A Collaborative Web-Based Approach to Planning Research, Integration, and Testing using a Wiki

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ABSTRACT

The National Aeronautics and Space Administration Integrated Vehicle Health Management program touches on many different research areas while striving to enable the automated detection, diagnosis, prognosis, and mitigation of adverse events at the aircraft and system level. At the system level, the research focus is on the evaluation of multidisciplinary integrated methods, tools, and technologies for achieving the program goal. The participating program members form a diverse group of government, industry, and academic researchers. The program team developed the Research and Test Integration Plan in order to track significant test and evaluation activities, which are important for understanding, demonstrating, and communicating the overall project state and project direction. The Plan is a "living document," which allows the project team the flexibility to construct conceptual test scenarios and to track project resources. The Plan also incorporates several desirable feature requirements for Plan users and maintainers. A wiki has proven to be the most efficient and effective means of implementing the feature requirements for the Plan. The wiki has proven very valuable as a research project management tool, and there are plans to expand its scope.

1 INTRODUCTION

This paper describes the development of a wiki to facilitate collaborative Web-based planning for the National Aeronautics and Space Administration (NASA) Integrated Vehicle Health Management (IVHM) Research Test and Integration Plan (RTIP). The RTIP is an approach to identify resources and integrate testing opportunities in order to perform a higher level of testing, including to higher Technology Readiness Levels. The wiki approach introduces partnerships between government, industry, and other potential customers in the performance of research.

The goal of the IVHM project is to develop validated tools, technologies, and techniques to enable the automated detection, diagnosis, prognosis, and mitigation of adverse events at the aircraft and system level. At the system level, the research focus is on the evaluation of multidisciplinary integrated methods, tools, and technologies for achieving the IVHM goal. At the aircraft level, the research focus is on the evaluation of the interaction between faults in different systems and the net effect on the health of the aircraft. For example, an error in the air data system can affect the indications given to the pilot, the flight control system, and the engine control system.

The Research Test and Integration (RTI) team keeps track of significant IVHM test and evaluation activities, which are important for understanding, demonstrating, and communicating the overall state and direction of the project. The RTI team engages many partners from government, industry, and academia. The RTI team will formally track cross-project activities pertaining to IVHM testing. The RTIP provides traceability of requirements and directly contributes to construction of quantified project metrics. An integral part of the RTIP will be to document established test beds within NASA, other government agencies, and other partners, that could be useful for testing technologies developed in

the program. For example, new engine sensors developed by the NASA Glenn Research Center (Cleveland, Ohio) will be tested in an engine on a United States Air Force Flight Test Center transport airplane with engineering assistance from the engine company. The RTIP will be a "living document" (one that is updated as the need arises) in order to allow the project team the flexibility to incorporate new test beds that may become available through the course of the project.

The "living document" format provides several desirable features in response to the unique needs of the RTIP users and maintainers. The RTIP content must be accessible to RTIP users, wherever they may be physically located, at the same time presenting accurate and relevant information that can frequently change. The RTIP content must be easily editable, distributable, and maintainable. The RTIP content will require input from many different sources, thus, a content format that is easily and rapidly editable by many users is highly desirable.

2 WHY A WIKI?

The RTI team needed a flexible system that could be used by individuals at four NASA Centers as well as by partners in industry and academia. A Web-based interface was desirable in order to enable efficient collaboration.

Security is another important concern for the RTI team. No critical information or technical data is stored on the RTIP server, including proprietary or Sensitive But Unclassified information, or items covered under the International Traffic in Arms Regulations (ITAR). All changes made to the wiki are tracked and auditable.

The ability to link between RTIP sections was highly desirable. The RTI team wanted the capability to link from a milestone to an asset and from an asset to a milestone, and the capability to link to other Web sites, including existing public or internal Web sites. The system also had to support access control and revision tracking. The conventional approach to documenting plans for research test and integration utilizes a hierarchal collection of documents. The heirarchical approach was rejected because configuration control using this approach would be cumbersome for the RTI team. Also, the hierarchical approach did not support the Web-based approach, did not easily support hyperlinking, and could not be edited by more than one person at a time.

