VISTA - A 21st Century UAV Testbed

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ABSTRACT

The Variable-stability In-flight Simulator Test Aircraft (VISTA) NF-16D is a unique national development, test, evaluation, and training asset owned by the United States Air Force (USAF). The VISTA is managed by the USAF Test Pilot School and operated by Veridian Flight Research personnel at Edwards Air Force Base, California. VISTA provides flight test, evaluation, and in-flight simulation capabilities for guidance, navigation, and control (GN&C) systems and cockpit display research and development. Using VISTA the entire Uninhabited Air Vehicle (UAV) system (which includes simulated aircraft dynamics, guidance, navigation, flight control laws, ground stations, communication links, etc.) can be tested in a real world flight environment without risking an actual test article or compromising test results. Higher risk testing including unproven or unconventional control concepts, system failure and reversion modes, sensor, propulsion or actuation system failure modes, safe modes, and auto-land can be performed without increased risk due to the presence of on-board safety pilots. Full-fidelity risk-reduction testing can demonstrate that a new UAV system functions properly and provide added confidence prior to first flight.

Figure 1: NF-16D Variable-stability In-flight-simulator Test Aircraft (VISTA)

INTRODUCTION

The NF-16D VISTA is a Vehicle Management System (VMS) and flight control test-bed aircraft developed jointly by the United States Air Force Research Laboratory (AFRL), Veridian Engineering Flight Research Group (formally known as Calspan), and Lockheed-Martin Aeronautics. The USAF Test Pilot School has recently taken over the management of VISTA from AFRL. USAFTPS will use VISTA to support student training, student research projects, Air Force research projects, and research and development projects from outside customers. Veridian Engineering Flight Research Group will continue to maintain and operate the VISTA at Edwards AFB under a support contract to the USAFTPS. Veridian will also continue to provide engineering and hardware and software modifications that are required for research and development projects.

The VISTA NF-16D aircraft has unique flight research test-bed and in-flight simulation capabilities that make it the ideal test bed to support UAV development. The fight research capability is provided by many on-board systems that are unique to the VISTA flying test-bed including: fully programmable flight control and avionics computer systems, fully programmable variable center-stick and side-stick feel systems, fully programmable Multi-Function Display (MFD), Head-Up Display (HUD) and Helmet-Mounted Display (HMD) systems, a voice recognition system, and significant provisions (power, cooling, and Mil-Std-1553 busses, etc.) for customer supplied hardware flight testing capability, in-flight refueling (both probe/drogue and boom/receptacle type) systems, weapon systems flight test, a fully accessible and programmable instrumentation system, and provisions for an axi-symmetric thrust vectoring system.

In-Flight Simulation (IFS) is the process of augmenting a "host" aircraft, the VISTA, through a control system to simulate the flight characteristics and dynamics of another aircraft. The actual GN&C system of the "simulated" aircraft is implemented in the "host" aircraft during the in-flight simulation. Subsequently, the characteristics of the "simulated" aircraft can be tested and evaluated in a real world environment. In this way specific flight control system changes (e.g., failure modes, gain changes, and control system testing) can be evaluated. All inputs to the GN&C can be provided including ground or airborne based commands, GPS, and inertial and body axis measurements. In addition, telemetry up and down links can be provided, if necessary.

The unique built-in safety characteristics and extended systems capabilities of VISTA allow flight testing of many functions associated with autonomous vehicles. These functions can be safely and efficiently tested in-flight with the built-in safety system that monitors aircraft limitations and an on-board safety pilot who can take control of the aircraft at any time.

HISTORY

The initial concept for VISTA originated in the mid-1970s when the USAF recognized the need for a replacement for the NT-33A in-flight simulator aircraft shown in figure 2. Various design studies were conducted from the mid-1970s to the mid-1980s for the development of a full six Degree-Of-Freedom (DOF) in-flight simulator. The desire for VISTA was to develop a full in-flight simulation capability for small fighter-type aircraft using an airframe that had performance characteristics representative of modern day fighter aircraft. The design studies resulted in the selection of the F-16 airframe for a 5 DOF in-flight simulator (pitch, roll, yaw, direct lift, thrust modulation). The direct side force vertical control surfaces on the wings were removed from the design due to various technical and budget constraints. A go-ahead for production of the VISTA NF-16D was given to the General Dynamics Fort Worth Division (now Lockheed Martin Aeronautics) in 1988. Calspan (now Veridian) was selected as the subcontractor for the development and integration of the aircraft's Variable Stability System (VSS) because of its expertise in flight control system development and in-flight simulation.

Figure 2: NT-33A AND NF-16D VISTA Aircraft

Developmental checkout flights were conducted at Edwards Air Force Base, including checkout flights of an X-29 simulation and the demonstration configurations intended for use at the USAF Test Pilot School (USAFTPS) and the Navy Test Pilot School (NTPS). The development testing was completed and VISTA became operational in January 1995 at which point it was delivered to Veridian's Flight Research Facility in Buffalo, NY from where VISTA began supporting the USAFTPS and NTPS curricula with demonstrations and Test Management Project (TMP) research flights. One benefit of these programs was the validation of safety trip methodology and safety pilot capabilities, all necessary to carry out landing evaluations to touchdown, when presented with significant degradations in flying qualities, close to the ground.

