REAL-TIME TELEMETRY DATA SUPPORT FOR THE F-22 FLIGHT TEST PROGRAM

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ABSTRACT

This paper describes the recently developed F-22 real-time telemetry data processing system. The F-22 Combined Test Force (CTF) and the Range Division worked together to develop a real-time telemetry processing system able to support the F-22's fast paced flight test program. This paper provides an overview of the Ridley Mission Control Center (RMCC) modernization effort for F-22. The paper also describes how the F-22 uses the Advanced Data Acquisition and Processing Systems (ADAPS) Real-Time/Post Flight Processing (RT/PFP) system, the Integrated Analysis and Display System (IADS), and other mission control room system's for F-22 mission control support.

KEYWORDS

F-22, Telemetry Display, Air Force Flight Test Center, Mission Control Room

INTRODUCTION

The F-22 uses a state-of-the-art instrumentation and telemetry data processing system to support flight testing at Edwards Air Force Base. The F-22 telemetry data processing is managed by the F-22 Data Processing Integrated Product Team (DP IPT). The F-22 DP IPT is a joint contractor government team. The F-22 DP IPT broke the F-22 telemetry processing task into three segments. Lockheed Martin Aeronautical Systems Company (LMASC) performs telemetry data processing at Marietta Georgia. Post-test telemetry data processing at Edwards AFB is accomplished by a joint F-22 CTF team. The Range Division performs real-time telemetry processing at Edwards AFB. This paper will describe the development of the F-22 mission control capability at Ridley Mission Control Center.

