Scientific and Technical Information (STI)

# STI BULLETIN ONLINE

**A quarterly publication of the NASA Scientific and Technical Information (STI) Program produced by the NASA Center for AeroSpace Information (CASI) for the users of our information products and services.**

**July 2004**


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## Featured Articles

### Small Team Has Big Impact

*NASA Technical Monitor Janelle Turner (far right) and Spinoff Team (from left to right) Jutta Schmidt (project manager), Jamie Janvier and Michelle Birdsall (editors), and John Jones (graphic designer) at the 2004 Agency Honor Awards ceremony.*

The NASA *Spinoff* Team, based at the Center for AeroSpace Information (CASI), takes pride in disseminating information about the down-to-Earth benefits derived from NASA's aeronautics and space missions. From helping students access materials about the Shuttle engine know-how behind a life-saving heart pump to explaining how Apollo technology contributed to improved thermal insulation, the *Spinoff* Team stays on top of daily public outreach activities while producing the annual *Spinoff* magazine.

Consisting of Project Manager Jutta Schmidt, Editors Michelle Birdsall and Jamie Janvier, Graphic Designer John Jones, and Publications Specialist Deborah Drumheller, the small team was recognized for its big impact at the 2004 Agency Honor Awards. NASA Administrator Sean O'Keefe presented Schmidt with the Public Service Group Achievement Award on behalf of the team, which is also supported by CASI's Webmaster David Eminizer and Publications Web Coordinator Bernadette Gilliam. The award commends non-Government personnel for an outstanding accomplishment while participating in a significant program or project that contributes substantially to the NASA mission.

The *Spinoff* Team, nominated by *Spinoff* Technical Monitor Janelle Turner of NASA Headquarters, was selected for the award based upon its outstanding service and production of a quality *Spinoff* publication. As NASA's premiere publication featuring successfully commercialized NASA technology, *Spinoff* profiles between 40 to 50 products each year in the categories of health and medicine, transportation, public safety, consumer and recreational goods, industrial productivity, environment and resources management, and computer technology.

When asked to describe one of his favorite NASA spinoff technologies, Janvier was quick to respond, "Without a doubt, I would have to say that the Video Image Stabilization and Registration (VISAR) software tool for clearing up dark, jittery video is at the top of my list. The technology's success rate in revealing clues about crimes truly speaks for itself." Originally developed by NASA to study violent explosions on the Sun and examine hazardous weather conditions on Earth, VISAR allowed Federal and State law enforcement authorities to enhance video footage to uncover important details about the 1996 Olympic Summer Games bombing in Atlanta, and identify and subsequently charge the murderer of an 11-year-old girl who was abducted at a carwash in Sarasota, Florida, earlier this year.

Producing the magazine requires intense research and strong partnerships with NASA's field centers to identify and confirm successful technology transfer relationships between NASA and private industry. Once the story leads are identified, Birdsall and Janvier write articles that explain how rocket science and cutting-edge space technologies become a part of our everyday lives. The team then relies on Jones to bring the articles to life with a captivating and colorful layout and cover. Drumheller adds her expertise by assisting with the detailed proofing process before the magazine goes to print. Once the printing process is over, Eminizer and Gilliam assist with putting the publication on the NASA *Spinoff* Web site, which includes online versions of past issues and a searchable database of article abstracts for every product featured since the publication's origin in 1976.

According to Birdsall, "The award is truly a testament to the strength of our publication team. It's overwhelming to receive such public recognition on the Agency level. Just being in the auditorium with Administrator O'Keefe was an honor, not to mention being in the company of the other honorees."

During his opening remarks at the awards ceremony, Administrator O'Keefe stressed the importance of taking the time to acknowledge the tremendous accomplishments that take place every day throughout the organization. The *Spinoff* Team is proud to be awarded for doing just that, by documenting the tremendous technology transfer accomplishments that occur through NASA's Innovative Technology Transfer Partnership program.

## What's New at NTRS

*The Advanced Search page of the NTRS: NASA Technical Reports Server.*

In the spring of 2003, the NASA STI Program Office (STIPO) released a new version of the NTRS: NASA Technical Report Server at http://ntrs.nasa.gov. STIPO replaced the distributed metadata search functionality (WAIS-based) version with a new system configuration based upon a relational database, created a new search interface, and implemented the Open Archive Initiative Protocol for Metadata Harvesting (OAI-PMH), http://openarchives.org.

The new configuration of NTRS enhances the functionality of the technical report server. Using MySQL as the relationship database allows for organization and maintenance of metadata content and links to full-text images. Searching content is improved in the new version of NTRS with a simple interface and an advanced search interface. The simple search interface searches only the NASA repositories by default. The advanced search interface (which features fielded searching) offers the possibility of including non-NASA repositories and allows more targeted searching, including limiting the number of repositories to search.

