Using a Web-based Test Management Tool:

Taking Advantage of Web Based Tools To Facilitate Test Execution and Documentation Processes

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ABSTRACT

At Lockheed Martin Astronautics Independent Verification and Validation (IV&V) software test area, we have been successfully using World Wide Web (WWW) technology to facilitate test procedure execution. We have created a Web based system that generates HTML test procedures which directly supports test creation, execution, analysis, and documentation of results. This system constitutes a successfully implemented "groupware" test tool which has been in production use for over two years. The WWW tool supports our integrated team of systems, hardware, software test, and quality assurance engineers. Our Web-based tool and associated processes have contributed to a 20-to-50 percent cost savings, while at the same time improving consistency, documentation, review of results, and product control.

Keywords**:** Hypertext Markup Language (HTML), the World Wide Web (WWW), Test Tools, Documentation, Accessibility, ISO 9000

Introduction

Our product area at Lockheed Martin Astronautics has been developing a variety of support and documentation aids based on the Web and Hypertext Markup Language (HTML). Web tools and support technology are readily available. We find that Web technologies offer information sharing that can be very useful to "real world" projects. Our particular area of application is the use of the WWW to support software test engineering activities associated with several verification and validation projects. The Web tools and technologies have been used in a production mode for several years now. Our project environment, while small, is oriented around our one product—providing an Independent Verification and Validation (IV&V) service on flight software systems. Areas we have supported or currently support include booster rockets and several spacecraft systems within Lockheed Martin Astronautics.

We have implemented test execution support tools and information access on a local segment of the Web. For our team, an important aspect of testing is the ease and quick access to correct test information used in test procedure generation and execution. Information that is important to all members of test teams includes:

- Product configuration control and management;

- Test documentation in the form of plans, procedures, results and reports;

- Accessibility of product versions (items under test); and

- Test automation, execution repeatability, traceability, and process.

In this presentation, we will describe how the Web approach to information access directly supports us in these areas. We have implemented executable test procedures in HTML that were themselves generated by a Web based tool system. These WWW test procedures have numerous advantages including being all electronic and able to interface with other Web resources. The Web test procedures are resulting in more efficient use of engineering time, parallel reviews by all engineering areas, and reducing paper use. Our excursions in this domain demonstrate that real contributions can be made to production testing using Web concepts, Graphical User Interfaces (GUIs), and tools.

We see the WWW as a viable tool that is still in its infancy and directly supports process integration, improvements, and control. Our team area recently (in February 1997) passed an ISO 9000 audit. Our Web based tools were presented to and reviewed by the ISO software auditor. Our approaches received favorable comments and the auditor was impressed with our use of on-line technology to reduce paper, support process adherence, provide traceability, and improve communication across engineering groups.

This presentation examines our work in this area. We define the type of testing and environment to which we are applying Web technologies. We outline our Web related applications and introduce how we developed these tools using WWW technology. A final section looks at the advantages and problems encountered during this work as well as our plans for continuing efforts. Our work to date has been internal to the company firewall with limited access to other parts of the company. This is because of company procedures and the nature of some of our work and/or the information we provide.

What and How We Test

Lockheed Martin Astronautics in Denver, Colorado has produced critical software systems for several decades. Production systems are usually one of a kind that must work the first time or hundreds of millions of dollars may be lost. These systems are typically very complex, consequently failures or errors could be introduced from many sources. These software-systems have the following characteristics: real-time; spacecraft/booster flight control; minimal human intervention possible; and numerically intensive calculations of such critical items as, trajectories, flight dynamics, vehicle body characteristics, and orbital targets.

Development programs are small—under 30,000 source lines of code (with small staffs), yet these programs are critical to the control and success of the flight system. Avionics systems with software produced at Lockheed Martin Astronautics include the Titan family of launch vehicles, upper stage boosters, and spacecraft, as well as the associated ground systems. The software addresses both mission related requirements as well as hardware/system related characteristics. Production of software on these systems followed a historic and similar development process. In depth software testing combined with IV&V have been used on most of these systems as part of our practices to assure mission success.

Testing practice has always included the use of written and controlled test procedures (step by step test descriptions detailing inputs, environment, output, and success criteria). Test procedures are planned, developed, reviewed, and documented to provide programmatic support throughout the life cycle. Also, test procedures define such things as, test objects, references, special considerations, execution steps, analysis methods and ultimately, pointers to "as run" results. Historically test procedures were large hard-copy documents which had a very large "thud" factor (many pages and pounds of paper).

