Enhancing Diagnostics through the visualization of Air Vehicle Data

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Abstract— **To achieve an affordable system the JSF is implementing Autonomic Logistics capability which includes a diagnostics function to review flight collected data and correlate fault event to flight maneuvers.**

This flight recreation capability provides, for example a maintainer, the capability to recreate a flight based on the data stored by the air vehicle. The recreation of a flight consists of providing a 3D flight viewer, a graph viewer to view fused signal data and a flight data player to navigate the data. This tool set provides the maintainer with insight into the state of the air vehicle when an event occurred. This supports more efficient maintenance of air vehicles.

The Flight Recreation Module permits using data visualization by an engineer to replay the stored flight data. The Flight Recreation Module has the capability to graphically display the behavior of multiple, selectable flight and health parameters in a multi-window, time-synchronized user interface.

This paper discusses how the Flight Recreation Module supports the future sustainment of the JSF while delivering an affordable fighter.

I. Introduction

A long held belief by maintainers everywhere is that if they knew exactly what was going on with the system at the time of failure that they would be able to identify the cause of failure more quickly. With the advent of the computer more data is being captured by aircraft today than ever before. Methods are being put in place to capture that data and make it available to the people that need it including the maintenance technicians. As true everywhere we now are facing a situation that is termed information overload, there is so much data available that the user can not see, review or understand it all. Part of the solution to this problem is to provide ground based processing for the aircraft data with interpretation, analysis, fusion, and other computer techniques to correlate and arrange the information to aid in making decisions or understanding of system behavior. One technique being used on the Joint Strike Fighter program to support both the maintenance technician and the engineers is what we call a Flight Recreation Module. This Flight Recreation Module, which is the focus of this paper, provides the capability to recreate a flight based on the data stored by the air vehicle.

The paper provides an overview of this Flight Recreation Module and how it supports more efficient maintenance of air vehicles. In the background we discuss how the Flight Recreation Module became part of the JSF product and then the Flight Recreation Module will be discussed. Followed by an example of how it helps maintenance of air vehicles. Benefits of having the Flight Recreation Module are discussed in the conclusion.

II. Background

Several key concepts have been brought together to help provide an affordable Joint Strike Fighter (JSF) to our customers.

One key is the Autonomic Logistics capability that supports operational organizations (e.g. wing or squadrons), pilots, maintainers, land and sea infrastructure, and the greater Defense organizations operations by providing business operations, support services, training services and an information system for the Joint Strike Fighter.

A second important key concept is the Prognostics and Health Management (PHM) capability [1][2] with both on aircraft and off aircraft, or Off-Board, capabilities that include:

- Testability and Built In Test capabilities
- Pertinent data acquisition at sensor, component, and subsystem levels;
- Enhanced diagnostics, beyond the legacy testability and Built In Test capabilities, through system models, corroboration, correlation, and information fusion;

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- Prognosis, the prediction of impending failure and the estimation of remaining component life; and
- Health management that provides the capability to maximize system effectiveness in the presence of system anomalies.

A third key concept to affordability is the use of fewer and less skilled, more generalist, maintenance technicians to support the aircraft which puts an increased burden on the support system to provide more and better information to these technicians.

The fourth key to success for the program is the bringing together the "best of breed" suppliers and team members as part of the development team from across the globe.

These key components come together in a system of support that provides the foundation for the Flight Recreation Module to provide the visualization of key aircraft parameters to better understand aircraft events.

The Flight Recreation Module is part of the toolset available in Off-Board PHM for maintainers and engineers. Fig. 1 shows the Flight Recreation Module related to the PHM capabilities.

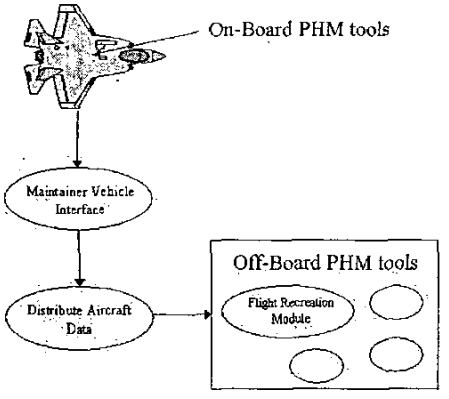

Figure 1. Flight Recreation Module uses the data distributed from the air vehicle

The aircraft collects information through the On-Board PHM capabilities with the data being transferred through the Maintainer Vehicle Interface capability. The data is distributed to information system components such as the Off-Board PHM function which includes the Flight Recreation Module, Prognostics, Diagnostics, and Life Management.