The RTI team considered a HyperText Markup Language (HTML) -based Web system, but major disadvantages compared to a wiki-based system were found: increased complexity for content creators, decreased ease of use for content maintainers, and the lack of automatic revision control.

A wiki-based system was chosen, the primary reason being that the wiki system is Web-based, allowing content to be easily created and linked to other content and enabling multiple users in different locations to simultaneously edit different sections. Revision tracking and access control are implemented by the core wiki framework.

The wiki system does have multiple disadvantages compared to traditional approaches. One of the first problems encountered was that in order to print the wiki for offline viewing every page must be individually printed. The project team is living with this limitation and is not working to address it.

Other problems encountered were the learning curve for wiki markup language, and the creation of large tables, which can be cumbersome. An automated tool to generate tables from a spreadsheet was developed by the RTI team to solve the problem of creating large tables.

3 WIKI IMPLEMENTATION

The initial wiki implementation was performed as a proof of concept using the wiki feature of the NASA Langley Research Center (Hampton, Virginia) NX system, which is based on the Xerox DocuShare® (Xerox Corporation, Norwalk, Connecticut) software package. The NX system contained much detailed project and schedule information for multiple NASA programs, and access was tightly controlled. Every member of the RTI team was required to be approved for an access account; it would not be possible to enable access for industry and university partners. Although the NX system was not the end solution, it was highly valuable as a proof of concept.

The current wiki implementation is the Trac (Edgewall Software, www.edgewall.org) project, an open source software package that includes a wiki feature providing robust access control and full revision tracking. In addition, the Trac wiki offers the capacity to distribute content into dual public and private versions; preliminary work can be completed in the private version before migrating it to the public version.

Efforts to develop the RTIP wiki began in the autumn of 2008. The wiki is hosted on servers residing at the Ames Research Center (Moffett Field, California) and contains a significant number of identified research items and test assets. Four NASA research centers are contributing to the wiki, and the RTI team hopes that commercial industry and academia will soon become contributors.

The wiki is divided into seven major sections, most of which are divided into subsections in order to better organize and present the content. Section 1.0, "Introduction," is an overall introduction to the RTIP. It is intended to provide an IVHM partner with an overview of the structure and goals of the RTIP.

Section 2.0, "Test and Integration Overview," provides a high-level view of the major RTI test and integration research areas. The major research areas are divided into four subsections: 1) the IVHM systems architecture; 2) a matrix table of the specific adverse events called out in the IVHM RTIP; 3) a table listing the enabling IVHM technologies for future generations of transport-class aircraft; and 4) information about the Integrated Architecture Assessment Working Group, which is an advisory board consisting of government and industry partners who provide information on industry needs in the field of IVHM.

Section 3.0, "Test and Integration Theme Level" is the list of each test milestone in the IVHM program, divided into the multiple themes of "Detection," "Diagnosis," "Prognosis," "Mitigation," and "Integrity Assurance." Each theme has an assigned Associate Principal Investigator and an area author or cognizant engineer from the RTI team who is responsible for that section, as shown in Figure 1.

Section 3.0, "Test and Integration Theme Level" is expected to be a heavily-used section within the RTI wiki. The IVHM team members will use this section and its subsections to track IVHM milestones, milestone due dates, milestone necessary resources, and milestone owners. This section is a critical source of project information, with the capability for enhanced content searching and cross-referencing using hyperlinks. The subsections within it present the data in a table format that can be sorted by the "Milestone," "Metric Due Date," "Test Type," and "Owner/Agreement" columns. A column showing related milestones is also included, in the hope that this may reveal opportunities for cross-research collaboration. Figure 2 shows an example screenshot of Section 3.1, "Detection."