A significant feature of the new NTRS is the implementation of OAI-PMH. Using OAI-PMH turns NTRS into an aggregator of content from sources within NASA and external sources of scientific and technical information. OAI-PMH allows sites that are OAI-compliant to share content with one another in an automated way using Internet protocols and XML. New in the OAI-PMH version of NTRS is the inclusion of repositories that are not in the nasa.gov domain. At the moment, we include repositories from the Physics eprint Server (arXiv), Biomedcentral, Aeronautical Research Council (the UK-equivalent of NASA) and the U.S. Department of Energy.

The transition to the new configuration has not been without challenges and these challenges are currently being addressed by the STI Program Office. Currently, NTRS searches and displays a limited amount of data points. NTRS users expressed the need for searching on the accession number and document identification number for documents as ways of finding information. They requested that more information be displayed in search results. Users commented on the change in the content provided by NTRS stating that they liked being able to search on aerospace related citations from other Federal agencies and organizations beyond NASA.

NTRS user satisfaction is extremely important to the STI Program Office and changes are under way to respond to user feedback. Many of the enhancements will be completed by November 30, 2004. Also, NTRS searches will expand to include accession and document identification numbers; search results will display more citation information for NASA records; and several thousand full-text NASA documents will be available through the NTRS system.

As of January 3, 2005, paid subscriptions to NASA's metadata will be discontinued. In support of the E-Gov Act of 2002, NASA's publicly available scientific and technical information metadata will be available via the NTRS: NASA Technical Reports Server at http://ntrs.nasa.gov on November 30, 2004.

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# Focus On ... Space Exploration Systems

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*NASA's Project Constellation aims to streamline the process of defining spaceship designs and issuing contracts to create them. The image to the left shows a conceptual Exploration Transportation Systems mission profile with all stages of the mission for the capsule-shaped Crew Exploration Vehicle depicted. For other system concepts, see http://www.projectconstellation.us/articles/concept-gallery/.*

On January 14, 2004, the President of the United States established a new policy and strategic direction for the U.S. space program, making human and robotic space exploration the primary goal. In response, NASA created a new Office of Exploration Systems (OExS, http://exploration.nasa.gov/index.html) at the Agency's headquarters. OExS is responsible for setting priorities and implementing them through three divisions: Business Operations, Requirements, and Development Programs. The Development Programs Division is responsible for three primary areas: Human and Robotic Technology, Exploration Transportation Systems, and Nuclear Systems Technologies. This issue focuses on these areas, providing sources of relevant STI.

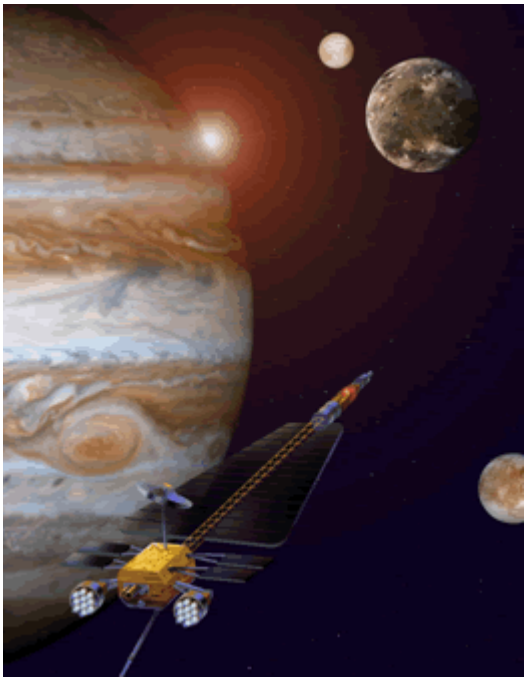
## Human and Robotic Technology

NASA's future exploration missions into the solar system and beyond will coordinate the unique capabilities of humans and robots to maximize safety, affordability, and effectiveness. To learn more, see the July 2003 issue of the STI Bulletin (Focus on Robotics).

## Exploration Transportation Systems

NASA's goal is to develop and test a new spacecraft, the Crew Exploration Vehicle (CEV, see http://exploration.nasa.gov/constellation.html), by 2008 and to conduct the first manned mission no later than 2014. The Crew Exploration Vehicle will be capable of transporting astronauts and scientists to the Space Station after the Space Shuttle is retired. The main purpose of this spacecraft, however, will be to carry astronauts beyond Earth orbit to other worlds. This will be the first spacecraft of its kind since the Apollo Command Module. To capture the advances since Apollo, the STI Program generated the bibliography "Next Generation Spacecraft, Crew Exploration Vehicle" (CASI Document ID 20040045215) in January 2004. Contact the STI Help Desk if you would like to obtain this bibliography.