The VISTA also went to work for program development such as the USAF F-22. During the F-22 program the VISTA was programmed to represent the nominal characteristics of the F-22 as well as several failure conditions which included single and dual hydraulic system failures and a single engine failure. In addition, several aerodynamic uncertainty conditions were simulated. Evaluations tasks in the up and away air-to-air target tracking, formation and refueling environments were conducted. Extensive landing evaluations were also performed in severe turbulence and crosswind environments.

Concurrently with the F-22 program, the VISTA was enlisted to carry out the flight demonstration of the Self Designing Controller (SDC). This controller was able to determine the existence of a system failure (loss of a horizontal tail or its actuator) and reconfigure the flight control system to compensate for the failure with no apparent effect on the flying qualities. Successful landings to touchdown were accomplished with one of the VISTA's horizontal tails frozen in position throughout the approach.

The VISTA's ability to support multiple programs was demonstrated when schedule pressures required the concurrent preparation of the Indian Light Combat Aircraft (LCA) program while the F-22 and SDC program were being flight tested. The delta winged LCA is India's entry into the indigenous development of fighter aircraft and recently completed its first flight. Several aircraft configurations were programmed. Evaluations in the air-to-air, air-to-ground and formation envelope were conducted. Extensive landing evaluations including failures and aerodynamic variations were also performed. During these programs, the VISTA continued to support the USAFTPS. Funding constraints at the NTPS resulted the deletion of VISTA from its curriculum during this period. The Have Track TMP sponsored by AFRL was conducted during this period, evaluating the impacts of prefilters in various positions of the longitudinal control system and the susceptibility to PIOs in the refueling environment.

Interest in modifying the VISTA grew to the point that a program to integrate a P&W-229 engine with an axi-symmetric thrust vectoring nozzle and programmable display system was proposed. The original intent of this modification was the complete integration of a redundant, thrust vectoring system, allowing its use with the F-16 control laws as well as the programmable VSS through an extensive flight envelope. This program also funded the development of a programmable display system, which includes both the HUD and a Viper II HMD (Helmet Mounted Display). Funding constraints within AFRL prevented the completion of the entire thrust vectoring system, although the Group A provisions for these systems were installed, and the necessary structural modifications to the airframe have been completed. In addition, the original GE-F110 engine was replaced with a P&W-229 engine, making the VISTA the only F-16 airframe with a 'wide mouthed' inlet combined with a P&W-229, validating this compatibility.

Computational limitations of the VISTA were identified during the F-22, SDC and LCA programs and prompted the first upgrade to the Variable Stability System. It was determined the easiest path to enhancing the capabilities of the VISTA was to replace the original Titan Feel System Computer (FSC) with a ½ ATR sized VME 64X based chassis. The original 386 processor was replaced with a 200 Mhz Pentium processor, and new A/D, D/A and Mil-Std-1553 interfaces. This highly successful upgrade was funded by the JSF Program Office. The enhanced computation capacity of the new FSC allowed the movement of the majority of the research flight control elements to be moved into the FSC. This was a critical element of the next program—JSF.

Due to the extensive downtime caused by the modifications for the thrust vectoring system, the USAFTPS also discontinued the use of the VISTA in its curriculum. The next major program for VISTA was the Lockheed Martin X-35 JSF Concept Demonstrator Aircraft. This program was the first implementation of AutoCode from MatrixX in the VISTA and the first use of the modified FSC. To support the need to evaluate the Probe and Drogue refueling task, the Sargent Fletcher 370 ARTS tank was also integrated with the VISTA. The ARTS tank provides the unique ability to perform dry probe and drogue hookups with the KC-130 and KC-10 drogue systems. Structural considerations prevent its use with the KC-135 BDA. Carrier approaches utilizing the FLOLS were conducted, as well as up and away formation, probe and drogue and target tracking evaluations during the X-35 evaluation program. Following the JSF flight test, the HAVE FILTER TMP was conducted. This was the first program to utilize AutoCode from Matlab/Simulink.

The next program—the X-38, was significant in terms of showcasing VISTA's capability to support 21st century UAV research and development programs. The X-38 shown in figure 3 is a prototype spacecraft that could become the first new human spacecraft built in the past two decades that travels to and from orbit. The immediate goal of this project is to develop the technology for a prototype emergency Crew Return Vehicle (CRV), or lifeboat, for the International Space Station. The X-38 is designed to glide from orbit unpowered like the Space Shuttle and then use a steerable, parafoil parachute for its final descent to landing. The spacecraft's return from orbit and landing is intended to be totally automated, resembling typical autonomous UAV operations, although the crew will be able to switch to backup manual systems should the need arise.

