INTERACTIVE ANALYSIS AND DISPLAY SYSTEM (IADS) TO SUPPORT LOADS/FLUTTER TESTING

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ABSTRACT

The Interactive Analysis and Display System (IADS) provides the structures flight test engineer with enhanced test-data processing, management, and display capabilities necessary to perform safety critical aircraft analysis in near real time during a flight test mission. Germane to hazardous, fast-paced flight test programs is a need for enhanced situational awareness in the Mission Control Room (MCR). The IADS provides an enhanced situational awareness by providing an analysis and display capability designed to enhance the confidence of the engineer in making clearance decisions within the MCR environment. The IADS will allow the engineer to achieve this confidence level by providing a real-time display capability along with a simultaneous near real-time processing capability consisting of both time domain and frequency domain analyses. The system provides for displaying real-time data while performing interactive and automated near real-time analyses. The system also alerts the engineer when displayed and non-displayed parameters exceed predefined threshold limits. Both real-time data and results created in near real-time may be compared to predicted data on workstations to enhance the user's confidence in making point-to-point clearance decisions. The IADS also provides a post-flight capability at the engineers project area desktop. Having a user interface that is common with the real-time system, the post-flight IADS provides all of the capabilities of the real-time IADS plus additional data storage and data organization to allow the engineer to perform structural analysis with test data from the complete test program. This paper discusses the system overview and capabilities of the IADS.

KEY WORDS

Flight Test, Structures, Loads, Flutter

INTRODUCTION

The Interactive Analysis and Display System (IADS) is being developed for the Air Force Flight Test Center (AFFTC) at Edwards Air Force Base by a team of Air Force and SYMVIONICS, Inc. software engineers to increase the efficiency of the flight testing process. The flight test engineers in the Mission Control Room (MCR) primarily monitor data for safety-of-test considerations and for data quality because the data is later evaluated to determine aircraft specification compliance. The IADS provides the engineer with advanced data organization, processing and display capabilities, both in the MCR and at the office desktop. Previous real-time structural analysis systems were very time consuming and limited, so most of the flutter testing analysis was conducted in a post-flight environment. At critical test conditions, real-time flutter clearance decisions came very slowly by using interactive analysis techniques designed for a post-flight analysis environment. Stripcharts were the main tool for displaying time domain data. A flutter analysis system running on one independent workstation provided spectral analyzer tools such as real-time power spectral density (PSD) and Nyquist plots. For loads testing, stripcharts were used as the primary data display source. In many cases, loads analysis decisions required the engineer to hand plot peak loads from the stripchart time histories onto paper cross-plots containing design load limit envelopes.

The primary source of post-flight data for the structures engineer was analog tapes processed after the completion of the test mission. This process introduced delays into the test-point clearance process, ranging from several hours to days. The engineers at the AFFTC are now being faced with program objectives which require much higher flight test efficiency rates than in the past, and these rates cannot be supported with the previous analysis systems. The engineers need to make quicker clearance decisions based on more detailed MCR analysis, and analysis results obtained during the flight test mission must be made available to the engineer at the desktop within a short period of time after the flight. In response to these needs, the AFFTC structures test community developed a set of operational requirements for the next generation of structural test analysis systems. The IADS is being developed to meet these requirements. The purpose of the real-time IADS is to provide the engineer sufficient resources within the MCR to allow enhanced safety-of-test monitoring and advanced near real-time analysis capabilities to support test-point clearance decisions in a timely manner. The post-flight IADS is designed to provide advanced data organization and processing at the engineers desktop.

The IADS provides for displaying real-time data while simultaneously performing manual and automated near real-time analyses. Summary reports in the form of plots and tables are available during and after the test flight, and these reports can be updated both manually and in an automated fashion. The IADS provides the capability for automated analytical processing. These can be triggered and/or driven by either user entered data or telemetered

parameters (e.g., flutter excitation system state parameters), or both. The IADS allows the engineers to transport selected Engineering Unit test data from the MCR back to their desktop for use in post-flight analysis. The requirement to obtain data from the aircraft tape before next-flight clearance is no longer necessary. Rather, the engineer will use data collected in real-time and transported to the post-flight IADS to make timely analysis decisions. Aircraft tape data will be used only to supplement the data collected in real-time, and the amount of data requested from the aircraft tape will be significantly reduced, thus saving time and money.

