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F-18 Systems Research
Aircraft Facility

Joel R. Sitz

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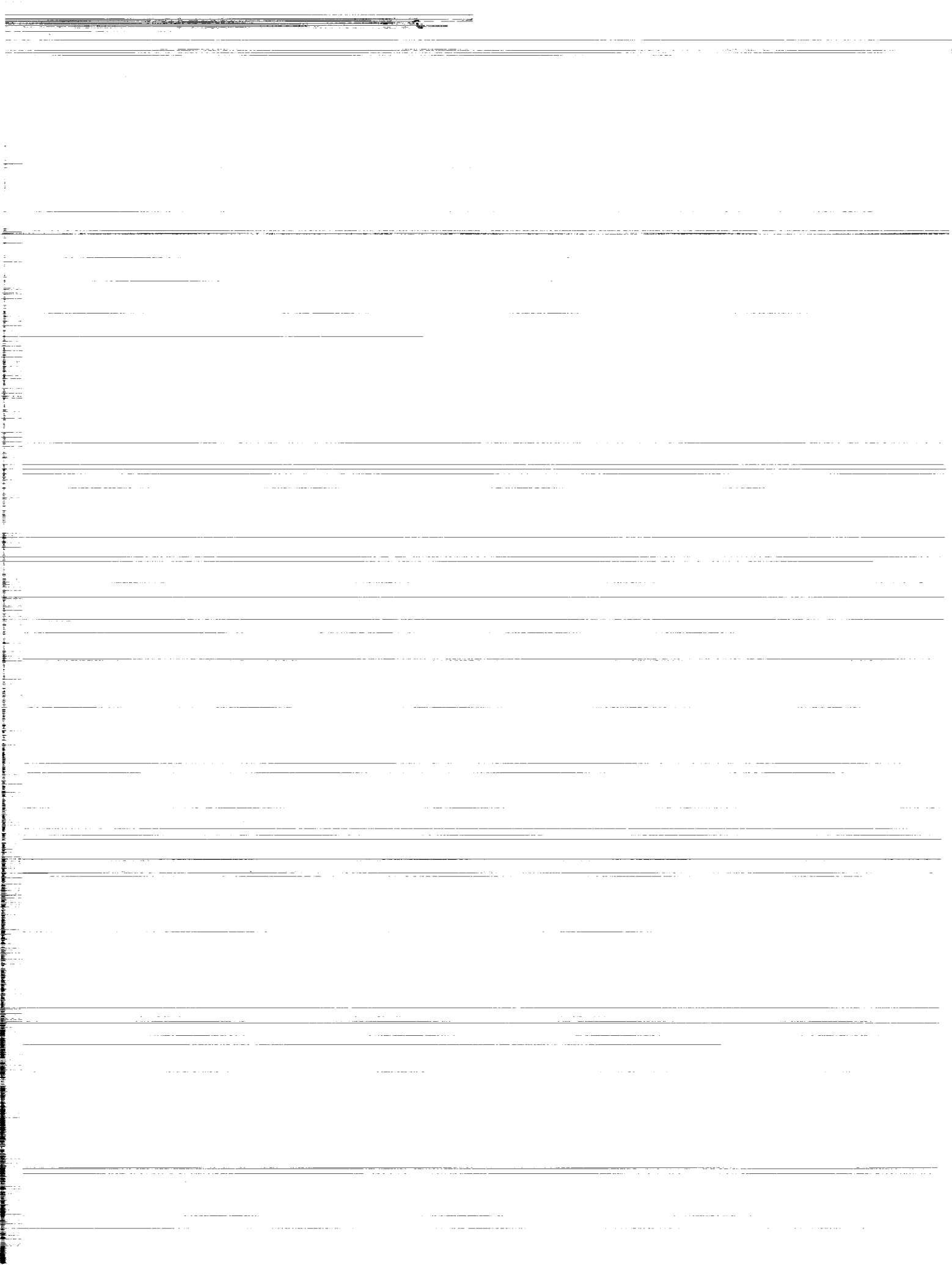NASA Technical Memorandum 4433

F-18 Systems Research Aircraft Facility

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ABSTRACT

To help ensure that new aerospace initiatives rapidly transition to competitive U.S. technologies, NASA Dryden Flight Research Facility has dedicated a systems research aircraft facility. The primary goal is to accelerate the transition of new aerospace technologies to commercial, military, and space vehicles. Key technologies include more-electric aircraft concepts, fly-by-light systems, flush airdata systems, and advanced computer architectures. Future aircraft that will benefit are the high-speed civil transport and the National AeroSpace Plane. This paper describes the systems research aircraft flight research vehicle and outlines near-term programs.

NOMENCLATURE

ADS	airdata sensor
AOA	angle of attack
AP	application processor
ARTS	airborne research test system
BIT	built-in test
CAST	computer-aided systems testing
DDI	digital display indicator
DDV	direct drive valve
DOD	Department of Defense
EHA	electrohydrostatic actuator
EMA	electromechanical actuator
EOA	electro-optic architecture
EPAD	electrically powered actuation design
EU	engineering unit
FADS	flush-mounted airdata system
FBL	fly-by-light
FBW	fly-by-wire
FCC	flight control computer
FOCSI	fiber-optic control systems integration
FOPSN	fiber-optic position sensor network
F.S.	fuselage station
HARV	High Alpha Research Vehicle
IOP	input-output processor
ITF	Integrated Test Facility
LED	leading edge down
LEU	leading edge up
LVDT	linear variable differential transformer
NASA	National Aeronautics and Space Administration
PCME	power control and monitoring electronics

RAM   random access memory
RFCS   research flight control system
RT-FADS real-time, flush-mounted airdata system
SA   SMART actuator
SRA   systems research aircraft
TAS   true airspeed
TED   trailing edge down
TEL   trailing edge left
TER   trailing edge right
TEU   trailing edge up
VME   Versa-module Eurocard
WDM   wave division multiplex

INTRODUCTION

The systems research aircraft (SRA) at NASA Dryden Flight Research Facility is a dual-purpose facility benefitting both commercial and military developments. A primary goal is to identify and flight-test high-leverage technologies beneficial to subsonic, supersonic, hypersonic, or space applications. Demonstrating new system concepts in flight will greatly promote the transition of research and development technology from widespread, highly specialized ground-based laboratories to cost-effective flight research and production applications. The SRA flight test facility will enable government and industry to focus the integration, ground test, and flight validation of breakthrough technologies. The intent of flight testing new technologies is to eliminate perceived and real technical barriers. The development and flight test of vehicles such as the high-speed civil transport[1] and the National AeroSpace Plane are expected to use technologies that can be flight-validated with the SRA.

Both flight-critical and other experiments can be targeted for the SRA facility. Examples of experiments that would be considered flight critical include systems such as electric actuation for critical surfaces and closed-loop, fly-by-light (FBL) options. The systems testbed approach used by the SRA facility lowers development cost, decreases the time needed to develop new technologies, and focuses research efforts.

Flight test goals for the next one to two years include validating concepts in advanced actuators, fiber-optic sensors, flush airdata systems, sensor data fusion techniques, inertial guidance algorithms, and advanced, open systems computer architectures. Longer term goals are the flight test of an FBL control system and an integrated more-electric aircraft power management and distribution system with power-by-wire actuators for critical surfaces. Several candidate technological areas being considered by NASA Dryden for SRA ground or flight experiments include

- Active flutter suppression

- Onboard envelope expansion techniques

- Pilot associate systems

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- Advanced displays

- Massive parallel processing architectures

- Vehicle management techniques

- Automated vehicle checkout techniques

- Advanced vehicle system interfaces

The SRA facility takes advantage of several NASA Dryden F-18 related resources that increase the capabilities of ground test systems, flight test facilities, and analysis applications. The SRA facility provides system researchers with a cost-effective approach to flight test. This paper describes the SRA flight research facility and outlines the first series of experiments to be flight-tested.

SYSTEMS RESEARCH AIRCRAFT FACILITY DESCRIPTION

Background

NASA Dryden acquired several F-18 aircraft from the U.S. Navy for use as operational support aircraft. In selecting an SRA, several aspects to reduce facility development costs were considered. Many advantages were seen in choosing an operational support F-18 aircraft. The primary advantage was the presence of many F-18 resources at Dryden. There is an F-18 spare parts pool, and ground crews are familiar with the F-18 aircraft. Maintenance procedures and technical documentation libraries are established.

A key factor was the comprehensive F-18 ground test environment that has been established which includes hardware in the loop and Iron Bird test facilities. Software support for the F-18 was another advantage. NASA Dryden can maintain and modify the F-18 mission computer software and the F-18 Research Flight Control System (RFCS) Ada® software. The RFCS is an active control system that is selectable by the pilot for flight testing research control system applications. Since the RFCS applications are not considered flight critical, the cost of verifying and validating software is reduced. Using an F-18 allows the SRA facility to consider an inexpensive flight control computer (FCC) upgrade to incorporate the RFCS option. The RFCS computers would be identical with those used by the F-18 High Alpha Research Vehicle (HARV) program already flying at Dryden.[2]

Another significant reason for selecting an F-18 was the availability of a dual-place aircraft with a full-authority, digital fly-by-wire (FBW) control system. The rear cockpit can be dedicated to pilot associate, human factors, and displays-related research. An aircraft with a full-authority, digital FBW control system also was preferred to allow maximum flexibility in potentially developing new control system-related technologies. Important also was the need for two engines, allowing the flexibility to modify one engine while maintaining a conventional configuration on the other.

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After a consideration of existing Dryden resources, the operational support aircraft, TF-18, Bureau Number 160781, (fig. 1) was chosen. The aircraft was dedicated as a systems research aircraft in October 1991.
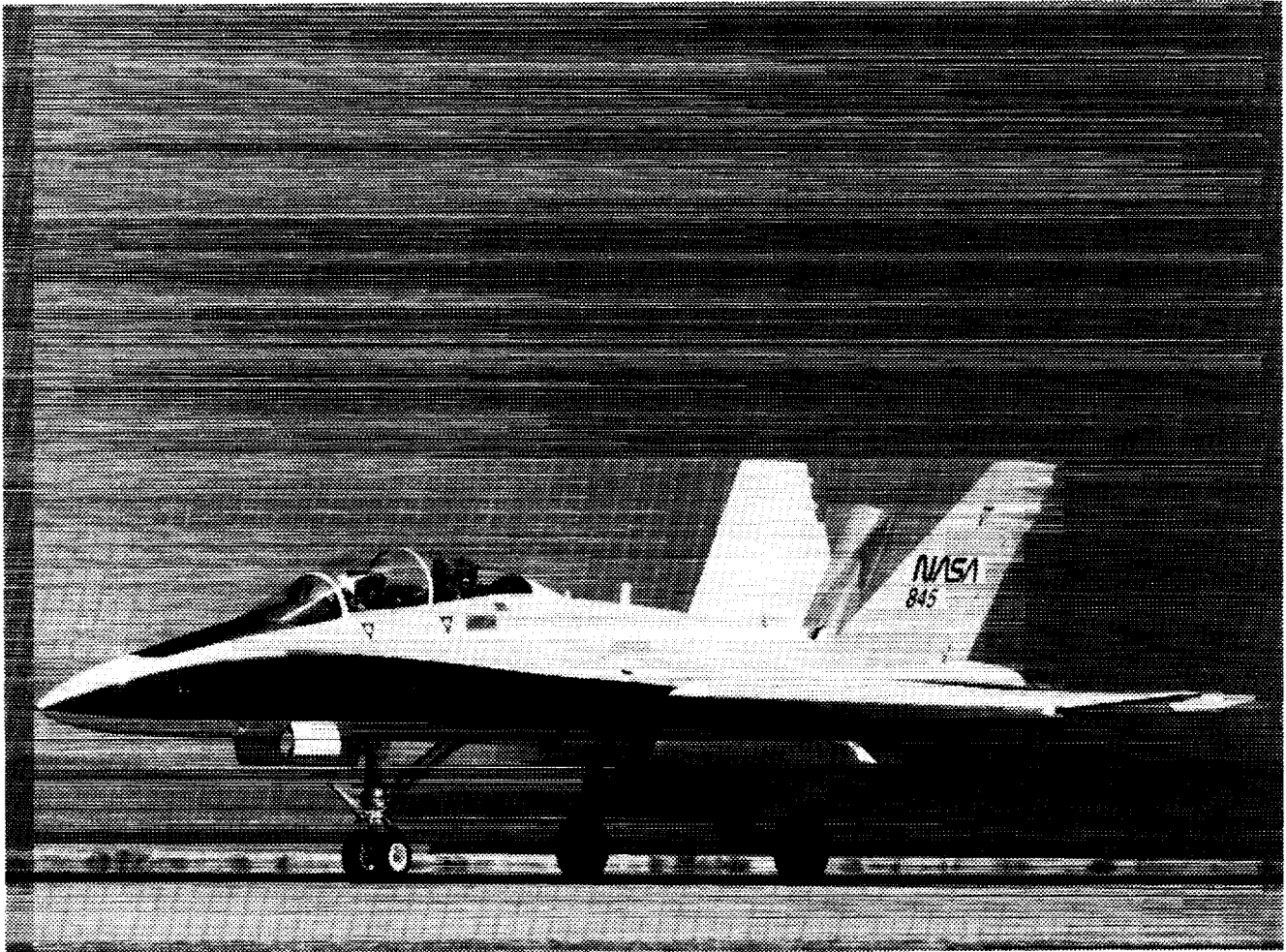
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Figure 1. The systems research aircraft.

