VISTA – a 21st Century Testbed

Software Enabled Control Principle Investigators Meeting

November 13-15, 2001

Major Andrew "Rocket" Thurling
USAF Test Pilot School

Mr. Thomas Landers
Veridian Engineering

Outline

- Outline
- VISTA…………
- What is it?
- What has it done?
- How would I use it?
- What can it do for me?

VISTA

- **Variable-stability Inflight Simulator Test Aircraft**
- **Very Highly Modified NF-16D Aircraft**
  - **S/N 86-048**
  - **Block 30 Airframe, Peace Marble II Configuration**
  - **Block 40 DFLCC (Digital Flight Control Computer)**
  - **Block 40 (FMS) Avionics System**
  - **Heavy Weight Landing Gear**
  - ***Variable Stability System (5-DOF Simulator)***

VISTA History

- Removed from F-16 production line late in production for modification
- First flight April 9, 1992
- Four more initial checkout flights in April, 1992
- MATV (Multi-Axis Thrust Vectoring) test bed 1993-1994 (95 flights)
- VSS Test Flights, July 1994 – Jan. 1995 (63 flights)
- Delivered to USAF (Wright-Patterson AFB) in Jan. 1995

VISTA in the MATV Configuration

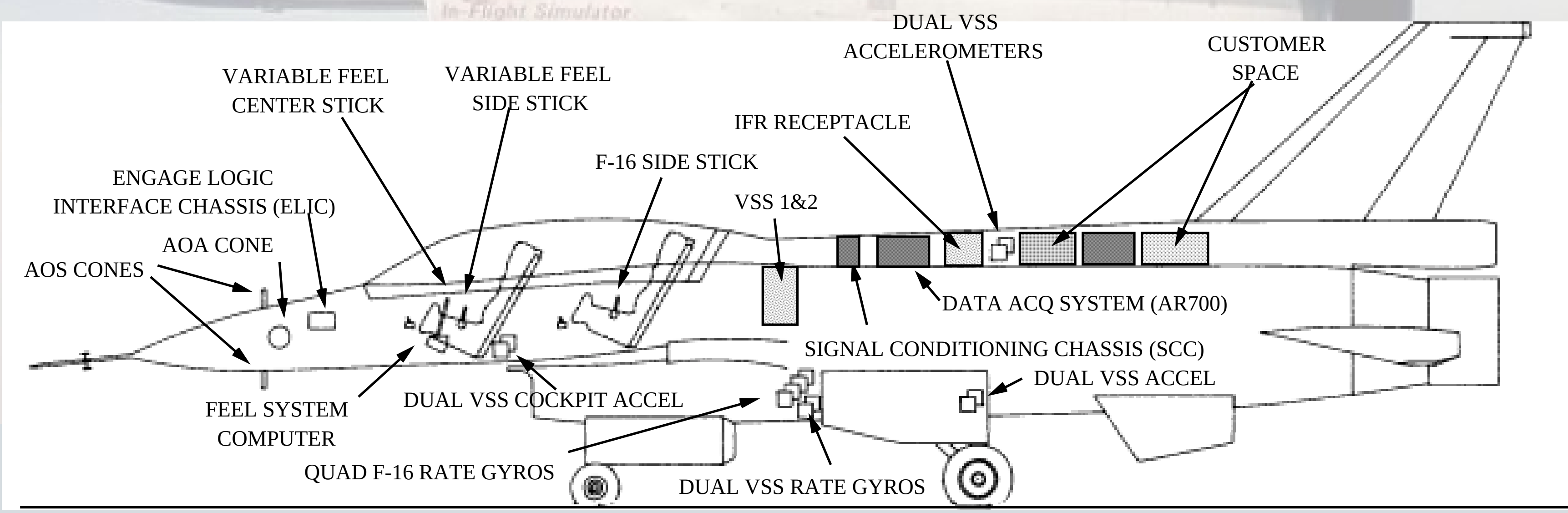
VISTA History (con't)

- Operated by Veridian Engineering (Calspan) since January, 1995 under USAF contract
- July '96 – June '97: P/W-229 engine conversion, along with wiring modification for P/W Thrust Vectoring, HMD system

- October 2000: relocated to USAF TPS (Edwards AFB)

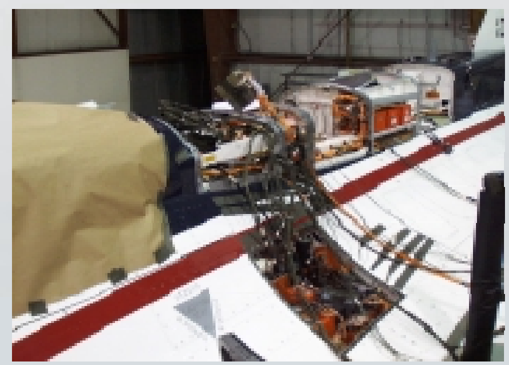
VISTA Equipment Layout

- “Customer” sits in the front cockpit
  - –Minimal F-16 responsibility
- Pilot-in-command sits in the rear cockpit
  - –Has all primary aircraft controls