F-22 LARGE MISSION CONTROL ROOM

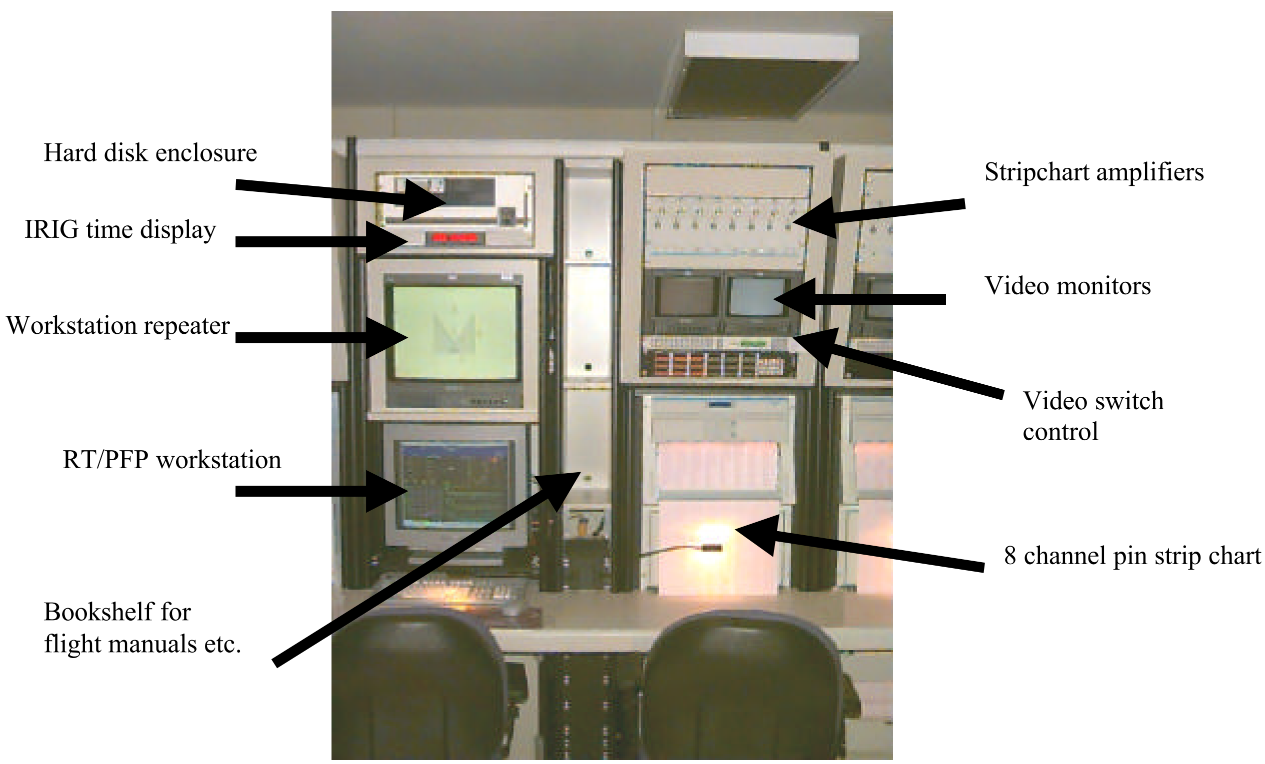
CONTROL ROOM DESIGN AND CAPABILITIES

We at the Range Division had the rare opportunity to redesign our control rooms for the Air Force's next generation fighter aircraft and their testers. Because of the long period between the end of the F-22 demonstration and validation (DEM-VAL) test program and the start of F-22 engineering and manufacturing development (EMD) flight testing, we had some time to do this control room redesign and we wanted to do it right. A common mistake seen in the past at the Range Division was to design and build a product in-house without outside input and then try to sell it to the customer. Neither the control room customer nor the control room operator/maintainer were involved in the design process. Consequently, the control room design was not optimized either for operation and maintenance or the flight test customer's needs. We did not want to fall into that trap.

Our first step was to query our users on what they liked and disliked about the control rooms they had used in the past. Surveys were sent out to every flight test engineer at Edwards AFB (both government and contractor). We received many detailed responses from many organizations. The most detailed response came from the F-22 CTF. The F-22 CTF was just being staffed up, and many flight test engineers had recently left other flight test programs at Edwards AFB to join the F-22. This provided us a great cross section of control room experience from a wide spectrum of test programs.

Designing a control room with so much input from the customer became easier than it may seem. A general theme emerged from the Edwards AFB flight test community. For the customer, a work area with as much capability as possible was highly desired in the control room. For the test conductors, the ability to see everyone in the room and have everyone in the room see the test conductor was their number one request. Along with customers from the F-22, customers from other CTFs met with the Range and started designing consoles to meet the needs of all parties. Along with console rack elevation drawings came proposed control room floor layouts. Each console was designed from the start to support two flight test engineers. In past control room designs, additional personnel were always crowded into space designed for a single person. Range engineering personnel rather than focusing on console design or room layout, worked on solving problems, which in earlier control room designs had prevented us from meeting the customer’s expectations.

Each console is built around two custom 19-inch instrumentation racks. A high console was developed which was to be located around the control room perimeter. A low console was also developed and this was to be placed in the center of the control room. Each console has two primary display devices. The primary data display can either be a workstation supporting a graphical software package or a pen/ink stripchart unit (high console only). The high console is divided into upper and lower sections. The upper section of the high console contains video monitors and communications terminals, which provides a dual video display.



F-22 CONTROL ROOM FLIGHT TEST ENGINEER STATION

The customers were not the only group to be involved with the design of the mission control room. The Range Division Operations and Maintenance (O&M) group was also consulted in the design of the mission control rooms. The O&M group came up with several ideas that were incorporated into the design of the control room to help troubleshoot and repair equipment quickly. Space was allocated around each console to provide room to work. Lighting, access doors, and cabling were all optimized for quick turnaround maintenance.

The best O&M idea was to create a built-in cart to house the primary display unit in each high console. If a workstation or stripchart fails, the cables can be disconnected, the cart then unhooked and removed, and a standby cart placed back into the empty spot. The cabling and power would be reconnected and the console would be ready for use. The whole process takes about 5 minutes. As an example, when a stripchart failed during a recent F-22 mission, a Range maintenance crew was called and rolled a backup stripchart into the control room. While the F-22 was air-refueled from a KC-135 tanker, the test conductor gave the "go" to replace the stripchart. The maintenance crew went to work and had the unit replaced in 5 minutes. Because of the many test disciplines present in an envelope expansion test program, even losing a single display device can hamper the mission.

Four mission control rooms were required to support the F-22 flight test program at Edwards AFB. Six existing mission control rooms at Ridley Mission Control Center were rebuilt into two 48-person and two 32-person mission control rooms. An existing Time Space Position Information (TSPI) data processing room and a classified conference room were converted into a telemetry data processing room and a video processing room respectively.

