Mapping Our Progress

NASA IV&V Facility Activities, Processes, and Programs 2003

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OUR VISION

To be recognized as the preeminent organization applying and improving independent verification and validation for software and systems.

OUR MISSION

To ensure that our customer's mission-critical software and systems are reliable and safe and of the highest quality by applying software and systems expertise and tools while researching new approaches, deploying innovative solutions, providing a learning environment, and participating in the vitality of the community.

DEAR READER:

This inaugural edition of *Mapping Our Progress* offers a comprehensive review of NASA IV&V activities during the past year with emphasis on the significant programs we proudly support. I invite you to read how we are doing and learn why NASA IV&V continues to be an important partner in the integrated work of NASA.

Whether you are well versed in the technical aspects of our work or a casual reader with general interest about what we do, I think you will find something of interest inside. If you are seeking more technical program details about what we do, you will find the program abstracts section of particular value.

During the past year, the Facility has worked diligently to make our customer interface process easier and more productive. Over the past two years, we have increased the NASA staff two-fold and along the way have more than tripled the programs we currently support.

Notwithstanding these achievements, we have worked relentlessly to improve our processes of Independent Verification and Validation (IV&V) with the identification and enabling of research opportunities. We have built a stronger organization and established a firm financial foundation. We can proudly and confidently point to the recognized quality of our work, at the accomplishments made over the past twelve months, and the positive promise of our future.

In 2003 NASA IV&V also completed a multiple-year implementation plan that is now shaping our work. The plan, available under separate cover, provides an appropriate balanced approach to our work on programs, research, and education. Further, it clearly states a commitment to be actively involved in our local communities. You will find information in this report in all these vital areas.

I am so very proud of our NASA IV&V staff and the many contractors who provide services to us. Together, we are gratified by the strong, meaningful support from all parts of NASA and by the stakeholders who have continued to believe in our work and the value of IV&V, both today and for tomorrow.

Our success depends on our daily work, but also on our research, training, and the support of our community. This report clearly demonstrates our commitment to our customers and to our community. I wholeheartedly welcome direct feedback on our efforts.

Sincerely,

Keeler

Nelson H. (Ned) Keeler
Director
NASA IV&V Facility
Fairmont, West Virginia

OVERVIEW

ACHIEVEMENTS & MILESTONES

The IV&V Facility took on a much more pronounced role as an Agency resource starting in July 2000, when it was transferred from Ames Research Center to the Goddard Space Flight Center (GSFC). The connectivity with a flight center doing hardware and software systems development for NASA missions provided a better fit for the primary mission of the Facility to service these flight programs.

This role encompasses the improvement of NASA's software in two key areas. For the Office of Safety and Mission Assurance (Code Q), the Facility performs IV&V on critical mission software as part of the OSMA software assurance responsibility. For the Office of the Chief Engineer (Code AE during CY03 reorganized to Code D in CY04), the Facility provides software systems engineering services.

The August 2001 mission of the Facility, put forth in a program plan (signed by GSFC management and the HQ enterprise associate administrators), enhanced the role of the Facility as an Agency resource in software IV&V, both the practice and associated research. These research efforts address the assurance functions incorporated in the software IV&V that we perform on behalf of the Agency.

The IV&V Facility has worked to position itself to perform its assigned roles in today's world, and to prepare for the changing roles envisioned over the next five years. Guided by the Program Plan and other pertinent documents, the Facility developed a strategic implementation plan, delineating the vision and mission for today and establishing a roadmap to the future.

Attaining and maintaining such a position requires continual research into the software assurance technologies. We now perform such research through a broad program that includes NASA Research Announcements (NRAs), directed Center initiatives, internal research by staff members, and our local consortium of industry and academia. These practitioner and research efforts are described in more detail in a later section of this document.

In addition, the Facility has an aggressive outreach program with a commitment to the community. We proudly fund and host a very active Educator Resource Center (ERC) to stimulate interest in math and science throughout the entire state. Our staff voluntarily participated in school events, career days, and other efforts including United Way/Combined Federal Campaigns, and supported specific United Way-funded agencies performing social support within the community.

Toward the end of 2003 the position of the IV&V Facility within the Agency began to further evolve. IV&V has been recognized as an Agency-level program, delegated from Code Q to GSFC and managed by the Facility. Our primary business, that of independent verification and validation of software, is being sponsored by NASA HQ Code Q as a software assurance technology, and we have been reassigned as GSFC, Code 180 (Center Director's direct report). The intent is to give the function-IV&V Services the attention of being a HQ level function. In the process, the budget for programmed IV&V services has been incorporated into Agency G&A and will no longer be a direct lien on the program being serviced.

As a part of managing this mission-capability growth, IV&V has established two major competency improvement goals: 1) to maintain ISO certification of the IV&V Management System; 2) to become Capability Maturity Model® Integration (CMMI) maturity level 3 in its applicable process areas.

ISO-Certified Management System

The NASA IV&V Management System became ISO certified in October 1998, one of the first NASA facilities to complete the process. In 2003, IV&V completed the process of upgrading the certification to the new ISO 9001:2000 standard, improving the process orientation of the management system, and establishing performance metrics as a way of measuring business successes.

Capability Maturity Model® Integration (CMMI)

In the Facility's strategic implementation plan, the planning team recognized the importance of being a technical leader in our areas of expertise.

The Facility underwent an external CMMI assessment during the year and exceeded its first year objective, being evaluated level 3 in one process area and level 2 in five more process areas. With some additional work in the metrics and analysis process area over the next year, the Facility plans to reach the CMMI level 3 objective by the end of 2005.

Performance Metrics System

During 2003, the Facility developed an internal series of measurements to track and monitor its performance across the critical success factors it deems vital to the success of the organization. These metrics are largely driven by customer survey/satisfaction indices, helping the organization grow in customer satisfaction, repeat business, and consequently, putting us on the path of being known by our good name. This performance metrics system has passed its first audit and is well on the way to being a significant process for continuous improvement within the Facility's operations.

COMMITMENT TO OUR EMPLOYEES

Our employees are the foundation of our success and our greatest resource. We value each employee and are committed to providing a safe, comfortable, well-equipped workplace while being conducive to creativity, learning, and productivity. Through our guiding principles we will appreciate our diversity, respect each other, and focus on ensuring a balance between professional and personal time.

NASA IV&V GUIDING VALUES

INTEGRITY

Doing what was said would be done; having trust; being honest, fair, and accountable, both personally and organizationally; having steadfast ethical conduct; living by high standards of individual behavior.

TEAMWORK

Working together; supporting each other; collaborating effectively; sharing accomplishments and successes; providing collective wisdom; being responsible; helping others; leveraging synergy; exhibiting open communication.

RESPECT

Noticing individual worth; being open-minded; accepting diversity; seeking first to understand and then to be understood; having credibility; empowering oneself and others; welcoming every idea; listening; being civil.

EXCELLENCE

Producing quality goods and services; doing the right thing; performing second to none; practicing continuous improvement; being distinctive, creative, and committed; leading in best practices; being efficient.

BALANCE

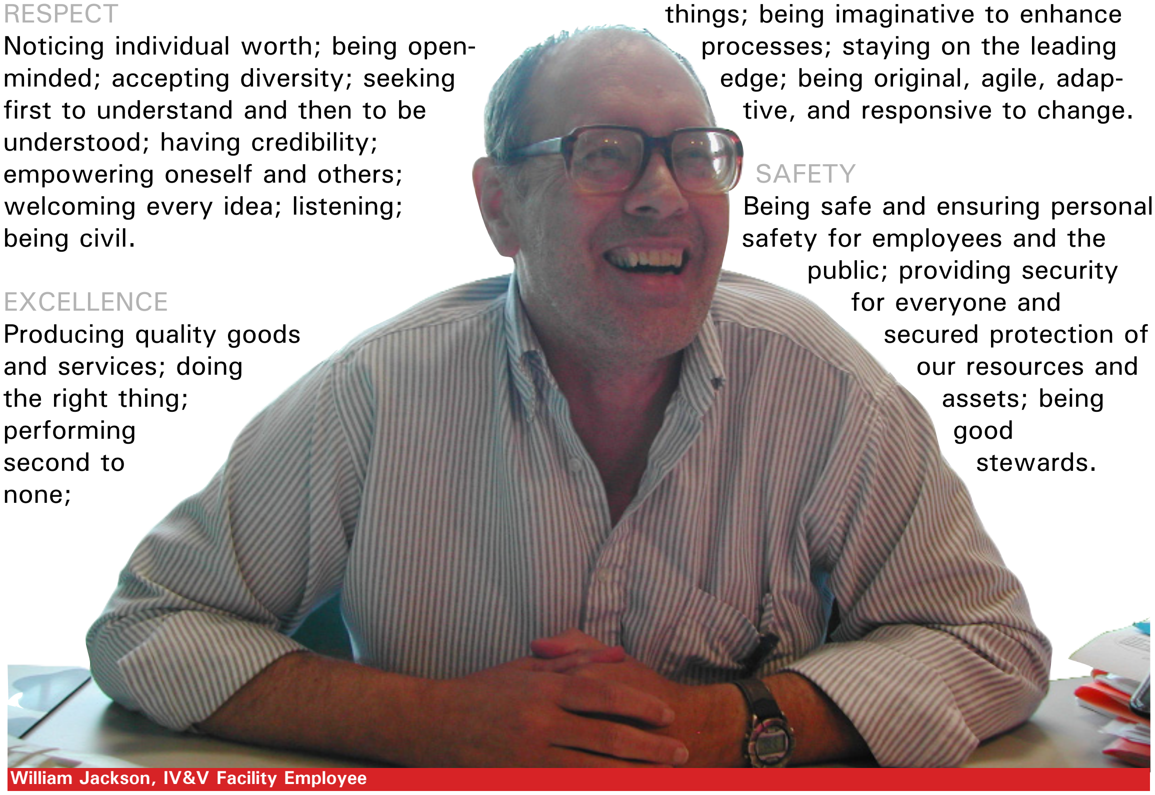
Being well rounded with work, family, and self; balancing professional and personal time; giving to the community; practicing wellness of living; having a balanced involvement that enhances all; being there; coaching others.

INNOVATION

Seeking better ways or new methods to do things; being imaginative to enhance processes; staying on the leading edge; being original, agile, adaptive, and responsive to change.

SAFETY

Being safe and ensuring personal safety for employees and the public; providing security for everyone and secured protection of our resources and assets; being good stewards.



William Jackson, IV&V Facility Employee

PEOPLE & PLANNING

The work performed by the IV&V Facility staff supports the entire Agency software assurance program and is aimed at betterment of all NASA Mission or Safety - Critical software efforts, ranging from the NASA Integrated Financial Management Program to human-rated space flight and robotic science missions.

With this diverse charge, the NASA HQ chartered an independent assessment of the IV&V services we provide. This team was led by the Office of Safety and Mission Assurance (OSMA). As a result of that assessment, a NASA IV&V Board of Directors (IBD) was established and they determined that IV&V should be considered an Agency-level service. The IV&V Program is therefore now designated as an Agency level service, delegated from OSMA to GSFC for management. In addition, beginning in fiscal year 2004 IV&V will be funded by the corporate General and Administrative (G&A) budget and the IBD will determine the priority of projects to receive IV&V services.

A transition team is working to affect this new program implementation with the goal of completing it by the beginning of FY '05.

During 2003, the Facility added nine civil servants (to 37, a 33% growth) to its ranks. From administrative support to additional project managers, the Facility has been successful in finding talented individuals to join the team.

Partners

The NASA IV&V staff work closely with a cadre of contractors who provide services across a myriad of projects. During 2003 approximately 118 Full Time Equivalent (FTE) contractors were engaged on-site supporting IV&V work. In addition, we had 69 Full Time Equivalent contractors residing off site in conjunction with our customers. Thus, the IV&V Facility involves 224 employees working at some level to support IV&V work.

In addition to the contractors focusing on direct IV&V project work, there were a number of research efforts underway in 2003. From specific relationships with West Virginia University to specific initiatives with a variety of researchers, the Facility continued to expand its presence in research, especially in practical and applied research initiatives. The **OUR RESEARCH** section spells out in detail these many exciting efforts.

The One NASA initiative provides the agency's overarching strategic framework for direction, expectations, high level goals, and ultimately strategies that focus all of NASA. One NASA challenges both the tasks to be completed, as well as how the entire agency must work together to reach the success envisioned. From the encompassing One NASA initiative to the IV&V reports on progress, there is clearly alignment of planning and organization linkages. The intent is to garner the synergies of integration within the Facility and across entities within NASA. Diagram 1 below reflects the Facility's interpretation of how different planning and activities are interrelated.

In December 2003, the IV&V Implementation Plan 2003-2008 was reviewed and updated to ensure alignment with the One NASA initiative.

Customer Focus

Serving the customer is a central purpose for the NASA IV&V organization and thus, a credo or statement of commitment to all customers was forged in our Implementation Plan to visibly reflect this to all.

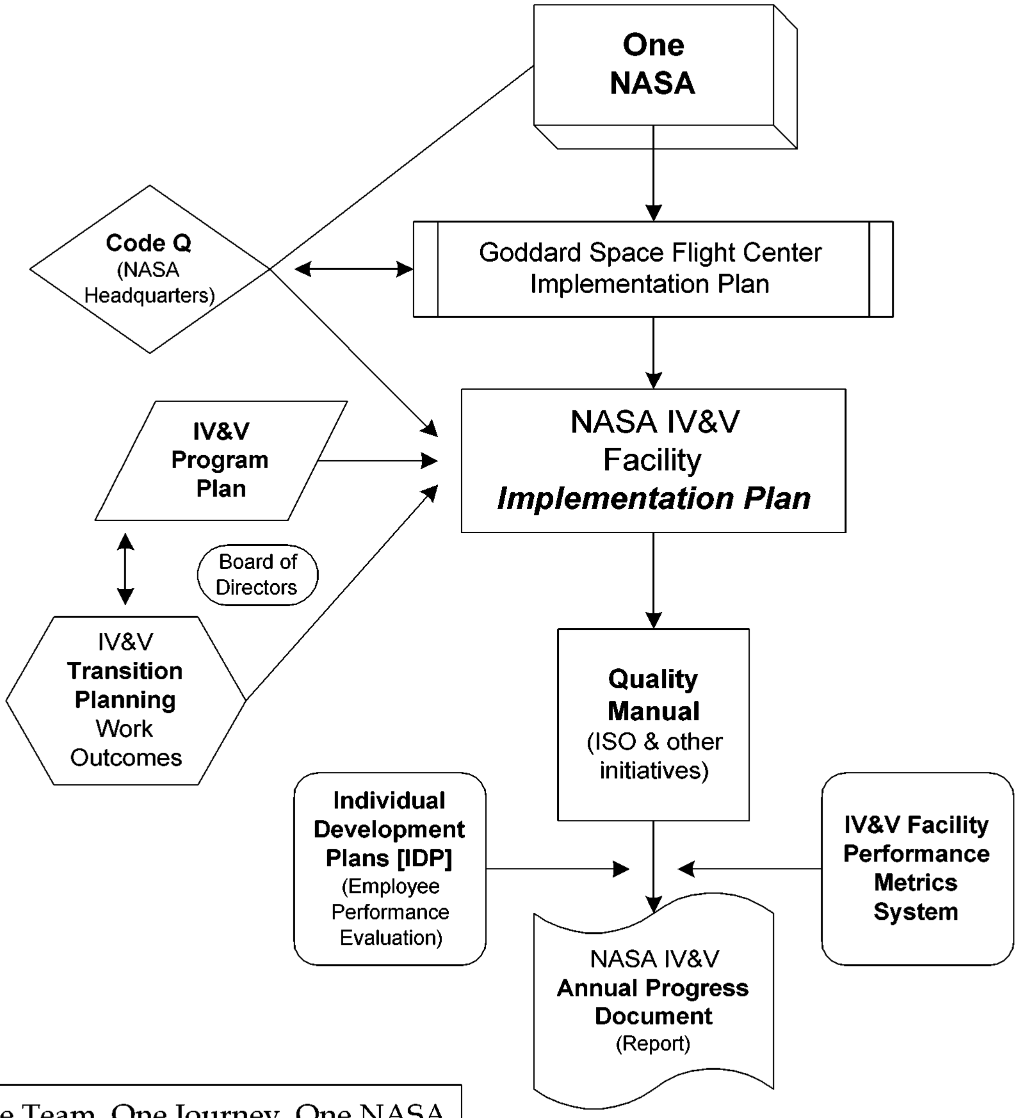
COMMITMENT TO OUR CUSTOMERS

Our customers are first and foremost in all we do. For every customer we work with, regardless of the purpose or the length of time, we pledge to do what it takes to truly exceed the customer's expectations. We do this by being responsive, learning and understanding customer requirements, and doing what we promise.

NASA IV&V

Forging an Integrated Approach in
Planning, Processes, and Operations

National Aeronautics and Space Administration



One Team, One Journey, One NASA
Building the Future Together

Diagram 1
Forging an Integrated Approach in Planning, Processes, and Operations
National Aeronautics and Space Administration

The NASA IV&V Facility rigorously analyzes systems and software to assure quality, resilience, and efficacy.

NASA IV&V uses an organizational-wide planning process that results in a multi-year implementation plan. On an annual basis this plan is reviewed and updated based on actions completed and emerging strategies. Elsewhere in this document you will find elements of our implementation plan from vision to our core values.

The implementation plan focuses on nine overarching goals NASA IV&V is working to achieve. Our progress and activities, as found in this report, reflect much of how we are going about reaching our goals.

Overarching Goals 2003-2008

Institutionalize IV&V services throughout NASA as a natural 'best practice' and as a wise investment of time and resources.

Become nationally recognized as a preeminent leader in IV&V expertise, tools, and processes.

Develop fully an internationally known and valued software assurance research presence.

Establish a desired organizational culture that engages and rewards employees and cultivates their long-term commitment to the NASA IV&V organization's workforce.

Ensure a focus on customers that is second to none.

Achieve continued quality improvement, compliance, and innovation throughout the NASA IV&V organization to advance effective and efficient operations.

Capitalize on appropriate direct and collaborative opportunities to ensure maximization of existing resources and advance planned future growth.

Be an active partner in our communities' future through educational and community outreach activities, and proactive service.

Ensure a safe, comfortable, and well-equipped workplace that is conducive to high performance and supports individual and team productivity.

Independent Verification & Validation, Independent Assessments, and Software Systems Engineering Background

Software systems continue to grow in both size and complexity. As a result, the cost of developing software has been increasing and, in some cases, has actually exceeded the cost of developing hardware. In response to these increases, management has become increasingly concerned about the feasibility of developing software within initial cost and schedule estimates while achieving and maintaining high quality products.

NASA has elected to incorporate Independent Verification and Validation as a part of the software assurance for all NASA Mission Critical and/or Safety Critical software. As the reader will see, this includes NASA business systems as well as flight systems.

We at IV&V bring assurance disciplines to the programs to help achieve quality products that are on time and within cost.

Independent Verification and Validation (IV&V) is a systems-engineering process used to evaluate the correctness and quality of the software product and processes throughout the lifecycle. IV&V consists of three distinct, but complementary processes (technical, managerial, financial):

Independence is ensured by having this assurance technology applied with financial, managerial, and technology external to the line work of the program development cycle.