Web Based Test Procedure and Execution Tool

An innovation we have realized is the use of WWW tools to generate our test procedures. This came about because we were interested in ways to speed up the generation of test procedures, test execution, and documentation as well as approval of these by engineering, management, and quality assurance people. We were also looking for ways to take advantage of our large scale corporate and project computer network. We felt that electronic soft-copy versus hard-copy might have a variety of advantages. This search led us to the WWW and HTML which are supported by commercial network tools such as NETSCAPE (TM). Using these tools, we created a system that allows the generation of executable test procedures [1].

Various HTML templates and forms have been created that allow first the generation of specific test cases, and then the execution of tests using the completed HTML-based test procedures in an on-line, interactive mode. This approach highly automates and standardizes test procedure generation and execution, which we call the Software Test and Evaulation Procedure (STEP). Tests are designed by filling in HTML template forms which in turn generate test procedures in the form of other HTML documents. The basic STEP generation process is seen in Figure 1©. All test inputs and outputs, UNIX shell files used, and the STEP itself, are stored in the specified location for review and analysis by engineering after the run.
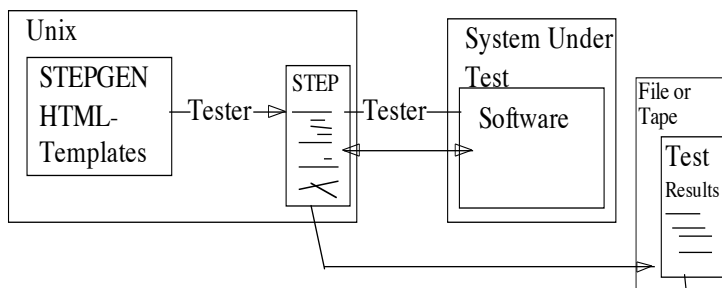

Figure 1 STEP Generation Process ©

As fields are entered, the system "builds" a new HTML file that is itself an executable test procedure. In order to allow the user to process smaller pieces of the STEP, the tool offers the feature of partial submittals at the end of logical sections of the test procedure. The user can then exit the browser and begin generation of the later test procedure sections at a subsequent time. This supports test design over a number of sessions or designers. Custom and pre-designed procedures can be mixed freely with order independence.

When completed, test procedures are submitted for electronic on-line review and approval (peer, management, and quality assurance review). Once approved for use, the

test procedure file can be executed via the Web. Test procedures prompt testers (test engineers) for actions interactively and spawn actual test tool execution, as well as providing both the input and output retention.

We have found that use of Web technology with STEPs has numerous advantages, some of which are listed below.

- Breaks test generation and execution into smaller more manageable pieces.

- Utilizes hyperlinks to quickly and easily view input, output, and analysis that exists on-line.

- Provides a standard test procedure form used by all groups, adding consistency to the testing.

- Provides an intuitive and easy to use user interface

- Browsers are device independent and allow multi-platform use with consistent results.

- Use of an "electronic only" option helps eliminate paper and encourages a paper-less office.

While this system works and is useful, it was a learning experience setting it up. Issues were raised early on by management about the security of data and whether this was more a system for "play" than work. Both of these have been addressed by standard company policies and properties of the Web tool we are using.

Implementation and Design

We have implemented our system with a WWW server which has a number of advanced capabilities that meet many of the needs of our project. Any individual within the corporation may access our Web server using a networked computer and Web browser software. It is important to note, however, that the information that is distributed via the Web is both hardware and software independent. We may at any time substitute the server software with a number of other free or commercial server packages. These packages are available to any project area within Lockheed Martin wishing to implement concepts like ours. The Web pages and documents can be quickly re-hosted to another server platform (Macintosh, PC, or UNIX).

Our server exists on a Sun/Solaris UNIX platform which can distribute information to Macintosh, PC, and other UNIX client machines. The server software consists of several zero-cost applications, namely W3C httpd (formerly CERN httpd) 3.0 and a few support tools that assist with maintenance and enhance the server capabilities (i.e., Common Gateway Interface (CGI) parsing). The server resides behind a corporate firewall for information security and is equipped with two additional methods of information protection - password and machine recognition - to further restrict access of selected documents and pages to only our project. The server has the capability to distribute documents from a variety of popular commercial software. The server also supports image maps (clickable pictures), and a usage meter that informs the project as to who is accessing the pages, and what areas are more frequently accessed. Information distributed from the server can be received from most networked computer platforms. Finally, the

server has the capability to execute CGI scripts, which have automated some of our testing processes.