Currently each 48-person mission control room at Ridley Mission Control Center is equipped with 23 Unix workstations, 14 Windows NT-based workstations, 11 strip chart recorders and 4 positions equipped with video display repeaters. Each 32-person mission control room at Ridley Mission Control Center is equipped with 21 Unix workstations, 2 Windows NT-based workstations, and 8 strip chart recorders.

The primary graphical workstation used in each control room is the SGI Indigo^2 workstation. Each Indigo^2 runs the ADAPS RT/PFP System software. The RT/PFP system uses a modified version of the commercial off-the-shelf program, DataViews, to display flight test telemetry. Early on in F-22 flight test planning, Data Views was chosen as the common display development environment to be used for testing the F-22. The same Data Views displays were used in the mission control room at Marietta, Georgia and in the F-22 Vehicle Management System (VMS) simulator at Fort Worth, Texas. The F-22 structures test community has supported a new processing system also developed by ADAPS called IADS, which supports complex data processing for structural analysis of aircraft and weapon systems. The IADS operates on Windows-NT based workstations, and uses many advanced display capabilities.

The F-22 control rooms have a mix of old and new display technology. Along with RT/PFP and IADS, traditional 8-pin stripchart recorders are also installed in the mission control room. The control room is populated with this type of stripchart recorder rather than thermal (or any other type) stripchart recorders to meet the requirement that the engineers need to see and hear the pens move. Rather than force the customer to adapt to a new display device, existing pin stripchart recorders were reconfigured to the new console design. We hope that as the capabilities of the graphical software in the area of the video stripchart increase, more engineers will move off the paper units for the graphical type. The goal of the Range division is to achieve a paperless control room (similar to the goal of the F-22 CTF to become paperless as well).

The video capability in the F-22 control rooms is a significant improvement over the equipment that was previously installed in Range Division control rooms. Previous control rooms had several large video display screens mounted at the front of the control room. Often the text on these screens was too small to be viewed by the control room user. The test conductor centrally controlled the screens. Many customers indicated to us that these screens were of little value except to impress control room visitors. Additional flight test engineer consoles replaced the space that was formerly used for large screen displays. Customers indicated that video at there console, with the video sources controlled by them, and including the capability to view other workstations in the control room was what was really needed.

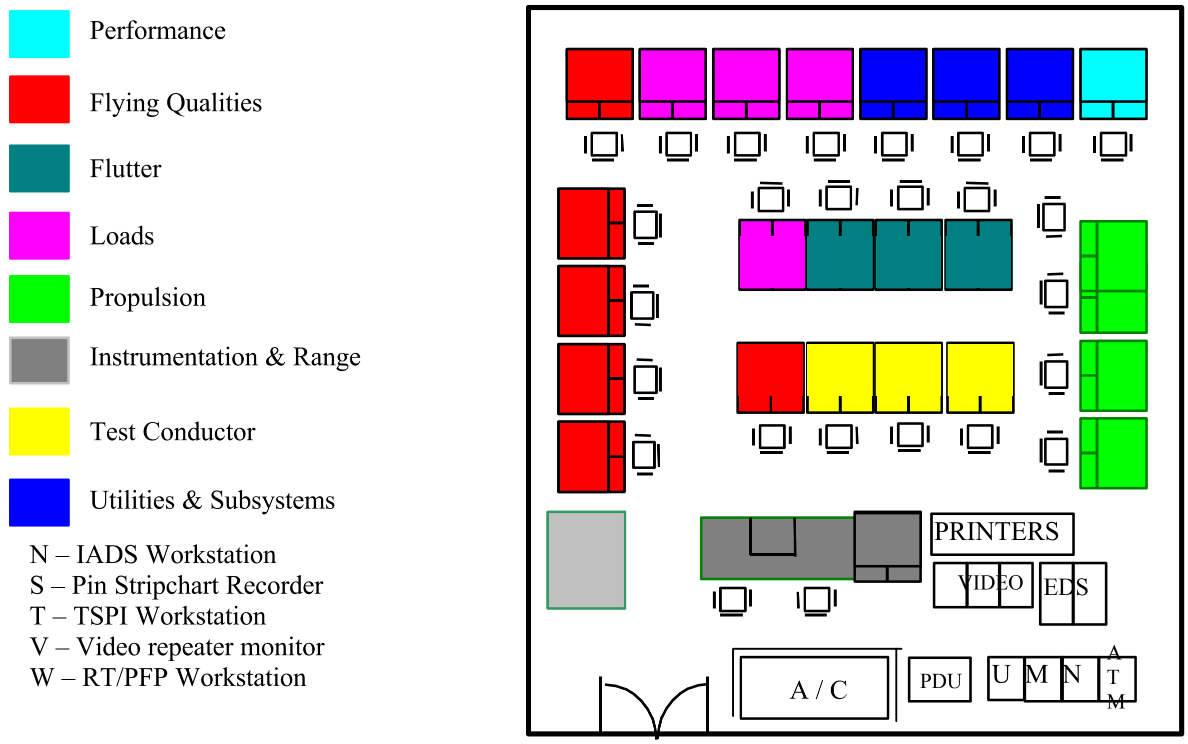
An off-the-shelf dedicated Red-Green-Blue (RGB) video switch is located in each control room. This video switch is capable of rerouting workstation video to a repeater video monitor mounted in each console in the control room. All video entering the control room is converted to the same high resolution as the control room workstations. This preserves the quality of the workstation video for display on a repeater workstation. The video switching capability gives each engineer at their console the capability of watching the video source of their choice for that mission or repeating a data display from another workstation in the control room. The TSPI and Edwards AFB weather information is also repeated on this video system. Two additional small video monitors are mounted in each high console and can be used to view video from outside the control room. Each control room can receive eight video feeds from outside the control room. Outside video sources include Heads Up Display (HUD) video telemetered from the F-22, and video of the F-22 from telemetry trackers, and tracking radars. Cameras located in the F-22 CTF compound are used during pre-mission operations, and this video is sent through the base local area network to RMCC.