## Nuclear Systems Technologies



*The Jupiter Icy Moons Orbiter, part of the Project Prometheus Program, is examining the use of Nuclear Electric Propulsion to carry scientific payloads to three Jovian moons. A potential power system concept includes dual 100 kWe Brayton converters, a deployable pumped loop heat rejection subsystem, and a 400 Vac Power Management and Distribution bus.*

NASA is conducting research on and development of nuclear systems that could provide power for a wide range of exploration systems such as scientific instrument, robotic, electrical propulsion, and high-speed communications systems to support human explorers as they travel through space and explore other worlds.

Investment is focused on making such power sources available this decade for proposed missions to Pluto and Mars and an unprecedented mission to Jupiter in the next decade. The Jupiter Icy Moons Orbiter (JIMO) mission would have capabilities far beyond those possible with current power and propulsion systems. Powered by a nuclear reactor and propelled by electric engines, the spacecraft would make up-close, long-term visits to three of the solar system's most intriguing moons, Europa, Ganymede and Callisto. These moons may contain oceans of water that could have provided an environment in which life evolved in the past, or perhaps they are supporting life in the present.

The following citations provide a sample of recently published nuclear propulsion material found in the NTRS: NASA Technical Report Server. Some documents are available in full-text Portable Document Format (PDF) that you can download, while others can be purchased through the STI Help Desk at 301-621-0390 or help@sti.nasa.gov or available elsewhere. Please use the document identification numbers listed below when contacting the Help Desk. You can also keep up to date on this topic by checking the Spacecraft Power and Propulsion topic in Scientific and Technical Aerospace Reports (STAR), a biweekly abstract journal.


Benford, Andrew. Comparison of Structural Optimization Techniques for a Nuclear Electric Space Vehicle. 20040034016

Borowski, Stanley; Dudzinski, Leonard A. 2001: A Space Odyssey Revisited: The Feasibility of 24 Hour Commuter Flights to the Moon Using NTR Propulsion with LUNOX Afterburners. 20030067859

Borowski, Stanley K.; McGuire, Melissa L.; Mason, Lee M.; Gilland, James H.; Packard, Thomas W. "Bimodal" Nuclear Thermal Rocket (BNTR) Propulsion for an Artificial Gravity HOPE Mission to Callisto. 20030006859

Bragg-Sitton, Shannon M.; Holloway, James Paul. Reactor Start-up and Control Methodologies: Consideration of the Space Radiation Environment. 20040020203

Bragg-Sitton, S. M.; Kapernick, R.; Godfroy, T. J. Single Channel Testing for Characterization of the Direct Gas Cooled Reactor and the SAFE-100 Heat Exchanger. 20040020218

El-Genk, Mohamed S.; Tournier, Jean-Michel. Performance Analysis of Potassium Heat Pipes Radiator for HP-STMCs Space Reactor Power System. 20040020224

Falck, Robert D.; Borowski, Stanley K. High Power Nuclear Electric Propulsion (NEP) for Cargo and Propellant Transfer Missions in Cislunar Space. 20030006861

Gavert, Raymond B. Market Driven Space Exploration. 20040020153

Houts, Mike; Schmidt, Glen L.; Van Dyke, Melissa; Godfroy, Tom; Martin, James; Bragg-Sitton, Shannon; Dickens, Ricky; Salvail, Pat; Harper, Roger. Space Fission System Test Effectiveness. 20040020209

Joyner, Claude Russell, II; Fowler, Bruce; Matthews, John. A Closed Brayton Power Conversion Unit Concept for Nuclear Electric Propulsion for Deep Space Missions. 20030006840

Klein, Milton. Nuclear Thermal Rocket —An Established Space Propulsion Technology. 20040020180

McGuire, Melissa L.; Borowski, Stanley K.; Mason, Lee M.; Gilland, James. High Power MPD Nuclear Electric Propulsion (NEP) for Artificial Gravity HOPE Missions to Callisto. 20030006860

Powell, James; Maise, George; Paniagua, John; Borowski, Stanley. MITEE-B: A Compact Ultra Lightweight Bi-Modal Nuclear Propulsion Engine for Robotic Planetary Science Missions. 20030006809

Soltis, James V. Space Nuclear Power and Propulsion Systems Technology: Enabling Future Planetary Exploration. Segment 7: Power Management and Distribution. 20030027869

Tournier, Jean-Michel; El-Genk, Mohamed S. Reactor Lithium Heat Pipes for HP-STMCs Space Reactor Power System. 20040020223

Van Dyke, Melissa. Early Flight Fission Test Facilities (EFF-TF) To Support Near-Term Space Fission Systems. 20040020214

Wright, Mike. Marshall Space Flight Center and the Reactor-in-Flight Stage: A Look Back at Using Nuclear Propulsion to Power Space Vehicles in the 1960's. 20030066010

Wright, S. A.; Lipinski, R. J.; Godfroy, T. J.; Bragg-Sitton, S. M.; Van Dyke, M. K. Direct-Drive Gas-Cooled Reactor Power System: Concept and Preliminary Testing. 20030006811

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  - NASA Thesaurus
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## From the Users

### NASA Images and Videos

**Q.** I am a graphic designer for the United States General Accounting Office. I am currently working on an audit report on NASA. I am looking for a decent picture of the Checkout and Launch Control System. A picture of the building would be fine. Any help would be great.

