National Aeronautics and
Space Administration

NASA IV&V 2005

NASA Independent Verification and Validation Facility

www.nasa.gov

Cover art:
Artist's concept of NASA's new spaceship. Launched by a redesigned shuttle solid rocket booster and upper stage engine similar to those used during Apollo. The crew of four would rendezvous with the ship carrying the lunar module in earth orbit.

Inside front cover art:
Artist's concept of the new spaceship as it breaks earth's orbit for the moon.

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"…what's past is prologue…"

– Shakespeare, The Tempest, Act II, Scene I, line 248

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IV&V Facility

Vision

Be acknowledged as the preeminent organization applying and improving independent verification and validation for software and systems.

Mission

NASA IV&V provides assurance for our customers' safety and mission critical software in the areas of safety, reliability and availability; performs leading-edge research that improves IV&V and software assurance methods, practices, and tools; participates in the vitality of the community, as well as engages the public in the experience and benefits of exploration and discovery.

Future Moon Exploration

"Until we have proven to ourselves that we have finally reached perfection as designers, we owe it to the flight crews and the nation to do the very best job we can to verify that critical element of the future we call human spaceflight software."

Bryan O'Connor

Chief Safety Mission Assurance Officer, NASA Office of Safety and Mission Assurance

From the Director

Dear Reader:

In 2005, the NASA Independent Verification and Validation Facility experienced more fully the credibility and reliability we have worked together to earn in our discipline and throughout our Agency.

Asked to evaluate the quality and the value of the IV&V services that we provide, our customers responded this year with the highest praise and superlative indicators of satisfaction. We have fulfilled our mission by providing value above and beyond expectations, resulting in greater safety. We have realized our vision by enhancing appreciation and understanding of our discipline. Our researchers presented and published an impressive array of applicable and inventive research for a variety of audiences. Our research will serve NASA and the nation as we pursue the Moon and Mars in exploration and our Solar System and beyond in discovery.

If we need more to celebrate in 2005, we can look to our visitor lists and our travel itineraries. Those who care about software assurance and mission-critical safety issues came to us from the Japanese Space Agency, the European Space Agency, the National Security Agency, the Department of Homeland Security and many other national and international agencies to learn more about what we do and how we do it so well.

Most of all, I ask you to celebrate with me those who have conducted the work of 2005 at the NASA IV&V Facility with integrity, determination and innovation: our civil service employees and contractors. You will understand my pride in their achievements as you read of their work in the pages that follow and on the Web sites we recommend to you in this document. They are a value-driven, motivated team of individuals who come together from every corner of West Virginia and the nation to share in a mission mightier and a vision brighter than any they can conceive of individually…NASA's mission and NASA's vision.

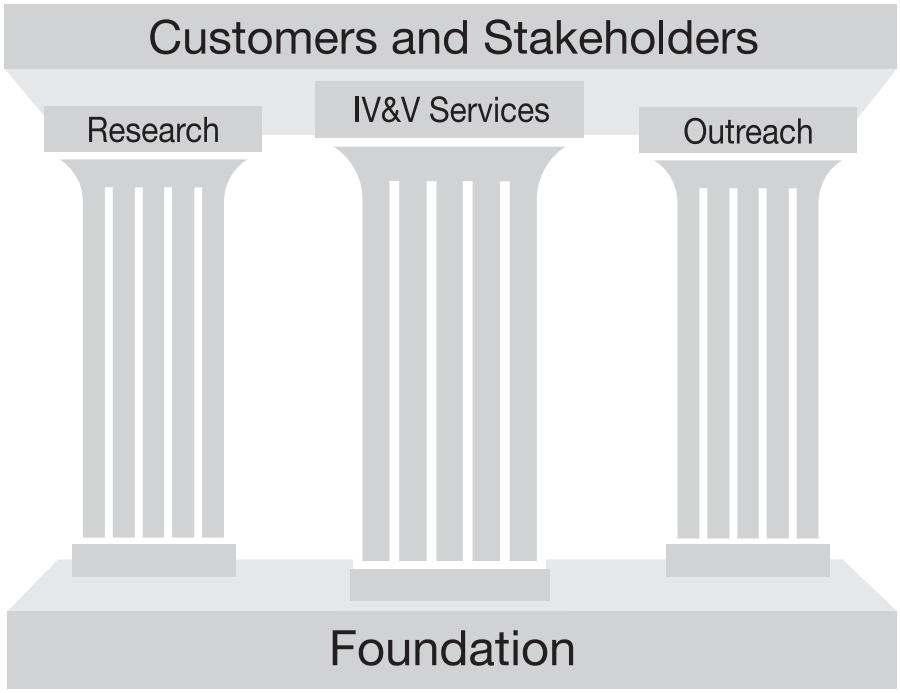
I hope you will join me in celebrating our work of 2005, its impact and the people who are committed to its implementation.

Sincerely,

Nelson "Ned" Keeler
Director

Mission Pillars

The pillars of our mission are IV&V Services, Research and Outreach. Our success rests upon the ability to effectively and efficiently carry out our mission every day. The diagram shows an underlying foundation of administration, operations and maintenance through Facility management, management systems and a well-administrated organization.



Pillar I - **IV&V Service**

Assure our customers' mission and safety critical software meets all requirements for safety, reliability and availability.

The IV&V Services pillar encompasses all aspects of our fundamental responsibility: the delivery of the highest quality state-of-the-art independent verification and validation services to our customers.

Pillar II - **Research**

Perform leading-edge research that improves IV&V and software assurance methods, practices and tools.

The Research pillar represents the myriad research efforts undertaken to expand IV&V's research presence in practical and applied initiatives.

Pillar III - **Outreach**

Participate in the vitality of the community, as well as engage the public in the experience and benefits of exploration and discovery.

The Outreach pillar stands as a solid commitment to inspire, inform and pursue collaborations in our community.

Introduction 5

"Never let the future disturb you. You will meet it, if you have to, with the same weapons of reason which today arm you agianst the present."

- Marcus Aurelius Antoninus (121 AD - 180 AD)

Image of Earth Taken by Galileo Spacecraft

In 2005, we took great strides toward achieving our vision to be acknowledged as the preeminent organization applying and improving independent verification and validation for software and systems at home and abroad. We demonstrated in 2005 that IV&V provides a value added/needed service to the projects upon which we work and a positive return on investment.

On the international front, we signed a memorandum of understanding with the Japanese Space Agency and have another under review at the European Space Agency. These agreements will cement the working relationships we have developed with those organizations into an International IV&V Working Group.

The NASA IV&V staff, consisting of a total of 44 civil service employees, works closely with contractors who have significant domain knowledge and experience. During a year of contract transition, the IV&V Facility involved 208 contractor employees who skillfully provided services across a variety of projects. In 2005, approximately 143 Full Time Equivalent (FTE) contractors were engaged on-site supporting IV&V services and research initiatives, and 65 FTE contractors resided off-site with our customers.

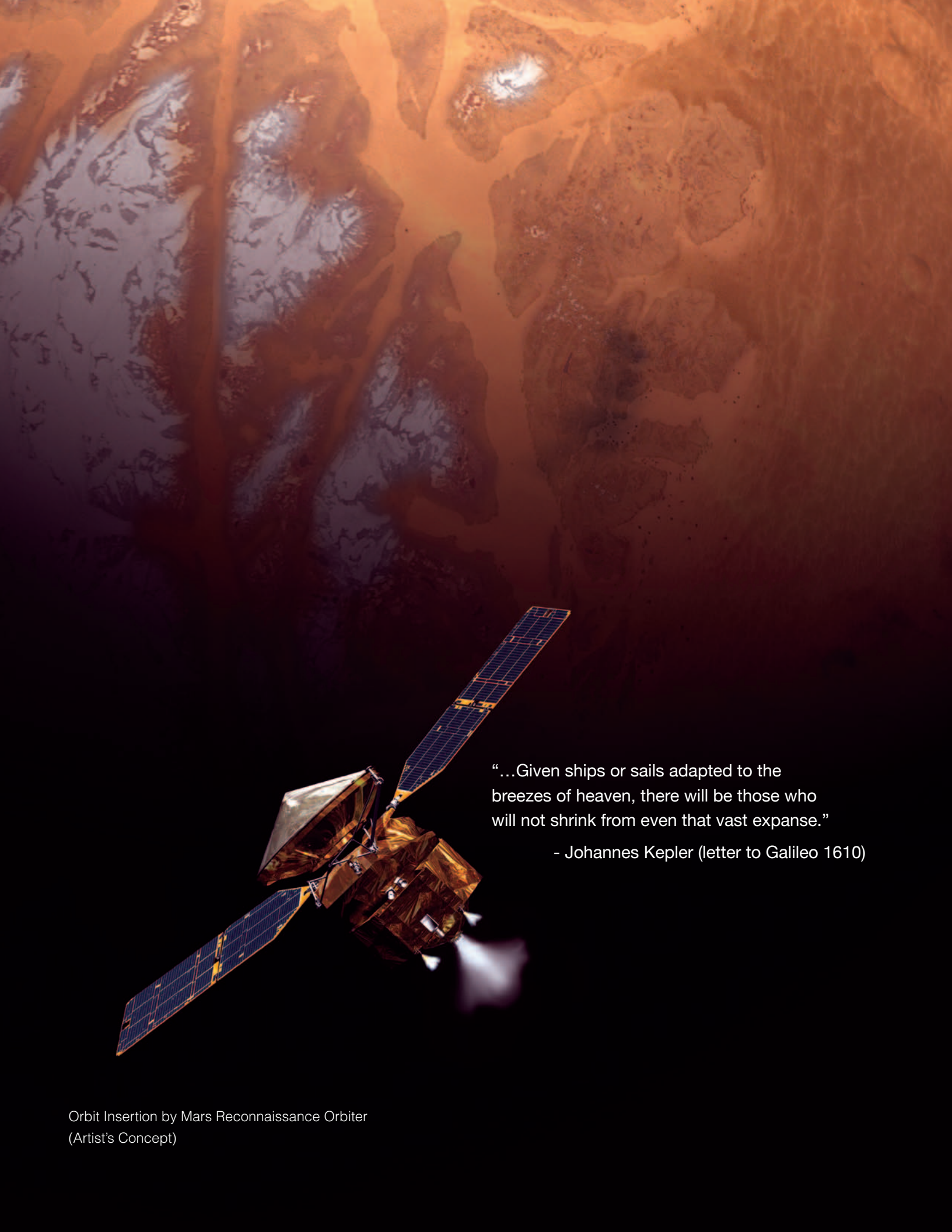
Along with L-3 Communications/Titan Group and Northrup Grumman Information Technology, our principal suppliers of IV&V services, we provided software and systems assurance on the most critical of NASA missions. Some projects are already deployed, some await deployment and others are in various phases of development. Our hopes and our pride accompany each mission.

We continued managing and executing research Agency-wide and within the Facility to improve the disciplines of software assurance. The infusion of the results of this research into the day-to-day practice of software assurance is already benefiting development projects. The Facility continued to expand its research presence especially in practical and applied initiatives in collaboration with researchers from universities in West Virginia and from academic institutions around the country.

In 2005, the IV&V Facility collaborated with many NASA offices and programs and continued long- and short-term initiatives with businesses and institutions from across the state and the nation to further NASA's mission. Many of these affiliations are software-related, enhancing software assurance and software engineering to advance state-of-the-art tools, techniques and methodologies. We demonstrated our commitment to the community by training prospective and in-service teachers and conducting events designed to inspire students in classrooms and on campuses throughout West Virginia.

The map above shows where NASA Independent Verification and Validation Services were provided in 2005.

This exciting and successful year found us working exceedingly well as a team. We have focused our efforts and our resources along with the rest of NASA to begin the countdown to launch into an exciting future of exploration and discovery. We look back on our accomplishments in 2005 with a sense of satisfaction. At the same time, we are eager to meet the new challenges that will come with implementing the Vision for Space Exploration. We will continue to assure that our customers' safety- and mission-critical software and systems are reliable, safe and of the highest quality by applying software and systems expertise and tools. We will lead the way in researching new approaches and deploying innovative solutions. And because people are our greatest resource, we will maintain our commitment to providing a learning environment and participating in the vitality of the community. These key elements have enabled the Facility to grow and mature into the successful and essential organization it is today and they will carry us forward into the exciting future we see before us.



"…Given ships or sails adapted to the breezes of heaven, there will be those who will not shrink from even that vast expanse."

- Johannes Kepler (letter to Galileo 1610)

Orbit Insertion by Mars Reconnaissance Orbiter
(Artist's Concept)

IV&V Defined

The IV&V Facility staff's work supports the software assurance program throughout NASA.

Our work is aimed at improving all NASA safety and mission-critical software efforts ranging from the human-rated spaceflight and robotic science missions to the NASA Integrated Enterprise Management Program.

Software Independent Verification & Validation (IV&V) is a systems-engineering process employing rigorous methodologies for evaluating the correctness and quality of the software products throughout the development life cycle. Software IV&V is adapted and tailored to the characteristics of the project.

Independent (Ensure objective analysis)

- Technical: IV&V prioritizes its own efforts
- Managerial: Independent reporting route to NASA Headquarters
- Financial: Budget is allocated by NASA to the IV&V Facility such that IV&V effectiveness is not compromised

Verification (Build the product right)

- Determine whether the products of a given phase of the software development life cycle fulfill the requirements established during the previous phase
- Determine if the product is internally complete, consistent and correct and if it will support the next phase of development

Validation (Build the right product)

- Evaluate software throughout its development process to assure compliance with software requirements. This process ensures
  - Expected behavior when subjected to anticipated events
  - No unexpected behavior when subjected to unanticipated events
  - Performance to the customer's expectations under all operational conditions

Software IV&V is an effective technique on large, complex software systems to increase the probability that the delivered software meets requirements and is safe, within cost and within schedule. When performed in parallel with the development life cycle, software IV&V provides for the early detection and identification of risk elements. Action may then be taken to mitigate these risks early in the life cycle often reducing cost, schedule impact and the need for rework while increasing the system's safety.

4 Foundation

"When you do the common things in life in an uncommon way, you will command the attention of the world."

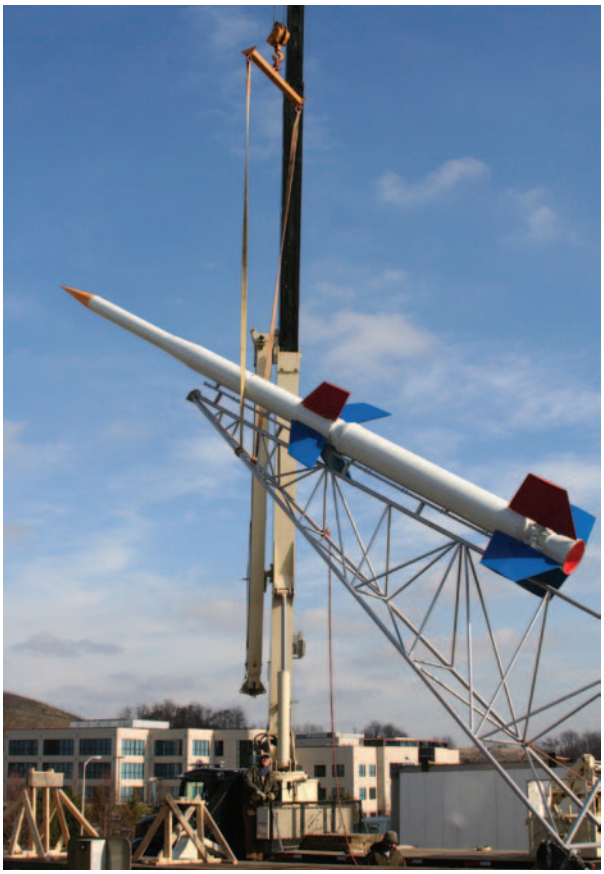
- George Washington Carver (1864-1943)

Cassini Spacecraft Image on Mimas, Against Saturn's Rings

It has been our goal throughout 2005 to continue our reputation as a center of excellence, providing the services and systems necessary for the success of our entire organization. We encourage innovative ideas and continuous improvements vital to NASA IV&V's future competitiveness. In 2005, a year of solid progress, we launched many new initiatives and enhanced current processes to improve safety, efficiency and effectiveness.

We enhanced the IV&V Management System (an ISO-certified, coordinated quality management system), to ensure the quality of all products, processes and services offered by the NASA IV&V Facility.

We implemented a Virtual Private Network using the Sygate Secure Enterprise capability to protect the integrity of Facility services and allow secure access from off-site by all employees. We implemented anti-spam and anti-spyware capabilities to reduce wasted time by all employees. We implemented a new automated software inventory system to ensure adherence to applicable rules and regulations and reduce costs. We automated financial processes supporting the Agency's Integrated Enterprise Management Program (IEMP) system to reduce workload and enhance accuracy. We initiated phase one of the Centralized Badging Access Control System (CBACS).