VISTA's contributions to the X-38 development program included validating performance of aerodynamics and control laws prior to the X-38 V132's first flight. During the VISTA evaluation of the X-38, data for comparison with flight tests was generated. These data helped validate Flush Air Data System fail performance, and exercised the VISTA model development path in preparation for the X-38 V201 (Re-entry vehicle) testing which is expected to occur during 2002.

Figure 3: X-38 V-132 CREW RECOVERY VEHICLE

Subsequent to the X-38 program, the VISTA conducted two TMPs—Have Track and Have OLOP. The Have Track program evaluated the use of pre-programmed tasks on the HUD to replace the need for a target aircraft. The Have OLOP TMP provided flight test data to help validate the OLOP flying qualities criteria utilized to predict the occurrence of PIOs in aircraft development programs. In addition, VISTA has been used to support JSF displays development.

The near term future of the VISTA includes its transfer to the USAFTPS and its extensive support of the curriculum and the support of NASA's X-34 program and the 2nd Generation Reusable Launch Vehicle programs. The VISTA has also been identified to support the JSF EMD program.

AIRCRAFT CONFIGURATION

The VISTA aircraft configuration consists of several unique features specifically installed for its mission as a VMS test bed. A list of some of these features is given below:

- NF-16D, S/N 86-0048
- Block 30 airframe, Peace Marble II configuration, including large dorsal fairing for additional electronic equipment
- Pratt and Whitney F100-229 engine with wide inlet

- Heavyweight landing gear
- Heavier wing carry-through structure
- Block 40 avionics and Digital Flight Control Computer (DFLCC)
- GEC/Marconi Viper-II HMD
- Wide field of view HUD
- APG-68 targeting radar
- Dry hook-up utilizing the probe/drogue system while in the Variable Stability Mode
- Provisions for a P&W Axi-symmetric thrust vectoring nozzle
- Nine external store stations for tanks, pods, and weapons with programmable digital interface to each station
- Integration of the weapon system with the programmable avionics, display and flight control systems

Additional modifications have been made to the VISTA including: upgraded hydraulic system with larger hydraulic pumps and hydraulic lines, and removal of hydraulic flow restrictors from the control surface actuators to meet increased VISTA's control surface slew rate requirements. A larger electrical generator was also installed to meet increased electrical needs.

FLIGHT-TESTING CAPABILITIES

Flight-testing and in-flight simulation are conducted using the Variable Stability System (VSS). The VSS is a digital and analog system that interfaces with existing F-16 avionics and sensors (in addition to custom VSS sensors). Some primary components of the VSS include:

- Two identically configured VME 64X based 233 MHz Pentium computers (VSS1 and VSS2) connected to six MIL-STD 1553B data busses.
- One VME64X-based 200 MHz Pentium Feel System Computer (FSC).
- Programmable Variable Feel Center-Stick.
- Programmable Variable Feel Side-Stick
- Programmable Display System (including MFD, HUD and HMD).
- Engage Logic and Interface Chassis (ELIC).
- Custom VSS Panels and Displays
- Sensor Conditioning Chassis (SCC).

All of the VSS computers can be programmed using Ada, FORTRAN, or C and using rapid prototyping methods such as Matlab/Simulink and Matrix X autocode generation. Because of the parallel presence of an independently verified and validated set of F-16 flight control laws and real time monitors, the VSS is not a safety-of-flight critical system and changes to the system therefore do not require extensive verification and validation testing. This makes the VSS a useful tool for rapid prototyping and allows quick turnaround of desired system changes. A diagram of the present VSS equipment layout on VISTA is shown in Figure 4.

