The Role of a Real-Time Flight Support Facility in Flight Research Programs

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Abstract

This paper presents some of the approaches taken by the NASA Western Aeronautical Test Range (WATR) of Ames Research Center to satisfy the ever-increasing real-time requirements of research projects such as the F-14, F-15, advanced fighter technology integration (AFTI) F-16, YAV-8B, and the X-29A. The approaches include the areas of data acquisition, communications (video and audio), real-time processing and display, data communications, and tracking.

Nomenclature

AFTI advanced fighter technology integration
CCD charge-coupled device
CDI cockpit display indicator
CID controlled impact demonstrator
CIMS calibration and information management system
CRT cathode-ray tube
DFBW digital fly-by-wire
FPS-16 precision C-band tracking radar
GPS global positioning system
HMAT highly maneuverable aircraft technology
HUD heads-up display
MCC mission control center
MLS microwave landing system
NALF Naval Auxiliary Landing Field
NATC Naval Air Test Center
PCM pulse code modulated
RPRV remotely piloted research vehicle
SRV spin research vehicle
TDRSS tracking data relay satellite system
TRAPS telemetry and radar acquisition and processing system
Triplex L-, S-, and C-band antenna system
WATR Western Aeronautical Test Range

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Introduction

In the relatively short time since the first supersonic flight, the amount of data acquired and telemetered to ground-based, real-time experimental support facilities has increased dramatically. The capabilities of these facilities had to be expanded at an even greater rate. The capability of a real-time ground support facility has a direct impact on the cost, both in time and dollars, of flight research.

The primary mission of the NASA Western Aeronautical Test Range (WATR) of Ames Research Center is to provide a capability for the conduct of aeronautical flight research missions through real-time processing and display systems, tracking systems, and communications systems (Fig. 1). The WATR has experienced an almost exponential demand for increased facility capability at its three sites (Fig. 2) at Ames-Moffett, Ames-Dryden, and Crow's Landing at the Naval Auxiliary Landing Field (NALF). The mission control center (MCC) or control room (Fig. 3), where the researcher interacts with, interprets, and bases decisions on real-time downlinked and computed data, has become a vital partner in research and flight test. The capability of a real-time support facility to acquire data, perform real-time computations, and display the results in a readily usable and understandable form is critical to the schedule of a research vehicle program. The computational techniques, types of displays, and the ability to "turn around" flight data make the modern real-time ground support facility – with its hardware, software, and staff – a vital member of the experimental research flight test team.

The specific requirements of research and flight test activities vary widely among aeronautical test programs. However, the basic needs are generic to all research aircraft programs: (1) to communicate with the vehicle, pilot, and test team; (2) to acquire, compute, and display real-time data; and (3) to know the exact location of the research vehicle at all times. The never-ending challenge to the real-time ground support facility is to perform these tasks and present the integrated results to the research team in real time (Fig. 4). The evolution of these tasks has seen emphasis placed on different elements of the basic WATR capabilities and need for expansion. This paper presents some of the approaches taken to satisfy the specific requirements of certain types and classes of research aircraft programs.

Communications

In the formative years of research flight testing, the only means of transmission between the research vehicle and the ground test team was by way of radio communications. The methods of
communications today between the pilot and vehicle and the ground-based test team are limited only by the capability of the facility supporting the research program in real time. The classifying method of voice communications using UHF and VHF radio are still used. This method has been augmented by a wide variety of techniques. On programs such as the F-14-1X, the advanced fighter technology integration (AFTI) F-16, and X-29A, the addition of a "hot mike" has proven to be a valuable addition to the test procedure (Fig. 5). The hot mike allows for a continuous flow of pilot comments and observations without requiring the pilot to key a transceiver. This is accomplished by transmitting the pilot's voice, by means of a pulse code modulated (PCM) stream to the ground facility. Within the facility the PCM stream is reconverted to an analog stream and inserted into the facilities ground intercommunications network and supplied to each researcher. On the X-29A program, this concept has been carried further to include retransmission of the hot mike to the test vehicles by means of a voice-activated UHF transceiver. This allows chase pilots access to the same information provided to the ground test team members.

