Using the Web to Facilitate Team Interactions and Communications

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Extended Abstract: *At Denver's Independent Verification and Validation (IV&V) area, we have been successfully using World Wide Web technology to distribute information internally at corporate and project levels. Web technology is used to support our team environment in engineering activities like software testing, configuration management, product approvals, and quality assurance. In addition, we have successfully implemented "groupware" tools that generate tests and support execution of software testing. Our Web tool and its usage has supported our integrated team of systems, hardware, software, and quality assure engineers, who support different IV&V efforts. Our Web-based tools and processes have reduced costs by 20-to-50 percent.*
Keywords**:** Hypertext Markup Language (HTML), the World Wide Web (WWW), Test Tools, Documentation, Accessibility, Integrated Product Teams (IPT)

1.0 Introduction

The most rapidly expanding area of the Internet has been the World Wide Web (WWW or the Web). It is flashy, fun, relatively new, intriguing and "all the rage," but can it be a serious tool for engineering and project use? Can the Web, home pages, and information pages be used to aid and trap the understanding needed to do engineering in an integrated product and process development (IPPD) environment?

Our product area at Lockheed Martin Astronautics (LMA) 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 very much 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 Inertial Upper Stage (IUS), Transfer Orbit Stage (TOS), Reusable Launch Vehicle (RLV) and Evolved Expendable Launch Vehicle (EELV) within LMA. Many of the WWW concepts and tools in this paper are being evaluated for broader use across numerous Integrated Product Teams (IPTs).

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. 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; and
• Test automation, repeatability, traceability, and process.

In this paper, we will describe how the Web approach to information directly supports us in these areas. Besides the basic Web-based information system, we have implemented executable test procedures in HTML that were themselves generated by HTML programs. These test procedures have numerous advantages including being all electronic and able to interface with other Web resources. These are resulting in more efficient use of engineering time, parallel reviews by all engineering areas, and less paper. Our excursions in this domain demonstrate that real contributions can be made to production testing and IPPD projects. The following are descriptions of tools that our project has implemented based on the Web/HTML:
• Automatic test procedure generation via an easy graphical user interface (GUI);
• Configuration and information management with easy on-line access to project documentation and software including controlled files, test tools, status, and reference information;
• Test procedure execution and results retention; and
• Reuse and asset repository/library;

We see this media 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. These 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 and improve communication across engineering groups. With our team's support, Denver Lockheed Martin Astronautics (LMA) passed the ISO 9000 audit.

This paper 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 lessons encountered during this work as well as our plans for continuing efforts. Our work to date has been internal to the company firewall with only 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.

1.1 Our Project Test Environment

LMA in Denver, Colorado, has been producing and testing critical software systems for several decades. Our test group is responsible for the verification and validation of flight control software. An example mission profile, including mission and vehicle characteristics that the software must support, is depicted in figure 1. The software that we test is: embedded within and interfaces with the hardware components of this system; a hard real time system; and is responsible for guidance, navigation and control of the system. Our testing shows that the software will accomplish its mission, be reliable, and have good quality. However these goals must be accomplished within cost and schedule constraints. These constraints lead us to look for automation and processes improvement within our test environment

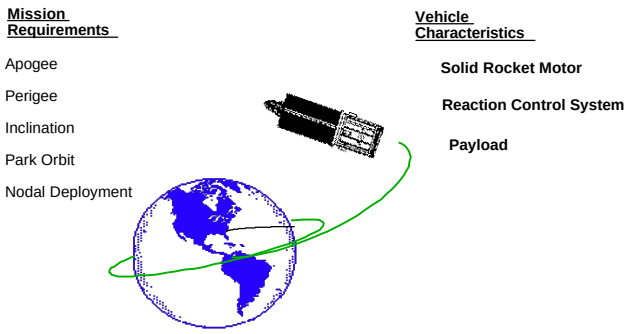

Figure 1 - Complex System-Software Requirements

As with most test areas, our testers are faced with a series of problems:

• Product Configuration Control and Management—numerous tasks and software versions exist, necessitating the need for Configuration Management (CM) of products specific to particular test activities.

