DBMDFP

Purpose:

An integer function to reorder the bytes in an integer word.

MAPOL Calling Sequence:

None

Application Calling Sequence:

DBMDFP (INUM)

INUM	An integer word whose bytes are to be reordered

Method:

On certain machines (notably VAX), the bytes in an integer word are stored in an order right to left. When hollerith data are used, this feature complicates the comparison of two hollerith words. This routine is called to reorder the bytes in an integer word to be left to right, independent of the storage format on the machine. On machines that do not swap bytes, the **DBMDFP** function value should be set equal to the **INUM** value.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDHC

Entry Point: DBMDHC

Purpose:

To convert an integer array with four hollerith characters per word into a character variable of arbitrary length.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDHC ( IVAR, CVAR, LEN )
```

IVAR	The input integer array containing the hollerith characters.
CVAR	An output character variable containing the character representation of the hollerith **IVAR**.
LEN	An input integer denoting the number of characters in **IVAR** to convert and place in **CVAR**. **LEN** should always be a multiple of four, the routine truncates or pads with blanks as needed.

Method:

The **DBMDHC** routine is used extensively by the database routines to convert hollerith integer into character variables for subsequent processing. It is critical for performance that this routine be efficient. For implementation purposes it must be assumed that the output character string can be of any length and the input hollerith variable must have four characters per word as generated by **DBMDHC**.

The only way standard FORTRAN provides to convert hollerith data to character data is with an incore file operation using the FORTRAN write. While this method works on all machines, it is typically very slow and causes severe performance penalties. This method can be avoided in most cases since compilers typically pass two arguments for every character length. The virtual argument either follows the character argument directly or is passed at the end of the list of actual arguments. Knowing this, this routine can usually be written using all integer data which produces much faster code.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDHX

Entry Point: DBMDHX

Purpose:

To dump a portion of memory in a hexadecimal or octal format.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDHX ( ARRAY, LEN )
```

ARRAY	Input array containing data to be dumped
LEN	Number of single precision words to dump

Method:

If a database error occurs, portions of the in core control tables are dumped to help diagnose the problem. It is most often desirable to see this data in a combined hex/octal and character format. This routine usually dumps the desired data in the following form:

OFFH OFFD .....hex/octal data .....character data

OFFH - hex/octal offset of the data from **/MEMORY/**

OFFD - decimal offset of the data from **/MEMORY/**

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDIX

Entry Point: DBMDI1

Purpose:

Phase 1 of database I/O initialization.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDI1 ( NAME, STAT, RW, USRPRM, NFILE, NWORD )
```

NAME	Database name (Character, Input)
STAT	Database status (**OLD**, **NEW**, **TEMP**, **SAVE**, or **PERM**) (Input)
RW	Read/write flag (**RO**, **WO**, **R/W**, Input)
USRPRM	User parameters (Character, Input)
NFILE	Number of data files in database (Integer, Output)
NWORD	Number of words required for each file in **DBDB** (Integer, Output)

Method:

Phase 1 of the I/O initialization is responsible for determining two values: the number of data files in the database and the number of system dependent words required for each file in the **DBDB**. The **DBINIT** call is provided with an argument called **USRPRM**. The contents of this character string are completely machine dependent and can be used to specify any special processing. Examples of these fields are provided in Section 1 of the User's Manual.

The most difficult function of this routine is to determine the number of data files for a database. The following ways could be used.

1. If the database has a status of **NEW** or **TEMP**, the number of data files is either the default or entered using the **USRPRM**.
2. If the database has a status of **OLD**, the number of data files can either be a hard coded value (usually 1) or can be determined by opening files with the appropriate names until an open fails.

For OLD databases this routine should also determine the index and data file block sizes. This can usually be done by one of the following two methods.

1. Inquire as to the physical attributes of the file to determine the block sizes.
2. Do a sequential read of the first block of the index file and extract the index and data file block sizes that are stored there.

Design Requirements:

None

Error Conditions:

None

Entry Point: **DBMDI2**

Purpose:

Phase 2 of database I/O initialization.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDI2 ( DBDB  )
```

DBDB Database Descriptor Block (Integer, Input)

Method:

When phase 2 of the database I/O initialization is performed, the **DBDB** table has been allocated and partially initialized. This routine must initialize the system dependent portion of the table. There are also several words in the machine independent portion of the **DBDB** that must be initialized for each index and data file. The following code shows how these words are located.

For the Index file:

```
DBDDBO = DBDB + DBDIFB
```

For the Data files:

```
DBDBO = DBDB + DBDDTA + (IFILE-1)*LENDDE
```

For all files:

```
DBDBSD = Z(DBDBO+DBDOSD)
Z(DBDB+DBDIBS) = Index file block size in words
Z(DBDB+DBDDBS) = Data file block size in words
Z(DBDB+DBDMDF) = Maximum number of data files
Z(DBDB+DBDONB) = Current number of blocks in the file
Z(DBDB+DBDOMB) = Maximum number of blocks allowed in the file
Z(DBDBSD+XX) = Machine dependent data
```

This routine will typically do any physical open or assign calls that are required to make all the index and data files for this database available for processing.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDLC

Entry Point: DBMDLC

Purpose:

An integer function to provide the memory manager with an address of a character memory location in particular precisions.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
DBMDLC ( BASE, PREC, STAT )
```

BASE	An input character array whose absolute address is desired.
PREC	An input integer denoting the desired precision of the address **= 0** byte address **= 1** word address **= 2** double precision word address
STAT	An output integer value that is nonzero if any error conditions occurred.

Method:

The routine determines the absolute address of **BASE** and modifies the offset value to account for the precision of the desired address. For example, the VAX machine returns the byte address from the system utility **%LOCF**. To obtain the word address for the VAX, the byte address is divided by the number of bytes per word (four). A check is made to determine if the byte address is an even multiple of four and/or eight to check the single and double word alignment.

Design Requirements:

1. This routine is identical to **DBMDLF** except that the **BASE** array in this routine is character rather than integer.

Error Conditions:

1. On certain machines, there is a requirement that the memory addresses be aligned on single and/or double word boundaries. This routine should perform these checks and return the proper **STAT** value if the required alignments are not met.

Machine Dependent Utility Module: DBMDLF

Entry Point: DBMDLF

Purpose:

An integer function to provide the memory manager with an address of an memory location in particular precisions.

MAPOL Calling Sequence:

None

Application Calling Sequence:

DBMDLF (BASE, PREC, STAT)

BASE	An input integer array whose absolute address is desired.
PREC	An input integer denoting the desired precision of the address **= 0** byte address **= 1** word address **= 2** double precision word address
STAT	An output integer value that is nonzero if any error conditions occurred.

Method:

The routine determines the absolute address of **BASE** and modifies the offset value to account for the precision of the desired address. For example, the VAX machine returns the byte address from the system utility **%LOCF**. To obtain the word address for the VAX, the byte address is divided by the number of bytes per word (four). A check is made to determine if the byte address is an even multiple of four and/or eight to check the single and double word alignment.

Design Requirements:

1. This routine is identical to **DBMDLC** except that the **BASE** array in this routine is integer rather than character.

Error Conditions:

1. On certain machines, there is a requirement that the memory addresses be aligned on single and/or double word boundaries. This routine should perform these checks and return the proper **STAT** value if the required alignments are not met.

Machine Dependent Utility Module: DBMDMM

Entry Point: DBMDMM

Purpose:

Initializes machine dependent parameters for the memory manager.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDMM ( ICAWA, IWLIC )
```

ICAWA An output integer indicating if characters are word aligned on the host machine:
= 0 if character variables are word aligned
= 1 if character variables are not word aligned

IWLIC An output integer containing the number of characters stored in a single precision word on the host system.

Method:

None

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDOF

Entry Point: DBMDOF

Purpose:

An integer function to return a FORTRAN index such that the location of one array can be accessed via another array

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
DBMDOF ( ARRAY1, ARRAY2 )
```

ARRAY1	One FORTRAN array (Input)
ARRAY2	Second FORTRAN array (Input)

Method:

The result, **DBMDOF**, is a FORTRAN index such that the same memory location is referenced by **ARRAY1** (**DBMDOF**) and **ARRAY21.**. In the **DBOPEN** call, the user provides a 20-word **INFO** array. The last 10 words of this block are available for any required user data. These 10 words can be modified anytime up to the **DBCLOS** call for the entity. Since the **INFO** array is not passed on the **DBCLOS** call, the **DBOPEN** call must remember where it is for later access by the **DBCLOS** call. The **DBMDOF** function allows the database to remember where the **INFO** block is by saving its location relative to the **/MEMORY/** common block at open time.

The actual implementation of the call usually requires some method for obtaining the actual address for a subroutine argument.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDOR

Entry Point: DBMDOR

Purpose:

Machine dependent integer function that returns the logical **OR** of **INT1** and **INT2**.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
DBMDOR ( INT1, INT2 )
```

INT1	Integer (Input)
INT2	Integer (Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDRD

Entry Point: DBMDRD

Purpose:

To read a block from the database.

MAPOL Calling Sequence:

None

Application Calling Sequence:

CALL DBMDRD (DBDB, FILE, BLK, BUFHD)

DBDB	Database Descriptor Block (Integer, input)
FILE	File Number (for index files, **FILE = 0**) (Integer, input)
BLK	Block Number; if **FILE < 0** then **BLK** is **IBLK*DBMFIL + FILE** (Integer, input)
BUFHD	The I/O header location (Intger, input)

Method:

The function of this routine is to read a block from the database. The first step is to determine the database file and block number to be read. the following code will perform this.

```
IF(FILE .LT. 0) THEN
     IBLK = BLK/DBMFIL
     IFILE = BLK - IBLK*DBMFIL
ELSE
     IBLK = BLK
     IFILE = FILE
ENDIF
```

The block should then be read into the I/O buffer using the appropriate calls for the target system. The machine independent **DBDB** data, referenced from **DBDBO**, and machine dependent **DBDB** data, referenced from **DBDBSD** can be obtained from the buffer header. The number of words to transfer, **BLKSIZ**, is obtained from the **DBDB**.

```
IF(IFILE .EQ. 0) THEN
     DBDBO = DBDB + DBDIFB
     BLKSIZ = Z(DBDB+DBDIBS)
ELSE
     DBDBO = DBDB + DBDDTA + (IFILE-1)*LENDDE
     BLKSIZ = Z(DBDB+DBDDBS)
ENDIF
BUFIO = Z(BUFHD+BFIOBF)
DBDBSD = Z(DBDBO+DBDOSD)
```

After the I/O operation, the following two words of the buffer header should be updated:

```
Z(BUFHD+BFPBLK) = IBLK*DBMFIL + IFILE
Z(BUFHD+BFDBDB) = DBDB
```

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDSI

Entry Point: DBMDSI

Purpose:

To return the integer represented by a character string.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDSI ( STR, IVALUE )
```

STR	An input character string containing digits and signs representing an integer value.
IVALUE	An output integer variable containing the integer value represented by the input character string

Method:

This routine is typically written in standard FORTRAN, but may be available as a host system utility.

Design Requirements:

1. A leading **+** or **–** sign is permitted as are all the decimal digits. Any other characters are illegal.

Error Conditions:

1. If the character string does not represent an integer, no warnings are given and **IVALUE** is set to zero.

Machine Dependent Utility Module: DBMDTR

Entry Point: DBMDTR

Purpose:

To terminate processing of a database.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDTR ( DBDB )
```

DBDB	Database Descriptor Block (Integer, Input)

Method:

This routine is called at program termination to do any system dependent termination processing for each database. It is not required to do anything. Typically it will close all database files.

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDWR

Entry Point: DBMDWR

Purpose:

To write a block to the database.

MAPOL Calling Sequence:

None

Application Calling Sequence:

CALL DBMDWR (BUFHD)

BUFHD I/O buffer header location (Integer, Input)

Method:

The function of this routine is to write a block to the database. The processing is similar to **DBMDRD** and the same information is available to the routine.

When writing this routine one special case must be considered. Because of the dynamic way in which database blocks are allocated and used, it can never be assumed that the database blocks are appended in sequential order. For example block 10 may be written before block 9. If this situation is not allowed on the target system then this routine should write dummy blocks to fill any gap before writing the target block. The contents of these dummy blocks is unimportant.

After the I/O operation, the "buffer modified" flag in the buffer header should be set to zero.

```
Z(BUFHD+BFMOD) = 0
```

Also, this routine should maintain the word in the machine independent portion of the **DBDB** which indicates the number of blocks on the physical file.

```
Z(DBDBO+DBDONB) = MAX(IBLK,Z(DBDBO+DBDONB))
```

Design Requirements:

None

Error Conditions:

None

Machine Dependent Utility Module: DBMDZB

Entry Point: DBMDZB

Purpose:

To find the first zero bit in a word

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBMDZB ( WORD, BITNO )
```

WORD	Word to be searched for a zero bit (Integer, Input)
BITNO	Bit number found. It will be a number ranging from 1 to 31 if a zero bit was found. It will be –1 if all 31 bits are on. (Integer, Output)

Method:

The free Block Bit Map (**FBBM**) uses a bit to represent each block on the particular database file. If the bit is on, the block is allocated and if the bit is off, the block is unallocated. Each word in the **FBBM** is used to represent 31 blocks. The bits are numbered as follows:

unused	01	02	03	...	31

This bit numbering scheme must be maintained regardless of the bit numbering scheme of the target system.

The **DBMDZB** routine should return the first zero bit, starting from left to right. If all bits are one, then a –1 is returned. This function typically uses the FORTRAN **BTEST** function (if one is provided) with appropriate calculations to use the proper bit numbering scheme.

Design Requirements:

None

Error Conditions:

None

3.2. THE SYSTEM GENERATION PROGRAM

After development of the machine dependent source code for the target host machine, the next step in the ASTROS system installation is the assembly of the executable image of the ASTROS system generation program, SYSGEN. The libraries that must be linked to generate this program have been outlined in Section 2 of this manual while this section discusses the function of the SYSGEN program and details the structure of its inputs. These inputs not only define the standard ASTROS system but are also a powerful tool for an advanced user to expand the capabilities of the system. SYSGEN represents one of the most useful features of the ASTROS system architecture in that it provides for automated modification of many of the procedure's capabilities without requiring modification of any existing source code.

The purpose of SYSGEN is to create a system database (SYSDB) defining system parameters through the interpretation of several input files. Also, a FORTRAN routine is written by SYSGEN that provides the link between the ASTROS executive system and the application modules that comprise the run-time library of the procedure. This program unit is then linked with the system during the assembly of the ASTROS executable image. The resultant procedure makes use of the system database as a pool of data that defines the system at run time. These data are

1. the contents of the ASTROS run-time library of MAPOL addressable modules including both utility and application modules, usually delivered as **MODDEF.DAT** or **MODDEF.DATA**;

2. the ASTROS standard executive sequence composed of MAPOL source code statements, usually delivered as **MAPOLSEQ.DAT** or **MAPOLSEQ.DATA**;

3. the set of bulk data entries interpretable by the system and defined through the specification of bulk data templates to be interpreted by the ASTROS Input File Processor (IFP), usually delivered as **TEMPLATE.DAT** or **TEMPLATE.DATA**;

4. the set of relational schemata used by the executive system to satisfy the declaration of relational variables in the MAPOL sequence without forcing the user to explicitly define each schema at run time, usually delivered as **RELATION.DAT** or **RELATION.DATA**; and

5. the set of error message texts from which the **UTMWRT** system message writer utility builds error messages at run time, usually delivered as **SERRMSG.DAT** or **SERRMSG.DATA**.

There is an input file for each of these data which is interpreted by SYSGEN and used to write data to SYSDB in particular formats. These database entities are then used by the ASTROS executive system, application modules and utilities to perform certain functions. Since these program units are designed to interpret the set of data that are present in the SYSDB entities, they are flexible in that virtually any changes to the set of data can be accommodated without modification of the software that uses the data.

The following sections each contain a description of a SYSGEN input file and of the SYSDB database entities that are filled with the corresponding data. These input files contain the definition of the system as developed for the ASTROS procedure. The advanced user may, through the appropriate changes to these inputs, add new modules, add new error messages that may be useful as part of the additional module(s), add new bulk data inputs, add new relational schemata to those that exist or add new attributes to an existing schema. Finally, the standard solution algorithm itself can be modified, either to include (as a permanent modification) a new feature or to modify an existing capability. The advanced

user is cautioned, however, that the standard sequence represents a very tightly interwoven set of functions and any changes should be carefully considered for their ramifications on the multidisciplinary features of the system as it is currently defined.

3.2.1. Functional Module Definition

The functional modules form the computational heart of the ASTROS system. A sequential file contains character data records that define the following information for each module:

1. The name of the module
2. The number of formal parameters
3. If the module is a function or a procedure
4. The type of each formal parameter
5. FORTRAN code lines defining the module call

The purpose of these data is three-fold:

1. To provide the names of modules that are a part of ASTROS
2. To allow the validation of module calls including type checking of the input parameters
3. To define the way in which the results of a module are used and to provide the actual FORTRAN link to activate a module

The format used to provide these data is described in the following section

3.2.1.1 The File Format

The module definition file is organized as a sequence of module entries.

```
MODULE1. ENTRY
MODULE2. ENTRY
   ...
```

Each module entry has the following form:

```
MODNAME, NPARM       (A8,I4)
MODTYPE, PARMTYPE(I) (20I4)
   ...
FORTRAN LINES        (A80)
   ...
END                  (A8)
```

where the first line consists of **MODNAME** and **NPARM** and the second line consists of **MODTYPE** and the first 19 **PARMTYPE**s. The **PARMTYPE**s continue, 20 per line, on subsequent lines, as required to supply **NPARM PARMTYPE**s.

The lines following the **PARMTYPE**s consist of FORTRAN code (including, but not requiring, comments or blank lines) which implements the module interface to MAPOL.

The last line of a module entry is the word END starting in column 1.

MODNAME is the module name as it appears in MAPOL; 1 to 8 characters beginning with a letter. The name is left-justified in an 8-character field.

NPARM is the number of formal parameters in the calling list of the module. This is a right-justified integer in a 4-digit field. There is a limit of 50 parameters.

MODTYPE is a four-digit code for the module type:
100 means the module is a function with a fixed number of parameters
101 means the module is a function with a variable number of parameters
102 means the module is a procedure

PARMTYPE The declared type of each parameter in the calling list selected from the following codes, each a four-digit integer:

1 Integer
2 Real
3 Complex
4 Logical
5 Not Used
6 Not Used
7 Relational Entity
8 Matrix Entity
9 Unstructured Entity
10 Real, Integer, or Complex

If the **PARMTYPE** is entered as a negative value, the parameter is optional. Note that character **PARMTYPE**s are not supported.

Procedures

For procedures, a call is made to the ASTROS name with a parameter list having symbolic arguments of the correct types. For example, if a module has the following parameters (in order) with the specified data types:

3 Integers
1 Logical
1 Integer
1 Relation
1 Integer
1 Optional integer
1 Optional matrix
1 Matrix
1 Optional matrix

1 Logical

1 Matrix

1 Optional matrix

2 Matrices

1 Unstructured

2 Optional matrices

1 Optional logical

2 Optional matrices

1 Optional unstructured

then the call to this routine is coded as:

```
AROSNSDR  23
 102   1   1   1   4   1   7   1  -1  -8   8  -8   4   8  -8   8   8   9  -8  -8
  -4  -8  -8  -9
C
C     PROCESS 'AROSDR' MODULE - SAERO CONSTRAINT SENS. DRIVER
C
      CALL AROSDR ( IP1., IP2., IP3., LP4., IP5., EP6., IP7.,
     1              IP8., EP9., EP(10), EP(11), LP(12), EP(13),
     2              EP(14), EP(15), EP(16), EP(17), EP(18), EP(19),
     3              LP(20), EP(21), EP(22), EP(23) )
END
```

The subscripted array elements are used by the ASTROS executive to pass the actual parameter values. The subscripts must correspond to the order of the arguments in the MAPOL calling list. The following array names are used:

IP – Integer Parameter
RP – Real Parameter
CP – Complex Parameter
LP – Logical Parameter
EP – Entity name

This method passes only scalar parameters to the FORTRAN driver. No mechanism is available to pass FORTRAN arrays.

Functions

For a function, the resultant value is returned to MAPOL on the execution stack. To accomplish this, the programmer ***must*** assign the numeric function result to the FORTRAN variables **IOUT**, **ROUT**, and **COUT** that define the number to the executive. This is analogous to a function in FORTRAN, in which the value must be assigned to the function name within the function unit.

A numeric value is defined as follows:

IOUT1.	Variable type key with the same definitions as in **PARMTYPE**
IOUT(2,3) or ROUT(2,3) or COUT	Contain the actual integer, real or complex variable value. These arrays are all equivalenced:

If the value is integer, only **IOUT2.** must be defined. If the value is real, only **ROUT2.** must be defined. If the value is complex, then either **COUT** must be defined, or **ROUT**2. and **ROUT3.** must be defined. What is important is that the data in the second and third words be consistent with the type in **IOUT1.**.

Further if the function operation depends on the types of arguments (as do the FORTRAN generic functions, e.g. **MAX**, **SIN**), the array

```
TP(I), I=1, NPARAM
```

may be read in the module definition code to determine the type of argument passed. The **PARMTYPE** definition should then be 10 to allow any type to be passed. **TP** uses the same definitions as **PARMTYPE**, except the actual type of the argument is stored. In other words, **TP** contains a 1, 2, or 3 in the location associated with type 10 parameters, depending on the actual type passed in the current call.

For example, if the sine function is desired, the following module definition would be used:

```
SIN        1
 100  10
C
C     SIN - RETURN THE SINE OF THE ARGUMENT
C
   IF( TP1. .LE. 2 ) THEN
         IOUT1. = 2
         IF ( TP1. .EQ. 1 ) RP1. = IP1.
         ROUT2. = SIN(RP1.)
      ELSE
         IOUT1. = 3
         COUT    = SIN(CP1.)
      ENDIF
END
```

3.2.1.2 SYSGEN Output for Modules

The data defined by the module file are processed and the results are stored on the system database in two entities. The first is a relation called **MODINDEX**. This relation has two attributes: the first, **MODL-NAME**, is the module name and the second, **ARGPONTR**, is a pointer to the second entity. This second entity is called **MODLARGS**. Each record of this unstructured entity contains the **MODTYPE** and **PARMTYPE** data from the module definition file for a particular module. Additionally, the output of SYSGEN includes a FORTRAN subroutine called **XQDRIV**. This routine is the module driver for the ASTROS execution monitor. It must be compiled and linked into the system when adding or changing module definitions.

3.2.2. Standard Solution Algorithm Definition

The standard multidisciplinary solution algorithm, in the form of MAPOL source code statements, is contained in a sequential file. The SYSGEN program reads this file and compiles a standard sequence. The results of the compilation are stored on the system database in the form of two relations and an unstructured entity. The first relation is called **&MAPMEM** and has three attributes: **ADDRESS**, **VARTYPE**, and **CONTENT**. This relation stores the execution memory map for the standard MAPOL sequence. **ADDRESS** is an integer containing the address of the variable, **VARTYPE** is an integer denoting the variable type and **CONTENT** is a two-word integer array containing the current value of the variable.

The second relation output from the compilation of the standard sequence is called **&MAPCOD** and has three attributes: **INSSEQ**, **OPCODE**, and **ARGUMENT**. This relation contains the ASTROS machine instructions that represent the compiled MAPOL sequence. **INSSEQ** is an integer containing the instruction sequence number, **OPCODE** is the machine operation code to determine the action to be taken, and **ARGUMENT** is the argument to the operation -- either a memory address of an immediate operand.

The final output from the standard algorithm definition is not directly related to the compilation of the sequence. It is a relation called **&MAPSOU** containing the standard sequence source code statements verbatim. This is stored on the system database, allowing the user to edit the standard sequence to generate a new MAPOL program which directs the ASTROS procedure. The relation has two attributes: **LINENO** and **SOURCE**. **LINENO** is an integer containing the line number and **SOURCE** is a string attribute containing the 80-character source code line.

3.2.3. Bulk Data Template Definition

The ASTROS bulk data decoding module (**IFP**) is driven by templates that are stored on the system database during system generation. The template format for **IFP** was adopted to allow for easy installation of new bulk data entries and for easy modification of existing bulk data entries. The sequential file used by SYSGEN contains the bulk data templates for all the bulk data inputs defined to the ASTROS system in arbitrary order.

3.2.3.1 The File Format

The template definition file has the following format:

```
MAXSET (I8)
NLPTMP (I8)
TEMPLATE 1
TEMPLATE 2
   ...
   ...
```

MAXSET is the maximum number of template sets used to define one bulk data input. Currently, this value is five. **NLPTMP** is the number of lines in each template set. Currently there are six lines in each set. A bulk data template therefore consists of **1,2,3,...MAXSET** template sets, each of which consist of **NLPTMP** template lines which define the structure of the input entry. The definition includes the field

size, the field label, the field data type, the field defaults, the field checks, the field database loading position and, if necessary, a list of relational attributes. The structure of the template set is as follows:

```
BULK DATA ENTRY LABEL
FIELD DATA TYPES
DEFAULT VALUES
ERROR CHECKS
FIELD LOADING POSITION
DATABASE ENTITY DEFINITION
```

A typical bulk data entry template is:

```
CQUAD4 |EID    |PID    |G1     |G2     |G3     |G4     |TM     |ZOFF   |CONT   |
CHAR    INT     INT     INT     INT     INT     INT     INT/REALREAL    CHAR
DEFAULT         EID                                     0.      0.
CHECKS  GT 0    GT 0    GT 0    UG 2    UG 3    UG 4    GT 0
        1       2       3       4       5       6       7       9
CQUAD4  EID     PID1    GRID1   GRID2   GRID3   GRID4   CID1    THETA
+CQUAD4|       |TMAX   |T1     |T2     |T3     |T4     |                       |
CHAR            REAL    REAL    REAL    REAL    REAL
DEFAULT         1.E4
CHECKS          GE 0.   GE 0.   GE 0.   GE 0.   GE 0.
                10      11      12      13      -14
                OFFST0  TMAX    THICK1  THICK2  THICK3  THICK4                $
```

The LABEL *Template Set Line*

The first seven columns of the first template set line define the name of the input data entry. The eighth column is reserved for a field mark, "**|**". Columns 9 through 72 define the field labels and these are separated by the field mark "**|**". Columns 73 through 79 indicate to the decoding routines if a continuation card is supported for this entry. On the first template set's **LABEL** line (the template set for the parent line of the bulk data entry), the character string **CONT** indicates that a continuation line is supported. Otherwise, these columns are ignored and a continuation will not be allowed for the entry defined by this template. A continuation template set's **LABEL** line differs from the parent template in that the character string **ETC** can be used in columns 73 through 79 of the continuation template set's **LABEL** line to indicate an open ended entry having a repeating continuation. In this case, the same continuation template will be used to decode all remaining continuation entries. For free format input, the continuation entries must have the input extend to the third field (the second data field). Also, note that ALL template set's **LABEL** lines must have a field mark in column 80 to end the line.

The FIELD DATA TYPE *Template Set Line*

The **FIELD DATA TYPE** Template Set Line defines the types of data that are allowed for each field. Possible data types include: blank, **INT** (integer), **REAL** (real), **CHAR** (character), **INT/REAL** (integer or real), **INT/CHAR** (integer or character), and **REL/CHAR** (real or character). The data type definition characters (i.e., **INT**) must be left justified in the fields.

The DEFAULT *Template Set Line*

The **DEFAULT** template set line defines the default values of the fields. If the input data entry has an empty field, the default value will be used as the input. All values, like the data types, must be left justified in the fields. Three special cases for default values have been incorporated into the decoding routines. The first is the case of a special user input entry to define the defaults for a template. In this case the user supplied values will be substituted for the normal default values. The **BAROR** and **GRDSET** entries are examples of special inputs used to define the defaults. The addition of any other special inputs like these requires program changes in routines **IFPBD**, **BDMERG**, and **IFPDEC**. Another special case is in the referral to another field of the same template to obtain the default value. Referral values can exist for all data types except character (**CHAR**) data. In the case of a default referral, the current template set **LABEL** line is searched for the label referred to and, if the label string is not found, all other template sets, starting at the parent template set, are searched for the string. When the string is found, the corresponding entry field is decoded to obtain the default value. An example of a referral is the **PID** field of the **CQUAD4** card template. The third special case for defaults is the use of a multiplier for an integer default referral. This is only valid for integer type data and the presence of a multiplier is defined by an asterisk "*****". For example, **3*NDN**, where **NDN** is the label associated with another integer data field.

The ERROR CHECK *Template Set Line*

The **ERROR CHECK** template set line directs data checking for the decoded fields. Each error check specifies both the type of check and the check value. The available check types depend on the data type (for example, Integer, Real, or Character). Checks that are currently encoded are shown in Table 1.

If additional checks are needed, subroutine **INTCHK** must be modified for integer checks, **RELCHK** must be modified for real checks and **CHRCHK** must be modified for character checks.

When two check values are needed, as for the **IB** and **EB** checks, the first is located on the **ERROR CHECK** template set line and the second is located in the same column position on the **FIELD LOADING POSITION** line.

The FIELD LOADING POSITION *Template Set Line*

The **FIELD LOADING POSITION** template set line is used to place the converted data into the database loading array. The sequence of the numbering is dependent on three conditions. The first is the existence of **CHAR** data on the card. In this case, two hollerith single precision words will be used to store an eight character input and the numbering must account for the two words. The second condition is the sequence of the attribute list for a relational bulk database entity. In this case the loading sequence is determined by the sequence of the attribute list. The third condition occurs when a multiple data type field is present, (e.g., **REL/CHAR**). In this case the first variable type is loaded at the given value and the second variable type is loaded in the next word(s). Again this must be accounted for in the numbering sequence. Finally, when a negative integer value is given as the loading position, the database loading array will be loaded onto the database if input errors have not occurred. A negative value should be used on the field associated with the last attribute of the relational projection. At least one negative loading position must be defined.

Table 3-1. Bulk DataTemplate Error Checks

CHECK TYPE	DATA TYPE	MEANING
blank	all	No check
GT	Int,Real	Greater than
GE	Int,Real	Greater than or equal
NE	Int,Real	Not equal
LT	Int,Real	Less than
LE	Int,Real	Less than or equal
EQ	All	Equal
EB	Int,Real	Exclusive in between
IB	Int,Real	Inclusive in between
EOR	Int,Real	Either or
GEP	Int,Real	Greater than or equal to the previous value
UG	Int	Unique grid
EUG	Int	Empty or unique grid
COMP	Int	A set of component numbers
MID3	Int	PSHELL MID3 material check
MID4	Int	PSHELL MID4 material check
SA	Int	SPCADD, MPCADD combination check
EIGG	Int	Grid check on the EIGI family of input entries
EIGC	Int	Component check on the EIGI family of input entries
I12	Int	I12 check on the CBAR entry
MATG	Int	E and G check on the MAT1 entry
NU	Real	Check E, G and NU for the MAT1 entry
IDES	Real	Design variable range check
F.T.	Char	Failure theory for the PCOMP entry
YORN	Char	Yes or No
PTYP	Char	Property type for the PLIST entry
ETYP	Char	Element type for the ELIST entry
NORM	Char	Normalization method for the EIGi family of input entries
CMETH	Char	Solution method for the EIGC entry
RMETH	Char	Solution method for the EIGR entry
L.O.	Char	Lamination option for PCOMPi entries
ACMP	Char	Component type for airfoil and CAERO6 entries
BCMP	Char	Component type for BODY and PAERO6 entries
BTYP	Char	Body orientation type for the PAERO6 entry
CONV	Char	Conversion factor quantity type for the CONVERT entry
CTYP	Char	Upper or Lower bound constraint check for DCON**XXX**, entries
FMETH	Char	Flutter analysis method for the flutter entry
DTYPE	Char	Damping type for the TABDMP1 entry
MPREC	Char	Matrix precision for DMI and DMIG entries
MFORM	Char	Matrix form for DMI and DMIG entries
FFT1	Char	Interpolation method for the FFT entry

CHECK TYPE	DATA TYPE	MEANING
FFT2	Char	Output format selector for the FFT entry
MASSF	Char	Mass matrix form option for the MFORM entry
ETYPL	Char	Element name for the ELEMLIST and D**CONT**HK entries
CCI	Int	Material property defaulting check for the PCOMP entry
CCR1	Real	Laminae thickness defaulting check for the PCOMP entry
CCR2	Real	Laminae orientation angle defaulting check for the PCOMP entry
CCR3	Real	Laminae orientation angle and thickness defaulting check for PCOMP1 and PCOMP2 entry
GTZOB	Int,Real	Greater than zero or blank
GEZOB	Int,Real	Greater than or equal to zero or blank
ULC	Int	IUST, ILST, and/or ICAM check for the AIRFOIL entry
LAMCHK	Int	DCONLAM/DCONLMN laminate definition check
PLYNORS	Int	DCONLAM/DCONPMN ply definition check
NEBLK	Char	Not equal to blank
ETYPC	Char	Element name for the DCONFTP and DCONTWP entries
PTYPC	Char	Property name for the DCONFTP and DCONTWP entries
ETYPS	Char	Element name for the DCONEP and DCONVM entries
PTYPS	Char	Property name for the DCONEPP and DCONVMP entries
STYPE	Char	Control surface symmetry type
TRIM	Char	TRIM type
UM	Char	UM flag for RBEi entries
TRMACC	Char	Acceleration label check for DCONSCF entry
SCFPRM	Char	Parameter label check for DCONSCF entry
SCFUNIT	Char	Unit label check for DCONSCF entry
VTYPE	Char	Velocity type check for DCONFLT entry
DCNTYP	Char	Constraint type check for DCONLIST entry
FLTFIT	Char	Curve fit type check for FLUTTER entry
LAMCHK	Char	DCONLAM/DCONLMN laminate check

The* DATABASE ENTITY DEFINITION *Template Set Line

The **DATABASE ENTITY DEFINITION** template set line names the database entity to be loaded in the first eight columns of the parent template set, and the database attribute list for relational entities (Columns 9-72), of the parent template set. Column 80 is reserved for a map-end character ($). The map-end character indicates the end of the template, and so must occur only on the last database entity definition line for the final set of the template.

3.2.3.2 SYSGEN Output for Template Definitions

The SYSGEN outputs consist of an unstructured entity called **SYSTMPLT** which contains the templates and a relation called **TMPPOINT** which allows efficient access to particular templates. The **SYSTMPLT** entity contains one **RECORD** for each bulk data template in the order it appears in the input template definition file. Therefore, the **RECORD**s are of variable length with the longest **RECORD** containing 80 characters for each of **MAXSET** template sets of **NLPTMP** lines. The **TMPPOINT** relation has two attributes: **CARD** and **RECORD**. **CARD** is an eight character string attribute containing the name of the bulk data entry and **RECORD** is the number where the template is stored in **SYSTMPLT**.

3.2.4. Relational Schema Definition

Each relational database entity requires a SCHEMA that defines its data attributes. A sequential file, containing character data, is used to define these schemata. For each relation there is a list of the attribute names, their types, and, if they are arrays or character data, their length. The details of this file are described below:

3.2.4.1 The File Format

The schema definition file is organized as shown below:

```
REL1. ENTRY
REL2. ENTRY
   ...
   ...
REL(NREL) ENTRY
```

Each **RELATION** entry has the following form of free field input. Each input may appear anywhere on the line separated by one or more blanks except "**RELATION**" and "**END**".

```
RELATION RELNAME
ATTRNAME ATTRTYPE ATTRLEN
END
```

where

RELATION	is the keyword "**RELATION**" which signifies that a new **RELATION** schema follows. Must begin in column 1.
RELNAM	is the name of the **RELATION**; it may be one to eight characters beginning with a letter.

ATTRNAME is the name of the attribute; it may be one to eight characters beginning with a letter.

ATTRTYPE is the type of the attribute selected from:

'**INT**'	Integer
'**KINT**'	Keyed Integer
'**AINT**'	Array of Integers
'**RSP**'	Real, single precision
'**ARSP**'	Array of real, single precision
'**RDP**'	Real, double precision
'**STR**'	Character string
'**KSTR**'	Keyed character string

ATTRLEN is the optional length of the Attribute. If it is of type **AINT**, **ARSP**, **ARDP**, **STR**, or **KSTR**, the length is not optional. For other types, it should be zero or not present.

END is the keyword "**END**" which signifies the **END** of the **RELATION** schema.

3.2.4.2 SYSGEN Output for Relations

The data defined by the **RELATION** schema file are processed and the results are stored in two entities on the system database. The first is a **RELATION** called **RELINDEX**. This entity has an attribute **RELTNAME** containing the name of the **RELATION** and an attribute **SCHMPNTR** which is an integer pointer to an unstructured entity called **RELSCHEM**. The **RELSCHEM** entity contains a list of attribute names, types and lengths for each **RELATION**. Each **RELATION** has one tuple in the **RELINDEX RELATION** and one **RECORD** in the **RELSCHEM** entity. Each **RELSCHEM RECORD** consists of a four-word entry for each attribute: two hollerith words containing the attribute name, one hollerith word containing the attribute type and an integer word containing the attribute length.

3.2.5. Error Message Text Definition

The text of ASTROS run time messages is stored and maintained on a sequential file which is used during system generation to create SYSDB entities for use by the ASTROS message writer utility module. There are two reasons for maintaining the message text on an external file (and on SYSDB). First, the storage of message text within the functional modules would use a large amount of memory during execution. Second, storing the messages together in an external file allows for easier maintenance and aids in avoiding needless duplication in message texts. The messages stored on SYSDB from this file are used by the ASTROS utility **UTMWRT** to build error messages during execution.

3.2.5.1 The File Format

The message text file is organized as follows:

*MODULE 1 {<**header**>}
messages
*MODULE 2 {<**header**>}
messages
*MODULE 3 {<**header**>}
...
...
*MODULE <n> {<**header**>}

The **header** is an optional label of any length or content up to 120 characters that typically would describe the relationship among the messages for the specified module. In this way, messages that are logically related (for example, all error conditions from the **IFP** module) can be grouped together for simplified maintenance. The module number <n> is a unique integer identifying the base module number for the group of error messages. It need not be consecutive, which allows for randomly numbered modules.

The format of the message text is as follows:

```
'message text $ more text $ ...'
```

the string is enclosed in a single quotation marks because the message will be used as a character string in a FORTRAN write statement. The $ (dollar sign) is used by the **UTMWRT** utility to place character arguments into the string. For example,

```
'$ ELEMENT $ IS ATTACHED TO SCALAR POINT $.'
```

would appear for CTRMEM element 100 attached to scalar point 1001:

```
CTRMEM ELEMENT 100 IS ATTACHED TO SCALAR POINT 1001.
```

If the user wishes the message to carry over to the next output record, the FORTRAN format **RECORD** terminator (/) can be used *outside* the quotation marks to cause a record advance. For example:

```
'THIS IS ON LINE 1'/' THIS IS ON LINE 2.'
```

Currently there is an implementation limit of 128 characters for the length of the message text after including the arguments. Further details are given in the documentation for the **UTMWRT** utility module.

3.2.5.2 SYSGEN Output for Error Message Text

The data in the message file are used to create two system database entities. The first is an indexed unstructured entity called **ERRMSG**. This entity contains one line of the message text file in each record. The second is an unstructured entity called **ERMSGPNT** which has one record. That record has two words

for each module defined in the message file. Those words are the module number **<n>** and the record number of the **ERRMSG RECORD** containing the module header. These are used by the **UTMWRT** to position to the proper message text when called.

3.3. GENERATION OF THE ASTROS SYSTEM

Following the execution of the SYSGEN program the system installation proceeds to the generation of the ASTROS executable image. As indicated in Section 3.2, the SYSGEN program writes a FORTRAN program called **XQDRIV** which must be linked with the remainder of the source code to form the ASTROS system. It is this FORTRAN program which provides the flexible interface between the ASTROS executive and the remainder of the ASTROS modules. To generate the ASTROS system, therefore, it is essential to execute the SYSGEN program as a first step.

The SYSGEN execution is only required once to generate the standard version of ASTROS. This is the version that is defined by the delivered set of SYSGEN input files described in Section 3.2. If, however, the users of the system at a particular installation desire to insert additional modules, the SYSGEN program must be re-executed to recreate the **XQDRIV** submodule. The users may also want to modify other SYSGEN inputs to update the system database to include additional input entries or new relational schema. These changes also require the re-execution of the SYSGEN program (to update the system database) but do not require an update of the ASTROS system. For most purposes, only the module definition file described in Section 3.2.1 requires that the ASTROS executable image be recreated.

Chapter 4.

EXECUTIVE SYSTEM

The ASTROS executive system, as described in Chapter 3 of the Theoretical Manual, may be viewed as a stylized computer with four components: a control unit, a high level memory, an execution monitor and an Input/Output subsystem. The first three components comprise the executive system modules, while the I/O subsystem is embodied in the database. The modules that form the executive system perform tasks to establish the ASTROS/host interface, initiate the execution and, upon completion of the MAPOL instructions, terminate the execution. These modules also compile the MAPOL sequence, if necessary, and initiate the execution monitor that interprets the MAPOL instructions and guides the execution. This Chapter documents the modules of the ASTROS executive system.

The typical user of ASTROS need not be familiar with the executive system modules since their execution path does not have the flexibility that is available for the engineering modules. The executive modules, however, are important from the viewpoint of the system manager and the program developer for several reasons. First, problems with the machine dependent library on a new host system often show up during the executive modules' initialization tasks. The executive system modules are also important in understanding the treatment of the user's input data stream. To isolate the use of external files to the executive system, for example, the **PREPAS** executive module reads the input data stream and loads those portions that deal with the MAPOL, Solution Control and Bulk Data packets to the database. The system manager, therefore, may find it useful to study the nature of the executive modules and their interrelationships to better understand the implementation of the ASTROS architecture.

Executive System Module: ASTR0S

Entry Point: ASTR0S

PURPOSE:

ASTROS is the main entry point for the ASTROS procedure. It controls the execution path through the executive system modules.

MAPOL Calling Sequence:

None

Application Calling Sequence:

None

Method:

The ASTROS routine first sets a flag to tell the executive modules that subsequent calls are associated with the ASTROS procedure rather than with the SYSGEN program. This flag is required since the compiler and other executive routines are shared between the two programs and require sightly different execution paths. The machine dependent initialization routine, **XXINIT**, is then called to perform the initialization tasks required on the current host system. The initialization is completed by zeroing the execution monitor's stack length, calling the machine independent initialization routine, **XQINIT**, labeling the output listing and the starting the timing summary.

The **PREPAS** module is then called to read the user's input data stream. On return from **PREPAS**, the MAPOL compiler is called if a MAPOL compilation is required. Finally, the execution monitor, **XQTMON**, is called to interpret the ASTROS machine instructions representing the compiled MAPOL sequence. All subsequent activities in the ASTROS execution are controlled by this module until all the MAPOL instructions have been completed. Upon return from **XQTMON**, the main driver terminates the execution by writing the closing label, calling the **XQENDS** module to close the database, dumping the timing summary and performing any other closing tasks.

The engineering modules (addressed by the execution monitor) may also terminate the execution of the system. In these cases, the general application utility module, **UTEXIT**, is used since this routine assumes that an error exit has occurred. **UTEXIT**, however, also calls the **XQENDS** executive module to assure clean termination of all executions.

Design Requirements:

None

Error Conditions:

None

Executive System Module: XQINIT

Entry Point: XQINIT

PURPOSE:

To perform machine independent system initialization tasks.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XQINIT
```

Method:

This routine completes the page titling information on the **TITLE** line used by the **UTPAGE** utility. The ASTROS version number is placed in **TITLE** (which is in the **/OUTPUT2/** common block) in characters 88 through 107. The current date is obtained using **XXDATE** and placed in characters 109 to 117. The page number label is then placed in characters 120 to 121. Thus, the page number itself is left to fit in characters 123 to 128.

Design Requirements:

None

Error Conditions:

None

Executive System Module: PREPAS

Entry Point: PREPAS

PURPOSE:

To perform the first pass through the user's input data stream, to initialize the open core memory manager and to attach the scratch and system databases.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL PREPAS ( MAPFLG, SOLFLG, BLKFLG )
```

MAPFLG	Integer flag denoting the presence or absence of a MAPOL packet in the input data stream (Output) **0** if no MAPOL packet **1** if a MAPOL packet exists in the input stream
SOLFLG	Integer flag defined like **MAPFLG** denoting the presence or absence of a Solution Control packet in the input data stream (Output)
BLKFLG	Integer flag defined like **MAPFLG** denoting the presence or absence of a Bulk Data packet in the input data stream (Output)

Method:

This routine performs the first pass over the user's input data stream, performs actions based on the **ASSIGN DATABASE**, **DEBUG** and MAPOL **EDIT** command inputs and prepares MAPOL, solution control and bulk data inputs for access by the appropriate modules. The order of operations is crucial and can be summarized as follows:

1. The debug packet must be processed first since the debug flags can affect the memory management system.
2. Immediately following the debug packet, the memory manager must be initialized, and the scratch (run-time) database (based on the **ASSIGN DATABASE** entry) and the system database must be attached, ***in that order***. The order is dictated by the requirement that the memory manager be available for the **DBINIT** calls and the scratch database must be allocated before the system database. The system database must be allocated in order to process the MAPOL packet (which may apply **EDIT** operations to the standard MAPOL sequence stored on the system database).

Once the **ASSIGN DATABASE** and debug packets are processed, the remaining packets could be ordered in any fashion, but a fixed sequence of MAPOL, solution control and bulk data packets has been imposed.

The procedure used in **PREPAS** is to read the input stream one 80-character record at a time. The first nonblank records must be the **ASSIGN DATABASE** entry. The corresponding records are set aside in **ASNCRD** for use after the debug packet is processed. After the **ASSIGN DATABASE** entry has been encountered, each input record is read and searched to see if one of the input stream keywords appears in the first eight characters following the first nonblank character. The keywords are:

1. **DEBUG** denoting the start of the debug packet
2. **MAPOL** denoting the start of the MAPOL packet containing a complete new MAPOL sequence

3. **EDIT** denoting the start of the MAPOL packet containing edit commands to be applied to the standard sequence
4. **SOLUTION** denoting the start of the solution control packet
5. "**BEGIN**_" denoting the start of the bulk data packet. Note the trailing blank after **BEGIN** and the absence of the optional **BULK** keyword.
6. **ENDDATA** denoting the end of the bulk data packet
7. **INCLUDE** naming the secondary file from which to read the input

Note that all the keywords except **ENDDATA** and **INCLUDE** mark the beginning of a new packet. The **INCLUDE** keyword does not change the current packet and **ENDDATA** marks the end of the valid input. If the current record is one of the keyword records, flags are set to indicate that a new packet has been initiated or, for **INCLUDE**, the include file is opened and processing continues with the new input file until it is exhausted. Records that are not keyword records are processed as follows:

1. **DEBUG** packet records are sent to the **CRKBUG** utility to interpret the debug commands and set the executive system debug command flags in the **/EXEC02/** common and set the other debug command flags by **UTSFLG** to activate run time debugs.
2. MAPOL packet records representing a replacement MAPOL sequence are written to the unstructured entity **&MAPLPKT** for processing in the MAPOL module.
3. MAPOL packet records representing an **EDIT** of the standard sequence are passed to the **MAPEDT** subroutine to be interpreted. The resultant MAPOL sequence is written to the unstructured entity **&MAPLPKT** for processing in the MAPOL module.
4. **SOLUTION** packet records are written to the unstructured entity **&SOLNPKT** for processing in the **SOLUTION** module.
5. Bulk Data packet records are written to the unstructured entity **&BKDTPKT** for processing in the IFP module.

Design Requirements:

None

Error Conditions:

1. Input stream does not begin with an **ASSIGN DATABASE** entry.
2. An input stream keyword appears out of order.
3. An **ENDDATA** statement appears outside the bulk data packet.
4. No filename was found on an **INCLUDE** statement.
5. **INCLUDE** file cannot be opened.
6. Input record lies outside any input packet (typically following an **ENDDATA**).
7. FORTRAN read error on the primary input stream or included file.
8. An **INCLUDE** statement appearing in a included file.

Executive System Module: MMINIT

Entry Point: MMINIT

PURPOSE:

To initialize the memory manager.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MMINIT ( SIZE , MAXCOR )
```

SIZE	The number of single precision words in open core (Integer, Input)
MAXCOR	Maximum memory available in single precision words (Intger, Input)

Method:

This routine establishes the initial block headers for open core memory. A block header is written representing one free block of **SIZE** words less those required for the block header. The block header is either six or eight words depending on whether the **MEMORY** debug has been selected by the user in the input stream. The size must correspond to the actual declared length of the open-core common block **/MEMORY/**.

Design Requirements:

Prior to calling this routine, you must get the value of **MAXCOR** with the call:

```
CALL SYSGET('MAXCORE',MAXCOR)
```

Error Conditions:

None

Executive System Module: DBINIT

Entry Point: DBINIT

PURPOSE:

To initialize the processing for a database.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBINIT ( DBNAME, PASSWD, STAT, RW, USRPRM )
```

DBNAME	The database name (Character, Input)
PASSWD	The database password (Character, Input)
STAT	The database status (Character, Input) One of **OLD**, **NEW**, **SAVE**, **PERM** or **TEMP**
RW	Read/Write status (Character, Input) **RO** Read Only **R/W** Read/Write
USRPRM	Installation dependent user parameters (Character, Input)

Method:

This routine opens the named database for access. It performs any machine and installation dependent processing by accessing the database machine dependent library routines **DBMDCX** and **DBMDIX**. All the in-core buffers required for subsequent database access are allocated using the database memory management routines.

Design Requirements:

1. The first call to **DBINIT** must define the run-time or scratch database. Any other databases may then be initialized.

Error Conditions:

1. Any error conditions on the file operations occuring in **DBINIT** will terminate the execution.

Entry Point: DBCINI

PURPOSE:

To initialize the processing for a database and return a status code rather than terminate on error.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBCINI ( DBNAME, PASSWD, STAT, RW, USRPRM, ISTAT )
```

DBNAME	The database name (Character, Input)

PASSWD	The database password (Character, Input)
STAT	The database status (Character, Input) One of **OLD**, **NEW**, **SAVE**, **PERM** or **TEMP**
RW	Read/Write status (Character, Input) One of **RO** or **R/W**
USRPRM	Installation dependent user parameters (Character, Input)
ISTAT	Return status: **1** Duplicate database name **2** Too many databases open **3** Bad RW parameter **4** Index file block size too small **5** Bad data in file found on old open **6** Password check failure on old open **7** Old formatted database not supported **8** Read only open on new database illegal **9** Bad STAT parameter **100** Values are machine dependent - see **DBMDIX**

Method:

This routine opens the named database for access. It performs any machine and installation dependent processing by accessing the database machine dependent library routines **DBMDCX** and **DBMDIX**. All the in-core buffers required for subsequent database access are allocated using the database memory management routines.

Design Requirements:

1. The first call to **DBINIT** must define the run-time or scratch database. Any other databases may then be initialized.

Error Conditions:

1. Any error conditions on the file operations occuring in **DBCINI** will be flagged using the **ISTAT** parameter and control returned to the calling routine.

Executive System Module: MAPOL

Entry Point: MAPOL

PURPOSE:

To compile a MAPOL program.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MAPOL( ISTAT )
```

ISTAT	Return code. (Integer, Output)	
	0	Normal return
	1	MAPOL error encountered

Method:

The input MAPOL program or a MAPOL program representing a modified standard sequence is read from the **&MAPLPKT** unstructured entity and compiled. The resultant machine code instructions and memory map are written to the **MCODE** and **MEMORY** entities for use by **XQTMON** in executing the MAPOL program.

Design Requirements:

None

Error Conditions:

1. MAPOL syntax errors
2. Illegal argument types used in MAPOL module calls

Executive System Module: XQTMON

Entry Point: XQTMON

PURPOSE:

To execute a set of ASTROS machine instructions representing a MAPOL program.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XQTMON
```

Method:

If no MAPOL packet was in the input stream, **XQTMON** copies the standard sequence machine instructions and memory map from the system database into the **MCODE** and **MEMORY** entities. If a MAPOL compilation took place, the current sequence's data are already in **MCODE** and **MEMORY**. Beginning with the first instruction, which is passed to **XQTMON** from the MAPOL compiler or retrieved from the system database, the machine instructions are executed by this module.

Most instructions are processed directly by the **XQTMON** module; for example, stack operations, entity creations and scalar arithmetic operations. If the instruction is a module call, however, the **XQDRIV** executive subroutine, previously written by the SYSGEN program, is called to access the MAPOL module to which the machine instruction refers.

Design Requirements:

None

Error Conditions:

MAPOL run time errors

Executive System Module: XQENDS

Entry Point: XQENDS

PURPOSE:

To cleanly terminate the ASTROS execution.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XQENDS( ISTAT )
```

ISTAT	Return code. (Integer, Output)	
	0	Normal return
	1	Fatal error encountered

Method:

The database entities used by the executive module that remain open throughout the ASTROS execution are closed and the **DBTERM** executive module is called to close the database(s).

Design Requirements:

None

Error Conditions:

None

Executive System Module: DBTERM

Entry Point: DBTERM

PURPOSE:

To terminate processing of all open database.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBTERM ( DBNAME )
```

DBNAME Database name or blank (Character, Input)

Method:

The database entity name table (**ENT**) is searched and all open entities corresponding to **DBNAME** are closed and the **ENT** deleted. If **DBNAME** is blank, all open entities on all databases are closed but the **ENT**s are not deleted. If all databases are to be closed, the database name table (**DBNT**) is searched and all in-core buffers are freed. The first record of each database is updated to indicate that it was properly closed and any system dependent termination is performed. If a particular database is to be closed, these operations are done only for the named database. Finally, if all databases are closed, the **ENT**, **DBNT** and the name substitution table (**NST**) are released at the close of the **DBTERM**.

Design Requirements:

None

Error Conditions:

None

Chapter 5.

ENGINEERING APPLICATION MODULES

The modules documented in this section fall under the category of engineering application modules. These modules constitute the majority of the ASTROS software and do the tasks necessary to perform the analyses supported by the ASTROS system. Unsurprisingly, the difference between an "engineering application" module and other modules in the ASTROS system is not always clear. The most useful definition may be that an engineering application module is one that does not fall into any other category. They do, however, share some common attributes that can be used to help distinguish them from other modules. First, an engineering application module has no application calling sequence: it is only accessible through the executive system. A related attribute is that no engineering module may be called by another module, whereas utility modules may be called by other modules or by the executive system. Finally, an engineering application module is one that establishes an open core base address by calling the **MMBASE** and/or **MMBASC** utilities and uses that one base address throughout its execution.

The following subsections document each of the engineering application modules that comprise the ASTROS system. Each module is documented using the standard format shown in the introduction, but some additional comments are necessary. First, the MAPOL language allows the use of optional arguments in the calling sequences. This feature has been used in many modules to provide optional print selections or to allow the module to be used in slightly different ways. This is particularly true for the matrix reduction "modules" (**GREDUCE**, **FREDUCE** and **RECOVA**) which may almost be considered utilities. When the argument in the MAPOL calling sequence is optional, it is so indicated in the calling list. The **Method** section then describes the alternative operations that take place depending on the presence of the optional argument.

A second point to emphasize is the general nature of the **Method** sections for the engineering module documentation. In no way does this documentation attempt to lead the reader through the code segments of the module. Instead, a general descripton of the algorithm is given which, in combination with the in-line comments, should give the programmer an adequate understanding of the module. The system programmer

wanting to make extensive software modifications to existing modules will still need to study the actual code segments in some detail. The level of detail in the engineering module documentation is considered more appropriate for the ASTROS analyst/designer who wants to understand how ASTROS uses the existing pool of engineering modules and to know the "initial state" that the module expects to exist when it is called. The analyst may then make "nonstandard" use of the module to perform alternative analyses. These, therefore, are the data emphasized in the module documentation that follows.

A final note should be made relative to the description of the MAPOL module calling sequences. Version 12 of ASTROS has introduced user defined boundary condition identification numbers, called **BCID** in this chapter, which are used when specifying user defined functions. These are not to be confused with the boundary condition index, or subscript, which is a sequential counter used in MAPOL. This counter is shown as the entity subscript **BC**.

Engineering Application Module: ABOUND

Entry Point: ABOUND

Purpose:

To generate flags for the current boundary condition that indicate which constraint types are active. These are then returned to the executive sequence to direct the execution of the required sensitivity analyses.