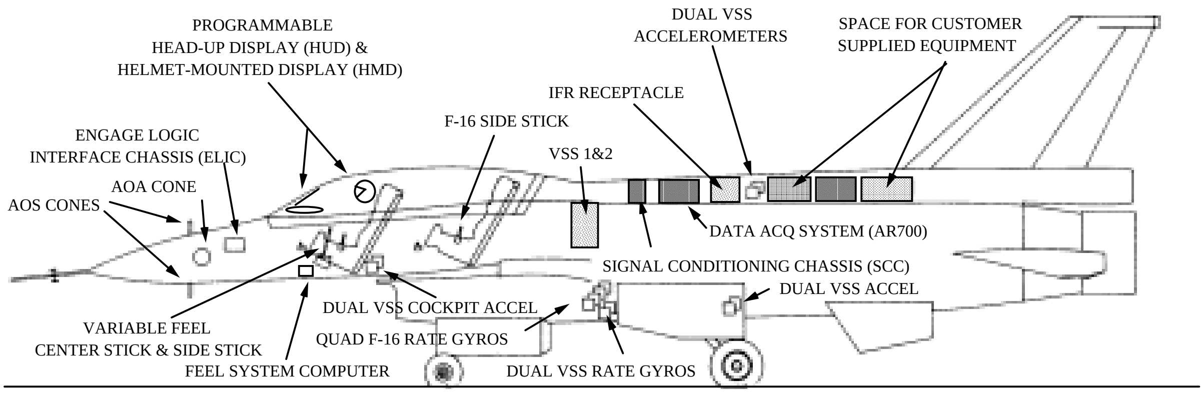

Figure 4: VISTA Equipment Layout

The controls and displays for the pilot-in-command, or safety pilot, are located in the aft cockpit station. The safety pilot controls the VSS configuration through the MFDs and the VSS Control Panel. The safety pilot controls engagement of the VSS. The observer's controls include the programmable variable feel center-stick and side-stick controllers as well as the Upfront Control Panel Keyboard, the Feel Engage Logic Panel and its spare switches, and the MFDs. When the VSS is engaged, the front cockpit pilot or GN&C has direct control of the aircraft. The pilot or GN&C flies the aircraft through the VSS control laws with full authority of the F-16 aircraft control surfaces. The VSS control laws include the simulated aircrafts' control laws as well as augmentation to modify the F-16's basic stability and control characteristics to mimic the simulated aircrafts' basic dynamics. Safe flight is maintained through multiple safety trips and the safety pilot or observer-initiated disengage functions.

Both manual and automatic safety trips are included in VISTA. When a safety trip occurs, the VSS disengages and control of the VISTA is returned to the safety pilot who then flies the VISTA through the production F-16 control laws. In addition, both pilots have the ability to manually disengage the VSS and return control of the aircraft to the safety pilot. Manual VSS disengage switches are located on the center-stick and side-stick and also on the aft cockpit VSS display panel. The safety pilot can also override the evaluation pilot and automatically disengage the VSS and regain control of the aircraft if the aft cockpit side-stick controller forces exceed safety trip thresholds. When the VSS is disengaged, the F-16 control surfaces smoothly transition to the F-16 control law commands. Safety pilot and observer are alerted to the safety trip through both aural and visual alarms.

Automatic safety trips will disengage the VSS to provide protection against exceeding the simulation operating envelope and/or over-stressing the airframe. The VISTA Integrity Management (VIM) software, resident in the F-16 DFLCC, monitors critical aircraft parameters and generates a disengagement prior to exceeding a limit. Safety trips are also set for hardware or software faults detected by the Engage Logic and Interface Chassis or by the VSS computers' monitoring systems.

An F-16 or ‘Convenience’ mode can be selected that allows the evaluation pilot to fly the normal F-16 control laws while the safety pilot is involved with other tasks (e.g. setting up a new VSS configuration). The evaluation pilot selects the F-16 mode using the push button on the F-16 Engage Panel in the front cockpit. The VIM safety trips are disabled when the aircraft is operated in this mode, except for the throttle and side-stick servo safety trip monitors. This mode can be manually disengaged in the same manner as the VSS.

The F-16 Engage Panel in the front cockpit also has a guarded quad-redundant push button for engaging the Emergency Mode. This mode allows the evaluation pilot to control the aircraft through F-16 like control laws in the unlikely event of safety pilot incapacitation or malfunction of the safety pilot’s controls. All automatic safety trips are disabled when this mode is active.

A summary of VISTA’s flight envelope with the Variable Stability System engaged and capabilities are presented below and shown in Figure 5:

- Maximum airspeed: 440 KIAS / 0.9 Mach
- Angle-of-attack limits: -10° to +16°
- Normal load factor limits: -2.4 to +6.8 gs
- Maximum sideslip: ±10°
- Up to 300 knot approach speeds
- Touchdown speeds up to 220 knots
- Minimum L/D ~2

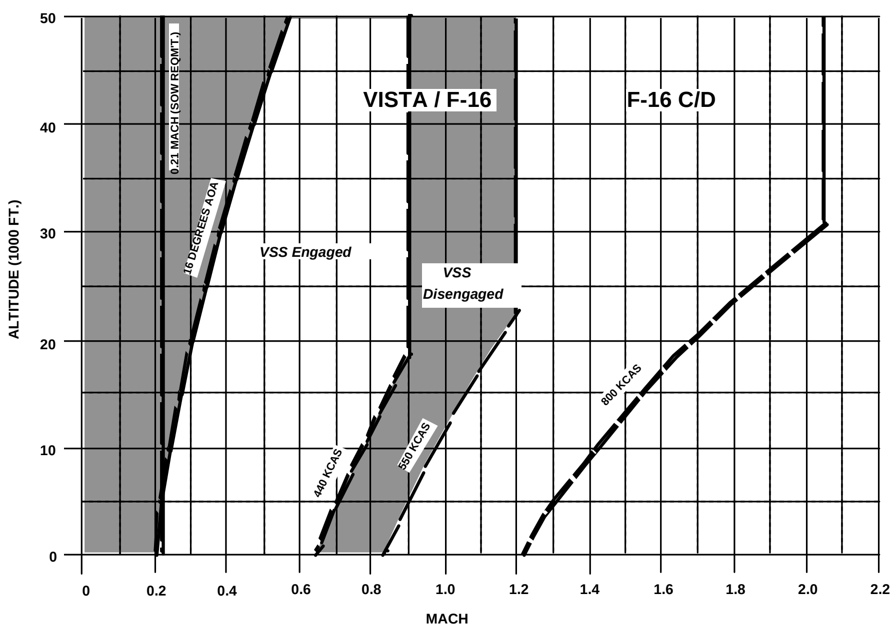

Figure 5. VISTA Flight Envelope

Flight duration varies from 1.2 hours with a clean configuration to 1.6 hours with a centerline tank installed; in-flight refueling can extend flight time if required. Due to built-in safety and redundancy features, VISTA is also one of the few in-flight simulation aircraft that is capable of landing while the VSS is engaged allowing UAV autoland functions to be tested through touchdown. Multiple approaches can be accomplished on any flight with the potential for back-to-back comparisons, variations in aerodynamics characteristics, failures or modifications to be completed on each flight test.