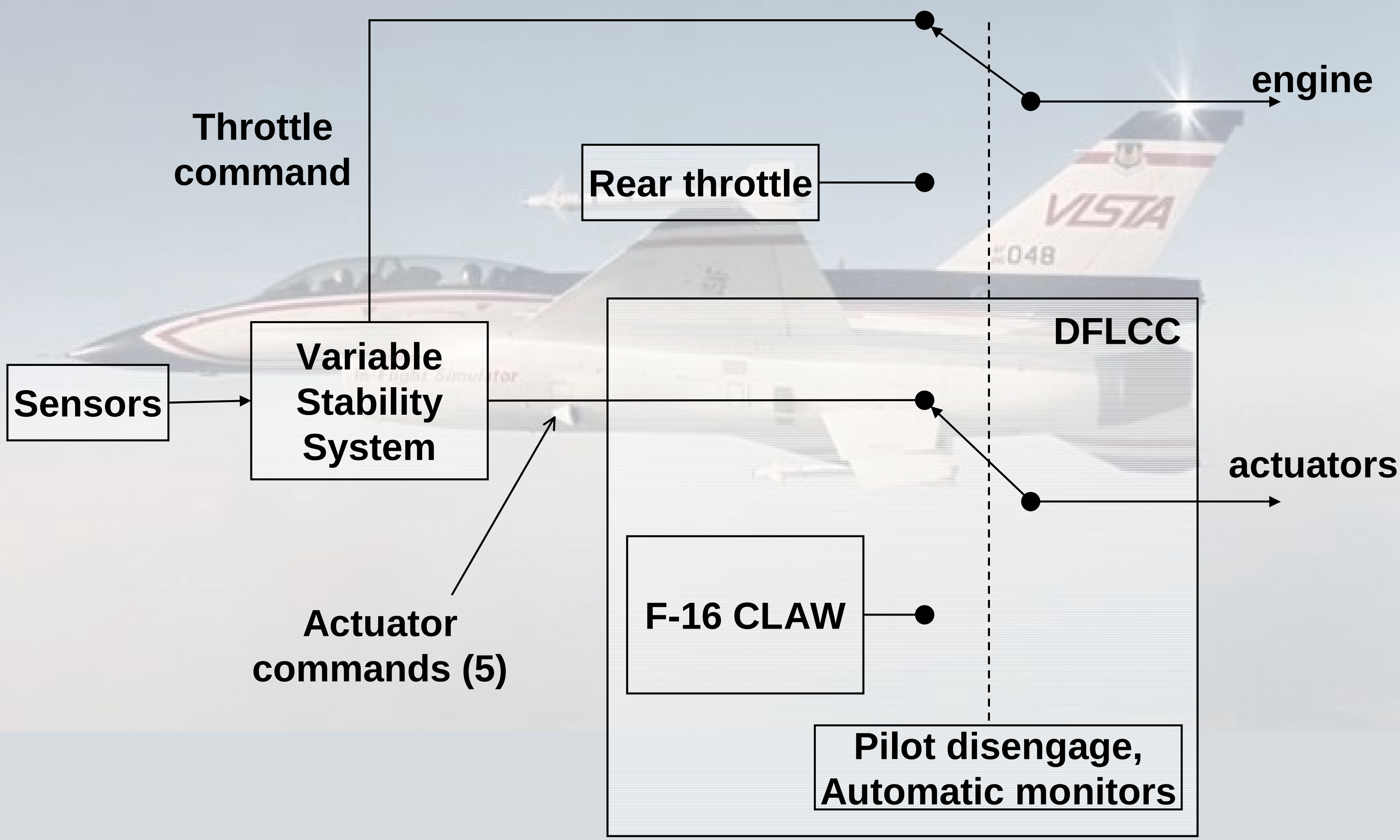


VISTA VSS Computers

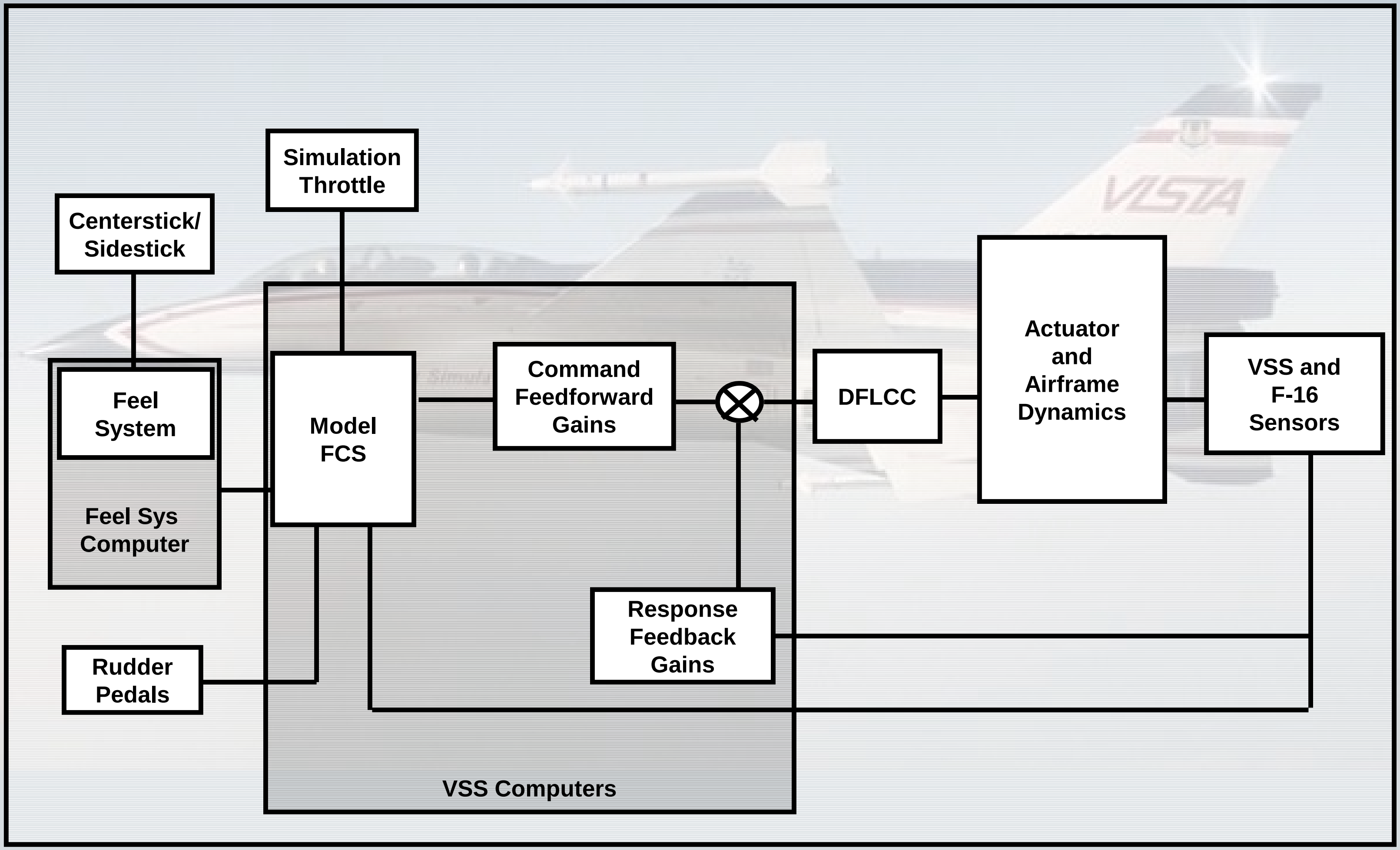
- Full ATR Size 15 Slot Chassis
- VME Open Architecture
- Each Chassis:
  - 233 Mhz Pentium w/512KB Cache
  - 128 MB ECC RAM
  - Analog and discrete I/O
  - 6 Dual Redundant 1553 Bus Interfaces
  - Flash Card Memory (85-330 MB)
  - RS-232, RS-422, SVGA, SCSI-2, Ethernet
- Interfaced to F-16 Core avionics, flight controls, “experimental systems”
- Programmed by Veridian
  - NOT safety of flight critical
  - Reprogramming can be done with a minimal amount of “administrative overhead”
  - Changes can be made in less than one hour (ready to fly!)



