THE USE OF HDF IN F-22 AVIONICS TEST AND EVALUATION

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ABSTRACT

Hierarchical Data Format (HDF) is a public domain standard for file formats which is documented and maintained by the National Center for Super Computing Applications. HDF is the standard adopted by the F-22 program to increase efficiency of avionics data processing and utility of the data. This paper will discuss how the data processing Integrated Product Team (IPT) on the F-22 program plans to use HDF for file format standardization. The history of the IPT choosing HDF, the efficiencies gained by choosing HDF, and the ease of data transfer will be explained.

KEY WORDS

Hierarchical Data Format (HDF), Format Standardization, F-22 Avionics Data Processing.

INTRODUCTION

Utilizing HDF as the standard file format will allow analyzed data to be used and reused by Commercial Off The Shelf (COTS) analysis programs at any team facility without costly or time consuming format conversion. Due to standardization, laboratory data, Flying Test Bed data, and flight test data will be easily transferable between locations, aiding in model updating and validation. Laboratory data obtained using validated models will be used along with flight test data to prove specification compliance. Utilizing laboratory data to prove specification compliance will greatly reduce the cost of flight test. Key to using laboratory data is being able to readily compare results with F-22 open air test results. HDF format will allow this comparison without costly reprocessing of data.

USING HDF

HDF was chosen by the Data Processing (DP) IPT on the F-22 program for file format standardization. The DP IPT plans to make the HDF standard data available to all laboratories that process F-22 avionics data. Global PI bus, High Speed Data Bus, 1553B, as well as inter module (Ada) messages of interest will be recorded on an Ampex DCRsi 240 Mbps recorder, through the use of a Harris Data Acquisition Unit multiplexer. The

Data Acquisition Unit selections will be programmed by the Operational Flight Program via a Measurement Activation Table (reference Figure 1. Using HDF).

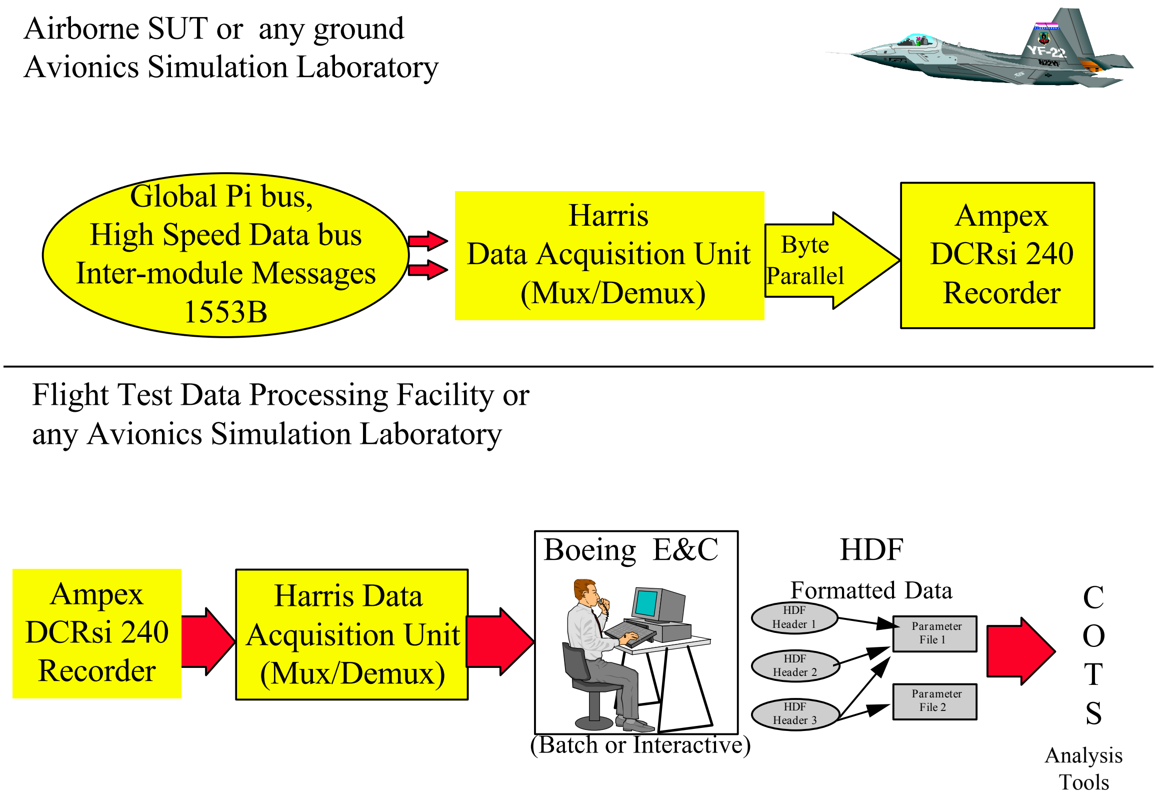

Figure 1. Using HDF.

