2003 MARSHALL SPACE FLIGHT CENTER ANNUAL REPORT

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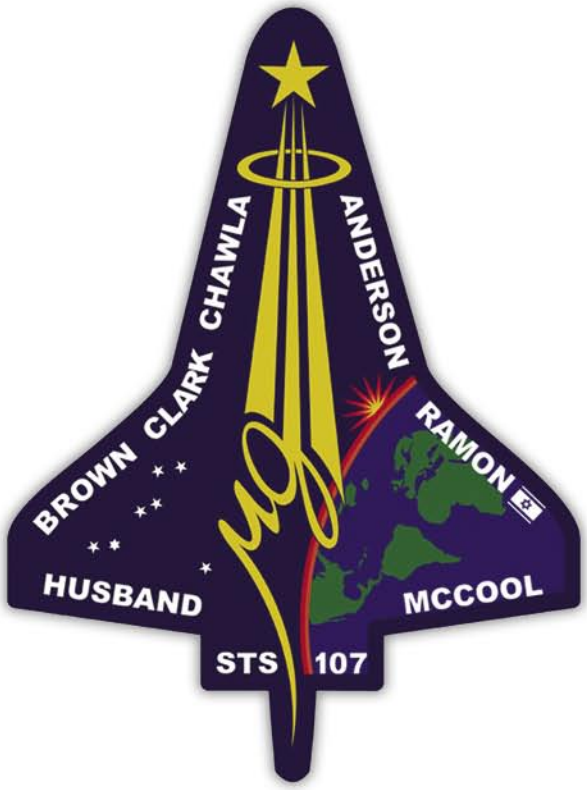
In memory

America's space program will go on. This cause of exploration and discovery is not an option we choose; it is a desire written in the human heart. We are that part of creation which seeks to understand all creation. We find the best among us, send them forth into unmapped darkness, and pray they will return. They go in peace for all mankind, and all mankind is in their debt.

President George W. Bush
February 4, 2003



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STATEMENT OF THE DIRECTOR

The *2003 Annual Report* serves as a summary of the Marshall Team's performance and dedication to the Center's mission areas for the year. The year began with significant experimental returns from the *International Space Station (ISS)*, followed by a spectacular image of a spiral galaxy—thanks to the Marshall-managed Chandra X-ray Observatory.

Marshall Space Flight Center (MSFC) civil servants and contractors also began the year with the launch of STS–107. An exciting and productive 16-day science mission turned into tragedy as the Space Shuttle *Columbia* broke apart over East Texas on February 1, only 16 minutes before its scheduled landing. All seven crew members perished.

In the weeks and months that followed, NASA Administrator Sean O'Keefe reiterated his pledge to the crew families that NASA would do everything to "find the problem, fix it, and fly again." The Marshall Center was in lockstep with the investigation into the mishap from day one, tasked with the job of closing hundreds of potential causes by reviewing flight data and conducting analyses and tests. The findings were then reported to the Agency Mishap Response Team (MRT), and the MRT then provided the findings to the *Columbia* Accident Investigation Board (CAIB).

On August 26, the CAIB released its much-anticipated report detailing the causes that led to the loss of the *Columbia* and her crew. On September 8, the Agency released the *NASA Implementation Plan for Return to Flight and Beyond*, a detailed and updatable plan outlining each step the Agency will take to comply with the CAIB's recommendations. Prior to this release, the Agency had begun identifying potential problem areas and making critical changes. Significant changes continue and there is solid commitment by Agency leadership and its employees and contractors to follow through to implement all recommended technical and process improvements, including those cultural changes required to assure safety of flight and thorough risk assessment.

During the STS–107 investigation and subsequent startup of the return to flight activities, MSFC sustained its commitment to our existing programs and missions. The Space Shuttle Main Engine (SSME) Project continued its work on the development of the Advanced Health Monitoring System, which will be essential in determining the robustness of the SSMEs**.** The Reusable Solid Rocket Motor (RSRM) Project successfully fired the five-segment Engineering Test Motor (ETM–3), providing critical understanding into the RSRM performance. In June, Node 2, the second of three pressurized modules for the Space Station managed by Marshall and built by Alenia Spazio, an international contractor for the European Space Agency (ESA), was delivered to the Kennedy Space Center (KSC). And in July, the Gravity Probe B spacecraft was delivered to Vandenberg Air Force Base for its final preparations for launch. The year ended with the 30th anniversary of *Skylab*, complete with a visit by eight of the nine *Skylab* astronauts.

The year 2003 was marked by triumph and tragedy. It will be a year known not only for the events and technical milestones that defined it but for the outstanding teamwork that was demonstrated every step of the way. The example the Marshall Center has set is an honorable one. The commitment and dedication of the workforce is evident, and I look forward to leading this remarkable Center to a safe Return to Flight.

David A. King
Director

Launch of STS–100.

SAFETY AND MISSION ASSURANCE

Safety and Mission Assurance (S&MA) supports NASA, MSFC, and their customers in establishing requirements and approving and assessing the implementation of plans for providing quality, reliability, and safety products and programs. The MSFC safety program promoted a safe working environment for both the workforce and MSFC-managed high-value equipment and property. Worksite safety analyses were performed and verified, along with support for worksite hazard prevention and control. Safety awareness and safety training promoted management commitment and employee involvement.

The number of Safety, Health, and Environmental (SHE) systemic issues found as a result of the FY 2003 self-assessments was significantly lower than those identified in previous years. There was an increase in random safety surveillance of activities across the Center, with special emphasis on Lockout/Tagout and construction monitoring. S&MA initiated a review of all MSFC contracts to eliminate wording that penalized the contractor for having a mishap. As a result, contractors are now penalized for not reporting mishaps. Although the Center is not pursuing Voluntary Protection Program certification at this time, it continues to aggressively improve the overall SHE Program with a focus on the safety and health of our workforce.

S&MA initiated improvements to the Safety Concerns Reporting System (SCRS), based on recommendations from a cross-Center team. S&MA also facilitated, with great success, the development of a new ad hoc SCRS Closure Subcommittee to investigate and facilitate the resolution of disputed SCRS reports.

S&MA developed a new Web-based tool for anonymous reporting of unsafe acts called the Safety Observation Survey. The new SHEtrak database, which replaced the HAZtrak system, permits direct access by actionees and combines Industrial Safety, Environmental Health, and Environmental findings in one database.

In the area of Workers' Compensation (WC), MSFC surpassed the goal of reporting claims on time; 89 percent of claims filed reached the Department of Labor within 14 days of the employee's injury. The Agency WC Program Manager performed a semiannual assessment of the MSFC WC Program; no nonconformances were identified. In addition, a nurse case manager was hired to support the Medical Center. The nurse case manager provides consultation and medical case management for civil servant on-the-job injuries or illnesses.

S&MA continued to provide safety awareness to employees with MSFC Safety Bulletins, Inside Marshall messages, Employee TV postings, the SHE Web site front page, Marshall Star articles, and monthly training modules posted on the Supervisor Safety Web Page (SSWP). A monthly item was added on Inside Marshall Today, briefly describing the previous month's mishaps, thus increasing employees' awareness of recent MSFC mishaps. A new Web site was introduced that enables employees to print SHE posters that are tailored to specific work areas at MSFC. S&MA also initiated the development of a new Industrial Safety Department publication, entitled SHE ShopTalk, designed to fill gaps in the Center's safety communication program targeted by both the annual and the independent SHE Program assessments.

S&MA continued to participate in many education and community outreach events, such as the Annual Moonbuggy Race, Combined Federal Campaign, Minority Recognition Events, Robotics Competition, Annual Marshall Egg Hunt, and workshops for Take Our Children to Work Day and MSFC Family Fun Day.

A 5-day back injury prevention awareness campaign, Watch Your Back, was conducted to heighten employees' awareness on the second leading cause of injury at MSFC. Part of the campaign included a uniquely tailored video that was specifically filmed for this campaign. The video

used an informative news magazine format, which included interviews with doctors and physiotherapists. The video also included interviews with Center employees who have sustained back injuries, allowing them to tell their personal story of how it has affected their everyday lives.

S&MA was heavily involved in all aspects of the advanced project work being conducted at MSFC during 2003. This included the major human exploration development programs, Orbital Space Plane (OSP) and Next Generation Launch Technology (NGLT). The major effort in these Programs was the development of the requirements needed to successfully fly a human-rated space vehicle. OSP was the first program to comply with the new Agency Human Rating Requirements. S&MA ensured that all the requirements needed to successfully meet human-rated standards were included in the proposed design. This effort was highly praised by several NASA Agency Enterprises. In addition, S&MA provided valuable safety and reliability studies to the Jupiter Icy Moons Observation (JIMO) Project. The analysis will be instrumental in ensuring the best design is selected to ensure mission success. S&MA also provided Quality Assurance support to the critical testing efforts needed to return the Space Shuttle to flight. Extensive External Tank (ET) and Solid Rocket Motor (SRM) tests were successfully completed due to stringent quality oversight and inspection support.

S&MA supported Microgravity Science and Applications, the *ISS*, and Space Science research in the following areas:

- Assessed readiness and supported shipment of the Node 2 from Turin, Italy, to the KSC.
- Assessed readiness and supported shipment of the Gravity Probe B Space Vehicle to the launch site at Vandenberg Air Force Base.
- Provided coordination of payload hardware recovery and impounding of documentation following the Space Transportation System (STS)–107 mishap.
- Developed a process for documenting S&MA certification rationale for Acceptance, Shipment, and Flight Readiness for all MSFC-managed payloads and cargo elements.
- Supported an engineering initiative to automate the design process.
- Hosted the biannual visit of the KSC Ground Safety Review Panel.

RS–88 test firing.

Marshall Management System Management Representative, Axel Roth, and Marshall Management System Coordinator, Don Miller, received Certification to AS9100.

S&MA participated in the STS–107 Contingency Working Group investigation by leading an independent assessment of the Working Group's fault tree analysis. The assessment included comparing the fault tree analysis to baseline risk documentation—hazard reports, Failure Mode and Effects Analysis/Critical Items Lists, and integrated hazards. The assessment demonstrated that the investigation fault tree encompasses all hazardous causes documented in the baseline.

S&MA return to flight activities:

- Based upon STS–107 *Columbia* Accident Investigation Board (CAIB) and MSFC Working Group findings and other hardware redesign activities, S&MA supported the development and certification of redesigned hardware on the Solid Rocket Booster (SRB) and the ET.
- S&MA led the update of Hazard Analyses and Failure Modes and Effects Analysis/Critical Items Lists for the MSFC elements of the Space Shuttle.
- S&MA provided assessments/briefings to Code MX/ Johnson Space Center (JSC) S&MA on issues and change requirements going to the Space Shuttle Program Boards.

Led by the center International Standardization Organization (ISO) Manager and S&MA personnel, MSFC has been awarded the aerospace industry's AS9100 certification—the first NASA Center and first Government facility to achieve this milestone. AS9100 is a quality management system certification based on ISO 9001, but with additional stringent requirements related to the aerospace industry. The scope of AS9100 certification at MSFC includes flight hardware, flight software, and associated ground support equipment. In addition, MSFC maintains its certification to ISO 9001. This scope includes all products and services provided by MSFC. MSFC supports the NASA Agency infrastructure and is a major contributor to all its scientific and technical enterprises. MSFC had two external audits performed in FY 2003, resulting in continuation of the ISO 9001 registration.

S&MA coordinated the review and selection of the four winners of the MSFC Contractor Excellence Awards for 2003. One winner was selected from the Small Business—Service Category and one winner from the Large Business—Service Category. Dual winners were selected from the Large Business—Product category. The Huntsville-based company, Lockheed Martin Space Systems—Integrated Technology Solutions, one of the three

MSFC applicants for the 2003 George M. Low Award, was selected by the Agency Validation Team to be a semifinalist.

In May of 2003, MSFC achieved a Capability Maturity Model (CMM) Level 3 Rating by the Software Engineering Institute at Carnegie Mellon University. The CMM is recognized worldwide by government and industry as the framework for advancing the state of the practice of software engineering. MSFC's Level 3 Rating was a NASA first, and S&MA had a significant role in the achievement of the rating. Software Quality Assurance (SQA) is a key process area of the model and S&MA provided all of the support and effort needed to demonstrate to the evaluation team that Marshall's SQA processes are well defined, documented, and followed.

The S&MA external supplier audit representative participated as a consultant in the MSFC Prime Contractor Supplier Council. The Council's purpose is to create a productive environment for networking among MSFC prime contractors and strengthen diversity within MSFC's subcontracting programs with the development of a forum for exchange of information that will ultimately result in the creation of a model subcontracting program and best practices manual to be shared with all prime contractors supporting NASA. This will improve efficiency, help in cost savings, and increase small business/prime contractor/NASA participation.

S&MA's Independent Assessment (IA) Team completed a number of Independent Assessments in 2003. Two major assessments were of the Space Shuttle and *ISS* Programs' Certification of Flight Readiness (CoFR) processes. IA's final report included many of the same observations and recommendations that were noted in the CAIB report. A significant number of the recommendations made to improve the CoFR process have been accepted by the programs for implementation.

The Continuous Risk Management (CRM) course was taught to over 100 civil service and contractor personnel during 2003. Fifty students and 10 Project/Program Managers were trained on the Integrated Risk Management Application Database System. S&MA assisted 10 MSFC Project/Program Managers in establishing a CRM process tailored to their project needs, which aided them in CRM plan development, risk identification, risk tracking, and other risk documentation. S&MA assessed over 82 programs/projects to verify adequate implementation of CRM. All MSFC documentation—Management Work Instructions (MWIs) and Data Requirements Descriptions (DRDs)—associated with CRM was rewritten or updated to comply with NASA Headquarters-approved documents for Risk Management.

At the April, 2003 meeting of NASA representatives for the Government-Industry Data Exchange Program (GIDEP), MSFC ALERT processing was announced the winner of GIDEP's Highest Cost Avoidance Award for FY 2002. The official announcement was made to S&MA jointly by the NASA Associate Administrator for S&MA, Mr. Bryan O'Conner, and the GIDEP Program Manager, Captain Mary Beth Newton.

Static firing test of the Solid Rocket Motor.

During its ascent into orbit, the Space Shuttle is powered by two SRBs and three reusable, high-performance SSMEs fed by a propellant-filled ET. The SSMEs, ET, RSRMs, and SRBs are overseen by MSFC's Space Shuttle Propulsion Office (SSPO). The SSPO works closely with five prime contractors—Rocketdyne Propulsion and Power of The Boeing Company; Pratt and Whitney, a United Technologies Company; Lockheed Martin Space Systems–Michoud Operations; ATK Thiokol Propulsion, an Alliant Techsystems Inc., Company; and United Space Alliance—to build and deliver the components.

During FY 2003, NASA flew two *ISS* Assembly missions, adding two major truss assemblies to the Station. The loss of the Space Shuttle *Columbia*, which occurred on February 1, 2003, required a reprioritization of SSPO activities to support the STS–107 accident investigation and return-to-flight. However, the SSPO was also able to continue process improvements for the manufacturing and testing of propulsion elements.

Space Shuttle Main Engine

The SSME Project continued to oversee improvements to SSME safety and reliability. The three Shuttle missions were powered by Block II SSMEs. Block II combines a new high-pressure fuel turbopump (HPFTP) with the previously flown redesigned high-pressure oxygen turbopump (HPOTP).

The SSME Project continued development of the Advanced Health Management System (AHMS), a system that couples vibration sensors with advanced digital signal processing with upgraded computing technology. Last year, SSME saw significant progress in AHMS Phase 1, the goal of which is to improve the engines' controllers. Phase 1 improvements will enable the controllers to safely shut down an engine when excessive vibrations are detected in the high-pressure turbopumps. Recent accomplishments included: Phase 1 hardware qualification; completion of Phase 1 hot-fire certification testing at Stennis Space Center (SSC); and completion of the Phase 1 Design Certification Review.

The SSME Project also continued implementing AHMS Phase 2 digital computer unit flight software, working toward completion of the Phase 2 Software/System Preliminary Design Review.

Also during the past year, the Space Shuttle Program Manager approved reactivation of SSME test stand A–1, at SSC in Mississippi, to support main propulsion system liquid hydrogen inlet flowliner testing. The program will test multiple low-pressure fuel turbopump/flowliner configurations to better characterize various flight environments.

External Tank

The ET Project continued to implement changes to enhance production processes at the Michoud Assembly Facility (MAF) near New Orleans, Louisiana. The specific steps that were taken to increase production included substituting aluminum 2219 for aluminum 2195 on domes and ogive structures. In conjunction with this change, the ET Project combined the current fusion welding process for domes and ogives with friction stir welding (FSW) for aluminum 2195 barrels.

FSW vastly simplifies and greatly enhances the strength and quality of the ET's welded joints. FSW joins two elements through frictional forces combined with forging pressures. Tools specifically designed for FSW are being used to weld the longitudinal barrel welds for both the ET hydrogen and oxygen tanks. The second FSW tool was activated in January 2003. Friction stir welds are proving to be virtually defect-free. They are approximately 48 percent stronger than welds produced by previous fusion weld techniques. The result is a safer, more reliable welded joint for the ET.

Following the *Columbia* accident, the ET Project was at the center of activities in the Shuttle Program's efforts to eliminate potential debris sources. The External Tank Working Group, which convened shortly after the accident, determined that foam, lost from the left bipod fitting during ascent, may have contributed to damage of the left wing of

the orbiter. The foam is part of the tank's thermal protection system (TPS). The ET Bipod Area Preliminary Design Review, held at MAF in June 2003, proposed a redesign of the bipod fitting area that would remove TPS foam from the bipod fittings and install heaters around the base of the metal fitting to prevent ice formation.

The ET Project, following NASA guidelines, has implemented a three-phased approach to return-to-flight activities. Phase 1 includes those activities to be performed prior to return to flight. Phase 2 covers debris elimination enhancements that can be incorporated into the ET production lines as the enhancements become available. Phase 3 covers long-term development activities.

The Phase 1 redesign areas include the bipod ramp, liquid hydrogen/intertank flange, and the liquid oxygen feedline bellows. In addition, all ET thermal protection areas are being recertified, and a camera is being installed in the liquid oxygen feedline fairing to provide a real-time view of the critical areas of ET performance during flight.

Solid Rocket Booster

The SRB Project continued work on the upgrade of the SRB integrated electronics assembly (IEA) wiring harness. The IEAs distribute power, provide data transmission, and route command signals. During flight, the IEAs are subjected to rigorous in-flight vibration, splashdown impact shock, and exposure to salt water. Replacement of the IEA wiring harness and associated blocks and connectors will increase the ability of the assemblies to withstand the harsh flight and recovery environments, thus increasing reliability and reducing requirements for repair and maintenance. The SRB Project also implemented safety improvements for the divers who prepare the SRBs for retrieval and towing.

One primary return-to-flight concern is the ET/SRB forward separation bolt catchers. The ET is attached to the SRBs by the forward separation bolt. This pyrotechnic bolt is fired at SRB separation, releasing the SRBs from the ET. The bolt catcher attached to the ET fitting retains the forward half of the separation bolt. The other half of the separation bolt is retained within a cavity in the SRB forward skirt. The SRB Project initiated a bolt catcher redesign effort. This activity was supported through extensive testing performed by the MSFC Engineering Directorate, with participation by personnel from industry and across the Agency.

The SRB Project also obtained resources to develop an alternate source for Booster Separation Motors. The new source will incorporate design and process enhancements that will improve quality, reliability, and performance.

Reusable Solid Rocket Motor

The RSRM Project continued its efforts toward ensuring that the RSRM motors are as safe and reliable as possible. The RSRM Project successfully fired Flight Support Motor FSM–10 in January, 2003, providing insight into RSRM performance. In addition, three 24-inch Solid Rocket Test Motors and one 48-inch Modified NASA Motor were tested at MSFC. These motors were used to evaluate new insulation and nozzle materials that are candidates for use on the RSRM.

The project also continued to improve RSRM manufacturing processes and technologies to increase RSRM hardware reliability and reduce risk for personnel who work with the motors. Improvements include an automated eddy current inspection system for metal parts. Automated eddy current is an electronic sensor-based inspection technique that reduces reliance on human sight and judgment in identifying flaws. A robotic glass bead system was implemented that enhances case cleanup after high-pressure water blast removal of the RSRM TPS. The system replaces the use of hand-held high-pressure equipment, thus increasing personnel safety. The robotic system also offers a consistent rotation speed and blast pressure, reducing the chance for hardware damage.

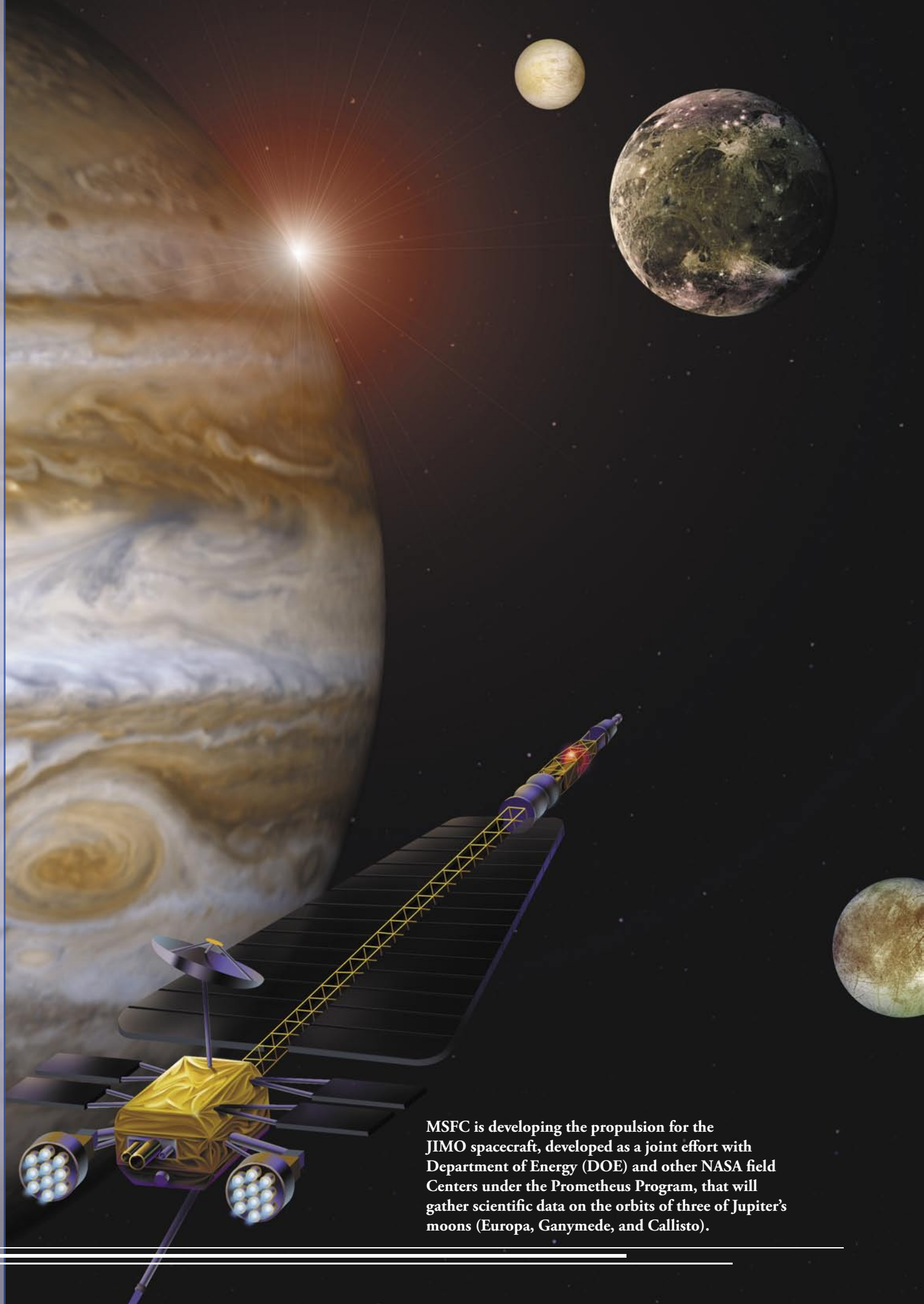
Another major enhancement is the development of chemical fingerprinting techniques used to detect and understand subtle variations in raw materials. Over 100 critical raw materials are used by ATK Thiokol Propulsion to prepare the RSRM for flight. Examples include propellant components, rubber insulation components, and nozzle ablative and insulating composites. In many RSRM critical applications, even minor uncontrolled material variations could alter material performance. Chemical fingerprinting uses a standardized approach to build a comprehensive information base for material characterization.

The RSRM Project also initiated a design change making the actuator bracket bolt system stronger and eliminating bolt-hole thread damage in the RSRM aft exit cone shell and compliance ring.

Propulsion Systems Integration

The Propulsion Systems Integration (PSI) office continued to perform as integrator for SSPO engineering, business, and project office support requirements. Responsibilities included managing Shuttle Engineering Support Center activities related to shuttle launches. Launch data was also downloaded and provided to the SSPO community for analysis. The electromagnetic effects effort continued to identify and analyze Shuttle electromagnetic compatibility issues. The Shuttle Environmental Assurance (SEA) Initiative addressed environmental materials obsolescence and materials replacement issues. The PSI-managed Shuttle Outreach program visited trade shows, seminars, schools, and museums, providing students and the aerospace community with a hands-on look at Marshall's Shuttle role.

PSI played a central role in coordinating and integrating SSPO and MSFC *Columbia* accident investigation activities, including coordination of data impoundment requirements and responsibilities; preparation, tracking, and closure of formal Data Requests; providing configuration management expertise to Data and Records Handling Working Group; coordinating and implementing SSPO Web and data security requirements; coordinating responses to Freedom of Information Act (FOIA) and other public inquiries; staffing the Shuttle Propulsion Action Center; and, preparing SSPO information for presentation to the CAIB.



MSFC is developing the propulsion for the JIMO spacecraft, developed as a joint effort with Department of Energy (DOE) and other NASA field Centers under the Prometheus Program, that will gather scientific data on the orbits of three of Jupiter's moons (Europa, Ganymede, and Callisto).

The Space Transportation Directorate (TD) is responsible for MSFC's designated role for space propulsion and for advanced space transportation systems development activities. The Directorate is a unique blend of project offices, research and engineering departments, and support functions directed toward the advancement of space transportation for the Agency. TD plans, directs, and executes research, technology maturation, advanced design and development, and testing. In addition, TD seeks to advance science and engineering excellence for NASA's space transportation systems, including earth-to-orbit and in-space transportation systems.

A major component and driver of activities in FY 2003 was the Integrated Space Transportation Plan (ISTP). The ISTP was a long-range investment strategy to revolutionize space transportation, thus ensuring our Nation's leadership in space. Currently, activities are focused in supporting and executing the MSFC's role in returning the Space Shuttle safety to flight, the ongoing Space Station operations, development, and construction, and any related programs/projects/tasks to execute the Vision for Space Exploration, a newer initiative and long-range investment strategy.

Advanced Concepts and Planning Office

TD supports many of the Agency's concept development activities and future projects for Earth-to-orbit and in-space vehicles. The Center's Advanced Concepts and Planning Office is uniquely qualified to perform conceptual analyses and trade studies. The Office contains a small, yet flexible set of core competencies necessary to perform system analyses for a broad spectrum of space vehicles.

During FY 2003, the Advanced Concepts and Planning Office supported conceptual definition and technology assessments of Space Architectures, 2nd and 3rd Generation Reusable Launch Vehicles, Code R Goals Assessments, Exploration Blueprint, JIMO, Prometheus, Revolutionary Aerospace System Concepts, In-space Propulsion Project Office (low-thrust trajectory tool development, solar sail, tethers, etc.), Hubble Reboost Study, and Mars Ascent Vehicle. The Planning Office also initiated development of an enhanced integrated in-space analysis capability.

Exploration and Space Vehicle Development

At the request of the Office Of Space Science (OSS) in Washington, TD led a concept feasibility study of an upper stage to deorbit the Hubble Space Telescope. This six-month study supported by 20 disciplinary experts from MSFC organizations investigated different propulsion system options, as well as earth-to-orbit options. Interim results on design, schedule, and cost were presented to the Bahcall Independent Review Panel. Final results were presented to the Astronomy and Physics Division Director and the Goddard Space Flight Center's (GSFC's) Hubble Space Telescope Project Office.

