

Inspiring the Next Generation: Student Experiments and Educational Activities on the International Space Station, 2000–2006

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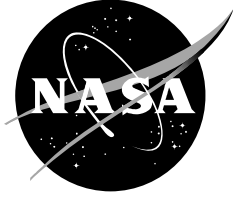
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ACRONYMS AND ABBREVIATIONS

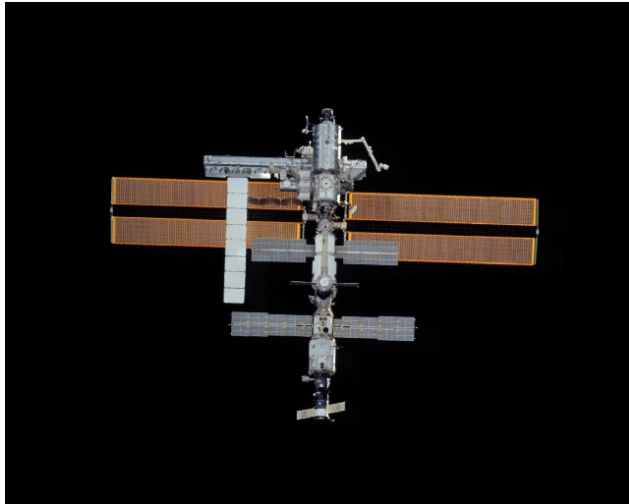
AdvAsc	Advanced Astroculture
AEB	Agência Espacial Brasileira
AESP	Aerospace Education Services Program
AFB	Air Force Base
AFRL	Air Force Research Laboratory
AgCam	Agricultural Camera
AIDS	Acquired Immune Deficiency Syndrome
AMASE	Arctic Mars Analog Svalbard Expedition
AMSAT	Amateur Radio Satellite
ARC	Ames Research Center
ARISS	Amateur Radio on the International Space Station
ARRL	American Radio Relay League
ASI	Agenzia Spaziale Italiana
ATP	adenosine triphosphate
BPS	Biomass Production System
BCAT-CP	Binary Colloidal Alloy Test-Critical Point
BSME	bachelor of science in mechanical engineering
BXF-MABE	Boiling eXperiment Facility-Microheater Array Boiling Experiment
BXF-NPBX	Boiling eXperiment Facility-Nucleate Pool Boiling eXperiment
CASPER	Cardiac Adapted Sleep Parameters Electrocardiogram Recorder
CBTM	Commercial Biomedical Test Module
CCM	Chlorophyll Chromatography
CEO	Crew Earth Observations
CFE	Capillary Flow Experiment
CGBA	Commercial Generic Bioprocessing Apparatus
CGBA-APS	Commercial Generic Bioprocessing Apparatus-Antibiotic Production in Space
CHeCS	Crew Health Care System
CNES	Centre National d'Etudes Spatiales
CO ₂	carbon dioxide
CORE	Central Operation of Resources for Educators
COSI	Center of Science and Industry
CPCG-H	Commercial Protein Crystal Growth-High Density
CSA	Canadian Space Agency
CSI	Commercial Generic Bioprocessing Apparatus Science Insert
CTB	cargo transfer bag
DCPCG	Dynamically Controlled Protein Crystal Growth
DELTA	Dutch Expedition for Life Science, Technology, and Atmospheric Research
DLN	Digital Learning Network
DNA	deoxyribonucleic acid
DoD	Department of Defense
EarthKAM	Earth Knowledge Acquired by Middle School Students
ECG	electrocardiogram
EDA	Education Demonstration Activity
EGN	Enhanced Gaseous Nitrogen
EMU	extravehicular mobility unit

EPO	Education Payload Operations
ERC	Educator Resource Center
ERSI	Environmental Systems Research Institute
ESA	European Space Agency
ESD	Electronic Self-assembly Demonstration
EVA	extravehicular activity
FGB	functional cargo block (Zarya)
FGBA	fluids generic bioprocessing apparatus
FMVM	Fluid Merging Viscosity Measurement
FPA	fluids processing apparatus
GAP	Group Activation Pack
GENIP	Geography Education National Implementation Project
GIS	geographic information systems
GLA	generic luminaries assembly
GLOBE	Global Learning and Observations to Benefit the Environment
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
HUNCH	High School Students United with NASA to Create Hardware
IGA	a grocery store chain
ISIS	international subrack interface standard
InSPACE	Investigating the Structure of Paramagnetic Aggregates from Colloidal Emulsions
ISPR	international standard payload rack
ISS	International Space Station
ISSI	In-space Soldering Experiment
ISSP	International Space Station Program
ITSC	Imaging Technology Space Center
JAXA	Japanese Aerospace Exploration Agency
JSC	Johnson Space Center
KSC	Kennedy Space Center
LAN	local area network
LaRC	Langley Research Center
LOCAD PTS	Lab-on-a-Chip Application Development Portable Test System
LTC	Lab Training Center
MACE	Middeck Active Control Experiment
MAEA	Museum Aerospace Education Alliance
MEPS	microcapsulation electrostatic processing system
MFMG	Miscible Fluids in Microgravity
MISSE	Materials International Space Station Experiment
MIT	Massachusetts Institute of Technology
MPLM	multi-purpose logistics module
MRI	magnetic resonance imaging

MSFC	Marshall Space Flight Center
MSG	microgravity sciences glovebox
NaMAS	NASA Middle School Aerospace Scholars
NEEMO	NASA Extreme Environment Mission Operations
NIH	National Institutes of Health
NSBRI	National Science Biomedical Research Institute
NSF	National Space Foundation
PAO	Public Affairs Office
PCG	Protein Crystal Growth
PCG-EGN	Protein Crystal Growth-Enhanced Gaseous Nitrogen
PCG-STES-RGE	Protein Crystal Growth-Single Locker Thermal Enclosure System-Regulation of Gene Expression
PCSat	Prototype Communications Satellite System
PEACE	Polymer Erosion and Contamination Experiment
PESTO	Photosynthesis Experiment and System Testing and Operation
PFMI	Pore Formation and Mobility Investigation
PGBA	Plant Generic Bioprocessing Apparatus
PMDIS	Perceptual Motor Deficits in Space
PSU	Portland State University
PuFF	Pulmonary Function in Flight
RSR	resupply stowage rack
SAIC	Science Applications International Corporation
SEEDS	Space Exposed Experiment Developed for Students
SEI	Space Engineering Institute
SEM	Space Experiment Module
SIP	stand-off interface panel
SNFM	Serial Network Flow Monitor
SpaceDRUMS	Space-Dynamically Responding Ultrasonic Matrix System
SPHERES	Synchronized Position Hold, Engage, Reorient, Experimental Satellites
STP-H2-ANDE	Space Test Program-H2-Atmospheric Neutral Density Experiment
STP-H2-RAFT	Space Test Program-H2-Radar Fence Transponder
SuitSat-1	Suit Satellite-1
TERC	Technology Education Research Center
TFS	Teaching From Space (Office)
THEBAS	Test of the Basic Principles of Mechanics
USGS	U.S. Geological Survey
WORF	Window Observation Research Facility
ZCG	Zeolite Crystal Growth
ZSR	zero-g soft rack

INTRODUCTION

One important objective of NASA has always been to inspire the next generation. NASA and human space flight have a unique ability to capture the imaginations of both students and teachers. The presence of humans onboard ISS for more than five years now has provided a foundation for numerous educational activities aimed at capturing that interest and motivating study in the sciences, technology, engineering and mathematics.



STS113-701-049—Backdropped by the blackness of space, the ISS was photographed by a crewmember aboard the space shuttle *Endeavour* during rendezvous and docking operations.

Even before the Expedition 1 crew arrived at International Space Station (ISS) in November 2000, experiments with student participation were being conducted onboard ISS in support of the NASA mission. One of NASA's protein crystal growth experiments was delivered to station by space shuttle *Atlantis* during the STS-106 mission in September 2000, and was returned six weeks later aboard space shuttle *Discovery* during the STS-92 mission. Many of the protein samples that were flown had been prepared with the help of middle and high school students from across the country. From very early on it was thus recognized that students would have a strong interest in the ISS, and that this provided a unique opportunity for them to get involved and participate in science and engineering projects on the ISS.

In the first five and a half years of continuous human presence on the ISS, a wide range of student experiments and educational activities has already been performed by the United States, the 16 International Partner countries officially participating in the International Space Station Program (ISSP), and a number of other countries under special commercial agreements. Many of these programs still continue, and others are being developed and added to the station tasks on a regular basis. These diverse student experiments and programs fall into one of the following five areas:

Student-developed Experiments on ISS – These experiments, which are typically developed by students under the aegis of a teacher or scientist mentor, are performed solely for the benefit of the students. The Earth Knowledge Acquired by Middle School Students (EarthKAM) observation experiment—where students take their own pictures of the Earth from the ISS for later classroom study—is one example of this category of student participation.

Students Performing Classroom Versions of ISS Experiments – These experiments, which are performed by students in their classrooms, mimic experiments that are being conducted, or have been conducted, by professional researchers on the station. The focus of these experiments is for students to observe differences in their results as compared to the experiments being performed by crews on the ISS. A typical example of this type of experiment would be students growing seeds in their classroom on Earth at the same time an astronaut is growing similar seeds on the ISS.

Students Participating in NASA Investigator Experiments – Many of the NASA research investigators have enlisted students to help them on their experiments. Some of these experiments are done solely to “inspire the next generation of explorers.” Others involve undergraduate and graduate students as well as postdoctoral fellows who are working under the guidance of investigators and university professors on their NASA research.

Students Participating in ISS Engineering Activities: Hardware Development and Space Operations – These activities typically involve high school and college students developing hardware to support the ISSP or working in a Science Support Center and learning about and participating in space operations. The Agricultural Camera (AgCam) that is being developed at the University of North Dakota is one example in which students have been involved in the design and development of the ISS experiment hardware, and will be involved in future mission operations.

Educational Demonstrations and Activities – In addition to the numerous experiments that students are supporting on ISS, a number of other educational activities and demonstrations are performed to be used as teaching aids, to supply educational resource materials, or simply to provide additional mechanisms to inspire students. From astronauts demonstrating how simple and familiar phenomena such as soda bubbles behave on the ISS to allowing students of all ages to pose questions to the crews onboard the station, these diverse activities are rich with opportunity to connect with students and bring the ISS experience into their lives.

The opportunities that these programs provide to the students are as rich and open-ended as the imaginations of the students, and these programs have allowed participation of students at all academic levels, from K–12 to undergraduate and graduate students and postdoctoral fellows. Even first-graders have had the opportunity to design their own experiments to be performed on ISS (e.g., the Alien Catcher experiment flown to the ISS in August 2001) or to grow seeds that have flown in space in their classroom. Numerous high school students have been involved in ISS research projects that have helped steer their careers to mathematics, science, and other technical areas. Many college students have also been involved in ISS research, and have completed various projects and theses related to ISS experiments.

There may be no better way of inspiring the next generation of explorers than to inspire the current generation of teachers. Besides being of benefit to the students, many of these ISS programs have seen tremendous success in benefiting teachers. Some of the station experiments have encouraged significant participation by teachers through workshops that help these teachers prepare for the student experiments. By “teaching the teachers,” the impact of the ISS experience can thus become even broader. Taking what they have learned back to their classrooms and getting more students involved, teachers have demonstrated that they are a great resource for spreading the enthusiasm of exploration. A great example of this has been the Student Access to Space project, which involved experiments on the growth of protein crystals on ISS. In preparation for student activities on this experiment, more than 45 teacher workshops were held involving over 1,200 teachers from all 50 states and the District of Columbia, as well as many teachers from Department of Defense (DoD) bases in Germany and elsewhere. As a result of the tremendous success of these teacher workshops, nearly 58,000 students participated in the program.

One of the greatest features of student involvement on ISS has been the breadth and diversity of participation. Typically the student experiments and activities have involved schools from a number of states, while a few of them have seen participation from all 50 states. Schools that have participated have included inner city public schools, small rural schools, schools on Native American reservations, and various private schools as well as a wide range of university and colleges across the United States to name a few.

In addition to the participation across the U.S., the participation of international schools is quite impressive as well. Since the student Earth observation experiment EarthKAM is an experiment with few language barriers, it easily allows students from around the world to participate in it. To date, students from 48 of the 50 states and Puerto Rico and from 13 other nations have participated in EarthKAM. Experiments such as this highlight the true international nature of the station, illustrating how it benefits students worldwide. The Amateur Radio on the International Space Station (ARISS) experiment has also seen worldwide appeal with schools from 22 different countries participating in it, making it possible for

people in some of the most remote regions of the world to communicate with and become involved in the ISSP.

Student involvement in the ISS has not been restricted to experiments and projects developed only within the United States. Many of the ISS International Partner countries and other countries such as South Africa have developed programs, experiments, and activities to involve and inspire students. The universal appeal of space exploration among students has been a great asset for drawing students to studies in science, technology, engineering, and mathematics.

This technical paper summarizes the main student experiments and educational activities that have been performed onboard the ISS during its first years of operation, from 2000–2006, involving over 31 million students. Although the main focus is on experiments and activities developed within the United States, summaries of the educational activities from other countries that are participating in the ISSP are included in Appendix 3 for completeness.

While the immediate impact that these programs have had on our students is understandably difficult to measure, there are a number of examples of students who have pursued advanced education in technical areas as a result of their participation in these programs and their exposure to the excitement provided by the ISSP. Some of these former students have even gone on to work for NASA and its contractor team as a result of their start in these activities.

The activities summarized here represent the groundswell of interest in using ISS for educational purposes—among university researchers, a variety of educational organizations inside and outside of NASA, and the educators themselves. Despite the fact that the early focus of ISS has been on completing its assembly with limited utilization, the diverse and successful set of educational activities already completed hints at the great potential of future student involvement on ISS. It is clear that, based on the student experiments and activities already completed, the ISS has the unique ability to inspire the next generation of explorers to master science and engineering and to prepare them for the challenges they will face once the torch of exploration has been passed to their generation.



STUDENT-DEVELOPED EXPERIMENTS ON ISS

These experiments, which are typically developed by students under the aegis of a teacher or scientist mentor, are performed solely for the benefit of the students.

EARTH KNOWLEDGE ACQUIRED BY MIDDLE SCHOOL STUDENTS (EARTHKAM)

Expedition(s): 2, 4–13, ongoing

Grade Level(s): 6–8, undergraduate

Impact: Nearly 1,000 schools with 66,000 middle school students in the United States and 15 other countries have participated in EarthKAM. A total of 150 undergraduate students from the University of California at San Diego, San Diego, Calif., have also participated in integrating and operating the experiment.

EXPERIMENT DESCRIPTION/STUDENT ACTIVITY

EarthKAM is a NASA-sponsored education program that enables thousands of students to photograph and examine the Earth from the unique perspective of space. Using the EarthKAM Web pages available at <http://earthkam.ucsd.edu/>, students control a special digital camera that is mounted in a window on the ISS. From this window, these students are able to photograph a wide range of beautiful and fascinating features on the surface of Earth. They are also able to investigate a wide range of topics such as deforestation, urbanization, volcanoes, river deltas, and pollution to name a few.

During an active EarthKAM session, middle school students select photographic targets linked to the curriculum of each school. Next, undergraduate students at the University of California, San Diego integrate the requests from the schools at the Mission Operations Center and send a camera control file to the NASA Johnson Space Center (JSC) in Houston for uplink to ISS. The resulting photographs of the Earth are downlinked from the station back to EarthKAM, and are made available on the World Wide Web for viewing and study by participating classrooms and the general public.



Hannah and Charlie from Wickford CE Infant School, Essex, England, show a picture of the Yangtze River in China that they took during Expedition 10 in December 2004.



Third-graders from Sacaton, Ariz., track the ISS for their EarthKAM project.

Curriculum development for EarthKAM was done in partnership with the Center for Earth and Space Science Education, which developed teacher guides and supporting materials. In addition, the Geography Education National Implementation Project (GENIP), Texas A&M University, College Station, Texas, has partnered with NASA to create a set of curriculum support materials called “Mission Geography.” These materials provide K–12 students with hands-on geography modules that are set in the context of NASA research and missions. Many of the modules involve interpreting satellite imagery, and new modules are being built that integrate student-acquired imagery from EarthKAM.

STUDENT PARTICIPATION

Two EarthKAM sessions are scheduled for each ISS Expedition, resulting in one session approximately every three months. To date over 1,000 schools from Argentina, Brazil, Canada, Chile, Great Britain, Germany, Italy, Japan, Mexico, Spain, and the United States have participated in EarthKAM (TABLE I). The students involved have received over 20,000 photographs from the ISS since EarthKAM began

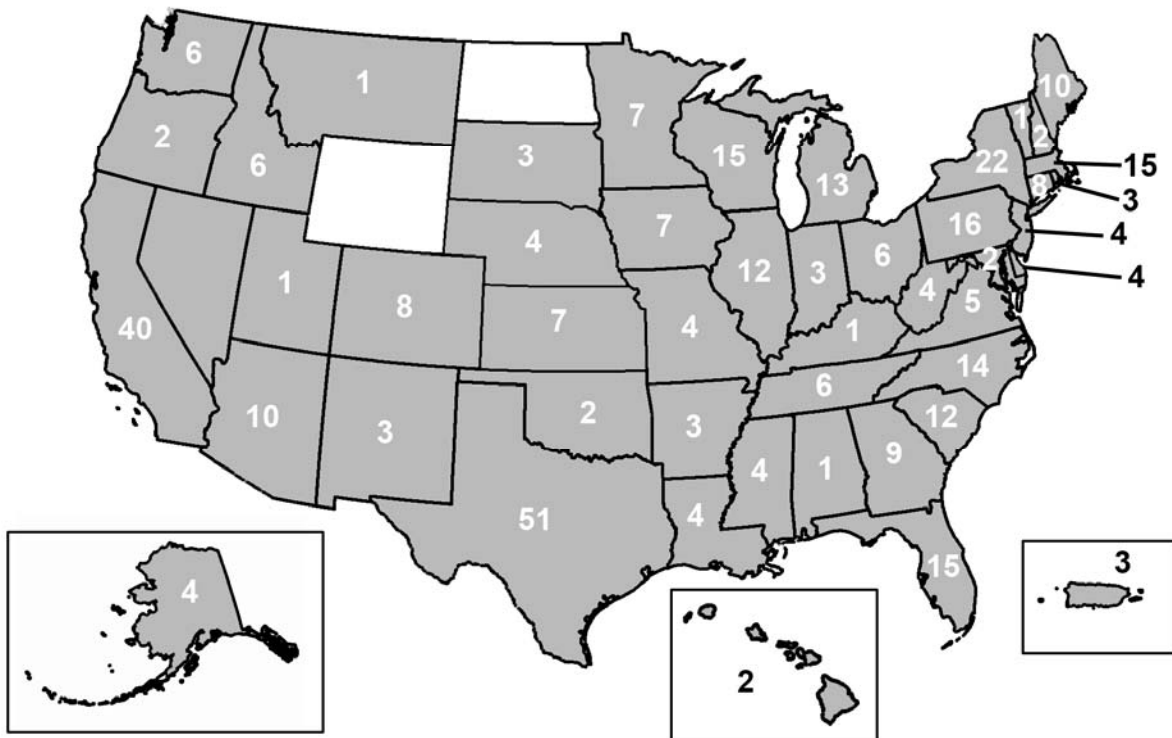
on Expedition 2. One hundred and fifty undergraduate students have been involved in learning about space operations and mission control by running the Mission Operations Center at the University of California at San Diego, San Diego, Calif.

The Girls Exploring Engineering class at Clifton Middle School in Houston, Texas, chose to study how the building of a new liquefied natural gas terminal on Quintana Island on the Texas Gulf Coast will affect the island.

Students at Kennedy Middle School in Natick, Mass., used the images obtained in a joint social studies/science project. They had just completed studying the expansion of the Islamic Empire and the Crusades and decided to focus their EarthKAM photos on western Asia, northern Africa, and Europe to study what the impact of landforms in those areas may have had on the Crusades and expansion.

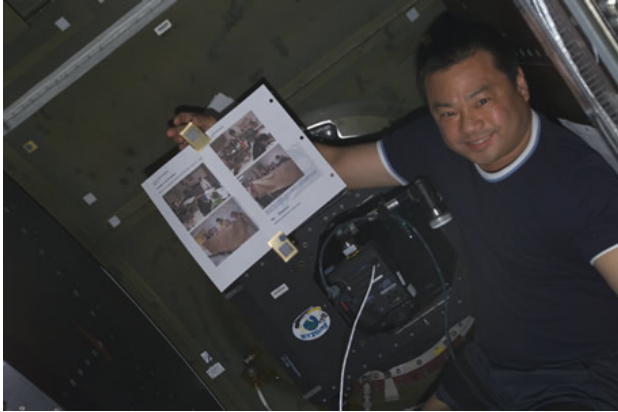
A number of schools have used EarthKAM to aid in their studies of the planet Mars. The students from W.F. West High School in Chehalis, Wash., proposed to study canyons on Earth as part of a project to compare them to the major canyon system on Mars, while students from Turtle Hook Middle School in Uniondale, N.Y., wanted to compare their images of Earth landforms to images obtained from previous Mars orbiters. These are two examples of how the EarthKAM experiment is helping to prepare our next generation of explorers for their own missions in the future.

EarthKAM Participating Schools (2001-2005)



Distribution of participating schools across 48 states (plus Puerto Rico). Schools that have participated in multiple sessions are only counted once, for a total of 382 unique schools participating.

Principal Investigator(s): Sally Ride, University of California, San Diego, San Diego, Calif.
Education Lead(s): Karen Flammer, University of California, San Diego, San Diego, Calif.
Education Web Site(s): <http://earthkam.ucsd.edu/>



Expedition 10 Science Officer and Commander Leroy Chiao in front of the EarthKAM camera holding a student greeting from Wissahickon Middle School, Ambler, Pa.



EarthKAM students captured this picture of fragile coral reefs in the Tuamotu Islands in the South Pacific. The students are investigating the formation of atolls, the kinds of plants and animals found on this remote island, and how people who live there support themselves.



During EarthKAM operations, ISS Deputy Program Scientist Julie Robinson uses a globe to showcase a potential photo target to sixth-grader Lucas at Westbrook Middle School, Friendswood, Texas.



Seventh-graders Emily and Jessica from Westbrook Middle School, Friendswood, Texas, use a map and the internet to determine the latitude and longitude of their next picture during a February 2006 EarthKAM run.

Table I. Student participation in the EarthKAM experiment on ISS, 2001–April 2006.