III. Flight Recreation

The National Aerospace Laboratory NLR has supported the maintenance of F-16 fighter aircraft for several years. During these years NLR has built up extensive maintenance knowledge on fighter aircraft. This knowledge amongst others resulted in the Flight Recreation Module to aid in detecting failures in aircraft.

The Flight Recreation Module supports problem solving of the Air Vehicle by recreating the flight (or ground power cycle) of the Air Vehicle during which the problem occurred.

The objective of the Flight Recreation Module is to provide support to support-engineers and maintainers in getting insight into the problem that occurred with the Air Vehicle by providing three displays to the user:

- Flight Data Player
- Flight Viewer
- Graph Viewer

These displays are discussed in more detail below.

A. Flight Data Player

The Flight Data Player (Fig. 2) enables the user to navigate and play a set of signal data (recorded from sensors in the Air Vehicle). The output is directed to one or more flight viewers and graph viewers.

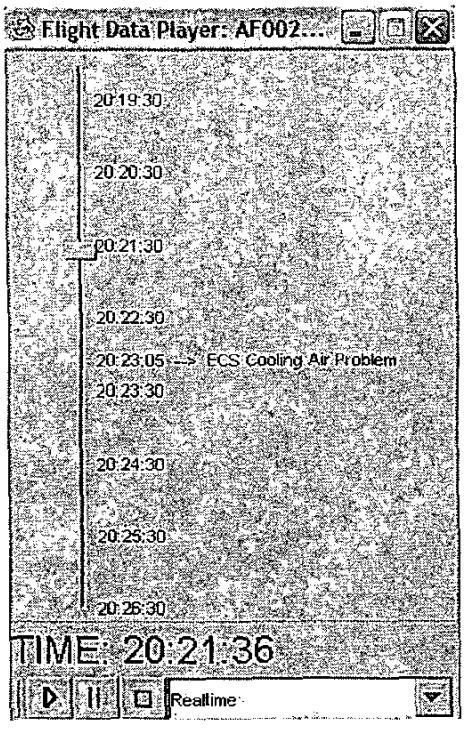

Figure 2. The Flight Data Player supports the navigation through the flight data, time and events; it also allows the selection of playback speed.

The Flight Data Player consists of a vertical timeline that the user can use to jump or navigate to certain moments in time or events as the timeline also lists events that were marked in the Air Vehicle data. The Flight Data Player also provides a play, pause and stop functionality as well as the capability to adjust the replay rate, e.g. 0.5X, real-time, 2X, etc.

B. Flight Viewer

The Flight Viewer (Fig. 3) uses data provided by the Flight Data Player to visualize in 3D the outside of the aircraft (clean surface) so the user can get more insight in the position, attitude and motion of the Air Vehicle during a certain moment in flight. This Flight Viewer is synchronized with the Flight Data Player; every action of the user in the Flight Data Player is reflected in the Flight Viewer.

A. Graph Viewer

The Graph Viewer (Fig. 4) shows flight parameters simultaneously in a graph, supporting the inspection of flight data [3][4][5]. Multiple parameters can be selected using drop down boxes. Different parameter sets exists for different user interests. The Graph Viewer is also synchronized with the Flight Data Player.

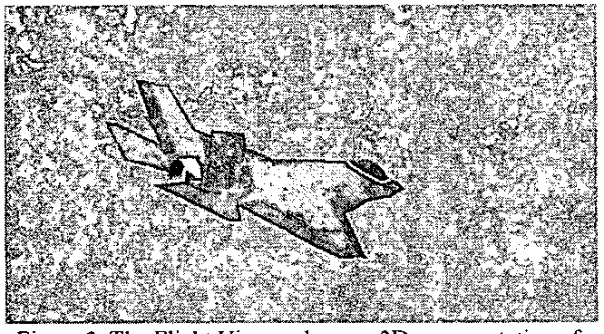

Figure 3. The Flight Viewer shows a 3D representation of the aircraft, supporting better understanding of the attitude of the aircraft

IV. SUPPORTING THE MAINTAINER AND SUPPORT ENGINEER

The Flight Recreation Module is used by the maintainer for finding out what happened to the aircraft during flight that could have caused a difficult to diagnose problem with the aircraft. The following scenario describes an example of the use of the Flight Recreation Module:

A maintainer is confronted with a problem with the air vehicle that he cannot resolve with the standard procedures. In this case the maintainer can use the Flight Recreation Module. The maintainer selects a flight ID of which he or she wants to view the flight data.