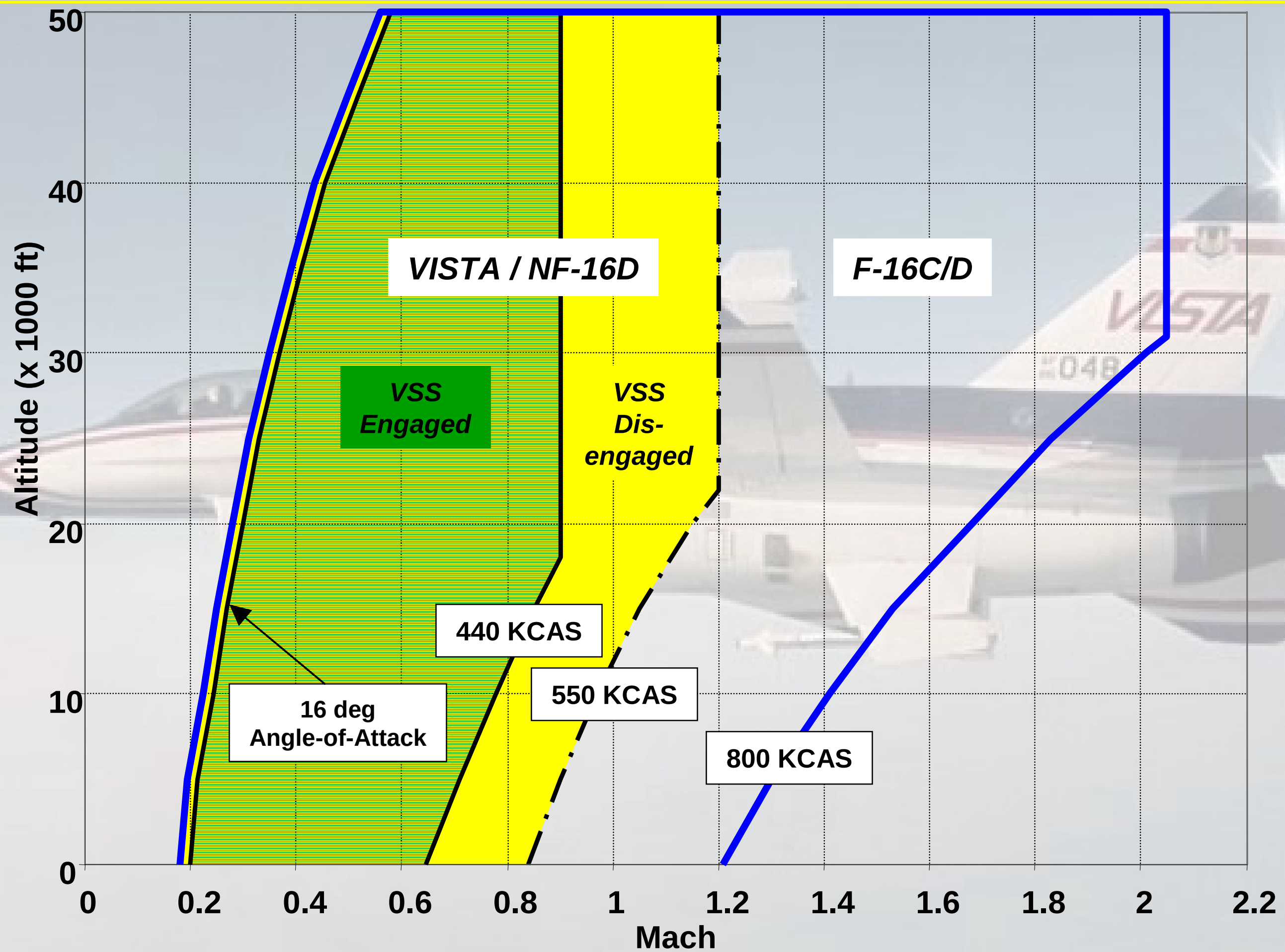
VISTA: Variable Flight Controls



VISTA: Simulation Architecture



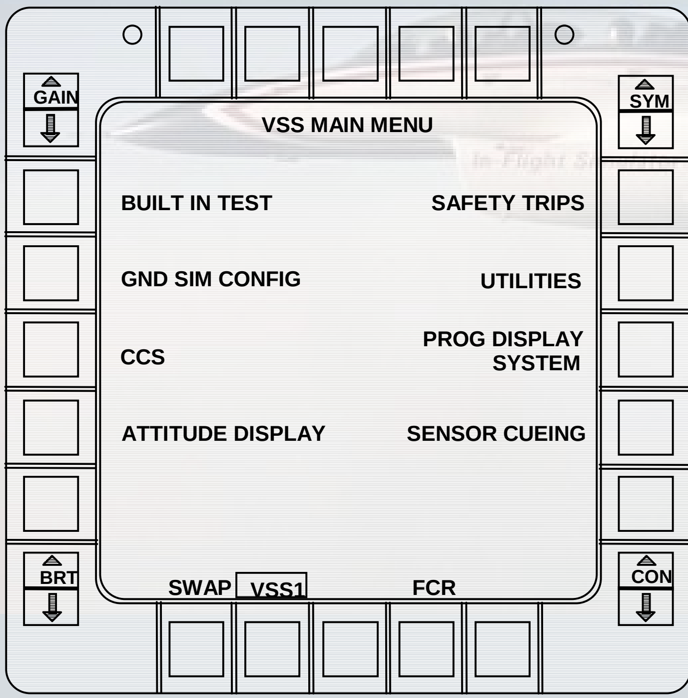
VISTA Flight Envelope

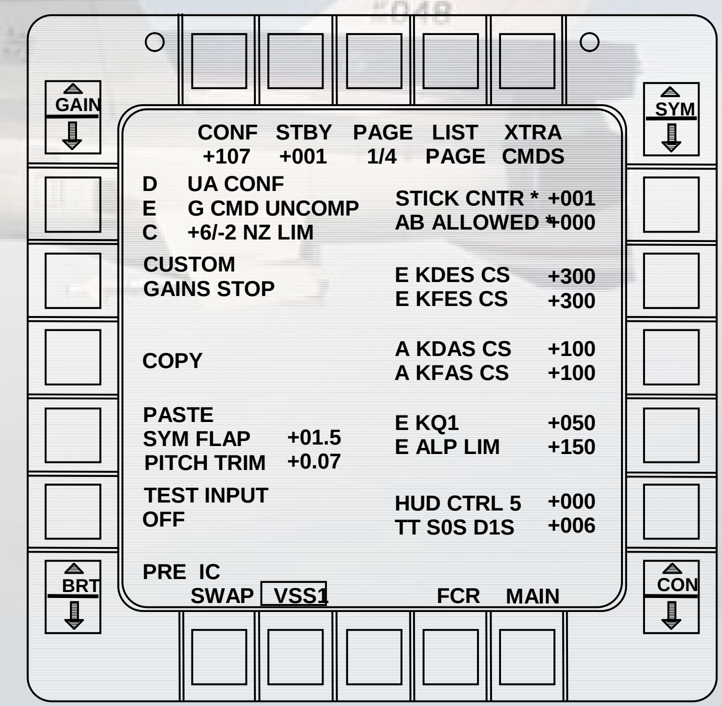


- **VSS operational envelope slightly reduced from basic F-16 (Nz limits are +6.8/-2.44 G's)**

VSS Computer Operation and Control

- **VSS computers are interfaced with the Multi-Function Display System (MFDS) and Up-Front Controller (UFC) to allow the VSS computers to display information and receive keystrokes**
- **This allows test parameters to be varied *in-flight* at the touch of a button**





VISTA - Research Role

- In-flight simulation of flight control system & aircraft combinations
- Basic research in the development of FCS requirements
- F-22, Indian light combat aircraft, AFRL fighter handling qualities projects, self designing controller, LM JSF, X-38