• Information Access—Engineers need finger-tip access to a product's test documentation in the form of plans, procedures, data, software, test results, and reports.

• Test Design and Execution—We must create, control, and execute test processes, which include the use of numerous computers, commercial products, and custom tools as well as manual activities necessitated by our test environment.

These problems are not unique to software testing, but are common to most engineering IPTs. To be successful, our test approach depends on a multi- disciplined group of engineers with different backgrounds and skills that work well in an IPPD environment:

• Software Engineers—trained in software engineering, software testing, programming, life cycles, etc.

• Systems Engineers—skilled in guidance, navigation, and control problems, with knowledge about technologies such as ring laser gyros.

• Hardware/Test Lab Engineers—experienced in the construction, operation, and maintenance of computer-based test facilities where the software can be executed using large simulations.

• Software Quality Assurance (SQA) Engineers—skilled in review, s oversight, and independent audit functions.

We had already implemented numerous computer aided software engineering (CASE) technologies within our basic test processes. Several years ago, we began looking for additional supporting technologies that would solve some of our problems, allowing for process improvement, facilitate our multi-disciplined team, and support our distributed test environment. A study starting several years ago led to our interest in the possible use of WWW concepts, mixed with our existing environment and tools.

2.0 Process Improvement Study

An integrated IV&V team conducted a process improvement study. Team members included Hardware Engineering, Software and Systems Engineering, Software Quality, and Management.

This specialized IPT conducted brainstorming sessions and problem analysis. The team identified and then eliminated candidates to improve our V&V efforts. Once candidates were defined, the team focused on the "highest paying" choices. Budgets and schedules to implement the ideas were allocated and the work performed.

One large area that resulted from this improvement study was the use of the WWW to address several "problem areas." These areas targeted are detailed later in this paper. And while each may have been implemented by individual engineers from within the IPT, all IV&V groups use these concepts.

It should be noted that some training and a focus on work habits were necessitated by these changes, but the user friendly nature of the Web facilitate improvement efforts.

3.0 Implemented Uses of Web Technologies

3.1 On-line Software Quality Assurance (SQA) and Configuration Management (CM) Pages

A major concern, for engineers is that products (files, documents, tools, programs, data, drawings, etc.) used in testing must be easily and quickly accessible, correct, and current. Modern software systems have numerous levels of documents (requirements, design, code, data, and test) all of which must be managed efficiently while allowing for a change process. Providing the CM information, controlling

the files, and accessing the data are all necessary for success.

To support the team, we established informational pages for each integrated product configuration under test. Within these pages are links to designated files and documentation. These links are defined and used by the engineers, but maintained and controlled by our internal SQA group. This separation allows ease of access while establishing and maintaining configuration control for accuracy, traceability, and repeatability. The system is on line and easy to use for quick support of project test needs.

Activities that previously involved manual interaction and hardcopy review have been automated with the use of the Web. These areas include:

- Notification, tracking, and access to software files and documentation deliveries via email generated by Web support tools;
- Identification of and access to the most current software configuration using a Web browser; and
- Consolidation of project configuration information into one location on a Web server.

This automation has resulted in :

- Timely electronic notification to engineers and correspondents;
- Improved status identification that in turn is accessible to other Web based tools;
- Improved configuration control; and
- Improved test design and execution, since tools have direct access to Web information on the same system that they are executing.

We have also placed our plans, status reports, resumes, software development files, software test tools, test reports, and other information in a non-SQA project library which is accessible by all team members. Information placed in our library includes test cases and test software information as well as presentations and papers (such as this paper) written by project personnel in a variety of formats and implementations. These provide a repository of lessons learned, reference information, and current documentation accessible to all project staff.

3.2 Electronic Test Procedures Written in HTML

Another significant area where we have used Web technology is test automation. Here we have created a tool that allows the generation of executable test procedures. Both the tool and test procedures are done using HTML. These test procedures are similar to any test procedure whether hardware, systems, site, or software testing.

To implement them, we created various templates and forms that allow first the generation of specific test case procedures, and then the execution of the tests themselves. Execution is accomplished using the completed HTML-based test procedures (called a STEP) in an on-line, interactive mode. This approach highly automates and standardizes test processes for generation and execution. Tests are designed by filling in HTML templates which in turn generate test procedures in the form of other HTML documents. The basic process is seen in figure 4 and is performed using an HTML-based tool called STEPGEN.