Section 4.0, "Capabilities and Assets for IVHM RTI," lists the research resources made available by the IVHM partners and contains five subsections: 1) "Laboratory;" 2) "Test Fixture;" 3) "Ground Test;" 4) "Flight Test;" and 5) "Other." The resources are tabulated within each subsection, identifying the resource owner's affiliation, contact information, and directly related IVHM milestones and themes, as well as any references and notes. The IVHM partners will likely be most involved in this section of the wiki, as they are the primary provider of the information. This section was designed in a manner that will hopefully encourage IVHM partners to browse the inventory of IVHM resources, once again toward encouraging cross-research collaboration. Figure 3 shows an example screenshot of Section 4.1, "Test Fixture."

Section 5.0, "Integration," is the main working area for the IVHM team, having many subsections containing IVHM project information such as team meeting notes and testing and integration scenarios. Section 5.2, "Testing and Integration Scenarios," is further divided into areas of "Pending Approval," "Approved," "Considered But Not Approved," and "Completed." The RTI developers felt that there was value in retaining all proposed testing and integration scenarios; within the historical perspective on past test scenario work provided by the contents of the "Considered But Not Approved" subsection, an IVHM partner might discover a test scenario that inspires a future test scenario.

Section 5.2 is likely to be the most dynamic area of the RTI wiki. The research efforts of the IVHM project will be captured in this section in a document unique to a specific testing and integration scenario and based on a standard format. This document will outline the testing and integration scenario, touching on milestone metrics, showing overall cost and labor benefits resulting from the implementation of the scenario, mapping the milestones to the IVHM architecture structure, and outlining the testing and integration activities. Figure 4 shows an example of an approved scenario from Section 5.2, "Testing and Integration Scenarios."

Other subsections of Section 5.0 contain the team meeting notes and schedules for the testing and integration scenarios. In addition, tools are being developed to aid in the project management aspects, such as a sortable milestone table, which would help the IVHM team to data-mine the milestone activities. A blog for the IVHM team is also being explored, which could enable users to communicate easily with each other and present helpful ideas to improve the RTIP. The IVHM team is developing proficiency using the wiki, and is exploring new capabilities and ways of increasing their effectiveness and efficiency.

Section 6.0, "RTI Results Reporting," will contain links to RTI research reports. As the IVHM team achieves milestones and successfully conducts research, the resulting research publications will be listed in this section.

Section 7.0, "Attachments (Public)," contains ancillary documentation for the IVHM team. No sensitive material resides here; sensitive material resides on a private server.

4 CURRENT STATUS

The wiki has been populated with the most current RTIP information, is being actively maintained, and

contains significant amounts of identified research items and test assets with more being actively sought out and added.

The wiki has proven instrumental in identifying multiple research test scenarios, partnering with NASA centers and other government agencies (Koelfgen and Faber, 2010). One of the first tests proposed involved actuator prognostic algorithms from the NASA Ames Research Center and an engine model developed by the NASA Glenn Research Center, and flew on an asset owned by the Air Force Flight Test Center.

Seven test scenarios have been identified and entered into the wiki: one is in work, two have been approved for implementation (one started a series of flights in March that will continue into June), one was considered but not implemented, one has been completed, and two are being proposed. Additional test scenarios are being actively pursued; the IVHM team is beginning to see how current IVHM partners are spreading word about the existence and effectiveness of the project, which is helping to bring new IVHM partners forward.

The wiki is now a reliable reference tool used by project members at all four participating NASA Centers. The wiki is accessed by individual team members who are provided accurate and up-to-date information. The wiki is similarly useful during project meetings. The RTIP wiki and other Web-collaborative online meeting tools are used to maintain the focus of the meeting and to avoid potential misunderstandings by participants who are attending through a remote site.