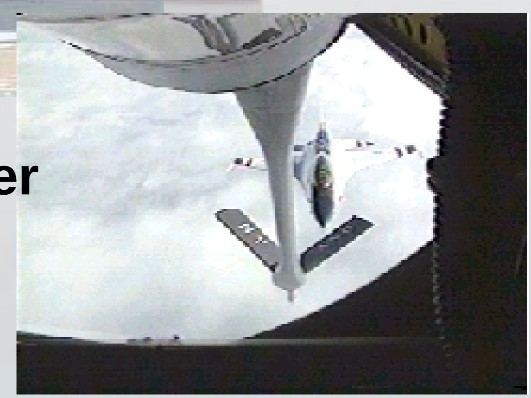

F-22


X-38


LM JSF

VISTA PROGRAMS

- F-22 In-Flight Simulation (Jan-May ’96)
  - –Powered approach evaluations
    (offset approaches to touchdown)
    - Mid weight/Mid CG
    - Light weight/Aft CG
    - Aero uncertainty
    - Single Engine failure
    - Single and Dual Hydraulic failure
  - –Aerial Refueling
    - Simulated in-flight refueling with KC-135 tanker
    - Air to Air tracking with Learjet
    - Formation with Learjet and KC-135



VISTA PROGRAMS

- LCA Simulation (May-July '96)
  - Powered Approach evaluations
    - Heavy weight/Nominal CG
    - Mode transitions
    - Failure modes

  - Formation & Air to Air Tracking
    - Air to Air tracking with Learjet
    - Formation with Learjet and NT-33
    - Mode transitions
    - Air data failure
    - Aero uncertainty

VISTA PROGRAMS

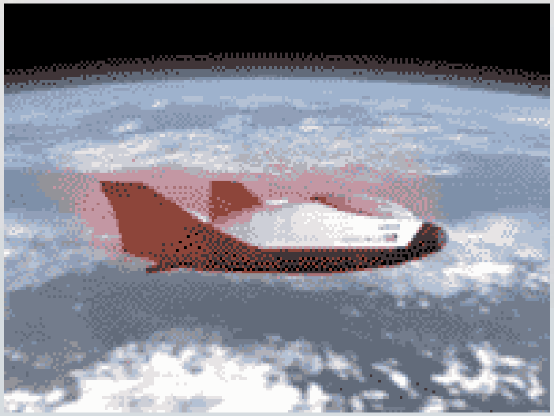
- Self Designing Controller (SDC) (May-July '96)
  - –Demonstrated Real-time Parameter ID with simulated failure
    - Missing one horizontal tail
    - Modified Sequential Least Squares Parameter Estimation
  - –Receding Horizon Optimal Control Law
  - –Handling Qualities adequate for landing with failure

VISTA PROGRAMS

- LM JSF CDA (Mar-Jun '98)
  - Evaluated flying Qualities in PA, AR and UA flight conditions
  - Various flight control options evaluated
  - Clearance of 370 gal ARTS with VISTA
- Evaluation of Landing, AR, UA (formation and A-A)
  - Contractor and Government pilots
  - Conventional and Carrier type with FLOLS approaches (98)
  - Air-to-air tracking & formation with F-18
  - Probe and drogue refueling (no fuel transfer) w/ KC-130

FIRST UAV-CLASS VISTA PROGRAM

- **X-38 CRV IFS (Oct '98)**
  - **First IFS of UAV by VISTA**
  - **IFS performed on V132 Configuration**
  - **Equipped with GN&C**
  - **GN&C -- C Autocode from MatrixX integrated easily with VSS**
  - **Validate performance of aerodynamics and control law prior to V132 flight**
  - **Generate data for comparison with flight tests**
  - **FADS fail performance**
  - **Exercise the VISTA model development path in preparation for V201 (Re-entry vehicle) testing**



WHY VISTA?

- **Use VISTA as closed-loop test bed to minimize risks associated with unknown/unproven control laws**
  - **VISTA provides fewest compromises in conduct of tests**
  - **Minimal modification of aircraft required**
  - **VSS concept allows for rapid prototyping, easy design “tweaks”**
  - **Evaluates complete system**
    - **Dynamics**
    - **GN&C**
    - **Weapons system surrogates**
    - **Up/Down links, if necessary**
  - **Saves $$$**

UAV TESTING

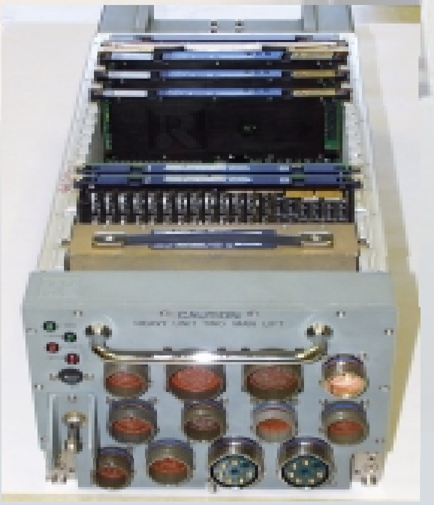
- **VISTA is an ideal test bed for UAVs**
  - **VISTA can represent the L/D and responses typical of UAVs**
  - **Simulates UAV flight profiles (up to and including landing)**
  - **On board safety pilot provides for safe testing**
    - **Failures**
    - **Aero-uncertainty**
    - **Unproven control law strategies/methodologies**
  - **Rapid prototyping allows for proof of concept testing**
    - **Reduced Verification and Validation**
    - **Rapid turn around between software changes**
    - **Customer software development cycle limiting factor**

UAV TESTING

- **Pilot backup allows increased productivity**
  - **–Mission planning errors not program stoppers**
  - **–Increased aggressiveness in envelope expansion**
  - **–Increased aggressiveness in failure mode investigation**
  - **–Mission may be broken into logical segments**
- **Range safety considerations reduced with pilot onboard**
  - **–Flight Termination Systems not required**
  - **–Footprint analysis simplified**
- **Easily integrated with manned aircraft**
  - **–Reduced risk**
  - **–Less interference with manned operations**
  - **–Leads to less resistance to UAV testing**

UAV TESTING

- **Additional equipment space in Dorsal Equipment Bay**
  - **Closed-loop test with hardware-in-the-loop**
  - **Cooling & power available**
  - **VME slots available**
  - **Mounting locations for additional equipment**



UAV SIMULATION

- **VISTA Capable Of Simulating UCAV class Dynamic Responses**
  - **VSS uses VISTA control surfaces to simulate open-loop vehicle dynamics**