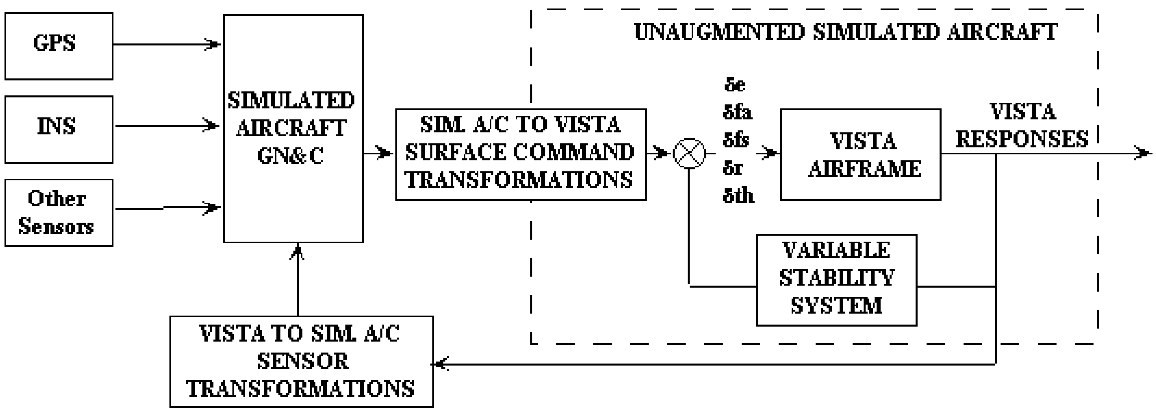

Figure 6: VARIABLE STABILITY SYSTEM (VSS) ARCHITECTURE

A simplified diagram of VISTA's in-flight simulation control law architecture is shown in Figure 6. The simulated aircraft (i.e., the system represented within the dashed box in Figure 6) is developed using the Command Feed Forward System and the Response Feedback System. The simulated aircraft acceleration commands are converted into VISTA control surface actuator commands by the Command Feed Forward System control laws. The Response Feedback & Model Following System modifies VISTA's F-16 aircraft dynamics to match those of the simulated aircraft.

The VSS can be programmed to provide a wide range of aircraft characteristics within its flight envelope. Examples of this range are given in Table 1.

Table 1: Examples of VSS Aircraft Dynamics Modeling Capabilities

Parameter	Minimum Value	Maximum Value
Short Period Frequency, ω_{sp} (rad/sec)	0.5	14.7
Short Period Damping Ratio, ζ_{sp}	-0.05	3.2
Nz/α (g/rad)	-3.2	85
Dutch Roll Frequency, ω_{dr} (rad/sec)	1.2	7.9
Dutch Roll Damping Ratio, ζ_{dr}	-0.2	2.1
Dutch Roll Phi/Beta Ratio, $\lvert \phi/\beta \rvert$	0.9	14

The VSS includes aircraft feedback signals from various sources on the aircraft. The aircraft linear and angular acceleration signals are determined from three sets of dual redundant three-axis accelerometers (two sets near aircraft CG and one set near the evaluation pilot's station). Angular rates are provided by the VSS dual redundant gyros located near the F-16 quad-redundant rate gyros. Aircraft attitude, inertial position, and inertial velocity are obtained from the standard F-16 block 40 ring laser gyro inertial platform. Angle-of-attack (AOA) and angle-of-sideslip (AOS) are determined from signals generated by the left and right AOA probes and the upper and lower AOS probes on the nose of the F-16. Air data information is provided by the standard F-16 air data system. A Garmin GPS-25 12 Channel DGPS and provisions for an uplink are also available.

The details of VSS capabilities for modeling all of the aircraft dynamic characteristics are not as easily generalized as the examples above and is beyond the scope of this document. Additional details may be found in References 4 through 7. An example time history comparison of actual flight test data with simulation model data of a delta wing planform aircraft demonstrating VISTA test quality is shown in Figure 7.