Boeing written Ada code called Evaluation and Control (E&C) software will be used by all laboratories, and in flight test to select, demultiplex, and convert the data to Engineering Units. Post E&C processing is the point in the process where the Data Processing IPT will use the HDF standard. Laboratories are dependent on the data acquisition unit to record requested data on the DCRsi, and E&C software to retrieve and make sense of requested recorded data. By taking advantage of laboratory dependencies on existing hardware and software standardization (Data Acquisition Unit and DCRsi hardware, and E&C software), the DP IPT plans to achieve standardization to HDF without having to pre-coordinate with each laboratory. Generation of E&C parameter files trigger creation of HDF header files. HDF header files allow the requester of the data to point to the data of interest using COTS software, in particular PV~Wave. By following this plan the DP IPT plans to achieve HDF compliance. Only one copy of the data will actually reside in storage, but multiple users will be pointing to that data for use by their COTS analysis routines.

HISTORY OF CHOOSING HDF

Early in the program the F-22 Avionics team realized that to be successful in the planned build-up approach, flight test data would be required at each laboratory to validate models and predictions. In May 1994 the DP IPT started researching file format standards. A technical interchange meeting was held to consider file formats and their effects on data processing operations. The technical interchange meeting also addressed COTS products like PV~Wave and how they might be used by avionics engineers for analysis.

Various file formats were discussed: glass file formats, a Lockheed proprietary format; universal data format, which was the file format used by the Lockheed Martin team in the Demonstration/Validation portion of the F-22 program; flat files such as SANDS and C-file used by an Air Force Flight Test Center at Edwards Air Force Base; Z and W files which use external data representation protocol permanent files; HDF, common data format, and Net common data format, which are public domain standards. A robust common data format was deemed necessary by the DP IPT to insure data consistency from laboratory to laboratory to flight test and back to laboratories. HDF began to emerge as the choice with the best chance of success.

The avionics DP IPT tasked the AFFTC Range Software Development Branch lead by Dr. William Kitto, to analyze the HDF file format and make a recommendation to the IPT on a standard file format. Dr. Kittos' team was directed by the F-22 DP IPT to test the candidate format on the DEC Alpha platform, using PV~Wave as the interface tool. Initial prototypes identified HDF performance concerns, but in early 1995 Visual Numerics Inc. provided an HDF interface to PV~Wave at no cost to the F-22 program.

Test cases were conducted using both SUN and DEC Alpha computers. Test data included five different types of data: multi file, native float, external data representation integer, native integer, and single file formats. Various read/write scenarios were tested using C, FORTRAN, and PV~Wave interfaces. Analysis of the results of HDF performance on both the SUN and DEC Alpha computers showed that utilizing HDF would not significantly impact performance.

There were added benefits of selecting HDF over any other format considered. HDF is public domain software and is free to anyone who wishes to use it. HDF is the National Super Computer file format standard and is being used by projects which handle larger quantities of data than the F-22 expects. As platforms and/or interfaces change over the long term F-22 program the benefits of choosing HDF will continue to grow because it is not computing platform dependent. Maintenance and hosting HDF will be supported by the National Center for Super Computing Applications, University of Illinois, Urbana Campus, at no cost to the F-22 program. After completing the compatibility and performance analysis, Dr. Kitto recommended HDF to the team. In March 1995 the Data Processing IPT led by, Dean Fox of Lockheed Martin, selected HDF as the F-22 standard file format for both airframe and avionics. Today prototype software is running which builds HDF header files for E&C parameter file output so PV~Wave can access the data.

PROPOSED IMPLEMENTATION

Prototype software was used to evaluate the efficiencies of the proposed HDF implementation. Avionics analysis engineers were able to request specific recorded data to be retrieved from the recorder for post flight analysis. Requested data will be demultiplexed by the data acquisition unit, and pre-processed by E&C software. Parameter files and HDF headers can be produced for any parallel interface message data requested.