Verification is the process of determining whether or not the products of a given phase of the software development cycle fulfill the requirements established during the previous phase.

Validation is the process of evaluating the software throughout the development process to ensure compliance with user needs. This process ensures that the software produces expected system behavior when subjected to anticipated events, and does not produce unexpected system behavior when subjected to unanticipated events.

There are times when providing full IV&V support to a mission may not be possible or appropriate; however, an Independent Assessment may be called for. An Independent Assessment (IA) is a 'snapshot' view of the health of a program or development effort. We conduct two types of assessments for our customers:

Systems Assessment

When short-term involvement is negotiated with the customer, the independent assessment manager (IAM) may recommend a system-level assessment at any phase of the lifecycle development. The independent assessment team (IAT) then performs a systems assessment to evaluate basic requirements, design, testing, and processes of systems under development. The IAT identifies risks associated with the safety and criticality of the mission software and makes recommendations for corrective action.

Lifecycle Assessment

When long-term involvement is negotiated with the customer, the IAT manager recommends a lifecycle assessment. A lifecycle development assessment identifies risks associated with mission success during any software development lifecycle phase and makes recommendations for corrective action. The IAT may also perform a lifecycle assessment of updated systems software changes and anomalies per mission as requested by the customer.

Community Outreach

Be an active partner in our communities' future through educational and community outreach activities, and proactive service.

Goal from the NASA IV&V Mapping a Successful Future, dated August 2002

Above: NASA Civil Servant Steve Raque enjoys time spent participating in educational outreach with youth.

The NASA IV&V Facility

Encourages and enables employees to participate in community activities;
Strives to increase the awareness of the NASA IV&V organization within the community it serves;
Strives to be a significant resource for pre-service and in-service teachers related to science and math.

Above: Students enter the Facility as they participate in the "Day in the Park" activities.

EDUCATION & OUTREACH

COOPERATIVE EDUCATION PROGRAM

The Cooperative Education Program is an important link in the educational process that integrates college level academic study with full-time meaningful work experience. This is achieved through a working agreement between GSFC and a number of educational institutions. This agreement allows the students, through study and work experience, to enhance their academic knowledge, personal development, and professional preparation. Additionally, co-op employees earn income that is based on the level of education and work experience they have attained.

The NASA IV&V Facility benefits from the co-op program in many ways. The program attracts students preparing for careers in a shortage category (engineering and science), permits selection for career jobs on the basis of proven performance, supports equal opportunity, and generally helps to more directly relate the efforts of educators to occupational needs of employers and students. Students can rotate from work to school on a semester or quarterly basis or work while attending school. The academic disciplines desired are engineering, mathematics, physics, earth and space science, and computer science. To support this program, GSFC currently has co-op agreements with more than 60 universities, and new agreements can be made with other schools.

Applicants must

- have completed 30 semester hours,
- be a student at an accredited university,
- be enrolled in their school's Cooperative Education Program,
- be a U.S. citizen, and
- have a good scholastic standing (2.9 G.P.A. overall).

IV&V Facility co-op participants for fiscal year 2003 were:

Wes Deadrick, West Virginia University. Wes's project was to assist the Research Lead with day-to-day operations.

Brian Kesecker, Fairmont State College. Brian's projects were IV&V Facility webmaster, ISO 9000 document editor, technical writer, and graphic artist. He was converted to a full-time permanent civil servant in August, 2003 after graduating from FSC.

Phillip Merritt, West Virginia University. Phil's projects were developing a shuttle simulator and performing test script analysis.

Kaci Reynolds, West Virginia University. Kaci's project was to assist the IV&V Facility Business Management Office with day-to-day operations. She was converted to a full-time permanent civil servant in August 2003 after receiving her degree from WVU.

Aaron Wilson, West Virginia University. Aaron's projects were developing a shuttle simulator and performing test script analysis.

The Cooperative Education Program at the NASA IV&V Facility receives significant management attention and support, and it is our intent to help continue this tradition. For further information on the NASA IV&V Facility Co-op program please contact the Coordinator at 304-367-8234 who will be glad to assist you, or visit the NASA IV&V website for details at http:/www.ivv.nasa.gov.

INTERNSHIPS

The IV&V Facility strives to bring new talent to the Agency through internships. These internships cover many ranges of academic skill and encompass the common practices within the government that instill a high degree of competency to further prepare students for success in their careers.

The purpose of the NASA IV&V Facility's internship program is to provide added support to projects and research within the IV&V Facility while providing paid work experience for undergraduate students in order to create learning opportunities along with the additional potential for joining the COOP program. Intern participants this year were as follows:

Jay Cann, West Virginia University.
Jay's project was to assist in the development of the ERC and technical library websites and to assist with the technical library functions.

Brendan Gibit, West Virginia University.
Brendan's project was to update and revise the tools lab website and IV&V simulator.

Dave Knight, Fairmont State College.
Dave's project was to provide code analysis definition and coordinate the code analysis discussion group.

Matt Menas, Fairmont State College.
Matt assisted with the technical library functions and created websites for the ERC and technical library.

Dan Nawrocki, West Virginia University.
Dan's project was to expand the capability of the shuttle simulator and develop the Facility simulation lab.

Ty Petrice, Fairmont State College.
Ty's project was the development of a visualization traceability tool.

Nadia Sawtarie, Linsly High School.
Nadia's project was to process public release notifications for all research initiatives and create initiative revision requests.

In addition to the undergraduate internship program, the NASA IV&V Facility also offers the following summer intern programs:

SEAP-The Science and Engineering Apprenticeship Program provides invaluable experience and exposure to the world of scientific research. The program offers apprenticeships for high school students who are U.S. citizens interested in science and engineering. The students are assigned to a scientist or engineer who serves as a mentor to the apprentice for eight continuous weeks during the summer.

The following are the 2003 SEAP interns:

Leah Baker, East Fairmont High School:
“Titan Project Database”

Connie Boggs, East Fairmont High School:
“Machine Learning Analysis and the Prediction of Software Errors”

Stephen Cook, Lewis County High School:
“The Educator Resource Center Webpage and Database Interface”

John Marinaro II, University High School:
“NASA IV&V Shuttle Simulator Glass Cockpit Upgrade”

Eric McGlumphy, Fairmont Senior High School:
“Traceability Analysis Tool”

Ryan Murphy, Philip Barbour High School:
“Ion-Cyclotron Instabilities in the Parallel Shear Dispersion of Plasma”

Ray Parrish, North Marion High School:
“Artifact Evaluation List Manager”

Lauren Riggs, University High School:
“Synthesis and Characterization of Cobalt-doped Zinc Oxide”

Mark Soderholm, University High School:
“XSL Stylesheets for Statically Analyzing C++ and Java”

Jennifer Zhang, Morgantown High School:
“Million-Atom Molecular-Dynamics Simulations of Silicon/Silicon Nitride Interfaces”

Above: NASA Civil Servant Phil Merritt instructs students on how to fly using the Facility's space shuttle simulator.

SHARP-Each year the Summer High School Apprenticeship Program offers the opportunity to participate in an intensive science and engineering apprenticeship program. High school students are selected on the basis of having shown aptitude for and interest in science and engineering careers. The program operates during the summer months for a minimum of eight weeks or longer. As apprentices, the students have the opportunity to learn and earn a salary.

Following are the 2003 SHARP interns:

Michael Anderson, University High School: “NASA IV&V Shuttle Simulator Glass Cockpit Upgrade”

Cori Bilotta, East Fairmont High School: “Facility Financial Spreadsheet User's Guide”

Sean Gibat, Bridgeport High School: “PHP Inventory Database”

Kelly McGill, Fairmont Senior High School: “Facility Civil Servant Biographies and Mars Project”

For further information on the NASA IV&V Facility intern program please contact the Coordinator at 304-367-8234 who will be glad to assist you.

PARTNERSHIPS IN EDUCATION

Since 1999, the NASA IV&V Facility has been a Partner in Education with Fairmont Senior High School, East Fairmont High School, and North Marion High School.

In fiscal year 2003, the IV&V Facility

- Visited schools to work with students, teachers and administrators on projects that educators thought would be meaningful and business people feel qualified to accomplish;
- Gave students and teachers a realistic picture of what careers are available at the IV&V Facility and of the preparation students need for success;
- Supplemented classroom studies with relevant learning experiences in business and industry; and
- Gave employees at the IV&V Facility an understanding of the education system, how it works, and its strengths and weaknesses.

EDUCATOR RESOURCE CENTER (ERC)

The NASA IV&V Facility Educator Resource Center (ERC) was established in 1997 by a steering committee consisting of NASA personnel, educators, higher education representatives, and community members. The goals were to create a center for demonstrating cutting edge technologies and disseminating NASA educational information to educators. NASA IV&V Facility's unique support has allowed the ERC to exceed expectations. Over 1,600 educators have been served throughout the state of West Virginia since 2000. Involvement with the NASA Linking Leaders program and the National Alliance for State Science and Mathematics Coalitions (NASSMC), as well as serving on advisory councils for several state and educational entities, has allowed the ERC to help improve systemic initiatives in West Virginia. The first grant in 1998 was with West Virginia University's Concurrent Engineering and Research Corporation. The second (1999 - 2002) and the current grant (2002 - 2005) are with West Virginia University’s College of Human Resources and Education, Department of Educational Theory and Practice.

Goals:

To provide exposure and experiences to educators, faculty, and students to support the enhancement of knowledge and skills, and to provide access to NASA information in science, mathematics, technology, engineering, and geography.

To inspire the next generation of explorers . . . as only NASA can.

Mission Statement from the NASA 2003 Strategic Plan

To develop, utilize, and disseminate science, mathematics, technology, and geography instructional materials based on NASA's unique mission and results, and to support the development of higher education curricula.

To use NASA's unique assets to support local, state, regional, and national science, mathematics, technology, engineering, and geography education change efforts through collaboration with internal and external stakeholders.

To research and develop products and services which facilitate the application of technology to enhance the educational process for formal and informal education and lifelong learning.

During Fiscal Year 2003, the NASA IV&V ERC accomplished the following:

Twenty workshops were held.

These workshops ranged from pre-service education students to experienced educators from across the state.

Examples are:

- STARLAB certifications - Once the educator has been trained to use the STARLAB (portable planetarium), it is available for them to checkout and use in their classroom.
- Centennial of Flight curriculum training.
- Kindernaut certification - Once the educator has been trained to use the Kindernaut kit and curriculum, it is available for them to check out and use in their classroom.
- Sun-Earth Connection curriculum - This integrates geometry concepts with NASA research and curriculum materials.
- Global Positioning with Space Grant Consortium Partners - Once the educator has been trained to use a GPS unit, it is available for them to checkout and use in their classroom.

Seven conferences were attended.

These conferences were attended to become more involved in the systemic initiatives within West Virginia and to become more knowledgeable about resources available to ERCs.

Examples are:

- WV Science and Teachers Association Conference
- National Science Teachers Association (WVSTA) Regional Conference
- West Virginia Educators Association (WVEA) Professional Issues Conference
- GEAR UP
- International Space Station Educators Conference (ISSEC) in Houston, TX
- West Virginia Council for Teachers of Mathematics (WVCTM)
- Educator Resource Center Network (ERCN) at NASA Langley Research Center

For further information on the NASA IV&V Educator Resource Center, go to http://erc.ivv.nasa.gov/.

OTHER OUTREACH ACTIVITIES

DAY IN THE PARK

The NASA Independent Verification and Validation (IV&V) Facility, in collaboration with the West Virginia High Technology Consortium Foundation, held an educational event called "Day in The Park 2003" at I-79 Technology Park in Fairmont, WV, on September 23, 2003. At this event approximately 650 seventh graders from North Central West Virginia (Monongalia, Marion, Harrison, and Preston Counties) participated in hands-on activities and visited with representatives of various technical fields. ”Day in The Park 2003” encouraged students to pursue careers in math, science, and technology.

Dr. Richard M. Linnehan (DVM), NASA astronaut, provided one of the presentations. Dr. Linnehan has flown on three space shuttle missions, the last being STS-109. STS-109 was the fourth Hubble Space Telescope servicing mission that included Dr. Linnehan performing four EVAs (space walks).

COMBINED FEDERAL CAMPAIGN

The Combined Federal Campaign is a government-sponsored charitable-giving mechanism, much like the public United Way, where federal employees can contribute to the support of approved local social service organizations of their choice through either direct cash or payroll deduction (approved in this case means charitable organizations with US IRS tax status of 501c3.

The NASA IV&V Facility staff of 37 civil servants contributed a record $14,899 to the local CFC campaign during the Fall 2003 campaign, an average of $400 per civil servant. This is an excellent example of how our staff members are vitally interested in the growth and prosperity of the communities we live in. In addition, one of the staff is the vice-chair of the local federal coordinating committee and will chair that committee next year.

FEDERAL EXECUTIVE ASSOCIATION

Federal Executive Associations and Federal Executive Boards were established in 1963 by an Executive Order of President John F. Kennedy. The Boards, found in locations with a high density of federal employees, have a line-item budget in a sponsoring federal agency's budget and at least one federal loan executive. Associations, on the other hand, have no established budget or employees and work in a more cooperative, loose-knit manner between the local agencies in regions of the United States where there is not a large federal employee population.

The purpose of these associations is for self-help for the common good among all agencies in a given regional location. For example, the larger agency installations often sponsor visits by federal health and life insurance providers during the open season periods when employees are encouraged to revisit their support.

In the North Central West Virginia region, the NASA IV&V Facility has had the privilege of serving twice in the 10 years of our existence as president of the association. The NASA IV&V Facility Director, Ned Keeler, served as the president in FY03. This is a time when local participative efforts helped all agencies more than at any time in the past. A catalogue of local federal facilities and training opportunities was generated to encourage sharing between organizations.

TEAMING TO WIN

From the first conference on May 15, 1990, the Teaming to Win concept has evolved into a 501(c)(6) nonprofit organization, providing business support conferences, educational activities, promotional forums, networking resources, and workforce and business growth opportunities. The organization's charitable purpose is to advance and improve small business prospects in West Virginia and to facilitate educational opportunities, which promote higher business standards, methods, and practices.

The 14th Annual Teaming to Win Conference was held at Mountaineer Race Track and Gaming Resort in Chester, West Virginia, with a near-record number of more than 530 registered attendees. The event attracted nearly 100 exhibitors.

One of the many events at the conference recognized companies and individuals that have been instrumental in fostering relationships with West Virginia. The Teaming Leadership Award was presented to Ned Keeler, Director of the NASA IV&V Facility.

The 2003 conference also included an exhibit area composed of businesses and agencies, which offered one-on-one counseling sessions to provide businesses with opportunities to meet with potential agencies and business with whom they might partner. Keynote speakers included Congressman Nick J. Rahall (D-WV) and Al V. Diaz, NASA GSFC Director.

Ned Keeler receiving Teaming Leadership award from Congressman Alan B. Mollohan (left).

PARTNERS & PROGRAMS

In 2003, the NASA IV&V Facility, while working in cooperation with our contractors and other NASA Centers, provided a significant level of safety and mission assurance support to 24 NASA missions in the development phase of their lifecycles. This work was principally focused on independent verification and validation of critical and safety-related software components and functionality. The IV&V Facility truly became an Agency-needed service and, for the first time, began to work with missions early in their formulation phases where the greatest return on investment should be realized. We are looking forward to a breakthrough 2004 as we refine the IV&V approach, implement and improve the advantages of corporate G&A funding, and directly help NASA successfully accomplish its technical mission and objectives:

Missions supported in FY2003:

Earth Science Enterprise (Code Y)

Advanced Air Transportation Technologies (AATT): The major focus of this project is to improve the capacity of transport aircraft operations at and between major airports in the National Airspace System (NAS) by developing decision support tools (DST) to help air traffic controllers, airline dispatchers, and pilots improve the air traffic management and control process from gate-to gate.

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO): Satellite mission to provide new information about the effects of clouds and aerosols on changes in the Earth's climate.

Earth Observing System (EOS) Aura: This satellite hosts a suite of scientific instruments designed to make the most comprehensive measurements ever taken of atmospheric trace gases.

Geostationary Operational Environmental Satellites (GOES-N) Series: New satellite that will provide more accurate location of severe storms and other weather phenomena, resulting in more precise warnings to the public.

Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS): Science instrument (THORPEX) for high spectral resolution temperature and water vapor retrievals.

Space Science Enterprise (Code S)

Cosmic Ray Energetics And Mass Balloon Experiment (CREAM): Balloon mission to observe cosmic ray spectral features and abundance changes that might be related to a supernova acceleration limit. It will also demonstrate the new ULDB balloon vehicle technology.

Deep Impact: Mission to create an impact with Comet Tempel 1, then observe how the crater forms, measure its depth and diameter, the composition of the interior of the crater and its ejecta, and then determine the changes in natural outgassing produced by the impact.

Galaxy Evolution Explorer (GALEX): Satellite mission designed to detect ultraviolet (UV) light from tens of millions of star-forming galaxies.

Gravity Probe-B (GP-B): Experiment that will check, very precisely, tiny changes in the direction of spin of four gyroscopes contained in an Earth satellite orbiting a 400-mile altitude directly over the poles. The ideal gravitational orbit, exactly over the Earth's poles, at relatively low altitude, with GPS tracking, makes Gravity Probe B an exceptionally sensitive instrument for exploring the fine structure of the Earth's gravitational field.

Hubble Space Telescope (HST): Servicing Missions 3 & 4, the last two scheduled missions to maintain Hubble and install new instruments.

Mars Exploration Rover (MER): Mission to provide two rovers as part of the long-term effort of robotic exploration of the red planet.

Mercury Surface, Space Environment, Geochemistry and Ranging (MESSENGER): Satellite mission to provide scientific investigation of the planet Mercury.

New Horizons: Pluto-Kuiper Belt (PKB): Satellite mission to help us understand worlds at the edge of our solar system by making the first reconnaissance of Pluto and Charon.

Solar Terrestrial Relations Observatory (STEREO): Dual satellite mission that will provide revolutionary views of the Sun-Earth system, trace the flow of energy and matter from the Sun to the Earth, reveal the true 3D structure of coronal mass ejections and determine why they happen, and provide unique alerts for Earth-directed solar ejections.

Space Infrared Telescope Facility (SIRTF): Mission to obtain images and spectra by detecting the infrared energy, or heat, radiated by objects in space between wavelengths of 3 and 180 microns.

Space Technology 5 (ST-5): Miniaturizing concept to build very small spacecraft that will perform just like the big ones.

Swift: Multi-wavelength satellite observatory dedicated to the study of gamma-ray burst (GRB) science.

Aerospace Technology Enterprise (Code R)

Demonstration of Autonomous Rendezvous Technology (DART): Satellite mission to develop and prove the technologies required for spacecraft to locate and rendezvous with other spacecraft without direct human guidance.

Fluids and Combustion Facility (FCF): Modular, multi-user experimentation facility for conducting fluid physics and combustion science experiments in the microgravity environment of the International Space Station (ISS).