MAPOL Calling Sequence:

```
CALL ABOUND ( NITER, BCID, CONST, NDV, ACTBOUND, NAUS, NACSD, [PGAS], PCAS,
              PRAS, ACTAERO, ACTDYN, ACTFLUT, ACTPNL, ACTBAR, NMPC,
              NSPC, NOMIT, NRSET, NGDR, USET(BC) );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
CONST	Relation of constraint values (Character, Input)
NDV	Number of design variables (Integer,Input)
ACTBOUND	Logical flag, **TRUE** if boundary condition is active. (Logical,Output)
NAUS	Number of active STATICS displacement vectors. (Integer, Output)
NACSD	Number of active STATICS stress and/or displacement constraints. (Integer, Output)
[PGAS]	Partition vector for active STATICS displacement vectors. (Output)
PCAS	Unstructured entity which contains the unique STATICS subcase numbers for the displacement dependent STATICS constraints that are active for the boundary condition. Only constraints for the current boundary condition are included in the list. (Output)
PRAS	Unstructured entity which contains the unique STATICS subcase numbers for the response functions that are required by active user function constraints. (Output)
ACTAERO	Logical flag, **TRUE** if any active aeroelastic effectiveness constraints and/or responses. (Logical,Output)
ACTDYN	Logical flag, **TRUE** if any active frequency constraints and/or responses. (Logical,Output)
ACTFLUT	Logical flag, **TRUE** if any active flutter constraints and/or responses. (Logical,Output)
ACTPNL	Logical flag, **TRUE** if any active panel buckling constraints. (Logical,Output)
ACTBAR	Logical flag, **TRUE** if any active Euler buckling constraints. (Logical,Output)
NMPC	Number of **MPC** degrees of freedom. (Integer, Output)
NSPC	Number of **SPC** degrees of freedom. (Integer, Output)
NOMIT	Number of omitted DOF. (Integer, Output)
NRSET	Number of support DOF. (Integer, Output)

NGDR	Denotes dynamic reduction in the boundary condition. (Integer, Output) **0** No **GDR** **-1** **GDR** is used
USET(BC)	The unstructured entity defining structural sets for each degree of freedom, where **BC** represents the MAPOL boundary condition loop index number. (Character, Input)

Application Calling Sequence:

None

Method:

The module first reads the **CONST** relation for active constraints associated with the boundary condition. If any entries are found, the **ACTBOUND** flag is set to on. If not, control is returned to the executive.

The **CASE** relation is then read for all subcases associated with the boundary condition. The number of **STATICS** subcases is counted in preparation for determining the partitioning vector of active subcases and the counts of right-hand-sides and constraints that will determine if the gradient or virtual load method will be used in sensitivity analysis. **SAERO** disciplines cannot use the virtual load method and are therefore not treated in this manner.

Then the **USET** and **CASE** entities are searched to set the boundary condition flags that are output to control the reduction processes during the sensitivity phase. Then the work of the module begins.

The active subcases and constraint types are determined for each of the entries in **CONST** that were read. During the pass through the active constraint set, the partitioning vector for the STATICS displacement matrix is built (of the number of right-hand-sides columns, only the **NAUS** columns will be active). For **STATICS** constraints that are dependent on the displacement vector derivatives, the active subcase is identified and the partitioning vector, **PGAS**, and the set of subcase ids that are active, **PCAS**, are loaded. Any subcases which have displacement or element stress/strain response functions required because there are active user functional constraints, are also defined as active. The partitioning vector, **PGAS**, and the set of subcase numbers that are active, **PRAS**, are loaded.

Then a summary of all the active constraints for the boundary condition is echoed to the output file.

Design Requirements:

1. This module must follow the complete analysis phase for all the boundary conditions and is the first module called within the sensitivity boundary condition loop.

Error Conditions:

None

Engineering Application Module: ACTCON

Entry Point: ACTCON

Purpose:

To determine whether the design task has converged. If the optimization has not converged, this module selects which constraints are to be included in the current redesign. On print request, this routine computes and prints the values of the local design variables.

MAPOL Calling Sequence:

```
CALL ACTCON ( NITER, MAXITER, NRFAC, NDV, EPS, APPCNVRG, GLBCNVRG, CTL,
              CTLMIN, CONST, [AMAT], DESHIST, PFLAG, LSTPUNCH );
```

NITER	The current iteration number. (Integer, Input)
MAXITER	The maximum number of allowable iterations. (Integer, Input)
NRFAC	Determines the minimum number of retained constraints equal to **NRFAC*NDV**. (Real, Input)
NDV	The number of global design variables. (Integer, Input)
EPS	A second criteria for constraint retention. All constraints greater than or equal to **EPS** will be retained. (Real, Input)
APPCNVRG	The approximate problem converge flag from module **DESIGN** or **FSD**. (Logical, Input) **= FALSE** if not converged **= TRUE** if no change in objective function value and design variables
GLBCNVRG	Final convergence flag. (Logical, Output) **= FALSE** if not converged **= TRUE** if global converge was achieved
CTL	Constraint tolerance for active constraints. (Real, Input)
CTLMIN	Constraint tolerance for violated constraints. (Real, Input)
CONST	Relation of constraint values. (Character, Input)
[AMAT]	The matrix entity of constraint gradients. (Output)
DESHIST	Relation of design iteration information. (Character, Input)
PFLAG	The logical flag to indicate if design model punching is requested for the current iteration. (Logical, Input)
LSTPUNCH	The logical flag to indicate if design model punching is requested for the final iteration. (Logical, Input)

Application Calling Sequence:

None

Method:

The initial action of the **ACTCON** module is to flush the **[AMAT]** matrix of constraint gradients for the sensitivity analysis that is to follow. This erases the constraint sensitivities from the previous design iteration and prepares the matrix to be loaded by the constraint sensitivity evaluation modules. Following this bookkeeping task, the **ACTCON** module begins the process of selecting the active constraints for the next redesign cycle. The first computation of the number of retained constraints is done using the value **NRFAC*NDV**. This represents a minimum number of constraints to retain. The vector of current constraint values is brought into core and sorted. Then the **EPS** value and initial number of retained constraints are used to determine the cutoff value for the active constraints. This cutoff value, **CMIN**, will either be the constraint value such that **NRFAC*NDV** constraints are retained, the constraint value closest to, but less than, **EPS** or the minimum constraint value if there are fewer than **NRFAC*NDV** constraints. During this phase the count of thickness constraints that are retained even though they do not satisfy the **NRFAC** and **EPS** retension criteria is kept. A summary is printed that indicates the number of constraints kept for each reason: **NRFAC**, **EPS** and **DCONTHK**.

If the approximate problem convergence flag, **APPCNVRG**, is **TRUE**, the maximum constraint value is tested to determine if global convergence has been achieved based on **CTL** and **CTLMIN**. The **GLBCNVRG** flag is set to **TRUE** if global convergence has been reached.

The next task of the **ACTCON** module is to set the active constraint attribute in the **CONST** relation. This is done by retrieving each tuple of the **CONST** relation and comparing the constraint value against the cutoff value, **CMIN**. The appropriate constraints are then marked active by setting the **ACTVFLAG** attribute to unity. Finally, the **ACTCON** module prints out the results of the design process if global convergence or the maximum number of iterations has been reached. This includes the print of the design iteration history and, if requested by Solution Control, the summary of global and local design variables.

Design Requirements:

1. **ACTCON** must be the first module called following the analysis phase of the optimization segment of the standard sequence. That is, it follows all the analysis boundary conditions but precedes the sensitivity evaluations.

Error Conditions:

1. No design constraints have been applied in the optimization problem.

Engineering Application Module: AEROEFFS

Entry Point: AROSEF

Purpose:

Evaluates aeroelastic effectiveness sensitivities.

MAPOL Calling Sequence:

```
CALL AEROEFFS ( NITER, BCID, SUB, SYM, NDV, CONST, PCAE, [EFFSENS], [AMAT] );
```

NITER	Current iteration number. (Input, Integer)
BCID	User defined boundary condition identification number. (Integer, Input)
SUB	Current static aeroelastic subscript number. (Input, Integer)
SYM	Symmetry flag for the current call. Either 1 for symmetric or -1 for antisymmetric. (Input, Integer)
NDV	Number of global design variables. (Input,Integer)
CONST	Relation of design constraints. (Input)
PCAE	Unstructured entity containing information indicating which pseudodisplacements (displacements due to unit configuration parameters) are active for the current design iteration. (Input)
EFFSENS	The matrix of dimensional stability derivative sensitivities. (Input)
AMAT	The matrix of constraint gradients. (Output)

Method:

The **CASE** relation is read first to retrieve the **SUPPORT** set for the current boundary condition. The number and location of the support DOF are returned from the utility routine **SEFCHK**. Then the **CONST** relation is read for active lift effectiveness (**DCONCLA**), aileron effectiveness (**DCONALE**) and stability coefficient constraints (**DCONSCF**) for the current boundary condition, subscript and iteration.

The **EFFSENS** matrix, of dimension **NSUP*NDV*NAUE** where **NSUP** is the number of support dofs and **NAUE** is the number of active pseudodisplacement fields of the set computed in **SAERO** for the applied constraints.

The whole **EFFSENS** matrix is read into memory and then the loop over active constraints begins. For each active constraint, the **DISPCOL** attribute of the **CONST** relation is used to determine which column of pseudodisplacements is associated with the constraint. The **PCAE** entity is then used to determine which column of the reduced set of active pseudodisplacement fields is the proper column. Once located, the constraint sensitivities may be computed from the dimensional stability coefficient derivatives and the normalization data stored in the **CONST** relation in the **SAERO** module. The constraint derivatives are computed from the following relationships.

The flexible stability coefficient response sensitivities which are required by the active user function constraints are also computed in this module. Those sensitivities are stored into relational and matrix entities to be used by the user function evaluation utilities.

Lift Effectiveness:

Upper Bound

```
CLAREQ > 0.0
   DG/DX =  SENS ROW / (CLA      * CLAREQ )
                              RIGID
CLAREQ < 0.0
   DG/DX =  -SENS ROW / (CLA      * CLAREQ )
                               RIGID
CLAREQ = 0.0
   DG/DX =  SENS ROW / CLA
                               RIGID
```

Lower Bound

```
CLAREQ > 0.0
   DG/DX =  -SENS ROW / (CLA      * CLAREQ )
                               RIGID
CLAREQ < 0.0
   DG/DX =  SENS ROW / (CLA      * CLAREQ )
                              RIGID
CLAREQ = 0.0
   DG/DX =  -SENS ROW / CLA
                              RIGID
```

where CLA_{RIGID} is stored in the **SENSPRM1** attribute of **CONST** and **CLAREQ** is stored in the **SENSPRM2** attribute of **CONST**

Aileron Effectiveness:

Upper Bound

```
AEREQ > 0.0
   DG/DX =(-SENS * CMXP + SENS * CMXA ) / (AEREQ *  CMXP **2)
                  1      FLX    2      FLX               FLX
AEREQ < 0.0
   DG/DX =( SENS * CMXP - SENS * CMXA ) / (AEREQ *  CMXP **2)
                  1      FLX    2      FLX               FLX
AEREQ = 0.0
   DG/DX =(-SENS * CMXP + SENS * CMXA ) / CMXP ** 2
                  1      FLX    2      FLX     FLX
```

Lower Bound

```
AEREQ > 0.0
   DG/DX =( SENS * CMXP - SENS * CMXA ) / (AEREQ *  CMXP **2)
                  1      FLX    2      FLX               FLX
AEREQ < 0.0
   DG/DX =(-SENS * CMXP + SENS * CMXA ) / (AEREQ *  CMXP **2)
                  1      FLX    2      FLX               FLX
AEREQ = 0.0
   DG/DX =( SENS * CMXP - SENS * CMXA ) / CMXP ** 2
                  1      FLX    2      FLX     FLX
```

where $CXMA_{FLEX}$ is stored in the **SENSPRM1** attribute of **CONST** and $CMXP_{FLEX}$ is stored in the **SENSPRM2** attribute of **CONST** and **2.0*AEREQ/(57.3*REFB)** is in **SENSPRM3**

Stability Coefficient:

Upper Bound

```
REQ > 0.0
   DG/DX =  SENS ROW / REQ
REQ < 0.0
   DG/DX =  -SENS ROW / REQ
REQ = 0.0
   DG/DX =  SENS ROW
```

Lower Bound

```
REQ > 0.0
   DG/DX =  -SENS ROW / REQ
REQ < 0.0
   DG/DX =  SENS ROW / REQ
REQ = 0.0
   DG/DX =  -SENS ROW
```

where **REQ**, the dimensional required value is stored in the **SENSPRM1** attribute of **CONST**

The rows of **EFFSENS** associated with each constraint are dependent on the constraint type in the following way:

(1) Lift Effectiveness constraints always use the plunge DOF

(2) Aileron Effectiveness constraints always use the roll DOF

(3) Stability Coefficient constraints always use the row associated with the constrained axis. The constrained axis number (1,2,3,4,5,6) is stored in real form in the **SENSPRM2** attribute of **CONST**.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: AEROSENS

Entry Point: AROSNS

Purpose:

To compute the sensitivities of the rigid body accelerations and aerodynamic performance parameters (**DCONTRM**) for active steady aeroelastic subcases associated with the current subscript.

MAPOL Calling Sequence:

```
CALL AEROSENS ( NITER, BCID, MINDEX, SUB, CONST, SYM, NDV, BGPDT(BC), STABCF,
                [PGAA], [LHSA(BC,SUB)], [RHSA(BC,SUB)], [DRHS], [AAR],
                [DDELDV], [AMAT] );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
MINDEX	Mach number index for the boundary condition to recover the proper stability coefficient data (Integer, Input)
SUB	The subscript identifier for the current **SAERO** subcases (Integer, Input)
CONST	Relation of constraint values (Character, Input)
NDV	The number of global design variables (Integer, Input)
SYM	The symmetry flag for the current **SAERO** subcases (Integer, Input)
BGPDT(BC)	Relation of basic grid point coordinate data (Character, Input), where **BC** represents the MAPOL boundary condition loop index number
STABCF	Relation of rigid stability coefficient data (Character, Input)
[PGAA]	Partitioning vector used to obtain g-set active displacement and acceleration vectors for all static aero subcases that have active trim parameter, stress, strain and/or displacement constraints. (Input)
[LHSA(BC,SUB)]	Modified inertia matrix (Character, Input), where **BC** represents the MAPOL boundary condition loop index number
[RHSA(BC,SUB)]	Modified applied load matrix (Character, Input), where **BC** represents the MAPOL boundary condition loop index number
[DRHS]	Matrix entity containing the sensitivity of **[RHSA]** to the design variables (Character, Input)
[AAR]	Matrix entity containing the sensitivities of structural accelerations either zero (for fixed accelerations) or from solution of **LHSA*AAR = RHSA*DDELDV + DRHS** (Output)
[DDELDV]	Matrix entity containing the sensitivity of the configuration parameters to the design variables. Either zero (for **FIXED** control parameters) or from the solution of **LHSA*AAR = RHSA*DDELDV + DRHS** (Output)
[AMAT]	Matrix entity containing the sensitivities of the active aeroelastic control parameter (**DCONTRM**) constraints to the design variables (Character, Output)

Application Calling Sequence:

None

Method:

First the **CASE** relation is read for the **SAERO** subcases in the boundary condition. Then the **STABCF** entity is read for the terms associated with the current **MINDEX**. Then the **TRIM**, control linking and control effectiveness data are read. Finally, the **CONST** relation for the active **DCONTRM**, stress and displacement constraints associated with the current subscript value are read into memory. Then the number of trim subcases (active/associated with **SUB**) is determined and the **PGAA** matrix is read and the number of active subcases is determined. The number of columns in the **DRHS** matrix (=**NDV***number of active subcases for this **SUB** value) is determined.

At this point, an trim solution very similar to the one done in the **SAERO** analysis module is performed to solve for the **AAR** rigid body acceleration derivatives and the **DDELDV** trim parameter sensitivities. The **DRHS** matrix is difficult to deal with since it must be partitioned for each subcase to just the **NDV** columns associated with the subcase under consideration. (Just as in **SAERO**, each subcase must be solved for independently since the effectiveness and control linking are subcase dependent.) Given the correct **NDV** columns in **DRHS**, the following matrix expression is available:

$$\begin{bmatrix} LHS_{ff} & LHS_{fk} \\ LHS_{kf} & LHS_{kk} \end{bmatrix} \begin{bmatrix} AR_{free} \\ AR_{known} \end{bmatrix} = \begin{bmatrix} RHS_{fu} & RHS_{fs} \\ RHS_{ku} & RHS_{ks} \end{bmatrix} \begin{bmatrix} DEL_u \\ DEL_s \end{bmatrix} + \begin{bmatrix} DRHS_f \\ DRHS_k \end{bmatrix}$$

Where:	Represents:
F+K	Number of **SUPORT** point DOF
F	Set of free accelerations, **AR**
K	Set of known(**FIXED**) accelerations, **AR**
U+S	Number of **AERO** parameters
U	Set of unknown parameters
S	Set of set(**FIXED**) parameters
Note that AR_{known} and DEL_s sensitivities are zero by definition.	

These equations must be rearranged to get free accelerations and unknown delta's on the same side of the equation:

$$\begin{bmatrix} LHS_{ff} & -RHS_{fu} \\ LHS_{kf} & -RHS_{ku} \end{bmatrix} \begin{bmatrix} AR_{free} \\ DEL_u \end{bmatrix} = \begin{bmatrix} -LHS_{fk} & RHS_{fs} \\ -LHS_{kk} & RHS_{ks} \end{bmatrix} \begin{bmatrix} AR_{known} \\ DEL_s \end{bmatrix} + \begin{bmatrix} DRHS_f \\ DRHS_k \end{bmatrix}$$

We must handle the degenerate case where all accelerations or all delta's are known. Once the solution is obtained, the free acceleration derivatives and unknown trim parameter derivatives are unscrambled and loaded into subcase specific **AAR** and **DDELDV** entities.

Finally, if any active **DCONTRM** constraints exist, the **AAR** or **DDELDV** matrix for the current subcase is used to compute the **AMAT** terms for them.

Upper bound

```
REQ > 0.0
   DG/DX =  SENS / REQ
REQ < 0.0
   DG/DX =  - SENS / REQ
REQ = 0.0
   DG/DX =  SENS
```

Lower bound

```
REQ > 0.0
   DG/DX =  - SENS / REQ
REQ < 0.0
   DG/DX =  SENS / REQ
REQ = 0.0
   DG/DX =  - SENS
```

Where **REQ** is stored in the **SENSPRM1** attribute of **CONST** and **SENS** is the raw acceleration or deflection sensitivity.

The final operation for the subcase is to merge the **NDV AAR** and **DDELDV** columns for the current subcase into the output matrices. The output matrices have **NDV** columns for each active subcase in subcase order of **SAERO** disciplines in the **CASE** relation.

The trim parameter response sensitivities which are required by the active user function constraints are also computed in this module.

Design Requirements:

1. This module assumes that either strength and/or **DCONTRM** constraints exist for the static aeroelastic analyses in the current boundary condition.

Error Conditions:

None

Engineering Application Module: AMP

Entry Point: AMP

Purpose:

To compute the discipline dependent unsteady aerodynamic matrices for flutter and gust analyses.

MAPOL Calling Sequence:

```
CALL AMP ( [AJJTL], [D1JK], [D2JK], [SKJ], [QKKL], [QKJL], [QJJL], [AJJDC] );
```

[AJJTL]	Matrix containing the list of AIC matrices for each Mach number, reduced frequency and symmetry option in transposed form (Input)
[D1JK]	Real part of the substantial derivative matrix (Input)
[D2JK]	Imaginary part of the substantial derivative matrix (Input)
[SKJ]	Integration matrix (Input)
[QKKL]	Matrix list containing the matrix product: $[SKJ]*[TRANS(AJJT)]^{-1}*([D1JK] + ik[D2JK])$ used for flutter and gust analyses (Output)
[QKJL]	Matrix list containing the matrix product: $[SKJ] * [TRANS(AJJT)]^{-1}$ used for gust analyses (Output)
[QJJL]	Matrix list containing the matrix product: $[TRANS(AJJT)]^{-1}$ used for nuclear blast analyses (Output)
[AJJDC]	Optional scratch entity to store the intermediate matrix product: $[TRANS(AJJT)]^{-1} * ([D1JK] + ik[D2JK])$ from the **QKK** matrix calculation (Output)

Application Calling Sequence:

None

Method:

The **AMP** module begins by querying the **CASE** relation and determining if any **GUST**, **BLAST** and/or **FLUTTER** cases exist. If any of these disciplines or options are selected, the **AMP** module proceeds to compute the requisite matrix lists. The **FLUTTER** bulk data and the **UNMK** data are prepared in core using the **PREFL** and **PRUNMK** utilities. As a separate step, the second record of the **UNMK** is queried to determine the number of aerodynamic interference groups in the model so that the structure of the aerodynamic matrices can be interpreted correctly. As a final initialization task, the existence of both subsonic and supersonic matrices is checked since the **D1JK** and **D2JK** matrices are different for subsonic and supersonic aerodynamics due to the different control point used.

The module then begins to loop through the set of m-k pairs in the **UNMK** entity. For each new Mach number/symmetry group (denoted by the **SGRP** flag), the **UNMK** and **CASE** relation data formed in **PRUNMK** is checked to determine which of the three discipline dependent matrix lists are to be formed for the reduced frequencies associated with the Mach number and symmetry group. If **FLUTTER** or **GUST**

disciplines are associated with the Mach/**SGRP** set, the corresponding **NJ** columns of **SKJ** are extracted from the **SKJ** list input in the calling sequence. Also, the **NJ** columns of **AJJTL** are extracted irrespective of the discipline options. Finally, if the **QKK** matrix is to be formed, the **D1JK** and **D2JK** are processed depending on the presence of both subsonic and supersonic forms. This processing consists of the extraction of the second **NK** columns of **D1JK** and **D2JK** on the first supersonic Mach number encountered. The appropriate matrices are then added together for the current reduced frequency as:

$$[DCJK] = [D1JK] + (0+ik)[D2JK]$$

At this point, the module is ready to deal with the **AJJT** matrix previously extracted. The processing of this matrix depends on the presence of different interference groups in the unsteady aerodynamics model. For the case with a single interference group, the extracted **AJJT** matrix is transposed and then decomposed. If the **QKK** matrix is required, the following matrix is formed using the **GFBS** utility:

$$[SCRDC] = [AJJ]^{-1}[DCJK]$$

If either the **QJJ** or **QJK** matrices are needed, the actual inverse of **AJJ** is formed and stored as **QJJ**. If the **QJK** matrix is needed as well, the **QJJ** matrix is used to form the **QJK** matrix as:

$$[QJK] = [SKJ][QJJ]$$

If there is more than one interference group, the alternate path is used to obtain the **SCRDC**, **QJJ** and/or **QJK** matrices. In this path, a loop is performed for each interference group. The second record of the **UNMK** entity is used to determine the number of j-set and k-set degrees of freedom in the current interference group. These are used to generate the **PRTJ** partitioning vector for the **AJJ** matrix. This vector acts as a floating **NJG**-sized vector to extract the **NJG** columns and rows associated with the current group. The **AJJT** matrix is then partitioned, transposed and decomposed to form **AJJG**. If the **QKK** matrix is needed, the **PRTK** partitioning vector is also required. This vector is a floating **NKG**-sized vector to extract the **NKG** columns or rows for the current interference group. The **DCJK** matrix is then partitioned for the current group and used as follows:

$$[AJJDCG] = [AJJG]^{-1}[DCJKG]$$

The **INMAT** utility is then used to merge this matrix into the **SCRDC** matrix using the interference group partitioning information. As before, if the **QJJ** or **QJK** matrices are needed, the **AJJG** matrix is inverted and stored as **QJJG**. The **INMAT** utility merges this matrix into the **QJJ** matrix. At the conclusion of the interference group loop, the **SCRDC** and **QJJ** matrices are complete. At this point, the logic recombines for both paths. If the **QKK** matrix is needed, the **SCRDC** matrix is used to compute **QKK** as:

$$[QKK] = [SKJ][SCRDC]$$

which is then appended onto the list of **QKK** matrices, **QKKL**. If the **QJK** matrix is needed, the **QJJ** matrix is used to comput **QJK** as:

$$[QJK] = [SKJ][QJJ]$$

which is then appended onto the list of **QJK** matrices, **QJKL**. Finally, the computed **QJJ** matrix is appended to the **QJJL** matrix list if it is required for this m-k/**SGRP** matrix. The module then continues with the next m-k/**SGRP** matrix in the **UNMK** entity. Note that all the matrix lists are formed in the order the m-k/**SGRP** data appear in the **UNMK**, although each list need not have all sets. Once the entire set of mk/**SGRP** sets in the **UNMK** have been processed, the module terminates by destroying the numerous scratch matrices used in the computations.

Design Requirements:

1. The **FLUTTER** bulk data entries and the **CASE** relation are used to determine the set of m-k/symmetry pairs for each aerodynamic matrices required for each discipline. The data on the database will be used to determine the set of matrices to be computed.

Error Conditions:

None

Engineering Application Module: ANALINIT

Entry Point: ANINIT

Purpose:

Initializes the final analysis pass. This module should be called at the beginning of the final analysis loop to set parameters as needed for that pass.

MAPOL Calling Sequence:

```
CALL ANALINIT;
```

Application Calling Sequence:

None

Method:

This module is called to perform any actions needed to transition from the optimization segment of ASTROS to the analysis segment. Currently, the only action taken by the module is to overwrite the portion of the **SUBTITLE** that is used to denote the design iteration number (set in **ITERINIT**) with the label **"FINAL ANALYSIS SEGMENT."**

Design Requirements:

1. This routine overwrites the characters 88-128 of the **SUBTIT** variable in **/OUTPT2/** used by **UTPAGE**. No other application modules except **OFP** should modify the **TITLE**, **SUBTIT**, **LABEL** variables beyond the 72nd character, since these fields are used to set dates, page numbers and subcase information.

Error Conditions:

None

Engineering Application Module: APFLUSH

Entry Point: APFLUSH

Purpose:

Flushs user function related intrinsic response and response gradient entities which are design iteration dependent. This module should be called at the beginning of each design iteration.

MAPOL Calling Sequence:

```
CALL APFLUSH;
```

Application Calling Sequence:

None

Method:

This module must be called at the top of each design iteration loop. It checks the existence of all design iteration dependent relational and matrix entities containing response functions and their gradients, and flushes any that exist.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: AROSNSDR

Entry Point: AROSDR

Purpose:

MAPOL director for saero sensitivity analyses

MAPOL Calling Sequence:

```
CALL AROSNSDR ( NITER, BCID, SUB, NDV, LOOP, MINDEX, CONST, SYM, NGDR,
                [PGDRG(BC)], [UAG(BC)], [AAG(BC)], ACTUAG, [UGA], [AGA],
                [PGAA], [PGAU], PCAA, PRAA, [UAGC(BC,SUB)], [AAGC(BC,SUB)],
                ACTAEFF, [AUAGC], [AAAGC], PCAE );
```

NITER	Current iteration number (Input, Integer)
BCID	User defined boundary condition identification number (Integer, Input)
SUB	Current static aeroelastic subscript number (Input, Integer)
NDV	Number of deisgn variables (Input, Integer)
LOOP	A logical flag set to indicate whether additional **MINDEX** subscripts are needed to complete the processing of all the active Mach number/Symmetry conditions on all the **TRIM** entries. One pass for each unique active Mach number will be performed with **MINDEX** set as appropriate for the active pass until this routine returns **LOOP=FALSE** (Logical, Output)
MINDEX	Mach number index value of the current pass (Output, Integer)
CONST	Relation of design constraints (Input)
SYM	Symmetry flag for the current pass. Either 1 for symmetric or -1 for antisymmetric (Output, Integer)
NGDR	Denotes dynamic reduction in the boundary condition (Input, Integer) **0** No **GDR** **–1** **GDR** is used
[PGDRG(BC)]	A partitioning vector that removes the additional **GDR** scalar points from the g-set sized displacement and acceleration vectors. Required only if **NGDR** ≠ **0** (Input), where **BC** represents the MAPOL boundary condition loop index number
[UAG(BC)]	g-set displacement vector for all static aero subcases in the current boundary condition (Input), where **BC** represents the MAPOL boundary condition loop index number
[AAG(BC)]	g-set acceleration vector for all static aero subcases in the current boundary condition (Input), where **BC** represents the MAPOL boundary condition loop index number
ACTUAG	Logical flag that is set to **TRUE** if there are any active constraints that require the displacements or accelerations. Those constraints are trim parameters, stresses, strains and displacements (Output, Logical)

[UGA]	Reduced g-set active displacement vectors for all static aero subcases that have active trim parameter, stress, strain and/or displacement constraints. This is a subset of the columns of **[UAG(BC)]** and does not include the **GDR** scalar points, if any (Output)
[AGA]	Reduced g-set active acceleration vectors for all static aero subcases that have active trim parameter, stress, strain and/or displacement constraints. This is a subset of the columns of **[AAG(BC)]** and does not include the **GDR** scalar points, if any (Output)
[PGAA]	Partitioning vector used to obtain **[UGA]** and **[AGA]** from **[UAG(BC)]** and **[AAG(BC)]** (Output)
[PGAU]	Partitioning vector relative to **[UAG(BC)]** and **[AAG(BC)]** that marks the displacement/acceleration columns associated with subcases having active stress, strain or displacement constraints. This vector will be identical to [**PGAA**] unless there are subcases in which **DCONTRM** constraints are active and no stress, strain or displacement constraints are active (Output)
PCAA	An unstructured entity with one word for each active stress, strain or displacement constraint in the current subscript related subcases. That word is the subcase number associated with the constraint (Output)
PRAA	An unstructured entity with one word for each element stress, strain or displacement response function required by the active user function constraints in the current subscript related subcases. That word is the subcase number associated with the response (Character,Output)
[UAGC(BC,SUB)]	g-set pseudodisplacement vectors (displacement fields due to loads arising from unit values of trim configuration parameters) for all aeroelastic effectiveness constraints (Input), where **BC** represents the MAPOL boundary condition loop index number
[AAGC(BC,SUB)]	g-set pseudoacceleration vectors (acceleration fields due to loads arising from unit values of trim configuration parameters) for all aeroelastic effectiveness constraints (Input), where **BC** represents the MAPOL boundary condition loop index number
ACTAEFF	Logical flag that is set to **TRUE** if there are any active constraints that require the pseudodisplacements or pseudoaccelerations. Those constraints are **DCONALE**, **DCONCLA** and **DCONSCF** (Output, Logical)
[AUAGC]	Reduced g-set active pseudodisplacement vectors for all active effectiveness constraints. This is a subset of the columns of **[UAGC(BC)]** and does not include the **GDR** scalar points, if any (Output)
[AAAGC]	Reduced g-set active pseudoacceleration vectors for all active effectiveness constraints. This is a subset of the columns of **[AAGC(BC)]** and does not include the **GDR** scalar points, if any (Output)
PCAE	An unstructured entity with one word for each active effectiveness constraint (**DCONALE**, **DCONCLA**, **DCONSCF**) in the current subscript's related subcases. That word is the column id of the first column associated with the constraint (Output)

Application Calling Sequence:

None

Method:

This module treats two distinct families of aeroelastic constraints for the current boundary condition and subscript number: the active aeroelastic effectiveness constraints **DCONALE**, **DCONCLA** and **DCONSCF**; and the active displacement dependent constraints **DCONTRM**, **DCONDSP,** stress and strain. Two parallel sets of partitioning operations take place to extract the active pseudodisplacements needed for effectiveness constraints and active displacements needed for the displacement-dependent constraints. The control information for the presence or absence of each type of constraint and the additional control information to extract data from downstream entities is also prepared for each constraint family. Finally, the need to loop through another subscript value is determined and the **LOOP** variable is output. **LOOP** will be false after the last needed **AROSNSDR** call for the current **BC**.

First **CASE** is queried to obtain the **TRIM** identification number and symmetry. Then **TRIM** is read to obtain the subscript numbers, **MINDEX** values and subcase ids for each **SAERO** subcase in the current **BC**. These data are then assembled into a master table containing the trim identification number, the subscript number and the subcase id.

The **CONST** relation is then read to count the number of active stress, strain, displacement, aileron effectiveness, lift effectiveness, stability coefficient and trim parameter constraints. A loop over each **CONST** entry is then made to assemble the partitioning vectors and control information for sensitivity computations. Each family of constraints is treated separately.

For effectiveness constraints, the **DISPCOL** attribute in **CONST** is used to build a partitioning vector for the active pseudodisplacements and accelerations. The partitioning vector is later destroyed but the active column numbers are stored as a contiguous string of numbers and written to **PCAE**. For lift effectiveness constraints there is one **UAGC/AAGC** column for each applied constraint: the disp/accel. due to a unit angle of attack. For aileron effectiveness, there are two columns: the first due to unit control surface deflection and the second due to unit roll rate. For stability coefficients, there is one column due to a unit deflection of the constrained parameter. As the constraints are looped over, only those with the current subscript value are considered. Those with lower subscript values have already been processed and, if any active constraints are found with a higher subscript value, the **LOOP** flag is set to **TRUE** to ensure another pass is done.

A similar path exists for the displacement-dependent constraints except the matrices being partitioned are the actual displacement and acceleration fields. Separate partitioning vectors are assembled for 1) active columns due to all displacement dependent constraints (**PGAA**) and 2) active columns due to stress, strain and displacement constraints (**PGUA**). Again, previously processed subscripts are ignored and **LOOP** is set to true if larger subscripts are encountered.

Finally, the assembled partitioning vectors are written to their respective entities and the **PCAE** and **PCAA** entities are determined from the partitioning data and written to the unstructured entities. The presence of active constraints in the effectiveness family or displacement-dependent family is then known and the **ACTAEFF** and **ACTUAG** flags, respectively, are set.

The element stress and strain responses; displacement responses; aeroelastic flexible stability coeffcient responses; and trim parameter responses which are required by active user functional constraints at the current boundary condition and subscript number are treated in the similar manner as those corresponding constraints. The subcases which have active displacement or element stress/strain response functions are also defined as active. The partitioning vector, **PGAA**, and the set of subcase numbers that are active, **PRAA**, are loaded if necessary. The **ACTAEFF** and **ACTUAG** flags are also set for active responses.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: AROSNSMR

Entry Point: AROSMR

Purpose:

Merges the static aero sensitivities for each subscript (stored in the matrix **[MATSUB]**) into the **[MATOUT]** matrix in case order for active subcases rather than subscript order for the current active boundary condition.

MAPOL Calling Sequence:

```
CALL AROSNSMR ( BCID, SUB, NDV, [PGAA], [PGAU], [MATOUT], [MATSUB] );
```

BCID	User defined boundary condition identification number (Integer, Input)
SUB	Current static aeroelastic subscript number (Input, Integer)
NDV	Number of design variables (Input,Integer)
[PGAA]	Partitioning vector used denoting active displacement fields for the current boundary's static aeroelastic subcases (Input)
[PGAU]	Partitioning vector used denoting active displacement fields that are active due only to stress, strain and displacement constraints for the current boundary's static aeroelastic subcases (Input)
[MATOUT]	On input, **MATOUT** must contain the merged, reordered displacement or acceleration sensitivities for all the subcases processed for the earlier subscript values. On output the **SUB**'th subscript is included. This matrix will contain one column for each active vector for the 1st design variable, followed by another set for the second and so on. The order of the vectors within each variable's set will be the order of the **SAERO** subcases in the **CASE** relation (Input and Output)
[MATSUB]	The input matrix of displacement or acceleration sensitivities for all the subcases processed for the **SUB**'th subscript. This matrix will contain one column for each active vector associated with the **SUB**'th subscript for the 1st design variable, followed by another set for the second and so on. The order of the vectors within each variable's set will be the order of the **TRIM** ids appearing in the **TRIM** relation associated with the **SUB**'th subscript value (Input)

Application Calling Sequence:

None

Method:

First the **CASE** relation is read to retrieve the trim id's for the **SAERO** subcases in the current boundary condition. The the **TRIM** relation is read to obtain the subcase numbers associated with each trim id having the current **SUB**script value. Then the **PGAA** and **PGUA** vectors are read into memory to assist in the partitioning operation.

Then the **MATSUB** and **MATOUT** matrices are opened. If **MATOUT** is uninitialized ***or*** if **SUB = 1**, it is initialized (flushed and the number of rows, precision and form set to those of **MATSUB**. If **MATOUT** already exists and has data in it, a scratch matrix is created to hold the final merged data.

For each design variable in the model, each **SAERO CASE** entry for the current boundary is processed. For each **CASE** entry, the partitioning vector **PGAA** is used to determine if it is active and therefore ***may***

have a column in either **MATSUB** or **MATOUT**. For the active subcase id, the **TRIM** data are searched to determine the subscript number associated with the subcase. If the subscript is less than **SUB**, a column from **MATOUT** may be taken (if it was stored there on an earlier pass). If the subscript is equal to **SUB**, it may be stored on the output matrix from **MATSUB**. If greater than **SUB**, it is ignored till later passes.

Once a column is identified as active in **MATSUB** (**PGAA** indicates active and subscript = **SUB**), an additional check is made to see if the column is active in **PGUA**. Only those columns that are active in **PGUA** are copied to **MATOUT**. This filtering is done to limit the amount of computational effort in the stress, strain and displacement constraint sensitivity computations that proceed using the **MATOUT** matrix. The **MATSUB** columns that are active due to **DCONTRM** constraints are no longer needed as these sensitivities are assumed to have been computed already in the **AEROSENS** module.

Once the final matrix is formed, if **MATOUT** had had data in it, the name of the scratch matrix that was loaded is switched with that of **MATOUT**. The scratch entity is then destroyed.

Design Requirements:

1. The assumption is that each **MATSUB** matrix contains the results from the "**SUB**"th subscript value in the order of the trim id's for that **SUB** appear in the **TRIM** relation.

2. The same **MATOUT** matrix must be passed into the **AROSNSMR** module on each call since the columns associated with earlier subscript values are read from **MATOUT** into a scratch entity. The merged matrix that results then replaces the input **MATOUT**.

3. The **AEROSENS** module is called upstream of the **AROSNSMR** module to process active **DCONTRM** constraints for the current subscript. Thus, those columns that are active only for **DCONTRM** constraints may be filtered out for the downstream processing of stress, strain and displacement constraints.

Error Conditions:

None

Engineering Application Module: BCBGPDT

Entry Point: BCBGPD

Purpose:

Builds the boundary condition-dependent grid point coordinate relation **BGPDT** for the specified boundary condition.

MAPOL Calling Sequence:

```
CALL BCBGPDT ( BCID, GSIZEB, BGPDT(BC), ESIZE(BC) );
```

BCID	User defined boundary condition identification number (Integer, Input)
GSIZEB	Basic g-set size (the size independent of **GDR**-added scalar points) (Integer, Input)
BGPDT(BC)	Relation of basic grid point data for the boundary condition (including any extra points but excluding **GDR** scalar points which may be added by the **GDR** module) (Output), where **BC** represents the MAPOL boundary condition loop index number
ESIZE(BC)	Number of extra point DOF defined for the boundary condition (Integer, Output), where **BC** represents the MAPOL boundary condition loop index number

Application Calling Sequence:

None

Method:

The invarient basic grid point data is read from the **BGPDT** relation (an unsubscripted relation that is formed in **IFP**). The user's extra points selected in the **CASE** relation are then appended in memory and sorted on external id. Uniqueness of the external id's are checked and the new **BGPDT(BC)** is written.

Design Requirements:

1. The invariant **BGPDT** must exist on the data base. It is a hidden output from the **IFP** module.

Error Conditions:

1. Nonunique **GRID/EPOINT** id's are flagged.

Engineering Application Module: BCBULK

Entry Point: BCBULK

Purpose:

Builds boundary condition-dependent matrices, transfer functions, and initial conditions.

MAPOL Calling Sequence:

```
CALL BCBULK ( BCID, PSIZE(BC), BGPDT(BC), USET(BC) );
```

BCID	User defined boundary condition identification number (Integer, Input)
PSIZE(BC)	The size of the physical set for the current boundary condition (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number
BGPDT(BC)	The relation of basic grid point data for the current **BC** (including any selected extra points) (Input), where **BC** represents the MAPOL boundary condition loop index number
USET(BC)	The unstructured entity of DOF masks for all the points in the current boundary conditions (Input), where **BC** represents the MAPOL boundary condition loop index number

Application Calling Sequence:

None

Method:

All the outputs from this routine are *hidden* — meaning that they do not appear in the call. The purpose of this module is to assemble those data that depend on the boundary condition selection of extra points.

For the data of each type that is referenced in **CASE** for the current boundary condition, the data are retrieved from the bulk data relations that were loaded in **IFP** and are error checked relative to the set of DOF that comprise the current boundary condition. The following hidden entities are output:

BULK DATA	SUBROUTINE	GENERATED ENTITY
DLONLY	PREDOL	UDLOLY
DMIG	PREDMG	named matrix entities
TF	PRETF	TFDATA
IC	PREIC	ICDATA

In each case, these entities contain only those data that relate to the current boundary condition. They will be replaced in subsequent boundary conditions and/or iterations with the appropriate data on each pass.

Design Requirements:

None.

Error Conditions:

1. Initial error checking of each bulk data entry type is performed within this module.

Engineering Application Module: BCEVAL

Entry Point: BCEVAL

Purpose:

Evaluates the current values of BAR element cross-sectional dimension relationship constraints.

MAPOL Calling Sequence:

```
CALL BCEVAL ( NITER, NDV, GLBDES, LOCLVAR, [PTRANS], CONST );
```

NITER	Design iteration number (Integer,Input)
NDV	Number of design variables (Integer,Input)
GLBDES	Relation of global design variables (Character,Input)
LOCLVAR	Relation containing the relationship between local variables and global variables in the design problem (Character,Input)
[PTRANS]	The design variable linking matrix (Character,Input)
CONST	Relation of constraint values (Character,Output)

Application Calling Sequence:

None

Method:

This module analyzes each designed BAR element which uses PBAR1 property Bulk Data to define its cross-sectional parameters. A set of cross-sectional parameter relationship constraints are computed based on the BAR element cross-sectional shape. Constraints for these relationships are formulated as follows:

"I" Shape:

G1 = (D3 + D4 - D2) / (2*DMAX) and
G2 = (D5 - D1) / DMAX; where **DMAX = MAX(D1,D2,D3,D4,D5)**

"T" Shape:

G1 = (D4 - D1) / DMAX and
G2 = (D3 - D2) / DMAX; where **DMAX = MAX(D1,D2,D3,D4)**

"BOX" Shape:

G1 = (2*D3 - D1) / (2*DMAX) and
G2 = (2*D3 - D2) / (2*DMAX); where **DMAX = MAX(D1,D2,D3)**

"TUBE" Shape:

G1 = (D2 - 0.5*D1) / DMAX; where **DMAX = MAX(D1,D2)**

"HAT" Shape:

G1 = (D3 - D1) / DMAX and
G2 = (2*D4 - D3) / (2*DMAX) and
G3 = (2*D4 + D5 - D2) / (3*DMAX); where **DMAX = MAX(D1,D2,D3,D4,D5)**

"GBOX" Shape:

G1 = (2*D5 + D6 - D1) / (3*DMAX)
G2 = (D3 + D4 - D2) / (2*DMAX); where **DMAX = MAX(D1,D2,D3,D4,D5,D6)**

Note that **D1**, **D2**, **D3**, **D4**, **D5**, and **D6** are **BAR** element cross-sectional parameters.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: BCIDVAL

Entry Point: BCIDVL

Purpose:

Converts the boundary condition index number (**BC**) into the boundary condition identification number (**BCID**).

MAPOL Calling Sequence:

```
CALL BCIDVAL ( BC, CASE, BCID );
```

BC	MAPOL boundary condition loop index number (Integer,Input)
CASE	Relation containing the case parameters for each subcases within each boundary condition (Character,Input)
BCID	User defined boundary condition identification number (Integer, Input)

Application Calling Sequence:

None

Method:

This module counts the boundary contion number through **CASE** entries and obtains the corresponding boundary condition identification number **BCID** from **CASE** for the input boundary condition index number **BC**.

Design Requirements:

None

Error Conditions:

BCID = -1 if relation **CASE** is nonexistent or empty.

Engineering Application Module: BOUND

Entry Point: BOUND

Purpose:

To return flags to the MAPOL sequence that define the matrix reduction path for the current boundary condition.

MAPOL Calling Sequence:

```
CALL BOUND ( BCID, GSIZE, ESIZE(BC), USET(BC), BLOAD, BMASS, DMODES, BMODES,
             BSAERO, BFLUTR, BDYN, BDRSP, BDTR, BMTR, BDFR, BMFR, BGUST,
             NMPC, NSPC, NOMIT, NRSET, NGDR, GPSP );
```

BCID	User defined boundary condition identification number (Integer, Input)
GSIZE	The number of degrees of freedom in the structural set (Integer, Input)
ESIZE(BC)	The number of extra point degrees of freedom in the boundary condition (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number
USET(BC)	The unstructured entity defining structural sets (Character, Input), where **BC** represents the MAPOL boundary condition loop index number
BLOAD	Static load flag; **=1** if any static loads in the current boundary condition (Integer, Output)
BMASS	Mass matrix flag; **=1** if the mass matrix is needed for any discipline(s) in the current boundary condition (Integer, Output)
DMODES	Modes discipline flag; **=1** if any modal dynamic response discipline(s) (Integer, Output)
BMODES	Modal analysis flag; **=1** if any disciplines in the current boundary condition require that a real eigenanalysis be performed (Integer, Output)
BSAERO	Static aeroelastic flag; **=1** if any static aeroelastic analyses are in the current boundary condition (Integer, Output)
BFLUTR	Flutter discipline flag; **=1** if any flutter analyses in the current boundary condition (Integer, Output)
BDYN	Dynamics flag; **=1** if any disciplines requiring dynamic matrix assembly are in the current boundary condition (Integer, Output)
BDRSP	Dynamic response flag; **=1** if any transient or frequency response analyses in the current boundary condition (Integer, Output)
BDTR	Direct Transient Response flag; **=1** if any direct transient response analyses are in the current boundary condition (Integer, Output)
BMTR	Modal Transient Response flag; **=1** if any modal transient response analyses are in the current boundary condition (Integer, Output)
BDFR	Direct Frequency Response flag; **=1** if any direct frequency response analyses are in the current boundary condition (Integer, Output)
BMFR	Modal Frequency Response flag; **=1** if any modal frequency response analyses are in the current boundary condition (Integer, Output)

BGUST	Gust option flag; **=1** if any dynamic response disciplines include the **GUST** option in the current boundary condition (Integer, Output)
NMPC	Number of degrees of freedom in the m-set, (Integer, Output)
NSPC	Number of degrees of freedom in the s-set, (Integer, Output)
NOMIT	Number of degrees of freedom in the o-set, (Integer, Output)
NRSET	Number of degrees of freedom in the r-set, (Integer, Output)
NGDR	Denotes dynamic reduction in the boundary condition. (Output, Integer) **0** No **GDR** **–1** **GDR** is used
GPSP	Flag controlling output (Integer, Input) **0** Standard output ≠**0** Update standard to show GPSP results

Application Calling Sequence:

None

Method:

The **USET** entity and **CASE** relation are read to determine the sizes of the dependent structural sets and to ensure that no illegal combinations of disciplines and matrix reduction methods reside in the same boundary condition. The matrix reductions and analysis steps in the standard MAPOL sequence are then guided by the flags from **BOUND**. A summary of the structural sets is printed to the output file followed by a summary of the disciplines and subcases that have been selected.

Design Requirements:

1. The **CASE** relation must be filled with the information from the Solution Control Packet by the **SOLUTION** module. Also, the **MKUSET** module must have loaded the **USET** entity.

Error Conditions:

None

Engineering Application Module: BOUNDUPD

Entry Point: BOUNDUPD

Purpose:

To echo the updated boundary condition summary.

MAPOL Calling Sequence:

```
CALL BOUNDUPD ( BCID, GSIZE, ESIZE(BC), USET(BC),NSPC, NOMIT, NRSET );
```

BCID	User defined boundary condition identification number (Integer, Input)
GSIZE	The number of degrees of freedom in the structural set (Integer, Input)
ESIZE(BC)	The number of extra point degrees of freedom in the boundary condition (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number.
USET(BC)	The unstructured entity defining structural sets (Character, Input), where **BC** represents the MAPOL boundary condition loop index number.
NSPC	Number of degrees of freedom in the s-set, (Integer, Output)
NOMIT	Number of degrees of freedom in the o-set, (Integer, Output)
NRSET	Number of degrees of freedom in the r-set, (Integer, Output)

Application Calling Sequence:

None

Method:

The **USET** entity and **CASE** relation are read to determine the sizes of the dependent structural sets and to ensure that no illegal combinations of disciplines and matrix reduction methods reside in the same boundary condition. The matrix reductions and analysis steps in the standard MAPOL sequence are then guided by the flags from **BOUND**. A summary of the structural sets is printed to the output file followed by a summary of the disciplines and subcases that have been selected.

Design Requirements:

1. The **CASE** relation must be filled with the information from the Solution Control Packet by the **SOLUTION** module. Also, the **MKUSET** module must have loaded the **USET** entity.

Error Conditions: None

Engineering Application Module: CONORDER

Entry Point: CONORD

Purpose:

Reorders active constraints in boundary condition order to match the order in which constraint sensitivities are computed.

MAPOL Calling Sequence:

```
CALL CONORDER ( NITER, NUMOPTBC, CASE, CONST, CONSTORD );
```

NITER	Design iteration number (Integer,Input)
NUMOPTBC	Number of optimization boundary conditions (Integer,Input)
CASE	Relation containing the case parameters for each subcases within each boundary condition (Character,Input)
CONST	Relation of constraint values (Character,Input)
CONSTORD	Relation of reordered constraint values (Character,Output)

Application Calling Sequence:

None

Method:

This module first gets boundary condition independent active constraints (thickness constraints, cross-sectional parameter constraints for BAR's, and laminate gauge constraints) from relation **CONST** and put them into the new relation **CONSTORD**. Then, for each optimization boundary condition, active frequency and flutter constraints are boundary condition dependent, but not subcase dependent, therefore they precede any subcase dependent constraints for the current boundary condition in relation **CONSTORD**. Thereafter: active STATICS displacement and stress/strain constraints are placed in subcase order; active SAERO aeroelastic effectiveness and stability coefficient constraints, trim parameter constraints are placed in subscript order; and active SAERO displacement and stress/strain constraints are placed in subcase order. Finally, active panel buckling constraints and Euler buckling constraints are placed in subcase order in relation **CONSTORD**.

Design Requirements:

Since the reordered constraint relation **CONSTORD** is required by module **OFPGRAD** and **DESIGN**, module **CONORDER** must be called prior to those modules and after module **ACTCON**. Module **CONORDER** must be placed at the outside of optimization boundary condition loop.

Error Conditions:

None

Engineering Application Module: DCEVAL

Entry Point: DCEVAL

Purpose:

To evaluate displacement constraints in the current boundary condition.

MAPOL Calling Sequence:

```
CALL DCEVAL ( NITER, BCID, [UG(BC)], BGPDT(BC), CONST, BSAERO );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
[UG(BC)]	Matrix of displacement vectors in the g-set for the boundary condition (Input), where **BC** represents the MAPOL boundary condition loop index number.
BGPDT(BC)	Relation of basic grid point coordinate data (Character, Input), where **BC** represents the MAPOL boundary condition loop index number.
CONST	Relation of constraint values (Character, Input)
BSAERO	Static aeroelastic flag; **=1** if this call is associated with static aeroelastic analyses. (Optional, Integer, Input)

Application Calling Sequence:

None

Method:

The module first determines if there are any **DCONST** options for a **STATIC** (**BSAERO=0**) or **SAERO** (**BSAERO=1**) discipline for the current boundary condition and terminates if there are none. If there are, a loop is made through all the subcases for the current boundary condition and the necessary displacement constraint(s) are calculated and written to the **CONST** relation. Finally, the displacement responses which are required by any user functional constraints are computed.

Design Requirements:

1. This module appears within the analysis portion of the **OPTIMIZE** segment of the MAPOL sequence. It is within the analysis boundary condition loop and must follow the recovery of the displacement vector to the g-set.

Error Conditions:

None

Engineering Application Module: DDLOAD

Entry Point: DDLOAD

Purpose:

To compute the sensitivities of design dependent loads for active boundary conditions.

MAPOL Calling Sequence:

```
CALL DDLOAD ( NDV, GSIZEB, BCID, SMPLOD, [DPTHVI], [DPGRVI], [DDPTHV],
              [DDPGRV], DDFLG, [PGAS], [DPVJ] );
```

NDV	The number of global design variables (Integer, Input)
GSIZEB	The size of the structural set (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
SMPLOD	Unstructured entity of simple load vector information (Input)
[DPTHVI]	Matrix entity containing the linearly designed thermal loads (Character, Input)
[DPGRVI]	Matrix entity containing the linearly designed gravity loads (Character, Input)
[DDPTHV]	Matrix entity containing the nonlinear thermal load sensitivity (Character, Input)
[DDPGRV]	Matrix entity containing the nonlinear gravity load sensitivity (Character, Input)
DDFLG	Design dependent load flag: (Integer, Output) **0** if no design dependent loads **1** if any static loads are design dependent
[PGAS]	Matrix entity containing a partitioning vector of active applied static load conditions (Input)
[DPVJ]	Matrix entity containing the senstivities of each active static load to the design variables (Output)

Application Calling Sequence:

None

Method:

The module first determines if there are any static loads and if any of the applied static loads are potentially design dependent. This is done by reading the **SMPLOD** entity and checking if any gravity or thermal loads are defined. If any design dependent applied loads are found, the module continues by reading the remainder of the first **SMPLOD** record, the **CASE** relation for all **STATICS** disciplines in the current active boundary condition and all the **LOAD** relational tuples. Finally, the **PGA** vector is brought into core to allow the active loads to be identified. Once all the data are in core, the **PGA** data are used to identify the active static loads. For each active load, the **CASE** relation is searched to determine if any of the simple loads comprising the current active load are design dependent. This involves the **LOAD** relational data for **MECH** loads since the **LOAD** data may refer to **GRAV** loads which are design dependent. If any design dependent loads are found, their sensitivities are computed using the **DPGRVI**, **DDPGRV**, **DPTHVI** and/or **DDPTHV** matrix entities of simple load sensitivities. The **DPVJ** entity is loaded as active design

dependent loads are encountered with care taken that ***all*** active loads (including design independent loads) are accounted for in the column dimension of the matrix entity.

Design Requirements:

1. This module must be called to initialize the **DDFLG** flag that is used by the MAPOL sequence to direct subsequent matrix operations relating to the load sensitivities even if no design dependent loads exist in the boundary condition.

2. The module assumes that at least one active static applied load exists in the current boundary condition.

Error Conditions:

None

Engineering Application Module: DESIGN

Entry Point: DESIGN

Purpose:

To perform redesign by math programming methods based on the current set of active constraints and constraint sensitivities.

MAPOL Calling Sequence:

```
CALL DESIGN ( NITER, NDV, APPCNVRG, CNVRGLIM, CTL, CTLMIN,
              GLBDES, CONST, CONSTORD, [AMAT], DESHIST );
```

NITER	Design iteration number (Integer, Input)
NDV	The number of design variables (Integer, Input)
APPCNVRG	The approximate problem converge flag (Logical, Output) **FALSE** if not converged **TRUE** if converged in objective function value
CNVRGLIM	Tolerance for indicating approximate problem convergence (Real, Input)
CTL	Tolerance for indicating an active constraint (Real, Output)
CTLMIN	Tolerance for indicating a violated constraint (Real, Output)
GLBDES	Relation of global design variables (Character, Input)
CONST	Relation of constraint values (Character, Input)
CONSTORD	Relation of reordered constraint values (Character, Input)
[AMAT]	Matrix of constraint sensitivities (Input)
DESHIST	Relation of design iteration information (Character, Output)

Application Calling Sequence:

None

Method:

The module first brings design variable, objective, constraint, objective sensitivity and constraint sensitivity information into core. Calls to **ADS** then invoke the mathmatical programming algorithm which performs the redesign task. Function evaluations and gradient evaluations that are required as part of the math programming task are performed by subroutines **FEVAL** and **GREVAL**, respectively.

For a user defined objective function and user function constraints, all required response functions and their sensitivities are computed prior to this module. This module computes user function values and sensitivities by calling the user function evaluation utilities in subroutines **FEVAL** and **GREVAL**, respectively.

Once the appoximate optimizaton process is complete, the **GLBDES** relation is updated with the new values of the design variables and a new entry is written to the **DESHIST** relation.

Design Requirements:

1. This module is called after all the analysis and gradient information has been computed for a design iteration. It is therefore the last module within the design iteration loop.

Error Conditions:

1. The module does not have sufficient memory available.

Engineering Application Module: DESPUNCH

Entry Point: DESPCH

Purpose:

Punchs out the new Bulk Data cards with property values representing the current design model. The activation of this module depends on the **PUNCH** input.

MAPOL Calling Sequence:

```
CALL DESPUNCH ( NITER, PUNCH, OLOCALDV ) ;
```

NITER	Current design iteration number (Integer, Input)
PUNCH	Logical flag indicating that the user has requested the new model be punched (Logical, Input)
OLOCALDV	Relation of current local design variable values (Input)

Application Calling Sequence:

None

Method:

This module works in conjunction with the **IFP** module and the **ACTCON** module. **IFP** stores the design invariant bulk data and the design variant bulk data as a series of data base entities that are read here. The **ACTCON** module actually computes the current local design variable values and loads them in the **OLOCALDV** relation. It also sets the **PUNCH** logical flag if punched output has been requested for the current design iteration.

If the **PUNCH** flag is true, the data in the **OLOCALDV** relation are looped over and the new property and/or connectivity bulk data entries are punched to the ASTROS punch file.

Design Requirements:

1. **IFP** must have been called to store the bulk data deck for punch requests.

2. **ACTCON** must have been called during the current iteration to load the **OLOCALDV** relation.

Error Conditions:

None

Engineering Application Module: DMA

Entry Point: DMA

Purpose:

To assemble the direct and/or modal stiffness, mass and/or damping matrices including extra point degrees of freedom for transient, frequency and blast disciplines.

MAPOL Calling Sequence:

```
CALL DMA ( NITER, BCID, ESIZE(BC), PSIZE(BC), BGPDT(BC), USET(BC), [MAA],
           [KAA], [TMN(BC)], [GSUBO(BC)], NGDR, LAMBDA, [PHIA], [MDD], [BDD],
           [KDDT], [KDDF], [MHH], [BHH], [KHHT], [KHHF]);
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
ESIZE(BC)	The number of extra point degrees of freedom in the boundary condition (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number.
PSIZE(BC)	The size of the physical set for the current boundary condition. (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number.
BGPDT(BC)	Relation of basic grid point coordinate data (Character, Input), where **BC** represents the MAPOL boundary condition loop index number.
USET(BC)	The unstructured entity defining structural sets (Character, Input), where **BC** represents the MAPOL boundary condition loop index number.
[MAA]	Matrix entity containing the mass matrix in the analysis set (Input)
[KAA]	Matrix entity containing the stiffness matrix in the analysis set (Input)
[TMN(BC)]	Transformation matrix for multipoint constraints (Input), where **BC** represents the MAPOL boundary condition loop index number.
[GSUBO(BC)]	Transformation matrix for reduction to the analysis set (Input), where **BC** represents the MAPOL boundary condition loop index number.
NGDR	Denotes dynamic reduction in the boundary condition. (Input, Integer) **0** No **GDR** **-1** **GDR** is used
LAMBDA	Relational entity containing the output from the real eigenanalysis (Input)
[PHIA]	Matrix of eigenvectors from the real eigenanalysis in the analysis set (Input)
[MDD]	Direct dynamic mass matrix (Output)
[BDD]	Direct dynamic damping matrix (Output)
[KDDT]	Direct transient stiffness matrix (Output)
[KDDF]	Direct frequency stiffness matrix (Output)
[MHH]	Modal dynamic mass matrix (Output)

[BHH]	Modal dynamic damping matrix (Output)
[KHHT]	Modal transient stiffness matrix (Output)
[KHHF]	Modal frequency/flutter stiffness matrix (Output)

Application Calling Sequence:

None

Method:

The module begins by retrieving all the **CASE** tuples for **TRANSIENT**, **FREQUENCY** or **BLAST** disciplines for the current boundary condition. If any dynamic matrix assembly is required, the **BGPDT** data is also retrieved and the number of extra points in the current boundary condition is determined and the **PSIZE** variable set to be the size of the physical set. Continuing with the module initialization, the **DMAPVC** submodule is called to generate all the partitioning vectors for the dynamic degrees of freedom including the extra points. If there are extra points, the module proceeds to expand the analysis set structural matrices, mode shapes and transformation matrices to include the extra point degrees of freedom. This is done in the **DMAEXP** submodule.

Next, the **DMAX2** submodule is called to assemble any direct matrix input. These include **M2PP**, **B2PP** and **K2PP** inputs as well as transfer function data. The **DMAX2** submodule forms the zeroth, first and second order inputs in the direct dynamic degrees of freedom. The modal form is obtained during the actual dynamic matrix assembly.

The module then proceeds to obtain the information needed to assemble the damping matrix. The **DAMPING** attribute of the **CASE** relation is checked and the **VSDAMP** and **TABDMP** entries are searched for a matching identification number. Logical flags are set to indicate that damping, modal damping and/or direct damping are to be used. If modal damping is selected, the **LAMBDA** relation is read to obtain the natural frequencies for the computed modes. As a final initialization task, the **DMA** module prepares the data needed to generate the d-sized hidden matrix entity **ICMATRIX** used to perform direct transient analysis. The **ICDATA** information is brought into open core and the p-sized scratch matrix to be reduced to **ICMATRIX** is created.

Once these initialization tasks have been completed, the loop to form the direct and/or modal dynamic matrices begins. The **CASE** relation tuples for the dynamic disciplines are searched sequentially and the requisite matrices formed. Note that the restrictions in the definition of a boundary condition make it such that only one form of each matrix is possible. The **DMA** module forms up to eight matrices: **[MDD]**, **[BDD]**, **[KDDF]**, **[MHH]**, **[BHH]**, **[KDDT]**, **[KHHF]**, and **[KHHT]** depending on the requested disciplines and discipline options. The **INFO** arrays for the matrices are used to store flags denoting coupled or uncoupled matrices and the form of the damping used in the modal stiffness and/or damping matrices. When all the **CASE** tuples have been searched and the required dynamic matrices formed, the module begins the cleanup. The first task is to complete the generation of the initial conditions matrix by reducing the scratch p-sized matrix to the direct dynamic set. Following this action, the other scratch matrices used in the module are destroyed and control returned to the executive.

Design Requirements:

1. The **PFBULK** module must have been called to perform the preprocessing for the initial conditions, transfer functions, and direct matrix input.

Error Conditions:

None

Engineering Application Module: DVMOVLIM

Entry Point: DVMOVL

Purpose:

To determine the current design variable bound based on a user-supplied move limit.

MAPOL Calling Sequence:

```
CALL DVMOVLIM ( NITER, NDV, GLBDES, MOVLIM ) ;
```

NITER	Current design iteration number (Integer, Input)
NDV	Number of design variables (Integer, Input)
GLBDES	Relation of current global design variable values (Character, Input and Output)
MOVLIM	User-supplied design variable move limit (Real, Input)

Application Calling Sequence:

None

Method:

Relation **GLBDES** entries are processed to obtain each design variablevalue, and their allowed minima and maxima. From the user-specified move limits, the current design variable bounds are determined, and the attributes **VMINCRNT** and **VMAXCRNT** of Relation **GLBDES** are updated with these values. Move limits are not applied to global variables with shape function linking.

Design Requirements:

None.

Error Conditions:

None

Engineering Application Module: DYNLOAD

Entry Point: DYNLOD

Purpose:

To assemble the direct and/or modal time and/or frequency dependent loads including extra point degrees of freedom for dynamic response disciplines.

