Research and Development at JSC

Research and Development (R&D) at JSC covers a wide spectrum of disciplines in support of NASA's Human Exploration and Development of Space initiatives. Our Center's dedicated team of scientists, engineers and craftspeople have managed the design, development and testing of all U.S. human spacecraft and related systems – from the tight working space of the Apollo capsule to the expansive, and still expanding, research and living space aboard the International Space Station.

JSC leads NASA's research and development in several key areas. In bioastronautics research – the study of human physiology in space – we strive to understand the space frontier and the opportunities, capabilities and limitations of humans living and working on that frontier. As NASA's center of excellence for astromaterials, JSC coordinates the study of materials from space, including samples from the Moon, meteorites from Antarctica and cosmic dust from the Earth's stratosphere. And JSC leads NASA's engineering efforts for human spaceflight, turning the vision of design into the reality of a functional, orbiting spacecraft capable of supporting human life.

Bioastronautics

Bioastronautics research at JSC explores human health and performance in space. The research studies the effects of microgravity on humans for improved life support, health and longer mission duration.

JSC's Bioastronautics Program Office defines the medical standards NASA uses for astronaut selection, and provides physiological and psychological support to astronauts while they train. The Office provides medical care both in space and during postflight recovery and training, and monitors any test or training activities conducted in hazardous environments, such as the Neutral Buoyancy Laboratory, a large indoor pool used to train astronauts for spacewalks; the thermal vacuum chambers; the hypobaric training chambers; and the KC-135 aircraft used to simulate reduced gravity.

Through various partnerships between medical and research institutions, the Center also conducts spaceflight health studies to help understand and develop health solutions on Earth. For instance, we study areas such as: cardiovascular, neurovestibular, immunological, nutrition, musculoskeletal and barothermal physiology – all contributing to longer life here on Earth.

At JSC we develop onboard experiments in fascinating new biomedical frontiers. One way we accomplish this research is with the station-based Human Research Facility (HRF). The HRF provides an on-orbit laboratory that enables life science researchers to study and evaluate the physiological, behavioral and chemical changes induced in human beings by spaceflight. Since scientific research, including human research, is a primary goal of the International Space Station, areas of concern to humans' well-being and performance – such as renal stone risk, bone density deterioration and the effects of ionizing radiation – are studied using the HRF system.

Engineering and Design

JSC serves as the home of design and planning for human spacecraft. The Center controls both shuttle and

Robonaut

Our engineers created the Robonaut to aid astronauts in space and reduce the need for human EVAs. This project seeks to develop and demonstrate a robotic system that can function as a spacewalking astronaut equivalent, as well as a helping hand here on the ground. The futuristic humanoid Robonaut jumps generations ahead by replacing the special robotic grapples, targets and tools of traditional on-orbit robotics with two dexterous five-fingered hands, while still keeping the human operator in the control loop through its telepresence control system.

Engineers implemented Robonaut's new autonomous abilities this year, enabling it to understand voice commands from its human operator and to recognize and retrieve spacewalking tools. Working side-by-side with humans, or going where the risks are too great for people, machines such as Robonaut will expand the ability for construction and discovery.

Since our first payload reached the space station in September 2000, we have launched more than 4.6 tons of research hardware and experiments, and returned more than 1 thousand pounds of hardware, samples and other data to Earth.

John Uri, Expedition Four
science mission manager

the International Space Station operations and works in concert with partner countries in the development, launch, assembly and operation of the International Space Station hardware. The task of turning the vision of design engineers into the reality of a functional, orbiting spacecraft capable of supporting human life is a monumental one. With Mercury, Gemini, Apollo, Skylab, the Space Transportation System (shuttle) and now the International Space Station, NASA has accomplished the task time and again. And the success of these programs is due to the Center's broad depth of engineering expertise. This expertise encompasses all functions related to human spacecraft: life support systems; power systems; crew equipment; guidance, navigation and control; electrical power generation and distribution; cooling systems; structures; flight software; robotics; and space suits and spacewalking equipment. Our engineers work hard to ensure safe and efficient designs to support our goal at JSC to expand the human presence in space through exploration.

JSC scientists and researchers are also exploring advanced technologies and innovative integration of existing technology to help achieve success at lower costs. For example, JSC partnered with Cisco Systems and updated the telephone system for communications operations for the crew of the International Space Station – the Softphone. The Softphone makes calling someone from orbit as easy as placing a call from any desk at JSC – and it's free! This is a major revolution in the way people in space communicate with people on Earth. For decades the only way to communicate with astronauts was via radio, which has limitations and relatively low signal quality. By donning a headset plugged into their laptops, the astronauts can now speak directly with their families.