5 FUTURE DIRECTIONS

The RTIP wiki is a valuable research project management tool that provides needed RTI reference data. The tool's capabilities will be continued using new reference data such as new research topics, new test scenarios, or new test facilities. The RTI team plans to continue developing the wiki, creating an essential tool that will engage more partners and enable more IVHM research. The hope is that ultimately IVHM-partnered researchers will be able to advance the Technology Readiness Level of their research projects, taking IVHM research to a state-of-the-art level.

A more ambitious goal is to explore collaborations between IVHM and another NASA Agency programs, including but not limited to the Subsonic Fixed Wing program under the NASA Aeronautics Research Mission Directorate. Initial reaction has been very positive, and the IVHM team continues to pursue this opportunity. Efforts are ongoing to communicate with possible partners, many of whom are introduced to the IVHM project by existing IVHM partners.

The NASA Dryden Flight Research Center (DFRC) IVHM team is also sharing its experiences and successes using the RTIP wiki with other DFRC organizations. As a result, discussion concerning how wikis can be implemented and used as an institutional tool has begun. Although this is more a testament to the general usefulness of a wiki as an informational tool, the DFRC IVHM team is demonstrating a real-world instance of a wiki implementation. And although the results of a general DFRC wiki may not be specifically beneficial to the IVHM project, it is hoped that implementation of a general DFRC wiki would be found to be helpful to the DFRC organization.

6 CONCLUSION

The Research and Test Integration Plan wiki has shown significant benefits thus far in its use, yielding several research test scenarios that are proceeding onward to desired research test projects. Two of the proposed tests are in progress, and there are multiple tests under formulation that will fly in the next year. It is hoped that the wiki will continue to attract and engage partners, which in turn will lead to more collaborative synergistic opportunities and will accomplish more Integrated Vehicle Health Management research goals.

ACKNOWLEDGMENT

The authors thank the Integrated Vehicle Health Managemet project management team for allowing us to pursue the wiki concept and apply it to the Research and Test Integration Plan. We also thank the other members of the Research and Test Integration team.

NOMENCLATURE

DFRC	Dryden Flight Research Center
IVHM	Integrated Vehicle Health Management
RTI	Research and Test Integration
RTIP	Research and Test Integration Plan
NASA	National Aeronautics and Space Administration

REFERENCES

(Koelfgen and Faber, 2010) Syri J. Koelfgen and James J. Faber, "Using the Integrated Vehicle Health Management Research Test and Integration Plan Wiki to Identify Synergistic Test Opportunities," AIAA-2010-3499, AIAA Infotech@Aerospace 2010 conference, Atlanta, Georgia.