A single HDF header file will be built for each request. The HDF header will point to all E&C parameter files required to fulfill that users request. Since multiple users can request the same data, HDF headers share the parameter files, therefore parameter files will be stored only once on the DP storage system (reference Figure 2. Hierarchical Data Format).

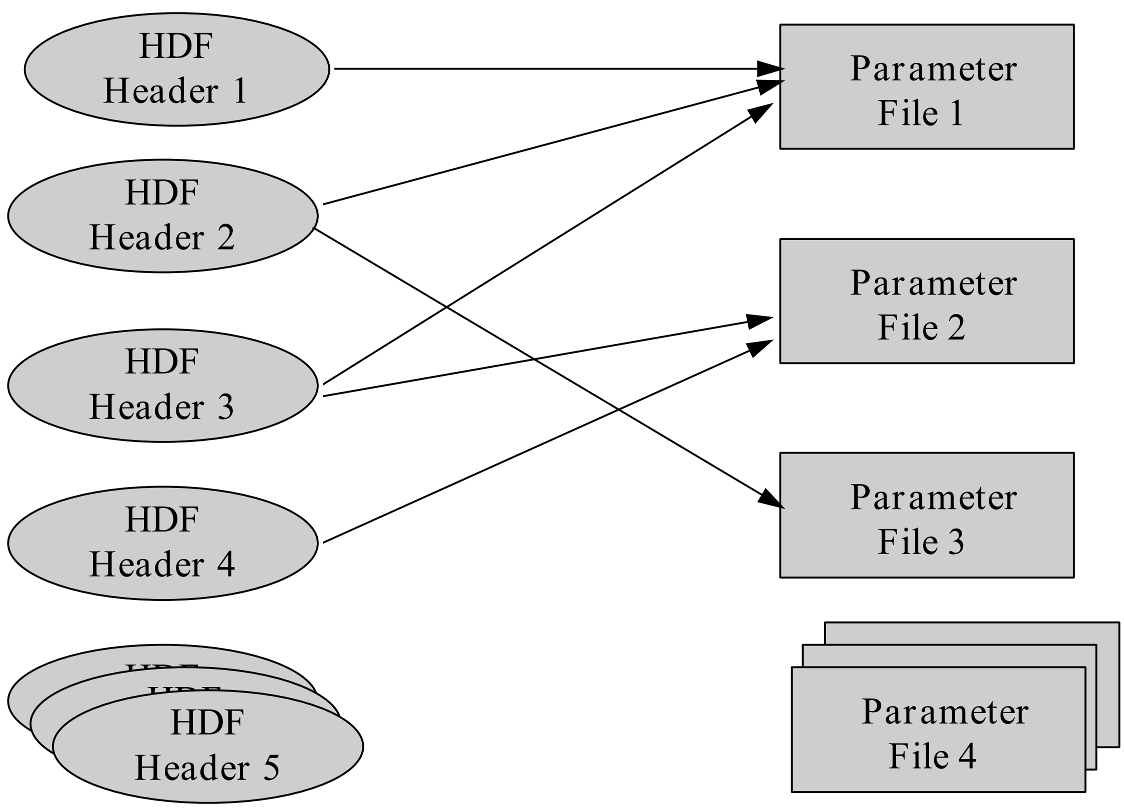

Figure 2. Hierarchical Data Format.

The header will point (give a path name) to its associated parameter files which contain the actual data. Once data has been retrieved from the recorder and processed, a user can re-request that data for later processing by simply knowing the path name of the HDF header file. The header will store metadata associated with requested processing of that data.

METADATA EFFICIENCIES GAINED

Efficiencies gained by choosing HDF are numerous. Metadata is a term used to document data about the data, and was considered a useful feature of HDF. For example, if the data is a test result, then the metadata is the circumstances about the test. More specifically, data includes airspeed, altitude, and heading whereas metadata includes project F-22, airplane 4004, test 10, altitude band, and pilot notes. Flight test data is typically first generation processed to engineering units with simple unit conversions made yielding plots. Second, third, and fourth generation processing may be required to determine if the data collected achieved the predicted results, validated the models, and proved specification compliance. Metadata logs the information about how results were processed over successive generations, what new measurements were created, and what limitations the test had. The volume of data will actually decrease for each processing stage, but the volume of metadata increases with each processing stage. HDF allows for metadata tracking either included as attributes with the data or external and linked to the data. F-22 HDF uses attributes to store metadata which allows data files to be self contained. Therefore, all information required to regenerate the results is maintained along with the data itself in HDF attributes.

