

ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS
IN-FLIGHT SOFTWARE TESTING

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Abstract

This Paper is intended to discuss the introduction of advanced information systems technologies such as Artificial Intelligence, Expert Systems, and advanced human-computer interfaces directly into Space Shuttle Software Engineering. Completion of this objective will validate that these technologies are sufficiently mature to use in NASA space mission operations and will benefit the Space Shuttle Program by improving the quality of software performance analysis.

The Process

The Space Shuttle flight software is built and tested within the Software Production Facility (SPF). The SPF is composed of several IBM 3000 Series Mainframes and is the backbone of the reconfiguration process.

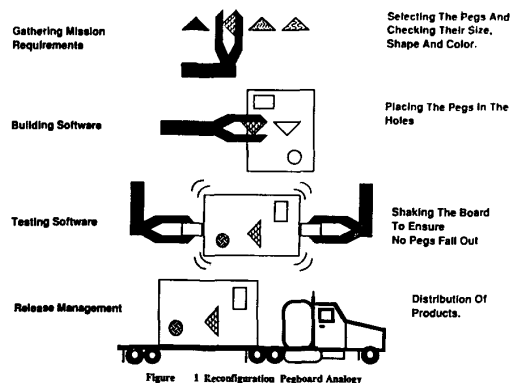
The SPF is used to collect mission specific flight software requirements from the data, payload, and development communities. Flight software is meshed with over 6000 mission specific parameters on each flight. These data are fed into the reconfiguration process which reformats and integrates the data together into functional groups. A serial build process then begins to form a flight-specific Mass Memory Unit (MMU).

Once the mission specific software is integrated onto the MMU, it must be tested for performance integrity prior to being loaded onto the Space Shuttle General Purpose Computers (GPC's) where it controls all phases of flight. The GPC's are hosted on the SPF where they are supported with simulation software. Within this environment, the GPC's are referred to as Flight Equipment Interface Devices (FEID's). Numerous FEID runs are performed putting the MMU through all potential

phases of the mission. Output of these runs is reduced into reams of paper plots with which engineers perform their analysis. This final, or "Level 8" performance testing, represents a significant manpower investment. Over 40 people are dedicated to regression testing of flight software with over 77 days of testing scheduled for flight preparation.

Figure 1, the pegboard example, animates and simplifies the reconfiguration process. The pegs (data inputs), are placed into the board (the build process) to form a complete entity (the MMU). Once the board is complete, it is shaken for errors (Level 8 testing) and delivered to Kennedy Space Center for flight.

After the testing has been completed and all anomalies have been identified and explained, the MMU is released to the vehicle for flight. Successful and accurate completion of this analysis is critical to flight safety and mission success.



The Problem

Completion of the flight software regression testing is a critical pacing factor in the launch schedule. An increased flight rate and decreasing federal budgets will drain the manpower resources available that are required to run these tests. Therefore, regression testing must be automated to maintain flight safety as the flight rate increases.

To appreciate a further complication of the problem, it should be noted that the nature of the testing is boring and tedious. Stacks of paper plots must be analyzed by hand. The tools of this analysis are limited to pencil and straight-edge. Engineers evaluate slopes and limits of Space Age software with Dark Age tools.

Although the tools may seem archaic, the skills to perform the analysis are not. This task is not suitable for transfer to the clerical skill level. Engineers are required to properly interpret the complex relations that the plots represent and track them through the flight software source code.

Most test cases produce few anomalies. Hence, completing this verification task is sometimes compared to the routine involved with being an airline pilot. In other words, 99 percent boredom and 1 percent terror. When a flight software problem is discovered, it must be immediately analyzed and elevated to the appropriate level. Any error that goes undetected could ultimately cause loss of human life. This creates an environment that produces unusually high stress. Consequently, the turnover rate of engineers is extremely high.

A more productive environment which allows for stimulating analysis and prompt accurate results is required.

The Solution

Extensive test criteria are formally defined and documented. These definitions help create an environment easily suited to automation. These criteria become the rule base for the expert systems.

Investigation of software engineering and application of an expert system in the area of Level 8 mission-critical software regression testing will reduce manpower requirements, improve documentation, and streamline the efficiency of critical mission software development and production. The Reconfiguration Automation Project (RAP) was initiated to coordinate this move towards 1990's software technology.

The idea behind RAP is to automate several phases of the flight software testing procedure and to introduce AI and ES into Space Shuttle flight software testing.

The Approach

The approach to this project is to use automation as a springboard into Artificial Intelligence and expert system development.

In the first phase of RAP, conventional tools to automate regression testing have already been developed or acquired. There are currently three tools in use.

Plot Package

Limited, but specific Commercial Off-the-Shelf Software (COTS) is necessary to enable quick startup and minimal development time for certain project areas. A COTS product (Precision Visuals PV-WAVE) was acquired to alleviate the dependency on the paper plots that are used for the engineering analysis. When the plot file is available after post processing completion, the plot file will be downloaded into the high power color workstation operating with a X-11 windowed environment. Here, the plot package will load the plots and provide a point and click interface to the data. Several plots can be viewed at one time and access to data is not delayed by the 1 day turnaround time required to receive paper plots.