MSFC was represented on the Comet Nucleus Tour (CONTOUR) Mishap Investigation Board. This board, chaired by the Headquarters Chief Engineer, was formed shortly after the mishap occurred at the request of the Office Of Space Science. The board was active from August 22, 2002 through June 2003. The CONTOUR mission utilized a spacecraft managed for NASA by the John Hopkins Applied Physics Laboratory. CONTOUR was expected to conduct a comet nucleus tour. The investigation was hampered by the lack of flight telemetry during the critical motor burn that would have sent CONTOUR on its trajectory toward a comet encounter. The board conducted independent analysis of the spacecraft and SRM designs, and integration throughout the investigative period.

TD manages the Mars Ascent Vehicle portion of the Mars Sample Return (MSR) Mission for Jet Propulsion Laboratory (JPL) as part of the Office of Space Science Mars Exploration effort led by the Mars Exploration Office Director. MSFC supplies members to the Mars Program System Engineering Team and the MSR Technical Board,

which reports to the JPL Mars Exploration Program Manager on Mars exploration activities. During FY 2003, the MSR Technical board has been active in preliminary design architecture studies leading to a 2013 Earth launch. The MSR mission is expected to be one of the first Mars missions of the next decade.

The Directorate also serves as point of contact on upper-stage studies for space science missions that require unique modifications of existing launch vehicle upper stages or new/concept upper stages for exploration activities that call for additional performance energy.

The Directorate provides, as requested by NASA's Office Of Space Flight Assistant Associate Administrator for Launch Services, technical assessment and feasibility of upper stages to be used on both shuttle and expendable launch vehicle missions for the Office of Space Flight and OSS.

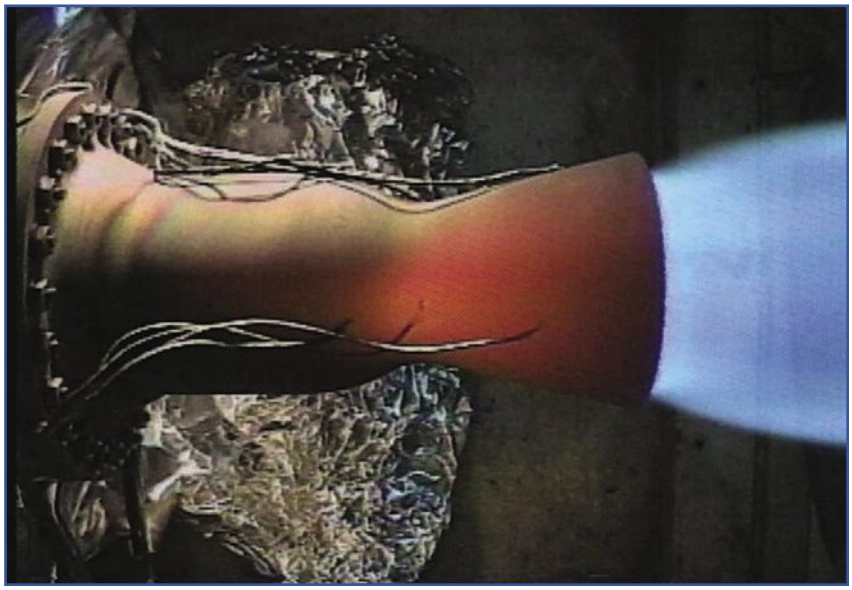
The Launch Services Project Office manages the engineering support to KSC's Launch Services Program in the electrical, mechanical, EMI/EMC thermal, structural, and environmental areas. The Office also offers technical support on a requested basis for existing and future vehicle assessment.

MSFC provided KSC with the software and manpower necessary to update their analog data acquisition system to a real time digital acquisition, analysis and display system. Experts in the solid rocket propulsion area provided their expertise and insight into the ongoing Atlas V SRM redesign to increase the motor's safety and reliability for NASA missions. In addition, MSFC maintains a resident office at the Boeing-Delta Launch Vehicle Factory in Decatur, Alabama.

In-space Propulsion

MSFC and partners working under TD project management have continued the research and development of advanced propulsion technologies needed to meet in-space transportation requirements of NASA's OSS. Through these technologies, OSS missions will deliver the benefit of greater and earlier science return. These new technologies help by making propulsion systems lighter, which allows more launch payload to be devoted to science instruments; and by using propellant more efficiently over a longer period, which shortens trip time and avoids the need for propellant altogether for certain kinds of missions.

In 2003, TD competitively selected research and development activities in Aerocapture Technology, Solar Sails Propulsion,



Reaction Control Engine (RCE) undergoes vernier (low thrust level) testing at Aerojet as part of the Auxiliary Propulsion Project component development.

Shown here is Vacuum Plasma Spray (VPS) GRCop-84 lining material hardware from the MSFC manufacturing and test facilities. The 5K hardware was successfully tested 100 times in Test Stand 115 of the East Test Area at MSFC. Manufacturing processes demonstrated the capability of producing liners up to a full-size SSME.

Next Generation Electric Propulsion, Emerging Propulsion Technologies, and Advanced Chemical and Thermal Propulsion. These selections included activities for types of advanced technology that will bring improvements in the near future, and also those that may bring greater improvement in the long run—described as high-payoff/high-risk technologies. Significant accomplishments were made during 2003 in the following in-space propulsion technology areas:

Aerocapture

Significant investments in rigid aeroshell systems were started in 2003. Advanced materials, TPS, advanced structures, guidance and control algorithms, and in-flight instrumentation systems were the primary focus. Heating tests of candidate TPS materials were also conducted. Investments in inflatable aerocapture systems also began, focusing on concept definitions, materials identification, and guidance algorithm development. Wind tunnel testing of a preliminary inflatable aerocapture concept was completed.

Solar Sails

There was continued design, development, and testing of sail and boom subsystem components for a future integrated ground demonstration of a 20-m sail system. Development began on integrated diagnostics for in-flight sensor systems, high-fidelity computational models, and quantitative laboratory testing and characterization of materials for future flight systems. Tool development for orbital mechanics and attitude control continued as well.

Next Generation Electric Propulsion

The NASA Evolutionary Xenon Thruster (NEXT) Phase I objectives were met in FY 2003, which included defining the NEXT ion propulsion system requirements and performing mission analyses of Deep Space Design Reference Missions. In August, under an MSFC-managed task at Glenn Research Center (GRC), researchers completed a successful demonstration of system-level performance of an engineering model NEXT at power levels exceeding 7.0 kW. In addition, the 40-cm ion thruster was operated

for more than 2,000 hours. Under this task, evaluation of grid erosion is continuing, in order to identify design improvements for a prototype ion thruster being developed in Phase 2 for a multiengine ground system demonstration. Under another MSFC-managed task at GRC, functional and performance testing up to 90 kW was performed on a NASA 457M Hall thruster to support further development of a flight-type thruster in 2004. Under an MSFC-managed task at JPL, the Extended Life Test of a NASA Solar Electric Propulsion Technology Application Readiness (NSTAR) ion thruster was conducted. This was the longest test ever performed on an ion engine. The test was recently ended in order to begin evaluation of data and hardware to support NEXT development.

Emerging Propulsion Technologies

Investigation of Momentum-Exchange/Electrodynamic Reboost (MXER) tethers continued. MXER is a high-payoff/high-risk technology. A Technology Assessment Group, which included independent experts, met in July to identify gaps in technology and to recommend areas for investment. Also, a Plasma Sail Working Group met to independently review and assess the fundamental feasibility of plasma sail technology, with reports due in early 2004.

Advanced Chemical and Thermal Propulsion

Investigation into ways to increase specific impulse, lifetime, and overall performance of state-of-the-art chemical systems is continuing, as well as investigation of ways to develop new chemical propulsion technologies. To optimize and enhance technologies beyond the current state-of-the-art, the team is investing in three separate areas associated with chemical propulsion systems: advanced fuels, cryogenic fluid management, and lightweight components.

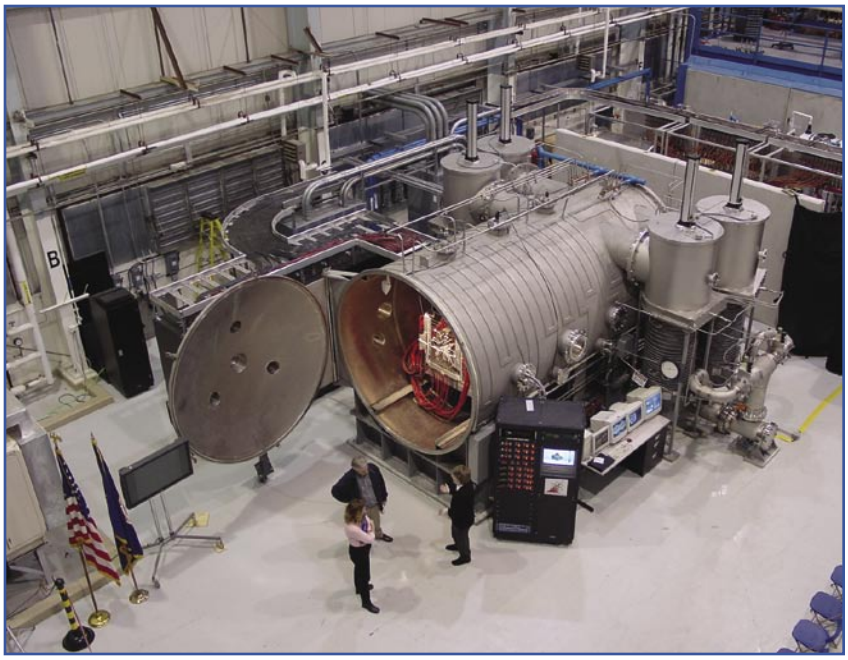
High-powered Propulsion

The High Powered Propulsion Systems Office was created in FY 2003 to assist the NASA HQ Prometheus Program, formerly known as the Nuclear Systems Initiative. The primary goal of this program is to develop technologies to safely explore the outer planets using nuclear systems. Support to the Prometheus Program is focused in two areas. The first area is a project known as JIMO. JIMO is a technology demonstration and science acquisition spacecraft. Scheduled to launch after 2012, this spacecraft will draw primary power from a nuclear fission reactor to power next generation electric thrusters and vehicle systems. The spacecraft will use these new technologies to travel to and orbit three different moons of Jupiter and use an extensive array of scientific instruments to explore those moons. MSFC is assisting the JIMO Project Office at the JPL in Pasadena, CA, by providing expertise in system analysis and integration.

The second area of support to the Prometheus Program is advanced technology development for nuclear systems to enable further exploration of space. Included in FY 2003 studies in this area were the viability of indirect nuclear thermal propulsion systems, the identification and solicitation of new concepts for advanced electric propulsion, the examination of the most likely evolution paths of nuclear electric systems, the testing of reactor concepts using a non-nuclear test-bed, and the advancement of readiness levels in several key technologies such as ultra lightweight fuel tanks and environmental effects modeling and monitoring.

Next Generation Launch Technology

MSFC is hosting the NGLT Program Office, which was formulated by transitioning projects from the Advanced Space Transportation Program (ASTP) and projects from the Space Launch Initiative (SLI) Program to ensure a coordinated technology development effort. This NGLT Program has focused on the most critical, state-of-the art, high-payoff technology development and risk reduction activities to enable low-cost, reliable, and safe future generations of launch vehicles in support of NASA's ISTP. The NGLT Program brings together a nationwide team that builds on the extensive experience base offered by each NASA Center, as well as the U.S. aerospace industry and



Components and subsystems for nuclear propulsion systems are tested in a nonnuclear test-bed by the Propulsion Research Center for High-powered Propulsion.

academic partners from coast to coast. The program has pursued commonality with the Department of Defense (DOD) through the National Aerospace Initiative (NAI).

MSFC has implemented a systems analysis process to integrate the activities within the NGLT Program. The NGLT team at MSFC is integrally involved in the disciplined systems analysis process to support NGLT research and technology development investment decisions. This process will produce and deliver a set of linked missions, concepts of operation, system requirements, characteristics, architectures, and conceptual system designs. These will serve as the basis for evaluating the impact of investing in various portfolios of advanced technologies. These technology evaluations also will provide valuable information to the NGLT Program for prioritizing and allocating funding to develop propulsion system technology, vehicle systems technologies, and hypersonic flight demonstrations.

NGLT Projects

The following MSFC NGLT Projects within TD support the NGLT Program technology development, with efforts focused on the most critical technology development and risk reduction activities. The project goals are to:

- Develop technology to make a next-generation space transportation system safer, more affordable, and more reliable.
- Enhance the Nation's security by leveraging access to space technology investments in partnership with the DOD.

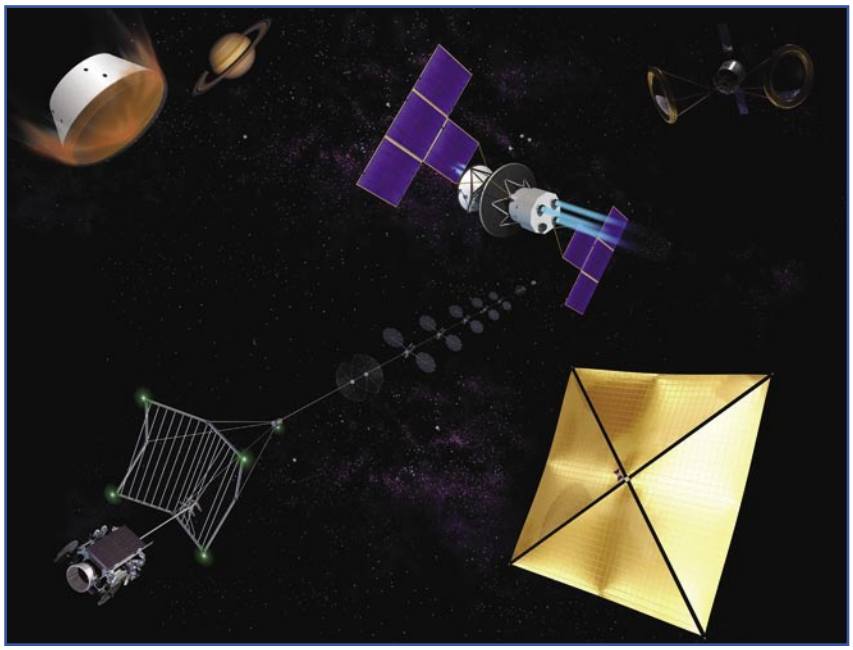
The Rocket Engine Prototype Project (REP) achieved significant milestones, including completing a Preliminary Design Review in August 2003 for the RS–84 liquid oxygen (lox)/rocket propellant (RP) prototype engine design; successfully testing a 40K Subscale Preburner; and successful development tests of a new high-strength material, called Mondaloy 200, that is compatible with high-pressure oxygen environments. Breakthrough innovations like this new material, which could result in weight savings for the RS–84 engine—a key technical performance measure—are critical to NGLT Program goals. REP also demonstrated use of a powder metallurgy process for fabricating large, complex engine components using oxygen-compatible materials.

Air-breathing propulsion technology is being advanced through the Rocket-based Combined-cycle (RBCC) Project. Spacecraft powered by air-breathing rocket engines would be completely reusable, able to take off and land at airport runways, and ready to fly again within days. The Ground Test Engine Conceptual Design Review in July 2003 was completed by the Project, along with a consortium of contractors that provided a full picture of a combined-cycle engine complete system design.

Component testing by the Integrated Powerhead Demonstrator (IPD) Project focused on the feasibilities of technologies to improve reliability, operability, and life of lox turbopumps and hydrogen turbopumps, utilizing hydrostatic bearings, clutching bearings, and advanced materials. Major accomplishments during FY 2003 included testing the first large-scale, flight-weight, oxygen-rich preburner in the U.S. and fabrication of the first channel-wall nozzle designed and fabricated in the U.S.

The Auxiliary Propulsion Project is testing a lox/ethanol dual-mode Reaction Control Engine (RCE) configuration to simplify the engine design by incorporating a 12-lb thrust vernier thruster and an 870-lb primary thruster in the same engine. The lox/ethanol propellants are safer, less expensive, and more environmentally friendly than traditional on-orbit propellants. The Project also investigated hydrogen peroxide as a safer, more efficient propellant through component testing. This testing expanded the technical knowledge database being developed by Government, industry, and academic institutions regarding safe, efficient use of hydrogen peroxide in rocket propulsion applications.

Major milestones were accomplished by the Propulsion Technology and Integration (PT&I) Project toward enabling significantly improved vehicle safety and operations, with advanced leak detection technology. Sensor systems must detect the presence of fuel and/or oxygen to provide information on fire and explosion hazards. Both an integrated fuel/oxygen sensor array and its postage stamp-sized supporting system hardware were successfully demonstrated through collaboration between NASA Centers, academia, and industry. Commercialization of the technology has already begun. The Project is developing many other technologies, such as the successful manufacturing of a platinum-iridium (Pt-Ir) thrust chamber—a technology



In-space Propulsion technology development competitively selected in 2003 leads the way to greater and earlier space science return.

that could increase safety and reduce cost versus existing technologies. The Pt-Ir chamber was tested with a 120-second firing of a lox/ethanol thruster in September 2003.

Rocket engine combustion chamber liners have been a limiting factor for the life and performance of the SSME. A promising new copper-chromium-niobium alloy named GRCop-84 has the potential to replace the current material. Efforts are focused on developing technologies, such as FSW, required to take GRCop-84 from the laboratory and place it in a next generation production main combustion chamber. A major breakthrough was the successful development and demonstration of vacuum plasma spray (VPS) material deposition for manufacturing a liner in the MSFC manufacturing and test facilities. The demonstrations included manufacturing samples for 5,000-lb thrusters up to the SSME liner size. The 5,000-lb thruster was also used in a hot-fire test series and successfully demonstrated at least a threefold increase in the low-cycle fatigue life of the liners before crack initiation. This small demonstration VPS test article also demonstrated another key benefit for VPS—producing a functional gradient coating that is not susceptible to debonds and chipping, thus protecting the copper-based liner materials. GRCop-84 will be the first new combustion chamber alloy introduced into commercial practice in over 30 years.

TD Research and Engineering Departments and Support Functions

Propulsion Research Center

The Propulsion Research Center (PRC) serves as the MSFC focal point in propulsion research. The PRC conducts basic and applied research programs leading to advanced space propulsion capabilities or to improvements in existing propulsion systems. The PRC interacts with the national and international scientific and propulsion research communities to guarantee MSFC's access to the state of the art in propulsion technology. Achievements in FY 2003 include advances in high-power propulsion through experimental and theoretical work in pulsed plasma thrusters and in field-reversed configuration plasma thrusters. In addition, there was significant progress in the advanced chemical propulsion area including characterization of the ignition properties of new hypergolic propellants. Research and technology development work in the PRC supported NGLT and In-space Propulsion, and the high-power thruster research represents potentially enabling technology for space exploration. The test-bed for performing non-nuclear testing for the characterization of nuclear propulsion systems directly supports the Prometheus/JIMO program.

Test and Evaluation Department

The Directorate's research into new propulsion systems is complemented by state-of-the-art testing equipment and facilities under the Test and Evaluation Department. From engine function to structural endurance, TD has the test stands to ensure proper performance on the launch pad and in space. These facilities can be adapted to accommodate a wide variety of test articles and can be used by NASA and aerospace industrial partners.

TD Engineering Departments

Additional TD engineering efforts were performed by the Vehicle and Systems Development Department and the Subsystem and Component Development Department in support of multiple customers under Agency Codes M, S, and R Programs in the following areas:

- Launch vehicles.
- Liquid and solid rocket engines.
- Main propulsion systems.
- In-space propulsion systems.
- Launch vehicle operations.
- Trajectories for launch and space vehicles.
- Vehicle guidance and navigation.
- Mission analysis.
- Control system design.
- Actuation subsystems.

- Stabilization systems.
- The design, development, test, and operation of turbo machinery and combustion devices.
- Mechanical design of propellant and engine systems.
- Definition, prediction, test, and analysis of induced environments.
- Development and use of advanced computation fluid dynamic tools and techniques.

The programs and projects supported by these TD engineering departments includes those managed within TD and those managed elsewhere, such as the Orbital Space Plane (OSP); X–37—a flight demonstrator for OSP; Demonstration of Automated Rendezvous Technology (DART); and the Space Shuttle Program.

TD Engineering Support for Space Shuttle Propulsion Office

TD engineering participated in many Shuttle support activities. For example, TD supported the Shuttle STS–107 investigation and Return To Flight efforts involving various ET redesign activities from analysis to subscale and full-scale tests. Initially, sensitivity studies of STS–107 ET foam debris impact velocity to debris size, drag coefficient, and flow orientation were performed using a simple uniform flow model to obtain a feel for the physics of the debris problem that caused damage to the Shuttle. Also, the MSFC photographic imagery group used a similar type model to derive estimated foam densities for various debris sizes that were somewhat larger than that typical of ET bipod foam.

During follow-on redesign efforts, panel testing was performed to gather fundamental data about the behavior of hand-packed and sprayed Super-light Ablator (SLA)—layered with Spray-on Foam Insulation (SOFI)—when cryogenic nitrogen is either cryo pumped or ingested into the SLA material. Working with the Air Force's Arnold Engineering Development Center Wind Tunnels nearby in Tennessee, full-scale ET bipod attachment redesigned closeout foam was successfully tested in simulated flow loads up to Mach 2 and ascent aerodynamic heating rates. Additionally, tests were performed at MSFC on ice formation on ET feedline bellows to help determine potential solutions or alternative design fixes to the problem of ice debris also experienced during Shuttle launches.

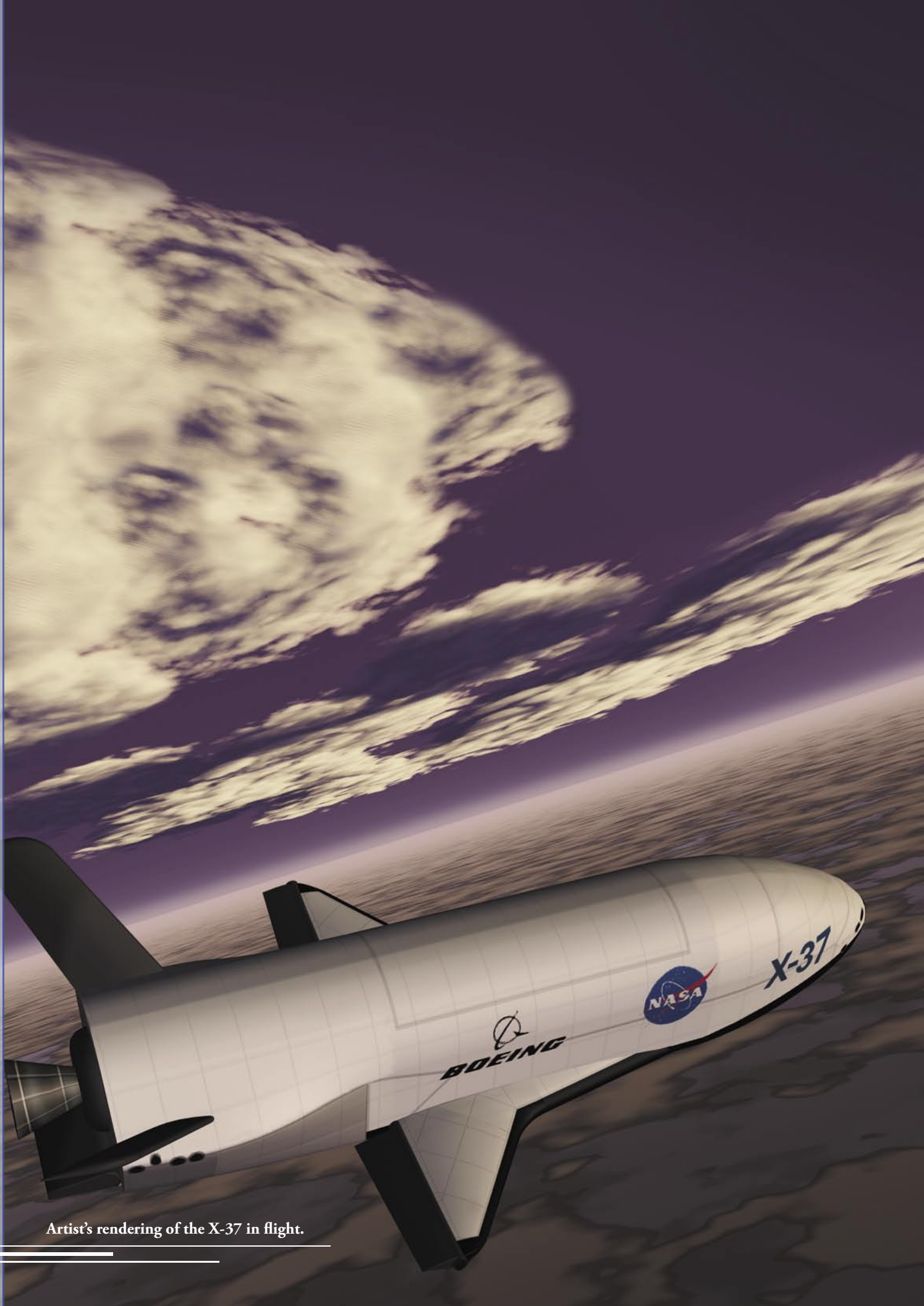
TD Business and Administrative Office

The Business and Administrative Office provides budget and resources management support to all Directorate projects, as well as TD Institutional departments, offices, and service pools. The Office also manages all the Directorate information technology requirements and resources from personal digital assistants and desktop workstations to large shared servers and even larger data acquisition systems. The Office also serves as the coordinator between TD managers and the MSFC Human Resources Department on employee personnel matters including performance plans and appraisals, promotions, reassignments, awards, etc.

Integration Office and Directorate-wide Activities

In FY 2003, TD participated in over 240 educational activities. TD researchers and engineers authored and presented 150 technical papers on the work including tests being performed at MSFC at various engineering, propulsion and rocket conferences throughout the world. The TD Integration Office hosted the Liquid Propulsion Conference with DOD in Chattanooga, Tennessee; the Joint Propulsion Conference, a major American Institute of Aeronautics and Aerospace conference; and the test instrumentation/sensor workshop, both in Huntsville, Alabama. Experts from across six space-faring countries including the United States came to give seminars and participate in technical interchanges. The TD In-space Propulsion Systems Office hosted several technology assessment working group meetings. These technical interchanges follow the goals of the ISTP and the Vision for Space Exploration for the research and development of advanced technologies vital to new space transportation systems.

Safety is the top priority within NASA and TD. The Directorate's nearly 500 civil service and 177 contractor employees, occupying 53 buildings—including propulsion testing areas, full-size rocket test stands, and numerous laboratories—are a living example of that priority, which they demonstrated during FY 2003 when TD achieved over 3,000,000 work hours without a lost-time accident.



Artist's rendering of the X-37 in flight.

ORBITAL SPACE PLANE

The OSP Program began in FY 2003 as an important element of the Nation's ISTP to ensure safe, affordable, and reliable access to space. The OSP Program's role was to develop the next generation of transportation system(s) for human space flight. The OSP, a single system with multiple capabilities, would initially serve as an *ISS* crew rescue vehicle (CRV), an operational capability originally planned for 2010. Later, the OSP would serve as a crew transfer vehicle (CTV), providing NASA with an enhanced fleet of space transportation vehicles.

The tragic loss of the Space Shuttle *Columbia* and her crew in February 2003, and the subsequent grounding of the Shuttle fleet, added urgency to the country's need for an alternative manned transportation system serving the *ISS*. In FY 2003, NASA took steps to provide the President and Congress with the option of accelerating the acquisition of the OSP system. Under an accelerated schedule, a CRV capability could be available as soon as 2008, but no later than 2010, and a CTV could be operational no later than 2012.

In FY 2003, the OSP Program made significant progress in requirements development, program documentation, independent design verification, acquisition, and risk identification and mitigation. Initially the OSP would be launched on an expendable launch vehicle (ELV), with sufficient design flexibility to transition to future reusable launch vehicle systems. The OSP system would be safer than either the Space Shuttle or the *Soyuz*, would offer increased operability and interoperability, and would reduce operations and lifecycle costs. The OSP vehicle would be able to operate autonomously and carry at least four astronauts, potentially increasing Space Station crew capacity, and therefore the resulting scientific returns. The new system would also reduce the Nation's sole dependency on the Russian *Soyuz* capsule for crew rescue.