EarthKAM Session	Expedition	No. Schools	No. Students	No. Photos	No. Countries	No. Schools per country															
						U.S.	Argentina	Australia	Belgium	Brazil	Canada	Chile	Germany	Italy	Japan	Mexico	New Zealand	Puerto Rico*	South Korea	Spain	United Kingdom
Oct 2001	3	18	1,134	557	1	18															
Feb 2002	4	26	1,638	809	1	26															
Mar 2002	4	21	1,323	422	1	21															
Nov 2002	5	10	630	866	2	9							1								
Jan 2003	6	27	1,701	753	3	25							1	1							
Apr 2003	6	69	4,347	696	5	65							1	1		1					
May 2003	6	27	1,701	1,832	2	25							2								
Jul 2003	7	10	630	791	2	8							2								
Nov 2003	8	46	2,898	627	2	45							1								
Jan 2004	8	58	4,111	867	4	53					1	1	2						1		
May 2004	9	39	4,148	1,101	5	34				1	1	2							1		
Jul 2004	9	27	214	719	5	23				1	1	1							1		
Oct 2004	10	45	3,405	958	5	41				1		1							1		
Feb 2005	10	137	9,046	1,923	8	128				2	1	1	2	1		1			1		
Apr 2005	11	115	8,344	1,337	6	109	1			1		2							1		
Jul 2005	11	45	1,923	968	4	41				2	1	1									
Oct 2005	12	119	9,451	1,660	6	112	1			1			3	1					1		
Feb 2006	12	118	9,004	1,974	9	108	1		1	1	2	2		1					1		
Apr 2006	13	105	5,717	1,196	8	96	1	1		2	1	2					1		1		
Total		1,062	65,648	20,056	16	987	4	1	1	1	11	1	9	1	26	4	1	2	1	8	4

*For the purpose of statistical tracking, Puerto Rico is treated separately from the U.S. states.

PROJECT MISSE

PART OF MATERIALS INTERNATIONAL SPACE STATION EXPERIMENT-2 (MISSE-2)

Expedition(s): 3–11, additional Expeditions planned for future MISSE carriers
Grade Level(s): 1–10
Impact: Twenty-seven schools from Ohio and Kentucky, involving nearly 300 students, developed student flight experiments that focused on solving problems related to long-duration space flight. Eleven of these experiments have flown to ISS.

EXPERIMENT DESCRIPTION

The Materials International Space Station Experiment (MISSE) is a suitcase-sized materials exposure facility mounted externally on space station that is designed to evaluate the durability of materials and coating exposed to the extreme environment of space (atomic oxygen, radiation, vacuum, thermal cycling, micrometeorites, etc.). The Air Force Research Laboratory (AFRL) at Wright Patterson Air Force Base (AFB), Dayton, Ohio, and the Materials and Manufacturing Directorate of the AFRL, partners in the MISSE, thought it would be great to offer any leftover space on MISSE carriers to local students and teachers to try some experiments of their own. Eleven of these student experiments were incorporated in MISSE-2, which was launched to the ISS aboard space shuttle flight STS-105 in August 2001 and retrieved on space shuttle flight STS-114 in August 2005.

STUDENT ACTIVITY

The students were challenged to identify a problem related to long-duration space flight, propose a solution, and then design a passive experiment to help solve the problem. It was also a goal of the experiment that the projects had to have Earth-based applications. More than 60 projects from students in Ohio and Kentucky were submitted, with 30 of the projects approved for further development. Mentors from Wright Patterson AFB worked with the students to develop and refine their projects.

STUDENT PARTICIPATION

Twenty-seven student experiments, involving nearly 300 students from grades 1–10, have completed development. Eleven of these experiments have flown on the MISSE-2 carrier and are completed. The remaining experiments are awaiting future flight opportunities.

The 11 student experiments that have already flown are as follows:

LASER EFFICIENCY

Grade 5, Mills Lawn Elementary School, Yellow Springs, Ohio

In this experiment, students built a semiconductor laser, obtained efficiency curves for it, and measured its degradation after exposure to space.

DIRTY SHIRTS – WE HAVE THE SOLUTION

Grade 10, Stebbins High School, Mad River Township, Ohio

This experiment investigated the effects of the space environment on terrestrial and space-certified fibers to test a lightweight method of cleaning clothes on long-duration missions. ILC Dover, which manufactures the extravehicular mobility unit (EMU)—commonly called the spacesuit—for NASA, supplied the students with Kevlar, VecTran, and Ortho fabric for the test.

ALTERNATIVE CROPS FOR KENTUCKY

Grade 10, Simon Kenton High School, Independence, Ky.

This experiment evaluated the effects of the space environment on fibers of traditional Kentucky crops in hope of discovering a byproduct use for the altered crops, with an ultimate goal of replacing tobacco as the state's agricultural focus.

SPACE MOLD

Grade 6, Ankeney Middle School, Beavercreek, Ohio

This experiment evaluated the nutritional value of non-processed stable foods after exposure to the space environment to supplement diets for crews on long-duration missions and to reduce agricultural mold damage to world food banks.

BIG CHILL FOR FOOD-A-WAY

Grade 8, Radcliff Middle School, Jefferson Township, Ohio

This experiment tested the ability of processed foods to maintain their nutritional value after being exposed to the space environment. It is hoped that these foods will help supplement the diets for crews on long-duration missions to Mars.

STOP BACTERIA DEAD IN ITS TRACKS

Grade 10, Stebbins High School, Mad River Township, Ohio

This experiment tested the ability of human flora bacteria to survive in a spore state in the space environment.

EFFECTED BACTERIA

Grade 8, Radcliff Middle School, Jefferson Township, Ohio

This experiment tested the ability of agricultural bacteria necessary for plant survival to survive exposure to the space environment. These bacteria will be necessary for plants to germinate and survive in agricultural plots in colonies on the moon and Mars.

SAVING HUMAN LIVES: VIRUS IN SPACE

Grade 10, Stebbins High School, Mad River Township, Ohio

This experiment, which used a protein from a chicken retrovirus, looked into whether the space environment disrupts the AIDS [Acquired Immune Deficiency Syndrome] virus reproduction cycle.

ALIEN CATCHER

Grade 1, Incarnation School, Centerville, Ohio

The objective of this experiment, which was thought up by a creative and imaginative group of first-graders, was to photograph an alien by luring the alien into camera range using Reeses Pieces candies sewn into a fishnet.

First-grade students from Incarnation School, Dayton, Ohio explain their ISS experiment, Alien Catcher.





Students conducting a test for their MISSE project.

OHIO CONEFLOWER SEEDS

Purple coneflower seeds from Ohio were donated by the Ohio Department of Transportation and were distributed to state schoolchildren. The seed growth for these hardy wildflowers will be compared to results obtained in NASA’s earlier tomato seed experiments. This experiment is being coordinated by the Educational Outreach Office, Wright Patterson AFB, which will be responsible for distributing the seeds to various local schools.

PRAIRIE SEEDS FOR HUFFMAN PRAIRIE

Huffman Prairie at Wright Patterson AFB, Dayton, Ohio, is where the Wright Brothers tested their airplanes and perfected controlled flight. The seeds for this experiment, which is being coordinated through the Educational Outreach Office at Wright Patterson AFB, were harvested by hand from Ohio prairies and were

planted at Huffman Prairie by local schoolchildren to celebrate the 2003 Celebration of Flight.

In addition to developing these experiments, students were also involved in the design of the official MISSE mission patch. Tenth-grade art students from Dayton Christian High School, Dayton, Ohio, designed the patch, which was painted on plaques attached to the MISSE carrier. The paints used in these plaques, which were also part of the experiment, were space-qualified paints produced by AZ Technologies. The painted plaques acted as test patches to evaluate how the paints survive the space environment over long periods of time.



This project MISSE patch was designed by tenth-grade art students Mike Erikson and David Lee at Dayton Christian High School, Dayton, Ohio. It was adopted by the U.S. Air Force as their official mission patch.

- Principal Investigator(s): Daniel Cleyrat, Materials Laboratory, AFRL, Wright Patterson AFB, Dayton, Ohio
- Education Lead(s): Kathy Levine, Educational Outreach Office, Wright Patterson AFB, Dayton, Ohio
- Education Web Site(s): <http://www.ascexe.wpafb.af.mil/project%20misse%20index.htm>

SPACE EXPERIMENT MODULE (SEM)

Expedition(s): 10–11, planned for 13–14

Grade Level(s): K–12

Impact: Approximately 300 students from 11 schools, including the Native American Shoshone-Bannock High School, Fort Hall, Idaho, participated in this experiment.

EXPERIMENT DESCRIPTION

The Space Experiment Module (SEM) introduces students to the concept of performing space-based research on ISS, thus providing them with the opportunity to conduct their own research on the effects of microgravity, radiation, and space flight on various materials. Research objectives for each experiment are determined by the students, but generally include hypothesis on changes in the selected materials due to the space environment. This is done by providing students with space capsules to contain their experiments. These capsules are clear, sealable polycarbonate vials, 1 in. in diameter and 3 in. in depth. The vials are packed in satchels (20 per satchel). Each vial is a self-contained “passive” experiment that requires no external power, communications, or data recording capability.

The SEM satchel was first flown to the ISS aboard a Russian Progress vehicle in December 2004 during Expedition 10 and was returned to Earth in August 2005 aboard the space shuttle *Discovery* during the STS-114 mission. Two more SEM satchels, which contain follow-up experiments from the same 11 schools, are scheduled to launch on STS-121 (ULF-1.1) in the summer of 2006.

STUDENT ACTIVITY

Students select the items that will be contained inside the vials. Some of the items include seeds such as corn, watermelon, cucumber, beans, peas, and several other vegetable seeds. Additional items include materials such as wool, Kevlar, silk, ultraviolet beads, chicken bones, copper, plastic, dextrose, yeast, over-the-counter medications, human hair, mineral samples, light bulbs, and brine shrimp eggs. Many students test for seed growth after microgravity exposure; other students test how these materials protect against radiation exposure or test survival rates of microscopic life forms. After the experiment vials are returned from ISS, they are distributed to the participating schools for analysis.

STUDENT PARTICIPATION

Eleven different schools participated in the SEM-2 experiments (TABLE II).

Table II. SEM satchel experiments.

School	Grade	Experiment
Central Park Middle School, Schenectady, N.Y.	7	Cosmic Veggies Experiment
J.M. Bailey School, Bayonne, N.J.	K	How Do Our Beans Grow Experiment
Mott Hall School, New York City, N.Y.	8	Wearable Radiation Protection Experiment
American Museum of Natural History, New York City, N.Y.		Hayden Astro Materials Testing Experiment
Shoshone-Bannock High School, Fort Hall, Idaho	7–12	Natural Space Art Experiment
Bishop Borgess Academy, Redford, Mich.	9–12	Experiments for the Advancement of Research
Ogdensburg Public School, Ogdensburg, N.J.	K-8	Glowing Rocks Experiment
East Norriton Middle School, Norristown, Pa.	8	Materials Experiment
Shady Side Elementary, West River, Md.	4	Bright Ideas Experiment
Columbus High School, Columbus, Ga.	9–12	Survivability of Hardened Materials
Walkersville Christian Family School, Stockton, Md.		Garden of Eden Experiment

One of the student experiments flown in SEM-2 that is particularly noteworthy is the Wearable Radiation Protection Experiment that was developed by a group of eighth-graders at the Mott Hall School, a fourth- to eighth-grade math, science, and technology magnet school in New York City, N.Y. The experiment consisted of a number of small dosimeters that were each wrapped in pieces of common clothing material such as cotton, wool, silk, Lycra, etc. The objective of this experiment was to investigate which clothing material provides the greatest radiation shielding. One of the most impressive elements of the experiment was having eighth-graders tackling issues such as radiation shielding, which is one of the most challenging problems to be solved for our future exploration missions to the moon, Mars, and beyond.

Susan Herzog, a teacher at Mott Hall School, New York City, N.Y., writes:

After 9/11 NASA offered New York City schools the opportunity to participate in its student experiments in space program. At a time of deep sadness and demoralization we jumped at the chance to reach for the stars. We were accepted to fly our experiment aboard the SEM-14 module on Columbia shuttle mission STS-107. We brought ten students and a parent to KSC for the unforgettable experience of watching the launch of the shuttle bearing our experiment. The horrible, tragic loss of the crew and shuttle made us want to honor their memory by recreating our experiment when NASA offered us the opportunity to join the SEM-ISS mission. My students were invited to participate in a welcome at the American Museum of Natural History for the STS-114 crew who returned our SEM satchel-1 experiments to Earth from ISS. Our participation in these NASA student experiment in space missions has been a life-changing experience for my students, and for their teacher.



Students from Mott Hall School, New York City, N.Y. wrap fabrics around radiation dosimeters as they prepare samples for the Wearable Radiation Protection Experiment that was part of SEM-2.

Another notable experiment is Natural Space Art, which was developed by Native American students at the Shoshone-Bannock High School, Fort Hall, Idaho. This experiment investigated how painted materials such as wood, plastic, metal, and ceramic survive in the space environment. In addition, these students investigated whether painting as an art form could help combat depression in space.

Principal Investigator(s): Ruthan Lewis and Ed Parrott, NASA Goddard Space Flight Center (GSFC), Greenbelt, Md.

Education Lead(s): Teachers at each school

Education Web Site(s): <http://www.space-explorers.com/internal/tours/orblab.html>

STUDENTS PERFORMING CLASSROOM VERSIONS OF ISS EXPERIMENTS

These experiments, which are performed by students in their classrooms, mimic experiments that are being conducted, or have been conducted, by professional researchers on the station. The focus of these experiments is for students to observe differences in their results as compared to the experiments being performed by crews on the ISS.

ORBITAL LABORATORY

PART OF ADVANCED ASTROCULTURE (AdvAsc) AND PHOTOSYNTHESIS EXPERIMENT AND SYSTEM TESTING AND OPERATION (PESTO)

Expedition(s): 2, 4, 5

Grade Level(s): K–12

Impact: Since the performance of the first Orbital Laboratory during Expedition 2, a total of 2,423 teachers and 58,416 students have grown seeds in conjunction with seeds grown on ISS.



Dried *Arabidopsis thaliana* plants, from ISS Expedition 4, upon their return to Earth.

EXPERIMENT DESCRIPTION

Advanced Astroculture (AdvAsc) was a commercially sponsored payload that provided precise control of environmental parameters for plant growth, including temperature, relative humidity, light, fluid nutrients, and atmosphere. AdvAsc hardware was used in a series of tests over three different Expeditions. On Expedition 2, AdvAsc demonstrated the first “seed to seed” experiment in space by growing *Arabidopsis thaliana* (thale cress) through a complete life cycle. On Expedition 4, 35 percent of the space-grown seeds and 65 percent of the wild *Arabidopsis* seeds were grown on orbit, with samples preserved for genetic analysis. Finally on Expedition 5, soybean plants were grown through an entire life cycle from seed to seed.

Photosynthesis Experiment and System Testing and Operation (PESTO) grew wheat (*Triticum aestivum*) as part of a scientific investigation focusing on potential food production in space. Scientists measured the canopy photosynthesis (the rate of production of oxygen and carbohydrates [food] from carbon dioxide (CO₂) and water in the environment) under high light and controlled CO₂ conditions in microgravity.

TEACHER ACTIVITY

To prepare for student activities associated with this experiment, Space Explorers, Inc. performed several teacher workshops involving hundreds of teachers from schools across the United States. At the workshops, teachers reviewed the basic principles involved with growing plants on Earth and in microgravity and the differences between these environments. Different data collection exercises were summarized as well. Teachers were provided a detailed curriculum for the Orbital Laboratory, and the plant growth kits were mailed to the teachers’ classrooms for use.

STUDENT ACTIVITY

The Orbital Laboratory is an internet-based multimedia tool that allowed students and educators to conduct their own ground-based plant experiments and to analyze data returned from the AdvAsc units in their classrooms on Earth. The student activities for Expedition 2 focused on plant growth. The seeds growing in AdvAsc on ISS were mirrored by students on Earth growing seeds in their own plant growth systems. The on-orbit Expedition 4 activities used seeds harvested from the first generation of plants that grew on ISS. Focusing on genetics, the students grew the same seeds on Earth along with four mutations of the original seed. Daily status reports and images allowed the students to see how the experiment was doing on space station as they grew the seeds in their classrooms.

Expedition 5 combined two experiments from the space station into one classroom kit. Both the AdvAsc and PESTO investigations were studied by students during Expedition 5. “Cultivating Our Future” focused students on growing dwarf wheat and soybean crops as potential food for long-term

space travel. In this experiment, students grew these plants in the classroom to analyze a wide variety of plant characteristics, including three kinds of growth media—potting soil, zeolite, and vermiculite—to determine which media was the best for long-duration space flight. Students also researched the use of these plants on Earth to compare their value as potential food crops. Using the Orbital Laboratory database, students were able to compare their data to data that had been gathered by other students within this nationwide program, discuss their results, and exchange ideas with one another.

STUDENT PARTICIPATION

Approximately 58,416 students have participated in the Orbital Laboratory during Expeditions 2, 4, and 5. Experiment kits developed for the classroom remain available to teachers on a subscription basis, together with a set of 20 lesson plans. More than 2,000 teachers have subscribed to the lesson plans, which are in three modules: the first module teaches about the plants and data collection, the second module teaches about microgravity and the ISS, and the third module covers human physiology in space to teach students about the effects of microgravity on the human body.

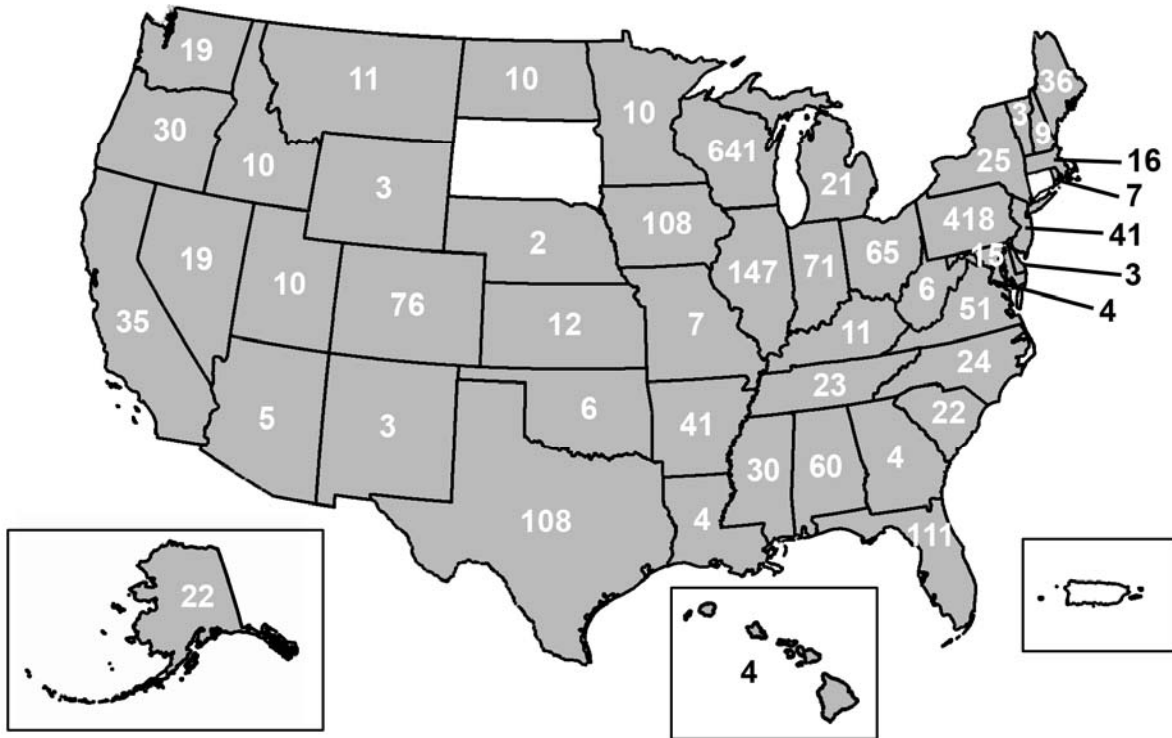
Karen Schonauer, whose classes in East Rochester, Ohio, took part in planting seeds for the Orbital Laboratory for three years, writes:

My two fifth-grade classes planted soybeans and wheat from October–December. They loved comparing plants between the classes. A little competition added to their excitement. I like the fact that metric measurements are used. It correlates with our metric measurements we collect for Global Learning and Observations to Benefit the Environment (GLOBE). It gives them more practice for comparison. My special needs students are also able to collect the data and could send the data with the help of peers in their group. This makes them feel successful. I'm looking forward to participating again next year. The program gives the students responsibility while they are learning. We need to give our students any opportunity we can to enrich their knowledge and "let them shine" in their own area. Our experience with Orbital Laboratory was especially enriching for one of my fifth-grade girls. IGA sponsored an essay contest as an Explore the Store project. They were to answer the question, "How would you use space exploration to benefit your hometown?" IGA chose 12 winners who won a free trip to USA Space Camp. One of my girls is a winner. I attribute her experience with the Orbital Laboratory seed experiment and our participation with the GLOBE program as part of the reason she was able to write a winning essay.



Tyler and Andrew, students in one of Karen Schonauer's fifth-grade classes in East Rochester, Ohio, measure plant growth as they participate in the Orbital Laboratory program.

Nationwide School Participation in Orbital Laboratory (2001-2002)



A total of 2,423 teachers across 48 states (plus the District of Columbia) subscribed to the Orbital Laboratory over its three missions.

Principal Investigator(s): Weijia Zhou, University of Wisconsin-Madison, Madison, Wis.; Tom Corbin, Pioneer Hi-Bred International, Inc., a DuPont Company (AdvAsc); and Gary Stutte, Dynamac Corporation, NASA Kennedy Space Center (KSC), Cape Canaveral, Fla. (PESTO)

Education Lead(s): James Schmidt, Space Explorers, Inc., De Pere, Wis.

Education Web Site(s): <http://www.space-explorers.com/internal/tours/orblab.html>

FARMING IN SPACE

PART OF BIOMASS PRODUCTION SYSTEM (BPS)

Expedition(s): 4

Grade Level(s): K–12

Impact: Forty-seven teachers participated in special workshops; four undergraduate pre-service teachers also participated in operating the project. Students and teachers in eight classrooms in Wheeling, W. Va., participated in Farming in Space.

EXPERIMENT DESCRIPTION

The Biomass Production System (BPS) evaluated the performance of a new piece of equipment for growing plants onboard ISS. *Brassica rapa* (field mustard) was used as a test species to validate the plant growth system and performance of the equipment. A coupled experiment, PESTO, grew wheat (*Triticum aestivum*) in the apparatus as part of a scientific investigation that focused on potential food production in space.