Control rooms with many disciplines need a multi-channel communications system. Each engineering discipline has a separate intercommunication network. Another intercommunications network ties the whole mission control room to the test conduct team (test conductor, test director, scribe – who documents mission events, and range control officer). The test conductor then relays information to the test aircraft. The communication terminal at each console can be configured with up to fifteen separate channels for internal room intercoms, support areas internal to RMCC, or to radios to communicate with the pilot and other support groups (instrumentation, aircraft crew chief…) on the flight line. Each communications panel can be configured differently so that they can be customized to the needs of different control room users.

MODE OF OPERATIONS

At the Air Force Flight Test Center (AFFTC), the start of a new high profile flight test program is a unique experience. Usually the experts from every flight test discipline migrate to the new flight program because of their experience and insight. This provides a wealth of knowledge but also a wealth of differing opinions about how flight test operates. A hierarchical structure was developed to incorporate all the test requirements for all the flight test disciplines. This system avoided conflicts between disciplines and set operations standards for the control rooms. The operations structure mirrored the F-22 test team structure. The test conductor group at the F-22 CTF became our single point for general control room requirements. These personnel are the leads for all flight test operations and it is their responsibility to insure that the control room and the test support engineers are prepared in a manner to support their tests. The test director also has the responsibility to insure the mission is productive and safe. This means "to give the support engineer team everything they need to support a mission but not too much as to distract them from the mission." Each flight test engineering discipline has a unique requirement set to gather, organize, and display data in realtime. Using the standard configuration of the high consoles, sections of the control room were organized and laid out for each discipline to accomplish their mission.

To support a mission, the Range Telemetry O&M Group loads the mission file onto the Telemetry Pre-Processor (TPP) and then into the control room from an Iomega Jaz removable hard disk. The Jaz cartridge contains the telemetry processor load file, all the Data Views displays, and all the other components needed to support an F-22 mission in a mission control room. Each workstation is loaded with all display and setup files. A flight test engineer can sit at any workstation in the room and retrieve all the files they need to run their part of the mission. Four Indigo^2 workstations are brought on-line and loaded with data analysis programs (DAPs) that will run during the mission. The DAPs allow each workstation to gather input data from telemetry, calculate derived parameters from the data, and output the results to the data network. Other RT/PFP workstations on the network can then view this data in realtime. The IADS Compute Data Server is brought on-line, the interconnectivity with the RT/PFP system is checked out, and IADS workstations are prepared for the arrival of the F-22 structures engineers.