The OSP Program placed crew survival as the ultimate priority and most stringent metric for the design, development, and operation of the OSP system. Recommendations by the CAIB were evaluated for integration with OSP Program plans. After crew survival, efficiency of operations was a principal requirement for the OSP system design. The OSP Program required a system that would be significantly more efficient to prepare, launch, operate on-orbit, return, and refly or dispose than past transportation systems.

The OSP system would build on existing technology to achieve its objectives, rather than placing new technology development in the critical path of its success. Flight demonstrators and technology development activities undertaken as part of the SLI were continued. The DART project would develop and demonstrate autonomous rendezvous and proximity operations between a chase vehicle (DART) and an on-orbit satellite. The Pad Abort Demonstrator project, which began its formulation phase in FY 2003, would develop the fundamental capability to test crew escape technologies in a pad abort situation. The X–37 Approach and Landing Test Vehicle (ALTV) project is discussed below in the X–37 Flight Demonstrator Project section.

In FY 2003, the Program met its major program milestones at an accelerated pace to provide the option of accelerating the OSP system's acquisition. In February 2003, the OSP mission needs statement and operational requirements (Level 1) were baselined. By September 2003, the OSP system requirements (Level 2) were defined. The OSP Program also developed the Request for Proposals (RFPs) within its scheduled delivery date for a planned release in November.

The OSP Program Office is hosted by MSFC and draws on expertise from across the Agency to create a One NASA team. The Manager and Deputy Manager of the OSP Program Office are responsible to Office of Aerospace Technology Management for program performance and report to the MSFC Center Director.

X–37 Flight Demonstrator Project

In FY 2003, the Boeing Company successfully competed for SLI funding through the NASA Research Announcement (NRA) 8–30 Cycle 2 procurement. Subsequently, authority to proceed was granted on November 29, 2002, and the original Cooperative Agreement in place since 1999 ended. Under Boeing's proposal, the X–37 Flight Demonstrator Project was rescoped to two automated reusable spacecraft that would validate reentry technologies for the OSP Program. First, the X–37 ALTV is designed for multiple high-altitude flights to reduce risk in the reentry phase of proposed orbital missions. Second, the X–37 Orbital Vehicle (OV) could potentially serve as a reentry technology test-bed—unlike any other ground laboratory or flight platform—as well as prove a variety of long-term mission technologies in real-world environments.

The X–37 Project delivered numerous accomplishments during FY 2003, most notably ALTV airframe structural proof testing (June 2003) and the OV System Requirements Review (SRR) (July 2003). The ALTV proof test paved the way for component installation into the airframe and vehicle assembly.

The OV SRR process established a baseline for the mission objectives and Concept of Operations previously presented at a Mission Concept Review. Risk-based Acquisition Management was applied to integrate the analysis of Project risk with the formulation of its acquisition strategy, focusing investments on high-priority areas such as TPS. Also during this reporting period, an independent aerospace panel conducted a comprehensive management assessment in Spring 2003, resulting in increased Government insight and greater visibility within NASA to ensure mission success.

The X–37 Project Office is located at MSFC, with expertise provided by numerous NASA Centers and U.S. Air Force partners. The X–37 Project is organized to facilitate accountability and provide checks and balances between business and technical management. The Project has established Resident Offices at Boeing's Huntington Beach, CA, facility, and at NASA's Dryden Flight Research Center. Communication and integration among functional management systems are keys to empowering the One NASA team dedicated to building and successfully flying the X–37.

The X–37 OV could test critical new technologies in the orbital, reentry, and landing mission phases.

Materials scientist Dr. Aleksandar Ostrogorsky examines a sample container in the Microgravity Science Glovebox.

Space Partnership Development

Creating partnerships between industry and NASA is an important step in facilitating the sustainable exploration of space and enabling the production of new technologies to bring benefits to Earth. Through such partnerships, industry's marketplace innovation and academic expertise can be used to enhance NASA's capabilities in a cost-effective manner.

NASA's Space Partnership Development (SPD) Program Office facilitates joint efforts by uniting NASA researchers with industry, universities, and other Government agencies to create technologies and conduct research that can advance NASA's goals in space exploration and yield worldwide benefits. The development of these partnerships occurs at Research Partnership Centers (RPCs) located primarily at universities throughout the country. NASA provides the RPCs with base funding, and the remainder of their funds comes from industrial and other partners. RPCs also collaborate with researchers in other academic institutions and/or other Government agencies. Through these partnerships, NASA and industry have created exciting new research opportunities and products that can advance space exploration and improve life on Earth.

One area of research on which several RPCs are focusing research efforts is bone loss. Bone loss is not only an issue for aging adults on Earth, but also a concern for astronauts due to the bone loss that occurs while on extended space flight missions. BioServe Space Technologies, an RPC, has worked with the biotechnology company Amgen, Inc., since 1995 on this area of research. BioServe has conducted successful ground- and space-based studies examining the effectiveness of an Amgen-discovered compound called Osteoprotegerin (OPG). OPG is currently in Phase II clinical trials for the treatment of osteoporosis and bone loss associated with metastatic bone cancer. BioServe has successfully tested this compound for Amgen in mice during a Shuttle mission to the *ISS*. Currently, BioServe and Amgen are working to develop and design a bed rest study that will evaluate the effectiveness of OPG in preventing bone loss in healthy human subjects during 30–60 days of bed rest. BioServe also is using its knowledge and experience in bone loss research to partner with Isis Pharmaceuticals and Procter & Gamble to conduct similar studies.

The Center for Biophysical Sciences and Engineering (CBSE), an RPC, centers its research on protein structural information and the discovery and development of new drugs for areas such as bone loss. In addition to bone loss, CBSE is working in collaboration with industry to address another long-term space exploration concern—radiation exposure. CBSE and Athersys Inc. recently have made advances in understanding of DNA repair mechanisms, which led to the identification of the DNA repair endonuclease Artemis. Understanding the structure motifs necessary for Artemis to function allows researchers to identify, through conventional screening and structure-based drug design, small molecule activators of the enzyme that can be used to render individuals radiation-resistant. These activators could have utility in space flight against radiation, as well as in a variety of industrial settings where individuals are exposed to DNA-damaging agents. CBSE and Athersys will work to advance research for regenerative medicines designed to repair—and ultimately replace—damaged, injured, or diseased tissues.

While some RPCs concentrate on how to improve human health in space, others focus their research on producing the technology that helps maintain astronaut health, nutrition, safety, and security. For example, ProVision Technologies (PVT), an RPC, focuses much of its research on hyperspectral imaging technology. PVT is working with Photon Industries, Inc., to develop hyperspectral imaging technology, which uses sensors to capture electromagnetic energy in the ultraviolet, visible, infrared, and thermal regions. These lightweight, portable sensors slice this energy into hundreds of bands, where each band represents a unique image of a target—e.g., a flesh wound. These images contain reflective, refractive, and transmissive properties unique to the target as a function of wavelength

or band. These properties can be used to detect and identify the target. Specific areas for development of hyperspectral imaging sensors to support a human presence in space include:

- Visible/near-infrared (IR) sensors for characterizing and quantifying blood perfusion and oxygen in flesh wounds. A blood oxygen map can be generated to show the various oxygen levels in various tissues affected by the wound. Additional research and development will enable monitoring of the wound healing process by comparing images of the wound collected sequentially, and comparing the most recent image to the last image collected.
- Ultraviolet, visible, and near-IR sensors for detection of molds and toxins. Work has been initiated to evaluate pure molds and molds grown on corn. The goal is to develop a spectral library of molds and toxins, each of which is identifiable by its spectral signature. The research will be expanded to address long-term space vehicle habitat problems that can occur when molds grow in the water supply or on interior surfaces of the spacecraft.

While partnering with industry, some RPCs have partnered with each other to produce human health support technologies. PVT, the Imaging Technology Space Center, and the Medical Informatics Technology Applications Consortium are working together to develop an integrated surveillance system for physiologic sensing, monitoring, and response. The system would use noninvasive sensors that can monitor astronaut health, with wireless communication to a data repository onboard a space vehicle in transit, in low Earth orbit, or in expeditions of long duration.

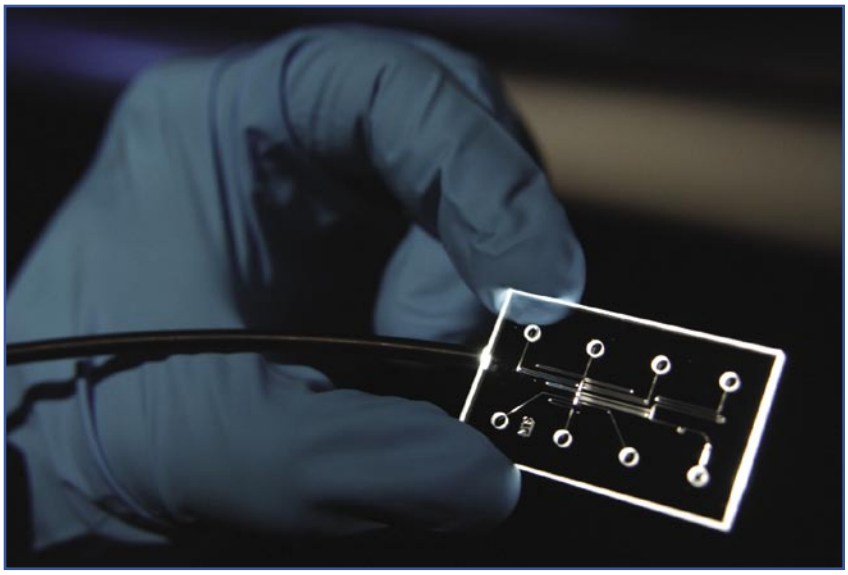
Although several RPCs focus research efforts on human health on Earth and in space, other centers create the technologies that will sustain long-term space flight exploration. The Wisconsin Center for Space Automation and Robotics (WCSAR), an RPC, has developed an array of technologies suiting in-space/in-situ fabrication, maintenance, and repair. In early FY 2003, WCSAR, in collaboration with Friction Stir Link, Inc., a private company specializing in the material joining process, and faculty members on the University of Wisconsin campus initiated a robotic-assisted material joining process using the solid-phase friction stir principle. The immediate goal is to characterize the material joining process and to develop a prototype that will demonstrate suitability for space-based applications. The long-term goal is to deliver the validated technologies and tools to be used in space exploration.

The Center for Commercial Applications of Combustion in Space (CCACS), an RPC, is collaborating with Lockheed Martin Astronautics Corporation in the development of membranes for the separation of nitrogen and carbon dioxide as a preparatory step for the production of propellant from the atmosphere of Mars, for use in robotic or human missions to Mars. CCACS has prepared membranes, while Lockheed has developed a test facility where they can measure membrane performance at low temperatures and pressures typical of the Martian atmosphere for pure gases (CO_2, N_2, and Ar) as well as a gas mixture typical of Mars.

Each RPC provides technical expertise that can further develop NASA's space exploration capabilities. Through the SPD Office, the centers are able to share their knowledge and expertise when partnering with industry, academia, and other Government agencies. These collaborations produce research and create technologies that support near and long-term space exploration while continuing to bring benefits to people on Earth.

Microgravity Science and Applications Department

The Microgravity Science and Applications Department (MSAD) is responsible to NASA's Office of Biological and Physical Research (OBPR), Physical Science Research Division, for advancing research programs and exploration goals in the areas of materials science and biotechnology.



Lab-on-a-Chip device (LOC) custom-made by Caliper Life Sciences for MSFC

The department also integrates and manages the operation of experiments in the *ISS* Microgravity Science Glovebox (MSG) for NASA and the ESA.

An integrated structure of scientists, engineers, and project managers is used to formulate fundamental and strategic technology programs, perform advanced research, and implement fight hardware programs. The organization also acts as a bridge between the U.S. science and technology communities and unique NASA research requirements. In this role, science-related workshops and conferences are sponsored to inform the broader research community of NASA's objectives. This approach encourages national participation and establishes collaboration between MSFC and other prominent research groups.

During 2003, the group advanced its leadership role by defining programs that meet the challenges posed by NASA's space exploration goals, while continuing to implement fundamental science research experiments on the *ISS*. In the materials discipline, exploration roadmaps were developed for strategic programs in Radiation Shielding, Materials Science for In-space Propulsion, and In-space Fabrication and Repair. In the biotechnology discipline, research programs were defined to explore the molecular level effects of long-term weightlessness on bone and muscle tissue and space radiation on human cells.

The year's research activities on the *ISS* continued until the interruption of Shuttle flights severely restricted the scheduled flow of new experiment hardware to the Station. To meet this challenge, the group developed innovative low-mass investigations that utilized materials and equipment already on board to explore reduced gravity effects in such diverse areas as zero-gravity soldering and the initial interactions that occur when miscible fluids are mixed (honey and water).

In 2003, hardware development activities continued on the Materials Science Research Rack (MSRR). Upon completion this facility will be installed on the *ISS* in the U.S. laboratory module *Destiny*. Once on Station, the MSRR will provide the capability to answer significant questions about the influence of reduced gravity on a variety of materials processes critical to achieving Agency exploration goals.

Finally, MSAD-sponsored science teams advanced their research and reported new findings based on data and sample analysis from materials and biotechnology flight and ground experiments. This included the analysis of

the partial data returned from the Mechanics of Granular Materials investigation on the Space Shuttle *Columbia*'s final mission.

Macromolecular Biotechnology

In 2003, as the Macromolecular Biotechnology program moved to align with NASA's exploration priorities, two key groups were formed to establish and implement future strategic research. The first, the Strategic Biomolecular Research for Exploration (SBRE) team, set in motion plans for a molecular-based research program that will join with other NASA Centers and research institutions to address astronaut health during lengthy exposure to the space environment. The group is interested in identifying, at the molecular level, the mechanisms that explain the formation and breakdown of bone and muscle tissue and how these may change as a reaction to reduced gravity. SBRE is also looking into the molecular pathways relevant to radiation damage, repair, and risk assessment.

During 2003, three separate working groups were formed to concentrate on structuring molecular research in each of the focus areas: bone, muscle, and the effects of radiation damage to the human body in space. To gain insight into cutting-edge research in the focus areas, members of each research working group engaged with leading medical professionals, NASA scientists, and academic researchers nationwide. During the year, SBRE hosted 11 seminars in which top researchers with expertise in each of the three areas briefed the entire group on their research. Two important presenters were Dr. Kenneth Baldwin, National Space Biomedical Research Institute (NSBRI) Team Leader for Bone Research, and Dr. Jay Shapiro, NSBRI Team Leader for Muscle Research. As a result of these activities, four important collaborative relationships were established, and the bone working group received funding for a joint proposal with Drs. Jane Lian and Gary Stein, of the University of Massachusetts Medical School in Worcester, to study pivotal molecules for bone formation. By the end of the fiscal year, several other research institutions expressed interest in forming research associations.

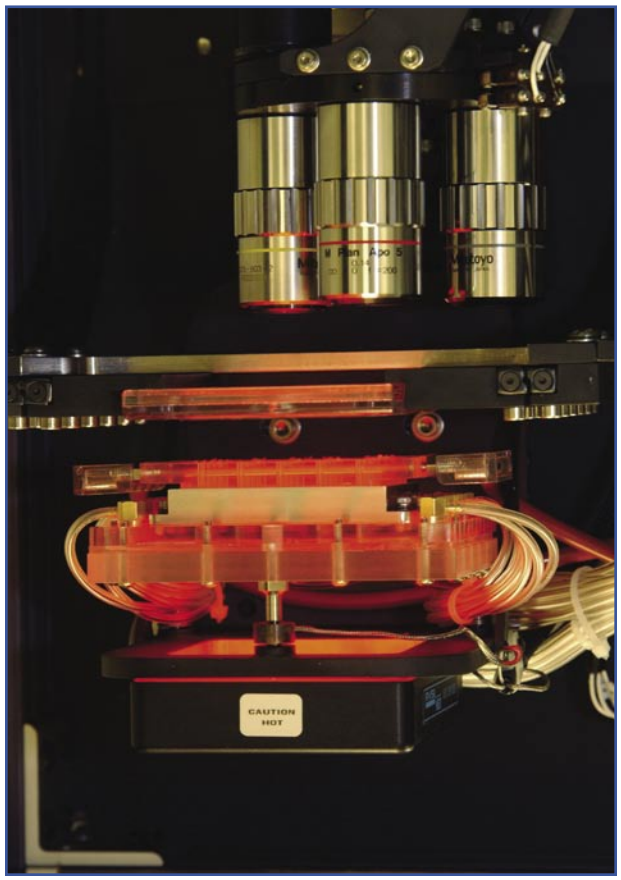
The second group, established to implement strategic research, Lab-on-a-Chip (LOC) Applications Development (LOCAD) grew out of NASA's Iterative Biological Crystallization (IBC) program. After developing LOC technology for use in crystallography, the IBC group discovered that their capabilities in microfluidics were well suited for LOC technologies that will allow humans traveling in space to maintain good health and a safe environment. Lab-on-a-chip

Dr. Lisa Monaco, Project Scientist, views an LOC device.

technology is a potential springboard for environmental monitoring and medical diagnostics that may help NASA develop tools that will diminish the negative effects of long-term space travel on humans.

The LOCAD team soon began collaborations with researchers at other NASA facilities, other nonmilitary Government agencies, and the U.S. Army for developing custom chip and flight hardware and for feasibility testing and process development. Projects assisted by LOCAD during the fiscal year included the Modular Assay for Solar System Exploration project, the National Center for Microgravity Research on Fluids and Combustion, and the Marine Biology Laboratory—Woods Hole, Massachusetts.

MSFC built Application Development Unit–25 for microfluidics



LOCAD engineers and scientists also began building an LOC Control Unit in support of applications development that would advance NASA's critical mission objectives. This one-of-a-kind microfluidics control unit, which was completed in FY 2003, allows the precise control of fluids on a chip via pressure; it will be configured to include fluid control by electrokinetics once the first unit completes testing in early FY 2004. The unit is designed to allow operation by a person situated near the unit or operated from a remote location via the Internet. LOCAD developers anticipate that future space travelers will use handheld devices to monitor water, detect microbes, and perform biological and clinical analyses important to maintaining crew health.

Flight Experiments

The biological crystallization payload for STS–111 was launched on June 5, 2002. Protein Crystallization Apparatus for Microgravity (PCAM) cylinders carrying 10 different macromolecules (378 total samples) were flown to the *ISS* aboard STS–111 and remained on orbit until October 18, 2002. STS–112, launched on October 2, 2002, also carried PCAM experiments. Analysis of data obtained from these flights continued through 2003 at the various investigators' institutions.

Experiments included cell membrane transport molecules, DNA-binding proteins, blood proteins, plant proteins, and antioxidant enzymes, as well as proteins involved in optical properties of the lens of the eye and in diseases such as diabetes. The experiments were returned to Earth on December 7, 2002. Preliminary analytical results indicate that some samples produced good crystals suitable for data collection.

Additional macromolecules for crystallization were flown to the *ISS* aboard STS–113 on November 23, 2002. This flight represented the first space station experiment for the Diffusion Controlled Apparatus for Microgravity hardware. A total of 81 individual experiments are housed inside the Single-locker Thermal Enclosure System in three separate tray assemblies.

Flight Hardware Development

The Macromolecular Biotechnology Program in 2003 continued the engineering and development of three types of hardware for use with fundamental crystal growth studies in space. Dr. Lori Wilson, of Eastern Kentucky University, completed testing and made improvements to her investigation—Metastable Solution Structure and Optimization Strategies in Protein Crystal Growth. Her goal is to further the understanding of the fundamental processes of protein nucleation and crystal growth both on the ground and in low gravity.

The Delta-L flight hardware is designed to study the process of protein crystal growth itself rather than growing the crystals for structure determination. Dr. Edward Snell is the principal investigator for Delta-L. Final verification testing for flight was completed on the Observable Protein Crystal Growth Apparatus hardware. This equipment, developed by principal investigator Dr. Alexander McPherson, is designed to provide a roadmap leading to optimal crystal diffraction and structural information in low gravity.

Cover Stories

The research of some principal investigators in the Macromolecular Biotechnology program was featured on the covers of scientific journals. Dr. Geoffrey Chang, of the Scripps Research Institute in La Jolla, California, is an active NASA Principal Investigator whose work in membrane proteins made the cover of the Journal of Molecular Biology. Dr. Edward Snell and Dr. Mark van der Woerd, both of MSFC and BAE Systems, Huntsville, Alabama, also had their research cryocrystallography using infrared imaging featured as the cover article in the Journal of Synchrotron Radiation.

The Journal of Structural Biology published a special issue for research articles on macromolecular crystallization and its importance in an era of structural genomics research. NASA Principal Investigator, Dr. Alexander McPherson, edited this special issue in which nine of 19 articles were written by NASA-funded investigators. Dr. McPherson's article was also the cover story for this issue.

Approximately 60 other articles by NASA-funded Macromolecular Biotechnology researchers were accepted and published in scientific, peer-reviewed journals.

NASA-supported Conferences

NASA organized two external sessions on biological crystal growth at the American Crystallographic Association's Annual Meeting in Covington, Kentucky, July 26–31, 2003. The first, "Biological Neutron Diffraction," a transactions symposium, was organized by Principal Investigators Drs. Gerard Bunick and Leif Hanson and covered a number of topics. Sessions on neutron crystallography, low-resolution neutron crystallography, and contrast variation in single crystals of biological molecules were included, plus topics like hydrogen and hydration in protein structural chemistry, D_2O exchange in protein crystals, spallation—a process in which neutrons are ejected from the nucleus of a heavy element target as a result of bombardment with high-energy protons, neutron protein crystallography, and neutron diffraction.

The second conference, "Biomacromolecular Solutions, Phase Separation, and Nucleation," chaired by Principal Investigator Dr. Alex Chernov, dealt with intermolecular interactions and the thermodynamics and kinetics of phase transitions in protein solutions; modeling tetragonal lysozyme crystal growth rates; structure, morphology, and mechanical properties of two-dimensional protein crystals on lipid layers; two- and three-dimensional crystallization of membrane proteins; and the development and application of membrane protein crystallization screens based in detergent phase behavior.

In June 2003, LOCAD hosted a workshop for 40 participants to discuss the benefits and challenges of LOC technology as it pertains to NASA's missions. Participants came from four research centers—JSC, GRC, JPL, and MSFC—and the U.S. Army Aviation and Missile Command—Redstone Arsenal, Huntsville, Alabama. The newly assembled SBRE team hosted 11 workshops and seminars, in which many notable researchers participated.

Patents

Macromolecular Biotechnology Program researchers were granted four patents in FY 2003. In December 2002, Drs. Gloria Borgstahl, Jeffrey Lovelace, and Edward Snell received a patent for a method of measuring the physical characteristics of crystals. In June 2003, a patent for a method for growing protein crystals devised by Dr. Lawrence Delucas, Robyn Rouleau, Barbara Williams, and Helen Powell was assigned to University of Alabama at Birmingham (UAB) Research Foundation, Birmingham, Alabama. Patents also were awarded in July and September 2003 for methods for high-density protein crystal growth devised by Drs. Delucas and Rouleau, as well as Drs. Kenneth Banasiewicz and Barbara Williams; both patents were also assigned to UAB Research Foundation.

Materials Science

While continuing to conduct a vigorous fundamental research program during 2003, the Materials Science discipline launched a new interdisciplinary MSFC Strategic Research program to perform targeted research that is necessary to accomplish NASA's vision for space exploration. Both of these program areas, fundamental and strategic, are aligned to the OBPR Enterprise Strategic Research Plan and are mapped to the Organizing Questions posed by OBPR's Associate Administrator.

- How can we assure the survival of humans traveling far from Earth?
- How does life respond to gravity and space environments?
- What new opportunities can research bring to expand understanding of the laws of nature and enrich lives on Earth?
- What technology must we create to enable the next explorers to go beyond where we have been?

Clearly, materials research must provide the basis for removing the technological barriers that block the advance of new propulsion systems, lighter space structures, and the efficient utilization of space resources.

Materials Science Strategic Research Programs

To address NASA goals of deep-space exploration and extending human presence across the solar system, MSAD materials scientists have made significant progress in reorienting their traditional research program to focus on the science and technology underpinnings required for space exploration. Materials research is fundamental to meeting those challenges of humans traveling and living in the hostile deep space environment. As a result, an interdisciplinary Strategic Research Program was established that encompasses each of the Agency's three initiatives: Radiation Shielding, In-space Fabrication and Repair, and In-space Propulsion Materials. Accomplishments during FY 2003 in each of these areas are summarized below.

Radiation Shielding Program

Deep-space radiation fields consist of high-energy protons and high-energy heavy ions from solar events, including particles from outside the solar system. The heavy-ion component of radiation is the factor of most serious health concern, because radiation damage is mostly affected by ionization—the larger the charge of the ion, the more acute the damage. The interdisciplinary Radiation Shielding Program was launched in FY 2003 to address the challenges of sustained manned habitation of distant planets. Eighteen researchers have been funded to support ground-based radiation shielding research.

In 2003, two workshops were conducted—the Kick-off Radiation Shielding Consortium at the National Space Science and Technology Center (NSSTC) in Huntsville, AL, and the Deep Space Test-bed Engineering Requirements Workshop. Detailed roadmaps for technology development were created as a result of these workshops, and draft language was developed and submitted to NASA Headquarters for support of an NRA release.

The Radiation Shielding Web site—www.radiationshielding.nasa.gov—was also launched. This site includes an online feature that allows researchers to model new radiation shielding materials using various shielding elements.

In-space Propulsion Materials

In 2003 the In-space Propulsion Materials program began to address key technology gaps that impede the progression of new propulsion systems. The program hosted a workshop at the Marshall Institute in Huntsville, Alabama, where world-class engineers and scientists from multiple organizations worked together to begin to bridge the Technology Readiness Level (TRL) gap in the development of innovative materials for propulsion. Research is underway to accelerate the delivery of new in-space propulsion systems in areas such as lightweight materials for solar sails, efficient radiator materials advancements, materials leading to zero boil-off cryogenic tanks, advanced electric propulsion materials, and other efforts.

In-space Fabrication and Repair

The In-space Fabrication and Repair Research program focuses on three primary areas: (1) fabrication, (2) in situ resource utilization, and (3) repair. This research area spans a broad section of NASA requirements to lead NASA's exploration efforts into an era of self-help while in the space environment. During FY 2003, the program hosted a workshop at the Marshall Institute in Huntsville, Alabama, where invited experts and customers shared knowledge to generate a plan that would direct the future path of materials research in advanced space propulsion.

Materials Science Flight Investigations

During FY 2003, materials science investigators on Earth collaborated with the crew onboard the *ISS* to perform multiple experiments using the work area and resources of the MSG. These investigations furthered understanding of physics and chemistry involved in materials processing in a low-gravity environment. Research results of these fundamental science investigations can help define and solve the problems associated with a continued presence in space.

Pore Formation and Mobility Investigation (PFMI)

When molten metals or alloys are solidified for commercial applications, controlling or eliminating gas pockets is crucial to ensuring the materials' strength. MSFC Investigator Richard Grugel designed the PFMI investigation to study how bubbles move and interact with one another while a material is melted and solidified in low gravity. Results of his research could lead to improvements in mathematical models and commercial processing techniques, and are also relevant to NASA's exploration goals requiring in situ fabrication on distant planets.

By the end of 2003, a total of 15 samples had been processed in the PFMI apparatus. The PFMI apparatus has proven to be a versatile and effective means of observing and recording the formation and mobility of bubbles during controlled directional solidification processing in a microgravity environment. The success of the current investigation indicates that the furnace may have extended future use on other materials science investigations in the future.

Coarsening of Solid-Liquid Mixtures 2 (CSLM–2)

The CSLM–2 experiment was delivered to the *ISS* in November 2002, and engineering runs were successfully completed in the work volume of the MSG during FY 2003. Led by Peter Voorhees, Northwestern University, Evanston, Illinois, the CSLM–2 experiment examines the competitive growth of microscopic tin particles within a liquid tin-lead matrix. The phenomenon of coarsening occurs by diffusion at high temperatures when large particles grow at the expense of smaller ones in a matrix. The coarsening process is important because during manufacturing, coarsening can degrade the strength of such commercial products as turbine blades. Turbine alloys containing a few large particles are weaker than those containing many small ones.

With the *ISS* on-orbit engineering tests completed, the CSLM–2 facility is currently awaiting the STS Return to Flight to deliver science samples and the Minus Eighty Laboratory Freezer for the *ISS* (MELFI) Freezer sample storage. The low-gravity *ISS* environment will produce data that can be compared directly to understanding coarsening in high-temperature alloys without interference from convection and sedimentation.