TEACHER ACTIVITY

To prepare for student activities associated with this experiment, four teacher workshops were performed to demonstrate Farming in Space to 47 teachers. At the workshops teachers reviewed the basic principles involved with growing plants on Earth and microgravity, and the differences in these environments. Materials were distributed including fluorescent lights, soil, and seeds so the teachers and students would have everything they needed to perform the plant experiments.

STUDENT ACTIVITY

While creating useful technology and science, BPS allowed students in grades kindergarten through 12 to work as co-investigators on real space research by participating in the Farming in Space program. Farming in Space examined the basic principles and concepts related to plant biology, agricultural production, ecology, and the space environment. These activities encouraged curiosity in the sciences while teaching scientific methodology. By performing these activities, the students involved in them learned fundamental aspects of plant biology and also gained scientific inquiry skills.



Students at White Mountain Elementary School, White Mountain, Alaska, participated in the Farming in Space activity.



Video screen shot of mustard plants 36 days after planting on station during Expedition 4. Students grew these same plants in their classrooms and compared their plants to the ones grown on ISS.

Some of the questions for investigation included:

- When do developmental changes—such as plant heights, formation of flowers, and development of seedpods—occur?
- How do various conditions influence outcomes?
- How many seeds are produced by each plant?
- What are the wet and dry masses of the plants?
- What are the harvest indices of the plants?
- How much starch do the plants produce?

These student investigations lasted from 21 to 100 days, depending upon the specific topic being researched by the students.

STUDENT PARTICIPATION

Students from eight classrooms in Wheeling, W. Va., participated in Farming in Space during Expedition 4. Students from kindergarten through high school worked online or in a laboratory to research, design, and run plant growth experiments. Their research paralleled the experiments flown on ISS.

Four undergraduate students, preparing for careers in education, contributed to the development of the lesson plans for the Farming in Space activity by setting up the experiments that were used in the classroom to collect baseline data.

When Meghan Nook from Rapids-Rice High School in Minnesota peers into the night sky, she imagines scientists on station conducting experiments similar to the ones that she is doing. The high school student spent February 2001 carefully observing the growth of four plant varieties in the corner of her high school's aerospace classroom. Meghan is participating in one of NASA's Classroom of the Future projects involving Farming in Space. Observations included the number of seeds that germinated, whether the wick was drawing the nutrient solution up into the soil efficiently, and root growth. Throughout the experiment, Meghan was able to discuss findings with NASA scientists and receive advice from them. She was surprised to find the scientists were so easily accessible.



Expedition 4 Flight Engineer Dan Burch, in the Destiny U.S. Laboratory, harvests Brassica plants from plant growth chamber 2 as part of BPS.

Principal Investigator(s): Robert Morrow, Orbital Technologies Corporation, Madison, Wis. (BPS), and Gary Stutte, Ph.D., Dynamac Corporation, NASA KSC, Cape Canaveral, Fla. (PESTO)

Education Lead(s): Laurie Ruberg, Wheeling Jesuit University, Center for Education Technologies, Wheeling, W. Va.

Education Web Site(s): <http://quest.arc.nasa.gov/lrc/farming/farming.html>
<http://www2.cet.edu/ISS/activities/newfarming.html>

JASON XI – GOING TO EXTREMES

EDUCATION-SPACE EXPOSED EXPERIMENT DEVELOPED FOR STUDENTS (EDUCATION-SEEDS)

Expedition(s): 1

Grade Level(s): 4–9

Impact: A total of 750,000 students across the U.S. have been introduced to the effect microgravity has on plants through live broadcasts and classroom exercises due to the Jason XI – Going to Extremes project.

EXPERIMENT DESCRIPTION

During JASON XI, researchers and students grew seeds in a series of artificial environments to see how different factors affected their growth and development by testing different conditions of light and pressure on plant growth at NASA JSC in Houston and the *Aquarius* Underwater Laboratory in the Florida Keys. During this two-week period, scientists and students conducted five live broadcasts daily to report on the progress of the seeds and to demonstrate how humans live and work in extreme environments. On Expedition 1, the seeds that were grown for the JASON XI project were sent to the station to have the crew observe seed growth in microgravity conditions. On-orbit videotape and photographic images were taken of plant germination and early growth. Imagery was converted to educational videos to excite and engage students in science and technology, and to motivate and provide professional development for educators.

STUDENT ACTIVITY

JASON XI – Going to Extremes looked at sea and space through the eyes of modern-day explorers. The *Aquarius* Underwater Laboratory in the Florida Keys was compared to the ISS as research platforms that enable humans to go beyond their physical limitations to explore the unknown. The JASON XI project had two educational components: First, students were selected from across the country and traveled to conduct the experiment with scientists. Second, classroom curricula were created from the experiments that were conducted and applied by all the participating schools.

Students participating in the “extreme environment” portion of the project assisted scientists during daily one-hour broadcasts from NASA JSC and *Aquarius*. Five live broadcasts occurred each day during the two weeks of the JASON project from NASA JSC and *Aquarius*.



Student Mitchell Graves and educator Vicki Hamilton at the alluvial fans of Death Valley National Park, Calif., during the JASON project: Mysteries of the Earth and Mars in 2005.

Following completion of JASON XI at the remote locations, packets of seeds exposed to microgravity on ISS and accompanying curriculum were provided to teachers across the country for use in their classrooms. Students grew the seeds the same way the seeds were grown at NASA JSC, *Aquarius*, and ISS. Using the JASON Web site, the students compared their results to results from NASA JSC, *Aquarius*, and ISS. The

curricula provided by the JASON project met National Science Education Standards, National Geography Standards, and National Educational Technology Standards for Students.

Mitchell Graves, a student from Clarksdale, Miss., was selected to travel to NASA JSC in Houston to be a part of the live broadcasts. While at NASA JSC, Mitchell had the opportunity to learn firsthand what it takes to be an astronaut working on a space shuttle or the ISS, how astronauts train for space missions, and the importance of spacesuits and robotics in space. Regarding this experience, Mitchell stated: "Becoming an astronaut is a goal I set when I was four or five years old. I want to be the first astronaut on Mars." Mitchell is on his way to achieving his goal of becoming an astronaut. He is now a student at Embry-Riddle Aeronautical University, Daytona Beach, Fla.

Principal Investigator(s): Howard Levine, NASA KSC, Cape Canaveral, Fla., and Fredrick Smith, NASA JSC, Houston, Texas

Education Lead(s): Robert Ballard, JASON Project, Ashburn, Va.

Education Web Site(s): <http://www.jasonproject.org>

Expedition 1 commander Bill Shepherd is shown with a SEEDS pouch. Additional pouches are attached to the panel in front of Shepherd above the "Astronauts at Work" sign.



BASIL SEEDS IN SPACE

PART OF MATERIALS INTERNATIONAL SPACE STATION EXPERIMENT-3 AND -4 (MISSE-3/4)

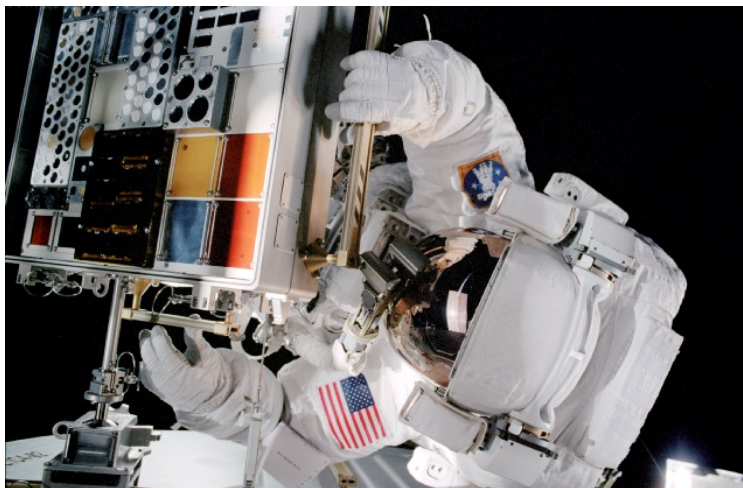
Expedition(s): 13–15 (planned), scheduled to launch on STS-121 and remain on ISS for 1 year

Grade Level(s): K–12

Impact: As many as two million students will grow seeds exposed to space to compare with control seeds that remain on the ground.

EXPERIMENT DESCRIPTION

MISSE is a suitcase-sized materials exposure facility mounted externally on ISS that is designed to evaluate the durability of materials and coating exposed to the extreme environment of space (atomic oxygen, radiation, vacuum, thermal cycling, micrometeorites, etc.). On the MISSE-3 and -4 carriers that are scheduled to fly to ISS on STS-121 in 2006, a package of 8 million basil seeds from the Park Seed Company of South Carolina have been included that will be exposed to the space environment for approximately one year, subjecting the seeds to microgravity, vacuum, radiation, and thermal cycling.



An astronaut installs an MISSE carrier on the outside of station during the STS-105 mission.

STUDENT ACTIVITY

After the seeds are returned to Earth (following a 1-year period mounted to the outside of ISS), they will be packaged and made available to schoolchildren along with packs of “control” seeds that remained on Earth and were not exposed to the space environment. Students will grow the “space” seeds and “ground” seeds side by side to look for differences resulting from space exposure. This activity is modeled closely after the successful tomato seeds student experiment SEEDS that flew on NASA’s Long-Duration Exposure Facility in the 1980s.

STUDENT PARTICIPATION

Sufficient seeds will be available for an estimated 2 million students to participate in this experiment. Exact details of distribution, student experiment reporting, etc. are pending.

Principal Investigator(s): William Kinard, NASA Langley Research Center (LaRC), Hampton, Va.

Education Lead(s): To be appointed

CGBA SCIENCE INSERT (CSI)

Expedition(s): 14–15 (planned)

Grade Level(s): 5–8

Impact: When fully implemented, the goal of this experiment is to reach at least 500 schools and, correspondingly, many thousands of students.

STUDENT ACTIVITY

Simple educational payloads targeting middle school students will be placed inside the Commercial Generic Processing Apparatus (CGBA) and monitored via an electronic still camera and video camera. The first payloads scheduled for CSI will study seed germination and early plant development, *Caenorhabditis elegans* as a model organism, and the behavior of blue-banded (stingless) bees for their ability to adapt to the space environment.

Using curriculum developed by BioServe Space Technologies, its partners, and NASA, students will start the experiment in the classroom on the same day (or a later date, if the teacher chooses) as the astronauts initiate the Commercial Generic Bioprocessing Apparatus Science Insert (CSI) experiment on ISS. Students will use the internet to compare the progress of their experiment with the corresponding



Expedition 2 ISS crewmember Jim Voss listens to high schools students from New York explaining their space flight research experiment for the STARS program.

experiment onboard the space station. At the conclusion of the experiment cycle, students can upload their results on the Web site to be compared to results from students at other schools participating in the program. Once the experiment is complete, the entire program will be archived and available to other educators via the internet for use in their classrooms.

STUDENT PARTICIPATION

This project is in the development phase but is scheduled for activities during future ISS Expeditions. The initial goal for Expedition 14 is to reach 100 schools, involving approximately 7,500 students, with expansion over subsequent Expeditions.

CGBA has flown on over 20 space flight missions to date. BioServe Space Technologies has a long history of educating the next generation of scientists and engineers. The company has been involved in previous space flight educational programs including “Lady Bugs in Space” onboard STS-93 involving students from Chile and the United States and Spacehab’s STARS program onboard STS-107, which involved thousands of students from around the world.

CSI will be used to inspire future generations of engineers and scientists as well. CSI provides a yearly ISS-based, two-week educational program that includes a standards-based curriculum to middle school teachers. In addition, because the program enables students to participate in actual, near-real-time science being conducted onboard ISS and to conduct their own concurrent ground controls, they experience the excitement of space-based research firsthand. This allows for a unique educational experience that the students will remember for many years.

Principal Investigator(s): Louis Stodieck, BioServe Space Technologies, Boulder, Colo.

Education Lead(s): Stefanie Countryman, BioServe Space Technologies, Boulder, Colo.

EDUCATOR ASTRONAUT

PART OF EDUCATION PAYLOAD OPERATIONS-EDUCATOR (EPO-EDUCATOR)

Expedition(s): 15, planned to begin with STS-118/13A.1, April 2007

Grade Level(s): K–12

Impact: It is expected that many thousands of students, and a large number of schools across the United States, will participate in activities associated with astronaut Barbara Morgan's space shuttle flight to the ISS during Expedition 15. Special outreach will link to the 176 NASA Explorer School teams.

EDUCATIONAL ACTIVITY

Educator Astronauts are full-time NASA astronauts who have experience and skill in K–12 classroom education. Their role is to help lead NASA in the development of new ways to connect space exploration with the classroom, and to inspire the next generation of explorers. Educator Astronaut Barbara Morgan is scheduled to fly to ISS on shuttle flight STS-118 (13A.1) during Expedition 15. The theme for educational activities on the flight will be habitats. Three shuttle crewmembers and a space station crewmember will demonstrate aspects of the space shuttle mission in building and re-supplying ISS. Seeds and growth chambers will be set up by the crew, and growth will be completed on ISS after the shuttle returns to Earth. Students will participate in their classrooms by using identical growth chambers and seeds. The curriculum will focus on aspects of the human habitat in the station, and how that relates to habitats on Earth.



Educator Astronaut Barbara J. Morgan.

STUDENT ACTIVITY

Students will participate in their classrooms by using identical growth chambers to grow plants from seeds. They will also compare the growth of space-flown seeds with control seeds kept on the ground. The curriculum will focus on aspects of ISS and its mission, the human habitat in the station, and how living in space relates to habitats on Earth.

STUDENT PARTICIPATION

Thousands of students from schools across the United States are expected to participate in this program associated with the flight of the first Educator Astronaut, Barbara Morgan, on STS-118 in April 2007. Full details on this project are still under development.

Education Lead(s): Cynthia McArthur, NASA JSC, Houston, Texas

Education Web Site(s): <http://edspace.nasa.gov/>



Video screen shot of ISS Expedition 9 Science Officer Mike Fincke performing the EPO Puzzles demonstration.

STUDENTS PARTICIPATING IN NASA INVESTIGATOR EXPERIMENTS

Many of the NASA research investigators have enlisted students to help them on their experiments. Some of these experiments are done solely to “inspire the next generation of explorers.” Others involve undergraduate and graduate students as well as postdoctoral fellows who are working under the guidance of investigators and university professors on their NASA research

STUDENT ACCESS TO SPACE

PART OF PROTEIN CRYSTAL GROWTH-ENHANCED GASEOUS NITROGEN (PCG-EGN) DEWAR

Expedition(s): 0–2, 4

Grade Level(s): 5–12

Impact: Approximately 58,000 students and almost 1,200 teachers have been involved in this program thus far. Of that number, more than 420 students and 260 teachers have been involved in the Student Flight Sample Workshops.

EXPERIMENT DESCRIPTION

The primary objective of the Protein Crystal Growth-Enhanced Gaseous Nitrogen (PCG-EGN) experiment was to provide a low-cost, simple platform for the production of a large number of protein crystals in space. Prior to launch, scientists placed the samples in the EGN Dewar (a thermos-like container that has an absorbent inner liner saturated with liquid nitrogen). Launched aboard the shuttle, the sample Dewars were transferred to ISS for processing. After about 10 days, when the nitrogen had evaporated and thawing was complete, the biological solutions began to form crystals. Once returned to Earth, the crystals were analyzed for internal quality, three-dimensional structure, and the factors that influenced crystal growth.

TEACHER ACTIVITY

In preparation for the student activities associated with this experiment, more than 45 teacher workshops were held involving over 1,200 teachers from all 50 states, the District of Columbia, and many teachers from the DoD bases in Germany and other countries. Teachers went through the basics of protein crystal growth and structural biology and were taught how to extract DNA [deoxyribonucleic acid] from strawberries and other samples and how to grow protein crystals. They were provided with detailed curriculum guides, National Institutes of Health (NIH) Science Guides, and hands-on protein crystal growing kits for their students.

STUDENT ACTIVITY

Classroom protein crystal growing kits were distributed to the classrooms with each kit supporting three classroom experiments that took 7–10 days to complete. The experiments compared eight different conditions for crystal growth, and students counted the number of crystals grown and measured their size over time for each growing condition. By doing this students were taught the process of making observations, recording data, and preparing experiment reports.

Students also competed to participate in the Protein Crystals in Space Program, where they attended a Student Flight Sample Workshop. In the workshops, which were held before each experiment flight to ISS, students and teachers worked beside scientists from the University of California, Irvine and NASA. They prepared, froze, and sealed the protein solutions in small tubes. This activity taught students how to perform crystallization experiments in the classroom and on the ISS. The students prepared and loaded actual flight samples into the flight EGN-Dewar facility, were present at launch, and received their samples back after flight. On Earth, students viewed photos, on a special Web site, of some crystals grown during NASA workshops.

STUDENT PARTICIPATION

More than 1,000 high school and 300 elementary/middle school experiment kits were distributed with approximately 45,000 students participating in the ground-based classroom activity growing protein crystals. These schools represented 38 of the 50 states. More than 420 students (grades 6–12) and 260 teachers participated in the Student Flight Sample Workshops that actually prepared protein crystal samples for the ISS experiment.



Leann, a student from Ridgeview High School in Orange Park, Fla., and Danielle, a student from Terry Parker High School in Jacksonville, Fla., complete sample preparation as part of Student Access to Space Activities.

Student Access to Space focused on providing access to all students by seeking to reach underserved inner-city and rural schools, special needs and gifted students, and mainstream schools. Including students with disabilities was a particular goal. Leann from Ridgeview High School in Clay County, Fla., performed all of the tasks involved in the program despite being confined to a wheelchair during the NASA KSC workshop. Her space sample launched to ISS in February 2001. Danielle, a student at Terry Parker High School in Jacksonville, Fla., who has been blind since birth, completed the lab activity at her high school. She produced a research project using special internet search software and participated in the protein crystallization activity at NASA Marshall Space Flight Center (MSFC), Huntsville, Ala. All of the lab equipment was labeled in Braille, allowing Danielle to complete the activity. Danielle produced a lysozyme protein sample that flew to space station in September 2000.

Principal Investigator(s): Alexander McPherson, University of California-Irvine, Irvine, Calif.
Education Lead(s): Anna Holmes, Ph.D., University of Alabama-Huntsville, Huntsville, Ala., and Greg Jenkins, NASA MSFC, Huntsville, Ala.
Education Web Site(s): <http://crystal.uah.edu/holmes/menagerie.htm>

CREW EARTH OBSERVATIONS (CEO)

Expedition(s): 1–13, ongoing

Grade Level(s): 3–12, undergraduate, teachers (formal and informal)

Impact: Although the primarily informal educational activities associated with CEO are difficult to track, an estimated 1,663 teachers have been trained to use CEO imagery in their classrooms. In addition to the students and teachers around the country who may have implemented online curriculum materials, at least 275 students have participated directly in Lewis and Clark Expedition-related activities. A further 6,300 teachers and 2,700 students have subscribed to Earth Observatory and receive the ISS Image of the Week. Additional projects are under development, including one expected to reach 1.8 million museum visitors.

EXPERIMENT DESCRIPTION

The goal of Crew Earth Observations (CEO) is to obtain qualitative and quantitative digital photographs of Earth for use in educational and scientific applications. The imagery is taken by space station crews using digital cameras over specified regions of the Earth. CEO target site selection criteria include indicators of global change, conservation management monitoring sites, terrestrial analogs of features found on other planetary surfaces, human settlements, and topical events demonstrating our dynamic planet. Examples of selected targets include river deltas, glaciers, and water level changes in lakes (global change); ecological preserves and coral reefs (conservation); impact craters and volcanic fields (planetary studies); cities, agriculture, and explorer trail geography (human settlements); and large storms, forest fires, or dust storms (dynamic events). Image data resulting from the CEO experiment are distributed via the publicly accessible “Gateway to Astronaut Photography,” found at <http://eol.jsc.nasa.gov>, which contains more than 185,000 images of the Earth taken from ISS. The database, which is accessed by educators, students, scientists, and the general public from over 130 countries, supports roughly 750,000 image downloads per month.

EDUCATION ACTIVITIES

Because of its popularity with students and educators, CEO has participated in a wide variety of formal and informal educational activities since the beginning of the ISSP. The activities reach from third to twelfth grades and include the teachers as well as college/university students and professors. Many of the educational activities were funded by other groups or organizations and CEO provided knowledge, guidance, briefings, training classes, desk space, and/or computers to support activities. Often, Earth scientists in the CEO project identify suitable images collected from ISS and help to link them to specific educational objectives. These scientists also develop captions, labels, and other interpretive tools to help students and teachers understand the images they are using. TABLE III highlights some of the projects that have incorporated astronaut photography of Earth from ISS into their education products.



University educators and students examine CEO-acquired imagery of the Lewis and Clark Expedition route at an Environmental Systems Research Institute (ESRI)-sponsored conference on Geographical Information Systems, 2003.

During Expedition 7, crewmember Ed Lu participated in the celebration of the 200th anniversary of the Lewis and Clark Expedition by taking images along specified points along the trail. CEO coordinated through the JSC Teaching from Space Program with Alex Philp, President of GCS Research L.L.C. and Director, Geospatial Research Group, Department of Geography, The University of Montana, Missoula, Mont. GSC Research included NASA data and astronaut imagery in a Web site that highlighted the Lewis and Clark Expedition. Alex Philp said “We want people to be able to explore the geography of the Lewis and Clark Trail and discover a sense of change occurring across these diverse landscapes . . .” Other partners included AESP Education Specialists from Montana and Nevada; Earth Observing System Education Project based at the University of Montana, Missoula, Mont.; Oregon Public Education Network; Dr. Ken Karzminski, a leading Lewis and Clark archeologist researcher; the Columbia Gorge Discovery Center, The Dalles, Ore.; and the Natural Science Museum, Marietta, Ohio. As a further result of the project, CEO images were included in a book on the natural history of the Lewis and Clark Trail entitled *Beyond the Stony Mountains, Nature in the American West from Lewis and Clark to Today* (Daniel B. Botkin, Oxford University Press, N.Y., 2004).

Principal Investigator(s): Sue Runco, NASA JSC, Houston, Texas
Education Web Site(s): <http://eol.jsc.nasa.gov>



Astronaut Dan Bursch, a member of the Expedition 4 crew on ISS, took this CEO image of Mt. Everest in late March 2002. The image is part of “Find Mt. Everest,” a geographical tutorial available on the Gateway to Astronaut Photography Web site.



The terminus of the Veidma Glacier is shown in this photograph taken from ISS by the Expedition 13 crew. This image, which was the image of the week on NASA’s Earth Observatory, was published with an explanation of the various data sets scientists are using to monitor the effects of global climate changes on glaciers worldwide.

Table III. Educational projects incorporating CEO images of Earth from ISS.