DATA MERGE EFFICIENCIES GAINED

PV~Wave, Mathmatica, and other COTS analysis tools can enhance efficiencies of using HDF by automatically merging together any data which exist in an HDF format. Target time space position information, radio frequency truth (spectrum), and radio frequency mode data can be merged with F-22 target time space position information, PI bus, 1553B, and transducer data by the engineer using PV~Wave in an interactive or batch mode.

Data merge for flight test missions is not a trivial task. F-22 aircraft data will be compared to other types of time tagged or event driven data. All types of data used for F-22 post flight are required to be provided or converted to HDF. Target time space position information, range data, radio frequency truth, and non F-22 data products will be delivered to the F-22 DP IPT in HDF. Therefore, HDF is by default becoming a post flight standard format for various test ranges like Edwards and China Lake. COTS analysis routines such as PV~Wave and Mathmatica can use any HDF formatted data automatically. No data merge is required by data processing because the COTS analysis routines will align timelines for multiple data by interpolation. The COTS can be run either interactively by the analysis engineer or batch by the DP IPT.

DATA TRANSFER EFFICIENCIES GAINED

The ease of data transfer is the greatest efficiency gained by format consistency. Specialized tools will not be required at each facility to pass data from one facility to another. For example, flight test data will be used to validate the models used in simulation. Since laboratories and flight test are all using HDF, flight test data can be easily fed back into any laboratory without requiring data reformatting. An “apples-to-apples” comparison of data can be made. Once data at any facility is recorded on the DCRsi by the data acquisition unit, requested data can be pulled off the recorder into a parameter file by E&C software in an HDF format, and used by COTS analysis tools at any team location.

Further standardization or software reuse can potentially be achieved using HDF. Laboratories require analysis routines to complete unit testing followed by integration testing. The flight test team plans to co-develop laboratory analysis software algorithms so flight test requirements are fulfilled and the analysis routines can be reused. The premise is that if all locations have the same data format and the same analysis routines then any difference in results can quickly be identified. Furthermore, regression testing costs are minimized because no format conversions or analysis routine rewrites are required.

The F-22 modeling and build-up approach minimizes the requirement for actual flight test data. Less expensive laboratory data will be used to prove specification compliance, while costly flight test data is used primarily to validate models.

Applying the HDF standard requires a specific implementation be adopted by the F-22 program to increase efficiency of avionics data processing and utility of the data. The Data Processing IPT on the F-22 program is developing an HDF interface control document. The interface control document will further clarify HDF file format standardization to the scientific data set to gain efficiencies and ease data transfer. Additionally, the interface control document is required to describe standard attributes. Once the interface control document identifies standard attributes any team location could independently decipher how the data was processed and reproduce the same results.

CONCLUSION

Testing of F-22 avionics will utilize a modeling and build-up approach to minimize use of costly assets. Unit and integration testing will be conducted at integration laboratories, simulation laboratories, on Flying Test Bed laboratories, and during Flight Test. Digital PI buses, High Speed Data Buses, and inter-module messages will be instrumented to record data digitally.

Data processing standardization such as multiplexing hardware, demultiplexing software, and the HDF file format will increase test efficiency and reduce development efforts required at each facility. HDF formatted data takes advantage of metadata, data merge, and data transfer efficiencies since it can be used by COTS analysis programs at any facility without format conversion. COTS analysis programs such as PV~Wave and Mathmatica support HDF and will be utilized at each facility. Application of a standard file format eases the transportability and usability of flight test data at the laboratories for model validation. Using less expensive laboratory data to prove specification compliance is less difficult partly due to the DP IPT selecting HDF. By selecting HDF as a file format standard for the F-22 program, the F-22 Avionics program increases their efficiency of data processing, eases data transfer, and allows for better utilization of the data.

HDF is a public domain standard for file formats that is documented and maintained by the National Center for Super Computing Applications at the University of Illinois, at Urbana Campus. For more information, connect to the Internet and use a WEB browser to search for HDF to acquire full documentation.