Astromaterials and Earth Observations

The people at JSC help make NASA an innovator in space exploration. Yet, space exploration is only one component of our jobs – research plays an enormous role in our discoveries. One particular area of study that helps us understand the makeup of our solar system is the study of astrobiology, or extraterrestrial materials.

JSC is the curator of all extraterrestrial materials for NASA, from the first Moon rocks to meteorites from Antarctica. The newly developed Astromaterials Acquisition and Curation Office was established at JSC in July 2001. The mission of the Office is to support the international planetary science community. This is accomplished through the curation of current extra-terrestrial sample collections, curation of samples from future spacecraft missions, advanced planning efforts for all sample return missions, and focused research and development in support of current and future sample curation.

From Earth to Mars, the newly formed Astro-materials Research and Exploration Science (ARES) Office provides fascinating insight into a complex subject matter. ARES conducts astromaterials curation and basic research in planetary and Earth sciences as well as space debris. Additionally, ARES supports human spaceflight missions through image analysis, monitoring orbital debris and training astronauts in Earth observation.

NASA gave the ARES curation team the leadership role in planning for sample handling, which includes quarantine and curation, for the eventual Mars Sample Return mission. We have more than 300 kilograms (66 pounds) of Moon rocks, which have been studied for more than 30 years by scientist worldwide, and they continue to be a source of important scientific information about the makeup of the Moon.

The National Science Foundation – in cooperation with the Smithsonian and NASA – collaborates to further this research by sending a team of scientists and explorers to Antarctica for meteorite collection. Each year JSC acquires approximately 1,000 meteorites, in a frozen state, from Antarctica. JSC has many notable meteorites in its collection, including meteorites that are from the planet Mars.

Martian meteorite and experimental studies provided insight into the earliest history of Mars' formation and differentiation, the evolution of Mars' atmosphere, magmatic history, and the existence of a magma ocean on Mars. ARES scientists also provided new evidence on both sides of the debate over fossil life in meteorite ALH84001 – a 4.5-billion-year-old rock. It is believed to have once been a part of Mars, and to contain fossil evidence that primitive life may have existed on Mars more than 3.6 billion years ago.

Expanding our knowledge of Earth and environmental science and processes of change over time helps us to explore our natural world. And Earth observations studies help us to analyze global changes, climactic conditions and the impact of humans on our environment. When our astronauts photograph the Earth from the International Space Station's optical-quality window, ARES is responsible for cataloging all the images that are taken as well as making them available to the public.

The future is extremely exciting for ARES. We have a number of sample return missions planned over the next 10 to 15 years. One of the sample return missions we are anticipating is the Mars Sample Return. We plan to go to Mars by way of a robotic mission that will collect soil from the surface and subsurface, looking for Martian life.

The NASA *Stardust* mission will be the first mission to return samples from a comet. This mission was launched in 1999 and is expected to return in February 2006. The spacecraft will fly through the tail of Comet Wild 2 with a collector plate exposed, collecting comet

Biotechnology Research on the International Space Station

In August 2001, the Cellular Biotechnology Operations Support System (CBOSS) experiment was installed in an EXPRESS Rack, a facility designed for quick and easy installation of hardware and experiments, in the space station's Destiny laboratory.

CBOSS consists of a cryodewer, an incubator and a refrigeration device for cells, a gas containment and delivery system, and a stowage system for necessary supplies. The overall mission of CBOSS is to support a series of flight experiments using bioreactors to provide the environment and metabolic support necessary for three-dimensional tissue development in the microgravity environment of space. The cells under study, include ovarian and colon cancer cells, as well as human kidney cells.

Prior to experiment initiation, the cells are maintained in a cryogenic state. Over a period of days the crew thaws, feeds and incubates the cells. Upon experiment completion, the cell cultures are preserved and refrigerated until return to Earth for further investigation. Scientists then study the samples for analyses of cell alterations and for molecular expression of genes, proteins and other molecular markers. The first cells grown in CBOSS were returned to Earth for analysis in December 2001, and more cell cultures will be grown aboard the space station in 2002.

NASA and The National Space Biomedical Research Institute

JSC's bioastronautics research leads and complements the NASA-funded efforts of other scientists and organizations such as the National Space Biomedical Research Institute (NSBRI). NSBRI is a JSC cooperative partnership managed by Baylor College of Medicine, and includes 12 other prominent research institutions. NSBRI studies the effects of microgravity on astronauts in orbit, including aging, osteoporosis and sleep disorders. Exploring the way humans react and adapt to space may help lead to a better understanding of these conditions and to develop advances that will lead to treatments on Earth.

dust for study and curation. Scientists thus expect to learn more about the birth and evolution of life in the solar system by studying these comet and dust particles.

