VISTA – a 21st Century Testbed

Software Enabled Control Principle Investigators Meeting
November 13-15, 2001

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Outline

- Outline
- VISTA.............
- What is it?
- What has it done?
- How would I use it?
- What can it do for me?
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)
- 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)
- Delivered to USAF (Wright-Patterson AFB) in Jan. 1995
- 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)
“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

- Sensors
- Variable Stability System
- Actuator commands (5)
- Throttle command
- Rear throttle
- DFLCC
- F-16 CLAW
- Pilot disengage, Automatic monitors
- Engine
- Actuators
**VISTA: Simulation Architecture**

![Diagram of VISTA Simulation Architecture]

- **Centerstick/Sidestick**
- **Simulation Throttle**
- **Model FCS**
  - **Command Feedforward Gains**
  - **Response Feedback Gains**
- **DFLCC**
- **Actuator and Airframe Dynamics**
- **VSS and F-16 Sensors**
- **Feel System**
- **Feel Sys Computer**
- **Rudder Pedals**

**VSS Computers**
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.

![VSS Computer Operation and Control Diagram]
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
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
- 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
    - Ixx= 436 slugs-ft\(^2\)
    - Iyy= 1593 slugs-ft\(^2\)
    - Izz= 2013 slugs-ft\(^2\)
    - Ixz= -81.26 slugs-ft\(^2\)
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

VISTA

- canard cmd
- pitch rate (d/s)
- alpha (deg)
- time

HIMAVISTA
HIMAT ELEVATOR COMMAND

HIMAT

VISTA
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
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

Deputy Program Manager
Sharlene Lim

Production & Mx Super
MSgt Charles Olden

VISTA Maintenance Team
Veridian/USAF

Contract Manager
Jeanne Gare

Plans/Programs
Major Thurling

Veridian Program Mgr
Tom Landers

Technical Advisor, Systems Research
John Minor

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**
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- **Veridian Flight Research POC**
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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
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