Project Name	Activity	Impact	Link
Informal Education			
Earth Observatory, David Herring, NASA GSFC	The NASA Earth Observatory Web site highlights a wide variety of remotely sensed data through an “image of the day” that is accompanied by a descriptive article with background information relevant to the image (geology, biology, climatology, history, etc.) Feature articles discuss topics in more detail. Weekly, CEO contributes one of the “images of the day”—an Earth image taken from ISS.	The Web site is accessible to general public education and provides a resource for educators. Of the approximately 45,000 subscribers worldwide, survey responses indicated that 14 percent were teachers and 6 percent were students (about 6,300 teachers and 2,700 students), primarily college level.	http://earthobservatory.nasa.gov
Windows on Earth, Dan Barstow, Technology Education Research Center (TERC)	National Space Foundation (NSF)-funded museum exhibit (in work) displaying an orbiting lab and an interactive exhibit and Web page about understanding Earth processes through various types of Earth observations from orbit. Displays featured at the Museum of Science, Boston, Mass.; National Air & Space Museum, Washington, D.C.; St Louis Science Center and Montshire Museum of Science (Vt.), plus three additional museums by project end.	In work (May 2008 completion). Anticipates reaching 1.8 million museum visitors, targeted at K–8 students.	
Teacher Training			
NASA Middle School Aerospace Scholars (NaMAS) Workshop	NaMAS is providing both teachers and students in eight states opportunities to learn about and experience information technologies and how they are used within the context of science, technology, engineering, and mathematical applications. Participating teachers complete training at NASA JSC and online over the course of a year, including use of CEO images of Earth, in their science curricula.	Approximately 325 K–12 teachers have participated in these workshops.	http://www.aerospaceacademy.org/math_science.shtml
Astronaut Photography: Observing Earth’s Systems from Space, Rebecca Dodge, Univ. of West Georgia, Carrollton, Ga.	Use of astronaut photography in training pre-service teachers about Earth system science and remote sensing, and helping them use CEO imagery to facilitate inquiry-based investigations by students.	A total of 415 pre-service and in-service teachers have taken part in this training.	http://eol.jsc.nasa.gov/Education/ES/ (sample Web material)

Project Name	Activity	Impact	Link
Teachers on the Leading Edge, Robert Butler, Univ. of Portland, Portland, Ore.	Combine contributions from classroom teachers and geoscientists to promote active learning of Earth science in Oregon and southwest Washington schools.	Six K–12 teachers and 20 geoscientists from universities and government agencies from the Portland area planned an NSF workshop targeting K–12 educators, under development.	http://lewis.up.edu/TOLE/
Materials and Direct Participation			
Lewis and Clark Geosystem Project, Alex Philp, GCS Research and the University of Montana, Missoula, Mont.	During Expedition 7, crewmember Ed Lu participated in the celebration of the 200 th anniversary of the Lewis and Clark Expedition by taking images along specified points along the trail. The Quickbird satellite data and astronaut photography were used in a Web site that highlighted the Lewis and Clark Expedition. Materials were extended to educational products by the Mars Society, U.S. Geological Survey (USGS), ESRI K–12 Education program, museums, and others.	Most of the educational impact was not enumerated. The 800 geography teachers who were members of the Montana Geographic Alliance used the materials in their classes. Approximately 275 students and 25 teachers participated in field trips to the display at geographic information systems (GIS) day in Washington D.C. An uncounted number of students and teachers used the Web sites and participated in accompanying activities in their classrooms.	http://www.eoscenter.com/index.cfm?fuse=imagery (click on “Astronaut Photography”)
Time Travelers, Teaching American History Competition award, Sally Thomas, University of Montana, Missoula, Mont.	CEO images will be requested to link with the study of historical trails in the Pacific Northwest. The project targets teachers as part of the continuing education requirements for teachers in the Northwestern U.S. The images will be used in an online learning curriculum during the school year as well as during summer institutes for the next three years.	Eighty-two teachers will be reached by this project (i.e., 22 in 2006 and 30 each expected in 2007 and 2008).	
Americaview Texasview	Americaview is a collaboration between the USGS and a consortium of universities that seeks to increase the use of remotely sensed data as an educational resource. The affiliation will incorporate images of Earth from CEO into educational outreach products made by the consortium.	Under development.	http://www.americaview.org/ http://www.texasview.org/

POLYMER EROSION AND CONTAMINATION EXPERIMENT (PEACE)

PART OF MATERIALS INTERNATIONAL SPACE STATION EXPERIMENT-2 (MISSE-2)

Expedition(s): 3–11, student data analysis continues

Grade Level(s): 9–12

Impact: Seventeen students have gone through or are currently working in the program.



Members of the MISSE-PEACE team from Hathaway Brown School, Shaker Heights, Ohio, in a clean room at NASA GRC, Cleveland, Ohio.

EXPERIMENT DESCRIPTION

MISSE, a suitcase-sized materials exposure facility mounted externally on ISS, is designed to evaluate the durability of materials and coating exposed to the extreme environment of space (atomic oxygen, radiation, vacuum, thermal cycling, micrometeorites, etc.). MISSE-2 was launched to station aboard STS-105 in August 2001 and retrieved on STS-114 in August 2005. The Polymer Erosion and Contamination Experiment (PEACE) consisted of 41 polymer samples mounted on the MISSE-2 carrier. The scientific aim was to evaluate how the polymers survived exposure to the space environment. Results will provide a better understanding of the durability of various materials when they are exposed to

the space environment. Many of the materials that will be tested may have applications in the design of future spacecraft.

STUDENT ACTIVITY

Two of the MISSE principal investigators, Kim deGroh and Bruce Banks, both from the NASA Glenn Research Center (GRC) in Cleveland, Ohio, initiated a partnership between NASA and Hathaway Brown, an all-female high school located near GRC. Students assisted the scientists in the laborious process of preparing the samples for the flight to ISS. Now that the samples have been returned, another set of students is assisting scientists in the data analysis.

STUDENT PARTICIPATION

The program has been successful in encouraging female students to enter careers in the physical sciences and engineering. Since the NASA GRC-Hathaway Brown partnership began in 2001, a total of 17 students have gone through or are currently working in the program. The success rate is high, with many of the 17 students who have graduated pursuing careers in science and technology. Two graduates of the program are attending the Massachusetts Institute of Technology (MIT), one just graduated from West Point with a degree in physics, and another is now completing her doctorate in chemistry from Washington State University.



PEACE experiment students Maura Lillis, Chris Youngstrom, and Laura Marx received bronze medals and \$500 scholarships for their research paper entered in the Siemens Westinghouse Math and Science Technology Competition in 2002.

Principal Investigator(s): William H. Kinard, NASA LaRC, Hampton, Va. (MISSE-2), Kim deGroh, NASA GRC, Cleveland, Ohio (PEACE Investigator)

Education Lead(s): Patty Hunt, Hathaway Brown School, Shaker Heights, Ohio

Education Web Site(s): <http://www.hb.edu/school/upper/spotlight/srp/peace/>

STUDENT INVOLVEMENT IN OTHER ISS RESEARCH PAYLOADS

Grade Level(s): Undergraduate, graduate, and postdoctoral, K-12
Impact: A total of 105 undergraduates, 189 graduate students, 27 postdoctoral fellows, and 162 K–12 students participated in 27 different ISS research investigations.

As part of information gathered for this document, all ISS principal investigators were contacted to supply information about student involvement in their research. A sustained and cumulative impact of ISS research was reported by many investigators. There is likely additional student involvement in projects that did not respond to our survey. In most cases the responding investigators had invited university students at a variety of levels to participate in some aspect of their ISS research. Payloads and impacts that have not been included elsewhere in this document along with associated student activities are summarized below. We first describe the basic objectives of the research, and then the student participation. Numbers of participating students are summarized in [TABLE IV](#).

ANALYSIS OF A NOVEL SENSORY MECHANISM IN ROOT PHOTOTROPISM (TROPI), PLANNED FOR 2006

John Kiss, Miami University, Oxford, Ohio

Plants sprouted from seeds will be videotaped and samples collected will be analyzed at a molecular level to determine what genes are responsible for successful plant growth in microgravity. Insights gained from Tropi can lead to sustainable agriculture for future long-duration space missions.

In this experiment, undergraduate, graduate students, and postdoctoral fellows completed basic ground-based research to support the flight experiment. Graduate students and postdoctoral fellows also optimized postflight protocols for analysis of flight samples. In addition, postdoctoral fellows assisted in the development, testing, and assembly of flight hardware, developed flight products, performed biocompatibility experiments, and will complete postflight data analysis.

BINARY COLLOIDAL ALLOY TEST-3-CRITICAL POINT (BCAT-3-CP), EXPEDITIONS 8–10, 12, 13, ONGOING

David Weitz, Harvard University, Cambridge, Mass.

Astronauts photograph samples of polymer and colloidal particles (tiny nanoscale spheres suspended in liquid) that model liquid/gas phase changes. Results will help scientists understand the phase behavior of a model colloid-polymer system that is near its critical point, the point at high pressure and temperature in atomic systems where the materials has properties of both liquid and gas.

A graduate student has assisted with training astronauts, helped design the science, prepared the samples, and presented the results.



Expedition 10 Science Officer Leroy Chiao performs the BCAT experiment in the Destiny U.S. Laboratory on ISS.

BOILING EXPERIMENT FACILITY-NUCLEATE POOL BOILING EXPERIMENT (BXF-NPBX), PLANNED FUTURE

Vijay Dhir, University of California at Los Angeles, Los Angeles, Calif.

BXF-NPBX will provide an understanding of the heat transfer and vapor removal processes that take place during nucleate boiling from a well-characterized surface in microgravity. Such an understanding is needed for optimum design and safe operation of heat exchange equipment employing phase change for transfer of heat in microgravity.

Undergraduate students were involved in the development of the control logic required such that the ground-based experiments could be conducted with minimal interaction. Graduate students were involved in the design and fabrication of the experiment, as well as in conducting the experiments in the laboratory and in the low-gravity environment of the KC-135 aircraft while they also developed the numerical simulations for this experiment. Postdoctoral students supervised the graduate students while conducting the experiments and performing the numerical simulations.

CAPILLARY FLOW EXPERIMENT (CFE), EXPEDITIONS 9, 12, 13, ONGOING

Mark W. Weislogel, Portland State University, Portland, Ore.

CFE is a suite of fluid physics flight experiments that investigates capillary flows and flows of fluids in containers with complex geometries. Results will provide computer models that may be applied by designers of low-gravity fluid systems in future spacecraft.

High school students conducted analyses and ground-based experiments. At the same time, undergraduate students provided experiment support, while graduate and postdoctoral students worked on modeling and data reduction efforts.

Astronaut William S. (Bill) McArthur Jr., Expedition 12 commander and NASA space station science officer, prepares the CFE for video documentation.



COMMERCIAL BIOMEDICAL TEST MODULE (CBTM), EXPEDITION 4

Ted Bateman, BioServe Space Technologies, Boulder, Colo., and Paul Kostenuik, Amgen, Thousand Oaks, Calif.

CBTM provided the capability to use the microgravity environment to evaluate new pharmaceutical candidates in small mammals. Results may expedite the review of new pharmaceuticals for allowing immediate access to new disease treatments.

All students, undergraduate through postdoctoral, participated in the design and development of the research as well as the mission operations and integrations activities in support of this experiment. The graduate students were also involved extensively in the research, hardware, mission integration and operation, tissue analysis, and data reporting activities associated with this experiment, while the postdoctoral students led many of the postflight tissue analyses.

COMMERCIAL GENERIC BIOPROCESSING APPARATUS-ANTIBIOTIC PRODUCTION IN SPACE (CBGA-APS), EXPEDITIONS 2-4

David Klaus, BioServe Space Technologies, Boulder, Colo.

Previous studies showed increased antibiotic production during short-duration space flights. The CBGA-APS investigation examined actinomycin D (an antibiotic) production during long-term exposure to microgravity to determine the mechanism that caused increased antibiotic production.

Undergraduate and graduate students were involved in all aspects of the design, test, and operation of the payload, as well as in the research conducted for this project.



Astronaut, Carl Walz works with CPCG-H in the Destiny U.S. Laboratory during ISS Expedition 4.

COMMERCIAL PROTEIN CRYSTAL GROWTH-HIGH DENSITY (CPCG-H) AND DYNAMICALLY CONTROLLED PROTEIN CRYSTAL GROWTH (DCPCG), EXPEDITIONS 2-4

Lawrence DeLucas, University of Alabama-Birmingham, Birmingham, Ala.

The objectives of CPCG-H and DCPCG were to produce large, well-ordered crystals of several different macromolecules for use in X-ray diffraction studies. Both investigations examined the performance of the new hardware developed for macromolecular crystal growth experiments in microgravity. A detailed knowledge of the atomic, three-dimensional structure of protein molecules has important applications in structure-based drug design.

Royalties from previous drug development stemming from protein crystal growth were used to develop a protein crystal growth kit for use in high schools. The kit used gels as a microgravity simulation. One student made it to the Alabama state science finals based on these results. This activity ended when further crystal growth on ISS was cancelled. Undergraduate students participated in sample preparation and analysis, while Ph.D. students used protein crystal growth data as a component of their dissertations.

CREWMEMBER AND CREW-GROUND INTERACTION DURING INTERNATIONAL SPACE STATION MISSIONS (INTERACTIONS), EXPEDITIONS 2-9

Nick A. Kanas, Veterans' Affairs Medical Center and University of California at San Francisco, San Francisco, Calif.

Weekly questionnaires were completed to identify and define important interpersonal factors that may impact the performance of the crew and ground support personnel during ISS missions in Interactions. The results of the study may be used to improve methods for crew selection, training, and in-flight support.

A postdoctoral student created a questionnaire and distributed it to flown astronauts, then analyzed the data provided and presented results in several papers.

EFFECTS OF EXTRAVEHICULAR ACTIVITY (EVA) AND LONG-TERM EXPOSURE TO MICROGRAVITY ON PULMONARY FUNCTION IN FLIGHT (PUFF), EXPEDITIONS 3–6

John B. West, University of California-San Diego, La Jolla, Calif.

Various breathing tests were performed as part of PuFF before, during, and after flight to determine whether pulmonary function is affected by long-term exposure to microgravity or EVAs (extravehicular activities, or spacewalks). Changes due to long stays on orbit, either from removal of gravity or from exposure to contaminants in the closed spacecraft environment, could adversely affect crew health.

An undergraduate student assisted with real-time data analysis from subjects on ISS.

EFFECTS OF WEIGHTLESSNESS ON SKELETAL MUSCLE (BIOPSY), EXPEDITIONS 5–11

Robert Fitts, Marquette University, Milwaukee, Wis.

Changes in limb skeletal muscle and cellular mechanisms of muscle degradation are assessed in Biopsy to predict the effects on humans during long-duration exploration missions. Tests include calf muscle biopsies, performance tests, and MRIs [magnetic resonance imaging].

Two K–12 students were responsible for the gel electrophoresis process in identifying protein typing.

FLUID MERGING VISCOSITY MEASUREMENT (FMVM), EXPEDITIONS 9, 11

Edwin C. Ethridge, NASA MSFC, Huntsville, Ala.

The FMVM experiment is designed to test a new method for measuring the viscosity of high-viscosity materials by measuring the time it takes two nearly free-floating drops of liquid to merge. The materials used are of known viscosities (corn syrup, glycerin, and silicone oil) so that the accuracy of the fluid merging test can be compared to the methods used on Earth.

Undergraduate students participated in analyzing the data on coalescence of unequal size drops.



FOOT/GROUND REACTION FORCES DURING SPACE FLIGHT (FOOT), EXPEDITIONS 6, 8, 11, 12

Peter Cavanagh, The Cleveland Clinic Foundation, Cleveland, Ohio

Mechanical loads and joint range of motion of the lower extremities together with muscle activity in both the lower and upper extremities were compared during periods of typical daily activity on Earth and the ISS. This research will provide insight into mechanical loading in the loss of bone mineral in the lower extremities that is widely viewed as a factor that could limit long-term human habitation of space or during planetary missions.

All of the students—K–12, undergraduate, and graduate—assisted in developing data analysis algorithms and techniques. They also assisted in ground-based hardware and protocol testing and validation experiments.

Astronaut Bill McArthur, Expedition 12 commander and science officer, uses the cycle ergometer with vibration isolation system while participating in the Foot experiment in the Destiny U.S. Laboratory of the ISS. McArthur is shown wearing the specially instrumented lower extremity monitoring suit, cycling tights outfitted with sensors, during the experiment.

INVESTIGATING THE STRUCTURE OF PARAMAGNETIC AGGREGATES FROM COLLOIDAL EMULSIONS (INSPACE), EXPEDITIONS 6, 7, PLANNED ONGOING

Alice P. Gast, Massachusetts Institute of Technology, Cambridge, Mass.

Particle dynamics of magnetorheological fluids (fluids that change properties in response to magnetic fields) were studied InSPACE to help understand adaptable new fluids for use in such applications as brake systems and robotics.

Undergraduate students assisted with real-time data analysis during operations on ISS.

LAB-ON-A-CHIP APPLICATION DEVELOPMENT PORTABLE TEST SYSTEM (LOCAD PTS), PLANNED 2006

Jake Maule, Carnegie Institution of Washington: NASA Astrobiology Institute, Washington, D.C.

LOCAD PTS is a portable test system that will provide quick analysis of environmental samples during space flight. Surfaces will be sampled with a swabbing device, and those samples (25 microliters each) will then be placed into a cartridge for analysis by the handheld unit.

The undergraduate students prepared LOCAD PTS for flight to the station and operation in the Arctic while the graduate students performed field tests of LOCAD PTS in volcanic environments in Kamchatka, Russia, and during the Arctic Mars Analog Svalbard Expedition (AMASE) in 2005. A postdoctoral student tested the LOCAD PTS on the KC-135 (2002–2004), in Kamchatka, and in the Arctic (2004) and was also principal investigator for the experiment on NASA Extreme Environment Mission Operations (NEEMO) Expedition 5.

MISCIBLE FLUIDS IN MICROGRAVITY (MFMG), EXPEDITIONS 8–11

John Pojman, University of Southern Mississippi, Hattiesburg, Miss.

The MFMG experiment will demonstrate the existence of tension-induced convection in miscible (mixable) fluids. This work will help researchers and manufacturers understand miscible polymer processing in microgravity and on Earth.

All students—undergraduate, graduate, and postdoctoral—provided hands-on support of the MFMG experiment by setting up ground-based experiments, collecting data, monitoring the payload, or analyzing data.

MIDDECK ACTIVE CONTROL EXPERIMENT-II (MACE-II), EXPEDITIONS 1–2

R. Rory Ninneman, Air Force Research Laboratory, Albuquerque, N.M.

MACE tested self-reliant, adaptive technologies that can detect problems with ISS hardware and correct those problems as needed. These technologies decreased the effects of vibration on station, allowing operation of sensitive payloads.

Undergraduate students assisted with testing in 1g at MIT prior to launch. Graduate students developed nonlinear dynamic models whose predicted response was compared with flight data to identify the limitations of predictive models.

PHOTOSYNTHESIS EXPERIMENT AND SYSTEM TESTING AND OPERATION (PESTO), EXPEDITION 4

Gary Stutte, Dynamac Corporation, NASA KSC, Cape Canaveral, Fla.

PESTO studied the photosynthetic response of plant tissues grown in microgravity. Results derived from this experiment can lead to the development of regenerative life support systems on future missions to the moon or Mars.

In PESTO, K–12 students analyzed data for local science fair projects. Undergraduate students supported the experiment by setting up experiments and collecting data, while graduate students set up ground-based experiments, collected data, and monitored the payload. Finally, postdoctoral students

supervised undergraduate and graduate students in the laboratory, and analyzed data from the completed ISS investigation.

PLANT GENERIC BIOPROCESSING APPARATUS (PGBA), EXPEDITION 5

Gerard Heyenga, NASA Ames Research Center (ARC), Moffett Field, Calif.

PGBA monitored and maintained light, temperature, humidity, and oxygen levels to study lignin production changes in *Arabidopsis thaliana* (a fast-growing plant) as it was grown in ISS microgravity.

All students, both undergraduate and graduate, were involved with the preparation of the hardware, integration of the plant biology experiment, and evaluation of the remote data.

PORE FORMATION AND MOBILITY INVESTIGATION (PFMI), EXPEDITIONS 5, 7, 8, ONGOING

Richard Grugel, NASA MSFC, Huntsville, Ala.

Using a transparent model material, the PFMI experiment studies the fundamental phenomena responsible for the formation of certain classes of defects in metal castings. Investigators examine the physical principles that control the occurrence of defects in manufacturing on Earth to develop methods by which to reduce flaws, defects, or wasted material.

Graduate students conducted ground-based PFMI investigations and compared the results with the data from ISS.

PROMOTING SENSORIMOTOR RESPONSE GENERALIZABILITY: A COUNTERMEASURE TO MITIGATE LOCOMOTOR DYSFUNCTION AFTER LONG-DURATION SPACE FLIGHT (MOBILITY), EXPEDITIONS 5-12, PLANNED ONGOING

Jacob Bloomberg, NASA JSC, Houston, Texas

The goal of the Mobility study is to develop an in-flight treadmill training program that is designed to improve adaptability of gait function, thereby facilitating recovery of functional mobility after long-duration space flights. To date, studies have been conducted on control subjects pre- and postflight.

Undergraduate, graduate, and postdoctoral students were involved in supporting ground-based studies. They also worked on processing and analysis of data obtained from the flight study.

PROTEIN CRYSTAL GROWTH-SINGLE LOCKER THERMAL ENCLOSURE SYSTEM-REGULATION OF GENE EXPRESSION (PCG-STES-RGE), EXPEDITIONS 6-10

Gerald Bunick, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Protein crystals were grown in a temperature-controlled environment. The PCG-STES-RGE investigation grew high-quality crystals for ground-based research that examined two proteins—one used in the food industry and the other used in gene expression.

Using crystallization methods performed by the PCG-STES hardware, undergraduate students crystallized proteins. Graduate and postdoctoral students prepared the samples for flight and analyzed these samples following their return from microgravity.

SERIAL NETWORK FLOW MONITOR (SNFM), EXPEDITIONS 9-11

Carl Konkel, Boeing, Houston, Texas

Using a commercial software CD and minimal upmass, SNFM monitored the payload local area network (LAN) to analyze and troubleshoot LAN data traffic. Validating LAN traffic models may allow for faster and more reliable computer networks to sustain systems and science on future space missions.

An undergraduate student assisted in running various tests on the software to verify its operation prior to qualification testing at the Payload Software Integration and Verification Facility and delivery to station.

SPACE-DYNAMICALLY RESPONDING ULTRASONIC MATRIX SYSTEM (SPACEDRUMS), PLANNED FUTURE

Jacques Guigné, Guigne Space Systems, Inc., Golden, Colo.