Vehicle Description

The SRA is a high-performance, dual-cockpit aircraft operated by NASA. The SRA is a full-scale development, preproduction vehicle that incorporates many production equivalent modifications. Table 1 gives the approximate dimensions, weights, and inertias of the aircraft. The inertias reflect a dual-place, production F-18 aircraft with no stores or external fuel tanks.

The aircraft has a variable camber wing with hinged leading and trailing edge flaps. The leading edge and trailing edge flaps and ailerons actuate hydraulically. Leading edge extensions run from the wing roots to just forward of the cockpit. Twin vertical stabilizers are at a 20° angle from vertical. The twin rudders and differential stabilators are also hydraulically actuated. The speed brake is mounted on the top side of the aft fuselage between the vertical stabilizers. The cockpit is pressurized and enclosed

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by an electrically operated clamshell canopy. On the aircraft, equipment bays house experiments in the left and right fuselage, radar bay, rear cockpit, and nose-cone area.

Table 1. Physical characteristics of the SRA.

Overall length, ft	56
Height (to top of vertical fins), ft	15
Height (to top of closed canopy), ft	10.5
Reference mean aerodynamic chord, ft	11.52
Center of gravity	
Percent mean aerodynamic chord	23.8
Fuse, reference, F.S.	456.88
Water line, F.S.	105.35
Basic aircraft weight, lb	25,295
Maximum takeoff gross weight, lb	40,000
Roll inertia, slug-ft^2	18,111
Pitch inertia, slug-ft^2	120,464
Yaw inertia, slug-ft^2	135,094
Product of inertia, slug-ft^2	-2,305
Wing span, ft	37.5
Reference wing area, ft^2	400
Reference span, ft	37.4
Wing aspect ratio	3.5
Stabilator span, ft	21.6
Stabilator area, ft^2	86.48

Engines and Fuel Capacity

Two General Electric (Lynn, Massachusetts) F404-GE-400 turbofan engines with afterburner power the SRA. The military thrust of each engine is approximately 10,700 lb with maximum afterburner thrust in the 16,000-lb class. The maximum Mach number of the F-18 is approximately 1.8. The aircraft thrust-to-weight ratio is in the 1-to-1 class. The engine control system consists of the throttle, main fuel control, electrical control assembly, and afterburner fuel control. An aircraft-mounted auxiliary power unit starts the engines. An engine monitor display may be selected on either digital display indicator in the cockpit. The total internal fuel quantity with full tanks can vary, based on temperature, from approximately 9,120 to 10,980 lb. The SRA has an in-flight refueling capability and can support an external centerline tank configuration for extended range.

The option of using one of two engines during a flight test experiment is an extremely valuable asset as proved by the F-15 Flight Research Facility.[3] No modifications have been made to the SRA engines so far; however, fiber-optic engine parameter measurement sensors will be installed for the

fiber-optic control systems integration (FOCSI) experiments. The FOCSI section of this paper presents an overview of the fiber-optic engine sensors.

Flight Controls and Avionics

The SRA has a full-authority, digital flight control system with a limited-capability mechanical backup (fig. 2). The pilot's control stick is linked to the manual input of the stabilator actuators; however, no mechanical interconnections link the pilot controls to the ailerons or rudders. The two digital FCCs are quad-channel redundant with two channels per computer. Current control system characteristics are similar to the Navy fleet F-18 aircraft and are determined by the 8.3.3 version of the programmable read-only memory installed. Primary control surfaces using electrically driven hydraulic servo valves include two stabilators, two rudders, two ailerons, two leading flaps, and two trailing edge flaps. Two separate hydraulic systems supply redundant hydraulic power to the primary control surfaces. Two ac generators are the primary, redundant source of electrical power for the FCCs and associated avionics.

Redundant left and right surfaces offer advantages for experiments relating to comparisons between new and conventional applications. The ability to apply experiments to surfaces considered to be noncritical in most areas of the envelope, such as the ailerons, offers risk-reduction advantages. Table 2 lists the F-18 SRA aerodynamic control surface position and actuator rate limits.

Table 2. F-18 SRA surface position and rate limits.

Surface	Position limit		Rate limit, deg/sec
Stabilator	24°	TEU	40
	10.5°	TED	
Aileron	25°	TEU	100
	45°	TED	
Rudder	30°	TEL	82
	30°	TER	
Trailed edge flap	8°	TEU	18
	45°	TED	
Leading edge flap	3°	LEU	15
	33°	LED	
Speed brake	60°	TEU	20 to 30

The avionics subsystem was designed for one-pilot operability. Primary avionic subsystems on the SRA include an airdata computer and an inertial navigation computer operated under the control of two mission computers. The mission computers interface with the FCCs, cockpit digital displays, and other avionic systems over two MIL-STD-1553B multiplex busses. A third multiplex bus interconnects the two mission computers. The SRA has no stores, weapon systems, or electronic warfare equipment installed. Radar systems are available and could be installed if needed. Figure 3 shows a block diagram of the SRA flight control and avionic subsystems.
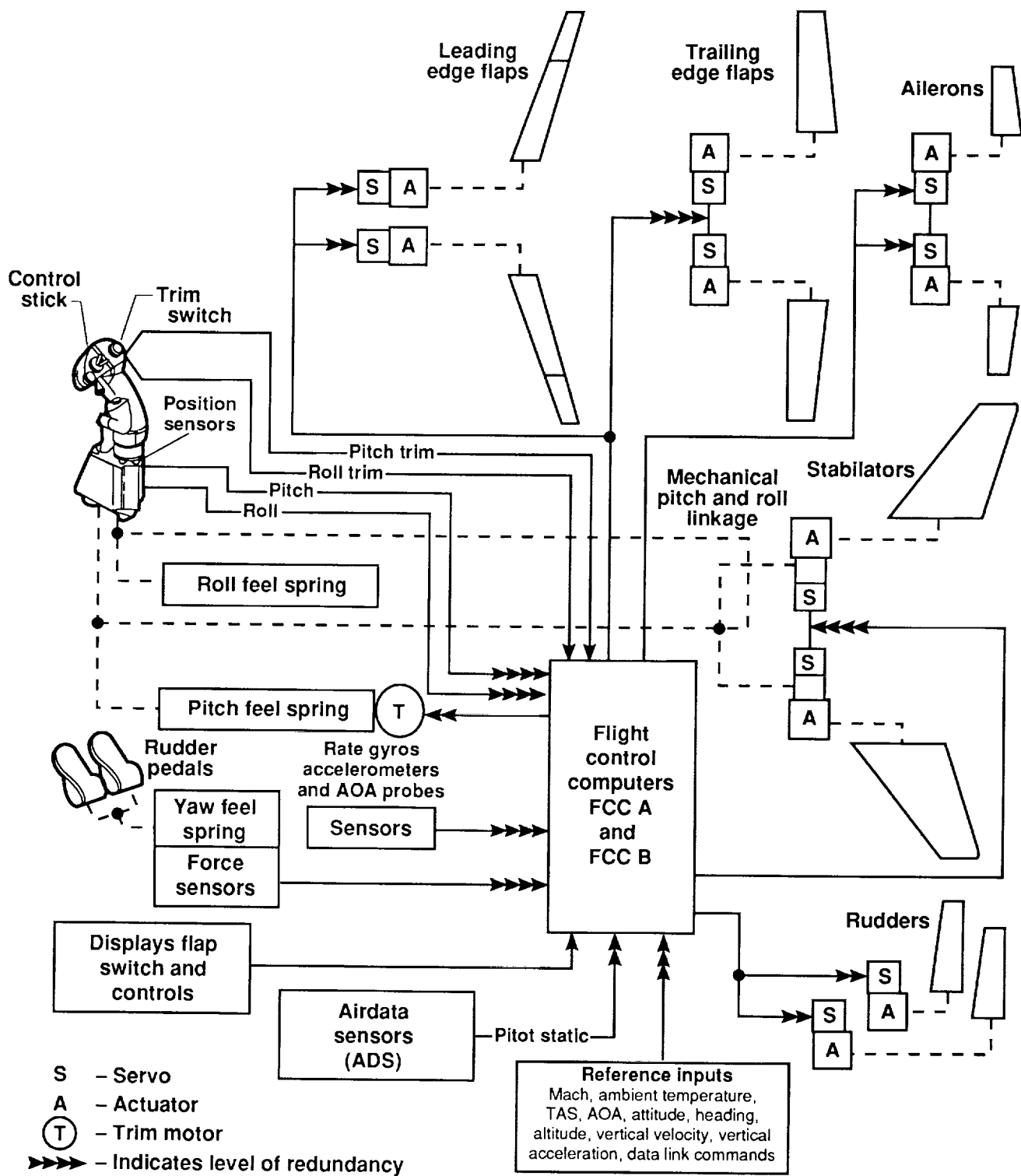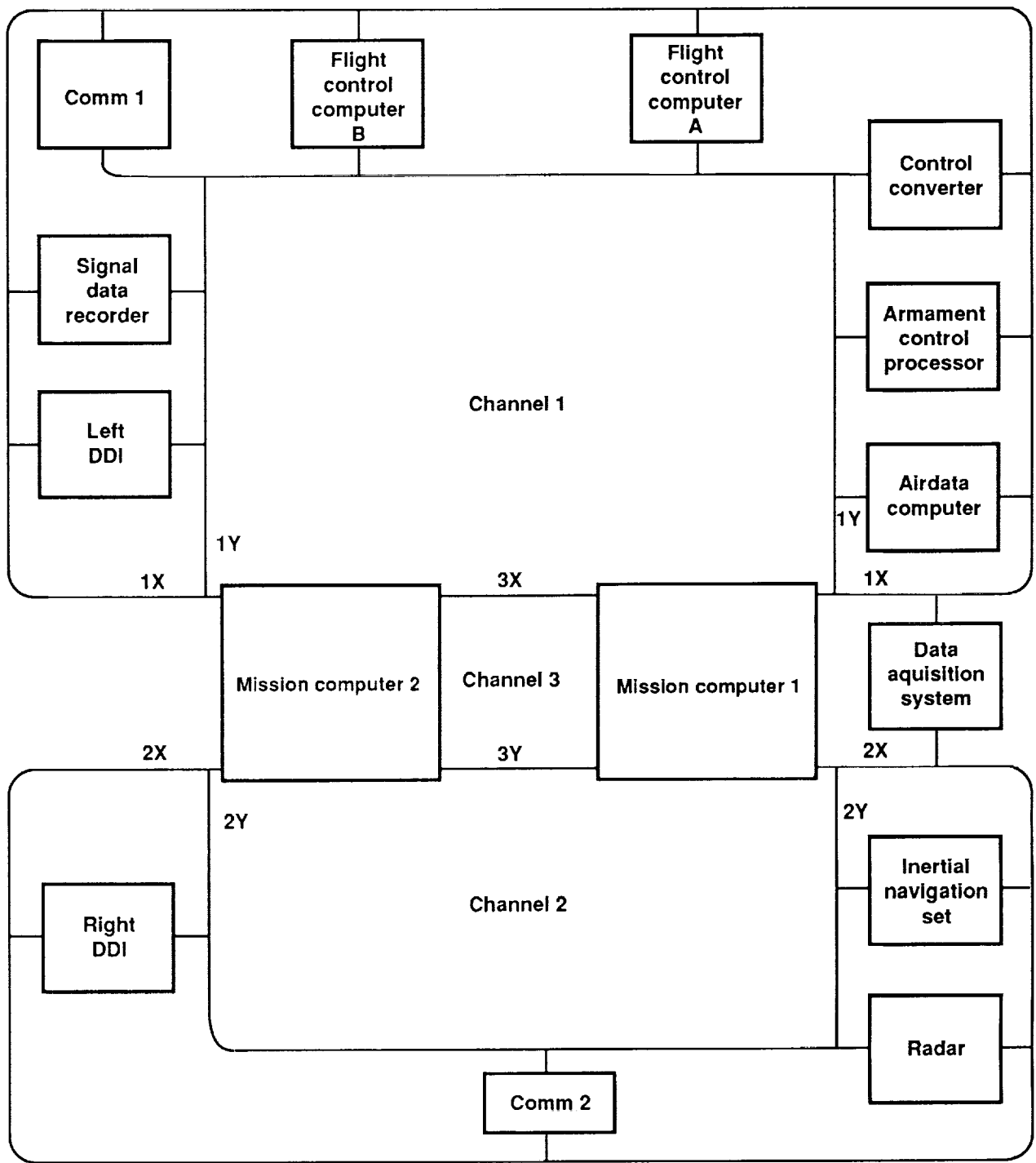
Figure 2. The SRA digital flight control system.