Another approach that has proven valuable to the ground test team is downlinking of the video data from the test vehicle. On the AFTI/F-16, a small charge-coupled device (CCD) camera, located in the heads-up display and inserted into the facilities ground intercommunications network and supplied to each researcher. On the X-29A program, this concept has been carried further to include retransmission of the hot mike to the test vehicles by means of a voice-activated UHF transceiver. This allows chase pilots access to the same information provided to the ground test team members.

As depicted in Fig. 2, the increased capability required by the types of research aircraft using the WATF facility today have dictated a significant increase in real-time computation and data capability. These types of aircraft can be generically called systems-driven vehicles. They usually have large amounts of data downloaded to the ground test team in real time. The amount of data downloaded is so large that, without real-time computation support, the researcher would have great difficulty assimilating the data for the required time decisions in the MCC. To augment the researcher's natural ability, the WATF provides real-time processing support to the MCCs at all sites. The increased number of real-time computations is depicted in Fig. 9. The ordinate *V* in Fig. 9 is the number of processor words, in engineering units, delivered to the MCCs.

The architecture of the telemetry and radar acquisition and processing system (TRAPS) provides a current values table of all computed and downloaded data for access by the displays in the MCCs (Fig. 10). The researcher interface to TRAPS is centered in the WATF MCCs. Two basic types of consoles are available in the MCCs (Figs. 11 and 12). Each MCC at Ames-Dryden is configured with six researcher consoles. Other consoles are available in the MCCs for display, safety and vehicle operations, the flight director, and public affairs. The variety of display devices and the interactive nature of the displays allow for much flexibility for a research program.

The X-29A necessitated expanding the WATF facility to include new displays and procedures that were developed prior to the first flight of the vehicle. Cathode-ray tube (CRT) displays were developed to allow for the display of more than 400 parameters in real time by interaction with the TRAPS. Figure 13 shows several types of displays utilized by the X-29A program. As the program progressed and the envelope expansion continued, it was necessary to provide the researchers with menu selection capability for each stripchart recorder. The researcher was then able to change the parameter lineup for any recorder with a key stroke. The interactive graphics unit shown in Fig. 11 gives the researcher the maximum flexibility. The display allows for different pages of graphics information. Changes can be made in the parameters, values, and appearance of the displays, in real time. Another feature of this console is...
the key-stroke callable least squares curve fit for cross-plots. In addition, the key stroke can average certain parameters over a maneuver. The unit can make a hard copy of any page on the CRT, and any page can be distributed to any other console in the MCC.

One of the most cost-effective functions available in the MCC was developed for the F-15 program. This function allows the researcher to uplink computed values to the research vehicle (Fig. 14). The function requires special uplink equipment on the research vehicle and the cockpit displays. When the program is operating in this mode, downlink data values are used to create computed values that are then uplinked to the vehicle in the form of error signals. The algorithms and vehicle displays are developed in the simulation facility. Prior to its development, the pilot had to perform the function using standard cockpit instrumentation. A conservative estimate of the F-15 project pilot was that, by utilizing this function, the required number of test flights was reduced by 50 percent.

The researcher can interact with the real-time computation to change equation coefficients and parameter values depending on the test point desired for a given maneuver. Given the high cost of flight test time, any function that can optimize the data collected has a significant positive impact on program cost and schedule.

Tracking and Data Acquisition

The WATR has an ongoing development program to insure the most accurate downlink data available in real time. High-gain tracking antenna systems and precision tracking radars are used to acquire the optimum data signal. Research vehicles such as the remotely piloted HIMAT (Fig. 15) require continuous uplink and downlink communications at all times at all aircraft altitudes during flight.1 To accomplish this, two antennas were installed on the vehicle. The PCM downlink was transmitted on two different frequencies, one from each antenna.

