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REAL-TIME DATA DISPLAY FOR AFTI/F-16 FLIGHT TESTING

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ABA: S.L.

ABS: Advanced fighter technologies to improve air to air and air to surface weapon delivery and survivability is demonstrated. Real time monitoring of aircraft operation during flight testing is necessary not only for safety considerations but also for preliminary evaluation of flight test results. The complexity of the AFTI/F-16 aircraft requires an extensive capability to accomplish real time data goals; that capability and the resultant product are described.

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REAL-TIME DATA DISPLAY FOR AFTI/F-16 FLIGHT TESTING

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INTRODUCTION

The advanced fighter technology integration/F-16 (AFTI/F-16) program is jointly sponsored by the Air Force, Navy, and NASA to demonstrate advanced fighter technologies, with the overall technical and management responisibility assigned to the Air Force Flight Dynamics Laboratory, AFTI/F-16 Advanced Development Program Office (ADPO), Wright-Patterson AFB, Ohio. Flight testing of the AFTI/F-16 aircraft is accomplished by a joint test force, including the above government agencies and a contractor operating at the NASA Dryden Flight Research Facility, Edwards, California. Demonstration of these fighter attack technologies has been divided into two elements: the digital flight control system (DFCS), and the automated maneuvering attack system (AMAS). We are presently in the DFCS phase of the program.

The DFCS project objectives are (1) to validate the practicality and safety of a triply redundant digital fly-by-wire multimode flight control system for an advanced fighter aircraft employing decoupled flight control; (2) to demonstrate improved mission performance and effectiveness through the use of task-tailored multimodes and supporting flight management displays for an advanced fighter airplane; (3) to evaluate the operational utility, incuding reliability, costs, survivability, maintainability, and flexibility, of a digital flight control system; (4) to provide a proved digital flight control system with sufficient flexibility and growth capacity to support additional integration efforts; and (5) to provide design criteria for future digital control systems and associated integration technologies.

To meet such ambitious project objectives, an equally ambitious flight test program, in terms of flight frequency and amount of data gathered, has been implemented. While complete evaluation of DFCS and AMAS performance depends on detailed second-generation data analysis, significant amounts of real-time data must be available during and soon after a flight for preliminary analysis. Not only must in-flight behavior of the aircraft be monitored in some detail because of the extremely advanced and experimental nature of the DFCS, but, faced with three or more flights a week, some data must be available immediately after a flight either to verify that it is safe to advance further into the flight program, or to aid in troubleshooting aircraft or system malfunctions. These real-time and nearly real-time data requirements for the AFTI/F-16 program are fulfilled using the capability of the Aeronautical Test Range (ATR) at NASA's Dryden Flight Research Facility.

AFTI/F-16 AIRCRAFT

The AFTI/F-16 is a modified full-scale development F-16A aircraft (Fig. 1). The F-16A basic flight control system was replaced with a three channel, digital fly-by-wire flight control system (DFCS) and is mechanized so that the pilot can select any one of four mission-tailored flight control modes (bombing, air combat, strafe, or normal). Each flight control mode is integrated with the appropriate avionics to accomplish the desired task, and includes decoupled flightpath control. In effect, the AFTI/F-16 aircraft has eight separate, pilot-selectable flight control systems, each integrated with supporting avionics.

The vertical canards augment the rudder, and can provide sideslip and lateral acceleration characteristics. These surfaces are driven by the hydraulic system, and are controlled by rudder pedals. Directional decoupled control is accomplished by canard deflection coupled with proportional rudder and aileron to achieve the commanded response. The flight control system also provides similar decoupled longitudinal capabilities by use of the flaperons and stabilators, which are controlled by the throttle twist grip. The cockpit (Fig. 2) contains multipurpose displays and controls that present information from and control of the radar, flight control, and stores management systems, and other mission-related avionics.

The modified F-16 avionics system architecture (Fig. 3) extends the basic F-16 avionics system design to integrate the DFCS and interface the interactive multipurpose displays. A multiplex data bus structure is employed on the AFTI/F-16 aircraft to insure sufficient multiplex data transmission bandwidth margin to accommodate future growth and provide architectural flexibility. The existing F-16 avionics subsystem elements are interfaced on a common MIL-STD-1553 F-16 avionics multiplex A-MUX data bus. For the AFTI/F-16 aircraft, the A-MUX data bus is extended to interface the three DFCS processors. The fire control computer (FCC) continues in its rôle as the primary A-MUX bus controller. The stores management set (SMS) provides backup A-MUX bus control capability. The second display multiplex (D-MUX) is a MIL-STD-1553 bus that interfaces the redundant cockpit set.

INSTRUMENTATION SYSTEMS

Information about the AFTI/F-16 aircraft is processed through two pulse code modulation (PCM) systems, and simultaneously telemetered and recorded on board (Fig. 4). PCM system 1 samples about 200 hardwired parameters—standard measurements such as positions, temperatures, strain gages, rates, accelerations, and air data that are signal conditioned and put directly on the PCM system. PCM system 2 samples about 200 words selected from the A-MUX bus through an interface box. These multiplex bus words contain information about mode controls and selections, avionic and fault systems status, and parameters in engineering units. The total multiplex bus traffic is recorded on board and is available only for postflight data processing. Both PCM serial bit streams are transmitted on L-band telemetry. Video from a forward-looking cockpit TV camera, or video from either the right or left multipurpose display is transmitted on a C-band transmitter (Fig. 5). Video selection for transmission can be switched from the cockpit by the pilot, as can the selection for recording the video on an onboard recorder. The aircraft uses a C-band beacon for radar space positioning.

The detailed ground data processing flow for the AFTI/F-16 aircraft is shown in Figure 6. While our present discussion concerns real-time processing, there is an interrelationship with postflight processing. For instance, the calibration data base file is resident in the postflight processor, as is the "lineup sheet" file, a list of all parameters on the aircraft coded by parameter and calibration identification numbers. These files are transferred to tape, which is then carried to the real-time processor.

THE AERONAUTICAL TEST RANGE

Considering the complexity of the aircraft controls and systems, it is apparent that sufficient data must be displayed to evaluate the aircraft's behavior for safety of flight and for efficiency of flight planning (for example, is the pilot on test conditions?). Additionally, nearly real-time data must be rapidly obtained to assure that test objectives were indeed achieved, or that a malfunction can be located and explained. The Aeronautical Test Range at the NASA Dryden Flight Research Facility fulfills these requirements with general purpose capabilities in telemetry processing, communications, and space positioning systems (Fig. 7).

The telemetry processing systems are the heart of the real-time mission support in the ATR. They supply the acquisition, real-time processing and display, and modal/spectral analysis of telemetry data to one of two mission control centers (Fig. 8), the focal points of any flight tests at the Dryden Flight Research Facility. There, at various command and observation stations, Dryden engineers and technicians monitor and communicate with the test aircraft. In the case of the AFTI/F-16 aircraft, the full capability of the mission control center is used, including CRT displays, strip chart recorders, x-y plotters, discrete displays, meters, video displays, and modal/spectral analysis.