SYSTEM OVERVIEW

The IADS is comprised of two primary configurations: real-time and post-flight. For each configuration, the IADS has an architecture which combines both data-driven and client/server elements. The primary real-time data path through the IADS, from acquisition through display, is data driven. Data is sent from the Telemetry Preprocessor to the Compute Data Server, where it is stored, buffered, and filtered (if applicable). The data is then forwarded to the Display Station for presentation to the engineer. The engineer may also initiate near real-time analysis requests from the Display Station. These requests are processed in a client-server fashion by the Compute Data Server, which then returns the results to the Display Station. Each of these configurations provides consistent capabilities through common software and hardware. As shown in Figure 1., each IADS configuration consists of four major components: Compute Data Server, Data Distribution, Display Stations, and Group Data Storage.

The Compute Data Server (CDS) provides both data management and computational capabilities. The CDS is a multi-processor high-speed UNIX-based computer which supports both the real-time and post-flight processing needs of the IADS.

Data Distribution provides the distribution of real-time and analysis data to the display stations from the Compute Data Server. In the real-time configuration, an Asynchronous Transfer Mode (ATM) network provides the needed throughput for data distribution. In the post-flight configuration, Fiber Distributed Data Interface (FDDI) is used. The IADS data distribution software is designed such that it may be modified to use any packed-based technology.

Display Station provides the graphics and user interface to perform real-time processing. UNIX graphics workstation are used for the real-time configuration and Windows NT workstations are used for the post-flight configuration. Each display station is capable of displaying up to 100 parameters simultaneously at data rates of 800 samples per second. The maximum data rate is 4000 samples per second, however only 20 parameters can be