Client implementation includes Macintosh, PC and UNIX workstations using Netscape, Mosaic and Internet Explorer. This multi-platform server and client capability is one of the greatest strengths of the WWW. All standard Web documents (HTML/CGI) and many popular commercial applications (Microsoft Office, etc.) can be distributed seamlessly from any Web server to any Web client. Thus, implementation of these tools can be achieved by most projects without extensive effort.

The procedure generation tool itself was designed to provide the user with a friendly interface and minimize the interface between user and tools wherever appropriate. The Entry page allows the user to review the tool requirements, documentation, and/or on-line help. There is also a menu that permits the user to:

- Open an existing STEP;

- Create a new STEP;

- Edit an existing STEP;

- Change, Replace, or Delete an existing STEP;

- Submit a STEP for Engineering/ Software Quality Assurance (SQA) approval; and

- Approve a STEP for execution.

The user navigates through the tool graphically entering information based on individual user needs. Following is a brief tour of the tool following the entry page.

Open an existing Procedure

By choosing one of the files in the main action window the procedure is opened for execution or review. The default directory is the predetermined STEP collector area.

Create a New Procedure

By filling in the appropriate fields and submiting the form the STEP is initiated with the chosen name and information. Additionally, support files are copied to the STEP collection area for future use. These files include the base Analysis and Flag files, Mail files etc.

The fields entered for this portion of the STEP are:

- "Official Test Copy";

- Procedure Identifier;

- Brief Procedure Purpose;

- Procedure Creation Date;

- Authors Name;

- Test Conductors Name;

- Location of Test;

- Run Date and Number;

- Modification History;

- Requirements Verified; and

- Procedure Template (if one exists and is available).

By submiting this form the user is then able to choose the sections that are to be created by template or customized. By clicking the appropriate radio button and submiting the form the user chooses the way the STEP sections are created.

After submission of the custom/template choices the user is led through the STEP design phase and is provided forms to enter the following:

Environment Section

- Software Under Test;

- Hardware Under Test;

- H/W or S/W Tools; and

- Special Considerations.

Data Section

- Data that may be needed to execute the test; and

- Description of the expected output and it's location.

Procedural Section

- Recursive Designer to allow users the ability to enter any number of Procedure descriptions, Actions and Responses (1 to many Descriptions with any combination of 1 to many Actions and 1 to many responses).

Attachments

- The ability to create custom or pre-canned attachments shall be provided.

Edit an Existing Procedure

Once a procedure has been created a method for modifying the procedure was required. By choosing the procedure section and submiting the form the user is presented a method for editing the procedure section. The procedure involves opening the procedure section using the browser, the HTML editor, and the ftp facility of the UNIX platform. Another option, as an alternative to ftp, would be to use the publish feature of the HTML editor to replace the previous version of the STEP.

After modifying the procedure section and replacing the section on the UNIX system the user recreates the STEP by submiting the form. The STEP is then ready for execution or re-review.

Copy, Rename, or Delete an Existing Procedure

A provision has been provided by which the user can copy a procedure, rename a procedure (destructive), or delete an existing procedure. By entering the appropriate information the action is performed. Below are the fields required to execute the action.

Copy

- Procedure Path Identifier;

- Source Procedure Identifier; and

- Target Procedure Identifier.

Rename

- Procedure Path Identifier;

- Source Procedure Identifier; and

- Target Procedure Identifier.

Delete

- Procedure Path Identifier; and

- Procedure Identifier.

Submit the Procedure for Engineering/SQA Approval

An electronic STEP approval form is provided to notify members of the team that they should review a STEP for execution. The user provides information through a form that is then sent via automated e-mail upon submital. An electronic, time tagged, electronically signed (with IP number) copy of the e-mail is retained to document the approval. The information to be entered by the user are:

- Procedure Path Identifier; and

- Procedure Identifier.

Procedure Approval

Following the SQA/Engineering review of the STEP the reviewer is provided a form to accept the STEP. Automated e-mail is sent to individuals on the electronic team roster to advise them that the STEP has been reviewed and accepted. In the case where there are problems with the STEP a comments field is provided for each section and the e-mail is sent automatically to inform the creator of the problems. An electronic, time tagged, electronically signed (with IP number) copy of the mail is retained within the test directory area to document the approval. The information to be entered by the user are:

- Procedure Path Identifier; and

- Procedure Identifier.

After a STEP has been successfully created and approved by the group to execute the user can open the STEP from the main page and enter the information associated with the test. In section 3.0 the user enters test information, notes and checks the checkbox for the action performed. When the form is submitted an electronic record of what was tested and a time tag is retained in the STEP collector area. This allows testing to span several test sessions or days of effort with documenting evidence that it was performed. Additionally, there is a checkbox for each action that can be checked by SQA or auditors to indicate that the process(s) were witnessed.