A sounding rocket became part of the NASA Independent Verification and Validation Facility landscape in 2005

The NASA Independent Verification and Validation Facility, Fairmont, West Virginia

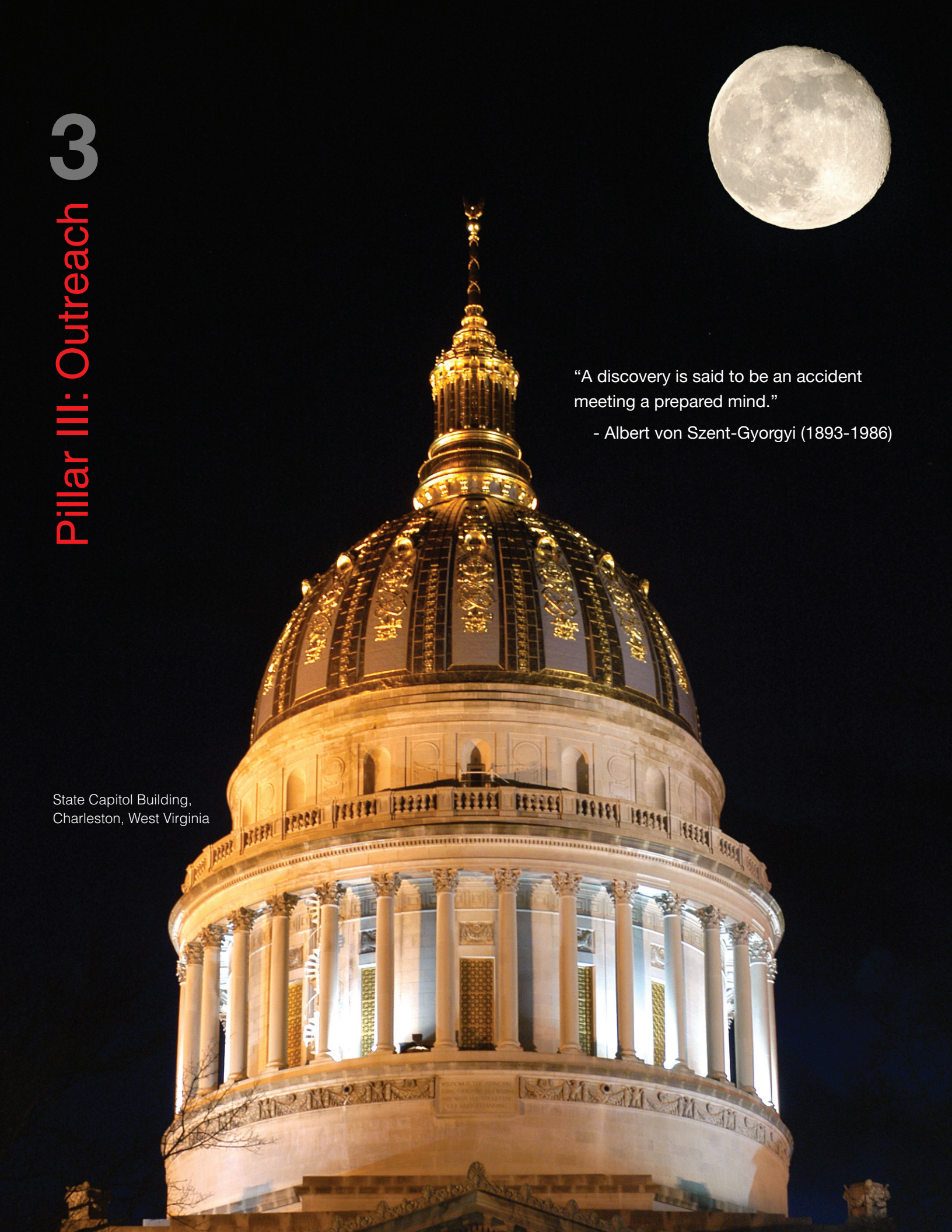
As a precursor to earning OSHA recognition as a Voluntary Protection Program (VPP) member, the Facility hosted environmental and occupational inspections by NASA and passed with flying colors.

We installed new HVAC controls in the spring to enhance capabilities while reducing energy consumption through tighter controls of the system. We are pursuing and implementing additional energy-saving initiatives per the President's directive.

The Facility continues to promote and provide a vibrant training program. Beyond the NASA-required training, the Facility has been involved in Earned Value Management training and Knowledge Sharing initiatives. Many employees participated in CPR and Automated External Defibrillator (AED) training.

Finally, with the support of the NASA Wallops Flight Facility in Virginia, the NASA IV&V Facility erected a sounding rocket in front of the building to ensure that the NASA IV&V Facility in Fairmont, West Virginia, stands out in our high technology corridor as one of NASA's own.

Pillar III: Outreach 3



"A discovery is said to be an accident meeting a prepared mind."

- Albert von Szent-Gyorgyi (1893-1986)

State Capitol Building,
Charleston, West Virginia

The NASA IV&V Facility plays a leading role in NASA's mission. The excitement of NASA countdowns and awe-inspiring images of planets and galaxies allow aeronautics and space exploration to ignite the imaginations of young and old. The NASA mission depends upon people with ingenuity to invent new tools, passion to solve problems and courage to ask difficult questions. To inspire the next generation of scientists, technologists, engineers and educators, we cannot rely on the past. We must engage the community and invite them to participate in our ongoing work and process of discovery.

Community Outreach

Throughout the exciting year of 2005 we became more fully engaged with those that we serve throughout NASA and the community in which we live.

We developed the IVView Newsletter to provide insight and information about the people and work of IV&V. We enthusiastically participated in such regional organizations as the West Virginia High Technology Consortium Foundation (WVHTCF) and Teaming to Win. We supported the ongoing efforts of our region and state to tell the story of the exciting and vibrant business climate in which we operate. We supported the efforts of neighboring federal agencies through the Federal Women's Coordinating Committee and the Combined Federal Campaign to provide information about opportunities for public service and charitable contributions. This year at our Facility, NASA IV&V proudly hosted events that brought together entrepreneurs, educators and the current and future leaders of our state and our Agency. These rewarding experiences built upon relationships we have nurtured for over a decade.

Educator Resource Center

A steering committee consisting of NASA personnel, educators and community members established the NASA IV&V Facility Educator Resource Center (ERC) in 1997. The ERC provides expertise and facilities to help educators throughout West Virginia access and utilize science, technology, engineering and math instructional products based on NASA's unique mission results and aligned with national standards and appropriate state frameworks.

In 2005, the ERC demonstrated and facilitated the use of educational technology and NASA curriculum-supported products by conducting 49 in-service and pre-service workshops. The ERC partnered with local, state, and regional educational institutions to reach 681 educators throughout West Virginia.

Day in the Park

In collaboration with the WVHTCF, the NASA IV&V Facility once again held its unique outreach event, Day in the Park, designed specifically to encourage students to pursue careers in science, technology, engineering and mathematics. On September 20, 2005, approximately 900 seventh-graders from North Central West Virginia participated in hands-on science activities and explored exhibits from "The Traveling Space Museum" of Los Angeles, California.

This year's guest astronaut, Paul Richards, shared his experiences with students in an inspiring story about his flight on STS-102 (March 8-21, 2001), the eighth Shuttle mission to visit the International Space Station.

Astronaut Paul Richards and NASA Independent Verification and Validation Facility Director Ned Keeler visited with students and faculty of one of West Virginia's NASA Explorer Schools, Tucker Valley Middle School.

Cooperative Education Program

An important link in the educational process, NASA IV&V's Cooperative Education Program integrates college-level academic study with meaningful work experience. This allows the students, through study and work experience, to enhance their academic knowledge, personal development and professional preparation. Additionally, Co-op Program employees earn income based on the level of education and work experience they have attained.

The NASA IV&V Facility benefited from the Co-op Program in 2005 with two Co-op positions and by converting one Co-op to the status of full-time civil servant. The program attracts students preparing for careers in a shortage category (engineering and science), permits selection for professional positions on the basis of proven performance, supports equal opportunity and helps to relate the efforts of educators more directly to occupational needs of employers and students. Applicants must be U.S. citizens who are students at an accredited university, have completed 30 semester hours, be enrolled in their school's Cooperative Education Program and have a good scholastic standing (2.9 G.P.A. overall).

Internship Program

The IV&V Facility brings new talent to the Agency through internships that require academic skill and offer experience in common practices within the government to instill a high degree of competency and prepare students for success in their careers.

Seven interns participated and provided support to projects and research conducted at the NASA IV&V Facility in 2005. The program creates an invaluable work and learning experience for the undergraduate students.

Apprenticeship Program

The NASA IV&V Facility offered a select group of fourteen high school students the opportunity to participate in intensive science and engineering apprenticeship programs. The Summer High School Apprenticeship Research Program (SHARP) and the Science and Engineering Apprentice Program (SEAP) are conducted for eight weeks each summer.

After participating in an orientation process, selected students work with NASA IV&V or West Virginia University mentors in a specific technical area. During the apprenticeship, the students carry out assignments, prepare written reports, make oral presentations and participate in a variety of enrichment activities such as career counseling and tours.

The SHARP and SEAP programs teach students the skills needed to pursue careers in science, mathematics, engineering, technology and geography. From such activities as installing and configuring operating systems and applications to developing programs for current NASA projects, the students build a foundation from which to make educational and career decisions. In addition to technical achievements, students acquire superior skills that will benefit them academically and professionally as they pursue future goals.

Student Outreach

In April 2004 NASA IV&V established the Student Outreach Program to inspire and motivate students of every age to pursue their interests in science, technology, engineering and mathematics. The program also engages the public in shaping and sharing the experience of exploration and discovery.

The NASA IV&V Student Outreach Program reached approximately 2,500 students throughout West Virginia in 2005 by increasing scientific literacy through presentations, career fairs, science fair-judging and special activities.

For further information about the NASA IV&V Community and Outreach Programs, contact Donna.S.Ozburn@nasa.gov.

The Student Outreach Program engaged 2,500 students in 2005 in the experience of exploration and discovery.

Pillar II: Research 2

All truths are easy to understand once they are discovered; the point is to discover them.

- Galileo Galilei (1564-1642)

Casini's View of Titan

To ensure that NASA IV&V is performing leading-edge research that improves IV&V and software assurance methods, practices and tools, we continually seek new ideas, relevance and excellence. Our challenges include integrating our services with vehicles yet to be designed and missions yet to be fully planned by infusing today's practicalities with innovations that support tomorrow's missions to the Moon and beyond.

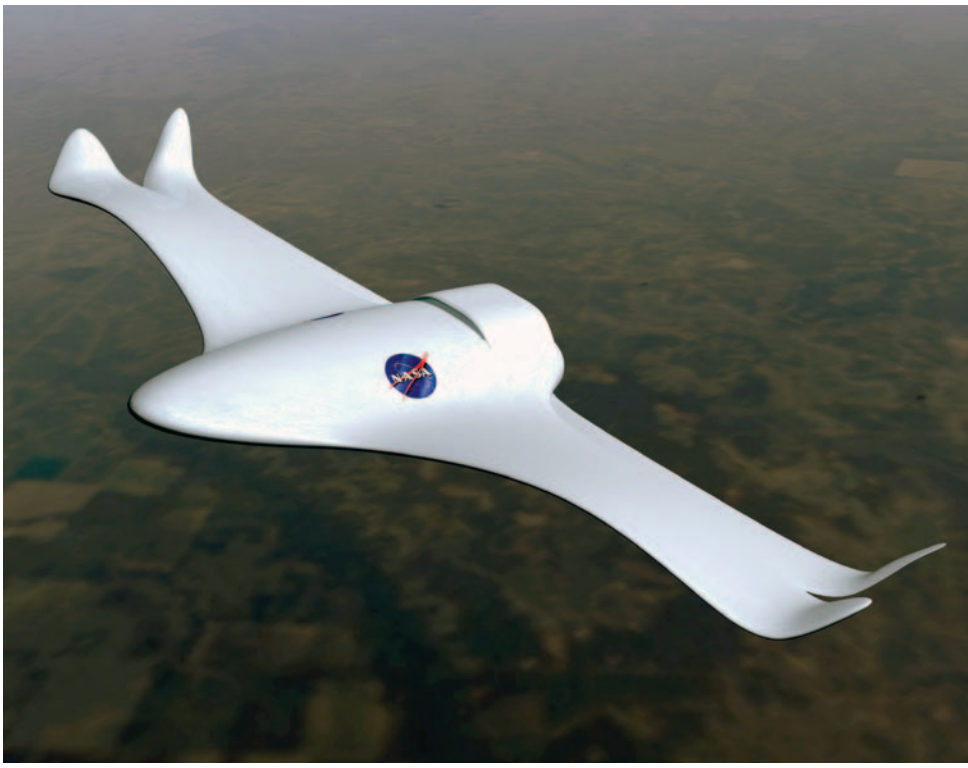
Under the Office of Safety and Mission Assurance (OSMA) the IV&V Facility supports comprehensive software assurance research that results in more thorough and efficient evaluation of critical software and encourages research with specific applications for NASA projects.

The NASA-wide Software Assurance Research Program (SARP) addresses fundamental software assurance problems in the field of software engineering, primarily as it relates to software safety, quality, verification and validation (V&V), testability and reliability. SARP also develops better tools, methods and techniques for assuring software quality and transfers proven improvements to NASA projects. The program oversees research across NASA centers, universities and private corporations.

Internally funded Facility Research Initiatives must advance efforts to keep pace with developing technology and find more effective ways to conduct IV&V. The IV&V Facility monitors, encourages and facilitates the use of real NASA data and the transition of cutting-edge research tools and practices to NASA projects, although transition can be funded as discrete research projects.

To further technology transfer, the Facility implemented and manages the SARP Results Web Site and the Software Assurance Symposium. The SARP Results Web Site (SRWS) highlights NASA-sponsored research that has made a significant impact in the professional field and has been officially cleared for public release.

To view software research results produced by NASA's SARP, please visit http://sarpresults.ivv.nasa.gov.



NASA engineers are working to make planes quieter and fly more like birds with the help of new materials and designs. This photo shows an artist's rendering of the 21st Century Aerospace Vehicle, sometimes nicknamed the Morphing Airplane.

The OSMA-sponsored Software Assurance Symposium (SAS) hosted by the IV&V Facility also highlights SARP research. In 2005, we celebrated the fifth annual SAS with over 200 researchers from around the globe and hosted the OSMA directors' annual meeting. The confluence of the two events ensured that researchers and directors alike experienced a unique opportunity to share in their considerable knowledge and insight, not to mention the unmatchable experience of taking time out of a demanding schedule of activities to view NASA's return to flight as members of the same team.

Center and university initiatives presented at the annual Software Assurance Symposium can be found at http://sas.ivv.nasa.gov/conclusion2005.html.

Innovation

We are challenged to solve potential problems as well as current ones. Although we don't yet know all the necessary details about our return to the Moon and even more uncertainty exists about a voyage to Mars, we are exploring ideas that may help us on both missions.

Testing Framework for Reproducible Execution & Race Condition Detection in Real-Time Systems (CI05)

PI: Ken Chen – JSC
Government POC: Ken Chen – JSC
Period of performance: 1/2005–12/2007

http://sarpresults.ivv.nasa.gov/ViewResearch/96.jsp

In many NASA exploration missions, embedded software systems control physical devices subject to real-time constraints. These systems often consist of concurrent threads and exhibit non-deterministic behavior, which makes verification of temporal behavior a great challenge. This research is developing a testing framework for system-level testing in temporal domain. The two major issues addressed include reproducible execution and race condition detection. The framework enables points of control and observation during testing execution. With automated test sequence generation and result evaluation, scenarios driven from prefixed test sequences will be used to exercise different execution paths to ensure software quality for critical space mission applications.

Race-Conditions and Threads

A complex system can process many tasks seemingly at one time, much like many of us who feel as though we are masters of multi-tasking. If you were a computer system going about your day answering e-mail while double-checking budget numbers and returning a phone call, we would refer to each of those tasks as a thread. Now suppose that you needed a piece of information from the person on the phone in order to finalize the budget, which has to happen before you send the e-mail. Most of us have also had the experience, analogous to a race condition, where we manage to get our multi-tasking muddled and hit the send before we double-check the numbers. Race conditions are not desirable for any type of complex system.

Empirical Assurance of Embedded Software Using Realistic Simulated Failure Modes

PI: Ted Bennett and Paul Wennberg – Triakis Corporation
Government POC: Phillip Merritt – IV&V
Period of Performance: 1/2004–12/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/53.jsp

Because the effects of failure modes are untestable in an integration lab setup, relying solely on analysis to test their effectiveness cannot lessen the risks possible as systems become more complex and software is designed using the intelligent behavior method. And although evaluating system behavior in its target environment is the best method, this is rarely feasible for NASA space hardware. This research will simulate the NASA Mini-AERCam nanosatellite, running its unmodified software in its orbital environment. It will demonstrate how a high-fidelity virtual environment simulation can be used for thorough empirical assessment of system and software behavior in response to a wide range of enhanced system and component failure conditions.