**A.** We recommend that you try searching the NASA Image eXchange (NIX) at http://nix.nasa.gov/. If you type “checkout launch control system” in the search box labeled 'With all of these words,” you will get some results that may be useful to you.

*December 6, 2000. The ribbon is cut and the new Checkout and Launch Control System (CLCS) is declared operational. Those taking part in the ceremony are (from left) Joseph Rothenberg, NASA Associate Administrator for Space Flight; Pam Gillespie, from Rep. Dave Weldon's office; Roy Bridges, Kennedy Space Center Director; Dave King, Director of Shuttle Processing; Retha Hart, Deputy Associate Director, Spaceport Technology Management Office; and Ron Dittemore, Manager, Space Shuttle Program. The new control room will be used to process the Orbital Maneuvering System pods and Forward Reaction Control System modules at the Hypergolic Maintenance Facility (HMF). This hardware is removed from Space Shuttle orbiters and routinely taken to the HMF for checkout and servicing.*

**Q**. Is there a searchable database to view video clips? And what is the cost to purchase clips and use them?

**A.** There is no single database for video clips. The STI Program sponsors the NASA Image eXchange (NIX, http://nix.nasa.gov/), where you can search for video clips as well as images. For a more comprehensive look at what is available, we recommend you go to the NASA Web site (http://www.nasa.gov) and either select the Multimedia tab or use the Find

It@NASA search box (upper right hand of pages throughout the Web site) and type in some appropriate keywords (e.g., “video clips”). Most publicly available video clips are free.

If you are interested in video tapes rather than video clips, you can search the STI Program’s NTRS: NASA Technical Reports Server (http://ntrs.nasa.gov) or, if you are a NASA employee, contractor, or grantee, the NASA Aeronautics and Space Database (http://www.sti.nasa.gov). The STI Web site also gives you access to the STI Video Catalog (http://www.sti.nasa.gov/Pubs/Videocat/videocat.pdf), which is searchable and gives you descriptions of more than 2,000 vides. The videos are available in VHS, VHS-PAL, BETA-SP NTSC, and upon request, in BETA-PAL formats. Prices vary (e.g., domestic prices range from $85 to $145 for a Beta-SP NTSC tape).

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## NASA Thesaurus

**Q.** I'm trying to decide between the NASA Thesaurus, Volumes 1 and 2 and the NASA Thesaurus Hierarchical Listing Data File for Site Usage, or whether we should simply get both. The hierarchical listing looks as if it would certainly be very useful to us, so my questions are:

1. What format is the Thesaurus in? Is it just PDF, like the free samples available on the Web site?

2. The Thesaurus seems to contain definitions, which the hierarchical listing does not: is this correct? Is there any other information in the Thesaurus that doesn't appear in the hierarchical listing, and vice versa?

**A.** The NASA Thesaurus Hierarchical Listing for Site Usage is a data file formatted for machine manipulation. This is the product you will need if you want a machine readable format. The file is conveyed to you via FTP. Prior to purchasing the Thesaurus Hierarchical Listing, we require you to read and sign a copy of the Agreement for the Terms and Conditions of Use for NASA Thesaurus Data-File Products (available at http://www.sti.nasa.gov). Note that this product and the data contained therein are intended for the sole use of the customer or site-specific use by the customer’s organization.

To answer your second question, the NASA Thesaurus Volume 1 (PDF version on CD-ROM) does contain definitions, however since some of these definitions appear with permission from the originating organization, their use is limited to this CD-ROM product as is; the definitions are not available for machine extraction or presentation outside of this product.

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## NASA Technical Reports Server (NTRS)

**Q.** Is there any description of NASA's plans and priorities for digitizing older NASA documents?

**A.** It is the intent of the NASA Scientific and Technical Information (STI) Program Office to make all NASA formal series reports available online through the NTRS: NASA Technical Reports Server at http://ntrs.nasa.gov/. Reports that are coming in are being added in PDF format as resources permit. We are working backwards daily to add in the older material.