At CRT screens located throughout the control center (Fig. 9), one of three alphanumeric formats can be selected for display. Figure 10 shows one such display, or page, which is in color and can be configured as an annunciator panel. This page is used to display various control mode options and other functions of significant interest that must be readily noticed. The other two pages (Figs. 11 and 12) contain more detailed information and are monochrome. Most information on the CRT pages requires extensive decoding of multiplex bus words in PCM system 2 by the telemetry processing system. Calibrations for parameters required to be displayed in engineering units are resident in the processing system.

There are 17 strip chart recorders in the ATR, 12 in the mission control center, and 5 in the modal/spectral analysis facility (Fig. 13), which is a separate room but part of the control center.

The strip charts are grouped at observer stations by discipline; the preliminary phases of DFCS checkout require extensive monitoring of stability and control and structures parameters, so the majority of the strip charts are presently devoted to these areas. Later phases of testing involving stability and control at high angles of attack, or weapons delivery will require new strip chart layouts. The information displayed can be calibrated information directly from the PCM system, or computed information from the telemetry processor. For instance, the gross weight and center of gravity of the aircraft are computed and displayed in real time. The same program referred to in the Instrumentation Systems section, which transfers parameters and calibrations to the real-time processor, also generates PCM simulator scaling information for each strip chart channel.

Other displays used in the control center are x-y plotters, discrete displays, and panel meters (Fig. 13). The AFTI/F-16 program uses these for data requiring special implementation, either for unique or unusual monitoring or for quick status recognition.

Television monitors in the control center can display information from numerous video sources (Fig. 14). On the AFTI/F-16 program, an important source is the video downlink from the aircraft. As discussed previously, this video can duplicate either of the cockpit multipurpose displays or the cockpit TV camera video, which provides a forward view through the heads-up display (HUD). Other video sources include the long-range optics camera mounted on a rotatable pedestal on top of the Dryden main building, handheld TV cameras that might be sending video from chase aircraft accompanying the test aircraft, and radar boresight cameras.

The modal/spectral analysis system supplies random high-frequency analysis capability in real time for mission support (Fig. 15). The AFTI/F-16 program uses two strip chart recorders for display of flutter data from accelerometers. These data are also analyzed concurrently with a Fourier analyzer system and CRT spectrum display unit. Determinations are made in real time to clear flight test points designed to examine potential flutter conditions and to proceed to points that further expand the flutter envelope.

To assure that a record of the control system states and conditions is retained for further evaluation a significant subroutine in the telemetry processor program monitors 200 discrete bits or codes, and saves the information if any one of them changes state at any time during the flight. This information is stored on disk file and labeled by time of occurrence. After the flight, a telemetry processor program is run against this file to produce formatted listings. This information aids in evaluating the success of the test points flown or in troubleshooting malfunctions, and is a critical factor in determining the aircraft's readiness to fly again.

Communications systems in the ATR provide all UHF or VHF radio communication to the AFTI/F-16 aircraft. Ground audio systems allow local communication among test observers in the mission control center and for ATR control personnel in the various space positioning sites and acquisition/processing areas (Fig. 16).

Space positioning systems in the ATR include an FPS-16 radar system, which uses the C-band tracking beacon on the AFTI/F-16 aircraft. Altitude and distance information from the radar is displayed on plot boards in the mission control center (Fig. 17). In conjunction with a radar data processor, computed radar information can be displayed on CRTs in the mission control center, and digital tapes can be generated that are compatible with postflight processing requirements. Telemetry data are received by a triplex antenna system capable of receiving L-, S-, and C-band frequencies. This antenna and the FPS-16 radar are at a site remote from the mission control center (Fig. 18). Telemetry information is demodulated in receivers at the antenna site and is tape-recorded in the telemetry acquisition area near the mission control center. There the data are decommutated and supplied to the telemetry processing system.

CONCLUDING REMARKS

The AFTI/F-16 is a complex test aircraft designed to demonstrate advanced technologies in flight and fire control. Monitoring and evaluation of large amounts of data in real time or nearly real time is necessary for the expeditious completion of a tightly scheduled flight program. The Aeronautical Test Range at the NASA Dryden Flight Research Facility has the capability to support such an activity.

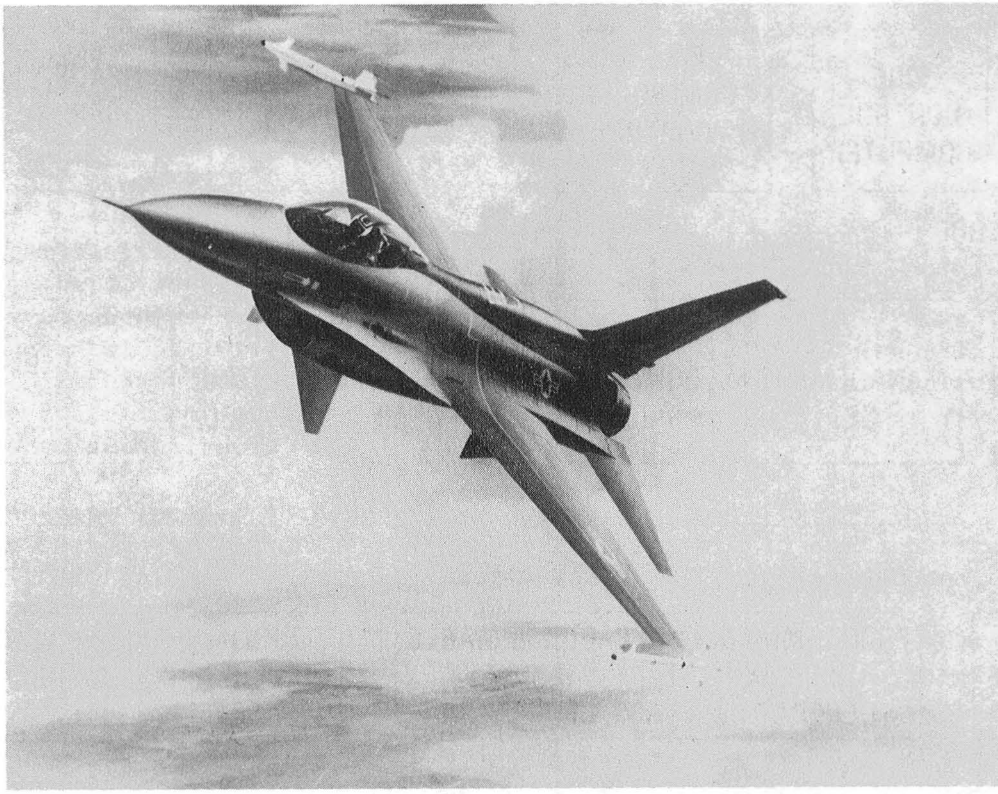

Figure 1. AFTI/F-16 aircraft.