Formal Approaches to Swarm Technologies

PI: Christopher Rouff – SAIC
Government POC: Walt Truszkowski – GSFC
Period of Performance: 2/2002–12/2005

http://sarpresults.ivv.nasa.gov/ViewResearch/56.jsp

Autonomous swarms of satellites are being proposed for missions that have complex behaviors and interactions. A significant challenge when dealing with swarms of interacting agents critical to the mission success is how to determine that the possible exponential interactions and emergent behaviors are producing the desired results. The research hypothesis is that one or more formal methods are needed to assure the correct behavior of the interactions and emergent properties of satellite swarms. Formal methods are proven approaches for assuring the correct operation of complex interacting systems.

Model Checking Artificial Intelligence-Based Planners

PI: Margaret Smith – JPL
Government POC: Allen Nikora – JPL
Period of Performance: 10/2003–12/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/57.jsp

This ongoing research explores the suitability of logic model checking, specifically the suitability of the model checking tool SPIN to test Artificial Intelligence (AI) planning engines. AI planners enable autonomous control of spacecraft such as the Mars rovers. Verification must ensure that the software will not endanger the mission under any circumstances. Traditional software testing samples a small subset of conditions that the AI planner will encounter. A testing method is needed that checks every possible combination of conditions under well-thought-out assumptions. Model checking has been applied successfully to industrial projects to exhaustively test the correctness of critical software components. This research tests the technique in the NASA domain.

Software Process Assurance for Complex Electronics (SPACE)

PI: Kalynnda Berens – SAIC
Government POC: Cynthia Calhoun – GRC
Period of Performance: 1/2005–12/2007

http://sarpresults.ivv.nasa.gov/ViewResearch/90.jsp

Complex electronics (such as FPGAs and ASICs) are hardware/software hybrids used across NASA in everything from wind tunnels to the International Space Station. Previous SARP research has shown that assurance methods for these devices have not kept up with the technology. Following the lead of the FAA, this research will apply software process assurance methods and techniques to complex electronics in multiple projects across three NASA centers and determine what techniques improve product quality and provide additional safety assurance.

Bayesian Verification & Validation Tools for Adaptive Systems

PI: Johann Schumann – USRA/RIACS
Government POC: Michael Lowry – ARC
Period of Performance: 1/2004–12/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/54.jsp

Safety and reliable operation in a complex, changing and uncertain environment are important requirements for NASA missions. The design phase cannot support the evaluation of system behavior because conditions change during the mission. Using adaptive controllers is one way to increase reliability and to ensure that any action taken is safe and accurate in the current state of the system. Such adaptive systems lack a theoretically sound and practical V&V approach, which limits their use. The research, which applies adaptive control architectures (e.g., with neural networks), is developing and maturing a V&V software process, as well as tools for performance analysis of adaptive systems. Its focus is on a Bayesian approach that provides probabilistic estimates about the system performance and a safe operation envelope. These V&V and monitoring tools will be evaluated in NASA-relevant case studies with the ultimate aim of guaranteeing system robustness for a wide variety of NASA missions.

Lyapunov Stability Analysis and Online Monitoring

PI: Bojan Cukic – West Virginia University
Government POC: Lisa Montgomery – IV&V
Period of Performance: 5/2003–4/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/65.jsp

A major obstacle precludes the widespread use of ANNs (Artificial Neural Networks) in navigation and control systems: today's V&V technology cannot meet most of the certification standards that NASA and other federal agencies (such as FAA) impose on these life-critical and mission-critical applications. No existing software V&V method/technique can be applied to systems that contain online learning artificial neural networks. This ongoing project will produce a framework for reasoning about adaptive systems.

The function of online adaptive systems evolves over time as they improve performance through online learning. Adaptive systems offer the advantage of using judicious learning to react to situations that the designer never individually identified and analyzed. These systems are attracting increasing attention in application domains where autonomy is an important feature or where it is virtually impossible to forecast all possible combinations of environmental conditions that may arise. Autonomy is important, for example, in long-term space missions where communication delays to ground stations are prohibitively long and the systems' local capabilities must deal with unforeseen circumstances.

Experimental success suggests significant potential for neural networks and other soft-computing paradigms in process control applications. This research will help develop autonomous learning as well as learning with confidence. These techniques will help a craft learn

[continued on next page]

Innovation (continued)

[Lyapunov Stability Analysis and Online Monitoring continued]

how to operate safely in normal states, how to react in failure modes, how to stabilize itself and to learn from the failure.

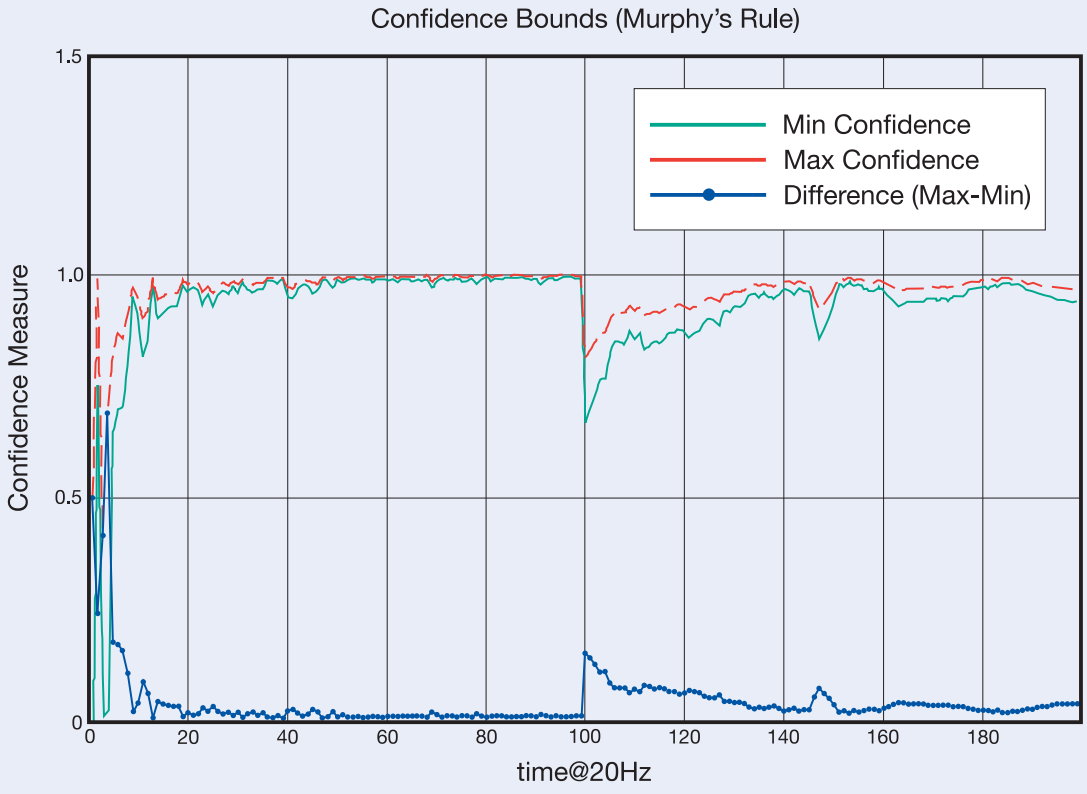
To verify and validate a network architecture involving a non-deterministic component such as an unsupervised neural network, this research analyzes network performance as scenarios are encountered. Lyapunov analysis has helped in understanding the stability of the non-deterministic nature of neural nets. A system of monitors that yield confidence measures for the dynamic cell structure's (DCS) neural network performance in online implementations has been constructed and a systematic way to approximate recovery times for a neural network that encounters perturbed data has been developed.

Lyapunov and V&V of Adaptive Systems

This chart shows what happens to an adaptive controller on a test flight using a scale model of an F-22. This is a single training flight and a single fault is introduced. Look at the chart and consider when the fault might have been introduced.

Now look at the red and green lines in the upper part of the chart. They show how confident the learner is in how well it understands its world. One way to think about this minimum and maximum confidence is to liken it to a poll where often the confidence in the data is given as + or – some number. Early on in the flight, the controller is not very confident; there are variations of more than 60 percent. From time 0 to 20 the learner is getting its bearing as the plane gains speed and altitude. Note how much variation there is between the red and green lines. Once the plane reaches a steady speed and altitude, around time 40, the controller starts to become more comfortable. Notice how through time 40 to 100 the controller is completely confident. It knows the world in which it has been operating.

At time 100.5 seconds into the flight, a fault is introduced in the plane. A control surface becomes unresponsive. It is easy to see that when the fault is introduced the controller detects this abnormality and becomes quite uncertain again. But note how quickly it adjusts to and compensates for the new reality. It has stabilized in about 3 seconds. But also note, that just like a human, it is not quite as confident as before. The range of possible states has increased, and so too has the uncertainty. One of the most interesting things is just how human the learning seems.



Verification and Validation of Adaptive Systems

PI: Bojan Cukic – West Virginia University
Government POC: Lisa Montgomery – IV&V
Period of Performance: 10/2001–12/2005

http://sarpresults.ivv.nasa.gov/ViewResearch/35.jsp

Interestingly, neural networks use an unconventional, non-sequential approach to learning. This feature enables them to solve highly complex problems with minimal computational effort compared to conventional computation methods and expert systems. It also increases the quandary in understanding their learning behavior.

A V&V methodology for evaluating neural networks or adaptive systems is needed because understanding and predicting neural network behavior is critical before deployment into such safety-critical systems as aircraft control.

Traditional software V&V methods assume non-adaptation and don't account for changes that occur after deployment. Neural nets, on the other hand, are sometimes designed for online adaptation, which takes place after deployment into a system. A change in behavior leads to model uncertainty, unacceptable by traditional software evaluation methods. The development of non-traditional V&V methods that can enable real-time neural network evaluation is needed.

Development of Methodologies for IV&V Neural Networks

PI: Brian Taylor – ISR
Government POC: Markland Benson – IV&V
Period of Performance: 5/2002–9/2005

http://sarpresults.ivv.nasa.gov/ViewResearch/11.jsp

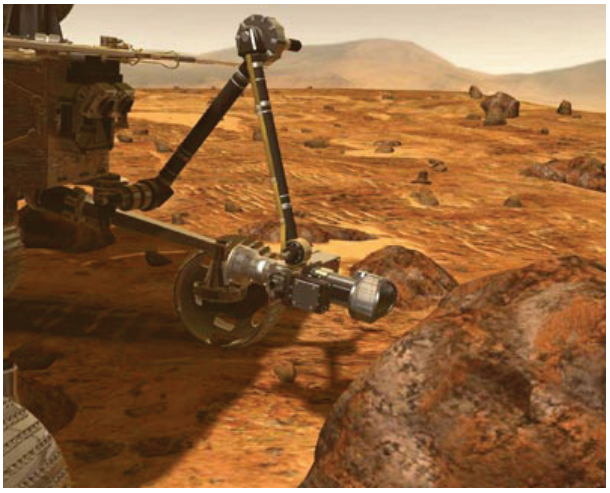
Little research has been found that addresses IV&V of neural nets in adaptive flight controllers that are learning in real time and adapting to live flight conditions. A neural network has the ability to adapt over time based on data observed. This is unlike traditional software that has a fixed behavior when written. The dynamic nature of neural networks allows developers to solve problems that were difficult or impossible with traditional software. Assuring that a neural network will not perform an unsafe behavior cannot be done with current software verification processes. Such assurance is particularly important in NASA missions where errors can lead to loss of life or loss of critical assets. The initiative has a goal of creating a set of processes and advice that will allow IV&V practitioners to assure quality of neural networks used in NASA applications. The initiative will produce techniques for selecting the right type of neural network for a given task; techniques to test neural networks and extract neural network knowledge for evaluation; and methods for assessing the risks posed by the neural network on its environment.

Contingency Software in Autonomous Systems

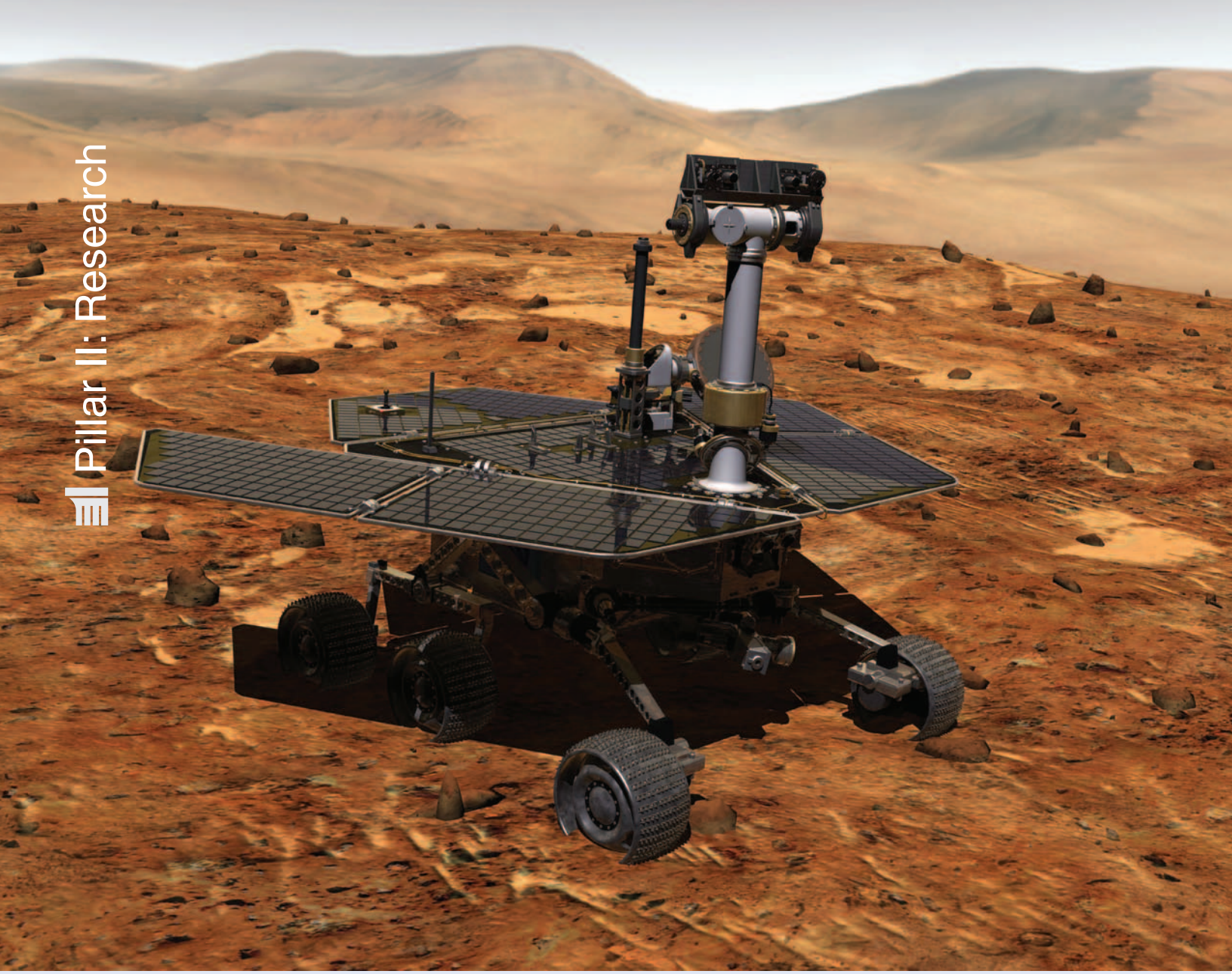
PI: Robyn Lutz and Ann Patterson-Hine – AMES
Government POC: Allen Nikora – JPL
Period of Performance: 1/2004–1/2007

http://sarpresults.ivv.nasa.gov/ViewResearch/55.jsp

The need for autonomous agents, such as the Mars rovers, will increase as NASA fulfills new exploration objectives. These new autonomous vehicles such as rotorcraft and spacecraft operate in harsh environments with limited capacity to mitigate failures. Currently, when a failure occurs, vehicles may switch to a safe mode while ground crews devise a solution. Solutions are difficult because failures are hard to pinpoint and contingencies may be too complex, novel or high-risk for current autonomous software. This work will enhance diagnostic techniques to identify failures, provide software contingency planning to mitigate failures, perform tool-based verification of contingency software and investigate contingencies in safely relinquishing control to autonomous controllers. Results, applied to current NASA programs, will pave the way to more resilient, adaptive unmanned systems.



The Mars rovers make use of contingency software.



Autonomy and Failure Mitigation

Due to distance or planet position the human members of a team can't always be in contact with a spacecraft. If a craft has no human pilot we need one that can operate, to some degree, on its own. The trick is to help the vehicle be smart enough to survive an unexpected situation long enough to learn from it. A standard option when a vehicle encounters an unexpected situation involves switching to a safe mode. Think of a safe mode as some limited subset of behaviors that should lessen the chances that a bad situation will become worse. Suppose we have a little rover on a distant planet, and suppose that rover makes decisions about where to go based on information from image sensors by looking at pictures. Imagine those pictures can help our rover decide whether the terrain ahead is too steep, too rocky or in some other way too challenging to safely traverse. Now suppose something happens and the rover loses the ability to see. It's not difficult to understand that moving forward when our rover doesn't know what's ahead of it could cost us the vehicle. In this instance, a safe mode might tell the rover to stay put until a way to compensate for the loss of vision can be found. As the complexity of our missions increases, thereby increasing the need for our vehicles to be able to act without human assistance for longer periods of time, so too does the complexity of the necessary failure-mitigation strategies.