Another mission we are looking forward to returning is the NASA *Genesis* mission, which will collect solar wind ions and atoms. The Genesis mission began its 1.5 million-km (932,057-mile) journey Sunward in July 2001. Solar wind samples will be collected for approximately two years, before the mission returns to Earth. The mission's return date is August 2004; this will be the first sample return since Apollo 17. JSC is responsible for sample curation and overall mission contamination control. The latter included the clean storage and subsequent installation of the collector materials into the payload hardware, as well as the precision cleaning of the disassembled flight payload hardware.

University Research Activities Through JSC

JSC benefits from numerous University Research partnerships. NASA dollars spent through University Research Grants and Cooperative Agreements support joint research projects that fulfill many early developmental needs of the agency, while helping guide the future R&D strategies of space exploration. These relationships help to build a pipeline of talent that advances knowledge for the country.

Since the beginning of the Apollo Program in the 1960s, JSC has supported university faculty and students who are conducting basic and applied research. We support scientific research, engineering research and technology development. Much of this research is at the early Technology Research Levels (TRL 0-3). Some of this research is directly used by JSC and its contractors for implementation into flight, hardware/software, and some research data form the basis by which NASA scientists and engineers make better judgments for guiding the future R&D strategies of space exploration. The students who participated in this work, undergraduate and graduate, have become a part of the pipeline of talent that has advanced microgravity science and engineering, human physiology in space, spacecraft design and spaceflight operations. Doctoral students supported by NASA have, in turn, become university faculty educating the next generation of space-exploring scientists and engineers.

During FY 2001, NASA appropriated $1,118,241,050 into university research programs. Approximately $97,505,001 of that was coordinated through JSC. An example of how this type of investment can be used, to further research that may be beneficial to humankind, is the study currently under way at Baylor College of Medicine. The National Space Biomedical Research Institute (NSBRI), at Baylor College of Medicine, has been tasked to collectively study the effects of space on the human body, and to develop medical countermeasures so that humans may continue to explore longer and farther into space. The NSBRI forms the center of focus for the developing discipline – BioAstronautics, involving universities throughout the U.S. The NSBRI is a consortium of 12 universities and laboratories led by the Baylor College of Medicine. Other participants include Brookhaven National Laboratory, Harvard Medical School, the Massachusetts Institute of Technology, Morehouse School of Medicine, and the University of Washington.

Another way JSC supports university research is through a cooperative agreement between the Center and Rice University. This research examines the field of nanotechnology materials. It has resulted in an improved

NASA's Reduced Gravity Student Flight Opportunities Program

NASA's Reduced Gravity Student Flight Opportunities Program (RGSFOP) is designed to provide students practical and theoretical knowledge of science. Approximately 1500 students representing more than 200 schools in 46 states have participated in NASA's RGSFOP since it began in 1995.

NASA's university research programs serve not only to unlock new discoveries about our world, but also to train and inspire the next generation of scientific explorers who will be vital to maintaining the United States' technical and economic leadership in years to come.

Bonnie Dunbar, Ph.D., Astronaut
Assistant Director for University Research

process for making single-wall carbon nanotubes. These nanometer-diameter hollow tubes have the extraordinary properties of being 10 to 100 times stronger than steel at one-sixth the weight, while also being as electrically conductive as copper and as thermally conductive as a diamond. The collaboration with Nobel Prize winner Richard Smalley's group has resulted in a spin-off company in Houston to commercialize and develop this new technology.

JSC also supports "no exchange of funds" programs. In this unique program, JSC partners with the University of Houston (UH) to expose both faculty and students to "real life" engineering problems while providing support to the Engineering and Space and Life Sciences Directorates. This program has proven itself mutually beneficial to JSC, the faculty and the students. The partnership allows JSC engineers and UH faculty to work together during the summer, with the students participating in actual design problems. This program attracts the top students and faculty, which has greatly benefited engineering research at JSC.

UH Dean of Engineering, Dr. Ray Flummerfelt, stated early in the program that NASA was his first choice because of the powerful motivation that human spaceflight provides for both his students and his faculty. Industrial and Mechanical Engineering students have supported projects in manufacturing, thermal analysis, development of the International Space Station Human Research Facility, and advanced exploration with the Gateway-Moon Project as well as research into noise suppression.