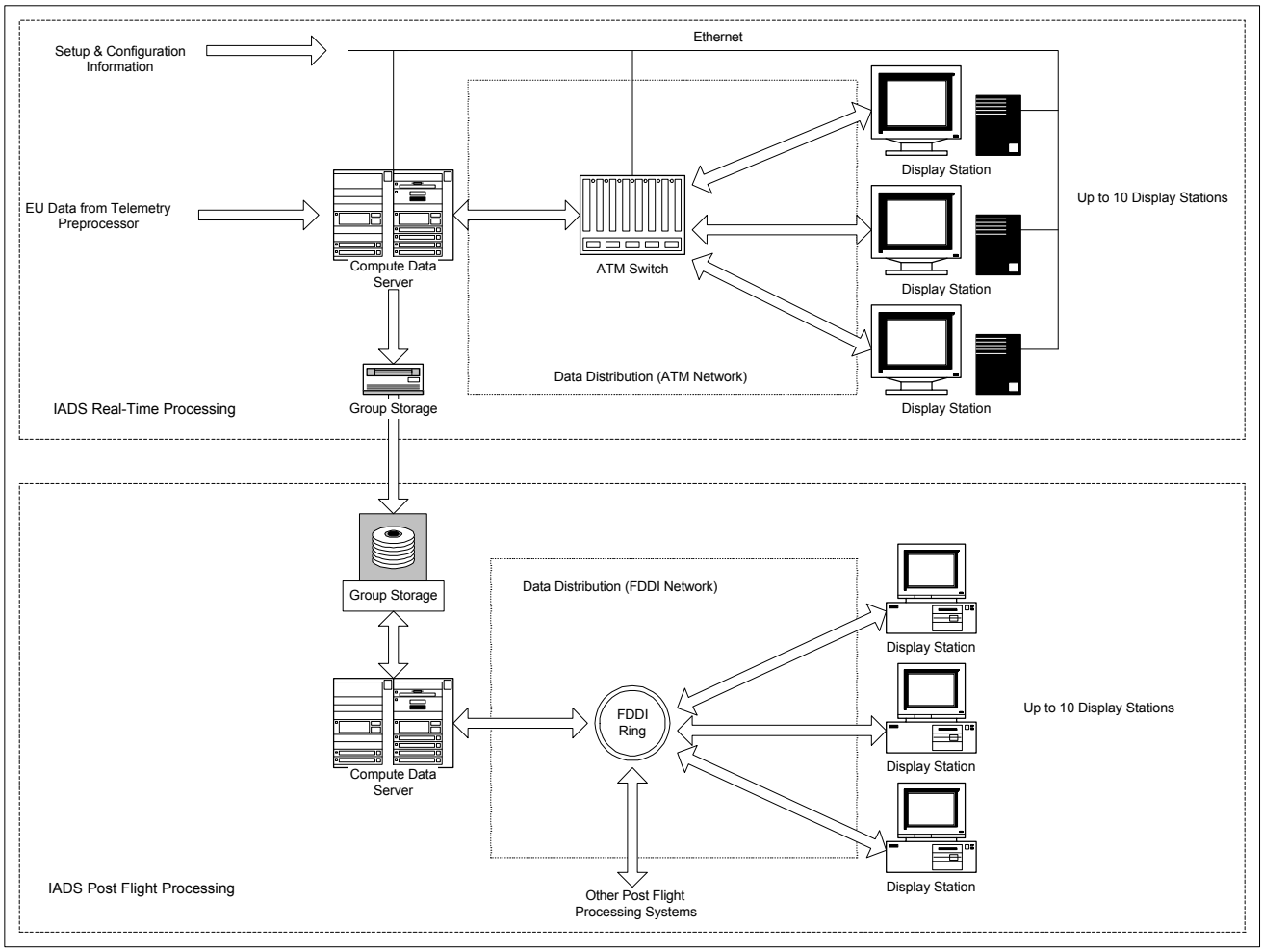

Figure 1. The IADS System Architecture

monitored at this rate. The display update rate is at least 30 updates per second, depending on analysis window complexity.

Group Data Storage retains the information requested by the engineers for future analysis. The system has the capability to store up to 90 minutes of data (200 parameters at 800 samples per second) during real-time operations. This data, along with setup information and analysis results data, is transferred to the post-flight configuration via removable media. This media is installed into a large jukebox for multiple flight access in the post-flight environment.

In order to meet the needs of the user community, the development team chose an object-oriented, incremental, and iterative development process which involves the user community in all phases of the development, from requirements analysis through system testing. The process accommodates successive refinements of the system as the user community has opportunities to evaluate incremental builds. This process allows the

development team and user community flexibility in meeting requirements which change and mature as the system is developed.

CAPABILITIES

The IADS is designed to support an engineering workgroup concept. In this concept, a group of engineers from the same engineering discipline share the system during a flight. The IADS provides both group and individual support to the workgroup. For example, digital filtering defaults are set at the group level, but may be modified by each individual engineer. The IADS organizes the test data so that each engineer may monitor a specific set of data, but the data is removed from the MCR at the workgroup level. Each engineer may perform their own data analysis, or the system may compute automated analyses, but all engineers within the workgroup have access to the results of the individual and automated analysis.

Currently, the IADS is sized to support ten Structures engineers simultaneously, providing the following capabilities:

- both interactive and/or automated time and frequency domain analysis and display
- processing of an aggregate data input to IADS of 200,000 samples per second
- scratch storage for each user of at least 90 minutes for up to 100 parameters
- workgroup storage on a walk-away media of at least 90 minutes for up to 200 parameters
- post-flight report quality plot environment

As described in more detail in the following sections, the IADS provides the engineer with capabilities in the areas of analysis, display, data organization, and report quality plotting.