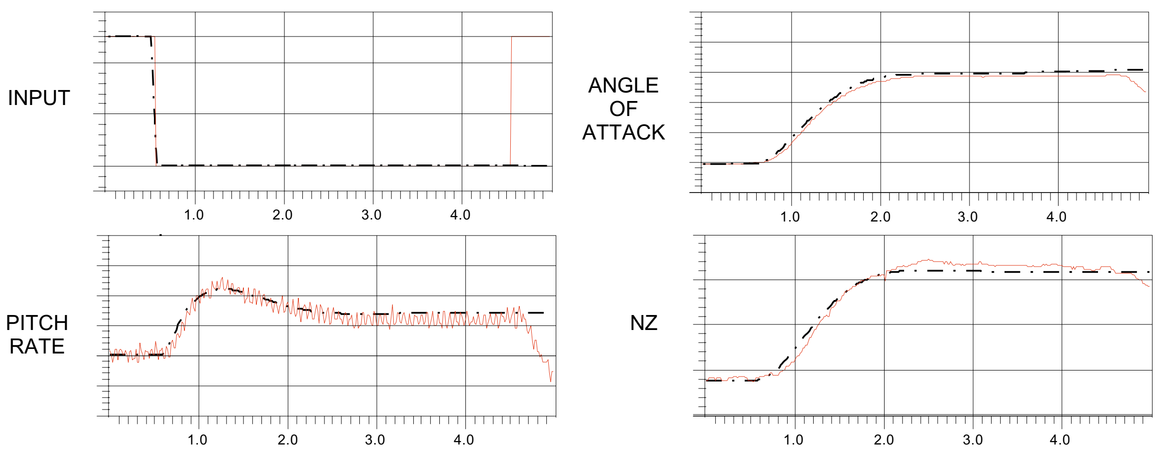

Figure 7: EXAMPLE TIME HISTORY MATCH - PITCH AXIS (DASHED = MODEL DATA, SOLID = VISTA DATA)

As previously mentioned, the VSS characteristics are controlled by the safety pilot via the MFDs and the VSS control panel. VSS configuration characteristics may be selected during flight from a group of stored configurations. Specific characteristics may also be changed individually using the VSS Configuration Control System (CCS) menus.

For test data recording purposes and post flight data reduction, the VISTA aircraft is equipped with an on-board AR700 digital data tape recorder capable of recording up to 214 channels of data utilizing the USAF Airborne Test Information System (ATIS). Either pilot controls data acquisition using switches on the VSS Display Panel located in each cockpit. Audio and video information (HUD/MFD/voice) is also recorded using a single VHS VCR and a triple deck 8mm VCR with video splitting capability. A split screen image of the HUD and an MFD can be recorded side-by-side in this mode. The aircraft is capable of L-band or S-band telemetry for transmission of PCM data, hot mike audio, and video signals. In addition up to 330 MBytes of data can be stored on an onboard Flash disk.

VSS COMPUTER HARDWARE CONFIGURATION

The VISTA NF-16D VSS is primarily comprised of 3 Computer chassis, these are the FSC and VSS1 and VSS2. The FSC drives the variable feel center and sidesticks and would not normally be needed for UAV flight-testing. The VSS1 and VSS2 chassis are identical configured (for future dual redundancy capability of the VSS) full-ATR sized boxes, each containing a VME64X back-plane with 15 card slots (Figure 8). Each slot can accommodate a 6U sized conduction cooled card, utilizing wedgelocs and conforming to the IEEE 1101.2 requirement. There are 7 card slots within each chassis are available for use. The other 8 cards consist of:

- 1 - SBS (nee Or Computer) VR6, 233 MHz Pentium, with 128 MBytes of ECC RAM, 80 MBytes of Flash memory, also provides discrete, RS-232, RS-422, SVGA, SCSI-2 and Ethernet interfaces
- 3 - Radstone A/D (8) & D/A (4) cards
- 1 - SBS 6 Dual redundant 1553 Bus interface card
- 1 - Discrete Input (64) card
- 1 - Discrete Output (64) card

Each VSS computer has analog interfaces with its respective channel of analog inputs. Dependent upon the needs already set out in the VSS each of these cards communicates to the front panel of the VSS computer. All information can be made available to additional cards via the shared memory features inherent in the VME64X architecture.

Figure 8. VSS1 Full-ATR Sized Computer

The VSS1 and VSS2 computers are located in the ammo bay (Bay 1, Figure 10). Significant free space is presently available in Bays 5 (7.5 cu-ft) and 7 (7.6 cu-ft) also shown in Figure 10. Bay 6 (8.3 cu-ft) contains engine instrumentation and can be removed if necessary to accommodate additional hardware.