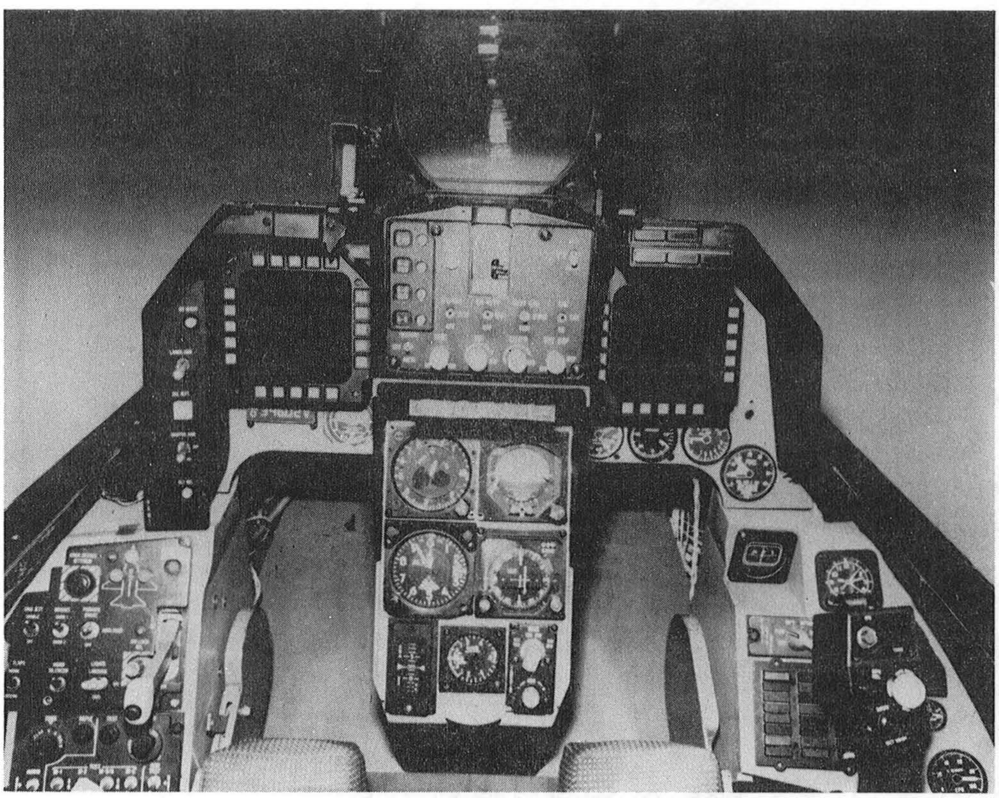

Figure 2. AFTI/F-16 cockpit.

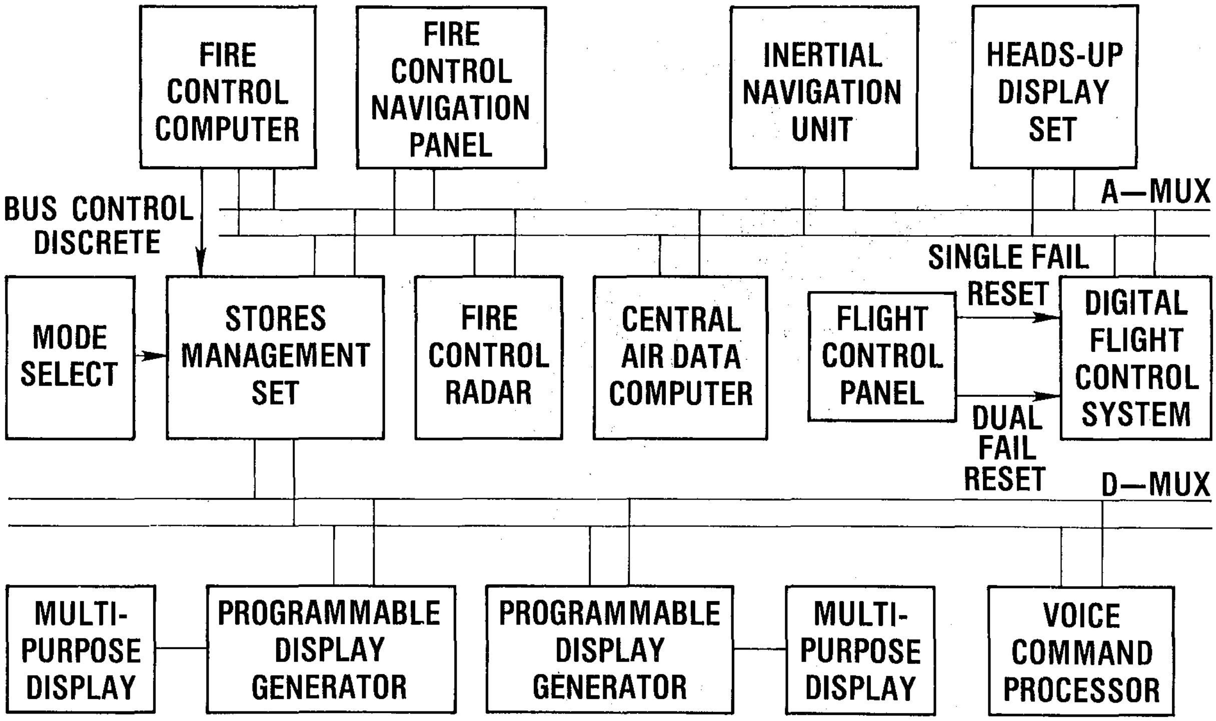

Figure 3. AFTI/F-16 MUX bus schematic.