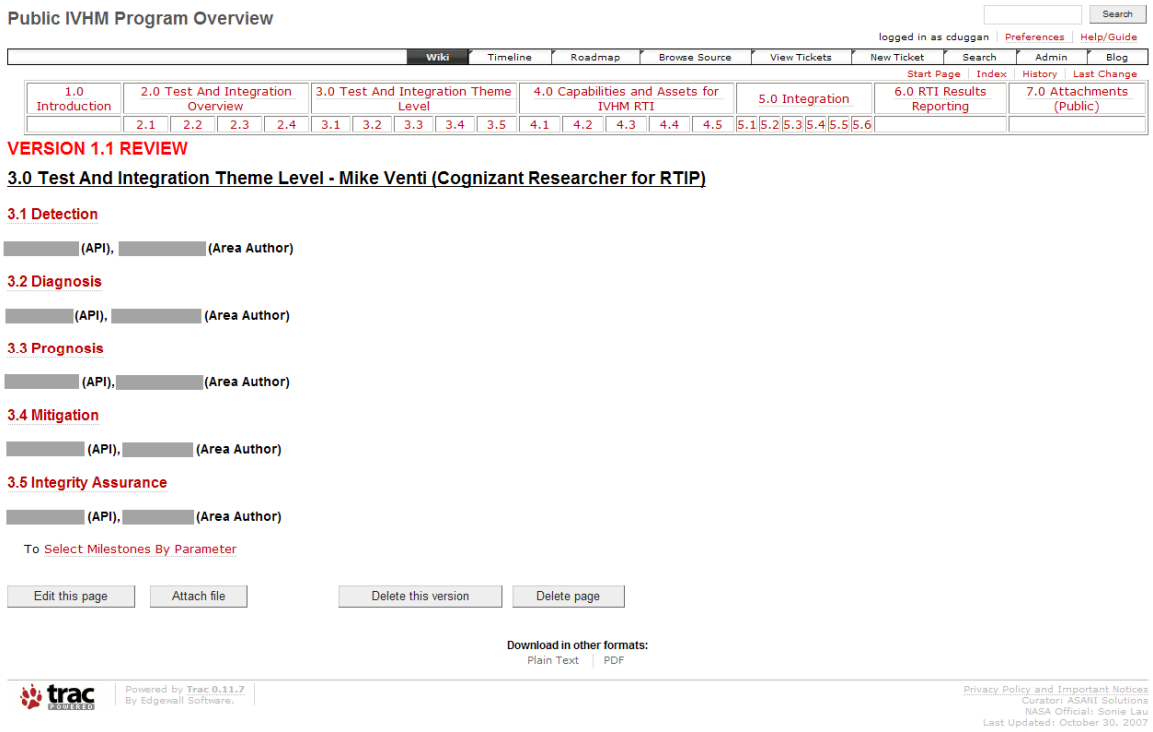