S – Servo
A – Actuator
(T) – Trim motor
▶▶▶▶ – Indicates level of redundancy

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Figure 3. Avionics architecture for the SRA.

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Cockpit

The SRA is a dual-place aircraft. The displays and pilot-interface functions are the same as those of the fleet F-18 aircraft. Specific cockpit modifications for the electrically powered actuation design (EPAD) program include a push-button switch for EPAD-initiated built-in test (BIT), an EPAD reset button, and a lever-locked switch for EPAD on-off functions. The EPAD section of this paper gives more details of these EPAD modes.

Minor changes to allow pilot control of the airborne research test system (ARTS) also will be made. A following section discusses the ARTS. The instrumentation system includes a new pilot-interface panel that will be located on the center console. The intent of the SRA facility is to use the rear cockpit mainly as a research cockpit for technologies such as human factors development and advanced displays. New displays also could be added to the front cockpit when necessary. A more detailed description of the F-18 aircraft is found in Ref. 4.

Data Acquisition System

The SRA is equipped with a data acquisition system that can measure, record, and telemeter more than 8000 parameters. The SRA data acquisition system is a distributed system. A programmable master unit (PMU) resides in the gun bay of the aircraft with up to 48 remote units located throughout the aircraft. The PMU schedules and executes the user's program for data acquisition, thus building a serial pulse code modulated (PCM) data stream. A remote MIL-STD-1553 data bus monitor can gather information from up to eight dual-redundant 1553 data busses. The system contains an IRIG-B standard time code generator to allow all data collected and telemetered to be time-correlated for later analysis.

The current configuration for the EPAD and FOCSI programs is for 713, 12-bit word, parameters. Sixteen programmable bit rates up to 2 Mbit/sec are available. The current configuration will be 500 Kbit/sec. Three of the 48 remote units will be used. Output of the data acquisition system is recorded on board and telemetered to a ground receiving station for real-time display and evaluation.

Airborne Research Test System

The ARTS is an advanced, open systems, computer architecture being developed as an onboard experiment support capability unique to the SRA facility. Figure 4 gives an overview of the ARTS concept. The primary goal of the ARTS is to enable researchers to rapidly transition desktop applications to flight test. This goal is met by providing research application software with easy access to real-time, engineering-unit (EU) data. These applications minimize the need for research engineers to develop custom program support hardware. A few specific examples of these applications are vehicle health monitoring, image processing, redundancy management, parallel processing, sensor fusion techniques, and advanced displays.

Figure 5 shows the overall ARTS architecture. The ARTS comprises two major subsystems: the input-output processor (IOP) and the application processor (AP). The IOP is a single-board
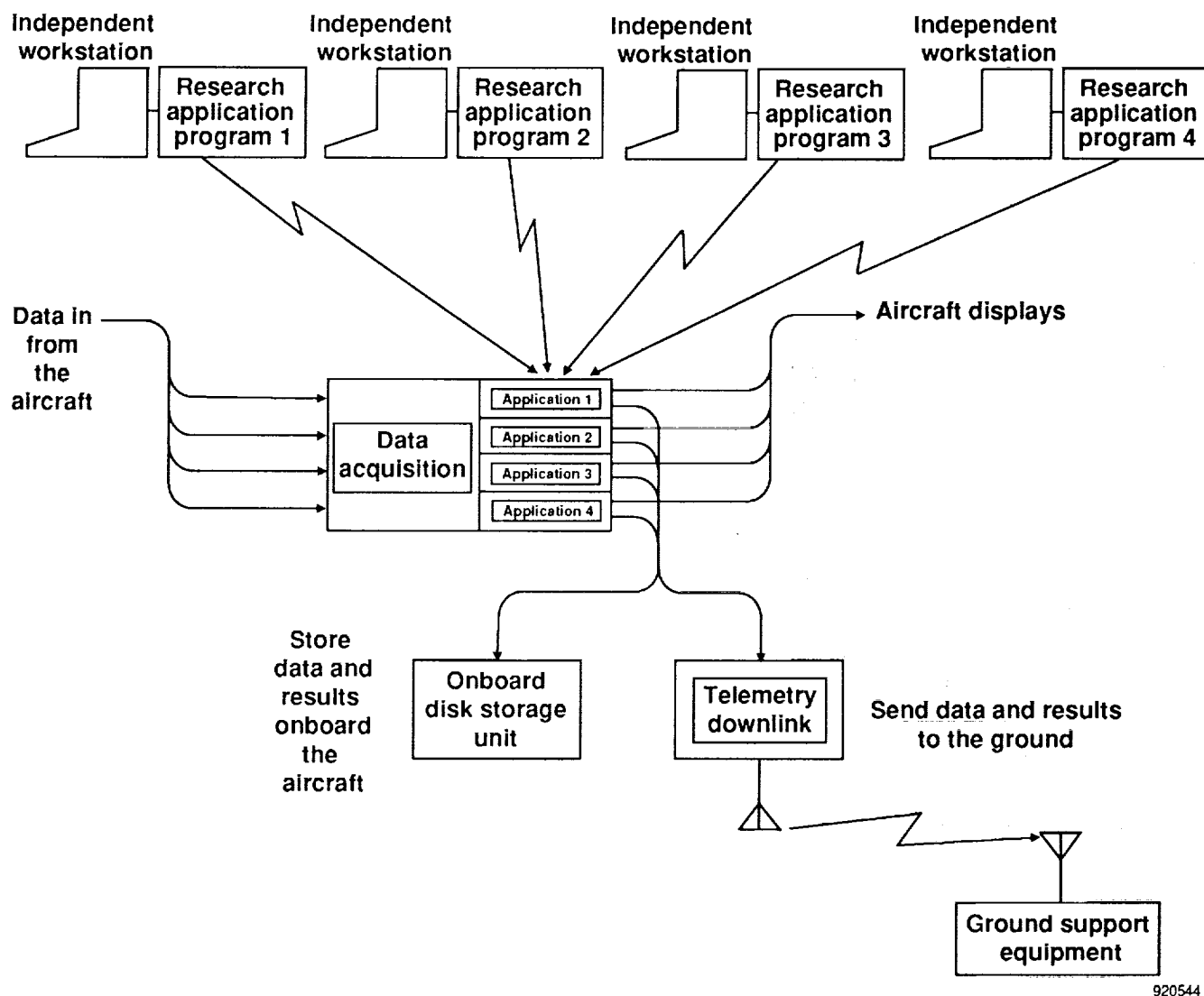
Figure 4. Overview of the ARTS concept.

Versa-module Eurocard (VME) computer supported by a real-time operating system. The AP is a single-board VME computer supported by the UNIX® operating system.

The IOP can input data at rates from 5 to 400 sample/sec. The IOP inputs include analog signals, digital signals, serial inputs (MIL-STD-1553, MIL-STD-1773, 422), and other onboard processors or sensors that may be associated with a specific experiment. The acquired data are then converted to EU data and written to a dual-port, VME-based random access memory (RAM). UNIX applications executing on the AP can then access the data from the dual-port RAM using calls to an application-interface library to standardize application software. All prime value (raw) data and current value (EU) data are buffered. Data-buffering mechanisms between the two processors compensate for the asynchronous, nonreal-time nature of the UNIX operating system.

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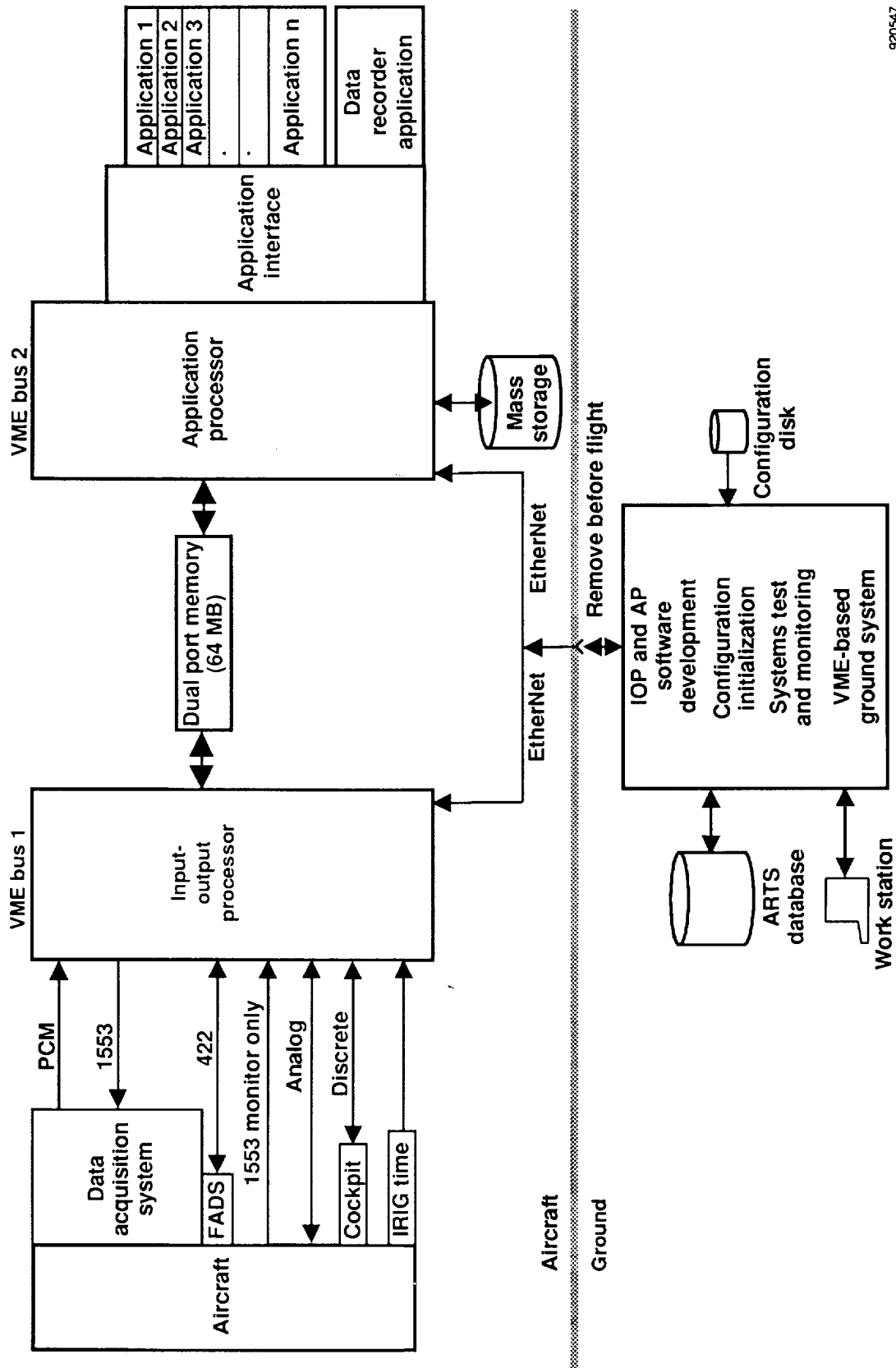
Fig. 5 Architecture for the overall ARTS.