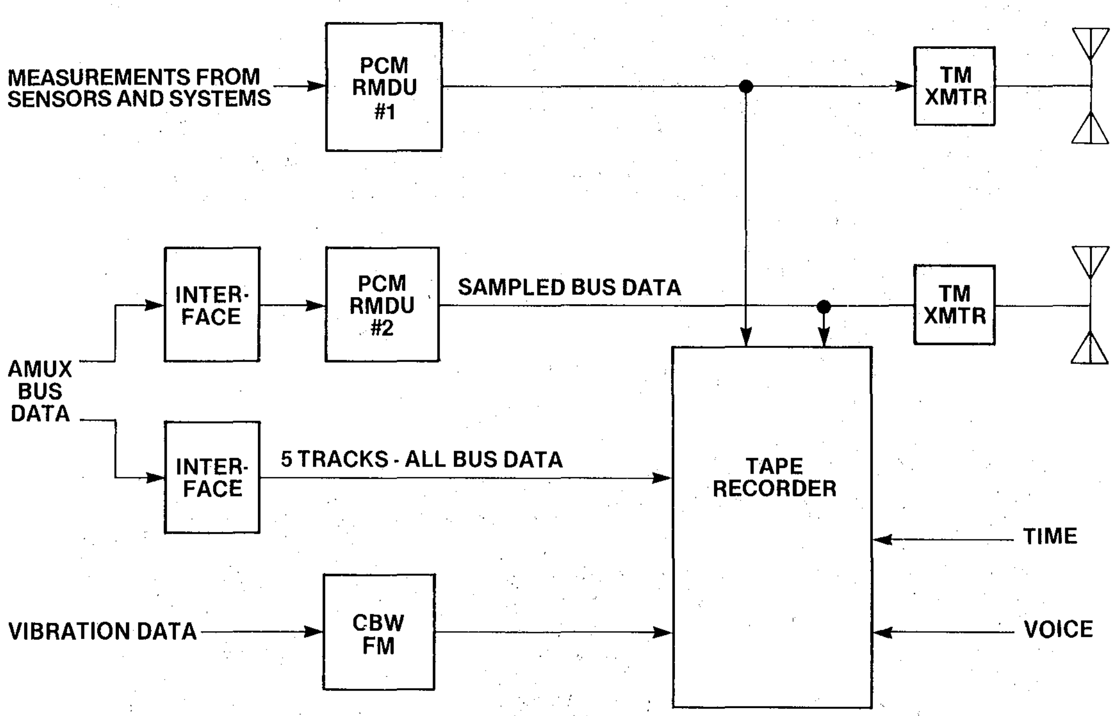

Figure 4. Instrumentation system.

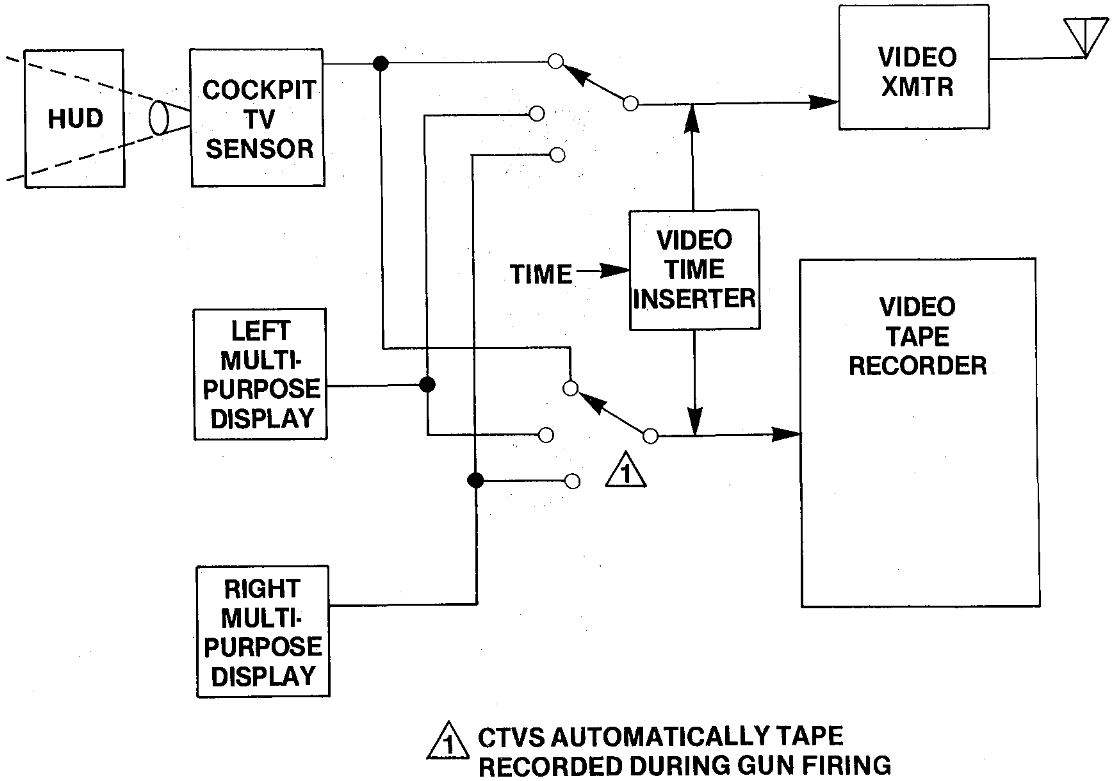

Figure 5. Video system.

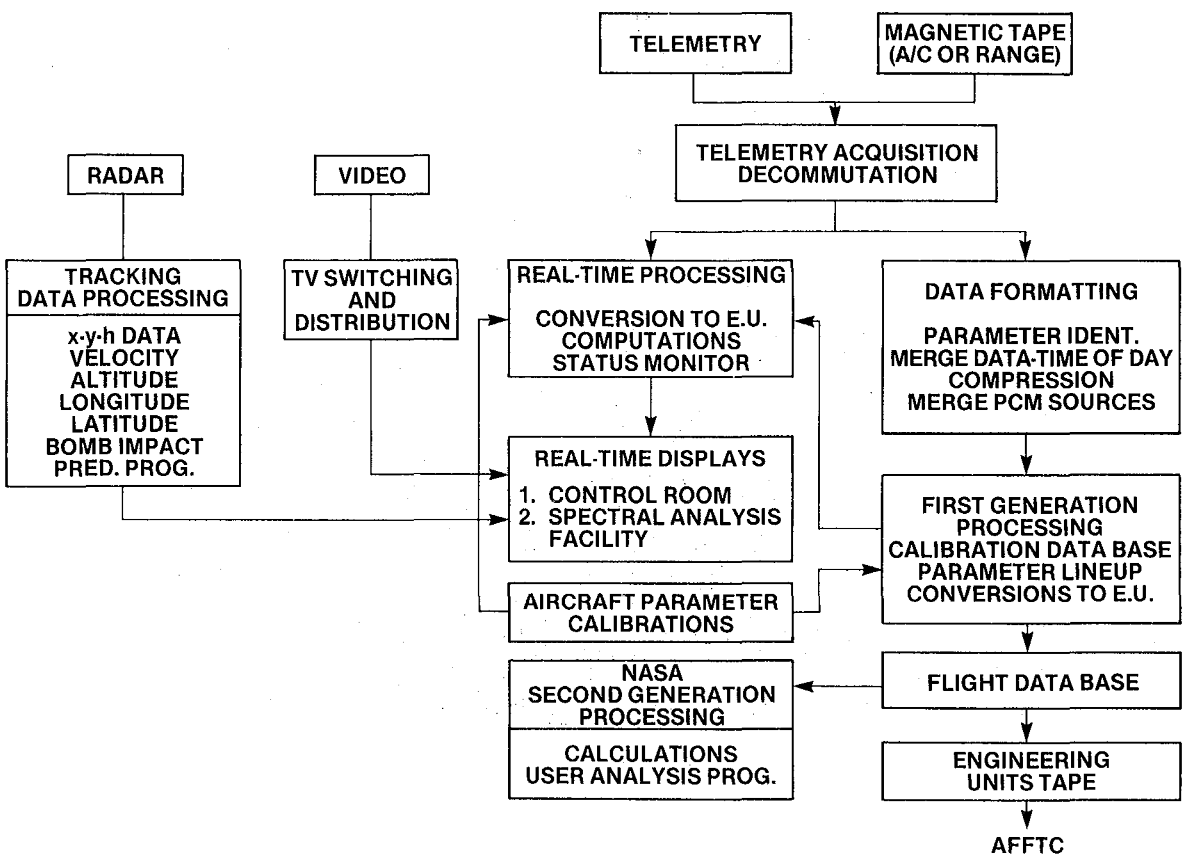

Figure 6. Detailed data flow.