MAPOL Calling Sequence:

```
CALL DYNLOAD ( NITER, BCID, GSIZE, ESIZE(BC), PSIZE(BC), SMPLOD, BGPDT(BC),
               USET(BC), [TMN(BC)], [GSUBO(BC)], NGDR, [PHIA], [QHJL], [PDT],
               [PDF], [PTGLOAD], [PTHLOAD], [PFGLOAD], [PFHLOAD] );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
GSIZE	Length of the g-set vector (Integer, Input)
ESIZE(BC)	The number of extra point degrees of freedom in the boundary condition (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number.
PSIZE(BC)	The size of the physical set for the current boundary condition. (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number.
SMPLOD	Unstructured entity of simple load vector information (Input)
BGPDT(BC)	Relation of basic grid point coordinate data (Input), where **BC** represents the MAPOL boundary condition loop index number.
USET(BC)	The unstructured entity defining structural sets (Input), where **BC** represents the MAPOL boundary condition loop index number.
[TMN(BC)]	Matrix for reducing **MPC**s (Input), where **BC** represents the MAPOL boundary condition loop index number.
[GSUBO(BC)]	Matrix for reducing omitted DOF (Input), where **BC** represents the MAPOL boundary condition loop index number.
NGDR	Denotes dynamic reduction in the boundary condition. **0** No **GDR** **-1** **GDR** is used (Input, Integer)
[PHIA]	Natural modes matrix in the a-set (Input)
[QHJL]	Aerodynamic matrix for gust (Input)
[PDT]	Dynamic load vector for transient analysis (Input)
[PDF]	Dynamic load vector for frequency analysis (Input)
[PTGLOAD]	Applied load matrix for the time dependent loads when **LOAD** print is requested (Character, Output)
[PTHLOAD]	Applied load matrix for the time dependent loads when **MODAL GUST** print is requested (Character, Output)

[PFGLOAD] Applied load matrix for the frequency dependent loads when **LOAD** print is requested (Character, Output)

[PFHLOAD] Applied load matrix for the frequency dependent loads when **MODAL GUST** print is requested (Character, Output)

Application Calling Sequence:

None

Method:

The module first interrogates the **CASE** relation to see whether any dynamic analyses are to be performed for the current boundary condition. If not, the module terminates. Error checking is performed to make sure legal requests have been made and bookkeeping is performed to set up for matrix reductions and extra points. Call(s) are then made to **DMAPG** to generate the applied loads in the p-set. **DMAPG** reduces these loads to the d-or h-set, depending on the approach. Separate routines generate loads in the frequency and time domains.

Design Requirements:

1. Follows computation of quantities in the a-set. If the **MODAL** approach is being used, the natural mode shapes must be computed.

Error Conditions:

1. No more than one frequency and/or transient load is allowed per boundary condition.

Engineering Application Module: DYNRSP

Entry Point: DYNRSP

Purpose:

To compute the direct or modal displacements, velocities and accelerations for transient and frequency analyses.

MAPOL Calling Sequence:

```
CALL DYNRSP ( BCID, ESIZE(BC), [MDD], [BDD], [KDDT], [KDDF], [MHH], [BHH],
              [KHHT], [KHHF], [PDT], [PDF], [QHHL], [UTRANA], [UFREQA],
              [UTRANI], [UFREQI], [UTRANE], [UFREQE] );
```

BCID	User defined boundary condition identification number (Integer, Input)
ESIZE(BC)	The number of extra point degrees of freedom in the boundary condition (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number.
[MDD]	Mass matrix in the d-set (Input)
[BDD]	Damping matrix in the d-set (Input)
[KDDT]	Stiffness matrix in the d-set for transient analyses (Input)
[KDDF]	Stiffness matrix in the d-set for frequency analyses (Input)
[MHH]	Modal mass matrix (Input)
[BHH]	Modal damping matrix (Input)
[KHHT]	Modal stiffness matrix for transient analyses (Input)
[KHHF]	Modal stiffness matrix for frequency analyses (Input)
[PDT]	Matrix of applied loads for transient analysis (Input)
[PDF]	Matrix of applied loads for frequency analysis (Input)
[QHHL]	Generalized aerodynamic forces for gust analyses (Input)
[UTRANA]	Transient response vectors in the a-set (Output)
[UFREQA]	Frequency response vectors in the a-set (Output)
[UTRANI]	Transient response vectors in the i-set (Output)
[UFREQI]	Frequency response vectors in the i-set (Output)
[UTRANE]	Transient response vectors in the e-set (Output)
[UFREQE]	Frequency response vectors in the e-set (Output)

Application Calling Sequence:

None

Method:

The module first interrogates the **CASE** relation to see whether any dynamic analyses are to be performed for the current boundary condition. If not, the module terminates. Bookkeeping is performed to set up for any gust analyses and to process extra points. A loop on the number of cases with dynamic response requirements for the current boundary condition is then made. Time or frequency points at which the response is required are established and the required analyses are performed. Separate subroutines control the performance of requested analyses:

ROUTINES	PURPOSE
TRUNCS/D	Uncoupled transient analysis
TRCOUP	Coupled transient analysis
FRUNCS/D	Uncoupled frequency analysis
FRCOUP	Coupled frequency analysis
FRGUST	Frequency response with gust

These routines fill output vectors with response quantities (displacement, velocity and acceleration). If there are extra points, a partitioning operation is performed to segregate extra point data into separate matrix entities.

Design Requirements:

1. Modules **DMA** and **DYNLOAD** prepare matrix quantities that are required for this module. If a gust analysis is being performed, module **QHHLGEN** must have been processed as well.

Error Conditions:

None

Engineering Application Module: EBKLEVAL

Entry Point: EBKEVA

Purpose:

Evaluates the current values of the Euler buckling constraints.

MAPOL Calling Sequence:

```
CALL EBKLEVAL ( BCID, NITER, NDV, GLBDES, LOCLVAR, [PTRANS], CONST,
                FDSTEP, OEULBUCK );
```

BCID	User defined boundary condition identification number (Integer, Input)
NITER	Design iteration number (Integer,Input)
NDV	Number of design variables (Integer,Input)
GLBDES	Relation of global design variables (Character,Input)
LOCLVAR	Relation containing the relationship between local variables and global variables in the design problem (Character,Input)
[PTRANS]	The design variable linking matrix (Character,Input)
CONST	Relation of constraint values (Character,Output)
FDSTEP	Relative design variable increment for finite difference computation (Real,Input)
OEULBUCK	Relation containing Euler buckling constraint output (Character,Output)

Application Calling Sequence:

None

Method:

This module first checks if any **DCONBKE** Bulk Data entries are referenced by any STATICS and/or SAERO disciplines for the current boundary condition to determine if there any Euler buckling constraints have been applied. If any are found, the BAR and/or ROD element data are obtained from relation **BEAMEST** and/or **RODEST**, and the element force data are obtained from relation **EOBAR** and/or **EOROD**, and the Euler buckling constraint values are evaluated and stored into relation **CONST**. The constraint sensitivity data are also prepared in this module.

Design Requirements:

This module needs element output relation from module **EDR**, therefore should only be called after module **EDR**.

Error Conditions:

1. Euler buckling control elements with improper boundary condition type are flagged.

2. Euler buckling control elements with improper moment of inertia parameters are flagged.

Engineering Application Module: EBKLSENS

Entry Point: EBKSNS

Purpose:

Evaluates the Euler buckling constraint sensitivity.

MAPOL Calling Sequence:

```
CALL EBKLSENS ( BCID, NITER, NDV, CONST, DESLINK, GLBDES, [AMAT] );
```

BCID	User defined boundary condition identification number (Integer, Input)
NITER	Design iteration number (Integer,Input)
NDV	Number of design variables (Integer,Input)
CONST	Relation of constraint values (Character,Input)
DESLINK	Relation of design variable linking information (Character,Input)
GLBDES	Relation of global design variables (Character,Input)
[AMAT]	Matrix containing the sensitivity of the constraints to changes in the design variable (Character,Output)

Application Calling Sequence:

None

Method:

This module first checks if there any active Euler buckling constraints for the current boundary condition. If so, the constraint sensitivity data are retrieved from relation **CONST**. Then the design variable identification list is then obtained from relation **GLBDES**, and the design variable linking data are obtained from relation **DESLINK**. For each active Euler buckling constraint, the sensitivity to the design variables is computed and stored into matrix **[AMAT]**.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: EDR

Entry Point: EDRDRV

Purpose:

To compute the stresses, strains, grid point forces and strain energies for elements selected for output for the particular boundary condition.

MAPOL Calling Sequence:

```
CALL EDR ( BCID, NITER, NDV, GSIZE, K6ROT, EOSUMMRY, EODISC, GLBDES,
           LOCLVAR, [PTRANS], BGPDT(BC), [UG(BC)], [UAG(BC)], [BLUG],
           [UTRANG], [UFREQG], [PHIG(BC)], [PHIGB(BC)] );
```

BCID	User defined boundary condition identification number (Integer, Input)
NITER	Iteration number for the current design iteration (Integer, Input)
NDV	The number of global design variables (Integer, Input)
GSIZE	The size of the structural set (Integer, Input)
K6ROT	Rotational stiffness default value (Real, Input)
EOSUMMRY	Relation containing the summary of elements, design iterations and boundary conditions for which output is desired (Input)
EODISC	Unstructured entity referred to by **EOSUMMRY** containing the disciplines for which output is required for each element/iteration/boundary condition (Input)
GLBDES	Relation of global design variables (Character, Input)
LOCLVAR	Relation containing the relationship between local variables and global variables in the design problem (Character, Input)
[PTRANS]	The design variable linking matrix (Character, Input)
BGPDT(BC)	Relation of basic grid point coordinate data (Character, Input), where **BC** represents the MAPOL boundary condition loop index number
[UG(BC)]	Matrix of global displacements from **STATICS** analyses (Input), where **BC** represents the MAPOL boundary condition loop index number.
[UAG(BC)]	Matrix of global displacements from **SAERO** analyses (Input), where **BC** represents the MAPOL boundary condition loop index number.
[BLUG]	Matrix of global displacements/velocities/accelerations for **BLAST** response analyses (Input)
[UTRANG]	Matrix of global displacements/velocities/accelerations for **TRANSIENT** response analyses (Input)
[UFREQG]	Matrix of global displacements/velocities/accelerations for **FREQUENCY** response analyses (Input)
[PHIG(BC)]	Matrix of global eigenvectors from real eigenanalysis for **MODES** analyses (Input), where **BC** represents the MAPOL boundary condition loop index number.

[PHIGB(BC)] Matrix of global eigenvectors for **BUCKLING** analyses (Input), where **BC** represents the MAPOL boundary condition loop index number.

Application Calling Sequence:

None

Method:

The **EOSUMMRY** relation is opened and read for the current boundary condition. If any element output requests exist, processing continues by loading the input matrices associated with the discipline dependent displacement fields into an character array such that the order in which disciplines are processed correspond to the order of the matrices. Following this, there is a section of code set aside for discipline dependent processing. Currently, two tasks are performed:

(1) The number of mode shapes computed in the real eigenanalysis (if one was performed) is determined by opening the **PHIG** matrix; and (2) any thermal load set ID's in the **CASE** relation are replaced by the record number in **GRIDTEMP** that corresponds to the applied load case.

The initialization tasks continue with a call to the **PRELDV** utility to set up for computation of the local design variables associated with designed elements. The transformation matrices and material properties are also prepared for fast retrieval by the element routines. The **GPFDATA** relation is opened for output and the **EODISC** data is read into memory. At this point, the **EODISC** record number in the **EOSUMMRY** data is replaced by the open core pointer where the record begins in memory. With the initialization complete, the **EDR** module proceeds to compute the desired element response quantities for all the "subcases" (considered by **EDR** to be represented by a single displacement vector) for any or all disciplines that have been analyzed in the current boundary condition. The computation occurs in the following three steps:

(1) Determine the set of disciplines and subcases for which any element response quantities are needed

(2) Read into open core as many displacement vectors (real and/or complex) as will fit

(3) Call element dependent routines to compute the stress, strain, strain energy, forces and grid point forces for each displacement vector

To perform step (1), the **EOSUMMRY** data is read for each discipline and the corresponding **EODISC** data is used to form a unique list of subcases for each discipline in the current boundary condition. A list of the form:

```
NDISC,(DISC TYPE(I),NSUBCASE,SUBCASE ID(J),J=1,NSUBCASE),I=1,NDISC)
```

These data are sorted by discipline type in the order defined in the **/EDRDIS/** common block and by the subcase "identification numbers" within each discipline. The subcase ID's refer to the column number in the displacement matrix for the discipline. For statics and modes, these numbers are incremented by one for each new load condition or eigenvector while transient, frequency and blast results use an increment of three to accommodate the velocity and accelerations that are stored in the same matrix. After this in-core list has been formed, it is read to determine which displacement vectors are to be brought into open core. The module determines the amount of remaining memory and brings as many displacement vectors into memory as possible. The terms are converted to single precision at this point. Once all the displacements are in memory, or memory is full, the element dependent routines are called. Within each element dependent routine, the geometrical portion of the element processing is performed once followed by a loop over all incore displacements to compute the element response quantities. For each displacement set, all the element response quantities including grid point forces, stresses, strains, strain energies and element forces are computed and stored on the **EOxxxx** element response quantity relations. Note that the exact quantities requested by the user are not used at this point, but will only

be used to determine which data to print. Once all the elements have been processed, the module loops back for any remaining displacement vectors and, when all of these are processed, terminates.

Design Requirements:

1. The **PFBULK** processing of the element output requests must have been completed and be compatible with the data currently resident in the **CASE** relation.

2. The module may be called when no element output requests exist in the Solution Control.

Error Conditions:

None

Engineering Application Module: EMA1

Entry Point: EMA1

Purpose:

To assemble the linearly designed element stiffness and mass matrices (stored in the **KELM** and **MELM** entities) into the linear design sensitivity matrices **DKVI0** and **DMVI0**.

MAPOL Calling Sequence:

```
CALL EMA1 ( NDV, CSTM, GENEL, DVCT, KELM, MELM, GMKCT0, DKVI0, GMMCT0,
            DMVI0, DWGH1 );
```

NDV	Number of design variables (Integer, Input)
CSTM	Relation containing the coordinate transformation matrices for all external coordinate systems (Character,Input)
GENEL	Unstructured entity containing information from **GENEL** Bulk Data entries (Character,Input)
DVCT	Relation containing the data required for the assembly of the linear design sensitivity matrices (Character, Input)
KELM	Unstructured entity containing the linear design element stiffness matrix partitions (Character, Input)
MELM	Unstructured entity containing the linear design element mass matrix partitions (Character, Input)
GMKCT0	Relation containing connectivity data for the **DKVI0** sensitivity matrix (Output)
DKVI0	Unstructured entity containing the linear design stiffness sensitivity matrix in a highly compressed format (Output)
GMMCT0	Relation containing connectivity data for the **DMVI0** sensitivity matrix (Output)
DMVI0	Unstructured entity containing the linear design mass sensitivity matrix in a highly compressed format (Output)
DWGH1	Unstructured entity containing the linear (invariant) part of the sensitivity of weight to the design variables (Output)

Application Calling Sequence:

None

Method:

This module deals with linearly designed stiffness and mass matrices, while module **NLEMA1** deals with nonlinear design stiffness and mass matrices. The module is executed in two passes; once for linear design stiffness matrices and a second time for linear design mass matrices. In the first pass, **DVCT** information is read into core one record at a time. The algorithm is structured to maximize the amount of processing done on a given design sensitivity matrix (typically all of it) in core. Spill logic is in place if a matrix cannot be completely held in core. For the assembly, subroutine **RQCOR1** performs bookkeeping tasks to expedite the assembly and to determine whether spill will be necessary. Subroutine **ASSEM1** retrieves **KELM** information, performs the actual assembly operations and places the results into the **GMKCT0** and **DKVI0** entities. When the **DVCT** data have been exhausted a check is made as to whether

mass assembly is required. If a discipline which requires a mass matrix is included in the solution control, the mass terms are assembled in the second pass. If there are **OPTIMIZE** boundary conditions, this module calculates the linear portion of sensitivity of the objective to the design variables regardless of whether the **DMVI0** matrices are required. If no mass information is required, control is returned to the executive and the second pass through the module is not made. For the second pass, **MELM** data are used. The structure of the assembly operation is otherwise much the same and **GMMCT0** and **DMVI0** data are computed and stored.

Design Requirements:

1. This assembly operation follows the **MAKEST** and **EMG** modules.

2. Since gravity loads require **DMVI0** data, it is necessary to perform **EMA1** prior to calling **LODGEN**. **EMA1** must always be called before **EMA2**.

Error Conditions:

None

Engineering Application Module: EMA2

Entry Point: EMA2

Purpose:

To assemble the element stiffness and mass matrix partitions (stored in the **DKVIG** and **DMVIG** entities) into the global stiffness and mass matrices for the current design iteration.

MAPOL Calling Sequence:

```
CALL EMA2 ( NITER, NDV, GSIZEB, GLBDES, GMKCTG, DKVIG, [K1GG], GMMCTG,
            DMVIG, [M1GG] );
```

NITER	Design iteration number (Integer, Input)
NDV	The number of design variables (Integer, Input)
GSIZEB	Length of the g-set vectors (Integer, Input)
GLBDES	Relation of global design variables (Character, Input)
GMKCTG	Relation containing connectivity data for the **DKVIG** sensitivity matrix (Character, Input)
DKVIG	Unstructured entity containing the stiffness matrix partitions in a highly compressed format (Character, Input)
[K1GG]	Assembled stiffness matrix in the g-set (Output)
GMMCTG	Relation containing connectivity data for the **DMVIG** sensitivity matrix (Character, Input)
DMVIG	Unstructured entity containing the mass matrix partitions in a highly compressed format (Character, Input)
[M1GG]	Assembled mass matrix in the g-set (Output)

Application Calling Sequence:

None

Method:

The structure of this module resembles that of **EMA1** and is also executed in two passes. In the first pass, **GMKCTG** information is read into core one record at a time. The algorithm is structured to maximize the number of columns of the global stiffness matrix that are assembled at one time. Spill logic is in place if all the columns cannot be assembled at once. For the assembly, subroutine **RQCOR2** performs bookkeeping tasks to expedite the assembly and to determine whether spill will be necessary. Subroutine **ASSEM2** retrieves the **DKVIG** information, performs the assembly in core using the current values of the design variables, and stores the data into **KGG**. When the **GMKCTG** data have been exhausted a check is performed as to whether mass assembly is required. Flags were written by **NLEMA1** on the **INFO** array of the **DKVIG** entity to indicate whether mass assembly is required. If no mass information is required, control is returned to the executive; if it is, the second pass through the module takes place. For the second pass, **DMVIG** and **GMMCTG** data are used to generate the **MGG** matrix. The structure of the assembly operation is otherwise much the same and the **MGG** matrix is computed and stored.

Design Requirements:

1. For **OPTIMIZE** boundary conditions, **EMA2** precedes the optimization boundary condition loop. For **ANALYZE** boundary conditions, the module immediately precedes the loop on analyze boundary conditions and the **NITER** argument is not required. In both cases, **EMA2** must always follow **NLEMA1**.

2. **NITER** must be nonzero for optimization boundary conditions.

Error Conditions:

None

Engineering Application Module: EMG

Entry Point: EMG

Purpose:

To compute the linear design variable part of element stiffness, mass, thermal load and stress component sensitivities for all structural elements.

MAPOL Calling Sequence:

```
CALL EMG ( NDV, GSIZEB, K6ROT, GLBDES, LOCLVAR, [PTRANS], DESLINK, [SMAT],
           SMATCOL, DVCT, DVSIZE, KELM, MELM,TELM, TREF );
```

NDV	The number of design variables (Integer, Input)
GSIZEB	The size of the structural set (Integer, Input)
K6ROT	Stiffness value for plate element "drilling" degrees of freedom (Real,Input)
GLBDES	Relation of global design variables (Character, Input)
LOCLVAR	Relation containing the relationship between local variables and global variables in the design problem (Input)
[PTRANS]	The design variable linking matrix (Input)
DESLINK	Relation of design variable connectivity from **MAKEST** module containing one record for each global design variable connected to each local variable. (Character, Input)
[SMAT]	Matrix entity containing the linear portion of sensitivity of the stress and strain components to the global displacements (Character, Output)
SMATCOL	Relation containing matrix **[SMAT]** column information (Character,Output)
DVCT	Relation containing the data required for the assembly of the linear design sensitivity matrices (Character, Output)
DVSIZE	Unstructured entity containing memory allocation information on the **DVCT** relation (Character, Output)
KELM	Unstructured entity containing the linear design element stiffness matrix partitions (Character, Output)
MELM	Unstructured entity containing the linear design element mass matrix partitions (Character, Output)
TELM	Unstructured entity containing the linear design element thermal load partitions (Character, Output)
TREF	Unstructured entity containing the linear design element reference temperatures for thermal loads (Character, Output)

Application Calling Sequence:

None

Method:

The **EMG** module performs the linear design variable part of the second phase of the structural element preface operations with the **MAKEST** module performing the first phase. The **NLEMG** module performs the nonlinear design variable part of the second phase. As a result, modules **EMG** and **MAKEST** are very closely related. The first action of the **EMG** module is to determine if design variables and/or thermal loads are defined in the bulk data. If they are, the special actions for design variable linking and thermal stress corrections are taken in the element dependent routines. The **PREMAT** utility to set up the material property data also returns the **SCON** logical flag to denote that there are stress constraints defined in the bulk data. The initialization of the module continues with the retrieval of the **MFORM** data to select lumped or coupled mass matrices in the elements that support both forms. The default is lumped although any **MFORM/COUPLED** (even if **MFORM/LUMPED** also exists) will cause the coupled form to be used. If thermal loads exist, the module prepares the **TREF** entity to be written by the element dependent routines. The **GLBDES** relation is opened and the design variable identification numbers are read into memory. Finally, the **DVCT** entity is opened and flushed and memory is retrieved to be used in the **DVCTLD** submodule to load the **DVCT** relation. The module then calls each element dependent routine in turn. The order in which these submodules are called is very important in that it provides an implicit order for the **MAKEST**, **EMG**, **SCEVAL**, **EDR** and **OFP** modules. That order is alphabetical by connectivity bulk data entry and results in the following sequence:

(1) Bar elements

(2) Scalar spring elements

(3) Linear isoparametric hexahedral elements

(4) Quadratic isoparametric hexahedral elements

(5) Cubic isoparametric hexahedral elements

(6) Scalar mass elements

(7) General concentrated mass elements

(8) Rigid body form of the concentrated mass elements

(9) Isoparametric quadrilateral membrane elements

(10) Quadrilateral bending plate elements

(11) Rod elements

(12) Shear panels

(13) Triangular bending plate elements

(14) Triangular membrane elements

Within each element dependent routine, the **xxxEST** relation for the element is opened and read one tuple at a time. If the **EST** relation indicates that the element is designed, the **DESLINK** data is used to write one set of tuples to the **DVCT** relation for each unique design variable linked to the element. The set of tuples consists of one row for each node to which the element is connected. If the element is not designed, a single set of tuples is written connected to the "zeroth" (implicit) design variable. The element dependent geometry processor is then called to generate the **KELM**, **MELM** and **TELM** entries for the element. Note the **KELM** and **TELM** entities related to nonlinear design stiffnesses are empty, and MELM entries related to nonlinear design mass are empty. These data must be generated before the next call to **DVCTLD** since the **DVCT** forms the directory to all three of these entities. Once all the elements are processed within the current element dependent routine, the **TREF** entity is appended with the vector

of reference temperatures for the current set of elements. Again, the order of these reference temperatures are determined by the sequence listed above and is assumed to hold in other modules. When all the element dependent drivers have been called by the **EMG** module driver, clean up operations begin. The entities that have been open for writing by the element routines are closed, the remaining in-core **DVCT** tuples are written to the data base and the **DVCT** relation is sorted. If there are design variables, the **DVCT** is sorted on the **DVID** attribute and, within each unique **DVID**, by **KSIL**. If there are no design variables (all **DVID**'s are zero), the **DVCT** is sorted only on **KSIL**. Finally, if stress or strain constraints were defined in the bulk data stream, the **SMAT** matrix of constraint sensitivities to the displacements is closed. **SMAT** was opened by the **PREMAT** module when the **SCON** constraint flag was set.

Design Requirements:

1. The **MAKEST** module must have been called prior to the **EMG** module.

Error Conditions:

1. Illegal element geometries and nonexistent material properties are flagged.

Engineering Application Module: FCEVAL

Entry Point: FCEVAL

Purpose:

To evaluate the current value of all frequency constraints.

MAPOL Calling Sequence:

```
CALL FCEVAL ( NITER, BCID, LAMBDA, CONST );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
LAMBDA	Relational entity containing the output from the real eigenanalysis (Input)
CONST	Relation of design constraint values (Character, Output)

Application Calling Sequence:

None

Method:

The **FCEVAL** module first determines if any frequency constraints are applied to the modal analysis in the current boundary condition. If any constraints are applied to the modal analysis, the module proceeds to open the **DCONFRQ** relation to obtain the applied constraints and the **LAMBDA** relation to obtain the computed frequencies. The final initialization task is to open the **CONST** relation to store the computed frequency constraints. The actual computation involves looping through the **DCONFRQ** relation for the current frequency constraint set and conditioning the **LAMBDA** relation to retrieve the results for the modes that are constrained. Having retrieved the mode number and the computed modal frequency from **LAMBDA**, the applied upper or lower bound constraint is computed and stored on the **CONST** relation. Finally, the frequency responses which are required by any user function constraints are also computed.

Design Requirements:

1. The **FCEVAL** module assumes that the current boundary condition is an optimization boundary condition.

Error Conditions:

1. The frequency constraint set referenced by Solution Control does not exist in the **DCONFRQ** relation.
2. The frequency or eigenvector for the constrained mode was not extracted in the real eigenanalysis.
3. The constrained mode is a rigid body mode (zero frequency) and therefore cannot be constrained.

Engineering Application Module: FLUTDMA

Entry Point: FLTDMA

Purpose:

Assembles the dynamic matrices for the flutter disciplines.

MAPOL Calling Sequence:

```
CALL FLUTDMA ( NITER, BCID, SUB, ESIZE(BC), PSIZE(BC), BGPDT(BC), USET(BC),
               [MAA], [KAA], [TMN(BC)], [GSUBO(BC)], NGDR, LAMBDA, [PHIA],
               [MHHFL(BC,SUB)], [BHHFL(BC,SUB)], [KHHFL(BC,SUB)] );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
SUB	Flutter subcase number (Integer, Input)
ESIZE(BC)	Number of extra points for the current boundary condition (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number
PSIZE(BC)	Number of physical degrees of freedom in the current boundary conditions (**GSIZE+ESIZE**) (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number
BGPDT(BC)	Current boundary condition's relation of basic grid point data (expanded to include extra points and any **GDR** scalar points) (Input), where **BC** represents the MAPOL boundary condition loop index number
USET(BC)	Current boundary condition's unstructured entity of set definition masks (expanded to include extra points and any **GDR** scalar points) (Input), where **BC** represents the MAPOL boundary condition loop index number
[MAA]	Mass matrix in the analysis set (Input)
[KAA]	Stiffness matrix in the analysis set (Input)
[TMN(BC)]	Multipoint constraint transformation matrix for the current boundary condition (Input), where **BC** represents the MAPOL boundary condition loop index number
[GSUBO(BC)]	Static condensation or **GDR** reduction matrix for the current boundary condition (Input), where **BC** represents the MAPOL boundary condition loop index number
NGDR	Denotes dynamic reduction in the boundary condition (Input, Integer) **= 0** No **GDR** **= –1 GDR** is used
LAMBDA	Relation of normal mode eigenvalues output from the **REIG** module (Input)
[PHIA]	Matrix of normal mode eigenvectors in the analysis set output from **REIG** (Input)

[MHHFL(BC,SUB)] Generalized mass matrix for the current flutter subcase in the h-set (normal modes+extra points) including any transfer functions and **M2PP** input (Output), where **BC** represents the MAPOL boundary condition loop index number

[BHHFL(BC,SUB)] Generalized damping matrix for the current flutter subcase in the h-set (normal modes+extra points) including any transfer functions, **B2PP** input and **VSDAMP** input (Output), where **BC** represents the MAPOL boundary condition loop index number

[KHHFL(BC,SUB)] Generalized stiffness matrix for the current flutter subcase in the h-set (normal modes+extra points) including any transfer functions **K2PP** input and **VSDAMP** input (Output), where **BC** represents the MAPOL boundary condition loop index number

Application Calling Sequence:

None

Method:

CASE is checked to see if any **FLUTTER** subcases exist for the current boundary condition. If not, control is returned to the MAPOL sequence. If **FLUTTER** subcases exist, the dynamic matrix descriptions for the current subcase (as indicated by the **SUB** input) are brought into memory from **CASE**. Then the **BGPDT** data are read into memory and the **DMAPVC** submodule is called to generate partitioning matrices to expand the input matrices to the p-set from the g-set and to strip off the **GDR** extra points where appropriate. If extra points are defined, the **MAA**, **KAA**, **PHIA**, **TMN** and **GSUBO** are then expanded to include the d-set extra point DOF.

Following the expansion of the input matrices, the direct matrix input **M2PP**, **B2PP** and **K2PP** are assembled and reduced to the direct d-set DOF in the submodule **DMAX2**. Modal transformations occur later in the module. Following the **x2PP** formation, the **VSDAMP** data are set depending on the **DAMPING** selection for the **FLUTTER** subcase. Finally, the **LAMBDA** relation is read into memory to have the modal frequencies available for modal damping computations.

Following all these preparations, the utility submodules **DMAMHH**, **DMABHH** and **DMAKHH** are used to assemble the modal mass, damping and stiffness matrices accounting for all the dynamic matrix options. Control is then returned to the MAPOL program.

Design Requirements:

1. The **FLUTDMA** module is intended to be called once for each **FLUTTER** subcase in the boundary condition. The ordering of subcases is that in the **CASE** relation. Each set of dynamic matrices in the standard sequence is saved in a doubly subscripted set of matrices to be used in sensitivity analysis. It is not necessary to save these matrices unless the sensitivity phase will be performed.

Error Conditions:

1. Missing damping sets called for on the **FLUTTER** entry are flagged.

2. Errors on **TABDMP** entries are flagged.

Engineering Application Module: FLUTDRV

Entry Point: FLUTDR

Purpose:

MAPOL director for flutter analyses.

MAPOL Calling Sequence:

```
CALL FLUTDRV ( BCID, SUB, LOOP );
```

BCID	User defined boundary condition identification number (Integer, Input)
SUB	Flutter subcase number (ranging from 1 to the total number of **FLUTTER** subcases) of the subcase to be processed in this pass (Integer, Input)
LOOP	Logical flag indicating that more flutter subcases exist in the boundary condition (Logical, Output)

Application Calling Sequence:

None

Method:

The **SUB**'th **FLUTTER** subcase's **TITLE**, **SUBTITLE** and **LABEL** are retrieved from the **CASE** relation and set in the **/OUTPT2/** common for downstream page labeling. If more than **SUB FLUTTER** subcases exist, the **LOOP** flag is set to **TRUE** to tell the MAPOL sequence that more passes through the flutter analysis modules are needed.

Design Requirements:

1. This module is the driver for a set of MAPOL modules that together perform the **FLUTTER** analysis for a subcase. These modules are **FLUTDMA**, **FLUTQHHL** and **FLUTTRAN**.

Error Conditions:

None

Engineering Application Module: FLUTQHHL

Entry Point: FLTQHH

Purpose:

Processes matrix **QKKL** with normal modes for flutter.

MAPOL Calling Sequence:

```
CALL FLUTQHHL ( NITER, BCID, SUB, ESIZE(BC), PSIZE(BC), [QKKL], [UGTKA],
                [PHIA], USET(BC), [TMN(BC)], [GSUBO(BC)], NGDR, AECOMPU,
                GEOMUA, [PHIKH], [QHHLFL(BC,SUB)], OAGRDDSP );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
SUB	Flutter subcase number (Integer, Input)
ESIZE(BC)	Number of extra points for the current boundary condition (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number
PSIZE(BC)	Number of physical degrees of freedom in the current boundary conditions (**GSIZE+ESIZE**) (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number
[QKKL]	Matrix containing a list of k x k complex unsteady aerodynamic matrices for each m-k pair defined by **MKAERO1** and **MKAERO2** entries. These matrices were output from the **AMP** module (Input)
[UGTKA]	The matrix of splining coefficients relating the aerodynamic pressures to forces at the structural grids and relating the structural displacements to the streamwise slopes of the aerodynamic boxes reduced to the a-set DOF (Input)
[PHIA]	Matrix of normal modes eigenvectors in the a-set (Input)
USET(BC)	Current boundary condition's unstructured entity of set definition masks (expanded to include extra points and any **GDR** scalar points) (Input), where **BC** represents the MAPOL boundary condition loop index number
[TMN(BC)]	Multipoint constraint transformation matrix for the current boundary condition (Input), where **BC** represents the MAPOL boundary condition loop index number
[GSUBO(BC)]	Static condensation or **GDR** reduction matrix for the current boundary condition (Input), where **BC** represents the MAPOL boundary condition loop index number
NGDR	Denotes dynamic reduction in the boundary condition (Input, Integer) **0** No **GDR** **–1** **GDR** is used
AECOMPU	A relation describing aerodynamic components for the unsteady aerodynamics model. It is used in splining the aerodynamics to the structural model (Input)

GEOMUA	A relation describing the aerodynamic boxes for the unsteady aerodynamics model. The location of the box centroid, normal and pitch moment axis are given. It is used in splining the aerodynamics to the structure and to map responses back to the aerodynamic boxes (Input)
[PHIKH]	A modal tranformation matrix that relates the box-on-box aerodynamic motions to unit displacements of the generalized structural coordinates (modes) (Output)
[QHHLFL(BC,SUB)]	A matrix containing the list of h x h unsteady aerodynamics matrices for the current flutter subcase related to the generalized (modal) coordinates and including control effectiveness (**CONEFFF**), extra points and **CONTROL** matrix inputs (Output), where **BC** represents the MAPOL boundary condition loop index number
OAGRDDSP	A relation containing the structural eigenvectors (generalized DOF) mapped to the aerodynamic boxes for those **AIRDISP** requests in the Solution Control. These terms are the columns of **PHIKH** put in relational form to satisfy the output requests (Output)

Application Calling Sequence:

None

Method:

The **CASE** relation is read to obtain the **SUB**'th flutter subcase parameters: **CONTROL** and **AIRDPRNT**. Then the **FLUTTER** relation is read for the current subcase and the **KLIST** and **EFFID** entries are recovered.

If there is no **CONTROL** matrix, **PHIA** and **UGTKA** matrices are expanded to include dynamic degrees of freedom using the utility module **QHHEXP**. **GDR** scalar points are handled to ensure that the final matrices are in the d-set. If a **CONTROL** matrix does exist, its conformability is checked. The **DMAPVC** utility submodule is used to create partitioning vectors and matrix reduction matrices to allow reduction of the **CONTROL** matrix to the d-set. The **FLCNTR** submodule is then called to append the reduced **CONTROL** matrix to the expanded **UGTKA** matrix. The **PHIKH** matrix is then computed as the product of the expanded **PHIA** and the expanded and **CONTROL**-modified **UGTKA**:

$$[PHIKH] = [PHID]^T[UGTKD]$$

Then, if control effectiveness correction factors are selected for the subcase, the **PHIKH** matrix terms are adjusted by the input factors. This completes the computation of the **PHIKH** output matrix. The input **AIRDISP** output requests are then processed to load the **OAGRDDSP** relation with the generalized displacements on the unsteady aerodynamic geometry.

Finally, the **QKK** matrices that are associated with the user's input Mach number and **KLIST** for the subcase are reduced to the generalized degrees of freedom using the **PHIKH** matrix.

$$[QHHL] = [(PHIKH)]^T[QKKL][PHIKH]$$

The premultiplication takes place in one **MPYAD** and the postmultiplication is done by looping over each reduced frequency in the set, extracting the k columns of each h x k matrix and performing a separate **MPYAD**. The results are then appended onto the output **QHHL**.

Design Requirements:

None

Error Conditions:

1. **CONTROL** matrix errors in conformability are flagged.
2. **CONEFFF** errors are flagged.

Engineering Application Module: FLUTSENS

Entry Point: FLTSTY

Purpose:

To compute the sensitivities of active flutter constraints in the current active boundary condition.

MAPOL Calling Sequence:

```
CALL FLUTSENS ( NITER, BCID, SUB, LOOP, GSIZEB, NDV, GLBDES, CONST, GMKCT,
                DKVI, GMMCT, DMVI, CLAMBDA, LAMBDA, [QHHLFL(BC,SUB)],
                [MHHFL(BC,SUB)], [BHHFL(BC,SUB)], [KHHFL(BC,SUB)],
                [PHIG(BC)], [AMAT] );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
SUB	Flutter subcase number (ranging from 1 to the total number of **FLUTTER** subcases) of the subcase to be processed in this pass. (Integer, Input)
LOOP	Logical flag indicating that more flutter subcases exist in the boundary condition. (Logical, Input)
GSIZEB	The size of the structural set (Integer, Input)
NDV	The number of global design variables (Integer, Input)
GLBDES	Relation of global design variables (Character, Input)
CONST	Relation of constraint values (Character, Input)
GMKCT	Relation containing connectivity data for the **DKVI** sensitivity matrix (Character, Input)
DKVI	Unstructured entity containing the stiffness design sensitivity matrix in a highly compressed format (Character, Input)
GMMCT	Relation containing connectivity data for the **DMVI** sensitivity matrix (Character, Input)
DMVI	Unstructured entity containing the mass design sensitivity matrix in a highly compressed format (Character, Input)
CLAMBDA	Relation containing results of flutter analyses (Character, Input)
LAMBDA	Relational entity containing the output from the real eigenanalysis (Character, Input)
[QHHLFL(BC,SUB)]	Matrix list of modal unsteady aerodynamic coefficients (Input), where **BC** represents the MAPOL boundary condition loop index number
[MHHFL(BC,SUB)]	Modal mass matrix (Input), where **BC** represents the MAPOL boundary condition loop index number
[BHHFL(BC,SUB)]	Modal flutter damping matrix (Input), where **BC** represents the MAPOL boundary condition loop index number
[KHHFL(BC,SUB)]	Modal flutter stiffness matrix (Input), where **BC** represents the MAPOL boundary condition loop index number

[PHIG(BC)]	Matrix of real eigenvectors in the structural set (Input), where **BC** represents the MAPOL boundary condition loop index number
[AMAT]	Matrix of constraint sensitivities (Output)

Application Calling Sequence:

None

Method:

The **FLUTSENS** module is very similar to the **FLUTTRAN** module except that the **CONST** and **CLAMBDA** relations control the execution of the module rather than the **CASE** relation. The module begins by retrieving all the active flutter constraints from the **CONST** relation that are associated with the current subcase (**SUB**) and determining the **CLAMBDA** tuples that correspond to the active constraints. The next task of the module is to prepare for the actual flutter sensitivity analysis by setting up the **FLFACT** bulk data and the **UNMK** data using the **PREFL** and **PRUNMK** utilities, respectively. The generalized mass and damping matrices are then read into memory and converted to single precision, followed by the natural frequencies associated with the computed eigenvectors. Lastly, the generalized stiffness matrix is read in and converted to single precision and the generalized aerodynamic influence coefficients are opened for retrieval. A final operation creates the scratch flutter eigenvector matrices that will be used in the sensitivity evaluation.

For the **FLUTTER** case, a number of tasks are performed to set up for the current Mach number. These consist of the retrieval of the set of m-k pairs for the current **FLUTTER** entry from the **UNMK** data and the set of normal modes that are to be omitted. If modes are omitted, a partitioning vector is created and used to partition the input **PHIG** matrix to include only the desired normal modes. As a final step before the active constraint loop for the current **FLUTTER** set id, the local memory required by the flutter analysis submodules is retrieved.

The module continues with the loop on the **CLAMBDA** tuples associated with the current **FLUTTER** set identification number. The scalar parameters identifying the flutter root are retrieved from **CLAMBDA** and the set of reduced frequencies associated with the **QHLL** matrices for this flutter case are retrieved from the **UNMK** data. The **FA1PKI** submodule is called with this data to compute the interpolation matrix for the **QHLL** matrix list under the **ORIG** curve fit option. Otherwise, the fitting coefficients are computed on the fly within the **QFDRV** family of routines. Then, the subset of the full **QHLL** matrix associated with this flutter analysis is read into core and converted to single precision.

At this point, the imaginary part of the **QZHH** matrix is divided by the reduced frequency. Finally, the **QFDRV** utility is called to generate the **QRS** interpolated aerodynamic influence coefficients for the current flutter eigenvalue. At the same time the **QFDRV** module computes the sensitivity of this matrix to the reduced frequency (**DQRS**). Finally, the flutter eigenmatrix is computed using the **FSUBS** sub-module. The corresponding right-hand eigenvector is then computed, the eigenmatrix is transposed and the left-hand vector computed. At this point, the scalar (complex) sensitivities of the mass, damping, stiffness and aerodynamics are computed as outlined in Section 10.3 of the Theoretical Manual. The **FLUTSENS** module performs all these computations using real arithmetic. Finally, the 2 X 2 left-hand side matrices of equation 10-27 of the Theoretical Manual:

$$\begin{bmatrix} DF_{11} & DF_{12} \\ DF_{21} & DF_{22} \end{bmatrix} \begin{Bmatrix} DR \\ DI \end{Bmatrix} = \begin{Bmatrix} P2R * MR - P2I * MI + KR + damping \\ P2R * MI - P2I * MR + KI + damping \end{Bmatrix}$$

are stored and the left- and right-hand eigenvectors packed into a scratch entity. The value ***damping*** is:

$$\begin{Bmatrix} -g * KI \\ g * KR \end{Bmatrix}$$

if structural damping, **g**, is included.

Simliarly, it is:

$$\begin{Bmatrix} P1R * \frac{g}{\omega_3} * KR - P1I * \frac{g}{\omega_3} * KI \\ P1R * \frac{g}{\omega_3} * KI - P1I * \frac{g}{\omega_3} * KR \end{Bmatrix}$$

if equivalent viscous damping is used at frequency ω_3.

The module then continues with the next active constraint for the current **FLUTTER** entry. Once all the active constraints are treated for the current **FLUTTER** entry, the matrix of left- and right-hand eigenvectors are expanded to physical coordinates using the (partitioned) normal modes matrix. The **FLCSTY** module is then called to complete the solution of the constraint sensitivities to the global design variables. These computations involve the eigenvectors and the mass, damping and stiffness sensitivities to compute the right-hand side of the equations shown in the Theoretical Manual. The flutter response sensitivities which are required by the active user function constraints are also computed in this module. Once the **FLCSTY** module is complete, the **FLUTSENS** module proceeds with the next **FLUTTER** entry with active flutter constraints. When all have been completed, control is returned to the executive.

Design Requirements:

1. The module assumes that at least one active flutter constraint exists in the current boundary condition.

Error Conditions:

None

Engineering Application Module: FLUTTRAN

Entry Point: FLUTAN

Purpose:

To perform flutter analyses in the current boundary condition and to evaluate any flutter constraints if it is an optimization boundary condition with applied flutter constraints.

MAPOL Calling Sequence:

```
CALL FLUTTRAN ( NITER, BCID, SUB, [QHHLFL(BC,SUB)], LAMBDA, HSIZE(BC),
                ESIZE(BC), [MHHFL(BC,SUB)], [BHHFL(BC,SUB)], [KHHFL(BC,SUB)],
                CLAMBDA, CONST );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
SUB	Flutter subcase number (ranging from 1 to the total number of **FLUTTER** subcases) of the subcase to be processed in this pass. (Integer, Input)
[QHHLFL(BC,SUB)]	Matrix list of modal unsteady aerodynamic coefficients (Input)
LAMBDA	Relational entity containing the output from the real eigenanalysis (Input)
HSIZE(BC)	Number of modal dynamic degrees of freedom in the current boundary condition (Input), where **BC** represents the MAPOL boundary condition loop index number
ESIZE(BC)	The number of extra point degrees of freedom in the boundary condition (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number
[MHHFL(BC,SUB)]	Modal mass matrix (Input), where **BC** represents the MAPOL boundary condition loop index number
[BHHFL(BC,SUB)]	Modal flutter damping matrix (Input), where **BC** represents the MAPOL boundary condition loop index number
[KHHFL(BC,SUB)]	Modal flutter stiffness matrix (Input), where **BC** represents the MAPOL boundary condition loop index number
CLAMBDA	Relation containing results of flutter analyses (Character, Output)
CONST	Relation of constraint values (Character, Input)

Application Calling Sequence:

None

Method:

The **FLUTTRAN** module begins by retrieving the flutter discipline entries from the **CASE** relation for the current boundary condition. If the boundary condition is an optimize boundary condition, the **CONST** and **CLAMBDA** relations are opened to store the constraint and root extraction data needed for the optimization task. For analysis boundary conditions, the hidden entities **FLUTMODE** and **FLUTREL** are opened and initialized to prepare for possible flutter mode shape storage. These mode shapes are stored so that the **OFPDISP** module can satisfy flutter mode shape print requests.

The next task of the module is to prepare for the actual flutter analysis by setting up the **FLFACT** bulk data and the **UNMK** data using the **PREFL** and **PRUNMK** utilities, respectively. Then the reference unsteady aerodynamic model data is retrieved from the **AERO** relation. Lastly, the velocity conversion factor, if one has been defined, is read from the **CONVERT** relation. The generalized mass and damping matrices are then read into memory and converted to single precision, followed by the natural frequencies associated with the computed eigenvectors. Lastly, the generalized stiffness matrix is read in and converted to single precision and the generalized aerodynamic influence coefficients are opened for retrieval. This completes the preparations for the flutter discipline loop.

For the **SUB**'th flutter discipline requested in the **CASE** relation, a number of tasks are performed to set up for the Mach number requested on the **FLUTTER** entry. These consist of the retrieval of the set of m-k pairs for the current **FLUTTER** entry from the **UNMK** data and the lists velocities (which are converted to the proper units, if necessary) and densities. If the boundary condition is an optimization boundary condition, the table of required damping values is prepared using the **PRFCON** utility. Lastly, the set of normal modes that are to be omitted are retrieved and the data prepared to perform the "partitioning" of the generalized matrices. As a final step before processing the current **FLUTTER** entry, the local memory required by the flutter analysis submodules is retrieved.

The subset of m-k pairs in the **QHLL** matrix list for the current Mach number is determined and the set of associated reduced frequencies determined. The **FA1PKI** submodule is called with this data to compute the interpolation matrix for the **QHLL** matrix list if the **ORIG** curve fit is used. Otherwise, the fitting coefficients are computed on the fly in the **QFDRV** module. Then, the subset of the full **QHLL** matrix associated with this flutter analysis is read into core and converted to single precision. At this point, the imaginary part of the **QZHH** matrix is divided by the reduced frequency. Finally, the Mach number dependent memory blocks are retrieved and the inner-most analysis loop on the density ratios is begun.

For each density ratio associated with the Mach number for the current flutter analysis discipline, the **FLUTTRAN** module performs the flutter analysis. There are two distinct paths through the inner loop: one for optimization and one for analysis. They differ in that the analysis loop refines the set of user selected velocities to find a flutter crossing, while the optimization path computes the flutter eigenvalues only at the user specified velocities and computes the corresponding flutter constraint value based on the required damping table. Once all the loops have been completed, the module computes the flutter responses which are required by any user function constraints, and then returns control to the executive.

Design Requirements:

1. The module assumes that at least one flutter subcase exists in the current boundary condition.

Error Conditions:

1. Referenced data on **FLUTTER** entries that do not exist on the data base are flagged and the execution is terminated.

Engineering Application Module: FNEVAL

Entry Point: FNEVAL

Purpose:

Evaluates the current values of user functional constraints.

MAPOL Calling Sequence:

```
CALL FNEVAL ( NITER, CONST );
```

NITER	Design iteration number (Integer,Input)
CONST	Relation of constraint values (Character,Output)

Application Calling Sequence:

None

Method:

This module first computes the user defined objective function value if it is required. This objective function value is stored in relation **CONST** with the **OBJECTIVE** indication flag set. The function value is set to be "active" so that its required response sensitivities will be computed thereafter. Then, all instances invoked by the objective are computed. They are treated as subcase independent user functional constraints.

Finally, case dependent user functional constraints are computed for each subcase for which functional constraints have been specified. All user function values are computed using the evaluation utilities. These utilities retrieve all required response function values.

Design Requirements:

1. All response functions must be computed prior to this module.

Error Conditions:

None

Engineering Application Module: FPKEVL

Entry Point: FPKEVL

Purpose:

Compiles the FUNCTION packet and instantiates the user functions that have been invoked by Solution Control.

MAPOL Calling Sequence:

```
CALL FPKEVL ( EIDTYPE );
```

EIDTYPE	Relation containing element identification numbers and corresponding element type (Character,Input)

Application Calling Sequence:

None

Method:

This module compiles the function packet statements and loads the compiled information onto the CADDB database. Compilation determines the validity of each function in terms of its syntax and the other functions it may use. Once the validity of the functions is determined, each function is instantated. Instantiation determines that the supporting Bulk Data, if any, is present on the database and the actual number of instances. The instantiation process creates the data structures that describe each constraint. These data structures are then used by ASTROS to request the computation of the constituent responses.

Design Requirements:

1. A Function packet must be included in the input data stream.

Error Conditions:

1. Syntax errors and inconsistent or illegal function requests are flagged and the execution is terminated.

Engineering Application Module: FREDUCE

Entry Point: FREDUC

Purpose:

To reduce the symmetric or asymmetric f-set stiffness, mass and/or loads matrix to the a-set if there are omitted degrees of freedom.

MAPOL Calling Sequence:

```
CALL FREDUCE ( [KFF], [PF], [PFOA(BC)], SYM, [KOOINV(BC)], [KOOU(BC)],
               [KAO(BC)], [GSUBO(BC)], [KAA], [PA], [PO], USET(BC) );
```

[KFF]	Optional Stiffness or mass matrix to be reduced (Input)
[PF]	Optional loads matrix to be reduced (Input)
[PFOA(BC)]	The partitioning vector splitting the free degrees of freedom into the analysis set and the omitted degrees of freedom (Input), where **BC** represents the MAPOL boundary condition loop index number
SYM	Optional symmetry flag; **=1** if **KFF** is not symmetric (Integer, Input)
[KOOINV(BC)]	Matrix containing the inverse of **KOO** for symmetric stiffness matrices or the lower triangular factor of **KOO** for asymmetric matrices (Output), where **BC** represents the MAPOL boundary condition loop index number
[KOOU(BC)]	Optional matrix containing the upper triangular factor of **KOO** for asymmetric stiffness matrices (Output), where **BC** represents the MAPOL boundary condition loop index number
[KAO(BC)]	Optional matrix containing the off-diagonal partition of **KFF** required for recovery when **KFF** is asymmetric (Output), where **BC** represents the MAPOL boundary condition loop index number
[GSUBO(BC)]	Matrix containing the static condensation transformation matrix (Input and Output), where **BC** represents the MAPOL boundary condition loop index number
[KAA]	The stiffness matrix in the analysis set degrees of freedom (Output)
[PA]	The loads matrix in the analysis set degrees of freedom (Output)
[PO]	Matrix containing the loads on the omitted degrees of freedom (Output)
USET(BC)	The unstructured entity defining structural sets (Character, Input), where **BC** represents the MAPOL boundary condition loop index number

Application Calling Sequence:

None

Method:

FREDUCE module begins by checking if the **KFF** argument is nonblank. If so, the reduction by static condensation is performed in one of two ways depending on the **SYM** flag. If the **SYM** flag is zero or omitted from the calling sequence the following operations are performed:

$$\left[\ \mathbf{KFF}\ \right] \rightarrow \begin{bmatrix} \mathbf{KOO} & \mathbf{KOA} \\ \mathbf{KOA}^{T} & \overline{\mathbf{KAA}} \end{bmatrix}$$

[KOOINV] = [KOO]$^{-1}$ symmetric decomposition

[GSUBO] = -[KOOINV][KOA] symmetric Forward-Backward Substition

$$\left[\ \mathbf{KAA}\ \right] = \left[\ \overline{\mathbf{KAA}}\ \right] + \left[\ \mathbf{KOA}\ \right]^{T} \left[\ \mathbf{GSUBO}\ \right]$$

The **KOOINV**, **GSUBO** and **KAA** arguments must be nonblank in the calling sequence. If the **SYM** flag is nonzero in the calling sequence the following operations are performed:

$$\left[\ \mathbf{KFF}\ \right] \rightarrow \begin{bmatrix} \mathbf{KOO} & \mathbf{KOA} \\ \mathbf{KAO} & \overline{\mathbf{KAA}} \end{bmatrix}$$

[KOOINV] and **[KOOU]** are the Lower and Upper triangular factors of **[KOO]**

[GSUBO] = - [KOO]$^{-1}$**[KOA]** asymmetric Forward-Backward Substition

[KAA] = [$\overline{\text{KAA}}$] + [KAO][GSUBO]

The **KOOINV**, **KOOU**, **KAO**, **GSUBO** and **KAA** arguments must be nonblank in the calling sequence. Note that **KAO** is required since the asymmetric nature of **KFF** prohibits the transpose operation used in the symmetric case. The module then checks if **PF** is nonblank. If so, the loads matrix reduction is performed. Once again, there are two paths depending on the symmetry flag. If **SYM** is zero (symmetric), the following operations are performed:

$$\left[\ \mathbf{PF}\ \right] \rightarrow \left\{ \begin{matrix} \mathbf{PO} \\ \overline{\mathbf{PA}} \end{matrix} \right\}$$

[SCR1] = [PO]^{T}**[GSUBO]**

[SCR2] = [SCR1]^{T}

[PA] = [$\overline{\text{PA}}$] + [SCR2]

With the odd order of operations dictated by efficiency considerations in the matrix operations. Note that the **GSUBO**, **PA** and **PO** arguments must be nonblank with the **GSUBO** argument an input if the stiffness matrix was not simultaneously reduced. If **SYM** is nonzero (asymmetric), the following operations are performed:

$$\left[\ \mathbf{PF}\ \right] \rightarrow \left\{ \begin{matrix} \mathbf{PO} \\ \overline{\mathbf{PA}} \end{matrix} \right\}$$

$\mathbf{[SCR1] = [KOO]^{-1}\ [PO]}$ (Asymmetric **FBS**)

$\mathbf{[PA] = [\overline{PA}] + [KAO][SCR1]}$

Note that the **KOOINV**, **KOOU**, **KAO**, **PA** and **PO** arguments must be supplied with the **KOOINV**, **KOOU**, **and KAO** arguments input if the (asymmetric) stiffness matrix is not being reduced in the same call.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: FREQSENS

Entry Point: FQCSTY

Purpose:

To compute the sensitivities of active frequency constraints in the current active boundary condition.

MAPOL Calling Sequence:

```
CALL FREQSENS ( NITER, BCID, NDV, GLBDES, CONST, LAMBDA, GMKCT, DKVI, GMMCT,
                DMVI, [PHIG(BC)], [AMAT] );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
NDV	Number of design variables (Integer, Input)
GLBDES	Relation of global design variables (Character, Input)
CONST	Relation of constraint values (Character, Input)
LAMBDA	Relational entity containing the output from the real eigenanalysis (Input)
GMKCT	Relation containing connectivity data for the **DKVI** sensitivity matrix (Character, Input)
DKVI	Unstructured entity containing the stiffness design sensitivity matrix in a highly compressed format (Character, Input)
GMMCT	Relation containing connectivity data for the **DMVI** sensitivity matrix (Character, Input)
DMVI	Unstructured entity containing the mass design sensitivity matrix in a highly compressed format (Character, Input)
[PHIG(BC)]	Matrix of eigenvectors for the current boundary condition (Input), where **BC** represents the MAPOL boundary condition loop index number
[AMAT]	Matrix containing the sensitivities of the constraints to the design variables (Output)

Application Calling Sequence:

None

Method:

This module first computes the frequency response sensitivities which are required by the active user function constraints. Then it obtains design variable information from **GLBDES**, frequency constraint information from **CONST** and eigenvalue information from **LAMBDA**. Space is reserved for design sensitivity matrices and then the number of eigenvectors that can be held in core simultaneously is determined. Spill logic is provided if this number is less than the number of eigenvectors that have eigenvalue constraints.The eigenvectors are read into core and a loop on the design variables brings the connectivity data into core. Calls to **TUNMLS/D** perform the required triple matrix products involving the eigenvector and the design sensitivity matrices. This information is required to form the frequency constraint information, which is written to the **AMAT** matrix.

Design Requirements:

1. The module is only called if there are active frequency constraints and therefore must follow the **ABOUND** module.

2. The **DESIGN** module makes the assumption that data were written to **AMAT** from this module prior to any subcase dependent sensitivities.

Error Conditions:

None

Engineering Application Module: FSD

Entry Point: FSDDRV

Purpose:

To perform redesign by Fully Stressed Design (**FSD**) methods based on the set of applied stress constraints. All other applied constraints are ignored.

MAPOL Calling Sequence:

```
CALL FSD ( NDV, NITER, FSDS, FSDE, MPS, ALPHA, CNVRGLIM, GLBDES,
           LOCLVAR, [PTRANS], CONST, APPCNVRG, CTL, CTLMIN, DESHIST );
```

NDV	The number of global design variables (Integer, Input)
NITER	Iteration number for the current design iteration (Integer, Input)
FSDS	The first iteration to use **FSD** (Integer, Input)
FSDE	The last iteration to use **FSD** (Integer, Input)
MPS	The first iteration to use math programming (Integer, Input)
ALPHA	Exponential move limit for the **FSD** algorithm (Real, Input)
CNVRGLIM	Relative percent change in the objective function that indicates approximate problem convergence (Real, Input)
GLBDES	Relation of global design variables (Character, Input)
LOCLVAR	Relation containing the relationship between local variables and global variables in the design problem (Character, Input)
[PTRANS]	The design variable linking matrix (Character, Input)
CONST	Relation of constraint values (Character, Input)
APPCNVRG	The approximate problem converge flag (Logical, Output) **FALSE** if not converged **TRUE** if converged in objective function value and design vector move
CTL	Tolerance for indicating an active constraint (Real, Output)
CTLMIN	Tolerance for indicating a violated constraint (Real, Output)
DESHIST	Relation of design iteration information (Character, Output)

Application Calling Sequence:

None

Method:

The first task performed in the **FSD** module is to determine if the **FSD** option is to be used. The assumption of the module is that the Solution Control **STRATEGY** requests have been satisfied by the MAPOL sequence such that, if **FSD** is called, **FSD** has been requested by the user for this iteration.

The module checks that the **ALPHA** parameter is a legal value (**>0.0**). If it is not, the default value of 0.50 is used. Then **FSD** brings the required data into memory. These data consist of the local design variable data (in the **PTRANS**, **LOCLVAR** and **GLBDES** entities), which are accessed through the design

variable utility module **PRELDV** with entry points **LDVPNT** and **GETLDV**. Finally, the **CONST** relation tuples associated with the stress constraints are retrieved. If no stress constraints are found, the module cannot do any resizing and so modifies the MAPOL control parameters **FSDS**, **FSDE**, and **MPS** as outlined below to prevent the further use of **FSD** in subsequent iterations.

If the appropriate constraints were found, the module loops through each local design variable and determines which (if any) stress constraint is associated with that variable. When the matching constraint is found, the new local variable is computed from:

$$t_{new} = (g + 1.0)^{\alpha}$$

If any shape function linked local variables are encountered during this phase, the starting and ending iterations (**FSDS** and **FSDE**) and the appropriate other starting iteration number (**MPS**) are modified such that **FSD** will not be called again. Then execution is returned to the executive. This prevents any further attempts to use **FSD** with the shape function linking and directs that the current iteration be performed used the appropriate alternative method. A warning is given and the execution continues.

Once the vector of new local variables are retrieved, the **PTRANS** data is brought into memory along with the **GLBDES** data. The **GLBDES** data are used to reset any local variable values that are outside their valid ranges to maximum or minimum gauge. Then the new vector of global variables are computed as:

$$v_{new} = \max_{P_i} \left(\frac{t_{new}}{P_i} \right)$$

These constitute the new design from the **FSD** algorithm and are stored back to the **GLBDES** relation. The **DESHIST** relation is updated and an informational message indicating the changes in the objective function is written. The active and violated constraint tolerances are set to their **FSD** default values: **CTL=-1.0 x 10^{-3}** and **CTLMIN=5.0x10^{-3}**. This completes the action of the **FSD** module.

Design Requirements:

1. Only stress constraints (strain constraints are excluded) are considered in the **FSD** module. If none are found, the module terminates cleanly with the **FSD** selection flags reset to avoid any further **FSD** cycles.

2. Shape function design variable linking causes the module to terminate cleanly with the **FSD** selection flags reset to avoid any further **FSD** cycles.

Error Conditions:

None

Engineering Application Module: GDR1

Entry Point: GDRDR1

Purpose:

To compute the shifted stiffness matrix and the rigid body transformation matrix **[GGO]** to be used in phase 2 of Generalized Dynamic Reduction.

MAPOL Calling Sequence:

```
CALL GDR1 ( [KOO], [MOO], [KSOO], [GGO], LKSET, LJSET, NEIV, FMAX, BCID,
            BGPDT(BC), USET(BC), NOMIT, LSIZE );
```

[KOO]	Stiffness matrix in the o-set (Input)
[MOO]	Mass matrix in the o-set (Input)
[KSOO]	Shifted **KOO** matrix (Output)
[GGO]	Matrix to compute displacements at the g-set due to displacements at the origin (Output)
LKSET	Length of the k-set vectors, **LKSET = -1** if there is no k-set (Integer, Output)
LJSET	Length of the j-set, **LJSET= –1** if there is no jset
NEIV	Computed number of eigenvalues below **FMAX** (Integer, Output)
FMAX	Maximum frequency of interest. This is user supplied through the **DYNRED** entry, but may be modified after output to give the desired number of eigenvalues on input to **GDR2** (Real,Output)
BCID	User defined boundary condition identification number (Integer, Input)
BGPDT(BC)	Relation of basic grid point coordinate data (Input), where **BC** represents the MAPOL boundary condition loop index number
USET(BC)	The unstructured entity defining structural sets (Input), where **BC** represents the MAPOL boundary condition loop index number
NOMIT	The number of DOF in the o-set (Integer, Input)
LSIZE	The number of DOF in the L-set (Integer, Input)

Application Calling Sequence:

None

Method:

The module begins by calling subroutine **GDR1S** to input bulk data information. **NEIV,** the number of eigenvalues, is then determined using **FMAX** and the Sturm sequence theorem. The **LJSET** parameter is computed as a combination of structural DOF in the a-set plus any user input nonstructural DOF. The **LKSET** parameter is specified to be **1.5 *NEIV** and the shift parameter is computed based on **FMAX**, **LKSET** and the machine precision. The shifted stiffness matrix is then computed, the **GGO** matrix is computed and control is returned to the executive.

Design Requirements:

1. This module is an alternative to Guyan reduction and therefore parallels the reduction to the a-set.

Error Conditions:

1. j-set DOF have been constrained
2. o-set does not exist
3. Only a subset of roots are guaranteed to be accurate.

Engineering Application Module: GDR2

Entry Point: GDRDR2

Purpose:

To compute the orthogonal basis **[PHIOK]** for the subspace to be used in phase 3 of Generalized Dynamic Reduction.

MAPOL Calling Sequence:

```
CALL GDR2      ( [LSOO], [MOO], [PHIOK], LKSET, LJSET, NEIV, FMAX, BCID );
```

[LSOO]	Decomposed shifted stiffness matrix (Input)
[MOO]	Mass matrix in the o-set (Input)
[PHIOK]	Matrix of approximate vectors (Output)
LKSET	Length of the k-set vectors (Integer, Input)
LJSET	Not used
NEIV	Number of eigenvalues below **FMAX** (Integer, Input)
FMAX	Maximum frequency of the **NEIV** eigenvalues (Real,Input)
BCID	User defined boundary condition identification number (Integer, Input)

Application Calling Sequence:

None

Method:

After performing initialization tasks, random starting vectors are generated and an iteration procedure is performed to obtain an initial set of solution vectors. These solution vectors are transformed into a orthogonal base for the approximate vectors. If an insufficient number (<< **LKSET**) vectors are generated by this process, additional solution vectors are obtained and transformed.

Design Requirements:

1. This module follows **GDR1** and a decomposition of **KSOO** into **LSOO**.

2. If **LKSET** is zero in the standard MAPOL sequence, **GDR2** is not called.

Error Conditions:

None

Engineering Application Module: GDR3

Entry Point: GDRDR3

Purpose:

To compute the transformation matrix **[GSUBO]** for Generalized Dynamic Reduction.

MAPOL Calling Sequence:

```
CALL GDR3 ( [KOO], [KOA], [MGG], [PHIOK], [TMN(BC)], [GGO], [PGMN(BC)],
            [PNSF(BC)], [PFOA(BC)], [GSUBO(BC)], BGPDT(BC), USET(BC), LKSET,
            LJSET, ASIZE, GNORM, BCID );
```

[KOO]	Stiffness matrix in the o-set (Input)
[KOA]	Partition of the stiffness matrix (Input)
[MGG]	Mass matrix in the g-set (Input)
[PHIOK]	Matrix of approximate eigenvectors (Input)
[TMN(BC)]	Matrix relating m-set and n-set DOF's (Input), where **BC** represents the MAPOL boundary condition loop index number
[GGO]	Rigid body transformation matrix (Input)
[PGMN(BC)]	Partitioning vector from g to m and n-sets (Input), where **BC** represents the MAPOL boundary condition loop index number
[PNSF(BC)]	Partitioning vector from n to s and f-sets (Input), where **BC** represents the MAPOL boundary condition loop index number
[PFOA(BC)]	Partitioning vector from f to o and a-sets (Input), where **BC** represents the MAPOL boundary condition loop index number
[GSUBO(BC)]	General transformation matrix for dynamic reduction (Output), where **BC** represents the MAPOL boundary condition loop index number
BGPDT(BC)	Relation of basic grid point coordinate data (Input), where **BC** represents the MAPOL boundary condition loop index number
USET(BC)	The unstructured entity defining structural sets (Input), where **BC** represents the MAPOL boundary condition loop index number
LKSET	Length of the k-set (Integer, Input)
LJSET	Length of the j-set (Integer, Input and Output)
ASIZE	The number of DOF's in the A-set (Integer, Input)
GNORM	The sum of **LKSET** and **LJSET** (Integer, Output)
BCID	Boundary condition identification number (Integer, Input)
BC	Boundary condition index number (Integer, Input)

Application Calling Sequence:

None

Method:

The module calculates an overall transformation matrix which relates DOF's in the a-, j- and k-sets to the o-set. The task is simplified if some of the sets are empty.

Design Requirements:

1. This module must follow **GDR1**.

2. If **LKSET** is nonzero, **GDR2** must also have been called.

Error Conditions:

None

Engineering Application Module: GDR4

Entry Point: GDRDR4

Purpose:

To compute updated transformations between displacement sets. Useful for data recovery from Generalized Dynamic Reduction.

MAPOL Calling Sequence:

```
CALL GDR4 ( BCID, GSIZE, PSIZE(BC), LKSET, LJSET, [PGMN(BC)], [TMN(BC)],
            [PNSF(BC)], [PFOA(BC)], [PARL(BC)], [PGDRG(BC)], [PAJK],
            [PFJK], BGPDT(BC), USET(BC) );
```

BCID	User defined boundary condition identification number (Integer, Input)
GSIZE	Length of the g-set vector (Integer, Input)
PSIZE(BC)	The size of the physical set for the current boundary condition. (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number
LKSET	Length of the k-set (Integer, Input)
LJSET	Length of the j-set (Integer, Input)
[PGMN(BC)]	Partitioning vector from g to m and n-sets (Input), where **BC** represents the MAPOL boundary condition loop index number
[TMN(BC)]	Matrix relating m-set and n-set DOF's (Input), where **BC** represents the MAPOL boundary condition loop index number
[PNSF(BC)]	Partitioning vector from n to s and f-sets (Input), where **BC** represents the MAPOL boundary condition loop index number
[PFOA(BC)]	Partitioning vector from f to o and a-sets (Input), where **BC** represents the MAPOL boundary condition loop index number
[PARL(BC)]	Modified partitioning vector to partition the a-set to r and l-sets (Output), where **BC** represents the MAPOL boundary condition loop index number
[PGDRG(BC)]	A partitioning vector that removes the additional **GDR** scalar points from the g-set sized displacement and acceleration vectors. (Output), where **BC** represents the MAPOL boundary condition loop index number
[PAJK]	Partitioning vector to divide the a-set DOFs that may include **GDR** generated scalar points into the original a-set DOF's. (Output)
[PFJK]	Partitioning vector to divide the f-set DOFs that may include **GDR** generated scalar points into the original f-set DOF's. (Output)
BGPDT(BC)	**GDR** modified relation of basic grid point coordinate data which, on output, will include the scalar points generated by **GDR**. (Input and Output), where **BC** represents the MAPOL boundary condition loop index number
USET(BC)	**GDR** modified unstructured entity defining structural sets which, on output, will include the scalar points generated by **GDR**. (Input and Output), where **BC** represents the MAPOL boundary condition loop index number

Application Calling Sequence:

None

Method:

The module computes the partitioning matrix **PGDRG** to allow reduction of the downstream g-set matrices to be only the original g-set (before **GDR** scalar points were added). Similarly the **PFJK** partitioning vector does the same for f-set matrices. The **USET** and **BGPDT** entities are updated to include the **GDR** extra points (which are assigned external id's greater than any existing scalar points and internal id's greater than the g-size). These degrees of freedom will belong to the k- and/or j-sets. Lastly, a modified **PARL** partitioning vector is also computed in which the a-set are the generalized **GDR** degrees of freedom (scalar points and/or physical DOF) and the r-set are the support point DOFs.

Design Requirements:

1. This is the final module in the **GDR** sequence

Error Conditions:

None

Engineering Application Module: GDVGRAD

Entry Point: GDVGRD

Purpose:

Computes the sensitivity of design variable intrinsic functions to the changes of design variables.

MAPOL Calling Sequence:

```
CALL GDVGRAD ( NITER, NDV, CONST, GLBDES );
```

NITER	Design iteration number (Integer,Input)
NDV	Number of design variables (Integer,Input)
CONST	Relation of constraint values (Character,Input)
GLBDES	Relation of global design variables (Character,Input)

Application Calling Sequence:

None

Method:

This module first determines the active user functional constraints at the current design iteration. Then the design variable intrinsic entity is searched to find the design variable intrinsic functions which are required. The sensitivities to the design variables are computed for those functions and stored into the design variable intrinsic function sensitivity relation and matrix entities.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: GDVPRINT

Entry Point: GDVPRT

Purpose:

To print global design variables.

MAPOL Calling Sequence:

```
CALL GDVPRINT ( NITER, NDV, GLBDES, MOVLIM, LASTITER, GPRINT, ALLPRINT ) ;
```

NITER	Design iteration number (Integer, Input)
NDV	Number of design variables (Integer, Input)
GLBDES	Relation of current global design variable values (Character, Input)
MOVLIM	User-supplied design variable move limit (Real, Input)
LASTITER	Integer flag indicating the last iteration (Integer, Input) **= 0** Not the last iteration **> 0** Last iteration
GPRINT	Logical flag indicating if the global design variables have been printed (Logical, Input)
ALLPRINT	Flag indicating that all global variables will be printed. (Integer, Input) **= 0** Not to be printed **> 0** To be printed

Application Calling Sequence:

None

Method:

The input flags are checked to determine if the global design variables are to be printed. This is obtained from the **OPTIMIZE** relation. All global variables in relation **GLBDES** are then printed.

Design Requirements:

None.

Error Conditions:

None

Engineering Application Module: GDVPUNCH

Entry Point: GDVPCH

Purpose:

To print global design variables.

MAPOL Calling Sequence:

```
CALL GDVPRINT ( NITER, NDV, GLBDES, GPUNCH, LASTITER, ALLPUNCH ) ;
```

NITER	Design iteration number (Integer, Input)
NDV	Number of design variables (Integer, Input)
GLBDES	Relation of current global design variable values (Character, Input)
GPUNCH	Flag indicating if the global design variables have been printed (Logical, Input)
LASTITER	Flag indicating the last iteration (Integer, Input) **= 0** Not the last iteration **> 0** Last iteration
ALLPUNCH	Flag indicating that all global variables will be printed. (Integer, Input) **= 0** Not to be printed **> 0** To be printed

Application Calling Sequence:

None

Method:

The input flags are checked to determine if the global design variables are to be punched. This is obtained from the **OPTIMIZE** relation. All global variables in relation **GLBDES** are then punched.

Design Requirements:

None.

Error Conditions:

None

Engineering Application Module: GDVRESP

Entry Point: GDVRSP

Purpose:

Computes the design variable intrinsic function values.

MAPOL Calling Sequence:

```
CALL GDVRESP ( NITER, NDV, GLBDES );
```

NITER	Design iteration number (Integer,Input)
NDV	Number of design variables (Integer,Input)
GLBDES	Relation of global design variables (Character,Input)

Application Calling Sequence:

None

Method:

This module searches through all design variable intrinsic entity entries and obtains all design variable identification numbers which are required to evaluate user functions. The values of those required design variables are obtained from relation **GLBDES** and stored into the design variable intrinsic response entity.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: GENELPRT

Entry Point: GENLPT

Purpose:

To print the unstructured entity **GENEL** which defines general elements.

MAPOL Calling Sequence:

```
CALL GENELPRT ( GENEL ) ;
```

GENEL	Unstructured entity of general element data (Character, Input)

Application Calling Sequence:

None

Method:

The requested entity is printed.

Design Requirements:

None.

Error Conditions:

None

Engineering Application Module: GPSP

Entry Point: GPSP

Purpose:

Processes the n-set stiffness matrix to identify singularities, and, if requested, automatically removes them.

MAPOL Calling Sequence:

```
CALL GPSP ( NITER, BCID, NGDR, [KNN], BGPDT(BC), [YS(BC)],
            USET(BC), GPST(BC) );
```

NITER	Design iteration number (Integer,Input)
BCID	User defined boundary condition identification number (Integer, Input)
NGDR	Denotes dynamic reduction in the boundary condition (Input,Integer) **0** No **GDR** is requested **-1** **GDR** has been requested
[KNN]	A partition of the **KGG** matrix which contains global stiffness matrix (Character,Input)
BGPDT(BC)	Relation of basic grid point coordinates (Character,Input), where **BC** represents the MAPOL boundary condition loop index number
[YS(BC)]	The vector of enforced displacements (Character,Input), where **BC** represents the MAPOL boundary condition loop index number
USET(BC)	Unstructured entity defining structural sets for each degree of freedom (Character,Input), where **BC** represents the MAPOL boundary condition loop index number
GPST(BC)	Unstructured entity contains the grid point singularity table information (Character,Output), where **BC** represents the MAPOL boundary condition loop index number

Application Calling Sequence:

None

Method:

In this module, for each grid or scalar point the following basic processing is done. For grid points two 3 x 3 stiffness matrices are processed and for scalar points the single diagonal stiffness term is processed. Each of these is checked for potential singularities by performing an eigenvalue analysis. If any singularities are found and the degree of freedom in question is not in the s-set, m-set or connected to an MPC equation, then a Single Point Constraint (SPC) is generated. This module processes the n-set matrix and will assure that any singularities left are removed using the same basic processing occurs except only SPC's are generated and **RG** is purged so that no MPC connection processing occurs.

Design Requirements:

None

Error Conditions:

If a non-positive definite partition of the stiffness matrix is detected during AUTOSPC processing, or if the eigenanalysis fails to converge, the program terminates.

Engineering Application Module: GPWG

Entry Point: GPWG

Purpose:

Grid point weight generator.

MAPOL Calling Sequence:

```
CALL GPWG ( NITER, BCID, GPWGGRID, [MGG], OGPWG );
```

NITER	Design iteration number (Optional, Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
GPWGGRID	Relation containing the data from the **GPWG** Bulk Data entries (Input)
[MGG]	Mass matrix in the g-set (Input)
OGPWG	Relation of Grid Point Weight Generation Output (Output)

Application Calling Sequence:

None

Method:

The existence of the **MGG** matrix is checked first. If it does not exist or has no columns, control is returned to the MAPOL sequence without error. Then the **CASE** relation is read for the current boundary condition to determine if any **GPWG** print or punch requests exist. If not, the module terminates.

The invariant basic grid point data are read from **BGPDT** and checked to ensure that at least one grid point exists. If all the points are scalar points, the module terminates without warning. Then the **CONVERT/MASS** entry is recovered (if one exists) to allow output of the Grid Point Weight from the mass matrix. Then the coordinates of the reference point are found from the first **GPWG** entry in the **GPWGGRID** relation or are set to {**0.0,0.0,0.0**}.

The grid point weight is then computed and the results are stored on the **OGPWG** relation. If a **PRINT** request exists for the current design iteration or analyse boundary condition, the results are read from **OGPWG** and printed to the output file.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: GREDUCE

Entry Point: GREDUC

Purpose:

To reduce the symmetric g-set stiffness, mass or loads matrix to the n-set if there are multipoint constraints in the boundary condition.

MAPOL Calling Sequence:

```
CALL GREDUCE ( [KGG], [PG], [PGMN(BC)], [TMN(BC)], [KNN], [PN] );
```

[KGG]	Optional matrix containing the global stiffness or mass matrix to be reduced (Input)
[PG]	Optional matrix containing the global applied loads to be reduced (Input)
[PGMN(BC)]	The partitioning vector splitting the structural degrees of freedom into the independent and the multipoint constraint degrees of freedom (Input), where **BC** represents the MAPOL boundary condition loop index number
[TMN(BC)]	The transformation matrix for multipoint constraints (Input), where **BC** represents the MAPOL boundary condition loop index number
[KNN]	Optional matrix containing the reduced **KGG** matrix for the independent degrees of freedom (Output)
[PN]	Optional matrix containing the reduced **PG** matrix for the independent degrees of freedom (Output)

Application Calling Sequence:

None

Method:

The **GREDUCE** utility module performs the multipoint constraint reduction on the stiffness and/or mass and/or loads matrix based on the presence or absence of input arguments. The only required arguments are the partitioning vector **PGMN** and the rigid body transformation matrix **TMN**. If the **KGG** argument is not omitted, the following operations are performed using the large matrix utilities:

$$\begin{bmatrix} KGG \end{bmatrix} \rightarrow \begin{bmatrix} KMM & KMN \\ KNM & \overline{KNN} \end{bmatrix}$$

$$[SCR1] = [\overline{KNN}] + [KNM][TMN]$$

$$[SCR2] = [SCR1] + [TMN]^T[KMN]$$

$$[SCR1] = [KMM][TMN]$$

$$[SCR2] = [SCR1] + [TMN]^T[KMN]$$

$$[KNN] = [SCR2] + [TMN]^T[KMN]$$

These operations require the creation of four scratch matrix entities for the intermediate results and the partitions of the **KGG** matrix.

If the **PG** argument is not omitted, the following operations are performed using the large matrix utilities:

$$\left[\ \mathbf{PG}\ \right] \rightarrow \left\{ \begin{matrix} \mathbf{PM} \\ \overline{\mathbf{PN}} \end{matrix} \right\}$$

$$\mathbf{[PN] = [\overline{PN}] + [TMN]^T[PM]}$$

These operations require the use of two scratch matrix entities for the partitions of the **PG** matrix. When both **KGG** and **PG** are reduced, the scratch partition matrices are shared.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: GTLOAD

Entry Point: GTLOAD

Purpose:

To assemble the current static applied loads matrix for any statics subcases in the current boundary condition.

MAPOL Calling Sequence:

```
CALL GTLOAD ( NITER, BCID, GSIZE, BGPDT(BC), GLBDES, SMPLOD, [DPTHVI],
              [DPTHVD], [DPGRVI], [DPGRVD], [PG], OGRIDLOD );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
GSIZE	The size of the structural set (Integer, Input)
BGPDT(BC)	Relation of basic grid point coordinate data (Input), where **BC** represents the MAPOL boundary condition loop index number
GLBDES	Relation of global design variables (Input)
SMPLOD	Unstructured entity of simple load vector information (Input)
[DPTHVI]	Matrix entity containing the linear thermal load sensitivities (Input)
[DPTHVD]	Matrix entity containing the nonlinearly designed thermal loads (Character, Input)
[DPGRVI]	Matrix entity containing the linear gravity load sensitivities (Input)
[DPGRVD]	Matrix entity containing the nonlinearly designed gravity loads (Character, Input)
[PG]	The matrix of applied loads in the global structural set (Output)
OGRIDLOD	Relation of loads on structural grid points. (Output)

Application Calling Sequence:

None

Method:

The **CASE** relation tuples for the current boundary condition are brought into memory to obtain the mechanical, thermal and/or gravity simple load identification numbers for each **STATICS** discipline. The **LOAD** bulk data relation is also read into memory to process combined simple loads requests. Finally, the **SMPLOD** data are read to determine the number and types of each simple load defined in the bulk data packet. The **PG** matrix is flushed and initialized prior to the start of the loads assembly loop. This loop consists of a search to determine if the load case is

(1) a simple mechanical load

(2) a simple gravity load

(3) a simple thermal load

(4) a combination of mechanical and/or gravity loads

The column of the **PG** matrix associated with each right-hand side is assembled using the **SMPLOD** (and **LOAD**) data. The thermal and gravity loads are special in that the **GLBDES** information must be retrieved in order to assemble the loads representing the current design. The case where no design variables are defined does not represent a special case, however, since the **DPVRGI** and **DPTHGI** entities always include terms representing the "zeroth" design variable. Once all the **STATICS** cases have been processed, the module terminates.

Design Requirements:

1. The module assumes that at least one **STATIC** load case is defined in the **CASE** relation for the current boundary condition.

2. The **SMPLOD** entity from the **LODGEN** module must exist as must the **DPVRGI** and **DPTHGI** gravity and thermal load sensitivity matrices.

Error Conditions:

1. No simple loads are defined in the **SMPLOD** entity

Engineering Application Module: IFP

Entry Point: IFP

Purpose:

To process the Bulk Data Pocket and to load the input data to the data base. Also, to compute the external coordinate system transformation matrices and to create the basic grid point data.

MAPOL Calling Sequence:

```
CALL IFP ( GSIZEB, EIDTYPE );
```

GSIZEB	The size of the structural set (Integer, Output)
EIDTYPE	Relation containing element identification numbers and their corresponding element type (Character,Output)

Application Calling Sequence:

None

Method:

The Input File Processor module performs several tasks to initialize the execution of ASTROS procedure. It begins by setting the titling information for the **IFP** bulk data echo (should that option be selected).

Following these tasks, the module continues with the interpretation of the bulk data packet of the input stream. This packet resides on an unstructured entity called **&BKDTPKT** which is loaded by the executive routine **PREPAS** during the interpretation of the input data stream. The **IFP** module proceeds in two phases. In the first phase, the bulk data are read, expanded from free to fixed format and sorted on the first three fields of each bulk data entry. If an unsorted echo is requested, that echo is performed as the **&BKDTPKT** entity is read. If a sorted echo is desired, it is performed after the expansion and sort has taken place. In either case, the bulk data is sorted by the **IFP** module. The resultant data are stored on one or more scratch unstructured entities depending on how many passes must be performed to accomplish the sort in the available memory. If all the bulk data fits into open core, only a single scratch file is required.

For the **MODEL** punch option request, the expanded and sorted input Bulk Data entries are divided into following categories:

(1) element definition entries (e.g. **CBAR**)

(2) property definition entries (e.g. **PBAR**)

(3) design variable linking and design constraint definition entries (e.g. **DESELM**, **DESVARP**, **DESVARS** and **DCONVMM**, **DCONxxx**)

(4) the rest of the Bulk Data

Those entries in categories (1), (2) and (4) are stored in corresponding unstructured entities for use in module **DESPUNCH**. Those in category (3) are not saved for **DESPUNCH**, since it will output a **MODEL** without the design entries.

The second phase of the bulk data interpretation proceeds based on the sorted bulk data from the expansion phase. This phase begins by reading the first bulk data entry in the sorted list and locating its bulk data template in the set of templates stored on the system data base by the SYSGEN program. This template defines the card field labels, the field variable type, the field default value, the field error checks and information on where to load the field into the data base loading array. The template is

compiled once and all like bulk data entries are processed together. Any user input errors that are detected are flagged with a message indicating the field that is in error and whether the error consists of an illegal data type (i.e, an integer value in a real field) or of an illegal value for the given field (i.e., a negative element identification number). Note that the **IFP** module is only checking errors on a single bulk data entry and does not perform any inter-entry compatibility checks.

This process is then repeated for each different bulk data entry type in the sorted list of bulk data entries. If any errors have occured, the module terminates the ASTROS execution. As a final two steps, the **IFP** module performs calls to the **MKTMAT**, **MKBGPD** and **MKUSET** submodules to create the transformation matrices for any external coordinate systems, to generate the basic grid point data and to make an error checking pass over the structural set definitions. These three tasks are not explicitly part of the **IFP** module but are so basic to every execution that they cannot properly be considered MAPOL engineering application modules. Any errors resulting in these two tasks will also cause the run to terminate with the appropriate error messages.

Design Requirements:

None

Error Conditions:

1. User bulk data errors are flagged and cause program termination.
2. Inconsistent or illegal coordinate system definitions.
3. Illegal grid/scalar and/or extra point definitions.
4. Illegal structural set definitions in the **MODEL**.

Engineering Application Module: INERTIA

Entry Point: INRTIA

Purpose:

To compute the rigid body accelerations for statics analyses with inertia relief.

MAPOL Calling Sequence:

```
CALL INERTIA ( [LHS(BC)], [RHS(BC)], [AR] );
```

[LHS(BC)]	Rigid body reduced mass matrix (Input), where **BC** represents the MAPOL boundary condition loop index number
[RHS(BC)]	Applied load vector reduced to the r-set (Input), where **BC** represents the MAPOL boundary condition loop index number
[AR]	Matrix of acceleration vectors (Output)

Application Calling Sequence:

None

Method:

Matrices **LHS** and **RHS** are read into memory and **AR** is computed by solving **[LHS][AR] = [RHS]**

Design Requirements:

1. There must be an r-set and the reductions to the r-set must have been performed.

Error Conditions:

1. The **LHS** matrix is singular.

Engineering Application Module: ITERINIT

Entry Point: ITITDR

Purpose:

Initializes the up to 10 relations for the current iteration.

MAPOL Calling Sequence:

```
CALL ITERINIT ( NITER, EP1, EP2, EP3, EP4, EP5, EP6, EP7, EP8, EP9, EP10 );
```

NITER	Design iteration number (Integer, Input)
EPi	Name of relations to be initialized (Character, Input and Output)

Application Calling Sequence:

None

Method:

This module ***must*** be called at the top of each design iteration loop. Its function is twofold: 1) to set the iteration number page header into **SUBTITLE(88:)** in the **/OUTPT2/** common and 2) to reset the **CONST** relation on restart runs.

Each page of output during the design iterations is labeled in the **SUBTITLE** line with the iteration number. It is this module that sets that part of the **SUBTITLE** line that contains that information.

The specified relations are opened and, if not empty, a conditioned retrieval is done to see if any entries exist with an iteration number greater than or equal to the current **NITER**. If so, the relational entries with **NITER** values less than the current **NITER** are copied to a scratch relation, the scratch name is exchanged for the old name and the scratch entity (now pointing to the original relation) is destroyed. Thus, all entries with **NITER** values associated with iterations that have not yet occurred are flushed. This resetting of the specified relation is done so that ASTROS can be restarted at a previous design iteration merely by setting the value of **NITER** in the MAPOL sequence back to the desired starting iteration number.

If the specified relation is empty or if no restart actions are required, the relation is closed and the module terminates without action.

Design Requirements:

1. **ITERINIT** is one of the few application modules that is allowed to touch the **TITLE**, **SUBTITLE** and **LABEL** entries of the **/OUTPT2/** common beyond the 72nd character. While applications may set the first 72 characters with the input **TITLE**, etc., generally only the system may modify them beyond that. These labels are used by **UTPAGE**.

Error Conditions:

None

Engineering Application Module: LAMINCON

Entry Point: LAMCON

Purpose:

To evaluate composite laminate constraints defined on **DCONLAM**, **DCONLMN** and **DCONPMN** bulk data entries.

MAPOL Calling Sequence:

```
CALL LAMINCON ( NITER, NDV, DCONLAM, DCONLMN, DCONPMN, TFIXED, GLBDES,
                LOCLVAR, [PTRANS], CONST );
```

NITER	Design iteration number (Integer, Input)
NDV	The number of global design variables (Integer, Input)
DCONLAM	The relation containing the **DCONLAM** entries (Input)
DCONLMN	The relation containing the **DCONLMN** entries (Input)
DCONPMN	The relation containing the **DCONPMN** entries (Input)
TFIXED	Relation of fixed thicknesses of undesigned layers of designed composite elements (Output)
GLBDES	Relation of global design variables (Input)
LOCLVAR	Relation containing the relationship between local variables and global variables in the design problem (Input)
[PTRANS]	The design variable linking matrix (Input)
CONST	Relation of constraint values (Output)

Application Calling Sequence:

None

Method:

The **LAMINCON** module begins by checking if the **DCONxxx** entities contain any entries. If there are any entries, they are considered to be design constraints and are imposed (computed). To set up for the computations, the local design variable data, **ELEMLIST** and **PLYLIST** data are read into memory. Then each type of constraint is processed in the order: ply minimum gauge, laminate minimum gauge and laminate composition. As each constraint is computed, it is stored to the **CONST** relation. The **TFIXED** relation contains the thicknesses of all undesigned layers of composite elements and is used in the evaluation of these constraints to determine the thicknesses of layers defining either the *ply* or the *laminate*.

Design Requirements:

None

Error Conditions:

1. Missing **PLYLIST** or **ELEMLIST** data referenced on **DCONxxx** entries
2. Ply or laminate definitions that include only undesigned layers.

Engineering Application Module: LAMINSNS

Entry Point: LAMSNS

Purpose:

To evaluate the sensitivities of composite laminate constraints defined on **DCONLAM**, **DCONLMN** and **DCONPMN** bulk data entries.

MAPOL Calling Sequence:

```
CALL LAMINSNS ( NITER, NDV, GLBDES, LOCLVAR, [PTRANS], CONST, [AMAT] );
```

NITER	Design iteration number (Integer, Input)
NDV	The number of global design variables (Integer, Input)
GLBDES	Relation of global design variables (Input)
LOCLVAR	Relation containing the relationship between local variables and global variables in the design problem (Input)
[PTRANS]	The design variable linking matrix (Input)
CONST	Relation of constraint values (Input)
[AMAT]	Matrix of constraint sensitivities (Output)

Application Calling Sequence:

None

Method:

The **LAMINSNS** module begins by checking the **CONST** relation to see if any of the active constraints are **DCONLAM**, **DCONPMN** or **DCONLMN**. These constraint types are processed in this module if any are active.

If any active laminate constraints are present, their sensitivities are computed from the data in the **CONST** relation and the **[PTRANS]** matrix of sensitivities. The format of the **LOCLVAR** and **[PTRANS]** data are such that, for each row in **LOCLVAR**, the corresponding column in **[PTRANS]** is the sensitivity of the local design variable.

$$P_{ij} = \frac{\partial t_i}{\partial v_j}$$

These are the constituents of the derivative computations. To compute each of the constraint derivatives, the appropriate columns, $\frac{\partial t_i}{\partial v}$, are summed and combined with scale factors such as the current thickness and allowable value as shown below.

For ply and laminate minimum gauges, the constraint derivative is computed as:

$$\frac{\partial g}{\partial v} = -\frac{1}{t_{\min}} \sum_{i=1}^{nply} \frac{\partial t_i}{\partial v}$$

where

$t_{\min}$ = *ply* or *laminate* minimum gauge

nply = number of *designed* plies defining the ply or laminate

For laminate composition constraints, the constraint derivatives are different depending on whether an upper or lower bound constraint is imposed:

$$\frac{\partial g_{upper}}{\partial v} = \frac{1}{t_{lam}^2}\left[t_{lam} \sum_{i=1}^{npp} \frac{\partial t_{ply_i}}{\partial v} - t_{ply} \sum_{j=1}^{npl} \frac{\partial t_{lam_j}}{\partial v} \right]$$

$$\frac{\partial g_{lower}}{\partial v} = \frac{1}{t_{lam}^2}\left[t_{lam} \sum_{j=1}^{npl} \frac{\partial t_{lam_j}}{\partial v} - t_{ply} \sum_{i=1}^{npp} \frac{\partial t_{ply_i}}{\partial v} \right]$$

where

t_{lam} = current *laminate* thickness

t_{ply} = current *ply* thickness

npp = number of layers in the current *ply*

npl = number of layers in the current *laminate*

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: LDVLOAD

Entry Point: LDVLOD

Purpose:

To compute the values of local design variables and store them in relation **OLOCALDV**.

MAPOL Calling Sequence:

```
CALL LDVLOD ( GLBDES, LOCLVAR, [PTRANS], OLOCALDV, NITER, NDV,
              LASTITER, LOADLDV, ALLLOAD );
```

GLBDES	Relation of global design variables (Character, Input)
LOCLVAR	Relation containing the relationship between local variables and global variables in the design problem (Character, Input)
[PTRANS]	The design variable linking matrix (Input)
OLOCALDV	Relation of local design variables (Character, Input)
NITER	Design iteration number (Integer, Input)
NDV	The number of global design variables (Integer, Input)
LASTITER	Integer flag indicating the last iteration (Integer, Input) **= 0** Not the last iteration **> 0** Last iteration
GPRINT	Logical flag indicating if the local design variables have been loaded into the relation (Logical, Input)
ALLPRINT	Flag indicating that all local variables will be loaded. (Integer, Input) **= 0** Not to be loaded **> 0** To be loaded

Application Calling Sequence:

None

Method:

The input flags are checked to determine if the local design variables are to be computed and loaded. This is obtained from the **OPTIMIZE** relation. All local variables selected are loaded into relation **OLOCALDV**.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: LDVPRINT

Entry Point: LDVPRT

Purpose:

To print local design variables.

MAPOL Calling Sequence:

```
CALL LDVPRINT ( OLOCALDV, NITER, LASTITER, LPRINT, ALLPRINT ) ;
```

OLOCALDV	Relation of current local design variable values (Character, Input)
NITER	Design iteration number (Integer, Input)
LASTITER	Integer flag indicating the last iteration (Integer, Input) **= 0** Not the last iteration **> 0** Last iteration
LPRINT	Logical flag indicating if the global design variables have been printed (Logical, Input)
ALLPRINT	Flag indicating that all local variables will be printed. (Integer, Input) **= 0** Not to be printed **> 0** To be printed

Application Calling Sequence:

None

Method:

The input flags are checked to determine if the local design variables are to be printed. This is obtained from the **OPTIMIZE** relation. All local variables in relation **OLOCALDV** are then printed.

Design Requirements:

None.

Error Conditions:

None

Engineering Application Module: LODGEN

Entry Point: LODGEN

Purpose:

To assemble the linearly designed simple load vectors and linear simple load sensitivities for all applied loads in the Bulk Data packet.

MAPOL Calling Sequence:

```
CALL LODGEN ( GSIZEB, GLBDES, DVCT, DVSIZE, GMMCT0, DMVI0, TELM, TREF, SMPLOD,
              [DPTHVI], [DPGRVI] );
```

GSIZEB	Length of the g-set vectors (Integer, Input)
GLBDES	Relation of global design variables (Input)
DVCT	Relation containing the data required for the assembly of the linear design sensitivity matrices (Input)
DVSIZE	Unstructured entity containing memory allocation information on the **DVCT** relation (Input)
GMMCT0	Relation containing connectivity data for the **DMVI0** linear sensitivity matrix (Input)
DMVI0	Unstructured entity containing the linear mass design sensitivity
TELM	Unstructured entity containing the linear design variable element thermal load partitions (Input)
TREF	Unstructured entity containing the element reference temperature (Input)
SMPLOD	Unstructured entity of simple load vector information (Output)
[DPTHVI]	Matrix entity containing the linear thermal load sensitivities (Output)
[DPGRVI]	Matrix entity containing the linear gravity load sensitivities (Output)

Application Calling Sequence:

None

Method:

The module begins with a call to subroutine **LDCHK** which performs extensive error checking on the bulk data and solution control commands related to applied loads and performs bookkeeping tasks prior to the computation of the simple loads. Control is then returned to **LODGEN** and **CSTM** and **BGPDT** data are read into core. A loop on the number of unique external load ID's is then begun. Calls to **PCONST** and **PFOLOW** place mechanical loads bulk data information into a **GSIZE** loads vector. This vector is then written to the **SMPLOD** unstructured entity and the process is repeated for the remaining external loads. If there are thermal loads, a call to **THRMLS/D** creates columns of the **DPTHGI** matrix based on linear design element thermal matrices and temperature data. If there are gravity loads, a call to **GRAVTS/D** constructs acceleration vectors and then computes **DPVRGI** columns based on the acceleration vectors and the **DMVI0** unstructured entity. The **DVCT**, **TELM** and **TREF** entities are purged and control is returned to the executive.

Design Requirements:

1. For the general case, this should be the last preface module because it may require inputs from **EMG** and **EMA1**.

Error Conditions:

None

Engineering Application Module: MAKDFU

Entry Point: MAKDFU

Purpose:

To assemble the sensitivities to the displacements of active stress and displacement constraints in the current active boundary condition.

MAPOL Calling Sequence:

```
CALL MAKDFU ( NITER, BC, GSIZEB, [SMAT], [NLSMAT], SMATCOL, NLSMTCOL,
              [GLBSIG], [NLGLBSIG], CONST, BGPDT, [DFDU], ACTUAGG, SUB );
```

NITER	Design iteration number (Integer, Input)
BC	Boundary condition identification number (Integer, Input)
GSIZEB	The size of the structural set (Integer, Input)
[SMAT]	Matrix entity containing the linear portion of the sensitivity of the stress and strain components to the global displacements (Input)
[NLSMAT]	Matrix entity containing the nonlinear portion of the sensitivity of the stress and strain components to the global displacements (Input)
SMATCOL	Relation containing matrix **SMAT** column information (Character,Input)
NLSMTCOL	Relation containing matrix **NLSMAT** column information (Character,Input)
[GLBSIG]	Matrix of stress/strain components for all the applied linearly designed stress constraints for the current boundary condition (Input)
[NLGLBSIG]	Matrix of stress/strain components for all the applied nonlinearly designed stress constraints for the current boundary condition (Input)
CONST	Relation of constraint values (Input)
BGPDT(BC)	Relation of basic grid point coordinates (Character,Input)
[DFDU]	Matrix containing the sensitivities of active displacement and/or stress-strain constraints to the displacements (Output)
ACTUAGG	Logical flag to indicate whether any **DFDU** terms exist (Logical, Output)
SUB	An optional flag which indicates whether statics or static aeroelasticity is associated with the constraints in this call. The discipline flag **0** if **STATICS** **i** subscript identifier, **SUB**, of the aeroelastic subcases if **SAERO** (Integer, Input)

Application Calling Sequence:

None

Method:

For the current active boundary condition, the **MAKDFU** module begins by processing the active displacement constraints. The **CONST** relation is queried for all active displacement constraints (**CTYPE=3**). Each tuple that qualifies the active condition is processed using the **PNUM** attribute to position to the appropriate location within the **DCENT** entity. The **DCENT** terms are loaded in the **DFDU**

matrix in the order that active displacement constraints are encountered in the **CONST** relation. Constraints are evaluated for each load condition within the active boundary condition in constraint type order. The **DFDU** matrix is thus also formed in this order but the inactive constraints are ignored.

After processing the active displacement constraints (if any), the **MAKDFU** module processes the active stress/strain constraints. The **CONST** relation is conditioned to retrieve the active stress and/or principal strain constraints (**CTYPE**'s **4**, **5** and **6**). For each active constraint, the current boundary condition number and the load condition number (stored on the **CONST** relation in the **SCEVAL** module) are used to determine the column number of the **SMAT** or **NLSMAT** matrix that holds the sensitivity of the current stress term to the displacements. Having recovered the **SMAT** or NLSMAT columns for the current active constraint, the **DFDU** terms are computed based on the element type and constraint type. Where the sensitivity is a function of the stress/strain values, the appropriate rows of the **GLBSIG** or **NLGLBSIG** column associated with the current boundary condition/load condition/discipline are retrieved for use in the computations.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: MAKDFV

Entry Point: MAKDFV

Purpose:

To assemble the sensitivities of active thickness constraints.

MAPOL Calling Sequence:

```
CALL MAKDFV ( NITER, NDV, [PMINT], [PMAXT], CONST, GLBDES, DESLINK,
              FDSTEP, [AMAT] );
```

NITER	Design iteration number (Integer, Input)
NDV	The number of global design variables (Integer, Input)
[PMINT]	Matrix entity containing the minimum thickness constraint sensitivities (Input)
[PMAXT]	Matrix entity containing the maximum thickness constraint sensitivities (Input)
CONST	Relation of constraint values (Input)
GLBDES	Relation of global design variables (Character,Input)
DESLINK	Relation of design variable linking information (Character,Input)
FDSTEP	Relative design variable increment for finite difference (Real,Input)
[AMAT]	The matrix of constraint sensitivities to the global design variables (Output)

Application Calling Sequence:

None

Method:

The **MAKDFV** module begins by determining if any active thickness constraints exist for this design iteration. The **CONST** relation is conditioned to retrieve active minimum and maximum thickness constraints. If any active constraints are found, they are processed in the order recovered from the **CONST** relation; that is, active minimum thickness constraints followed by active maximum thickness constraints. Since the constraint sensitivities are functions of the current local variable value when they are controlled by move limits rather than gauge limits, the execution of the module proceeds with the calculation of all the individual layer thicknesses for all the elements designed by shape functions. Since move limits are considered to be desirable in the vast majority of cases and because there is no reliable way to determine before-hand if any particular active constraint is move limit controlled, the local variables are always computed in this module. The **PTRANS** matrix, prepared in the **MAKEST** module is used to evaluate these thicknesses:

$$\{t\} = [PTRANS]^T\{v\}$$

After the local variables have been computed, the **LOCLVAR** relation (also built in the **MAKEST** module) is used to determine the current total thickness for a layered composite element. The **VFIXED** entity gives that portion of the thickness of composite elements that is not designed. The sensitivities of the thickness constraints are essentially the appropriate column of the **PMINT** or **PMAXT** matrix. The column is identified by the **PNUM** attribute of the **CONST** relation. If the particular local variable constraint is

controlled by move limits, however, the sensitivity becomes a function of the current thickness and must be adjusted accordingly. This applies only to minimum gauge constraints, however, since move limits are not applied to maximum thickness constraints. The resulting constraint sensitivities are loaded, in the order processed, onto the **AMAT** matrix.

Design Requirements:

1. The move limit that is passed into this routine ***must*** match the value used to evaluate the constraints in the **TCEVAL** module. If not, the constraint sensitivities will be in error with no warning given.

Error Conditions:

1. The move limit must be greater than 1.0 if it is imposed.

Engineering Application Module: MAKDVU

Entry Point: MAKDVU

Purpose:

To multiply the stiffness or mass design sensitivities by the active displacements or accelerations.

MAPOL Calling Sequence:

```
CALL MAKDVU ( NITER, NDV, GLBDES, [UGA], [DKUG], GMKCT, DKVI );
```

NITER	Design iteration number (Integer, Input)
NDV	Number of design variables (Integer, Input)
GLBDES	Relation of global design variables (Input)
[UGA]	Matrix of "active" displacements or accelerations for the current boundary condition (Input)
[DKUG]	The product of the design sensitivity matrices and the active displacement/acceleration vectors (Output)
GMKCT	Relation containing connectivity data for the **DKVI** sensitivity matrix (Input)
DKVI	Unstructured entity containing the stiffness or mass design sensitivity matrix in a highly compressed format (Input)

Application Calling Sequence:

None

Method:

This is a utility module that performs a matrix multiplication of a g-set matrix of displacements or accelerations and the g-set sized design sensitivities **DKVI** or **DMVI** entities that are the **NDV** g x g design sensitivity matrices stored in a highly compressed format.

The module first reads in design variable information (**ID** and value) and then space is reserved for the maximum **DKVI** record. A determination is made as to how many columns of **UGA** and **DKUG** can be held in core simultaneously. Spill logic is used if not all the columns can be processed simultaneously. Columns of **UGA** are read into core and a loop on the number of design variables is made to calculate the columns of the **DKUG** matrix. Care is taken to write null columns when a particular design variable has no **DKVI** entries. The **UNMTML** subroutine is called by **MAKDVU** to multiply the unstructured data and the response vector.

Design Requirements:

1. The format of the **DKVI**/**GMKCT** inputs is assumed to parallel the structure of those entities output from **EMA1**.

Error Conditions:

None

Engineering Application Module: MAKEST

Entry Point: MAKEST

Purpose:

To generate the element summary entities for all structural elements. Also, to determine the design variable linking and generate sensitivities for any thickness constraints.

MAPOL Calling Sequence:

```
CALL MAKEST ( NDV, GLBDES, [PTRANS], [PMINT], [PMAXT], LOCLVAR,
              TFIXED, DESLINK );
```

NDV	The number of global design variables (Integer, Output)
GLBDES	Relation of global design variables (Output)
[PTRANS]	The design variable linking matrix (Output)
[PMINT]	Matrix entity containing the minimum thickness constraint sensitivities (Output)
[PMAXT]	Matrix entity containing the maximum thickness constraint sensitivities (Output)
LOCLVAR	Relation containing the relationship between local variables and global variables in the design problem (Output)
TFIXED	Relation of fixed thicknesses of undesigned layers of designed composite elements (Output)
DESLINK	Relation of design variable connectivity from **MAKEST** module containing one record for each global design variable connected to each local variable. (Output)

Application Calling Sequence:

None

Method:

The **MAKEST** module performs the first phase of the structural element preface operations with the **EMG** and **NLEMG** module performing the second phase. The first action of the module is to perform the uniqueness error checks on the element bulk data as stored on the data base by the **IFP** module. These checks ensure that all property entries have unique identification numbers within each property type (with the exception of the **PCOMPi** entries where duplicate ID's signify different composite layers). Also, unique identification numbers for the **MATi** entries are enforced across all **MATi** types. The **MAKEST** module then performs the initial processing of the design variable linking in the **PREDES** module. The **GLBDES** relation is set up in memory with several columns to be filled in as the design variable linking is continued later in the module. If there are design variables defined in the bulk data, the number of global design variables, **NDV**, is determined for output to the MAPOL sequence and a number of scratch and hidden entities are opened to prepare for the design variable linking task performed in this module.

The **MAKEST** module continues by reading in the **BGPDT** data and initializing the **PTRANS**, **PMINT**, and **PMAXT** matrix columns that are built on the fly in the element dependent routines. The module then calls each element dependent routine in turn. The order in which these submodules are called is very important in that it provides an implicit order for the **MAKEST**, **EMG**, **NLEMG**, **SCEVAL**, **EDR** and **OFP** modules.

That order is alphabetical by connectivity bulk data entry and results in the following sequence:

(1) Bar elements

(2) Scalar spring elements

(3) Linear isoparametric hexahedral elements

(4) Quadratic isoparametric hexahedral elements

(5) Cubic isoparametric hexahedral elements

(6) Scalar mass elements

(7) General concentrated mass elements

(8) Rigid body form of the concentrated mass elements

(9) Isoparametric quadrilateral membrane elements

(10) Quadrilateral bending plate elements

(11) Rod elements

(12) Shear panels

(13) Triangular bending plate elements

(14) Triangular membrane elements

Within each element dependent routine, the **xxxEST** relation for the element is opened and flushed. If design variables exist in the **MODEL**, the **ELIST**, **PLIST** and **SHAPE** entries associated with this element type (if the element can be designed) are opened and read into memory for use in the design variable linking. Then the connectivity relation for the element is opened and the main processing loop begins. Each tuple is read, the grid point references are resolved into internal sequence numbers and coordinates, the property entry is found from the proper property relation(s) and the **EST** relation tuple is formed in memory. Numerous checks on the existence of grid points, property entries and the uniqueness of the element identification number within each element type are performed.

Finally, if there are design variables, the **DESCHK** submodule is called to determine whether the element is linked to a design variable. The **DESCHK** utility searches the in-core **GLBDES**, **ELIST**, **PLIST** and/or **SHAPE** data and determines if the current element is designed. Also, the final attributes of the **GLBDES** relation for physical and shape function linking are completed. The module performs error checks to ensure that the rules for design variable linking are satisfied for each particular global design variable and element.

On return to the element **EST** routine, the **LOCLVAR**, **PTRANS**, **PMINT** and/or **PMAXT** entities are built for the local design variable if the element was found by **DESCHK** to be designed. Finally, the constraint flags, design flags, design variable nonlinear flag, composite type flag and thermal stress information are set. The constraint and thermal stress attributes will be revised as needed in the **EMG** and **NLEMG** module.

When all the elements have been processed, the **EST** relation for the element type is loaded to the data base. Care is taken that the final relation is sorted by the element identification number. When all the element routines have been called, the **DESLINK** entity, which was formed on the fly in the element routines, is loaded to the data base. This entity contains the number of and identification numbers for each design variable connected to each designed element. These data are used to generate the **DVCT**, **DVCTD** and/or **DDVCT** relations in the **EMG** and NLEMG module. All the other design variable linking entities that have been built on the fly are also closed. Any queued error messages are dumped to the user file and the module terminates.

Design Requirements:

1. The basic connectivity data from the **IFP** module must be available.

Error Conditions:

1. Numerous error checks are performed on the consistency of the bulk data for structural element definition as well as of element geometry and connectivity.

2. Design variable linking errors are flagged.

Engineering Application Module: MK2GG

Entry Point: MK2GG

Purpose:

Interprets case control for the current boundary condition and outputs the **M2GG** and/or **K2GG** matrices if any.

MAPOL Calling Sequence:

```
CALL MK2GG ( BC, GSIZEB, [M2GG], M2GGFLAG, [K2GG], K2GGFLAG );
```

BC	Boundary condition identification number (Integer, Input)
GSIZEB	Number of g-set DOF's excluding any that may have been added on earlier iterations by **GDR** (Integer, Input)
[M2GG]	Direct input g-set mass matrix for the current **BC** (Optional, Output)
M2GGFLAG	Flag indicating whether **M2GG** was loaded with data (Optional, Logical, Output)
[K2GG]	Direct input g-set stiffness matrix for the current **BC** (Optional, Output)
K2GGFLAG	Flag indicating whether **K2GG** was loaded with data (Optional, Logical, Output)

Application Calling Sequence:

None

Method:

First the **CASE** relation is read for the current boundary condition to determine if **M2GG** or **K2GG** matrices were named. Error checking is performed to ensure that an output matrix is passed to **MK2GG** for both matrices if both are named in **CASE**. The arguments are otherwise optional. Further, the entities named in **CASE** are checked to ensure that they are matrices and that they are square and of the proper row and column dimensions (**GSIZEB** x **GSIZEB**).

Then the named output matrix is created, or if it already exists, flushed. The **APPEND** utility is used to copy the named entity onto the output entity.

Design Requirements:

1. The **DMIG** or **DMI** entries that may be sources of the **M2GG** and/or **K2GG** matrices must be processed prior the the calling of this module. This module assumes that the named entities already exist.

Error Conditions:

1. **x2GG** entities do not exist.
2. **x2GG** entities are not matrix entities
3. **x2GG** entities are not of the proper dimension.
4. All errors cause ASTROS termination.

Engineering Application Module: MKAMAT

Entry Point: MKAMAT

Purpose:

To assemble the constraint sensitivity matrix from the sensitivity matrices formed by **MAKDFU** and the sensitivities of the displacements for active static load conditions in the current active boundary condition.

MAPOL Calling Sequence:

```
CALL MKAMAT ( [AMAT], [FIRST], [SECOND], [THIRD], PCA, PRA, [PGA] );
```

[AMAT]	Matrix of sensitivities of the constraints to the design variables (Input and Output)
[FIRST]	Leading matrix in the multiplication to obtain **AMAT** (Input)
[SECOND]	Trailing matrix in the multiplication to obtain **AMAT** (Input)
[THIRD]	The matrix to be added is the multiplication to obtain **AMAT** (Input)
PCA	Unstructured entity which contains the unique subcase numbers for the constraints that are active for the boundary condition. Only constraints for the current boundary condition are included in the list (Input)
PRA	Unstructured entity which contains the unique subcase numbers for the displacement and/or element stress/strain response functions that are required by active user function constraints (Character,Input)
[PGA]	Partition vector for active displacement vectors (Input)

Application Calling Sequence:

None

Method:

Conceptually, the module multiplies the transpose of the **FIRST** matrix times the **SECOND** and adds the **THIRD**. The data in the three matrices are determined based on whether the gradient method or the virtual loads method of sensitivity analysis is being employed (see Subsection 6.3 of the Theoretical Manual). The matrix multiplication is complicated by the fact that it may be necessary to partition the matrices for each subcase that is active in the boundary condition.

The module begins by reading the **PCA** and **PGA** information into core. The number and identity of the active subcases is determined. If the number is greater than one, thirteen scratch matrix entities are created to store intermediate data. A loop on the number of active subcases then occurs. If it is not the last pass through this loop, the **FIRST** matrix is partitioned to obtain the **NDV** columns that apply for the current subcase, and the **SECOND** matrix is partitioned to obtain only the columns that correspond to active constraints for the subcase and the **THIRD** matrix is partitioned to obtain the **NDV** rows that apply for the current subcase and the columns that correspond to active constraints for the subcase.

PRA and **PGA** are used to partition the **FIRST**, **SECOND** and **THIRD** matrices to obtain the displacement and/or element stress and strain response sensitivities which are required by active user function constraints. Those sensitivities are stored into relation and matrix entities to be used by user function evaluation utilities.

The algorithm is somewhat more complicated than this in that the parts of the matrices that remain after partitioning are renamed to **FIRST** and **SECOND** so that the partitioning operation becomes successively smaller and no partition is required on the last pass through the loop. The extracted matrices are then multiplied and the resulting matrix is either **AMAT** (when there is only one active subcase and the **AMAT** matrix was empty on entering the module) or it is appended to **AMAT**. Once the loop is completed, any scratch matrices are destroyed and control is returned to the executive.

Design Requirements:

1. This module is invoked at the end of the boundary condition loop in the sensitivity analysis portion of the MAPOL sequence.

2. It is called only if there are active stress and displacement constraints for the boundary condition.

Error Conditions:

None

Engineering Application Module: MKDFDV

Entry Point: MKDFDV

Purpose:

Computes the sensitivity of BAR element cross-sectional dimension relation constraints to design variables

MAPOL Calling Sequence:

```
CALL MKDFDV ( NITER, NDV, CONST, DESLINK, GLBDES, [AMAT] );
```

NITER	Design iteration number (Integer,Input)
NDV	Number of design variables (Integer,Input)
CONST	Relation of constraint values (Character,Output)
DESLINK	Relation of design variable linking information (Character,Input)
GLBDES	Relation of global design variables (Character,Input)
[AMAT]	Matrix of sensitivities of constraints to the design variables (Character,Output)

Application Calling Sequence:

None

Method:

This module first gets all active BAR element cross-sectional dimension relation constraints. The sensitivities of each active constraint to the design variables are computed by multiplying the sensitivities of the constraint to the dimensions (factors in relation **CONST**) with the sensitivities of the dimensions to the design variables (**PREF** in **DESLINK**). Those sensitivities are then stored in columns of matrix **[AMAT]**.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: MKDFSV

Entry Point: MKDFSV

Purpose:

To calculate matrix **[DFSV]** which contains the S-matrix derivatives related to active stress/strain constraints. The stress/strain constraints are functions of the product of the S-matrix and the displacements:

$$g = f\ (\boldsymbol{S}\boldsymbol{u})$$

The sensitivities of these constraints to the designed variables is decomposed into two parts. The first is a function of the product of the S-matrix derivatives and displacements, and the second is a function of the product of the S-matrix and the displacement derivatives:

$$\frac{\partial g}{\partial v} = \bar{f}\left(\frac{\partial \boldsymbol{S}}{\partial v}\boldsymbol{u}\right) + h\left(\boldsymbol{S}\frac{\partial \boldsymbol{u}}{\partial v}\right)$$

The **DFSV** matrix represents the first part:

$$\mathbf{DFSV} = f\left(\frac{\partial \boldsymbol{S}}{\partial v}\boldsymbol{u}\right)$$

MAPOL Calling Sequence:

```
CALL MKDFSV ( NITER, BC, GSIZEB, [NLGLBSIG], CONST, [NLSMAT], NLSMTCOL,
              [UGA], DESLINK,DSCFLG, NDV, GLBDES, LOCLVAR, [PTRANS],
              [DFSV], DELTA );
```

NITER	Optimization iteration number (Integer, Input)
BC	The MAPOL boundary condition loop index number (Integer, Input)
GSIZEB	number of dofs in the structural set (Integer, Input)
[NLGLBSIG]	Stress vectors for design variable nonlinearly constrained elements (Character, Input)
CONST	Relation of constraints (Character, Input)
[NLSMAT]	Matrix entity containing the nonlinear portion of the sensitivity of the stress and strain components to the global displacements (Character,Input)
NLSMTCOL	Relation containing matrix **NLSMAT** column information (Character,Input)
[UGA]	Active displacement vectors at current boundary condition (Character, Input)
DESLINK	Relation of design variable linking
DSCFLG	Discipline flag (Integer, Input) **0** statics ≠**0** static aeroelasticity
NDV	Number of design variables (Integer, Input)
GLBDES	Global design variable relation (Character, Input)

LOCLVAR	Local design variable relation (Character, Input)
[PTRANS]	Design variable linking matrix (Character, Input)
[DFSV]	Matrix contains S-matrix derivatives related active stress/strain constraints (Character, Output)
DELTA	The relative design variable increment for finite difference computation. (Real, Input)

Application Calling Sequence:

None

Method:

This module first gets the **DVID** list from **GLBDES**. The module then gets **EST** entries for nonlinearly designed constraint **QUAD4** and **TRIA3** elements and places them into incore lists. Then the module determines the number of active displacement constraints, and gets active stress and strain constraints for this design iteration. Null columns are stored in **DFSV** corresponding to active displacement constraints so that **DFSV** will be compatible in module **MKAMAT**. For each active stress/strain constraint, the following operations are applied. If it is a linearly designed constraint, a null column is stored in **DFSV**, otherwise, matrix **DSDT** which contains the sensitivities of the nonlinear S-matrix to the related local design variables is computed for the element related to this constraint. Matrix **DSDV** which contains the sensitivities of the nonlinear S-matrix to the related global design variables is computed by using the **DSDT** matrix and design variable linking factors from **DESLINK**. Matrix **DSVU** is the multiplication of the transposed active displacement vector **UGA** times **DSDV**. The **DFSV** term at the row number corresponding to that active constraint is computed from **DSVU**, the constraint value, the related stress/strain values from **NLGLBSIG**, and the constraint allowables.

Design Requirements:

1. This module must be called prior to **MKAMAT** and after the active displacement vector is available.

Error Conditions:

None

Engineering Application Module: MKPVECT

Entry Point: PVCDRV

Purpose:

To generate partitioning vectors from unstructured entity **USET**.

MAPOL Calling Sequence:

```
CALL MKPVECT ( USET(BC), [PGMN(BC)], [PNSF(BC)], [PFOA(BC)], [PARL(BC)] );
```

USET(BC)	Unstructured entity defining structural sets for each degree of freedom (Character,Input), where **BC** represents the MAPOL boundary condition loop index number
[PGMN(BC)]	The vector partitioning the structural degrees of freedom into the independent and the multipoint constraint degrees of freedom (Character, Output), where **BC** represents the MAPOL boundary condition loop index number
[PNSF(BC)]	The vector partitioning the independent degrees of freedom into the free and the single point constraint degrees of freedom (Character, Output), where **BC** represents the MAPOL boundary condition loop index number
[PFOA(BC)]	The vector partitioning the free degrees of freedom into the analysis set and the omitted degrees of freedom (Character, Output), where **BC** represents the MAPOL boundary condition loop index number
[PARL(BC)]	The vector partitioning the analysis set degrees of freedom into the l-set and the support degrees of freedom (Character, Output), where **BC** represents the MAPOL boundary condition loop index number

Application Calling Sequence:

```
CALL PVCDRV ( USET, PGMN, PNSF, PFOA, PARL )
```

Method:

This module first reads the **USET** record which contains the number of degrees of freedom in each dependent set and the bit masks defining the structural sets to which the degrees of freedom belong. Then, for each requested partitioning vector, the bit masks in **USET** are checked for all degrees of freedom with the related structural sets, and then the vector is generated.

Design requirements:

Any of the partitioning vector names may be blank if the corresponding partition will not be used subsequently.

Error:

None

Engineering Application Module: MKUSET

Entry Point: MKUSET

Purpose:

To generate the structural set definition entity, **USET**, for each boundary condition and to form the partitioning vectors and transformation matrices used in matrix reduction.

MAPOL Calling Sequence:

```
CALL MKUSET ( BCID, GSIZEB, [YS], [TMN], [PGMN], [PNSF], [PFOA],
              [PARL], USET );
```

BCID	User defined boundary condition identification number (Integer, Input)
GSIZEB	The size of the structural set (Integer, Input)
[YS(BC)]	The vector of enforced displacements (Output)
[TMN(BC)]	The transformation matrix for multipoint constraints (Output)
[PGMN(BC)]	The partitioning vector splitting the structural degrees of freedom into the independent and the multipoint constraint degrees of freedom (Output)
[PNSF(BC)]	The partitioning vector splitting the independent degrees of freedom into the free and the single point constraint degrees of freedom (Output)
[PFOA(BC)]	The partitioning vector splitting the free degrees of freedom into the analysis set and the omitted degrees of freedom (Output)
[PARL(BC)]	The partitioning vector splitting the analysis set degrees of freedom into the l-set and the support degrees of freedom (Output)
USET(BC)	The unstructured entity defining structural sets (Output)

Application Calling Sequence:

None

Method:

The **MKUSET** module performs four tasks. The first is to build the **USET** entity of structural set definition masks for the input boundary condition. At the same time, the rigid constraint matrix, **TMN**, relating the dependent multipoint constraint degrees of freedom to the independent degrees of freedom is formed. Also, the vectors of enforced displacements for single point constraints are formed. Lastly, the partitioning vectors for the structural sets are formed.

The generation of boundary condition dependent subscripted matrix entities requires that the **MKUSET** module be called once for each boundary condition in the Solution Control packet. The looping logic is contained in the standard executive sequence rather than within the module itself. Each structural degree of freedom (DOF) is assigned a word in each record of the **USET** entity (aerodynamic degrees of freedom and extra points are ignored). One record is created for each boundary condition in the Solution Control packet. The **MKUSET** module determines to which sets a structural DOF belongs and sets the corresponding bits in the **USET** word associated with that degree of freedom. That word is the bitmask for that degree of freedom.

The assignment of a bit position for each structural set is defined as shown below and are stored in the **/BITPOS/** common block:

SET	BIT POSITION	DESCRIPTION
UX	**16**	Used for dynamic reduction
UJJP	**17**	
UJJ	**18**	
UKK	**19**	
USB	**20**	Single point constraints (**SPC**)
USG	**21**	Permanent **SPC**s
UL	**22**	Free points left for solution
UA	**23**	Analysis set
UF	**24**	Free degrees of freedom
UN	**25**	Independent degrees of freedom
UG	**26**	Dependent degrees of freedom
UR	**27**	Support set DOF
UO	**28**	Omitted (Guyan Reduction) DOF
US	**29**	Unions of **USB** and **USG** sets
UM	**30**	Dependent **MPC** DOF

The **MKUSET** module begins by preparing memory blocks for use by the module subroutines. The **BGPDT** tuples associated with structural nodes are brought into core for use in conversion of external identification numbers to internal identification numbers. Each separate structural set is processed by an individual submodule of **MKUSET** with the defaulting for unspecified DOF taking place in the module driver. The **CASE** relation is read to determine the boundary condition definition for the current boundary condition. The submodule **UMSET**, responsible for multipoint constraint set definition also build the **TMN** matrix while the **USSET** submodule for single point constraints builds the **YS** vector. After the **USET** masks have been built for the boundary condition, extensive error checking occurs to ensure that each point is placed in no more than one dependent structural set. If no errors have occured, the **USET** record is written and the associated partitioning vectors are formed.

Design Requirements:

1. The **MKUSET** module requires that the **CASE** relation be complete from the **SOLUTION** module and that the **BGPDT** be formed either by the **BCBGPDT** or **IFP** modules prior to execution.

Error Conditions:

1. Any inconsistent boundary condition specifications are flagged.

2. Any missing bulk data referenced by Solution Control is flagged.

Engineering Application Module: MSWGGRAD

Entry Point: MWGRAD

Purpose:

Gets element mass and/or weight intrinsic sensitivities.

MAPOL Calling Sequence:

```
CALL MSWGGRAD ( NITER, NDV, GLBDES, DESLINK, CONST );
```

NITER	Design iteration number (Integer,Input)
NDV	Number of design variables (Integer, Input)
GLBDES	Relation of global design variables (Character,Input)
DESLINK	Relation of design variable linking information (Character,Input)
CONST	Relation of constraint values (Character, Input)

Application Calling Sequence:

None

Method:

The active user function constraint instances are obtained from relation **CONST**. The element mass and or weight intrinsic sensitivites are computed for the active instances, and loaded into the mass/weight derivative entities using the user function utilities.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: MSWGRESP

Entry Point: MWRESP

Purpose:

Computes element mass and/or weight intrinsic responses.

MAPOL Calling Sequence:

```
CALL MSWGRESP ( NITER, NDV, GLBDES, DESLINK );
```

NITER	Design iteration number (Integer,Input)
NDV	Number of design variables (Integer, Input)
GLBDES	Relation of global design variables (Character,Input)
DESLINK	Relation of design variable linking information (Character,Input)

Application Calling Sequence:

None

Method:

This module searches through all element weight and mass intrinsic entity entries and obtains all element identification numbers which are required by user function instances. The values of those required element weight and/or mass are obtained from relation **ELMASS** which are generated in module **EMG/NLEMG** and stored into element weight and/or mass intrinsic response entity with instance information.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: MXFRMSYM

Entry Point: FRMSYM

Purpose:

Sets the symmetry flag for selected matrices.

MAPOL Calling Sequence:

```
CALL MSWGRESP ( M1, M2, M3, M4, M5, M6, M7, M8, M9, M10 );
```

Mi Matrix names (Character,Input)

Application Calling Sequence:

None

Method:

This module provides a MAPOL interface to eBASE utility **MXFORM** to set the symmetry flag for the specified matrices.

Design Requirements:

1. The maximum number of matrices specified in a single call is ten.

Error Conditions:

None

Engineering Application Module: NLEMA1

Entry Point: NLEMA1

Purpose:

To assemble the nonlinearly designed element stiffness and mass sensitivity matrix partitions (stored in **DKELM** and **DMELM** entities) with linear stiffness and mass sensitivity matrix partitions (**DKVI0** and **DMVI0**) into the design sensitivity matrices **DKVI** and **DMVI**. To assemble the nonlinear design stiffness and mass matrix partitions (**KELMD** and **MELMD**) with entities **DKVI0** and **DMVI0** into the stiffness and mass matrices **DKVIG** and **DMVIG** for global stiffness and mass matrix assembling.

MAPOL Calling Sequence:

```
CALL NLEMA1 ( NITER, NDV, GLBDES, DVCTD, DDVCT, KELMD, DKELM, MELMD, DMELM,
              GMKCT0, DKVI0, GMMCT0, DMVI0, DWGH1, GMKCT, DKVI, GMMCT,
              DMVI, GMKCTG, DKVIG, GMMCTG, DMVIG, GMMCTD, DMVID, DGMMCT,
              DDMVI, DDWGH2 );
```

NITER	Optimization iteration number (Integer, Input)
NDV	Number of design variables (Integer, Input)
GLBDES	Relation of global design variables (Character, Input)
DCVTD	Relation containing the data required for the assembly of the nonlinear design stiffness and mass matrices (Character, Input)
DDVCT	Relation containing the data required for the assembly of the nonlinear design sensitivity matrices (Character, Input)
KELMD	Unstructured entity containing the nonlinear design stiffness matrix partitions (Character, Input)
DKELM	Unstructured entity containing the nonlinear stiffness sensitivity matrix partitions (Character, Input)
MELMD	Unstructured entity containing the nonlinear design mass matrix partitions (Character, Input)
DMELM	Unstructured entity containing the nonlinear mass sensitivity matrix partitions (Character, Input)
GMKCT0	Relation containing connectivity data for the **DKVI0** linear sensitivity matrix (Character, Input)
DKVI0	Unstructured entity containing the linear stiffness sensitivity matrix in a highly compressed format (Character, Input)
GMMCT0	Relation containing connectivity data for the **DMVI0** linear sensitivity matrix (Character, Input)
DMVI0	Unstructured entity containing the linear mass sensitivity matrix in a highly compressed format (Character, Input)
DWGH1	Unstructured entity containing the linear (invariant) portion of the sensitivity of weight to the design variables (Character, Input)

GMKCT	Relation containing connectivity data for the **DKVI** sensitivity matrix (Character, Output)
DKVI	Unstructured entity containing the total stiffness design sensitivity matrix in a highly compressed format (Character, Output)
GMMCT	Relation containing connectivity data for the **DMVI** sensitivity matrix (Character, Output)
DMVI	Unstructured entity containing the total mass design sensitivity matrix in a highly compressed format (Character, Output)
GMKCTG	Relation containing connectivity data for the **DKVIG** stiffness matrix (Character, Output)
DKVIG	Unstructured entity containing the stiffness matrix in a highly compressed format (Character, Output)
GMMCTG	Relation containing connectivity data for the **DMVIG** mass matrix (Character, Output)
DMVIG	Unstructured entity containing the mass matrix in a highly compressed format (Character, Output)
GMMCTD	Relation containing connectivity data for the **DMVID** mass matrix (Character, Output)
DMVID	Unstructured entity containing the nonlinear part of mass matrix in a highly compressed format (Character,Output)
DGMMCT	Relation containing connectivity data for the **DDMVI** nonlinear mass sensitivity matrix (Character, Output)
DDMVI	Unstructured entity containing the nonlinearly designed mass sensitivity matrix in a highly compressed format (Character, Output)
DDWGH2	Unstructured entity containing the nonlinear portion of the sensitivity of weight to the design variables (Character, Output)

Application Calling Sequence:

None

Method:

The module is executed in two passes; once for nonlinear design stiffness matrices and nonlinear stiffness sensitivity matrices, and a second time for nonlinear design mass matrices and nonlinear mass sensitivity matrices.

In the first pass, **DVCTD** information is read into core one record at a time. The algorithm is structured to maximize the amount of processing done on a given design matrix(typically all of it) in core. Spill logic is in place if a matrix cannot be completely held in core. For the assembly, subroutine **NLRQCR** performs bookkeeping tasks to expedite the assembly and to determine whether spill will be necessary. Subroutine **NLASM1** retrieves **KELMD** information, performs the actual assembly operations and place the results into the **GMKCT8DKVI**, and results in **DGMKCT** and **DDKVI** entities.