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Outputs from the applications executing on the AP can be sent to specified output destinations such as cockpit displays, the telemetry data stream, or a mass storage device on the aircraft. After a flight, EU data or raw data can be downloaded from the mass storage device using standard network connections to the application processor. The EU data will be in the GETDATA format used at NASA Dryden.[5] Software languages that will be supported by the ARTS system include the C programming language, FORTRAN, and Ada.

The ARTS system is under development at Dryden (fig. 6). First flight of the IOP is scheduled for June 1993. The ARTS experiment support concept will initially be tested by supporting the real-time flush airdata system (RT-FADS) program. The RT-FADS section of this paper discusses specific details of this effort.
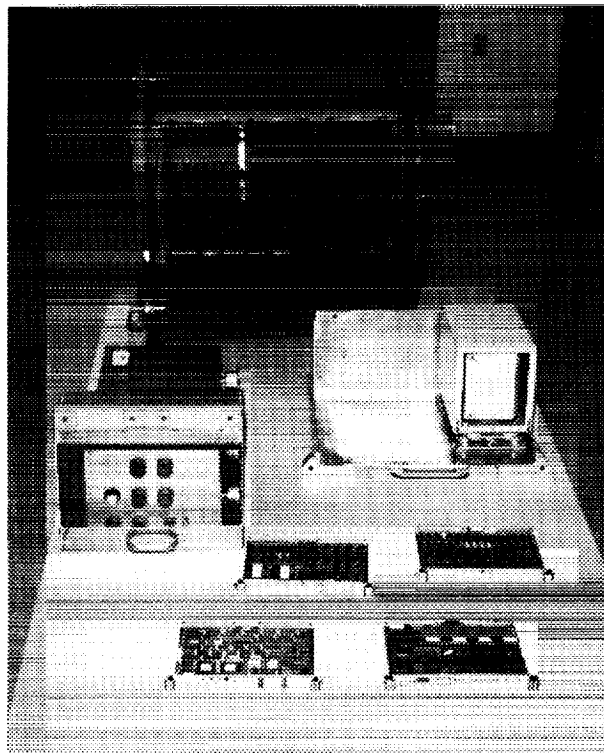
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Figure 6. Hardware used in the ARTS.

SUPPORTING GROUND TEST FACILITIES

Most major ground tests on the SRA facility will be accomplished in NASA Dryden's Integrated Test Facility (ITF).[6] The ITF ground test systems include real-time, nonlinear, aerodynamic simulation systems; real-time data recording systems; and a suite of computer-aided systems testing (CAST) software tools. The CAST tools provide real-time data capture, monitoring, and analysis. The CAST tools include closed-loop, automated testing techniques that are continually being maintained and improved at Dryden.[7] The CAST tools were developed under the F-18 HARV program and can be used by the SRA facility. The ITF systems allow for batch simulations, real-time software simulations, flight-hardware, iron bird, and aircraft-in-the-loop ground test configurations for the SRA facility.

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The SRA ground test facilities include the F-18 Iron Bird Facility that is shared by the HARV and SRA programs (fig. 7). The Iron Bird Facility has hydraulically operated horizontal stabilators, rudders, and ailerons. Other F-18 aircraft surfaces are simulated using analog actuator models. The Iron Bird Facility also includes a test bench to perform open-loop, standalone testing of the FCCs (figure 8). Using the ITF systems, the Iron Bird can be integrated with the F-18 aerodynamic simulation. A Dryden-developed simulation-interface device interconnecting the real-time aerodynamic models and the FCC hardware provides a hardware-in-the-loop and aircraft-in-the-loop simulation capability. The Dryden F-18 aerodynamic models will be upgraded to model the dual-place configuration accurately.
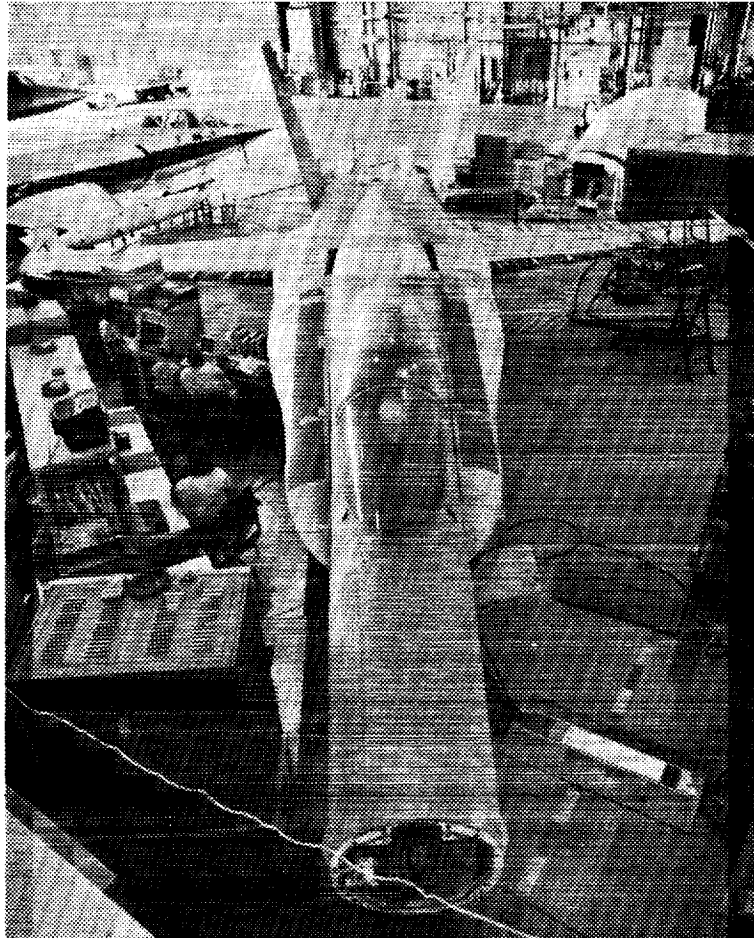
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Figure 7. F-18 Iron Bird Facility at NASA Dryden.
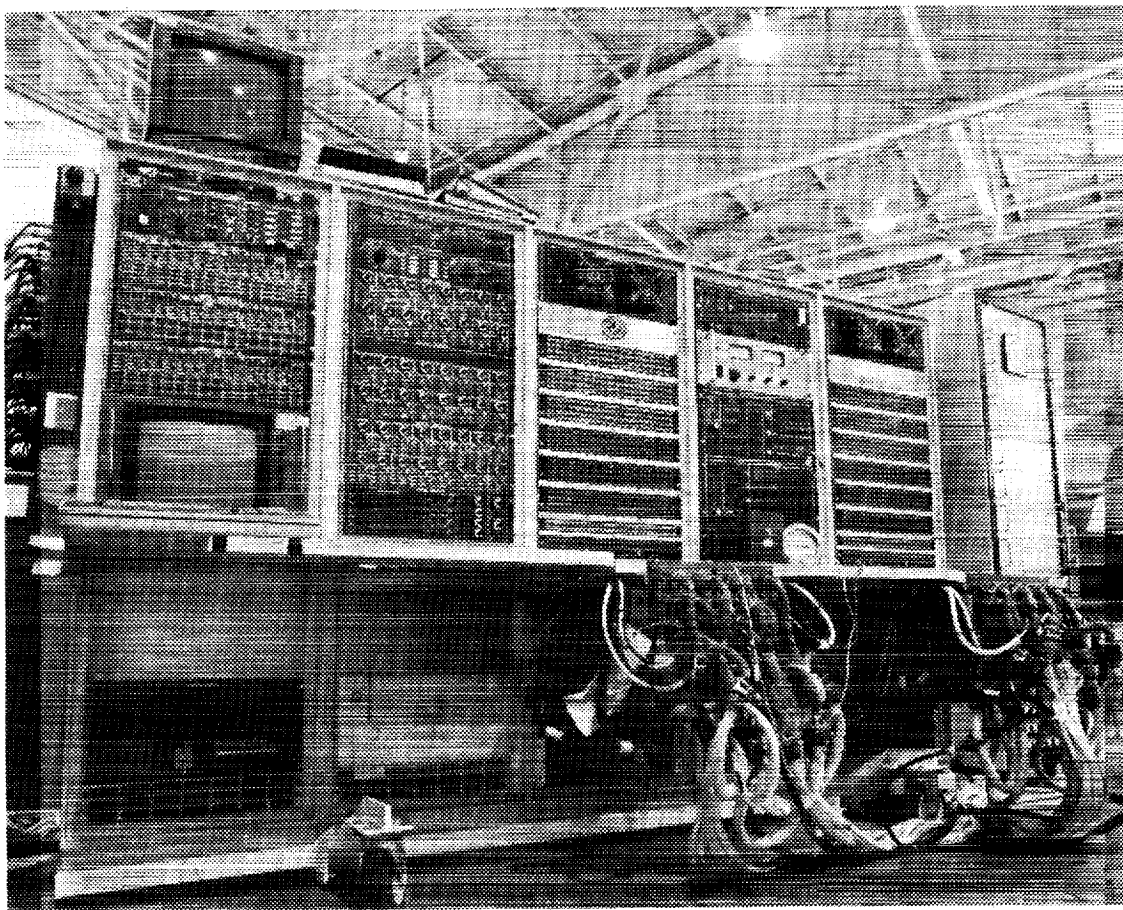
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Figure 8. Test bench for F-18 Iron Bird Facility.

CURRENT FLIGHT TEST PROGRAMS

The next section of this paper provides an overview of the specific experiments that will be flight-tested on the SRA during the next one to two years. The major programs using the SRA are the EPAD program, the FOCSI program, the fiber-optic position sensor network (FOPSN) experiment, and the RT-FADS program. The EPAD program discussion begins the EPAD test actuators, then discusses the SMART^{TM} (HR Textron, Valencia, California) actuator (SA), the electrohydrostatic actuator (EHA), and electromechanical actuator (EMA) experiments.

Electrically Powered Aactuation Design Validation Program

The purpose of the EPAD program is to examine the reliability and performance issues associated with advanced actuators. The EPAD program is a joint U.S. Air Force, U.S. Navy, and NASA program. The Air Force Wright Laboratory (Dayton, Ohio) is responsible for system selection and integration of candidate actuator concepts. NASA Dryden is responsible for conducting the flight test program. The EPAD program will flight-test advanced actuators to demonstrate their capabilities and to develop the

database required to incorporate them in newer Navy and military aircraft designs. The flight tests will use the SRA left aileron as the target application.