X-37 Project: A reusable launch vehicle, designed to operate in orbital and reentry phases of flight, will demonstrate dozens of advanced airframe, avionics, and operations technologies.

Office of the Chief Financial Officer (Code B)

Integrated Financial Management Program: This enterprise resource planning (ERP) system will improve the agency's management of its financial, physical, and human resources through the implementation and utilization of multiple enterprise module applications.

Office of Space Flight (Code M)

Enhanced Caution and Warning System (eCWS): Monitors the Extravehicular Mobility Unit (EMU) by analyzing data and reporting how it is operating on the Display and Control Module (DCM) and by tones heard in the astronaut's headset when significant events occur.

International Space Station (ISS): Since 1994, the IV&V Facility has been examining the safety and mission-critical software in every US component of the international space station.

Space Shuttle: Software enhancements are continuously being made to the Space Shuttle with respect to the Shuttle core components, the Advanced Health Management System, and the Cockpit Avionics Upgrade.

The set examples of programs supported by the Facility in the IV&V, IA, and software systems engineering arena illustrate:

a) the breadth of NASA Safety and Mission Critical programs we support, and

b) a discussion of the work and results we bring to the programs.

IV&V Startup Assessments are in-process on the following projects:

DAWN: Satellite mission to characterize the conditions and processes of the solar system's earliest epoch by investigating in detail two of the largest protoplanets remaining intact since their formations (Ceres and Vesta). These protoplanets reside in the asteroid belt between Mars and Jupiter. (Project Manager: Ken Costello, Contractor: Titan)

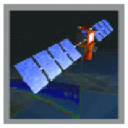
Gamma-Ray Large Area Telescope (GLAST) Large Area Telescope (LAT) Instrument: Instrument that will provide a superior tool to study how black holes, notorious for pulling matter in, can accelerate jets of gas outward at fantastic speeds. (Project Manager: Steve Pukansky, Contractor: SAIC)

Global Precipitation Measurement (GPM): Satellite mission that will build on the success of the Tropical Rainfall Measuring Mission (TRMM) and initiate the measurement of global precipitation which is a key climate factor. (Project Manager: Stephanie Ferguson, Contractor: Titan)

James Webb Space Telescope (JWST): Orbiting infrared observatory that will take the place of the Hubble Space Telescope at the end of this decade. (Project Manager: Frank Huy, Contractor: SAIC)

National Polar-Orbiting Operational Environmental Satellite System (NPOESS): Satellite missions that will provide systematic measurements of key environmental variables to study long-term climate and global change. (Project Manager: Stephanie Ferguson, Contractor: Titan)

X-43C Project: This project will develop a hypersonic flight demonstration vehicle that will fly seven times the speed of sound. (Project Manager: Christina Moats, Contractor: Titan)



CLOUD-AEROSOL LIDAR AND INFRARED PATHFINDER SATELLITE OBSERVATIONS (CALIPSO)

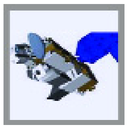
Project Manager: Steve Pukansky
IV&V Contractor: Titan

The composition of the global atmosphere has changed during this century because of human activities. Climate models now predict a significant global warming in response to the rising concentrations of carbon dioxide and other greenhouse gases in the atmosphere. However, confidence in these predictions is low because of significant uncertainties in the modeled radiative effects of aerosols and clouds. Current predictive capabilities must be improved to enable policy makers to reach balanced decisions on mitigation strategies.

CALIPSO is being developed to help scientists answer significant questions and provide new information about the effects of clouds and aerosols on changes in the Earth's climate. Understanding these components will provide the international science community with a more comprehensive data set that is essential for a better understanding of the Earth's climatic processes.

The overall scope of the IV&V effort is focused on the requirements and test analysis aspects of the Payload Flight Software (FSW) and Mission Operations Ground System (MOGS) Software. Specific activities included software requirements analysis, Software Requirements Specification review, and a Payload Mission Test Plan review.

Based on the analysis of the Test Program, IV&V identified a risk that indicated an End-to-End Test of the Payload and subsequent analysis of test data would not be performed prior to the payload Pre-Ship Review. The Project accepted this risk and responded by conducting adequate testing and test data analysis prior to the payload Pre-Ship Review.



EARTH OBSERVING SYSTEM (EOS) AURA

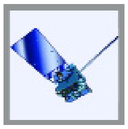
Project Manager: Marcus Fisher
IV&V Contractor: Titan

Earth Observing System (EOS) Aura is a NASA mission to study the Earth's ozone, air quality, and climate. This mission is designed exclusively to conduct research on the composition, chemistry, and dynamics of the Earth's upper and lower atmosphere employing multiple instruments on a single satellite.

EOS Aura is the third in a series of major Earth observing satellites to study the environment and climate change and is part of NASA's Earth Science Enterprise. The first and second missions, Terra and Aqua, are designed to study the land, oceans, and the Earth's radiation budget. Aura's chemistry measurements will also follow up on measurements that began with NASA's Upper Atmospheric Research Satellite and continue the record of satellite ozone data collected from the TOMS missions.

The IV&V Team performed analysis on the requirements, source code, and tests of the Aura spacecraft and instrument flight software. Analysis on the source code is supported with the following tools; Polyspace Code Verifier, Flexelint, and Source Navigator. In house tools have also been developed in order to perform analysis on the test cases, which were written in the CSTOL scripting language. The tool set enables our analysts to determine whether software requirements have been adequately tested as well as assessing the spacecraft commands that have been exercised.

As a result of our work, the IV&V Team has improved the robustness and confidence of the Aura Test Program. Instances where the actual results differed from expected results in the tests, test steps not being run, as well as inaccurate traceability between functionality and tests are just a few examples of our results. The Project accepted all our recommendations and developed additional tests, re-ran tests, and updated documentation. All of our activities have greatly benefited the Program and provided additional confidence as the Program prepares for launch in 2004.



GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITES (GOES-N) SERIES

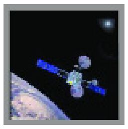
Project Manager: Richard Grigg
IV&V Contractor: Titan

The new GOES satellites will provide more accurate location of severe storms and other weather phenomena, resulting in more precise warnings to the public. The spacecraft design and geostationary positioning enable the primary sensors to 'stare' at Earth and thus frequently image 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, two 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 any source equipped with the appropriate transmitter (e.g., hikers, ships, and airplanes). GOES will also 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 has analyzed the test documents and test procedures this year in preparation for most of the end-to-end testing. The IV&V team also observed two actual tests of the software in use.

The IV&V Facility helped focus attention on parts of the tests that did not function properly. These problems were then corrected by the development team prior to the follow-on tests. Also, some ambiguities in the test documents were corrected making errors in future tests less likely as these tests will also be used for GOES-O and GOES-P satellites.



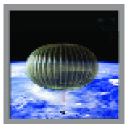
GEOSYNCHRONOUS IMAGING FOURIER TRANSFORM SPECTROMETER (GIFTS)

Project Manager: Richard Grigg
IV&V Contractor: Titan

Knowing how the Earth is changing is key to understanding the consequences of those changes. In mankind's endeavor to understand our planet's ”system” and the interactions of its components (land, sea, and atmosphere) we must strive to increase our scientific, technological, and operational expertise. GIFTS is the first step in improving our operational weather observing systems. In addition to being the mission name, “GIFTS” is also the mission instrument--the Geosynchronous Imaging Fourier Transform Spectrometer. This instrument incorporates the breakthrough technologies of an innovative atmospheric measuring concept developed at NASA's Langley Research Center in Hampton, Virginia.

The IV&V Facility reviewed some of the preliminary requirements and prepared a plan for complete IV&V of the GIFTS project. Near the end of the year, this project was put on hold.

IV&V conducted a requirements analysis of the Instrument Controller Software Requirements Specification (SRS), generated a report and submitted several issues related to the SRS. The project is currently reviewing the issues. As a result of the project being put on hold, the team is preparing a close-out report for assistance if/when the project work resumes.



COSMIC RAY ENERGETICS AND MASS BALLOON EXPERIMENT (CREAM)

Project Manager: Raju Raymond
IV&V Contractor: SAIC

Large unmanned balloons provide NASA with an inexpensive means to study the Earth and space and to place payloads into a space environment. The unique capabilities of this program are vital for the development of new technologies for NASA's space flight missions. The ULDB is a revolutionary research balloon designed to fly higher and longer than anything before it, and the flight could open a new era in scientific research. The Cosmic Ray Energetics and Mass (CREAM) Balloon Experiment will be the first ULDB payload.

The CREAM experiment will study ultra high energy cosmic rays. The goal is to observe spectral features and/or abundance changes that might be related to a supernova acceleration limit. It will also demonstrate the new ULDB balloon vehicle technology.

IV&V is performing an Independent Assessment on selected ULDB/CREAM software components and focusing on the requirements and implementation of the software. IV&V has completed requirements and code analysis on the Over The Horizon (OTH) Iridium System and provided related issues to the project.

The project has accepted all recommendations from IV&V and incorporated appropriate changes in the software. In addition, based on this work the project made a special request for the IV&V Facility to perform code analysis (not originally planned) on the ballooncraft flight software.

DEEP IMPACT

Project Manager: Ken Costello
IV&V Contractor: Titan

By forming a deep crater in Comet Tempel 1, scientists want to find clues to the formation of the solar system. The Deep Impact objectives are to observe how the crater forms, measure the crater's depth and diameter, measure the composition of the interior of the crater and its ejecta, and to determine the changes in natural outgassing produced by the impact.

Despite all the observations of comets over the centuries and what we have learned from those observations, there is still much that we do not know. The aim of Deep Impact is to determine more about the reality of comets and their role in the universe.

The IV&V Facility is performing an Independent Assessment of the most critical aspects of the Deep Impact Flight Software, specifically: the Attitude Determination and Control System (ADCS); the Auto Navigation (AutoNav) software; and, the Fault Protection (FP) software. The IV&V Facility tasks have focused on the traceability between the requirements, the design, the code, and the test procedures. The IV&V Facility also analyzed the unit, functional qualification, and system-level test procedures for each of the identified software subsystems. When performing traceability analysis and test analysis the goal was to provide in-depth technical feedback to the project. This information would then help the project to better understand the state of its software, note where potential pitfalls lie within the software, and give them an indication of how these pitfalls could be overcome.

The IV&V Facility participated in a series of technical interchange meetings between the primary Deep Impact developer, the Jet Propulsion Laboratory (JPL), and their contractor, Ball Aerospace. The IV&V Facility found several possible holes in the software that the project was able to quickly correct and, due to the timeliness of the IV&V Facility findings, limit the impact of the problems. Additionally, the IV&V

Facility was able to respond to a request from the project to provide additional analysis on the AutoNav Scene Analysis code which was not planned. The project deemed this critical to mission success and asked the IV&V Facility to review the code to ensure its correctness. The resulting review identified 14 issues, two being Severity Level Two. The project responded appropriately and corrected all 14 issues.

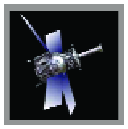
GALAXY EVOLUTION EXPLORER (GALEX)

Project Manager: Frank Huy
IV&V Contractor: Titan

The Galaxy Evolution Explorer (GALEX) is an orbiting space telescope that will observe galaxies in ultraviolet light across 10 billion years of cosmic history. Such observations will tell scientists how galaxies, the basic structures of our universe, evolve and change. Additionally, GALEX will probe the causes of star formation during a period when most of the stars and elements we see today had their origins.

The IV&V Facility conducted an Independent Assessment to provide the GALEX project with an evaluation of the GALEX Fault Detection and Correction (FDC) software for the spacecraft and instrument. The key areas the IV&V Facility reviewed were logic pertaining to spacecraft "survival" mode, safing process of the spacecraft, safing process of the instrument, and analysis of the over-voltage protection logic.

IV&V performed static code analysis on the flight software. From the analysis, IV&V identified issues with the "heritage" code in the attitude control (AC) module. IV&V also performed a manual analysis to identify potential risks and was able to identify issues to the project regarding consistency between documentation and flight software. The project's response has been positive and the project incorporated all IV&V recommendations.



GRAVITY PROBE-B (GP-B)

Project Manager: Richard Grigg
IV&V Contractor: Titan

Gravity Probe-B is the relativity gyroscope experiment being developed to test two extraordinary, unverified predictions of Albert Einstein's general theory of relativity.

The experiment will confirm, very precisely, any changes in the direction of spin of the four gyroscopes contained in an Earth satellite orbiting at a 400-mile altitude directly over the poles. The gyroscopes, nearly free from any disturbance, will provide an almost perfect space-time reference system. They will measure how space and time are warped by the presence of the Earth, and more profoundly, how the Earth's rotation drags space-time around with it. These effects, though small for the Earth, have far-reaching implications for our understanding of the nature of matter and the structure of the universe.

IV&V examined the software developer's Formal Qualification Test (FQT) documentation for completeness and traceability to the software requirements, evaluated samples of FQT test activities, and provided additional support for software testing verification activities and test engineering. IV&V also presented findings at the GP-B Space Vehicle Acceptance Review in Jan 2003.

The IV&V Facility identified various issues with test cases related to requirements and requirements verification. The IV&V Facility recommended a 72-hour test be done for the final software validation process. As a result of IV&V's recommendation to run this additional test (and the subsequent test results), several new issues were discovered that could have caused problems with the spacecraft. These issues were mitigated by the project.

HUBBLE SPACE TELESCOPE (HST)

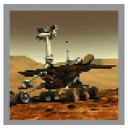
Project Manager: Frank Huy
IV&V Contractor: Titan

The Hubble Space Telescope is NASA's space-based cosmic observer and has been collecting data since its launch and deployment in April of 1990. Hubble is also an integral part of NASA's Origins Program, which is designed to aid us in obtaining knowledge of our solar system's roots. Hubble works around the clock to map the universe by using excellent pointing precision, powerful optics, and state-of-the-art instruments to provide stunning views of the universe that cannot be made using ground-based telescopes.

The Hubble Servicing Mission 4 (SM4) scheduled for 2005 had planned to further improve Hubble's capabilities and extend its life by installing a new cooling system, replacement batteries and gyros, and two new instruments: the Cosmic Origins Spectrograph (COS) and the Wide Field Camera 3 (WFC3).

The IV&V Facility has performed work on critical HST software components. The IV&V Facility used the Critical Functions List to define the analysis level for selected software components and their analysis level. The analysis consists of requirements, design, code, test, and interface analysis, as applicable for the lifecycle of the software being analyzed. This is referred to as scoping and implies greater emphasis on IV&V results.

IV&V has completed the COS and WFC3 Requirements and FQT Test Analysis. Issues were generated as a result of these analysis activities, identifying improvements to requirements and deficiencies in testing. The project has been making great strides to close the issues in a timely fashion. Updates to requirements text and detailed test analyses have occurred in response to IV&V concerns.



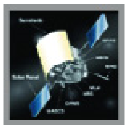
MARS EXPLORATION ROVER (MER)

Project Manager: Ken Costello
IV&V Contractor: Titan

The Mars Exploration Rover (MER) is part of NASA's Mars exploration program, a long-term effort to conduct robotic exploration of the red planet. The MER project was an aggressive project that was designed to take advantage of the closeness of Mars during the summer of 2003. Two robotic explorers are scheduled to land on Mars in January 2004. The goal of the explorers supports the goals of the Mars Exploration Program in general, that is, to follow the water. NASA's scientists hope that by examining the surface of Mars in areas that once held water or perhaps still hold water today, they can determine if life ever existed, or perhaps still exists on Mars. The resulting analysis may also pave the way for future human visitations to the red planet.

The IV&V Facility is providing full software development lifecycle (SDLC) support to the MER program. This support includes requirements analysis, interface, design evaluations, behavioral architecture analysis, code analysis (using LINT and McCabe tools) and test analysis of the MER flight software (includes the spacecraft and the rovers). The goal of the effort was to provide the MER project with a detailed technical analysis of the software that would allow them to make timely and informed decisions about possible issues and risks in the software.

The overall MER SDLC was an excellent approach to building the software on the aggressive schedule needed to meet the mid-2003 launch dates. The IV&V Facility was able to identify some risk areas that allowed the project to make modifications to their development approach and development products. These changes lowered the risks associated with their aggressive schedule and allowed both launches to occur within their respective windows of opportunity. The IV&V Facility continues to work with the project, identifying areas of risk to the landing and operation of the rovers on the surface as the spacecraft travels to Mars. Specifically, the project has requested that the IV&V Facility provide code analysis of the Field Programmable Gate Arrays. The IV&V Facility identified 78 possible code issues out of 3,400 warning messages that may result in unwanted operational characteristics of the rover and provided this information to the project prior to the last uplink opportunity.



MERCURY SURFACE, SPACE ENVIRONMENT, GEOCHEMISTRY AND RANGING (MESSENGER)

Project Manager: Wes Sweetser
IV&V Contractor: Titan

The MESSENGER mission, spacecraft, and science instruments are focused on answering six key questions that will allow us to understand Mercury as a planet.

MESSENGER uses gravity assists from both Venus and Mercury to lower its speed relative to Mercury at orbit insertion. Three Venus flybys significantly resize and rotate the spacecraft's trajectory closer to Mercury's orbit. Two 200-kilometer (124-mile) minimum-altitude Mercury flybys, each followed about two months later by a course correction maneuver, rotate and resize MESSENGER's orbit enough to enable Mercury orbit insertion in early July 2009.

IV&V has performed an Independent Assessment of the MESSENGER flight software system to help ensure all requirements flow down to the computer code. This work provides additional assurance that the mission will be a success.

IV&V has provided input to the Guidance and Control design, in addition to uncovering inconsistencies resulting in several issues being provided to the project. The project responded to 25 significant findings and improved their requirements documents, code and test procedures. An additional 71 significant IV&V findings were still under review by the project at the end of the year.

NEW HORIZONS: PLUTO-KUIPER BELT (PKB)

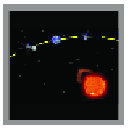
Project Manager: Peter Medley
IV&V Contractor: Titan

The New Horizons Pluto-Kuiper Belt (PKB) mission is designed to help us understand worlds at the edge of our solar system by making the first reconnaissance of Pluto and Charon - a ″double planet″ system and the last in our solar system to be visited by spacecraft. The mission would then visit one or more Kuiper Belt Objects, in the region beyond Neptune.

New Horizons is scheduled to launch in January 2006, swing past Jupiter for a gravity boost and scientific studies in February 2007, and reach Pluto and its moon, Charon, in July 2015. Then the spacecraft would head deeper into the Kuiper Belt to study one or more of the icy mini-worlds in that vast region, at least a billion miles beyond Neptune's orbit. Sending a spacecraft on this long journey could help us answer basic questions about these bodies' surface properties, geology, interior makeup, and atmospheres.

IV&V conducted a Startup Assessment and then began the formal IV&V analysis effort, encompassing full software development life cycle (SDLC) support beginning in March of 2003. The scope of the PKB IV&V includes Flight Software (Guidance and Control (G&C), Command and Data Handling (C&DH)), Autonomy, Instrumentation (5 of the 7 instruments) and Ground Software. IV&V has completed the Requirements Analysis and delivered reports detailing G&C, C&DH and all instrument issues uncovered during the analysis. The Design Analysis phase is currently underway.