In-space Soldering Investigation (ISSI)

Sent to the *ISS* aboard a *Soyuz* in April 2003, the ISSI is one of several experiments with low-to-zero upmass that was selected for flight after rigorous discipline review. The ISSI experiment is considered to be fast-track strategic research because soldering has direct application to Physical Science Research's In-space Fabrication and Repair initiative.

Investigators for ISSI are Richard Grugel, MSFC, and Fay Hua, Intel Corporation, Santa Clara, California. The experiment investigates soldering practices and behavior in low gravity—an environment especially relevant to in-space fabrication and repair. In particular, this investigation addresses flow phenomena driven by surface tension forces, interfacial phenomena, and the possible incorporation of bubbles. The investigation used hardware already available on the *ISS*: a battery-operated soldering iron, the *ISS* Maintenance Work Area, and a portable workbench. After samples have been processed, they will be returned for material property testing and metallographic examination.

Solidification Using a Baffle in Sealed Ampoules (SUBSA)

During FY 2003, Principal Investigator Aleksander Ostrogorsky and his research team at Rensselaer Polytechnic Institute used computed tomography—the same technology as used for medical computed tomography scans—to conduct ground testing of certain flight samples processed in the MSG in 2002—namely, the SUBSA samples. Early findings indicate successful positioning and movement of the submerged baffle. Ostrogorsky is now evaluating techniques for measuring dopant distribution throughout the sample. Results will reveal how effective the baffle is in controlling convection in low gravity. Information obtained from the SUBSA experiments will add to our understanding of the solidification process in low gravity and determine how effective baffles can be in producing quality semiconductors on orbit.

Materials Science Hardware Development

During 2003, development and fabrication of the MSRR–1 and associated experiment modules has marked significant progress. Currently scheduled for launch to the *ISS* in FY 2007, the MSRR–1 will be the first comprehensive on-orbit facility dedicated to extended research on the structure, processing, and properties of materials. The facility can also play a vital role in supporting NASA's exploration goals by providing a test-bed for developing special materials to be used on future space systems.

In its initial configuration, the MSRR–1 will house independent experiment modules, each designed for different materials processing techniques. The first experiment module, the Materials Science Laboratory (MSL), is being developed by the European Space Agency (ESA). Occupying approximately one-half of the rack, the MSL module will be integrated into the MSRR–1 core facility in the first quarter of 2004.

Patents and Publications

Materials science researchers were granted four patents during 2003, and their work was published in a total of 147 articles in peer-reviewed journals. Two key publications are highlighted here. An article that reported the research of Dr. K.F. Kelton, professor at Washington University, was featured as the cover article of Physics Today. Dr. Kelton and his team used electrostatic levitation techniques and synchrotron x-ray facilities to obtain the first complete proof of a 50-year-old hypothesis explaining how liquid metals resist turning into solids. This same paper was selected in May by the editor of Science as the Highlight of Recent Literature for Physics in the May 2003 issue.

Also, researchers from the Radiation Shielding program published accelerator-based studies suggesting the promising use of polyethylene (PE) and PE-based composites as mission-enabling technology for deep-space exploration.

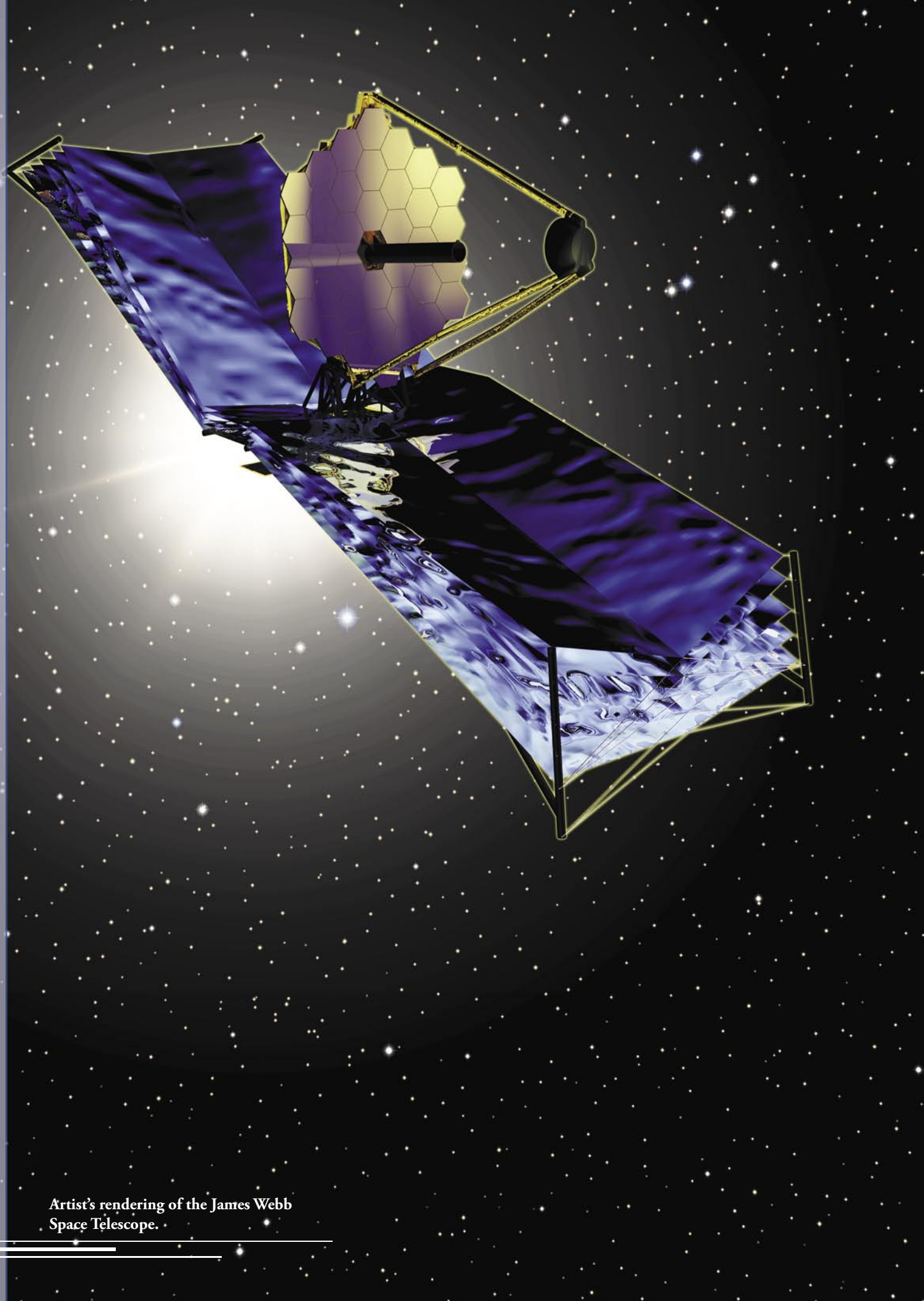
These studies indicate that PE materials can indeed be multifunctional, serving both as structure and as shielding. This research was featured in the Radiation Research Journal.

Microgravity Science Glovebox

The MSG is the first research facility installed on the *ISS* to support the research programs of NASA's PSR Division. This MSAD-managed facility is designed to accommodate small science and technology experiments in a workbench-type environment. The concept allows scientific flight hardware to be constructed in close parallel with bench experiments developed in ground-based laboratories. As such, the facility is ideally suited to provide a quick vehicle for performing the exploratory type of investigations that are necessary to gain an initial understanding on the role of gravity in the basic physics of new research initiatives.

The facility was installed on the *ISS* in June of 2002, concluding a joint development effort between MSAD and the ESA. In 2003, prior to the *Columbia* disaster, two MSFC materials experiments and one fluids experiment from GRC were completed in the MSG work volume. The materials experiments—the PFMI and SUBSA experiments—studied the role of bubbles in casting processes and the role of convection in crystal growth. The fluids experiment, the Investigation of the Structure of Paramagnetic Aggregates from Colloidal Emulsions, was developed to explore the evolution of particle aggregation in a magnetorheological fluid in a pulsed magnetic field. The ability of these fluids to stiffen in a magnetic field is envisioned to have important applications in future development of robotic manipulators.

The ESA also continued their use of the MSG with a series of experiments during the visits to the *ISS* by the Russian *Soyuz*. These experiments were performed by the ESA crew members accompanying the 10-day visit. The MSG team also participated in the definition and integration of several zero-mass experiments, which were developed to make use of equipment and supplies that were already on board the *ISS*. One example is the Miscible Fluids in Microgravity experiment, which uses honey and water to test how miscible fluids—that is, fluids that completely dissolve in each other—interact without the interference of gravity.



Artist's rendering of the James Webb Space Telescope.

Optics is an essential part of NASA's missions. The development of lightweight optics and optical systems is vital to the reduction of launch costs for advanced imaging systems. The Space Optics Manufacturing Technology Center (SOMTC) is continuing the development of new technologies for the production of large-aperture, lightweight optics for space-based systems.

James Webb Space Telescope

MSFC is supporting GSFC in the Astronomical Search for Origins Enterprise in the development of ultralight optics for the James Webb Space Telescope (JWST). The design goal for the JWST mirror is 20 kg/m^2. MSFC managed the Advanced Mirror System Demonstrator (AMSD), a major mirror development program.

Evaluation and analysis on the AMSD was completed this year in the SOMTC X-ray Calibration Facility. The critical testing selected beryllium as the material to be used for the JWST mirror design. MSFC's continuing tasks on JWST are oversight of the optical components—i.e. primary, secondary and tertiary mirrors—and the cryogenic testing of the Flight Primary Mirror Segments.

Constellation X

SOMTC is a significant resource in mirror technology support to GSFC on the next generation x-ray mission called Constellation X. This mission will be a follow-on to the Chandra X-ray Observatory (CXO). It supports the Structure and Evolution of the Universe theme.

During this year, MSFC's contributions were to clean and recoat a 50-cm diameter x-ray mirror mandrel, which was then used to replicate x-ray mirror segments. A six-degree-of-freedom optical test mount was fabricated, tested, and vacuum-certified in preparation for x-ray testing of a prototype x-ray mirror module in the Straylight Facility. MSFC took delivery of two precision mandrels for replicating x-ray mirror segments completing the work on contract NAS8-01005 with Carl Zeiss, Oberkocken, Germany. Metrology on a 1.6-m segment forming mandrel was completed, and metrology continued on the other mandrel delivered on this contract.

Extreme Universe Space Observatory

The Extreme Universe Space Observatory (EUSO) will use fresnel lenses to examine the interaction between the Earth's atmosphere and extremely energetic cosmic rays. SOMTC conducted research efforts in large-area and smaller-scale fresnel lens development. Fresnel lenses consist of concentric annular rings with a specific prescribed shape that allows all rings to act as a single lens with a common focus.

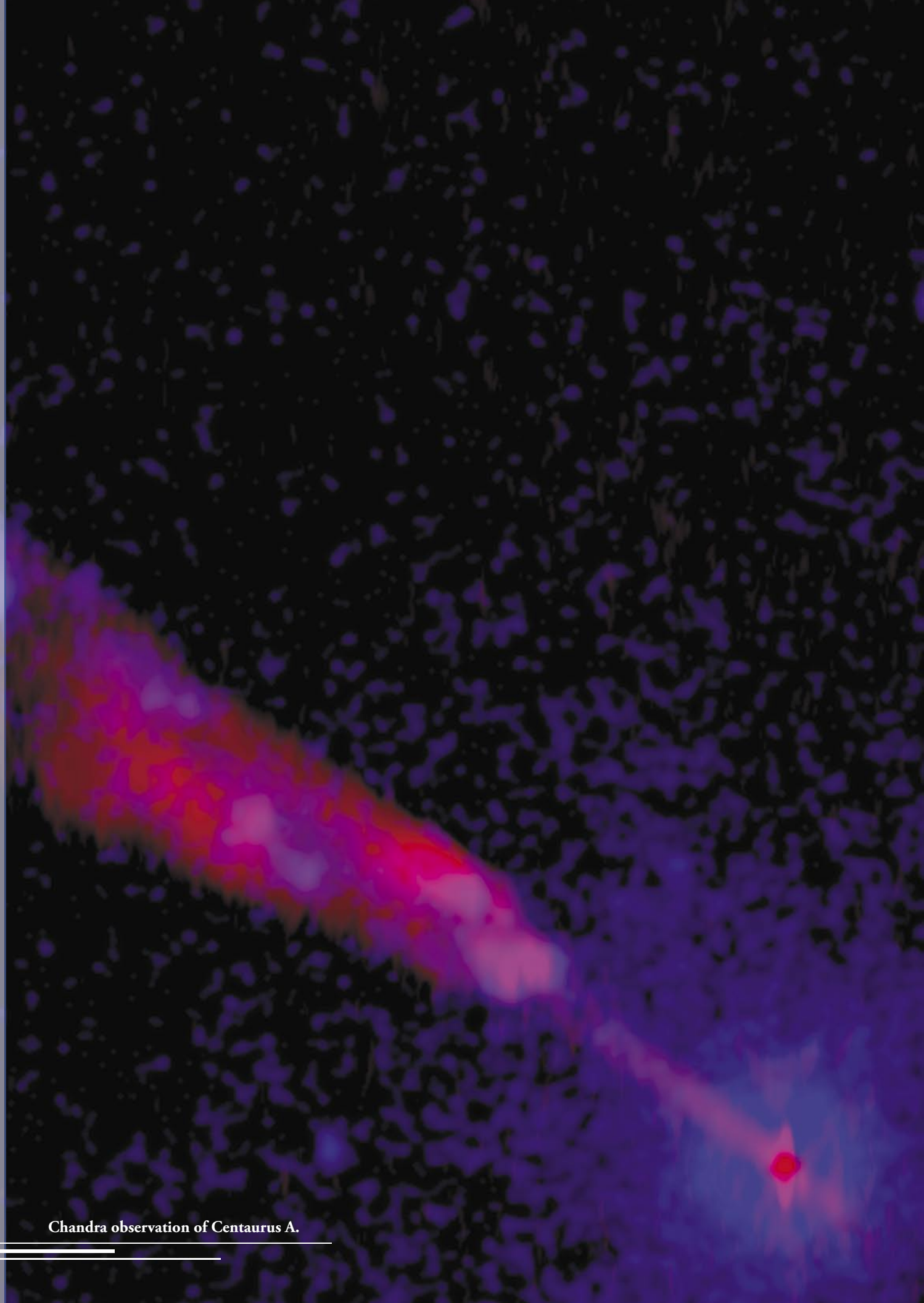
Two large 1-m diameter double-sided fresnel lenses were produced on the SOMTC Moore M40 diamond turning machine. Development of these lenses facilitated the improvement of the surface roughness capability of the Moore machine by an order of magnitude.

Laser Power Beaming

In a series of flights, the team of MSFC and Dryden Flight Research Center (DFRC) scientists demonstrated for the first time ever a system that beams enough light energy from the ground to power the propeller of an aircraft and sustain it in flight. Special photovoltaic cell arrays on the plane received the light energy and converted it to electric current to drive the propeller motor.

The aircraft is a custom-built, radio-controlled model airplane with a special panel of photocells optimized in efficiency for the laser wavelength. This demonstration was a collaborative effort between DFRC, where the aircraft was designed and built, and MSFC, where integration and testing of the laser and photovoltaic cells was done.

Laser power beaming is a promising technology for consideration in new aircraft design and operation. Laser power beaming also supports NASA's goals in the development of revolutionary aerospace technologies. Laser- and solar-powered aircraft have commercial importance in applications of telecommunications and remote sensing.



Chandra observation of Centaurus A.

The Flight Projects Directorate (FPD) within MSFC has the capabilities needed to take a new space flight project from formulation through implementation. The FPD conceptualizes, develops, integrates, and operates flight and ground systems.

The *International Space Station*

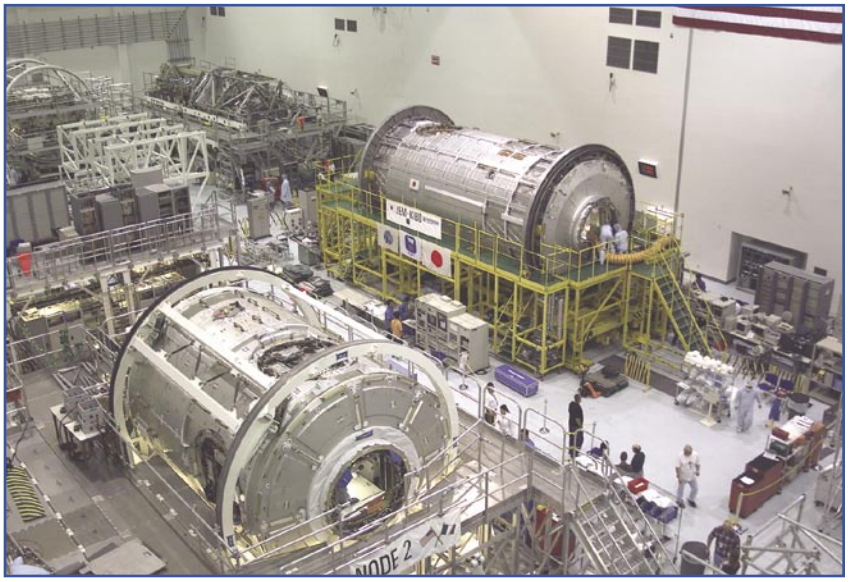
The *ISS* is an international partnership program that is led by the United States and is committed to building and operating a unique world-class orbiting laboratory that is free from the effects of gravity. FPD provides critical competencies to fulfill key *ISS* Program engineering and project management requirements. FPD provides discipline-related skills, project management functions, business office functions, and world-class flight operations. FPD leads the program integration of all payload-related activities and develops crew-training requirements to ensure the onboard payloads are operated to meet the science objectives. FPD manages MSFC *ISS* tasks and provides leadership to ensure other MSFC organizations are supported and included with *ISS* planning. FPD manages MSFC-related *ISS* tasks including MSFC's Testing, Manufacturing, and Support Team, which continues to provide technical expertise to *ISS* design and development teams, as well as supporting various areas of testing including structural, dynamic, environmental, electromagnetic, and acoustics.

Nodes 2/3 Program

During 2003, FPD continued to provide technical management of Nodes 2 and 3, which are being provided by Alenia. The final acceptance and preship reviews for Node 2 were completed on May 28, 2003, at Torino, Italy. Node 2 was delivered to KSC on June 1, with the final acceptance and transfer of ownership completed on June 17.

The Node 2 Integrated Systems Test was completed successfully on August 8, and the Multielement Integration Test between Node 2 and the Japanese Experiment Module was successfully completed on September 10.

The Node 3 primary structure welding was completed in March 2003. Preparation for proof testing of Node 3 was initiated after the completion of the structural welding. Alenia completed all Government-furnished equipment deliveries per the Bilateral Hardware/Software Exchange Agreements/Lists.



Node 2 provides habitable accommodations for sleeping four crew persons on-board the *ISS*.

Multiple-use Payloads

During FY 2003, FPD continued the development of the Biological Research Project (BRP) Habitat Holding Racks (HHRs). Integration and testing of HHR–1 was ongoing, with verification being closed in a proactive manner to facilitate the delivery of the rack. HHR–1 is currently scheduled to be delivered in the second quarter of FY 2004.

FPD provided sustaining engineering support to on-orbit operations of the Expedite the Processing of Experiments to the Space Station (EXPRESS) and derivative racks, and worked closely with the Payload Operations Team to resolve and close Payload Anomaly Reports throughout the year. In addition, FPD delivered one software upgrade and initiated development of another software upgrade to correct minor anomalies and enhance rack operations.

Multipurpose Logistics Module

FPD continued as the Multipurpose Logistics Module (MPLM) Element Manager in FY 2003, with hardware responsibility for all three modules, including sustaining engineering and cargo integration support. FPD completed the MPLM Programmable Thermostat Design and Development, the System Phase III Flight Safety Analysis, and delivered the first set of flight thermostats to KSC for installation. During FY 2003, FPD updated the MPLM Ground Processing Requirements to include water pump package integration and testing in preparation to support an MPLM active flight configuration.

Environmental Control and Life Support

FPD applied its core competency in the area of environmental control and life support (ECLS) to its continued roles supporting the *ISS* and the OSP programs.

In support of the *ISS*, FPD continued its development of the *ISS* Regenerative ECLS Systems. These systems, which include a Water Recovery System and an Oxygen Generation System, will, when deployed, provide a closed-loop supply of water and oxygen to enable the enhancement of *ISS* crew sizes beyond the current three-person capability. In FY 2003, substantial progress was made in transitioning from flight hardware manufacturing and assembly into acceptance testing. Integration and testing of the Water Recovery System's Water Processor Assembly (WPA) proceeded nearly to completion. Assembly of the Urine Processor Assembly (UPA)'s

Habitat Holding Rack No. 1.

MPLM attached to Node 1.

major Orbital Replacement Units (ORUs) also proceeded to near completion. Meanwhile, acceptance testing of the Oxygen Generation System's Oxygen Generator Assembly ORUs was nearly completed, and the assembly of the system's Power Supply Module proceeded. A physical configuration audit of the WPA was conducted as the fiscal year closed.

A significant milestone was achieved in FY 2003 with the successful operation of the Vapor Compression Distillation Flight Experiment on Shuttle mission STS–107. The flight experiment was conducted to validate, as a technology risk mitigation effort, a full-scale version of the UPA's core technology in a microgravity environment. Real-time telemetry data confirmed the operability of the technology.

FPD also provided expertise to the *ISS* Program through successful completion of assigned tasks in the area of sustaining engineering. Among noteworthy accomplishments were support provided to the troubleshooting and recovery planning to fix on-orbit problems encountered with the *ISS* carbon dioxide removal assembly, numerous requests for engineering assessments of trace contaminant control capabilities to support program toxicological assessments of the *ISS* environment, and troubleshooting of leakage issues associated with quick disconnect couplings utilized throughout the Program. Buildup of a high-fidelity engineering test-bed of the U.S. Laboratory Module's internal thermal control loops was also completed, providing the *ISS* Program with a critical tool for malfunction procedure checkout, crew training, and operational assessments.

Ground Systems

FPD conceives, prototypes, and implements cost-effective, innovative, and scalable ground systems for vehicle and payload tests and operations, meeting or exceeding the expectation of our customers. These customers include the *ISS*, the STS, and the CXO.

Huntsville Operations Support Center

Providing the technology infrastructure for payload operations is also part of the FPD charter and is implemented within the Huntsville Operations Support Center (HOSC). The HOSC provides facilities, systems, and services, both local and remote, that currently support the STS, the *ISS*, and the CXO, while maintaining the capability to support additional programs and projects as needed to meet Agency needs.

The HOSC systems and services support all mission phases including testing, simulations, prelaunch, launch, and near real-time flight operations. The ground systems within the HOSC include those needed for the command and control of vehicle systems; the acquisition, processing, distribution, retrieval, and archiving of data; and voice and video communications. Unique payload planning, scheduling, and support systems are also a part of this infrastructure.

Telescience Resource Kit

The Telescience Resource Kit (TReK) is a PC-based telemetry and command system which allows payload teams to monitor and control their experiments on the *ISS* from anywhere in the world. TReK recently added the capability that allows facility class payloads to send commands to the Payload Rack Checkout Unit for ground testing. TreK Release 3, scheduled for June 2004, will provide a command management capability expected to be used by the Fluids and Combustion Facility and other TReK customers.

In addition to providing quality systems and services, FPD has several initiatives underway to improve system capabilities while reducing system costs. Three examples of this are the porting of the HOSC systems from Silicon Graphics servers to more efficient but less expensive Linux servers, changing from using workstations to PCs, and the *ISS* Downlink Enhancement Architecture (IDEA).

ISS Downlink Enhancement Architecture

The IDEA project is a collaborative effort between GSFC, the White Sands Complex, JSC, and MSFC. The IDEA system replaced a domestic satellite service, which transported the *ISS* 50-Mbps Ku-band data stream from the Tracking and Data Relay Satellite System at the White Sands Complex to the Mission Control Center at JSC and Payload Operations Integration Center (POIC) at MSFC. The IDEA service allows for an earlier acquisition of signal with greater real-time data transport reliability than that of the domestic satellite. In addition, the Phase 1 architecture lays the groundwork for the IDEA Phase 2 architecture, which will increase the *ISS* Ku-band downlink from 50 Mbps to 150 Mbps, while reducing long-term operations and maintenance costs, as well as providing a foundation for additional joint development and operational support efforts between MSFC and other Centers.

These and other initiatives will allow the ground systems developed at MSFC to continue to provide quality, low-cost ground systems to existing NASA programs as well as those of the future.

ISS Payload Operations

The FPD and its contractor team provide the critical competencies to manage and integrate the *ISS* payload operations activities for all NASA payloads, and the planning activities for both the NASA and International Partner payloads. They provide critical engineering expertise for payload operations command and control, and are responsible for the safe operation of all NASA payloads on-orbit. FPD is responsible for defining crew-training requirements and for certifying the flight crew is trained on payloads prior to their operation.

The on-orbit payload support to the *ISS* science community recently reached its 1,000th day of successful operations. During this time, FPD provided around-the-clock operations coverage for *ISS* payloads and crew. They worked continuously with the payloads to plan their activities and take full advantage of all resources available to them to benefit the science community.

Certified Controllers

To provide around-the-clock operations to the *ISS* crew and payloads, FPD provides trained and certified controllers in all positions. This certification process requires unique skills and extensive classroom, simulation, and on-the-job training hours with both written and oral exams. The Payload Operations Director (POD) is a key member of the Flight Director's team and is responsible for all decisions relative to integrated payload operations on the *ISS*.

Because of this level of responsibility, the POD must bring an extensive amount of experience to the job to be able to handle the real-time decisions that are required.

Successful *ISS* payload operations during FY 2003 required the dedication of many. It required the implementation of new and innovative ways of doing business to respond to a different carrier and late changes, while still trying to achieve the goal of maximizing science return.

Chandra X-Ray Observatory Program

FPD has overall responsibility for management of the CXO Program, which supports the Structure and Evolution of the Universe theme within the OSS. FPD manages the operation of the MSFC-developed CXO through the Operations Control Center and the Chandra X-ray Center at the Smithsonian Astrophysical Observatory (SAO) in Cambridge, Massachusetts. The overall objective of the CXO is to address some of the most fundamental and pressing questions in present-day astrophysics through observations of matter at the extremes of temperature, density, and energy content. The CXO carries out high spatial and spectral resolution observations of point objects and extended sources at x-ray wavelengths and provides critical insight about the most mysterious objects in the universe—neutron stars, black holes, and quasars. The CXO is the third of NASA's Great Observatories. The scientific objectives of the CXO mission are to determine the nature of celestial objects from normal stars to quasars, understand the nature of physical processes that take place in and between astronomical objects, and understand the history and evolution of the universe.

The Program continued to perform at a high level during the past year, exceeding all of the metrics and performance requirements. Over the previous 12 months, the CXO viewing efficiency has exceeded both the goal and the requirement. The data loss from all causes, including any ground or procedure error, has run well within the requirement. The extension of the CXO mission for another five years—for a total of 10 years—was realized during the past year with the award of a follow-on contract to SAO for continued support of the Program through July 2010. The fourth anniversary of the Program's launch occurred on July 23, 2003, and a major symposium—Four Years of Chandra Observations: A Tribute to Riccardo Giacconi—with international participation was hosted locally by MSFC and the Chandra Program in September 2003. The

Chandra X-ray Observatory.

symposium was in celebration and recognition of four years of highly successful scientific results and, also, in tribute to Riccardo Giacconi, recent recipient of the Nobel Prize in Physics and one of the original authors of the proposal to NASA for the development of the CXO.