For the past few years several actuator manufacturers have been developing advanced actuators for controlling aircraft. Although many hours of laboratory testing have been expended on advanced actuator concepts, flight experience is limited. The three actuators to be flight-tested are the SA, EHA, and EMA. The flight tests will validate reliability issues associated with actuator-mounted electronics (SA), power-by-wire with confined hydraulics (EHA), and power-by-wire with no hydraulics (EMA). The Naval Air Warfare Center (Warminster, Pennsylvania) is the primary sponsor of the SA, with the Air Force sponsoring the EHA and EMA actuators. NASA Dryden is responsible for system integration support, ground test, aircraft installation, and flight test. All three actuators will be ground-tested using the Dryden F-18 Iron Bird located in the ITF before installation and flight on the SRA. Figure 9 shows a generic EPAD system architecture.
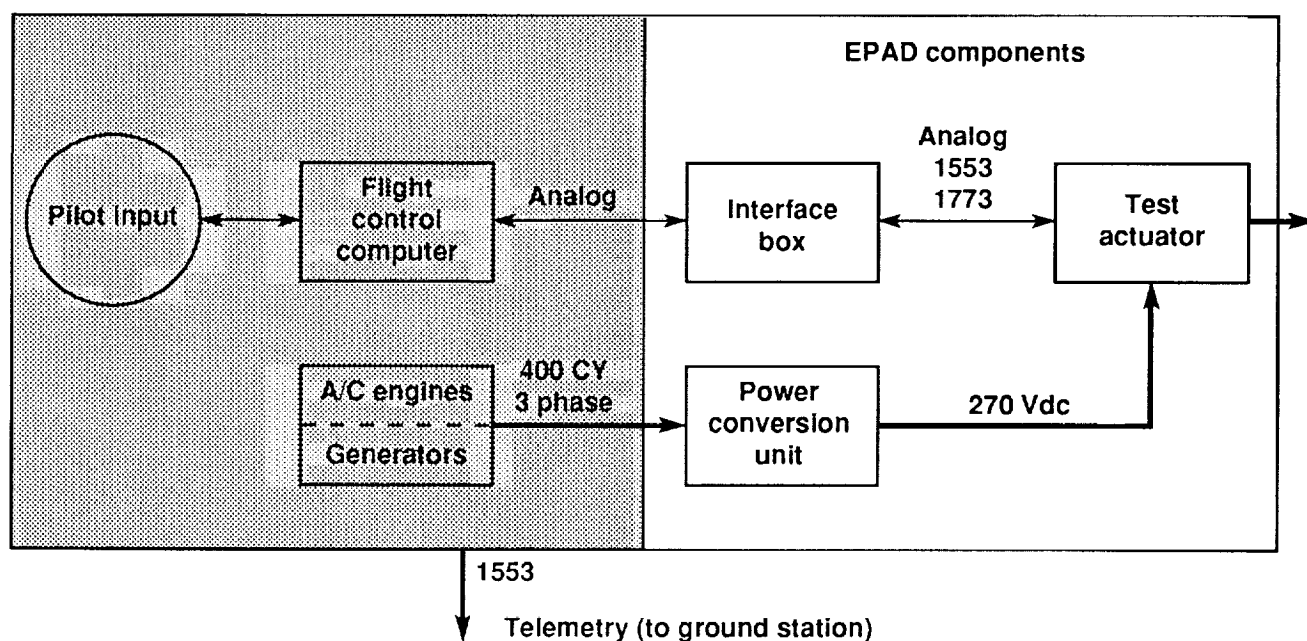
Figure 9. System architecture for EPAD.

Flight Control System Interface to the EPAD Test Actuators

To minimize EPAD program costs, interface boxes (fig. 10) were designed and built to transfer commands from each FCC channel to the test actuator. The interface boxes eliminated the need to modify the FCCs. Wright Laboratory has contracted to Dynamic Controls Incorporated (Dayton, Ohio) for the design, fabrication, test, and maintenance of the interface boxes.

The interface boxes will accept servo current commands from the FCCs for conversion into commands for the test actuator control electronics. The format of the command signal from each interface box to the test actuator control electronics is EPAD-actuator dependent. The SA electronics accept commands over a MIL-STD-1773 fiber-optic data bus. The EHA and EMA electronics accept commands in an analog format. The interface boxes will model the left-aileron actuator, provide a simulated left-aileron spool

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left-aileron spool and ram position feedback, and provide the hydraulic pressure indication to satisfy the FCC-interface requirements. For EPAD testing, there will be one interface box for FCC channel 1 and one interface box for FCC channel 4. The interface boxes are identical, channel independent, and electrically isolated from one another. No data are exchanged between the interface boxes. Electrical power for each of the two interface boxes will be provided from the aircraft essential 28-Vdc bus with emergency battery backup.
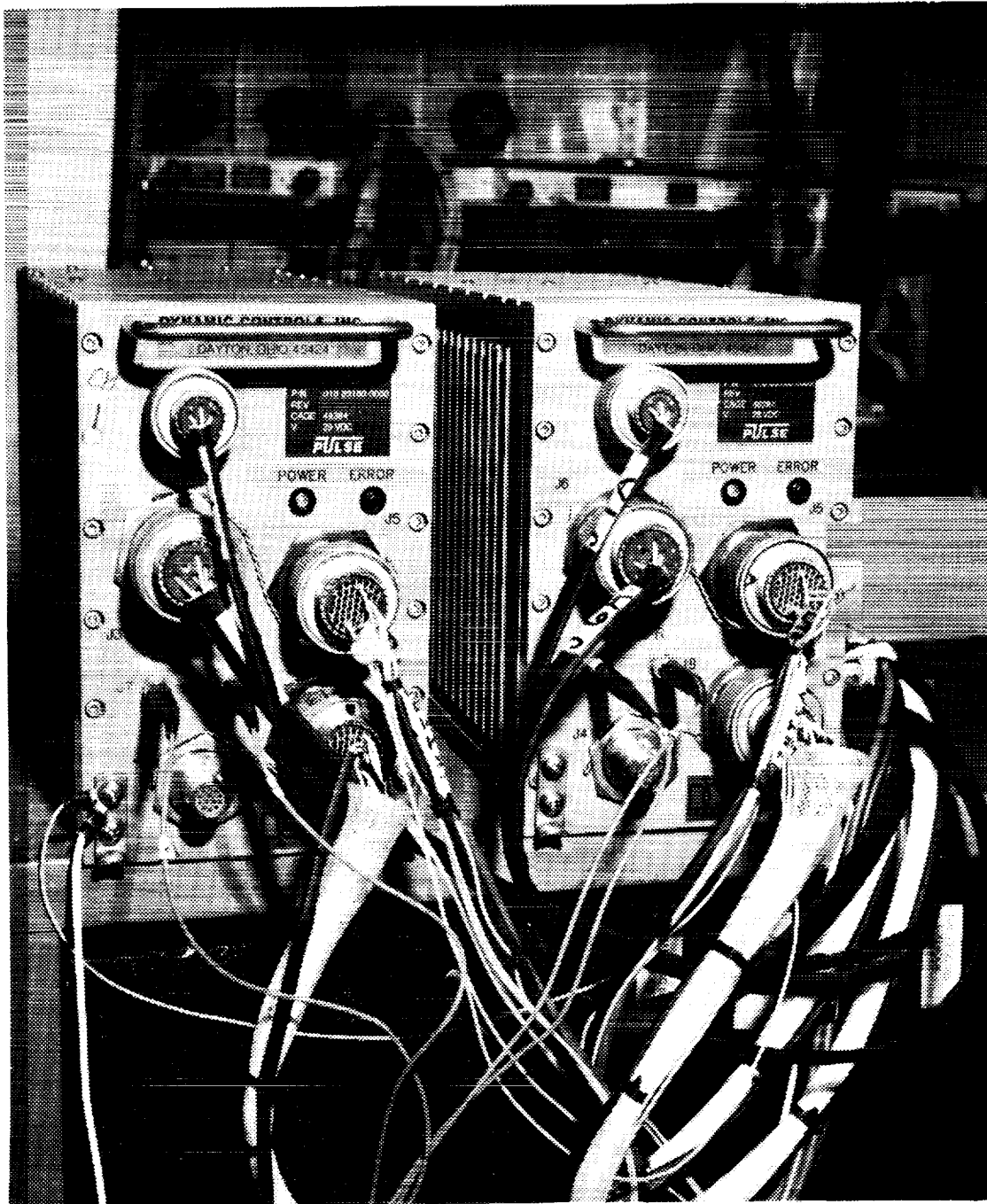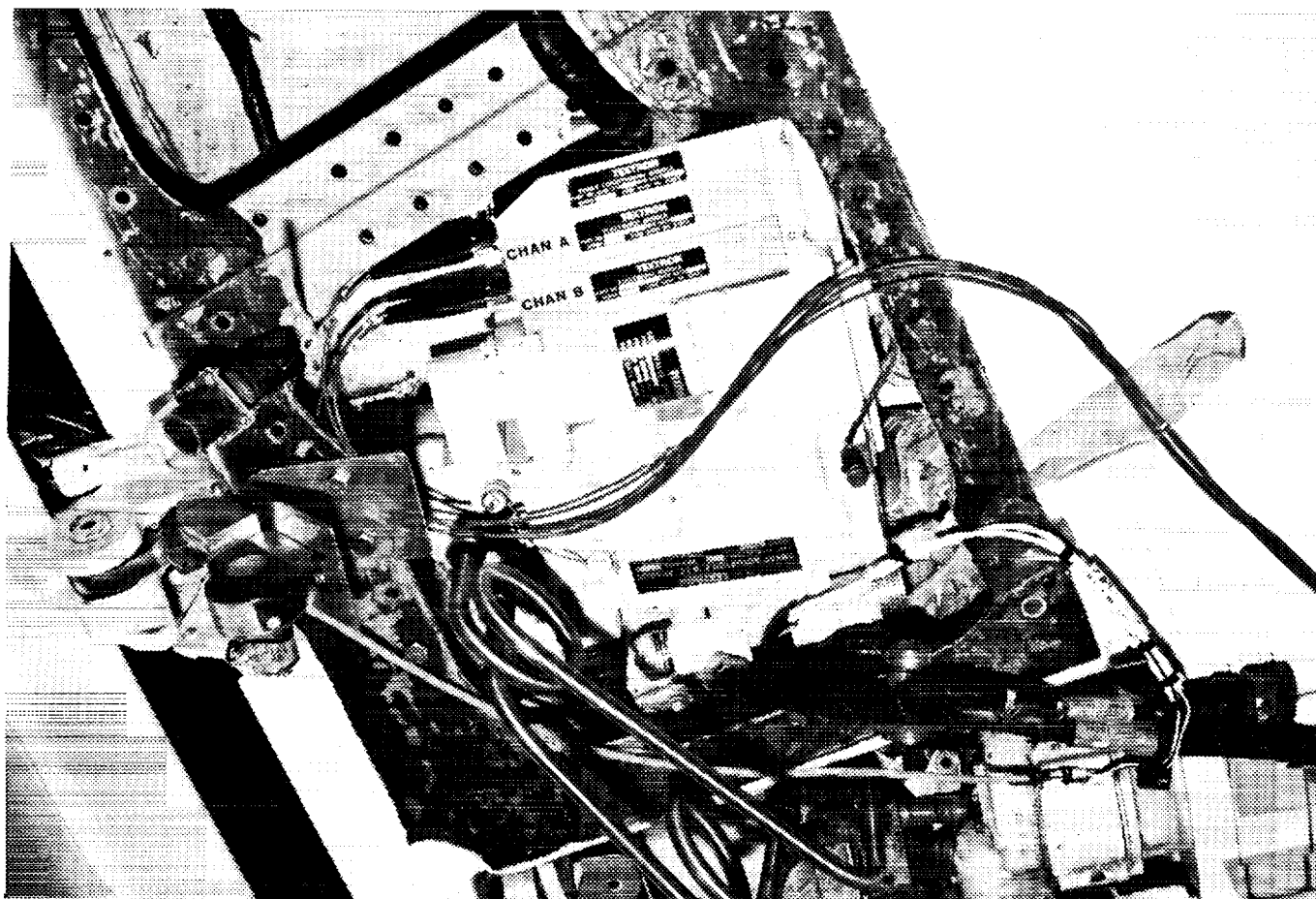

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Figure 10. Interface boxes for SA.