Integration

The work in this section is focused on more immediate needs: today's practical problems, improving our planning, making it easier to find more faults before launch and finding new ways to deal with faults that occur after launch.

Analysis of Defect Data and Defect Detectors

PI: Dolores Wallace – GSFC
Government POC: Al Gallo – GSFC
Period of Performance: 1/2005–12/2007

http://sarpresults.ivv.nasa.gov/ViewResearch/71.jsp

Extending previous work showing that certain defect detectors and their metrics predict defects in code will greatly benefit the Goddard Space Flight Center (GSFC) as well as the entire Agency. This research explores a focused data repository at GSFC to develop data collection and analysis of pertinent software issues. Pilot projects at GSFC will enable case studies that demonstrate the validity of assumptions about certain defect detectors and their relationship to error prediction. After careful analysis of the process for establishing the data schema of the repository, the data collection and analyses will provide NASA with a much-needed methodology for defect detection and prediction. The research will increase GSFC and NASA enterprise software quality via case studies that yield a means of collecting, analyzing, trending and storing defect data to determine how best to predict errors in code. Using previous findings in this area, a repository and case studies will be designed specifically for project data at GSFC, establishing a service available to all GSFC projects. A case study of the work itself will enable transfer to all NASA centers of a cost-model for developing and using such a repository, the collected metrics and defect detectors learned from them, effectiveness data on the merits of these defect detectors, the software tools developed as part of this work and guidebooks describing the methodology for using these tools.

Software Development Cost: How Much? You Sure?

PI: Jairus Hihn – JPL
Government POC: Allen Nikora – JPL
Period of Performance: 1/2005–12/2007

http://sarpresults.ivv.nasa.gov/ViewResearch/95.jsp

Experience has shown that the most expensive bad decisions are made earliest in the software lifecycle. Underestimating a project's costs, for example, may force developers into quality-threatening cost-cutting measures. Good cost estimation models can significantly help the managers of software projects to make totally accurate cost estimations. With a good model, project stakeholders can make informed decisions about buy-or-make, how to manage resources, how to control and plan the project, and how to deliver the project on schedule and on budget. This research improves COCOMO's estimates via WRAPPER, a feature subset selection method developed by the data-mining community. Using data sets from the PROMISE repository, WRAPPER significantly and dramatically improves COCOMO's predictive power. Two important elements of this research include improving accuracy of the predictions and increasing the speed at which a model can be tested.

Documenting Failures of MATLAB/Simulink Code Generator

PI: Mario Perhinschi – West Virginia University
Government POC: Lisa Montgomery – IV&V
Period of Performance: 1/2005–12/2005

http://sarpresults.ivv.nasa.gov/ViewResearch/91.jsp

How can we be sure that the tools necessary for more complicated work don't also add unexpected changes? Extensive NASA-sponsored research at West Virginia University (WVU) to design intelligent adaptive control laws based on neural networks (NNs) also flight tests the control laws using F22 aircraft scale models. The control laws are designed within a MATLAB/Simulink environment. For implementation purposes, a C code obtained using Real Time Workshop (RTW) is installed on the on-board computer. Previous experience has shown that occasionally the results obtained with the auto-generated C code are different from Simulink model results. The proposed research will investigate and identify Simulink model implementation characteristics that produce inconsistencies in the auto-generated C code, evaluate the nature and magnitude of the inconsistencies and provide good practice guidelines for Simulink model implementation to ensure proper conversion via the current version of RTW. Research results will improve V&V practices for NASA projects that involve MATLAB/Simulink models.

Integration (continued)

Completing the Loop: Linking Software Features to Failure

PI: Paul Garnett – MSIS
Government POC: Raju Raymond – IV&V
Period of Performance: 7/2003–7/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/10.jsp

It is not known how software features can predict software failures and defects. NASA has tools to identify system features and the NASA IV&V Facility has a database of system defects and failures. A link is needed between the defects and the system features in a form machine learning tools can use to show how features can predict faults. The research will develop tools and methods to integrate system analysis tools and defect tracking tools to create a link between software features and failures. Integrating the output from software analysis and defect tracking tools and applying machine learning to the results will help NASA find the predictors leading to software faults.

IV&V Technique for Object-Oriented Software Systems

PI: Khalid Lateef – Titan Corporation
Government POC: Melissa J. Bodeau – IV&V
Period of Performance: 10/2002–1/2007

http://sarpresults.ivv.nasa.gov/ViewResearch/52.jsp

NASA has considerable experience applying IV&V to traditional function-based software development programs. As NASA's use of object-oriented (OO) techniques to develop mission-critical software systems increases, IV&V techniques are needed that best suit the unique challenges and risks of this type of software development. Shifting from traditional function-based development to OO development, which can provide advantages for system development and maintenance, introduces a unique set of life cycle risks. This study seeks to identify, develop and evaluate the analysis techniques best suited for independent V&V of NASA systems developed using an OO approach.

Integrated Software into Probabilistic Risk Assessment

PI: Carol Smidts – University of Maryland
Government POC: Judith Connelly – IV&V
Period of Performance: 10/2000–1/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/18.jsp

Probabilistic Risk Assessment (PRA) is a technique to assess the probability of failure or success of a mission. Current PRA neglects the contribution of software to the risk of mission failure. This research extends current PRA methodology to integrate software in the risk assessment process. The approach will be applied in new space telescope software. The research team has developed techniques necessary for the systematic integration of software in PRA and has made advances toward proving the conceptual validity of the methodology on a specific subsystem of a project currently in development.

Optimizing IV&V Benefits Using Simulation

PI: David Raffo – Portland State University
Government POC: Thomas E. Robinson – IV&V
Period of Performance: 10/2002–9/2005

http://sarpresults.ivv.nasa.gov/ViewResearch/51.jsp

There is never enough time or money to check every line of code in a project. The purpose of this research has been to develop a means to improve decision-making about how to determine and optimize the economic benefit of V&V technologies. As an analogy, consider buying a pen and buying a car. The low cost of buying a pen coupled with the minimal consequences of it failing make the idea of spending extra for a warranty silly. Buying a car is a different situation. Now consider buying a car with a warranty that promised that nothing would fail—ever. How much would that cost? How much would that be worth? How would you decide? While performing V&V on software is not exactly a warranty, doing it does increase confidence in the code. This research looks at how to determine the cost and benefit of doing V&V in different ways and at different times and will enable better planning and allocation of scarce resources.

Practical Model Checking to Enforce Domain-Specific Interfaces and Requirements

PI: Michael Beims – SAIC
Government POC: Jerry Sims – IV&V
Period of Performance: 1/2004–1/2007

http://sarpresults.ivv.nasa.gov/ViewResearch/58.jsp

Domain-specific interfaces and requirements must be checked to ensure the integrity of complex software systems, which is very time-intensive and expensive because today most of it must be done manually. Most error-finding tools are neither powerful enough nor customizable enough to check complicated interface rules. The SPIN model checker only works on finite state machine systems, not C/C++ code. In contrast, push-down model checking is naturally suited to checking C/C++ code because of its stack-based nature. This initiative explores the use of push-down model-checking technology to automate the checking of domain-specific NASA requirements.

Program Model Checking Case Studies and Practitioner's Guide

PI: John Penix – ARC
Government POC: John Penix – ARC
Period of Performance: 1/2004–12/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/59.jsp

Program model checking is a verification methodology that uses state-space exploration to evaluate large numbers of potential program behaviors (executions). It can be effective at detecting critical software errors that are difficult to find through testing. While best practices for applying program model checking are emerging, they remain an ad hoc combination of methods for capturing properties, building special purpose test drivers, and modification and abstraction of application code. Also, the effect of design practice on verifiability (including model checking) has not been explored. The research will assemble these best practices, demonstrate and validate their use in several case studies, and document the results into a Practitioner's Guide for Program Model Checking.

Reducing Software Security Risk Through an Integrated Approach

PI: David Gilliam – JPL
Government POC: Allen Nikora – JPL
Period of Performance: 11/2000–12/2005

http://sarpresults.ivv.nasa.gov/ViewResearch/60.jsp

A recent report on NASA's Information Technology (IT) security posture points to numerous security vulnerabilities in NASA systems. An otherwise secure system can be compromised easily if system or application software on it or on a linked system has vulnerabilities. Currently, there are relatively few Security Assessment Tools (SATs) or instruments in the software development and maintenance life cycle that can help mitigate these vulnerabilities. Development and use of a Software Security Assessment Instrument (SSAI) will aid in assuring the security of NASA's software and systems. This effort has focused on the use of a formal analytical approach for integrating security into existing and emerging practices to enable development of a security assessment instrument consisting of tools, procedures and instruments that support the development of secure software. The NASA Office of the Chief Information Officer and the Department of Homeland Security are studying the results of this research.

Tandem Experiments in Finding Faults During Model-Based Development

PI: Kurt Woodham – Titan Corporation
Government POC: Aaron Wilson – IV&V
Period of Performance: 1/2004–12/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/62.jsp

Model-based development centers the software development effort on models of the intended software behavior and relies on code generation to produce the production software. Existing V&V analysis processes and tools do not readily accommodate models that contain numeric data variables involved in interrelated constraints including most control models expressed in languages such as Simulink® and SCADE. Such models are being used increasingly for NASA missions such as STEREO. New analysis methods and an expanded V&V toolset are required to effectively perform V&V on flight-critical software developed using such models. The effectiveness of existing V&V methods when data variables are present is currently very limited. This project aims at developing and empirically assessing alternatives to existing techniques.

Integration (continued)

A Compositional Approach to Validation of Formal Models

PI: Bojan Cukic – West Virginia University
Government POC: Lisa Montgomery – IV&V
Period of Performance: 1/2004–12/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/64.jsp

Proving the correctness of the developed specification with respect to the requirements is one of the most important and difficult tasks performed by NASA IV&V personnel. The research focuses on a compositional approach to validation of the formal specifications using visualization, simulation, formal methods and testing. The basis of our approach is the SCR (Software Cost Reduction) Formal Method and its finite state model of the system. An SCR specification can be executed by the existing SCR simulator and tested—either automatically (i.e., random testing) or manually. To facilitate testing of the specification simulation, we are investigating the creation of visual interfaces. The visual interfaces will hide the complexity of the model (and the formal mathematical notations being used) from the users and the domain experts. Performing testing using these visual interfaces will allow the V&V practitioner to focus on the expected behavior of the system and the correctness of the specification.

Implementing "Martha," A Next-Generation Testable Language

PI: Tim Menzies – West Virginia University
Government POC: Lisa Montgomery – IV&V
Period of Performance: 1/2004–12/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/69.jsp

The current generation of software tools is optimized for execution speed (e.g., C) or usability (e.g., Python or UML). Here we have taken a bold step away from current practice and ask the fundamental question: What would a software language look like if it was designed for testability? Our premise has been that a testable language is reflective language and automatically and routinely explores itself looking for previously undetected interactions. The object of the research is to design and implement an interpreter for a next-generation testable language that automatically seeks the unknown knowns.

Performability of Web-Based Applications Models

PI: Katerina Goseva-Popstajanova – West Virginia University
Government POC: Lisa Montgomery – IV&V
Period of Performance: 10/2002–9/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/66.jsp

Many factors affect dependability (e.g., availability, reliability, safety and security) and performance of complex computing systems and applications executing on them. Modeling and simulation methods and tools used to understand the isolated quality attributes have been reasonably successful when computing systems and the applications were relatively simple. These methods do not have the capability to provide system view and analysis nor can they provide a well-defined hierarchical analysis and structuring needed to model systems of the level of complexity under consideration. The research will develop scalable approaches that allow the combination of models, measurements and simulators with different levels of details and abstraction to analyze multiple quality attributes and their tradeoffs for complex distributed systems. To demonstrate the validity of the developed methods and techniques we will apply them on Web-based applications.

Risk Assessment of Software Architectures

PI: Hany Ammar – West Virginia University
Government POC: Lisa Montgomery – IV&V
Period of Performance: 10/2003–12/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/67.jsp

The report of the Columbia Accident Investigation Board (issued August 24, 2003) repeatedly mentions the keywords "risk/hazard analysis" and "mitigation" in its recommendations. This research addresses risk assessment of software specification and design artifacts based on software product metrics and will develop techniques for severity analysis and a methodology for maintainability-based risk assessment at the architectural level. The work builds on our recent techniques for risk assessment of UML dynamic specifications and attempts to integrate this work with risk assessment-based tools used in NASA projects. The objective is to extend and integrate the techniques for risk assessment of software artifacts into the Defect Detection and Prevention (DDP) process developed at JPL and the NASA Criticality Analysis and Risk Assessment (CARA) process.

Our challenges include integrating our services with vehicles yet to be designed and missions yet to be fully planned as well as infusing today's practicalities with innovations that support tomorrow's missions to the Moon and beyond.

View of the Moon from Earth's Orbit

Integration (continued)

See More! Learn More! Tell More!

PI: Tim Menzies – West Virginia University
Government POC: Lisa Montgomery – IV&V
Period of Performance: 12/2003–12/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/70.jsp

As the sole entity with the responsibility for IV&V of all NASA mission software, the IV&V Facility is uniquely positioned to create and maintain a master repository of software metrics. If the collected metrics aren't used, the stored numbers become a sarcophagus, not a repository. NASA needs an active group exploring the details of the collected data and reporting their findings. There exists within NASA projects repeated and important patterns about software development that can be found by machine learning queries to a metrics repository. If these patterns can be found, then the process of generating software for NASA can be optimized.

Toward More Realistic Software Reliability Predictions

PI: Katerina Goseva-Popstajanova – West Virginia University
Government POC: Lisa Montgomery – IV&V
Period of Performance: 10/2003–9/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/68.jsp

This initiative focuses on development of more realistic and accurate estimation and prediction of software reliability based on empirical studies. The research addresses two important phenomena: uncertainty in software reliability due to errors in the operational profile and the effect of failure clustering on software reliability predictions. The work on uncertainty in software reliability builds on recent contributions on methods for uncertainty analysis. Empirical case studies are being used to verify and validate our methodology for uncertainty analysis and to compare different methods based on real data. The same empirical studies are being used to build more realistic software reliability models that consider the correlation of successive software executions and analyze the effects of failure clustering on software reliability predictions. Accurate reliability prediction allows us to test what is most important. In this case, important is what is executed most, or what most frequently affects other pieces of code.

Constraint Determination on Simulink Models

PI: Mike Biems – SAIC
Government POC: Steve Pukansky – IV&V
Period of Performance: 10/2004–10/2007

http://sarpresults.ivv.nasa.gov/ViewResearch/92.jsp

The problem of determining variable constraints is not just theoretically interesting but rather is a significant pragmatic problem within programming, testing and safety assurance. Variables whose values can exceed safety and reliability limits can result in mission failure. Conversely, variables whose values cannot reach portions of their specified range can prevent software and the hardware it controls from providing required functionality. This research and development effort focuses on determining variable constraints with MATLAB/Simulink models and the corresponding automatically generated source code they produce. This effort will place software tools in the hands of practitioners who will quickly determine the constraints of internal and external variables of MATLAB/Simulink models and the source code they produce.

Improving Requirements Tracing and IV&V Via Information Retrieval and Text Mining

PI: Jane Hayes – University of Kentucky
Government POC: Stephanie Ferguson – IV&V
Period of Performance: 9/2004–8/2005

http://sarpresults.ivv.nasa.gov/ViewResearch/25.jsp

IV&V tracing of requirements to design, code and/or test cases is difficult. It must be quick and accurate and often must shortly be redone on updated documents/artifacts. IV&V tools are needed to automate linking levels of documents/artifacts as opposed to developers' tools that only record links during decomposition. This research is developing improved methods for finding candidate links between document/artifact levels using appropriate algorithms and techniques from the field of Information Retrieval. Further, it will develop a toolkit of tracing algorithms and integrate it with at least one IV&V tool currently in use.

Interface Validation for Distribution Software Systems

PI: Pavan Rajagopal – Titan Corporation
Government POC: Deborah Kromis – IV&V
Period of Performance: 10/2004–10/2007

http://sarpresults.ivv.nasa.gov/ViewResearch/74.jsp

Past history indicates that errors and deficiencies in interactions between software components account for many failures in distributed software systems. Comprehensive validation of command and data exchange between the components of a distributed software system is crucial to validation of the entire system but typically is not performed. Two major reasons for this omission are that the activity required to accomplish this validation has not been defined or the effort required is perceived as unfeasible in terms of time and cost. Instead, validation of interfaces between software components is typically performed through system integration testing. This type of testing, designed to concurrently exercise groups of Computer Software Component Interface (CSCIs), lacks the detail required to comprehensively validate command and data exchange across the interfaces. System integration testing also occurs late in the development cycle and deficiencies found at this stage are expensive to fix. The research and development in this study will attempt to address this deficiency by defining an IV&V process for performing software interface validation and developing tools to make it feasible.