Advanced Projects Office

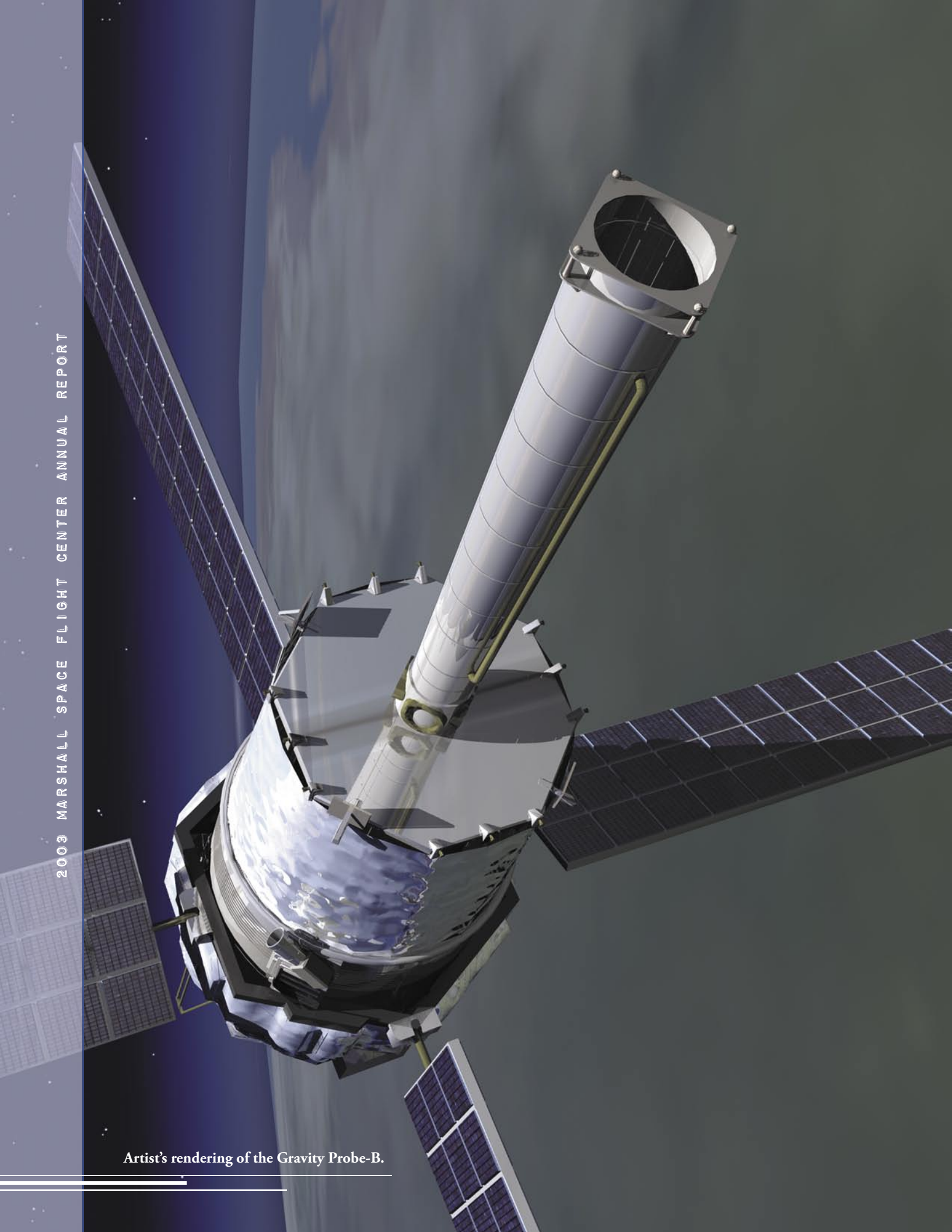
In FY 2003, FPD provided technical and management support to the Advanced Systems Office within the Office of Space Flight. Activities included conceptual design and analysis and workshop facilitation. In the summer of 2003, FPD hosted a Transformational Concepts and Technologies workshop with approximately 50 participants representing industry, academia, and other Government agencies. During the fall of 2003, FPD hosted a Technology Flight Demonstrations and Experiments workshop. Products from these workshops included planning materials for the Advanced Systems, Technology Research, and Analysis activity led by the Advanced Systems Office. Conceptual design and analysis activities included the development of a spreadsheet modeling system, a database of potential technology experiments, a computer animation of a potential lunar exploration system, and the preliminary design of several technology demonstration concepts. Other activities included research for far-term concept development such as nanotube material for space elevators and lasers for asteroid deflection. Outputs from these activities have led to the identification of new technologies and infrastructure capabilities, where investments can be made that could potentially increase human and robotic space flight capabilities while controlling cost and mitigating risk.

Orbital Space Plane

FPD supported the OSP program by providing ECLS expertise to review and critique contractor concepts for the vehicle and to ensure that necessary performance requirements were established and appropriately documented. Also, FPD completed development of the Operations Concept and Operations cost estimates for the OSP Program. In addition, FPD developed system-level operations requirements for input into the Level II System Requirements Document.

Next Generation Launch Technology

FPD was instrumental in the development of the Hypersonic Technology Experiment (HyTEx) reentry test-bed in association with the NGLT Vehicle Systems Research and Technology Project's Technology Flight Demonstration subproject. FPD initiated mission integration and development and integration of technology experiments for the HyTEx Proof of Concept flight, scheduled for July 2005. FPD played a major role in the development of key subproject documentation, including the subproject implementation plan, systems requirements document, and the experiment technical requirements document.



Artist's rendering of the Gravity Probe-B.

National Space Science and Technology Center

The NSSTC, headquartered in Huntsville, Alabama, is a collaborative research partnership between NASA's MSFC and the Alabama research universities, conducting and communicating research and development critical to NASA's mission. Selected areas of research include space science, earth science, information technology, space propulsion, optics and energy technology, materials science, and biotechnology.

Accomplishments during 2003 include:

- Establishing formal alliances with the University of Illinois at Urbana-Champagne, the University of Denver, Lockheed Martin, and the Montana Aerospace Development Authority to maximize the investment of research funds and to seek the most talented team feasible to perform the research.
- Completing laboratory and office outfitting and occupation of the 80,000-square foot NSSTC facility addition.
- Activating the Biotechnology Research Laboratory with a focus in muscle atrophy research.
- Completing a comprehensive benchmarking assessment of five national centers/institutes, incorporating best practices.
- Initiating a formal NSSTC education and outreach program.
- Integrating the Alabama Math, Science, and Technology Education Coalition into the NSSTC Education and Outreach Activities.
- Improving partner, affiliate, and stakeholder communications through the publication of an electronic quarterly newsletter.
- Initiating a new state economic development initiative to examine the feasibility of using surface water resources in Alabama for irrigation to rekindle agriculture in Alabama.
- NSSTC researchers Paul Meyer and David Hathaway receiving the 2003 NASA Commercial Invention of the Year Award for their Video Image Stabilization and Registration (VISAR) System.

Global Hydrology and Climate Center

The Earth Science Department performs scientific research and develops applications for NASA's Earth Science Enterprise. Advanced technology is used to observe and understand the global climate system, and this knowledge is applied toward understanding basic questions about the Earth system and how NASA datasets can be used for societal benefit. The major research themes are climate variability and change, landscape dynamics, and short-term weather forecasting. Areas of emphasis include observations of lightning, multispectral remote sensing of the Earth's surface, analysis of the global hydrologic and energy cycles, and assimilation of remotely sensed data into numerical models of weather and climate. Applications include operational meteorology, ecological forecasting, air quality, and disaster management.

The Earth Science Department is a member of the cooperative research center, the Global Hydrology and Climate Center (GHCC), at the NSSTC. The GHCC is a joint venture between the Earth Science Department, the University of Alabama in Huntsville (UAH), and the Universities Space Research Association. Through this partnership, expertise in the university community complements the NASA capabilities to achieving the mission objectives of the Earth Science Enterprise.

Significant advances have recently been made by GHCC scientists in quantifying changes to oceanic evaporation, precipitation, and other components of the global hydrologic cycle. Using a wide range of satellite-based observations, cloud process models, and climate model integrations, research has helped improve our understanding of how physical processes involving clouds, water vapor, soil moisture, and snow cover act to constrain or amplify climate variability.

The continued acquisition of global lightning data from the Lightning Imaging Senor onboard the Tropical Rainfall Measuring Mission is greatly contributing to an understanding of the relationship between lightning flash rate and severe storm onset, as well as volume of storm precipitation. Advanced lightning measurement techniques continue to be pursued to permit continuous lightning mapping from geostationary orbit. This capability will be a major asset to operational meteorology, allowing significant improvements to severe weather warnings.

A regional forecast improvement laboratory integrating space technology with ground-based data sets and numerical models has been set up as a cooperative venture with universities as well as the operational forecast offices of the National Weather Service (NWS). This effort is accelerating the use of NASA's Earth Observing System (EOS) data to improve regional short-term weather prediction and warning within the NWS and is part of NASA's contribution to the U.S. Weather Research Program. For further information, see http://www.uswrp.org.

Other regional activities include developing a better understanding of regional sources and sinks for tropospheric ozone and its transport, regional air chemistry and air quality, and water management questions. Researchers pursued new formalisms of incorporating urban heat island measurements and other satellite data into predictive meteorological and air quality models, as well as the use of intelligent system capabilities to aid state and local regional planning decision makers in dealing with societal issues. Other areas of expertise include developing improved satellite retrieval techniques to measure and monitor atmospheric aerosol concentration, its transport, and its influence on the radiative properties of clouds.

The GHCC also performed unique archaeological studies using remote sensing for studying impacts of climate variability on pre-Columbian American settlement patterns, contributing to Earth Science Enterprise global land-use classification. The use of this capability has been expanded to support the NASA Memorandum of Understanding with Central America to develop a Regional Visualization and Monitoring System known as SERVIR, a Spanish acronym. SERVIR will combine satellite imagery with environmental and other data in a geographical information system and generate visualization products for decision makers. These products will reach users through a series of information nodes located in each of the participating countries.

Other areas supported by the Earth Science community within the GHCC included the development of improved satellite retrieval techniques to measure and monitor atmospheric state variables, aerosol concentration, their transport and influence on radiative properties of clouds, and validation studies for various EOS instruments. As a research support function, GHCC continued developing its capabilities through component data information systems for lightning and microwave satellite measurements and the efficient accessibility of Earth science data in general by the science community.

Space Science Research

MSFC manages the CXO, Gravity Probe B (GP–B), Solar-B, Solar X-ray Imager (SXI), and the Gamma-ray Large Area Space Telescope (GLAST) Burst Monitor (GBM) for Code S. In addition, MSFC is responsible for the overall design, development, integration, testing, and flight operations of the GP–B flight experiment. The GP–B objective is to test two extraordinary predictions of Einstein's Theory of General Relativity, geodetic precession and frame dragging, both of which describe distortions in the space-time continuum. In order to test these subtle effects, GP–B will fly ultraprecise gyroscopes aboard a drag-free spacecraft containing the world's largest space-qualified dewar.

The MSFC Space Science group conducts fundamental research in six disciplines—cosmic-ray physics, gamma-ray astronomy, x-ray astronomy, solar physics, space plasma physics, and astrobiology.

Solar-B

MSFC also manages the U.S. contribution to the Japanese Solar-B mission. The goal of this international mission is to increase our understanding of the Sun and its impact on Earth. Scheduled for launch in 2005, this mission includes a significant contribution from U.S. investigators and industry. Flight instruments were fabricated in 2003 for testing and delivery in 2004.

Solar X-ray Imager

Another MSFC payload is the SXI, which flies on the National Oceanic and Atmospheric Administration Geostationary Operational Environmental Satellite (GOES)-M satellite. This instrument serves as a solar activity monitor by imaging the x-ray emission from the Sun.

Gravity Probe B

MSFC manages the GP–B science payload and will manage the upcoming science mission. This mission will measure key features of Einstein's General Theory of Relativity by making precise measurements of the space-time continuum in near-Earth orbit. The significant highlights for the program in FY 2003 included successful completion of GP–B Space Vehicle Thermal Vacuum testing, the GP–B Acceptance Review, shipment of GP–B to the launch site at Vandenberg Air Force Base, and successful prelaunch systems testing.

Gamma-ray Large Area Space Telescope Burst Monitor

This project is an international partnership project being conducted with the Max Planck Institute in Germany. The primary objective for GBM is to enhance the science return of the GLAST Large Area Telescope in the study of gamma ray bursts (GRBs). The GBM will detect GRBs over a large solid angle and will measure the spectra of the bursts over a wide energy band and with high temporal resolution. GBM will also determine the direction of the bursts in real time such that repointing of the main instrument can occur. Instrument design, including detectors, power supplies, and the data processing unit, was on schedule in 2003.

Scientific Research

Cosmic-ray Astrophysics

The Phase A study for the NASA portion of the EUSO mission was completed in 2003. After review by a NASA Headquarters team, an award was made to MSFC to provide the optics subsystem for this ESA mission that will measure the energies of the most energetic subatomic cosmic particles. A conceptual design of the Deep Space Testbed and a preliminary set of engineering requirements were developed in 2003. This balloon-borne payload will access the flux of galactic cosmic ray particles during high-altitude flights from Antarctica.

Gamma-ray Astronomy

A Concept Study Team consisting of three coinvestigators from the Space Science Department was selected to design the scientific and technical framework for a mission known as The Black Hole Finder. In related research, the cover article in the November 13, 2003, issue of Nature provides evidence that a gamma-ray burst originated at the location of a new supernova. According to this report, coauthored by one of the group's senior scientists, the observation supports the theory that a gamma-ray burst is produced in a relativistic jet formed during the collapse of a massive star into a supernova.

X-ray Astronomy

The CXO continued its breakthrough observations of pulsars, globular star clusters, hot intergalactic gas, and clusters of galaxies. For the second year in a row, a senior member of the Space Science Department won the prestigious Rossi Prize, awarded by the High Energy Astrophysics Division of the American Astronomical Society. Dr. Martin Weisskopf, Chief Scientist for X-ray Astronomy, and Dr. Harvey Tananbaum of the SAO received the award for their enabling efforts making Chandra such a successful Great Observatory.

A fundamental technology development—High-energy Replicated Optics—made headway in 2003 with the development of lightweight mirrors for focusing high-energy x rays. A balloon flight of this system will occur in 2004.

Space Plasma Physics

Investigation centered around the analyses of data from the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) spacecraft, revealing features of the core plasma trapped in Earth's magnetic field. This plasmasphere shows structure never before imaged. Signatures of the merging of magnetic fields at the magnetopause, the sunward boundary of Earth's magnetic bubble, have resulted in better understanding of a particle acceleration mechanism known as component merging. Dr. James Spann was awarded a major ultraviolet instrument development grant that would extend our knowledge of the auroral zones where energetic particles interact with Earth's upper atmosphere. Experiments in the Dusty Plasma Lab have concentrated this year on measuring the spin-rate of individual cosmic dust grains bathed in radiation. One goal of the investigation is to understand the reflection of light by dust grains, such as those in Saturn's ring system, and the dusty envelopes of young stars.

Solar Physics

Scientists have discovered a circulation deep in the Sun along meridians—north-south lines. Variations in this flow correlate with the amplitude or intensity of the sunspot cycle. Understanding this cycle is one major objective of solar research. Progress was made on the development of a compact solar ultraviolet magnetograph to be tested on a rocket flight in 2005. Such an instrument would measure magnetic instabilities in the Sun's chromosphere, leading to better understanding of flares and coronal mass ejections that often affect spacecraft and occasionally adversely impact power distribution systems on Earth.

Astrobiology

Research at the NSSTC Astrobiology Laboratory includes the study of novel microbial extremophiles. Extremophiles are microorganisms that live in the most extreme environments on Earth. They are important to astrobiology, as they help to establish the limitations and distribution of life on Earth. This knowledge provides clues as to where and how we should seek evidence of life elsewhere in the cosmos. Alkaliphiles and acidiphiles live at the extreme ranges of pH. Some flourish in hypersaline alkaline evaporate minerals of closed volcanic lakes such as Mono Lake in Northern California. Mono Lake represents a good model for conditions that might have existed in closed volcanic basins or impact craters of Mars or other extraterrestrial locations.

Workmen lower the nose cone into place to complete stacking of the left side of the SRB in the Dynamic Test Stand at the east test area of the MSFC.

The Engineering Directorate (ED) provides state-of-the-art engineering services for MSFC's product line directorates, including support to the Agency's Return to Flight and CAIB efforts, scientific investigations that broaden knowledge of Earth and the universe, and advanced technology development across a broad array of technical disciplines. FY 2003 was an outstanding year for ED, with significant accomplishments in providing unparalleled engineering services in support of the Space Shuttle, OSP, Space Transportation, Flight Projects, and Science customers, as well as technology development through both independent and team efforts. Incorporating the Marshall Values into every aspect of the service provided to MSFC's customers as well as collaborating with other NASA centers accomplished these activities.

Engineering Support for Space Shuttle Propulsion Office

In FY 2003, significant engineering contributions to the Space Shuttle Program included all MSFC-managed Shuttle elements and, following the loss of *Columbia*, participation on all five of the investigation working groups, where ED chaired four of the working groups for NASA: the SRB Working Group, the ET Working Group, the RSRM Working Group, and the Space Shuttle Systems Working Group. ED personnel made presentations to the Multielement Board at MSFC, the NASA Accident Investigation Board at JSC, and the CAIB at JSC in support of these Working Groups that focused much of the investigation.

Early in the investigation of *Columbia*, the ET SOFI debris was identified as a potential cause of the accident. ED applied its capability in computer-aided design modeling in conjunction with the Space Transportation Directorate's photographic analysis to identify the areas of ET foam loss, transport path, and orbiter impact region for the CAIB. ED, in partnership with MSFC's robotics experts, JSC's fluid dynamics experts, and an interagency Video Imagery Working Group, led the characterization of the SOFI debris event from *Columbia* for ET. The team was able to effectively reconstruct the debris trajectory, location, and angle of impact. Their results were used for designing the leading-edge Reinforced Carbon-Carbon (RCC) tests at Southwest Research for the CAIB. The leading-edge essential schedule dates were met due to the close working relationship between all the points of contact for the One NASA Fabrication Resource Team, which had members from five NASA field Centers. The process worked flawlessly, including meeting deliverable dates and fabricating pieces for the Shuttle's leading edge using specific materials. The accomplishments of this team should be considered a successful One NASA collaboration. ED also participated in the *Columbia* Image Analysis Team's analysis of the amateur videos taken of *Columbia* as it reentered over the western United States. Innovative analysis techniques were developed to determine the mass of the debris pieces that fell from *Columbia* several minutes before its breakup. These techniques employed hardware and software developed by the MSFC team to calibrate video cameras and extract photometric information on the debris objects from the videos. As part of another CAIB action, ED performed a comprehensive coupled thermal/venting analysis of the *Columbia* wing breach and provided thermal/gas flow characterization for various breach scenarios to the JSC aerothermodynamics team.

As the investigation continued and the Space Shuttle Return to Flight activities were identified, ED committed a major portion of its engineering resources to these activities. ED provided significant support with team members from across the Agency, to the development of debris testing protocols for all the Shuttle elements in support of the Shuttle's Return to Flight. ED provided support for the ET camera that will be used during vehicle ascent on future missions to detect flight vehicle damage, ET camera troubleshooting and augmentation activities, and to the SRB Fuel Isolation Valve Connector Redesign initiatives.

ED performed loads analysis, elastic/plastic fracture analysis, and tests involving static strength, modal, vibration, and pyrotechnic shock characterization of the SRB/ET

Interdisciplinary engineering team analyzes STS–107 foam debris trajectory.

attachment bolts in support of the return-to-flight activity. ED also assisted with many issues unique to the SRB electronic hardware caused by age, flight and recovery environments, and refurbishment activities.

The ET/SRB bolt catcher investigation team, in support of the CAIB committee action to characterize the bolt catcher performance, determined capabilities, and recommended corrective action. All aspects of the bolt catcher performance were evaluated, including bolt velocities, honeycomb dynamic crush strength, and dynamic loads. Extensive analysis and testing was performed in the Shuttle dynamic test tower, resulting in a recommended redesign of both the bolt catcher and the pressure cartridges. ED was instrumental in revising procedures involved in the magnetic particle inspection of critical SRB Forward Separation Bolts. Improved techniques developed at MSFC led to a sound approach for finding critical flaws. ED designed hardware used to test and then requalify the SRB forward separation bolt-catching system.

Other critical return-to-flight activities included the ET Bipod Redesign effort, verification of the leading edge substructural system of the Shuttle wing leading edges, verification of bonding and damage in Shuttle tiles, and support for the materials and processes problem resolution team at KSC for the *Columbia* reconstruction investigation.

Engineering support was supplied to the Shuttle Orbiter to provide the required solutions that were needed to reduce risks that have been identified in its systems. One major activity was the Space Shuttle on-orbit repair development for orbiter wing leading-edge RCC panels and thermal insulating tiles. ED continues to lead the effort to develop one of three critical RCC repair methodologies under consideration.

Extensive technical expertise was provided in reviewing and analyzing data from the Battleship and Gimbal Flowliner test articles in support of the Shuttle Orbiter Flowliner Investigation. ED participated in and provided dynamic modeling and stress analysis of the modal testing of the Gimbal test article at SSC, performed numerous modal tests at MSFC to characterize the dynamic behavior of the flowliners, and continued to support flowliner weld repair techniques.

An investigation was performed by ED of a crack found in the OV–103 Main Propulsion System line Ball Strut Tie Rod Assembly (BSTRA) ball. This led to a multi-Center effort involving three Centers and three contractors. ED helped down-select nondestructive evaluation (NDE)

methods for inspecting these balls and for potentially detecting cracks in situ. The existing inspections were based on a visual borescope method. NDE methods used in the support of the crack formation study at MSFC included eddy current, ultrasound, and penetrant methods. Eddy current, along with the borescope inspection, were down-selected for remote inspection in the OV. ED provided critical profilimeter measurements and a dynamic cryogenic ball tester. Also, ED's capabilities in materials combustion research were expanded to support investigations of materials concerns on the BSTRA. ED expanded materials test facilities capabilities in six areas to meet the required need.

In support of Shuttle upgrades to make the system safer and more reliable, ED provided technical support for upgrades to the SRB, including the Command Receiver Decoder, Altitude Switch Assembly, and IEA. Key support was provided in the STS–112 Pyrotechnic Initiation Failure Investigation of the SRB Hold-down Post. ED worked closely with the SRB Project to resolve issues and provide corrective actions for defective connectors on watertight reusable cables.

Significant support was provided for the SSME Turbomachinery Speed Sensor re-engineering. ED provided manufacturing and machining expertise in consultations with both sensor fabrication contractors and SSME prime contractors to resolve all sensor fabrication issues. Additionally, ED provided key engineering expertise for the SSME AHMS upgrade initiatives, with software/hardware support for the Phase 1 and 2B portions of the upgrade and an MSFC in-house Engineering Unit's development work in Phase 2A to verify hardware concepts and provide a test-bed for Phase 2B software development. Testing of the Phase 2A AHMS Engineering Unit started in FY 2003.

ED created dynamic models and integrated other pre-existing models to obtain a model representing the Shuttle Rollout Test configuration. The integrated models—including the Mobile Launch Platform, Crawler, SRB, Cross Brace, etc.—were used to perform a modal analysis. ED used KSC rollout test data to modify the models such that they are considered test-verified. Now ED is testing the models to determine rollout fatigue on the OV for the Space Shuttle Program.

Lastly, ED supported the successful regulatory review to permit the continued use of HCFC–141b in thermal protection systems for the Space Shuttle Program.

Engineering Support for Orbital Space Plane Program

The Directorate developed and reviewed OSP Level II and Level III system requirements, provided support for the two technology demonstrator vehicles, and provided hardware and software support to the OSP ELV human rating study. ED provided engineering support for OSP programs, with reviews of the contractor-developed architectures and numerous Systems Design Review boards. ED also provided engineering support to the OSP in design, development, and activation of a test position for testing a Pad Abort Demonstrator lox/ethanol engine.

For X–37, the first technology demonstration vehicle, ED provided a mirror of Boeing's avionics team providing support for design reviews, testing, and verification. ED collaborated with DFRC on the ALTV in Failure Modes and Effects Analysis (FMEA)/Critical Items Lists (CIL) evaluation and Flight Termination System implementation. ED completed a buy-off review of X–37 ALTV hardware—including Flight and Vehicle Management Computers—and supported the integration of the vehicle flight control system. On the OV, ED supported navigation system test planning and FMEA/CIL reviews. A study was performed on the OV lithium-ion batteries to assess their capability to meet life-cycle requirements.

The second of the technology demonstration vehicles is the DART, proving automated landing and automated on-orbit docking capabilities. ED developed the primary

rendezvous sensor for the DART mission. Orbital Science Corporation is developing the DART Advanced Video Guidance Sensor (AVGS) using technology pioneered at MSFC. ED's avionics qualification and acceptance test program, part of the Design Certification Review, was restructured to insure adequate testing of what is planned to fly. Software engineering insight was provided for DART. ED personnel provided extensive support for the development/testing of the AVGS, and supported the failure investigation of the AVGS laser diodes. The Dynamic Overhead Target Simulator was refurbished, and a hardware-in-the-loop simulation facility was developed for the DART mission.

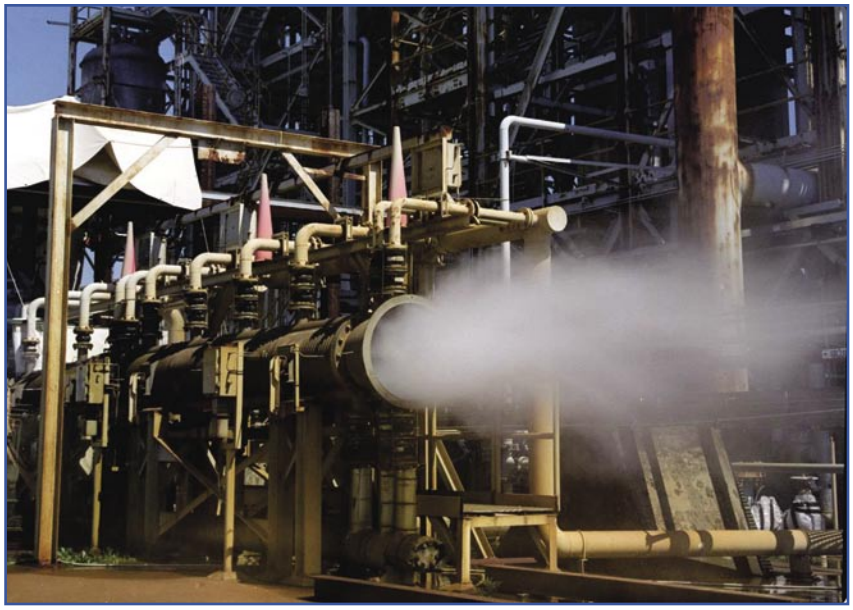
Engineering Support for Space Transportation Directorate

ED developed an engine simulation facility to be installed at MSFC to support the RS–84 Requirement/Concepts Review for the Propulsion High-impact Avionics Technology project. Dynamic, loads, and structural analyses were performed, including working in conjunction with Rocketdyne and the RS–84 project office to develop the fracture control, stress rupture, and low-cycle fatigue loading criteria for the RS–84 engine.

The Robust Integration and Technology Test-bed was developed and integrated, where performance tests were performed on the Coarse/acquisition code, Miniature Integrated GPS/INS Tactical System (C-MIGITS), and vehicle inertial navigation unit from X–40A. Operational support was furnished to the Magnetic Levitation track located at the U.S. Army Redstone Arsenal Test Area 6.

Various trade studies were conducted including preliminary requirements derivation for a propulsion module to return Hubble Space Telescope to Earth, and preliminary requirements reviews to evaluate proposals from selected contractors for the Alternate Access to Station initiative.

A Northrop Grumman (NG)/NASA ED team designed a reusable composite cryotank. The NG tank was fabricated at MSFC by an Alliant-Thiokol/MSFC/NG partnership. After multiple proof tests to demonstrate design margin (1.05×Design Limit), the 6-ft diameter test article made history as the first weight-optimized, composite sandwich wall design, reusable composite tank to safely contain liquid hydrogen at the simulated launch line load—1,400 psi. Also, the cryotank survived the simulated structural and



The Materials Environmental Test Complex provides cost efficient development and qualification of thermal protection systems and other material screenings under combined environments.

thermal loads of a full-scale reusable launch vehicle (RLV) launch. ED also supported NGLT with subscale composite cryogenic tank manufacturing and composite material characterization of a subscale tank that is currently in cryogenic testing. ED led the effort to correlate permeation to structural properties of composite materials for application to cryogenic tankage. Additionally, a Boeing-Langley Research Center (LaRC)-MSFC ED team performed the most extensive design effort ever for cylindrical reusable metallic tanks. NGLT architectures were used to define the requirements for the design effort that proved a reusable metallic tank could fit the weight requirements necessary for two stage-to-orbit.