If a discipline which requires a mass matrix is included in the solution control, the mass terms are assembled in the second pass. If there are **OPTIMIZE** boundary conditions, this module calculates the nonlinear portion of the sensitivity of the weight to the design variables (**DDWGH2**) and the nonlinear portion of the weight (**DWGH2**) regardless of whether the mass matrices are required. If no mass information is required, the second pass is not made. For the second pass, **MELMD** and **DMELM** data are

used. The structure of the assembly operation is otherwise much the same and **GMMCYD, DGMMCY, DMVID** and **DDMVI** data are computed and stored. After those two passes, the total weight is computed from **DWGH1** and **DWGH2. GMKCT0, DKVI0, DGMKCT, DDKVI** are merged into stiffness sensitivity entities **GMKCT** and **DKVI; GMMCT0, DMVI0, DDGMMCY, DDMVI** are merged into mass sensitivity entities **GMMCT** and **DMVI; GMKCT0, DKVI0, GMMCYD, DKVID** are merged into stiffness matrix entities **GMKCTG** and **DKVIG; GMMCT0, DMVI0, GMMCYD, DMVID** are merged into mass matrix entities **GMMCTG** and **DMVIG.**

Design Requirements:

1. This assembly operation follows **NLEMG** within the MAPOL **OPTIMIZE** iterations.

2. Since gravity loads require **DMVID** and **DDMVI** data, it is necessary to perform **NLEMA1** prior to calling **NLLODGEN**. **NLEMA1** must always be called before **EMA2**.

Error Conditions:

None.

Engineering Application Module: NLEMG

Entry Point: NLEMG

Purpose:

To compute the nonlinear design stiffness, mass, thermal load and stress component sensitivities and nonlinear design stiffness and mass matrix partitions.

MAPOL Calling Sequence:

```
CALL NLEMG ( NITER, NDV, GSIZEB, GLBDES, LOCLVAR, [PTRANS], DESLINK,
             [NLSMAT], NLSTMCOL, DVCTD, DDVCT, DVSIZED, DDVSIZE,
             KELMD, DKELMD, MELMD, DMELM, TELMD, DTELM, TREFD, FDSTEP );
```

NITER	Optimization iteration number (Integer, Input)
NDV	Number of design variables (Integer, Input)
GSIZEB	The size of the structural set (Integer, Input)
GLBDES	Relation of global design variables (Character, Input)
LOCLVAR	Relation containing the relationship between local variables and global variables in the design problem. (Character, Input)
[PTRANS]	The design variable linking matrix (Character, Input)
DESLINK	Relation of design variable connectivity from **MAKEST** module (Character, Input)
[NLSMAT]	Matrix entity containing the nonlinear portion of the sensitivity of the stress and strain components to the global displacements. (Output)
NLSMTCOL	Relation containing matrix **NLSMAT** column information (Character,Output)
DCVTD	Relation containing the data required for the assembly of the nonlinearly designed stiffness and mass matrices (Character, Output)
DDVCT	Relation containing the data required for the assembly of the nonlinearly designed sensitivity matrices (Character, Output)
DVSIZED	Unstructured entity containing memory allocation information on the **DVCTD** relation. (Character, Output)
DDVSIZE	Unstructured entity containing memory allocation information on the **DDVCT** relation. (Character, Output)
KELMD	Unstructured entity containing the nonlinearly designed stiffness matrix partitions (Character, Output)
DKELM	Unstructured entity containing the nonlinear stiffness sensitivity matrix partitions (Character, Output)
MELMD	Unstructured entity containing the nonlinearly designed mass matrix partitions (Character, Output)
DMELM	Unstructured entity containing the nonlinear mass sensitivity matrix partitions (Character, Output)

TELMD	Unstructured entity containing the nonlinearly designed thermal load partitions (Character, Output)
DTELM	Unstructured entity containing the nonlinear thermal load sensitivity matrix partitions (Character, Output)
TREFD	Unstructured entity containing the element reference temperatures for nonlinearly designed thermal loads. (Character, Output)
FDSTEP	Relative design variable increment for finite difference (Real, Input)

Application Calling Sequence:

None

Method:

The **NLEMG** module performs the nonlinear design variable part of the second phase of the structural element preface operations with the **MAKEST** module performing the first phase.The first action of the **NLEMG** module is to determine if nonlinear design variables and/or thermal loads are defined in the bulk data. If they are, the special actions for design variable linking and thermal stress corrections are taken in the element dependent routines. The **PREMAT** utility to set up the material property data also returns the **SCON** logical flag to denote that there are stress constraints defined in the bulk data. The initialization of the module continues with the retrieval of the **MFORM** data to select lumped or coupled mass matrices in the elements that support both forms. The default is lumped although any **MFORM/COUPLED** (even if **MFORM/LUMPED** also exists) will cause the coupled form to be used. If thermal loads exist, the module prepares the **TREFD** entity to be written by the element dependent routines. The **GLBDES** relation is opened and the design variable identification numbers are read into memory. Finally, the **DDVCT** and **DVCTD** entities are opened and flushed and memory is retrieved to be used in the **NLDVCT** submodule to load the **DDVCT** and **DVCTD** relations. The order in which these submodules are called is alphabetical by connectivity bulk data entry, i.e., (1) Bar elements, (2) Quadrilateral bending plate elements, and (3) Triangular bending plate elements.

Within each element dependent routine, the **xxxEST** relation for the element is opened and read one tuple at a time. If the **EST** relation indicates that the element is nonlinearly designed, the **DESLINK** data is used to write one set of tuples to the **DDVCT** and **DVCTD** relations for each unique design variable linked to the element. The set of tuples consists of one row for each node to which the element is connected. The element dependent geometry processor is then called to generate the **DKELM**, **KELMD**, **DMELM**, **MELMD**, **DTELM** and **TELMD** entries for the element. These data must be generated before the next call to **NLDVCT** since the **DDVCT** and **DVCTD** form the directory to all these entities. Once all the elements are processed within the current element dependent routine, the **TREFD** entity is appended with the vector of reference temperatures for the current set of elements. Again, the order of these reference temperatures are determined by the sequence listed above and is assumed to hold in other modules. When all the element dependent drivers have been called by the **NLEMG** module driver, clean up operations begin. The entities that have been open for writing by the element routines are closed, the remaining in-core **DDVCT** and **DVCTD** tuples are written to the data base and the relations are sorted. If there are no design variables (all **DVID**'s are zero), the **DVCT** is sorted only on **KSIL**. Finally, if stress or strain constraints were defined in the bulk data stream, the **NLSMAT** matrix of constraint sensitivities to the displacements is closed. **NLSMAT** was opened by the **PREMAT** module when the **SCON** constraint flag was set.

Design Requirements:

1. The **MAKEST** module must have been called prior to the **NLEMG** module.

Error Conditions:

1. Illegal element geometries and nonexistent material properties are flagged.

Engineering Application Module: NLLODGEN

Entry Point: NLLDGN

Purpose:

To assemble the nonlinear design variable simple load vectors and nonlinear simple load sensitivities for all applied loads in the Bulk Data packet.

MAPOL Calling Sequence:

```
CALL NLLODGEN ( GSIZEB, GLBDES, DVCTD, DDVCT, DVSIZED, DDVSIZE,GMMCTD,
                DGMMCT, DMVID, DDMVI, TELMD, DTELM, TREFD, [DPTHVD],[DDPTHV],
                [DPGRVD], [DDPGRV] );
```

GSIZEB	The size of the structural set (Integer, Input)
GLBDES	Relation of global design variables (Character, Input)
DCVTD	Relation containing the data required for the assembly of the nonlinearly designed stiffness and mass matrices (Character, Input)
DDVCT	Relation containing the data required for the assembly of the nonlinearly designed sensitivity matrices (Character, Input)
DVSIZED	Unstructured entity containing memory allocation information on the **DVCTD** relation. (Character, Input)
DDVSIZE	Unstructured entity containing memory allocation information on the **DDVCT** relation. (Character, Input)
GMMCTD	Relation containing connectivity data for the **DMVID** design mass matrix (Character, Input)
DGMMCT	Relation containing connectivity data for the **DDMVI** mass sensitivity matrix (Character, Input)
DMVID	Unstructured entity containing the nonlinear mass matrix in a highly compressed format (Character, Input)
DDMVI	Unstructured entity containing the nonlinear mass sensitivity matrix in a highly compressed format (Character, Input)
TELMD	Unstructured entity containing the nonlinear design thermal load partitions (Character, Input)
DTELM	Unstructured entity containing the element nonlinear thermal load sensitivity matrix partitions (Character, Input)
TREFD	Unstructured entity containing the element reference temperatures for nonlinearly designed thermal loads. (Character, Input)

[DPTHVD]	Matrix entity containing the nonlinearly designed thermal loads (Character, Output)
[DDPTHV]	Matrix entity containing the nonlinear thermal load sensitivities (Character, Output)
[DPGRVD]	Matrix entity containing the nonlinearly designed gravity loads (Character, Output)
[DDPGRV]	Matrix entity containing the nonlinear gravity load sensitivities (Character, Output)

Application Calling Sequence:

None

Method:

Design Requirements:

None.

Error Conditions:

None.

Engineering Application Module: NREDUCE

Entry Point: NREDUC

Purpose:

To reduce the symmetric n-set stiffness, mass or loads matrix to the f-set if there are single point constraints in the boundary condition.

MAPOL Calling Sequence:

```
CALL NREDUCE ( [KNN], [PN], [PNSF(BC)], [YS(BC)], [KFF], [KFS],
               [KSS], [PF], [PS] );
```

[KNN]	Optional matrix containing the independent stiffness or mass matrix to be reduced (Input)
[PN]	Optional matrix containing the applied loads to be reduced (Input)
[PNSF(BC)]	The partitioning vector splitting the independent degrees of freedom into the free and the single point constraint degrees of freedom (Input), where **BC** represents the MAPOL boundary condition loop index number
[YS(BC)]	Optional matrix containing the vector of enforced displacements (Input), where **BC** represents the MAPOL boundary condition loop index number
[KFF]	Optional matrix containing the reduced form of **KNN** (Output)
[KFS]	Optional matrix containing the off-diagonal partition of **KFF** (Output)
[KSS]	Optional matrix containing the dependent diagonal partition of **KFF** (Output)
[PF]	Optional matrix containing the reduced form of **PN** (Output)
[PS]	The load matrix partition for computation of spcforces (Output)

Application Calling Sequence:

None

Method:

If the **PN** argument is nonblank, the module determines the number of columns in the loads matrix. Further, if the **YS** vector is nonblank, it is expanded to have the proper number of duplicate columns. Having taken care of the **YS** matrix, the module proceeds to check if the **KNN** argument is nonblank. If so, and there are no enforced displacements, the **KNN** matrix is partitioned into **KFF** and **KFS** (if the **KFS** matrix is input). If there are enforced displacements, the **KSS** partition is also saved if the **KSS** argument is supplied. The module then proceeds to reduce the loads matrix if the **PN** argument is nonblank. If there are no enforced displacements, the matrix is simply partitioned to **PF**. When enforced displacements are present, the loads on the free degrees of freedom are computed as:

$$[PF] = [\overline{PF}] - [KFS][YS]$$

The module then terminates.

Design Requirements:

1. If there are nonzero enforced displacements, the stiffness and loads reductions must be done concurrently or the **KFS** partition must be included in the loads call as input.

2. The **KFS** argument is always required when **YS** is nonblank.

Error Conditions:

None

Engineering Application Module: NULLMAT

Entry Point: NULMAT

Purpose:

Breaks the equivalence of selected matrices.

MAPOL Calling Sequence:

```
CALL NULLMAT ( M1, M2, M3, M4, M5, M6, M7, M8, M9, M10 );
```

Mi Matrix names (Character,Input)

Application Calling Sequence:

None

Method:

This module breaks the equivalence on the specified matrices. For example, when the MAPOL statement:

```
[A] := [B]
```

is encountered, the matrix **A** is equivalenced to **B**. That is, the data are not physically copied, but only a pointer to the data is maintained. To break this pointer, you call **NULLMAT(A)**.

Design Requirements:

1. The maximum number of matrices specified in a single call is ten.

Error Conditions:

None

Engineering Application Module: OFPAEROM

Entry Point: OFPARO

Purpose:

This module solves for the static aero applied loads on the aero boxes and for the displacements on the aero boxes to satisfy the **AIRDISP** and **TPRESSURE** print/punch requests. It loads the **OAGRDLOD** and **OAGRDDSP** relation.

MAPOL Calling Sequence:

```
CALL OFPAEROM ( NITER, BCID, MINDEX, SUB, GSIZE, GEOMSA, [GTKG], [GSTKG], QDP,
                [AIRFRC(MINDEX)], [DELTA(SUB)], [AICMAT(MINDEX)], [UAG(BC)],
                OAGRDLOD, OAGRDDSP );
```

NITER	Design iteration number (Optional, Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
MINDEX	Mach number index associated with the current subscript (Integer, Input)
SUB	Current Mach number subscript number (Integer, Input)
GSIZE	Number of g-set DOF's including any that may have been added by **GDR** (Integer, Input)
GEOMSA	A relation describing the aerodynamic boxes for the steady aerodynamics **MODEL**. The location of the box centroid, normal and pitch moment axis are given. It is used in splining the aerodynamics to the structure and to map responses back to the aerodynamic boxes (Input)
[GTKG]	The matrix of splining coefficients relating the aerodynamic pressures to forces at the structural grids (Input)
[GSTKG]	The matrix of splining coefficients relating the structural displacements to the streamwise slopes of the aerodynamic boxes (Input)
QDP	Dynamic pressure associated with the current subscript (Real, Input)
[AIRFRC(MINDEX)]	Matrix containing the aerodynamic forces for unit configuration parameters for the current Mach number index. If both symmetric and antisymmetric conditions exist for the Mach number, both sets of configuration parameters will coexist in **AIRFRC** (Input)
[DELTA(SUB)]	Matrix containing the set of configuration parameters representing the user input fixed values and the trimmed unknown values for the **SUB** subscript's trim cases (Input)
[AICMAT(MINDEX)]	Matrix containing the steady aerodynamic influence coefficients for either symmetric or antisymmetric Mach numbers as appropriate for the symmetry of the cases in the current boundary condition (Input)
[UAG(BC)]	Matrix of static displacements for all **SAERO** subcases in the current boundary condition in the order the subcases appear in the **CASE** relation (Input), where **BC** represents the MAPOL boundary condition loop index number
OAGRDLOD	A relation containing the rigid, flexible correction and flexible forces and pressures for each **SAERO** subcase for the trimmed configuration parameters. Outputs are for the aerodynamic elements whose **TPRESSURE** output was

requested in Solution Control. These constitute the loads of the "trimmed" state of the configuration. (Output)

OAGRDDSP A relation containing the displacements for each **SAERO** subcase's set of configuration parameters for the aerodynamic elements whose **AIRDISP** output was requested in Solution Control. These constitute the trimmed displacements of the aerodynamic **MODEL**. (Output)

Application Calling Sequence:

None

Method:

The **CASE** relation is read to obtain the list of all **SAERO** subcases for the current boundary condition. The **AIRDISP** and **TPRESSURE** print/punch requests are checked and the module terminates if no output requests exist.

If output is needed, the **TRIM** relation is read to obtain the subscript values of each subcase. A partitioning vector is formed as the **TRIM** data are searched to extract the proper columns from the **UAG** matrix for the subcases associated with the current **SUB** value. Then, for each subcase to be processed, the particular print and punch requests are evaluated and, in the most general case, the following are computed:

Rigid Air Loads:

$$= QDP*[AIRFRC][DELTA]$$

Flexible Correction to the Rigid Air Loads:

$$= QDP*[AICMAT]^T[GSTKG]^T[UAG]$$

Total Applied Air Loads:

$$= Rigid + Flexible$$

Displacements on the aero boxes

$$= [GTKG]^T[UAG]$$

where in each case the **[DELTA]** and **[UAG]** matrices are partitioned to include only the relevant subcases for the current subscript.

Finally, the scratch matrices on which these results reside are read and output to the **OAGRDLOD** and **OAGRDDSP** relations for the loads and displacements, respectively.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: OFPALOAD

Entry Point: OFPALD

Purpose:

Solves for the static aero applied loads and **SPC** forces to satisfy the print/punch requests. The resultant loads are written to the **OGRIDLOD** relation.

MAPOL Calling Sequence:

```
CALL OFPALOAD ( NITER, BCID, MINDEX, SUB, GSIZE, BGPDT(BC), [GTKG], [GSTKG],
                QDP, [AIRFRC(MINDEX)], [DELTA(SUB)], [AICMAT(MINDEX)],
                [UAG(BC)], [MGG], [AAG(BC)], [KFS], [KSS], [UAF], [YS(BC)],
                [PNSF(BC)], [PGMN(BC)], [PFJK], NGDR, USET(BC), OGRIDLOD );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
MINDEX	Mach number index for the current subscript value (Integer, Input)
SUB	Subscript number of **SAERO** subcases considered in this cal. (Integer, Input)
GSIZE	Number of degrees of freedom in the g-set including those that may have been added by **GDR** (Integer, Input)
BGPDT(BC)	Relation of basic grid point data for the boundary condition (including any extra points and **GDR** scalar points which may be added by the **GDR** module) (Input), where **BC** represents the MAPOL boundary condition loop index number
[GTKG]	The matrix of splining coefficients relating the aerodynamic pressures to forces at the structural grids (Input)
[GSTKG]	The matrix of splining coefficients relating the structural displacements to the streamwise slopes of the aerodynamic boxes (Input)
QDP	Dynamic pressure associated with the current subscript (Real, Input)
[AIRFRC(MINDEX)]	Matrix containing the aerodynamic forces for unit configuration parameters for the current Mach number index. If both symmetric and antisymmetric conditions exist for the Mach number, both sets of configuration parameters will coexist in **AIRFRC** (Input)
[DELTA(SUB)]	Matrix containing the set of configuration parameters representing the user input fixed values and the trimmed unknown values for the **SUB** subscript's trim cases (Input)
[AICMAT(MINDEX)]	Matrix containing the steady aerodynamic influence coefficients for either symmetric or antisymmetric Mach numbers as appropriate for the symmetry of the cases in the current boundary condition (Input)
[UAG(BC)]	Matrix of static displacements for all **SAERO** subcases in the current boundary condition in the order the subcases appear in the **CASE** relation (Input), where **BC** represents the MAPOL boundary condition loop index number
[MGG]	Mass matrix in the g-set (Input)

[AAG(BC)]	Matrix of accelerations for all **SAERO** subcases in the current boundary condition in the order the subcases appear in the **CASE** relation (Input), where **BC** represents the MAPOL boundary condition loop index number
[KFS]	The off-diagonal matrix partition of the independent degrees of freedom that results from the **SPC** partitioning (Input)
[KSS]	The dependent DOF diagonal matrix partition of the independent degrees of freedom that results from the **SPC** partitioning (Input)
[UAF]	Matrix of free (f-set) static displacements for all **SAERO** subcases in the current boundary condition in the order the subcases appear in the **CASE** relation (Input)
[YS(BC)]	Vector of enforced displacements for the boundary condition (one column) (Input)
[PNSF(BC)]	Partitioning vector to divide the independent DOFs into the free and **SPC** DOFs (Input), where **BC** represents the MAPOL boundary condition loop index number
[PGMN(BC)]	Partitioning vector to divide the g-set DOFs into the **MPC** and independent DOF's (Input), where **BC** represents the MAPOL boundary condition loop index number
[PFJK]	Partitioning vector to divide the f-set DOFs that may include **GDR** generated scalar points into the original f-set DOF's
NGDR	Denotes dynamic reduction in the boundary condition. (Input, Integer) **0** No **GDR** **–1** **GDR** is used
USET(BC)	The unstructured entity of DOF masks for all the points in the current boundary conditions (Input), where **BC** represents the MAPOL boundary condition loop index number
OGRIDLOD	Relation of loads on structural grid points (Output)

Application Calling Sequence:

None

Method:

First the **CASE** relation entries for **SAERO** subcases in the current boundary condition are read. Then the **TRIM** relation is read to determine which subcases are associated with the current subscript value. Then the output **LOAD** and **SPCF** print/punch requests are examined to see if any further work is needed. If no print or punch requests are needed for the subcases associated with the **SUB**'th subscript, control is returned to the MAPOL sequence.

If **SPCF** requests exist, the preliminary computations are performed in the **ARSPCF** module. It computes:

$$[QGV1] = [KFS]^T\{UF\} + [KSS]\{YS\}$$

for all the appropriate columns of UAF that are associated with the **SUB**'th subscript. The input **YS** vector is expanded to contain the correct number of columns.

Then the computation of the applied loads is done. First, the **BGPDT** data are read and the **OGRIDLOD** relation is opened for output. Then the loads for each subcase in the subscript is solved for subject to the existence of a print request for that subcase (either **LOAD** or **SPCF**). The following loads are computed:

Rigid Air Loads on the Structural Grids

$$= QDP*[GTKG][AIRFRC][DELTA]$$

Flexible Correction to the Rigid Air Loads

$$= QDP*[GTKG][AIC]^T[GSTKG]^T[UAG]$$

Total Applied Load

$$= Rigid + Flexible$$

Inertial Load

$$= -[MGG][AAG]$$

Where the appropriate inputs are not available, the computations are simply ignored with no warning. Thus, the optional calling arguments may be used to perform parts of the computations without requiring that all pieces be provided.

Then, the output **LOAD**s matrices are opened and the **CASE LOAD**s print and punch requests are used to load the **OGRIDLOD** relation with the **RIGID**, **FLEXIBLE**, **APPLIED** and **INERTIA** loads.

Finally, if any **SPCF** output requests exist the **APPLIED** loads that were computed are combined with the **QGV1** terms to result in the **SPC** reaction forces:

$$[SPCF] = [QGV1] - [Applied\ load]$$

For each DOF for which **SPC** forces have been requested.

Design Requirements:

1. **SPC** force computations for other disciplines occur in the **OFPSPCF** module.

2. Only those arguments that are present will be used. If data are missing, the dependent terms will be omitted from the output.

Error Conditions:

None

Engineering Application Module: OFPDISP

Entry Point: OFPDSP

Purpose:

To print selected displacements, velocities and/or accelerations from any analyses in the current boundary condition.

MAPOL Calling Sequence:

```
CALL OFPDISP ( BCID, NITER, GSIZE, BGPDT(BC), ESIZE(BC), PSIZE(BC),
               OGRIDDSP, [UG(BC)], [AG(BC)], [UAG(BC)], [AAG(BC)], [BLUG],
               [BLUE], [UTRANG], [UTRANE], [UFREQG], [UFREQE], LAMBDA,
               [PHIG(BC)], [PHIBG(BC)], LSTFLG );
```

BCID	User defined boundary condition identification number (Integer, Input)
NITER	Iteration number for the current design iteration (Integer, Input)
GSIZE	The size of the structural set (Integer, Input)
BGPDT(BC)	Relation of basic grid point coordinate data (Input), where **BC** represents the MAPOL boundary condition loop index number
ESIZE(BC)	The number of extra point degrees of freedom in the boundary condition (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number
PSIZE(BC)	The size of the physical set for the current boundary condition. (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number
OGRIDDSP	Relation for storage of displacement data (Input)
[UG(BC)]	Matrix of global displacements from **STATICS** analyses (Input), where **BC** represents the MAPOL boundary condition loop index number
[AG(BC)]	Matrix of global accelerations from **STATICS** analyses (Input), where **BC** represents the MAPOL boundary condition loop index number
[UAG(BC)]	Matrix of global displacements from **SAERO** analyses (Input), where **BC** represents the MAPOL boundary condition loop index number
[AAG(BC)]	Matrix of global accelerations from **SAERO** analyses (Input), where **BC** represents the MAPOL boundary condition loop index number
[BLUG]	Matrix of global displacements/velocities/accelerations for **BLAST** response analyses (Input)
[BLUE]	Matrix of extra point displacements/velocities/ accelerations for **BLAST** response analyses (Input)
[UTRANG]	Matrix of global displacements/velocities/ accelerations for **TRANSIENT** response analyses (Input)
[UTRANE]	Matrix of extra point displacements/velocities/ accelerations for **TRANSIENT** response analyses (Input)
[UFREQG]	Matrix of global displacements/velocities/ accelerations for **FREQUENCY** response analyses (Input)

[UFREQE]	Matrix of extra point displacements/velocities/ accelerations for **FREQUENCY** response analyses (Input)
LAMBDA	Relational entity containing the output from the real eigenanalysis (Input)
[PHIG(BC)]	Matrix of global eigenvectors from real eigenanalysis for **MODES** analyses (Input), where **BC** represents the MAPOL boundary condition loop index number
[PHIGB(BC)]	Matrix of global eigenvectors for **BUCKLING** analyses (Input), where **BC** represents the MAPOL boundary condition loop index number
LSTFLG	Integer flag to indicate if for last iteration output only (Integer, Input) **1** for last iteration only **0** other general cases

Application Calling Sequence:

None

Method:

The module begins by reading the **CASE** relation nodal response quantity print options for the current boundary condition. The following print requests are treated in the **OFPDISP** module:

(1) **DISPLACEMENT**

(2) **VELOCITY**

(3) **ACCELERATION**

(4) **ROOTS** (for normal modes analyses)

As the **CASE** data are searched, the **FLTFLG** and **MODFLG** logicals are set to **TRUE** if either **FLUTTER** or **MODES** disciplines are associated with these print requests. If no prints are requested, the module terminates, otherwise, the **ITERLIST**, **GRIDLIST**, **MODELIST, TIMELIST** and **FREQLIST** data are prepared for easy retrieval in determining which nodes and subcases are requested in each case.

The **BGPDT** data are then read into open core and the number of extra point degrees of freedom in the current boundary condition is determined. Finally, the code checks to see if any flutter displacements (eigenvectors) have been requested for an optimization boundary condition. If so, the request is explicitly turned off since ASTROS does not compute the eigenvector for optimization boundary conditions. The next segment of code is set aside for special discipline dependent processing. In this module, the flutter eigenvector print requires the transformation of the modal participation factors for any flutter eigenvectors into physical coordinates using the input **PHIG** matrix and the **FLUTREL** and **FLUTMODE** entities that were created in the **FLUTTRAN** module. Again, if no flutter conditions were found in the analysis, the module explicitly turns off the print request. Otherwise, the physical mode shape is computed and stored in a pair of scratch entities: one for the structural degrees of freedom and one for the extra point degrees of freedom.

The main loop in the module now begins. This loop is over all the disciplines that have nodal response quantities. For each discipline, there is a loop over all the **CASE** tuples retrieved at the beginning of the module. Only those **CASE** tuples matching the current discipline are treated at each pass of the outermost loop. The **DSPSUB** submodule is called for each **CASE** tuple to determine the number and identification numbers for each subcase for which output is desired. A subcase is considered to be one displacement/velocity/acceleration vector for a particular time step, frequency step, load condition, etc. Then, depending on the nature of the discipline, one of five print routines is called to read into memory the proper nodal vector and print the terms to the user output file. Once all the subcases for the current **CASE** tuple have

been processed, the **CASE** tuple loop continues for the current discipline. When all disciplines or all **CASE** tuples have been processed, the module terminates.

Design Requirements:

1. The **OFPDISP** module is designed to be called at the conclusion of the boundary condition loop when all the physical nodal response quantities have been computed for all the analyzed disciplines.

Error Conditions:

None

Engineering Application Module: OFPDLOAD

Entry Point: OFPDLD

Purpose:

Processes the solution control load output requests for the current boundary condition for dynamic loads (transient, frequency and gust) and stores the loads on the physical degrees of freedom to the **OGRIDLOD** relation for those subcases and grids selected in solution control.

MAPOL Calling Sequence:

```
CALL OFPDLOAD ( NITER, BCID, BGPDT(BC), PSIZE(BC), ESIZE(BC), [PHIG(BC)],
                [PTGLOAD], [PTHLOAD], [PFGLOAD], [PFHLOAD], OGRIDLOD );
```

NITER	Current design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
BGPDT(BC)	Relation of basic grid point data for the boundary condition (including any extra points and **GDR** scalar points which may be added by the **GDR** module) (Input), where **BC** represents the MAPOL boundary condition loop index number
PSIZE(BC)	The size of the physical set for the current boundary condition (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number
ESIZE(BC)	Number of extra point DOF's defined for the boundary condition (Integer, Output), where **BC** represents the MAPOL boundary condition loop index number
[PHIG(BC)]	Matrix of normal mode eigenvectors in the structural g-set (Input), where **BC** represents the MAPOL boundary condition loop index number
[PTGLOAD]	Matrix of g-set applied dynamic loads for the direct transient analyses in the current boundary condition (Input)
[PTHLOAD]	Matrix of h-set applied dynamic loads for the modal transient **GUST** analyses in the current boundary condition (Input)
[PFGLOAD]	Matrix of g-set applied dynamic loads for the direct frequency analyses in the current boundary condition (Input)
[PFHLOAD]	Matrix of h-set applied dynamic loads for the modal frequency analyses with **GUST** in the current boundary condition (Input)
OGRIDLOD	Relation of applied loads on structural grid points (Output)

Application Calling Sequence:

None

Method:

The **CASE** relation is read for all transient and frequency response analysis and the **LOADPRNT** print and punch requests for **LOAD**s are examined. If any requests exist, processing continues by opening the **BGPDT** and reading the internal/external point identifications to allow storing the matrix data or the **OGRIDLOD** relation labelled with the external ids.

If any **GUST** loads are requested, the modal dynamic loads are transformed to the physical degrees of freedom as:

[PGUSTT] = [PHIG][PTHLOAD] for transient gust
[PGUSTF] = [PHIG][PFHLOAD] for harmonic gust

To perform these operations, the normal modes must be expanded to include extra points for the single subcase of transient and or frequency that is allowed. Then the multiplications are performed.

Finally, once all the direct matrices are available, the **CASE** control print requests are processed, the corresponding columns are identified by interpreting the **TIME** or **FREQ** options and the **GRIDLIST** data are read to determine which points are chosen. The terms are then written to the **OGRIDLOD** relation as **APPLIED** loads.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: OFPEDR

Entry Point: OFPEDR

Purpose:

To print selected element stress, strain, force and/or strain energies from any analyses in the current boundary condition.

MAPOL Calling Sequence:

```
CALL OFPEDR ( BCID, HSIZE(BC), NITER, LSTFLG );
```

BCID	User defined boundary condition identification number (Integer, Input)
HSIZE(BC)	Number of modal dynamic degrees of freedom in the current boundary condition (Input), where **BC** represents the MAPOL boundary condition loop index number
NITER	Iteration number for the current design iteration (Integer, Input)
LSTFLG	Integer flag to indicate if for last iteration output only (Integer, Input) **1** for last iteration only **0** other general cases

Application Calling Sequence:

None

Method:

The module begins by reading the **CASE** relation element response quantity print options for the current boundary condition. The following print requests are treated in the **OFPEDR** module:

(1) **STRESS**

(2) **STRAIN**

(3) **FORCE**

(4) **ENERGY**

If no prints are requested, the module terminates, otherwise, the **ITERLIST**, **ELEMLIST**, **MODELIST, TIMELIST** and **FREQLIST** data are prepared for easy retrieval in determining which elements and subcases are requested in each case. The main loop in the module now begins. This loop is over all the disciplines that have element response quantities.

For each discipline, there is a loop over all the **CASE** tuples retrieved at the beginning of the module. Only those **CASE** tuples matching the current discipline are treated at each pass of the outermost loop. The **OFPSUB** submodule is called for each **CASE** tuple to determine the number and identification numbers for each subcase for which output is desired. A subcase is considered to be one displacement vector for a particular time step, frequency step, load condition, etc. For each subcase, the set of element response print utilities (one for each element type) are called for each of the four quantities that can be printed. If the strain energy is requested, the **OFPESE** submodule is called to compute the total strain energy for the current displacement field as a preface operation prior to the element dependent print routines. Once all the quantities for all the subcases for the current **CASE** tuple have been processed, the **CASE** tuple loop continues for the current discipline. When all disciplines or all **CASE** tuples have been processed, the module terminates.

Design Requirements:

1. The **OFPEDR** module is designed to be called at the conclusion of the boundary condition loop when all the physical nodal response quantities have been computed for all the analyzed disciplines.

2. The **EDR** module must have been called to store the computed element response quantities onto the **EOxxxx** entities which are read by the **OFPEDR** module.

Error Conditions:

None

Engineering Application Module: OFPGRAD

Entry Point: OFPGRA

Purpose:

Stores the data necessary to satisfy the solution control print and punch requests **OGRADIENT** and **CGRADIENT** (objective function gradient and constraint gradient, respectively).

MAPOL Calling Sequence:

```
CALL OFPGRAD ( NITER, [AMAT], GLBDES, CONST, CONSTORD, GRADIENT );
```

NITER	Design iteration number (Integer, Input)
[AMAT]	The matrix of constraint gradients for active constraints in the current design iteration (Input)
GLBDES	The relation of global design variable values and objective function sensitivities for all design iterations that have been analyzed. (Input)
CONST	The relation of applied design constraints for all design iterations (Input)
CONSTORD	The relation of reordered design constraints for the current design iteration (Input)
GRADIENT	The relation of output constraint gradients for the requested constraints and design variables that satisfy the Solution Control **CGRADIENT** and **OGRADIENT** output requests (Output)

Application Calling Sequence:

None

Method:

The **OPTIMIZE** relation is read to determine if any **OGRADIENT** or **CGRADIENT** print or punch requests exist. If they do, processing continues by determining if this iteration is in the set of iterations selected. If it is, the the **AMAT** matrix is opened and read into memory as are the **GLBDES** entries for the current iteration. The **CONST** relation is read into memory and reordered to match the **AMAT** matrix. Then the **GRADIENT** entity is loaded with the objective or constraint gradient terms for the requested constraints and global design variables.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: OFPLOAD

Entry Point: OFPLOD

Purpose:

To print selected applied external loads from any analyses in the current boundary condition.

MAPOL Calling Sequence:

```
CALL OFPLOAD ( BCID, NITER, GSIZE, BGPDT(BC), PSIZE(BC), [PG],
               TRMTYP, QDP, [GTKG], [AIRFRC(MINDEX)], [DELTA] );
```

BCID	User defined boundary condition identification number (Integer, Input)
NITER	Iteration number for the current design iteration (Integer, Input)
GSIZE	The size of the structural set (Integer, Input)
BGPDT(BC)	Relation of basic grid point coordinate data (Input), where **BC** represents the MAPOL boundary condition loop index number
PSIZE(BC)	The size of the physical set for the current boundary condition. (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number
[PG]	Matrix of applied loads for **STATICS** analyses in the current boundary condition (Input)
TRMTYP	The trim type for the steady aeroelastic analyses **= 0** zero degree of freedom trim **= 1** lift only trim **= 2** lift/pitching moment trim (Integer, Input)
QDP	Dynamic pressure for the **SAERO** analyses in the current boundary condition (Real, Input)
[GTKG]	Matrix containing the steady aerodynamic spline in the structural set (Input)
[AIRFRC(MINDEX)]	Matrix containing the aerodynamic forces for unit configuration parameters for the current Mach number and Symmetry (Input)
[DELTA]	Matrix containing the configuration parameter values resulting from the current trim condition (Input)

Application Calling Sequence:

None

Method:

The module begins by reading the **CASE** relation applied load print options for the current boundary condition. The **LOAD** print requests are treated in the **OFPLOAD** module for all ASTROS disciplines. As the **CASE** data are searched, the **AROFLG** logical is set to **TRUE** if any **SAERO** cases with a **TRMTYP** greater than zero are found. If no prints are requested, the module terminates, otherwise, the **GRIDLIST**, **MODELIST**, **TIMELIST** and **FREQLIST** data are prepared for easy retrieval in determining which nodes and subcases are requested in each case. The **BGPDT** data are then read into open core and the number of extra point degrees of freedom in the current boundary condition is determined. The next segment of code is set aside for special discipline dependent processing. In this module, the steady air loads associated with **TRIM** analyses must be computed from the **AIRFRC** matrix of loads due to "unit" configuration parameters and the **DELTA** matrix of trimmed configuration parameters. The result must then be splined to the structural degrees of freedom using the **GTKG** spline transformation matrix. The

structural applied loads are stored in a scratch entity for use in the subsequent print processing. The main loop in the module now begins. This loop is over all the disciplines that have applied loads. For each discipline, there is a loop over all the **CASE** tuples retrieved at the beginning of the module. Only those **CASE** tuples matching the current discipline are treated at each pass of the outermost loop. The **LODSUB** submodule is called for each **CASE** tuple to determine the number and identification numbers for each subcase for which output is desired. A subcase is considered to be one load vector for a particular time step, frequency step, load condition, etc. Then, depending on the nature of the discipline, one of two print routines is called to read into memory the proper vector and to print the terms to the user output file. Once all the subcases for the current **CASE** tuple have been processed, the **CASE** tuple loop continues for the current discipline. When all disciplines or all **CASE** tuples have been processed, the module terminates.

Design Requirements:

1. The **OFPLOAD** module is designed to be called at the conclusion of the boundary condition loop.

Error Conditions:

None

Engineering Application Module: OFPMROOT

Entry Point: OFPMRT

Purpose:

Processes the solution control normal modes root output requests.

MAPOL Calling Sequence:

```
CALL OFPMROOT ( NITER, BCID, LAMBDA, LASTFLAG );
```

NITER	Current design iteration number. (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
LAMBDA	The relation of normal modes eigenvalues for all boundary conditions and design iterations (Input)
LASTFLAG	An optional argument which, if nonzero, implies that the call is being made only to satisfy **ITER=LAST** print or punch requests (Integer, Input)

Application Calling Sequence:

None

Method:

The **CASE** relation is read to obtain the print/punch requests for **ROOTS**. If any requests exist, they are processed. If the **LASTFLAG** is nonzero, only those requests in which the **ITER=LAST** flag is set in the **ROOTPRNT CASE** relation attribute are considered.

For the modes selected by the **MODELIST**, the **OEIGS** and **LAMBDA** entities are read and the eigenvalue extraction summary table and the extracted eigenvalues are printed to the output file. Punch requests are ignored since the data are stored already on the **LAMBDA** relation.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: OFPSPCF

Entry Point: OFPSPF

Purpose:

Recovers single-point forces of constraint and loads the results to the **OGRIDLOD** relation

MAPOL Calling Sequence:

```
CALL OFPSPCF ( NITER, BCID, DISC, CMPLX, GSIZE, ESIZE(BC), NGDR, [KFS],
               [KSS], [UF], [YS(BC)], [PS], [PNSF(BC)], [PGMN(BC)], [PFJK],
               [PHIG(BC)], [PGLOAD], [PHLOAD], BGPDT(BC), OGRIDLOD );
```

NITER Current design iteration number (Optional, Integer, Input)

BCID User defined boundary condition identification number (Integer, Input)

DISC Integer key indicating the discipline whose **SPC** forces are to be recovered.

- **1** for statics
- **2** for modes
- **4** for flutter
- **5** for transient analysis
- **6** for frequency analysis
- **8** for nuclear blast

Note that static aeroelasticity (**DISC=3**) is supported in the **OFPALOAD** module. (Integer, Input)

CMPLX Integer flag indicating whether the discipline's displacement field is real (**=1**) or complex (**=2**) (Integer, Input)

GSIZE Number of degrees of freedom in the g-set including those that may have been added by **GDR** (Integer, Input)

ESIZE(BC) Number of extra point DOF's defined for the boundary condition (Integer, Output)

NGDR Denotes dynamic reduction in the boundary condition. (Input, Integer)

- **0** No **GDR**
- **–1** **GDR** is used

[KFS] The off-diagonal matrix partition of the independent degrees of freedom that results from the **SPC** partitioning (Input)

[KSS] The dependent DOF diagonal matrix partition of the independent degrees of freedom that results from the **SPC** partitioning (Input)

[UF] Matrix of free (f-set) static displacements for all the **DISC** subcases in the current boundary condition in the order the subcases appear in the **CASE** relation (Input)

[YS(BC)] Vector of enforced displacements for the boundary condition (one column) (Optional, Input)

[PS] Matrix of static loads applied to the **SPC** DOF's (Partition of the free DOF loads matrix) (Optional, Input)

[PNSF(BC)] Partitioning vector to divide the independent DOFs into the free and **SPC** DOFs (Input)

[PGMN(BC)]	Partitioning vector to divide the g-set DOFs into the **MPC** and independent DOF's (Input)
[PFJK]	Partitioning vector to divide the f-set DOFs that may include **GDR** generated scalar points into the original f-set DOF's (Optional, but required if **NGDR <>0**; Input)
[PHIG(BC)]	Matrix of normal mode eigenvectors in the structural g-set (Optional, Input)
[PGLOAD]	Matrix of g-set applied dynamic loads for the direct transient or frequency analyses (as appropriate for **DISC**) in the current boundary condition (Optional, Input)
[PHLOAD]	Matrix of h-set applied dynamic loads for the modal transient or frequency **GUST** analyses (as appropriate for **DISC**) in the current boundary condition (Optional, Input)
BGPDT(BC)	Relation of basic grid point data for the boundary condition (including any extra points and **GDR** scalar points which may be added by the **GDR** module) (Input), where **BC** represents the MAPOL boundary condition loop index number
OGRIDLOD	Relation of loads on structural grid points (Output)

Application Calling Sequence:

None

Method:

This module computes the **SPC** reaction forces for all disciplines in ASTROS except **SAERO** and **NPSAERO**. **NPSAERO** has no structural loads and the **SAERO SPC** forces are computed in the **OFPALOAD** module where the applied loads (an input to the **SPC** computations) are computed.

First the **CASE** relation is read for all entries with a **DISFLAG** of **DISC** for the current boundary condition. Then the **SPCF** print requests are examined to determine if any output is needed for this discipline, design iteration, etc. If not, the module terminates otherwise computations continue with the creation of scratch entities to hold the constituent parts of the **SPC** calculations. The **BGPDT** data are read into memory and the **OGRIDLOD** relation is opened in preparation for output.

The existence of enforced displacements, **YS** and loads on the **SPC** dofs, **PS** is checked and logical flags are set for downstream computations. If **GDR** was used (as indicated by **NGDR <>0**), the **PFJK** partition matrix is used to extract the original f-set DOF from **UF** from the input set which includes **GDR** scalar points.

Then some discipline dependent processing takes place. If **DISC = 4** (**FLUTTER**), the **FLMODE** hidden entity is read and the flutter eigenvectors (if any) are read, stripped of the extra point degrees of freedom and reduced to the f-set. Transient and frequency disciplines require special processing because of the nature of the displacement matrices (containing velocities and accelerations). This processing is done in **DYSPCF** and results in a g-set sized matrix of the loads applied to the **SPC** DOFs for each time or frequency step. **GUST** loads are treated here to recover the direct applied loads from the **PHLOAD** input. Extra points are partitioned out of these loads matrices if needed.

Then the actual recovery process begins. First the **QSV** matrix of **SPC** forces are computed from the appropriate constituent terms

$$[QSV] = [KFS]^T\{UF\} + [KSS]\{YS\} - \{PS\}$$

where **YS** has been expanded to have the appropriate number of columns and the proper terms are ignored if **YS** or **PS** is blank or empty.

Then the **QSV** matrix is expanded to the g-set, the nonzero terms are read and compared to the output requests and the appropriate terms are loaded to the **OGRIDLOD** relation. For the dynamic response disciplines, the applied loads **PS** are extracted from the g-set output of the **DYSPCF** submodule and the reaction forces are adjusted accordingly.

Design Requirements:

1. **SAERO** single point constraint reactions are computed in the **OFPALOAD** module where the applied loads are computed.

Error Conditions:

None

Engineering Application Module: PBKLEVAL

Entry Point: BKLEVA

Purpose:

Evaluates the current values of the panel buckling constraints.

MAPOL Calling Sequence:

```
CALL PBKLEVAL ( BCID, NITER, NDV, GLBDES, LOCLVAR, [PTRANS], CONST,
                PDLIST, OPNLBUCK );
```

BCID	User defined boundary condition identification number (Integer, Input)
NITER	Design iteration number (Integer,Input)
NDV	Number of design variables (Integer,Input)
GLBDES	Relation of global design variables (Character,Input)
LOCLVAR	Relation containing the relationship between local variables and global variables in the design problem (Character,Input)
[PTRANS]	The design variable linking matrix (Character,Input)
CONST	Relation of constraint values (Character,Output)
PDLIST	Relation containing panel buckling constraint sensitivity information. (Character,Output)
OPNLBUCK	Relation containing panel buckling constraint output (Character,Output)

Application Calling Sequence:

None

Method:

This module first checks if any **DCONBK** bulk data entries referenced by any STATICS and/or SAERO disciplines at the current boundary condition to determine if there are any panel buckling constraints applied. If any are found, the QUAD4 and/or TRIA3 element data are obtained from relation **QUAD4EST** and/or **TRIA3EST**; the element force data are obtained from relation **EOQD4** and/or **EOTR3**; and the panel buckling constraint values are evaluated and stored into relation **CONST**. The constraint sensitivity data are also prepared in this module.

Design Requirements:

Because this module requires the element output relation from module **EDR**, it should only be called after that module.

Error Conditions:

The element has no force data for buckling constraint evaluation is flagged.

Engineering Application Module: PBKLSENS

Entry Point: BKSENS

Purpose:

Evaluates the panel buckling constraint sensitivity.

MAPOL Calling Sequence:

```
CALL PBKLSENS ( BCID, NITER, NDV, CONST, GLBDES, LOCLVAR,
                [PTRANS], PDLIST, [AMAT] );
```

BCID	User defined boundary condition identification number (Integer, Input)
NITER	Design iteration number (Integer,Input)
NDV	Number of design variables (Integer,Input)
CONST	Relation of constraint values (Character, Input)
GLBDES	Relation of global design variables (Character,Input)
LOCLVAR	Relation containing the relationship between local variables and global variables in the design problem (Character,Input)
[PTRANS]	The design variable linking matrix (Character,Input)
PDLIST	Relation containing panel buckling constraint sensitivity information (Character,Input)
[AMAT]	Matrix containing the sensitivity of the constraints to changes in the design variable (Character,Output)

Application Calling Sequence:

None

Method:

This module first check if any active panel buckling constraints for the current boundary condition and obtained the prepared constraint sensitivity data from relations **PDLIST** and **CONST**. Then the local design variable data is obtained from relation **LOCLVAR**. For each active panel buckling constraint, the sensitivity to the design variables is computed and stored into matrix **[AMAT]**.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: PFBULK

Entry Point: PFBULK

Purpose:

To perform a number of preface operations to form additional collections of data and to make error checks not done in **IFP** to identify input errors before costly analyses are performed.

MAPOL Calling Sequence:

```
CALL PFBULK ( GSIZEB, EOSUMMRY, EODISC, GPFELEM );
```

GSIZEB	Length of the g-set vectors (Integer, Input)
EOSUMMRY	Relational entity containing the summary of entities for which element response quantities are desired (Output)
EODISC	Unstructured entity referred to by an attribute of **EOSUMMRY** containing the set of disciplines and subcases for the element response quantities
GPFELEM	Relational entity containing the set of elements connected to grid points for which grid point forces are desired (Output)

Application Calling Sequence:

None

Method:

This module first computes the coordinate functions and centroid functions which are required by any user function constraints. Those response values are stored into relational entities to be used by the function evaluation utilities. Then the module performs tests on selected bulk data entities to see if they contain data. If they do, the indicated subroutine is called to generate further data and perform error checks:

BULK DATA	SUBROUTINE	GENERATED ENTITY
TEMP, TEMPD	PRETMP	GRIDTEMP
FREQ, FREQ1, FREQ2	PREFRQ	FREQL
TSTEP	PRETST	OTL

The module also checks that constraint requests specified in the **FLUTTER** solution control command have corresponding **DCONFLT** bulk data entries.

As a final step, the **PFBULK** module performs the preliminary processing of solution control print requests that depend on elements. These include all the element response quantities (i.e., stress or strain) and the grid point force balance. The first stage is performed in the **PREGPF** submodule which builds the **GPFELEM** relation from the element connectivity data and the sets of nodes for which a force balance in requested. Then the **PREEDR** submodule is called to build the **EOSUMMRY** and **EODISC** entities which list those elements for which element data recovery should be performed in the **EDR** module. These entities are also used in **OFPEDR** to direct the printing of the computed quantities.

Design Requirements:

1. This is a preface module that called after **EMG** and **MAKEST**

Error Conditions:

None

Engineering Application Module: QHHLGEN

Entry Point: QHHGEN

Purpose:

To compute the discipline dependent unsteady aerodynamic matrices for gust analyses in the modal dynamic degrees of freedom.

MAPOL Calling Sequence:

```
CALL QHHLGEN ( BCID, ESIZE(BC), [QKKL], [QKJL], [UGTKA], [PHIA], [PHIKH],
               [QHHL], [QHJL] );
```

BCID	User defined boundary condition identification number (Integer, Input)
ESIZE(BC)	The number of extra point degrees of freedom in the boundary condition (Integer, Input), where **BC** represents the MAPOL boundary condition loop index number
[QKKL]	Matrix list containing the matrix product (Output): $[SKJ][AJJT]^{-T}([D1JK] + ik[D2JK])$ used for flutter and gust analyses (Input)
[QKJL]	Matrix list containing the matrix product: $[SKJ][AJJT]^{-T}$ used for gust analyses (Input)
[UGTKA]	Matrix containing the unsteady aerodynamic spline in the analysis set (Input)
[PHIA]	Matrix containing the real eigenvectors in the analysis set (Input)
[PHIKH]	Matrix containing the matrix product (Output): $[UGTKA][PHIA]$ with the analysis set expanded to include extra points (Output)
[QHHL]	The modal unsteady aerodynamic influence coefficients for gust (Output): $[PHIKH]^{T}[QKK][PHIKH]$
[QHJL]	The modal unsteady aerodynamic influence coefficients for gust (Output): $[PHIKH]^{T}[QKJ]$

Application Calling Sequence:

None

Method:

The **QHLLGEN** module begins by retrieving all the **CASE** tuples for the current boundary condition. The number of gust options on transient or frequency response disciplines are counted to determine what actions are required by the module. If gust conditions do not exist, control returns to the executive. If **QZHH** and **QJH** are required, the module continues by reading the **BGPDT** data to determine the size of the direct dynamic degrees of freedom including extra points. If extra points exist, the normal modes and the unsteady spline matrix (input in the analysis set) are expanded to include the extra point degrees of freedom. The module then computes the **PHIKH** matrix of structural mode shapes splined to the

aerodynamic degrees of freedom. **QHLLGEN** then calls the **PRUNMK** utility to prepare the **UNMK** data for the discipline dependent unsteady aerodynamic matrices. The total number of m-k/symmetry sets associated with the **QKK** matrix are computed and the requisite memory for the subsequent computations is obtained. The module then proceeds with the premultiplication of the **QKK** matrix list by the **PHIKH** matrix:

[QHKL] = [PHIKH][QKKL]

The **QHLL** output matrix is then flushed and computed using one of two paths. If there is only one m-k/symmetry set (which is very rare), the **QHLL** matrix may be formed by a post-multiplication of **QHKL** in one step. If more than one matrix is in the **QHKL** matrix list, however, the module extracts each matrix individually using the **EXQKK** utility and performs the multiplication:

[QZHH] = [QHK][PHIKH]

and appends the resultant matrix onto **QHLL**.

The matrix **QHJL** is also output. Since this matrix only requires a premultiplication of the input **QKJL** matrix list by **PHIKH**, it is performed in one step and the module terminates.

Design Requirements:

1. The **UNSTEADY** module must have been executed to generate the aerodynamic matrices and generate the **UNMK** entity.

Error Conditions:

None

Engineering Application Module: RBCHECK

Entry Point: RDGCHK

Purpose:

To compute the rigid body strain energies associated with displacements of each support degree of freedom.

MAPOL Calling Sequence:

```
CALL RBCHECK ( BCID, USET(BC), BGPDT(BC), [D(BC)], [KLL], [KRR], [KLR] );
```

BCID	User defined boundary condition identification number (Integer, Input)
USET(BC)	The unstructured entity defining structural sets (Input), where **BC** represents the MAPOL boundary condition loop index number
BGPDT(BC)	Relation containing basic grid point coordinate data (Input), where **BC** represents the MAPOL boundary condition loop index number
[D(BC)]	Rigid body transformation matrix (Input), where **BC** represents the MAPOL boundary condition loop index number
[KLL]	The stiffness matrix in the l-set degrees of freedom (Input)
[KRR]	The stiffness matrix in the r-set degrees of freedom (Input)
[KLR]	The off-diagonal l-r partition of the a-set stiffness matrix (Input)

Application Calling Sequence:

None

Method:

The **RBCHECK** module begins by checking if the **USET** entity contains any support (r-set) degrees of freedom. If not, the module returns. The module continues by reading the **BGPDT** into memory and then computing the strain energy associated with the rigid body displacements:

$$\mathbf{[X]} = \mathbf{[KLR]}^{T}\,\mathbf{[D]} + \mathbf{[KRR]}$$

The **X** and **KRR** matrices are then read into memory and two normalization measures are computed. The first is the overall norm of each matrix:

$$X_{norm} = \sum_{i=1}^{nr}\sum_{j=1}^{nr} | X_{ij} |$$

$$\mathbf{KRR}_{norm} = \sum_{i=1}^{nr}\sum_{j=1}^{nr} | \mathbf{KRR}_{ij} |$$

$$\varepsilon_{matrix} = \frac{X_{norm}}{\mathbf{KRR}_{norm}}$$

The second is the norm of each of the *nr* columns:

$$X_{j_{norm}} = \sum_{i=1}^{nr} | X_{ij} |$$

$$\mathbf{KRR}_{j_{norm}} = \sum_{i=1}^{nr} | \mathbf{KRR}_{ij} |$$

$$\varepsilon_{col} = \frac{X_{j_{norm}}}{\mathbf{KRR}_{j_{norm}}}$$

These error ratios and norms are then printed out along with the associated diagonal of **X** (the strain energy) for each support degree of freedom.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: RECOVA

Entry Point: RECOVA

Purpose:

To recover the symmetric or asymmetric f-set displacements or accelerations if there are omitted degrees of freedom.

MAPOL Calling Sequence:

```
CALL RECOVA ( [UA], [PO], [GSUBO(BC)], NRSET, [AA], [IFM(BC)], SYM,
              [KOOINV(BC)], [KOOU(BC)], [PFOA(BC)], [UF] );
```

[UA]	Matrix of displacements or accelerations in the analysis set (Input)
[PO]	Optional matrix of static loads applied to omitted degrees of freedom (Input)
[GSUBO(BC)]	Static condensation transformation matrix (Input), where **BC** represents the MAPOL boundary condition loop index number
NRSET	Flag indicating that inertia relief effects are to be included. (Integer, Input)
[AA]	Optional matrix of analysis set accelerations for inertia relief (Input)
[IFM(BC)]	Optional matrix containing terms needed for inertia relief, where **BC** represents the MAPOL boundary condition loop index number. (Input)
SYM	Optional symmetry flag; **=1** if any **KFF** is not symmetric (Integer, Input)
[KOOINV(BC)]	Matrix containing the inverse of **KOO** for symmetric stiffness matrices or the lower triangular factor of **KOO** for asymmetric matrices, where **BC** represents the MAPOL boundary condition loop index number. (Input)
[KOOU(BC)]	Optional matrix containing the upper triangular factor of **KOO** for asymmetric stiffness matrices (Input), where **BC** represents the MAPOL boundary condition loop index number
[PFOA(BC)]	The partitioning vector splitting the free degrees of freedom into the analysis set and the omitted degrees of freedom (Input), where **BC** represents the MAPOL boundary condition loop index number
[UF]	Matrix containing the displacements or accelerations for the free degrees of freedom (Output)

Application Calling Sequence:

None

Method:

The **RECOVA** module begins by checking if the **PO** argument is nonblank. If so, the displacements at the omitted degrees of freedom due to the loads at the omitted degrees of freedom, **UOO**, are computed. These computations depend on whether inertia relief and/or asymmetric stiffnesses exist. If inertia relief is required (**NRSET > 0**) the loads on the omitted DOF's are modified using the **IFM** matrix and the analysis set accelerations, **AA**; both of which must be input:

```
[PO] = [PO] - [IFM][AA]
```

The **UOO** terms are then computed from the inverted **KOO** terms based on the **SYM** flag; with the symmetry flag indicating whether the general or symmetric forward backward substitution is used:

[UOO] = [KOO]$^{-1}$[PO] using Forward Backward Substitution

Finally, the omitted displacements, **UO**, are computed from:

[UO] = [GSUBO][UA] + [UOO]

Note that the module assumes that the correct set of **KOOINV, KOOU**, **IFM**, **AA**, and **PO** matrices are supplied to match the **SYM** and **NRSET** flags. If the **PO** argument is omitted from the calling sequence, the **UO** terms are computed directly from:

[UO] = [GSUBO][UA]

with the **GSUBO** argument required to perform the computation. Note that these computations are the same irrespective of the **NRSET** flag. When **UO** is complete, the module merges the computed **UO** terms with the supplied **UA** terms to form the **UF** output.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: SAERO

Entry Point: SAERO

Purpose:

To solve the trim equation for steady aeroelastic trim analyses and to compute the rigid and flexible stability coefficients for steady aeroelastic analyses and the aerodynamic effectiveness constraints for constrained optimization steady aerodynamic analyses.

MAPOL Calling Sequence:

```
CALL SAERO ( NITER, BCID, MINDEX, SUB, SYM, QDP, STABCF, BGPDT(BC),
             [LHSA(BC,SUB)], [RHSA(BC,SUB)], [AAR], [DELTA(SUB)], [PRIGID],
             [R33], CONST, AEFLG(SUB), [AARC], [DELC] );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
MINDEX	Mach number index for the current subscript value. (Integer, Input)
SUB	Subscript number of **SAERO** subcases considered in this call (Integer, Input)
SYM	The symmetry flag for the current **SAERO** subcases (Integer, Input)
QDP	Dynamic pressure associated with the current subscript (Real, Input)
STABCF	Relation of rigid stability coefficient data (Input)
BGPDT(BC)	Relation of basic grid point coordinate data (Input), where **BC** represents the MAPOL boundary condition loop index number
[LHSA(BC,SUB)]	Matrix of modified inertia coefficients (Input), where **BC** represents the MAPOL boundary condition loop index number
[RHSA(BC,SUB)]	Matrix of applied load vectors reduced to the r-set (Input), where **BC** represents the MAPOL boundary condition loop index number
[AAR]	Matrix of acceleration vectors (Output)
[DELTA(SUB)]	Matrix of configuration parameters (Output)
[PRIGID]	Rigid load matrix (Input)
[R33]	Reduced rigid body mass matrix (Input)
CONST	Relation of constraint values (Input)
AEFLG(BC)	The logical flag denoting presence of aeroelastic constraints (Logical, Output), where **BC** represents the MAPOL boundary condition loop index number
[AARC]	Matrix of structural accelerations due to unit configuration parameters for use in sensitivity evaluation (output)
[DELC]	Matrix of "unit" flight configuration parameters used to generate the **AARC** accelerations (output)

Application Calling Sequence:

None

Method:

The module begins by bringing into memory the **CASE** entries associated with **SAERO** subcases in the current boundary condition. Then, the **STABCF** relation is read into memory for the current **MINDEX** value. The **TRIM** relation is read for all entries that have the current subcript value and other trim data from **AEROS**, **CONEFFS**, and **CONLINK** are also read into memory.

Then an evaluation of the trim data is done to determine the number of trim subcases that will be solved during this pass (for the current subscript). The **AROCHK** utility is used to evaluate the **SUPORT** condition to ensure (again) that it satisfies the requirements of the **TRIM** solver and to get the names and DOFs of the supported degrees of freedom. Then, after creating needed scratch entities, the grand loop on the trim subcases begins.

Each trim subcase must be solved separately because of the options for control effectiveness and control linking. The first step is to determine which **TRIM** entries are associated with the current subcase (note all are associated with the current subscript). Once the **TRIM** id of the current case is known, the **CASE** relation data are searched to determine the subcase number (1 to n over all **SAERO** entries in **CASE** for each **BC**). Then the **AROLNK** routine is called to assemble a linking matrix of control effectiveness factors and linking relationships for the current subscript such that:

$$\{\delta\} = [TLINK] * DELRED$$

where the **DELRED** matrix is reduced to only the active trim parameters and the effectiveness factors have been included. Then the rigid and flexible loads are hit with the linking matrix to reduce the problem to the relevant configuration parameters:

$$P2RED = P2 * TLINK$$

$$RHSRED = RHS * TLINK$$

P2RED and **RHSRED** contain one row for each structural acceleration and one column for each label on the trim entry This means that the total number of stability parameters (either fixed or free) is the number of columns in **P2** and **RHS**. Further, the order of the parameters is the order given on the **TRIM** tuples.

Now the trim equations can be assembled. From the input, we have the relationship

$$\begin{bmatrix} LHS_{ff} & LHS_{fk} \\ LHS_{kf} & LHS_{kk} \end{bmatrix} \begin{bmatrix} AR_{free} \\ AR_{known} \end{bmatrix} = \begin{bmatrix} RHS_{fu} & RHS_{fs} \\ RHS_{ku} & RHS_{ks} \end{bmatrix} \begin{bmatrix} DEL_{u} \\ DEL_{s} \end{bmatrix}$$

Where:	Represents:
F+K	Number of **SUPORT** point DOFs
F	Set of free accelerations, **AR**
K	Set of known(**FIXED**) accelerations, **AR**
U+S	Number of **AERO** parameters
U	Set of unknown parameters
S	Set of set(**FIXED**) parameters

These equations must be rearranged to get free accelerations and unknown delta's on the same side of the equation:

$$\begin{bmatrix} LHS_{ff} & -RHS_{fu} \\ LHS_{uf} & -RHS_{uu} \end{bmatrix} \begin{bmatrix} AR_{free} \\ DEL_u \end{bmatrix} = \begin{bmatrix} -LHS_{kk} & RHS_{ks} \\ -LHS_{sk} & RHS_{ss} \end{bmatrix} \begin{bmatrix} AR_k \\ DEL_s \end{bmatrix}$$

and we must handle the degenerate case where all accelerations or all delta's are known.

Following rearrangement of the equations, the unknowns are solved for in the ARTRMS/D routine. First the rigid masses and loads, **P2RED** and **MRR** are used to obtain the rigid trim and then the flexible inputs **RHSRED** and **LHS** are used for the "real" solution.

Then, the flexible results are unscrambled and the rigid body accelerations (either input on the **TRIM** or output from the solution of the above) are stored on the **AAR** matrix and the same is done with the trim parameters after the **TLINK** matrix is used to recover the full vector from the reduced set. Then the results for the rigid and flexible trim are printed.

Only if the print is requested or if constraints are applied are the stability coefficients computed. These data are recomputed in each subcase because the effectiveness terms affect the stability derivative outputs. The **ARSCFS/D** module is called to compute the flexible data from the forces on the support degrees of freedom due to the unit configuration parameters:

$$[F] = [MRR][LHS]^{-1}[RHS]$$

The **P2** matrix contains the same information for the rigid aerodynamic loads (computed in the MAPOL sequence). These data are then normalized and the stability coefficient table stored into memory. Once complete, the stability coefficient table is printed using the effectiveness factors and linking terms to assemble the "dependent" coefficients and factor all coefficients according to the user input.

Finally, using the in-core table of derivatives, the **ARCONS/D** submodule is called to evaluate the constraints for the current subcase. These constraints are evaluated from the stability coefficient table but, to prepare for eventual sensitivity computations, the additional outputs **AEFLG**, **AARC** and **DELC** are needed. The first is a logical flag to indicate to the MAPOL sequence that the **AARC** and **DELC** matrices are full. The **AARC** matrix and **DELC** matrix contain one or more columns for each constraint (appended in the order the constraints are evaluated). The **AARC** contains the accelerations of the support DOFs due to the unit configuration parameter vectors in **DELC**. This pair of matrices will allow the computation of the derivative of the accelerations due to the unit parameters which is an essential ingredient in the sensitivity computation.