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## From the Centers

### Visionary Library Leader Retires

Janet Ormes has provided outstanding leadership and vision to the Goddard Library for the last 17 years. Ormes joined the Goddard Space Flight Center in 1987, following a 10-year career supervising and managing contractor operations in Federal Libraries and Information Centers. In addition to her position as the Branch Head, Ormes became the Assistant Chief Information Officer (CIO) for Library and Information Services at Goddard in 2001.

Ormes was born in Aberdeen, South Dakota. She received her Bachelors of Arts degree in Philosophy and Master of Library Science degrees from the University of Minnesota, where she worked in the university library before relocating to the Washington, D.C. area.

Early in her career, Ormes visualized a world where computers would bring researchers easy access to the information they need. Indeed, her life's ambition was to see libraries bringing together all the information researchers need to do their work through a single computer interface.

Ormes' commitment to the advancement of library and information sciences extends beyond Goddard. Her expertise in library science is far reaching; librarians from around the world, including recent visitors from universities in Kenya and Ireland, have sought her advice and knowledge. She co-authored a chapter for a NASA publication on Knowledge Management, Knowledge Ontologies and Knowledge Codification: NASA's History and Future. She has presented at the Library of Congress and the American Library Association on the Open Archival Information System (OAIS) Reference Model for managing and preserving electronic resources. Ormes is a member of the American Library Association and the Federal Library and Information Center Committee (FLICC) Content Management Working Group, and has served as an elected representative to FLICC. She served as Secretary of the Federal Armed Forces Librarians Round Table (FAFLRT) of the American Library Association (ALA). She has been an invited speaker or discussion panel member at ALA Conferences, the American Institute of Physics Assembly of National Officers, the

National Academy of Science Librarian Advisory Group, FLICC programs, and the Special Interest Group on CD-ROM Applications and Technology (SIGCAT).

Without sacrificing traditional library services, and despite continually more restrictive budget constraints, Ormes had the vision and perseverance to take the Goddard Library fully into the 21st century. Dedicated to utilizing information science and technologies to support the research initiatives of the Center, Ormes was a trailblazer in developing the ability to share electronic information from Library resources directly to users' desktops. All the services available from the Goddard Library are now accessible in electronic format through the Web. Today, Ormes can see the fruition of her life's work in the Goddard Library, which is recognized as a first-class organization. Her library team was recently selected as Federal Library of the Year and has received two Goddard Honor Awards, a NASA Honor Award, and several outstanding Web site awards.

Recently, Ormes has turned her attention to knowledge management initiatives for the Center and leveraged several pilot projects into a fledgling Digital Archive System for Center knowledge assets. Digital video, images, Web sites and documents are among the content types currently reflected in the system. She pioneered a collaboration with the Center's Knowledge Architect, Dr. Ed Rogers, to bring the information management skills of the Library staff to bear on management of the Center's internal knowledge assets. Indeed, the citation for the Federal Library of the Year credited the Goddard Library with, "Bridging the gap between traditional library services and knowledge management."

Ormes has been recognized both at Goddard and within the library world as an expert in her field. Under her leadership, the Goddard Library has become a state-of-the-art library and information center. Ormes has received the NASA/Goddard Excellence in Information Science and Technology Award, Goddard's Exceptional Achievement Award, ALA's Federal Librarian Outstanding Achievement Award, the Federal Executive Board's Excellence in Federal Career Award, and a lifetime career Award of Merit from Goddard Space Flight Center.

Janet's retirement plan includes moving to Colorado, spending countless hours with her grandchildren, bird watching, reading, square dancing, traveling, and snorkeling. We only hope she'll have the time to reflect on a worklife well spent.

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## NASA UNILIB Meeting

Librarians from across NASA met at Goddard on April 27-29 to discuss Agency-related library issues and to identify opportunities for partnering. Librarians from Ames, Dryden, Glenn, JPL, Langley, and Goddard reported on activities and projects underway within their organizations, and Goddard, Glenn, and JPL identified future partnership opportunities in the area of metadata projects. Additionally, librarians from Goddard and JPL shared results from their strategic assessments. Cooperative agreements to share resources were discussed and opportunities identified. Metadata projects were explored in the light of the Open Archives Initiative and Metadata harvesting.

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## From the STI Program Office

### President's Commission Report and STI

The NASA STI Program is currently highlighting existing NASA STI and drafting a plan to acquire or link to external STI from areas that are highlighted in the Report of the President's Commission on Implementation of United States Space Exploration Policy – June 2004; these areas are as follows:

Enabling Technologies

- Affordable heavy lift capability
- Advanced structures
- High acceleration, high life cycle, reusable in-space main engine
- Advanced power and propulsion
- Cryogenic fluid management
- Large aperture systems
- Formation flying
- High bandwidth communications
- Entry, descent, and landing
- Closed-loop life support and habitability
- Extravehicular activity systems
- Autonomous systems and robotics
- Scientific data collection/analysis
- Biomedical risk mitigation
- Transformational spaceport and range technologies
- Automated rendezvous and docking
- Planetary in situ resource utilization