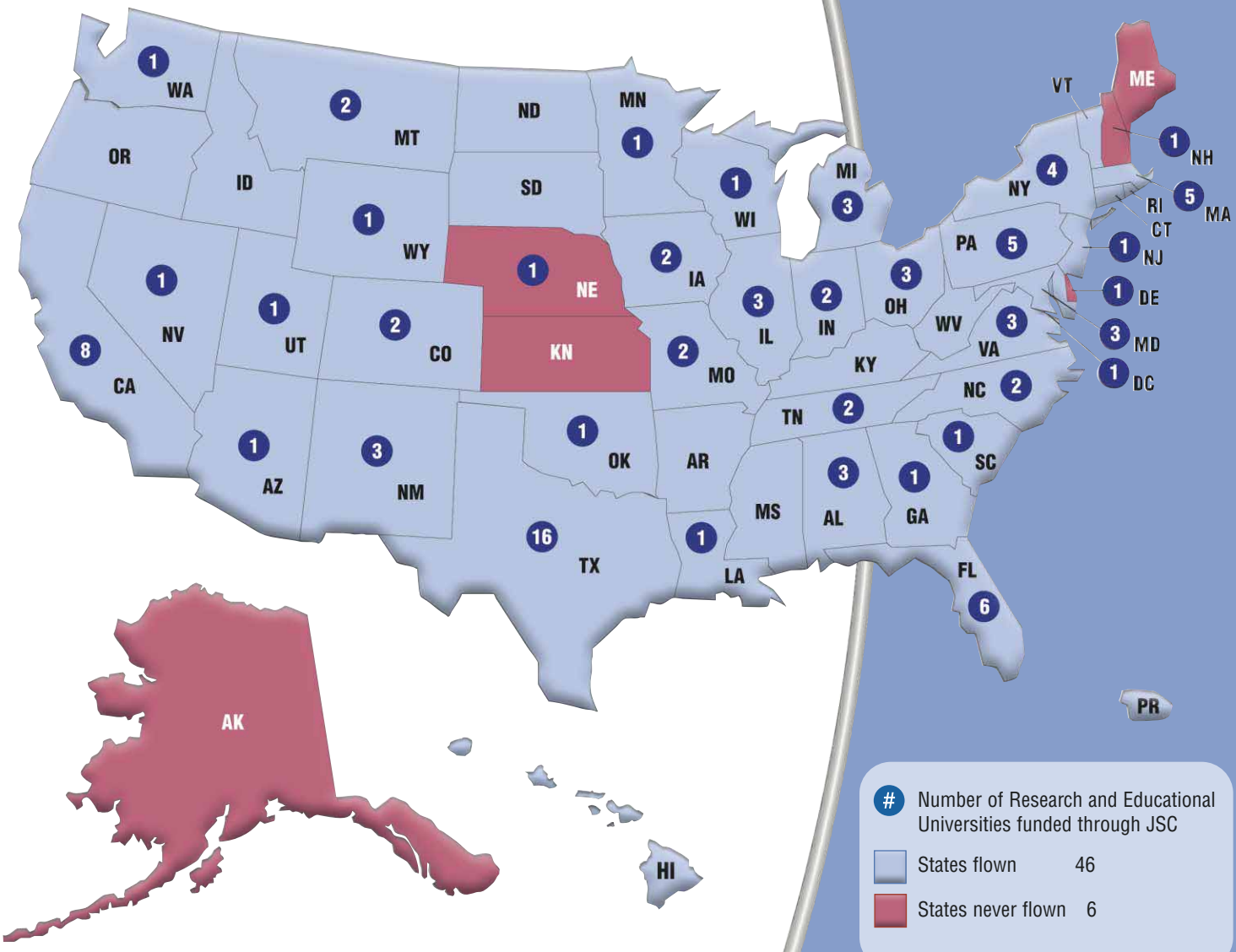
JSC also supports university research through cooperative agreements. Currently JSC has a Cooperative Agreement with Texas Tech University (TTU). In this program, Advanced Life Support research is being conducted in the areas of plant growth in closed environments; this research is applicable to long-duration space missions. TTU is examining plant performance and engineering challenges associated with maintaining atmospherically sealed plant growth environments. Research is also under way to examine biological bioreactors for recycling wastewaters, and the fate of pharmaceuticals in water recycling systems. Additionally, a special project with TTU faculty and students is dedicated to the application of NASA water recycling technology for processing waste waters in "colonias" along the Texas-Mexico border, which does not have water treatment infrastructures. Finally, a computer science research task is addressing the development of a new computer language, Sequence L, that will simplify the representation of algorithms that have parallel computational properties, thus allowing for faster processing.

JSC and the University of Texas Medical Branch (UTMB) have entered into two new programs. The first provides for specialized training in Space Life Sciences for selected doctoral students at both UTMB and at the University of Texas Health Sciences Center in Houston. The program was started in 2000, curriculum has been developed, and 15 students are now enrolled. Additionally, UTMB and JSC have developed a combined internal medicine-aerospace medicine residency program. Both the American Board of Internal Medicine and the American Board of Preventive Medicine have approved the program.

NASA Reduced Gravity Student Flight Opportunities Program

Participating States: 1997–2001

University Research Grants



Number of Research and Educational Universities funded through JSC

States flown 46

States never flown 6