Optionally, if maintainers want to focus on a certain failure event they can also select a certain signal set associated with that event.

To navigate the flight data the maintainer can use a slider (timeline) to view the relevant parts of the flight. Besides the timeline the maintainer can also use the event viewer to select a time at which a specific event (or events) occurred. The 3D (Flight Viewer) and 2D (Graph Viewer) views of the flight data are automatically updated to reflect the new time selected. To enhance the understanding of the aircraft state during a certain moment in time, the user has the opportunity to concurrently show several different flight signals in a 2D graph.

Without a Flight Recreation Module the maintainer would have to interpret the air vehicle represented as numbers, which makes it a more difficult to construct what happened during the flight that could have caused the problem with the air vehicle.

If a maintainer cannot solve a problem on the aircraft, he can also contact a support engineer who is part of a customer support center. The customer support center provides 24/7 technical support to the JSF user. The support engineer will investigate the problem for the maintainer. The support engineer is typically located offsite and is trained in solving difficult failure scenarios. The support engineer, aside from the Flight Recreation Module, also has access to other tools that aid the resolution of difficult failure scenarios.

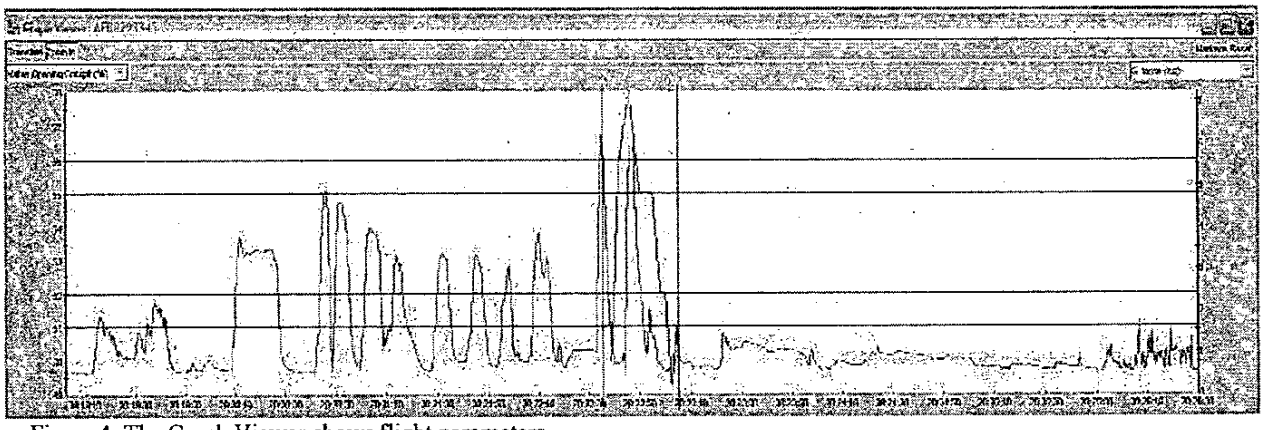

Figure 4. The Graph Viewer shows flight parameters simultaneously in a graph, supporting the inspection of flight data

To summarize the fusion of data parameters allows for better understanding and decision support and the effect summaries the effect of these parameters on how the system responded to the changes in those parameters.

A. Case Example

The following case description will further illustrate the use of the Flight Recreation Module.

The user (maintainer or support engineer) is confronted with a difficult to diagnose problem, in this case an Electronics Cooling System problem. This system failed and the user cannot find the cause of this failure. To identify the cause the user loads the data recorded from the air vehicle, with the Electronic Cooling System failure marked in the data, into the Flight Recreation Module. The user selects the correct parameter set associated with Electronic Cooling System problem.