IV&V Code Level Metrics Data Program

PI: Mike Chapman – Galaxy Global Corporation
Government POC: Pat Callis – IV&V
Period of Performance: 8/2003–4/2007

http://sarpresults.ivv.nasa.gov/ViewResearch/75.jsp

For serious research to thrive, researchers must have access to sufficient relevant data. For researchers whose work will impact NASA projects and practices, data from NASA development projects and missions is crucial. The Code Level Metrics Data Program exists to help give other researchers access to relevant data that would otherwise be inaccessible. One of the most important aspects of this effort is that information from important NASA projects is sanitized, thus making it available to inform research. This effort will also support and enhance the generation of software metrics including recommendations of the types of metrics to generate for a given project. This effort will assist researchers in generating additional data for an original data set to broaden or deepen their data set for that project. Software metrics currently generated include, but are not limited to, complexity, Halstead, object-oriented metrics and error density metrics.

Mitigating the Risk of Legacy Software on NASA Spacecraft

PI: Lydia Sorenson – TMC
Government POC: Gerald Gilley – IV&V
Period of Performance: 9/2004–8/2005

http://sarpresults.ivv.nasa.gov/ViewResearch/78.jsp

Routinely, the reuse of spacecraft software is a part of NASA's IV&V program scenario. Legacy software is not currently verified or validated for its new environment even though the legacy artifacts may be available to the IV&V team. While the various IV&V teams often see the need to evaluate the reused code, they have no data to make an argument for re-verifying it.

The study identified and determined the impact of using legacy software on NASA spacecraft and developed tools that mitigate the risks of using it.

NASA IV&V Common Data Repository Pilot Project

PI: Paul Garnett – MSIS
Government POC: Aaron Wilson – IV&V
Period of Performance: 9/2004–9/2005

http://sarpresults.ivv.nasa.gov/ViewResearch/79.jsp

The Common Data Repository project provided a data dictionary (DD), which captured all data fields used at the NASA IV&V Facility. The dictionary will be utilized during the first phase of the NASA IV&V Enterprise Architecture project, which will integrate all systems and share data across all business/functional areas.

Programmable Logic Device in IV&V Research

PI: Mike Biems – SAIC
Government POC: Richard Grigg – IV&V
Period of Performance: 7/2004–6/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/81.jsp

The use of Programmable Logic (PL) is becoming commonplace within NASA projects, facilities and research. PL is seen more frequently in space systems' software undergoing IV&V at NASA's IV&V Facility. Programmable logic chips such as Field Programmable Gate Arrays

[continued on next page]

[Programmable Logic Device in IV&V Research continued]

(FPGAs) are employed to standardize functionality formerly performed by the Central Processing Unit (e.g., battery-charging algorithms) and to create custom capabilities (e.g., science domain specific massively parallel data compression) within satellites and instrumentation. PL software is tested for functionality, boundary conditions and operational simulation, but most of this logic programming software is not subjected to V&V methods employed in mainstream software. This research will focus specifically on FPGAs within the PL family and aims to identify design fault characteristics specific to the FPGA. It will explore the feasibility of applying existing inspection methods that may be candidates for direct application to FPGA designs. Once a suitable set of methods has been identified, the research will result in the development of modifications to the design phase, peer and design review methodologies. Incorporating and prototyping those methods will be done by providing IV&V in a NASA case study.

Return on Investment for IV&V

PI: James Dabney – Titan Corporation
Government POC: Wes Deadrick – IV&V
Period of Performance: 9/2002–2/2006

http://sarpresults.ivv.nasa.gov/ViewResearch/24.jsp

IV&V has many benefits that are difficult to quantify. The effort of this research is to produce a Return on Investment (ROI) model that could be tailored to an individual project, allowing for the consideration of the effects of different development reliability requirements, different personnel talent, different tool sets, etc. Beyond anecdotal statements that demonstrate the benefit of IV&V, this research outlines a set of activities to produce a customizable ROI model suitable for NASA mission-critical software projects, based on historical data and the baseline NASA IV&V process. It is important to start with a clear definition of ROI. In the case of software IV&V, ROI has multiple components. The primary benefit of IV&V is the reduction in the number of high-severity software errors in the deployed software. High-severity errors when manifested during operations could plausibly result in the loss of life, loss of high-value asset or mission failure. Attempts to ascribe dollar values to such errors are controversial due to the many elements of cost that could be involved. Even for cases in which the component has an identified dollar value (e.g., loss of high-value asset), it is difficult to achieve consensus on whether detection of a defect or even a set of defects really approaches that value. A second ROI approach is to consider only cost-to-fix (referred to as Simple ROI in this proposal). In this approach, the cost of an error is limited to the cost to correct it. Since IV&V results in earlier detection of many errors, a direct and less controversial cost savings can be computed. ROI can then be defined as the ratio of cost savings to the cost of IV&V although that approach lacks the large intangibles that come from detection of high-severity defects. The most recent phase of the ROI for IV&V study has resulted in a prototype approach to modeling defect introduction and defect removal efficiency for IV&V and developers for the entire software life-cycle. This model can be used to assess the potential ROI for new IV&V projects using project data available early in the project life-cycle.

Hubble Telescope Deployment

Validation of System Safety Using Bayesian Belief Networks

PI: Joanne Dugan – University of Virginia
Government POC: Daniel Solomon – IV&V
Period of Performance: 10/2001–3/2005

http://sarpresults.ivv.nasa.gov/ViewResearch/63.jsp

Excellent analysis techniques exist for safety assessment, including formal (axiomatic methods) testing, fault injection, inspections, etc. No one method is appropriate for the entire system and all are difficult to apply to novel systems. A methodology is needed for combining and evaluating qualitative and quantitative evidence of safety gathered via different techniques. The objective of the research is to develop a methodology to validate the safety of a safety-critical computer-based system through the safety case approach. A safety case is built by collecting and evaluating information related to V&V activities. Bayesian belief networks (BBN) are then used to create a qualitative and quantitative evaluation process.

Infusion

Sometimes what seems sensible in the lab does not always translate to the field as we would hope. Research Infusion initiatives provide a practical test for more mature research efforts.

Software Engineering Research/Developer Collaborations

PI: Tom Pressburger – ARC
Government POC: Tom Pressburger – ARC
Period of Performance: 1/2004–12/2007

http://sarpresults.ivv.nasa.gov/ViewResearch/61.jsp

The NASA Software Engineering Initiative Research Infusion is an innovative effort to ensure that theoretical research supports current practicalities. These initiatives pair cutting-edge research with a current development project. The goal is to make sure research that looks good in the lab translates seamlessly to practice. One of the challenges with our work is finding new ways to make our test conditions as much like the real thing as possible. The research infusion effort is our way to make sure that a theory works even under the less than ideal reality inherent in most human-led efforts. In 2005 there were three Research Infusion initiatives: Application of SCR to ISS Biological Research Project On-Orbit Crew Displays at ARC, Application of SpecTRM at JPL's Advanced Project Design Team (TeamX) and Infuse Code Surfer into NASA Code S IV&V Process.

Application of SCR to ISS Biological Research Project On-Orbit Crew Displays at ARC (CI05)

PI: Susan Moran – ARC
Government POC: Tom Pressburger – ARC
Period of Performance: 2/2005–8/2005

http://sarpresults.ivv.nasa.gov/ViewResearch/84.jsp

NASA faces significant challenges and concomitant risks with successful and timely implementation of on-orbit host systems, payloads and crew displays scheduled for the Fundamental Space Biology 1 (FSB 1) Mission. The challenges largely result from multiple and interdependent developments that lack clear and systemic requirements and cross-system conformance to desired properties and behavior. Time and resource constraints that prohibit prototyping with shared lessons learned further magnify NASA's risks. The proposed application of the SCR toolset to one crew system, the incubator display, will result in validation of requirements specifications with the construction of a state-based Software Requirements Specification (SRS), validation of critical properties and intended system behavior and construction of a rapid prototype via the SCR toolset simulation capability. The primary goal is technology infusion on a system already in development to provide a valuable baseline for future developments and transfer of technology expertise. This can be exported to other NASA mission-critical systems and projects, lowering future development and cost risks. A secondary goal is to incrementally validate the SCR toolset.

Application of SpecTRM at JPL's Advanced Project Design Team (TeamX) (CI05)

PI: Lelia Meshkat – JPL
Government POC: Allen Nikora – JPL
Period of Performance: 2/2005–12/2005

http://sarpresults.ivv.nasa.gov/ViewResearch/73.jsp

In final reports generated from a typical TeamX session it is often unclear which design options were considered and dismissed and why they were dismissed. It is not possible to investigate the sensitivity of the design to changes in the design parameters or trace back the many decisions to their causes afterwards. This research will use SpecTRM during the course of a typical TeamX session for capturing the design process, the design options considered, the basis for making the design decisions and the hazards and risk associated with these decisions. The unique features of SpecTRM will be used to provide traceability and hazard analysis to ensure that the reasons behind design decisions are not lost.

Infuse Code Surfer into NASA Code S IV&V Process (CI05)

PI: Michael Beims – SAIC
Government POC: Steve Pukansky – IV&V
Period of Performance: 1/2005–9/2005

http://sarpresults.ivv.nasa.gov/ViewResearch/94.jsp

The IV&V Facility inspects software systems composed of multiple modules often written by different development groups. A critical—and labor-intensive—part of the inspection process is verifying dataflow and control flow across interfaces. Current code-analysis tools provide limited support for this; information from multiple tools must be combined manually. The research will reduce the time to inspect complex software systems for control and data flow issues by using an off-the-shelf software analysis tool with direct forward and backward data and control flow analysis capabilities. The time saved on inspection of auto-generated code is expected to be significant.

1 Pillar I: Services

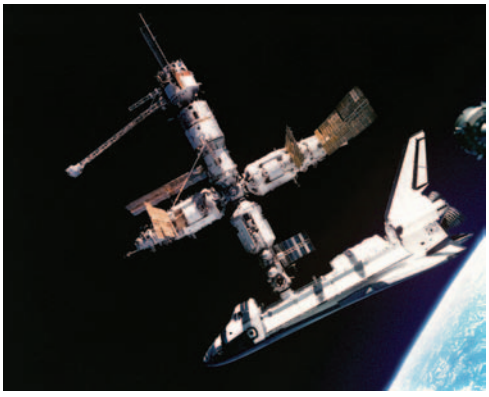
"Man belongs wherever he wants to go—and he'll do plenty well when he gets there."

- Wernher von Braun, Time Magazine, 1958

Hubble First Servicing Extravehicular Activity (EVA)

The NASA IV&V Facility plays a vital role across the entire spectrum of NASA's mission. The Services Project Managers managed IV&V efforts on 34 projects in 2005, as well as supporting planning and scoping efforts for 11 projects. Services and projects vary in size and scope, running the gamut from continuing support of our human spaceflight missions to assessing aspects of the Agency's Integrated Enterprise Management Program, from analysis of flight software components on a space science mission to analysis of software used in an aeronautics test project. In addition to managing IV&V work, many of the project managers act as points of contact for research initiatives, helping to ensure that active IV&V projects benefit from research as well as providing real-life IV&V experience to the research initiatives.

IV&V's work on a given software development project is determined by the results of the criticality analysis performed by IV&V. The criticality analysis process assesses each software component against a set of criteria to determine its relative importance. Criteria include the size of the development effort, its complexity, the risk involved and the consequences if the software component were to fail. The process results in a critical functions list (CFL) that documents the software integrity level of each software component. Based on the CFL, IV&V creates a plan detailing what tasks will be performed on each component—more critical functions demand more extensive analysis. IV&V creates an assessment report, which includes this criticality and risk information, a list of appropriate IV&V tasks and a refined estimate of the IV&V cost for the planned work. Finally, IV&V develops a detailed IV&V plan in accordance with the IV&V work breakdown structure (WBS) and IV&V activities begin.



Supporting Us Here On Earth

Most people naturally think of the Space Shuttle, International Space Station or the Mars Exploration Rovers when they think of NASA. They may not be aware that NASA also works to improve life on Earth. NASA has a variety of aeronautics projects aimed at improvements to air transportation and supports projects that help us learn more about the weather, the atmosphere and other facets of the planet we currently call home. The IV&V Facility supported several of these essential, beneficial efforts in 2005.

Aft Flight Deck (AFD)

IV&V Project Manager: Raju Raymond
IV&V Contractor: L3-Com/Titan Group

The NASA Langley Research Center operates a highly modified B-757 aircraft as a flying laboratory for aeronautical research. Called ARIES, or Airborne Research Integrated Experiments System, the extensively modified aircraft supports a broad range of flight research programs to benefit the U.S. aviation industry. The Aft Flight Deck (AFD) project involves installing a full-size cockpit that supports two crew members in the passenger cabin of the NASA ARIES Flying Laboratory. The project provides government and industry with an efficient means of developing and testing new technology concepts to enhance aircraft safety, capacity and operational needs of the ever-changing Air Traffic Control System and the National Airspace System.

The NASA IV&V Facility started analysis on the selected software components of AFD. IV&V has performed requirements analysis on the research control interface unit (RCIU) and submitted related findings to the project. Future work includes design analysis, software code analysis, software test analysis and interface analysis on the redesigned RCIU. Based on IV&V's analysis and input, the AFD project has been provided additional assurance that no significant risks exist.

For further information on NASA's aeronautics research, visit http://www.aerospace.nasa.gov/

Geostationary Operational Environmental Satellite (GOES) N-Series

IV&V Project Manager: Richard Grigg
IV&V Contractor: L3-Com/Titan Group

The National Oceanic and Atmospheric Administration (NOAA) funds and operates the GOES program. GOES, commonly called weather satellites, do more than just report on the weather. The new N-series satellites, as

compared to the previous series of GOES satellites, will more accurately locate severe storms and other weather phenomena, resulting in more precise warnings to the public. The spacecraft design and geostationary positions enable the primary sensors to stare at Earth and frequently take images of clouds, monitor Earth's surface temperature and sound Earth's atmosphere for its vertical temperature and water vapor distribution. Atmospheric phenomena can be tracked, ensuring real-time coverage of short-lived dynamic events such as severe local storms and tropical hurricanes and cyclones, types of meteorological events that directly affect public safety, property and ultimately economic health and development. The GOES satellites also have a search-and-rescue capability to detect distress signals from hikers, sailors and pilots. In addition to monitoring Earth weather, GOES also will monitor the sun's x-rays for the early detection of solar flares and other space weather. This early warning is important because these solar flares affect not only the safety of humans in high-altitude missions, such as the Space Shuttle, but also military and commercial satellite communications. The IV&V Facility participated in a Mission Readiness Review (MRR) and a Safety and Mission Assurance Readiness Review (SMARR) in 2005. The GOES-N satellite launch has been delayed due to problems unrelated to the software.

For further information about GOES-N, visit http://www.osd.noaa.gov/GOES/ or http://www.nasa.gov/mission_pages/goes-n/main/

Orbiting Carbon Observatory (OCO)

IV&V Project Manager: Wes Sweetser
IV&V Contractor: (To be selected in 2006.)

OCO will make global, space-based observations of atmospheric carbon dioxide (CO^2) with the precision, resolution and coverage needed to significantly increase our understanding of the geographic distribution of CO^2 sources and sinks (surface fluxes) and the processes controlling their variability over the seasonal cycle.

There are three mission objectives:

1. Successfully launch the OCO spacecraft into a sun-synchronous near-polar orbit that provides near global coverage at monthly intervals. The OCO orbit insertion will be synchronized with the A-Train spacecraft to maximize coordination of science observations.
2. Make space-based measurements of atmospheric O^2 and CO^2 to meet the mission goal using an instrument that incorporates three high-resolution grating spectrometers.
3. Record, calibrate, validate, publish and archive science data records and calibrated geophysical data products in the NASA Distributed Active Archive Center for use by the scientific community.

IV&V began a startup assessment of the OCO flight software system to determine the needed level of IV&V support for FY05-FY07. The OCO project team now has a greater understanding of the importance of IV&V in helping to achieve mission success.

For further information about OCO, visit http://oco.jpl.nasa.gov/

Aeronomy of Ice in the Mesosphere (AIM)

IV&V Project Manager: Raju Raymond
IV&V Contractor: SAIC

The AIM mission, part of NASA's Explorers program, is slated for launch in Fall 2006. The AIM mission will provide unprecedented advances in the understanding of polar mesospheric clouds (PMCs), also called noctilucent or "night shining" clouds. The overall goal of the AIM mission is to study why noctilucent clouds form and why they vary. By measuring noctilucent clouds and the environment in which they form, we will learn more about the connection between these clouds and the meteorology of the mesosphere. In the end, this will provide the basis for study of long-term variability in the mesospheric climate and its relationship to global climate changes.[1]

The AIM mission will result in a rigorous validation of predictive models that can reliably use past changes and present trends of noctilucent clouds as indicators of global change. This goal can only be achieved by a complement of instruments on-board the AIM satellite, which will orbit Earth at an altitude of 550 km. These instruments will take wide-angle photos of noctilucent clouds, measure their temperatures and chemical abundances, monitor dusty aerosols and count meteoroids raining down on Earth, all critical factors associated with the formation of noctilucent clouds.