Analysis Capabilities

In the area of test data analysis, the IADS provides capabilities to the Structures engineer at the workgroup and individual level. The IADS analysis capabilities include algorithms for both time and frequency domain processing, in real-time and near real-time, for both interactive (manual) and automated modes. The engineers may choose to use the workgroup level settings for the system or may chose to override these with their own settings, including digital filtering, sample rate decimation, parameter threshold limits, and parameter scaling. The engineer may also change display types, change the size of an individual display, or drag and drop new parameters into existing displays, all of which can be performed on the fly in real time. The engineer may perform analysis on real-time data from the current test-point or on data from previous test points within the current or previous missions (post-flight). The engineers may combine their analysis results with results from others within the workgroup. The engineers may monitor real-time

parameters, both time and spectral, or they may chose to freeze a set a parameters and perform more detailed analysis. This detailed analysis may be of time or frequency domain data, including:

Time Domain Analysis:

- Log Decrement
- Log Decrement Averaging
- Log Amplitude Picking
- Time History Curve Fitting
- Randomdec
- Pseudo Randomdec
- Auto-Correlation

Frequency Domain Analysis:

- Spectral Analysis
    - Auto-Spectrum
    - Power Spectral Density (PSD)
    - Inverse Fourier Transform (IFT)
    - Transfer Function (Magnitude, Phase, Real, Imaginary, Coherence, Bode Plot, Nyquist)
    - Damping Calculations (Half-Power Method, Frequency Curve Fitting)

Display Capabilities

The IADS provides the engineer with a display tool set optimized to aid in the task of data analysis and situational awareness, and displays the test data in a format which allows the engineer to efficiently and confidently make test point clearance decisions. This display tool set includes high fidelity time history displays eliminating the need for strip chart recorders. The engineer can fully interact with the time history display to freeze and scroll back in time, zoom, annotate/mark events and select data points on which to perform requested analysis. These interactive capabilities are available through drag and drop, toolbars, mouse selections, and menus.

In addition to time history displays, IADS provides numerous display tools for the engineer to perform these analyses. These include:

- Cross Plots with Envelopes
- Table Displays
- Alpha Numeric Displays
- Figure Displays

Figure 2 represents a depiction of an analysis window with time history displays, alpha numeric displays, and PSDs. Various editing functions can be applied to any of the displays, such as filtering (Butterworth and Elliptic), color thresholds and wild point editing. Additional editing functions like adding spectral lines, averaging, and windowing (Hanning, Hamming, Kaiser-Bessel and Blackman) are also available in the frequency domain.

The IADS displays analysis results in the form of summary plots and summary tables. The IADS plots the results of the predefined primary analysis method(s) for each summary plot and summary table. These results can be used for comparisons of current as well as previous flight test results to analysis model predictions, and to establish trends in the data. Results from secondary analysis method are also available to the engineer to compare with predicted data.

Data Organization Capabilities

Efficient data organization within the IADS is essential to support the analysis and display capabilities described above and to provide the engineer with the flexibility in what is brought into and carried away from the MCR. The IADS provides the engineer with the mechanism for importing data from previous flights and results of analytical computations into the MCR for comparison with the current mission test data. Ongoing summary analysis may also be imported, with results from the current mission added to the summary information. The IADS provides each user with sufficient scratch (temporary) storage to store at least 90 minutes of test data for up to 100 separate parameters. This data is available to the engineer for further analysis and for comparison (overlay) with real-time data. The IADS provides the workgroup with a "walk-away" storage capability of at least 90 minutes of test data for up to 200 parameters. The workgroup may use this storage to transport test data of interest, user configurations, analysis results, and other necessary data from the MCR back to their desktop for further analysis. The post-flight IADS provides the engineer with additional data organization and archival, allowing the engineer access to all of the data accumulated during the entire test program.

Report Quality Plot Capabilities

The Post-flight IADS Configuration provides the capability to generate report quality plots for all display types. The user is provided with the ability to attach annotations to the plots, specify whether the annotations are free or boxed, and be able to attach arrows pointing from the annotations to areas of interest on the plots. The IADS will allow the user to specify titles and plot headers, text font, text size, text alignment, symbol type, symbol size, and symbol color. The engineer creates plot templates with a report quality plot environment to produce presentation files with the applicable data imported into them. This process can be created either automatically or manually.

CONCLUSION

The IADS is a combination of current state-of-the-art commercial technology (Telemetry Preprocessor, Compute Data Server, Display stations, and networks) and custom software. This system is being developed to provide the Structures engineer with advanced data organization and processing both in the MCR and at the engineers desktop, increasing the efficiency of the engineer for point-to-point flight clearance decisions and during post-flight analysis. The cost savings expected from reduced flight time and reduced post-flight data processing will far exceed the combined cost of developing the IADS software and the cost of the necessary hardware.