For lift effectiveness constraints

AARC - 1 column due to unit **ALPHA**

DELC - 1 column containing a unit **ALPHA** with all others 0.0

For aileron effectiveness constraints

AARC - 2 columns; the first for unit **SURFACE** rotation and the second for unit roll rate (**PRATE**).

DELC - 2 columns containing a unit rotation of the named **SURFACE** and the second a unit **PRATE**

For stability coefficient constraints (**DCONSCF**)

AARC - 1 column due to unit **PARAMETER** where **PARAMETER** is that named on the constraint entry

DELC - 1 column containing a unit **PARAMETER** with all others 0.0

DCONTRM are evaluated at this time, but do not require any pseudodisplacements for sensitivity evaluation. The pseudodisplacements are those which arise due to the unit accelerations that arise due to unit configuration parameters.

After the stability coefficients (and constraints) are computed and printed, the rigid and flexible trim results are printed and the module repeats the entire process for all the subcases that are associated with the current **SUB**script. Then the module terminates.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: SAERODRV

Entry Point: SARODR

Purpose:

MAPOL director for steady aeroelastic analyses.

MAPOL Calling Sequence:

```
CALL SAERODRV (BCID, SUB, LOOP, MINDEX, SYM, MACH, QDP, PRINT );
```

BCID	User defined boundary condition identification number (Integer, Input)
SUB	Current Mach number subscript number (Integer, Input)
LOOP	Logical flag indicating whether another subscript is required to complete the set of all subcases (Logical, Output)
MINDEX	Mach number index associated with the current subscript. (Integer, Output)
SYM	**SYM**metry flag for the current subscript. (Integer, Output) **1** Symmetric **-1** Antisymmetric
MACH	Mach number associated with the current subscript (Real, Output)
QDP	Dynamic pressure associated with the current subscript (Real, Output)
PRINT	Optional print flag indicating that the summary of trim cases associated with the current pass (subscript) is to be printed to the standard output. (In the standard sequence, **PRINT** is used only during analysis not during sensitivity analysis) (Optional, Integer, Input)

Application Calling Sequence:

None

Method:

First the **CASE** relation is read to determine the **TRIM** ids and **SYM**metries of all **SAERO** cases in the current boundary condition. If any exist, the **TRIM** relation is opened and read into memory. Each trim entry referenced in **CASE** is then compressed into a format containing the **TRIM** id, Mach number, dynamic pressure, trim type, Mach number index, subscript and subcase id.

Once these data are collected, the **CASE** tuples read into memory are looped over to choose which **TRIM** cases are to be analyzed for this subscript value. There are four steps in choosing the proper trim cases:

(1) Take the first **SAERO** subcase in **CASE** that has not been done on an earlier pass — cases already analyzed will reference trims with a "subscript" value that is not "null" (uninitialized) and that is less than the current value of **SUB** — on the first design iteration all subscript values will be "null"

(2) Once the parent case is known, choose that case and all others with the same Mach, **QDP** and **TRMTYP**

(3) Update the "subcript" attribute in **TRIM** to mark all the cases that are being processed. Also load the **SUBID** to assist in re-merging the answers into **CASE** subcase order

(4) Check if any more saero subcases need to be processed and set the "loop" flag

After these steps have been completed, if the **PRINT** flag is nonzero, a summary of the selected **TRIM**s is printed to the output file.

Design Requirements:

1. The **TRIM** relation is assumed to contain **NULL** values for **SUBSCRPT** on the first subscript of the first design iteration (for **OPTIMIZE** boundary conditions) and for the first subscript of all **ANALYZE** boundary conditions.

Error Conditions:

None

Engineering Application Module: SAEROMRG

Entry Point: SAROMR

Purpose:

Merges the static aero results for each subscript (stored in the matrix **[MATSUB]**) into the **[MATOUT]** matrix in case order rather than subscript order for the **BCID**'th boundary condition.

MAPOL Calling Sequence:

```
CALL SAEROMRG ( BCID, SUB, [MATOUT], [MATSUB] );
```

BCID	User defined boundary condition identification number (Integer, Input)
SUB	Current Mach number subscript (Input, Integer)
[MATOUT]	Merged output matrix reordered to be in **CASE** order for the current boundary condition (Input and Output)
[MATSUB]	Generic input matrix containing data for the current subscript value in **TRIM** id order of **TRIM** cases associated with the current subscript (Input)

Application Calling Sequence:

None

Method:

First the **CASE** relation is read to retrieve the trim id's for the **SAERO** subcases in the current boundary condition. The the **TRIM** relation is read to obtain the subcase numbers associated with each trim id having the current **SUB**script value.

Then the **MATSUB** and **MATOUT** matrices are opened. If **MATOUT** is uninitialized ***or*** if **SUB = 1**, it is initialized (flushed and the number of rows, precision and form set to those of **MATSUB**. If **MATOUT** already exists and has data in it, a scratch matrix is created to hold the final merged data.

For each **SAERO CASE** entry for the current boundary, the **TRIM** data are searched to determine the subscript number associated with the subcase. If the subscript is less than **SUB**, a column from **MATOUT** will be taken (it was stored there on an earlier pass). If the subscript is equal to **SUB**, it will be stored on the output matrix from **MATSUB**. If greater than **SUB**, it is ignored till later passes.

Once a column is identified as active in **MATSUB** (**PGAA** indicates active and subscript = **SUB**), an additional check is made to see if the column is active in **PGUA**. Only those columns that are active in **PGUA** are copied to **MATOUT**. This filtering is done to limit the amount of computational effort in the stress, strain and displacement constraint sensitivity computations that proceed using the **MATOUT** matrix. The **MATSUB** columns that are active due to **DCONTRM** constraints are no longer needed as these sensitivities are assumed to have been computed already in the **AEROSENS** module.

Once the final matrix is formed, if **MATOUT** had had data in it, the name of the scratch matrix that was loaded is switched with that of **MATOUT**. The scratch entity is then destroyed.

Design Requirements:

1. The assumption is that each **MATSUB** matrix contains the results from the "**SUB**"th subscript value in the order the trim id's for that **SUB** appear in the **TRIM** relation.

2. The same **MATOUT** matrix must be passed into the **AROSNSMR** module on each call since the columns associated with earlier subscript values are read from **MATOUT** into a scratch entity. The merged matrix that results then replaces the input **MATOUT**.

3. The **AEROSENS** module is called upstream of the **AROSNSMR** module to process active **DCONTRM** constraints for the current subscript. Thus, those columns that are active only for **DCONTRM** constraints may be filtered out for the downstream processing of stress, strain and displacement constraints.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: SCEVAL

Entry Point: SCEVAL

Purpose:

To compute the stress and/or strain constraint values for the statics or steady aeroelastic trim analyses in the current boundary condition.

MAPOL Calling Sequence:

```
CALL SCEVAL ( NITER, BCID, [UG(BC)], [SMAT], [NLSMAT], SMATCOL, NLSMTCOL,
              TREF, TREFD, [GLBSIG],[NLGLBSIG], CONST, DSCFLG );
```

NITER	Design iteration number (Integer, Input)
BCID	User defined boundary condition identification number (Integer, Input)
[UG(BC)]	The matrix of global displacements for all static applied loads in the current boundary condition (Input), where **BC** represents the MAPOL boundary condition loop index number.
[SMAT]	Matrix entity containing the linear portion of the sensitivity of the stress and strain components to the global displacements (Input)
[NLSMAT]	Matrix entity containing the nonlinear portion of the sensitivity of the stress and strain components to the global displacements (Input)
SMATCOL	Relation containing matrix **SMAT** column information (Character,Input)
NLSMTCOL	Relation containing matrix **NLSMAT** column information (Character,Input)
TREF	Unstructured entity containing the linearly designed element reference temperatures (Input)
TREFD	Unstructured entity containing the nonlinearly designed variable element reference temperatures (Input)
[GLBSIG]	Matrix of stress/strain components for all the applied linearly designed stress constraints for the current boundary condition (Output)
[NLGLBSIG]	Matrix of stress/strain components for all the applied nonlinearly designed stress constraints for the current boundary condition (Output)
CONST	Relation of constraint values (Const)
DSCFLG	The discipline flag (Integer, Input) **0** Statics **>0** Static aeroelasticity

Application Calling Sequence:

None

Method:

The **SCEVAL** module begins by determining if there are any stress constraints applied and any user functions which require element response functions. If any are found, execution continues.

First the **CASE** relation is read. Then, if the call is associated with **SAERO** disciplines, the **TRIM** relation is read to associate, for each subcase, the subcase id and the subscript id. Then an in-core table is formed that contains, for the subcases in this boundary condition the **DISFLAG**, **SUBSCRIPT**, and **THERMID**. The

latter is for thermal load corrections to the stresses and strains. If any thermal load cases were found, the **GRIDTEMP** and **TREF** entities are opened.

If the current boundary condition is the first with stress or strain constraints, the running constraint type count variables are reinitialized for the current design iteration. This type count provides a link between the **ACTCON** print of design constraints and the debug print option supported by the **SCEVAL** module. If any thermal loads exist for the current boundary condition, the **GRIDTEMP**, **TREF** and **TREFD** entities are brought into memory to be available for the computation of the stress-free thermal strain correction to the element stresses. Once these preparations have been made, the **SMAT** and **NLSMAT** matrices of stress/strain sensitivities and the **GLBSIG** and **NLGLBSIG** matrices are opened and the **GLBSIG** and **NLGLBSIG** matrices are positioned to the proper columns to pack additional stress/strain components. Note that the **GLBSIG** and **NLGLBSIG** matrices store all the columns associated with the current boundary condition since they are required for the constraint sensitivity computations.

Finally, the **UG** matrix of global displacements is opened. For each column in the **UG** matrix, the matrix products

[GMA] = [SMAT]{UG} and **[NLGMA] = [NLSMAT]{UG}**

are calculated to obtain the component stress or strain values for linearly designed elements and nonlinearly designed elements, respectively. Having calculated and stored in core these values, the element dependent constraint evaluation routines are called to process each constraint. Note that the order in which the element routines are called must be the same as the order the **SMAT** and **NLSMAT** columns were formed. That order is:

1. Bar elements, **BARSC** (Using both **[GMA]** and **[NLGMA]**)
2. Isoparametric quadrilateral membrane elements, **QD1SC** (Using **[GMA]** only)
3. Quadrilateral bending plate elements, **QD4SC** (Using both **[GMA]** and **[NLGMA]**)
4. Rod elements, **RODSC** (Using **[GMA]** only)
5. Shear panels, **SHRSC** (Using **[GMA]** only)
6. Triangular bending plate elements, **TR3SC** (Using both **[GMA]** and **[NLGMA]**)
7. Triangular membrane elements, **TRMSC** (Using **[GMA]** only)

On the first pass through the element dependent routines, all the **xxxxEST** tuples (i.e., **RODEST** and **TRMEMEST**) with nonzero stress/strain constraint flags are retrieved from the data base. For subsequent passes, this information is used directly from core. Each constraint is evaluated in turn with the stress components modified by the thermal stress correction if the displacement field includes thermal strain effects. The **CONST** relation is loaded with one tuple for each constraint as they are processed. When all the constraints have been evaluated for the current loading condition, the adjusted linear design variable and nonlinear design variable stress/strain constraint terms are packed to the **GLBSIG** and **NLGLBSIG** matrices.

The element stress and strain responses which are required by any user function constraints are also computed in this module. Those response values are stored into a relation entity to be used by user function evaluation utilities.

Design Requirements:

1. The **SMAT** (or **NLSMAT**), **GRIDTEMP** and **TREF** (or **TREFD**) entities must exist.
2. The **CASE** relation must be complete from **SOLUTION**.

Error Conditions:

1. A zero material allowable may cause division by zero in the computation of some of the constraints.

Engineering Application Module: SOLUTION

Entry Point: SOLUTN

Purpose:

To interpret the solution control packet.

MAPOL Calling Sequence:

```
CALL SOLUTION ( NUMOPTBC, NBNDCOND, K6ROT, MPS, MPE, FSDS, FSDE,
                MAXITER, MOVLIM, WINDOW, ALPHA,CNVRGLIM,
                NRFAC, EPS, FDSTEP );
```

NUMOPTBC	Number of optimization boundary conditions (Integer, Output)
NBNDCOND	Total number of optimization and analysis boundary conditions (Integer, Output)
K6ROT	Stiffness value for plate element "drilling" degrees of freedom (Real,Output)
MPS	The first iteration to use math programming (Integer, Output)
MPE	The last iteration to use math programming (Integer, Output)
FSDS	The first iteration to use **FSD** (Integer, Output)
FSDE	The last iteration to use **FSD** (Integer, Output)
MAXITER	The maximum number of allowable iterations (Integer, Output)
MOVLIM	Limit on how much a design variable can move for this iteration in using math programming (Real, Output)
WINDOW	The window around the zero in which the **MOVLIM** bound is overridden to allow the local variable to change sign. If **WINDOW = 0.0**, the local variable may not change sign. If **WINDOW** is nonzero, the half width of a band around zero, **EPS** is computed **EPS = WINDOW/100 * MAX (ABS(TMIN), ABS(TMIN))** If the local variable falls within the band, the new minimum or maximum for the current iteration is changed to lie on the other side of zero from the local variable. The bandwidth **EPS** is a percentage of the larger of **TMAX** or **TMIN** where **WINDOW** specifies the percentage. (Real, Output)
ALPHA	Exponential move limit for the **FSD** algorithm (Real, Output)
CNVRGLIM	Relative percent change in the objective function that indicates approximate problem convergence (Real, Output)
NRFAC	Determines the minimum number of retained constraints equal to **NRFAC*NDV** (Real, Output)
EPS	A second criteria for constraint retention. All constraints greater than or equal to **EPS** will be retained (Real, Output)
FDSTEP	Relative design variable increment for finite difference computations (Real,Output)

Application Calling Sequence:

None

Method:

The **SOLUTION** module interprets the solution control statements and loads the resultant information to the **CASE** relation. On completion of the routine, the total number of all boundary conditions, the number of analysis boundary conditions and the user's optimization strategy are output to the executive sequence to direct the MAPOL execution path.

Design Requirements:

1. A Solution Control packet must be included in the input data stream.

Error Conditions:

1. Syntax errors and inconsistent or illegal solution control requests are flagged and the execution is terminated.

Engineering Application Module: SPLINES

Entry Point: SPLINE

Purpose:

Generates the interpolation matrix that relate displacements and forces between the structural and steady aerodynamic models.

MAPOL Calling Sequence:

```
CALL SPLINES ( GSIZEB, GEOMSA, AECOMPS, AEROS, [GTKG], [GSTKG] );
```

GSIZEB	The number of degrees of freedom in the set of all structural GRID and SCALAR points (Integer, Input)
GEOMSA	A relation describing the aerodynamic boxes for the steady aerodynamics model. The location of the box centroid, normal and pitch moment axis are given. It is used in splining the aerodynamics to the structure and to map responses back to the aerodynamic boxes (Input)
AECOMPS	A relation describing aerodynamic components for the steady aerodynamics model. It is used in splining the aerodynamics to the structural model (Input)
AEROS	A relation containing the definition of the aerodynamic coordinate system (Input)
[GTKG]	The matrix of splining coefficients relating the aerodynamic pressures to forces at the structural grids (Output)
[GSTKG]	The matrix of splining coefficients relating the structural displacements to the streamwise slopes of the aerodynamic boxes (Output)

Application Calling Sequence:

None

Method:

All the **SPLINE1**, **SPLINE2** and **ATTACH** data are read and those associated with the steady aerodynamic model as described by the **AECOMPS** entity are used to assemble a list of aerodynamic boxes and structural grids for each spline. The **GEOMSA** relation is used to obtain the basic coordinates of the aerodynamic boxes and the **BGPDT** relation is used to obtain the locations of the structural grids. The spline matrix consisting of two columns (displacement and slope) for each aerodynamic box and 6 rows for each structural grid is then assembled for the aerodynamic boxes and structural grids attached to the spline.

The spline matrix is then expanded to include two columns for each aerodynamic box in the steady aerodynamic model and **GSIZEB** rows. It is then split into two pieces with each odd-numbered column (displacement) merged with previously processed splines to form the **GTKG** matrix and each even numbered (slope) column merged to form **GSTKG**. The process is repeated until all splines have been completed. The final matrices are returned to the MAPOL sequence.

Design Requirements:

None

Error Conditions:

1. Each aerodynamic box may appear on only one **SPLINE1**, **SPLINE2** or **ATTACH** entry although not all boxes need appear. Missing boxes will not influence the aeroelastic response.

2. Missing structural grids or aerodynamic elements appearing on the spline definitions will be flagged.

Engineering Application Module: SPLINEU

Entry Point: SPLINE

Purpose:

Generates the interpolation matrix that relate displacements and forces between the structural and unsteady aerodynamic models.

MAPOL Calling Sequence:

```
CALL SPLINEU ( GSIZEB, GEOMUA, AECOMPU, AERO, [UGTKG] );
```

GSIZEB	The number of degrees of freedom in the set of all structural GRID and SCALAR points (Integer, Input)
GEOMUA	A relation describing the aerodynamic boxes for the unsteady aerodynamics model. The location of the box centroid, normal and pitch moment axis are given. It is used in splining the aerodynamics to the structure and to map responses back to the aerodynamic boxes (Input)
AECOMPU	A relation describing aerodynamic components for the unsteady aerodynamics model. It is used in splining the aerodynamics to the structural model (Input)
AERO	A relation containing the definition of the aerodynamic coordinate system (Input)
[UGTKG]	The matrix of splining coefficients relating the aerodynamic pressures to forces at the structural grids and relating the structural displacements to the streamwise slopes of the aerodynamic boxes (Output)

Application Calling Sequence:

None

Method:

All the **SPLINE1**, **SPLINE2** and **ATTACH** data are read and those associated with the unsteady aerodynamic model as described by the **AECOMPU** entity are used to assemble a list of aerodynamic boxes and structural grids for each spline. The **GEOMUA** relation is used to obtain the basic coordinates of the aerodynamic boxes and the **BGPDT** relation is used to obtain the locations of the structural grids. The spline matrix consisting of two columns (displacement and slope) for each aerodynamic box and 6 rows for each structural grid is then assembled for the aerodynamic boxes and structural grids attached to the spline.

The spline matrix is then expanded to include two columns for each aerodynamic box in the unsteady aerodynamic model and **GSIZEB** rows. It is then merged with previously processed splines. The process is repeated until all splines have been completed. The final **[UGTKG]** matrix is returned to the MAPOL sequence.

Design Requirements:

None

Error Conditions:

1. Each aerodynamic box may appear on only one **SPLINE1**, **SPLINE2** or **ATTACH** entry although not all boxes need appear. Missing boxes will not influence the aeroelastic response.

2. Missing structural grids or aerodynamic elements appearing on the spline definitions will be flagged.

Engineering Application Module: STEADY

Entry Point: STEADY

Purpose:

To perform preface aerodynamic processing for planar steady aerodynamics.

MAPOL Calling Sequence:

```
CALL STEADY ( MINDEX, TRIMDATA, AECOMPS, GEOMSA, STABCF, [AICMAT(MINDEX)],
              [AAICMAT(MINDEX)], [AIRFRC(MINDEX)], AEROGEOM, CAROGEOM );
```

MINDEX	Mach number index for the current pass. Controls which Mach Number/symmetry conditions will be processed in this pass of **STEADY**. One pass for each unique Mach number will be performed with **MINDEX** incrementing by one until **TRIMCHEK** returns **LOOP=FALSE** (Input)
TRIMDATA	A relation created by **TRIMCHEK** that contains the description of the **TRIM** entries for each boundary condition and each subcase. Additional subscripts have been added to the **TRIM** data to associate Mach number values with **MINDEX** subscripts and the input accelerations have been normalized to be in consistent units (Input)
AECOMPS	A relation describing aerodynamic components for the planar **STEADY** aerodynamics **MODEL**. It is used in splining the aerodynamics to the structural model (Output)
GEOMSA	A relation describing the aerodynamic boxes for the planar **STEADY** aerodynamics **MODEL**. The location of the box centroid, normal and pitch moment axis are given. It is used in splining the aerodynamics to the structure and to map responses back to the aerodynamic boxes (Output)
STABCF	A relation of rigid stability coefficients for unit configuration parameters. The rigid coefficients are stored in **STABCF** and the corresponding distributed forces are stored in **AIRFRC**. The **STABCF** relation is used to pick the appropriate rigid loads from **AIRFRC** when performing the aeroelastic trim as well as for retrieving the **RIGID/DIRECT** stability coefficients for each configuration parameter (Output)
[AICMAT(MINDEX)]	Matrix containing the **STEADY** aerodynamic influence coefficients for **SYM**metric Mach numbers (Output)
[AAICMAT(MINDEX)]	Matrix containing the **STEADY** aerodynamic influence coefficients for anti-**SYM**metric Mach numbers (Output)
[AIRFRC(MINDEX)]	Matrix containing the aerodynamic forces for unit configuration parameters for the current Mach number index. If both **SYM**metric and anti**SYM**metric conditions exist for the Mach number, both sets of configuration parameters will coexist in **AIRFRC** (Output)
AEROGEOM	An aerodynamic geometry relation output only for geometry checking. The "grids" defined in **AEROGEOM** are "connected" to 2-node (RODs) and 4-node (**QUAD**s) elements in the **CAROGEOM** in such a way as to emulate the structural **MODEL**. ICE may then be used to punch an equivalent structural **MODEL** to allow graphical presentation of the **STEADY** aero model

CAROGEOM A aerodynamic geometry relation output only for geometry checking. The "grids" defined in **AEROGEOM** are "connected" to 2-node (**ROD**s) and 4-node (**QUAD**s) elements in the **CAROGEOM** in such a way as to emulate the structural **MODEL**. ICE may then be used to punch an equivalent structural model to allow graphical presentation of the **STEADY** aero model

Application Calling Sequence:

None

Method:

The **STEADY** preface module performs initial aerodynamic processing for planar **STEADY** aerodynamics. It is driven by the the **TRIMDATA** relation and the **MINDEX** value.

On each call, the **TRIMDATA** relation is queried to determine the **MINDEX**'th Mach number and whether symmetric, antisymmetric or both boundary conditions are to be applied.

On the first call (determined by **MINDEX=1**) the **STEADY** module computes the planar **STEADY** aerodynamic geometry in calls to **GEOM**. It then processes the current Mach number and stores the resultant **AIC** terms in the **AICMAT** and/or **AAICMAT** entity (depending on the symmetry options) and in the resultant rigid forces in the **AIRFRC** matrix. The **STABCF** relation is loaded for the current **MINDEX** value with the symmetric and antisymmetric stability derivatives in the same order that the **AIRFRC** matrix columns are loaded. Hence, the **STABCF** relation points to the corresponding **AIRFRC** column.

Design Requirements:

1. The **STEADY** module interacts with the executive in that the **MINDEX** parameter should be unique for each call (although it need not be monotonically increasing). The **MINDEX** value must be 1 on the first call to ensure that the geometry processing is done.

Error Conditions:

1. Errors in the **STEADY** aerodynamic **MODEL** specifications are flagged.

Engineering Application Module: TCEVAL

Entry Point: TCEVAL

Purpose:

To compute the current values of thickness constraints for this optimization iteration.

MAPOL Calling Sequence:

```
CALL TCEVAL ( NITER, NDV, MOVLIM, WINDOW, GLBDES, LOCLVAR, [PMINT],
              [PMAXT], [PTRANS], TFIXED, CONST );
```

NITER	Design iteration number (Integer, Input)
NDV	The number of design variables (Integer, Input)
MOVLIM	Move limit to apply to the local design variables (Real, Input): `t/MOVLIM < t < t * MOVLIM; MOVLIM > 1.0`
WINDOW	The window around the zero in which the **MOVLIM** bound is overridden to allow the local variable to change sign. If **WINDOW = 0**.0, the local variable may not change sign. If **WINDOW** is nonzero, the half width of a band around zero, **EPS** is computed `EPS = WINDOW/100 * MAX ( ABS(TMIN), ABS(TMAX) )` If the local variable falls within the band, the new minimum or maximum for the current iteration is changed to lie on the other side of zero from the local variable. The bandwidth **EPS** is a percentage of the larger of **TMAX** or **TMIN** where **WINDOW** specifies the percentage. (Real, Input)
GLBDES	Relation of global design variables (Input)
LOCLVAR	Relation containing the relationship between local variables and global variables in the design problem (Input)
[PMINT]	Matrix entity containing the minimum thickness constraint sensitivities (Input)
[PMAXT]	Matrix entity containing the maximum thickness constraint sensitivities (Input)
[PTRANS]	The design variable linking matrix (Character,Input)
TFIXED	Relation of fixed thickness of layer (Input)
CONST	Relation of constraint values (Output)

Application Calling Sequence:

None

Method:

This module first computes the element thickness functions which are required by any user-defined functional constraints. Those response values are stored into a relational entity to be used by the function evaluation utilities. Then the module determines if any minimum and maximum gauge constraints exist in the problem. These constraints are generated by ASTROS if, and only if, shape function design variable linking is used. If any constraints exist, the vector of design variable values from **GLBDES** and all the **LOCLVAR** data are brought into core. The next step is to determine if any user

specified move limit on the local variables is to be applied to the minimum thickness constraints (note that the maximum thickness constraints are always computed relative to their gauge limits rather than to a move limit).

If move limits are applied (as they almost always are), the **DCONTHK** or **DCONTH2** data are also brought into core to identify which elements minimum gauge constraints are always to be retained by the constraint deletion algorithm in the **ACTCON** module. The minimum gauge constraints are then computed by performing the matrix multiplication:

$$\{g\} = 1.0 - [PMINT]^T\{v\} = 1.0 - \frac{t}{t_{min}}$$

The **LOCLVAR** data is then used to determine to which element each "g" applies. If the constraint value is less critical (more negative) than the move limit value of

$$g_{move} = 1.0 - MOVLIM$$

it is stored on the **CONST** relation as a computed constraint ***only*** if it appears on a **DCONTHK** or **DCONTH2**entry (in which case it will end up as an active constraint from **ACTCON**), otherwise, the constraint is ignored for this design iteration. If the constraint value is more critical than the move limit value, it is only stored on **CONST** if it is on a **DCONTHK** or **DCONTH2** entry ***or*** if the constraint violates a cutoff value set to

$$g_{retain} = 0.10$$

Any minimum thickness constraints that are stored on **CONST** that do not appear on **DCONTHK** or **DCONTH2** entries will be subject to the normal constraint deletion criteria. The maximum gauge constraints are then computed by performing the matrix multiplication:

$$\{g\} = [PMAXT]^T\{v\} + \{v\}_{fixed} - 1.0$$

The **LOCLVAR** data is then used to determine to which element each "g" applies. No move limits are applied to these constraints and they are stored directly to the **CONST** relation to undergo the normal constraint deletion in **ACTCON**.

Design Requirements:

1. This module should be the first module called in the optimization phase of the MAPOL sequence.

2. The move limit that is passed into this routine ***must*** match the value used to evaluate the constraints in the **MAKDFV** module. If not, the constraint sensitivities will be in error with no warning given.

Error Conditions:

1. A local variable has become negative due to insufficient **DCONTHK** or **DCONTH2** entries or illegal gauge constraints.

Engineering Application Module: TRIMCHEK

Entry Point: TRMSOL

Purpose:

To perform preface aerodynamic processing on the requested **SAERO** discipline requests and their referenced **TRIM** Bulk Data entries.

MAPOL Calling Sequence:

```
CALL TRIMCHEK ( MINDEX, LOOP, GOAERO, CASE, TRIMDATA );
```

MINDEX	Mach number index for the current pass. Controls which Mach Number/symmetry conditions will be processed in this pass of **STEADY**. One pass for each unique Mach number will be performed with **MINDEX** incrementing by one until **TRIMCHEK** returns **LOOP=FALSE** (Input)
LOOP	A logical flag set by **TRIMCHEK** to indicate whether additional **MINDEX** subscripts are needed to complete the processing of all the Mach number/symmetry conditions on all the **TRIM** entries. One pass for each unique Mach number will be performed with **MINDEX** incrementing by one until **TRIMCHEK** returns **LOOP=FALSE** (Output)
GOAERO	A logical flag set by **TRIMCHEK** to indicate whether the **STEADY** module should be called to process the **MINDEX**'th Mach Number (Output)
CASE	A relation describing the Solution Control Case Definitions (Input)
TRIMDATA	An output relation that contains the description of the **TRIM** entries for each boundary condition and each subcase. The **TRIM** entries for each subcase are repeated, even if the data are the same so as to uniquely associate Mach Numbers, subcase identification numbers and **MINDEX** subscripts. Input accelerations are normalized to be in consistent units (Output)

Application Calling Sequence:

None

Method:

The **TRIMCHEK** preface module performs initial aerodynamic processing for planar **STEADY** aerodynamics. It is driven by the the **TRIM** data present in the bulk data packet and the **SAERO** disciplines in the **CASE** relation. The **CASE** relation provides the symmetries while the **TRIM** relation provides the Mach numbers. Only if **SAERO** disciplines are in **CASE** is any processing done and both **TRIM** and **AEROS** entries must be found.

On each call, the **PASSDF** submodule is called to determine the set of all Mach numbers and, for each Mach number, whether symmetric, antisymmetric or both boundary conditions are to be applied. Having determined all unique Mach numbers, the **PASSDF** then determines the **MINDEX**'th Mach number in numerical order (lowest to highest) and that is flagged to be processed using the **GOAERO** flag. If the chosen Mach number is the last one, the **LOOP** flag is set to false to tell the MAPOL sequence that no more calls are needed. At this point, the **GOAERO** flag will still be true to allow processing of the last Mach number. Only if no **SAERO** are called for in **CASE** will **GOAERO** be false on output.

Design Requirements:

1. The **TRIMCHEK** module interacts with the executive in that the **LOOP** variable is output on the first call and the module expects to be called again as long as **LOOP** is true. For each time called, the **MINDEX** parameter should be unique although it need not be monotonically increasing.

Error Conditions:

1. Errors in the **TRIM** specifications are flagged.

Engineering Application Module: UNSTEADY

Entry Point: UNSTDY

Purpose:

Unsteady aeroelastic analysis preface.

MAPOL Calling Sequence:

```
CALL UNSTEADY ( GEOMUA, AECOMPU, [AJJTL], [D1JK], [D2JK], [SKJ]
                AERUGEOM, CAROUGEO );
```

GEOMUA	A relation describing the aerodynamic boxes for the un**STEADY** aerodynamics model. The location of the box centroid, normal and pitch moment axis are given. It is used in splining the aerodynamics to the structure and to map responses back to the aerodynamic boxes (Output)
AECOMPU	A relation describing aerodynamic components for the un**STEADY** aerodynamics model. It is used in splining the aerodynamics to the structural model (Output)
[AJJTL]	A matrix containing the transposed unsteady **AIC** matrix for each Mach number, reduced frequency and symmetry option in the Bulk Data **MKAERO1** and **MKAERO2** entries (Output)
[D1JK]	Real part of the substantial derivative matrix (Output)
[D2JK]	Imaginary part of the substantial derivative matrix (Output)
[SJK]	Integration matrix to take pressures to force. (Output)
AERUGEOM	Relation containing the aerodynamic planform geometric grid points for the flutter model (Character, Output)
CAROUGEO	Relation containing the connectivity data for the aerodynamic planform geometric grid points for the flutter model (Character, Output)

Application Calling Sequence:

None

Method:

The unsteady aerodynamics preface module is activated under the following conditions:

1. If any **FLUTTER** cases are in the **CASE** relation
2. If any **BLAST** cases are in the **CASE** relation
3. If there are any **TRANSIENT** or **FREQUENCY** cases that invoke the **GUST** option.

After checking for the presence of the proper cases, the **MKAERO1** and **MKAERO2** data are read from the database and a list of all {symm,m,k} sets are assembled. The first record of the **UNMK** table is then written containing a count of the number of {m,k} pairs in each of the six symmetry classes. The second record will be loaded within the **APD** submodule and closed on return to **UNSTEADY.**

Then the unsteady aerodynamics model is read from the database into memory for the **APD** submodule. That module is then called to form the geometrical description of the unsteady model. The **ACPT**, the **GEOMUA** and the **AECOMPU** entities are written along with the second record of the **UNMK**.

Once the geometry data are complete, the **AMG** submodule is called to compute the **AJJTL**, **D1JK**, **D2JK** and **SKJ** matrix. These computations are done for all the {symm,m,k} sets in the bulk data. Each **AJJT** matrix is appended to the **AJJTL** output matrix. The **D1JK**, **D2JK** and **SJK** matrices will have two separate matrices stored in a similar fashion if and only if both subsonic and supersonic Mach numbers appear in the **UNMK** sets. Once these computations are complete, **UNSTEADY** returns control to the MAPOL sequence.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: WOBJGRAD

Entry Point: WOBJGD

Purpose:

To compute weight function sensitivity to the design variables.

MAPOL Calling Sequence:

```
CALL WOBJGRAD ( NITER, NDV, GLBDES, DWGH1, DDWGH2 );
```

NITER	Design iteration number (Integer,Input)
NDV	Number of design variables (Integer,Input)
GLBDES	Relation of global design variables (Character,Input)
DWGH1	Unstructured entity of invariant linear portion of the weight function sensitivity (Character,Input)
DDWGH2	Unstructured entity of nonlinear portion of the weight function sensitivity (Character,Input)

Application Calling Sequence:

None

Method:

This module first reads all **DVID** from relation **GLBDES**. Then the module reads entities **DWGH1** and **DDWGH2** into memory. Because **DWGH1** and **DDWGH2** have the design variable **DVID** index as their first record, the weight function sensitivities may be generated by searching for this **DVID** in **DWGH1** and **DDWGH2** and obtaining the corresponding sensitivity terms.

Design Requirements:

None

Error Conditions:

None

Engineering Application Module: YSMERGE

Entry Point: YSMERG

Purpose:

To provide a special purpose merge utility for merging **YS**-like vectors (vectors of enforced displacements) into matrices for data recovery.

MAPOL Calling Sequence:

```
CALL YSMERGE ( [UN], [YS(BC)], [UF], [PNSF(BC)], DYNFLG );
```

[UN]	Matrix containing the nodal response quantities for the independent degrees of freedom (Output)
[YS(BC)]	Optional matrix containing the vector of enforced displacements on the single-point constraint degrees of freedom. If the **YS** argument is omitted, null vectors are merged (Input), where **BC** represents the MAPOL boundary condition loop index number
[UF]	The matrix of free nodal response quantities to be merged with the **YS** vector
[PNSF(BC)]	The partitioning vector splitting the independent degrees of freedom into the free and the single point constraint degrees of freedom (Input), where **BC** represents the MAPOL boundary condition loop index number
DYNFLG	Dynamic matrix form flag: if **DYNFLG** is nonzero, the matrix **UF** is assumed to have the form of a dynamic response matrix: three columns per subcase; (1) displacement, (2) velocity and (3) acceleration (Integer, Input)

Application Calling Sequence:

None

Method:

The **YSMERGE** engineering utility module is a general utility to merge a column vector, **YS**, (or a null column) that represents a partition of the desired output matrix with the other partition, **UF**, based on an input partitioning vector. The column dimension of **UF** is used to determine the number of times **YS** is to be duplicated in the merge operation. The result is loaded into the **UN** matrix. As a special option, the **DYNFLG** input is used to direct the module to assume that the **UF** and **UN** matrices have, or are to have, the form of a dynamic response "displacement" matrix. These matrices have three columns for each time/frequency step:

(1) Displacement

(2) Velocity

(3) Acceleration

When **DYNFLG** is nonzero, the **YS** matrix is merged with the first column (displacements) of each triplet with null partitions used for the corresponding velocities and accelerations.

Design Requirements:

1. The **YS** matrix entity, if it is included in the calling sequence, must be null (no columns) or be a column vector. If the matrix is null, the routine acts as though it were not included in the calling sequence.

Error Conditions:

None

Chapter 6.

APPLICATION UTILITY MODULES

Large software systems such as ASTROS require that similar operations be performed in many code segments. To reduce the maintenance effort and to ease the programming task, a set of commonly used application utilities were identified and used whenever the application required those tasks to be performed. This section is devoted to the documentation of the set of application utilities in ASTROS. The suite of utilities in ASTROS includes small (performed entirely in memory) matrix operations like linear equation solvers, matrix multiplication and others. Another suite of utilities have been written to sort tables or columns of data on real, integer and character values in the table. Other utilities search lists of data stored in memory for particular key values, initialize arrays, operate on matrix entities and perform other disparate tasks of a general nature. The ASTROS user who intends to write application programs to be used within the ASTROS environment is strongly urged to study the suite of utilities documented in this section. ASTROS software designed to make use of the suite of application utilities can be much simpler to write, debug and maintain since these well-tested utilities can be substituted for code that would otherwise require programming effort.

The following subsections document the interface to the application utilities in two formats; using the executive system (MAPOL) and using the FORTRAN calling sequence. In most cases, there is no MAPOL language interface since these utilities are useful only within an application module. In other cases, however, the utility has been identified as a feature accessible through the executive. Finally, a small number of these application utilities are intended for access only by the executive system. This family of utilities is always associated with obtaining formatted output of data stored on the database.

Application Utility Module: APPEND

Entry Point: APPEND

Purpose:

This routine adds all the columns of one input matrix to the end of another.

MAPOL Calling Sequence:

```
CALL APPEND ( MATOUT, MATIN );
```

Application Calling Sequence:

```
CALL APPEND ( MATOUT, MATIN, IKOR )
```

MATOUT	The name of the output matrix to which the columns are added (Character, Output)
MATIN	The name of the input matrix from which the extra columns are extracted (Character, Input)
IKOR	Open core base address for local dynamic memory allocation (Integer, Input)

Method:

Matrix **MATOUT** is first initialized. Error checks are made to see if the matrices are conformable for the append operation. The columns of **MATIN** are then appended to the **MATOUT** matrix with special provisions given to handle null columns in **MATIN**.

Design Requirements:

None

Error Conditions:

1. **MATOUT** has not been created first (**APPEND** does an **MXINIT**, but the entity must already exist as a matrix).
2. **MATOUT** and **MATIN** have different types (precision/real or complex).
3. **MATOUT** and **MATIN** have a different number of rows.

Application Utility Module: DAXB

Entry Point: DAXB

Purpose:

This routine takes the double-precision cross product of vectors in a three-dimensional space.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DAXB ( A, B, C )
```

A	First vector (3x1) (Double, Input)
B	Second vector (3x1) (Double, Input)
C	Cross product **A X B** (Double, Output)

Method:

None

Design Requirements:

None

Error Conditions:

None

Application Utility Module: GMMATC

Entry Point: GMMATC

Purpose:

Perform the in-core complex matrix multiplications:

$$[A][B] = [C]$$
$$[A][B]^T = [C]$$
$$[A]^T[B] = [C]$$
$$[A]^T[B]^T = [C]$$

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL GMMATC ( A, IROWA, ICOLA, MTA, B, IROWB, ICOLB, NTB, C )
```

A	Matrix of **IROWA** rows and **ICOLA** columns stored in row order in a linear array (Character,Input)
B	Matrix of **IROWB** rows and **ICOLB** columns stored in row order in a linear array (Character,Input)
MTA,NTB	Transpose flags (Character,Input) **0** if no transpose **1** if transpose
C	Result of the matrix multiplication (Character,Output)

Method:

The **GMMATC** routine assumes that sufficient storage space is available in core to perform the multiplication. The matrices are checked to ensure that they are of proper dimensions to be multiplied. Complex single-precision is used throughout the routine.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: GMMATD

Entry Point: GMMATD

Purpose:

Perform the in-core double-precision matrix multiplications:

$$[A][B] = [C]$$
$$[A][B]^T = [C]$$
$$[A]^T[B] = [C]$$
$$[A]^T[B]^T = [C]$$

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL GMMATD ( A, IROWA, ICOLA, MTA, B, IROWB, ICOLB, NTB, C )
```

A	Matrix of **IROWA** rows and **ICOLA** columns stored in row order in a linear array (Character,Input)
B	Matrix of **IROWB** rows and **ICOLB** columns stored in row order in a linear array (Character,Input)
MTA,NTB	Transpose flags (Integer,Input) **0** if no transpose **1** if transpose
C	Result of the matrix multiplication (Character,Output)

Method:

The **GMMATD** routine assumes that sufficient storage space is available in core to perform the multiplication. The matrices are checked to ensure that they are of proper dimensions to be multiplied. Double precision is used throughout the routine.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: GMMATS

Entry Point: GMMATS

Purpose:

Perform the in-core single-precision matrix multiplications:

$$[A][B] = [C]$$
$$[A][B]^T = [C]$$
$$[A]^T[B] = [C]$$
$$[A]^T[B]^T = [C]$$

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL GMMATS ( A, IROWA, ICOLA, MTA, B, IROWB, ICOLB, NTB, C )
```

A	Matrix of **IROWA** rows and **ICOLA** columns stored in row order in a linear array (Character,Input)
B	Matrix of **IROWB** rows and **ICOLB** columns stored in row order in a linear array (Character,Input)
MTA,NTB	Transpose flags (Integer,Input) **0** if no transpose **1** if transpose
C	Result of the matrix multiplication (Character,Output)

Method:

The **GMMATS** routine assumes that sufficient storage space is available in core to perform the multiplication. The matrices are checked to ensure that they are of proper dimensions to be multiplied. Single precision is used throughout the routine.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: INVERC

Entry Point: INVERC

Purpose:

Single precision complex in-core matrix inversion and linear equation solver. Finds solution to the matrix equation:

[A]{X} = {B}

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL INVERC ( NDIM, A, N, B, M, DETERM, ISING, WORK2 )
```

NDIM	The leading dimension of **A** as declared in the calling routine. **A(NDIM,N)** (Integer, Input).
A	Array containing the partition to be inverted. On output, the contents of the upper left **N** x **N** partition are replaced by the inverse. (Complex, Input)
N	Size of the upper left **A** partition to be inverted. (Integer, Input)
B	Column of constants (optional input of minimum size: **B(NDIM,1)**). On output, contains the solution vector(s) of the linear equations (Complex, Input)
M	Number of columns of **B** (Integer, Input)
DETERM	Determinant of **A** if nonsingular (Complex, Output)
ISING	Error flag **1** if **A** nonsingular **2** if **A** singular (Integer, Input and Output)
WORK2	Additonal working storage **(N,3)** (Complex, Input)

Method:

Note that all or the upper left square partition of the input array **A** may be inverted. If on input, the value of **ISING** is less than zero, the determinant of the **A** matrix is not calculated. The value of **DETERM** on return will be zero. The matrix inversion routine uses the Gauss-Jordian method with complete row-column interchange. Sufficient core storage must be set aside in **INDEX** to complete the inversion.

Error Conditions:

None

Application Utility Module: INVERD

Entry Point: INVERD

Purpose:

Double precision in-core matrix inversion and linear equation solver. Finds solution to the matrix equation:

[A]{X} = {B}

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL INVERD ( NDIM, A, N, B, M, DETERM, ISING, WORK2 )
```

NDIM	The leading dimension of **A** as declared in the calling routine. **A(NDIM,N)** (Integer, Input).
A	Array containing the partition to be inverted. On output, the contents of the upper left **N** x **N** partition are replaced by the inverse. (Double, Input)
N	Size of the upper left **A** partition to be inverted. (Integer, Input)
B	Column of constants (optional input of minimum size: **B(NDIM,1)**). On output, contains the solution vector(s) of the linear equations (Double, Input)
M	Number of columns of **B** (Integer, Input)
DETERM	Determinant of **A** if nonsingular (Double, Output)
ISING	Error flag **1** if **A** nonsingular **2** if **A** singular (Integer, Input and Output)
WORK2	Working storage **(N,3)** (Double, Input)

Method:

Note that all or the upper left square partition of the input array **A** may be inverted. If on input, the value of **ISING** is less than zero, the determinant of the A matrix is not calculated. The value of **DETERM** on return will be zero. The matrix inversion routine uses the Gauss-Jordian method with complete row-column interchange. Sufficient core storage must be set aside in **INDEX** to complete the inversion.

Error Conditions:

None

Application Utility Module: INVERS

Entry Point: INVERS

Purpose:

Single precision in-core matrix inversion and linear equation solver. Finds solution to the matrix equation:

[A]{X} = {B}

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL INVERS ( NDIM, A, N, B, M, DETERM, ISING, WORK2 )
```

NDIM	The leading dimension of **A** as declared in the calling routine. **A(NDIM,N)** (Integer, Input).
A	Array containing the partition to be inverted. On output, the contents of the upper left **N** x **N** partition are replaced by the inverse. (Real, Input)
N	Size of the upper left **A** partition to be inverted. (Integer, Input)
B	Column of constants (optional input of minimum size: **B(NDIM,1)**). On output, contains the solution vector(s) of the linear equations (Real, Input)
M	Number of columns of **B** (Integer, Input)
DETERM	Determinant of **A** if nonsingular (Real, Output)
ISING	Error flag **1** if **A** nonsingular **2** if **A** singular (Integer, Input and Output)
WORK2	Working storage **(N,3)** (Real, Input)

Method:

Note that all or the upper left square partition of the input array **A** may be inverted. If on input, the value of **ISING** is less than zero, the determinant of the A matrix is not calculated. The value of **DETERM** on return will be zero. The matrix inversion routine uses the Gauss-Jordian method with complete row-column interchange. Sufficient core storage must be set aside in **INDEX** to complete the inversion.

Error Conditions:

None

Application Utility Module: MSGDMP

Entry Point: MSGDMP

Purpose:

Retrieves messages queued by the **UTMWRT** module and writes them to the system output file.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MSGDMP
```

Method:

The **MSGDMP** routine reads the queued messages written by **UTMWRT** from the queue file and writes them onto the system output file. The queue file is then reset to accept the next set of messages. The intention is that **MSGDMP** will be called after each module's execution to allow easy determination of the last module executed, should the execution terminate.

Error Conditions:

None

Application Utility Module: POLCOD

Entry Point: POLCOD

Purpose:

This routine computes double-precision polynomial fit coefficients.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL POLCOD ( X, Y, N, S, COF )
```

X	The vector of scalar variables of length **N** (Input, Double Precision)
Y	The vector of terms such that **[Y(1)] = [Y]** at **X(1)** (Input, Double Precision)
N	The rank of vectors **X** and **Y** (Input, Integer)
S	The scratch array of length **N** to store the master polynomial coefficients (Input, Double Precision)
COF	The vector of coefficients such that **[Y(Z)] = [COF(1)] + Z[COF(2)] + Z**2[COF(3)] + ...** (Output, Double Precision)

Method:

This routine computes polynomial fit coefficients from solution of Vandermonde matrix equations. It is taken from "Numerical Recipes," Section 3.5, routine **POLCOE**.

Design Requirements:

1. Use **POLEVD** to evaluate the polynomial values based on the computed coefficients.
2. Use **POLSLD** to evaluate the polynomial derivative values based on the computed coefficients.

Error Conditions:

None

Application Utility Module: POLCOS

Entry Point: POLCOS

Purpose:

This routine computes single-precision polynomial fit coefficients.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL POLCOS ( X, Y, N, S, COF )
```

X	The vector of scalar variables of length **N** (Input, Real)
Y	The vector of terms such that **[Y(1)] = [Y]** at **X(1)** **[Y(2)] = [Y]** at **X(2)** **...** (Input, Real)
N	The rank of vectors **X** and **Y** (Input, Integer)
S	The scratch array of length **N** to store the master polynomial coefficients (Input, Real)
COF	The vector of coefficients such that **[Y(Z)] = [COF(1)] + Z[COF(2)] + Z**2[COF(3)] + ...** (Output, Real)

Method:

This routine computes polynomial fit coefficients from solution of Vandermonde matrix equations. It is taken from "Numerical Recipes," Section 3.5, routine **POLCOE**.

Design Requirements:

1. Use **POLEVS** to evaluate the polynomial values based on the computed coefficients.
2. Use **POLSLS** to evaluate the polynomial derivative values based on the computed coefficients.

Error Conditions:

None

Application Utility Module: POLEVD

Entry Point: POLEVD

Purpose:

This routine performs double-precision polynomial evaluation from fit coefficients.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL POLEVD ( COF, N, X, Y )
```

COF	The vector of coefficients such that **[Y(Z)] = [COF(1)] + Z[COF(2)] + Z**2[COF(3)] + ...** (Input, Double Precision)
N	The rank of vectors **X** and **Y** (Input, Integer)
X	The scalar value at which polynomial is evaluated (Input, Double Precision)
Y	The function value at **X** (Output, Double Precision)

Method:

This routine performs double-precision polynomial evaluation from fit coefficients from solution of Vandermonde matrix equations. It is taken from "Numerical Recipes," Section 3.5, routine **POLCOE**.

Design Requirements:

1. Use **POLCOD** to evaluate the fit coefficients.
2. Use **POLSLD** to evaluate the polynomial derivative values based on the computed coefficients.

Error Conditions:

None

Application Utility Module: POLEVS

Entry Point: POLEVS

Purpose:

This routine performs single-precision polynomial evaluation from fit coefficients.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL POLEVS ( COF, N, X, Y )
```

COF	The vector of coefficients such that `[Y(Z)] = [COF(1)] + Z[COF(2)] + Z**2[COF(3)] + ...` (Input, Real)
N	The rank of vectors **X** and **Y** (Input, Integer)
X	The scalar value at which polynomial is evaluated (Input, Real)
Y	The function value at **X** (Output, Real)

Method:

This routine performs single-precision polynomial evaluation from fit coefficients from solution of Vandermonde matrix equations. It is taken from "Numerical Recipes," Section 3.5, routine **POLCOE**.

Design Requirements:

1. Use **POLCOS** to evaluate the fit coefficients.
2. Use **POLSLS** to evaluate the polynomial derivative values based on the computed coefficients.

Error Conditions:

None

Application Utility Module: POLSLD

Entry Point: POLSLD

Purpose:

This routine performs double-precision polynomial derivative evaluation from fit coefficients.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL POLSLD ( COF, N, X, Y )
```

COF	The vector of coefficients such that `[Y(Z)] = [COF(1)] + Z[COF(2)] + Z**2[COF(3)] + ...` (Input, Double Precision)
N	The rank of vectors **X** and **Y** (Input, Integer)
X	The scalar value at which polynomial is evaluated (Input, Double Precision)
Y	The slope of function at **X** (Output, Double Precision)

Method:

This routine performs double-precision polynomial derivative evaluation from fit coefficients from solution of Vandermonde matrix equations. It is taken from "Numerical Recipes," Section 3.5, routine **POLCOE**.

Design Requirements:

1. Use **POLCOD** to evaluate the fit coefficients.
2. Use **POLEVD** to evaluate the polynomial values based on the computed coefficients.

Error Conditions:

None

Application Utility Module: POLSLS

Entry Point: POLSLS

Purpose:

This routine performs single-precision polynomial derivative evaluation from fit coefficients.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL POLSLS ( COF, N, X, Y )
```

COF	The vector of coefficients such that `[Y(Z)] = [COF(1)] + Z[COF(2)] + Z**2[COF(3)] + ...` (Input, Real)
N	The rank of vectors **X** and **Y** (Input, Integer)
X	The scalar value at which polynomial is evaluated (Input, Real)
Y	The slope of function at **X** (Output, Real)

Method:

This routine performs single-precision polynomial derivative evaluation from fit coefficients from solution of Vandermonde matrix equations. It is taken from "Numerical Recipes," Section 3.5, routine **POLCOE**.

Design Requirements:

1. Use **POLCOD** to evaluate the fit coefficients.
2. Use **POLEVD** to evaluate the polynomial values based on the computed coefficients.

Error Conditions:

None

Application Utility Module: PS

Entry Point: PS

Purpose:

Character function returns the character string as the matrix precision needed for **MXINIT**, memory management and others based on the machine precision

MAPOL Calling Sequence:

None

Application Calling Sequence:

PS (TYPFLG)

TYPFLG	Character string, either "**R**" or "**C**" for real or complex (Character, Input)

Method:

PS returns character string **RDP** on double-precision machines or **RSP** on single-precision machines for input **TYPFLG** of **R**, in other words **PS('R')** returns either **RSP** or **RDP**. The complex equivalent **CDP** or **CSP** is returned if **TYPFLG** is **C**.

Design Requirements:

None

Error Conditions:

1. If **TYPFLG** in **PS** is neither "**R**" nor "**C**", **PS** will return blank.

Application Utility Module: RDDMAT

Entry Point: RDDMAT

Purpose:

Reads a double-precision matrix entity into memory.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL RDDMAT ( MATNAM, NROW, NCOL, BLKN, GRPN, PNTR, DKOR )
```

MATNAM	Input Matrix database entity (Character, Input)
NROW	The number of rows in the matrix (Integer, Output)
NCOL	The number of columns in the matrix (Integer, Output)
BLKN	The name of the open core block to which the data are written (Character, Input)
GRPN	The name of the open core group to which the data are written (Character, Input)
PNTR	The pointer relative to **DKOR** where the matrix data begin. (Integer, Output)
DKOR	The double-precision open core base address. (Double, Input)

Method:

The matrix is opened, its size determined and a memory block with group name **GRPN** and block name **BLKN** is allocated to hold the matrix data. The matrix is then read into core with special provisions being taken to handle the case of null columns. The matrix is then closed. The calling routine is responsible for freeing the memory block.

Design Requirements:

1. The matrix must be closed on calling this routine.

Error Conditions:

1. Insufficient open core memory will cause ASTROS termination.

Application Utility Module: RDSMAT

Entry Point: RDSMAT

Purpose:

Reads a single-precision matrix entity into memory.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL RDSMAT ( MATNAM, NROW, NCOL, BLKN, GRPN, PNTR, RKOR )
```

MATNAM	Input Matrix database entity (Character, Input)
NROW	The number of rows in the matrix (Integer, Output)
NCOL	The number of columns in the matrix (Integer, Output)
BLKN	The name of the open core block to which the data are written (Character, Input)
GRPN	The name of the open core group to which the data are written (Character, Input)
PNTR	The pointer realtive to **DKOR** where the matrix data begin. (Integer, Output)
RKOR	The single-precision open core base address. (Real, Input)

Method:

The matrix is opened, its size determined and a memory block with group name **GRPN** and block name **BLKN** is allocated to hold the matrix data. The matrix is then read into core with special provisions being taken to handle the case of null columns. The matrix is then closed. The calling routine is responsible for freeing the memory block.

Design Requirements:

1. The matrix must be closed on calling this routine.

Error Conditions:

1. Insufficient open core memory will cause ASTROS termination.

Application Utility Module: SAXB

Entry Point: SAXB

Purpose:

This routine takes the single-precision cross product of vectors in a three-dimensional space.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL SAXB ( A, B, C )
```

A	First vector (3x1) (Real, Input)
B	Second vector (3x1) (Real, Input)
C	Cross product **A X B** (Real, Output)

Method:

None

Design Requirements:

None

Error Conditions:

None

Application Utility Module: SHAPEGEN

Entry Point: SHAPGN

Purpose:

Processes the **SHPGEN** automated shape generation inputs and prints or punches resulting **SHAPE** or **SHAPEM** Bulk Data entries.

Mapol Calling Sequence:

```
CALL SHAPEGEN;
```

Application Calling Sequence:

```
CALL SHAPGN
```

Method:

This module generates relations **SHAPE and/or SHAPEM** based on the element centroids of the elements appearing in SHPGEN Bulk Data entries. It performs the linking relationship and, otionally, prints or punches the resulting **SHAPE and/or SHAPEM** Bulk Data entries.

Design Requirements:

The **DEBUG** command **SHPGEN** must be specified to print or punch the results.

Error Conditions:

None

Application Utility Module: USETPRT

Entry Point: USETPR

Purpose:

To print the structural set definition table for each boundary condition contained in the **USET** entity.

MAPOL Calling Sequence:

```
CALL USETPRT ( USET(BC), BGPDT(BC) )
```

USET	The **USET** entity for the current boundary condition (Character, Input)
BGPDT	The **BGPDT** entity for the current boundary condition (Character, Input)

Application Calling Sequence:

None

Method:

The **USET** entity is opened to determine which boundary condition is to be processed. The **CASE** relation is opened and the appropriate **TITLE**, **SUBTITLE** and **LABEL** information are obtained.

The **INTID**, **EXTID** and **FLAG** attributes of the **BGPDT** are brought into core and sorted on internal id. The **USET** record for the current boundary condition is also brought into an open core memory block. Each tuple of the **BGPDT** is processed; each point in the structural set has its corresponding **USET** bit mask decoded to determine to which structural sets the degree of freedom belongs. A running count in each dependent and independent structural set is maintained and echoed.

Error Conditions:

None

Application Utility Module: UTCOPY

Entry Point: UTCOPY

Purpose:

To copy a specified number of contiguous single-precision words from one location to another.

Application Calling Sequence:

```
CALL UTCOPY ( DEST, SOURCE, NWORD )
```

DEST	Destination array (Character,Input)
SOURCE	Source array to be copied (Character,Input)
NWORD	Number of single-precision words to be copied (Integer,Input)

Method:

The source and destination arrays are operated on as integer arrays inside the **UTCOPY** routine. If double-precision data are to be copied, the **NWORD** argument must be adjusted accordingly.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTCSRT

Entry Point: UTCSRT

Purpose:

To sort a table of numbers on a four or eight character hollerith column of the table

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTCSRT ( ISORT, ITBROW, BOTLIM, TOPLIM, KEYPOS, TOTLEN, KEYLEN )
```

ISORT	Array to be sorted (Any, Input)
ITBROW	An array of length **TOTLEN** single-precision words used to store a table row (Any, Input)
BOTLIM	The location in the **ISORT** array of the first word of the first entry to be sorted (Integer, Input)
TOPLIM	The location in the **ISORT** array of the last word of the last entry to be sorted (Integer, Input)
KEYPOS	The column in the table of the first word of the 1 or two word character field on which the sort occurs. It must be a value between 1 and **TOTLEN** (Integer, Input)
TOTLEN	The length in single-precision words of one table row (Integer, Input)
KEYLEN	The number of characters in the hollerith string. Must be either four or eight. If it is not four, it is assumed to be eight without warning (Integer, Input)

Method:

The **UTCSRT** routine uses a QUICKSORT algorithm out lined in "The Art Of Computer Programming, Volume 3 / Sorting And Searching" by D.E. Knuth, Page 116. Several improvements have been made over the pure quicksort algorithm. The first is a random selection of the key value around which the array is sorted. This feature allows this routine to handle partially sorted information more rapidly than the pure quicksort algorithm. The second improvement in this routine is that a cutoff array length is used to direct further array sorting to an insert sort algorithm (Ibid. Page 81). This method has proven to be more rapid than allowing small arrays to be sorted by the quicksort algorithm. Presently this cutoff length is set at 15 entries. Studies should be conducted on each type of machine in order to set this cutoff length to maximize the speed of this routine. This sorting algorithm requires a integer stack in which to place link information during the sort. The maximum required size for this stack array in twice the natural log of the number of rows in the table. At present, the **UTCSRT** routine has hard coded an array of size **(2,40)** which provides for 1 trillion entries to be sorted.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTEXIT

Entry Point: UTEXIT

Purpose:

To terminate the execution of the system when an error occurs.

MAPOL Calling Sequence:

```
CALL EXIT;
```

Application Calling Sequence:

```
CALL UTEXIT
```

Method:

The **UTEXIT** routine is called to cleanly terminate the execution of the ASTROS system. It calls the **DBTERM** database termination program to provide for normal closing of the database files, and dumps the queued messages from the **UTMWRT** utility. When these tasks have been completed, the program execution is terminated.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTGPRT

Entry Point: UTGPRT

Purpose:

To print to the system output file the contents of special database matrix entities that have rows associated with structural degrees of freedom.

MAPOL Calling Sequence:

```
CALL UTGPRT ( BCID, USET(BCID), MAT1, MAT2, ..., MAT10 )
```

BCID	Boundary condition identification number (Integer,Input)
USET	Entity defining structural sets (Character,Input)
MATi	Matrix entity names (up to 10) (Character,Input)

Application Calling Sequence:

None

Method:

The matrix names are tested against the list of supported matrices. If the matrix entity matches one of the supported entities it is printed in a format based on the structural degrees of freedom (similar to displacement and eigenvector output from **OFP**). If the matrix name is not recognized, a call to **UTMPRT** is made instead to print the matrix out in standard banded format. The print format results in one line of output for each grid or scalar point in the structural model for each column of the matrix. Each line of output contains one value for each of the (up to) six degrees of freedom associated with it.

Design Requirements:

1. Only certain g-size matrices are printable in the format of this routine. The currently available matrices are: **DKUG**, **DMUG**, **DPVJ**, **DUG**, **DPGV**, **DUGV**, **DPTHVI**, **DPGRVI**, **PG**,and **DFDU**. Other matrices used in this routine will result in a call to the **UTMPRT** utility.

Error Conditions:

None

Application Utility Module: UTMCOR

Entry Point: UTMCOR

Purpose:

A special purpose utility to write an error message that insufficient open core is available in a functional module.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTMCOR ( MORCOR, TYPE, SUBNAM )
```

MORCOR	Integer containing the number of entries of type **TYPE** requested in the module terminating execution (Integer, Input)
TYPE	String identifying the type of data entries requested: **RSP** for real, single-precision **RDP** for real, double-precision **CSP** for complex, single-precision **CDP** for complex, double-precision **CHAR** for character data (Character, Input)
SUBNAM	A character string containing the name of the module or subroutine that is terminating execution

Method:

The **UTMCOR** utility does an **MMSTAT** call to determine the maximum available open core. The **TYPE FLAG** is used to determine how many single-precision words are needed to satisfy the request for **MORCOR** entries. The difference between the required space and the maximum contiguous memory is used in a call to **UTMWRT** specifying the number of additional words needed. The **SUBNAM** is also sent to **UTMWRT** to identify the failure more precisely. Note that **TYPE=CHAR** is treated by **UTMCOR** as equivalent to **RSP**; the programmer must factor the number of words per entry and input **MORCOR** appropriately factored. After calling the message write utility, **UTMCOR** calls the **UTEXIT** utility to terminate the execution.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTMINT

Entry Point: UTMINT

Purpose:

A special purpose utility to initialize a matrix entity of the machine precision to a diagonal or null matrix.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTMINT ( MATNAM, VAL, NROWS, NCOLS )
```

MATNAM	Character name of matrix entity to be initialized (Character, Input)
VAL	Single precision real value to initialize diagonal terms (Real, Input)
NROWS	The number of rows to be initialized (Integer, Input)
NCOLS	The number of columns to be initialized (Integer, Input)

Method:

The **UTMINT** uses the **DOUBLE** function to determine if the matrix to be initialized is single or double-precision. The requested entity is then opened and flushed. No check is made to ensure that the requested matrix exists. Based on the value of **VAL**, one of several paths through the utility is taken. If **VAL** is not zero, a diagonal matrix with diagonal terms given the value of **VAL** is created. If the non-zero value is 1.0 and **NROWS** equals **NCOLS**, the resulting identity matrix is specifically declared as such in the **MXINIT** call. If the matrix is rectangular, extra columns, if any, are null. If **VAL** is zero, a null matrix of the requested row and column dimensions is created. Note that all the matrices created by this utility are of the machine precision as determined by the **DOUBLE** function.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTMPRG,UTRPRG,UTUPRG

Entry Point: UTXPRG

Purpose:

To purge the contents of database entities but leave the entity in existence.