Using a collection of 20 acoustic beam emitters, SpaceDRUMS can completely suspend a baseball-sized solid or liquid sample during combustion or heat-based synthesis. Since the samples never contact the container walls, materials can be produced in microgravity with an unparalleled quality of shape and composition.

Graduate students worked on research associated with developing the science for this experiment.

The sample processing chamber inside SpaceDRUMS will suspend samples inside it while they are processed on orbit. Undergraduate and graduate students from the Colorado School of Mines, Golden, Colo., have been involved in testing the science underlying this unique piece of equipment for ISS.

SPACE FLIGHT-INDUCED REACTIVATION OF LATENT EPSTEIN-BARR VIRUS (EPSTEIN-BARR), EXPEDITIONS 5, 6, 11-13, ONGOING

Raymond Stowe, Microgen Labs, LaMarque, Texas

The Epstein-Barr study will evaluate suppression of the human immune system as a result of space flight by analyzing stress hormones, measuring the amount of Epstein-Barr virus activity (a dormant or latent virus that can be reactivated in astronauts during space flight), and measuring the virus-specific activity of white blood cells.

Using raw data, undergraduate students completed and presented abstracts that described immune and viral results in astronauts. Student participation was funded by a grant from the National Science Biomedical Research Institute (NSBRI).

YEAST-GROUP ACTIVATION PACK (YEAST-GAP), EXPEDITION 8, PLANNED 2006

Cheryl Nickerson, Arizona State University, Tempe, Ariz.

Yeast-GAP studies the effects of the genetic changes of yeast cells that are exposed to the space environment. The results of this experiment will help scientists understand how cells respond to radiation and microgravity, impact the determination of health remedies, and increase our basic understanding of cell biology.

Undergraduate, graduate, and postdoctoral students were involved in every phase of the research—from proof-of-concept ground-based experiments to experiment verification test, setup, and execution of the flight experiment, setup and execution of ground controls, and analysis of flight samples.

ZEOLITE CRYSTAL GROWTH (ZCG), EXPEDITIONS 4-6

Albert Sacco, Jr., Northeastern University, Boston, Mass.

The ZCG investigations examined how subtle changes in the chemical formulation affected the nucleation and growth of zeolite crystals. The microgravity environment allowed researchers to grow higher-quality crystals. These crystals have a number of useful commercial applications as catalysts and absorbents.

Both undergraduate and graduate students designed experiment protocols for ZCG on ISS.

Table IV. Summary of student involvement in other ISS experiments.

Payload	Number of Students			
	K-12	Under-grad.	Grad.	Postdoc.
Analysis of a Novel Sensory Mechanism in Root Phototropism (Tropi)		11	4	3
Binary Colloidal Alloy Test-3-Critical Point (BCAT-3-CP)			1	
Boiling eXperiment Facility-Nucleate Pool Boiling eXperiment (BXF-NPBX)		2	6	3
Capillary Flow Experiment (CFE)	4	2	2	1
Commercial Biomedical Test Module (CBTM)		5	22	5
Commercial Generic Bioprocessing Apparatus-Antibiotic Production in Space (CGBA-APS)		15	28	
Commercial Protein Crystal Growth-High Density (CPCG-H) and Dynamically Controlled Protein Crystal Growth (DCPCG)	150	9	2	
Crewmember and Crew-Ground Interaction During International Space Station Missions (Interactions)				1
The Effects of Extravehicular Activity (EVA) and Long-term Exposure to Microgravity on Pulmonary Function Pulmonary Function in Flight (PuFF)		1		
Effects of Weightlessness on Skeletal Muscle (Biopsy)	2			
Fluid Merging Viscosity Measurement (FMVM)		3		
Foot/Ground Reaction Forces During Space Flight (Foot)	2	2	2	
Investigating the Structure of Paramagnetic Aggregates from Colloidal Emulsions (InSPACE)		2		
Lab-on-a-Chip Application Development Portable Test System (LOCAD PTS)		4	1	1
Miscible Fluids in Microgravity (MFMG)		3	1	2
Middeck Active Control Experiment (MACE)		2	2	
Photosynthesis Experiment and System Testing and Operation (PESTO)	6	15	2	2
Plant Generic Bioprocessing Apparatus (PGBA)		17	76	
Pore Formation and Mobility Investigation (PFMI)			2	
Promoting Sensorimotor Response Generalizability: A Countermeasure to Mitigate Locomotor Dysfunction After Long-duration Space Flight (Mobility)		3	4	4
Protein Crystal Growth-Single Locker Thermal Enclosure System-Regulation of Gene Expression (PCG-STES-RGE)		2	1	1
Serial Network Flow Monitor (SNFM)		1		
Space-Dynamically Responding Ultrasonic Matrix System (SpaceDRUMS)			7	
Space Flight-Induced Reactivation of Latent Epstein-Barr Virus (Epstein-Barr)		2		
Yeast-Group Activation Pack (Yeast-GAP)		1	5	4
Zeolite Crystal Growth (ZCG)		5	30	
Totals	162	105	189	27

STUDENTS PARTICIPATING IN ISS ENGINEERING ACTIVITIES – HARDWARE DEVELOPMENT AND SPACE OPERATIONS

These activities typically involve high school and college students developing hardware to support the International Space Station program or working in a Science Support Center and learning about and participating in space operations.

BOEING ISS PAYLOAD INTEGRATION INTERNSHIPS

Expedition(s): Ongoing since 2003
Grade Level(s): Undergraduate
Impact: Thirteen undergraduate students from seven universities participated in these four-month internships.

ACTIVITY DESCRIPTION

The Boeing ISS Payload Integration Team, working in support of NASA JSC, has developed an internship program for undergraduate students working on a variety of projects in direct support of payload integration activities for ISS. The students are colocated at the Boeing facility near NASA JSC in Houston, Texas, and on site at NASA MSFC in Huntsville, Ala. During these projects students gain valuable experience in space operations and payload development, and get involved in real applications of engineering principles.

STUDENT ACTIVITY

Students in these internships work as integral team members to Boeing and subcontractor personnel, and are assigned challenging short-term projects. These projects include general programming tasks, unique payload interface documentation development, assistance with ISS payload compatibility analyses, and support of contract extension proposal development to name a few. Some of project specifics include:

- One student's internship involved a project to establish design criteria for a new ballistic payload reentry vehicle. This return capsule was to be based on current requirements for payloads and vehicles that are planned for launch to and return from ISS. This project focused on a real need to develop a capability to return refrigerated payload samples from ISS after the space shuttles are retired in 2010.
- Student interns also worked on a number of software-related tasks. One student developed and enhanced an engineering schedule database that implemented new data entry and reporting features that are used to track payloads and experiments being developed and integrated for flight. Another student developed a payload certification of flight readiness Web-based application and database that is used to collect, track, and status certifications and associated open work.

STUDENT PARTICIPATION

Thirteen students have participated in the Boeing ISS Payload Integration Internships. These students came from Prairie View A&M University, Prairie View, Texas; Alabama A&M University, Normal, Ala.; University of Illinois, Chicago, Ill.; Auburn University, Montgomery, Ala.; Texas A&M University, College Station, Texas; Texas Tech University, Lubbock, Texas; and Vanderbilt University, Nashville, Tenn. Several among these students have participated in two or more of the internship semester rotations.

SPACE SYSTEMS PRODUCT AND DEVELOPMENT CAPSTONE COURSE, MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT)

PART OF SYNCHRONIZED POSITION HOLD, ENGAGE, REORIENT, EXPERIMENTAL SATELLITES (SPHERES)

Expedition(s): 8, 13–14

Grade Level(s): Undergraduate, graduate

Impact: Thirty students at MIT, Cambridge, Mass., participated in the Aero-Astro Capstone course through three semesters of work.

EXPERIMENT DESCRIPTION

Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES) was developed by MIT for NASA and the United States Air Force to demonstrate the dynamics of formation flying in satellites. This demonstration includes testing of relative attitude control and station-keeping between satellites, re-targeting and image plane filling maneuvers, collision avoidance and fuel balancing algorithms, and an array of geometry estimators used in various missions.

STUDENT ACTIVITY

MIT Aero-Astro engineering has developed a new curriculum linking engineering fundamentals with real-world demands on engineers. Students gain engineering experience along all stages of the process from concept, to design, to implementation, and to operations. The course features active group learning experiences in both classrooms and laboratory, rigorous assessment, and evaluation. Junior, senior, and graduate students attending MIT have the opportunity to enroll in this three-semester course that focuses on preparing the students for engineering in the “real world.” Students design and build aerospace vehicle prototypes. These cutting-edge vehicles are then transferred to the Aero-Astro graduate program where they are used in research. Student projects are complemented by internships in industry.

During the first semester of the course, students develop requirements and conduct design trades to balance cost, complexity, risk, performance, and safety. They also conduct full system reviews and, once completed, begin development of the highest risk subsystem(s) and procure long-lead components. For the second semester, students refine the design, begin assembly, test system components, and finally complete a critical design review. For students in the third semester, assembly is completed, and environmental and performance verification tests are conducted followed by a hardware acceptance review, and finally the system is deployed.



MIT students participating in the Aero-Astro Capstone course that developed SPHERES aboard the KC-135 in March 2000.

STUDENT PARTICIPATION

Since the course was developed, 30 MIT students have participated in the Aero-Astro Capstone course.

A student in the Aero-Astro Capstone course writes:

When I first came to MIT I had no clue that I would be doing anything as cool as this. After two years of work on real satellites, the skills I learned in the three-semester...course are the ones I most often apply from my undergraduate education. It has given me a taste of the real world before I get a chance to get out there.

Principal Investigator(s): David Miller, Massachusetts Institute of Technology, Cambridge, Mass.
Education Lead(s): Sharon Brown, , Massachusetts Institute of Technology, Cambridge, Mass.
Education Web Site(s): <http://ssl.mit.edu/spheres/>



Expedition 8 Commander Michael Foale holds the SPHERES ultrasound beacon and beacon tester while performing functionality checks between the beacon/beacon tester and its proximity to a general luminaire assembly in Unity Node 1.

HIGH SCHOOL STUDENTS UNITED WITH NASA TO CREATE HARDWARE (HUNCH)

Expedition(s): 2003–present

Grade Level(s): 7–12

Impact: More than 550 students at 20 schools are impacted by HUNCH, which reaches “at-risk” students in vocational education classes.

STUDENT ACTIVITY

Students in high school and middle school, who are in career and technology classes, study real flight hardware as they fabricate training hardware in this project. NASA provides materials and documentation, and the teacher provides direction to the students and a safe working environment. The goal of High School Students United with NASA to Create Hardware (HUNCH) is to inspire the next generation of explorers through hands-on application by fabricating products that will be used at NASA. Students are taught the mathematics and science that are involved with the fabrication of flight and training hardware. This training hardware is then used to prepare astronauts and ground support personnel for jobs on orbit. This hardware is used both at NASA MSFC and NASA JSC.



Two high school students working on an RSR that will be used for astronaut training at NASA JSC. RSRs are used within the multi-purpose logistics module (MPLM) to carry cargo to ISS aboard the space shuttle.

Students have made two Crew Health Care System (CHeCS) racks, four zero-g soft racks (ZSRs), two resupply stowage racks (RSRs), nine stand-off interface panels (SIPs), 24 ISS single stowage lockers, 18 generic luminaire assemblies (GLAs), 11 ISS tool drawers, seven half-size cargo transfer bags (CTBs), two full-size CTBs without windows, 20 international standard payload rack (ISPR) power switches, 80 handrails, a Lab Training Center (LTC) control cabinet, 33 international subrack interface standard (ISIS) slides and handles, and numerous virtual hardware. Other projects will not finish up this year but are on target to finish next year.

STUDENT PARTICIPATION

More than 550 students and 30 teachers, in 20 schools, from ten school districts, in four states—Alabama, Montana, Tennessee, and Texas—participated in these tasks. Most of the schools that NASA

works with have students who are “at risk.” Most of these at-risk students have never thought about the possibility of going to college or working for NASA.

Matt was a bright tenth-grader from Laurel High School in Laurel, Mont. Although Matt was an A/B student, he hated going to school. He felt school was a waste of time and planned to go to work on the family farm after high school. Matt became one of three students on the HUNCH team at Laurel. Matt and the other students had done a great job of assembling four SIPs in only two months. After working on the project, Matt now looks forward to coming to school and has become the student leader for the school's HUNCH project. Matt will be a senior next year and plans to go to college, majoring in engineering.

Education Lead(s): Stacy L. Hale, NASA JSC, Houston, Texas

PROTOTYPE COMMUNICATIONS SATELLITE SYSTEM-2 (PCSAT-2) ***PART OF MATERIALS INTERNATIONAL SPACE STATION EXPERIMENT-5 (MISSE-5)***

Expedition(s): 11–14
Grade Level(s): Undergraduate (U.S. Naval Academy midshipmen)
Impact: Eighteen midshipmen from the U.S. Naval Academy designed and developed this attached satellite and are currently gaining valuable experience for the U.S. Navy in space operations.

EXPERIMENT DESCRIPTION

In August 2005 the STS-114 crew installed MISSE-5 on the P6 truss of the ISS during the third EVA of their mission. This suitcase-size materials exposure facility is designed to test out the durability of various materials in the space environment. One of the three major components of MISSE-5 is called the Prototype Communications Satellite System-2 (PCSat-2). PCSat-2 is an amateur satellite communications system (amateur radio system) that is similar to the free-flying satellite called PCSat. The radio system provides telemetry on the health of the system and the status of new solar cell technology also being tested as part of MISSE-5. In addition, it supports educational and student outreach objectives of the Amateur Radio Satellite (AMSAT), American Radio Relay League (ARRL), and NASA.



Midshipmen at the U.S. Naval Academy , Annapolis, Md., are shown working on PCSat-2 hardware before launch on STS-114.

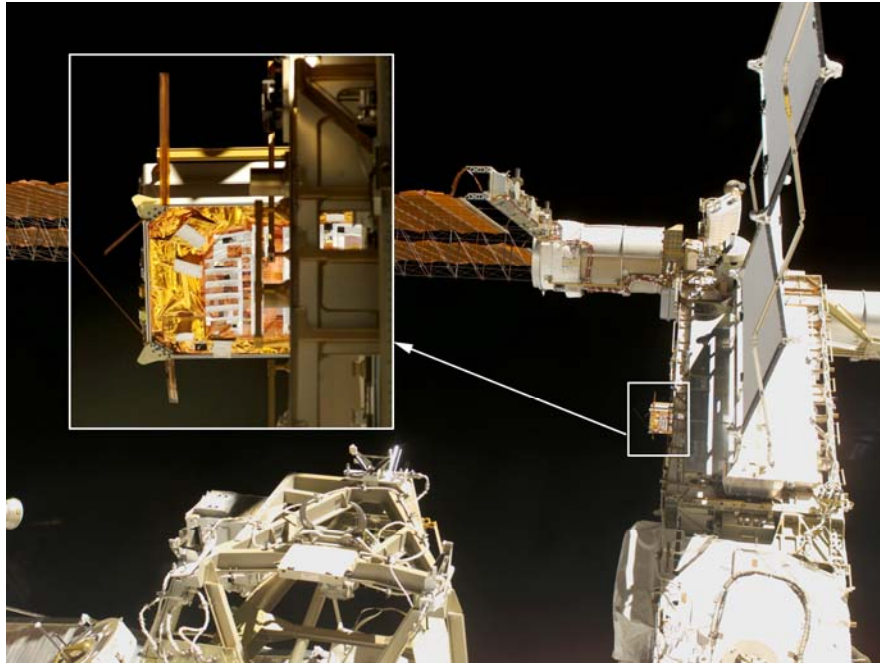
STUDENT ACTIVITY

PCSat-2 was designed and built by midshipmen at the U.S. Naval Academy Satellite Lab in Annapolis, Md. This project gave the midshipmen real hands-on training in the design, development, and operation of space hardware.

STUDENT PARTICIPATION

A total of 18 midshipmen at the U.S. Naval Academy participated in the design and development of the PCSat-2 hardware and its ongoing operations.

The principal use of the PCSat-2 is to downlink performance data from the advanced solar cells that are part of MISSE-5. During the Gulf hurricane disaster late in the summer of 2005, these midshipmen tested out the emergency communications capabilities of PCSat-2 for relaying mobile position data, messages, and e-mail. They also used PCSat-2 to track their traditional football run from Annapolis, Md. to Philadelphia, Pa., prior to their Dec. 2, 2005, Army-Navy football game.



View of MISSE-5 mounted on the ISS P6 truss during Expedition 11. PCSat-2 is protected by a golden thermal blanket with flexible material samples attached.

Principal Investigator(s): Robert Walters, Naval Research Laboratory, Washington D.C. (MISSE-5)
Education Lead(s): Bob Bruninga, U.S. Naval Academy Satellite Lab, U.S. Naval Academy, Annapolis, Md.
Education Web Site(s): <http://eng.usna.navy.mil/~bruninga/pcsat2.html>

SPACE ENGINEERING INSTITUTE, TEXAS A&M

Expedition(s): 2002–present

Grade Level(s): Undergraduate, graduate

Impact: A total of 73 undergraduate and 12 graduate engineering students participated, from 2002–2006, in designing and building space flight hardware and experiments. Three other undergraduate and eight graduate students from Florida Atlantic University, Boca Raton, Fla., also worked on HDMax hardware development.

STUDENT ACTIVITY

The Space Engineering Institute (SEI) Program at Texas A&M’s Spacecraft Technology Center, College Station, Texas, is a partnership with NASA that is focused on providing an opportunity for students to work in the space industry. Throughout the school year, selected students will have hands-on projects and practical training in various fields of engineering. First-year students at Texas A&M work on projects that aid NASA in development of the ISS and human exploration of the solar system. The projects are multi-disciplinary and require expertise from aerospace, mechanical, and electrical engineering to computer science and other engineering disciplines.

SEI program goals are: (1) to give practical training and hands-on experience that strongly encourages students to pursue engineering degrees leading to careers in space systems; (2) provide real-world projects and experiences that support the engineering curriculum; and (3) specifically to encourage women and ethnic minorities to choose careers in space engineering.

STUDENT PARTICIPATION

A total of 73 undergraduate and 12 graduate engineering students have participated from 2002–2006. The undergraduate students have worked on a variety of relevant ISS engineering design challenges, including stowage and docking, and have built a scale mockup of space station. Student activities have been linked to the ISS technology or hardware development projects developed as part of the Spacecraft Technology Center. The projects include Express Pallet, Mini AeroCam, wireless communication testing, HEOCam, HDMAX, MPLM stowage, edge detection, urine pretreatment, and EVA hatch design. Through collaboration with the Imaging Technology Space Center (ITSC) at Florida Atlantic University, Boca Raton, Fla., an additional three undergraduate and eight graduate students worked on imaging technologies for the HDMAX camera system.



Texas A&M University students assemble a mockup of the ISS for reference in a number of different engineering design projects.

Kelli Boehringer was part of a team of SEI students who worked on an EVA hatch design project. These students worked to design a minimum gas loss and low-power EVA airlock that would provide quick exit and entry for space-suited crewmembers. The airlock would be an element of a space station, a future crewed vehicle, a planetary lander, or a human pressurized rover. The goal was to minimize the gas that is lost during depressurization by creatively designing the layout and the operation of the inner and outer airlock hatches. The students worked with two NASA JSC engineers for one semester in the design project. A redesign was presented in December 2005. Of her experiences, Kelli writes:

SEI has allowed me to know what is going on when we start talking about different engineering principles in class. Learning different engineering programs has allowed me to be ahead of the class when we start designing and computing in engineering class. I also feel I have an advantage simply because I have worked in a team atmosphere on projects that have a real-life impact and use. Not many freshman have a chance to work with a team through the entire design process, including research, designing, fabrication, and testing.

Education Lead(s): Jan Reinhart, Texas A&M University, College Station, Texas
Education Web Site(s): <http://sei.tamu.edu>



Texas A&M students worked on the use of commercially available wireless communication technology such as Bluetooth and IEEE 802.11 for use onboard ISS. They submitted a report to NASA JSC engineers that was used in the decision on what equipment to recommend for use on station. These students also wrote a technical paper and presented its findings at the International Wireless Conference in May 2005 in San Jose, Calif.



The HDMAX camera was developed with the participation of students in the Florida Atlantic University, Boca Raton, Fla., and licensed to Panavision. Students from Florida Atlantic University and Texas A&M participated in the development of a flight version of the camera for use on ISS.

AGRICULTURAL CAMERA (AGCAM)

Expedition(s): Hardware launch possible in 2008
Grade Level(s): K–12, undergraduate, graduate
Impact: The AgCam project involves researchers and students from eight universities in five upper Midwest states (North Dakota, South Dakota, Wyoming, Montana, and Idaho). A total of 750 K–12 teachers from the region have participated in training for AgCAM, and some of them will be hired each year to support the AgCAM operations center to gain hands-on space operations experience.

EXPERIMENT DESCRIPTION

AgCam is a multi-spectral imaging system designed for use in NASA's Window Observation Research Facility (WORF) rack that is being planned for launch to ISS in 2008. This camera will collect images in both the visible and near-infrared portions of the spectrum and will allow a wide range of studies in evaluating crop health, rangeland productivity, forest sustainability, wild land fire impacts, and other natural resource management issues. Specifically, AgCam will be capable of generating data with high spatial resolution (10 meters), repeat images of an area every 2–3 days, and rapidly deliver the images to the ground team researchers (24–48 hours). This combination will provide a unique time series of plant development imagery not otherwise available.



STUDENT ACTIVITY

AgCam is being built at the University of North Dakota, Grand Forks, N.D., by undergraduate and graduate students in electrical engineering, mechanical engineering, and computer science. Students from many different departments at the university will conduct the on-orbit mission planning and operations. Students will process user requests for images, determine ground target access times, send commands, manage onboard data recorders, process the telemetry, perform science data processing, and deliver the final data to the requested user via the Web.

TEACHER ACTIVITY

Approximately 750 K–12 teachers from North Dakota, South Dakota, Wyoming, Montana, and Idaho have participated in AgCAM training sessions over the last several years. AgCAM plans to operate a Space Operations Center that will command AgCAM on ISS and process data from it. Most of the AgCAM data will be collected during the summer growing season in the Northern Great Plains. Since this coincides with the time when most K–12 teachers are on summer break, plans have been made to hire some of these trained teachers to work in the Space Operations Center each summer, providing them with valuable hands-on experience in space operations that they can then take back to the classroom in the autumn.



Faculty and students at the University of North Dakota, Grand Forks, N.D., are pictured working on the design, testing, and assembly of the AgCAM flight hardware.