In-space propulsion systems are nonchemical systems with planetary destinations, and ED supported this through the characterization of candidate solar sail material in an emulated space environment. Also, ED developed global reference atmospheric models for Titan and Neptune. These models are utilized for aerocapture systems analysis studies sponsored by the Advanced Space Transportation Office and the In-space Propulsion Systems Analysis Group, an inter-Center working group represented by the JPL, JSC, Ames Research Center (ARC), LaRC, and MSFC. A joint MSFC/JPL NGLT NRA was funded to produce ultralight composite over-wrapped pressure vessels for in-space applications. A key part of this effort is to reduce the coefficient of variation in the performance of the pressure vessels, resulting in weight savings.

Engineering Support for Flight Projects Directorate

ED was a major player in the *ISS* effort to extend crew capacity from three to six with the additions of Node 2 and Node 3. ED provided significant support to the *ISS* ECLS System project in several key areas. The UPA flight software was completed ahead of schedule and UPA Special Test Equipment was modified and re-certified to support testing of the ECLS System Data Module, Power Module, and Firmware Control Assembly (FCA). The FCA and Data Module final acceptance testing was initiated. All UPA FCA printed wiring boards were built and tested. Fabrication, test, and certification were completed for two ECLS System UPA ORU test sets. ED supported the printed wiring boards fabrication, inspection, and test for the ECLS System Oxygen Generation Assembly Power Supply Module (PSM). Fabrication was completed for all mechanical piece parts for PSM assembly and flight cable harnesses for the ECLS System Oxygen Generation System and Water Recovery System. ED also supported weld qualification activities, general failure analyses, conducted corrosion tests, and conducted site visits to support issue resolution for the ECLS System Project during fabrication.

Significant colocated sustaining engineering and integration expertise was provided for *ISS* Node 2 hardware and software integration testing at Alenia and KSC. Technical assistance was provided in resolving various Node 2 and Node 3 issues. Design, fabrication, and testing of the first flight set of Data Recording Module and Programmable Thermostat Module units for the MPLM was completed, and a patent application was submitted for the Distributed Solid State Programmable Thermostat/Power Controller invention.

Personnel from ED supported the resolution of *ISS* on-orbit audio systems anomalies and Node 2 audio system failures during testing at Alenia. ED led a joint MSFC/JSC/Boeing team in the effort to close the very large number of Node 2 structural, dynamic, and mechanisms verification requirements prior to Node 2 acceptance by NASA. This activity was far behind schedule, with little hope of completing the verification closures prior to shipment of the Node 2 to KSC, but ED took the management lead, formed the joint team of contractors and civil servants, and completed the required portions of the task prior to the shipment of the Node 2 to KSC. ED was also requested to investigate the Foreign Object Debris (FOD) issue that was identified with Node 2 after it was received at the KSC. Working closely with representatives from both JSC and KSC, members of ED verified the FOD findings and are

taking steps to insure that the development of Node 3 has proper FOD mitigation measures to prevent a reoccurrence of FOD contamination.

ED provided attitude control components life testing for the *ISS* prototype Control Moment Gyroscope. Real-time support was provided for *ISS* on-orbit assembly operations utilizing the MSFC Contact Dynamics Simulation Laboratory. ED completed *ISS* Remote Manipulator System math model studies in the Contact-Dynamics Simulation Lab, and delivered integration data for simulation correlation checkout for the *ISS* Common Berthing Mechanism.

Engineering Support for Science Directorate

Extensive ED support was provided to a wide range of scientific projects during FY 2003. One of the key projects was GP–B with many activities leading to near-term launch, including resolution of thermal vacuum test anomalies, redesign of the Gas Management Assembly, requirements verification, and assessment of the Acceptance Data Packages. ED's GP–B teams support to Lockheed Martin and Stanford University was critical to prepare GP–B for launch.

Throughout 2003, ED worked closely with the Space Radiation Shielding Program (SRSP), a new research initiative sponsored by OBPR. ED provided technical support in the establishment of a radiation shielding materials development laboratory that has included layout planning for the two-room laboratory as well as equipment and supply specifications development. The laboratory will be made available to all materials researchers who win funding under this Code U research program. Further ED support of the SRSP occurred in the form of an NRA program for the development of radiation shielding materials for long-duration manned space missions. The four-year Code U grant for this development was awarded in 2002. Several candidate materials have been developed and have been tested at the Brookhaven National Laboratory's NASA Space Radiation Lab. Additionally, an extensive mechanical test program was initiated to generate property databases for these materials. ED engineers serve as both principal and co-investigators in this effort, and a second shielding materials research proposal was submitted under this NRA.

Significant support was provided to the MSRR by finalizing the design of the MSRR Thermal and Environmental Control System with the ground unit hardware being delivered from the vendor and tested in a combined integrated test at MSFC. Design drawings were released for numerous components including cable harnesses, Power Control Rack, Master Controller, and Video Box. Following drawing release, in-house manufacturing was completed for the ground unit cable harnesses, ground unit Master Controller, development unit Video Box, and Prototype Power Control Rack. ED identified the hardware, and then the vendor corrected the design and returned the hardware. Testing of Boeing's Ground Unit Solid State Power Control Module was accomplished. This unit, along with the in-house developed flight software, performed successfully during Combined Component Interface Testing. Environmental testing of the Ground Unit Master Controller was accomplished and ground/flight fiber optic cables were delivered. Fabrication support was initiated to manufacture the flight hardware components. All Review Item Discrepancies against the system completed closure as well as the Requirements, Verification, and Compliance documentation for MSRR. The MSRR secondary structure, UAH experiment cage structure, faceplates, and integrated design were completed, and the secondary structure and UAH experiment cage, for both flight and ground hardware, were fabricated. The secondary structure and cage were fit-checked in the MSRR rack in conjunction with ESA.

Numerous other science payload activities completed during FY 2003 by ED included environmental testing/requirement verification activities for g-LIMIT and Delta-L—both are MSFC in-house developed payloads. These payloads completed their development activities in preparation for launch. Support provided to the MSG

ED employee Alan Patterson shows bolt catcher and composite tank test articles to the Real Property Mission Assessment team.

concerning an on-orbit circuit breaker anomaly resulted in extensive redesign of ESA's Power Distribution Conversion unit. ED supported development of the Quench Module Insert (QMI), including resolution of thermocouple degradation issue, thermal and dynamic characterization testing, modification of the Motor Control Board, and ground unit hardware manufacturing. ED supported the successful extensive testing in the ESA's Microgravity Science Laboratory. The QMI thermal control system was developed thru the Critical Design Review (CDR) and a Delta CDR maturity. Numerous tests were conducted in the Material Development Lab in support of the design development and checkout. Solar-B project verification assistance was provided for all three Solar-B experiments. ED developed a unique and successful particle injection method for the Spaceflight Holography Investigation in a Virtual Apparatus (SHIVA) experiment to inject particles in a fluid meeting the requirements of no disturbance of the fluid. ED provided continuing support to the SHIVA experiment in preparation for Requirements Design Review.

ED has performed significant thermal analyses and testing for the development and predicting the gradient and quench performance of the Sample Ampoule Cartridge Assembly (SACA). The design of the SACA is very challenging. The baseline design is double-walled—two tubes, one within the other—for safety reasons, but still has extremely challenging thermal requirements. Therefore, the gap filler material and thermal performance has been a significant technology development by ED.

Technology Development

ED continued to be actively engaged in technology research and development in line with MSFC core strategies in FY 2003, with emphasis in the Directorate's five Technology Thrust Areas: Advanced Avionics Architectures, Advanced Structures and Materials, Advanced Manufacturing, Advanced Cryotanks, and Space Environmental Effects.

In the area of Advanced Computing, ED, collaborating with JPL, used evolutionary computation techniques to evolve motor controllers on a JPL-developed Field

Programmable Transistor Array. This effort will support a NASA/DOD Evolvable Hardware Conference in June 2004. The results of a Center Director's Discretionary Fund (CDDF)-supported effort concerning the development of engine control software concepts using fuzzy logic and Bayesian belief network technologies is now scheduled to be demonstrated on the SR–30 Rocket Engine Test-bed during 2004. A report of this effort presented at the 22nd Digital Avionics Systems Conference was awarded best session paper. The technology of field programmable gate array (FPGA)-based reconfigurable computing completed its first-year effort in implementing a set of mathematical functions and genetic algorithms in the Star Bridge Computer using the VIVA programming language.

In 2003, both the importance of manufacturing technology and the value of interagency coordination on manufacturing research and development became increasingly more visible for the Nation. With a new focus on collaborative objectives, Federal agencies and industry continued to work together to align their unique research and development strategies, collectively working towards technology developments with broad application to NASA programs and industry. Through ED's National Center for Advanced Manufacturing (NCAM), NASA continued to participate in the Government Agencies Technology Exchange in Manufacturing (GATE-M). Concentrating on manufacturing research and development, GATE-M is maximizing the resources of the Federal Government to promote technological innovation and address challenges facing U.S. manufacturers. An important interagency program review was held in June to provide a forum for the Federal agencies to exchange program-level information about Agency manufacturing activities. The ongoing NCAM consortium of five universities led by the University of New Orleans—with Mississippi State University, Tennessee Technological University, Texas A&M University, and Virginia Polytechnic Institute and State University—produced new research primarily aimed at development of technologies to support advanced space transportation and space exploration. Key improvements were realized for world-class advanced manufacturing capabilities, including a large-scale universal FSW system and a highly sophisticated composite fiber placement machine. In maintaining its emphasis on education, NCAM also continued to support the SpaceTEC organization and its governing body, the National Aerospace Technology Advisory Committee, which initiated a national program in 2003 supporting the hands-on education of our future aerospace technicians.

ED continued advances in the development and uses of FSW. GRCop-84 barrels were successfully friction stir welded for eventual use as combustion chamber liners. A Boeing/Lockheed/MSFC ED team successfully performed two full-scale self-reacting FSW demonstrations that apply directly to Shuttle's ET and future metallic tanks for either ELVs or RLVs. Being able to perform FSW on both sides of the weld joint saves NASA potentially millions of dollars in tooling costs.

The capability to evaluate the permeability of candidate composite materials was also developed, in support of the composite cryotank task, and extensive testing was performed for various composite panels for the program. ED characterized by mechanical testing four aluminum-lithium alloys as candidate materials for reusable metallic cryotanks. Extensive mechanical and fracture testing was completed. ED supported value stream activities for the RS–84 engine and development activities for the engine.

Directorate personnel also supported activities coordinated by the Technology Transfer Department by managing multiple Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) activities, and by participating in the Technology Investment Program. ED also participated in the CDDF program, supporting 29 technology projects through the CDDF program relevant to the product lines and to MSFC core values. ED employees were active in publishing and presenting numerous scientific papers in trade journals and at technical conferences.

Additional Activities

NASA Technical Standards Program

During FY 2003, the NASA Technical Standards Program continued its efforts of developing/revising NASA Engineering Standards and adopting voluntary consensus standards (VCSs) for NASA use as follows:

- Two NASA Engineering Standards were developed/revised for a total of 59 published NASA Engineering Standards.
- 329 VCSs were adopted for a total of 2,241 adopted standards.
- 687 additional VCSs were identified as candidates for adoption as NASA Preferred Technical Standards.

The Program's Agencywide Full-text Technical Standards System provides one-stop, easy access to technical standards required for use by the Agency's programs and projects. Based on the Program's metrics, downloading of VCSs increased 34 percent from the previous year. NASA employees led or participated in the development of 197 Voluntary Consensus Standards from 34 different Standards Developing Organizations' Committees.

The Program's Standards Update Notification System provides update notification on a daily basis of changes to technical standards being utilized by programs and projects. Update notifications were requested for 1,149 documents during FY 2003, and update providers sent 704 update notifications for these documents. Almost 5,400 documents are being tracked for changes for the Agency.

The linking of lessons learned to relevant technical standards continues to enhance and improve engineering practices across the Agency. During FY 2003, over 299 lessons learned were electronically linked to technical standards. The results of this effort afforded NASA programs and projects with greater utility and applications, not only of the standards themselves, but also of potentially key lessons learned from past programs that are now being passed on and utilized in a new generation of flight and ground hardware and software. An innovative electronic tool has been developed to assist in the linking of this critical information. The tool correlates keywords to develop relevancy rankings, resulting in a reduction of time taken to determine that a relationship exists between the technical standard and the lessons learned. In addition, 137 Application Notes were

Marshall's Environmental Test Facility (ETF) provides world-class space simulation vacuum test capabilities to verify space flight article design, manufacturing processes, and workmanship through functional testing at extreme conditions. The ETF is the only facility in the country capable of automated rendezvous and capture inside a simulated space environment.

identified to document individual experiences gained from the Agency's application of specific technical standards.

A sampling survey on how technical standards are being used within NASA was conducted. The July–September 2003 results were that almost 29 percent were used for in-house research and development activities, approximately 23 percent were used to develop requirements for program and project development, and more than 18 percent were used for verification of a contractor's design and development processes on programs and projects. More information on the Program can be found at the NASA Technical Standards Program Web site at http://standards.nasa.gov.

NASA's Space Environments and Effects Program

During FY 2003, the Space Environments and Effects (SEE) Program continued its efforts to manage approximately 20 different technology development activities and bring to completion five others. Personnel from NASA, other Government agencies, industry, academia, and Canada are performing the efforts. These efforts represent seven space environment technical disciplines: spacecraft charging, ionizing radiation, meteoroids, spacecraft coatings, contamination, ionosphere, and thermosphere.

A major development during this time was the conversion of the online Satellite Contamination and Materials Outgassing Knowledgebase to a stand-alone product. Due to a major change in information technology (IT) security, this product was taken offline, which affected close to 125 users. This product is now being distributed via CD and is performing extremely well.

During FY 2003, the SEE Program experienced a considerable increase in visibility, participation, coordination, and management of space environment technology development activities for the JIMO. SEE is also the representative to JIMO for MSFC Government studies in support of the JIMO Mission Assurance Project.

The SEE Program also launched a new project called Surveying and Examination of Eroded Returned Surfaces (SEERS). The Project was formed in response to two Office of Space Science missions, Genesis and Stardust, which will return space-exposed hardware to Earth. This opportunity is unique in that hardware has never been returned from the Lagrange Point L1 (Genesis) or a comet (Stardust). The objective of SEERS is to perform measurements and analyses of hardware that is not considered part of the primary science mission. Studying actual space-exposed hardware will help design better spacecraft and reduce uncertainties in design margins. The results of the SEERS activities will be inserted into future SEE Program NRAs to help develop better space environment design guidelines and models.

MAPTIS-II

NASA recognized the advantage in providing an easily accessible focal point centralizing access to knowledge of aerospace materials, processes, and manufacturing. In response to this need, ED, in conjunction with the Computer Sciences Corporation, developed MAPTIS-II. The initial Internet version was released on October 1, 2003. MAPTIS-II technology provides ready access to accurate data using standard computers, software, and the Internet. Aligning with the Agency's One NASA initiative and the President's E-Business directive, MAPTIS-II allows engineers, analysts, designers, researchers, and other authorized users continuous remote access to a variety of standards and databases of relevant information from a single interface. The Extensible Markup Language (XML) allows the system to capitalize on the latest Internet and browser technology to exchange information.

Engineering Directorate Initiatives

The Engineering Directorate is in the process of implementing three initiatives to help achieve the Directorate's vision of engineering excellence enabling our customers' mission success. The initiatives focused on three aspects of ED performance—knowledge, processes, and tools.

- **Knowledge:** *Build a learning organization to enable a highly qualified and motivated workforce with proper skills.*

The ED vision for strengthening engineering excellence and innovation resonates with the CAIB Report recommendations and Al Diaz team's emphasis on communications and learning. Knowledge sharing and skills development are nurtured through formal and informal processes, including proactive on-the-job mentoring, unique assignments, new forums, fresh seminars, special classes, and other innovative approaches. In partnership with the NASA Engineering Training Program and its learning content management system, SOLAR, the initiative's team began transforming the Comprehensive Systems Skills curriculum into easily accessible e-learning modules in FY 2003. Nine new e-learning modules covering four discipline areas have been developed and made available through the SOLAR Web site.

- **Processes:** *Enhance the integration of engineering processes across the engineering disciplines.*

The Integrated Engineering Solutions (IES) team analyzed specific issues associated with core processes identified as significantly impacting the Directorate's ability to better serve the needs of both external customers and the internal engineering workforce. Working closely with process owners and customers, the IES team formulated constructive options for improving specific process flows and solving specific problems and issues. Small changes producing the largest returns in improved quality of products and services, on schedule, and within budget, were targeted for accelerated implementation. The IES team engaged improvements in design, manufacturing, parts procurement, and configuration management. Negotiation of system-level recommendations for improvements and production of an innovative integrated solutions manual is anticipated.

- **Tools:** *Integrate and fully utilize tools and equipment.*

The Integrated Engineering Capability (IEC) project made significant progress in establishing an advanced environment that will fully integrate engineering processes throughout the lifecycle of a product. The project worked closely with other Centers in the Code M collaboration in an effort to discover commonality and differences between each Center's processes and application customizations. The project continued to develop the use cases for the document management capability initiated in FY 2002 that formed the basis for modeling the process and associated workflow. Leveraging off of JSC's initial tool customization and the MSFC use cases, the IEC team implemented a document management capability that was established with a successful Operational Readiness Review at the end of FY 2003. The IEC project will build off of this foundation going forward to create additional functionality including change, parts, and computer-aided design management.

The *ISS* orbits the Earth.

NASA Automated Data Processing Consolidation Center

During FY 2003, the NASA Automated Data Processing (ADP) Consolidation Center (NACC) tested all of the logical partitions at one time, at the remote Disaster Recovery site at SunGard Facility. A full chargeback process using account codes for accumulating utilization was implemented for all Centers except MSFC. NACC provided support to a comprehensive data call with Pricewaterhouse Coopers, in response to the FY 2003 Federal Information System Controls Audit Manual (FISCAM) audit, for six NASA systems. Approximately 1,000 pages of information were organized in tabular format in response to the request. In addition, all prior year findings received final disposition and resolution. Approximately 1,800 pages of follow-on answers to questions were provided to the auditors. For the eighth consecutive year, NACC service goals were raised in more than one service area from 99.8 percent to 99.9 percent.

Sustaining Engineering Support for Agencywide Administrative Systems

Sustaining Engineering Support for Agencywide Administrative Systems (SESAAS) continued to provide sustaining engineering support to the Agencywide administrative systems. Regulatory/statutory and policy changes were implemented expeditiously into the various applications, including the NASA Personnel/Payroll System, Consolidated Agency Personnel/Payroll System, Acquisition Management System, NASA Equipment Management System, NASA Property Disposal Management System, NASA Supply Management System, NASA Online Supply Catalog, and the NASA AdminSTAR training system.

Agencywide Applications Support

In addition to the software applications included in the SESAAS, Agencywide Applications Support includes maintenance and operation of the Site for Online Learning and Resources, NASA Acquisition Internet Services, and NASA Online Registration System systems.

NASA Integrated Services Network

In FY 2003, the NASA Integrated Services Network (NISN) provided wide-area network video, voice, and data services to Agency customers at or above the established standards of excellence. In addition to managing services such as video teleconferencing (ViTS), administrative and mission voice, facsimile, inter-Center mission and administrative data, and Internet access, significant effort was expended to meet new and changing requirements for growing programs, such as the EOS, *ISS*, the Deep Space Network, Integrated Financial Management Program (IFMP), and Space-Based Telemetry And Range Safety.

In FY 2003, NISN immediately responded to the tragic loss of the Space Shuttle *Columbia* by deploying personnel and equipment to establish a communications infrastructure for the debris recovery team. NISN also provided connectivity for the CAIB and worked with the Shuttle program to establish return-to-flight requirements.

In September 2003, with Hurricane Isabel threatening the eastern U.S., NISN worked with National Oceanic and Atmospheric Administration (NOAA) to quickly absorb Internet queries from the general public requesting hurricane status.

In FY 2003, NISN refreshed the aging low-bandwidth ViTS systems, established an executive videoconferencing system, began developing an infrastructure to support collaborative tools in conjunction with voice and video teleconferencing, and initiated a plan to reduce voice teleconferencing cancellation fees across the Agency. NISN also supported on-orbit *ISS* crewmembers in establishing voice/video conferences with family members.

NISN initiated transition planning efforts to migrate from the Consolidated Space Operations Contract, which was not extended. These efforts include putting in place an integration contract—the Unified NASA Information

Technology Services contract—and migrating transmission to General Services Administration contracts.

Digital Television

Phase 1 of the planned transition of NASA's television distribution infrastructure to standard-definition digital was completed with installation of video distribution and encoding equipment at every Center. The equipment allows Centers to send and receive broadcast-quality video over the Internet. The *Columbia* disaster and subsequent plans to improve imagery of the Shuttle during ascent and landing dominated activities during FY 2003. Testing of candidate imaging systems and recording systems was conducted at MSFC and Cape Canaveral Air Force Station. Detailed plans and recommendations were provided to the Shuttle Program to upgrade the imagery and distribution of imagery of Shuttle ascent. Imaging systems for on-orbit inspection of the Shuttle were also evaluated and data provided to the Shuttle Program.

Financial Management and Accountability

Support for Agency Contract Administration and Audit Services

MSFC had responsibility for NASA's financial management support for Agency Contract Administration and Audit Services (CAAS) during FY 2003. Included was responsibility for managing the cost and billing information and Agency-level accounting for CAAS services provided to NASA by external audit organizations such as the Defense Contract Audit Agency and the Defense Contract Management Agency. MSFC also had responsibility for NASA financial management support for Agency Reimbursable Collections of Contract Administration and Corporate G&A Charges from NASA reimbursable customers. These collections are utilized to offset MSFC administrative salaries and NASA Federal Telephone Services costs.

Integrated Financial Management Program

The goal of NASA's IFMP is to improve financial management throughout the Agency. The mission of the IFMP is to improve the financial, physical, and human resources management processes throughout the Agency. IFMP is reengineering NASA's business infrastructure in the context of industry best practices and implementing enabling technology to provide necessary management information to support the Agency's Strategic Plan implementation. Successful implementation of the program will allow NASA to:

- Provide timely, consistent, and reliable information for management decisions.
- Improve accountability and enable full-cost management.
- Achieve efficiencies and operate effectively.
- Exchange information with customers and stakeholders.
- Attract and retain a world-class workforce.

Budget Formulation

In FY 2003, the Chief Financial Office (CFO) established a project team to implement IFMP's Budget Formulation Module. The mission of the Budget Formulation Module is to design and implement a single integrated Agencywide budget formulation process/system. Identified as a One NASA tool, the Budget Formulation Module has the capacity for bottom-up formulation of institutional, program, enterprise, and Agency-level budget formulation requirements while allowing for top-down decision-making to support the budget process. The Budget Formulation system will support six stages of the budget cycle including the Preprogram Operating Plan, Center Program Operating Plan, Enterprise Review, Agency Program Operating Plan, Office of Management and Budget (OMB) Release, and Congressional Budget. The Budget Formulation module is a Strategic Enterprise Management system that facilitates full-cost activities, automates manual processes, establishes standard reporting policies and procedures, consolidates budget data,

and shares budget data across the Agency. Training for superusers in the business community at MSFC was begun in September 2003 and the project's full implementation will continue through FY 2004.

Administrative Systems Implementation Project

MSFC has been asked to manage the implementation of the remaining IFMP projects that will utilize the SAP software suite. The IFMP Administrative Systems Implementation Projects Office will provide the management and technical leadership for the Agencywide implementation of standard systems and processes necessary to support the Agency's administrative activities. The scope of this office will include Human Resources, Procurement Management, and Integrated Asset Management. The first project to be formulated will be the Integrated Asset Management Project. The scope of the project will be finalized in FY 2004.

Integration Project

MSFC also manages the long-term IFMP Integration Project. This project manages all functional, application, and technical integration within the scope of the IFMP. The IFMP Integration Project is responsible for ensuring that the individual IFMP software modules work together and collectively satisfy the defined Agency IFMP business drivers. The Integration Project is responsible for maintaining the Agency business and software applications architecture and designing and implementing the IT architecture that supports the deployment and operation of the IFMP modules.

Logistics Business Systems Operations and Maintenance

Leadership was provided in implementing and sustaining Agency logistics business systems that provide the necessary automated tools to professionals supporting the NASA workforce. These logistics business systems provided responsive and cost-effective logistics business systems to all NASA strategic enterprises and logistic business process customers.

Other Support Activities

Earned Value Management (EVM)

During FY 2003, MSFC continued efforts to establish an effective, comprehensive, value-added EVM Program for NASA. MSFC supports the Agency in the planning and developing of EVM initiatives to be proposed for implementation through the NASA EVM Focal Point Council, chaired by the NASA Deputy Chief Engineer. Improvements in Agency performance management capabilities support the President's Management Agenda and OMB Circular A–11, which emphasizes needed improvements in budget and performance integration relationships. MSFC initiated actions to strengthen NASA policies and procedures that give NASA projects guidance for the implementation of EVM policy throughout the Agency. These actions are efforts that promote more consistent approaches to implementing EVM within NASA and to enhance capabilities for improved project management and control. MSFC supported initiatives to promulgate EVM throughout the Agency. MSFC developed a proposed Agency EVM training curriculum that will provide consistent training for project management and support personnel throughout NASA. MSFC has developed and implemented an EVM database that is capable of providing data analysis tools to projects across the Agency. MSFC is supporting the Agency effort to develop a simplified approach for implementation of EVM on NASA in-house projects. These efforts will provide support for the initiative of budget and performance reporting for NASA, which will assist projects in better project management and cost control. In addition, MSFC continued to provide the Agency EVM external interface for other Government organizations, industry, industrial community organizations, and the Project Management Institute. These external efforts have established communication and a multiorganizational relationship with a common goal of promoting consistent implementation, application, and utilization of EVM on Government contracts.

NASA Secure Network

Center Operations provided leadership and technical expertise by developing and implementing a dedicated NASA Secure Network (NSN). The NSN is a Web-based classified network encryption system with MSFC serving as the system host for the Agency. Beyond providing NASA with secure e-mail, file sharing, and classified processing of data/voice/video, the NSN is designed to provide secure Internet access to 2,300 intelligence community and DOD Web sites.

Agency Environmental Functional Review Support

The MSFC Environmental Engineering Department supported NASA Headquarters Code JE in their annual Environmental Functional Review at the White Sands Test Facility. Code JE conducts environmental audits at each Center on a three-year cycle utilizing other Center environmental personnel. This cross-utilization of personnel enhances technical knowledge while facilitating the One NASA concept.

The Space Shuttle *Atlantis* leaves a glowing arc as it disappears into the evening sky.

Marshall Space Flight Center Technology Transfer

MSFC's Technology Transfer Department utilizes focused program areas designed to innovate, incubate, and accelerate technological advances—from conception, through development, demonstration, and commercial realization. It is a strategically focused program aimed at complementing the missions and objectives of the Agency, while ensuring that NASA's scientific and technological advances help to sustain the competitiveness of U.S. industry. This multifaceted program fully aligns with the NASA Strategic Plan by leveraging technologies and resources from academia and industry, by fostering market-driven technology suppliers for NASA's future missions, and by utilizing a life-cycle approach to technology development and commercialization. The program supports National priorities by partnering with other agencies while remaining focused on NASA's major initiatives. In addition, the program contributes to the Nation's technology innovation and readiness by promoting awareness of NASA's market relevant technologies, by protecting and licensing our intellectual properties, and by contributing to the U.S. economic security and quality of life. The following paragraphs provide an overview highlighting the Department's accomplishments in FY 2003.

Center Employee Receives Federal Laboratory Consortium Honor

Fred Schramm of MSFC received the Award for Excellence in Technology Transfer for his work in compressed symbology for direct parts marking. Compressed symbology is a term that describes the marking of a permanent matrix symbol, resembling a checkerboard bar code, on the surface of a part. Mr. Schramm's work has resulted in a NASA Standard 6002 and Handbook 6003 revision A in 2003. The contents of these documents have been adopted in large part by the DOD and the automotive industry during the formulation of MIL STD 130L and the B–17 Guideline, respectively, for direct part marking.

Center Inventors Recognized at New Technology Reporting Ceremony

Innovators from around the Center were recognized on April 29 at an awards ceremony and luncheon hosted by the MSFC Technology Transfer Department in the Center Activities Building. This was the first of what is hoped will be an annual event to recognize the contributions of our Center's innovators.