This approach takes advantage of the frequency polarization feature of the telemetry autotracking antenna system. Complete radiation coverage is obtained by tuning one receiver to each frequency and using the combining feature of the antenna system. The outputs of the two receivers are combined in proportion to the relative signal strengths to present one PCM bit stream or video output to the ground demodulation station. This approach contributed very much to the success of the flight research program.

One of the most demanding tracking and data acquisition tasks undertaken by the WATR was that required for the B-720 controlled impact demonstrator (CID).2 Although no feedback paths from the airplane were necessary to be closed on the ground, precision G-band tracking radar (FPS-16) played a significant role in obtaining the final impact. Manual tracking through visual aids was used to overcome multipath problems. Accuracy could have been improved by using a microwave landing system (MLS). Nevertheless, the final impact was a success, and much valuable information was derived from the impact demonstration. The CID required all WATR tracking and data acquisition systems during each flight mission (Fig. 16). The nature of the project required redundant systems whenever possible.

For precision tracking information in a normal airfield environment, the WATR uses its facilities at Crows Landing in northern California (Fig. 17). The MLS and a laser tracker allow the research vehicle to obtain and use, as required, very precise space position information in a terminal area situation. The integration of these two tracking devices with the X-band radars located at Crows Landing gives the research program the full spectrum of space position information in the MCC.

Concluding Remarks

The NASA Western Aeronautical Test Range continues to implement approaches and systems to increase the productivity of research flight test. New interactive graphics systems are now under development to enhance the existing capabilities. The installation of new satellite systems will enhance the ability to transmit data from remote test sites to centralized mission control centers (MCCs). The combination of these new satellite systems with existing systems such as the global positioning system (GPS) and the tracking data relay satellite system (TDRSS) will greatly increase the flexibility and productivity of future flight test programs (Fig. 18). The ability to acquire data, track a research vehicle, maintain real-time communications with the research vehicle, and provide comprehensive real-time information in an integrated MCC will insure the close partnership between the research program and the ground-based facility in the future.

References


Provide capability for the conduct of aeronautical flight research through...

...real-time processing and display systems, tracking systems, and communications systems

Fig. 1 Western Aeronautical Test Range mission.

Fig. 2 Evolution of Ames-Dryden aeronautical research program requirements. (For vehicle depicted, number of missions per year includes flights, combined systems tests, and engine runs.)

Fig. 3 Mission control center at Western Aeronautical Test Range.
Fig. 4 Basic real-time ground support facility capability for support of research and flight test requirements.

Fig. 5 Typical flight research program and communications network.
Fig. 6 Heads-up display.

Fig. 7 F-18 real-time flow visualization techniques.
Fig. 8 X-29A transcontinental data link.

Fig. 9 Total number of real-time computations. (Unified tracking and data acquisition capability attained in 1985.)

Fig. 10 Real-time data processing and display system.
Fig. 11 Blue room analyst console No. 1 in WATR mission control center.

Fig. 12 Blue room analyst console No. 3 in WATR mission control center.
Fig. 13 Real-time interactive displays.

- Ground computer generates display information
- Algorithms developed on simulator

Fig. 14 Remotely computed display.
Fig. 16 Tracking and data acquisition requirements for highly maneuverable aircraft technology.

Fig. 16 Tracking and data acquisition requirements for controlled impact demonstrator.
Fig. 17 WÅTR precision tracking facility at Crow Landing in northern California.

Fig. 18 Future network possibilities.
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**Supplementary Notes**

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This paper presents some of the approaches taken by the NASA Western Aeronautical Test Range (WATR) of Ames Research Center to satisfy the ever-increasing real-time requirements of research projects such as the F-14, F-15, advanced fighter technology integration (AFTI) F-16, YAV-8B, and the X-29A. The approaches include the areas of data acquisition, communications (video and audio), real-time processing and display, data communications, and tracking.

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