STUDENT PARTICIPATION

Almost 40 students have contributed to AgCam development to date, and ten graduate theses or projects have been related to AgCam. Some of these master's theses from the University of North Dakota, Grand Forks, N.D., include:

- *Design of an Imaging System for AgCam – The International Space Station-based Earth Observing Camera for Precision Agriculture.* Brian G. Giesinger, May 2002.
- *Analysis and Development of a Vibration Isolation System for the Agricultural Camera (AgCam) Remote Sensing Camera System.* Adam Webster, May 2003.
- *Near-real-time Data Processing and Operation of an Earth-observing Remote Sensing Payload.* Nicholas E. Hulst, May 2004.
- *Substructure Coupling for Motion Profile Tuning for the Agricultural Camera (AgCam) Remote Sensing Camera System.* Jeffrey S. Hammes, December 2004.
- *Closed-cell Foam Characterization for Packaging and Testing of Agricultural Camera (AgCam) System.* Richard Voeller, May 2005.

In addition, there have been two graduate student projects and two independent study papers related to AgCAM. Several undergraduate students have worked on Senior Design teams, conducted independent studies, or participated in the Research Experience for Undergraduates programs at the University of North Dakota, Grand Forks, N.D.

The Science Operations Center that will be running this experiment at the University of North Dakota will be student-staffed, and the science applications and data analysis tasks will involve students from across the Upper Midwest Aerospace Consortium (membership includes the Universities of Montana, Wyoming, and Idaho; Montana and South Dakota State Universities; South Dakota School of Mines and Technology; and Sinte Gleska University in South Dakota). Regional public outreach is also planned.

Jason Barton is a former student at the University of North Dakota who had a strong interest in aerospace engineering and decided to join the AgCAM project. His responsibilities evolved into being the main interface with the operations teams and the payload safety panel at NASA JSC. From this experience Jason wrote an Independent Study Report titled “Critical Analysis of the NASA Payload Safety and Payload Integration Processes” for his Masters of Science degree in Space Studies in December 2004. As a further result of his experience working with NASA, he was offered a job with Science Applications International Corporation (SAIC), a contractor at NASA JSC, where he is currently a member of the EVA Safety Panel that oversees the safety of our station-based EVAs (spacewalks).

Principal Investigator(s): George Seielstad, University of North Dakota, Grand Forks, N.D.



Expedition 12 Commander William (Bill) McArthur and Flight Engineer Valery Tokarev pose inside the Destiny U.S. Laboratory with their respective EMUs. McArthur and Tokarev discussed the spacesuits as part of the Education Demonstration Activity for Teaching in Space.

EDUCATIONAL DEMONSTRATIONS AND ACTIVITIES

In addition to the numerous experiments that students are supporting on ISS, a number of other educational activities and demonstrations are performed to be used as teaching aids, to supply educational resource materials, or simply to provide additional mechanisms to inspire students. From astronauts demonstrating how simple and familiar phenomena such as soda bubbles behave on the ISS to allowing students of all ages to pose questions to the crews onboard the station, these diverse activities are rich with opportunity to connect with students and bring the ISS experience into their lives.

TEACHING FROM SPACE (TFS)

INCLUDES EDUCATION PAYLOAD OPERATIONS

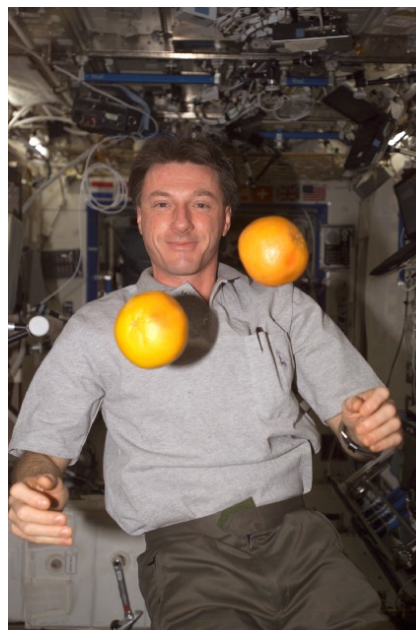
The NASA Teaching From Space (TFS) Office is responsible for facilitating the flight of education activities on the space shuttle and ISS. EPO is the term used to designate education payloads that are flown by NASA Education to the station to meet agency educational objectives. TFS activities focus on demonstrating science, mathematics, engineering, technology, or geography principles in a microgravity environment. Most activities involve video recording of the demonstrations and/or still photographic documentation of a crewmember. Demonstrations use materials available on orbit or unique materials brought to ISS through EPO. TFS also coordinates In-flight Education Downlinks, which provides schools with the opportunity to learn about science and the station by speaking to the crew in orbit. At the request of NASA Education, TFS also facilitates and supports education payloads for the informal education community and ISS International Partner education offices.

TFS includes the following major activities described in this section:

- International Toys in Space
- Museum Aerospace Education Alliance (MAEA)
- Education Demonstration Activities
- In-flight Education Downlinks
- Educator Astronaut (see p. 25)

Principal Investigator(s): Cynthia McArthur, NASA JSC, Houston, Texas
Education Lead(s): Cynthia McArthur, NASA JSC, Houston, Texas

Astronaut C. Michael Foale, Expedition 8 commander and NASA ISS science officer, “juggles” fresh fruit in the Destiny laboratory of the ISS. The weightless environment of space proves to be an ideal location for some tasks not so easily accomplished in Earth’s gravity.



INTERNATIONAL TOYS IN SPACE

Expedition(s): 5

Grade Level(s): 5–12

Impact: More than 500 videos have been distributed to teachers as part of this project. The activities are also presented to about 1,500 teachers each year by the Aerospace Education Services Program (impact described in the next section).

International Toys in Space activities were developed to involve students in principles of physics by studying how everyday items (toys and games) would act in a microgravity environment. During Expedition 5, a variety of toys were flown to the station, including international toys representing ISS International Partners, and video was captured of crewmembers experimenting with the toys. The video footage was used to produce a DVD and an accompanying teacher's guide. Following the activity guide, students investigated how the toys behave on Earth and compared their results to video footage taken onboard ISS. Both the video and the toys are available for teachers at NASA's Central Operation of Resources for Educators (CORE).

Distributed via NASA CORE: <http://education.nasa.gov/edprograms/core/home/>



Astronaut Leland D. Melvin answers questions for a group of students during the First Robotics Competition at the Reliant Astrodome in Houston, Texas. Together with ISS astronaut Peggy Whitson, Melvin narrated the video for "International Toys in Space."

MUSEUM AEROSPACE EDUCATION ALLIANCE (MAEA)

Expedition(s): 7–9

Grade Level(s): Informal education (science museums) and classroom applications

Impact: Five participating museums developed educational activities for diverse applications in exhibits and other informal educational activities.

The objective of MAEA activities on ISS was to develop additional resources for the informal educational arena to help increase student interest and awareness in NASA's Vision for Space Exploration. Completed over three Expeditions, on-orbit demonstrations were developed specifically to meet the educational needs of informal education at science museums. Lessons and activities developed were directly related to national science, technology, and mathematics education standards, and many focused on inquiry-based scientific investigations. Crewmembers performed video demonstrations using items such as paper airplanes and musical instruments. These videos were distributed to museum member organizations for use in lessons and museum exhibits. MAEA includes the Bishop Museum, Honolulu, Hawaii; St. Louis Science Center, St. Louis, Mo.; Denver Museum of Nature and Science, Denver, Colo.; Maryland Science Center, Baltimore, Md.; and Center of Science and Industry (COSI), Columbus and Toledo, Ohio.

During Expedition 7, a detailed scale model of the Wright Flyer, built by sixth-grade students at Orono Middle School in Orono, Maine, was flown on the ISS. As part of the Centennial of Flight activities in 2003, NASA provided educators around the country with plans to construct a model Wright Flyer out of balsa wood and tissue paper (see <http://wright.nasa.gov/model1902.htm>). Demonstrations of the Wright Flyer on orbit illustrated the basic elements of flight, including lift, thrust, and control. It was also used to compare the concepts of flight and orbit. Other activities that are part of MAEA are listed in TABLE V.



Students working on their balsa wood scale models of the Wright Flyer.

Table V. MAEA educational demonstrations performed on ISS.

Expedition	Item	Purpose
7	Wright Flyer Paper airplane	Educational activities to celebrate the "Centennial of Flight." Test flight performance using different configurations of wing tips and elastic-band propulsion.
	Pu'uli	Studying the role of vibration and sound and how microgravity affects the performance of this traditional Hawaiian musical instrument.
8	Balsa Airplane, Starfire Balsa Glider, Aero Prop, Tools Block	Investigate principles of flight using common toys for use in future museum activities and displays.
9	Blues Harp, Crazy Maze, Bits and Pieces Puzzle, Chicken Shake	Investigate how familiar objects may perform differently in the microgravity environment onboard the ISS for use in future museum activities and displays.



A middle school student examines plans for a Wright Flyer. NASA student activities for the celebration of the Centennial of Flight were linked to ISS when a Wright Flyer flew on station.

EDUCATION DEMONSTRATION ACTIVITIES (EDAs)

Expedition(s): 7–13, ongoing

Grade Level(s): K–12

Impact: To date, 24 EDAs have been completed by crewmembers on ISS.

An Education Demonstration Activity (EDA) is an on-orbit educational demonstration performed by ISS crewmembers using only hardware already onboard station. No special items are sent up to station as part of these activities. EDAs are intended for K–12 audiences and support national standards. They are designed to enhance existing NASA education products and programs. Educators, students, and NASA Education Programs suggest activity topics.

TFS has received numerous requests from a variety of customers who are interested in using EDA video for educational purposes. Some of these customers include the NASA JSC Public Affairs Office (PAO), a number of Public Broadcasting System television stations, the Canadian Space Agency (CSA) Education Office, and a large number of education organizations across the country. There has also been a great deal of media interest in these EDAs. TFS has recently conducted interviews with the NASA MSFC PAO, Alabama Public Radio, Space.com, and *The Huntsville Times*. A series of demonstrations completed during Expedition 12 by Commander Bill McArthur is in video production for release on NASA education Web sites. For an example of his video on recycling and supporting materials, see http://www.nasa.gov/audience/foreducators/5-8/features/F_Recycling_on_the_ISS.html.



Bill McArthur, Expedition 12 commander, is pictured holding a coffee drink bag during an ISS educational demonstration on space recycling.

IN-FLIGHT EDUCATION DOWNLINKS

Expedition(s): 6–12, ongoing

Grade Level(s): K–16

Impact: Thousands of students have had the opportunity to participate in a downlink event where ISS crewmembers answer their questions. Through educational broadcasting, more than 30 million students have been able to watch the live interviews.

Through in-flight education downlinks, students and educators can communicate live with the space station crew. Prior to the event, students study the ISS and onboard science activities and develop questions to ask the crew. Crewmembers answer the questions and perform simple educational demonstrations. Usually two education downlinks, approximately 20 minutes in length, occur each month. Members of the informal and formal education communities, NASA centers and education programs, and ISS International Partners host these events. The hosts make downlinks part of a comprehensive education package that supports national and state education standards and initiatives. Live in-flight education downlinks, which have one-way video (from ISS) and two-way audio, are broadcast live on NASA Television. TFS manages downlinks for three ISS increments simultaneously—facilitating evaluation for the previous increment; scheduling and implementation for the current increment; and coordinating the proposal process for the upcoming increment.

Table VI. In-flight education downlink activities on ISS.

Expedition	No. of Events	No. of Participants	Special Impact
6	10	11,108,315	Channel One broadcast a downlink to schools across the western U.S., reaching millions of students
7	15	749,134	
8	13	680,000	
9	7	846,534	
10	7	41,869	
11	1	180	
12	5	17,483,927	U.S. Department of Education hosted a downlink that reached millions of students around the country
TOTAL	58	30,909,965	



Students participating in an In-flight Education Downlink and the crew of Expedition 6, Nikolai Budarin, Ken Bowersox, and Donald Pettit, shown (right), answering questions from the students.

The following statements were written by seventh-grade students in Phelps, Ky., after participating in an In-flight Education Downlink during Expedition 10:

I have decided to become more educated and become some sort of scientist.

I have been influenced – I want to get an education in a field of science or technology.

Small towns have big technology too.

I think our school will get more respect.

I didn't know about all of the good jobs we could get when we grow up. My parents say they didn't have these opportunities when they were growing up but we do.

My family treats me like I know things now.

The following statement was written by Peter DeDominici, Ed.D., Director of Education for the Cincinnati Museum Center, Cincinnati, Ohio, after participating in an In-flight Education Downlink during Expedition 11:

The students and teachers were in awe. In fact, the teachers...along with me...had some tears once it was completed because of the enormity of such an event for "ordinary" citizens.

Education Lead(s): Cynthia McArthur, NASA JSC, Houston, Texas

Education Web Site(s): <http://www.insgc.org/modules/wfsection/article.php?articleid=4>



Astronaut Leroy Chiao (right), Expedition 10 commander and NASA ISS science officer, and cosmonaut Salizhan S. Sharipov, flight engineer representing Russia's Federal Space Agency, participate in a conference in the Destiny laboratory of ISS.

AEROSPACE EDUCATION SERVICES PROGRAM (AESP)

ALSO INCLUDES DIGITAL LEARNING NETWORK (DLN), EDUCATOR RESOURCE CENTER (ERC), AND CENTRAL OPERATIONS AND RESOURCES FOR EDUCATORS

Expedition(s): 1–12, ongoing

Grade Level(s): K–12

Impact: More than 5,000 teachers per year are trained to use educational materials and demonstrations based on ISS in their classrooms. Thousands of students each year, through the Digital Learning Network (DLN), also learn science lessons based on ISS from NASA educators.



AESP Education Specialist Ron Ernst demonstrates NASA activities at a New York school.

The Aerospace Education Services Program (AESP) takes educational products from across the agency out to practicing teachers. Educators in the program develop educational materials for NASA and present them to teachers through conferences and in-service training. AESP educators can be found at NASA JSC, NASA KSC, NASA ARC, and NASA GSFC, each serving their region. Video on ISS acquired through TFS (see p. 56) is combined with other innovative educational activities to complete a variety of education resources that teachers can use for classroom activities. All the activities are linked to specific education outcomes and science teaching standards in the local states. Educational materials are also distributed via the DLN at NASA JSC and

NASA MSFC, thereby providing a distance learning opportunity for classrooms. The Educator Resource Center (ERC), NASA JSC, and CORE serve as clearinghouses for materials. The focus of all of the programs is to provide teachers with lesson plans and activities that are linked to science education objectives. A summary of recent education products that have been made available to teachers through the AESP is given in [TABLE VII](#).

WEB SITES

AESP Web Site:

<http://www.okstate.edu/aesp/AESP.html>

NASA DLN Web Site:

<http://nasadln.nmsu.edu/dln/>

NASA CORE Web Site:

<http://education.nasa.gov/edprograms/core/home/>

NASA ERC Web Site:

[http://education.nasa.gov/about/contacts/
Educator_Resource_Center_Network.html](http://education.nasa.gov/about/contacts/Educator_Resource_Center_Network.html)

NASA Explorer Schools Web Site:

<http://explorerschools.nasa.gov/>

Table VII. Summary of recent ISS education products presented to teachers through the AESP (2005–2006).

ISS products presented	No. of teachers		
	2005	2006 (to date)	
Videos with classroom activities			
<i>International Toys in Space</i>	1,444	568	Demonstrates the actions of a variety of toys in microgravity for classroom comparison with the actions of similar toys on Earth (ED-2004-06-001-JSC, Resource guide and video or DVD, Grades 5–12)
<i>Meet Me at the Station</i>	659	102	Provides an overview of the ISS (EV-2000-01-001-JSC, Resource guide and video or DVD, Grades K–8)
Educational Briefs	450	179	
<i>Docking with the Station</i>			Students model ISS docking and Newton’s Laws of Motion (EB-1998-27-126-HQ, Activity guide, Grades 5–12)
<i>Solar Arrays</i>			Students construct a solar collection device to simulate power collection on ISS (ET-1998-07-003-HQ, Activity guide, Grades K–4)
<i>Clean Water</i>			Students construct a filter to demonstrate and simulate the water purification system on the ISS (ET-1998-07-002-HQ, Activity guide, Grades K–4)
Student Glovebox	324	175	Students learn about gloveboxes like the microgravity sciences glovebox (MSG) on ISS and complete inquiry-based activities in a model classroom glovebox (EG-2000-09-004-GRC, Activity guide, Grades 5–8); printed glovebox templates also available
EarthKAM	790	406	See separate narrative in this report, page 6
3,2,1, Liftoff	810	162	Students complete activities about the ISS and the role rockets play in its construction (EG-2002-02-001-JSC, Activity guide, Grades K–2)
Total	4,477	1,592	
DLN	4,850	students	ISS-based materials used in distance learning, Grades K–12

AMATEUR RADIO ON THE INTERNATIONAL SPACE STATION

Expedition(s): 1–13 (ongoing investigation)
 Grade Level(s): K–12
 Impact: Nearly 60,000 students have participated in ARISS from 235 schools worldwide (22 different countries). In the United States, more than 31,000 students from 125 schools (34 of the 50 states plus the District of Columbia and Puerto Rico) have participated.

EXPERIMENT DESCRIPTION

Ever since the ARISS hardware was first launched aboard space shuttle *Atlantis* on STS-106 and transferred to ISS during Expedition 1, it has been regularly used to perform school contacts. With the help of Amateur Radio Clubs and ham radio operators, astronauts and cosmonauts aboard station have been speaking directly with large groups of the general public, showing teachers, students, parents, and communities how amateur radio energizes youngsters about science, technology, and learning (TABLE VIII). The overall goal of ARISS is to get students interested in mathematics and science by allowing them to talk directly with the crews living and working aboard ISS.

STUDENT ACTIVITY

As the ISS passes over a school or over another location that receives a signal from station and relays it on to the participating school, there is typically a 5- to 8-minute window for students to make contact with the crews aboard ISS. In preparation, students research the ISS and learn about radio waves and amateur radio among other topics. Before their scheduled contact with the ISS, they prepare a list of questions on topics they have researched, many of which have to do with career choices and science activities aboard the ISS. Depending on the amount of time and complexity of the questions, from 10–20 questions can be asked during one of the sessions. While typically only a handful of students can ask questions due to the limited time available, hundreds of other students usually are listening in to the school event from their school classrooms or auditorium, so that each of these events typically reaches hundreds of students.



AMSAT joined the celebration of Space Day 2005 at the Steven F. Udvar-Hazy Center (Smithsonian Institution Air & Space Museum, Chantilly, Va.) by setting up an activity station for students and the general public and displaying and distributing ARISS lithographs.

Table VIII. Countries participating in the ARISS experiment.

Country	No. of Schools
Australia	12
Belgium	6
Brazil	2
Canada	12
Finland	2
France	7
Germany	6
Ireland	1
Israel	1
Italy	8
Japan	19
Netherlands	3
Poland	1
Russia	7
Slovenia	1
South Africa	4
Spain	2
Switzerland	3
Thailand	2
Turkey	2
United Kingdom	9
United States	125
Total	235

STUDENT PARTICIPATION

Recently the Expedition 12 crew of Bill McArthur and Valery Tokarev was quite active performing school contacts, completing a total of 36 during a six-month stay aboard the ISS. To date a total of 235 schools have participated in the ARISS program.



Astronaut William S. (Bill) McArthur Jr., Expedition 12 commander and NASA ISS science officer, talks to students at Tomioka Elementary School in Urayasu City, Chiba, Japan during an amateur radio session

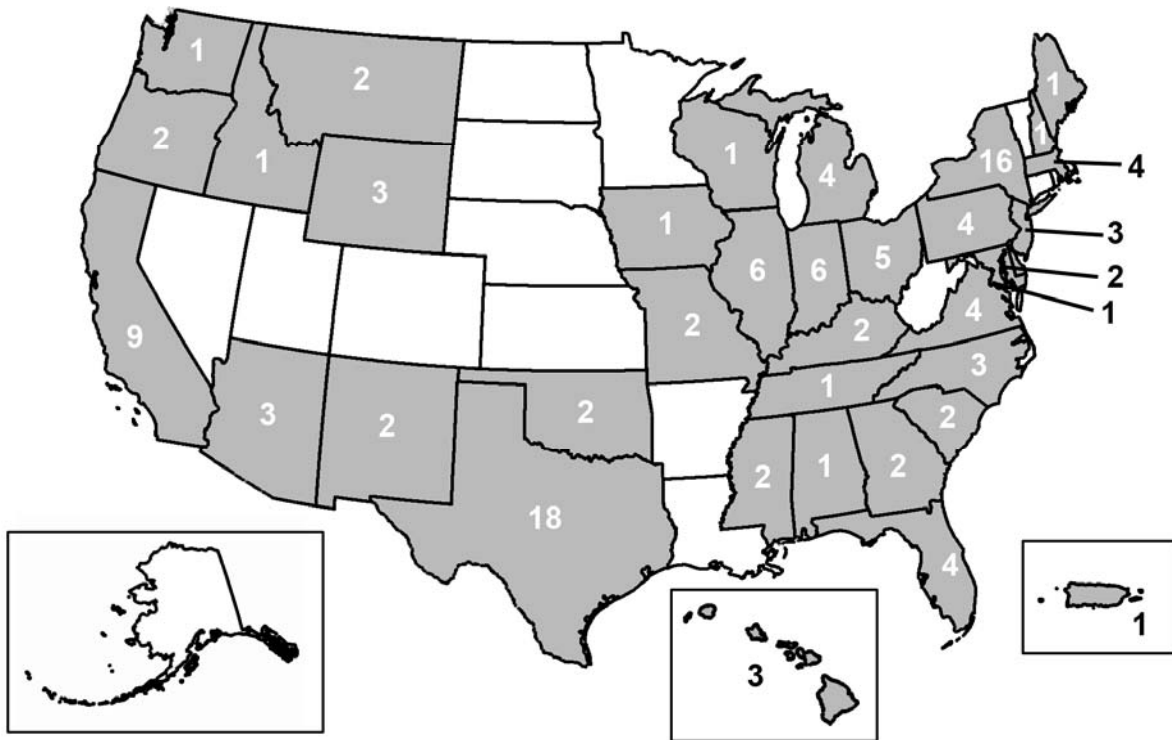
On April 4, 2006, Expedition 12 Commander Bill McArthur performed a school contact with the Robert McQueen High School in Reno, Nev. Among the numerous questions the students asked were:

- What kind of research do you conduct?
- Do you like it better in space or on Earth?
- What's the most important thing you've learned in space?
- Do you think we will ever live in space permanently?