The IV&V Facility is performing IV&V on the AIM spacecraft and three on-board instruments, including

[1] "Strange Clouds"
http://science.nasa.gov/headlines/y2003/18feb_nlc.htm

[continued on next page]

[Aeronomy of Ice in the Mesosphere continued]

the Solar Occultation For Ice Experiment (SOFIE), Cloud Imaging and Particle Size (CIPS) and Cosmic Dust Experiment (CDE). IV&V is contributing to the mission through meticulous analysis of each of the components. To date, IV&V has completed requirements and design analysis efforts. Code and test analysis activities are ongoing. The AIM project agreed to address technical issues associated with software requirements and flight software that IV&V identified and documented as part of its analysis efforts.

For further information about AIM, visit
http://aim.hamptonu.edu

Solar Terrestrial Relations Observatory (STEREO)

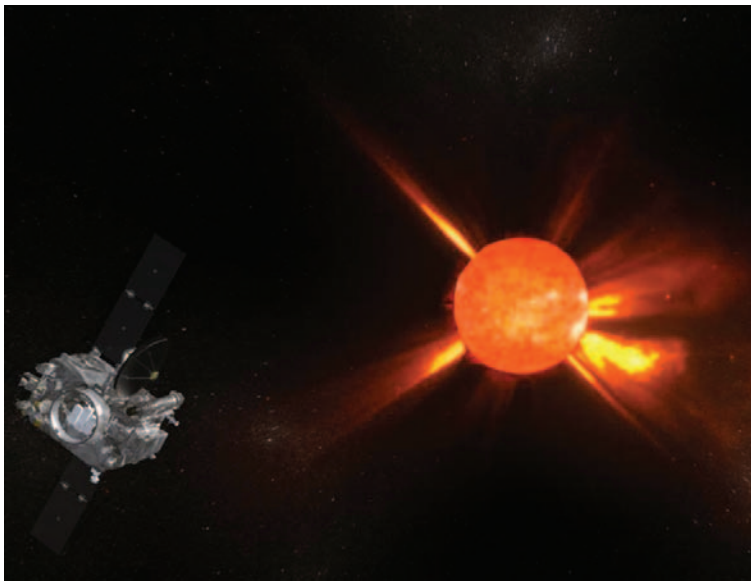
IV&V Project Manager: Steve Pukansky
IV&V Contractor: SAIC

The STEREO mission will provide a new perspective on solar eruptions by imaging coronal mass ejections (CMEs) and background events from two observatories simultaneously. To obtain unique views of the Sun, the twin observatories must be placed into a rather challenging orbit offset from each other. One observatory will be placed ahead of the Earth in its orbit and the other behind using a series of lunar swing-bys. Just as the slight offset between your eyes provides you with depth perception, this placement will allow the STEREO observatories to obtain 3-D images of the Sun.

The IV&V Facility is performing IV&V for the spacecraft flight software (FSW) that includes analysis activities for the command and data handling (C&DH), boot, guidance and control (G&C) and Earth Acquisition subsystems. The team plans to support all major milestone reviews throughout the life of the project. The IV&V team completed analysis of STEREO FSW Build 1 and code reviews on Build 2. Team focus included 1553 bus specification, G&C and C&DH/EA code, IMU data manager, digital solar altitude detector (DSAD) and thruster wheel data manager, flight GN&C algorithm MATLAB® models and the data collection buffers (DCB) package.

IV&V discovered a reaction wheel error message in the design models with incorrect values being sent to the flight software and to the ground. Under certain conditions, improper handling of the message could result in loss of control and eventual loss of spacecraft. The development team has accepted the finding and made the necessary corrections to the models so that the message is handled properly. Software-related discrepancies and issues have been conveyed to the developer and the project management and are being reviewed, resolved or mitigated. The team also participated in the memory object handler and command macro reviews and found no significant issues, providing the STEREO project with additional assurance in those components.

For further information about STEREO, visit
http://stp.gsfc.nasa.gov/missions/stereo/stereo.htm



Solar Terrestrial Relations Obsrvatory (STEREO)

Solar Dynamics Observatory (SDO)

IV&V Project Manager: Thomas Robinson
IV&V Contractor: SAIC

The Solar Dynamics Observatory mission is part of NASA's Living with a Star program. The Sun and Earth are a connected system. Solar variations directly affect Earth's magnetic fields and atmosphere. The Solar Dynamics Observatory, commonly called SDO, will help us develop a better scientific understanding of this Sun-Earth connection that directly affects our life and society. The basic SDO mission objectives seek answers to the questions: How and why does the Sun vary? How does the Earth respond? What are the impacts to humanity?

There are three primary scientific investigations implemented on the Solar Dynamics Observatory. The helio-seismic magnetic imager (HMI) will image the

NASA's ability to track and manage its resources is fundamental to achieving our goals and acting as responsible stewards of the public's money.

Sun's helio-seismic and magnetic fields over the Sun's entire visible disk and help us understand the Sun's interior and magnetic activity. The atmospheric imaging assembly (AIA) and guide telescopes (GT) will capture multiple, simultaneous, full-Sun-view high-resolution images of the Sun's chromosphere and low corona over a wide range of temperatures. The extreme ultraviolet variability experiment (EVE) will measure the solar extreme ultraviolet (EUV) spectral irradiance to help us understand solar variations. SDO is scheduled to launch in August 2008.

Computer software is very important on the Solar Dynamics Observatory. The on-board software for the SDO flight avionics is critical for communications and orbital maneuvering. The SDO instrument software is critical for successful collection of the science data. The NASA IV&V Facility started analysis of the SDO spacecraft and instrument flight software in March 2004. First, the mission critical flight software functions were identified. Then these critical software functions were ranked to establish a priority. This identification and ranking process was performed for the SDO spacecraft's main processor and subsystems and for the instrument systems (HMI, AIA and EVE). Finally, the appropriate IV&V efforts were assigned for each critical software function. Examples of IV&V efforts include software requirements evaluation, traceability analysis, interface analysis, design analysis, software code analysis and software test analysis.

NASA IV&V and the SDO project have developed an excellent working relationship and a number of spacecraft flight software technical issues have been identified and successfully resolved. The SDO project reports that IV&V is demonstrating real "value needed" to SDO mission assurance.

For further information on SDO, visit http://sdo.gsfc.nasa.gov/

Integrated Enterprise Management Program (IEMP) – formerly IFMP

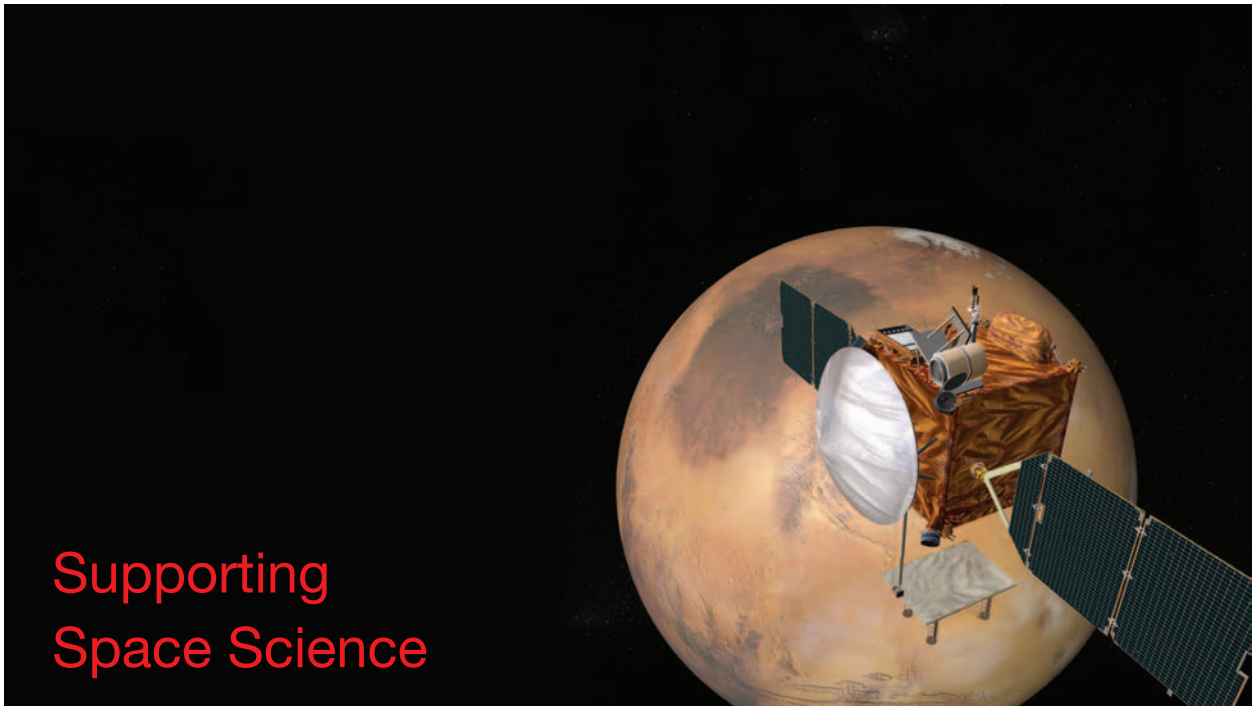
IV&V Project Manager: Pat Callis
IV&V Contractor: L3-Com/Titan Group

Agency-wide management and improvement of financial, physical and human resource processes are at the heart of the Integrated Enterprise Management Program (IEMP). IEMP will dramatically improve NASA's business processes and will greatly increase information collaboration among the centers, which will enhance their ability to support multiple programs by sharing accounting and financial data. This will help improve employee productivity and operational efficiency and increase NASA's fiscal and management accountability by delivering more reliable information. The IEMP will help NASA meet the president's objectives, specifically in the key areas of the President's Management Agenda, including expanded electronic government, strategic management of human capital, improved financial management and budget and performance integration.

The IV&V Facility performed an independent assessment (IA) on specific requirements, design documents, test coverage, application security and risk management aspects of the IEMP system. IV&V produced six requirements traceability reports that provided analysis results for four components of the IEMP effort: integrated asset management (IAM), contract management module (CMM), Agency labor distribution system (ALDS), and project management information improvement (PMII). The reports also provided issues and project risks.

An indication of the level of support IV&V provides comes from the IEMP director, Bobby German: "We value the analysis and reports that the IV&V perform. We use them as a basis for effecting improvements, and reducing risk. They've also served us well regarding external reviews and audits (GAO, OIG,...)"

For further information about IEMP, visit http://iemp.nasa.gov



Supporting Space Science

NASA remains a pioneer in missions to explore space and increase knowledge. NASA's missions are at the forefront of scientific exploration and NASA leads the planning and execution of the missions and their spacecraft. IV&V supports the increasingly software-intensive nature of these projects, providing additional assurance on the software that determines the missions' success.

Dawn

IV&V Project Manager: Stephanie Ferguson
IV&V Contractor: L3-Com/Titan Group

DAWN's goal is to characterize the conditions and processes of the Solar System's earliest epoch by investigating in detail Ceres and Vesta, two of the largest protoplanets remaining intact since their formation. Ceres and Vesta reside in the asteroid belt between Mars and Jupiter. The mission addresses the top-level question on the role of size and water in determining the evolution of the planets. DAWN will provide data on the role of size and water in planetary evolution and form a bridge between the exploration of the rocky inner Solar System and the icy outer Solar System. DAWN will complete the first-order exploration of the inner Solar System, address NASA's goal of understanding the origin and evolution of the Solar System and complement ongoing investigations of Mercury, Earth and Mars.

The IV&V Facility continued performing analysis on selected DAWN spacecraft and digital control interface (DCIU) flight software. This year, IV&V completed level 3 to level 4 traceability analyses for the on-board computer (OBC) and uplink components. The IV&V team performed OBC Build 3.0 code analysis and OBC Build 5.1 code and test analysis. IV&V completed design analysis and OBC flight software Build 4.0 code analysis for the attitude control system (ACS). IV&V also performed DCIU flight software code analysis on version 0.2.2 and code and test analysis on version 1.0.

Throughout our involvement, the DAWN project has been very supportive of IV&V activities and has agreed with our findings. Approximately 95 percent of all issues have been agreed-upon by the project and are awaiting developer implementation and resolution implementation.

For further information about DAWN, visit http://dawn.jpl.nasa.gov/

Gamma Ray Large Area Space Telescope (GLAST)

IV&V Project Manager: Steve Pukansky
IV&V Contractor: SAIC (1/2005–9/20/2005), Northrop Grumman (9/21/2005–present)

Some of the Universe's exotic and beautiful phenomena can generate almost inconceivable amounts of energy. The Gamma-ray Large Area Space Telescope (GLAST) will open the high-energy world of black holes to exploration. With GLAST, astronomers will at long last have a superior tool to study how black holes, notorious for pulling matter in, can accelerate jets of gas outward at fantastic speeds. Physicists will study subatomic particles at energies far greater than those seen in ground-based particle accelerators. Cosmologists will gain valuable information about the birth and early evolution of the Universe.

GLAST is part of the Structure and Evolution of the Universe (SEU) theme, one of four major science themes within the NASA Science Mission Directorate. Through the SEU program scientists seek to explore the limits of gravity and energy in the Universe, explain the structure of the Universe and forecast our cosmic destiny. For this unique endeavor, which brings together the astrophysics and particle physics communities, NASA is teaming up with the U.S. Department of Energy and institutions in France, Germany, Japan, Italy and Sweden. The launch is scheduled for May 2007.

The IV&V Facility is performing IV&V for the spacecraft flight software that includes analysis activities for the command and data handling (C&DH), guidance and control (G&C) and the large area telescope (LAT).

IV&V identified a discrepancy in the definition of the conditions in which the thrusters would be commanded to enable in three operational modes. In addition, IV&V identified a discrepancy in the attitude control policy for all modes in which the thrusters could be used. The nature of this discrepancy is such that under certain conditions, the thrusters could have been improperly operated. IV&V also identified a discrepancy in how the LAT flight software (FSW) requirement modes and FSW implementation modes are addressed through FSW test. This discrepancy could have resulted in incomplete implementation and testing of LAT operational modes. The development teams have accepted these findings and are making the necessary corrections.

For further information about GLAST, visit http://glast.gsfc.nasa.gov/

Hubble Space Telescope Servicing Mission 4 (HST SM4)

IV&V Project Manager: Markland Benson
IV&V Contractor: SAIC

The last originally planned Shuttle servicing mission to Hubble (known as SM4) was cancelled in January 2004 over concerns for astronaut safety in the wake of the Columbia Shuttle tragedy in February 2003. For essentially the remainder of 2004 and extending into early 2005, NASA and the HST program performed studies and early planning for a possible robotic servicing mission that, if successfully executed, would have achieved all of the primary SM4 goals. These included the installation of six fresh gyros, six new batteries, a fine guidance sensor and two advanced science instruments, the Cosmic Origins Spectrograph (COS) and the Wide-Field Camera 3 (WFC3). The goal of either type of servicing mission, Shuttle or robotic, was to extend Hubble's science life by at least five years and to bring it critical new scientific capabilities.

Hubble Space Telescope

The IV&V program supported the robotic servicing mission starting with attendance at technical interchange meetings in October 2004. IV&V reviewed system and software requirements for the Deorbit Module, Ejection Module, Hubble 486 and Robotic System subsystems

[continued on next page]

Supporting Space Science (continued)

[Hubble continued]

of the robotic servicing mission up to and including the Preliminary Design Review mission milestone.

At his April 2005 confirmation hearing before the U.S. Senate, as well as in subsequent statements, NASA Administrator Michael D. Griffin testified to the extraordinary scientific value of Hubble. He indicated his desire to take the robotic servicing mission "off the plate" on the basis of mission complexity, and reconsider an SM4 Shuttle-astronaut mission to Hubble. His rationale is that after the Shuttle's return to flight, particularly after all the Shuttle improvements that precede RTF, NASA will essentially have a new Shuttle vehicle and system in the context of astronaut and mission safety. After successes in RTF and the following flight, if analysis shows that the risk levels associated with a Hubble mission are sufficiently low and manageable, SM4 could be reinstated by the Administrator.

The IV&V program has reviewed prior analysis results from the original SM4 in preparation for revitalization of Shuttle-based Hubble servicing. IV&V plans to perform requirements traceability, test analysis and issue tracking to assure that the COS and WFC3 instruments are ready for installation aboard the Hubble Space Telescope.

Hubble Servicing Mission 4 is tentatively planned to launch in December 2007.