F-22 LARGE MISSION CONTROL ROOM DISCIPLINE CONFIGURATION

An Ampex DCRSi telemetry recorder is loaded with media and made ready to record the incoming telemetry streams. The DCRSi, RT/PFP, and the video control center (VCC) at RMCC are all configured to receive the incoming telemetry. The VCC videotapes any outside video sources used by the F-22 test on videotape. The air-to-ground communications system and the intercommunications networks used during the F-22 test are configured by the Edwards' Digital Switch. Several communications channels are sent to the data processing room and to VCC to be recorded on the DCRSi and videotapes.

Three telemetry-tracking antennas are used to support an F-22 mission. One antenna views the F-22 CTF compound, and follows the aircraft while it taxis to and from the runway. Another antenna located at Birk Flight Test Facility tracks the aircraft on the runway, and while the aircraft is in the landing and takeoff pattern. A third antenna located in the Rosamond hills about 10 miles west of RMCC tracks the F-22 for the majority of the test mission. The Range Data Acquisition and Transmission System (DATS) brings telemetry and tracker video from all three antenna sites to RMCC. Telemetry from each F-22 mission is also transmitted to Marietta, Georgia. Before and during the test mission the Range Control Officer can communicate with the entire Range F-22 support team over intercommunication networks.

After the control room is ready, the aircraft telemetry comes on-line and the control room support team performs an end-to-end system validation. When the real-time system passes validation, a telephone call is made to the CTF and the engineers are told the control room is ready.

The F-22 test team enters the room and starts setting up their console to support that day's mission. The communication panel needs to be configured with their discipline and room network requirements. Each communication channel can be activated by either a foot pedal switch or a hand switch. Their primary telemetry displays are brought up on the workstation. Both IADS and RT/PFP let the engineer make any last minute display changes that are needed. The engineer can configure the workstations to record a set of parameters during the flight for end-of-mission download. This data can be taken back to the F-22 CTF on a Jaz cartridge for data trend analysis and post-test time-slice refinement. Any workstation function key setups are loaded and the outside or workstation video sources are switched to the preferred monitor. Any last minute calibration changes or processing algorithm changes are brought by the instrumentation engineer and entered into the RT/PFP system.

Usually the last two of the test team to arrive are the test conductor and test director. After the test conductor and the test director have set up and are ready to go, they perform a control room communications check. Each discipline around the room calls the test conductor and gives a "go" indication or a problem report. At this point, anyone walking into the control room would find a quiet and still room but actually, this is not what is happening. Because of the communications system, the engineers can talk amongst themselves and to the test conductor without moving, turning, or speaking loudly. Once they put on a headset though, the room comes alive with disciplines discussing and evaluating their data, cross-discipline discussions about procedures, continuous updates to the test conductor and tests director, and communications between the test conductor and the test pilot and or chase aircraft.

The pilot arrives at the aircraft at the same time the test conductor arrives in the control room. All pilot audio is captured by the telemetry system and this "hot mike" is telemetered to the ground in the telemetry stream. The telemetry processing system extracts these voice communications out of the telemetry stream and sends it to the control room communications system. The pilot only has to talk and the "hot mike" will pick him up and send his voice to the control room. The pilot can continuously talk to the entire test team in the room without broadcasting over the radio. By giving the engineers as much information as possible about the test maneuver being executed, the engineers gain more insight as to what the aircraft is doing and what the data are showing them.

Once the mission is underway, the control room team stays prepared to handle any problems that occur with the control room or telemetry processing systems during the mission. A problem report could be anything including bad readings from data parameters, broken headsets, or a failed display workstation. On those occasions, the engineer will call the support team in the back of the room over another communications network to work the issue before reporting to the test conductor. The support team in the back of the room consists of the range control officer (RCO), a telemetry systems analyst, a customer support person from the Range O&M group, a customer support person from the IADS development team, and an instrumentation person from the F-22 CTF.

The support team is connected to every support area inside and outside the building by the control room communications system. Through this communications network, they have access to anyone needed to troubleshoot any problem that cannot be solved in the control room. Data problems and equipment problems can be looked at in the control room. Data issues can be worked concurrently by the Range person and the Instrumentation person. Information about problems being worked outside of the room can be relayed through the RCO to the test director or test conductor quickly. By having all parties on the communications network, problems, issues and last minute changes can be coordinated quickly and efficiently.