Following the execution of the STEP there may be many attachments associated with the STEP that are needed to document or reproduce the run which aids both regression testing as well as audits like ISO 9000. These files can be hyperlinked to the STEP by automated forms in section 4.0 Attachments, if appropriate. Automated mail is then used to contact team members to review the results of the STEP. The STEP can be reviewed

by any number of team members in tandem and reviews returned to the test engineer. Again, all mail is retained in the collector directory as well as being sent by e-mail.

The STEP, all associated mail correspondence, attachments, output files etc. are retained and/or archived for future reference and use in regression testing. Each test is then repeatable with a known environment, inputs, test procedure, and expected results.

Lessons Learned from Using a Web System

We have found that using Web technology has numerous advantages. For our test team the most notable advantages are:

- Products are readily available for simultaneous use, providing improved efficiency.

- Breaks process generation and execution into smaller, more manageable pieces.

- Assures consistency of test processes through the use of approved templates.

- Provides a custom process using a hybrid of approved templates and custom design.

- Provides a standard software test procedure form used by all functional groups, adding consistency to the software test procedure.

- Browsers are device independent and allow multi-platform use with consistent results. Documents are rendered successfully on whatever platform it is viewed. The use of Web-based tools helps to integrate or bring multiple platform independent tools together in one form. UNIX-based tools work in tandem with Macintosh/PC tools

- Using "electronic only" Web features helps eliminate paper and encourages a paper-less office.

- Engineering at light speed by facilitating quick and parallel production, execution, review, analysis, and audit of automated test procedures.

- The process is completely repeatable; this aids in documenting problems found while testing and provides documentation of the test environment at the time of the anomaly.

- All processes are in a standard, program-approved form aiding in cross-personnel utilization since little additional training is needed to create or use the procedures.

- Use of the e-mail system, with time tagging and authentication, has effectively created an on-line signature aiding in more time efficient reviews. Procedures can be reviewed concurrently by many reviewers all individually identified by their IP addresses and authenticated by individual passwords. Timeliness of the review process can be readily seen in the time tag attached to the electronic review.

- The automated e-mail system is self documenting, keeping an electronic record of who was sent e-mail, when it was sent, and what was being reviewed. It is very quick and easy to use and provides a consistent set of messages aiding in more timely reviews.

- Electronic Web-based process supports parallel review by many team members which is not possible with a single paper copy that gets "routed" around.

- The concepts and basic tool architecture can be easily implemented by other projects.

By using Web concepts, our team has seen improvements in our test process and products. We have reduced the time to produce a test procedure from several days to several hours. This time saved has been "reused" to support more engineering analysis time. As a result, we have detected errors that had been in existence for years. We find this approach supports the better-faster-cheaper concept.

The specific advantages of the Web test procedure tool are:

- Allows easy selection of data by use of pull-down menus, check boxes, and radio buttons.

- Exploits the incorporation of "value" fields to "hard-code" entries after they have been entered. This ensures repeatability and soft documentation of software test procedure inputs.

- Utilizes hyperlinks to quickly and easily view input, output, and analysis that exists on-line.

- Documents the version, if any, of all templates used in software test procedure generation decreasing the time needed for review of each software test procedure prior to approval.

- Intuitive and easy to use GUI.

- Educational links are available to help the user with the software test procedure generation and execution processes.

- HTML is a run-time language requiring no compilation.

- Implementation tools are readily available (even free sometimes).

- A known subset of files, standard operating procedures, and templates eliminate the use of out of date information. Since only software quality assurance controlled files can be used, no stale files can be accessed or inadvertently used in testing.

- The use of Web-based tools allows access to any tool that is accessible to the Net, common databases, COTS tools, etc. This may help eliminate some of the problems of using out of date tools, duplication of tools within the company, multiple system administration duties (maintenance of the same tool by many system administrators).

- A Web-base tool has made possible the sharing of the tool with other projects within the Lockheed Martin firewall since all interested parties need is a Web browser and access to a special "demo" area.

We have observed that the new techniques, ideas for implementing the ideas and a new way of looking at things (new paradigm) have increased interest in learning Web technologies. The Web itself supports many of test efforts by allowing the integration of different tools and systems to support "open systems" concepts. We feel in the long run,

this will result in more improvements and efficiencies. Our Web usage was a support element of our successful ISO 9000 audit. The Web allowed us to show that: we had a process (on-line information); we followed the process (e.g., electronic e-mail signatures and tags), and had documented proof (all information was on-line, current, controlled, and acceptable to all team members).