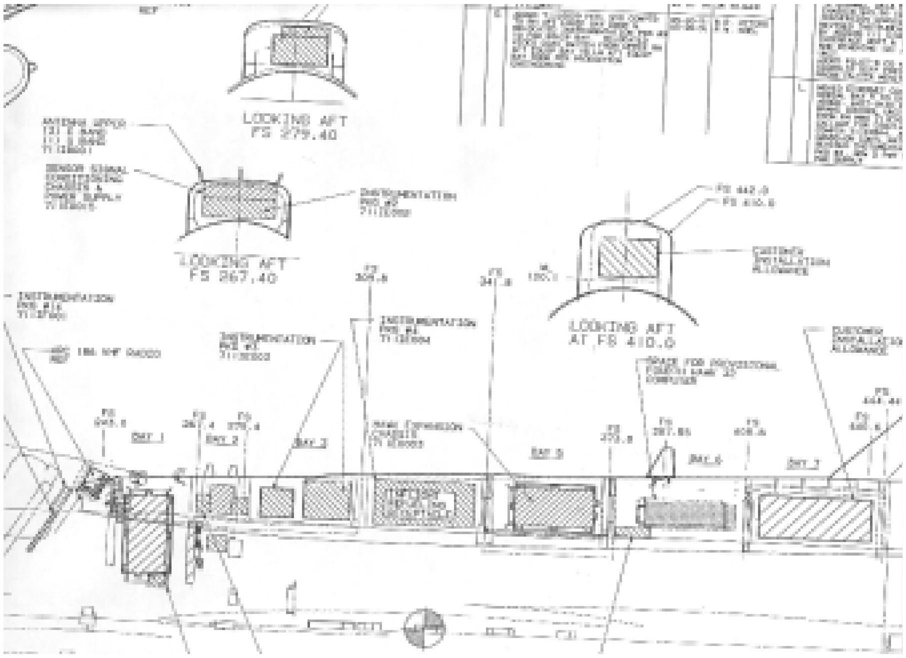

Figure 10. VSS Ammo & Dorsal Bays

In addition to the computers, the VSS contains a Sentinel SCSI-2 Data Transfer System (Figure 11) capable of accommodating two PCMCIA Type 2 cards (or 1 Type 3). Each card is capable of storing or loading up to 330 MBytes of information for use by the VSS. This may be used to load new software into the VSS, or may be as a mass storage device for active use during a flight (e.g., terrain data base) or recording of data for post flight playback. This is accessed through an existing quick release hatch on the upper left side of the vehicle.

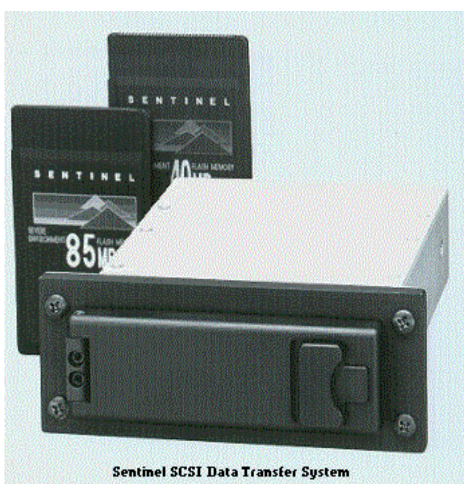

Figure 11. Sentinel PCMCIA Card Data Transfer System

VISTA VSS HOTBENCH

In order to reduce development costs for new programs, a hotbench that will allow the integration and testing of revised software is currently under development at Veridian's Flight Research facility in Buffalo. The system is composed of two separate VME-based computers with one computer system emulating the primary VISTA Simulation System (VSS) computer and the other computer system emulating the necessary core F-16 avionics (see Figure 12). This system is referred to as the VSS Software Development and Test Station (SDTS).