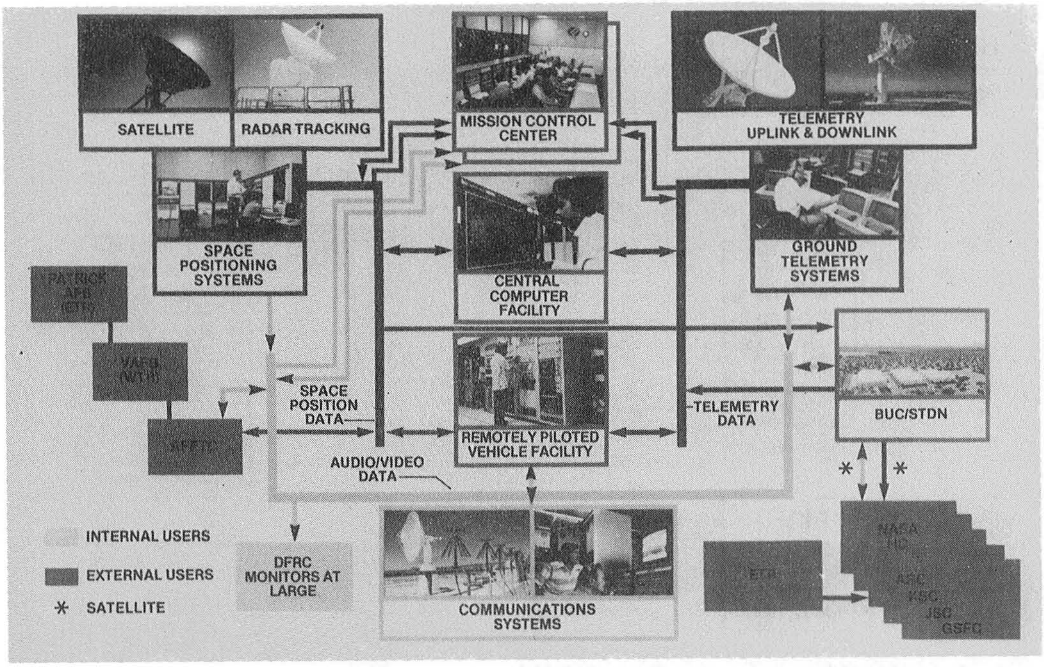

Figure 7. ATR systems and interfaces.

Figure 8. Mission control center.

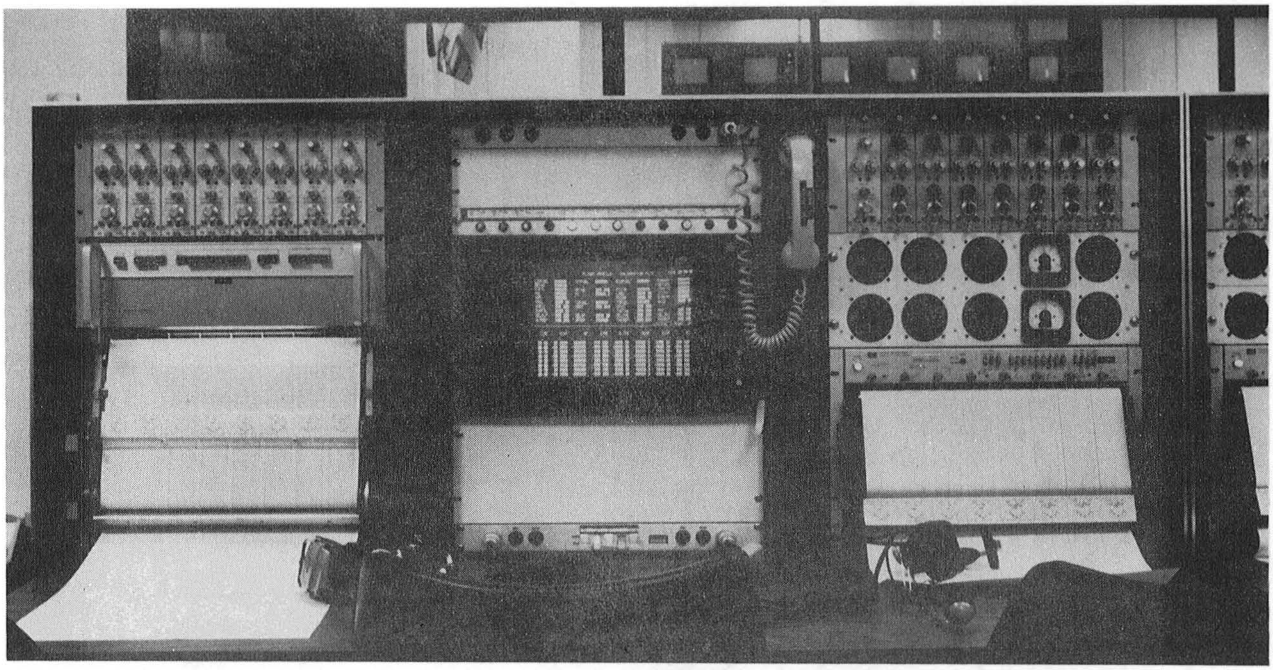

Figure 9. CRT display.