The test mission is very fast paced. Every test point is scripted to avoid any uncertainty that would waste valuable test time. Workload in the control room is heavy for every group in the control room throughout the length of the mission. The engineers monitor the health of the aircraft from engine start to engine shutdown. They also monitor critical parameters during mission test points. The control room mission support team also has a heavy workload. They validate the control room systems when the telemetry system comes on. If engineers report any problems, the team works quickly to resolve these problems to prevent flight delays.

Close coordination between the control room team and the telemetry antenna operators is needed when the aircraft taxis to and from the runway. Blind spots, telemetry multi-path off the hangers near the taxiway, and poor telemetry coverage zones make it difficult to track the aircraft from the compound to the runway. Hand-off calls need to be made between telemetry antennas as the aircraft moves from one coverage zone to the next. The telemetry processing system operators constantly choose the best source of telemetry for the telemetry processor during this time. Supporting an F-22 flight test mission demands a lot of concentration from all members of the F-22 control room team (flight test engineers and control room staff).

DATA GATHERING AND MONITORING

The amount of data monitored by each flight test engineer in the control room has increased by an order of magnitude from previous flight test projects. During envelope expansion flight testing of the F-16 aircraft, the telemetry data rate was 512 Kb/sec and the number of data parameters processed at that rate was about 1,000. Today the F-22 telemeters two 5-Mb/sec data streams. One data stream is dedicated to sending data parameters; the second data stream can be used for video telemetry or additional data parameters. When both F-22 data streams are used to send data parameters, the telemetry processor is receiving over 11,000 parameters at an aggregate rate of 10 Mb/sec in realtime. The previous telemetry processing benchmark at Edwards AFB was set by the Integrated Flight Data and Processing Systems (IFDAPS) in 1980, which processed 10,000 parameters in two 1.2 Mb/sec data streams from the B-2 Bomber.

The amount of data being sent to the ground for monitoring made the older telemetry processing and monitoring systems at RMCC obsolete. The new ADAPS systems can process and display more information than the engineer could previously look at in a control room. The engineers had to redesign their display concepts to take full advantage of the new workstation's capabilities. Color thresholds indicate when parameters start going out of limits. Hot keys on the displays allow the engineer to mouse click on the section of the display where the parameter is positioned to jump from a general display to a ten-parameter specific display for a detailed analysis on the parameter going out of limit. A logic tree of displays can be built to go from a general system display to specific displays showing exactly what is transpiring on the aircraft. Local recording groups can be loaded to record trend data throughout a flight. The aircraft data tape is a critical item for flight test and duration of the tape is limited. When the tape is full, the test mission is over. To conserve the tape, the pilot turns recording on at the start of a test maneuver and off at the end of a test maneuver. Trend data is impossible to obtain from the aircraft tape. Local recording allows an engineer to get this trend data digitally and to take it back with them at the end of the test mission. Post-test time slices can also be obtained from this data which helps the engineer to focus their post-test data requests to specific times needed. When an engineer can focus their post-test data sets, it means less time hunting and reviewing the previous mission and more time preparing for the next mission. This increases productivity and provides the capability for the engineers to make quick clearance calls that keep a fast paced project on schedule.

The F-22 structures engineers use the IADS system to monitor their data. IADS can perform the complex formula computations needed to analyze their data in a near real-time manner. The structures engineers can obtain results right after a test maneuver is performed and clear the aircraft to the next test point. Obtaining structural analysis answers while an aircraft is airborne, allows more test points to be accomplished per sortie and a more productive mission. The IADS system records all their needed data on the system's data hard drive. At the end of the mission, they download their data to a walk-away Jaz data cartridge, which is then uploaded to an IADS system located at the CTF. The same system used in realtime is also used for pre- and post-test analysis. IADS is another example of the convergence of realtime and post-test analysis being seen in flight test data processing at Edwards AFB.

CONCLUSIONS

We hope this paper has provided an understanding of the F-22 control room concept of operations. With the capabilities built into the F-22 control rooms, we have the means needed to support and execute complex F-22 missions. The control rooms have become a critical part of testing the F-22 aircraft. We are taking many of the lessons learned from the F-22 control room buildup and are feeding them back into other test projects and development efforts at the AFFTC.