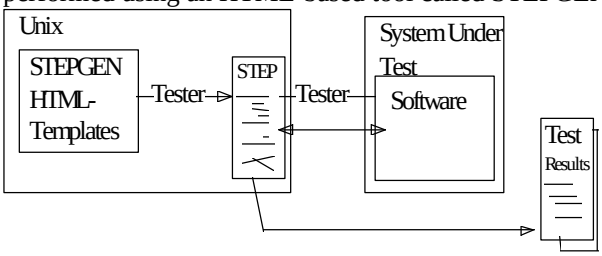

Figure 4 **Test Procedure Generation Process**

Software test procedure design is done by the test engineer, who specifies all input fields as well as a path name to store and execute the software test procedure. All software test procedure inputs and outputs, shell files used, and the software test procedure itself, are stored in the specified location for review and analysis. We have a variety of standard inputs that must be completed as well as customized options with each test procedure. These are filled in by either: selecting a preprogrammed selection list that is linked to the SQA CM page and project libraries, or by entering test unique information into pre-defined places on the form.

As fields are entered, the system “builds” a new HTML file (“STEP” in figure 4) that is itself an executable test procedure. In order to allow the user to process smaller pieces of the software test procedure, the STEPGEN tool offers the feature of partial submittals at the end of logical sections of the software test procedure. The user can then exit the browser and begin generation of the later software test procedure sections at a later time. This supports test design over a number of sessions or IPT designers.

The custom procedural section of the STEPGEN tool offers the user the ability to use previously designed procedure items or custom procedure fields, allowing greater latitude in design. Additionally, custom and pre-designed procedures can be mixed freely with order independence.

When completed, software test procedures are submitted for electronic on-line review and approval. This review process is accomplished by all affected team engineers and, unlike paper, can be done in parallel using the Web. Once approved for use, the software test procedure file can be executed via the Web. Test procedures prompt testers for actions interactively and spawn actual test tool execution, as well as providing both the input and output retention.

4.0 Advantages of Using the WWW

We have found that using Web technology has numerous advantages. For IPPD team and project the most notable are:
• Products are readily available for simultaneous use, providing improved efficiency.
• Breaks process generation and execution into smaller, more manageable pieces.
• Ensures consistency of test processes through the use of approved templates.
• Provides 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 paperless 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 my many team members which is not possible with a single paper copy that gets "routed" around.

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 SQA 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).

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 IPPD concepts by allowing the integration of different tools and systems to support "open systems" concepts. We feel 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). These factors impressed the auditor and we had no findings against us.

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 STEPGEN 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.

3.0 Implementation

We have implemented our system with a World-Wide-Web 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 wishing to implement concepts like ours. The World-Wide 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. 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 Common-Gateway Interface 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 World-Wide Web. 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.

5.0 Lessons Learned from Using a Web System

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. (Nothing for free in today's society.) We had to establish a maintenance effort on the STEPGEN 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, like HTML). 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 supports many different platforms, the best Web 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 whether this was more a system for "play" than work. 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 STEPGEN 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).

6.0 Summary

Our team is showing that the World Wide Web has much to offer towards in support IPTs. 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 group engineering efforts, show the direct support of Web technology to IPPD.

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Jon Hagar Biography
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. Jon has worked in software engineering, particularly testing/verification and validation, for more than 15 years. He has supported primarily booster and space related projects. Jon 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. Jon 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. Jon's work interests include software testing, verification, validation, system engineering, reliability, neural-networks/GAs in testing, test support tools, and quality assurance.

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Phil is an associate engineer in software engineering with Lockheed Martin Astronautics in Denver, Colorado. He is currently assigned to software test bed setup and programming for a flight control system, working with electronic, digital computer and software aspects. Phil holds a B.S. in Engineering - Electrical specialty from Colorado School of Mines, in Golden, Colorado, .Phil's professional interests range from Object Oriented Design)OOD) to real-time digital feedback control systems. Phil is also the Web administrator for the IVV project.

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