Besides asking the questions, students are also involved in supporting the ARISS program in a number of different ways. Young women at Sacred Hearts School in Honolulu, Hawaii, have been supporting ARISS for a number of years by running the Hawaii ground station under the direction of their teacher and a local AMSAT volunteer. The ARISS program extends beyond contacts with station. NASA Explorer School teachers from Pine Ridge Middle School, Naples, Fla., held a "NASA Nights" event to educate teachers, parents, and students about NASA programs. An amateur radio station was set up to allow students to question ham radio operators at NASA ARC in California. The NASA ARC radio operators then made contact with ham radio operators at NASA KSC and relayed students questions to experts on space station and space shuttles.

During Expedition 5, astronaut Peggy Whitson spoke to more than 100 students between the ages of eight and 15 who were attending a space camp in Belgium. The direct contact between the ISS and the European Space Center, Belgium, which hosted the camp, was arranged and coordinated through ARISS. "In the auditorium on a big screen, the children saw the ISS approaching Europe from over the Atlantic Ocean," said ARISS vice chairman Gaston Bertels. "They had been introduced to ham radio on the ISS, and now—a half an hour before the contact—they were putting dozens of questions to the ARISS representative and eagerly gathering answers." Because the youngsters spoke either Dutch or French, a computer program was used by those translating the astronauts' English into Dutch and French to display the translations on the screen.

Nationwide School Participation in ARRIS (2000-2006)

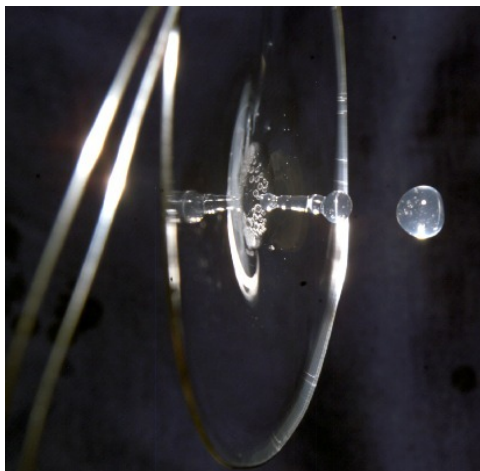


A total of 125 schools across 34 states (plus Puerto Rico and the District of Columbia) have participated in ARISS.

Principal Investigator(s): Frank Bauer, NASA GSFC, Greenbelt, Md.
 Education Lead(s): Rosalie White, American Radio Relay League
 Education Web Site(s): <http://www.arrl.org/ARISS/>

DON PETTIT'S SATURDAY MORNING SCIENCE

Expedition(s): 6
Grade Level(s): K-12, undergraduate, graduate
Impact: High school and college students are performing many of the activities that astronaut Don Pettit performed on ISS.



Water surface tension demonstration performed by ISS Expedition 6 NASA Science Officer Don Pettit.

EXPERIMENT DESCRIPTION

In his free time on the weekends during his six months on ISS as Expedition 6 Science Officer, astronaut Don Pettit enjoyed performing a number of experiments on his own that became known as Saturday Morning Science. Pettit performed demonstrations showing how bubbles behave in microgravity, experimented with thin films and fluid flows, and grew salt crystals out of a suspended thin film solution. While most of his work was done for fun and motivated by his own curiosity, much of it has been of great value to researchers involved in understanding how fluids and foams behave in space. Students have shown great interest in the demonstrations. Science@NASA published a series of stories about Pettit's Saturday Morning Science activities targeted for students, and suggested experiments that students could perform on their own to better understand the results obtained on station.

STUDENT ACTIVITY

Based on the science demonstrations Pettit performed during Expedition 6, high school and college students have performed similar ground-based experiments to compare their results with those obtained in space. The videos NASA produced from Pettit's Saturday Morning Science are being used by science teachers across the country to demonstrate some of the basic principles of fluid physics.

STUDENT PARTICIPATION

Students from across the country have performed many of Pettit's Saturday Morning Science demonstrations in their classrooms to compare their results with those obtained by Pettit aboard ISS. One college co-op student working in the CEO group at NASA JSC has helped with the image processing for Saturday Morning Science.

Principal Investigator(s): Astronaut Don Pettit,
Astronaut Office, NASA JSC,
Houston, Texas

Education Lead(s): Don Pettit, Astronaut Office,
NASA JSC, Houston, Texas

Education Web Site(s): <http://spaceflight.nasa.gov/station/crew/exp6/spacechronicles.html>



ISS Expedition 6 NASA Science Officer and Flight Engineer, Don Pettit, shown onboard station.

SUIT SATELLITE-1 (SUITSAT-1)

Expedition(s): 12, tentatively scheduled again for Expedition 14 or 15

Grade Level(s): K–12

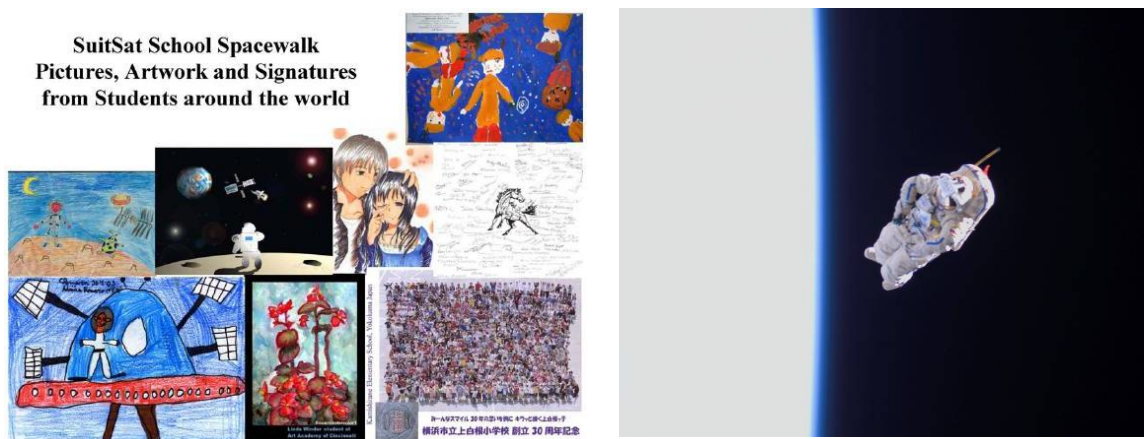
Impact: Hundreds of schools worldwide attempted to make contact with SuitSat-1, and nearly 300 schools and student groups participated in the “School Spacewalk” project that flew inside SuitSat-1. The SuitSat experiment generated tremendous public interest with nearly nine million hits logged at the www.suitsat.org Web site.

EXPERIMENT DESCRIPTION

A decommissioned Russian Orlan suit (used in EVAs) was outfitted with an amateur radio and was released into a retrograde orbit from ISS by the Expedition 12 crew during an EVA on Feb. 3, 2006. Known variously as Suit Satellite-1 (SuitSat-1) or Radio Sputnik, the radio continued transmitting prerecorded messages and images for approximately two weeks before the radio batteries expired. SuitSat-1 was able to downlink various images using a series of audio tones, similar to those of a computer modem, using the ham radio picture standard of Slow Scan Television and downlinked images of similar quality as received on cell phones. Students, teachers, scout troops, ham radio operators, and the general public were able to track the signals from SuitSat-1 and listen to the messages.

STUDENT ACTIVITY

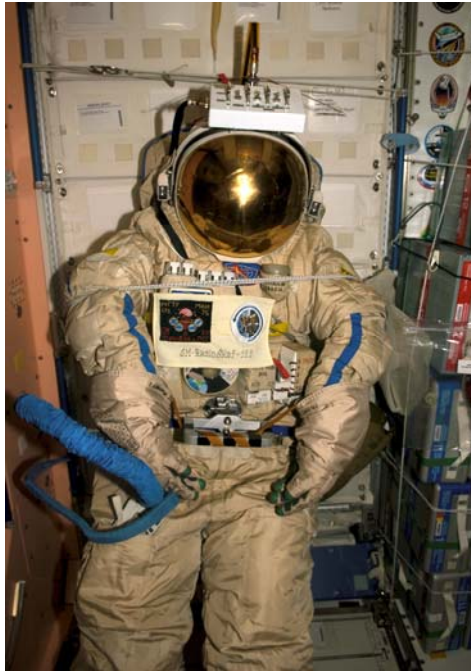
The voices and images coming from SuitSat-1 were collected from students around the world. As Suitsat-1 floated in space, it transmitted voice messages from students in Russia, Japan, Europe (Spanish and German), Canada (French), and the United States. (English). These messages contained a “hidden” special word that the students needed to identify. Students were able to copy these special words in different languages and submit them to the ARISS Team for special educational award recognition.



Students from all over the world contributed materials for the SuitSat-1 CD (left). SuitSat-1 is shown in orbit (right) after its release from station during Expedition 12.

Students submitted data on when they heard the SuitSat-1 transmission and suit temperature, battery power, and mission elapsed time that were continually being transmitted by SuitSat. These data were then posted on a Web site and were used to track the radio status and orbit and decay of the SuitSat. Students received certificates for making contact with SuitSat-1 plus a special endorsement on the certificates if they were able to identify the “hidden” words in the transmissions.

Placed inside the Orlan suit was a special student CD called “School Spacewalk” that contained images of student artwork, signatures, poems, class pictures, and scout logos.



An Orlan suit, with arms tied down and suit handrail attached, is shown being prepared for Radioskaf (also known as SuitSat-1) microsatellite operations on Expedition 12. The control box and antenna are visible, attached to the helmet. This image was taken inside the Unity Node 1 module on ISS.

STUDENT PARTICIPATION

Hundreds of schools from all over the world were represented on the “School Spacewalk” CD, including images from the United States, Japan, Europe, Russia, South America, and Africa. A number of NASA Explorer Schools were involved in the CD as well as schools sponsored by the European Space Agency (ESA) and the Russian Space Agency. Two identical CDs were flown. One was placed inside the spacesuit, and the other remained inside the ISS for the Expedition 12 crew to review. Approximately 300 items were on the CD, including student artwork, school and educational organization logos, student signatures, and student and school pictures.

The ARISS Team is planning to develop numerous science lessons plans for schools based on SuitSat-1. For example, one plan involves having students use the recorded audio together with the video of the Orlan spacesuit immediately after deployment to study the spin rates of the suit to see whether they slowed down or speeded up as the SuitSat-1 orbit decayed

Prerecorded messages and greetings to students were transmitted by SuitSat-1 in six different languages (English, French, Japanese, Russian, German and Spanish). The message to students in the United States was done by Ashley Liggins, a sixth-grade minority student at one of the NASA Explorer Schools—the Eastern Middle School in Silver Spring, Md. Ashley has a strong interest in pursuing a career in math or science, and her teacher nominated her for this project as a way of encouraging and motivating her. In addition the identification announcement being broadcast by SuitSat-1, “This is SuitSat-1 RS0RS,” was done by Michelle Bauer, a Korean-born girl enrolled at Paint Branch High School in Burtonsville, Md.

Principal Investigator(s): Frank Bauer, NASA GSFC, Greenbelt, Md., and Alexander Alexandrov, Russian Space Agency

Education Lead(s): Rosalie White, American Radio Relay League

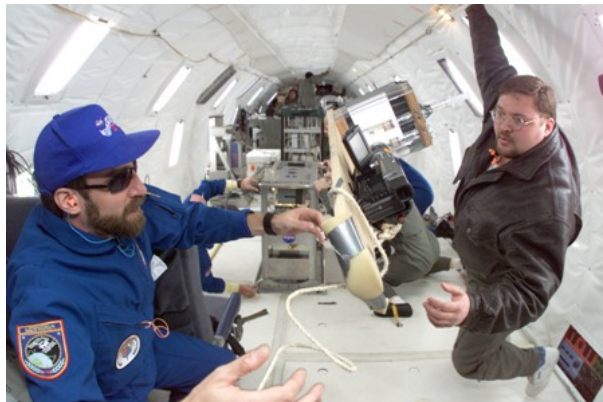
Education Web Site(s): <http://www.suitsat.org>

REDUCED GRAVITY RESEARCH PROGRAM

Dates: 1996–2004 (expected to resume in 2006)

Grade Level(s): 9–12, Undergraduate

Impact: For microgravity test flights directly linked to ISS experiments, 61 students participated in the Reduced Gravity Research Program—four high school, 52 undergraduate, and five graduate students. In addition 2,476 students from 620 schools nationwide have participated in the “Microgravity University,” including 2,010 undergraduate students and 466 high school students.



Principal investigator John Pojman and student William Ainsworth (University of Southern Mississippi, Hattiesburg, Miss.) perform the MFMG experiment onboard the KC-135 aircraft. MFMG would later fly onboard the ISS.

EXPERIMENT DESCRIPTION

Before experiments are sent to station, they are tested using a variety of microgravity simulations. Many new pieces of experimental hardware and research approaches are tested in parabolic flight simulations of microgravity. During these parabolic flights, experimenters have access to repeated short periods (25 seconds) of microgravity in which to conduct their experiments. Many of the microgravity simulations in parabolic flight are directly or indirectly linked to ISS research.

STUDENT ACTIVITY

The Reduced Gravity Research Program consists of two areas that allow for student participation. The first area is that of research prior to an experiment to ISS. Students who are affiliated with a

principle investigator have assisted in many capacities. These students design, build, and test hardware as well as collect and analyze data from the microgravity simulation flights.

The second program that students can participate in is the “Microgravity University.” Student involvement starts with the proposal of their experiment to the Microgravity University. Once the experiment is chosen for flight, the students are responsible for building the experiment, meeting the deadlines, and staying within budget. The students will fly, perform, and document the experiment during parabolic flights. They must record and analyze the results to provide a report on their findings. This program is designed to motivate students who have decided to study science, technology, and engineering. Additionally, it provides an opportunity to introduce students to science, technology, and engineering who may not have previously considered careers in those fields.



Students from the University of Wisconsin-Madison, Madison, Wis. (in green) and JSC support team (in blue) pose for a picture before flight in July 2005.

STUDENT PARTICIPATION

Since the Microgravity University program began in 1996, 2,010 undergraduate students from 154 schools from 45 states as well as 466 high school students from 73 schools from Texas and New Mexico have participated in it. Many of these students have gone on to careers in science and engineering.

Many of the students who participated in the Reduced Gravity Research Program assisted the principle investigator with analyzing the data that were collected during operation on the ISS (TABLE IX). These students compared the data collected during the parabolic flights to what was collected on ISS. The data were used to write scientific papers.

Dr. Mark Weislogel, a NASA principle investigator from Portland State University (PSU), Portland, Ore., participated in the Microgravity University and writes:

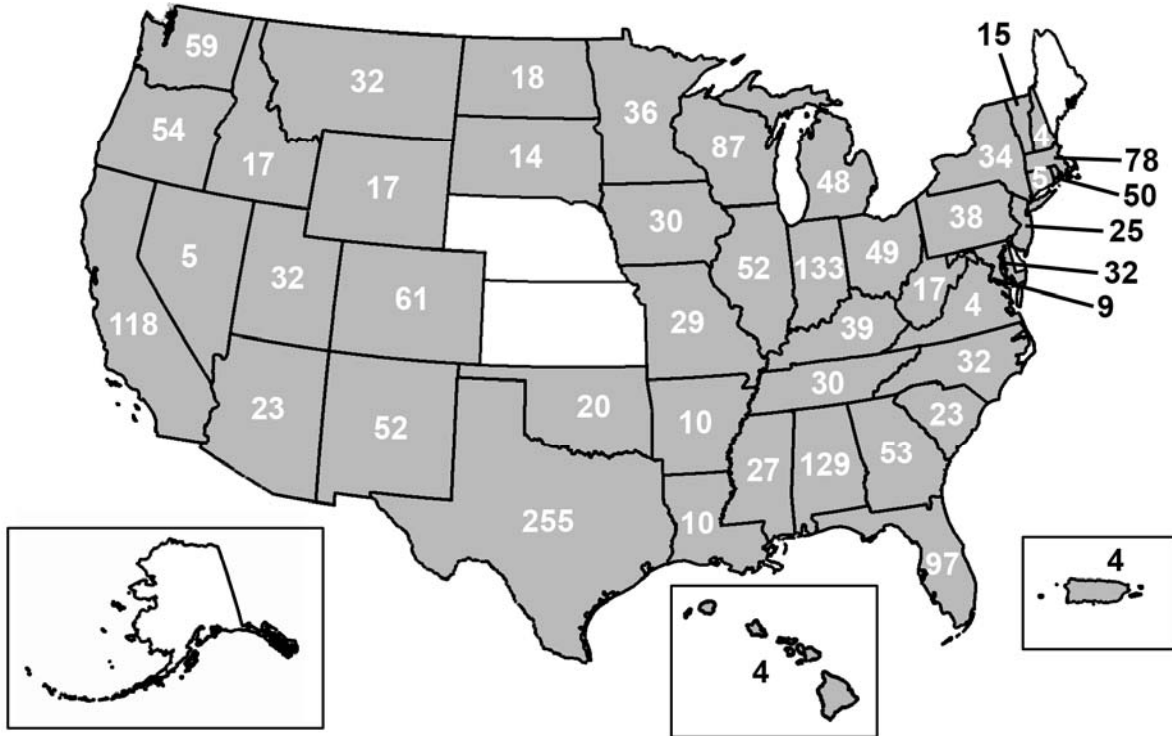
The real impact of the NASA funding over this period was simply a “NASA connection to the school” that has allowed outreach level support to student groups to propose and participate in NASA's undergraduate student research opportunities program using the KC-135. PSU has had five teams (20 undergraduates, 16 senior BSMEs [bachelors of science in mechanical engineering], and four architectural students) participate in the program over the last three years and has been able to fan the enthusiasm of current students, prospective students, and our local community.

Table IX. Undergraduate student participation in microgravity test flights related to the development of experiments for ISS.

Experiment	Principle Investigator, University Students	No. of Students	Description of Student Involvement
Boiling eXperiment Facility-Microheater Array Boiling Experiment (BXF-MABE)	Jungho Kim, Univ. Maryland, College Park, Md., and Univ. of Denver, Denver, Colo.	10	Students designed, built, and tested the hardware that is used for the BXF-MABE experiment. The students also took data during the parabolic flights; and reduced and analyzed these data. The data were used to write scientific papers.
BXF-NPBX	Vijay Dhir, Univ. of California, Los Angeles, Calif.	2	Students fabricated test heaters that were used during the parabolic flights. The students conducted the experiments by setting the parameters, nucleating the bubble, and recording and analyzing the data.
CFE	Mark Weislogel, Portland State University, Portland, Ore.	1	The student participated in assisting the principle investigator in conducting experiments in fluid physics during parabolic flights.
FMVM	Edwin C. Ethridge, Univ. of Tennessee, Tullahoma, Tenn.	2	Students tested the hardware and syringe pump, which released two liquid spheres and merged the spheres together. They also took video data, and reduced and analyzed these data for the principle investigator.
In-space Soldering Experiment (ISSI)	Richard Grugel, Univ. Of Alabama, Tuscaloosa, Ala.	5	Students conducted soldering experiments that compliment the ISS experiment to examine variables such as flux volume and composition.

Experiment	Principle Investigator, University Students	No. of Students	Description of Student Involvement
Microcapsulation Electrostatic Processing System (MEPS)	Dennis Morrison, Booker T. Washington Senior High School and High School for Engineering Professions, Houston, Texas	4	High school students conducted surface tension experiments and fluid flows between two fluids. They also tested the hardware that fills microcapsules with fluids; this was the precursor to the hardware that was used on ISS.
MFMG	John Pojman, Univ. of Southern Mississippi, Hattiesburg, Miss.	1	The student participated in testing an apparatus in which the interaction of glycerol and water was examined in weightlessness. This was the precursor to the honey and water experiment used on ISS.
SPHERES	David Miller, MIT, Cambridge, Mass.	13	Students activated the SPHERES hardware and performed systems checks.
BioServe Hardware	Louis Stodieck, Univ. of Colorado, Boulder, Colo.	23	Students built and validated hardware that flew on the ISS and was used for several payloads. The hardware that was tested included PGBA, fluids generic bioprocessing apparatus (FGBA), GAP, and fluids processing apparatus (FPA).
Total		61	

**NASA Microgravity University
Participating Undergraduate Students by State (1997-2004)**



Teams that have flown in the Reduced Gravity Research Program, Microgravity University, have represented 45 states (plus Puerto Rico and the District of Columbia). The number of undergraduate students participating from each state is indicated on the map. A total of 2,010 students from 154 schools nationwide have participated in the program.

Principal Investigator(s): John Yaniec, NASA's Reduced Gravity Program, NASA JSC, Houston, Texas
 Education Lead(s): Donn Sickorez, Microgravity University, NASA JSC, Houston, Texas
 Education Web Site(s): <http://microgravityuniversity.jsc.nasa.gov/>

SUMMARY AND CONCLUSIONS

A wide range of student experiments and educational activities was performed on the space station during 2000–2006, with many of these activities still continuing. Students and teachers from across the United States have participated in the programs, and students from kindergarten through college and university undergraduates, graduate students, and postdoctoral fellows have enjoyed the excitement of participating in the ISSP. It was not possible in all cases to accurately quantify all student participation because all activities were not documented. For those programs where counts of student participation were available, we have summarized that involvement in **TABLE X**. Complete details for each experiment, including identification of those for which student numbers were unavailable, are summarized in Appendix 1.

Table X. Summary of documented U.S. student participation in ISS-based educational activities (2000–2005).

Type of Activity	K–12	Undergraduate	Graduate/ Postdoctoral
Student-developed experiments	66,098	150	
Classroom versions of ISS experiments*	808,416		
Students working on NASA research	58,179	105	216
Students working on ISS engineering activities	550	164	30
Educational demonstrations	30,945,545		
Microgravity parabolic flight participation related to ISS research	4	52	5
Total*	31,878,792	471	251

*An additional 2–4 million students are expected to participate in new, upcoming projects (such as Basil Seeds in Space, CSI, and Educator Astronaut).

The total U.S. student involvement on ISS projects and activities to date is nearly 32 million. This number represents a minimum measure of participation because it does not include the projects in which student involvement was not tracked. Based on the autumn 2004 Department of Education estimate of 71.7 million students in the United States,¹ this represents the ISS touching the lives of almost half of the students in the U.S. (one in every 2.2), most of them via educational downlinks from ISS that are broadcast across the country.

Besides being of benefit to the students, many of these ISS programs have seen tremendous success in involving teachers. Some of the ISS experiments have encouraged significant participation by teachers through workshops that help the teachers prepare for the student experiments and activities. In **TABLE XI** we summarize the number of teachers in the U.S. that have participated in ISS-based education workshops.

¹Thomas D. Snyder and Alexandra G. Tan, 2005, Digest of Education Statistics 2004, NCES 2006005, National Center for Education Statistics, U.S. Department of Education. <http://nces.ed.gov/programs/digest/d04/>

Table XI. Summary of U.S. teacher participation in ISS-based education workshops.