Significant issues and more than a dozen risks have been discovered and brought to the developer's attention. The project has accepted and addressed some, but not all, of the risks and mission or incomplete requirements issues. The IV&V team is working to help the project understand the remainder of the risks, issues and the value that more formal software development processes and artifacts provide to ensure software readiness for flight and confidence in achieving mission success.



SOLAR TERRESTRIAL RELATIONS OBSERVATORY (STEREO)

Project Manager: Steve Pukansky
IV&V Contractor: SAIC

The STEREO mission will provide a totally 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 where they will be offset from one another. One observatory will be placed "ahead" of the Earth in its orbit and the other, "behind" using a series of lunar swingbys. 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 that includes analysis activities for the Command and Data Handling (C&DH), Boot, Guidance and Control (G&C) and Earth Acquisition subsystems. The Team is currently planning to also support all major milestone reviews and a Mission Operations Review planned for April 2004.

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 has discovered a reaction wheel error message in the design models with incorrect values being sent to the flight software and to the ground. The nature of this error message is such that given the right 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.

Several software-related discrepancies and issues have been conveyed to the developer and the project management and are currently being reviewed, resolved or mitigated. The Team also participated in the Memory Object Handler and Command Macro reviews and found no significant issues.

SPACE INFRARED TELESCOPE FACILITY (SIRTF)

Project Manager: Frank Huy
IV&V Contractor: Titan

SIRTF is a new platform for exploring the universe using infrared light. Astronomers find the infrared to be a valuable tool as it opens an important window into otherwise hidden regions of the universe. Research into the origin and composition of planets hinges on infrared observations which can reveal the composition of objects within our solar system as well as detect the material that may be forming worlds around other stars. Likewise, in the infrared, astronomers can study stars throughout their lives, from the earliest stages of formation in the hearts of dust clouds to their final years as they sputter and die. On larger scales, astronomers can probe distant galaxies individually or collectively, expanding our picture of the universe as a whole.

Consisting of a 0.85-meter telescope and three cryogenically-cooled science instruments, SIRTF will be the largest infrared telescope ever launched into space. Its highly sensitive instruments will give us a unique view of the universe and allow us to peer into regions of space that are hidden from optical telescopes. SIRTF is the final mission in NASA's Great Observatories Program—a family of four orbiting observatories, each observing the universe in a different kind of light (visible, gamma rays, X-rays, and infrared).

The IV&V Facility, based on its criticality analysis and risk assessment (CARA), performed a requirements review to verify that the traceability and contents of software-related system requirements found in the SIRTF project governing documents for both flight and ground systems were consistent and testable with the SIRTF project software products.

The IV&V Team identified several issues to the SIRTF project related to requirements flow-down and mission scenario tests. The project responded appropriately and assigned a lead engineer to review and solve the issues.

SPACE TECHNOLOGY 5 (ST5)

Project Manager: Wes Sweetser
IV&V Contractor: SAIC

The New Millennium Program's (NMP) ST5 will launch multiple miniature spacecraft, called nanosats or small-sats, to test innovative concepts and technologies in the harsh environment of space. During flight validation of its technologies, ST5 may measure the effect of solar activity on the Earth's magnetosphere, the region of upper atmosphere that surrounds our planet.

ST5's objective is to demonstrate and flight-qualify innovative technologies and concepts for application to future space missions.

The IV&V Facility conducts Independent Assessment reviews for the formal software acceptance test procedures and requirements verification test matrixes. The IV&V Team attends software test readiness reviews, software acceptance reviews, and reviews problem reports and change requests (CRs) throughout the software formal acceptance/qualification testing periods. The IV&V focus will also include an independent review of the configuration management procedures for maintaining slightly different versions of the same software on three constellation satellites. Prior to launch, IV&V will support the mission readiness review.

IV&V continues to perform short Independent Assessment reviews on various aspects of the ST-5 Flight Software. Specific reviews have included: Spacecraft Housekeeping; Transponder Management; Magnetometer Management; Command Ingest test procedures; Power Subsystem Management; Memory Checksumming Management; and, Health and Safety procedures. Reports have been provided to the project on each of these reviews. No significant issues were identified, but the project responded to all minor IV&V comments and appropriately improved their requirements documents and test procedures.

SWIFT

Project Manager: Christina Moats
IV&V Contractor: SAIC

Gamma-ray bursts (GRBs) are the most powerful explosions the universe has seen since the Big Bang. Approximately twice a week, satellites detect one of these brief, intense flashes of gamma radiation.

They come from all different directions of the sky and last from a few milliseconds to a few hundred seconds. So far scientists do not know what causes them.

With Swift, scientists would have a tool dedicated to solving the gamma-ray burst mystery. Swift's three instruments will give scientists the ability to scrutinize gamma-ray bursts like never before. Within seconds of detecting a burst, Swift will relay a burst's location to ground stations, allowing both ground-based and space-based telescopes around the world the opportunity to observe the burst's afterglow.

IV&V is conducting assessments of draft and final Swift project documentation, products and processes. The Team will ensure that the assessments are at the appropriate level required to support the current development phase and software maturity. The IV&V Team uses this information to support formal project reviews including, but not limited to, project-equivalent reviews of system concepts and requirements, system designs, system software requirements and designs, code, test plans, test readiness, delivery acceptance, and operational readiness for software in the catastrophic/critical/high risk functions list (CFL).

IV&V generated over 500 technical issue memorandums from requirements analysis, requirements traceability analysis, interface analysis, code analysis, and test analysis, and continually worked with the project to resolve and close them. Resolution of numerous issues have eliminated the need for increased test time, increased confidence in the correct operation of instrument software, corrected code that would lead to corrupted data and processor resets, and identified additional testing needed to completely verify requirements.

ADVANCED AIR TRANSPORTATION TECHNOLOGIES (AATT) AEROSPACE TECHNOLOGY

Project Manager: Peter Medley
IV&V Contractor: Titan

NASA, through the AATT project, is developing software tools, using an unconventional Software Development Life Cycle (SDLC), for use by the Federal Aviation Administration (FAA). The SDLC is divided into phases identified as Technology Readiness Levels (TRL). The tools being developed include McTMA (Multi-Center Traffic Management Advisory), D2 (Direct-To) and SMA (Surface Management Advisory). Once development reaches the necessary TRL (Technology Transfer Level), the tools will be transferred to the FAA.

The IV&V tasks are categorized around two types of activities. The first set of activities is for tasks that are independent of the software development life cycle. The second set of activities is for tasks that are dependent on the development life cycle (TRL's in the case of AATT). In addition, there are some AATT IV&V unique activities that are specific to the AATT project that relate to the support of technology transfer.

The AATT project uses the IV&V Facility in a system engineering support role to evaluate their software implementations of air traffic control research algorithms and applications. Additionally, AATT used IV&V to independently assess TRL readiness. IV&V conducted complexity analyses and reverse engineered design documentation for all the software functions of the McTMA, D2, and SMA applications which AATT plans to present to the FAA to use for general implementation understanding and further TRL development. AATT also placed one of the IV&V analysts in the V&V lab to perform regression testing for modifications to prototype applications being used in field trials.

DEMONSTRATION OF AUTONOMOUS RENDEZVOUS TECHNOLOGY (DART)

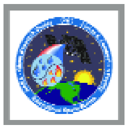
Project Manager: Peter Medely
IV&V Contractor: Titan

DART will examine the technologies required for spacecraft to locate and rendezvous with other spacecraft without direct human guidance. While NASA has performed docking missions in the past, astronauts have always piloted the spacecraft. The autonomous rendezvous technologies demonstrated by DART represent a critical step in establishing autonomous rendezvous capability and will lay the groundwork for future reusable manned and unmanned launch vehicles. Future applications of this technology include cargo delivery, space operations for the ISS, and other on-orbit activities such as satellite retrieval and servicing missions.

The DART vehicle will perform a series of orbit transfers to arrive at a point near a target satellite using state-of-the-art global positioning system (GPS) relative navigation techniques. Using the vehicle's main instrument, the Advanced Video Guidance Sensor (AVGS), DART will then approach the target satellite and perform a series of proximity operations including station keeping, docking axis approaches and circumnavigation. Finally the vehicle will demonstrate a collision avoidance maneuver, then depart the vicinity and transition to its final orbit. The entire sequence will be accomplished within 24 hours and under autonomous control.

The IV&V Facility is performing IV&V on selected critical DART software components. The analysis consists of requirements, design, code, test, and interface analysis applicable for the lifecycle of the software being analyzed. The IV&V Facility provides DART project management with the results of the IV&V analyses, identified issues and risks, and status reports.

The IV&V Facility's support of DART is a shining example of the impact that IV&V can have on a project. All issues that have been raised have been accepted and implemented by the project. The DART project Office views IV&V as an integral and valuable part leading to the success of the DART mission.



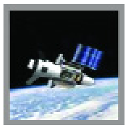
FLUIDS AND COMBUSTION FACILITY (FCF) - AEROSPACE TECHNOLOGY

Project Manager: Marcus S. Fisher
IV&V Contractor: Titan

The Fluids and Combustion Facility (FCF) shall serve as a modular, multi-user experimentation facility for conducting fluid physics and combustion science experiments in the microgravity environment of the International Space Station (ISS). FCF shall be a permanent facility aboard the ISS, and will be capable of accommodating up to ten science investigations per year. It will support the NASA Science and Technology Research Plans for the ISS, which require sustained systematic research of the effects of reduced gravity in the areas of fluid physics and combustion science. The FCF is being developed by the Microgravity Science Division (MSD) at the NASA Glenn Research Center.

The IV&V Facility is providing an Independent Assessment of FCF design and software. This assessment includes requirements analysis, design analysis, interface analysis, code analysis, fault and safety analysis, and software test analysis. The code analysis process includes static code analysis using FlexeLint and PolySpace, which are automated code analysis tools that aid analysts in determining existing and potential problems in software. The fault and safety analysis process includes assurance that FCF meets the safety requirements imposed on all ISS payloads.

The IV&V Facility has provided recommendations to the FCF project regarding the technical correctness between its interfaces and code. All recommendations have been accepted and the FCF project has made the necessary changes.



X-37 PROJECT - AEROSPACE TECHNOLOGY

Project Manager: Steve Raque
IV&V Contractor: Titan

NASA's X-37 is a reusable launch vehicle designed to operate in both the orbital and reentry phases of flight. The advanced technology flight demonstrator will operate at speeds up to Mach 25. It will demonstrate dozens of advanced airframe, avionics, and operations technologies that can support various launch vehicle and spacecraft designs. One other major focus of the X-37 will be improved thermal protection systems.

The IV&V Facility is performing requirements, design, code, and test analyses on the critical software of this demonstration vehicle. IV&V is particularly focused on the guidance, navigation, and control (GN&C) functions. These functions must perform a role similar to the GN&C of the space shuttle. These complex software routines control the X-37 as it reenters the atmosphere, glides, and lands on the runway. IV&V is also being performed on other parts of the software such as the flight management system and vehicle management system.

The X-37 project has undergone several iterations of rescoping and replanning to meet changing NASA and national needs. IV&V has helped the project team during these iterations by providing a constant source of software expertise and guidance to ensure eventual mission success. IV&V has helped the project identify and understand several software risks and assisted with appropriate mitigation strategies. The X-37 IV&V Team has several decades of combined space shuttle experience, and this experience has been valuable in identifying critical software and detecting defects in that software.

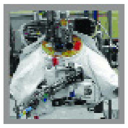
INTEGRATED FINANCIAL MANAGEMENT PROGRAM

Project Manager: Pat Callis
IV&V Contractor: Titan

Agency-wide management and improvement of financial, physical, and human resources are at the heart of the integrated financial management program (IFMP). IFMP will dramatically improve NASA's business processes and will greatly increase connectivity between 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 IFMP will help NASA meet the President's objectives, specifically in the key areas of the President's Management Agenda: strategic management of human capital; competitive sourcing; 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 IFMP system. An indication of the level of support IV&V provided comes from the Budget Formulation (BF) project Director: "The IV&V team has provided outstanding support in several areas. One of the most beneficial services received by the project was the complete traceability from Level I requirements through Level V. … The IV&V Team provided an in-depth review of the application level security and conducted extensive security testing. … The IV&V staff has always provided valuable insight in a non-threatening manner to the project team, allowing the project to benefit from the additional review without an impact to cost or schedule."

IV&V generated and maintained the BF requirements database which was accepted and used by the project for traceability purposes. A Lessons-Learned Risk Matrix was developed and used by the project for risk reporting and mitigation as a result of budget formulation lessons-learned gathered by IV&V from other source agencies. The information gained identified additional categories for classifying risk. IV&V performed negative and positive security tests on user access during budget formulation system integration testing which identified several security risks that the project was able to develop appropriate fixes for and close the issues.



ENHANCED CAUTION AND WARNING SYSTEM (ECWS)

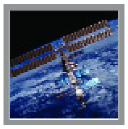
Project Manager: Marcus S. Fisher
IV&V Contractor: Titan

The enhanced Caution and Warning System (eCWS) monitors the Extravehicular Mobility Unit (EMU) by analyzing data and reporting how it is operating on the Display and Control Module (DCM) and by tones heard in the astronaut's headset when significant events occur.

The eCWS monitors consumables during a spacewalk. It will report when critical limits are reached to allow the crewmember sufficient time to return. The consumables that are monitored include primary and secondary oxygen, water (used for cooling), and battery power.

The IV&V Facility conducted an Independent Assessment (IA) of the eCWS software. The purpose of this assessment was to provide International Space Station (ISS) management with an independent view of the maturity of the software products and the thoroughness of the testing. This included: assessing the process used to create the software; analyzing the source code to identify potential issues; performing coverage analysis of the source to identify code paths that are not formally tested; performing requirements-based analysis of the eCWS certification test procedures to ensure that software requirements are thoroughly verified by testing; and, performing Failure Mode and Effects Analysis on the software to determine if all failure modes are tested.

The Independent Assessment Team (IAT) found that the eCWS software project was thorough, well-structured and well-managed. A significant contribution that the IAT made was the identification of out of range low sensor failures that the software requirements did not adequately address. Although these scenarios are remote, they could have posed risk to the safety of a crewperson. The project accepted these recommendations and updated the necessary documentation.



INTERNATIONAL SPACE STATION (ISS)

Project Manager: Marcus Fisher
IV&V Contractor: Titan

The ISS is NASA's space laboratory that utilizes 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 new insights into what is 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 were possible aboard the space shuttle.

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

The IV&V Facility is examining the safety and mission-critical software in every US component of the ISS. This is due to the diversity of applications, wide variety of domains, and discipline expertise requirements to support the subsystems of the ISS. Expertise of these subsystems is applied synergistically, or as a combined effort, to ensure that the ISS software functions as a complete system. Before each assembly is flown in 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. Finally, the assessment helps determine the approval for the Certificate of Flight Readiness.

The IV&V Team continuously provides benefit to the ISS Program and has been recognized by the program as the technical review experts for the ISS flight software. In addition to being recognized as the preeminent organization applying IV&V, the IV&V Team has successfully worked and certified the uplink of flight 9A, 11A, and ULF-1.

SPACE SHUTTLE

Project Manager: Steve Raque
IV&V Contractor: Titan

Software development on the space shuttle can be divided into two major areas. The first area is maintenance and improvement of the existing shuttle software that is located in its General Purpose Computers (GPC), Main Engine Controllers (MEC), and other hardware/software systems. The second area is upgrades to the space shuttle that add new software and replace existing software with more capable or safer systems.

IV&V is being done on both areas of software described above. 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 is performed on all critical changes to the existing GPC 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 correctness of the final software and that there are no unintended consequences to the unchanged areas.

IV&V is also being performed on two major shuttle upgrades, the Cockpit Avionics Upgrade (CAU), and the Advanced Health Management System (AHMS). As major new systems, the CAU and AHMS software is being analyzed in lock-step with the software development lifecycle. This ensures both the quality of the final system, and helps the projects stay on schedule and within budget by finding errors early when they are least costly to repair.

The IV&V Facility has been providing value to the space shuttle for seven years. In that time many defects have been found that, if gone undetected and manifested during flight, could have caused the loss of a crew. Add to this the many defects found early in the software development process, and IV&V feels it has saved money and time, and has provided the level of confidence in shuttle software that can only be achieved with a highly skilled IV&V team and the processes and infrastructure to support them.

INVESTMENTS & INITIATIVES

The IV&V Facility has two major research efforts. **The first** is the Software Assurance Research Program (SARP). The NASA Office of Safety and Mission Assurance (OSMA) sponsors this NASA-wide research program. Its purpose is to provide NASA with the software assurance practices, methods, and tools needed to produce safe and reliable software. This program is designed to address fundamental software assurance problems in the field of software engineering primarily as it relates to software safety, quality, independent verification and validation (IV&V), testability, and reliability. It is intended to develop and transfer to NASA projects, software assurance practices, methods, and tools to improve the quality of the software produced by and for NASA, and to assist NASA in becoming a leader in the development of safe and reliable, cost effective software. The IV&V Facility manages the SARP for OSMA in coordination with the OSMA Software Assurance Manager.

The program has an annual budget of $4.6 million spread across 42 research initiatives at NASA Centers, universities, and private corporations.

The IV&V Facility manages the SARP for the OSMA. The IV&V Facility's management responsibilities include:

Strategic Planning: Each year the Facility drafts a program plan listing SARP research topics as well as research selection, management, and funding strategies for the next three years.

Solicitation of Research Proposals: The IV&V Facility annually solicits proposals from NASA Centers, universities, and industry.

Proposal Evaluation: The Facility coordinates the review of the proposals by the NASA Software Working Group (SWG), organizes a source evaluation board (SEB), and compiles the winning proposals into an operating plan for OSMA approval.

Initiative Oversight: Regardless of where the initiative is actually conducted; the IV&V Facility maintains management oversight. This includes conducting quarterly progress reviews with the researchers, reviewing, accepting, and storing deliverables, and providing direction.

Reporting Research Results: The IV&V Facility hosts the annual Software Assurance Symposium (SAS) as a means of reporting progress to the OSMA and disseminating research results within NASA and the public. Additionally, the Facility maintains the SARP Results website where the public can review research results.

Transitioning Results into Practice: Throughout all the above steps, the IV&V Facility encourages research which can be applied to NASA projects. The potential for transfer is a leading factor in the selection of research as well as the evaluation of progress. Each quarterly review focuses attention on the use of real NASA data and the possibility for transition to a NASA project. Opportunities for transition can be funded as research projects of their own.

In addition to the program level management of the SARP, the IV&V Facility may be assigned to manage individual research initiatives. Center Initiatives (CIs) are SARP research initiatives assigned to a specific NASA Center for direct management. A number of these are typically assigned to the IV&V Facility for direct management. These fall into two categories: 1) Those research initiatives which were initially proposed by an IV&V Facility civil servant or contractor, and 2) Those which were proposed by someone not already associated with a NASA Center, JPL, or the IV&V Facility. These typically come from a university or private corporation. Since they are not initially associated with a NASA Center or Facility, they need a NASA civil servant to act as the government point of contact and contracting officer technical representative (COTR). The OSMA has assigned responsibility for these to the IV&V Facility.