MAPOL Calling Sequence:

```
CALL UTMPRG ( MAT1, MAT2, ..., MAT10 );
CALL UTRPRG ( REL1, REL2, ..., REL10 );
CALL UTUPRG ( UNS1, UNS2, ..., UNS10 );
```

Application Calling Sequence:

```
CALL DBFLSH ( ENTITY )
```

MATi	Matrix entity name (Character, Input)
RELi	Relation entity name (Character, Input)
UNSi	Unstructured entity name (Character, Input)
ENTITY	Any entity name (Character, Input)

Method:

The **UTMPRG**, **UTRPRG** and **UTUPRG** MAPOL calls are defined to allow up to 10 entities of a single type to be purged from the MAPOL sequence. The application interface is the **DBFLSH** routine which can take a single argument of an entity name of any type.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTMPRT

Entry Point: UTMPRT

Purpose:

To print the contents of database matrix entities to the system output file.

MAPOL Calling Sequence:

```
CALL UTMPRT ( METHOD, MAT1, MAT2, ..., MAT10 );
```

Application Calling Sequence:

```
CALL UTMPRT ( MAT1, METHOD, IKOR, DKOR )
```

METHOD	Print method selection (optional for the MAPOL call) (Integer, Input)
MATi	Matrix entity name (Character, Input)
IKOR,DKOR	Base addresses of dynamic memory (Real and Double, Input)

Method:

If **METHOD** is zero (or absent from the MAPOL call), the matrix entity **MATi** is printed in a banded format: that is, all the terms from the first non-zero term to the last non-zero term (inclusive) are unpacked and printed. Null columns and groups of null columns are identified as such. Note that the MAPOL sequence call allows for up to 10 matrix entities to be printed. A nonzero **METHOD** prints the column by string with no intervening zeros.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTMWRT

Entry Point: UTMWRT

Purpose:

This routine acts as the system message writer. It queues error messages to a temporary file for subsequent printing to the output file. The **MSGDMP** utility is used to actually print the queued messages.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTMWRT    ( LEVEL, NUMBER, ARGMTS )
```

LEVEL	Severity level of the message (Integer,Input) **<0** No message header is written **0** General Information **1** System Fatal Message **2** User Information Message **3** User Warning Message **4** User Fatal Message
NUMBER	Text string containing the message number in the form: **NN.MM.LL** (Character,Input)
ARGMTS	Text array containing arguments for the message text (Character,Input)

Method:

The **UTMWRT** routine cracks the message number **NUMBER** into its three component integers: **NN**, the module number, **MM**, the message number, and **LL**, the message length(in records). If **LL** is omitted (ie **NUMBER=NN.MM**), it defaults to one record in length.

The correct message text is then recovered from the message file by querying the **MSGLEN** for the module **NN** to obtain the starting record and adding the message number (**MM**) and message length (**LL**) to obtain the record numbers where the message text is stored. The message text is of the form:
'---text---$----text--$-------'

If any **$** (dollar signs) exist in the message text, they are replaced by the **ARGMTS** supplied in the call statement. Note that the final message text including the **ARGMTS** must be less than 128 characters in length.

Design Requirements:

1. The pointers to the system database entity that contains the error message texts for each "module" must be stored in memory. Currently, the array for pointer storage is 200 words long which means that no more than 100 distinct "modules" can be defined. Note that this does not imply any limit on the number of error messages within a particular module's group of messages.

Error Conditions:

1. **UTMWRT** error: the number of modules exceeds the limit of **$**. This message results in program termination and can only be fixed by increasing the size of the message pointer storage array.

2. Error in **UTMWRT** when processing message number $. This message is a system level error which usually implies that a non-valid message number **NN.MM.LL** was passed to the module.

3. If the resultant message is longer than 128 characters, the unexpanded text is printed (with **$**'s) and the arguments are echoed.

Application Utility Module: UTPAGE, UTPAG2

Entry Points: UTPAGE, UTPAG2

Purpose:

To handle paging of the system output file during execution of the system. **UTPAG2** performs a page eject based on an anticipated number of lines to print.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTPAGE
CALL UTPAG2 ( N )
```

N	Number of lines that will be printed (Integer, Input)

Method:

The **UTPAGE** routine keeps track of the total line count and the line count for the current page. The total number of output lines allowed is maintained for use by this module. These quantities are stored in the **OUTPT1** common block. The **OUTPT2** common block is also used to store the header and titling data for the current execution. When output to the system output file is being performed, the line count is checked by the current module against the number of lines per page, when the maximum lines per page is reached, a call to **UTPAGE** causes a page advance on the system output file and the total number of printed lines is updated. The header information can be modified by the application modules by simply overwriting the current entries in the **OUTPT2** common block. Note that all system output should be performed using this utility module.

The **UTPAG2** routine performs a page eject if the **N** lines will not fit on the current page.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTRPRT

Entry Point: UTRPRT

Purpose:

To print the contents of database relational entities to the system output file.

MAPOL Calling Sequence:

```
CALL UTRPRT ( REL1, REL2, ..., REL10 )
```

Application Calling Sequence:

```
CALL UTRPRT ( REL, IKOR, RKOR, DKOR )
```

REL	Relation to be printed (character,Input)
IKOR,RKOR, DKOR	Dynamic memory base addresses (Integer, Real and Double, Input)

Method:

The relational entity **RELi** is printed using the full relation projection. At present, if the full projection is too large to be output on one 132 character record, the remaining attributes are ignored. Each attribute, regardless of type, uses a 12 character format for output. The current version of **UTRPRT** has a few additional restrictions. The first is that any string attribute that is more than eight characters in length cannot be printed. The routine will ignore these attributes and write a message to that effect. In addition, double-precision attributes are first converted to single-precision before output.

Design Requirements:

1. Only the following attribute types are supported:
   INT, **KINT**, **AINT**
   RSP, **ARSP**
   RDP
   STR, **KSTR** (first 8 characters only)

Error Conditions:

1. Relational entity **REL** does not exist.
2. Relational entity **REL** is empty.
3. A string attribute cannot be printed when longer than eight characters.

Application Utility Module: UTRSRT

Entry Point: UTRSRT

Purpose:

To sort a table of numbers on a real column of the table

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTRSRT    ( ISORT, ITBROW, BOTLIM, TOPLIM, KEYPOS, TOTLEN )
```

ISORT	Array to be sorted (Any, Input)
ITBROW	An array of length **TOTLEN** single-precision words used to store a table row (Any, Input)
BOTLIM	The location in the **ISORT** array of the first word of the first entry to be sorted (Integer, Input)
TOPLIM	The location in the **ISORT** array of the last word of the last entry to be sorted (Integer, Input)
KEYPOS	The column in the table on which the sort occurs. It must be a value between 1 and **TOTLEN** (Integer, Input)
TOTLEN	The length in single-precision words of one table row (Integer, Input)

Method:

The **UTRSRT** routine uses a QUICKSORT algorithm outlined in "The Art Of Computer Programming, Volume 3 / Sorting And Searching" by D.E. Knuth, Page 116. Several improvements have been made over the pure quicksort algorithm. The first is a random selection of the key value around which the array is sorted. This feature allows this routine to handle partially sorted information more rapidly than the pure quicksort algorithm. The second improvement in this routine is that a cutoff array length is used to direct further array sorting to an insert sort algorithm (Ibid. Page 81). This method has proven to be more rapid than allowing small arrays to be sorted by the quicksort algorithm. Presently this cutoff length is set at 15 entries. Studies should be conducted on each type of machine in order to set this cutoff length to maximize the speed of this routine. This sorting algorithm requires a integer stack in which to place link information during the sort. The maximum required size for this stack array in twice the natural log of the number of rows in the table. At present, the **UTRSRT** routine has hard coded an array of size **(2,40)** which provides for 1 trillion entries to be sorted.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTSFLG, UTSFLR, UTGFLG, UTGFLR

Entry Points: UTSFLG, UTSFLR, UTGFLG, UTGFLR

Purpose:

These routines set a named **FLAG** to an integer value, real value, or retrieve a value previously set.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTSFLG( INNAME , INVAL )
CALL UTSFLR ( INNAME , INVALR )
CALL UTGFLG( INNAME , OUTVAL )
CALL UTGFLR( INNAME , OUTVLR )
```

INNAME	The name of the **FLAG** to set (Character,Input)
INVAL	The value to set for the **FLAG** (Integer,Input)
INVALR	The value to set for the **FLAG** (Real,Input)
OUTVAL	The current value of the **FLAG** (Integer,Output)
OUTVLR	The current value of the **FLAG** (Real,Output)

Method:

None

Design Requirements:

None

Error Conditions:

None

Notes:

1. Routine **SETSYS** uses **UTSFLG** to set output file unit number, **PRINT** (set to second word of **/UNITS/** from **XXBD**) and to set the system precision **PREC** (**=1** for single-precision; **=2** for double-precision) based on the **DOUBLE** function. Large matrix utilities fetch these **FLAG** values by using **UTGFLG**.
2. Some of the **DEBUG** parameters are set by **UTSFLG** and are retrieved by the application modules using **UTGFLG**.
3. Routine **TIMCOM** uses **UTSFLR** to set system timing constants for matrix operations. The **FLAG**s are named: **TMUNIO**, **TMMXPT**, **TMMXUT**, **TMMXPK**, **TMMXUP**, **TMMXUM**, **TMMXPM**, **TMTRSP**, **TMTRDP**, **TMTCSP**, **TMTCDP**, **TMLRSP**, **TMLRDP**, **TMLCSP**, **TMLCDP**, **TMCRSP**, **TMCRDP**, **TMCCSP**, and **TMCCDP**. Large Matrix utilities fetch these constants by using **UTGFLR**.

Application Utility Module: UTSORT

Entry Point: UTSORT

Purpose:

To sort a table of data on an integer column of the table

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTSORT ( ISORT, ITBROW, BOTLIM, TOPLIM, KEYPOS, TOTLEN )
```

ISORT	Array to be sorted (Any, Input)
ITBROW	An array of length **TOTLEN** single-precision words used to store a table row (Any, Input)
BOTLIM	The location in the **ISORT** array of the first word of the first entry to be sorted (Integer, Input)
TOPLIM	The location in the **ISORT** array of the last word of the last entry to be sorted (Integer, Input)
KEYPOS	The column in the table on which the sort occurs. It must be a value between 1 and **TOTLEN**. (Integer, Input)
TOTLEN	The length in single-precision words of one table row (Integer, Input)

Method:

The **UTSORT** routine uses a QUICKSORT algorithm outlined in "The Art Of Computer Programming, Volume 3 / Sorting And Searching" by D.E. Knuth, Page 116. Several improvements have been made over the pure quicksort algorithm. The first is a random selection of the key value around which the array is sorted. This feature allows this routine to handle partially sorted information more rapidly than the pure quicksort algorithm. The second improvement in this routine is that a cutoff array length is used to direct further array sorting to an insert sort algorithm (Ibid. Page 81). This method has proven to be more rapid than allowing small arrays to be sorted by the quicksort algorithm. Presently this cutoff length is set at 15 entries. Studies should be conducted on each type of machine in order to set this cutoff length to maximize the speed of this routine. This sorting algorithm requires a integer stack in which to place link information during the sort. The maximum required size for this stack array in twice the natural log of the number of rows in the table. At present, the **UTSORT** routine has hard coded an array of size **(2,40)** which provides for 1 trillion entries to be sorted.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTSRCH

Entry Point: UTSRCH

Purpose:

Search a table of values for an integer key from a table that is in sorted order on that integer key.

Application Calling Sequence:

```
CALL UTSRCH ( *ERR, KEY, LIST, LPNT, LSTLEN, INCR )
```

***ERR**	Error return if the **KEY** value is not found in the **LIST**.
KEY	Value being searched for in the **LIST** (Integer, Input)
LIST	Array in which the **KEY** should be located (Any, Input)
LPNT	On input, the pointer to the lowest key value in the **LIST** . On output, pointer to the matching value in the **LIST** (Integer)
LSTLEN	Length of the list including **INCR** - 1 trailing values following the last key (Integer, Input)
INCR	The spacing in the **LIST** between key values (Integer, Input)

Method:

The **UTSRCH** routine first calculates the number of key values to be searched. If there are less than a minimum number of key values (presently 15), then the list is searched sequentially. If more than the minimum exist, a binary search of the list is performed. If the value cannot be found, the routine returns to ***ERR**.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTSRT3

Entry Point: UTSRT3

Purpose:

Sort a table on one to three integer keys.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTSRT3 ( Z, NENT, LENT, ZZ, KEY1, LKEY1, KEY2, LKEY2, KEY3, LKEY3, TYPE )
```

Z	Array to be sorted (Any, Input)
NENT	The number of rows (entries) in **Z**. (Integer, Input)
LENT	The number of words in each row of **Z** (Integer, Input)
ZZ	An array of length **LENT** to be used as intermediate storage (Integer, Input)
KEY1	Word offset in **Z** for the first key on which to sort. **KEY1** must be in the range 1 to **LENT** (Integer, Input)
LKEY1	Number of words in the first key on which to sort; use 0 if **KEY** is not used. **KEY1 + LKEY1** must be less than **LENT** (Integer, Input)
LKEY2	Number of words in the second key on which to sort; use 0 if **KEY** is not used. **KEY2 + LKEY2** must be less than **LENT** (Integer, Input)
LKEY3	Number of words in the third key on which to sort; use 0 if **KEY** is not used. **KEY3 + LKEY3** must be less than **LENT** (Integer, Input)
TYPE	Type of sort to perform (Integer, Input) **≥0** for sorting in increasing order **<0** for sorting in decreasing order

Method:

The **UTSRT3** routine sorts each key in order from one to three, with multiple-word keys being treated as though they were distinct integer keys on which the ascending or descending sort is performed.

Design Requirements:

1. There is an implementation limit of no more than 200 total keys.

```
LKEY1 + LKEY2 + LKEY3 < 201
```

Error Conditions:

1. Too many sort keys cause ASTROS termination.

Application Utility Module: UTSRTD

Entry Point: UTSRTD

Purpose:

Sort a vector of double-precision numbers.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTSRTD ( Z, BOTLIM, TOPLIM )
```

Z	Double precision array to be sorted (Double, Input)
BOTLIM	The location in the **Z** array of the first entry to be sorted (Integer, Input)
TOPLIM	The location in the **Z** array of the last entry to be sorted (Integer, Input)

Method:

The **UTSRTD** routine uses a QUICKSORT algorithm outlined in "The Art Of Computer Programming, Volume 3 / Sorting And Searching" by D.E. Knuth, Page 116. Several improvements have been made over the pure quicksort algorithm. The first is a random selection of the key value around which the array is sorted. This feature allows this routine to handle partially sorted information more rapidly than the pure quicksort algorithm. The second improvement in this routine is that a cutoff array length is used to direct further array sorting to an insert sort algorithm (Ibid. Page 81). This method has proven to be more rapid than allowing small arrays to be sorted by the quicksort algorithm. Presently this cutoff length is set at 15 entries. Studies should be conducted on each type of machine in order to set this cutoff length to maximize the speed of this routine. The algorithm used in this utility requires a stack array for storing the linking information generated during the sort. The maximum size needed for this stack is twice the natural log of the number of entries in the array. Currently, a stack of dimension (2,40) is hard coded which allows for a trillion entries to be sorted.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTSRTI

Entry Point: UTSRTI

Purpose:

Sort a vector of integers.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTSRTI    ( Z, BOTLIM, TOPLIM )
```

Z	Integer array to be sorted (Integer, Input)
BOTLIM	The location in the **Z** array of the first entry to be sorted (Integer, Input)
TOPLIM	The location in the **Z** array of the last entry to be sorted (Integer, Input)

Method:

The **UTSRTI** routine uses a QUICKSORT algorithm outlined in "The Art Of Computer Programming, Volume 3 / Sorting And Searching" by D.E. Knuth, Page 116. Several improvements have been made over the pure quicksort algorithm. The first is a random selection of the key value around which the array is sorted. This feature allows this routine to handle partially sorted information more rapidly than the pure quicksort algorithm. The second improvement in this routine is that a cutoff array length is used to direct further array sorting to an insert sort algorithm (Ibid. Page 81). This method has proven to be more rapid than allowing small arrays to be sorted by the quicksort algorithm. Presently this cutoff length is set at 15 entries. Studies should be conducted on each type of machine in order to set this cutoff length to maximize the speed of this routine. The algorithm used in this utility requires a stack array for storing the linking information generated during the sort. The maximum size needed for this stack is twice the natural log of the number of entries in the array. Currently, a stack of dimension (2,40) is hard coded which allows for a trillion entries to be sorted.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTSRTR

Entry Point: UTSRTR

Purpose:

Sort a vector of real numbers.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTSRTR    ( Z, BOTLIM, TOPLIM )
```

Z	Real array to be sorted (Real, Input)
BOTLIM	The location in the **Z** array of the first entry to be sorted (Integer, Input)
TOPLIM	The location in the **Z** array of the last entry to be sorted (Integer, Input)

Method:

The **UTSRTR** routine uses a QUICKSORT algorithm outlined in "The Art Of Computer Programming, Volume 3 / Sorting And Searching" by D.E. Knuth, Page 116. Several improvements have been made over the pure quicksort algorithm. The first is a random selection of the key value around which the array is sorted. This feature allows this routine to handle partially sorted information more rapidly than the pure quicksort algorithm. The second improvement in this routine is that a cutoff array length is used to direct further array sorting to an insert sort algorithm (Ibid. Page 81). This method has proven to be more rapid than allowing small arrays to be sorted by the quicksort algorithm. Presently this cutoff length is set at 15 entries. Studies should be conducted on each type of machine in order to set this cutoff length to maximize the speed of this routine. The algorithm used in this utility requires a stack array for storing the linking information generated during the sort. The maximum size needed for this stack is twice the natural log of the number of entries in the array. Currently, a stack of dimension (2,40) is hard coded which allows for a trillion entries to be sorted.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTSTOD, UTDTOS

Entry Point: UTSTOD, UTDTOS

Purpose:

To convert a number of entries from single-precision to double-precision and copy them from one array into another and to convert a number of entries from double-precision to single-precision and copy them from one array into another.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTSTOD    ( RZ, DZ, TOTLEN )
CALL UTDTOS    ( DZ, RZ, TOTLEN )
```

RZ	Real array (Real,Input)
DZ	Double precision array (Double,Input)
TOTLEN	Length of array (Integer,Input)

Method:

For **UTSTOD, TOTLEN** entries of array **RZ** are copied to **DZ** and converted to double-precision. Similarly, for **UTDTOS**, the entries of **DZ** are copied to **RZ.**

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTUPRT

Entry Point: UTUPRT

Purpose:

To print the contents of database unstructured entities to the system output file.

MAPOL Calling Sequence:

```
CALL UTUPRT ( ENTNAM, TYPE )
```

ENTNAM	Entity name of array (Character,Input)
TYPE	Type of format to use in printing (Integer,Input) **0** for Integer **1** for Real **2** for Double Precision

Application Calling Sequence:

None

Method:

The unstructured entity **ENTNAM** is printed to the system output file using the format specified by **TYPE**. The available formats for output are: **0** for Integer, **1** for Real, and **2** for Double Precision.

Design Requirements:

None

Error Conditions:

1. Unstructured entity **ENTNAM** does not exist.
2. Unstructured entity **ENTNAM** is empty.
3. Invalid unstructured type $ in **UTUPRT** print request for entity $. Valid types are: **0, 1, 2** (**INT**, **RSP**, **RDP**; respectively)

Application Utility Module: UTZERD

Entry Point: UTZERD

Purpose:

To initialize the contents of an array with a specified double-precision value.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTZERD ( ARRAY, NWORDS, VALUE )
```

ARRAY	Name of array (Double,Input and Output)
NWORDS	Length of array in words (Integer,Input)
VALUE	Value to use in initializing array (Double,Input)

Method:

NWORDS of array **ARRAY** are initialized with the value **VALUE**. Note that **VALUE** and **ARRAY** must be double-precision.

Design Requirements:

None

Error Conditions:

None

Application Utility Module: UTZERS

Entry Point: UTZERS

Purpose:

To initialize the contents of an array with a specified integer or real value.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UTZERS ( ARRAY, NWORDS, VALUE )
```

ARRAY	Name of array (Any,Input and Output)
NWORDS	Length of array in words (Integer,Input)
VALUE	Value to use in initializing array (Integer or Real,Input)

Method:

NWORDS of array **ARRAY** are initialized with the value **VALUE**. Both **ARRAY** and **VALUE** must be single-precision

Design Requirements:

None

Error Conditions:

None

Application Utility Module: XISTOI

Entry Point: XISTOI

Purpose:

To convert a string to its integer equivalent.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XISTOI ( STR, IVALUE, RC )
```

STR	Character string representing an integer number (Character,Input)
IVALUE	Resulting integer number (Integer,Output)
RC	Return Code (Integer,Output) **0** if **STR** contained a legal integer **1** if **STR** contained an illegal character **2** if **STR** contained an illegal integer (overflow)

Method:

The character string **STR** is cracked one digit at a time with error checks made against the machine maximum integer to ensure that the resultant **IVALUE** is a legal integer.

Design Requirements:

1. Legal strings may contain plus (**+**), minus (**-**) and one or more decimal digits from 0 through 9.

Error Conditions:

1. Return codes

Application Utility Module: XISTOR

Entry Point: XISTOR

Purpose:

To convert a string to its real equivalent.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL XISTOR ( STR, VALUE, RC )
```

STR	Character string representing a real number (Character,Input)
VALUE	Resulting real number (Real,Output)
RC	Return Code (Integer,Output) **0** if **STR** contained a legal real number **1** if **STR** contained an illegal character **2** if **STR** contained an overflow value **3** if **STR** contained an underflow value

Method:

The character string **STR** is cracked into its three component parts: the leading whole number, the fractional digits and the exponential whole number. Each of the these pieces is optional. The three parts are then combined to form the real number.

Design Requirements:

1. Legal strings may contain plus (**+**), minus (**-**), one or more decimal digits from 0 through 9 and E or D and must contain a decimal point (.).
2. The Bulk Data style of real number representation is fully supported as is the FORTRAN **E**, **F** and **G** formats.

Error Conditions:

1. Return codes

Chapter 7.

LARGE MATRIX UTILITY MODULES

Finite element structural analysis, which forms the core of the ASTROS system, requires a suite of utilities for matrix operations which are able to efficiently handle very large, often sparse, matrices. This section is devoted to the documentation of the large matrix utilities in ASTROS. the designation ***large*** comes from the assumption made by each of these utilities that the relevant matrices are stored on the CADBB database and will be operated on in a fashion that allows them to be of arbitrary order. Other matrix operations are available in the general utility library documented in Section 6 for small matrices stored in memory. The suite of large matrix utilities in ASTROS includes partition/merge operations, decomposition and forward/backward substitutions, multiply/add and pure addition operations, transpose operations and real and complex eigenvalue extraction.

The following subsections document the interface to the large matrix utilities in two formats: using the executive system (MAPOL) and using the FORTRAN calling sequence. In some cases, the MAPOL language supports the particular matrix operation directly. In such cases, the user need not make a call to the particular utility, instead, the MAPOL compiler automatically generates the correct call to the appropriate utility. These direct interfaces are so indicated in the documentation.

Large Matrix Utility Module: CDCOMP

Entry Point: CDCOMP

Purpose:

To decompose a complex square matrix **[A]** into its upper and lower triangular factors:

$$A \rightarrow L\,U$$

MAPOL Calling Sequence:

```
CALL DECOMP ([A], [L], [U]);
```

Note that the calling sequence for **CDCOMP** is through the MAPOL **DECOMP** module. The method is automatically selected if the input matrix is complex.

Application Calling Sequence:

```
CALL CDCOMP    (A, L, U, IKOR, RKOR, DKOR)
```

[A]	The matrix to be decomposed (Input, Character)
[L]	The lower triangular factor (Output, Character)
[U]	The upper triangular factor (Output, Character)
IKOR,RKOR,DKOR	The dynamic memory base address (Integer,Real and Double,Input)

Method:

The **CDCOMP** module decomposes complex matrices. The resultant lower, **[L]**, and upper, **[U]**, triangular factors are specially structured matrix entities having control information in the diagonal terms. They may only be reliably used by the back-substitution module **GFBS**.

Design Requirements:

1. The back-substitution phase of equation solving is performed with module **GFBS**.
2. The triangular factors **[L]** and **[U]** may not be used reliably by matrix utilities other than **GFBS**.

Error Conditions:

None

Large Matrix Utility Module: CEIG

Entry Point: CEIG

Purpose:

To solve the equation:

$$\left[\boldsymbol{M} p^2 + \boldsymbol{B} p + \boldsymbol{K} \right] \boldsymbol{u} = \boldsymbol{0}$$

for the eigenvalues **p** and the associated eigenvectors **{u}** where **[M]**, **[B]** and **[K]** are mass, damping and stiffness matrices, respectively.

MAPOL Calling Sequence:

```
CALL CEIG      ( SETID, BCID, USET, [KDD], [BDD], [MDD], LAMDAC, [CPHID],
                 [CPHIDL], NPHI );
```

Application Calling Sequence:

```
CALL CEIG      ( SETID, BCID, USET, KDD, BDD, MDD, LAMDAC, CPHID, CPHIDL,
                 OCEIGS, IKOR, RKOR, DKOR )
```

SETID	An optional set identification for the **EIGC** entry. Used to define the extraction parentheses if omitted from MAPOL or 0. The CASE **CMETHOD** attribute will define the **SETID** used.
BCID	The boundary condition identification number (Integer, Input)
USET	Entity defining structural sets for the current BC
[KDD]	Dynamic stiffness matrix - D-set (Input, Character)
[BDD]	Dynamic damping matrix - D-set (Input, Character)
[MDD]	Dynamic mass matrix - D-set (Input, Character)
LAMDAC	A relation entity containing a list of extracted complex eigenvalues (Output, Character)
[CPHID]	A matrix whose columns are the complex eigenvectors corresponding to the extracted eigenvalues (Output, Character)
[CPHIDL]	A matrix containing the left complex eigenvectors (Output, Character)
NPHI	The number of complex eigenvectors computed (Output, Integer)
OCEIGS	The name of the output entity for statistical information (Character)
IKOR,RKOR,DKOR	The dynamic memory base address (Integer,Real and Double,Input)

Method:

The Complex Eigenvalue Analysis Module calculates the eigenvalues and eigenvectors for a general system which may have complex terms in the mass, damping and stiffness matrices. The eigenvectors are scaled according to the user requested normalization scheme (**MAX** or **POINT**).The eigenvalues p and the eigenvectors **{u}** are always treated as complex. These data are related to the ud displacements if a direct formulation is used or are related to the uh displacements if a modal formulation is used.

Presently, the complex eigenvalue analysis is used by manually inserting a call to module **CEIG** in the MAPOL sequence. The relation **EIGC** will be automatically retrieved in module **CEIG** and the first

method that appears in the relation will control the extraction. The Inverse Power Method or the Upper Hessenburg Method which is selected by **EIGC** data is used to solve the eigenvalue problem. (Subroutines **CINVPR** or **HESS1**). In case there is insufficient core for Upper Hessenburg Method, the Inverse Power Method will be used if the necessary data exist on **EIGC**.

Design Requirements:

1. The matrices **[KDD**,**[BDD]** and **[MDD]** must be complex, and matrices **[BDD]** and **[CPHIDL]** are not required.

Error Conditions:

1. **EIGC** is not in the Bulk Data packet.
2. **[KDD]** and/or **[MDD]** do not exist.
3. **[KDD]** and **[MDD]** are not compatible.
4. **[MDD]** is singular in **HESS** method.

Large Matrix Utility Module: COLMERGE

Entry Point: MXMERG

Purpose:

To merge two submatrices into a single matrix **[A]** column-wise:

$$A \leftarrow \left[A_{11} \; A_{12} \right]$$

MAPOL Calling Sequence:

```
CALL COLMERGE  ([A], [A11], [A12], [CP]);
```

Application Calling Sequence:

```
CALL MXMERG    (A, A11, BLANK, A12, BLANK, CP, BLANK, KORE)
```

[A]	The resulting merged matrix (Output, Character)
[Aij]	The input partitions as shown above (Input, Character)
[CP]	The column partitioning vector (Input, Character)
BLANK	A character blank (Input, Character)
KORE	The dynamic memory base address (Integer,Input)

Method:

The partitioning vector **[CP]** must be a column vector containing zero and nonzero terms. The **[A11]** partition will be placed in **[A]** at positions where **[CP]** is zero, and the **[A12]** partition is placed in **[A]** at positions where **[CP]** is nonzero. If either of the partitions **[A11] or [A12]** is null, it may be omitted from the MAPOL calling sequence or a **BLANK** may be used in the application calling sequence.

The **COLPART** large matrix utility module performs the inverse of this module.

Design Requirements:

None

Error Conditions:

None

Large Matrix Utility Module: COLPART

Entry Point: MXPRTN

Purpose:

To partition a matrix **[A]** into two submatrices column-wise:

$$A \rightarrow \left[A_{11} \; A_{12} \right]$$

MAPOL Calling Sequence:

```
CALL COLPART   ([A], [A11], [A12], [CP]);
```

Application Calling Sequence:

```
CALL MXPRTN    (A, A11, BLANK, A12, BLANK, CP, BLANK, KORE)
```

[A]	The matrix being partitioned (Input, Character)
[Aij]	The resulting partitions shown above (Output, Character)
[CP]	The column partitioning vector (Input, Character)
BLANK	A character blank (Input, Character)
KORE	The dynamic memory base address (Integer,Input)

Method:

The partitioning vector **[CP]** must be a column vector containing zero and nonzero terms. The **[A11]** partition will then contain those columns of **[A]** corresponding to a zero value in **[CP]**, and the **[A12]** partition is placed in **[A]** at positions where **[CP]** is nonzero. If either partition is not desired, it may be omitted from the MAPOL calling sequence or a **BLANK** may be used in the application calling sequence.

Design Requirements:

None

Error Conditions:

None

Large Matrix Utility Module: DECOMP

Entry Point: DECOMP

Purpose:

To decompose a general square matrix **[A]** into its upper and lower triangular factors:

$$A \rightarrow L\,U$$

MAPOL Calling Sequence:

```
CALL DECOMP    ([A], [L], [U]);
```

Application Calling Sequence:

```
CALL DECOMP    (A, L, U, IKOR, RKOR, DKOR)
```

[A]	The matrix to be decomposed (Input, Character)
[L]	The lower triangular factor (Output, Character)
[U]	The upper triangular factor (Output, Character)
IKOR,RKOR,DKOR	The dynamic memory base address (Integer, Real and Double,Input)

Method:

The **DECOMP** module can decompose both real and complex matrices. The resultant lower, **[L]**, and upper, **[U]**, triangular factors are specially structured matrix entities having control information in the diagonal terms. They may only be reliably used by the back-substitution module **GFBS**.

Design Requirements:

1. **DECOMP** can process both real and complex machine-precision matrices.
2. The back-substitution phase of equation solving is performed with module **GFBS**.
3. The triangular factors **[L]** and **[U]** may not be used reliably by matrix utilities other than **GFBS**.

Error Conditions:

None

Large Matrix Utility Module: FBS

Entry Point: FBS

Purpose:

To perform the forward/backward substitution phase of equation solving for symmetric matrices that have been decomposed with module **SDCOMP**.

MAPOL Calling Sequence:

```
CALL FBS       ([L], [RHS], [ANS], ISIGN);
```

Application Calling Sequence:

```
CALL FBSS      (L, RHS, ANS, ISIGN, IKOR, RKOR, DKOR)
```

[L]	The lower triangular decomposition factor obtained from **SDCOMP** (Input, Character)
[RHS]	The matrix of right-hand sides of the equations being solved (Input, Character)
[ANS]	The matrix of resulting solutions of the equations (Output, Character)
ISIGN	Sign of the right-hand sides in **[RHS]** (Input, Integer) **+1** for positive **-1** for negative
IKOR,RKOR,DKOR	The dynamic memory base address (Integer, Real and Double,Input)

Method:

Given a real symmetric system of equations

$$[K][X] = \pm[P]$$

the **SDCOMP** large matrix utility is used to compute

$$[K] = [L][D][L]^{T}$$

such that **[D]** is a diagonal matrix. This module then completes the solution for **[X]** as

$$[L][Y] = \pm[P]$$

$$[L]^{T}[X] = [D]^{-1}[Y]$$

If **[RHS]** is blank, the inverse of the decomposed matrix will be returned in **[ANS]**.

Design Requirements:

None

Error Conditions:

None

Large Matrix Utility Module: GFBS

Entry Point: GFBS

Purpose:

To perform the forward/backward substitution phase of equation solving for general matrices that have been decomposed with module **DECOMP**.

MAPOL Calling Sequence:

```
CALL GFBS      ([L], [U], [RHS], [ANS], ISIGN);
```

Application Calling Sequence:

```
CALL GFBS      (L, U, RHS, ANS, ISIGN, IKOR, RKOR, DKOR)
```

[L],[U]	The names of the lower and upper triangular decomposition factors from **DECOMP** (Input, Character)
[RHS]	The matrix of right-hand sides of the equation being solved (Input, Character)
[ANS]	The matrix of resulting solutions of the equations (Output, Character)
ISIGN	Sign of the right-hand sides in **[ANS]**(Input, Integer) **+1** for positive **-1** for negative
IKOR,RKOR,DKOR	The dynamic memory base address (Integer, Real and Double,Input)

Method:

Given a general, real, or complex system of equations

$$[K][X] = \pm[P]$$

the **DECOMP** large matrix utility is used to compute

$$[K] = [L][U]$$

This module then completes the solution for **[X]** as:

$$[L][Y] = \pm[P]$$

$$[U][X] = [Y]$$

If **[RHS]** is blank, the inverse of the decomposed matrix will be returned in **[ANS]**.

Design Requirements:

None

Error Conditions:

None

Large Matrix Utility Module: MERGE

Entry Point: MXMERG

Purpose:

To merge four submatrices into a single matrix **[A]** based on one or two partitioning vectors.

$$\begin{bmatrix} A_{11} \mid A_{12} \\ A_{21} \mid A_{22} \end{bmatrix} \rightarrow A$$

MAPOL Calling Sequence:

```
CALL MERGE     ([A], [A11], [A21], [A12], [A22], [CP], [RP]);
```

Application Calling Sequence:

```
CALL MXMERG    (A, A11, A21, A12, A22, CP, RP, KORE)
```

[A]	The resulting merged matrix (Output, Character)
[Aij]	The input partitions as shown above (Input, Character)
[RP]	The row partitioning vector (Input, Character)
[CP]	The column partitioning vector (Input, Character)
KORE	The dynamic memory base address (Integer,Input)

Method:

The partitioning vectors **[CP]** and **[RP]** must be column vectors containing zero and nonzero terms. The **[A11]** partition will be placed in **[A]** at positions where both **[RP]** and **[CP]** are zero. The **[A12]** partition will be placed in **[A]** at positions where **[RP]** is zero and **[CP]** is nonzero. The other partitions are treated in a similar manner.

If some of the partitions are null, they may be omitted from the MAPOL calling sequence or a character blank may be used in the application calling sequence. In a similar manner, if the row and column partition vectors are the same, one of them may be omitted or left blank in the MAPOL call. They must both be present in the application call.

If a row or column merge alone is required in the MAPOL sequence, the special purpose MAPOL utilities **ROWMERGE** and **COLMERGE** may be used.

Design Requirements:

None

Error Conditions:

None

Large Matrix Utility Module: MPYAD

Entry Point: MPYAD

Purpose:

To perform the general matrix multiply and add operations as shown below:

$$\boldsymbol{D} = \pm \boldsymbol{A}\,\boldsymbol{B} \pm \boldsymbol{C} \quad \text{or} \quad \boldsymbol{D} = \pm \boldsymbol{A}\,\boldsymbol{B}$$

$$\boldsymbol{D} = \pm \boldsymbol{A}^T\,\boldsymbol{B} \pm \boldsymbol{C} \quad \text{or} \quad \boldsymbol{D} = \pm \boldsymbol{A}^T\,\boldsymbol{B}$$

MAPOL Calling Sequence:

None, the MAPOL syntax supports algebraic matrix operations directly

```
[D] := ±[A]*[B] ±[C];

[D] := ±TRANS([A])*[B]±[C];
```

Application Calling Sequence:

```
CALL MPYAD     (A, B, C, D, TFLAG, SIGNAB, SIGNC, IKOR, RKOR, DKOR)
```

A	The name of the input **A** matrix (Character)
B	The name of the input **B** matrix (Character)
C	The name of the input **C** matrix or blank (Character)
D	The name of the output **D** matrix (Character)
TFLAG	The transpose flag (Integer, Input) **0** no transpose **1** transpose matrix **A**
SIGNAB	The sign on the **[A] [B]** product (Integer, Input) **+1** **+[A][B]** **-1** **-[A][B]**
SIGNC	The sign on the **[C]** matrix (Integer, Input) **+1** **+[C]** **0** no **[C]** matrix **-1** **-[C]**
IKOR,RKOR,DKOR	The dynamic memory base address (Integer, Real and Double,Input)

Method:

If no **[C]** matrix exists, the **C** argument should be blank and the **SIGNC** argument should be zero.

Design Requirements:

None

Error Conditions:

None

Large Matrix Utility Module: MXADD

Entry Point: MXADD

Purpose:

To perform the general matrix addition as shown below:

$$\boldsymbol{C} = \alpha \boldsymbol{A} + \beta \boldsymbol{B}$$

MAPOL Calling Sequence:

None, the MAPOL syntax supports algebraic matrix operations directly.

[C] := (α)[A]±(β)[B]

Application Calling Sequence:

CALL MXADD (A, B, C, ALPHA, BETA, DKOR, IKOR)

A	The name of the input **A** matrix (Character)
B	The name of the input **B** matrix (Character)
C	The name of the output **C** matrix (Character)
ALPHA	The constant complex multiplier of matrix **A**. Real array of length 2, the first word is the real part of the constant, the second is the imaginary part. (Input,Complex)
BETA	As **ALPHA** for the **B** matrix. (Input,Complex)
DKOR,IKOR	The dynamic memory base address (Double and Integer,Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Large Matrix Utility Module: PARTN

Entry Point: MXPRTN

Purpose:

To partition a matrix **[A]** into four submatrices based on one or two partitioning vectors:

$$A \rightarrow \begin{bmatrix} A_{11} \mid A_{12} \\ A_{21} \mid A_{22} \end{bmatrix}$$

MAPOL Calling Sequence:

```
CALL PARTN     ([A], [A11], [A21], [A12], [A22], [CP], [RP]);
```

Application Calling Sequence:

```
CALL MXPRTN    (A, A11, A21, A12, A22, CP,  RP,  KORE)
```

[A]	The matrix to be partitioned (Input, Character)
[Aij]	The resulting partitions as shown above (Output, Character)
[RP]	The row partitioning vector (Input, Character)
[CP]	The column partitioning vector (Input, Character)
KORE	The dynamic memory base address (Integer,Input)

Method:

The partitioning vectors **[CP]** and **[RP]** must be column vectors containing zero and nonzero terms. The **[A11]** partition will be formed from **[A]** at positions where both **[RP]** and **[CP]** are zero. The **[A12]** partition will be formed from **[A]** at positions where **[RP]** is zero and **[CP]** is nonzero. The other partitions are treated in a similar manner.

If some of the partitions are not desired as output, they may be omitted from the MAPOL calling sequence or a character blank may be used in the application calling sequence. In a similar manner, if the row and column partition vectors are the same, one of them may be omitted or left blank in the MAPOL call. They must both be present in the application call.

If a simple row or column partition is required in the MAPOL sequence, the special purpose MAPOL utilities **ROWPART** and **COLPART** may be used.

Design Requirements:

None

Error Conditions:

None

Large Matrix Utility Module: REIG

Entry Point: REIG

Purpose:

To solve the equation:

$$[\, \boldsymbol{K} - \lambda \boldsymbol{M} \,]\, \boldsymbol{u} = \boldsymbol{0}$$

for its eigenvalues, λ, and their associated eigenvectors $\{\varphi\}$.

MAPOL Calling Sequence:

```
CALL REIG      (ITER, BCID, USET(BCID), [K], [M], [MR], [DM], LAMA,
                [PHI], [MI], NPHI);
```

Application Calling Sequence:

```
CALL REIG      (ITER, BCID, USET, K, M, MR, DM, LAMA, PHI, MI,
                OEIGS, RKOR, DKOR)
```

ITER	The design iteration number (Integer, Input)
BCID	The boundary condition identification number (Integer, Input)
USET	The entity defining structural sets for the current boundary condition
[K],[M]	The stiffness and mass matrices (Input, Character)
[MR]	The rigid body mass matrix (Input, Character)
[DM]	The rigid body transformation matrix (Input, Character)
LAMA	Relation containing a list of extracted eigenvalues (Output, Character)
[PHI]	A matrix whose columns are the eigenvectors corresponding to the extracted eigenvalues (Output, Character)
[MI]	The modal mass matrix (Output, Character)
NPHI	The number of eigenvectors computed (Integer, Output)
OEIGS	The name of the output entity for statistical information (Character)
RKOR,DKOR	The dynamic memory base address (Real and Double,Input)

Method:

The matrices **[K]** and **[M]** must be real and the rigid body mass matrix **[MR]** and the rigid body transformation matrix **[DM]** are not required. The **REIG** module must query the **CASE** relational entity to determine which set of **EIGR** eigenvalue extraction data to use. Because of the multidisciplinary nature of the code, **REIG** assumes that, if called, an eigenanalysis is required. It uses the **EIGR** data that correspond to the selection for the current boundary condition, **BCID**.

Design Requirements:

None

Error Conditions:

None

Large Matrix Utility Module: ROWMERGE

Entry Point: MXMERG

Purpose:

To merge two submatrices into a single matrix **[A]** row-wise:

$$A \leftarrow \begin{bmatrix} A_{11} \\ A_{21} \end{bmatrix}$$

MAPOL Calling Sequence:

```
CALL ROWMERGE ([A], [A11], [A21], [RP]);
```

Application Calling Sequence:

```
CALL MXMERG (A, A11, A21, BLANK, BLANK, BLANK, RP, KORE)
```

[A]	The resulting merged matrix (Output, Character)
[A11],[A21]	The input partitions as shown above (Input, Character)
[RP]	The row partitioning vector (Input, Character)
BLANK	A character blank (Input, Character)
KORE	The dynamic memory base address (Integer,Input)

Method:

The partitioning vector **[RP]** must be a column vector containing zero and nonzero terms. The **[A11]** partition will be placed in **[A]** at positions where **[RP]** is zero. If either of the partitions **[A11]** or **[A12]** is null, it may be omitted from the MAPOL calling sequence or a **BLANK** may be used in the application calling sequence.

The **ROWPART** large matrix utility module performs the inverse of this module.

Design Requirements:

None

Error Conditions:

None

Large Matrix Utility Module: ROWPART

Entry Point: MXPRTN

Purpose:

To partition a matrix **[A]** into two submatrices row-wise:

$$A \rightarrow \begin{bmatrix} A_{11} \\ A_{21} \end{bmatrix}$$

MAPOL Calling Sequence:

```
CALL ROWPART ([A], [A11], [A21], [RP]);
```

Application Calling Sequence:

```
CALL MXPRTN (A, A11, A21, BLANK, BLANK, BLANK, RP, KORE)
```

[A]	The matrix being partitioned (Input, Character)
[Aij]	The resulting partitions shown above (Output, Character)
[RP]	The partitioning vector (Input, Character)
BLANK	A character blank (Input, Character)
KORE	The dynamic memory base address (Integer,Input)

Method:

The partitioning vector **[RP]** must be a column vector containing zero and nonzero terms. The **[A11]** partition will then contain those columns of **[A]** corresponding to a zero value in **[RP]**. If either partition is not desired as output, it may be omitted from the MAPOL calling sequence or a **BLANK** may be used in the application calling sequence.

Design Requirements:

None

Error Conditions:

None

Large Matrix Utility Module: SDCOMP

Entry Point: SDCOMP

Purpose:

To decompose a symmetric square matrix **[A]** into the form:

$$A \rightarrow L D L^T$$

where **[L]** is a lower triangular factor and the diagonal matrix and **[D]** has been stored on the diagonal of **[L]**.

MAPOL Calling Sequence:

```
CALL SDCOMP ([A], [L], USET(BC), SETNAM);
```

Application Calling Sequence:

```
CALL SDCOMP (A, L, CHLSKY, USET, SETNAM, IKOR, RKOR, DKOR)
```

[A]	The matrix to be decomposed (Input)
[L]	The lower triangular factor (Output)
CHLSKY	The input selection of Cholesky decomposition (Integer) **0** no Cholesky **1** use Cholesky
USET	The entity defining structural sets for the current boundary condition
SETNAM	The current structural set name
IKOR,RKOR,DKOR	The dynamic memory base address (Integer,Real and Double,Input)

Method:

The **SDCOMP** module can decompose real and complex symmetric matrices. The resultant lower factor, **[L]**, is a specially structured matrix entity having the terms of **[D]** on the diagonals. It may, therefore, only be reliably used by the back-substitution module, **FBS**.

Design Requirements:

None

Error Conditions:

1. Matrix **A** is singular.

Large Matrix Utility Module: TRNSP0SE

Entry Point: TRNSPZ

Purpose:

To generate the transpose of a matrix:

$$A \rightarrow A^T$$

MAPOL Calling Sequence:

```
CALL TRNSPOSE ([A], [ATRANS]);
```

Application Calling Sequence:

```
CALL TRNSPZ (A, ATRANS, IKOR, DKOR)
```

[A]	The name of the input matrix to be transposed (Input, Character)
[ATRANS]	The name of the resulting transposed matrix (Output, Character)
IKOR,DKOR	The dynamic memory base address (Integer and Double,Input)

Method:

The output matrix entity, **[ATRANS]**, must already exist on the database. It will be flushed and loaded by the transpose utility. All matrix types and precisions are supported. As a special feature, the user controlled 11th through 20th words of the **INFO** array for the input matrix are copied onto the transposed matrix.

Design Requirements:

1. The spill logic for the utility has a limit of eight scratch files to perform the transpose. If the transpose cannot be performed in eight passes using the available memory, the utility will terminate.

Error Conditions:

None

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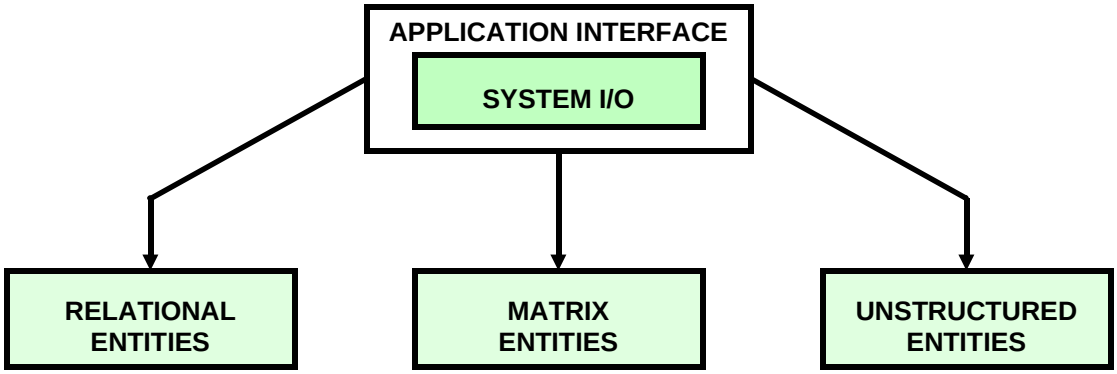
Chapter 8.

THE CADDB APPLICATION INTERFACE

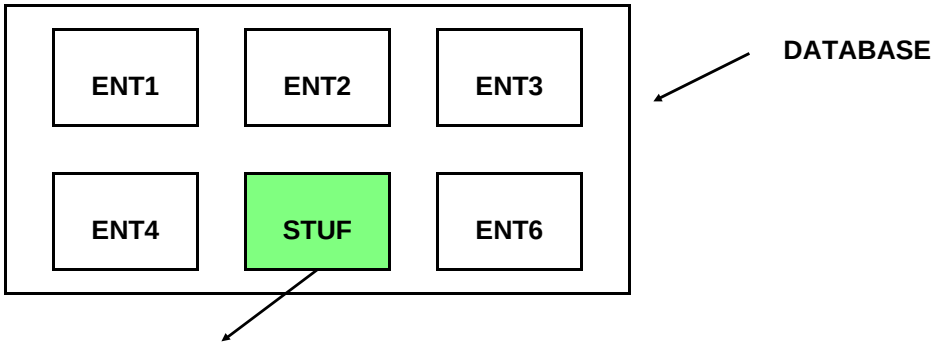
The Computer Automated Design Database (CADDB) is the heart of the ASTROS software system. It has been designed to provide the structures and access features typically required for scientific software applications development. CADDB can be viewed as a set of data entities that are accessible by a suite of utility routines called the application interface as shown below:



There are three types of entities: ***Unstructured***, ***Relational***, and ***Matrix***. These are described in the following sections.

Unstructured Entities.

Unstructured entities form the least organized data type that may be used. An unstructured entity may be considered as a set of variable length records which have no predetermined structure and which may or may not have any relationship with each other. This is illustrated by the following:

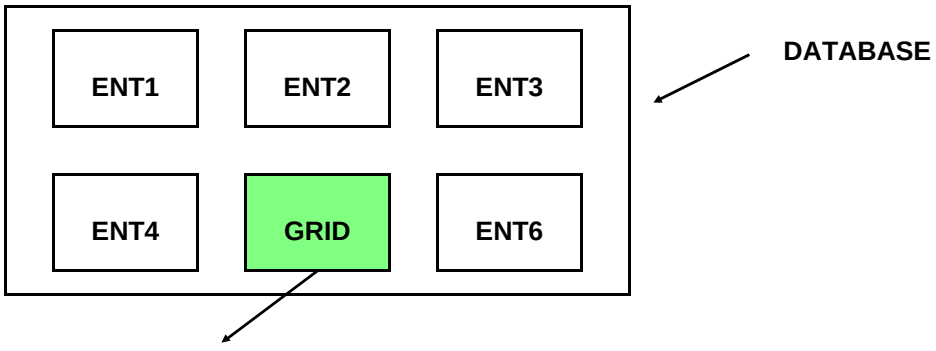


1	...	...	...	...	...	...	END
2	...	...	...	END			
3	...	...	...	...	END		
4	...	...	...	...	...	...	END
5	...	...	...	END			

Unstructured entities are typically used when "scratch" space is needed in an essentially sequential manner. Two important points, however, are that each record may be accessed randomly if the entity is created with an index structure, and that records may be read or written either in their entirety or only partially. Details of these features are discussed in Section 8.6.

Relational Entities.

Relational entities are completely structured tables of data. The rows of the table are called ***entries*** or ***tuples*** and the columns are called ***attributes***, as shown below:



ATTRIBUTES

GID	X	Y	Z
101	0.0	0.0	0.0
102	1.0	0.0	0.0
103	1.0	1.0	0.0
104	0.0	1.0	0.0

ENTRIES

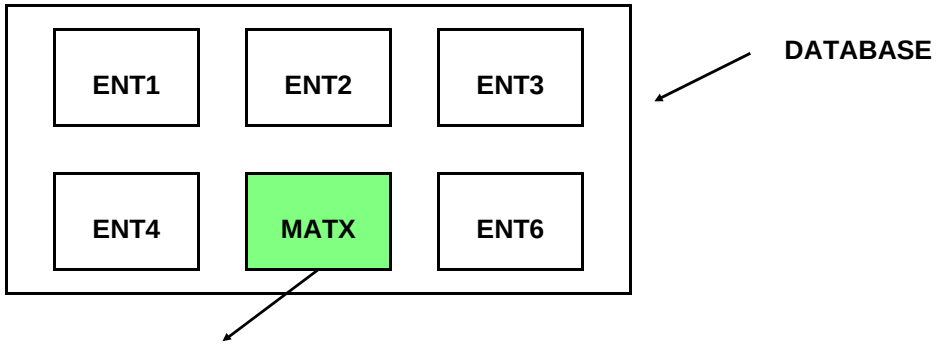
The definition of the attributes and their types is called the ***schema*** of the relation. Because the schema is an inherent part of the relational data structure, each attribute may be referred to by its name. In addition, because each of the attributes is independent of the others, it is possible to retrieve or modify only selected attributes by performing a ***projection*** of the relation. Attributes may also be defined with ***keys***. If an attribute is keyed, an index structure is built that allows rapid direct access to a given entry. There is a restriction, however, that a keyed attribute must have unique values for all entries.

Another powerful feature is the ability to retrieve entries that have been qualified by one or more ***conditions***. A condition is a constraint definition for an attribute value. For instance, in the example above, the condition of X=1.0 might be specified prior to data retrieval. Only those entries that satisfy the given constraint or constraints are then returned.

Relational entities are used when the data they contain will be accessed or modified on a selective basis. This eliminates the need to move large sequential sets of data back-and-forth when modifying or retrieving only small amounts of data. An additional feature available with CADDB is the "blast" access of a relation. This allows the data to be treated sequentially while maintaining the relational form. These and other features are fully described in Section 8.5.

Matrix Entities.

One of the most important data structures encountered in engineering applications is the matrix. Matrix algebra forms the basis for the finite element method employed by ASTROS. The efficient performance of this algebra, along with additional operations such as simultaneous equation solvers, eigensolvers and integration schemes, is critical to such a software system. CADDB represents matrices in ***packed*** format. This format has been used extensively by the NASTRAN system for the last 30 years with excellent success. The representation of a matrix on CADDB is shown below:



1	ROW	n	. . .	ROW	n	. . .	END
2	ROW	n	. . .	END			
3	ROW	n	. . .	END			
4	ROW	n	. . .	ROW	n	. . .	END
5	ROW	n	. . .	END			

Referring to the figure, note that only the non-null columns of a matrix are stored, thus reducing disk space utilization. Within each column are one or more ***strings***. A string is a sequential burst of data

entities with a header that indicates the first row position of the data in the given column and "n", the number of terms in the string. This representation allows a further data compression in that zero terms in the column are not physically stored.

A complete library of matrix utilities is available within the ASTROS system. These utilities are coded to use the packed format to its best advantage. All matrix data should be stored in this manner. Many access methods are available for matrix entities. A matrix may be positioned randomly to a given column, an entire column may be read or written, individual terms may be read or written and so on. These functions are described in Subsection 8.4.

The ASTROS internal database is the proprietary eBASE database developed by UAI. In addition to the CADDB interface described in this Chapter, you may directly use additional eBASE utilities. To do this, you must license the eBASE software separately. While this is generally not necessary, extremely advanced users may find that it provides additional power and flexibility for large scale development within the ASTROS environment. Contact the sales department of UAI for more information.

8.1. CADDB BASIC DESIGN CONCEPTS

The CADDB implementation had three fundamental design goals: open-endedness, performance, and structured programming methodology. The basic internal design of the database imposes no unrealistic restrictions. A virtually unlimited number of different databases and entities can be processed simultaneously as long as there is memory to hold the required information. The only fixed restrictions are those imposed by the computer hardware and not the design. For example, the maximum number of blocks in the entire database is 2^{31} and the maximum number of words in each entity is also 2^{31}. This restriction follows from the 32-bit word length of some of the target machines.

The performance goals of the database had to address both I/O and CPU issues. The optimization of I/O performance is usually in direct conflict with minimal memory utilization. When faced with an I/O versus memory conflict, reduced I/O was generally selected. Summarized in the following are typical design decisions impacted by this issue:

1. All bit maps required by the database are kept in memory to reduce I/O requirements of free block management.

2. Directory pointers for all entities, open or closed, are kept in memory to reduce directory search time.

3. While any type of entity is open, all schema definition data are kept in memory.

CADDB was designed in top-down structured manner. It is divided into functional modules that simplify implementation, testing, and maintenance. Generically, the functions of these modules are:

1. **ENTITY CODE**: Separate groups of routines are provided for each of the three entity types.

2. **RELATIVE BLOCK**: These routines process the block allocation tables to convert relative block numbers used by entity routines into physical blocks.

3. **BUFFER MANAGEMENT**: All buffer management is done by these routines.

4. **FREE BLOCK MANAGEMENT**: Performs the allocating and freeing of physical blocks.

5. **INDEX PROCESSING**: All index processing is done by these routines. Two sets of routines, one for sequential indices and one for binary indices, are provided.

6. **DIRECTORY**: A separate set of routine is provided to do all directory processing.

7. **MEMORY MANAGEMENT**: All memory management is provided by these routines.

This highly modular design provides several advantages. The most important is that new features can be added with a minimal effect on the existing code. For example, a double buffering scheme could be added to reduce I/O wait time by simply modifying the buffer management routines.

8.1.1. Physical Structure

Each physical database is comprised of a set of disk files. An index file and at least one data file are required for each database. The index file contains the necessary control information to find entities on the database. This information includes the following:

1. DIRECTORY: Contains information required to process each entity.

2. FBBM: The Free Block Bit Maps (FBBM) are used to keep track of the blocks which are allocated and free.

3. BAT: The Block Allocation Table (BAT) is used to keep track of the physical blocks used by each entity.

4. SCHEMA: The SCHEMA defines the attribute structure for each relational entity.

5. INDEX: Each matrix or unstructured entity can have optional indices built to allow quick access to any column or record. Relational entities can also have indices built for any attribute.

The data files are used to store the actual information in each entity. Multiple data files can be used to split the database over several physical disk drives. Free block allocation is performed in a cyclic fashion among the data files to balance the I/O load on the system.

8.1.2. Improvements Over Other Databases

The design of a new ASTROS database was required to address deficiencies in existing available codes. The GINO I/O system of NASTRAN, while efficient, is a file management system, not a database. Separate files are required for each entity and only matrix and unstructured entities are supported. The RIM database, developed by the IPAD program for NASA, supports the relational entity type but does not adequately support either unstructured or matrix types. Additionally, the RIM system suffers from severe restrictions and performance penalties. The following summarize the functional improvements that make CADDB superior to these existing systems:

1. The three entity types have been combined into one database in as consistent a manner as possible.

2. The dynamic memory manager (See Subsection 8.3) allows the database to be open-ended without overburdening an application code which also makes large demands on memory.

3. Multiple databases and as many entities as memory allows may be processed simultaneously.

4. Multiple jobs can have READONLY access to the same database. With CADDB, a system database, as described in Chapter 3.2, is provided. This database contains data required by each ASTROS job.

5. An improvement over GINO allows existing records or columns of unstructured and matrix entities to be rewritten without destroying any other data in the entity.

6. "Garbage-collection" of freed blocks is handled automatically by the database. The dump and restore requirement of some databases, such as RIM, is eliminated.

7. The concept of projections has been added to all relational entity access calls. This allows application codes to process only those attributes needed for each entry of the relation. This allows a new attribute to be added to a relation without impacting previously coded modules not requiring the new attribute.

8.1.3. Memory Requirements

As discussed in the introduction to this section, trade-offs in design between memory and I/O performance were generally made in favor of I/O. In this subsection, the general memory requirements of CADDB are summarized. The equations below use the following symbols:

I	the index block file size in words
D	the data file block size in words
E	the number of entities on all open databases
P	the number of physical files in the database
N	the number of attributes for a relation

The following memory is required:

1. For the entity name table: $M_1 = 10E$

2. For each open database: $M_2 = 21 + 6P + I(P+1)$

3. For each open entity without indexing: $M_3 = 40 + D + I$

4. For each open entity with indexing: $M_4 = 40 + D + 31$

5. For each relation, an additional requirement is: $M_5 = 49N$

Using an index file block size of 256 words and a data file block size of 2,048 words, these relations indicate that, for a typical engineering module, the memory requirement would be approximately 4,000 words greater than that required by the NASTRAN GINO system.

This is felt to be a small trade-off for the significant capability enrichment.

8.2. THE GENERAL UTILITIES

There are nine general CADDB utility routines as shown below:

SUBROUTINE	FUNCTION
DBCREA	Creates a database entity
DBOPEN	Opens a database entity prior to I/O
DBRENA	Renames a database entity
DBEQUV	Equivalences two entity names
DBSWCH	Interchanges the names of two entities
DBDEST	Destroys, or removes, an entity and all of its data from the database
DBFLSH	Removes the data contents of an entity
DBCLOS	Terminates I/O for an entity
DBEXIS	Checks for existence of an entity
DBNEMP	Checks for existence of data in an entity

General Utilities are those which apply to any entity type. Two additional general data utilities are **DBINIT** and **DBTERM**. These are system level modules and are presented in Chapter 4.

Creating a New Entity.

To create a new database entity, the routine **DBCREA** is used. This utility enters the new entity name and its type into the database directory. Although there are three entity classes, there are two options for both matrix and unstructured entities, indexed or unindexed. Typical calls to create the three entities pictured in Subsection 8.1 could be:

```
CALL DBCREA ('GRID', 'REL')
CALL DBCREA ('STUF', 'IUN')
CALL DBCREA ('MATX', 'MAT')
```

The ASTROS executive system automatically creates all database entities that are declared in the MAPOL program. An application programmer usually creates only scratch entities within a given module.

Accessing Entities.

Prior to adding new data, modifying existing data or accessing old data for an entity, the entity must be opened, and when I/O is completed it must be closed. This is done to allow optional use of memory resources as discussed in Subsection 8.1. Using the examples as before, I/O is initiated by the calls:

```
CALL DBOPEN ('GRID', INFO, 'R/W', 'FLUSH', ISTAT)
CALL DBOPEN ('STUFF', INFO, 'RO', 'NOFLUSH', ISTAT)
CALL DBOPEN ('MAXT', INFO, 'R/W', 'FLUSH', ISTAT)
```

The array **INFO** is very important. It contains 20 words that provide information about the data contents of the entity, such as the number of attributes and entries in a relation, the number of records in an unstructured entity and the number of columns in a matrix. The first 10 words of **INFO** are used by the database. The programmer may use the second 10 words for any purpose desired. The **INFO** array is then updated when the entity is closed. As an option, access to an entity may request that the data contents of the entity be destroyed, or **FLUSH**ed, when opening it.

When all activity is completed for a given entity, it must be closed to free memory used for I/O. This is done with a call such as:

```
CALL DBCLOS ('GRID')
```

8.3.THE USE OF eBASE

With Version 13 of ASTROS, UAI replaced the internal CADDB database with eBASE, a more advanced system developed by UAI for UAI/NASTRAN and other products. While most of the ASTROS code still uses the CADDB Applications Programming Interface described here, some of the new additions use eBASE directly.