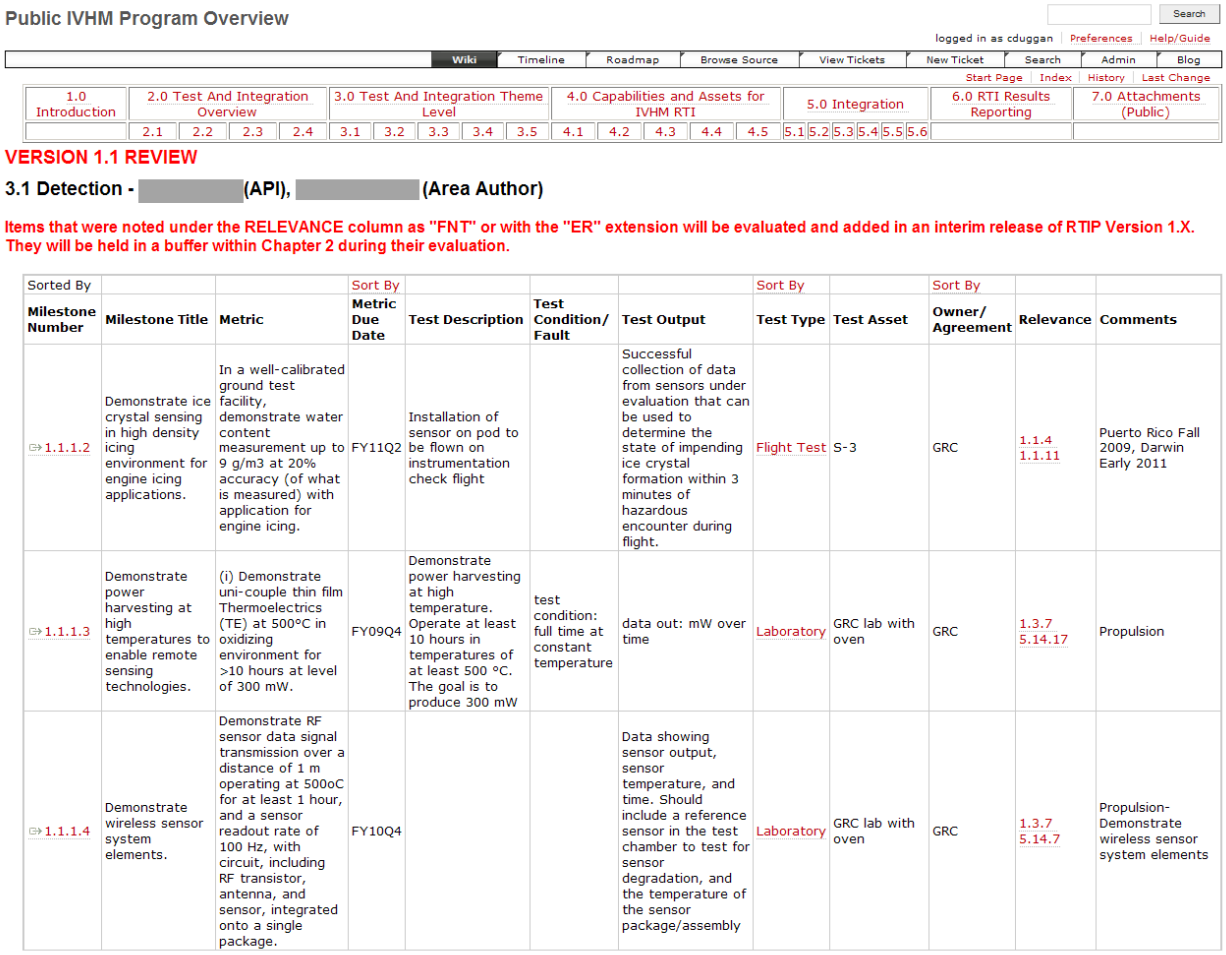