As part of SARP, the IV&V Facility has a longstanding research agreement with West Virginia University (WVU). The OSMA designates a part of the annual SARP budget to support new and ongoing software assurance research at WVU. SARP research initiatives at WVU are termed University Initiatives (UIs). WVU submits a list of potential UIs annually. The IV&V Facility, with OSMA concurrence, selects and manages WVU UIs.

The second major research effort at the IV&V Facility consists of our internally funded research initiatives. Research initiatives funded by the IV&V Facility are referred to as Facility Initiatives (FIs). Unlike the OSMA SARP, the IV&V Facility research is not a defined program. There are no fixed budgets, program plans, operating plans, or SEBs. The mission of the IV&V Facility requires it to keep pace with developing technology and to find more effective ways to conduct IV&V. This results in a need for new and better IV&V tools and practices. Many, but not all, of these research needs are addressed in the SARP. The SARP is much broader than IV&V and research requirements which are very IV&V specific are not always addressed in SARP. When funds become available, the IV&V Facility prioritizes its research needs and initiates FIs to address those needs. There are no formal solicitations, and the efforts are typically performed by in-house resources.

While the FIs are not part of a formal program, they are very structured at the individual initiative level. FIs are managed with the same rigor as the CIs. Each FI is assigned to a government point of contact. The Facility holds quarterly progress reviews to evaluate the FI's performance. Deliverables are tracked and evaluated, and FI progress towards transition to an IV&V project is monitored.

Software Assurance Research Program

Program Management

Several programmatic improvements were initiated this year.

In previous years, a researcher could propose a research initiative lasting up to 3 years. In the case of a university, a grant could be issued for up to 3 years, but the OSMA policy was that each researcher had to re-propose for funding each year. This year, OSMA approved a policy change which allows successful proposals to continue for up to 3 years without re-proposing. The IV&V Facility has implemented procedures so that each CI is graded 'A', 'B', or 'C' during the quarterly progress review. 'A's and 'B's will be continued for the full 3 years. 'C's will be given three months to improve. If not, they will be cancelled. This change will add more stability to the program. It puts the responsibility for grading the research on to the Facility research management team who are in frequent contact with the researchers.

OSMA in conjunction with the IV&V Facility also decided to fund fewer but larger research projects in the future. The management team noticed that transitioning research into practice often requires larger budgets than the SARP typically funds. Larger projects will more likely have the resources needed to support transition.

The Center Initiative Management (CIM) Tool is being re-implemented. The CIM Tool is the web-based data repository for storing and tracking research proposals and deliverables. Researchers submit their deliverable through the CIM Tool. The tool moves the deliverable through the acceptance process and permanently stores the accepted deliverable. ProLogic, the SARP support contractor, is in the process of commercializing a new development environment (KMSuite) to support web-based data repositories like the CIM Tool. The redevelopment of the CIM Tool in KMSuite was completed in November 2003 and is expected to reduce maintenance costs.

IV&V Facility Managed Center Initiatives

One hundred sixteen proposals were received for Fiscal Year 2003. Of those, 30 were selected to be funded as CIs. Twelve of the CIs were directly managed at the IV&V Facility. Six of the twelve were directly related to IV&V. The other six addressed a broader software assurance scope. The following are the twelve directly managed by the IV&V Facility:

RESEARCH SUPPORTED IN CY2003

A Spectrum of IV&V Modeling Techniques: Using a spectrum of IV&V modeling techniques, the IV&V Facility will determine best practices for using cost-effective automated techniques to the largest extent possible during the IV&V process.

Automated Testing and Quantitative Evaluation of Real-Time Source Code: Automated testing and quantitative evaluation of real-time source code will extend a measurement-based verification methodology and supporting test tools from MATLAB models to the automatically generated source code produced from these models.

Completing the Loop: Linking Software Features to Failures: The goal of this effort is to develop tools and methods to integrate system analysis tools and defect tracking tools to create a missing link between software features and failures.

IV&V Cost Estimation: NASA - U.S. Navy Collaboration: Collaborating with the Navy, NASA will create and test viable, dependable cost-estimating tools for IV&V of system software design, development, and integration.

IV&V Techniques for Object-Oriented Software Systems: The research team will identify, adapt, or develop analysis techniques to address the risks associated with developing software systems using OO methodologies.

Optimizing IV&V Benefits Using Simulation: By using simulation to optimize benefits, NASA will be able to assess the best way to allocate IV&V resources for a given project.

Research and Development (R&D) Required To Establish Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A) Guidance and Practices for Certifying Simulations Used for Software Requirements Verification: This R&D effort will critically assess the practices of the M&S VV&A discipline as a basis for proposing guidance and practices that may be used to establish credibility for simulations/simulation testbeds.

Robust Requirements Tracing via Internet Search Technology: IV&V tracing of requirements to design, code, and test cases is difficult and must be done quickly and accurately.

Semantic Metrics for Object-Oriented Design: The IV&V Facility will explore semantic metrics for object-oriented design to improve the identification of software features and qualities such as reusability, cohesion, coupling, and complexity.

The Use of a Virtual System Simulator and Executable Specifications to Enhance Software Verification, Validation, and Safety Assurance: The objective of this research is to test the validity of a new approach to the avionics development process based on the creation, simulation, and V&V of executable specifications.

Timing and Race Condition Verification of Real-Time Systems: With this effort, the IV&V Facility will investigate a novel approach to uncover all possible derivations of program execution and race conditions among multiple concurrent threads.

WEST VIRGINIA UNIVERSITY INITIATIVES

Architectural-Level Software Metrics: Once defined, the architectural-level software metrics alert the software architect to risks in the early stages of architectural design.

Fractal Analysis of Resource Exhaustion in Real-Time Operating Systems: Fractal analysis of resource exhaustion in real-time operating systems may allow the Facility to estimate and forecast the rate of ″decay″ of software.

Integrating Formal Methods and Testing: Significant advances can be made by merging formal verification and program testing in a unified software reliability assessment framework.

IV&V of UML: Risk Assessment of Dynamic Specifications: The project will develop automated techniques to verify and validate the system behavior based on UML dynamic specifications.

Lyapunov Stability Analysis and Online Monitoring: Lyapunov stability analysis and online monitoring will lay the groundwork for developing a V&V method/technique that can be applied to systems, which contain online learning artificial neural networks.

Performability of Web-Based Applications: The project will develop scalable measurement and modeling approaches that can be combined together to analyze multiple quality attributes of complex web-based systems.

Quantitative Relations Between Static and Dynamic SW Metrics: Our objective is to discover quantitative relationships between many static software metrics and their dynamic counterparts by using both analytical and empirical methods.

Sensitivity of Software Reliability to Operational Profile Errors: The sensitivity of software reliability to operational profile errors calls for the development of a methodology for uncertainty analysis of software reliability due to the operational profile errors that are suitable for large complex component-based software systems.

Translation Validation of Compilers/Interpreters: Translation Validation of Compilers/ Interpreters will develop a certification mechanism for the semantic equivalence of the source code developed in model-based programming languages.

Verification and Validation of Adaptive Systems: Verification and validation of adaptive systems will derive a computational model for adaptive systems, validate the proposed model, and investigate how it can be used to derive methods for the verification and certification of adaptive systems.

IV&V FACILITY-SPONSORED RESEARCH

Development of Methodologies for IV&V Neural Networks: Expanding on existing simulation research, mapping how military pilots are trained and certified, and using simulation techniques will make possible the development of IV&V methodologies for neural networks.

Integrating Model Checking and Procedural Languages: The IV&V Facility is integrating model checking and procedural languages to develop (from working prototype) a fast, memory-efficient, fault-detection tool for finite-state models of concurrent systems.

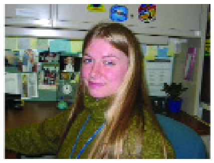
Optimizing IV&V for Mature Organizations: The objective of optimizing IV&V for mature organizations is to provide a complementary set of guidelines and criteria to assist in the planning of IV&V activities.

Return on Investment for IV&V: The NASA IV&V Facility will build a predictive model for IV&V, based on both the direct and indirect benefits, that will aid in selecting projects which will benefit most from finite IV&V resources.

Static Analysis of Software for Autonomous Spacecrafts: Static analysis of software for autonomous spacecrafts will extend those techniques for application to software for autonomous spacecrafts.

The Metrics Data Program: The creation of a centralized repository that provides consistent, fully-involved software product data across multiple domains will allow NASA to improve the effectiveness of software assurance and research, and improve the ability of projects to predict software errors.

All of our research efforts directly serve our larger goals as NASA's IV&V Facility. Work products of these initiatives that have been accepted and cleared for publication are available at the Software Assurance Research Program Results Web Site http://sarpresults.ivv.nasa.gov.



Above: NASA employees on the job.

A SPECTRUM OF IV&V MODELING TECHNIQUES

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Using a spectrum of IV&V modeling techniques, the IV&V Facility will determine best practices for using cost-effective automated techniques to the largest extent possible during the IV&V process.

Objective

The goal of this effort is to use cost-effective automated techniques to the largest extent possible during the IV&V process. The working hypotheses:

- There exists a range of validation techniques that can assess models built using a range of modeling techniques of increasing cost and complexity. Specifically, they hypothesize that the "cheaper" techniques can find faults cheaply and early in a project. These early results are then used to predict if this is a problem system and if a more elaborate and expensive IV&V effort is justified.
- There exists a set of migration procedures that let us seamlessly move from simple models using cheaper techniques into more elaborate models suitable for a more expensive and detailed analysis.
- The migration process is much cheaper than simply remodeling the system under investigation from scratch when moving to models needed for the more detailed and expensive IV&V assessments.

Approach

There are, however, several challenges that must be met before this experience can be applied to model-based IV&V. In particular, three key, unmet challenges relate to the foundation of the proposed approach. The foundation of model-based IV&V:

- Cost effective model migration,
- Application of fully automated analysis tools, and
- Prediction of which systems are problem systems through lightweight modeling and analysis.

All three are open research challenges. The approach to meeting these challenges and providing this foundation is outlined below.

Model Migration:

Plan to work with the formal notation RSML-e from the University of Minnesota—a model-based notation with a proven track record in industrial applications. RSML-e is simple enough to be used for early, draft modeling of a system and powerful enough to model the details that may be needed in more elaborate evaluations. What are lacking are guidelines for model-migration. It is hypothesized that recent guidelines developed for requirements model development (Family Oriented Requirements Methodology for Process Control Systems-FORMPCS) can be adopted for model-migration in the IV&V domain. They will evaluate the applicability of the FORMPCS method in this new domain and adopt it for the IV&V activities.

Automated Analysis:

It is proposed to augment the capabilities of the University of Minnesota's RSML-e tools with lightweight analysis so support early evaluation. The RSML-e tools already support translation to heavyweight tools such as the model checker SMV and the theorem prover PVS. They will integrate the NASA sponsored SP2 toolset for this lightweight task.

Problem Prediction:

They will apply their modeling methods to a collection of case examples to see if the problems discovered early on indicate that there are many more problems to be found and additional efforts are merited. They will seed various models with faults and apply a spectrum of analysis techniques to determine (1) if the lightweight techniques can be used to check that a subset of the properties are satisfied and (2) if the number of problems exposed with the lightweight analysis is indicative of the number of problems remaining in the system. They will also conduct this case study on a second avionics system (an altitude switch) and possibly, if resources are available, some existing NASA system of relevance to IV&V.

Significance

This research would have a wide and immediate applicability to projects across NASA conducting IV&V as well as NASA contractors conducting development.

Accomplishments

- Implemented a random search of a compact AND-OR state space graph in a tool called LURCH
- LURCH detected 90% of the defects in 1% of the runtime of NuSMV (an exhaustive model checker)

Selected to present in December 2003 at the IEEE NASA Software Engineering Workshop (SEW) at Goddard Space Flight Center.

AUTOMATED TESTING AND QUANTITATIVE EVALUATION OF REAL-TIME SOURCE CODE

Principal Investigator:
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Automated testing and quantitative evaluation of real-time source code will extend a measurement-based verification methodology and supporting test tools from MATLAB models to the automatically generated source code produced from these models.

Objective

This project extends a measurement-based verification methodology and supporting test tools from MATLAB models to the automatically generated source code produced from these models. The methodology and testing tools apply the same tests to code that are applied to models (via simulation) to verify and validate requirements and the corresponding software.

Approach

This project was based on the leading product in real-time systems development, MATLAB, used extensively across NASA and specifically on the Stereo Project, which this CI will directly support. While the verification methodology will be applicable across all real-time systems development, the automated testing tools will initially be limited to the PC Windows and Sun Solaris environments, with limited support for portability to additional SPARC platforms as requested by specific NASA projects.

This project focuses on extending the testing methodology currently in use for simulation testing of real-time systems to testing of source code generated from control system models. This project will allow the set of functions, referred to as test types that are used to test models via simulation to be applied to the testing of real-time source code. In extending the functionality of the testing tools to real-time code, additional defect detection capability will be integrated into the tool. This additional functionality will allow the users to configure more complex defect detection criteria that users will find extremely valuable. For example, an output value below 100 may be an error while a vehicle is within earth's atmosphere but not be an error once it enters space. These types of defect detection criteria (called state specific defect detection) will be added to the tool suite.

Significance

Automated testing tools and measurement-based reliability evaluation methodologies are needed to improve software quality, increase testing productivity, and enhance management insight into process and product risk. These needs must be met without investment in expensive hardware and achieved across multiple NASA projects.

Testing of real-time systems presents unique and challenging problems. Testing on target hardware requires solving problems including the acquisition and installation of expensive target hardware, safety hazards, and the risk of costly hardware damage. Many times target hardware cannot be taken off-line or is simply unavailable for testing when needed. In the case of aeronautics and aerospace applications, the target hardware may not even exist when software testing is needed. Potential software problems can be too dangerous to test on target hardware until some level of testing is done in advance to assure safety. Even if safety requirements are met, a software defect could damage expensive equipment such as a wind tunnel drive shaft.

This project is unique in that it provides a methodology and automated tools that allow real-time systems models built with MATLAB to be extensively tested and quantitatively evaluated. The project also allows the automatically generated source code created from these models to be tested using the exact same tests. The ability to test models and source code with identical tests suites allows comparison of results. Without question, this is a major advantage in that testing within verification and validation is moved forward in the process to points where detection and correction are more productive and cost efficient.

Accomplishments

This project has contributed to the ability of NASA to perform and evaluate the completeness and effectiveness of verification and validation in a number of important ways:

- A quantitative based verification and validation methodology utilizing a suite of testing tools can be applied across projects during the requirements specification phase.
- The same quantitative based verification and validation methodology utilizing a suite of testing tools can be applied across projects following code generation.
- The methodology involved in this research involves a mature and ready-for-use suite of testing tools that execute in the MATLAB environment. This permits verification criteria to be specified prior to system specification.
- The power of the tool allows literally thousands of tests to be executed in the time previously needed to execute just dozens of tests, both during simulation testing and source code testing.
- The testing tools allow independent verification and validation to be performed at multiple, possibly widely distributed, locations. Test files can be shared, archived, and the system retested to recreate defects and assess regression.

COMPLETING THE LOOP: LINKING SOFTWARE FEATURES TO FAILURES

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The goal of this effort is to develop tools and methods to integrate system analysis tools and defect tracking tools to create a missing link between software features and failures.

Objective

The goal of this effort is to develop tools and methods to integrate system analysis tools and defect tracking tools to create the missing link between software features and failures. The premise is that by integrating the output from software analysis tools and defect tracking tools, and then applying machine learning to the results, the predictors leading up to software faults can be identified. The result of this effort will also help NASA to address the following:

- Which IV&V analysis types are most productive?
- Which specific IV&V tasks discover the most faults?
- Which IV&V analysis tasks require more attention?

Approach

A tool (LINKER) will be created to generate the input required by machine learning tools from the output of both system analysis tools (e.g. SIAT) and defect tracking tools (e.g. PITS). To achieve the goal, PITS will be modified to implement the ODC methodology; and will perform testing using historical PITS data.

Significance

This activity will result in the implementation of Orthogonal Defect Classification (ODC) within specific NASA projects, which leads to consistency among issue data recorded for each of the projects. This effort provides the link that will enable NASA researchers to predict system faults and failures from system features.

Accomplishments

Contract was awarded in August. Work has started.

IV&V COST ESTIMATION: NASA - U.S. NAVY COLLABORATION

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Collaborating with the Navy, NASA will create and test viable, dependable cost-estimating tools for system software design, development, integration.

Objective

To employ the knowledge and experience of the U.S. Navy in creating and testing viable, dependable cost-estimating tools for system software design, development, and integration. More specifically, to take techniques developed and refined by the Naval Air Systems Command and apply them to the IV&V domain to successfully research, design and develop the tools necessary to improve the overall speed, accuracy, and consistency of NASA software IV&V cost estimating.

Approach

This is a collaborative research effort between NASA and the U.S. Navy; together they formed the IV&V Cost Estimating Team (the ICE Team). The ICE Team conducted a survey of industry best practices regarding software verification and validation and compared it to current NASA IV&V practices to establish a benchmark. Then the Team developed an initial IV&V task work breakdown structure (WBS) with associated IV&V task dictionary and IV&V task database. The Team conducted analyses of current NASA IV&V requirement assessment techniques to identify key estimating variables and weighting factors. Design synthesis followed for the bottoms-up, engineering based should-cost engine, and the research Team employed rapid prototyping to analyze and refine tool requirements and evaluate operational effectiveness. The ICE Tool User interface and interaction requirements were developed from transaction modeling and analysis of current scenarios.

The IV&V should-cost engine is now functional and the Team focus has turned to the refinement of data used in the tool, such as baseline effort (hours) per IV&V task/ activity. Plans for 2004 include an Independent Test of the IV&V should-cost engine, the design, development and implementation of a statistical cost engine, and the development of some 'maintenance assistant' tools to simplify the process and reduce the cost of updating and maintaining the IV&V Cost Estimating Tools.

Significance

The requirement for IV&V of NASA software intensive systems has increased significantly. IV&V budget requirements must be prepared and forwarded to stakeholders at NASA Headquarters as early as possible. However, each IV&V effort is unique and budget preparation is time consuming. Processes for IV&V cost estimating must be improved. The Naval Air Systems Command has developed a cost estimating tool for system software design/development, integration and test that uses a bottoms-up, engineering based work breakdown structure (WBS), combined with statistical regression analysis, that yields cost estimates with a high degree of confidence. This applied research is developing similar processes and tools for NASA IV&V projects.

Accomplishments

The PC based functional Prototype of IV&V Cost Estimating Tool was delivered in November 2002. The Pre-Production ICE Tool was delivered to NASA in February 2003, with updates to the User Interface delivered May 2003. The PC based Production version ICE Tool was delivered to NASA in July 2003. In FY-04 the ICE Tool will be migrated to a multi-user, server-based system with data tables hosted by NASA IV&V Tools Lab.

IV&V TECHNIQUES FOR OBJECT-ORIENTED SOFTWARE SYSTEMS

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The research team shall identify, adapt, or develop analysis techniques to address the risks associated with developing software systems using OO methodologies.