Database General Utility Module: DBCLOS

Entry Point: DBCLOS

Purpose:

To terminate I/O from a specified database entity.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBCLOS ( ENTNAM )
```

ENTNAM The name of the entity (Character, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database General Utility Module: DBCREA

Entry Point: DBCREA

Purpose:

To create a new data entity.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBCREA ( ENTNAM, TYPE )
```

ENTNAM	The name of the entity (Character, Input)	
TYPE	The entity type (Character, Input)	
	'REL'	Relation
	'MAT'	Matrix
	'IMAT'	Indexed matrix
	'UN'	Unstructured
	'IUN'	Indexed unstructured

Method:

None

Design Requirements:

None

Error Conditions:

None

Database General Utility Module: DBDEST

Entry Point: DBDEST

Purpose:

To destroy a database entity, removing all data from the database files and the entity name from the list of entities.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBDEST ( ENTNAM )
```

ENTNAM The name of the entity (Character, Input)

Method:

None

Design Requirements:

1. **ENTNAM** may not be open.

Error Conditions:

None

Database General Utility Module: DBEQUV

Entry Point: DBEQUV

Purpose:

To equivalence two entity names to point to the same data. After a **DBEQUV** operation, the two names are synonymous. The only way to break an established equivalence is to destroy one of the entities which destroys the equivalences along with the entity and its data.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBEQUV ( NAME1, NAME2 )
```

NAME1	Name of currently existing entity (Character, Input)
NAME2	Name to be made equivalent to **NAME1** (Character, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database General Utility Module: DBEXIS

Entry Point: DBEXIS

Purpose:

To determine if a given entity already exists on the database.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBEXIS ( ENTNAM, EXIST, ITYPE )
```

ENTNAM The name of the entity (Character, Input)

EXIST Status of the entity (Integer, Output)

- **0** does not exist
- **1** exists

ITYPE The entity type (Integer, Output)

- **0** undefined entity
- **1** relation
- **2** matrix
- **3** indexed matrix
- **4** unstructured
- **5** indexed unstructured

Method:

None

Design Requirements:

None

Error Conditions:

None

Database General Utility Module: DBFLSH

Entry Point: DBFLSH

Purpose:

To delete, or flush all of the data from a database entity. The entity itself remains in existence, but is empty.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBFLSH ( ENTNAM )
```

ENTNAM The name of the entity (Character, Input)

Method:

None

Design Requirements:

1. **ENTNAM** may not open.

Error Conditions:

None

Database General Utility Module: DBNEMP

Entry Point: DBNEMP

Purpose:

To return a logical TRUE or FALSE depending on whether an entity has entries, records or columns (TRUE) or if it is nonexistent or empty (FALSE).

MAPOL Calling Sequence:

None

Application Calling Sequence:

DBNEMP (ENTNAM)

ENTNAM The name of the entity (Character, Input)

Method:

DBNEMP is a LOGICAL FUNCTION that returns **TRUE** if and only if the named **ENTNAM** exists and contains entries if relational, columns if matrix or records if unstructured. Any other condition returns a **FALSE**.

Design Requirements:

1. **ENTNAM** may not open.

Error Conditions:

None

Database General Utility Module: DBOPEN

Entry Point: DBOPEN

Purpose:

To open a database entity for subsequent I/O operations.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBOPEN ( ENTNAM, INFO, RW, FLUSH, ISTAT )
```

ENTNAM The name of the entity (Character, Input)

INFO Array of length 20 words containing entity information (Integer, Output)

INFO	RELATION	MATRIX	UNSTRUCTURED
1	**TYPE**	**TYPE**	**TYPE**
2	**NATTR**	**NCOL**	**NREC**
3	**NENTRY**	**NROW**	**MAX REC LEN** in words
4	—	**PREC**	—
5	—	**DEN*100**	—
6	—	**FORM**	—
7	—	Maximum number of nonzero terms in any column	—
8	—	Maximum number of strings in column	—
9	—	Maximum length of a string	—
10	—	—	—
DEN is measured in percent ranging from 0.0 to 100.0			

Type Codes (TYPE) are:	
1	**REL**
2	**MAT**
3	**IMAT**
4	**UN**
5	**IUN**

Form Codes (FORM) are:	
1	rectangular
2	symmetric
3	diagonal
4	identity
5	square

Precision Codes (PREC) are:	
1	real, single-precision
2	real, double-precision
3	complex, single-precision
4	complex, double-precision

RW Type of access (Character, Input)
'R/W' Read/Write access
'RO' Read only access

FLUSH Flush option (Character, Input)
'FLUSH' flush entity on open
'NOFLUSH' do not flush entity on open

ISTAT Return status (Integer, Output)
0 entity opened
101 entity does not exist

Method:

None

Design Requirements:

1. The **INFO** array is loaded on the call to **DBOPEN** and not subsequently modified. The programmer may use the second 10 words for any purpose. **DBCLOS** will write the current **INFO** data to the database.
2. Multiple open entities must not share **INFO** array locations. Care must be taken not to modify the first 10 words within the application.

Error Conditions:

None

Database General Utility Module: DBRENA

Entry Point: DBRENA

Purpose:

To rename a database entity.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBRENA ( OLDNAM, NEWNAM )
```

OLDNAM Existing entity name (Character, Input)

NEWNAM New entity name (Character, Input)

Method:

None

Design Requirements:

1. The entity may be open.

Error Conditions:

None

Database General Utility Module: DBSWCH

Entry Point: DBSWCH

Purpose:

To switch the names of two database entities.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL DBSWCH ( NAME1 , NAME2 )
```

NAME1	Name of first entity (Character, Input)
NAME2	Name of second entity (Character, Input)

Method:

None

Design Requirements:

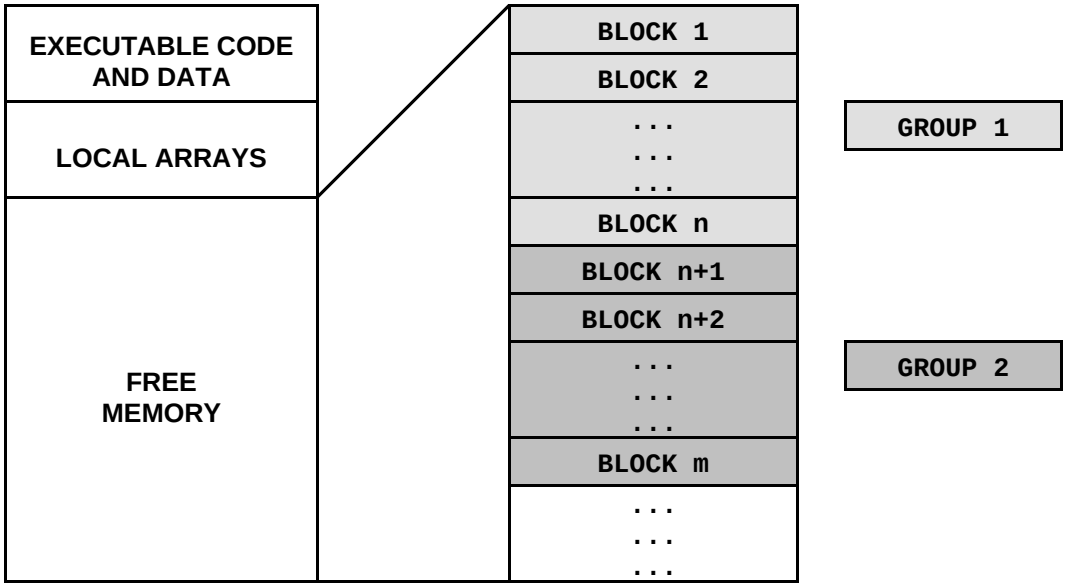
None

Error Conditions:

None

8.4. THE DYNAMIC MEMORY MANAGER UTILITIES

The dynamic memory manager (DMM) is a group of utility routines that allow the applications programmer to work with open-ended arrays in memory. This is important for two reasons. The first is that memory is not wasted by fixed length FORTRAN arrays. The second reason is to allow algorithms to use spill-logic. Spill-logic is code that can perform operations on only that portion of the required data that fits in memory at a given time. Free memory, (that beyond the fixed code and data areas) may be organized into any number of blocks, and groups of blocks, as shown below:



This dynamic memory area can be viewed as a type of virtual memory those paging is under control of the programmer. Static memory languages, such as FORTRAN, are very inefficient users of memory. The DMM can eliminate some of this inefficiency. As an example, consider a routine to perform the matrix addition

$$[A] + [B] = [C]$$

defined by the equations

$$C_{ij} = A_{ij} + B_{ij}$$

Three possible implementations are shown, all based on the assumption that the available memory, after all other components of the program are loaded, is 30,000 words.

The Classical FORTRAN Approach.

The classical brute-force FORTRAN solution to this problem is to see that 3 arrays each dimensions 100 by 100 will fit perfectly in the available memory. The routine is duly coded as:

```
      DIMENSION A (100, 100), B (100, 100), C (100, 100)
C
C  ASSUME THE MATRICES ARE ALL N*M
C
      DO 200 I=1, N
            DO 100 J=1, M
                C(I,J) = A(I,J) + B(I,J)
100         CONTINUE
200   CONTINUE
```

With this algorithm, the matrix sizes are fixed at 100 by 100. If the matrices are only 3 by 3, 99 plus percent of the memory is wasted. Further, although a 20 by 500 matrix would occupy the same 10,000 words, it cannot fit into the predefined array. This latter problem can easily be fixed by storing the matrix in a singly dimensioned array of 10,000, which already implies the programmer must manage the array.

By using the dynamic memory manager both problems shown in the last section disappear. Consider the code segment:

```
      COMMON/MEMORY/ Z (1)
C
C  ALLOCATE MEMORY FOR EACH MATRIX
C
      CALL MMBASE ( Z )
      CALL MMGETB ( 'AMAT', 'RSP', N*M, 'MAXT', IA, ISTAT )
      CALL MMGETB ( 'BMAT', 'RSP', N*M, 'MAXT', IB, ISTAT )
      CALL MMGETB ( 'CMAT', 'RSP', N*M, 'MAXT', IC, ISTAT )
      DO 100 I = 1, N*M
            II = I - 1
            Z ( IC + II ) = Z ( IA + II ) + Z ( IB + II )
100         CONTINUE
```

This code allows all 30,000 words of memory to be used regardless of the shape of the matrices. Additionally, it uses exactly the memory required if the operation is smaller than the available memory.

The Spill-logic Approach.

Spill-logic can be implemented in a number of ways using the matrix utilities described in Subsection 8.4. When spill-logic is used, only those portions of the matrices involved in an operation are brought into memory. Operations are then performed and intermediate or final results stored on the database. With this coding technique, problems of virtually unlimited size may be addressed. There are nine DMM utilities that may be used by an application programmer. Each routine is prefixed with the letters MM. A summary of these routines is shown below.

SUBROUTINE	FUNCTION
MMBASE **MMBASC**	Used by each module to define the location of the memory base address
MMDUMP	Prints a table of allocated memory blocks
MMFREE **MMFREG**	Frees allocated memory by individual blocks or by groups of blocks
MMGETB	Gets a block of memory of the specified type and length
MMREDU	Reduces the size of a block
MMSQUZ	Compresses memory I/O areas
MMSTAT	Returns the maximum contiguous memory that is available to the module

Database Memory Manager Utility Module: MMBASC

Entry Point: MMBASC

Purpose:

To define the base address of dynamic memory that contains character data.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MMBASC ( ARAY, LEN )
```

ARAY	The name of a character array from which memory pointers will be measured
LEN	The length of the character string elements in **ARAY**

Method:

None

Design Requirements:

1. Only one call to **MMBASC** may be made in a module.

Error Conditions:

None

NoneDatabase Memory Manager Utility Module: MMBASE

Entry Point: MMBASE

Purpose:

To define the base address of dynamic memory of reference to an array.

MAPOL Calling Sequence:

None

Application Calling Sequence:

CALL MMBASE (ARAY)

ARAY The name of an array from which memory pointers will be measured

Method:

None

Design Requirements:

1. This routine must be the first called in each module that uses the memory manager.
2. It cannot be used for memory containing character data (see **MMBASC**).

Error Conditions:

None

Database Memory Manager Utility Module: MMDUMP

Entry Point: MMDUMP

Purpose:

To print a formatted table of allocated memory blocks to the output file.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MMDUMP
```

Method:

None

Design Requirements:

1. The utility assumes the **MMINIT** has been called to initialize the open core memory block.
2. In some cases of corrupted memory, the use of this routine may result in an infinite loop.

Error Conditions:

None

Database Memory Manager Utility Module: MMFREE

Entry Point: MMFREE

Purpose:

To free a memory block for subsequent use.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MMFREE ( BLK )
```

BLK	Name of block to be freed (Character, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Memory Manager Utility Module: MMFREG

Entry Point: MMFREG

Purpose:

To

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MMFREG ( GRP )
```

GRP	Name of the group of blocks to be freed (Character, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Memory Manager Utility Module: MMGETB

Entry Point: MMGETB

Purpose:

To allocate a block of dynamic memory.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MMGETB ( BLK, TYPE, LEN, GRP, IPNT, ISTAT )
```

BLK The name assigned to this memory block

If the block name is blank, the block is a special unnamed memory block in that it can only be freed with a **MMFREG** call and **MMREDU** calls are not allowed for the block. (Character, Input)

TYPE The data type of the memory block: (Character, Input)

'RSP'	real, single-precision or integer
'RDP'	real, double-precision
'CSP'	complex, single-precision
'CDP'	complex, double-precision
'CHAR'	character

LEN Length of block measured in the units of **TYPE** (Integer, Input)

GRP Name defining a group to which this block belongs (Character, Input)

IPNT Pointer to the allocated block of memory referenced to the base location (Integer, Output)

ISTAT Status return

0	memory successfully allocated
101	insufficient memory available

Method:

None

Design Requirements:

1. The **BLK** and **GRP** names are truncated to a length of four characters. Thus, the names should be unique for these characters.

Error Conditions:

1. Attempt to allocate a memory block of zero length.
2. Attempt to allocate a duplicate block/group name.

Database Memory Manager Utility Module: MMREDU

Entry Point: MMREDU

Purpose:

To reduce the size of a memory block that is larger than needed.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MMREDU    ( BLK, TYPE, LENGTH )
```

BLK The name assigned to this memory block (Character, Input)

TYPE The data type of the memory block: (Character, Input)

'RSP'	real, single-precision or integer
'RDP'	real, double-precision
'CSP'	complex, single-precision
'CDP'	complex, double-precision
'CHAR'	character

LENGTH Length to be freed measured in units of **TYPE** (Integer, Input)

Method:

None

Design Requirements:

None

Error Conditions:

1. Attempt to reduce memory block to zero length.

Database Memory Manager Utility Module: MMSQUZ

Entry Point: MMSQUZ

Purpose:

To squeeze, or compress, any unused I/O buffer space used by the database.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MMSQUZ
```

Method:

None

Design Requirements:

1. This routine should not be used within an application routine, it is an executive memory management function.

Error Conditions:

None

Database Memory Manager Utility Module: MMSTAT

Entry Point: MMSTAT

Purpose:

To determine the maximum number of contiguous single-precision words available for dynamic allocation.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MMSTST ( CONTIG )
```

CONTIG	The maximum number of contiguous single-precision words available (Integer, Output)

Method:

None

Design Requirements:

None

Error Conditions:

None

8.5. UTILITIES FOR MATRIX ENTITIES

The matrix entity utilities are designed to provide a number of different methods for accessing complete columns, portions of columns, or single terms of a matrix. The use of these various methods depends on the source of data defining the matrix and the intensity of the computational algorithm. The routines available are:

SUBROUTINE	FUNCTION
MXINIT	Initializes a matrix entity for I/O
MXFORM	Change the form of a matrix
MXPOS	Positions to a specified matrix column
MXRPOS	
MXNPOS	
MXSTAT	Gets matrix column information
MXPAK	Packs a column of a matrix
MXUNP	Unpacks a column of a matrix
MXPKTI	Packs a column of a matrix either term-by-term or by partial column
MXPKT	
MXPKTM	
MXPKTF	
MXUPTI	Unpacks a column of a matrix either term-by-term or by partial column
MXUPT	
MXUPTM	
MXUPTF	

8.5.1. Creating a Matrix.

After a matrix entity has been created it must be initialized before it can be used. The **MXINIT** call provides information required for the storing of data into the matrix. For example, to create and initialize a matrix entity for a real, single-precision, symmetric matrix with 1,000 rows the following code is required:

```
INTEGER INFO (20)
CALL DBCREA ('KGG', 'MAT')
CALL DBOPEN ('KGG', INFO,'R/W', 'FLUSH', ISTAT)
CALL MXINIT ('KGG', 1000, 'RSP', 'SYM')
```

Whenever a matrix is flushed, with either a **DBOPEN** or a **DBFLSH** call, the initialization data are cleared. Therefore, an **MXINIT** call is required before reusing the matrix in this case. Similarly, if a matrix entity is going to be redefined, it must be flushed before a new **MXINIT** call may be made.

8.5.2. Packing and Unpacking a Matrix by Columns.

The simplest method to process a matrix is with the full column routines **MXPAK** and **MXUNP**. Each of these routines may process either a full column or a portion of a column. In either case, only one call is allowed for each column. The subsequent call will process the next column. The following code illustrates the packing and unpacking of matrix by columns:

```
C
C        PACK MATRIX BY COLUMNS
C
         DO 100 ICOL = 1, NCOL
             CALL MXPAK ('KGG', COLDTA(1,ICOL),1,1000)
100      CONTINUE
C
C        UNPACK MATRIX BY COLUMNS
C
         CALL MXPOS ('KGG',1)
         DO 200 ICOL = 1, NCOL
             CALL MXUNP ('KGG', DATA(1,ICOL),1,1000)
200      CONTINUE
```

8.5.3. Obtaining Matrix Column Statistics.

The **MXPAK** routine removes any zero terms in the column to reduce the amount of disk space required to store the matrix. Consecutive nonzero terms are stored in strings. Whenever a zero term is encountered, the current string is terminated and a new string is started. The **MXSTAT** routine may be used to obtain statistics about each column. The following code gives an example of how this information can be used to unpack only those terms between the first and last nonzero terms.

```
         DO 100 ICL = 1, NCOL
             CALL MXSTAT ('KGG', COLID, FNZ, LNZ, NZT, DEN, NSTR)
             CALL MXUNP ('KGG', DATA, FNZ, LNZ-FNZ + 1)
100      CONTINUE
```

8.5.4. Packing and Unpacking a Matrix by Terms.

A matrix can also be processed by individual terms. To pack a matrix termwise requires a series of calls for each column. The first call must be a column initialization call, followed by a series of calls to pack single terms and, finally, a column termination call. The following code shows the packing of an individual matrix column by terms:

```
C
C        INITIALIZE TERM-WISE PACKING
C
         CALL MXPKTI ('KGG', IKGG)
C
C        READ MATRIX TERM AND PACK
C
100      READ (5, *, END=200) IROW, VAL
         CALL MXPKT (IKGG, VAL, IROW)
         GO TO 100
C
C        TERMINATE COLUMN
C
200      CALL MXPKTF ('KGG')
```

Note that the termwise packing must be done in ascending row order.

A similar set of calls is required to unpack a matrix by terms. The **MXSTAT** routine is used to determine the number of nonzero terms that exist in the column. The following code will unpack and print the nonzero terms for a matrix column.

```
C        DETERMINE NUMBER OF TERMS
C
C
         CALL MXSTAT ('KGG', COLID, FNZ, LNZ, NZT, DEN, NSTR)
C
C        START UNPACKING THE MATRIX COLUMN
C
         CALL MXUPTI ('KGG', IKGG)
         DO 100 ITERM=1, NZT
             CALL MXUPT (IKGG, VAL, IROW)
             WRITE (6,*) 'ROW=', IROW, 'TERM=',VAL
100      CONTINUE
C
C
C
         CALL MXUPTF ('KGG')
```

It is not required that each term in the column be unpacked. If any terms are left, the **MXUPTF** routine will ignore them and position the matrix to the next column.

8.5.5. Packing and Unpacking a Matrix by Strings.

As explained earlier, matrix data are actually stored in strings of terms with intervening zero terms compressed. A series of routines is provided to allow matrices to be accessed by strings. The use of these routines is similar to the termwise routines in that there is a column initialization call, a call for each string, and a column termination call. The following code shows the packing of a matrix which contains two strings, the first with five terms and the second with three terms.

```
C
C        INITIALIZE FOR STRING PACKING
C
         CALL MXPKTI ('KGG', IKGG)
C
C        PACK OUT TWO STRINGS
C
         CALL MXPKTM (IKGG, STR1, 10, 5)
         CALL MXPKTM (IKGG, STR2, 20, 3)
C
C        TERMINATE STRING PACKING
C
         CALL MXPKTF ('KGG')
```

Packing a column by strings differs in several respects from packing by columns. First, more than one **MXPKTM** call is allowed for each column. With **MXPAK** only one call per column is allowed. Secondly, no compression of zero terms is done within a string. This feature can be used to insure that certain terms of a matrix are stored, even if zero, so they can later be rewritten randomly.

The unpacking of a matrix by strings is shown in the following code example. Note the use of the **MXSTAT** routine to determine the number of strings stored in the column.

```
C
C        DETERMINE THE NUMBER OF STRINGS
C
         CALL MXSTAT ('KGG', COLID, FNZ, LNZ, NZT, DEN, NSTR)
C
C        UNPACK COLUMN BY STRINGS
C
         CALL MXPKTI ('KGG', IKGG)

         DO 100 I=1, NSTR
             CALL MXUPTM ('KGG', VALS, IROW, NROW)
             WRITE (6,*) 'TERMS FROM ROW', IROW, 'TO ROW',
        * IROW+NROW-1, 'ARE', (VALS (I), I=1,NROW)
100      CONTINUE
C
C        TERMINATE COLUMN UNPACKING
C
         CALL MXUPTF ('KGG')
```

It is important that **MXSTAT** be used to determine the number of strings in a column because, under several conditions, the number may be different from the number of strings packed. First, if the string

packed does not fit in the current buffer, it will be automatically split over two buffers. Secondly, if two strings are packed consecutively, they will be automatically merged into one string in the buffer.

8.5.6. Matrix Positioning.

Several routines are provided to position a matrix randomly to a given column. This operation can be done on either indexed, **IMAT**, or unindexed matrices, but the presence of an index speeds up the processing greatly. The following code shows the use of these routines to randomly read three matrix columns.

```
C
C        POSITION TO COLUMN 10 AND UNPACK
C
         CALL MXPOS ('KGG', 10)
         CALL MXUNP ('KGG', DATA, 1, 1000)
C
C        POSITION FORWARD 5 COLUMNS
C
         CALL MXRPOS ('KGG', +5)
         CALL MXUNP ('KGG', DATA , 1, 1000)
C
C        POSITION TO NEXT NONNULL COLUMN
C
         CALL MXNPOS ('KGG', ICOL)
         CALL MXUNP ('KGG', DATA, 1, 1000)
```

The first **MXUNP** retrieves the data for column 10 and leaves the matrix positioned at the start of column 11. The **MXRPOS** call positions the matrix forward five columns to column 16. The second **MXUNP** call then retrieves the data for column 16. The results of the **MXNPOS** call depend on the data stored in the matrix. If column 17 has nonzero terms, it will be positioned there. If column 17 is null, the matrix will be positioned forward until a nonnull column is found. Note that both **MXPOS** and **MXRPOS** require that the column to which the matrix is positioned exists. The **MXNPOS**, utility is the more general in that it determines the next column that exists. Null matrix columns can be packed in two ways. The following code gives examples which are quite different in that the first example creates a column with no nonzero terms while the second example creates a null column which does not exist.

```
C
C        CREATE A COLUMN OF ZEROS WITH MXPAK
C
         CALL MXPAK ('KGG', 0.0,1,1)
C
C        CREATE NULL COLUMN
C
         CALL MXPKTI ('KGG', IKGG)
         CALL MXPKTF ('KGG')
```

8.5.7. Missing Matrix Columns.

For extremely sparse matrices it is possible to pack only the columns which contain data. This feature can greatly reduce disk space requirements for these matrices because space is not wasted for column headers and trailers. It also simplifies coding because it is not required to pack null columns. The following example shows the packing of an extremely sparse matrix which contains only two items.

```
C
C        PACK DIAGONAL TERM IN COLUMN 100
C
         CALL MXPOS ('KGG', 100)
         CALL MXPAK ('KGG', 1.0,100,1)
C
C        PACK DIAGONAL TERM IN COLUMN 500
C
         CALL MXPOS ('KGG', 500)
         CALL MXPAK ('KGG', 1.0,100,1)
```

When a matrix does not have all its columns stored, care must be used when unpacking it. Since the routines only operate on columns physically stored in the matrix only two sets of calls are required to unpack the matrix.

The following code example shows one method of unpacking this matrix.

```
C
C        UNPACK TWO MATRIX COLUMNS
C
         DO 100 ICOL = 1,2
             CALL MXSTAT ('KGG', COLID, FNZ,LNZ,NZT,DEN,NSTR)
             WRITE (6,*) 'DATA FOR COLUMN', COLID
             CALL MXUNP ('KGG', DATA,1,1000)
100      CONTINUE
```

This example illustrates a disadvantage. The code must know the exact number of columns stored in the matrix. There is no method provided to determine this. The next example shows how **MXNPOS** can be used to produce a code sequence that will work no matter how many physical columns are stored in the matrix.

```
C
C        POSITION TO NEXT COLUMN
C
100      CALL MXNPOS ('KGG',ICOL)
         IF ( ICOL.GT.0 ) THEN
             WRITE (6,*) 'DATA FOR COL', ICOL
             CALL MXUNP ('KGG', DATA,1,1000)
             GO TO 100
         ENDIF
```

The **MXPOS** and **MXRPOS** utilities should be used with extreme caution if the matrix does not contain all physical columns. These routines work on actual column numbers and will cause fatal errors if the column does not exist. For example, an **MXPOS** to column 200 will cause an error because the column is

not stored in the matrix. If the matrix is positioned at column 100, an **MXRPOS** of +100 will also fail because column 200 is not stored in the matrix.

8.5.8. Repacking a Matrix.

Once a matrix has been packed, it is possible to rewrite certain columns of the matrix without disturbing the data stored in any other columns. The only restriction is that the topology of the matrix terms cannot change. For example, if **MXPAK** was used to pack the column, all zero terms are compressed. Since these terms are not physically stored in the matrix, they cannot at a later time be replaced by a nonzero term. This can be avoided by using the termwise or stringwise calls, which perform no zero compression. The following example shows the packing of a matrix column and the subsequent repacking of it.

```
C
C        PACK COLUMN 1 OF MATRIX
C
         CALL MXPOS ('KGG',1)
         CALL MXPKTI ('KGG', IKGG)
         CALL MXPKTM (IKGG, STR, 10,10)
         CALL MXPKTF ('KGG')
C
C        READ COLUMN 1 OF MATRIX
C
         CALL MXPOS ('KGG',1)
         CALL MXPKTI ('KGG', IKGG)
         CALL MXPKTM (IKGG, DATA,IROW,NROW)
         CALL MXPKTF ('KGG')
C
C        DOUBLE EACH NUMBER IN THE STRING
C
         DO 100 I=1, NROW
             DATA (I)=DATA (I) * 2.0
100      CONTINUE
C
C        REPLACE THE STRING
C
         CALL MXPOS ('KGG',1)
         CALL MXPKTI ('KGG', IKGG)
         CALL MXPKTM (IKGG, DATA,IROW,NROW)
         CALL MXPKTF ('KGG')
```

All the matrix pack utility calls, i.e., column, term and string, may be used to repack matrix columns.

Database Matrix Utility Module: MXFORM

Entry Point: MXFORM

Purpose:

To change the form of a matrix entity.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXFORM ( NAME, FORM )
```

NAME	The matrix name (Character, Input)	
FORM	The new matrix form (Character, Input)	
	'REC'	Rectangular
	'SYM'	Symmetric
	'DIAG'	Diagonal
	'INDENT'	Identity
	'SQUARE'	Square

Method:

None

Design Requirements:

1. **MXFORM** may be called any time after the creation of the matrix.

Error Conditions:

1. Illegal **FORM** value; error **MXFORM01**.

Database Matrix Utility Module: MXINIT

Entry Point: MXINIT

Purpose:

To initialize a matrix prior to writing data.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXINIT ( MATNAM, NROW, PREC, FORM )
```

MATNAM	Name of matrix (Character, Input)	
NROW	Number of rows (Integer, Input)	
PREC	The precision of the matrix (Character, Input)	
	'RSP'	real, single-precision or integer
	'RDP'	real, double-precision
	'CSP'	complex, single-precision
	'CDP'	complex, double-precision
FORM	Form of the matrix (Character, Input)	
	'REC'	Rectangular
	'SYM'	Symmetric
	'DIAG'	Diagonal
	'INDENT'	Identity
	'SQUARE'	Square

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Matrix Utility Module: MXNPOS

Entry Point: MXNPOS

Purpose:

To position a matrix to the next nonnull column.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXNPOS ( MATNAM, ICOL )
```

MATNAM	Name of matrix (Character, Input)
ICOL	Column number positioned to (Integer, Output)

Method:

None

Design Requirements:

1. If there are no more nonnull columns in the matrix, **ICOL** is set to zero

Error Conditions:

None

Database Matrix Utility Module: MXPAK

Entry Point: MXPAK

Purpose:

To pack all , or a portion, of a matrix and then to move to the next column.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXPAK ( MATNAM, ARAY, ROW1, NROW )
```

MATNAM	Name of matrix to be packed (Character, Input)
ARAY	Array containing data to be packed (Any type, Input)
ROW1	First row position in column (Integer, Input)
NROW	Number of rows to pack (Integer, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Matrix Utility Module: MXPKT

Entry Point: MXPKT

Purpose:

To pack a column of a matrix one term at a time.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXPKT     ( UNITID, VAL, IROW )
```

UNITID	Unit identification from **MXPKTI** call (Integer, Input)
VAL	The value to be packed (Any type, Input)
IROW	The row position of the term. **IROW** must be positive and greater than the value in any previous **MXPKT** call for the current column (Integer, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Matrix Utility Module: MXPKTF

Entry Point: MXPKTF

Purpose:

To terminate the termwise or partial packing of a matrix column.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXPKTF ( MATNAM )
```

MATNAM	Name of the matrix being packed (Character, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Matrix Utility Module: MXPKTI

Entry Point: MXPKTI

Purpose:

To initialize a matrix column for term-by-term or partial packing.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXPKTI ( MATNAM, UNITID )
```

MATNAM	Name of the matrix to be packed (Character, Input)
UNITID	Unit identifier (Integer, Output)

Method:

None

Design Requirements:

1. A matrix may be packed by columns using **MXPAK**, by terms, or by partial columns, but not by any combination.

Error Conditions:

None

Database Matrix Utility Module: MXPKTM

Entry Point: MXPKTM

Purpose:

To pack a column of a matrix using partial columns.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXPKTM ( UNITID, VALARR, ROW1, NROW )
```

UNITID	Unit identifier from **MXPKTI** call (Integer, Input)
VALARR	Array of values to be packed (Any type, Input)
ROW1	Initial row position of **VALARR** (Integer, Input)
NROW	Number of rows to be packed (Integer, Input)

Method:

None

Design Requirements:

1. **ROW1** and **NROW** must be positive.

Error Conditions:

None

Database Matrix Utility Module: MXPOS

Entry Point: MXPOS

Purpose:

To position a matrix to a specified column.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXPOS ( MATNAM, COL )
```

MATNAM	Name of the matrix (Character, Input)
COL	Column number (Input, Integer)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Matrix Utility Module: MXRPOS

Entry Point: MXRPOS

Purpose:

To position a matrix to a column by specifying the column increment relative to the current column.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXPOS ( MATNAM, DELCOL )
```

MATNAM	Name of the matrix (Character, Input)
DELCOL	Column number increment (Integer, Input)

Method:

None

Design Requirements:

1. Positive **DELCOL** positions forward, negative position backward from current column.

Error Conditions:

None

Database Matrix Utility Module: MXSTAT

Entry Point: MXSTAT

Purpose:

To obtain status information for the current column.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXSTAT ( MATNAM, COLID, FNZ, LNZ, NZT, DEN, NSTR )
```

MATNAM	Name of the matrix (Character, Input)
COLID	Current column number (Integer, Output)
FNZ	First nonzero row in column(Integer, Output)
LNZ	Last nonzero row in column (Integer, Output)
NZT	Number of nonzero rows in column (Integer, Output)
DEN	Column density (Real, Output) (**DEN** is a decimal fraction, e.g., 40%=.40)
NSTR	Number of strings in column (Integer, Output)

Method:

None

Design Requirements:

1. Note that for very large matrices, **DEN** is a single-precision number and may be numerically zero even if there are nonzero terms in the matrix.

Error Conditions:

None

Database Matrix Utility Module: MXUNP

Entry Point: MXUNP

Purpose:

To unpack all, or a portion, of a matrix column and then to move to the next column.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXUNP ( MATNAM, ARRAY, ROW1, NROW )
```

MATNAM	Name of the matrix (Character, Input)
ARRAY	Array containing data to be unpacked (Any type, Output)
ROW1	First row position in column (Integer, Input)
NROW	Number of rows to unpack (Integer, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Matrix Utility Module: MXUPT

Entry Point: MXUPT

Purpose:

To unpack a column of a matrix one term at a time.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXUPT ( UNITID, VAL, IROW )
```

UNITID	Unit identification from **MXUPTI** call (Integer, Input)
VAL	The value of the term (Any type, Output)
IROW	The row position of the term (Integer, Output)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Matrix Utility Module: MXUPTF

Entry Point: MXUPTF

Purpose:

To terminate the termwise or partial unpacking of a matrix column.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXUPTF ( MATNAM )
```

MATNAM	Name of the matrix being unpacked (Character, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Matrix Utility Module: MXUPTI

Entry Point: MXUPTI

Purpose:

To initialize a matrix column for term-by-term or partial unpacking.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXUPTI ( MATNAM, UNITID )
```

MATNAM	Name of the matrix (Character, Input)
UNITID	Unit identifier (Integer, Output)

Method:

None

Design Requirements:

1. A matrix may be unpacked by columns using **MXUNP**, by term, or by partial columns, using **MXUPT** and **MXUPTM**, but not by any combination.

Error Conditions:

None

Database Matrix Utility Module: MXUPTM

Entry Point: MXUPTM

Purpose:

To unpack partial columns of a matrix.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL MXUPTM ( UNITID, VALARR, ROW1, NROW )
```

UNITID	Unit identifier from **MXUPTI** call (Integer, Input)
VALARR	Array that will contain the unpacked rows (Any type, Output)
ROW1	Initial row position being unpacked (Integer, Output)
NROW	Number of rows being unpacked (Integer, Output)

Method:

None

Design Requirements:

None

Error Conditions:

None

8.6. UTILITIES FOR RELATIONAL ENTITIES

Relational database entities are used to save highly structured data that will be accessed and modified in a random manner. Utilities to operate on relations are summarized below:

SUBROUTINE	FUNCTION
RESCHM	Defines the schema of a relation
REPROJ	Defines the projection of the relation prior to I/O activity
REQURY	Queries the schema of a relation
REGET	Gets, or fetches, a qualified entry from a relation
REGETM	
REUPD	Updates the current entry of a relation
REUPDM	
READD	Adds a new entry to a relation
READDM	
REPOS	Positions a relation to an entry
RECPOS	Checks for existence of a given entry
RECOND	Defines constraints or **WHERE** conditions for the relation
RESETC	
REENDC	
RENULD	Checks if an attribute has a **NULL** value
RENULI	
RENULR	
RENULS	
RECLRC	Clears conditions defined for a relation
REGB	Gets, or fetches, all of the qualified entries from a relation
REGBM	
REAB	Adds a group of entries to a relation
REABM	
RESORT	Sorts the entries of a relation

8.6.1. Examples of Relational Entity Utilities.

This subsection provides specific examples of operating with relations. Particular attention should be given the use of double-precision data attributes. Special routines are provided for such attributes when used by themselves or when "mixed" with other data types.

8.6.2. Creating a Relation.

A relational entity has both a name and a schema. The schema defines the attributes of a relation and their data types. Therefore, a call to the **RESCHM** routine is required in addition to a **DBCREA** call in order to complete the creation of a relational entity. For example, to create relation **GRID** (shown in the introduction to Section 8), the following code is required:

```
C
C        DEFINE ATTRIBUTES TYPES, AND LENGTHS
C
   CHARACTER *8      GATTR (4)
   CHARACTER *8      GTYPE (4)
   INTEGER           GLEN (4)
   DATA GATTR / 'GID', 'X', 'Y', 'Z'/
   DATA GTYPE / 'KINT', 'RSP', 'RSP','RSP' /
   DATA GLEN / 0,0,0,0 /
C
C  CREATE A RELATION AND SCHEMA
C
   CALL DBCREA ( 'GRID' , 'REL')
   CALL RESCHM ('GRID', 4, GATTR, GTYPE, GLEN )
```

The schema is specified by attribute name and data type. Various data types are available. In the example, the grid **ID**, **GID**, is called a keyed integer (**KINT**). This causes an index structure to be created that will allow fast direct access to a given entry. The coordinate values **X**, **Y**, and **Z** are defined as real, single-precision (**RSP**). The length parameters (**GLEN**) are only used for character attributes and for arrays of integers or real numbers. An array of values would be used if the overall data organization is relational but some groups of values are only used on an all-or-nothing basis.

8.6.3. Loading Relational Data.

Once a relation has been created it may be loaded with data. There are two modes of adding data: one entry at a time, or a "blast" add wherein the entire relation, or a large part of it, has been accumulated in memory. For each mode, there are two options, one when none of the attributes are real, double-precision, and a second if one or more attributes are real, double-precision. Using the relation **GRID**, the example below indicates how it could be loaded on an entry-by-entry basis.

```
C
C         ALLOCATE BUFFER AREA FOR ENTRIES AND INFO
C
          INTEGER IBUF (4), INFO (20)
C
C         USE EQUIVALENCES TO HANDLE REAL DATA
C
          EQUIVALENCE (IGID, IBUF (1)), (X, IBUF (2) )
          EQUIVALENCE (y, IBUF (3)), (Z, IBUF (4) )
C
C         DEFINE THE PROJECTION AS THE FULL RELATION
C
          CHARACTER *8 PATTR (4)
          DATA PATTR / 'GID', 'X', 'Y', 'Z'/
C
C         OPEN THE ENTITY FOR I/O
C
          CALL DBOPEN ('GRID', INFO, 'R/W', 'FLUSH', ISTAT)
          CALL REPROJ ('GRID', 4, PATTR)
C
C         READ AN ENTRY FROM INPUT, ADD TO RELATION
C
          DO 100 I=1, IEND
              READ (5, 101) IGID, X,Y,Z
              CALL READD ('GRID', IBUF)
100       CONTINUE
C
C
C
          CALL DBCLOS ('GRID')
```

Space must first be allocated to contain an entire entry of the relation. This buffer must be of a specific type so that equivalences must be used if the attributes are of mixed data types. The projection of the relation must be defined (via **REPROJ**) even if all attributes are being selected. If the data had been stored in memory first, the **READ** routine could have been used to "blast" all of the entries into the relation with a single call.

8.6.4. Accessing a Relation

A relation is accessed by a set of four routines: **REGET**, **REGETM**, **REGB**, and **REGBM**. Several other routines now come into play. The first are **REPOS** and **RECPOS**. These routines are used to find an entry within a relation whose key is equal to a specific value. The second is the group of routines **RECOND**, **RESETC**, **REENDC**, and **RECLRC**. These allow the specification of more complex "where" clauses that are used to qualify an entry of the relation.

As an example, suppose that the X, Y, and Z coordinates are to be retrieved for a grid point whose **GID** is 1. The code segment below could be used to perform this:

```
C
C        ALLOCATE BUFFER – ALL OUTPUT IS REAL
C
         DIMENSION COORDS (3), INFO (20)
C
C        DEFINE THE PROJECTION
C
         CHARACTER *8 PATTR (3)
         DATA PATTR / 'X', 'Y', 'Z'/
C
C        OPEN THE ENTITY FOR I/O
C
         CALL DBOPEN ('GRID', INFO, 'R/W', 'NOFLUSH', ISTAT)
         CALL REPROJ ('GRID', 3, PATTR)
C
C        POSITION TO THE DESIRED ENTRY
C
         CALL REPOS ('GRID', 'GID', 1)
C
C        GET THE ENTRY
C
         CALL REGET ('GRID', COORDS, ISTAT)
```

Note that **GID** must be a keyed attribute to use **REPOS**.

To qualify an entry by more than one attribute, a sequence of an **RECOND** call, any number of **RESETC** calls, and an **REENDC** call can be used. For instance, to find any or all grid points whose coordinates are X=1, Y=2, Z=3, the code segment below could be used:

```
    CALL RECOND ('GRID', 'X', 'EQ', 1.0)
    CALL RESETC ('AND', 'Y', 'EQ', 2.0)
    CALL RESETC ('AND', 'Z', 'EQ', 3.0)
    CALL REENDC
    CALL REGET ('GRID', BUF, ISTAT)
```

Each call to **REGET** will retrieve an entry that satisfies the specified conditions. An **ISTAT** value greater than zero indicates the end of successful retrievals. Conditions may include any of the relational operators, the **MAX** and **MIN** selectors and the Boolean operators **AND** and **OR**. If one of either **MIN** or **MAX** issued, however, it is the only condition allowed. To reset a new set of conditions on an open relational entity, the utility **RECLRC** may be called to destroy the current conditions.

8.6.5. Updating a Relational entry.

One of the most powerful features of the relational database is the ability to randomly modify a small number of data items efficiently. To do this, the utilities **REDUPD** and **REDUPM** are used. The update procedure is a simple one. First, the projection is set. This is followed by positioning to a row or rows by specifying a **REPOS**, **RECPOS** or an **RECOND**. Routine **REGET** is then used to fetch the entry. One or more of

attributes may then be modified in the buffer and an **REDUP** used to accomplish the update. Note that attributes not in the projection, and attributes not modified in the buffer, will remain unchanged.

8.6.6. Other Operations.

If it is necessary for an application to determine the schema of a given relation, this may be done with the utility **REQURY**. This routine returns the names and types of each attribute in the schema. Finally, a relation may be sorted in an ascending or descending manner on one or more of its attributes by using the utility **RESORT**.

Database Relational Utility Module: REAB

Entry Point: REAB

Purpose:

To add multiple entries, held in memory, to a specified relation.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL REAB ( RELNAM, BUF, INUM )
```

RELNAM	Name of the relation (Character, Input)
BUF	Array that contains the entries to be added to the relation (Any, Input)
INUM	The number of entries to be added (Integer, Input)

Method:

None

Design Requirements:

1. Only integer, real single-precision, or string attributes may be added with this routine.

Error Conditions:

None

Database Relational Utility Module: REABM

Entry Point: REABM

Purpose:

To add multiple entries, held in memory, to a specified relation where the relational attributes are double-precision, or mixed precision, types.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL REABM ( RELNAM, SNGL, DBLE, INUM )
```

RELNAM	Name of the relation (Character, Input)
SNGL	Array that contains the single-precision (Integer, Real, Single-Precision, or String) attributes to be added (Any, Input)
DBLE	Array that contains the double-precision attributes to be added (Double, Input)
INUM	The number of entries to be added (Integer, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Relational Utility Module: READD

Entry Point: READD

Purpose:

To add a new entry to a relation.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL READD ( RELNAM, BUF )
```

RELNAM	Name of the relation (Character, Input)
BUF	Array that contains the entries to be added to the relation (Any, Input)

Method:

None

Design Requirements:

1. Only integer, single-precision, or string attributes may be added with this routine.

Error Conditions:

None

Database Relational Utility Module: READDM

Entry Point: READDM

Purpose:

To add a new entry to a relation that contains double-precision, or mixed precision, attributes.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL READMM ( RELNAM, SNGL, DBLE )
```

RELNAM	Name of the relation (Character, Input)
SNGL	Array that contains the single-precision entry data (Any, Input)
DBLE	Array that contains the double-precision entry data (Double, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Relational Utility Module: RECLRC

Entry Point: RECLRC

Purpose:

To clear the conditions set on a relational entity without performing a **DBCLOS**.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL RECLRC ( ENTNAM )
```

ENTNAM	The name of the relational entity (Character, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Relational Utility Module: RECOND

Entry Point: RECOND

Purpose:

To define a condition, or constraint, for a relational attribute prior to performing a get operation (see also **RESETC**).

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL RECOND ( RELNAM, ATTRNAM, RELOP, VAL )
```

RELNAM	Name of the relation (Character, Input)
ATTRNAM	Name of the attribute (Character, Input)
RELOP	The relational operator for the constraint; one of **'EQ'**, **'NE'**, **'GT'**, **'LT'**, **'GE'**, **'LE'**, **'MAX'**, **'MIN'** (Character, Input)
VAL	The value to be tested (Any, Input)

Method:

None

Design Requirements:

1. **VAL** must be the same type as the **ATTRNAM**. All **RELOP**s are legal for attributes of type **'INT'**, **'KINT'**, **'RSP'**, and **'RDP'**. Only **'EQ'** and **'NE'** are valid for attribute types **'STR'** and **'KSTR'**. Attribute types of **'AINT'**, **'ARSP'**, and **'ARDP'** may not be used in a condition. Also, for attributes of type **'STR'** or **'KSTR'**, their length must be 8 or fewer characters. Note that string attribute values are passed as hollerith data.
2. Any **RECOND** call removes any existing conditions, that is, it performs an **RECLRC** internally.

Error Conditions:

None

Database Relational Utility Module: RECP0S

Entry Point: RECP0S

Purpose:

To position to a specific entry and return the row number, if present.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL RECP0S ( RELNAM, KEY, VAL, ROWNUM )
```

RELNAM	Name of the relation (Character, Input)
KEY	Name of a keyed attribute (Character, Input)
VAL	The desired value of the keyed attribute (Integer, Input)
ROWNUM	The row number satisfying the condition. If zero, no entries were found (Integer, Output)

Method:

None

Design Requirements:

1. If the **KEY** is a character attribute, it must be of length eight and **VAL** must contain the hollerith representation of the desired value. The conversion from character to hollerith must be made with the **DBMDCH** routine.

Error Conditions:

None

Database Relational Utility Module: REENDC

Entry Point: REENDC

Purpose:

To end the definition for a relational entity.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL REENDC
```

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Relational Utility Module: REGB

Entry Point: REGB

Purpose:

To fetch all of the entries of the requested relation that satisfy the specified projection and constraints (see also **REGBM**).

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL REGB ( RELNAM, BUF, INUM, ISTAT )
```

RELNAM	Name of the relation (Character, Input)
BUF	Array that will contain the entries (Any, Output)
INUM	The number of entries fetched (Integer, Output)
ISTAT	Status return (Integer, Output) **0** entries successfully fetched **201** no entries found

Method:

None

Design Requirements:

1. Only integer or real, single-precision or string attributes may be fetched with this routine.

Error Conditions:

None

Database Relational Utility Module: REGBM

Entry Point: REGBM

Purpose:

To fetch all of the entries of the requested relation that satisfy the specified projection and constraints and that contain double-precision, or mixed precision attributes.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL REGBM ( RELNAM, SNGL, DBLE, INUM, ISTAT )
```

RELNAM	Name of the relation (Character, Input)
SNGL	Array that will contain single-precision entry data (Integer, Real Single-precision, or String, Output)
DBLE	Array that will contain double-precision entry data (Double, Output)
INUM	The number of entries fetched (Integer, Output)
ISTAT	Status return (Integer, Output) **0** entries successfully fetched **201** no entries found

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Relational Utility Module: REGET

Entry Point: REGET

Purpose:

To fetch an entry of a relation that satisfies the given projection and constraint conditions.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL REGET ( RELNAM, BUF, ISTAT )
```

RELNAM	Name of the relation (Character, Input)
BUF	Array that will contain the entry data (Any, Output)
ISTAT	Status return (Integer, Output) **0** entries successfully fetched **201** no entries found

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Relational Utility Module: REGETM

Entry Point: REGETM

Purpose:

To fetch an entry of a relation that satisfies the given projection and constraint conditions, and that contains double-precision, or mixed precision attributes.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL REGETM ( RELNAM, SNGL, DBLE, ISTAT )
```

RELNAM	Name of the relation (Character, Input)
SNGL	Array that will contain single-precision entry data (Integer, Real Single-precision, or String) (Any, Output)
DBLE	Array that will contain double-precision entry data (Double, Output)
ISTAT	Status return (Integer, Output) **0** entries successfully fetched **201** no entries found

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Relational Utility Module: RENULx

Entry Points: RENULD, RENULI, RENULR, RENULS

Purpose:

To check if a double-precision, integer, real, or character attribute has a null value. Attributes excluded from the projection when a relational entry is added are given such null values.

MAPOL Calling Sequence:

None

Application Calling Sequences:

```
RENULD ( FIELDD )
RENULI ( FIELDI )
RENULR ( FIELDR )
RENULS ( FIELDS )
```

FIELDD	Double precision attribute value (Input)
FIELDI	Integer attribute value (Input)
FIELDR	Real, single-precision attribute value (Input)
FIELDS	String attribute value (Input)
RENULD **RENULI** **RENULR** **RENULS**	Logical values (output) **TRUE** if **FIELDx** is null

Method:

None

Design Requirements:

1. The string attribute, **FIELDS**, must be passed as a hollerith.

Error Conditions:

None

Database Relational Utility Module: REPOS

Entry Point: REPOS

Purpose:

To position a relation to an entry with a given keyed attribute.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL REPOS ( RELNAM, KEY, VAL )
```

RELNAM	Name of the relation (Character, Input)
KEY	Name of a keyed attribute (Character, Input). The special attribute name of **'ENTRYNUM'** with a **VAL=1** may be used to reposition an entity to the beginning.
VAL	The desired value of the keyed attribute (Integer, Input)

Method:

None

Design Requirements:

1. The attribute must be keyed.
2. If **KEY='ENTRYNUM'** then **VAL** must be 1.

Error Conditions:

1. A database fatal error occurs if the requested entry does not exist.

Database Relational Utility Module: REPR0J

Entry Point: REPR0J

Purpose:

To define the projection, or subset of attributes, for the relation prior to performing updates, adds or gets of entries.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL REPR0J ( RELNAM, NATTR, ATTRLIST )
```

RELNAM	Name of the relation (Character, Input)
NATTR	Number of attributes in the projection (Integer, Input)
ATTRLIST	Array containing the attribute names that define the projection (Character, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Relational Utility Module: REQURY

Entry Point: REQURY

Purpose:

To retrieve the schema of a relation.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL REQURY ( RELNAM, NATTR, ATTRLIST, ATTRTYPE, ATTRLEN, TOTLEN )
```

RELNAM	Name of the relation (Character, Input)
NATTR	Number of attributes (Integer, Output)
ATTRLIST	Array containing the attribute names (Character, Output)
ATTRTYPE	Array containing the attribute types (Character, Output) **'INT'** Integer attribute **'KINT'** Keyed integer attribute **'AINT'** Array of integers **'RSP'** Real, single-precision attribute **'ARSP'** Array of single-precision **'RDP'** Real, double-precision attributes **'ARDP'** Array of double-precision **'STR'** String attribute **'KSTR'** Keyed string attribute
ATTRLEN	Array defining the number of elements in an array attribute or the number of characters in a string attribute (Integer, Output)
TOTLEN	Total length of schema in words (Integer, Output)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Relational Utility Module: RESCHM

Entry Point: RESCHM

Purpose:

To define the schema of a relation being created by a functional module.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL RESCHM ( RELNAM, NATTR, ATTRLIST, ATTRTYPE, ATTRLEN )
```

RELNAM Name of the relation (Character, Input)

NATTR Number of attributes (Integer, Input)

ATTRLIST Array containing the attribute names (Character, Input)

ATTRTYPE Array containing the attribute types (Character, Input)

'INT'	Integer attribute
'KINT'	Keyed integer attribute
'AINT'	Array of integers
'RSP'	Real, single-precision attribute
'ARSP'	Array of single-precision
'RDP'	Real, double-precision attributes
'ARDP'	Array of double-precision
'STR'	String attribute
'KSTR'	Keyed string attribute

ATTRLEN Array defining the number of elements in an array attribute or the number of characters in a string attribute (Integer, Input)

Method:

None

Design Requirements:

1. The relation **RELNAM** must not already have a schema defined.
2. Keyed attributes must have uniform values for all rows.
3. No attributes may have the name **'ENTRYNUM'**
4. Attributes of the type **'KSTR'** must have length of 8 or fewer characters.

Error Conditions:

None

Database Relational Utility Module: RESETC

Entry Point: RESETC

Purpose:

To define additional conditions, or constraints, for a relational attribute prior to performing a get operation (see also **RECOND**).

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL RESETC ( BOOL, ATTERNAM, RELOP, VAL )
```

BOOL	The boolean operation **'OR'** or **'AND'** (Character, Input)
ATTRNAM	Name of the attribute (Character, Input)
RELOP	The relational operator for the constraint; one of **'EQ'**, **'NE'**, **'GT'**, **'LT'**, **'GE'**, **'LE'**, **'MAX'**, **'MIN'** (Character, Input)
VAL	The value to be tested (Any, Input)

Method:

None

Design Requirements:

1. **VAL** must be the same type as the **ATTRNAM**. A maximum of 10 conditions may be specified. All **RELOP**s are legal for attributes of type **'INT'**, **'KINT'**, **'RSP'**, and **'RDP'**. Only **'EQ'** and **'NE'** are valid for attribute types **'STR'** and **'KSTR'**. Attribute types of **'AINT'**, **'ARSP'**, and **'ARDP'** may not be used in a condition. Also, for attributes of type **'STR'** or **'KSTR'**, their length must be 8 or fewer characters. Only one condition may have a **'MAX'** or **'MIN' RELOP**. Note that string attribute values are passed as hollerith data.

Error Conditions:

None

Database Relational Utility Module: RESORT

Entry Point: RESORT

Purpose:

To sort a relation on one or more of its attributes.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL RESORT ( RELNAM, NATTR, SORTTYPE, ATTRLIST, KORE )
```

RELNAM	Name of the relation (Character, Input)
NATTR	The number of attributes to be sorted (Integer, Input)
SORTYPE	The type of sort for each attribute (Character, Input) **'ASC'** Ascending **'DES'** Descending
ATTRLIST	A list of the attributes to be sorted (Character, Input)
KORE	Base address of open core (Input)

Method:

None

Design Requirements:

1. The sort sequence is performed in the order that the attributes are specified in **ATTRLIST**.
2. The relation **RELNAM** must be closed when **RESORT** is called.

Error Conditions:

None

Database Relational Utility Module: REUPD

Entry Point: REUPD

Purpose:

To update the current relational entry.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL REUPD ( RELNAM, BUF )
```

RELNAM	Name of the relation (Character, Input)
BUF	Array that contains updated entry data (Any, Input)

Method:

None

Design Requirements:

1. Only integer, single-precision or string attributes may be updated with this routine.

Error Conditions:

None

Database Relational Utility Module: REUPDM

Entry Point: REUPDM

Purpose:

To update the current relational entry that contains double-precision, or mixed precision, attributes.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL REUPDM ( RELNAM, SNGL, DBLE )
```

RELNAM	Name of the relation (Character, Input)
SNGL	Array that contains the single-precision entry data (Any, Input)
DBLE	Array that contains the double-precision entry data (Double, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

8.7. UTILITIES FOR UNSTRUCTURED ENTITIES

Unstructured database entities are used primarily for scratch I/O by modules or for saving data that are generally used on an all-or-nothing basis. That is, random access to anything other than a complete record is not used. The utilities to support this type of data are shown below:

SUBROUTINE	FUNCTION
UNPOS	Positions to a given unstructured record
UNRPOS	
UNSTAT	Returns the length of a record
UNGET	Gets, or fetches, an entire record
UNGETP	Gets, or fetches, a partial record
UNPUT	Adds a new record to the unstructured entity
UNPUTP	Adds a partial record to the entity

8.7.1. Generating an Unstructured Entity

As seen in Subsection 8.2, the first step in generating any entity is to perform a **DBCREA**. This is followed by a **DBOPEN**, any desired I/O activity, and finally a **DBCLOS**. Suppose, for example, the local coordinates X, Y, and Z of 1000 grid points have been computed and are in a block of dynamic memory called **GRID** whose location pointer is **IGRD** (see Section 8.3). Further, assume that these coordinates have also been converted to the basic coordinate system, and that these transformed coordinates are located in block **NGRD** with pointer **IGND**. These data will be used in a subsequent routine or module in their entirety. It will therefore be written into an unstructured entity called **COORD** in two distinct records. The code segment to perform this is shown below:

```
C
C        CREATE THE NEW ENTITY AND OPEN FOR I/O
C
         CALL DBCREA ('COORD', 'IUN')
         CALL DBOPEN ('COORD', INFO, 'R/W', 'FLUSH', ISTAT)
C
C        WRITE THE TWO UNSTRUCTURED RECORDS
C
         CALL UNPUT ('COORD', Z (IGRD), 3000)
         CALL UNPUT ('COORD', Z (IGND), 3000)
C
C        I/O COMPLETE CLOSE ENTITY
C
         CALL DBCLOS ('COORD')
```

The **UNPUT** call loads a complete record into the entity. Therefore, the above operations generate two records in **COORD**. If an operation is being performed "on-the-fly," or complete records do not fit in memory, then a "partial" put, **UNPUTP**, may be performed.

Now assume that the local coordinates are all in memory, but that the transferred coordinates will be generated on a point-by-point basis and written to the **COORD** entity. Subroutine **TRANSF** transforms a set of three local coordinates to basic coordinates stored in a local array **XNEW**. This is illustrated below:

```
C
C        CREATE AND OPEN THE ENTITY
C
         CALL DBCREA ('COORD', 'UN')
         CALL DBOPEN ('COORD', INFO, 'R/W', 'FLUSH', ISTAT)
C
C        FIRST WRITE THE LOCAL COORDINATE
C
         CALL UNPUT ('COORD', Z (IGRD), 3000)
C
C        NEXT, COMPUTE NEW COORDINATES ONE-AT-A-TIME
C
         DO 100 I=0,2999,3
             CALL TRANSF (Z (IGRD+I), XNEW)
             CALL UNPUTP ('COORD', XNEW, 3)
100      CONTINUE
C
C        TERMINATE PARTIAL RECORD AND CLOSE
C
         CALL UNPUT ('COORD', 0,0)
         CALL DBCLOS ('COORD')
```

Note that a record of an unstructured entity that is created by partial puts must be "closed" by a call to **UNPUT**. In this case, the final put operation does not extend the record but only terminates it.

8.7.2. Accessing an Unstructured Entity.

The **UNPUT** and **UNPUTP** utilities have direct analogs in **UNGET** and **UNGETP** for the retrieval of data. Three other utilities are available for data access. The first two, **UNPOS** and **UNRPOS**, allow an unstructured entity to be positioned to a specific record. Note that this access is much faster if the entity was created with an index structure, that is, the **DBCREA** call specified type **'IUN'**. The third utility, **UNSTAT**, is used to find length of a given record. These utilities are demonstrated in the example below. the second record of **COORD** will be accessed and each coordinate set used individually. It is not assumed that the number of grid points is known to this application.

```
C
C        OPEN THE ENTITY, READONLY MODE
C

         CALL DBOPEN ('COORD', INFO, 'RO', 'NOFLUSH', ISTAT)
C
C        NOFLUSH PROTECTS AGAINST DESTROYING THE DATA,
C        NOW, POSITION TO RECORD 2, GET LENGTH OF RECORD
C
         CALL UNPOS ('COORD', 2)
         CALL UNSTAT ('COORD', IREC, LEN)
C
C        LEN IS THE NUMBER OF WORDS IN THE RECORD,
C        FETCH AND USE COORDINATES ONE-AT-A-TIME
C
         NGRID=LEN/3
         DO 100 I=1, NGRID
             CALL UNGETP ('COORD', XNEW, 3)
C
C        USE THE XNEW VALUES HERE
C
100      CONTINUE
C
C        I/O COMPLETE, CLOSE THE ENTITY
C
         CALL DBCLOS ('COORD')
```

8.7.3. Modifying an Unstructured Entity.

It is also possible to modify, or update, the contents of an individual record within an unstructured entity. The only limitation to this feature is that the length of the record must be the same as, or less than, the length of the originally created record.

Database Unstructured Utility Module: UNGET

Entry Point: UNGET

Purpose:

To fetch a complete record from an unstructured entity.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UNGET ( NAME, ARAY, NWORD )
```

NAME	Name of the unstructured entity (Character, Input)
ARAY	Array that will contain the unstructured record (Integer, Output)
NWORD	The number of single-precision words to be transferred (Integer, Input)

Method:

If **NWORD** is less than the total number of words, the remaining data will not be retrieved. **UNGET** positions the entity to the next record after the retrieval.

Design Requirements:

None

Error Conditions:

None

Database Unstructured Utility Module: UNGETP

Entry Point: UNGETP

Purpose:

To fetch a portion of an unstructured record.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UNGETP ( NAME, ARAY, NWORD )
```

NAME	Name of the unstructured entity (Character, Input)
ARAY	Array that will contain the unstructured record (Integer, Output)
NWORD	The number of single-precision words to be transferred (Integer, Input)

Method:

Following the retrieval, the entity is still positioned at the same record, a subsequent **UNGET** or **UNGETP** will get the next words in the record.

Design Requirements:

None

Error Conditions:

None

Database Unstructured Utility Module: UNPOS

Entry Point: UNPOS

Purpose:

To position an unstructured entity to a specific record.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UNPOS ( NAME, RECNO )
```

NAME	Name of the unstructured entity (Character, Input)
RECNO	Record number (Integer, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Unstructured Utility Module: UNPUT

Entry Point: UNPUT

Purpose:

To add a record to an unstructured entity. The record is terminated after the transfer.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UNPUT ( NAME, ARAY, NWORD )
```

NAME	Name of the unstructured entity (Character, Input)
ARAY	Array containing the record to be added (Any, Input)
NWORD	The number of words to be transferred (Integer, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Unstructured Utility Module: UNPUTP

Entry Point: UNPUTP

Purpose:

To add a partial record to an unstructured entity. The record is not terminated after the transfer.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UNPUTP ( NAME, ARAY, NWORD )
```

NAME	Name of the unstructured entity (Character, Input)
ARAY	Array containing the record to be added (Any, Input)
NWORD	The number of words to be transferred (Integer, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Unstructured Utility Module: UNRPOS

Entry Point: UNRPOS

Purpose:

To position an unstructured entity to a specific record defined as an increment from the current record.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UNSTAT ( NAME, DELRID )
```

NAME	Name of the unstructured entity (Character, Input)
DELRID	Record number increment relative to the current position (Integer, Input)

Method:

None

Design Requirements:

None

Error Conditions:

None

Database Unstructured Utility Module: UNSTAT

Entry Point: UNSTAT

Purpose:

To return the length, in single-precision words, of the current record.

MAPOL Calling Sequence:

None

Application Calling Sequence:

```
CALL UNSTAT ( NAME, RECNO, LEN )
```

NAME	Name of the unstructured entity (Character, Input)
RECNO	Current record number (Integer, Output)
LEN	Record length in single-precision words (Integer, Output)

Method:

None

Design Requirements:

None

Error Conditions:

None