Management Areas

- System of systems approaches
- Spiral, evolution development
- Lead system integration
- Independent technical and cost assessments

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## Current Topics

### Human and Robotic Technology

For each of NASA's cutting-edge projects and tasks, there are frequently many possible technological approaches competing to be funded and developed. Selecting those that offer the best chances of success within the constraints of budget and schedule is a challenging task in itself. START (STrategic Assessment of Risk and Technology, http://start1.jpl.nasa.gov) offers systems for quantifying the features of each technology, assessing its risk, calculating the probable return-on-investment, and using the results to compare candidates for development. These systems can be invaluable tools for selecting technologies, monitoring and guiding their development, and optimizing mission success. The following two publications evaluate human-robotic performance.

> G. Rodriguez and C.R. Weisbin, "A New Method to Evaluate Human-Robot System Performance," Special Issue of Journal on Autonomous Robotics, Kluwer-Publishers, Vol. 14, pages 165-178, March 2003.
>
> G. Rodriguez, C. Weisbin, and R. Easter, "A New Method for Human-Robot System Resiliency Evaluation," JPL Publication 02-26, November 2002.

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### Exploration Transportation Systems

IEEE Xplore (http://ieeexplore.ieee.org) provides access to IEEE transactions, journals, magazines, and conference proceedings published since 1988 plus select content back to 1950, and all current IEEE Standards. Take a look at the following citation and abstract from the IEEE Region 5 Conference: Annual Technical and Leadership Workshop, 2004:

> Frye, M.T.; Ji Li; Chunjiang Qian. Finite-time stabilization of the NASA CEV reaction control system with actuator saturation and by position measurements
> [Abstract]

## Nuclear Systems Technologies

AIAA, ASME, SAE, and ASEE will hold the 40th Joint Propulsion Conference and Exhibit in Fort Lauderdale, Florida, July 11-14, 2004, celebrating the 35th anniversary of the first manned lunar landing by working to develop a common vision of future propulsion requirements and potential (see http://www.aiaa.org/). Sessions of interest include:

> Session 24- EP-5: Project Prometheus I, chaired by S. Oleson, NASA Glenn Research Center, Cleveland, OH, and J. Fisher, Aerojet, Redmond, WA
>
> Session 36- NFF-1, Fusion Propulsion, chaired by T. Kammash, University of Michigan, Ann Arbor, MI.

Authors are encouraged to submit their papers for publication in the American Institute of Aeronautics and Astronautics archival journals (e.g., the Journal of Propulsion and Power).

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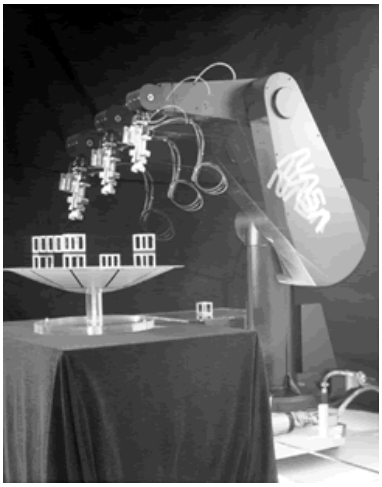
# NASA History

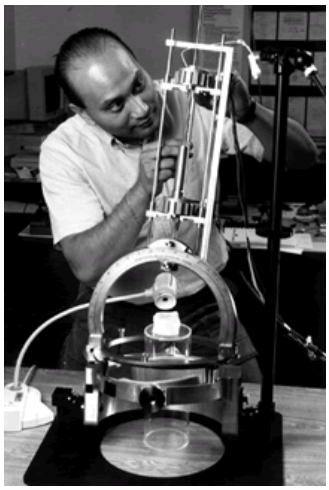
GReat Images in NASA (GRIN) is a collection of over a thousand images of significant historical interest scanned at high-resolution in several sizes. The following is a sample of great images in NASA history with radiation research.

## Human and Robotic Technology



**Puma Robotic Arm**

April 2, 1990. The Puma Robotic Sensor Arm for use in virtual reality development and studies at the NASA Ames Research Center, Mountain View, California.