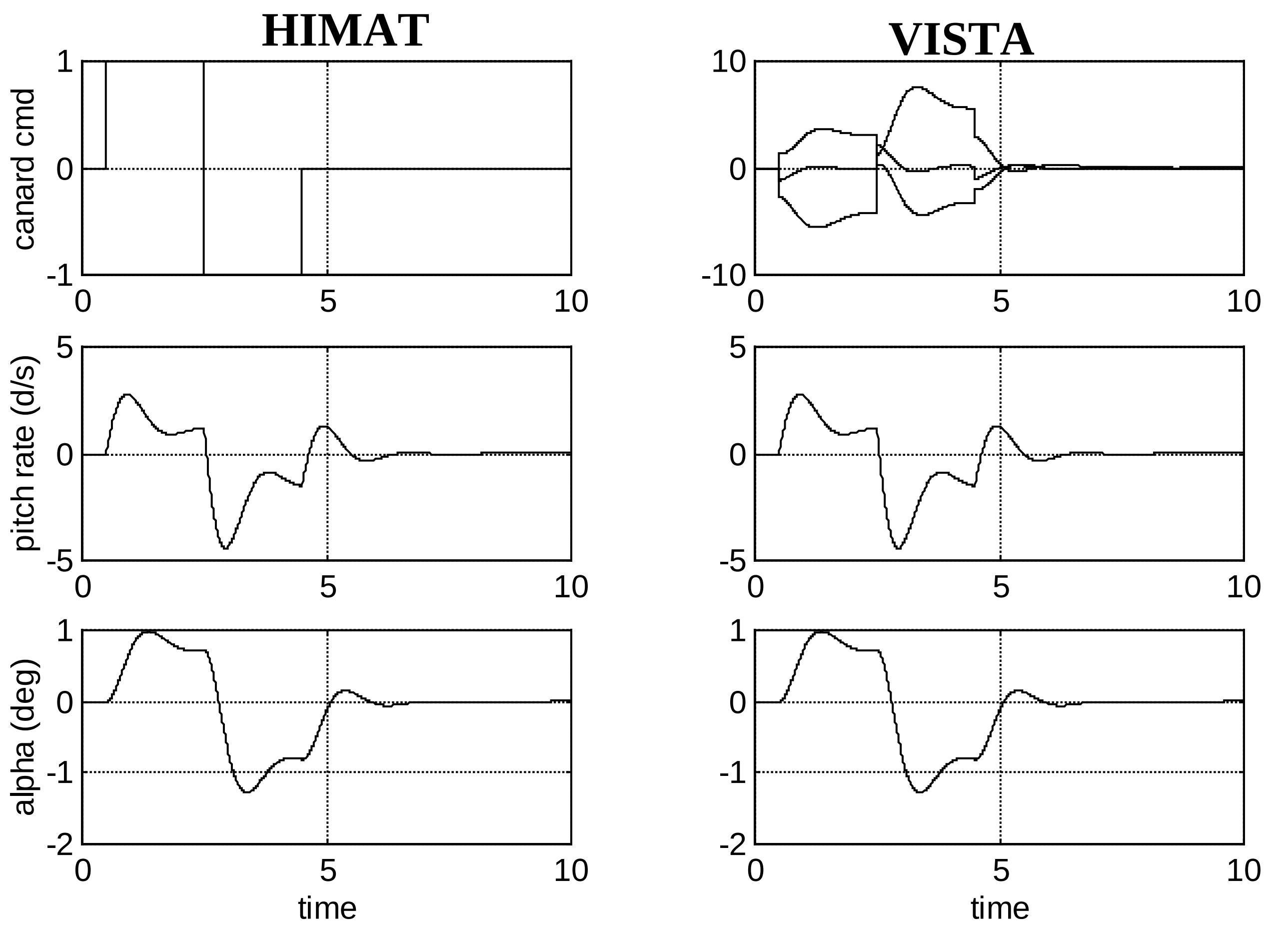
- **HIMAT RPV Simulation Example**
  - **NASA RPV, flight tested circa '79-'81**
  - **Geometric Data**
    - **Wing area 58.0 ft^2**
    - **Span 14.93 ft**
    - **MAC 4.35 ft**
    - **Weight 3163 lbs**
    - **I_{xx}= 436 $slugs\text{-}ft^2$**
    - **I_{yy}= 1593 $slugs\text{-}ft^2$**
    - **I_{zz}= 2013 $slugs\text{-}ft^2$**
    - **I_{xz}= -81.26 $slugs\text{-}ft^2$**