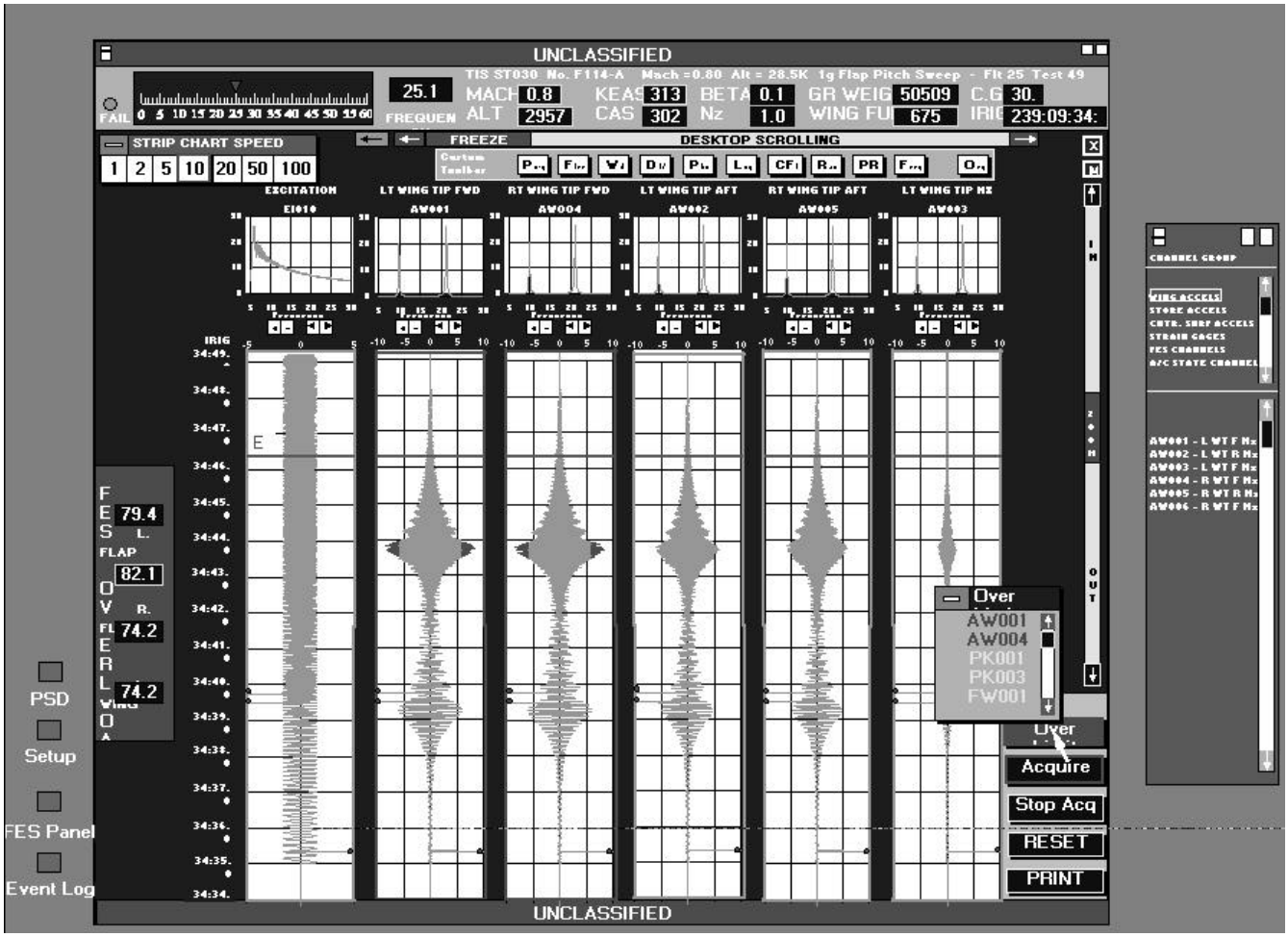

Figure 2. Example of an IADS Display