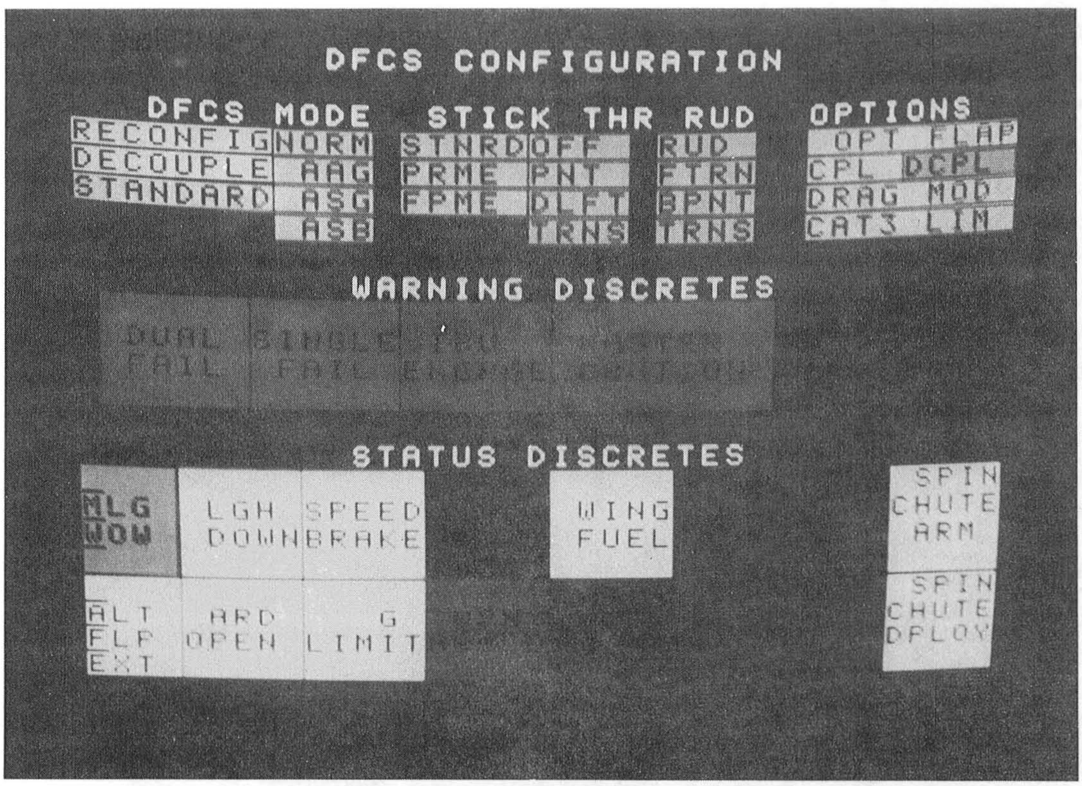

Figure 10. AFTI/F-16 annunciator panel.

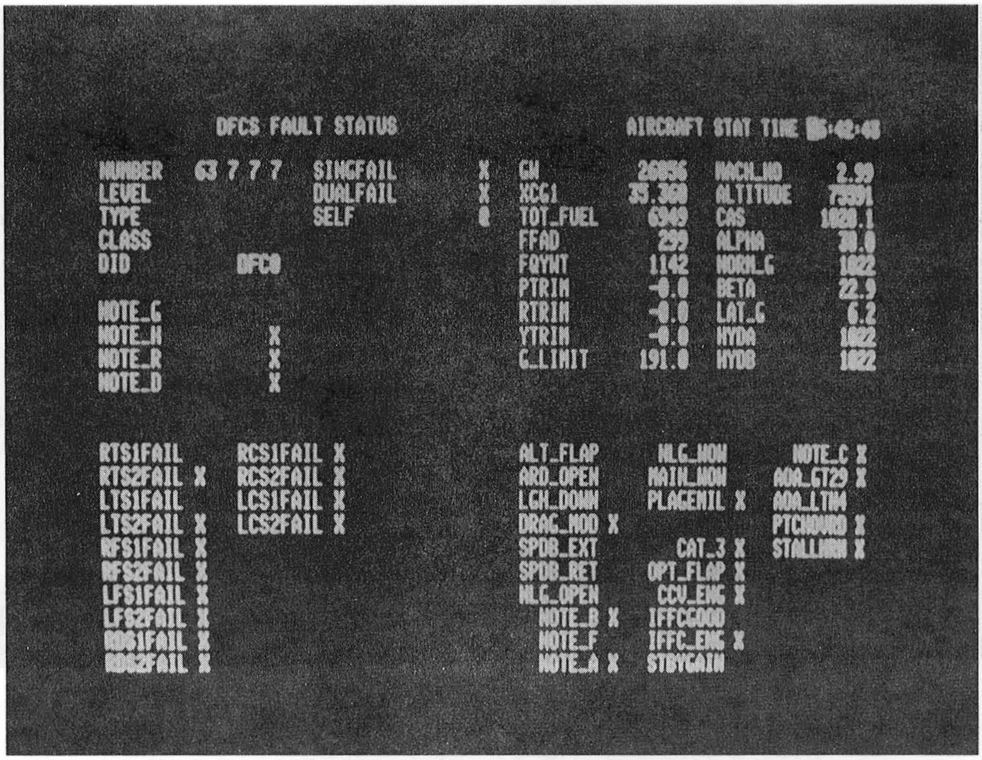

Figure 11. AFTI/F-16 CRT status page 1.

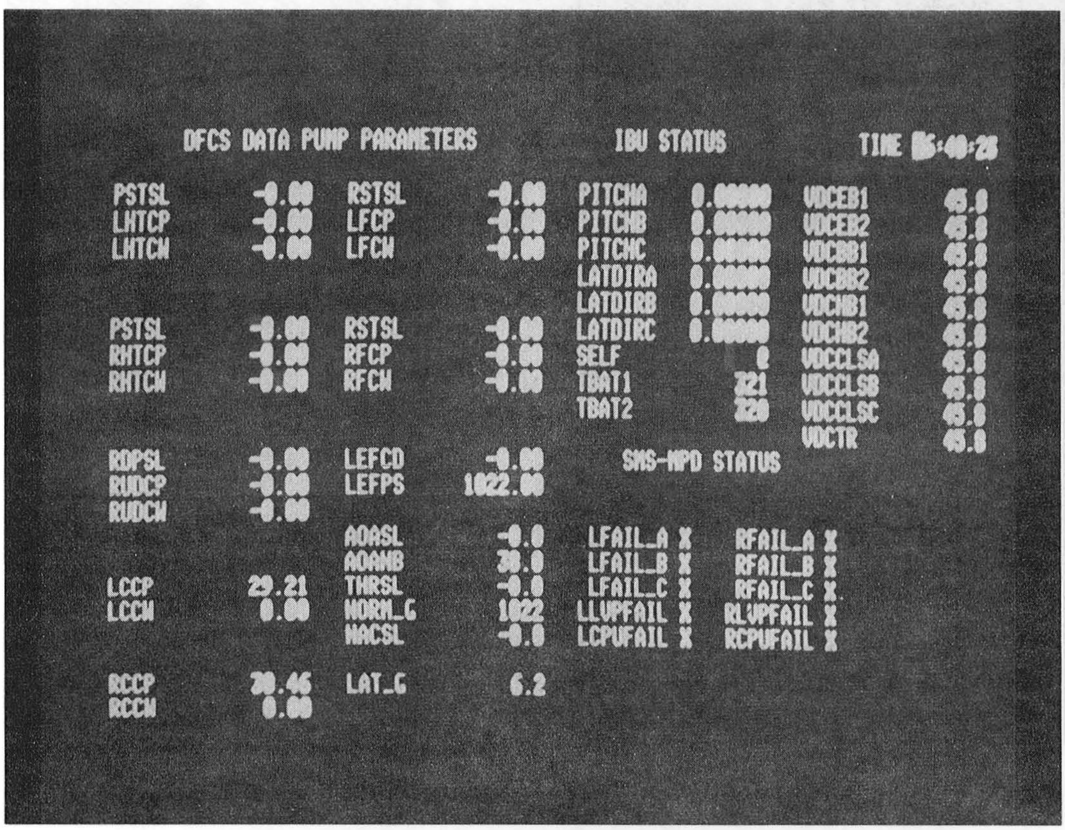

Figure 12. AFTI/F-16 CRT status page 2.