Dryden Flight Research Center ECN 14273 Photographed 1980
HiMat

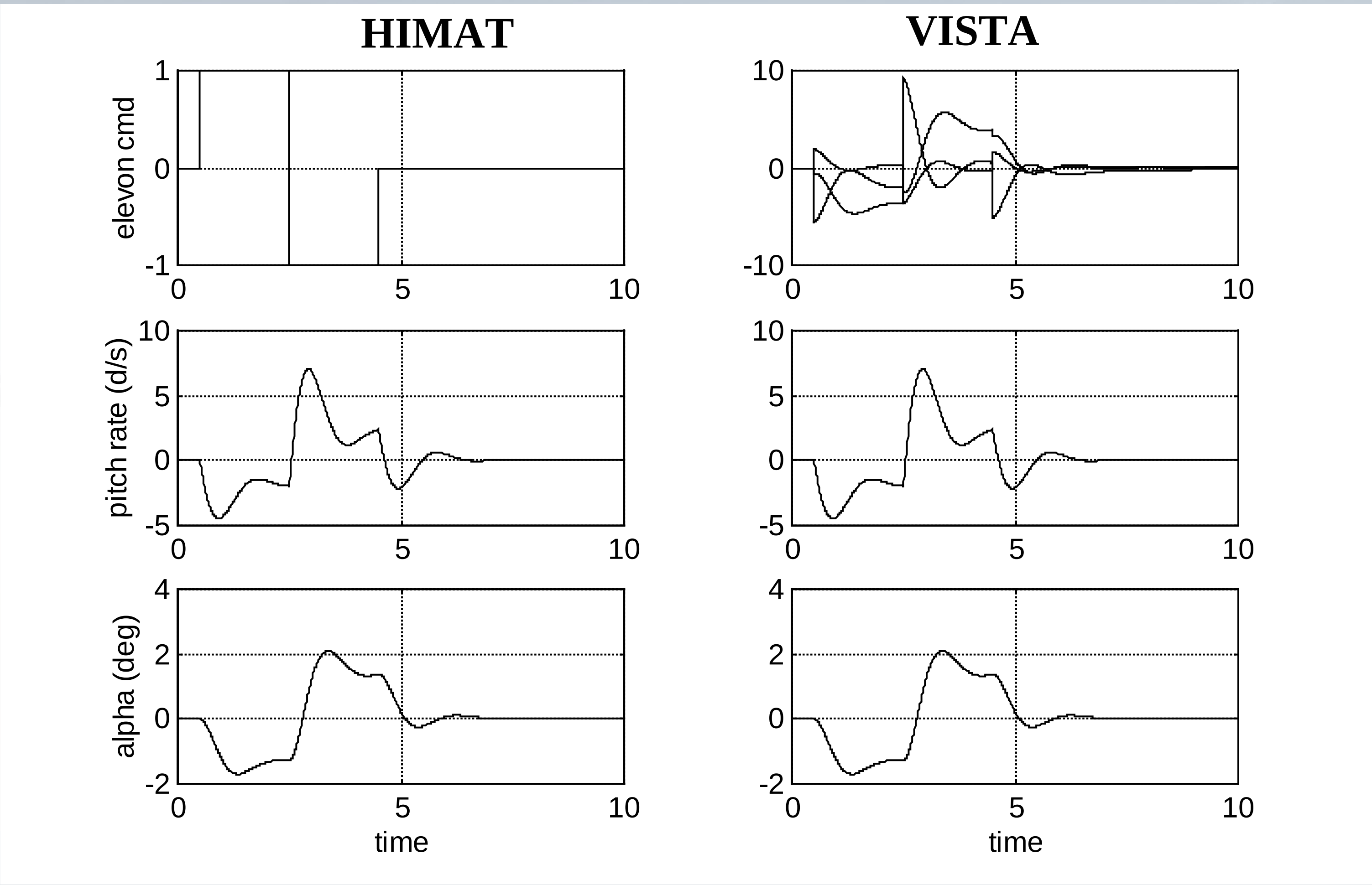
UAV SIMULATION

- Response Feedback Utilized
  - Longitudinal Response Evaluated
  - Elevator, Elevon & Canard inputs
  - M.6/10Kft
  - Open Loop response due to surface inputs examined
  - Model Following allows full envelope simulation, with non-linearities
- Response Feedback Gains
  - Eigenstructure Assignment, Output feedback
  - Pseudo-inverse of VISTA surface effectiveness
  - HIMAT actuator models not used
  - VISTA actuators impact time delay associated with simulating dynamics