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The interface boxes control the pilot-selectable functions to the EPAD system. The BIT function will check both interface boxes and also will signal the test actuator control electronics to perform built-in tests. The EPAD reset function will clear latched failures in the interface boxes and test actuator control electronics. All EPAD test actuators except the SA system are designed for fail-safe operation. The SA system is fail operate, fail-safe. The pilot also may disengage the EPAD system in the cockpit at any time. Disengagement places the actuator in a trail-damped mode. The interface boxes will transmit data to the SRA data acquisition system using a 1553 data bus.

SMART Actuator Program

The SA program will flight-test the actuator-mounted electronics concept. The performance goal of the SA is to match the performance of the conventional F-18 aileron actuator. Figure 11 shows a picture of the SA installed in the NASA Dryden F-18 Iron Bird Facility for ground testing. The Naval Air Warfare Center contracted to HR Textron for design, fabrication, and qualification of the SA.

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Figure 11. An SA installed on the F-18 Iron Bird Facility.

The SA was built to fit into the conventional F-18 left-aileron actuator cavity. Minor actuator manifold modifications were made to accommodate the direct drive valve (DDV) and the actuator-mounted electronic modules for power conditioning, control, and monitoring. The actuator uses a DDV

instead of an electrohydraulic servo valve. The SA features a dual-redundant set of integrated electronics attached to the actuator manifold. Each asynchronous, electrically isolated SA channel has two 8-bit microprocessors performing DDV loop closure, actuator ram loop closure, mode logic, and redundancy management.

The SA system is designed to be fail-operate, fail-safe. First failures will result in single-channel operation. Second failures will result in a trail-damped mode. Each SA channel accepts position command from an interface box over two fiber-optic communication lines (one transmits, one receives) in a MIL-STD-1773 format. The SA returns DDV position, actuator ram position, and other health-related data over the fiber-optic link upon request from the interface box. The SA and interface box health-related data are sent to the SRA data acquisition system for insertion into a downlinked telemetry message for ground monitoring purposes. The intent for the SA facility, however, is to fly the SA without the need of ground station monitoring.

The SA concept offers several advantages. Fiber-optic communication links and the elimination of low-level command signals from the FCC help to reduce susceptibility to electromagnetic interference. Reduced wire-counts between the FCC and the actuator provide weight savings, reduce system complexity, and improve reliability. An informal Navy review using a V-22 Osprey tilt-rotor aircraft showed a decrease in the number of actuator interface wires from 523 to 35 using the SA communication concept. Standard FCC and actuator communication formats can be established simplifying system integration. Actuator redundancy management is removed from the FCC software reducing software complexity. Maintenance procedures are enhanced with automatic rigging capability.

Before flight, ground test techniques and system integration issues associated with actuator-mounted electronics will be established for use on future programs. Beneficial flight data also will be collected. The practicality and reliability of fiber-optic communications will be tested. Data relating to procedures and equipment necessary for maintaining the fiber-optic communication lines and connectors on an aircraft will be developed and documented. The reliability of actuator-mounted electronics will be tested in the harsh environment of the F-18 wing. The SA is scheduled for flight test in the fourth quarter of 1992.

Electrohydrostatic Actuator and Electromechanical Actuator Programs

The main goal of the EHA and EMA programs is to validate electrically powered actuators as a primary method of control for surfaces in a high-performance, more-electric aircraft. The EHA and EMA flight programs are meant to ensure that power-by-wire actuation is not a limiting factor in more-electric aircraft. The performance goals of the EHA and EMA actuators are to match those of the conventional F-18 aileron actuator. Wright Laboratory is sponsoring the development of the EHA, EMA, and interface electronics under a prime contract to General Electric Aircraft Systems Department, Binghamton, New York. GE is responsible for integrating the EHA and EMA actuators with the remotely located control electronics. Dowty Aerospace, Los Angeles, California, is subcontracted to GE for developing the EHA actuator. MPC Products Incorporated, Skokie, Illinois, is subcontracted to GE for the EMA actuator development.

The EHA will be built to fit into an F-18 aileron actuator cavity with a modified hinge-half assembly. The test actuator power control and monitoring electronics (PCME) unit will be located in

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a separate wing cavity. The PCME will accept analog position commands from the EPAD interface boxes discussed earlier. The PCME will then generate an averaged motor velocity command to drive an integrated, internal motor and hydraulic pump assembly, resulting in actuator ram movement. Ram position, motor velocity, and current feedbacks to the PCME unit will provide information for closed-loop control and system health monitoring. Any errors or malfunctions detected will result in the actuator being commanded to a trail-damped position.

The EMA also will be built to fit into an F-18 aileron actuator cavity with a modified hinge-half assembly. The EMA and EHA actuators will use the same PCME unit. The PCME unit will accept analog position commands from the EPAD interface boxes discussed earlier. The PCME will then generate motor velocity commands to drive an integrated motor connected to a gear train. The gear train will move a ball-screw ram. Rotary gear train position, motor velocity, and current feedbacks to the PCME unit will provide information for closed-loop control and system health monitoring. Any errors or malfunctions detected will result in the actuator being commanded to a trail-damped position.

Flight test of the EHA and EMA actuators will provide reliability and performance data for electric actuation systems. The maturity of electric motors and high-power switching electronics will be demonstrated for use in a high-performance aircraft. In particular, regenerative and thermal energy dissipation techniques can be validated. Electric actuator damping and stiffness characteristics will be determined. The fidelity of electric actuator models as design tools also will be validated and improved. Future more-electric-aircraft designs will benefit from this information. The EHA and EMA actuators are scheduled for SRA flight test in 1993.

Fiber-Optic Control System Integration Program

The FOCSI program, originated at Lewis Research Center, is a NASA-DOD sponsored program. The purpose is to explore the advantages of using fiber-optic sensors and cables for gathering and transmitting airframe and engine information to control systems and pilots. The associated electro-optic architectures (EOAs) for servicing remote clusters of sensors and actuators are also being developed and evaluated.

The FOCSI program is a joint effort of NASA Lewis and NASA Dryden. NASA Lewis is sponsoring the development of 10 airframe sensors, 9 engine-mounted sensors, and the integration of these sensors with the appropriate electro-optic interfaces for data-acquisition purposes. Prime contracts were signed with McDonnell Aircraft Company, St. Louis, Missouri, and General Electric Aircraft Engines, Cincinnati, Ohio. McDonnell Aircraft is responsible for developing the airframe sensors and an associated EOA unit. General Electric is responsible for the engine sensors and an associated EOA unit. NASA Dryden is responsible for installing and flight testing the sensors and EOA units on the SRA. Figure 12 shows the overall FOCSI system architecture to be flight-tested.

The primary goals of the flight test are to demonstrate current technology capability, validate sensor operation in the flight environment of a high-performance aircraft, and develop operational experience in installing and maintaining fiber-optic systems. The flight test will be an open-loop, passive demonstration of the fiber-optic sensors. Some benefits of FBL technology are weight and volume reduction as a result

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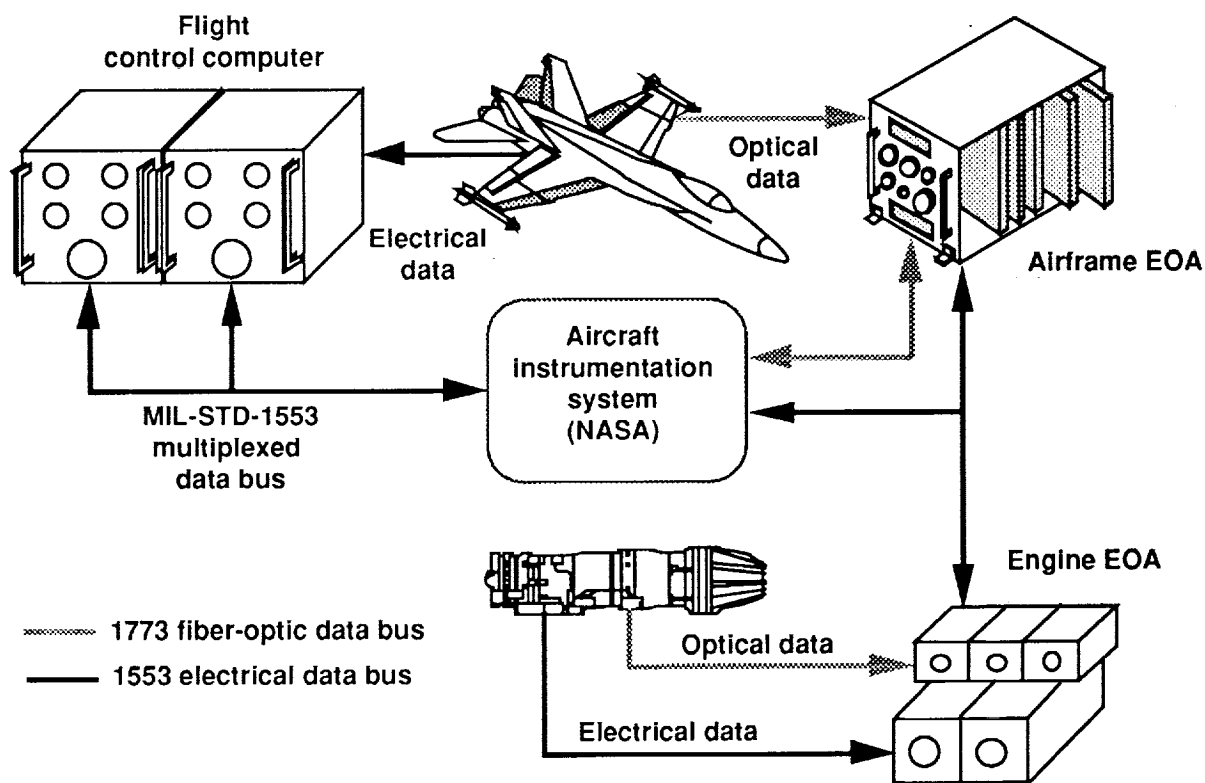
Figure 12. Open-loop architecture of FOCSI.

of using optical fibers instead of copper wire, increased immunity from electromagnetic effects, higher bandwidth data communications, and freedom from short-circuit sparking contacts. The FOCSI flight test program will compare conventional instrumentation techniques with the fiber-optic sensors to be installed on the SRA. Table 3 lists the fiber-optic sensors and techniques associated with the airframe parameters. Table 4 lists the engine-related sensors.

Table 3. FOCSI airframe-mounted sensors on the SRA.

Sensor	Technology	Vendor
Rudder position	WDM digital code	Litton Poly-Scientific, Blacksburg, VA
Trailing edge flap position	WDM analog ratio	BEI Motion Systems, Chatsworth, CA
Airdata temperature	Fluorescent decay	Rosemount Inc., Burnsville, MN
Pitch stick position	WDM digital ratio	Litton Poly-Scientific
Rudder pedal position	WDM digital code	Litton Poly-Scientific
Total pressure	WDM analog microbend	Babcock & Wilcox Co., Augusta, GA
Nose wheel steering	WDM analog ratio	BEI Motion Systems
Leading edge flap position	WDM digital code	Allied Signal - Bendix, Morristown, NJ
Power level control	WDM digital code	Litton Poly-Scientific
Stabilizer position	WDM digital code	Litton Poly-Scientific
Electro-optic chassis		Litton Poly-Scientific

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Table 4. FOCSI F404-GE-400 engine-mounted sensors on the SRA.