Using the timeline slider the user jumps to a point in time slightly prior to where the failure occurred. Based on the 3D representation of the aircraft the use notices that the aircraft is making a high G-force maneuver. Suspecting that the problem is related to this maneuver the user selects the G-force parameter to be plotted in the Graph Viewer window. Subsequently the user combines the G-force parameter with other parameters in the Graph Viewer in an attempt to find a correlation between parameters. Fig. 5 shows a screenshot of the correlation of the Flight Recreation Module.

When the user selects a cockpit-cooling valve related parameter, a change in the value of the valve parameter becomes evident. Suspecting that the problem is related to the cockpit-cooling valve the user focuses on physical characteristics, i.e. loose connectors or brackets, around the cockpit-cooling valve.

V. Conclusion

By adding the Flight Recreation Module to the toolbox of the JSF maintainer and engineer we provide a capability to relate and fuse data and information from several sources. This solution embedded in the ground based processing for the aircraft data supports interpretation, analysis, fusion, and other computer techniques to correlate and arrange the information to aid in making decisions or enhancing understanding of system behavior. Adding the Flight Recreation Module to the toolbox will go a long way in supporting the understanding of exactly what was going on with the system at the time of failure. User will more quickly be able to identify the cause of failures. On JSF we will add tools and methods to this basic capability to enhance user friendliness, to help identify parameters that are abnormal or unusual, and to help prescreen for interesting or useful events based on the design of the JSF and the parameters available for viewing.

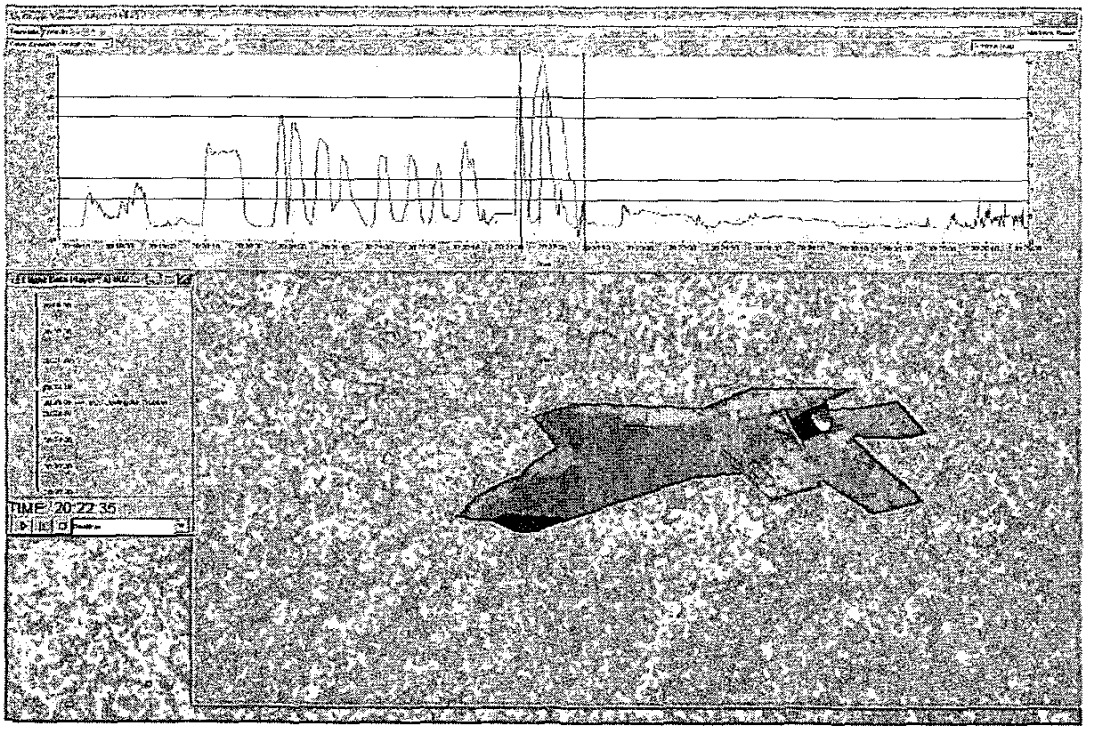

Figure 5: The view showing the correlation of G-forces to valve position and the attitude of the air vehicle.

ACKNOWLEDGMENT

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