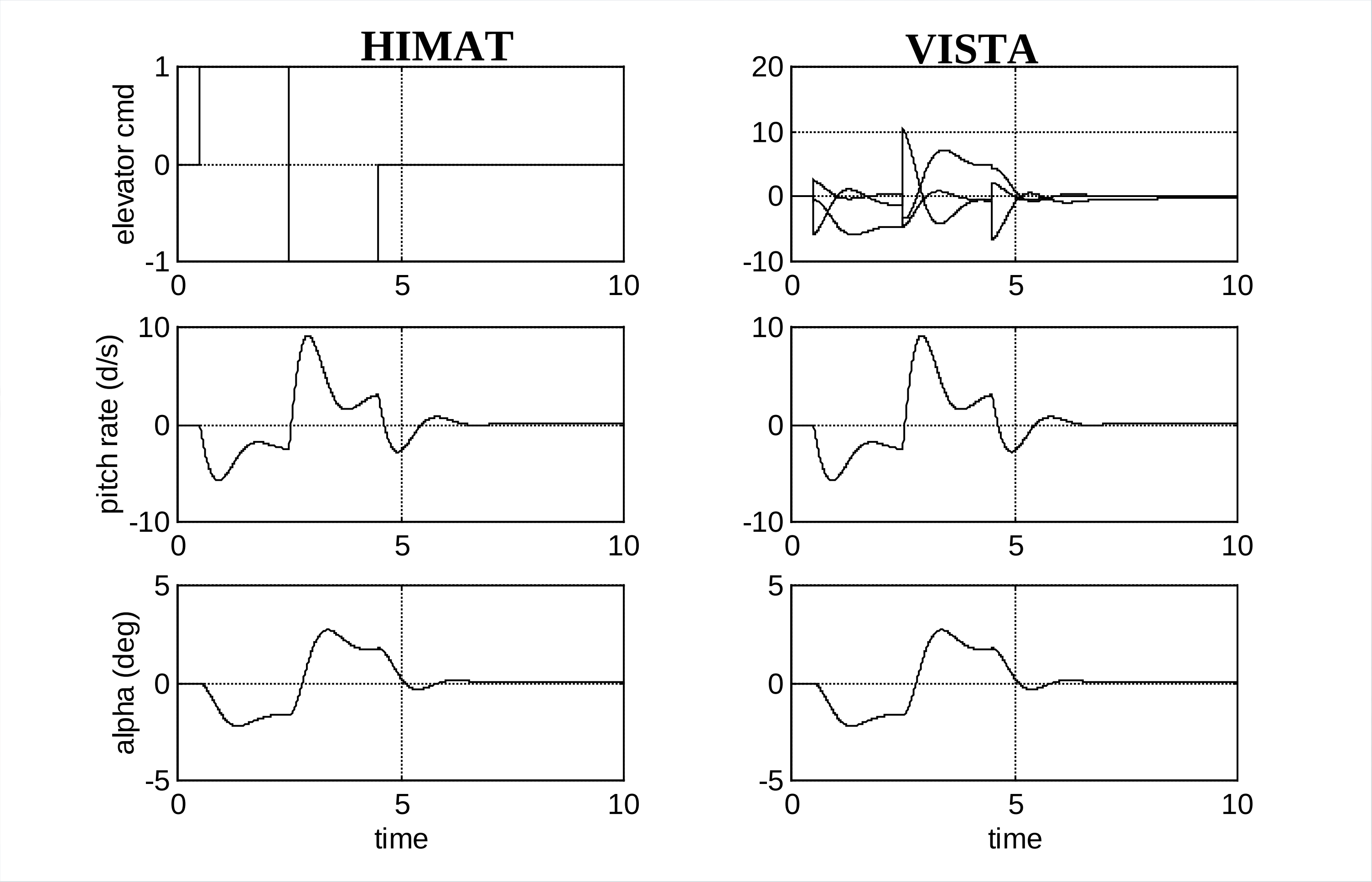
HIMAT CANARD COMMAND



HIMAT ELEVON COMMAND



HIMAT ELEVATOR COMMAND

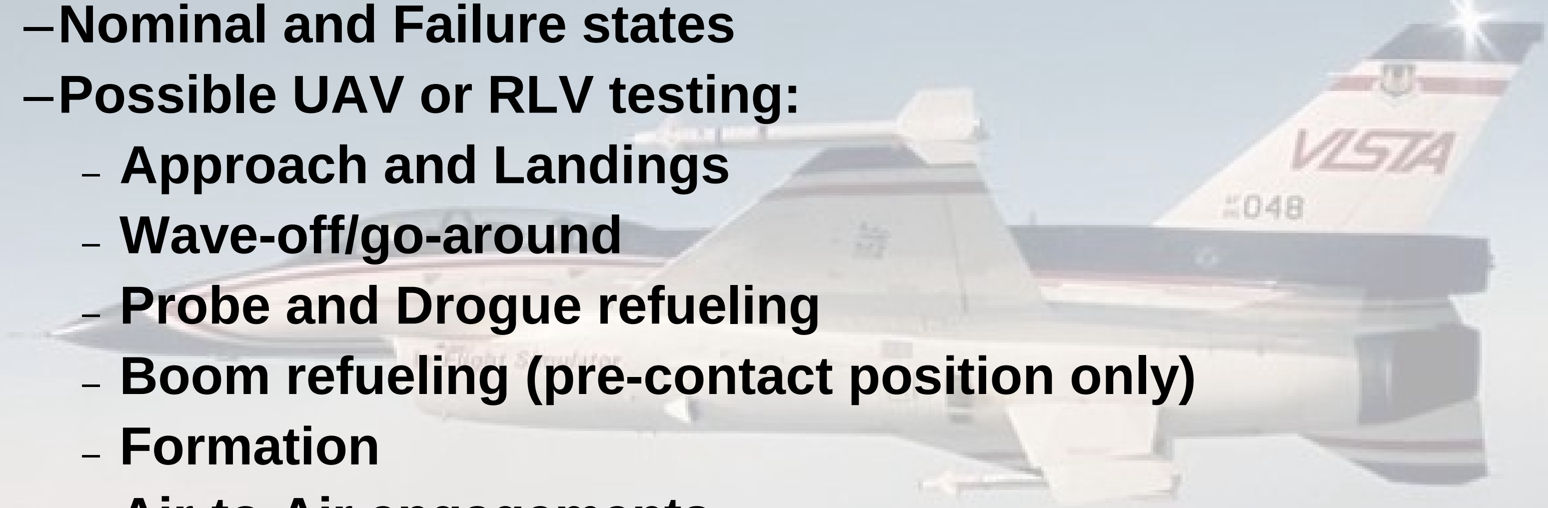


UAV SIMULATION

- **HIMAT Representative Of Small To Mid-sized UAV**
  - **Larger vehicles possible**
  - **Flight Control & Guidance System would be implemented identically to vehicle in question**
- **Possible Objectives**
  - **Control Law Development/Refinement/Validation**
  - **Failure modes and reconfiguration strategy testing/validation**
  - **Data Link Evaluation and Development**
  - **Weapons System Development**
  - **Concept of Operations development**

UAV TESTING

- **Potential Evaluations**
  - **Nominal and Failure states**
  - **Possible UAV or RLV testing:**
    - **Approach and Landings**
    - **Wave-off/go-around**
    - **Probe and Drogue refueling**
    - **Boom refueling (pre-contact position only)**
    - **Formation**
    - **Air-to-Air engagements**
    - **Air-to-Ground engagements**
    - **Failure modes**
    - **Reconfiguration/Safe modes**



UAV TESTING

- **Model/Data Requirements**
  - **Model and FCS Software**
    - **VISTA has successfully hosted the following software:**
      - **Ada 83 & 95 (primary software of VSS)**
      - **FORTRAN 77, 90**
      - **C, C++**
    - **VISTA has successfully hosted the following Autocode:**
      - **MatrixX C & Ada Autocode**
      - **Simulink/Matlab C Autocode**

CONCLUSIONS

- VISTA is a proven risk reduction tool
- VISTA provides simulated vehicle dynamics
- Minimal modifications to VISTA needed for your project (saves time and money in test prep.)
- Requires few compromises in test conduct
- Manned backup provides safety/risk mitigation
- Weapon systems surrogate for combat UAV test

- Low-cost insurance policy

VISTA ORGANIZATION

USAFTPS/CC
Col George Ka'iliwai

VISTA
Program Manager
Major Andy Thurling

Technical Advisor, Systems Research
John Minor

Deputy Program Manager
Sharlene Lim

Contract Manager
Jeanne Gare

Plans/Programs
Major Thurling

Production & Mx Super
MSgt Charles Olden

Veridian
Program Mgr
Tom Landers

VISTA Maintenance Team
Veridian/USAF

VISTA Test Pilots

- Major Andy Thurling - Chief Research & Development Pilot
- Major Rick Palo - Chief Systems Instructor Pilot
- Mark Dickerson - Veridian/Edwards Instructor Pilot
- Jeff Peer - Veridian/Buffalo Chief Instructor Pilot
- Major Om Prakash - Instructor Pilot

Veridian Flight Research

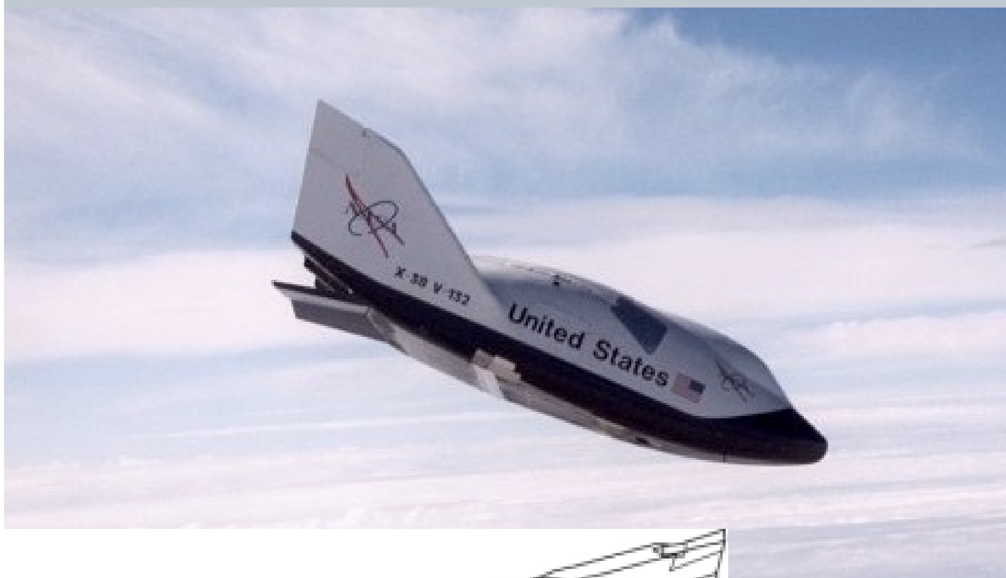
Buffalo, NY
VISTA Continuing Development
Test Pilot Training
Engineering Support
Maintenance Support