Figure 1: Example of a top-level wiki section and corresponding subsections



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	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.4	4.5	5.1	5.2	5.3	5.4	5.5	5.6		

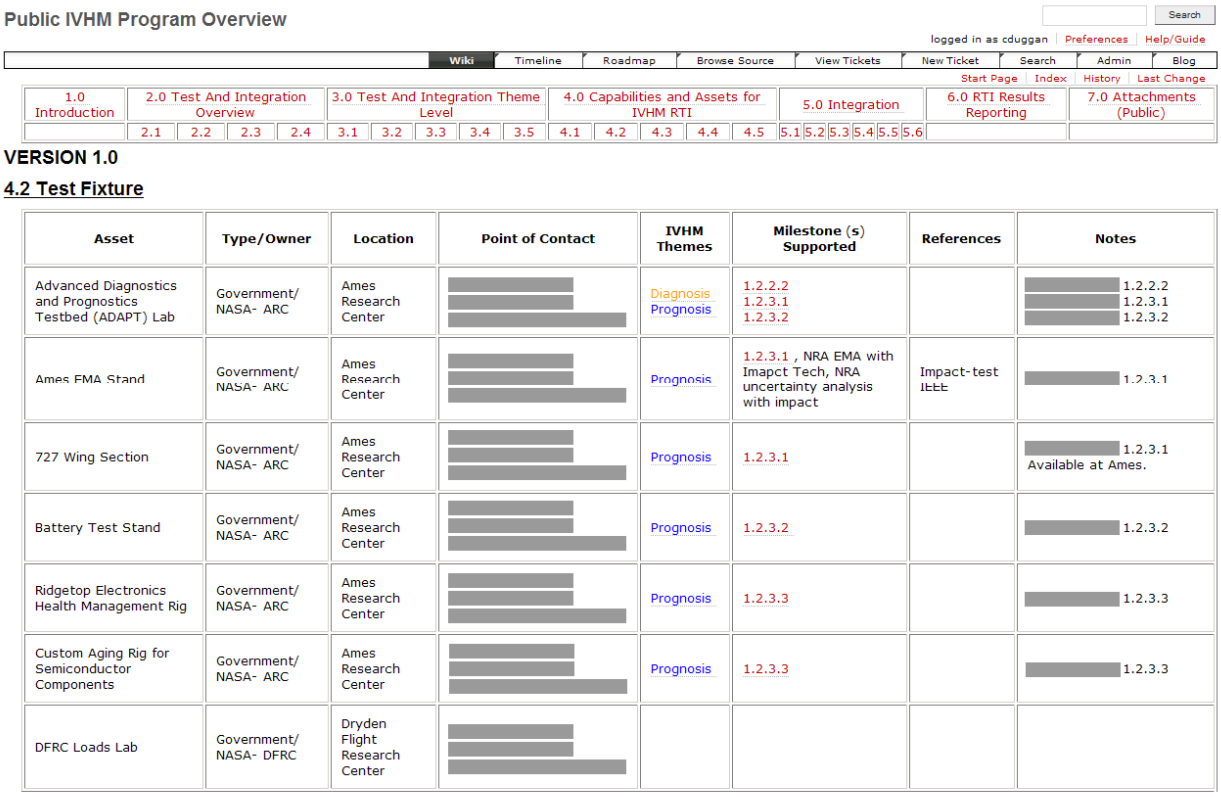
VERSION 1.1 REVIEW

3.1 Detection - [redacted] (API), [redacted] (Area Author)

Items that were noted under the RELEVANCE column as "FNT" or with the "ER" extension will be evaluated and added in an interim release of RTIP Version 1.X. They will be held in a buffer within Chapter 2 during their evaluation.

Sorted By			Sort By				Sort By		Sort By		
Milestone Number	**Milestone Title**	**Metric**	**Metric Due Date**	**Test Description**	**Test Condition/ Fault**	**Test Output**	**Test Type**	**Test Asset**	**Owner/ Agreement**	**Relevance**	**Comments**
1.1.1.2	Demonstrate ice crystal sensing in high density icing environment for engine icing applications.	In a well-calibrated ground test facility, demonstrate water content measurement up to 9 g/m3 at 20% accuracy (of what is measured) with application for engine icing.	FY11Q2	Installation of sensor on pod to be flown on instrumentation check flight		Successful collection of data from sensors under evaluation that can be used to determine the state of impending ice crystal formation within 3 minutes of hazardous encounter during flight.	Flight Test	S-3	GRC	1.1.4 1.1.11	Puerto Rico Fall 2009, Darwin Early 2011
1.1.1.3	Demonstrate power harvesting at high temperatures to enable remote sensing technologies.	(i) Demonstrate uni-couple thin film Thermoelectrics (TE) at 500°C in oxidizing environment for >10 hours at level of 300 mW.	FY09Q4	Demonstrate power harvesting at high temperature. Operate at least 10 hours in temperatures of at least 500 °C. The goal is to produce 300 mW	test condition: full time at constant temperature	data out: mW over time	Laboratory	GRC lab with oven	GRC	1.3.7 5.14.17	Propulsion
1.1.1.4	Demonstrate wireless sensor system elements.	Demonstrate RF sensor data signal transmission over a distance of 1 m operating at 500oC for at least 1 hour, and a sensor readout rate of 100 Hz, with circuit, including RF transistor, antenna, and sensor, integrated onto a single package.	FY10Q4			Data showing sensor output, sensor temperature, and time. Should include a reference sensor in the test chamber to test for sensor degradation, and the temperature of the sensor package/assembly	Laboratory	GRC lab with oven	GRC	1.3.7 5.14.7	Propulsion-Demonstrate wireless sensor system elements