For further information on HST, visit
http://hubble.nasa.gov/

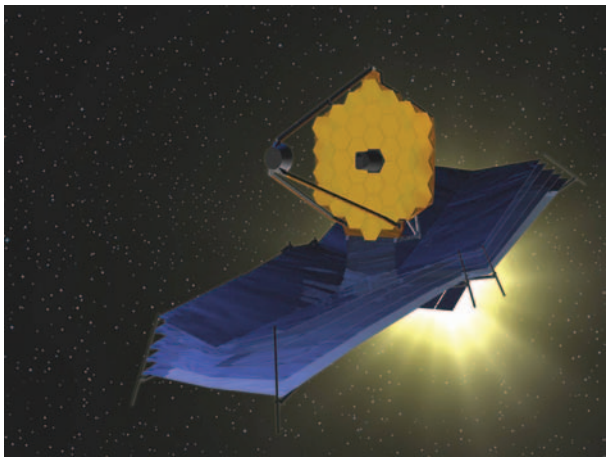
James Webb Space Telescope (JWST)

IV&V Project Manager: Ken Vorndran
IV&V Deputy Project Manager: Jerry Sims
IV&V Contractor: SAIC (7/2003–10/2005);
L3-Com/Titan Group (11/2005–present)

The James Webb Space Telescope (JWST) is an orbiting infrared observatory, scheduled for launch in 2013, that will take the place of the Hubble Space Telescope. The JWST will study the Universe at the important but previously unobserved epoch of galaxy formation. It will peer through dust to witness the birth of stars and planetary systems similar to our own. Using JWST, scientists hope to get a better understanding of the intriguing dark matter problem. JWST is designed to study the earliest galaxies and some of the first stars formed after the Big Bang. These early objects have a high red-shift from our vantage point, meaning that the best observations for these objects are available in the infrared.

JWST's instruments will be designed to work primarily in the infrared range of the electromagnetic spectrum, with some capability in the visible range.

Some of the goals of the JWST mission include determining the shape of the Universe, explaining galaxy evolution, understanding the birth and formation of stars, determining how the planetary systems form and interact, determining how the Universe came to have its present chemical/elemental composition and probing the nature of dark matter.



James Webb Space Telescope (JWST)

The IV&V Facility has performed IV&V on the Instrument Command and Data Handling (IC&DH) software. Specific analysis performed included code and test program analysis. During this year the IV&V Facility expanded the scope of the IV&V efforts to include performing IV&V on the spacecraft, Integrated Science Instrument Module (ISIM) applications and Ground Segment software. Specific analysis performed includes requirements and traceability analysis, design analysis, code analysis and test program analysis. All of these analysis activities resulted in the identification of defects that the JWST Project has acknowledged and on which it has taken or initiated corrective action.

In addition, as part of the IV&V Facility performing IV&V on JWST, IV&V personnel attended nearly 25 formal and informal lifecycle reviews. These activities provided an independent and objective perspective of the JWST software development efforts and software-related products.

For further information about JWST, visit
http://www.jwst.nasa.gov/

Kepler

IV&V Project Manager: Richard Grigg
IV&V Contractor: L3-Com/Titan Group

Kepler is a special-purpose space mission in the NASA Headquarters Discovery Program for detecting terrestrial (rocky and Earth-sized) planets around other stars. When a planet passes in front of (transits) its parent star, as seen by us, it blocks a small fraction of the light from that star. If the dimming is truly caused by a planet, then the transits must be repeatable. Observing a minimum three transits, all with a consistent period, duration and change in brightness provides a rigorous method for discovering and confirming planets, even those smaller than the Earth. From the brightness change, the planet size can be calculated. From the period, the orbital size can be calculated and the planet's temperature estimated. Kepler will work with Earth-bound telescopes to verify the planets it discovers.

In addition to finding Earth-like planets, the Kepler mission will strive to learn about the structure and diversity of planetary systems. Some of the things we hope to learn are the size, mass, frequency and semi-major axes of planets in or near the habitable zone of a wide variety of stars. Kepler will help us estimate the frequency and orbital distributions of planets in multiple-stellar systems. The Kepler mission also supports the objectives of the NASA Origins Space Interferometry Mission (SIM) and Terrestrial Planet Finder (TPF) Mission.

IV&V traced requirements and highlighted inconsistencies. IV&V will look at field programmable gate arrays (FPGA) and the software used to program them.

IV&V has helped the Kepler project team more fully understand the process and benefits of IV&V in achieving mission success. The Kepler team has requested that IV&V perform code analysis on heritage code, which is code "inherited" from other spacecraft missions and planned for reuse on the Kepler mission.

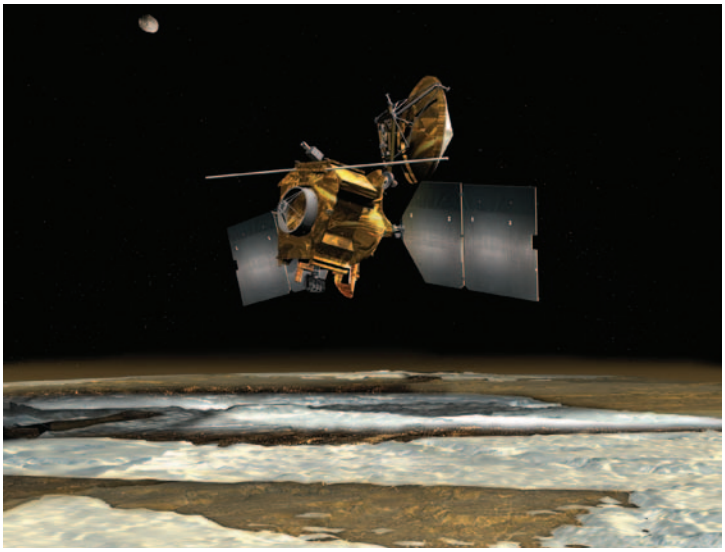
For further information about Kepler, visit http://www.kepler.arc.nasa.gov/

Mars Reconnaissance Orbiter (MRO)

IV&V Project Manager: Richard Grigg
IV&V Contractor: L3-Com/Titan Group

NASA's Mars Reconnaissance Orbiter (MRO), launched August 12, 2005, is on a search for evidence that water persisted on the surface of Mars for a long period of time. While other Mars missions have shown that water flowed across the surface in Mars' history, it remains a mystery whether water was ever around long enough to provide a habitat for life. After a seven-month cruise to Mars and six months of aerobraking to reach its science orbit, MRO will seek to find out about the history of water on Mars with its science instruments.

In its survey of the red planet, MRO will increase tenfold the number of spots surveyed close-up. One of the MRO's cameras is the largest ever flown on a planetary mission. While previous cameras on other Mars orbiters could identify objects no smaller than a school bus, this camera will be able to spot something as small as a dinner table. That capability will also allow the Orbiter to identify obstacles like large rocks that could jeopardize the safety of future landers and rovers. Its imaging spectrometer will also be able to look at small-scale areas about five times smaller than a football field, at a scale perfect for identifying any hot springs or other small water features.



Artists rendering of the Mars Reconnaissance Orbiter as it orbits over the martian poles

The Orbiter's telecommunications systems will establish a crucial service for future spacecraft, becoming the first link in a communications bridge back to Earth, an

[continued on next page]

Supporting Space Science (continued)

[Mars Reconnaissance Orbiter continued]

"interplanetary internet" that can be used by numerous international spacecraft in coming years. Testing the use of a radio frequency called Ka-band, MRO may demonstrate the potential for greater performance in communications using significantly less power. The Orbiter also carries an experimental navigation camera.

The IV&V Facility performed IV&V on the flight software and firmware known as Field Programmable Gate Arrays (FPGA). Specific analysis that IV&V has performed includes requirements, traceability, interface, code and test analysis. As a result of our code analysis activities, IV&V identified some portions of the code that might not work properly. The MRO project has since changed those portions of the code. IV&V will be providing analysis on a planned post-launch software upload. According to JPL MRO Project Manager Jim Graf, "The MRO project and the IV&V team worked well together towards a common goal: a successful MRO mission. A process was defined that enabled both organizations to complete their assigned tasks without conflicting with one another and together they reduced the risk posture of the mission."

For further information about MRO, visit
http://mars.jpl.nasa.gov/mro/

Mars Scout Phoenix Lander (PHOENIX)

IV&V Project Manager: Dan Solomon
IV&V Contractor: L3-Com/Titan Group
(5/2005–8/2005);
Northrop Grumman (8/2005–present)

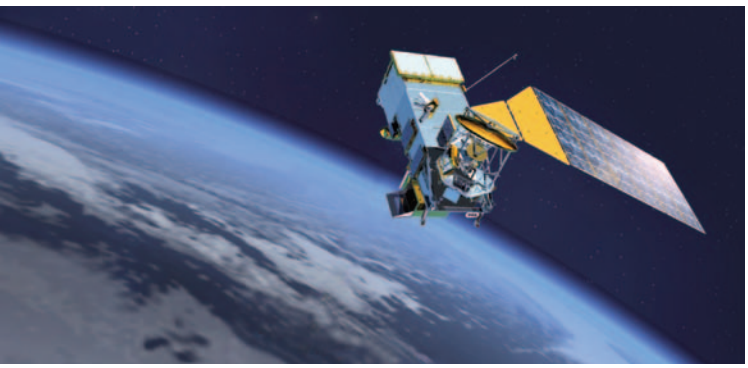
The Phoenix mission is the first chosen for NASA's Scout program, a competitive initiative for smaller, lower-cost, spacecraft. Named for the resilient mythological bird, Phoenix uses a lander intended for use by 2001's Mars Surveyor mission prior to its cancellation. It also carries a complex suite of instruments that are improved variations of those that flew on the lost Mars Polar Lander. In the continuing pursuit of water on Mars, the poles are a good place to probe, as water ice is found there. The Phoenix mission is scheduled for launch in August 2007 on a 10-month journey culminating in a landing in the high northern latitudes of Mars. During the course of the 90 Martian-day mission, Phoenix will deploy its robotic arm and dig trenches up to half a meter (1.6 feet) into the layers of water ice. These layers, thought to be affected by seasonal climate changes, could contain organic compounds that are necessary for life. To analyze soil samples collected by the robotic arm, Phoenix will carry an oven and a portable laboratory. Selected samples will be heated to release volatiles that can be examined for their chemical composition and other characteristics. Imaging technology inherited from the Pathfinder and Mars Exploration Rover missions will also be implemented in Phoenix's stereo camera, located on its 2-meter (6.6-foot) mast. The camera's two "eyes" will reveal a high-resolution perspective of the landing site's geology and will also provide range maps to enable the team to choose ideal digging locations. Multi-spectral capability will enable the identification of local minerals. To update our understanding of Martian atmospheric processes, Phoenix will also scan the Martian atmosphere up to 20 kilometers (12.4 miles) in altitude, obtaining data about the formation, duration and movement of clouds, fog and dust plumes. It will also carry temperature and pressure sensors.

The aeroshell which contains the Phoenix lander is visible in the close-up view of the spacecraft entering the martian atmosphere.

The IV&V Facility is performing IV&V for the Flight Software that includes analysis activities for the Spacecraft, Telecom, Guidance, Navigation and Control, and Payload subsystems. The team has supported all major milestone reviews since preliminary design review in March 2005. The IV&V team completed analysis of the software and interface requirements. Analysis has begun on the design, code and test artifacts.

To date, IV&V has found no issues that could prevent accomplishment of any essential capability. However, corrections and/or workarounds are being sought for those issues found by the team that could have an adverse affect on essential capabilities.

For further information about Phoenix, visit
http://phoenix.lpl.arizona.edu



National Polar-Orbiting Operational Environmental Satellite System Preparatory Project (NPP)

IV&V Project Manager: Stephanie Ferguson
IV&V Contractor: L3-Com/Titan Group

The National Polar-Orbiting Operational Environmental Satellite System (NPOESS) will provide long-term systematic measurements of key environmental variables beginning about 2009. In preparation for this system, NASA and the Integrated Program Office are conducting a joint mission, the NPOESS Preparatory Project (NPP). NPP will provide risk reduction for this future operational system and will maintain continuity of certain environmental data sets initiated with NASA's Terra and Aqua satellites. Launch is now scheduled for April 30, 2008.

These measurements will be taken by three different sensors:

VIIRS: Visible Infrared Imaging spectro Radiometer Suite

CrIS: Crosstrack Infrared Sounder

ATMS: Advanced Technology Microwave Sounder

The data collected by these sensors will be processed into sensor data records (SDRs). The SDRs are used to create environmental data records (EDRs), which are operational data products, and climate data records (CDRs) for long-term climate and global change studies.

IV&V participated in code and test procedure walkthroughs for the Spacecraft Control Computer (SCC) and the Command and Data Processor (CDP) spacecraft flight software. The developer has agreed to address all issues (project and IV&V) identified during the walkthroughs. Throughout the year, IV&V attended 1394 architectural and code reviews as well as the Pre-Mission Operations Review (MOR) in August, 2005.

For further information about NPOESS, visit http://jointmission.gsfc.nasa.gov/

New Horizons Pluto-Kuiper Belt (PKB)

IV&V Project Manager: Peter Medley
IV&V Contractor: L3-Com/Titan Group

Pluto, the smallest planet, is the only planet not yet visited by a spacecraft. Discovered in 1930, it is sometimes likened to a large asteroid or comet, or even a double planet system, since its moon, Charon, is about half the diameter and mass of Pluto. Today it is understood that Pluto and Charon were former inhabitants of the mysterious Kuiper Belt, which resides outside the orbit of Neptune. Most of what we know about Pluto we have learned since the late 1970s from ground-based observations, the Infrared Astronomical Satellite (IRAS) and the Hubble Space Telescope. Many of the key questions about Pluto and its satellite, Charon, await the close-up observation of a spaceflight mission. Recent discoveries of numerous planetoids outside of Pluto's orbit, some with companion moons, add to the excitement of the riches that the New Horizons project may return.

The spacecraft will use a remote sensing package that includes imaging instruments and a radio science investigation, as well as spectroscopic and other experiments, to characterize the global geology and morphology of Pluto and its moon, Charon, map their surface composition and characterize Pluto's neutral atmosphere and its escape rate.

IV&V is being performed on selected software components as described in the New Horizons critical functions list (CFL) report created by IV&V. All major software subsystems of the project are being analyzed, including Guidance and Control, Command and Data Handling, Autonomy, Instrumentation and Ground Systems. Requirements and design analysis have been completed, with code analysis and preliminary test analysis under way.

IV&V identified a risk regarding APL's command verification coverage. APL ultimately agreed and developed a tool to confirm what commands and command permutations have been exercised during acceptance testing. For cases where commands or significant portions of command parameters had not been tested, new acceptance tests were written to address those shortfalls.

IV&V identified 28 requirements in the Autonomy Software Requirements which were levied against the subsystems, but were not traced to the appropriate subsystem specifications. APL addressed this traceability issue. Ensuring that proper traceability is in place helps prevent functionality from being overlooked in development and verification. IV&V identified 16 critical

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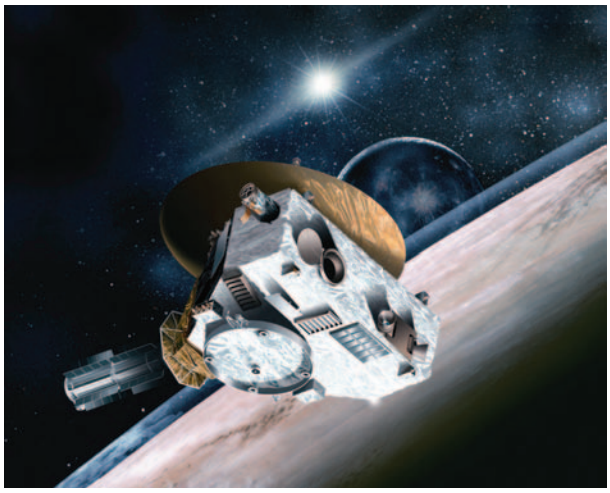
[New Horizons Pluto-Kuiper Belt continued]



The spacecraft shown in this artist's rendering will use a remote sensing package that includes imaging instruments and a radio science investigation, as well as spectroscopic and other experiments, to characterize the global geology and morphology of Pluto and its moon, Charon, map their surface composition and characterize Pluto's neutral atmosphere and its escape rate (artist rendering).

instances of autonomy persistence being in disagreement with requirements. In each case the differences would result in the system not responding during a fault as intended. Through a combination of autonomy rule changes and requirement changes these disagreements were fixed prior to acceptance testing and flight.

IV&V has provided feedback to the project on issues that have been identified by our analysis as well as on issues raised during appropriate project reviews and walkthroughs. IV&V has also provided feedback to the project on risk management processes and associated impact.

For further information about New Horizons, visit http://solarsystem.jpl.nasa.gov/

Time History of Events and Macroscale Interactions During Substorms (THEMIS)

IV&V Project Manager: Judi Connelly
IV&V Contractor: SAIC

THEMIS is a NASA Sun-Earth Connection mission under NASA's Science Mission Directorate. The program's primary goal is understanding the changing Sun, its effects on the Solar System and the Earth's environment. Understanding space weather near the Earth, in part, requires an understanding of how the Earth's magnetosphere reacts to the protons and electrons coming from the Sun via solar wind or through coronal mass ejections. Disruption of satellite communications and the polar auroral display known as the Northern Lights reveal evidence of these reactions.

Scheduled to launch in late 2006, the THEMIS mission contains a complement of instruments on five spacecraft probes deployed throughout the Earth's magnetic field and 20 ground observatories throughout Canada and the northern U.S. A solar event will trigger disruptions throughout the Earth's magnetic field. The instruments on the probes measure these disruptions in the form of electric field, magnetic field and plasma movement.