Objective

NASA has considerable experience applying independent verification and validation (IV&V) to traditional function-based software development programs. However, NASA's use of object-oriented (OO) techniques for the development of mission critical software systems continues to increase. The emerging use of OO necessitates the need to establish and evaluate the IV&V techniques best-suited for the unique challenges and risks of OO software development. The shift from the traditional function-based development to OO development, while capable of providing advantages for the development and maintenance of a system, introduces a unique set of lifecycle risks. In this study, the researcher proposes to identify and evaluate the analysis techniques best suited for independent verification and validation of NASA systems developed using an OO approach.

Approach

The research team shall identify, adapt, or develop analysis techniques to address the risks associated with developing software systems using OO methodologies. The research team will then analyze and evaluate their effectiveness using real-world development project products. As the nature of the products produced and the processes applied are not the same from one development project to the next, the analysis techniques identified under this study shall be defined in terms of discrete tasks and organized into an analysis framework. From this framework, the IV&V analysts will then be able to choose the set of most suitable analysis tasks specific to the development project context.

The proposed analysis framework will be defined in terms of:

- Outline of the end-to-end process to be applied over the life of an IV&V project.
- IV&V analysis goals and techniques.
- Development artifacts to be used as input to IV&V analysis tasks.
- Guidelines for tailoring the proposed framework to a specific project context.

Significance

This research further builds on a collection of published research work and adds missing links in order to provide an IV&V framework for OO based software development. This research will tailor and enhance metrics based on dynamic complexity and coupling. Such enhancement will allow IV&V analysts to develop a tailorable framework for OO based software systems. The proposed framework will increase the existing body of IV&V knowledge by adding, organizing, and validating techniques for verifying OO based software systems. The goal of the framework is to increase the efficiency and effectiveness of IV&V efforts on projects using OO development, resulting in an increase to the overall value added. By improving the state of practice in IV&V analysis, this work will add to mission assurance, mission success and can be used to reduce risks inherent in OO development.

Accomplishments

The IV&V team recently presented a paper about IV&V techniques for OO at the International Software Symposium on Reliability Engineering held on November 17, 2003. The paper was well received by the researchers present at the conference. The topic of use case prioritization was of particular interest as many other groups are trying to incorporate similar strategy in their future work. This reaffirms the direction of research being followed by the IV&V team.
Reports already delivered:

- Background study on OO V&V
- Analysis & ID Risks Unique
- Base Set of Tasks Requirements Phase
- Report on OO V&V Analysis Techniques

OPTIMIZING IV&V BENEFITS USING SIMULATION

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By using simulation to optimize benefits, NASA will be able to assess the best way to allocate IV&V resources for a given project.

Objective

The goal of this effort is to develop a tool to support NASA IV&V managers as they plan IV&V for new and existing NASA projects. Using this tool, NASA will be able to assess the best way to allocate IV&V resources for a given project. Some questions that NASA will be able to address with the tool:

- What is the best strategy for applying IV&V technologies?
- How can the economic benefit of IV&V technologies be optimized on a given NASA project?
- What is the benefit of applying one combination of IV&V techniques to a given process vs. another?
- What is the benefit of a given IV&V technique when applied at different insertion points in the development process or applied multiple times?

This tool has broad application within NASA and may be used to assess more general questions on a NASA project:

- What is the best lifecycle development method for a proposed NASA project?
- How can this process be modified to optimize performance?
- Which alternative process would be better to apply to a specific portion of the project?
- What is the impact of a proposed process change on overall process performance?
- What is the value of applying tools on the project?

Approach

This work is based on extensive research into software process modeling conducted at the Software Engineering Institute (SEI) by Watts Humphrey, Marc Kellner, Bill Curtis and others. Dr. Raffo's research specifically focuses on predicting project performance in terms of development cost, project schedule and product quality using software process simulation models (SPSMs). To this end, we are developing methods and tools for efficiently allocating scarce IV&V resources across projects by determining the value associated with implementing IV&V techniques in various combinations throughout the development lifecycle. The result is an economic justification/business case for IV&V and process improvement efforts that managers can understand and use when setting budgets and trading-off among multiple IV&V techniques or process improvement activities. The models are configured to specific development projects and utilize industry standards and project specific data as available.

Significance

This work contributes to mission assurance and success by making recommendations asto how IV&V technologies should be deployed on a given project. It reduces the amount of time and expense required to conduct trials of these techniques, reduces the risk associated with applying IV&V methods, and increases the benefit that might be obtained. This enables IV&V technologies to be applied to NASA projects more quickly,achieving a higher benefit at a lower cost.

This work has broad application within NASA to plan software development processes used on NASA projects, to assess alternatives and to predict the impact of potential process changes. This work contributes to more efficient development and lifecycle management practices and directly supports several CMMI Process Areas (PAs) levels 4 and 5.

Accomplishments

During the first 8 months of this project, the research team has:

- Developed the architecture and design for a rapidly deployable software process simulation model.
- Developed and demonstrated a prototype of this model using the IEEE 12207 software development process (replacement for DO-2167A software development lifecycle).
- Developed and demonstrated one prototype IV&V technique (Requirements Traceability).
- Demonstrated how the model can be used to assess the effectiveness of IV&V and developed a sample business case.

RESEARCH AND DEVELOPMENT (R&D) REQUIRED TO ESTABLISH MODELING AND SIMULATION (M&S) VERIFICATION, VALIDATION, AND ACCREDITATION (VV&A) GUIDANCE AND PRACTICES FOR CERTIFYING SIMULATIONS USED FOR SOFTWARE REQUIREMENTS VERIFICATION

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This R&D effort will critically assess the practices of the M&S VV&A discipline as a basis for proposing guidance and practices that may be used to establishing credibility for simulations/simulation testbeds.

Objective

The goal of this R&D effort is to exploit newly developed practices from the discipline of modeling and simulation (M&S) verification, validation and accreditation (VV&A) to propose acceptable guidance and practices for certifying simulations that are used as software requirements testbeds for NASA projects with major software-critical components. This will provide NASA with a proposed software engineering practice/tool needed to produce safe, reliable, mission critical software.

Approach

This R&D effort will critically assess the practices of the M&S VV&A discipline as a basis for proposing guidance and practices that may be used to establish credibility for simulations/ simulation testbeds used by contractors in requirements driven software verification testing for NASA programs/projects that have major software critical components. This effort will be broken down into three tasks:

- Conduct a detailed appraisal and analysis of Defense Modeling and Simulation Office (DMSO) recommended practices,
- Implement the tailored guidance and practices, and
- Use lessons learned from Task 2 to refine the tailored guidance practices.

Significance

The use of sophisticated computer-based models and simulations by NASA supports current and future missions. Not only are these models and simulators implemented by software, but they may be properly applied to the verification and validation of software that lies at the heart of many new NASA programs. However, there are issues associated with the credibility of legacy M&S when used to contribute to development of new M&S. Most of these issues arise not because the M&S lack inherent quality, but because they were developed with a specific mission in mind. NASA should ensure that some measure of VV&A be applied to accredit the M&S for new applications.

Accomplishments

Conducted a detailed appraisal and analysis of practices from the discipline of M&S VV&A and other resources to propose acceptable guidance.

ROBUST REQUIREMENTS TRACING VIA INTERNET SEARCH TECHNOLOGY

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IV&V tracing of requirements to design, code, and test cases is difficult and must be done quickly and accurately.

Objective

IV&V tracing of requirements to design, code, and test cases is difficult (often no mapping is provided). It must be done quickly and accurately, and often must shortly be redone on updated documents or artifacts. IV&V tools are needed to automate linking between levels of documents or artifacts vs. developer's tools that only record links during decomposition.

Approach

Continue developing improved methods for finding candidate links between document/artifact levels using information retrieval techniques with user feedback incorporated. The research aims to integrate the developed methods for requirements tracing with an existing requirements tracing tool.

Significance

The goal of the research is to create an automated process for requirements tracing activities. The automation of this activity will assist the V&V analyst in producing a higher level product in less time along with automating a mundane task.

Accomplishments

To date, the research team has successfully implemented three feedback processing and two information retrieval (IR) methods into their requirements tracing tool. The results obtained indicate that IR methods in combination with feedback processing loops can capture most of the true links of the traceability matrix. Feedback processing methods and filtering techniques also allow for acceptable signal-to-noise ratios.

SEMANTIC METRICS FOR OBJECT-ORIENTED DESIGN

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The IV&V Facility will explore semantic metrics for object-oriented design to improve the identification of software features and qualities such as reusability, cohesion, coupling, and complexity.

Objective

To research a new suite of object-oriented software metrics, called semantic metrics, which will help software engineers identify fragile, low-quality code sections much earlier in development than traditional metrics allow; require less information from source code than other techniques; and potentially resolve problems associated with traditional software metrics.

Approach

A software tool will be developed that calculates various semantic metrics based on object-oriented metrics, program understanding, natural language processing, knowledge-based systems, semantic networks, and conceptual graphs. The results will then be validated using previous studies of two object-oriented systems in which syntactical metrics were calculated and human experts evaluated.

Significance

To date, only syntactical metrics have been used to measure software qualities. They are based solely on the structure of the programming language as opposed to the actual problem domain. Semantic metrics provide a new dimension in the identification of software features and qualities such as reusability, cohesion, coupling, and complexity. They can help identify fragile, low-quality code sections much earlier in development than traditional metrics. They require less information from source code than other techniques, which makes them more applicable. They also help to resolve certain problems associated with traditional software metrics. All of these benefits will help software engineers to develop higher quality code using cost effective techniques.

Accomplishments

A semantic metrics tool has been developed that calculates various semantic and syntactical metrics. The tool has been used to produce metrics for two software projects. The results are being analyzed and compared to prior work on the two projects, and initial results look promising.

Future Plans

The semantic metrics tool will be used in order to calculate metrics for additional projects including projects in the Metrics Data Program's repository. The techniques used to calculate the metrics will then be applied so that the same metrics can be calculated for design documents.

THE USE OF A VIRTUAL SYSTEM SIMULATOR AND EXECUTABLE SPECIFICATIONS TO ENHANCE SOFTWARE VERIFICATION, VALIDATION, AND SAFETY ASSURANCE

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The objective of this research is to test the validity of a new approach to the avionics development process based on the creation, simulation, and V&V of executable specifications.

Objective

The objective of this research is to test the validity of a new approach to the avionics development process based on the creation, simulation, and V&V of executable specifications. Executable specifications are being studied as a means of reducing errors in defining requirements and communicating them to the team responsible for implementing designs. This approach will be tested on a small but non-trivial system and the full lifecycle of a software project. The research will explore the viability and benefits of using this development approach as it relates to systems and software IV&V, quality, testability, and reliability.

Approach

The approach used is the translation of requirements into executable specifications and creating and running system-level tests against the specifications. The hardware environment of the system is simulated such that when the software object code is available it is integrated, unchanged, into the simulation and the tests rerun.

Significance

This simulation approach proposes simple translation of narrative requirements to executable specifications. Using these specifications in the virtual environment, many problems normally not found until integration testing will be found early in the project lifecycle. Metrics that would not normally be feasible to collect in a hardware test bed are easily collectible in the virtual environment. Further, hardware faults can be simulated in the simulation to ensure correct operation of the software in off-nominal conditions.

Accomplishments

The narrative specifications for a contrived system to be modeled in the virtual system simulator have been produced. The virtual system simulator infrastructure is in place.

Future Plans

The executable specifications, tests, and object code will be produced for the contrived system. Tests will be run against the executable specification prior to production of the object code. Object code will be used, unmodified, in the virtual environment. Metrics will be collected during execution of the object code.

TIMING AND RACE CONDITION VERIFICATION OF REAL-TIME SYSTEMS

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With this effort, the IV&V Facility will investigate a novel approach to uncover all possible derivations of program execution and race conditions among multiple concurrent threads.

Objectives

The goal of this research is to investigate a novel approach to uncover all possible derivations of program execution and race conditions among multiple concurrent threads caused by different event arrival instances.

Approach

The approach is based on an integration of test analysis techniques with timing measurement, scheduling, control-data flow analysis, and structured Input/Output (I/O) models. The findings will enhance software verification tasks by identifying necessary timing patterns for testing and by eliminating those that are not required. They will also reveal all potential thread interaction sequences. As a result, the systems will be robust against unanticipated timing scenarios. To automate the proposed approach, a tool suite will be developed and experiments with NASA space applications will be carried out.

Significance

Real-time embedded systems differentiate themselves from computation-intensive applications by their concurrent threads of control and time-dependent operations. As NASA's space applications become more complex and timing constraints on control actions more stringent, the verification of temporal behavior of real-time software systems has become a great challenge.

Accomplishments

Thus far this research has produced a Survey of Race Condition Detection, which is a comprehensive catalog and evaluation of existing race condition detection and analysis approaches including the advantages and disadvantages of each approach.

WEST VIRGINIA UNIVERSITY INITIATIVES ARCHITECTURAL-LEVEL SOFTWARE METRICS

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Once defined, the architectural-level software metrics alert the software architect to risks in the early stages of the architectural design.

Objective

The objective of this work is to define a set of quantitative metrics so as to reflect relevant qualities of domain architectures, and to alert the software architect to risks in the early stages of architectural design. These metrics can be used to assess the qualities of product-line architectures. This work seeks to analytically and empirically validate the relationships between these metrics and a set of quantitative factors that reflect quality attributes of architectures.

In the first year of this effort we defined a set of information coupling and cohesion metrics at the hierarchical architectural level. We applied these metrics on a client server architecture example and a NASA case study. Our goal in the second fiscal year of this project is to automate the process of collecting these metrics and to develop a relationship between these metrics and the quantitative factors such as error propagation. In the third year of this work we intend to validate the set of architecture metrics that we defined to assess the quality of software products. We want to analyze, understand, and empirically validate the relationship between software architecture metrics and a set of quantitative factors that have direct impact on the external quality attributes of a software product in terms of maintainability, reusability, and reliability. We will focus on domain architectures where maintainability and reusability are more significant as external quality attributes.

Approach

Evaluating the quality attributes of software architectures has become a major research focus. We recognize that advances in quantitative measurement are crucial to the vitality of the discipline of software IV&V. We focus in this project on defining and investigating metrics for domain architectures. We wish to define such metrics so as to reflect relevant qualities of domain architectures, and to alert the software architect to risks in the early stages of architectural design. We envision that such metrics should be based on a theoretical background, primarily on information theory, and they should be specific to the architectural level.

Significance

The field of software metrics has long exploited attributes derived from source code to empirically predict software quality factors, such as the number of software faults. However, there has been little research on modeling to predict the quality of architectures.

Accomplishments

We have demonstrated that the Clarkson Model of Multi-Step Change Propagation in software can be implemented as information-theoretic measure system of UML design. This theoretical result has enabled the creation of the SWARCH Architecture Tool.

FRACTAL ANALYSIS OF RESOURCE EXHAUSTION IN REAL-TIME OPERATING SYSTEM

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Fractal analysis of resource exhaustion in real-time operating systems may allow the Facility to estimate and forecast the rate of "decay" of software.

Objective

Recent studies revealed the phenomenon of "software aging" as a major cause of outages in computer systems. The phenomenon is primarily due to the exhaustion of operating system resources, data corruption, etc. Thus, there is a need for an effective quantitative model, which would enable us to estimate/forecast the rate of resource exhaustion.

We conjecture that the resource exhaustion rate of a real time operating system, considered as a function of time, exhibits fractal behavior. We hope to verify this conjecture, and, subsequently, use the fractal analysis to estimate the system outage hazard.

Approach

We will estimate the multi-fractal spectra, e.g., f(alpha) of raw data describing resource exhaustion under various workload conditions. We will analyze the structure of the obtained spectra. Then we will synthesize a multi-fractal time series from the given spectra and compare it with the original data to determine the adequacy of the model. We can then extrapolate the synthetic resource exhaustion time series to estimate the optimal time for preventive shutdown.

Significance

The potential contribution offered by the multi-fractal based technique falls in the area of preventive maintenance. This pilot study will be based on the data sets collected in the case study "A Measurement-Based Model for Estimation of Resource Exhaustion in Operational Software Systems." If the multi-fractal analysis justifies our expectations in terms of its predictive power, we will collect and analyze the parameters of a real-time operating system frequently used in space applications. Collecting and analyzing the parameters of a real-time operating system would be a part of the second year effort.

Accomplishments

Produced technical report on: Using Fractal Analysis to Model Software Aging, Software Aging and Multifractality of Memory Resources, and Multifractal Description of Resource Exhaustion Data in Real Time Operating System.

INTEGRATING FORMAL METHODS AND TESTING

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Significant advances can be made by merging formal verification and program testing in a united software reliability assessment framework.

Objective

Traditionally, formal methods of program verification and program testing are studied in separate research communities. However, none of them alone is powerful and practical enough to provide sufficient confidence in ultra-high reliability assessment when used exclusively. We believe that significant advances can be made by merging formal verification and program testing in a unified software reliability assessment framework. Our work seeks to:

- Combine formal correctness verification and statistical testing with the aim of gaining higher confidence in software reliability assessment for high-assurance applications.
- Quantify the impact of formal methods on software reliability.
- Demonstrate that correctness proofs reduce the number of tests needed to attain a certain confidence level.
- Quantify and justify the reliability estimate for systems developed using various formal methods.

Approach

Bayesian statistics is in the center of the framework for combining formal methods and testing. The cornerstone of Bayesian inference is the notion of subjective probability. Such a notion contrasts with the well-perceived notion of frequency for probability estimation. The axiom of probability states that the probability of a binary event has to be estimated by determining the success ratio. To test this empirical estimation, one has to conduct trials in which the event occurs repeatedly.

Subjective probability deals not only with the events but with propositions as well. A proposition is formulated from a collection of events that contribute to the estimation based on observed behavior, or the reflection of one's belief in the system. In statistical terms, we hypothesize that the event does occur with the estimated probability. As evidence relevant to the hypothesis increases, we may change the degree of belief in the hypothesis. Bayesian approach to software reliability assessment has been investigated, but in our opinion, its potential advantages have not yet been given full consideration. Reliability estimates determined in the test environment are used as the basis for subjective probability (prior belief) and supplemental testing is conducted to form the prior distribution on the probability of failure.

Significance

The proposed research is methodologically unique. However, the idea of combining static analysis with testing dates back to the late 1970's. This approach can significantly reduce the testing effort, if used carefully, but its application is cumbersome and the methodology has not been applied except in the university centered case studies.

Software reliability assessment for safety critical systems is not practical, and no technique is widely accepted. For this reason NASA, for example, usually avoids specifying software reliability requirements. Formal methods of software development and verification, while holding significant promise, are not mature enough yet to be a part of mainstream projects. At different NASA Centers (Ames, JPL, Langley), significant research efforts consider practical applications and tools for formal methods. Utilizing mature formal verification methodologies in software reliability assessment (i.e., allowing for quantification of their benefits) might provide a convincing argument for their wider deployment. Furthermore, the long term goal of this research is to make software reliability assessment for mission and safety critical systems practical. This would represent a significant contribution to the state of the art in software reliability engineering with concrete consequences to the practice of software development across NASA.