IV&V Toolset

The second tool that is being used aids the engineer in doing further investigation into anomalies discovered in the plot analysis. When a plot anomaly is discovered, the pressing question is whether the code or the tools have caused the error. To determine this, the engineer must look into the Space Shuttle source or, HAL/S code.

HAL/S is a language that was developed for NASA by IBM for avionics applications. This language is used almost exclusively for the Space Shuttle flight software. The HAL/S language is similar to structured Fortran.

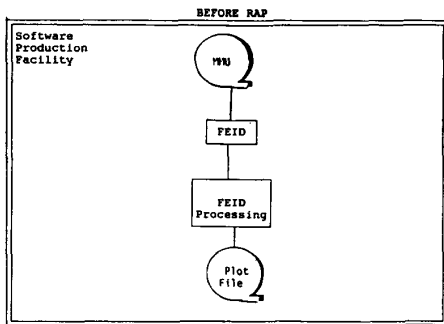
In order to expedite analysis of the HAL/S code, NASA chartered one of its contractors in the flight software testing arena to develop an analysis tool. Intermetrics Inc., delivered the IV&V Toolset. The toolset is a collection of programs designed to help engineers analyze this Space Shuttle source code. This tool, when given a version of the flight software, will automatically generate flowcharts, provide documentation, and allow for cross referencing of variables for quick analysis. This tool also operates in the X-11 windowing environment and hence, is a part of the engineering workstatic n environment that is being developed.

Criteria Checker

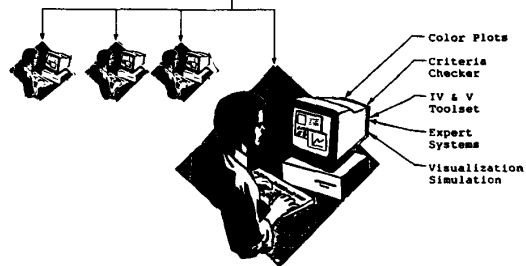
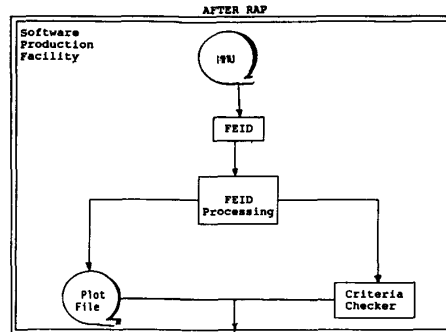
The third tool that is being used by RAP was also developed by Intermetrics Inc. This tool is entitled the Criteria Checker. The Criteria Checker is an expert system which further aids the engineer in the analysis of the plots.

It was pointed out before that the analysis criteria are very well documented. The criteria checker uses these criteria to form the rule base of the expert system. The plot job output is fed into the criteria checker and the COTS plotting package. The criteria checker identifies which plots have violated value limits or slope magnitudes and summarizes these data into a report. The tedious pencil and straight-edge analysis is now eliminated.

This method allows for the problem to be identified by the checker and seen by the plotter. If further analysis is required, the IV&V toolset window is opened and invoked. This all takes place within minutes while previous methods may take days for both analysis and paper plot delivery time.



Paper Plot Desktop Analysis



Color Window Data Analysis Environment

Schedule

The first year has involved acquisition of hardware, network connectivity to the flight critical mainframe, and use of conventional windowed plotting packages. These allowed application of conventional techniques and rule-based expert systems to analyze flight software and regression testing. Significant reduction of test time has occurred in the first year of development and operation. Specific achievements over the next 5 years are:

- Year 1 Expert System evaluation of ascent and abort test cases
- Year 2 Expert System evaluation of entry test cases
- Year 3 Remote Manipulator test visualization
- Year 4 Expert Systems evaluation of on-orbit test cases

It should be noted that as the platform is developed and applications begin to mature, it is expected that other spinoffs into the reconfiguration process may develop.

Summary

The methods and tools outlined in this paper have made a significant contribution to Space Shuttle software analysis. The template time to perform the testing will soon be reduced from 77 to 56 days. Further work will be done with RAP to implement more expert system and Artificial Intelligence technologies. Areas of emphasis now in work include plot submission and FEID timeline set up. Visualization and simulation of test runs will also be explored.

MOD has kept extensive statistics on the performance of the flight software testing group. These statistics will be carefully maintained to show the benefits of the application of knowledge based systems in flight software testing. Specific statistics that will be kept will include total time required to perform testing total manpower hours required to perform testing, problems discovered during automated test analysis, and problems that escape detection during testing.

Because the Reconfiguration Management Division is the operational organization that performs the flight software testing and analysis, it is guaranteed that the tools developed under this effort will be transferred to real use. This would further prove that these advanced technologies are sufficiently mature for critical operations.