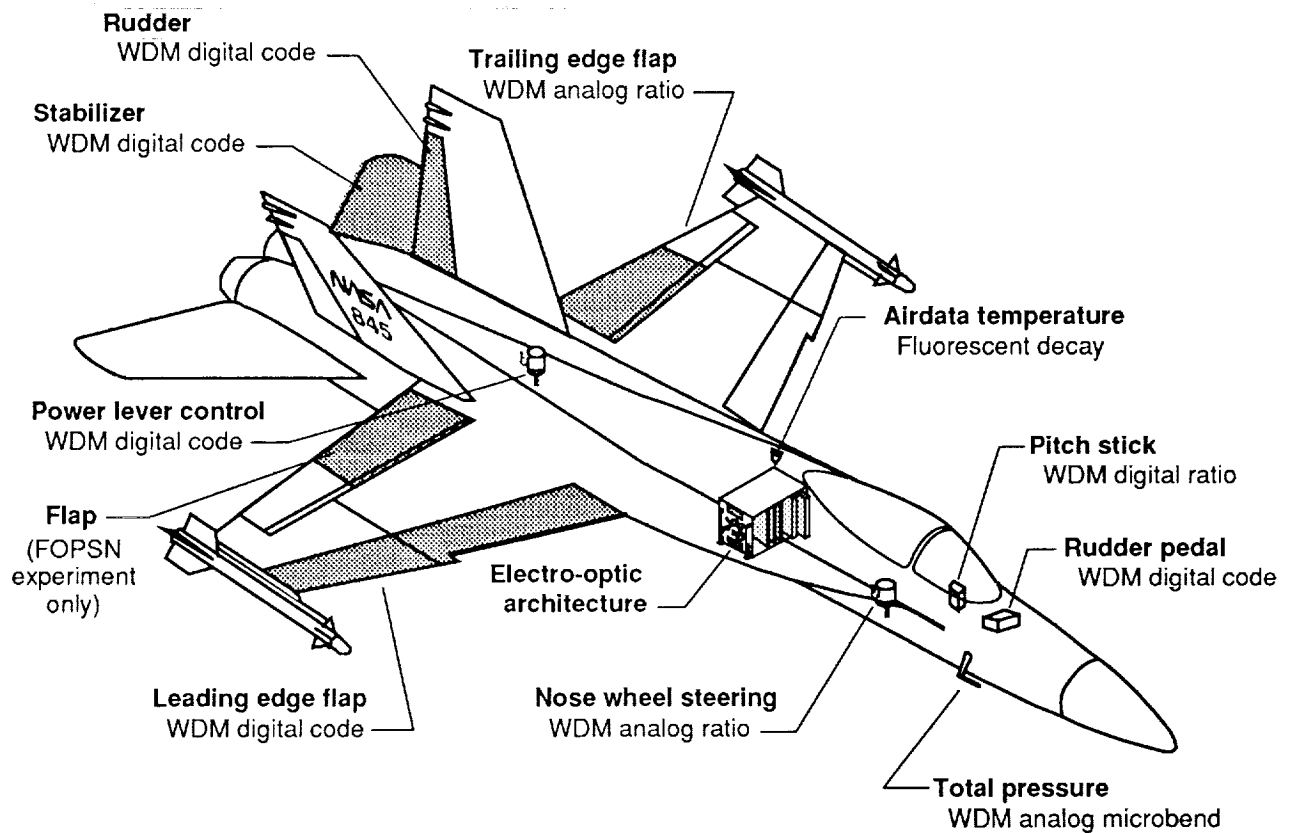| Sensor	Technology	Vendor
Inlet temperature	Fluorescent decay	Rosemount Inc., Burnsville, MN
Fan variable geometry position	WDM digital code	Litton Poly-Scientific, Blacksburg, VA
Compressor inlet temperature	Fabry Perot	MetriCor, Woodenville, WA
Compressor variable geometry	WDM analog ratio	BEI Motion Systems, Chatsworth, CA
Turbine exhaust gas temperature	Blackbody	Conax, Buffalo, NY
Afterburner flame detector	Ultraviolet tube	Ametek, El Segundo, CA
Variable exhaust nozzle position	WDM analog ratio	BEI Motion Systems
Fan speed sensor	Pockels effect	Banks Engineering, Sun Valley, CA
Core speed sensor	Faraday effect	Bendix, Morristown, NJ
Electro-optic chassis		Litton Poly-Scientific, Blacksburg, VA
		General Electric, Cincinnati, OH

Figure 13 shows the Rosemount (Rosemount Inc., Burnsville, Minnesota) total temperature sensor (left) and the leading edge flap rotary position sensor (right) to be flight-tested. Figure 14 shows the airframe sensors and electro-optic chassis position on the SRA. Figure 15 shows the engine-mounted sensors and electro-optic architecture position on the SRA engine. The heart of the airframe sensors is the EOA (fig. 16), which generates and delivers optical input power to remote optical sensors, processes the modulated optical signals returned from the sensors, and produces conditioned electrical signals suitable for the SRA data acquisition system. The optical sensors being developed are passive devices that modulate an optical input signal according to a sensed physical parameter such as position, temperature, or pressure. Both digital and analog optical sensors are being developed.

Options to develop a closed-loop, FBL control system are being considered. The use of the SRA's FBW system to mechanize an in-flight changeover to FBL offers significant advantages in flight testing FBL systems. The flight tests of the FOCSI system are scheduled for early 1993.
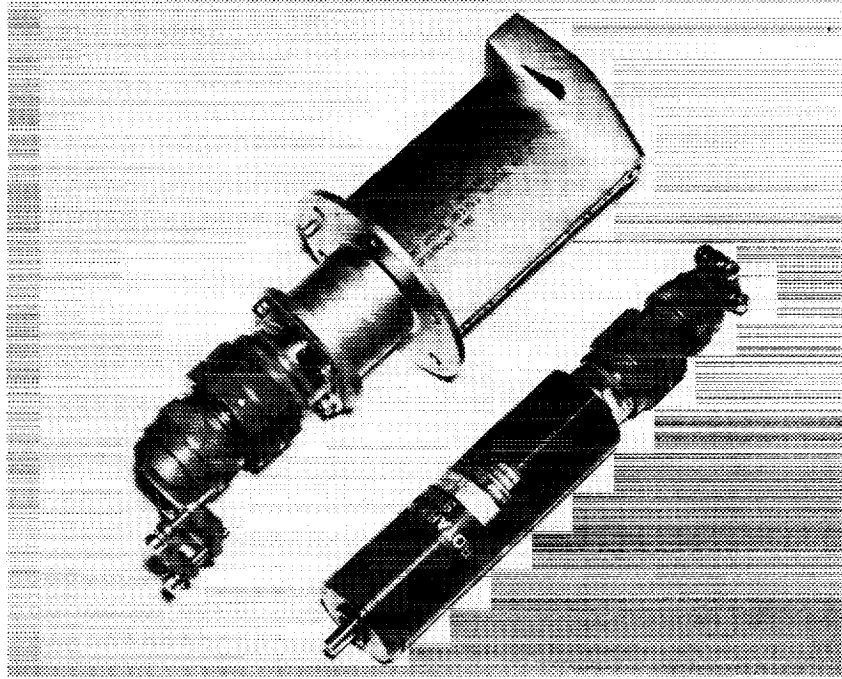
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Figure 13. Airframe sensors on FOCSI.

Rudder
WDM digital code

Trailing edge flap
WDM analog ratio

Stabilizer
WDM digital code

Airdata temperature
Fluorescent decay

Power lever control
WDM digital code

Pitch stick
WDM digital ratio

Flap
(FOPSN
experiment
only)

Rudder pedal
WDM digital code

**Electro-optic
architecture**

Leading edge flap
WDM digital code

Nose wheel steering
WDM analog ratio

Total pressure
WDM analog microbend

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Figure 14. FOCSI and FOPSN airframe sensor locations on the SRA.

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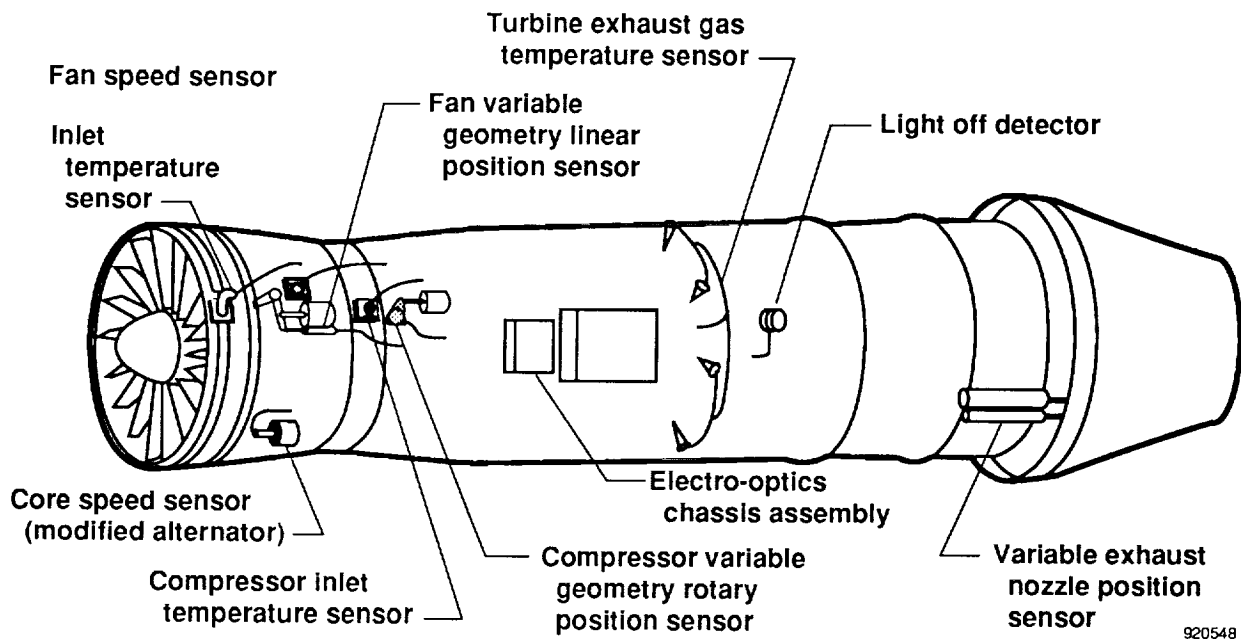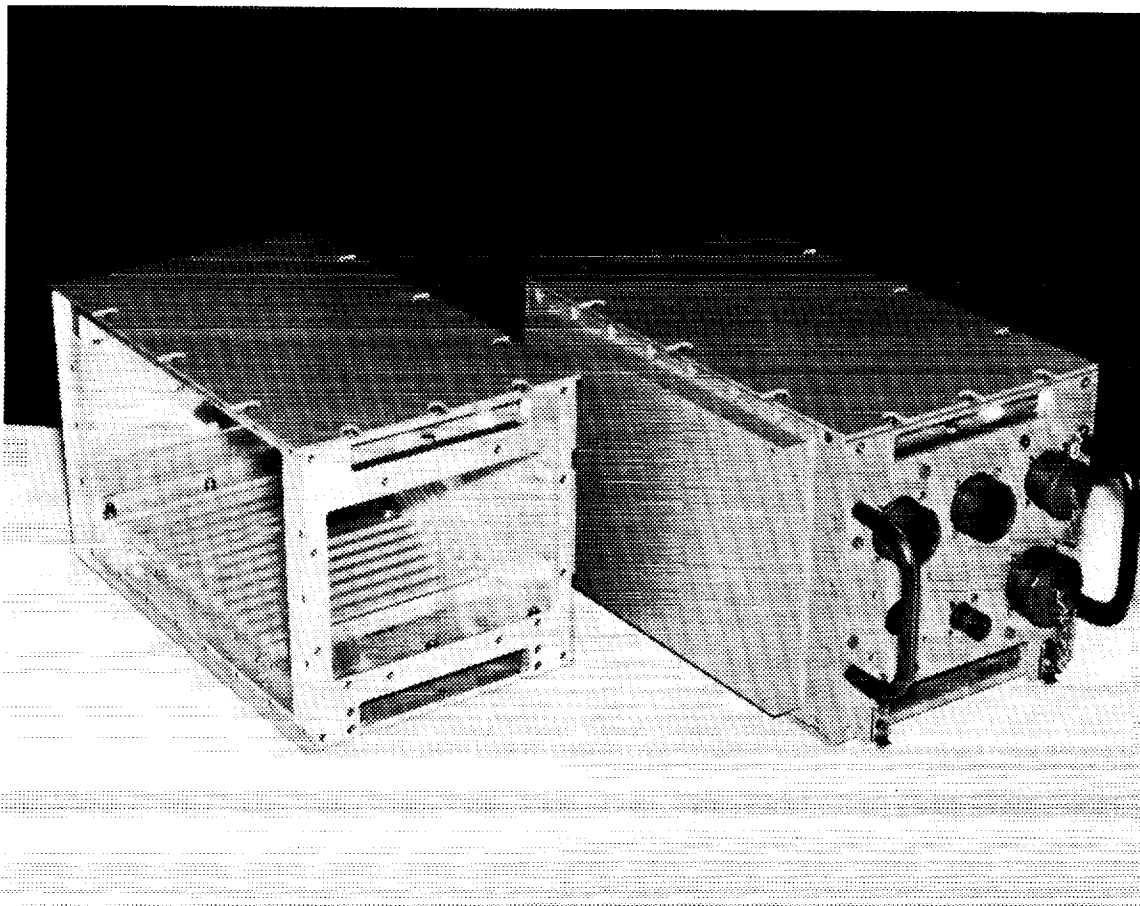
Figure 15. Fiber-optic sensors (FOCSI) on the F404-400.