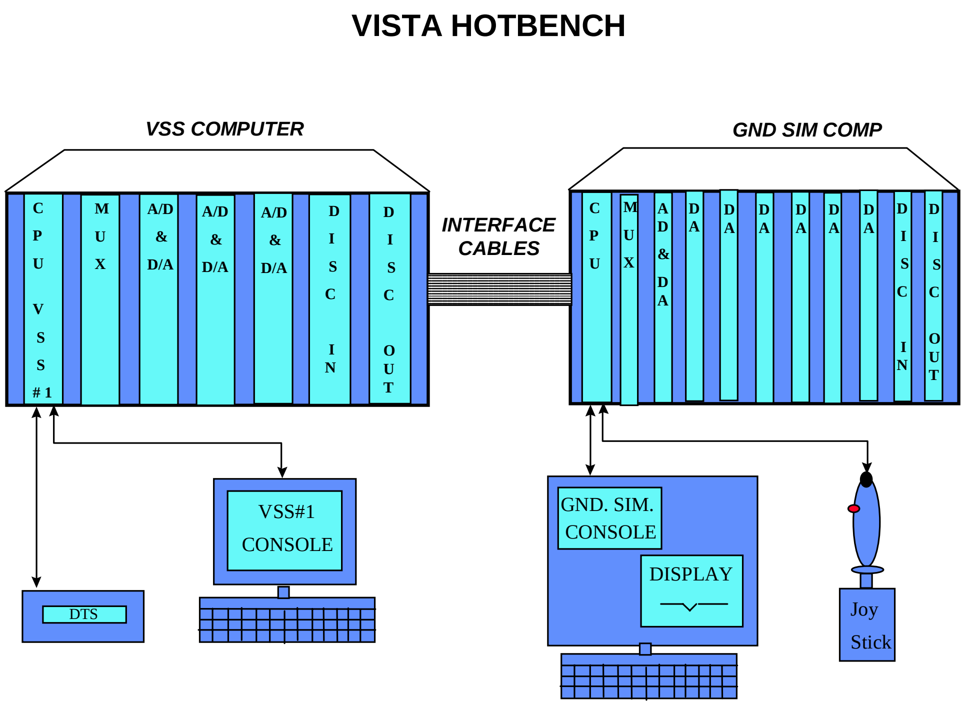

Figure 12 - VISTA SDTS - HOTBENCH Simulation

The VSS SDTS is a set of hardware and software that emulates the functionality of the VISTA NF-16D VSS (both core F-16 avionics and Veridian Variable Stability System components) with enough accuracy to develop and test new VSS OFP's. The SDTS uses an actual flight ready OFP that can be read in from a Raymond SCSI DTS cards identical to the VISTA. This system allows for customer supplied flight control laws (or other software) to be integrated into the VSS software and verified with a minimum of on-aircraft checkout.

The SDTS uses a Pentium VME-based architecture identical to what is used for the primary VSS computers installed in VISTA. To minimize costs, all hardware is convection cooled commercial equivalents to that used in the VISTA. The SDTS is composed of two 20-slot VME backplane enclosures with the necessary power supplies. The first system designated the VSS Computer System (VSSC), emulates the VSS1 computer and contains exact convection cooled, commercial equivalent VME cards as the VSS1 rugged computer installed in VISTA. By using the commercial equivalent VME cards, the VSS OFP will be able to run on the VSSC without modification. The second system, designated the Ground Simulation Computer (GSC), contains similar VME cards as the VSS1 computer and emulates the necessary core-F16 avionics to allow the VSS to engage and produce time history data. An interface cable connects the GSC with the VSSC. This interface cable connects the required digital and analog I/O between the two systems. Another interface cable is available to connect the GSC to the VISTA aircraft to allow the GSC to perform as a high fidelity ground simulation computer for actual on-aircraft checkout.

VISTA as a UAV TESTBED

Because of the NF-16D VISTA's unique capabilities, it is an ideal test bed for UAV development. VISTA can easily represent the L/D (min L/D ~2) and responses typical of UAVs (adjustable Nz/a and L/D). VISTA is capable of simulating typical UAV flight profiles including the landing phase with up to 300-knot approach speeds and touchdowns up to 220 knots with minimum risk to equipment. For example, VISTA can be programmed to duplicate X-33 and X-34 class subsonic flight dynamics, landing approach speeds, attitudes and flight path responses. VISTA is capable of accurately representing longitudinal axis (q, AOA, g and V_t) throughout approach, round-out, and touchdown. The VISTA on-board safety pilot provides for safe testing of failure modes, aero-uncertainties, and unproven control law strategies and/or methodologies. Rapid prototyping allows for proof of concept testing in a cost-effective and minimum risk development approach, with rapid turnaround between changes necessary as part of the development process.

The man-in-the-loop capability provided by the VISTA also allows for increased productivity. Flight testing may be split into several distinct phases such as cruise, early approach, final approach to touchdown, etc. Each phase may be repeated on a single sortie a number of times allowing for multiple test points examining wind and turbulence effects, DGPS uncertainties, anomalies in aerodynamic data, aerodynamic uncertainties, and flare effects. Entire profiles may be simulated once individual segments have been fully explored.

UAV reactions to various contingencies and emergencies may be tested with the security of a man-in-the-loop. Mission planning errors have been responsible for autonomous UAV mishaps in the past. With the manned backup capability of VISTA, mission planning software verification does not need to be as complete. Since UAV test hardware and software installed on the VISTA would not be safety of flight critical, mission planning bugs may be discovered, fixed, and retested as quickly as the client software development cycle allows. No additional validation or verification need be accomplished to assure safety of flight. Additionally, more aggressive failures or larger steps in the test build up may be accomplished.

Finally, integration of the UAV with manned aircraft in the airport traffic area may be accomplished with reduced risk and substantially less intrusion due to the manned backup. One author's personnel experience with Global Hawk as Test Wing Supervisor of Flying and F-16 test pilot reflects the intrusion into normal operations that an autonomous UAV launch or recovery makes. Considerable resistance to UAV operations in general is rooted in the deconfliction difficulties with manned aircraft. Add to that the additional uncertainties inherent in flight test of a new autonomous UAV. Having a pilot on board who is capable of taking control if necessary would eliminate this fairly large stumbling block to UAV flight test.

CONCLUSION

The NF-16D VISTA aircraft offers the UAV development community a 21st century UAV testbed platform with the unique capability to test actual flight hardware, software, and flight dynamics relatively risk free in the actual mission environment. The VISTA hotbench allows customer supplied flight control laws (or other software) to be integrated into the VSS software and verified with minimum on-aircraft checkout. The VIM safety trips and VISTA safety pilot offer a proven backup system should UAV GN&C hardware or software fail. The rapid prototyping capability provided by the VSS allows testers to fly a morning sortie, find a problem, fix it before lunch, and fly again in the afternoon without having to worry about extensive validation and verification. The VISTA system allows UAV engineers to rapidly develop and safely test new systems with the minimum amount of time and resources.

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