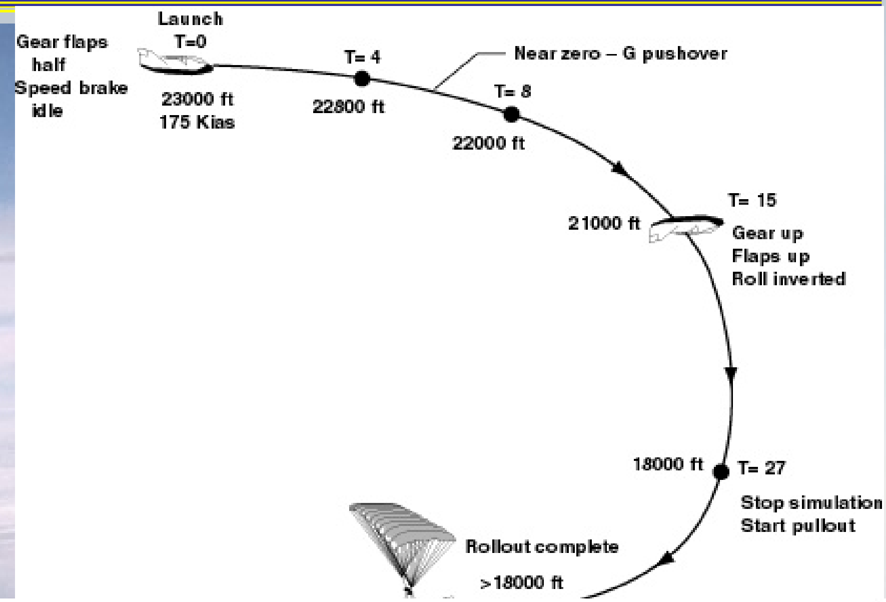
Who To Contact

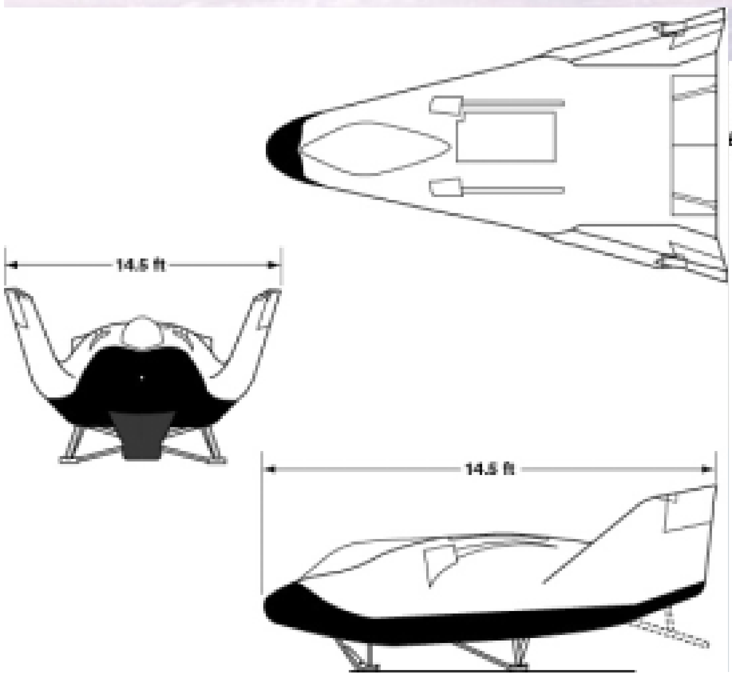
- **USAF TEST PILOT SCHOOL Points of Contact**
  - **Maj. Andy Thurling, VISTA Program Manager & Chief R&D Pilot**
    - **Comm. (661) 277-6554, DSN 527-6554**
    - **email: andrew.thurling@edwards.af.mil**
  - **Ms. Sharlene Lim, Deputy PM, Chief of Maintenance and Logistics**
    - **Comm. (661) 277-3046, DSN 527-3046**
    - **email: sharlene.lim@edwards.af.mil**
  - **http://www.edwards.af.mil/tps/vista/vista.htm**

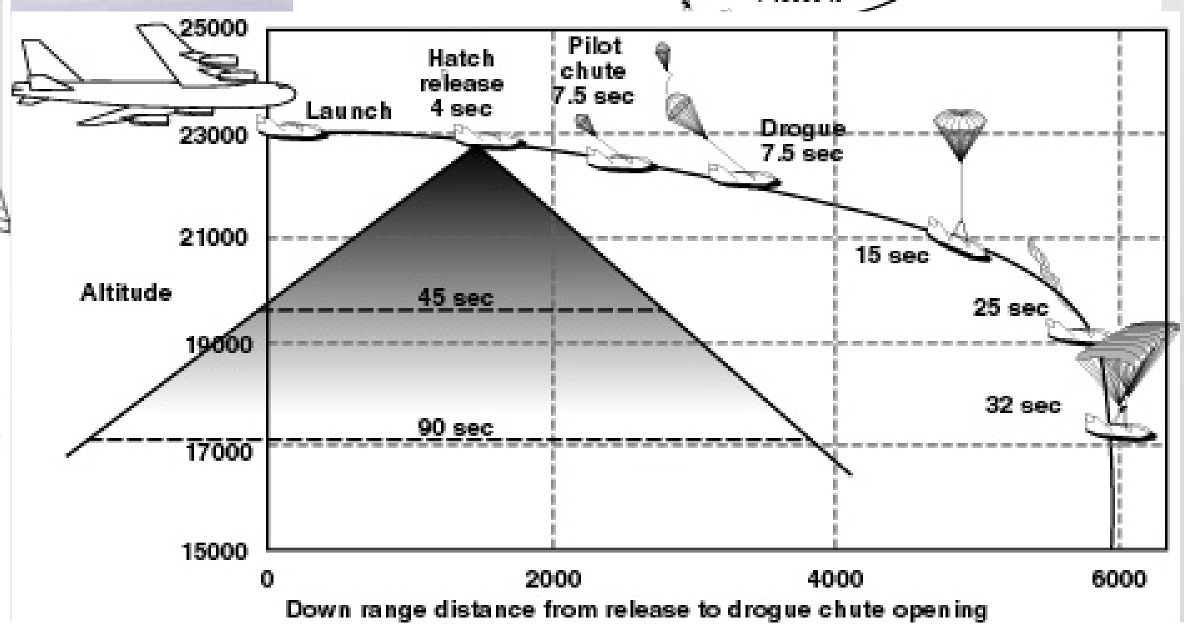
- **Veridian Flight Research POC**
  - **Mr. Thomas Landers, VISTA Program Manager**
    - **Comm. (716) 631-6943**
    - **email: tom.landers@veridian.com**

X-38 VISTA SUPPORT









UAV TESTING

- Validation Process
  - –Reference Time histories provided by Contractor
    - P, R, Y, Throttle steps, doublets
    - Small, moderate and large
  - –Predict characteristics of VISTA simulating model checked with off-line simulation
    - Verified on aircraft with ground simulation
  - –Flight Time Histories obtained during Calibration flights
    - Identical test inputs injected into system
  - –Overlaid with Reference Time histories
  - –Contractor/Veridian agree VISTA simulating model

UAV TESTING

- **Testing Procedures**
  - **Test Plan written by Contractor, TPS, or Veridian**
    - **Contractor review during generation (if needed)**
    - **Submitted to TPS and Veridian for review and approval**
  - **AFFTC Process**
    - **Technical Review Board (TRB)**
    - **Safety Review Board (SRB)**
  - **Evaluation Flights**
    - **Contractor Test Engineer(s) and Pilots on-site**
    - **Responsible for test points and objectives of evaluation flights**
    - **Access to data within 1-2 hours of landing**
    - **1 to 2 flights per day typical (surge to 4 possible based upon project needs/schedules)**

UAV TESTING

- Data
  - Post Flight data
    - Available 1 - 2 hours from landing
    - Hi-8 Video for Event log, pilot comments
  - Telemetry
    - Real time monitoring of flight data
    - Backup of flight data if necessary (loss of tape data)
- Test Report
  - Written by Veridian or TPS
  - Contractor review prior to distribution
  - Submitted to AFTPS, AFFTC, Contractor and Project Office
  - VISTA Contractual Requirement

UAV TESTING

- **Model/Data Requirements**
  - **–Flight Control System Block Diagrams/Code**
  - **–Known FCS variations to be tested**
  - **–FCS Gains & variations to be tested**
  - **–Update rates**
  - **–Un-augmented non-linear aero model**
    - **For specific flight conditions (if necessary)**
    - **Simulation model preferred**
  - **–Bare airframe modal characteristics**
    - **Open & closed loop time histories**
  - **–Datalink Characteristics**
    - **Update rates and Format**
    - **Frequency**
    - **Special Antennas**

UAV TESTING

- Model/Data Requirements (cont'd)
  - –Actuator models
    - Frequency response, rate & position limits
  - –Sensor and signal conditioning
    - Sensor dynamics
    - Special compensation (e.g., complementary filters)
  - –Definition of Axis Systems & Sign conventions
  - –CG and Sensor Locations