MSFC-developed Forceps Design Highlighted at the NASA Medical Technology Summit

Based on a new technology report on obstetrical forceps received by MSFC in 1994 and further developed through a license agreement with the Pregnancy Institute in 1998, the forceps were highlighted at the NASA Medical Technology Summit. The forceps use composite material and instrumented fiber optics derived from materials and technology first used in NASA's Space Transportation Program. This new forceps will offer a viable alternative to vacuum extraction and currently available steel forceps and would present less trauma to the baby and the mother during the birthing process.

MSFC-developed Alloy Used on Evinrude Outboard Engines

An aluminum alloy developed by MSFC was introduced on a new Evinrude outboard engine in 2003 through a licensing agreement with Bombardier Motor Corporation. The alloy was used to produce pistons for the engine because of its ability to withstand higher temperatures than previous alloys. NASA originally began work on the high-strength, high-temperature, wear-resistant aluminum alloy seven years ago when a major automobile manufacturer approached the Agency about developing a new, stronger, low-cost alternative to materials currently used in automotive applications.

Web-based Satellite Tracking Tools Receive Extensive External Recognition

The Web-based Satellite Tracking Tools are a set of Java components that are integrated with Web pages, back-end processes, a database, and scripts to provide a suite of satellite tracking services. This highly efficient system has been recognized in numerous national publications including PC Magazine, Sky and Telescope Magazine, Interactive Design Magazine, the New York Times, and Discover Magazine. It was also featured on CNN's Science and Technology Week program.

Four MSFC Software Projects Receive the NASA Space Act Awards

Four software projects developed at MSFC were awarded the NASA Space Act Award in 2003. They were WinPlot (the MSFC Software of the Year winner), Web-based Satellite Tracking Tools, Video Guidance Sensor Software, and Measurement and Controls Data Acquisition System. Each of these software projects represent a step forward in software development and have been used extensively in NASA, as well as being released to industry for commercial applications. A typical comment related to these innovative software projects was received from Boeing Rocketdyne concerning the WinPlot software. They noted that, "the jobs that used to take eight hours to perform are now done at the engineer's desktop in a matter of minutes."

New Technology Reporting: Capturing and Sharing Leading-Edge Technologies

One of NASA's primary goals is to share leading-edge technology with the U.S. industrial community. The New Technology Reporting process provides an avenue for inventors to disclose their inventions, discoveries, and innovations. In FY 2003, 185 new technologies were reported and assessed for commercial potential, with over $75,000 in incentive awards distributed to civil service and contractor inventors.

Technology Commercialization and Licensing: the Catalyst Uniting Technologies With Commercial Applications

MSFC's Technology Transfer Department works to facilitate the patenting and licensing of MSFC-owned technologies and innovations ensuring that their maximum commercial potential is realized. During FY 2003, MSFC filed 23 patent applications, resulting in the issuance of 12 patents, and entered into five new licensing agreements. Royalty income for the fiscal year was close to $170,000, bringing the cumulative total in royalties earned by the Center to well over $445,000. Through this licensing process, technologies developed by the Center are used by industry to impact the commercial market and advance the economy of those companies and the Nation as a whole. In FY 2003, Bombardier Motor Company Corporation received an exclusive license for use of High-strength Aluminum Silicon Alloy; HyPerComp Engineering received two licenses for use of Lightweight Composite Tank Technologies; A+Flow Tek received an exclusive license for use of the Balance Flow Meter with No Moving Parts; and Robotic Vision Systems received a nonexclusive license for use of the 2D Matrix Magneto-Optic Read-Thru Paint Scanner.

Software Commercialization and Licensing: Software Releases Maximize Benefits to the Nation

NASA-developed software is commercialized and licensed through Software Usage Agreements. These agreements ensure the software's release in a way that provides maximum benefit to the National economy. FY 2003 again saw MSFC set a new record in the award of 362 software usage agreements, bringing the cumulative number of such agreements to 1,171.

Small Business Programs: Leveraging America's Entrepreneurial Resources

The goal of NASA small business programs—the SBIR and STTR programs—is to strengthen the role of small businesses in meeting Federal technology needs.

In FY 2003, 34 SBIR Phase I and II contracts were awarded relative to MSFC activities with a total value of almost $24 million. There were also five STTR contracts awarded, valued at $0.5 million. In addition, 24 SBIR Phase III contracts were active in FY 2003 with a value of $16 million. Phase I awards are presented to determine the scientific and technical merit and feasibility of an innovation; Phase II awards are for the continuation of development of those innovations shown to be feasible in Phase I; and, finally, Phase III covers those activities capitalized by non-SBIR sources of funding for the pursuit of private sector or Government sales.

Technology Development and Deployment Partnerships: Ingenuity at Work

MSFC's Technology Transfer Department is discovering novel solutions for filling the technology needs of NASA, while supplying NASA ingenuity in ways that help America grow, through partnership opportunities with industry, small business, academia, and other Government entities. The department also works to facilitate partnerships through which educational and commercial partners may use MSFC facilities for a fee. There were 115 agreements active in FY 2003, of which 24 were new agreements.

Center Director's Discretionary Fund: Promoting Innovation in the Workforce

The CDDF provides funding opportunities for well-defined research or technology development projects in scientific or technical areas. The projects are required to be innovative and support new ideas or concepts relevant to current or planned NASA programs, and must be aligned with MSFC's roles and missions and clearly contribute to the core competencies of the technical workforce.

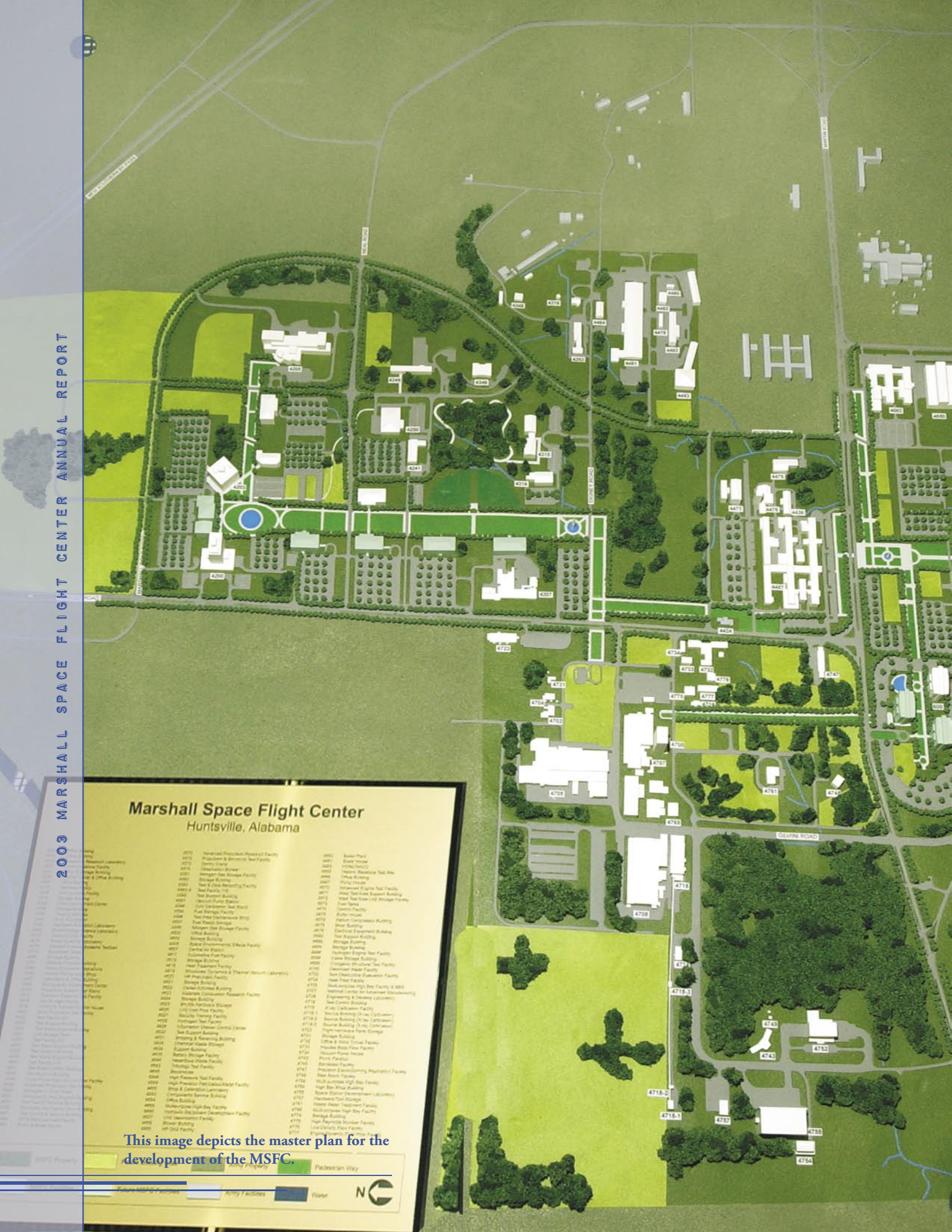
The projects are largely performed in-house, involving outside groups or contractors only to the extent necessary. An important CDDF objective is to cultivate MSFC talent through hands-on experience. During FY 2003, 32 new projects were initiated and 19 former projects were continued with a combined expenditure of almost $2.3 million.

Technology Investment Program: Providing Seed Money to Advance Commercialization Efforts

The MSFC Technology Investment Program (TIP) is funded and managed by MSFC's Technology Transfer Department to underwrite high-risk technologies that support established NASA goals and objectives while also exhibiting high commercial potential. These technologies typically require an infusion of resources to increase their potential for commercialization. The program works in conjunction with the Center's patenting and technology commercialization efforts, and maximizes the opportunities for commercial success of MSFC-developed innovations.

Projects selected for funding must be limited to in-house work, must have been formally disclosed, must demonstrate a high probability of commercial success, must be aligned with the roles and mission of the Center, and must be of one-year duration or less. In FY 2003, $656,000 was provided to MSFC product line organizations in support of 12 new projects.

A companion program to the TIP is the Commercial Investment Program, which is designed to provide Technology Transfer funds in support of local, regional, and state-level collaborations that have strategic value to NASA's mission and economic development of our region. Two hundred twenty-five thousand dollars in such funds were awarded to two projects during FY 2003.



This image depicts the master plan for the development of the MSFC.

The Center Operations Directorate provides essential support services in numerous functional areas, which enables our customers to achieve Mission success. Our contribution ensures that MSFC's work in research, development, and technology yields the greatest value to NASA, and ultimately, the American people. Specific service categories include:

- Integrated Financial Management Project Office
- Environmental Engineering
- Facilities Engineering
- Chief Information Officer
- Logistics Services
- Protective Services
- Integrated Customer Support
- Center Industrial Labor Relations
- Medical Services

In addition, Center Operations serves in an advisory capacity to the Center Director and works in partnership with our customers to understand and fulfill their needs. During the last year, Center Operations was dedicated to providing essential support services such as security and IT support for the *Columbia* recovery and Directoratewide resources to support the Agency's Return to Flight efforts.

Special Events

MSFC sponsored approximately 249 special events during FY 2003. Annual events supported included the Moon-buggy competition, Retiree Dinner, Centerwide picnic, Earth Day, and Safety Day.

Property Accountability

Major improvements in property management processes were realized in FY 2003. Lost property rates continued to decrease due to reengineered and improved processes. Joint inventories were conducted which allowed partnering with Center contractors.

Disposal Operations

During FY 2003, the Disposal Operations conducted 36 sales. These sales consisted of 6,516 line items with total sales proceeds of $224,486. Types of sales included an auction, a drop-by spot bid sale, and GSA Internet sales.

The Disposal Operation in FY 2003 transitioned their sales process and are now conducting all sales through the GSA Internet Sales Program, which has broadened their sales audience, increased sales, and improved timeliness of disposal dramatically.

The disposal team transferred 139 line items valued at $579,430 to other Federal and State agencies, and donated 495 line items valued at $2,543,736 to schools in the southern region surrounding MSFC.

Critical Hardware Moves

During FY 2003 the MSFC Center Operations Directorate supported numerous moves of program critical hardware (PCH). Components were moved onsite for the *ISS* Regenerative ECLS System WPA, PSM, and the Oxygen Generator Assembly. Technical support was provided in the preparation of Return-to-Flight hardware testing at MSFC and transport to other test facilities. Center Operations provided PCH support in preparing the setup of the Toxicity Chamber to perform thermo test to UPA. Center Operations provided unique receipt and delivery support to the SRB program for the qualification testing performed at MSFC of Forward and Aft Bolt Housings. The GP–B satellite was successfully transported from Sunnyvale, California, to Vandenberg Air Force Base in June. Additionally, transportation and logistics engineering support was provided to the OSP, DART, and X–37 programs.

Environmental Assessments

During FY 2003 the MSFC Environmental Engineering Department continued to ensure the necessary requirements

of the National Environmental Policy Act were implemented on programs such as OSP, X–37, and construction of Building 4600.

Environmental Excellence Team

The Environmental Excellence Team (EXT) hosted the 2003 Earth Day ceremony and events, which included a logo contest and environmental suggestion awards. Mr. Pat Byington, publisher and editor of Bama Environmental News—a Web-based environmental news source—was the featured speaker.

The EXT continues to sponsor events that will enhance environmental awareness throughout the MSFC and surrounding communities in areas such as pollution prevention, sustainability, energy and water conservation, and environmental compliance.

Chemical Inventory

The Environmental Engineering Department (EED) continued its effort to establish a chemical management system (CMS) based upon just-in-time (JIT) chemical delivery. The CMS will reduce onsite chemical storage and improve the accuracy of the chemical inventory. EED met with personnel throughout the Center to determine their chemical needs and try to tailor the CMS to meet those needs. Twenty software tracking systems were analyzed before EED finally selected one that best suited its needs. With the recent turnover of the logistics contract and the implementation of the new MSFC Retail Store, the CMS should be implemented by December 2003.

Compliance Auditing

During FY 2003, EED developed of an internal auditing plan based on NASA Headquarters Environmental Functional Review and MSFC Environmental policies. During development of the auditing program, EED physically toured and inspected approximately 150 structures on the MSFC and evaluated activities associated with sampling laboratories, underground and above-ground storage tanks, National Pollutant Discharge Elimination System outfalls, satellite accumulation areas, air emissions sources, and the Waste Water Treatment Facility. Operations and activities at these buildings were examined for compliance with major environmental regulations, including the Clean Air Act, the Clean Water Act, and the Resource Conservation and Recovery Act.

Superfund Cleanup

Under the Superfund Program at MSFC, advanced remediation techniques used for groundwater cleanup have lead to increased understanding of contaminant transport. The technique and results of one candidate groundwater remediation technology test were published in the Spring 2003 issue of Remediation Journal.

EED continued to promote technology transfer by hosting the 2003 Alabama Tier II Partnership Workshop. Tier II team includes the Alabama Department of Environmental Management, Environmental Protection Agency Region 4, Anniston Army Depot, Fort McClellan, Fort Rucker, MSFC, Maxwell Air Force Base/Gunter Annex, Redstone Arsenal, Air Force Center for Environmental Excellence, Army Corps of Engineers, and the Army Southern Regional Environmental Office. The workshop highlighted technology successes and innovative management approaches for investigation and cleanup activities.

Onsite Medical Services

To support a safe and healthy work environment, MSFC civil service personnel and onsite contractors were provided access, as dictated by the parameters of their jobs, to physical examinations, special screenings, immunizations, first aid, and emergency assistance. During FY 2003, approximately 12,700 patients received services at the MSFC Medical Center. The Medical Services team also administered over 2,500 preventive flu shots.

NASA's PRL nears completion in FY 2003. The PRL will provide state-of-the-art laboratory space for propulsion research.

FY 2003 Environmental Health Services Building Inspections

To support a healthier and safer workplace Environmental Health Services performed 253 walk-through inspections; 1,250 industrial hygiene surveys, which aided in identifying potential hazardous environments; 867 health physics activities; 6,528 respiratory protection-related activities; and trained 4,159 MSFC personnel on various topics such as hearing conservation, confined space entries, bloodborne pathogens, hazard communication, ergonomics, respiratory protection, radiation, and laser safety. During FY 2003, approximately 350 ergonomic evaluations were performed and 900 asbestos activities conducted.

Propulsion Research Laboratory

The Propulsion Research Laboratory (PRL) nears completion and will open in the second quarter of FY 2004. Center Operations provided the concept, project execution, infrastructure, information technology, moves, furniture, environmental support, security, and other resources to make this unique research facility a reality for NASA.

Replacement Building 4600

Replacement Building 4600 is a new office building to replace miscellaneous office/laboratory buildings at MSFC that are currently scheduled or being considered for demolition. The project design started in May 2002 and construction is well underway. The construction will be phased-funded over two fiscal years— FY 2003 and FY 2004—and is scheduled to be complete by the end of 2004.

New Facilities Master Plan

MSFC's new facilities master plan has been submitted for approval. The plan provides a detailed framework for many aspects of facilities planning for the next 20 years. The master plan takes into account the significant mission shifts that have occurred at MSFC over the past few years. The focus of the plan will be land-use zoning, potential facility locations, campus development, transportation, and facility standards.

Shipping and Receiving Facility

A new Shipping and Receiving Facility is being built to replace similar facilities that are currently housed in obsolete space.

Information Assurance Officer

The Information Assurance Officer (IAO) position has been approved through NASA Headquarters and now has been filled at MSFC. The IAO has the responsibility in auditing and providing policy to the IT Security Project at MSFC. In conjunction with the CIO Office, the IAO has provided significant achievements in assuring compliance with Federal and NASA policies and regulations.

Information Technology Security

Continued progress was made by the MSFC IT Program, supporting elements, and MSFC organizations during FY 2003 in all areas of the Center's IT Security posture, including program and policy development, training, risk management, engineering, and operations.

During FY 2003, MSFC reduced the number of key security vulnerabilities and weaknesses in the Center's computer systems, and reduced the number of MSFC computer system security compromises, in the face of significant increases in security intrusions experienced across U.S. corporations, industry, and academic institutions.

MSFC Protective Services Department Response to *Columbia* Accident

Within five hours of the *Columbia* Space Shuttle accident, members of the MSFC Protective Services Department arrived in East Texas with the Agency's designated representative, David King. The team immediately surveyed the major debris fields and joined with other Federal, state, and local authorities to establish the Incident Command Center in Lufkin, Texas. During the first days following the accident, the team helped forge an infrastructure that would remain intact throughout the recovery effort. Team members were directly involved in virtually every facet to further initial objectives: locate, secure, and assume custody of the STS–107 crew; locate, secure, and assume custody of sensitive and hazardous debris; and develop protocols to collect and inventory nonsensitive and nonhazardous debris.

Individual activities in which team members participated included: search for and recovery of the STS–107 crew; on-site representation for NASA's Chief Medical Officer; multiple searches and raids for stolen Shuttle debris; arrests of persons suspected of Shuttle debris theft; and escort of crew remains to facilities at Barksdale Air Force Base, LA.

MSFC Chief Information Officer Response to *Columbia* Accident

Members of the MSFC Office of the Chief Information Officer (CIO) also supported the recovery effort. The team assessed communications needs to support the NASA Incident response team. Within 48 hours of arrival on site, the CIO team had established reliable voice and data networks for both classified and unclassified communications. Prior to arrival of the Federal Emergency Management Agency, NASA provided assistance to all assembled Federal, state, and local agencies in the Incident Command Center in Lufkin, Texas. The CIO staff at MSFC established a 24-hour Operations Center to support the deployed team procuring equipment, coordinating communications circuits, and reacting to requirements from the deployed team. The CIO Office at MSFC also supported the investigative efforts by impounding data and video associated with the STS–107 Launch. The CIO Office maintained a presence in the Lufkin Command Center until recovery operations in East Texas were terminated.

Liftoff of STS–105.

Education Programs Department

Education plays a leading role in NASA's Mission to inspire the next generation of explorers. During FY 2003, MSFC provided meaningful, educational, and content-rich programs that inspire and motivate students at all levels to pursue careers in science, technology, engineering, and mathematics. MSFC partners with academia, professional associations, industry, and other agencies to provide teachers and faculty with experiences that capitalize on the excitement of NASA's missions to spark student interest and involvement. MSFC supported NASA's Educator Astronaut Program—a workforce pipeline strategic initiative—in formulating program objectives, identifying external partnerships, recruitment of superior educator nominees, and with the design and hosting of the associated EdSpace Web site at http://edspace.nasa.gov. NASA Explorer Schools, another NASA workforce pipeline strategic initiative, was created to establish partnerships between NASA, teachers, administrators, and state curriculum supervisors to address local challenges in science, technology, and mathematics education. MSFC established NASA Explorer Schools in Alabama, Arkansas, Iowa, Louisiana, and Tennessee during FY 2003.

Overall during FY 2003, more than 103,000 diverse students, teachers, and faculty representing all 50 states were reached through the operation of MSFC's education programs. The NASA/MSFC Educator Resource Center, which is located at the U.S. Space & Rocket Center, conducted 130 teacher workshop sessions for 1,288 educators and provided 10,909 educators with additional services. An MSFC-produced 30-minute instructional program, entitled "Festival of Flight: Inspiring the Next Generation of Explorers," for the NASA CONNECT series, drew an estimated audience of over 9 million and was nominated for a regional Emmy award. The audience reached by MSFC-managed Web sites totaled nearly 4 million. MSFC higher education research-based programs served a total 537 faculty and students.

As measures of customer satisfaction, over 93 percent of participants in major MSFC education programs agreed with the statement that they expect to apply what they learned in the programs in which they participated. Over 98 percent agreed that their participation in our programs was a valuable experience. Nearly 94 percent considered the program they participated in inspiring.

Media Relations Department

In FY 2003, the MSFC Media Relations Department worked closely with Public Affairs Officers from NASA Headquarters and other space flight Centers to provide timely, accurate information to the news media regarding the *Columbia* accident and Return to Flight activities.

In 2003, the department wrote 30 news releases on minority subjects from Code M and all four space flight Centers for distribution by NASA Headquarters. The department also distributed 231 news releases; conducted 193 live television interviews, 57 radio interviews, and a total of 496 media interviews; hosted 330 media visitors to MSFC. Additionally Media Relations' virtual newsroom Web site, which targets users within the media, received 30 million hits. In total, through the efforts of the Media Relations Department, MSFC received news coverage in 48 states, with print stories in 480 cities and radio and television stories in 169 cities.

The department also conducted 102 exhibit events in 29 states, attended by more than 7 million visitors. Media Relations was also responsible for conducting nationwide exhibit programs for NASA's Office of Space Flight and OBPR. The Starship 2040 traveling trailer exhibit made appearances in 27 cities in 12 states. In conjunction with 81 museums nationwide, the department showed exhibits, models, and artifacts to a combined attendance of over 14 million people. The group also supported NASA's Centennial of Flight activities in New York City, New York; Fayetteville, North Carolina; Cleveland, Ohio; Mobile, Alabama; and other venues. In FY 2003, Media Relations launched a new exhibit entitled Space Laboratories: Science in Orbit.

Government and Community Relations Department

The Government and Community Relations Department achieved its primary objectives in FY 2003. The objectives centered on the following areas: Developing strategic outreach activities to educate key stakeholders on benefits of MSFC contributions to NASA, and facilitating opportunities to engage government officials and the public in sharing the experience of exploration and discovery. Both of these objectives contributed to the Government and Community Relations Department's goal—to promote the understanding of NASA's missions and the role MSFC plays in ensuring the overall success of the agency.

The Government and Community Relations Department has implemented numerous outreach activities during FY 2003. Elected officials at all levels have been provided regular updates on NASA and MSFC programs. Also, this department coordinated Center visits by members of Congress and their staffs to attend groundbreakings, receive briefings, and participate in major announcements. Further, Congressional outreach activities were coordinated in Texas, New York, Alaska, Washington, Montana, and Ohio in conjunction with Center exhibits.

The MSFC's Speakers Bureau is part of the Government and Community Relations Department. During FY 2003, the Speakers Bureau booked 163 speaking engagements for 59 MSFC employees. Approximately 20,000 citizens were reached through the MSFC Speakers Bureau. Topics were presented from all of MSFC's main mission areas.

The Government and Community Relations Department processed 202 Freedom of Information Act requests for FY 2003. Of the 202 requests, 43 were related to the *Columbia* accident. A new process of putting all responses on a centralized NASA Web site was initiated at this time for *Columbia*-related requests only. The median response time for non-*Columbia* requests was 19 days, one day less than the 20-day required response time. Also, MSFC responded to over 4,300 public inquiry requests in 2003. Most inquiries were answered within five days of request.

The Government and Community Relations Department partnered with other Center organizations in leading the Center's Combined Federal Campaign Committee in raising $595,670 for the 2003 initiative.

Also, this department successfully partnered with the Huntsville/Madison County Chamber of Commerce and other community groups for the celebration of the *Skylab* 30th anniversary as part of our von Braun forum. Additionally, the Government and Community Relations Department coordinated the Director's Breakfast for community leaders and elected officials and the Center Director's luncheon with onsite contractors.

The department worked with the community and the Department of the Army to identify collaborative efforts at MSFC/Redstone Arsenal that make both NASA and the Army more efficient organizations.

This Department was responsible for the Annual Retiree's briefing. Over 300 MSFC Retirees were briefed by the Center Director and other Project Managers on current programs at MSFC.

Human Resources Department

During FY 2003, MSFC hired 73 new employees, including 33 full-time permanent employees, 18 term and temporary employees, and 22 cooperative education students. Twenty-two (30.14 percent) of the 73 employees hired during FY 2003 were female and 22 (30.14 percent) were minorities. In addition, during FY 2003 the U.S. Office of Personnel Management announced the results of its first Federal Human Capital Survey (FHCS)—the survey was conducted between May and August 2002. The FHCS is a tool that measures employees' perceptions of whether,

and to what extent, conditions that characterize successful organizations are present in their agencies. The survey was administered to employees of 24 major agencies represented on the President's Management Council. A total of 189 separate organizational subcomponents of the 24 agencies participated in the survey. Of the 24 Federal agencies surveyed, NASA employees reported the highest satisfaction in Government, and of the 189 subcomponents surveyed MSFC received the highest rating. Areas receiving the high ratings included compensation and benefits, strategic alignment, learning and knowledge sharing, job satisfaction, leadership, performance culture, strategic competencies, and personal experiences.

Protocol Office

The MSFC Protocol Office's mission is to promote and maintain NASA's and MSFC's world-class image by providing protocol expertise through professional courtesies and effectively communicating NASA's and the Center's capabilities to our customers and stakeholders.

Through the programs managed by the Protocol Office, they have accomplished their mission for FY 2003 by reaching people in at least 39 states and numerous foreign countries. Among these people were the Governor of Alabama, three Congressional members, 15 Congressional staffers, and many other distinguished visitors including the NASA Administrator.

Some of the events and visits the Protocol Office managed were three Space Shuttle Launch Guest programs at KSC, a Ribbon-cutting Ceremony, two Groundbreaking Ceremonies, four Retirement Ceremonies, four crew visits, and the *Columbia* Investigation Team visit. Others in which they played a key role were the STS–107 Memorial Service, Chandra Symposium, Apollo 17 30th Anniversary Celebration, IFMP Awards Ceremony, Community Leaders Breakfast, and the Contractor's Breakfast.