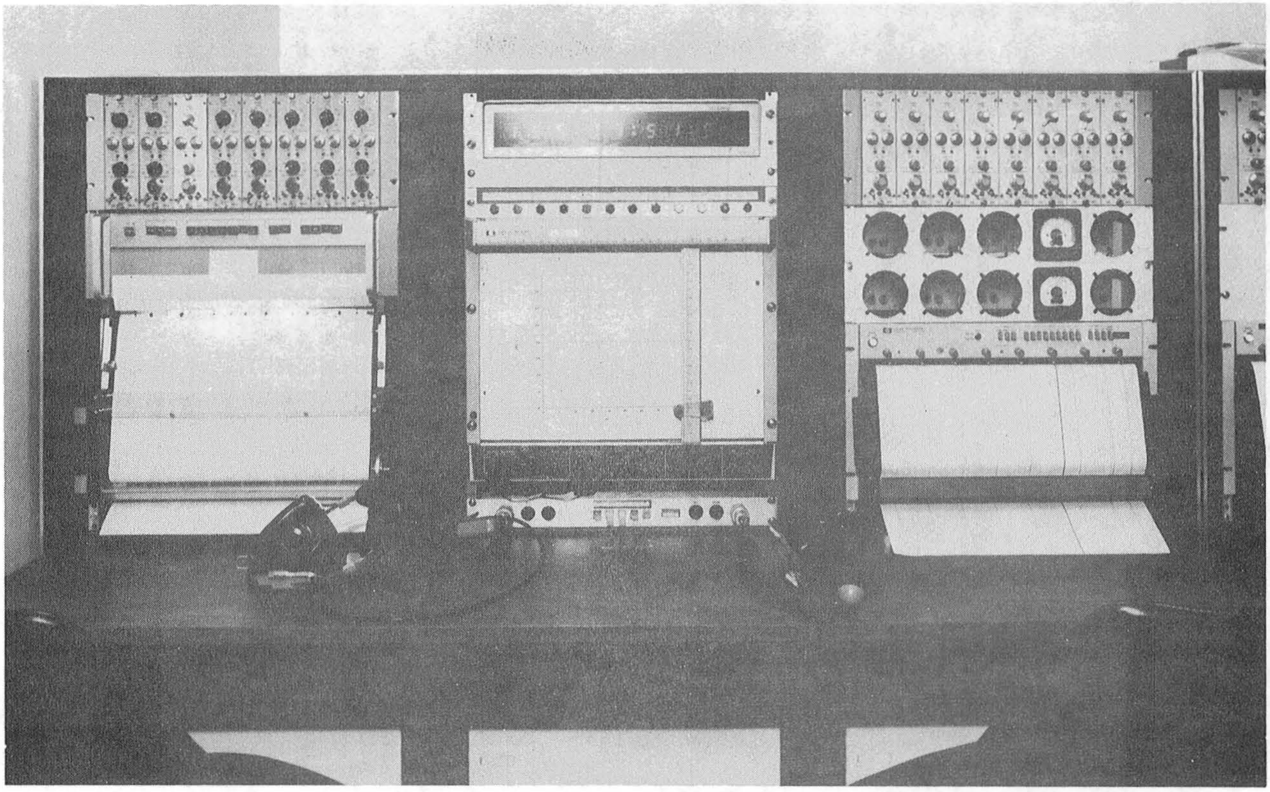

Figure 13. Analyst's console.

Figure 14. Video displays.

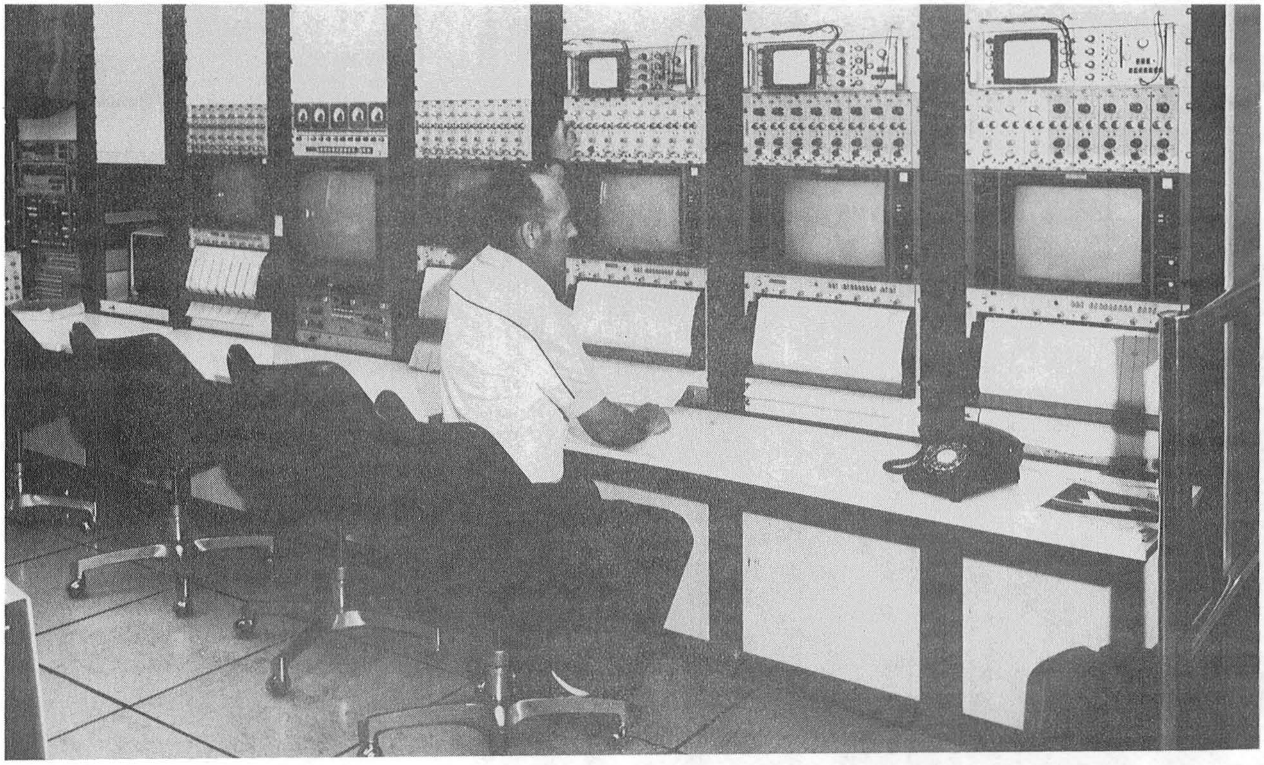

Figure 15. Spectral analysis facility.