Figure 16. EOA hardware assembly for the FOCSI.

Fiber-Optic Position Sensor Network Program

The purpose of the FOPSN program is to flight-test a new fiber-optic position sensing network for potential use in primary aircraft control. The FOPSN experiment is a joint effort by NASA Dryden and the control systems division of Parker-Hannifin Corporation, Rohnert Park, California. The program will be run in conjunction with the FOCSI program described earlier.

The FOPSN test involves removing the balance tube from the empty ram of a twin-ram trailing edge flap actuator used on the SRA. The tube will be replaced with a dual-channel fiber-optic linear position encoder. The linear variable differential transformer (LVDT) used for closed-loop position control in the other ram will not be disturbed. The performance of the FOPSN sensor will be evaluated by comparing it with the control surface position as measured with conventional means. Fiber-optic cables will transmit the position measurement from the FOPSN sensor to an interface decoding unit. The decoding unit will transmit position data to the SRA's data acquisition system over a MIL-STD-1553 multiplex bus.

NASA Dryden will provide the SRA for FOPSN flight test during the FOCSI program. Dryden will be responsible for aircraft installation, flight test data collection, and data results reporting. The FOPSN experiment will be flight-tested in early 1993.

Real-Time Flush Airdata System Program

The RT-FADS is a program to develop flight-worthy airdata systems that can obtain highly accurate and reliable airdata. The RT-FADS measurements are taken in adverse conditions using nonintrusive measurement techniques. The nonintrusive feature is particularly useful for research aircraft adversely affected by flow disturbances caused by external probes and vanes.

The RT-FADS is a NASA Dryden-originated program. Flush airdata sensor development has been contracted to Honeywell Incorporated, St. Louis Park, Minnesota. McDonnell Aircraft Company is responsible for the integration of the airdata sensors to a military-qualified computer for implementing computationally-intensive RT-FADS algorithms. After initial flight tests with the military-qualified computer, however, the RT-FADS will be interfaced to the ARTS, which was discussed earlier in this paper. The ARTS will increase computational power and provide greater potential for system algorithm enhancements.

Figure 17 presents the proposed RT-FADS architecture, using the ARTS system on the SRA. Serial data from flush mounted sensors will be acquired by the IOP and processed. Outputs will be inserted into the SRA telemetry stream for transmission to ground-based monitoring stations. The RT-FADS-processed data also will be recorded on board using the mass storage device.

Flight test objectives include assessing the suitability of the RT-FADS system as a feedback sensor in a high-gain flight control system. This will require demonstration of the end-to-end system robustness, reliability, frequency response, and measurement accuracy over a wide range of flight conditions. Sensor fusion techniques to blend RT-FADS data and inertial data for system fidelity and accuracy enhancement

also will be tested. This effort will use the SRA's inertial navigation system parameters. The initial RT-FADS system is scheduled for flight test in January 1993 with the ARTS integration being flight-tested in June 1993.
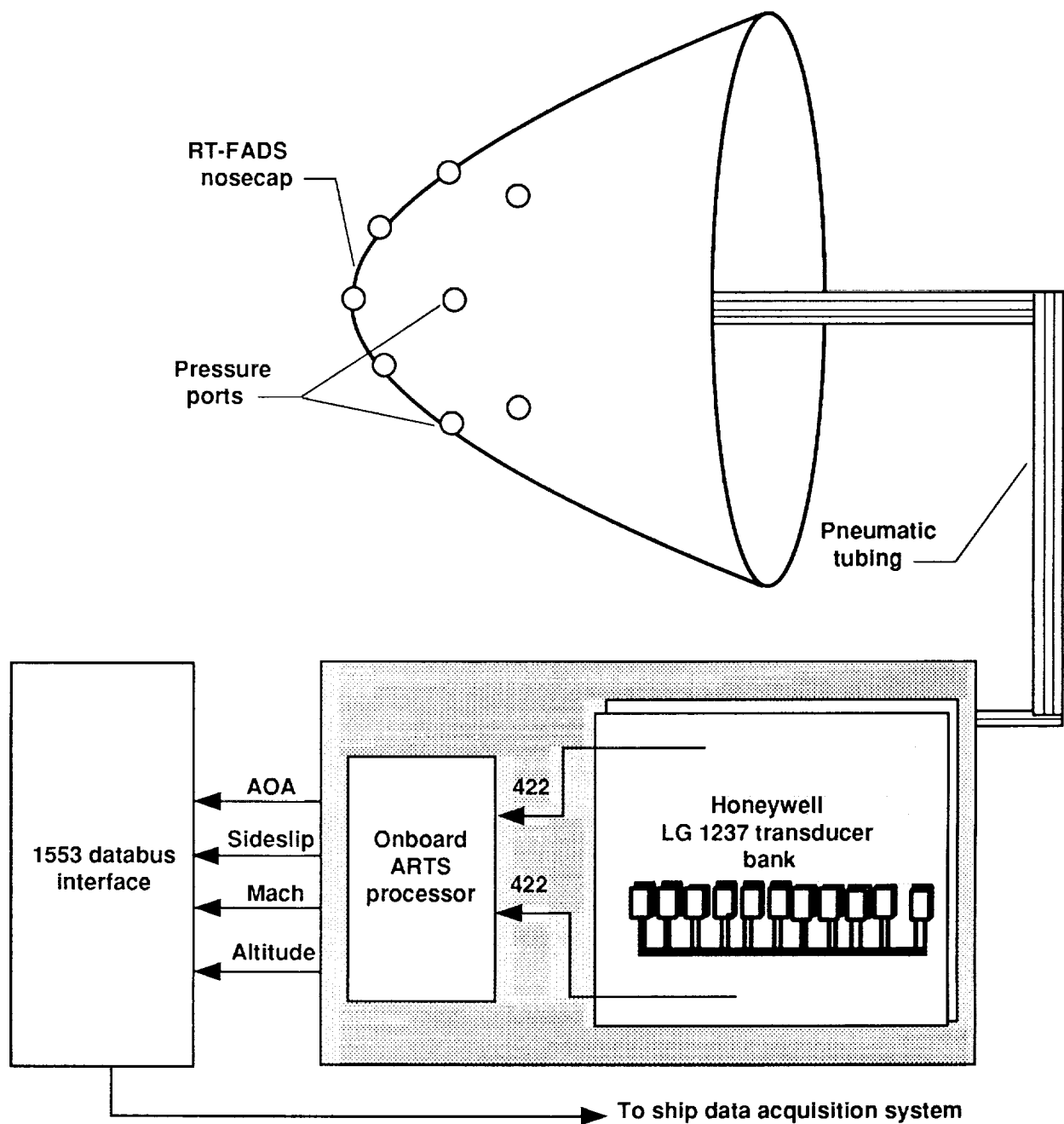
Figure 17. Proposed architecture for RT-FADS.

SUMMARY AND CONCLUSIONS

The NASA Dryden Flight Research Facility has dedicated a dual-place, high-performance, F-18 systems research aircraft (SRA) for purposes of flight testing new aerospace systems technologies. Dryden's primary goal is to assist government and industry initiatives in strengthening U.S. competitiveness by reducing the time from research and development laboratories to manufacturing. The SRA is an ideal flight test facility for systems research because experiments can take advantage of the aircraft's redundant surfaces, full-authority fly-by-wire control system, dual engines, dual seats, and comprehensive ground test facilities.

Electrically powered actuation experiments to be flown on the SRA will benefit the nation's more-electric-aircraft program and lead to a more focused flight test effort for future more-electric systems technology integration. The fiber-optic control system integration program on the SRA will produce several flight-tested technologies necessary to demonstrate a closed-loop, fly-by-light control system. Use of the SRA's fly-by-wire system as a fly-by-light system-backup offers significant risk reduction in testing FBL options. State-of-the-art, open systems computing architectures, such as the airborne research test system being developed for the SRA, will enable researchers to use commercial, off-the-shelf hardware and software for flight testing research algorithms. This will reduce experiment cost and prevent reengineering efforts for every experiment.

Recent advances in NASA Dryden's ground test facilities with the construction and development of the Integrated Test Facility and related test systems offer SRA users significant advantages in real-time ground test data capture, monitor, and analysis capability. The SRA is a national asset with a dual-purpose role in benefitting aerospace technology demonstration for commercial as well as military experiments.

Dryden Flight Research Facility
National Aeronautics and Space Administration
Edwards, California, November 3, 1992

REFERENCES

[1]Hewett, Marle D., *High-Speed Civil Transport Issues and Technology Program*, NASA CR-186020, 1992.

[2]Gilbert, William P., Luat T. Nguyen, Joseph Gera, "Control Research in the NASA High-Alpha Technology Program," AGARD Fluid Dynamics Panel Symposium on Aerodynamics of Combat Aircraft Control and of Ground Effects, AGARD CL 465, paper no. 3, 1989.

[3]Burcham, Frank W., Jr., Gary A. Trippensee, David F. Fisher, and Terrill W. Putnam, *Summary of Results of NASA F-15 Flight Research Program*, NASA TM-86811, 1986, or AIAA 86-9761.

[4]U.S. Navy, "NATOPS Flight Manual, Navy Model FA-18A and FA-18B," A1-F18AC-NFM-000, Dec. 1985.

[5]Maine, R.E., *Manual for GetData Version 3.1*, NASA TM-88288, 1987.

[6]Mackall, D., D. McBride, and D. Cohen, *Overview of the NASA Ames-Dryden Integrated Test Facility*, NASA TM-100418, 1988.

[7]Sitz, J.R. and T.H. Vernon, *Flight Control System Design Factors for Applying Automated Testing Techniques*, NASA TM-4242, 1990.

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To help ensure that new aerospace initiatives rapidly transition to competitive U.S. technologies, NASA Dryden Flight Research Facility has dedicated a systems research aircraft facility. The primary goal is to accelerate the transition of new aerospace technologies to commercial, military, and space vehicles. Key technologies include more-electric aircraft concepts, fly-by-light systems, flush airdata systems, and advanced computer architectures. Future aircraft that will benefit are the high-speed civil transport and the National AeroSpace Plane. This paper describes the systems research aircraft flight research vehicle and outlines near-term programs.

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