Figure 2: Example screenshot of a theme's test milestones



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VERSION 1.0

4.2 Test Fixture

Asset	Type/Owner	Location	Point of Contact	IVHM Themes	Milestone (s) Supported	References	Notes
Advanced Diagnostics and Prognostics Testbed (ADAPT) Lab	Government/ NASA- ARC	Ames Research Center	[redacted]	Diagnosis Prognosis	1.2.2.2 1.2.3.1 1.2.3.2		[redacted] 1.2.2.2 1.2.3.1 1.2.3.2
Ames EMA Stand	Government/ NASA- ARC	Ames Research Center	[redacted]	Prognosis	1.2.3.1 , NRA EMA with Imapct Tech, NRA uncertainty analysis with impact	Impact-test IEEE	[redacted] 1.2.3.1
727 Wing Section	Government/ NASA- ARC	Ames Research Center	[redacted]	Prognosis	1.2.3.1		[redacted] 1.2.3.1 Available at Ames.
Battery Test Stand	Government/ NASA- ARC	Ames Research Center	[redacted]	Prognosis	1.2.3.2		[redacted] 1.2.3.2
Ridgetop Electronics Health Management Rig	Government/ NASA- ARC	Ames Research Center	[redacted]	Prognosis	1.2.3.3		[redacted] 1.2.3.3
Custom Aging Rig for Semiconductor Components	Government/ NASA- ARC	Ames Research Center	[redacted]	Prognosis	1.2.3.3		[redacted] 1.2.3.3
DFRC Loads Lab	Government/ NASA- DFRC	Dryden Flight Research Center	[redacted]				

Figure 3: Example screenshot of Available Test Fixtures

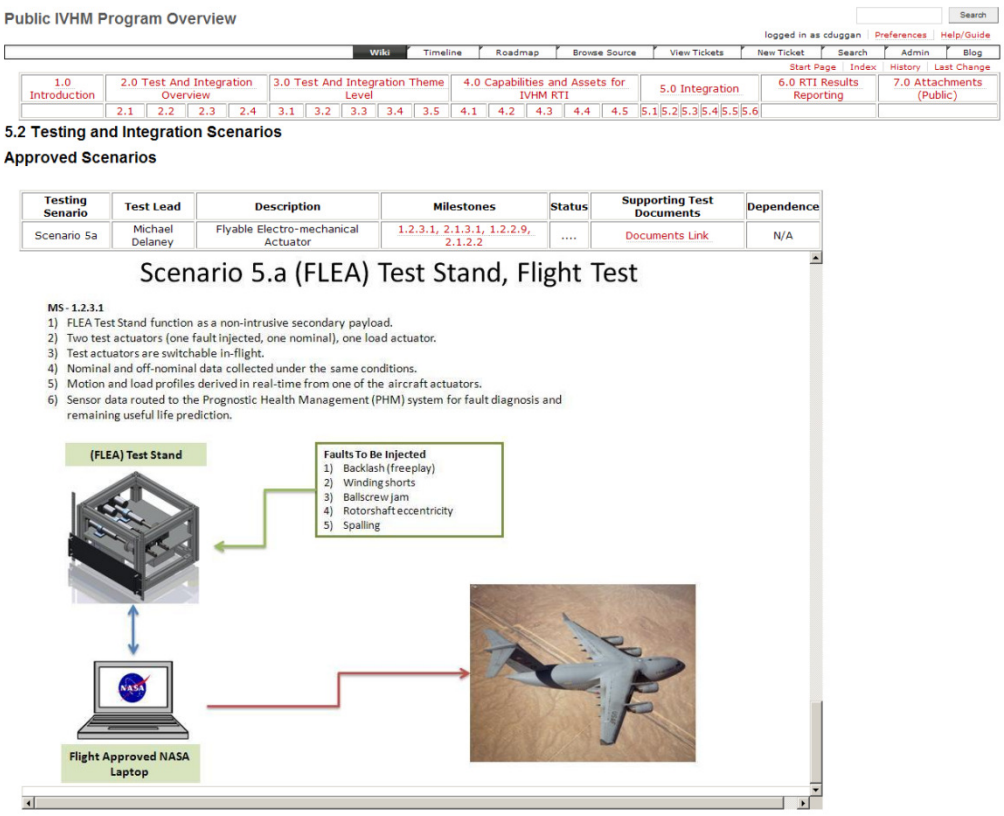

Figure 4: Example screenshot of an Approved Scenario