We have also started considering how this technology may be of benefit to other areas:

- Many of the sections, methods, and formats used in the test procedure generator tool could be used by other projects. Manufacturing could use it as a means to document progress, create products, use in production, etc. It could be used as a training aid to document standard operation processes used in any production environment.

- The use of images, sounds, graphics, video, in-line graphics and hyper-links makes the process more exciting.

- Distributed activities, e.g., activities at several field sites, could be done using networked computers accessing a centrally controlled Web-based process. This would support on-line interaction forms in geographically distributed locations without having multiple copies that might diverge if they were separate.

The WWW is a flexible, multi-function tool. It can be used for a variety of work processes from documentation maintenance to procedure automation. For IV&V, the transition to the WWW was easiest when we tailored the Web to our existing processes. The transition was most difficult when we changed our processes to work within the Web.

Some of the approaches we instituted required work to implement and maintain. We had to establish a maintenance effort on the test procedure generator tool and provide support for other Web tools. These costs have been more than offset by their advantages.

While the WWW has standards, not everything on the Web is standard. Support programs should be written in an environment that is easily transportable (i.e., Java, ANSI C, etc.). HTML should be standard code (i.e., not browser dependent). Application specific functionality should be avoided (e.g., Real-Audio). While these new features are often superior to standards, they cannot be guaranteed to run on any platform. And, finally, since the Web is supported by many different platforms, the best Web tools are designed to be platform independent. Not all users like the Web. There were learning curves and people must change their process and their thinking to accommodate the new system. This is not easy for everyone to do.

While our system works and is useful, it was definitely a learning experience setting it all up. Issues were raised early on by management about the security of data and the results of a cost-to-benefit analysis. Both of these have been addressed by standard company policy and properties of our implementation. We continue to have concerns about how quickly this technology area is changing and how that will affect our processes. There is always a danger when you are at the cutting edge of a technology that you may be heading down a path that becomes a "dead end." We believe that by staying current with Web technologies and trends we will minimize these risks.

Below are some specific issues with our current implementation that we felt everyone should know about.

- HTML and Common Gateway Interfaces are susceptible to corruption as it parses input strings with special characters (like <, $ etc.).

- Initial development of some features took planning and development time that increased as the complexity of the system expanded.

- Net traffic tends to slow response time.

- The server must have support parsers in place to work.

- The test procedure generator tool is approximately 6mB in size and requires adequate hard drive space to store the test procedures.

- Installation onto other machines includes modification of tool paths and file locations.

- There is no on-line editing built into the tool following test procedure generation. (Note: Raw HTML editing or the use of HTML editors can be used to alleviate this problem).

- In a large hardware based test labs, where testing may take place not in proximity to a computer keyboard, the entry of data was not always convenient. Options like use of personal digital assistants, recording devises, and temporary hardcopy forms have been looked at to solve this issue.

Summary

Our team is showing that the World Wide Web has much to offer in support of our test efforts. World Wide Web technology is a viable means of on-line internal and external information. The capability of providing a "user friendly" interface to quickly access and distribute current and controlled configuration files, documentation, and data is invaluable to a project. Further, the ability to support generation of hyper documents and Web tools that directly support test execution and documentation, show the direct support of Web technology to testing. The basic concept is easy to implement within the WWW and other test efforts should consider the benefits of implementing "on-line" electronic test execution.

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Jon Hagar is a lead software engineer supporting software verification and validation testing at Lockheed Martin Astronautics in Denver, Co. He has a B.S. in math with specialization in civil-engineering and software from Metropolitan State College of Denver, Colorado, and an M.S. in computer science with specialization in software engineering and testing from Colorado State University in Ft. Collins, Colorado. Mr. Hagar has worked in software engineering, particularly testing/verification and validation, for more than 15 years. He has supported primarily booster and space related projects. Mr. Hagar has experience in the software domain of real-time, reactive embedded control systems as well as test software development using numerous languages, including JOVIAL and Ada. Mr. Hagar is a member of ACM and IEEE and teaches classes at Lockheed Martin Astronautics., He has published articles on software reliability, testing, formal methods, and critical-systems, as well as presented papers at NASA and Software Productivity Consortium (SPC) working groups. Mr. Hagar's work interests include software testing, verification, validation, system engineering, reliability, neural-networks/GAs in testing, test support tools, and quality assurance.