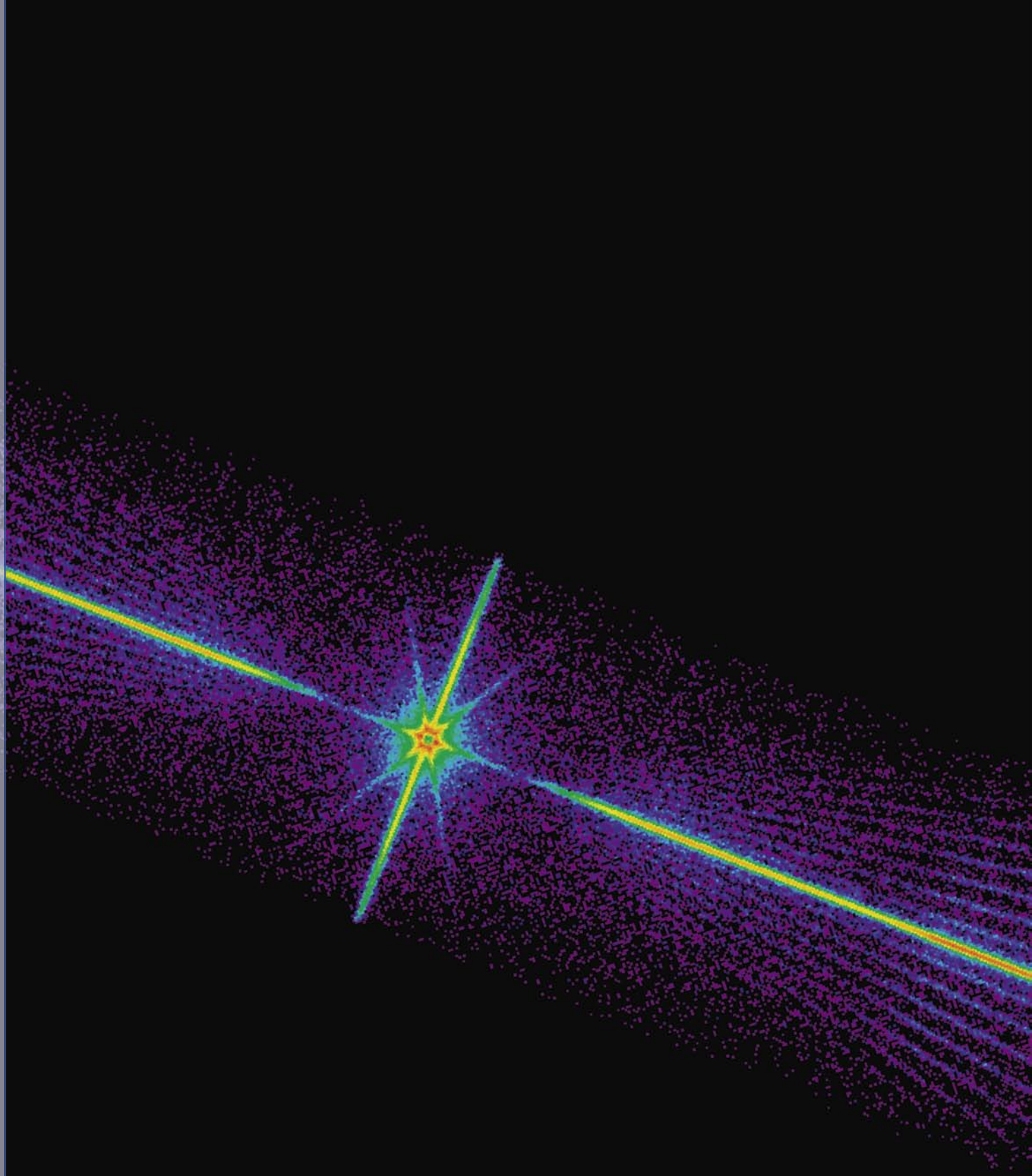
Employee and Organization Development Department

In FY 2003, the Employee and Organization Development Department (EODD) made great strides in the effort toward having a disciplined approach for Center organization performance consulting by strategically addressing the training and development needs of all employees.

An Individual Development Plan (IDP) tool and accompanying training was developed to be made available to all managers for the successful rollout of the IDP process for the Center.

A team of EODD employees was trained in Situational Leadership, which is the training that serves as a support structure for the IDP implementation. The IDP training coupled with Situational Leadership training is designed to equip managers with the tools, knowledge, and skills necessary to work effectively and efficiently with employees regarding individual developmental goals.

Several sessions of the Leadership Development series designed to train leaders at all levels were offered to approximately 20 employees per session.



This Chandra X-ray Observatory image is a spectrum of a black hole, which is similar to the colorful spectrum of sunlight produced by a prism.

Equal Opportunity

In an effort to recruit and maintain a diverse workforce at MSFC, the Center added a total of 33 full-time permanent employees to the Center in FY 2003. Of that total, six were white females, four were Black, and two Asian. The Center remains underrepresented in some ethnic groups. It is noteworthy that an Asian male at MSFC was appointed to the Senior Executive Service during FY 2003.

In FY 2003, the Equal Opportunity Office and Facilities Engineering Office conducted an extensive survey of MSFC's buildings to determine accessibility issues. Many areas were identified and will be pursued in upcoming years.

MSFC continued its support of Historically Black Colleges and Universities (HBCU) and Minority Institutions in FY 2003. Despite considerable funding restraints, the Center actively sought funding to sustain the HBCU/Minority Programs. These programs have allowed students to become immersed in the Center's research efforts and encouraged students to pursue careers in science, mathematics, and engineering.

The Center encouraged participation by faculty and students of Minority Institutions in educational programs to increase the number of students benefiting from scholastic programs. Also, MSFC has increased the pool of underrepresented minorities in the science and engineering fields by the enhancement of scholastic high-school student programs, the strengthening of the disability student programs, and enrichment of the Preservice Institute program. In addition, the Center has strengthened involvement in educational and research initiatives of HBCU/Minority Institutions by an increased presence on HBCU campuses.

The Equal Opportunity Office coordinated the annual Take our Children to Work Day, with approximately 800 children participating. Workshops, such as Space Shuttle Facts, Safety Safari, Living in the *ISS*, Rockets, and Spinoffs from Space Technology, were enjoyed by the children. The participants toured various worksites at the Center. In conjunction with the annual event, MSFC's Space Transportation Directorate sponsored an Expo with demonstrations of various propulsion technologies. The Equal Opportunity Office conducted a customer satisfaction survey of the Take our Children to Work participants. Of those responding, 99 percent were positive, agreeing that the event met specified requirements.

The Equal Opportunity Director and Assistant Director met with the head of each Directorate to provide and review organizational diversity profiles. This proved to be a very good tool to discuss diversity issues and also to serve as an indicator of customer satisfaction.

Office of Chief Counsel

FY 2003 was an active year for the MSFC Office of Chief Counsel. In direct support of the Center's missions, the Office was heavily involved in providing legal support for procurement activities, including serving as counsel to source evaluation boards and successfully defending four General Accounting Office bid protests. The Office of Chief Counsel also played a key role in reviewing requests for release of Space Shuttle-related documents to the news media and the public in the months following the *Columbia* accident.

The Office of Chief Counsel supported the Agency's technology transfer efforts by filing 23 new patent applications in FY 2003. During that year, 12 patents were awarded based on previous years' filings. One of those patents went to David Hathaway and Paul Meyer for an invention entitled VISAR. This technology improves the clarity of video footage by correcting distortion caused by adverse conditions. VISAR was used during the *Columbia* accident investigation, and has also been used by the Federal Bureau of Investigation and other law enforcement agencies in high-profile criminal investigations. VISAR enables law enforcement, consumers, and others to dramatically enhance videotape sequences on desktop computers. This invention was recognized as the NASA Commercial Invention of the Year.

To ensure that MSFC employees are fully aware of their obligations under Government ethics standards, the Office of Chief Counsel provided classroom ethics training to 1,014 MSFC employees. Additionally, 863 employee financial disclosure reports were reviewed.

In support of the wider Agency legal team, the MSFC Office of Chief Counsel—with support from MSFC's Employee and Organizational Development Department—hosted the 2003 NASA Legal Conference in April 2003, and also hosted the Agency Ethics Team in September 2003.

Office of Procurement

Procurement's Goal

The Procurement Office's goal is to provide highly effective and efficient acquisition and business support at the highest professional level to meet or exceed customer and stakeholder expectations. The Office of Procurement seeks to improve the effectiveness and efficiency of Center acquisitions through increased use of techniques and management tools that enhance contractor innovations and performance.

Small Business Programs: Leveraging America's Entrepreneurial Resources

The Office of Procurement supports the Small Business program objective of developing small business participation to optimize utilization of America's full entrepreneurial resources. The MSFC Small Business staff supported this objective by providing industry counseling in approximately 600 onsite business visits and 3,600 telephone information contacts. The Office also worked closely with large and small businesses in the identification of partnering opportunities for upcoming MSFC competitions. As a result of these outreach efforts, many local small businesses were able to establish ongoing relationships with prime contractors that, in time, will enhance their competitiveness in the Government marketplace. The performance against the small business implementation goals were 20.2 percent against a 16 percent small business goal, 8.1 percent against a 6 percent Small Disadvantaged Business goal, and 6.2 percent against a 3 percent Woman-owned Small Business goal.

MSFC continues its emphasis on socioeconomic initiative, with continued focus on the HBCU initiative to increase participation to one percent of contracting dollars. Small business also continued to focus on specific outreach efforts, aimed at providing assistance to small machining and fabrication companies. An outsourcing team supports these activities by providing assistance to small businesses in understanding the ISO process, MSFC's marketplace, and how small business firms can have their capabilities displayed on MSFC's Audited Vendor List. In FY 2003, more than 40 businesses were visited.

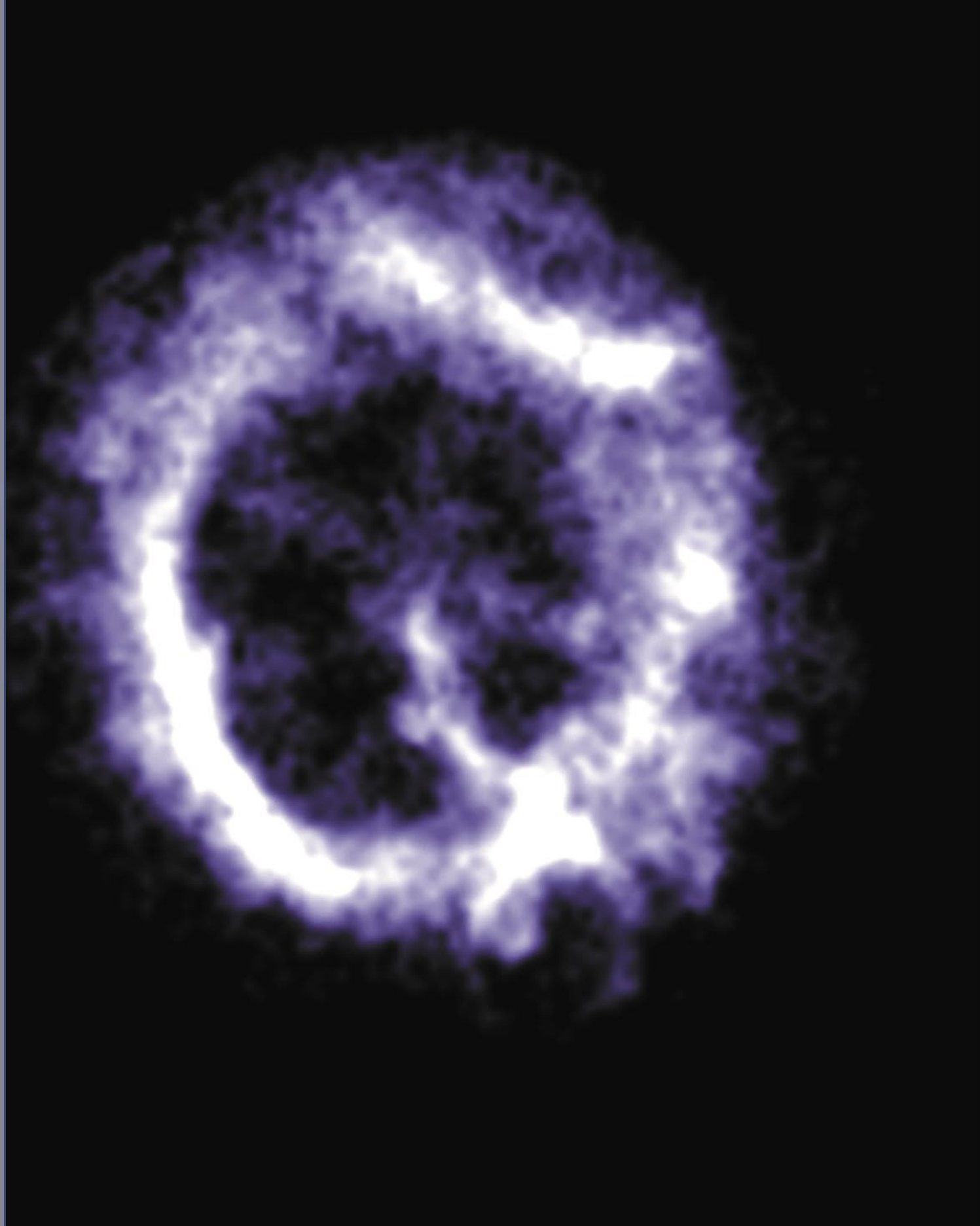
MSFC achieved 92.4 percent for performance-based contracts in FY 2003. Through the utilization of performance-based contracts, the contractor is informed as to what is required versus how to achieve the required product. Use of this type of contracting, which is NASA's preferred method of contracting, clearly defines the requirement, provides a performance standard, provides a method of surveillance, weighs each element of the task, and provides for a reward/penalty system for the quality of work provided.

Significant Contract Awards

In FY 2003, MSFC awarded several significant contracts. They are as follows:

- Awarded a contract to BAE Systems Analytical Solutions, Inc. for a requirement entitled Research and Education Efforts for MSFC Science Activities. The contract is a 5-year effort valued at $9.7 million.
- Awarded a contract to Optical Sciences for Specialized Data Analysis in Enhanced Diagnostic Systems. The contract is a 5-year effort valued at $4.5 million.

- Awarded a contract to AJT & Associates for Occupational Medicine & Environmental Health Services. The contract is a 5-year effort valued at $11 million.
- Awarded a contract to EG&G Technical Services for Center Operation Support Services. The contract is a 5-year effort valued at $60 million.
- Awarded a GSA delivery order to EG&G Logistics Services for Logistics Services. The delivery order is an 8-year effort valued at $60 million.
- Awarded a contract to SAO for Advanced X-ray Astro physical Facility Chandra Science Center Support. The contract is a 5-year effort valued at $375 million.



E0102-72 is a supernova remnant in the Small Magellanic Cloud, a satellite galaxy of the Milky Way.

NASA MSFC Boosts Alabama Economy With $983 Million in FY 2003 Expenditures

NASA's MSFC in Huntsville, Alabama, contributed $983 million to Alabama's economy in fiscal year 2003. Included were $292 million in salaries for civil service personnel and related costs, as well as travel. Also included was $691 million spent on locally procured services, prime contractor and subcontractor support, and local construction. The $983 million spent in Alabama was significantly more than the MSFC's expenditures in any other state.

Approximately $54 million funding was spent on NASA programs where MSFC had a supporting role and an additional $32.7 million was spent on programs where MSFC performed work for other agencies. MSFC received approximately 17 percent—or $2.6 billion—of NASA's total budget of $15.4 billion during fiscal 2003. Of MSFC's budget 54 percent was spent in support of Office of Space Flight for programs including Space Shuttle and Space Station activities with 46 percent for Space Science, Earth Science, Biological & Physical Research, and Crosscutting Technology Programs. Since it was established in 1960, the Marshall Center has had budget responsibility for more than $74 billion. When yearly figures are adjusted for inflation, this total is equivalent to more than $185 billion in today's dollar value.

Approximately $67 million in retirement annuities were paid in 2003 to 2,287 MSFC retirees residing in Alabama, with 1,541 retirees in Huntsville and Madison receiving $45 million of that amount. Through September 2003, MSFC paid $5.6 billion in Federal salaries since its creation in 1960. In 2003, MSFC civil service employees collectively paid about $34 million in Federal Income Taxes and about $8 million in Alabama State Income Taxes. At the end of September, MSFC's permanent and temporary civil service employees totaled 2,702, including employees at resident offices at prime contractor facilities and at NASA's MAF near New Orleans, La.

Of that workforce, 2,245 were college graduates, with 1,463 holding bachelor's degrees. There were 186 employees with doctorate degrees and 596 with master's degrees in fields of engineering and science—predominantly mathematics and physics—as well as other disciplines, predominantly business administration.

During 2003, 26,154 contractor personnel engaged in work for the MSFC, including 3,807 in mission support, 8,912 on prime contract work, and an estimated 13,435 as subcontractors and vendors. Of the total, 7,400 worked in Alabama. An additional 996 estimated jobs resulted from MSFC support to other NASA work and to other agencies.

During FY 2003, 22,801 people toured MSFC, including educators, conference and symposium visitors and news media. In 2003, the attendance at the U.S. Space & Rocket Center in Huntsville was 354,454. The U.S. Space & Rocket Center is MSFC's official NASA Visitor Center.

Additional ways MSFC supports the community is through participation in blood drives where in 2003, 1,203 pints of blood were collected from civil service and on-site contractors. Also, MSFC civil service employees contributed $595,150 to the Combined Federal Campaign—this contribution exceeded the Center goal, which was $500,000. Of the total contribution, $313,278 was designated to specifically help agencies in Alabama.

Additional Impact in the Education Community

In support of our Nation's higher education institutions, MSFC in FY 2003 funded 123 universities and colleges in 34 states. Of these 123 universities and colleges, there were 386 active research grants and training activities with a total contract value of $781 million. The obligations against these grants and training contracts for FY 2003 totaled $132 million.

In the state of Alabama, MSFC funded 11 colleges and universities that held 81 active contracts. The total contract

value equaled $123 million, with a funded amount of $30 million for FY 2003. The universities and colleges in Alabama that were funded include: Alabama A&M University, Alabama State University, Auburn University, Lawson State Community College, Oakwood College, Stillman College, Tuskegee University, UAB, UAH, the University of Alabama, and the University of South Alabama.

Nonprofit Institutions

MSFC also had 56 awards with nonprofit institutions that totaled a contract value of $744 million in 11 states. There were 21 institutions that held these 56 awards. A total of $72 million was funded to these nonprofit organizations for FY 2003.

In the state of Alabama, MSFC funded seven nonprofit institutions that held 21 contracts, which received $9 million in funding, with a total contract value of $28 million for FY 2003. The nonprofit organizations in Alabama that received funding were: Alabama Department of Environment Management, Alabama State Department of Education, ARC of Madison County, NASA Exchange @ MSFC, Southern Research Institute, U.S. Space & Rocket Center, and Universities Space Research Alliance.

Combined Universities, Colleges, and Nonprofit Organizations

MSFC funded a total of $204 million on 144 universities, colleges, and nonprofit organizations for FY 2003. This amount of funding was placed on a total of 442 contracts.

MSFC FY 2003 Dollars & Workforce by Benefiting State

State	FY03 $M	Jobs
Alabama	983	10153
Arizona	4	50
California	501	5755
Colorado	13	146
Connecticut	19	218
Delaware	0.4	5
District of Columbia	0.4	5
Florida	144	1638
Foreign	0.2	2
Georgia	5	57
Hawaii	0.2	3
Idaho	1	7
Illinois	2	24
Indiana	2	24
Iowa	8	92
Kansas	0.2	3
Kentucky	7	77
Louisiana	310	3563
Maine	0	0
Maryland	6	69
Massachusetts	51	590
Michigan	1	6
Minnesota	12	133
Mississippi	2	20
Missouri	1	16
Montana	0.5	5
Nevada	21	238
New Hampshire	0.2	2
New Jersey	1	14
New Mexico	1	9
New York	4	51
North Carolina	1	16
Ohio	6	65
Oklahoma	0	0
Oregon	0.2	2
Pennsylvania	5	53
Puerto Rico	0.3	3
Rhode Island	0.2	3
South Carolina	1	9
Tennessee	3	38
Texas	9	99
Unidentified/Misc	142	1637
Utah	313	3596
Vermont	0.3	3
Virginia	9	100
Washington	2	27
West Virginia	19	217
Wisconsin	6	65
Wyoming	0	0
Grand Total	2616	28906

NOTE: Includes Civil Service and Estimated Contractors resulting from MSFC work performed.

ACRONYM LIST

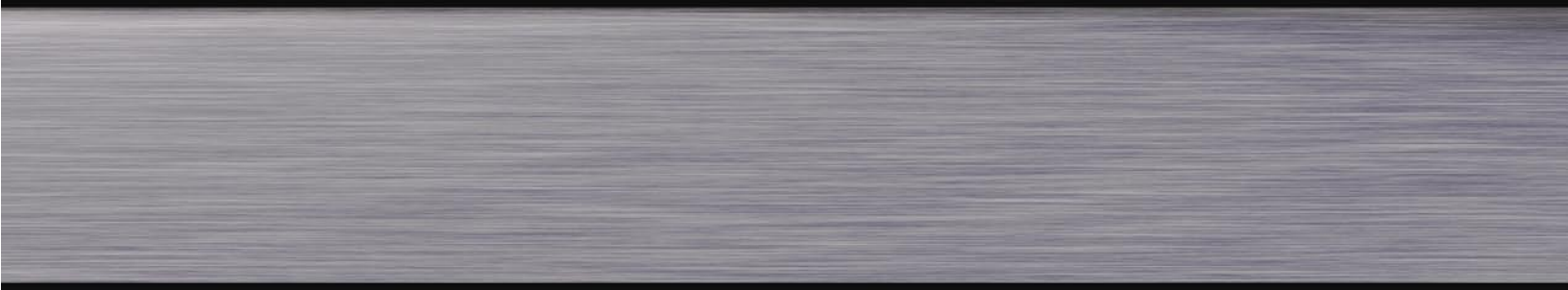
ADP	Automated Data Processing
AHMS	Advanced Health Management System
ALTV	Approach and Landing Test Vehicle
AMSD	Advanced Mirror System Demonstrator
ARC	Ames Research Center
ASTP	Advanced Space Transportation Program
AVGS	Advanced Video Guidance Sensor
BRP	Biological Research Project
BSTRA	Ball Strut Tie Rod Assembly
C-MIGITS	Coarse/acquisition code, Miniature Integrated GPS/INS Tactical System
CAAS	Contract Administration and Audit Services
CAIB	*Columbia* Accident Investigation Board
CBSE	Center for Biophysical Sciences and Engineering
CCACS	Center for Commercial Applications of Combustion in Space
CDDF	Center Director's Discretionary Fund
CDR	Critical Design Review
CFO	Chief Financial Officer
CIO	Chief Information Officer
CIL	Critical Items List
CMM	Capability Maturity Model
CMS	Chemical Management System
CoFR	Certificate of Flight Readiness
CONTOUR	Comet Nucleus Tour
CRM	Continuous Risk Management
CRV	Crew rescue vehicle
CSLM–2	Coarsening of Solid-Liquid Mixtures 2
CTV	Crew transfer vehicle
CXO	Chandra X-ray Observatory
DART	Demonstration of Autonomous Rendezvous Technology
DOD	Department of Defense
DOE	Department of Energy
DRD	Data Requirements Descriptions
DFRC	Dryden Flight Research Center
ECLS	Environmental Control and Life Support
ED	Engineering Directorate
EED	Environmental Engineering Department
ELV	Expendable launch vehicle
ERC	Educator Resource Center
ESA	European Space Agency
ET	External Tank

ETM	Engineering Test Motor
EUSO	Extreme Universe Space Observatory
EVM	Earned Value Management
EXPRESS	Expedite the Processing of Experiments to the Space Station
EXT	Environmental Excellence Team
FCA	Firmware Control Assembly
FHCS	Federal Human Capital Survey
FISCAM	Federal Information System Controls Audit Manual
FMEA	Failure Modes and Effects Analysis
FOD	Foreign Object Debris
FOIA	Freedom of Information Act
FPD	Flight Projects Directory
FPGA	Field programmable gate array
FSW	Friction stir welding
GATE-M	Government Agencies Technology Exchange in Manufacturing
GBM	GLAST Burst Monitor
GHCC	Global Hydrology and Climate Center
GIDEP	Government-Industry Data Exchange Program
GLAST	Gamma Ray Large Area Space Telescope
GP–B	Gravity Probe B
GRB	Gamma-ray burst
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
HBCU	Historically Black Colleges and Universities
HHR	Habitat Holding Rack
HOSC	Huntsville Operations Support Center
HPFTP	High-pressure fuel turbopump
HPOTP	High-pressure oxygen turbopump
HyTEx	Hypersonic Technology Experiment
IA	Independent Assessment
IAO	Information Assurance Officer
IBC	Iterative Biological Crystallization
IDEA	*ISS* Downlink Enhancement Architecture
IEA	Integrated electronics assembly
IEC	Integrated Engineering Capability
IES	Integrated Engineering Solutions
IFMP	Integrated Financial Management Program
IMAGE	Imager for Magnetopause-to-Aurora Global Exploration
IPD	Integrated Powerhead Demonstrator
IR	Infrared

ISO	International Standardization Organization
ISS	*International Space Station*
ISSI	In-space Soldering Investigation
ISTP	Integrated Space Transportation Plan
IT	Information technology
JIMO	Jupiter Icy Moons Orbiter
JIT	Just-in-time
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
JWST	James Webb Space Telescope
KSC	Kennedy Space Center
LaRC	Langley Research Center
LOC	Lab-on-a-chip
LOCAD	Lab-on-a-chip Applications Development
lox	Liquid oxygen
MAF	Michoud Assembly Facility
MELFI	Minus Eighty Laboratory Freezer for the *ISS*
MPLM	Multipurpose Logistics Module
MSAD	Microgravity Science and Applications Department
MSFC	Marshall Space Flight Center
MSG	Microgravity Science Glovebox
MSL	Materials Science Laboratory
MSR	Mars Sample Return
MSRR	Materials Science Research Rack
MWI	Management Work Instruction
MXER	Momentum-Exchange/Electrodynamic Reboost
NACC	NASA ADP Consolidation Center
NASA	National Aeronautics and Space Administration
NCAM	National Center for Advanced Manufacturing
NDE	Nondestructive Evaluation
NEXT	NASA Evolutionary Xenon Thruster
NGEP	Next Generation Electric Propulsion
NGLT	Next Generation Launch Technology
NISN	NASA Integrated Services Network
NSBRI	National Space Biomedical Research Institute
NSN	NASA Secure Network
NSSTC	National Space Science and Technology Center
NSTAR	NASA Solar Electric Propulsion Technology Application Readiness
NAI	National Aerospace Initiative
NRA	NASA Research Announcement

OBPR	Office of Biological and Physical Research
OPG	Osteoprotegerin
ORU	Orbital Replacement Unit
OSP	Orbital Space Plane
OSS	Office of Space Science
OV	Orbital vehicle
PCAM	Protein Crystallization Apparatus for Microgravity
PCH	Program critical hardware
PE	Polyethylene
PFMI	Pore Formation and Mobility Investigation
POD	Payload Operations Director
POIC	Payload Operations Integration Center
PRC	Propulsion Research Center
PSI	Propulsion Systems Integration
PSM	Power Supply Module
PT&I	Propulsion Technology and Integration
PVT	ProVision Technologies
QMI	Quench Module Insert
RBCC	Rocket-based Combined Cycle
RCC	Reinforced carbon-carbon
RCE	Reaction Control Engine
REP	Rocket Engine Prototype
RFP	Request for Proposals
RLV	Reusable Launch Vehicle
RP	Rocket propellant
RPC	Research Partnership Center
RSRM	Reusable Solid Rocket Motor
S&MA	Safety and Mission Assurance
SACA	Sample Ampoule Cartridge Assembly
SAO	Smithsonian Astrophysical Observatory
SBIR	Small Business Innovation Research
SBRE	Strategic Biomolecular Research for Exploration
SCRS	Safety Concerns Reporting System
SEA	Shuttle Environmental Assurance
SEE	Space Environments and Effects
SEERS	Surveying and Examination of Eroded Returned Surfaces
SESAAS	Sustaining Engineering Support for Agencywide Administrative Systems
SHE	Safety, Health, and Environmental
SHIVA	Spaceflight Holography Investigation in a Virtual Apparatus
SLA	Super-light Ablator

SLI	Space Launch Initiative
SOFI	Spray-on Foam Insulation
SOMTC	Space Optics Technology Manufacturing Center
SOTA	State-of-the-art
SPD	Space Partnership Development
SQA	Software Quality Assurance
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SRR	System Requirements Review
SRSP	Space Radiation Shielding Program
SSC	Stennis Space Center
SSME	Space Shuttle Main Engines
SSPO	Space Shuttle Propulsion Office
STS	Space Transportation System
STTR	Small Business Technology Transfer
SUBSA	Solidification Using a Baffle in Sealed Ampoules
SXI	Solar X-ray Imager
TIP	Technology Investment Program
TPS	Thermal protection system
TReK	Telescience Resource Kit
TRL	Technology Readiness Level
UAB	University of Alabama at Birmingham
UAH	University of Alabama in Huntsville
UPA	Urine Processor Assembly
VCS	Voluntary consensus standard
VISAR	Video Image Stabilization and Registration
ViTS	Video Teleconferencing
VPS	Vacuum plasma spray
WC	Workers' Compensation
WCSAR	Wisconsin Center for Space Automation and Robotics
WPA	Water Processor Assembly
XML	Extensible Markup Language



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