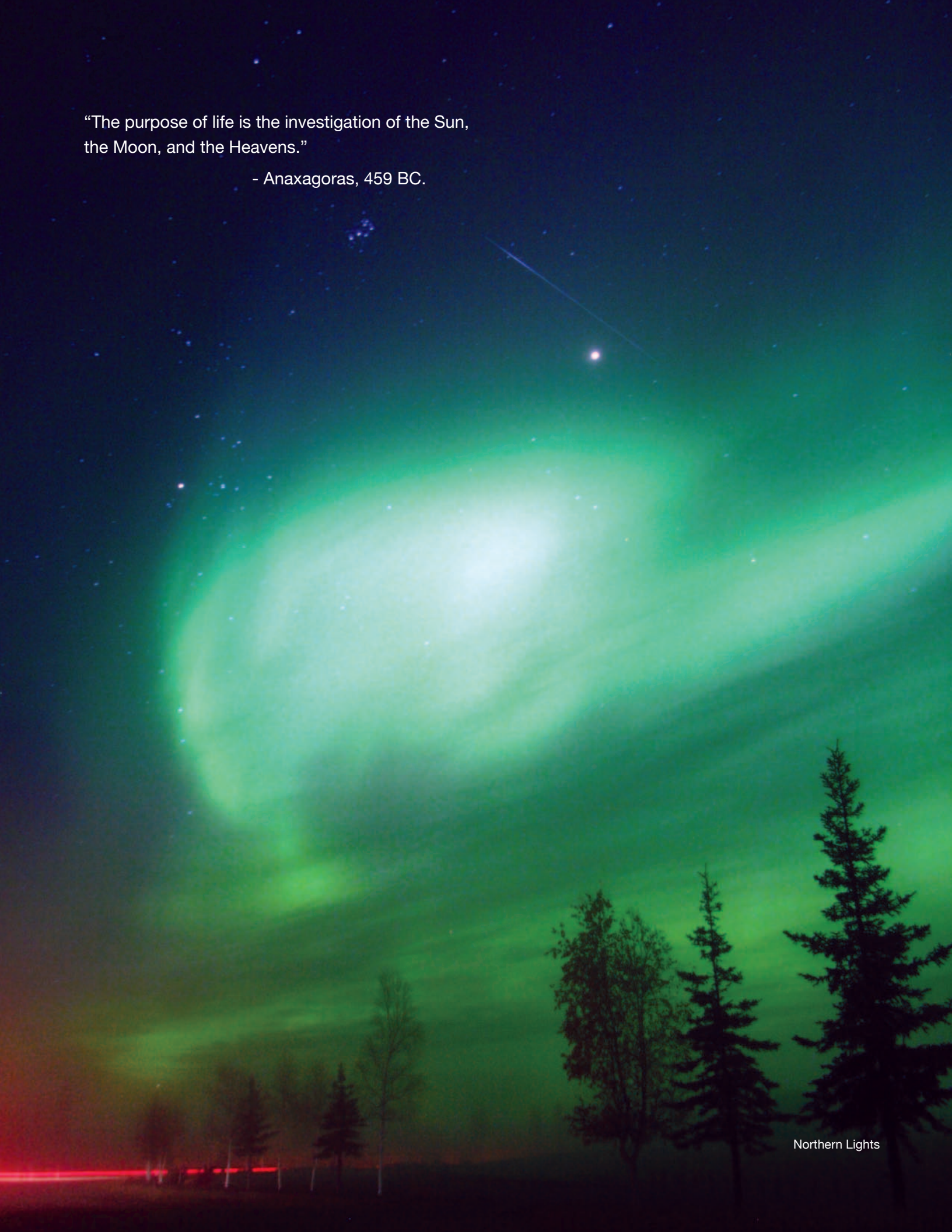
Three inner probes at~10 Earth radii (Re) monitor current disruption onset, while two outer probes at 20 Re and 30 Re remotely monitor plasma acceleration. The same disruption will eventually disturb the Earth's atmosphere by ionizing atoms causing them to travel along magnetic field lines resulting in the Northern and Southern lights. The ground observatories then measure the onset of the aurora in the northern pole region and coordinate this measurement with the probes' detection of the same event.

The flight software is critical for the successful collection of science data as well as various orbit maneuvering required throughout the mission lifetime. The critical flight software functions in each of three main subsystems are the Instrument Data Processing Unit (IDPU), the Bus Avionics Unit (BAU) and the Attitude Control and Maneuvering components of the Ground System. IV&V is contributing to the mission through analysis of each of the components. Specifically, the IV&V team identified a Severity 1 Technical Issue Memorandum (TIM) using the Polyspace Tool. The pointer used to reference the time of the updated thruster firing values was not set to a valid address before being used as a destination address. Since the data in question is the start and stop times for thruster firing, the impact to the mission could be severe if these values were lost or corrupted before they could be used. The Project developer responded immediately to correct this error.

For further information about THEMIS, visit http://sprg.ssl.berkeley.edu/themis/flash.html

“The purpose of life is the investigation of the Sun, the Moon, and the Heavens.”

- Anaxagoras, 459 BC.



Northern Lights

Supporting Human Space Exploration

The IV&V Facility got its start on the International Space Station. Since 1997, we have also provided services for the Space Shuttle program. In addition, we've worked on smaller projects that have safety impact on our human spaceflight programs. Human safety is always our first concern.

BUMPER-II – For the NASA Engineering and Safety Center (NESC)

IV&V Project Manager: Marcus Fisher
IV&V Contractor: SAIC

The BUMPER-II system is used at the Johnson Space Center (JSC) during International Space Station (ISS) and Space Shuttle missions to determine the probability of the impact or penetration of either vehicle by a meteoroid or orbital debris. The analysis code calculates the probability of no penetration (PNP) or the probability of no impact (PNI) for a spacecraft subjected to man-made orbital debris and meteoroid impacts.

The IV&V Facility, at the request of the NASA Engineering and Safety Center (NESC), performed an independent assessment on the BUMPER-II code to increase the confidence in the probabilities predicted by the system.

The objectives of the IV&V effort were to assure that the software performs as intended and that there were adequate artifacts (e.g., requirements and design documents) and processes in place to support the maintenance of the system. To achieve those objectives, the IV&V team performed numerous activities, including a detailed inspection of the system's Fortran 77 code. Code inspection was used to determine if there were any latent defects and to analyze how well the code conformed to the syntax of the language. In addition, a small set of test cases were run to assure the results were as expected and to assess the uncertainty of the numerical solution.

The IV&V team concluded their work in March 2005, which resulted in the generation of numerous recommendations so that the BUMPER-II code can be improved and maintained efficiently. The remainder of the year was spent working on the technical findings with the BUMPER-II stakeholders as well as supporting technical briefings at NASA Headquarters. The IV&V team was thoroughly impressed with the development of the BUMPER code, given its history, and they remain committed to the successful operation of the code.

For further information about the NESC's work, visit http://www.nesc.nasa.gov/

Fluids and Combustion Facility (FCF)

IV&V Project Manager: Tom Macaulay
IV&V Contractor: L3-Com/Titan Group

The Fluids and Combustion Facility (FCF) is a modular, multi-user facility developed by Glenn Research Center (GRC) to support microgravity fluid physics and combustion science experiments utilizing the United States Lab Module onboard the International Space Station (ISS).

Fluids and combustion experiments will be conducted within the FCF on orbit, controlled by Principal Investigators working in their laboratories and offices on the ground. Ground control is facilitated by the Telescience Support Center (TSC) at GRC. Astronauts onboard the ISS will be able to perform some FCF operations (setup, maintenance and troubleshooting) using a laptop computer known as the SSC (Station Support Computer). The primary FCF experimenters are intended to be scientists on the ground.

Thanks to the understanding of combustion processes in microgravity gained using the FCF, astronauts on orbit or en route to the Moon or Mars may be able to extinguish accidental fires more quickly, making long-duration spaceflights safer. FCF's research may lead to methods for lowering gas furnace pollution, a significant factor in atmospheric contamination. Additionally, fluid science experiments offer ways to improve commercial industrial practices and contribute to advances in public medicine and the treatment of disease.

Software plays a major role in the FCF. As most of the experiments will be conducted remotely, software is required to control and ensure the system is safe during combustion and fluid processes. An IV&V team is performing an independent assessment of the most mission-critical software components, focusing on requirements, testing and code analysis. By assuring that FCF software requirements are completely tested and inspecting the code for errors that cannot be caught by standard compilation tools, the IV&V team helps ensure that the objectives of the FCF will be met while maintaining the safety of the astronauts.

The IV&V Facility has helped the FCF project clarify its requirements and ensure that test procedures are accurate and complete. The IV&V team discovered three code sequences that could have led to unpredictable results. Based on IV&V's observations, the FCF project software team reworked those code sequences, improving the safety of the system. The IV&V code analysis team also discovered a difficult-to-detect coding error that potentially saved the FCF project team hardware replacement costs and hours of troubleshooting time.

For further information on FCF, visit
http://exploration.grc.nasa.gov/fcf/

International Space Station (ISS)

IV&V Project Manager: Deborah Kromis
IV&V Contractor: L3-Com/Titan Group

The International Space Station (ISS) is NASA's space laboratory, utilizing the microgravity environment present in space as a tool to do research. This research in microgravity unmasks phenomena that Earth's gravity can obscure, allowing researchers to gain useful insights into what are known as zero-g-induced occurrences that do not happen on Earth. Not only can the experiments only be done in zero gravity, those same experiments can be conducted for much longer durations than are possible aboard the Space Shuttle.

The successful work performed by the ISS IV&V team is exemplified through the receipt of numerous awards (i.e., Silver Snoopy, Flight Safety, Team Award and Leader Award). The team has been cited numerous times in Aerospace Safety Advisory Panel (ASAP) reports and has received the Space Station Program Office Team Excellence Award.

View of the International Space Station (ISS)

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[International Space Station continued]

The IV&V Facility is examining the safety and mission-critical software in every U.S. component of the ISS. This year, the IV&V Facility continued to support the Centrifuge Rotor software developed by the Japanese Space Agency (JAXA). The IV&V Facility also began support of the Regenerative Environmental Control and Life Support System (R-ECLSS) racks. Three major components comprise the R-ECLSS: Oxygen Generation Assembly (OGA), Water Processor Assembly (WPA) and Urine Processor Assembly (UPA). IV&V's primary focus is on the OGA as its development is being accelerated in order to fly the OGA in 2006.

Due to the diversity of applications, wide variety of domains and discipline expertise requirements to support the subsystems of the ISS, the IV&V ISS project is divided into nine different IV&V teams, each supporting specific ISS subsystems. Expertise is then applied synergistically, or as a combined effort, to ensure that the ISS software functions as a complete system, reliably and safely.

Before each assembly is flown into space, the IV&V Facility team performs a flight software readiness assessment. This assessment identifies the team's independent evaluation of the software readiness to support the assembly and helps determine the approval for the Certificate of Flight Readiness (CoFR).

The IV&V team continuously provides benefit to the ISS program and has been recognized by the program as the technical experts for the ISS flight software. In 2005, the IV&V team supported the uplink of the Payload Executive Processor Release 5 (PEP R5) and Portable Computer System Release 9 (PCS R9) system. The IV&V ISS team also supported the Safety and Mission Assurance Readiness Reviews (SMARR) for the Shuttle Return to Flight.

For further information about the ISS, visit http://spaceflight.nasa.gov/station/

Personal Computer Ground Operations Aerospace Language 2 (PCG2)

IV&V Project Manager: Wes Sweetser
IV&V Contractor: L3-Com/Titan Group

The Personal Computer Ground Operations Aerospace Language 2 (PCG2) system is an advisory system consisting of a set of computer platforms, network hardware and software aimed at providing increased situational awareness for Shuttle processing personnel. The PCG2 system collects, merges and filters data from other Shuttle ground processing systems and provides it to the user for display. The PCG2 system leverages the existing PC GOAL Certified Data Advisory System, providing new system advisory capabilities and enhancing existing ones. The ability to understand what is going where during Space Shuttle processing or launch operations is increased through additional and enhanced system capabilities and through additional advisory applications and user displays that execute on the PCG2 system. The PCG2 system has no command and control capabilities but the PCG2 software and hardware system will be certified to perform advisory functions on the Space Shuttle program. Possible advisory functions include using the PCG2 system to verify that Space Shuttle Operational and Maintenance requirements are being met, make Launch Commit Criteria violation calls, monitor trends or perform data analysis, system troubleshooting and problem resolution.

The IV&V Facility began performing IV&V on the PCG2 project in 2004. During Phase 0 of the project IV&V worked informally, documenting programmatic and technical issues. For Phase 1, IV&V put a formal agreement in place and is reviewing test procedures for Phase 1 of the project.

During the past year, IV&V identified critical programmatic areas of concern. These included the lack of a software safety plan and concept of operations (ConOps) document. The program accepted the issues and addressed them.

Space Shuttle

IV&V Project Manager: Melissa J. Bodeau
IV&V Contractor: L3-Com/Titan Group

The Space Shuttle is the world's first reusable spacecraft and the first spacecraft in history that can carry large satellites to and from orbit. The Shuttle launches like a rocket, maneuvers in Earth orbit like a spacecraft and lands like an airplane. The Space Shuttle and its software are immensely complex systems. IV&V of Shuttle software is crucial to providing the high level of safety and mission assurance necessary when human life is at stake.

IV&V's work on the Shuttle primarily involves the software in the onboard General Purpose Computers (GPCs) and Multi-function Electronic Display Subsystem (MEDS), in the Space Shuttle Main Engine Controller (MEC), and in the Miniaturized Airborne GPS Receivers (MAGR) flown onboard. IV&V is performed on critical changes to the existing GPC, MEDS and MEC software, as well as several other critical software areas. Each change is analyzed with appropriate requirements, design, code, test and systems analysis tasks to ensure both the correctness of the final software and that there are no unintended consequences to the unchanged areas.

In 2005, IV&V supported the Shuttle's Return to Flight. Over the past several years, IV&V analyzed the new release of flight software and flight-specific changes for the mission. As we have for Shuttle flights in the past, we participated in the Software Readiness Review conducted by the Shuttle's Flight Software Office. IV&V is also a voting participant in the Safety and Mission Assurance Readiness Reviews conducted by astronaut Bryan O'Connor, the Agency's Chief of Safety and Mission Assurance prior to any launch or safety-critical activity. All the members of the Shuttle IV&V team are proud of our contribution to the success of the STS-114 mission and look forward to the next time a crew safely soars into orbit and returns to Earth.

For further information about the Space Shuttle, visit http://www.nasa.gov/centers/johnson/missions/shuttle.html or http://spaceflight.nasa.gov/shuttle/

Liftoff of the Shuttle's return to flight in 2005

“We cannot rest on nor be satisfied with past accomplishments. The true space age, in which humans will explore the worlds beyond our own, is just getting underway.”

Dr. Mike Griffin
NASA Administrator

Footprints on Mars (Artist’s Rendering)

Our Future…

As we look back on 2005, we are proud of the great strides in advancing the discipline and practice of IV&V that have been made by our IV&V team. Now, our IV&V project managers, researchers, outreach, administrative and Facility support staff and our contractors expand their sights toward the Moon and beyond.

- Our Outreach initiatives will help ensure that there is a next generation of scientists, researchers, systems engineers and project managers to populate a new frontier of space science and technology that is now within reach only in our imaginations. These initiatives also help strengthen public knowledge, support, and appreciation for NASA's vision, mission, and accomplishments.

- Our Research promises new insight and practical processes, tools and procedures to take software development and software assurance to the next level, needed to carry out our ambitious and far-reaching missions. Our growing international partnerships and presence will generate further advances and benefits.

- Our IV&V Services are being requested by NASA's mission directorates, now convinced that we are needed on critical missions. This increased understanding of the value of IV&V has been driven by the persistence and demonstrated excellence of the IV&V team. We are now in a position to begin critical early support of NASA's boldest new initiative, the Constellation program. Under Constellation, projects will develop a new family of crewed exploration vehicles, payload delivery vehicles and a series of robotic explorers. The work ahead involves integrating new approaches to software development/assurance and new software technologies into these programs. The IV&V Facility anticipates its full involvement with the missions of the Crew Exploration Vehicle (CEV) and the Crew Landing Vehicle (CLV), providing our software expertise at the early stages of each project.

The IV&V Facility has certainly come of age. We provide analysis on the agency's most critical software efforts. Our expertise benefits the entire Agency, and our services and expertise are sought both inside and outside of the Agency. Our financial, technical and managerial independence ensures we are empowered to do the right thing. Our goal is simple and straightforward—we want the missions we work on to be safe and successful, and we take great pride in our contribution to their success.

We look forward to our future as we prepare to support humankind's most exciting adventures—returning to the Moon and then on to Mars. The efforts we will support will test our technical expertise and our managerial capabilities. The work is historic and our participation, along with that of thousands of other dedicated individuals, is vital. We are confident that we are up to the challenge of launching into a new era of exploration and discovery.

CREDITS

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"Liftoff!" Artist's Concept of NASA's New Spaceship
Credit: NASA/John Frassanito and Associates
http://www.nasa.gov/mission_pages/exploration/spacecraft/cev_hi_res.html

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Credit: NASA/John Frassanito and Associates
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