Accomplishments

We are currently seeing encouraging results with combining Reliability Prediction Systems (RPS), which include:

- Weighted sums used in initial experiments.
- RPS results weighted by the expert opinion index.
- Removing inherent dependencies/correlations.
- Dempster-Shafer (D-S) belief networks approach developed.
- Network automatically built from datasets by the Induction Algorithm.
- Existence of suitable NASA datasets.
- Pursuing leads with several CMM level 5 companies.

Software reliability corroboration which allows:

- Inclusion of IV&V quality measures and activities into the reliability assessment.
- A significant reduction in the number of (corroboration) tests.
- Reliability of safety/mission critical systems that can be assessed with a reasonable effort.

IV&V OF UML: RISK ASSESSMENT OF DYNAMIC SPECIFICATIONS

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The project will develop automated techniques to verify and validate the system behavior based on UML dynamic specifications.

Objective

The objective of this project is to develop automated techniques to verify and validate the system behavior based on UML dynamic specifications. This includes the development of risk assessment techniques based on dynamic specification.

Approach

The proposed research will be applied on the artifacts of the Hub Control System (HCS) project in the International Space Station (ISS) and other available projects. We acquired such artifacts from the IV&V analysts of Titan Systems during the first year of this project and developed a UML-RT model as described in the August 2001 deliverable of this project.

In the third year of this project (FY03), we propose to develop a methodology for performance-based/reliability-based risk assessment and validate the methodology on several NASA projects.

The following tasks will be the focus areas of our research:

1) Develop a cohesive methodology for performance-based and reliability-based risk analysis at the architectural level.

   The main thrust of our proposed work in FY03 is in the development of a cohesive methodology for performance- based and reliability- based risk assessment. We also intend to explore the extension of this methodology to other risk factors such as maintainability-based risk. The tradeoffs of these risk factors and their interdependencies will also be investigated. The following subtasks will also be performed to extend our proposed methodology:

   - Severity analysis and levels: Severity analysis is one of the important cornerstones of risk assessment. The methodology we developed for risk assessment is currently based on IVV of UML.
   - Performing Failure Mode and Effect Analysis together with hazard analysis: This is done to estimate the severity levels of components and connectors. We intend to formalize this process and explore a methodology for quantitative measures of severity levels based on a cost function.
   - Ranking of components and connectors: The result of our risk analysis is to rank use cases, scenarios, components, and connectors based on their risk factors. A statistical technique will be developed to formalize this process.

2) Validate the methodology.

   We propose to apply our methodology on several NASA case studies. The case study we used in FY02 is based on the Hub Control Software (HCS) resident in the Hub Control Zone Multiplexer/Demultiplexers, which are installed in the Node 3 Module of the International Space Station (ISS). We are currently exploring the Mission Data System (MDS) case study developed at Jet Propulsion Laboratory

(JPL). We also intend to explore the use of the IV&V Facility metrics data program. Finally, we intend to explore other case studies based on ITOS and X34.

Significance

There have been few attempts in developing techniques for verifying and validating the system behavior based UML dynamic specifications. There haven't been any attempts to automate this verification and validation process of performance and timing constraints and the development of dynamic metrics. Many of the current and previous works focus on mapping the UML specifications to formal specifications where analysis and verification techniques can be applied. The work we propose is different in that it is directly based on the UML specification models and on COTS CASE tools.

Accomplishments

In the first year of this project (FY01), we developed a simulation environment for UML dynamic specification models. These models are based on scenarios that are captured using UML interaction and sequence diagrams. The models are architectural; i.e., they are composed of components (or objects) as defined in UML-RT capsule diagrams, and connectors (links between actors and objects). State charts are used for specifying the dynamic behavior of each component. We also developed dynamic models for an observer component that initiates and controls the simulation runs, as well as a methodology to verify and validate the timing constraints and performance requirements. The environment produces a violation table for timing constraints and performance analysis measures. We applied the above environment on the HCS case study. We have developed a fault-injection technique for UML dynamic specs to assess the effectiveness of this environment. These techniques help further in developing the risk assessment methodology.

In the second year of this project (FY02) we developed a reliability-based risk assessment methodology. The methodology extends our previous work in risk analysis models and performs complexity and risk analysis on the dynamic specification models. We take a hierarchical approach; we first estimate risk factors for each component and connector and then estimate the overall risk factor at the scenario level, at the Use Case level, and at the application level as an aggregate of the risk factors of the individual architecture elements.

LYAPUNOV STABILITY ANALYSIS AND ONLINE MONITORING

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Lyapunov stability analysis and online monitoring will lay the groundwork for developing V&V methods and techniques that can be applied to systems which contain online learning artificial neural networks.

Objective

Artificial Neural Networks (ANN) play an increasingly important role in flight control and navigation, two focus areas for NASA. They are very useful in application domains that arise routinely within NASA's practice areas, where autonomy and adaptability are important features. A major obstacle, however, precludes the widespread use of ANN's in navigation and control systems. Most of the certification standards that NASA and other federal agencies (such as FAA) impose on such life-critical and mission-critical applications cannot be met with today's V&V technology. No existing software V&V method/technique can be applied to systems, which contain on-line learning artificial neural networks.

The objective of this project is to produce a better framework for reasoning about adaptive systems. In the short term, this objective involves the following goals:

- Derive understanding of the self-stabilization analysis techniques suitable for neural network verification.
- Develop an analysis model for static system analysis and run-time monitoring.
- Investigate the applicability of the developed analysis method with respect to the verification/certification techniques currently developed by WVU/ISR/NASA IV&V.

Approach

The methodologies currently being investigated under the auspices of this University Initiative are:

Data Monitoring Methods

The research team investigated approaches that analyze the stream of incoming data points used for the training and adaptation, as well as the stream of learning outcomes. Based on the originally defined measures of distance, we developed filtering techniques which prevent the data from being used in learning if the data points are considered of low quality, or prevent the learning results from entering the control system due to possible safety violations, and cause the learning device to unroll back to a safer state.

Development of Flight Simulation V&V Environment

Proper experimentation is required to justify realism and applicability of our research results to NASA practice. Therefore, we have embarked on developing modifications to a medium fidelity F15 simulator so that it supports data collection tasks needed for V&V research. We will continue our work on the simulator in FY03.

Lyapunov Stability Analysis

The research directs us towards the use of a stronger notion of stability than in the traditional self-stabilization approaches for discrete systems. The fact that Lyapunov's direct method or Lyapunov's second method can be systematically applied to validate the existence or non-existence of stable states in an adaptive system, directs us to use Lyapunov's concept of self-stabilization in our analysis as a means of answering the questions posed earlier.

Lyapunov Based On-Line Performance Monitoring

The ultimate goal of our analysis is to determine whether, under given usage conditions, the neural network is convergent, meaning that all trajectories converge to a stationary state, hopefully the one with a reasonably small estimation error. Since Task 3 is to provide the required mathematical foundation to support system stability, we need to assure and guarantee the robustness of system. In other words, if the online neural network encounters unusual data patterns that force the state of the system to deviate away from its current pattern, it always converges back to equilibrium within a finite amount of time. We may not always be able to assure robustness of the online network due to its implementation in an adaptive system, where the data patterns have no prior probability distribution. However, we should at least be able to detect deviations of state that could lead to unstability, which is the objective of the Online Stability Monitor.

Significance

Traditional methodologies for providing provable stability require knowledge of all system implementation variables in order to compute the required invariance conditions. The role of an invariance condition in proving the system's ability to self-stabilize is as follows: if the system is initiated appropriately, the invariant is always satisfied and if the system is placed in an arbitrary state to continue execution, it eventually reaches a state from where the invariant is always satisfied. A global stability criterion determines whether or not the overall system is currently in the legitimate state using the following conditions: (1) any possible transition from a legitimate system state will bring the system back to a legitimate state; (2) for any pair of legitimate states, there exists a sequence of moves that transfers the system from one legitimate state to another.

This definition applies to discrete state systems. In its pure form, it is inapplicable to a continuous control system, such as an adaptive flight control system. The project is expected to develop the methodologies that apply the above described traditional concepts in proving self-stabilization properties of continuously evolving, topologically complex, non-linear neural network structure in an adaptive flight control system environment.

Accomplishments

Currently we have produced an F-15 simulator customized for NASA/WVU research needs which uses input data sets from simulated flights as well as Dynamic Cell Structures (DCS) network (Mach, altitude, alpha (angle of attack). We are confident in the computational efficiency of Lyapunov, that the self-stabilization theory can guarantee that the network actually preserves and learns the input feature data manifold. Additionally, we are seeing indications that Lyapunov can offer effective monitoring of performance aspects of the neural network controllers.

PERFORMABILITY OF WEB-BASED APPLICATIONS

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The project will develop scalable measurement and modeling approaches that can be combined together to analyze multiple quality attributes of complex web-based systems.

Objective

The objective of this project is to develop scalable measurement and modeling approaches with different levels of details and abstraction that can be combined together to analyze multiple quality attributes of complex web-based systems. In addition to typical web-based applications, this research work will focus on mission-critical web-based applications developed at NASA. It is theorized the research results can be used for verification and validation of web-based systems before they are built, as well as for tuning and maintenance of existing web-based systems.

Approach

The core of the measurement and modeling framework is a set of layers that can be plugged onto each other. Each layer adds another level of detail to the measurements and models. Layers are created in a top-down fashion, starting always at the highest layer and then going down to the chosen level of detail. The more layers are plugged in, the more detailed will be the reliability, availability, and performance measurements and models and the more insights into the system behavior will be provided. The layered modeling framework provides basis for development of both dependability (i.e., reliability/availability) and performance models. The results of these two models will then be combined to derive performability measures and study their tradeoffs.

Significance

The significance of this research is in addressing the characteristics and challenges of web-based systems. Thus, due to the large-scale and complexity of Web based systems, the proposed approaches must be scalable and must allow models, measurements, and simulation techniques with different level of details and abstraction to be combined together. What makes this research unique, in addition to addressing fundamental limitations for quantitative assurance of each quality attribute treated in isolation, is the aspect of combining individual quality attributes within an integrated framework aimed at analyzing their tradeoffs. In addition to quality assurance of typical web servers, this project will focus on quality assurance of Tempest, the embedded web server developed at the Glenn Research Center. This will allow the researchers to focus on mission-critical web-based applications typical for NASA.

Accomplishments

A scalable measurement and modeling framework for quality assurance of web-based systems was developed. This framework provides basis for measurement and modeling of reliability, availability, and performance. Further, the usage and execution behavior of two Web servers, one at NASA Kennedy Space Center and one at West Virginia University Lane Department of Computer Science and Electrical Engineering, were characterized. The characteristics of user sessions were analyzed and the effect of the threshold value on total number of sessions was studied. The development of the methods for extraction of typical sessions for different group of users is currently in progress.

Future Plans

The future work will be focused on characterization of the Web workload and the failure/repair behavior based on measurements. These results will be used to develop performance models that consider unique characteristics of web workload (e.g., busy traffic and large number of clients) and reliability/availability models based on typical usage patterns. Finally, performance and reliability/availability measures will be combined in performability measures and their tradeoff will be studied.

QUANTITATIVE RELATIONS BETWEEN STATIC AND DYNAMIC SW METRICS

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Our objective is to discover quantitative relationships between many static software metrics and their dynamic counterparts by using both analytical and empirical methods.

Objective

In the current IV&V practices the early life cycle assessment of a software quality is performed based on evaluating the static metrics. However, unlike their dynamic counterparts, the static software metrics are obtained only by inspection of the artifacts, without actually executing the software. Therefore, it is not obvious whether their values reflect the actual quality characteristics of the software. This dilemma calls for an investigation of the actual quantitative relationships between various static and dynamic software metrics.

We conjecture that there are quantitative relationships between many static software metrics and their dynamic counterparts. We believe that these relationships exist in the form of statistical correlation and, sometimes, mathematical inequalities. Our objective is to discover such relationships using both analytical and empirical methods.

Approach

The project is planned for a two year period and will involve the following two tasks:

- Data Collection and Interpretation. This task will deal with the empirical study of the relationship between the static and dynamic metrics. The task will benefit from utilizing the case studies, tools and experience developed by the team while working on the NASA V&V project "Architectural Level Metrics".
- Analytical Study of Relationships between Static and Dynamic Metrics. Guided by the intuition developed in the experimental phase of the work (Task 1), in Task 2 we will address the problem using mathematical methods. Formal algebraic analysis of formulas defining software metrics will be carried out.

Significance

The identification of the set of static metrics that correlate with dynamic metrics at the early stages of development will enable IV&V practitioners to better assess the quality of software.

A bibliographic search on the topics related to the proposed research has been carried out. Although software engineering researchers appear to be aware of this interesting problem, very little actual research exploring the quantitative correlation between the static and dynamic metrics seems to have been done. Previous research focused mainly on code-level metrics.

The studies in this area are still sporadic and lack a unified, systematic methodology. In addition, the research on the subject of comparison of static and dynamic metrics so far has been purely empirical and was not supported by any analytical arguments, which would demonstrate the existence of mathematically expressible relationships between static/dynamic pairs of metrics. The research we propose would fill in this gap and lay the foundation for a more systematic approach to the problem of how much information on the dynamic behavior of a system can be captured from its static analysis.

Accomplishments

We have tested three hypotheses so far under this initiative:

- Hypothesis I: Static coupling metrics correlate with error propagation in software architectures.
  Current results are inconclusive.
- Hypothesis II: Static error propagation correlates with dynamic error propagation.
  Yes, hypothesis supported.
- Hypothesis III: "Change proneness" correlates with dynamic coupling of components.
  No, hypothesis not supported.

SENSITIVITY OF SOFTWARE RELIABILITY TO OPERATIONAL PROFILE ERRORS

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The sensitivity of software reliability to operational profile errors calls for the development of a methodology for uncertainty analysis of software reliability (due to the operational profile errors) that is suitable for large complex component-based software systems.

Objective

The objective of this project is to develop a methodology for uncertainty analysis of software reliability due to the operational profile errors that is suitable for large complex component-based software systems and applicable throughout the software life cycle. Within this methodology different methods for uncertainty analysis will be developed and compared based on several criteria. The methodology will be applied and validated on empirical case studies.

Approach

An architecture-based methodology for uncertainty analysis of software reliability will be developed. The methodology is based on stochastic models such as Markov chains and considers different approaches for building software architecture (uninformed approach, intended approach, and informed approach) and estimating component reliabilities (growth models, non-failed executions, and fault injection). Further, it addresses the parameter uncertainty problem and how it affects the system reliability estimates. Within this methodology several different methods for uncertainty analysis are considered and compared. The methodology is applied on empirical case studies from different phases of the software life cycle.

Significance

The uncertainty analysis of the software reliability due to operational profile errors is of essential importance for the NASA domain software which, on one side requires reliability estimates with high accuracy, while on the other side deals with events whose frequencies are difficult to predict. For such applications, traditional ways of plugging point estimates of the unknown parameters into the model to compute software reliability is not appropriate because there is a lot of uncertainty around the parameters. Our methodology can be used to assess the effects of the uncertainty in the operational profile and component reliabilities on software reliability estimates, thus leading to more realistic reliability predictions that can be used for software reliability assessment through the life cycle, allocation of time and resources for software validation and verification, and certification of component-based software systems.

Accomplishments

A methodology for uncertainty analysis of component-based software systems was developed. Within this methodology, the following five methods for uncertainty analysis were developed: entropy, method of moments, Monte Carlo simulations, perturbation, and confidence intervals. The methodology and different methods were applied on software developed for the European Space Agency and the NASA's Hub Control System (HCS) from the International Space Station (ISS). The above five methods for uncertainty analysis were compared accordingly to the following criteria: data requirements, reliability measures derived, accuracy of the solutions, and scalability with respect to the number of components. Comparison results were compiled in the “Make a choice” table which can be used as a sound guideline for choosing the most appropriate method for a given software application. The research results of this project were published in four conference papers and one journal paper.

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S. Kamavaram and K. Goseva-Popstojanova, "Entropy as a Measure of Uncertainty in Software Reliability", 13th IEEE International Symposium on Software Reliability(ISSRE 2002), Annapolis, MD, Nov. 2002, pp.209-210. (http://www.issre2002.org)

TRANSLATION VALIDATION OF COMPILERS/ INTERPRETERS

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Translation Validation of Compilers/Interpreters will develop a certification mechanism for the semantic equivalence of the source code developed in model-based programming languages.

Objective

This project intends to develop a certification mechanism that "certifies" semantic equivalence of the source code developed in model-based programming languages to the target code. In conjunction with the techniques developed for automatic/semi-automatic validation of software within NASA, such a certification mechanism should be able to provide more reliability guarantees for the compiled software output that will be flown on autonomous spacecrafts. We intend to use as a case study the model-based programming language MPL (Model Programming Language). MPL is the input language for the Livingstone real time system health manager architecture (L2) which is used in the next generation reusable launch vehicles X 34 and X 37.

Approach

The basis of our translation validation methodology is the notion of refinement checking where we verify whether every behavior of the implementation is an allowable behavior of the specification. In our case, the source code will be viewed as an abstract model of a system or the specification and the target code will be viewed as an implementation. A translation validator will take both the source code and the target code as input and produce a 'yes' output if the target code correctly "implements" the source code. Otherwise it will produce a counterexample showing how the target code can behave differently from the source code. In our case the problem of refinement checking is undecidable (i.e., no algorithm for solving this problem can exist). Hence we are going to follow a semi-automatic approach.

Given the source code as a parallel composition of sequential components we first establish a refinement mapping between each component and the target code (for the composed system). This can be done semi-automatically using refinement mappings. Once these refinement mappings have been established, we will use program slicing techniques to extract a skeleton from each component of the source code. A general purpose program slicer like CodeSurfer, developed by GrammaTech, can be used for this purpose. From each such synchronization skeleton we can automatically derive a quantified propositional temporal logic (QPTL) formula describing its behaviors. The conjunction of these QPTL formulae (still a QPTL formula) describes the behaviors of the composed system. We call this formula the abstract formula.

From the target code, we will automatically extract a control flow graph using program slicing techniques. This extraction will use the refinement mappings described above to identify the control points. Finally, from this control flow graph, we will automatically derive a QPTL formula (called the concrete formula) that describes the control flow with respect to the identified control points in the target code. Establishing refinement now amounts to proving that the concrete formula implies the abstract one. This can be done automatically using the tool TLV. Overall control and rigor in this research project must be high and the work of commercial/industrial quality as a real aerospace project is involved.

Significance

Translation validation has been used for the synchronous programming language SIGNAL as well as sequential Ada programs. Zuck et. al. used translation validation technology to validate output of optimizing compilers. Until now no work has been reported on the application of translation validation technology to compilers/interpreters for model-based programming languages.

In spite of the tremendous effort invested in developing tools and methodologies for building correct software, a big gap in software reliability remains, due to the potential presence of bugs in the compiler itself. Detection of the cause of such bugs by conventional debugging methods is extremely unlikely. Such bugs might lead to many accidents and fatal failures, the causes of which can be difficult to detect even after extensive postmortem. By developing methodology to ensure the correctness of the compilation process, mission assurance and mission success can more effectively achieved. The proposed project attempts to close a potential hole in the software development cycle.