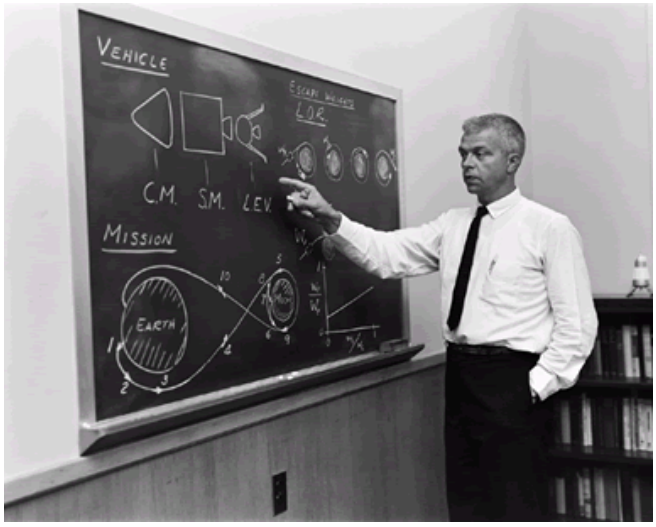


**NASA Robot Brain Surgeon**

June 6, 1997. Mechanical engineer Michael Guerrero works on the Robot Brain Surgeon test bed in the NeuroEngineering Group at the Ames Research Center, Moffett Field, California. Principal investigator Dr. Robert W. Mah states that potentially the simple robot will be able to feel brain

structures better than any human surgeon, making slow, very precise movements during an operation. The brain surgery robot that may give surgeons finer control of surgical instruments during delicate brain operations is still under development.

## Exploration Transportation Systems



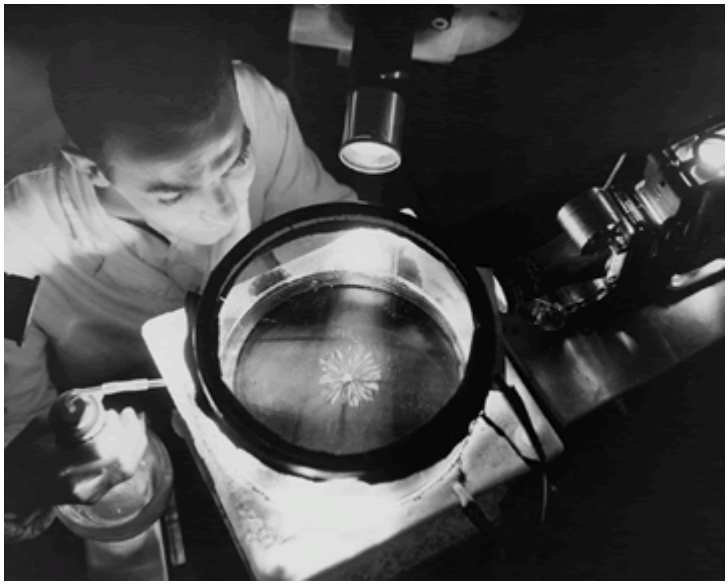

**John C. Houbolt**

July 24, 1962, John C. Houbolt at blackboard, showing his space rendezvous concept for lunar landings. Lunar Orbital Rendezvous (LOR) would be used in the Apollo program. Although Houbolt did not invent the idea of LOR, he was the person most responsible for pushing it at NASA.

**Odyssey On Deck**

April 17, 1970, Crewmen aboard the U.S.S. Iwo Jima, prime recovery ship for the Apollo 13 mission, hoist the Command Module aboard ship. The Apollo 13 crewmen were already aboard the Iwo Jima when this photograph was taken. The Apollo 13 spacecraft splashed down at 12:07:44 p.m., April 17, 1970 in the South Pacific Ocean.