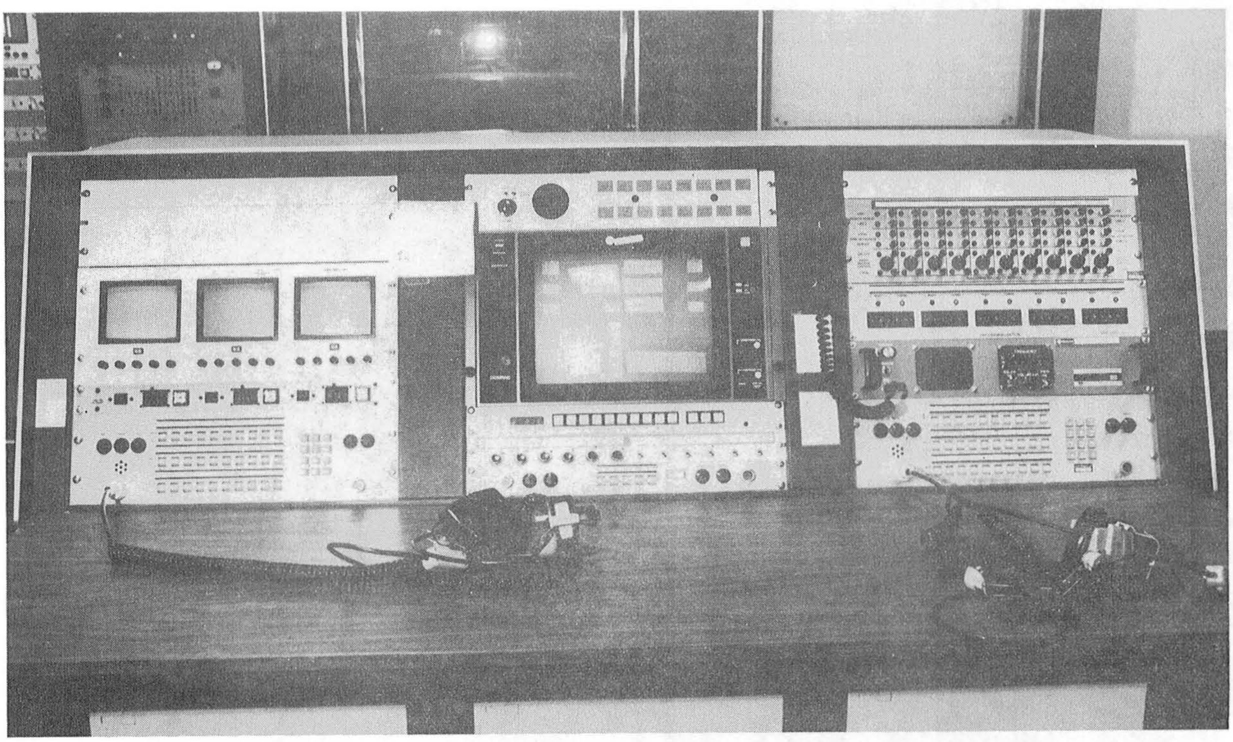

Figure 16. Mission control console.

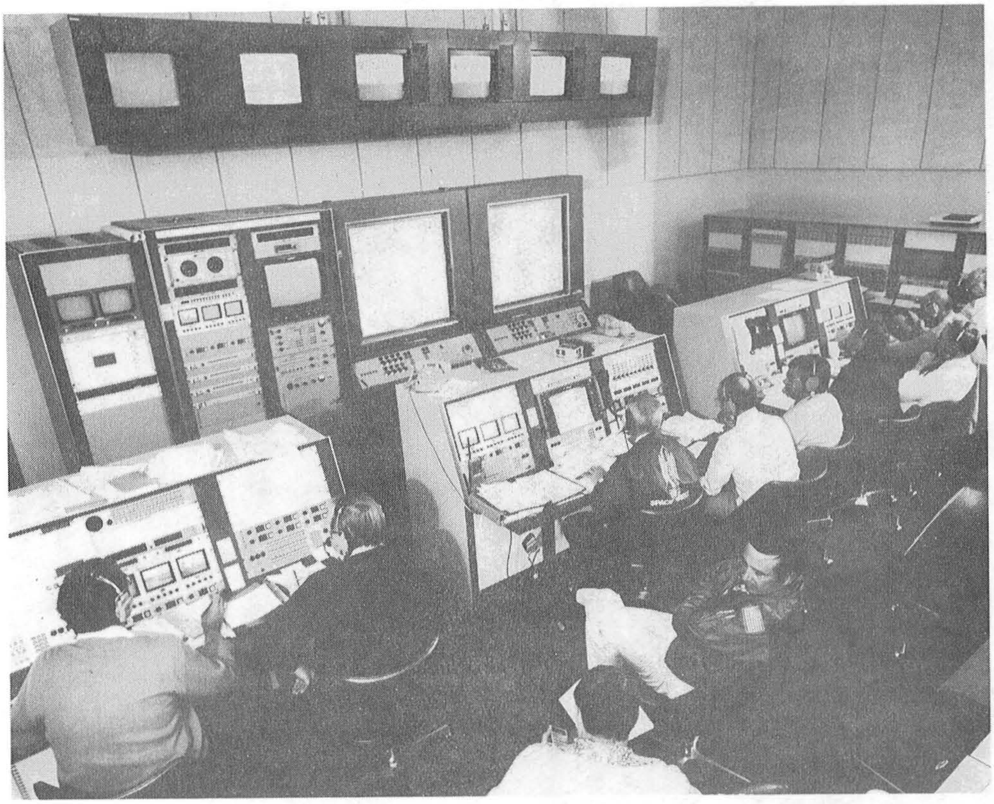

Figure 17. Plot board view.

Figure 18. Radar/telemetry antenna site.

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15. Supplementary Notes

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16. Abstract

The overall objective of the advanced fighter technology integration/F-16 (AFTI/F-16) advanced development program is to demonstrate, separately and in combination, advanced figher technologies to improve air-to-air and air-to-surface weapon delivery and survivability. Real-time monitoring of aircraft operation during flight testing is necessary not only for safety considerations but also for rapid preliminary evaluation of flight test results. The complexity of the AFTI/F-16 aircraft requires an extensive capability to accomplish real-time data goals; this paper describes that capability and the resultant product.

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