Despite the cancellation of the X 34 project in 2001, some of its code will be reused in later projects like X 37. Development of a translation validation methodology for validating compilers/interpreters of model-based programming languages used in developing software for autonomous spacecrafts will help in mission assurance for next generation shuttles like X 37 developed by NASA.

Accomplishments

This work is a three stage process of

1) tool building the toolkit's framework,
2) commissioning the toolkit on NASA case studies, then
3) carefully evaluating the utility of the tools.

This initiative has completed task (1) and is currently finishing task (2).

VERIFICATION AND VALIDATION OF ADAPTIVE SYSTEMS

Verification and validation of adaptive systems will derive a computational model for adaptive systems, validate the proposed model, and investigate how it can be used to derive methods for the verification and certification of adaptive systems.

Objective

The objective of this proposal is to attempt to produce a framework for reasoning about adaptive systems. In the short term, this objective involves the following goals:

- Derive a computational model for adaptive systems.
- Validate the proposed model against existing adaptive algorithms, to show its relevance.
- Validate the proposed model within existing application areas, to show its applicability.
- Investigate how this model can be used to derive methods for the verification / certification of adaptive systems.

In the medium term, we intend to derive engineering techniques for the verification of adaptive systems, and to investigate how these techniques can be used to meet predefined certification standards.

Approach

We have tentatively derived a computational model for neural nets based on the Multi-Layer Perception (MLP) learning algorithm, and are currently working on generalizing this model to fit other families of neural nets, and more generally all types of adaptive systems. This model is based on the premise that, to reason about an online adaptive system, we should not be concerned with the exact function that the system is computing, but rather with the range of possible functions that the system could be computing for the given learning algorithm and learning data. We capture the range of possible functions by a non-deterministic relation, which we call the functional envelope of the adaptive system, and we resolve to reason on the functional envelope of the system, rather than its function.

Verification Methods

We have derived two tentative methods for the verification of adaptive systems, which we briefly discuss below:

- Monotonic Learning. This method provides that the functional envelope of the adaptive system grows in the refinement ordering with each new learning sample; the challenge of this method is to characterize learning data that ensures monotonicity. This method can be viewed as a testing method for adaptive systems, in the sense that it ensures that any behavior that is observed under test is provably preserved (or surpassed) under subsequent field usage, even as the adaptive system evolves. A trivial extension of monotonic learning is a method, which we refer to as weak monotonic learning, where the functional envelope grows, not necessarily for each learning data, but for limited size sequences of learning data.
- Safe Learning. This method does not require strict monotonicity, but requires that as the adaptive system evolves, it remains above a pre-defined set of safety requirements. In practice, these minimal requirements typically include mission-critical imperatives (e.g. the adaptive system must, at all times, know enough to save the mission).

- Other methods are being investigated, at the same time as we assess these methods for relevance and applicability.

Significance

Our approach to this problem can be characterized by three premises, which we present below:

- Seeking Formality. Whether we use a verification-like method, a testing-like method, or a fault tolerance-like method, we wish to quantify the result of our effort by a logical or probabilistic /statistical statement about the fitness of the system under consideration.
- Seeking Generality. There is a wide range of families of adaptive systems today; each member can be characterized by a variety of design options and a variety of parameters. For the sake of generality, we will try to make as much progress as possible into the derivation and analysis of verification/ validation methods without committing to any particular design options. To this effect, and to serve the need for formality, we will derive a generic computational model for adaptive systems, which we discuss in the sequel.
- Seeking Diversity. We have found it useful to use an eclectic approach when devising a technique for verifying/ validating complex software systems. The eclectic approach can be rationalized by the Law of Diminishing Returns: each specific method is effective under some circumstances, for specific system aspects, and less effective in others. By using a variety of methods, we ensure that most aspects are adequately covered under most circumstances.

Accomplishments

- Defined a computational model of adaptive systems
- Compiled a study of flight simulation capabilities for adaptive systems
- Validated the models for applicability and relevance

IV&V FACILITY-SPONSORED RESEARCH DEVELOPMENT OF METHODOLOGIES FOR IV&V NEURAL NETWORKS

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Expanding on existing simulation research, mapping how military pilots are trained and certified, and using simulation techniques will make possible the development of IV&V methodologies for neural networks.

Objective

As technology allows flight at ever-faster speeds in increasingly complex vehicles, maintaining control of the crafts becomes comparably more difficult. The adjustments and timing necessary to maintain control of the next generation of jets are poised to exceed the capabilities of a human pilot. Unmanned aerial vehicles and pilot-less planes also bring challenges, resulting in efforts to produce adaptive flight controllers and other non-deterministic flight control systems.

Such non-deterministic systems often rely upon neural network (NN) technology to learn to manage flight systems under controlled conditions using carefully chosen training sets. The question becomes, how can these adaptive systems be certified to ensure that they will become increasingly efficient and behave appropriately in real-time situations?

The bulk of Independent Verification and Validation (IV&V) research of non deterministic software control systems, such as Adaptive Flight Controllers (AFC's), addresses NNs in well behaved and constrained environments such as simulations and strict process control. However, neither substantive research, nor effective IV&V techniques have been found to address AFC's learning in real-time and adapting to live flight conditions.

Adaptive flight control systems offer good extensibility into commercial aviation as well as military aviation and transportation. Consequently, this area of IV&V represents an area of growing interest and urgency. In support of this growing need, this project seeks to:

- Create a repository for IV&V of Non-Deterministic Systems at the Fairmont, WV NASA IV&V Facility;
- Conduct research into how human pilots are certified for flight readiness and to create a valid model for developing IV&V strategies and techniques for IV&V of non-deterministic software and systems; and
- Test the developed methods and techniques.

Approach

Many non-deterministic systems rely upon neural network (NN) technology to “learn” to manage flight systems under controlled conditions using carefully chosen training sets. To date, little has been found in the way of tools to perform IV&V for NN implementation of flight control systems. Much research is being done in constrained environments and ensuring the processes used while building and training a NN. Research in IV&V methods and techniques during the development of the ARTS II AFC Intelligent Flight Control System Project for NASA Dryden has shown that IV&V techniques are reasonably well-defined for pre-trained NNs in well-behaved and constrained environments. However, little research has been found that addresses IV&V of NNs in AFC's that are learning in real-time and adapting to the live flight conditions.

To fill this void, the project proposes to further the current body of knowledge to meet two objectives:

- Create a knowledge repository of research and information on IV&V of non deterministic software systems, and make this knowledge readily available to IV&V personnel; and
- Identify effective methods for IV&V of NNs that learn in real-time, including developing a prototype test bed for IV&V of AFC's.

Significance

All available research into the IV&V of non-deterministic adaptive flight control systems focuses on processes and simulation. The proposed approach considers the problem from a different angle by expanding on existing simulation research and mapping how military pilots are trained and certified, using simulation techniques, into the V&V of adaptive flight control systems. Currently, there is no practical approach to certifying adaptive flight control systems for flight operations. This research has the potential to solve that problem by proving an approach that mirrors what happens in “real life”.

Accomplishments

- Presented papers at the AISC and Aerosense SPIE conferences
- Submitted papers to the HASE and FLAIRS conferences
- Have begun training the DCS Neural Network with flight data and have extracted an initial set of rules completed the Data Sniffing subtask
- Developed a prototype software utility that has the ability to automatically generate test cases given a single continuous stream of data (AATG)
- Research has begun (research plan developed and in place) on Visualization methods
- Research has begun (research plan developed and in place) on Automated NN Selection
- Continuing to map IV&V procedures, IEEE 1012, AMES Guidance Documents, and the IFCS SVVP documents to IVVNN tasks in the methodology

INTEGRATING MODEL CHECKING AND PROCEDURAL LANGUAGES

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The IV&V Facility is integrating model checking and procedural languages to develop (from working prototype) a fast, memory-efficient, fault-detection tool for finite-state models of concurrent systems.

Objective

To develop (from working prototype) a fast, memory-efficient fault-detection tool for finite-state models of concurrent systems. The tool will allow as-is procedural code to make up part of the model, but provide close to the same functionality now provided by other software verification tools (which typically require that the whole model be rewritten). We hope to make possible:

- Faster development of software models, since less time and effort will be spent on making models amenable to verification tools
- Increased quality of complex systems now too large for verification with existing tools

Approach

Existing software verification tools use a systematic search of all behaviors represented by the model. Even for moderately complex models this may require very large amounts of time and memory. Our approach uses an efficient randomized search algorithm to quickly explore the space of possible behaviors. Although there is no guarantee that the randomized search will explore all possible behaviors, our experimental results are encouraging:

- For very large, randomly-generated models the randomized search was able to detect faults quickly and using very little memory, even when these models were much too large to be checked by existing verification tools.
- For a large model of a commercial flight guidance system the randomized search found nearly every fault found by full verification by the established model checking tool NuSMV, but much faster and with orders of magnitude less memory.

Significance

The so-called state-space explosion problem encountered by existing software model verification tools—that the space of possible behaviors represented by the model quickly explodes as more components are added to the system—makes it very difficult to find faults in complex systems using traditional deterministic search strategies. Our preliminary results suggest that a randomized search may provide an effective alternative for many of these very complex systems.

Accomplishments

Preliminary results mentioned above have been presented to the NASA community at the most recent Software Engineering Workshop.

On the Advantages of Approximate vs. Complete Verification: Bigger Models, Faster, Less Memory, Usually Accurate (for 28th Annual NASA Goddard Software Engineering Workshop, SEW'03).

OPTIMIZING IV&V FOR MATURE ORGANIZATIONS

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The objective of optimizing IV&V for mature organizations is to provide a complementary set of guidelines and criteria to assist in the planning of IV&V activities.

Objective

The objective of this research is to provide a complementary set of guidelines and criteria to assist in the planning of IV&V activities for a project using a prior knowledge of the measurable levels of maturity of the organization developing the software. The research examines what optimization strategies can be taken by IV&V planners, knowing the appraised level of maturity, based on the Capability Maturity Model Integrated (CMMI), of the development organization.

Approach

This research effort focuses on the relationship between IV&V activities and an organization's (documented and certified) mature processes. A two-pronged approach has been identified for this effort. First, the research team examined the CMMI Key Process Areas (KPA) top-down from an IV&V perspective, considering processes and their artifacts and where IV&V fits best.

Second, the team has identified the need for a bottom-up study of at least one IV&V project with a mature software organization certified CMMI Level 2 or higher. In this study the team will explore how IV&V activities were applied, their relation to the maturity of the organization, and in some manner, how effective they have been.

Upon conclusion of the second method, the combined results of the two methods should provide insightful conclusions about the hypothesis that IV&V can be better applied knowing how mature an organization's processes are, as well as to what degree a CMM Level rating allows for better IV&V.

Significance

The set of developed guidelines resulting from this effort will be helpful to IV&V planners for both ongoing and future IV&V project efforts. Results from the research could also demonstrate how the integration of an IV&V into a mature organization can best be accomplished. This is important as more organizations developing safety critical software are certified at certain levels of maturity.

The benefits of guidelines and strategies for best applying IV&V to a mature organization include:

- IV&V planners could be better prepared for projects involving more mature development organizations
- IV&V activities could be applied where they are most needed
- Possible refinements to CMMI (or other model) activities can be suggested to accommodate or improve IV&V, thereby improving the entire process
- Duplication of efforts performed by IV&V and internal QA could be reduced

Accomplishments

Adaptation of research initiative for the CMMI rather than the CMM

Draft analysis of CMMI PAs and work products in the context of IEEE 1012

Criteria for analysis of artifacts:

- Useful for IV&V planning?
- Useful/necessary in IV&V technical tasks?
- Possibility of compromising technical independence?

Two articles submitted to NASA Software Engineering Workshop (SEW)

- "Optimizing IV&V in Mature Organizations"
- "Software V&V and the RUP"

RETURN ON INVESTMENT FOR IV&V

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The NASA IV&V Facility will build a predictive model for IV&V, based on both the direct and indirect benefits, that will aid in selecting projects which will benefit most from finite IV&V resources.

Objective

There are many benefits that arise from application of software independent verification and validation (IV&V). These benefits can be categorized as either reduced development cost or indirect benefits, such as increased confidence in the final product, improved quality, reduced risk and improved safety, and reduction in development rework. Unfortunately, all of the indirect benefits are inherently difficult to measure.

The goal of this effort is to build a predictive model for IV&V, based on both the direct and indirect benefits, that will aid in selecting projects which will benefit most from finite IV&V resources. The predictive model for IV&V will be tailorable to individual projects and will therefore be a valuable management tool for identifying which projects should be subjected to IV&V. The predictive model will also be useful in demonstrating to members of the IV&V Board of Directors (IBD) and to project managers the value of performing IV&V.

Approach

The current approach builds on previous work which defined a method to successfully compute the direct return on investment (ROI) for IV&V, which considers only the cost-to-fix component of ROI, and then applied the method to five case studies. Direct ROI denotes direct reduction in development cost resulting from early issue detection by IV&V.

The research team then developed methods to determine value associated with the identified indirect components of ROI, and performed studies to extend the direct ROI model to include selected indirect components. The inclusion of the indirect components in the direct ROI model resulted in the development of a comprehensive ROI model which will form the basis of the predictive model.

Significance

The development of a predicative model for the ROI of IV&V will provide the IV&V Facility with a means of estimating the ROI of a potential effort based on certain project characteristics. This capability will allow the IV&V Facility New Business Lead and the IBD to accurately estimate what projects are going to deliver the greatest return and will therefore assist in the allocation of funds amongst projects. The data and methods resulting from this study have the potential to be adapted to developing ROI techniques for other disciplines within the software assurance community.

Accomplishments

As a result of this effort, the research team has successfully calculated the Direct ROI for five NASA IV&V Projects and documented ROI figures ranging from 1.24 up to 4.93. The research team also developed a list of 26 distinct indirect benefits of IV&V which, via successive refinement steps, resulted in a refined list of four benefits that appear to be well-suited for incorporation into the direct IV&V ROI model. A potential quantification method has been identified for each of the IV&V benefits in the refined list and current research is aimed at quantifying said benefits on the five previously examined case studies.

The overall results of this research effort have proved to be very promising; it appears that enhancing the successful direct ROI model with indirect benefits is feasible, defensible, and useful. Furthermore, the development of the Predictive ROI Model will certainly prove to be a valuable asset to the IV&V Facility and the members of the IBD.

STATIC ANALYSIS OF SOFTWARE FOR AUTONOMOUS SPACECRAFTS

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Static analysis of software for autonomous spacecrafts will extend those techniques for application to software for autonomous spacecrafts.

Objective

The intention is to use static analysis techniques to analyze and validate software for autonomous systems. Such analysis can be applied at compile time without any need for extracting formal models from the code, and can be used to detect different types of bugs ranging from memory leaks to concurrency errors. The techniques developed will be implemented in a tool that will be loosely integrated with the compilers/interpreters.

Case study material will be used from:

- the C++ version of Livingstone real-time system health manager architecture (L2)
- the Hubble Space Telescope Scheduler (HSTS) and the Smart Executive components (written in Lisp) of the Remote Agent autonomous spacecraft controller used in Deep Space 1 (DS1)
- the Fault Detection and Isolation Manager (FDIM), a standard command language (SCL) compatible derivative of Livingstone developed by the Interface and Control Systems Inc.
- hardware and software models encoded in the Model Programming Language (MPL)

Approach

Application of static analysis techniques to general purpose programming languages has been well-researched for a quarter of a century. Static analysis was applied to embedded systems only recently by the principal investigator in his PhD thesis and in several papers based on that. This work will extend those techniques for application to software for autonomous spacecrafts; in particular to model based programming languages.

The basic approach will consist of an initial slicing of the code to make it suitable for a particular analysis. This can be done by a general purpose slicing tool like CodeSurfer developed by GrammaTech Inc. Slicing not only makes the code suitable for a particular analysis, it also makes manual code review easier. The next steps will consist in automatically inferring constraints from the code and then compiling them into a constraint logic program (CLP). The final step consists in applying program transformation techniques on the resulting CLP and then using an inference engine either to refute or to saturate. The tool will then interpret the results of the analysis and warnings/error messages will be issued asking the programmer to take appropriate steps.

Significance

Static analysis techniques for general purpose programming languages have been known for more than 25 years. Only recently, however, has static analysis been applied to embedded software, and until now no work has explored the application of such techniques to model based programming languages that are used in developing software for autonomous spacecrafts. In particular, exploiting the constrained nature of such languages, inferring system-wide behavior from engineer-specified models of system components, as well as dealing with compositionality and concurrency issues are challenging problems that need to be explored.

Despite the cancellation of the X 34 project in 2001, some of its code will be reused in later projects like X 37. Development of a tool kit for static analysis will help in mission assurance for next generation shuttles developed by NASA. The tool kit can be used to improve software quality during the development of FDIM. Besides, integrating static analysis into the software development cycle will help in improving the quality of mission software developed at NASA as well as reducing the duration of software projects across NASA. Failures like those of the Mars Polar Lander and the Mars Climate Orbiter missions can be avoided.

Accomplishments

Completed Tasks

- Implemented tool for translating C++ source code to CQL clauses
- Developed tool for computing models of CQL programs
- Conducted preliminary case studies

Current Tasks

- Implement translator from JMPL to CQL
- Study new techniques to make the analysis faster e.g., randomized techniques
- Conduct more rigorous case studies

IV&V CODE LEVEL METRICS DATA PROGRAM

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The creation of a centralized repository that provides consistent, fully-involved software product data across multiple domains will allow NASA to improve the effectiveness of software assurance and research, and improve the ability of projects to predict software errors.

Objective

The goal of this effort is to establish a centralized repository that provides consistent, fully-involved software product data across multiple domains. This will allow NASA to do several things:

- Improve the effectiveness of software assurance.
- Improve the effectiveness of software research.
- Improve the ability of projects to predict software errors early in the lifecycle.
- Provide management at all levels with a tool to ask questions and make decisions about software products.

Approach

A NASA IV&V repository will be created and maintained to provide project data; however, the data will be sorted across multiple domains and include both researchers and management so that individual projects cannot be identified. The goal is to populate it with 15 programs. This repository will include:

- McCabe Software Metrics
- Halstead Metrics
- Line of Code Metrics
- Object-oriented metrics
- Error metrics derived from the association between errors and functions/modules
- Requirements Metrics
- Design Metrics

Significance

A survey of principal investigators for the Software Assurance Research Program revealed that 41% of them felt that the lack of NASA software artifact data greatly affected their research efforts. An additional 36% felt their efforts were moderately affected by the lack of data. The general poverty of data available for software research is common knowledge within the community. This activity provides NASA with a CMMI maturity level four activity.

Accomplishments

A repository has been established. Initially, it only had the project data from one project. It currently has the following data:

Identifier	Language	LOC	Domain	Error Data
JM-1	C	315K	Real-Time	8 years
KC	C + +	~750K	Data System	5 years
CM-1	C	20K	Instrument	2 years

Future Plans

Four additional programs have agreed to give their software artifact data to MDP. This includes two sets of software for spacecraft flight systems. We are currently supporting data requests from four universities.

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