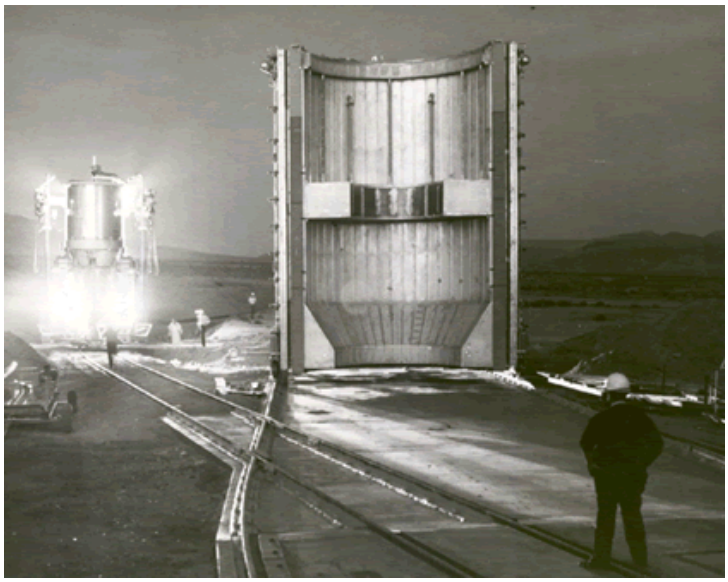
## Nuclear Systems Technologies



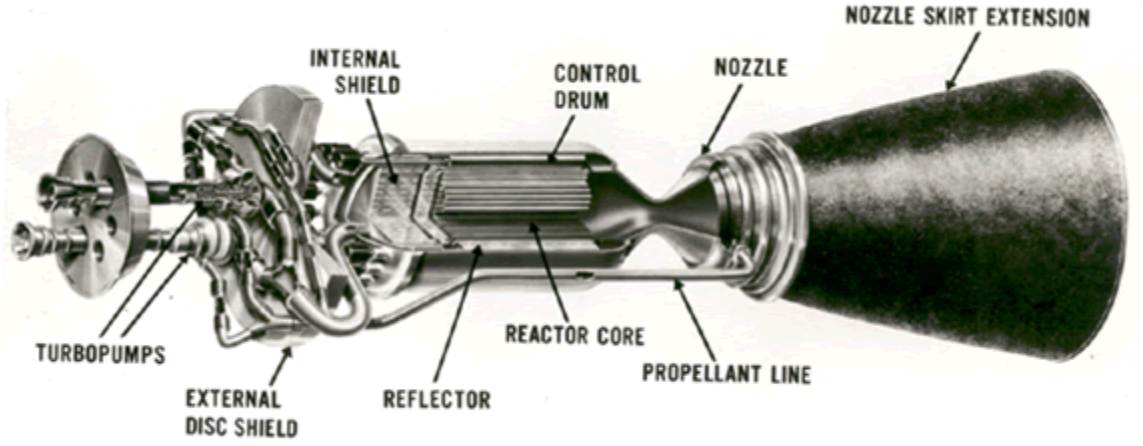
### NACA Physicist Studying Alpha Rays

September 12, 1957. A cloud chamber is used by Lewis (now Glenn) Research Center scientists to obtain information aimed at minimizing undesirable effects of radiation on nuclear-powered aircraft components. Here, alpha particles from a polonium source emit in a flower-like pattern at the cloud chamber's center. The particles are made visible by means of alcohol vapor diffusing from an area at room temperature to an area at minus -78 deg. Centigrade. Nuclear-powered aircraft were never developed and aircraft nuclear propulsion systems were canceled in the early 1960s.

### Nuclear Rocket Engine Being Transported to Test Stand



December 1, 1967. The first ground experimental nuclear rocket engine (XE) assembly, (left), is shown here in "cold flow" configuration, as it makes a late evening arrival at Engine Test Stand No. 1 at the Nuclear Rocket Development Station, in Jackass Flats, Nevada. Cold flow experiments are conducted using an assembly identical to the design used in power tests except that the cold assembly does not contain any fissionable material nor produce a nuclear reaction. Therefore, no fission power is generated. The large object at the right is one-half of an aluminum cylindrical closure that can be sealed about the engine, forming an airtight compartment, thereby permitting testing in a simulated space environment. The "cold flow" experimental engine underwent a series of tests designed to verify that the initial test stand was ready for "hot" engine testing, as well as to investigate engine start-up under simulated altitude conditions, and to check operation procedures not previously demonstrated. The XECF (Experimental Engine Cold Flow) experimental nuclear rocket engine was a part of project Rover/NERVA.




**Drawing of a NERVA Engine**

January 29, 1970. An explanatory drawing of the NERVA (Nuclear Engine for Rocket Vehicle Application) thermodynamic nuclear rocket engine. The main objective of project Rover/NERVA was to develop a flight rated engine with 75,000 pounds of thrust. The Rover portion of the program began in 1955 when the U.S. Atomic Energy Commission's Los Alamos Scientific Laboratory and the Air Force initially wanted the engine for missile applications. However, in 1958, the newly created NASA inherited the Air Force responsibilities, with an engine slated for use in advanced, long-term space missions. The NERVA portion did not originate until 1960 and the industrial team of Aerojet General Corporation and Westinghouse Electric had the responsibility to develop it. In 1960, NASA and the AEC created the Space Nuclear Propulsion Office to manage project Rover/NERVA. In the following decade, it oversaw a series of reactor tests: KIWI-A, KIWI-B, Phoebus, Pewee, and the Nuclear Furnace, all conducted by Los Alamos to prove concepts and test advanced ideas. Aerojet and Westinghouse tested their own series: NRX-A2 (NERVA Reactor Experiment), A3, EST (Engine System Test), A5, A6, and XE-Prime (Experimental Engine). All were tested at the Nuclear Rocket Development Station at the AEC's Nevada Test Site, in Jackass Flats, Nevada, about 100 miles west of Las Vegas. In the late 1960s and early 1970s, the Nixon Administration cut NASA and NERVA funding dramatically. The cutbacks were made in response to a lack of public interest in human spaceflight, the end of the space race after the Apollo Moon landing, and the growing use of low-cost unmanned, robotic space probes. Eventually NERVA lost its funding, and the project ended in 1973.

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