Workshop Focus	Number of Teachers Participating
Student-developed experiments	382
Classroom versions of ISS experiments	2,470
Students working on ISS research	2,863
Students working on ISS engineering	750
Educational demonstrations	6,069
Total	12,534

To date, over 12,000 U.S. teachers have participated in workshops related to ISS student experiments and other educational activities. As these teachers are likely to continue teaching future classes once the workshops are completed, the impact on students from teacher workshop participation could be quite high but is difficult to accurately assess.

Based on information collected from the wide assortment of educational programs that have used ISS as a platform, a number of observations and recommendations can be made regarding the future of student experiments and educational activities on the ISS:

- (1) NASA, the ISS International Partners, and numerous schools, colleges, universities, and businesses have done an outstanding job in developing programs that make the ISS accessible to students from across the United States and around the world; indeed, students from all age groups, from K–12 to university students, have had a chance to participate. Between the years 2000 and 2006, nearly 32 million students were involved in projects or activities associated with the ISS.
- (2) In many cases, there can be a long time between when the students develop their experiments and when they are flown and returned to them for analysis. Moreover, in many of these cases the students (and some teachers) have moved on to other schools or graduated, which has made completing the experiment analysis difficult. These long times are due in part to uncertainties in the launch schedules and recent problems and delays in the Space Shuttle Program. For this class of experiments, it is recommended that the experiments and programs be designed to hand off from one student or class to another and recognize that to conceive, develop, fly, and complete an experiment within the time limitations of a single school year present a formidable challenge. The natural disappointment in student experiments not flying or being completed within their school year can be minimized if the programs are set up to involve multi-generations of students where one class can hand the project over to another. This multi-generation approach has the added benefit of involving more students in the projects.
- (3) Projects such as those that involve students growing seeds in their classrooms, taking pictures of the Earth, or talking with the astronauts via amateur radio are much shorter-term activities that can usually be completed within the limited time of a semester or school year. These experiments and activities have been tremendously successful and have seen widespread participation.
- (4) Projects and experiments involving exposing seeds to space for later student classroom experiments have been highly successful in reaching large numbers of students. Pioneering these experiments was the Long Duration Exposure Facility, which was launched and deployed by the

shuttle *Challenger* during the STS-41C mission in 1984 and returned on the shuttle *Columbia* during the STS-32 mission in 1990. Nearly three million students were involved in growing these seeds once they were returned to Earth. Similar programs on ISS have been equally successful with nearly a million students involved. In addition, eight million basil seeds that will support nearly two million student experiments are set to launch to ISS on the STS-121 mission later in 2006.

- (5) Even relatively simple events such as astronauts answering student questions during educational downlink opportunities can have widespread impact by taking advantage of distance learning resources and NASA television. During the Expedition 12 mission, over 17 million students were able to participate in five different in-flight education downlinks from the ISS.
- (6) Due to the limitations on launching experiment and educational hardware to ISS, experiments or activities that require minimal upmass and crew time on orbit can be tremendously successful and should be encouraged. The EarthKAM experiment, for example, takes advantage of existing digital cameras on ISS and requires only an hour or two of crew time for experiment setup and checkout before control is turned over to the students. From this hour of crew time, anywhere from 1,000 to 2,000 student photos are downlinked that support the experiments of 5,000 to 6,000 students.
- (7) Opportunities for student experiments and involvement with NASA and university-funded researchers should be explored and developed as much as possible. Not only can students benefit from the mentorship of the professional investigator, but in many cases they can take advantage of opportunities to fly experiments piggybacked onto others. MISSE is a wonderful example of how a limited excess experiment capacity was turned into successful student experiments. Eleven student experiments were flown on MISSE-1 and -2, and eight million basil seeds that could be fit into the MISSE-5 carrier will support nearly two million experiments. Protein crystal growth experiments that have flown have also successfully incorporated both teachers and students into their research team by conducting workshops and involving teachers and students in the preparation of protein samples for flight. The Student Access to Space project involved more than 58,000 students and nearly 1,200 teachers as part of the Protein Crystal Growth-Enhanced Gaseous Nitrogen (PCG-EGN) experiment.
- (8) Developing teacher activities involving ISS have been successful in bringing the excitement of exploration into the classrooms. An EarthKAM session is typically conducted each summer in which teachers from across the country learn about space operations, thereby ensuring that the EarthKAM process can then be taken back to their schools for future sessions. The Student Access to Space project also involved teaching the teachers how to prepare protein crystals for flight. These “Flight Sample Workshops” involved 260 teachers, resulting in 420 students preparing actual flight samples for the NASA investigator experiments on ISS. In addition during Expedition 2, 2,423 teachers participated in the Orbital Laboratory project, growing seeds on Earth at the same time at which seeds were being grown on ISS.
- (9) Educational demonstrations recorded on ISS with their supporting teacher guides have a lasting impact on large numbers of students—beyond what could be tracked for this report. These activities are rolled in to the existing NASA infrastructure for distributing materials to teachers and training teachers to use them. They are also used by an uncounted number of other individuals in informal and formal settings to motivate students about math, science, and space exploration. To date, most of these materials are provided to teachers via print and recorded media. Transition of NASA materials such as International Toys in Space and other Education Demonstration Activities to Web distribution could also greatly expand their availability to

teachers and parents and increase their impact on students worldwide. A focused effort to identify and transition existing materials would increase the educational impact of activities already completed on orbit.

Since assembly began in 1998, the ISS has been providing valuable experience in space operations and helping to design, develop, and evaluate advanced technologies needed to support future long-duration exploration missions. During this same period, the ISS has also proved its value as a platform and focus for exciting our youth and increasing their interest in science, technology, engineering, and mathematics. As today's students are most likely part of the generation that will be the first to set foot on Mars, preparing them today for the challenges ahead is equally important to making sure that the technologies will be ready for these missions. The ISS is proving itself a valuable testbed for both of these activities.

**APPENDIX 1:
SUMMARY OF COLLECTED EDUCATION IMPACTS**

Table 1-I. Summary of student and teacher participation in ISS activities.

	Students			Teachers	
	K-12	Undergrad.	Grad./ Postdoc.	Workshops	Other
Student-Developed Experiments	66,098	150		382	38
EarthKAM	65,648	150		382	
Project MISSE	150				27
Space Experiment Module	300				11
Classroom Versions of ISS Experiments	808,416			2,470	4
Orbital Laboratory	58,416			2,423	
Farming in Space	Uncounted			47	4
JASON XI	750,000			Uncounted	
Basil Seeds in Space	Future			Future	
CGBA Science Insert	Future			Future	
Educator Astronaut	Future			Future	
Students Working on ISS Research	58,179	105	216	2,863	27
Student Access to Space	58,000			1,200	
Crew Earth Observations	Uncounted			1,663	
MISSE PEACE	17				1
Other ISS Research Payloads	162	105	216		26
Students Working on ISS Engineering	550	164	30	750	26
MIT Capstone		30			1
HUNCH	550				20
PCSat-2		18			1
Space Engineering Institute		76	20		4
AgCam	Uncounted	40	10	750	
Educational Demonstrations	30,945,545			6,069	1,073
Teaching From Space	Uncounted				Uncounted
<i>International Toys in Space</i>	Uncounted				500
MAEA	Uncounted				Uncounted
<i>Demonstration Activities</i>	Uncounted				Uncounted
<i>Education Downlinks</i>	30,909,695				58
Aerospace Education Services Program	4,850			6,069	
Amateur Radio on ISS	31,000				125
Don Pettit's Saturday Morning Science	Uncounted				90
Suit Satellite-1	Uncounted				300
Reduced Gravity Research Program-ISS	4	52	5		9
Total	31,878,792	471	251	12,534	1,177

**APPENDIX 2:
ISS EXPEDITIONS AND CREWMEMBERS**

Table 2-I. International Space Station Expeditions and crewmembers.

Expedition	Dates*	Astronauts and Cosmonauts†
0	Dec 1998 – Nov 2000	Assembly of ISS prior to continuous human occupation
1	Nov 2000 – Mar 2001	Bill Shepherd, Yuri Gidzenko (R), Sergei Krikalev (R)
2	Mar 2001 – Aug 2001	Yury Usachev (R), James Voss, Susan Helms
3	Aug 2001 – Dec 2001	Frank Culbertson, Vladimir Dezhurov (R), Mikhail Tyurin (R)
4	Dec 2001 – Jun 2002	Yury Onufrienko (R), Daniel Bursch, Carl Walz
5	Jun 2002 – Dec 2002	Valery Korzun (R), Peggy Whitson, Sergei Treschev (R)
6	Nov 2002 – May 2003	Kenneth Bowersox, Donald Pettit, Nikolai Budarin (R)
7	Apr 2003 – Oct 2003	Yuri Malenchenko (R), Ed Lu
8	Oct 2003 – Apr 2004	Michael Foale, Alexander Kaleri (R)
9	Apr 2004 – Oct 2004	Gennady Padalka (R), Mike Fincke
10	Oct 2004 – Apr 2005	Leroy Chiao, Salizhan Sharipov (R)
11	Apr 2005 – Oct 2005	Sergei Krikalev (R), John Phillips
12	Oct 2005 – Apr 2006	Bill McArthur, Valery Tokarev (R)
13	Apr 2006 – Sep 2006	Pavel Vinogradov (R), Jeffrey Williams. Thomas Reiter (ESA) is planned to join the crew with the launch of shuttle flight STS-121
14	Planned Sep 2006 –	Michael Lopez-Alegría, Mikhail Tyurin (R). Sunita Williams is planned to join the crew with the launch of shuttle flight STS-116

*Crew docking to crew undocking.

†Commander listed first; Rosaviakosmos or Russian Federal Space Agency cosmonauts are indicated with (R).

**APPENDIX 3:
INTERNATIONAL EDUCATIONAL ACTIVITIES**

Brazilian Space Agency



AEB astronaut Marcos C. Pontes uses a computer while conducting experiments in the Destiny laboratory of the ISS.

In April 2006, Brazilian astronaut Marcos Pontes participated in an ISS taxi flight for the Centauro Mission for the Brazilian Space Agency (Agência Espacial Brasileira (AEB)). In addition to his program of research experiments, he also completed on-orbit portions of two educational activities: the SEEDS experiment and the Chlorophyll Chromatography (CCM) experiment. The SEEDS experiment tested the germination and growth of Brazilian plant seeds under different light conditions, with students growing control seeds on the ground. As part of the CCM experiment, the chromatography of chlorophyll (i.e., the separation of pigment in plants on chromatography paper by capillary action) from Brazilian native

plants was completed on orbit for comparison with the same analysis on Earth. A Web site with classroom activities and photographs of the growing plants and chromatography results on ISS was developed by the Secretaria Municipal de Educação de São José dos Campos (<http://www.las.inpe.br/microg>). During the mission, Pontes also used ARISS to speak with students from Escola Americana in Rio de Janeiro. The contact was conducted in English and Portuguese as the ISS passed above the Aerospace Museum at the Afonsos Air Base.

Canadian Space Agency

FIRST CANADIAN CLASSROOM PRESENTATION FROM THE ISS

Expedition(s): 3
Grade Level(s): K–12
Impact: More than 70,000 students across Canada participated in this live educational downlink from ISS.

On Sept. 27, 2001, the first Canadian on-orbit interactive educational session took place on ISS. Titled “The First Canadian Classroom Presentation from the ISS,” this event featured NASA astronaut Frank Culbertson serving as guest-educator for a 20-minute live downlink during Expedition 3. The focus of the lesson was space robotics, and Culbertson illustrated the concept of inertia and microgravity as they pertain to moving payloads in space with the Canadarm2 robotic arm on the ISS. A supporting curriculum “Canadarm2: Moving Payloads in Space,” targeted ninth- and tenth-grade students. While the students used soda-straw models of the Canadarm2 on Earth, Culbertson used his own model of Canadarm2 to demonstrate the concepts of inertia and microgravity.

Education Lead(s): Marilyn Steinberg, Canadian Space Agency
Education Web Site(s): http://resources.yesican-science.ca/trek/canadarm2/real_time.html

TOMATOSPHERE

Expedition(s): 9–11, student activities began in spring 2006

Grade Level(s): 2–10

Impact: More than 6,000 classrooms are growing tomato seeds, comparing the growth of space-flown and control seeds.

EXPERIMENT DESCRIPTION

A group of tomato seeds was exposed to space conditions during 18 months onboard space station (January 2004 through August 2005). The seeds went into space on Progress flight 13P and returned to Earth on the shuttle *Discovery* (STS-114/LF-1). An identical set of seeds was kept on Earth as a control.

During a previous Tomatosphere program, students studied the growth of their tomato plants in Miss Smith's grade three class at Langley Fundamental Elementary, Vancouver, B.C., Canada.



Astronaut Edward M. (Mike) Fincke, Expedition 9 NASA ISS science officer and flight engineer, is pictured in the Zvezda Service. A bag of tomato seeds for the Tomatosphere II Project, an educational program sponsored by Canadian Space Agency, floats nearby.

STUDENT ACTIVITY

The Tomatosphere project uses the excitement of space exploration as a medium for teaching students about science, space, and agriculture. Students are experimenting with seeds exposed to 18 months on ISS and control seeds that remained on Earth. In grades 2–4 the curriculum focuses on plants and their growth patterns; in grades 5–7 the emphasis is on human needs, weather, and space; and in grades 8–10 students will start with the seeds and complete their studies with an application of the benefits of space exploration, research, and application to life on Earth. All of the results will be sent electronically to the Tomatosphere Web site and will be posted there to enable participants to compare their results with those of other classrooms across the country.

STUDENT PARTICIPATION

Tomatosphere activities using the seeds flown on ISS are expected to involve more than 6,000 classrooms in Canada (as well as in the United States and several other countries) in spring 2006.

Education Web Site(s): <http://www.tomatosphere.org/>

European Space Agency

ESA and the space agencies of its member countries have arranged with the Russian Space Agency to have their astronauts fly to ISS as the third crewmember in the Soyuz crew-exchange flights, stay for eight days onboard station to complete scientific and educational objectives, and then return with the departing ISS crew.

Table 3-I. Soyuz taxi flights sponsored by ESA or its member nations.

Mission	Date	Astronaut	Sponsor
Andromède	Oct 2001	Claudie Haigneré	French Space Agency (Centre National d'Etudes Spatiales (CNES))/ESA
Marco Polo	Apr–May 2002	Roberto Vittori	Italian Space Agency (Agenzia Spaziale Italiana (ASI))/ESA
Odissea	Oct–Nov 2002	Frank De Winne	Belgium/ESA
Cervantes	Oct 2003	Pedro Duque	Spain/ESA
DELTA*	Apr 2004	André Kuipers	Netherlands/ESA
Eneide	Apr 2005	Roberto Vittori	ASI/ESA

*Dutch Expedition for Life Science, Technology, and Atmospheric Research

Educational products developed by ESA for member states include ISS Education Kits with teaching material for primary and secondary schools. A total of 4,500 primary school kits have been produced in English, and 40,000 secondary school kits have been produced in all 12 ESA languages.

Three major types of educational initiatives have been linked to Soyuz taxi flights. University students have been challenged to design small science experiments for competitions. The experiments designed by the winners are carried on ISS during the taxi flights. Activities for primary schools (ages 8–12) have focused on live communication with astronauts on station through amateur radio or other communication methods. Activities for secondary schools (ages 12–18) have focused on acquiring videos of demonstration activities on ISS. In addition, some student activities have been linked to data collections for other science experiments.

During the summer of 2006, ESA astronaut Thomas Reiter is scheduled to launch to the ISS on the shuttle *Discovery* on the STS-121 mission; he will be joining the Expedition 13 crew for a six-month mission aboard the ISS. This long-duration mission will be called the ESA Astrolab Mission. Activities planned for this mission are also summarized below.

ESA STUDENT-DEVELOPED EXPERIMENTS ON ISS

DETERMINATION OF THE EFFECT OF GRAVITY ON THE DEVELOPMENT OF A COLONY OF BACTERIA (WINOGRAD), CERVANTES MISSION

The goal of Winograd was to understand how space affects bacteria by growing a type of bacterial colony, “Winogradski columns,” in a weightless environment and comparing the colony with bacteria that forms spontaneously on Earth. A Winogradski column is a colony of different types of bacteria in which the waste products of one bacterium serve as the nutrients of the other type of bacteria. These systems are found in ordinary ponds or lake water and need no other input than light for photosynthesis. The bacteria for the Winograd experiment came to ISS on a crewless Russian Progress capsule, and the experiment was completed as part of Cervantes. This student experiment was selected as part of the “Pyramid of Space” contest. *R. Dhir, D. Smillie, and T. Banerjee, University of Edinburgh, Edinburgh, Scotland.*

STUDY ON THE DEVELOPMENT OF METHODS TO PRODUCE ARTIFICIAL CARTILAGE (CHONDRO), CERVANTES MISSION

The objective of the Chondro space experiment was to find more stable bone cartilage structures by dissolving cartilage tissue from pig bones into its basic components and then re-growing those components into new cartilage. This student experiment was selected as part of the “Pyramid of Space” contest. *G. Keller, V. Stamenkovic, Technical University of Zurich (Switzerland).*

STUDY OF OUTPUT OF BACTERIAL FUEL CELLS IN WEIGHTLESSNESS (BUG-NRG), DELTA MISSION

The Bug-NRG experiment studied how weightlessness influences the efficiency of bacterial fuel cells. The aim was to acquire precise data on the output of these fuel cells in space. Some bacteria are capable, in the right circumstances, of converting carbohydrates into electrons and CO₂. This process can be used as a source of energy in so-called bacterial fuel cells. When placed inside a two-chamber fuel cell, these bacteria can produce an electrical current. The output of the cell can be measured and recorded to study the properties of the fuel cells. Bug-NRG is one of two experiments that were winners of a student competition organized by the Dutch government through the Department of Education, Culture and Science. *Sebastiaan de Vet and Renske Rutgers (Netherlands), <http://www.phys.uu.nl/~bugnrg/english/index.htm>.*

STUDY INTO INTERACTION OF EFFECT OF LIGHT AND GRAVITY ON THE GROWTH PROCESSES OF PLANTS (GRAPHOBOX), DELTA MISSION

On Earth, two major stimuli affecting plant growth are light and gravity. With respect to light, shoots grow towards light; this is called phototropism. Root growth direction, however, is affected by gravity; this is called gravitropism. The GraPhoBox experiment sought to assess the effects of phototropism and gravitropism on plants and to observe whether there was a link between the two. The goal was to germinate seeds from a variety of mustard plant common in genetic research in low-intensity light and without light both on the ground under Earth’s gravity and under weightlessness on the ISS. GraPhoBox is one of two experiments that were winners of a student competition organized by the Dutch government through the Department of Education, Culture and Science. *Karel Buizer (Netherlands).*

BONE PROTEOMICS, ENEIDE MISSION

This educational experiment was designed to study the molecular mechanisms that regulate the physiology of human osteoblasts in weightlessness. Long periods of weightlessness induce bone mass loss in astronauts. Previous experiments indicate that this negative effect is mainly due to the reduced activity of osteoblasts, the cells that physiologically produce bone material throughout our life. The experiment studied whether adenosine triphosphate (ATP) can stimulate osteoblast cells in weightless conditions, possibly balancing or overcoming the negative effects of weightlessness. This experiment, which is the first proteomic study (looking at the whole protein content) on mammalian cells in space, was the winner of the 2002 SUCCESS Student Contest. *A. Costessi, G. Tell (University of Trieste, Italy) and R. Schonenborg (ESA).*

ASTRONAUT MEMORY EXPERIMENT, ASTROLAB MISSION (PLANNED)

This student-developed experiment will investigate how human memory functions in space. ESA astronaut Thomas Reiter will learn one list of words on the ground and a second list while he is in space. After a period of time, he will attempt to recall the words from both lists. This experiment will attempt to determine whether there is a context-dependent effect in microgravity whereby recalling a list of words in the same environmental context in which they were learned aids in the recall of those words. *Matthew Atkinson (University of Cambridge, Cambridge, U.K.).*

CARDIAC ADAPTED SLEEP PARAMETERS ELECTROCARDIOGRAM RECORDER (CASPER), ASTROLAB MISSION (PLANNED)

The CASPER experiment provides a simple and accurate means to measure sleep parameters in space, including sleep disturbances, by measuring cardiac autonomic activity from an electrocardiogram (ECG). Together with a specialized sleep diary and a diagnostic program, CASPER will monitor and record sleep

disruptions in a noninvasive manner. *Marc O Griofa (University College, Dublin, Ireland) and Derek O’Keeffe (University of Limerick, Limerick, Ireland).*

STUDENTS PERFORMING CLASSROOM VERSIONS OF ESA ISS EXPERIMENTS

XENOPUS JEUNES (XENOPUS YOUTH), ANDROMÈDE MISSION

Tadpole larvae were bred on orbit out as part of the Aquarius scientific investigations. The effect of gravity was then determined by analyzing the filming done by Claudie Haigneré of the onboard tadpoles compared to the filming of other tadpoles done by students on the ground. *Varoquaux de Tomblaine High School, Meurthe et Moselle, France; Schubart Gymnasium, Ulm, Germany; Experimental Biology and Immunology Laboratory, H. Poincaré University, Nancy, France; University of Ulm, Germany.*

ODYSSÉE DES LEVURES (THE YEAST ODYSSEY), ANDROMÈDE MISSION

Also part of the Aquarius scientific investigations, this experiment used yeast to investigate whether the polarity of cellular budding is genetically determined or affected by the Earth’s gravity. The yeasts were transported to the ISS and, once onboard, the cell-division cycle was initiated. The cycle was then halted by freezing the yeast on return to the ground. *Alcide Dussolier High School, Nontron, Dordogne, France; CNES/GSBMS (French scientific space biology and medicine group); Bordeaux Biochemistry and Cellular Genetics Institute.*

SEEDS IN SPACE (SEEDS), DELTA MISSION

The main goal of SEEDS was to involve as many students as possible in an activity that shows that science is fun. The educational objectives of the experiment were to demonstrate to 10–15 year olds the influence of gravity on the germination and growth of plants. At the same time as schoolchildren back on Earth, ESA astronaut André Kuipers grew salad cress to show the effect of gravity on the growth of plants. By engaging in the comparable on-ground experiment, students learned that science is fun and that the weightless environment of space opens new possibilities. *J. van Loon and K. Weterings (Netherlands).* <http://www.seedsinspace.nl/seedsinspace/>

STUDENT PARTICIPATION IN ESA INVESTIGATOR EXPERIMENTS

COGNI JEUNES (COGNI YOUTH AND SENSING MOTION), ANDROMÈDE MISSION

Students participated in the COGNI [Cogni Jeunes] experiment by performing a theoretical study of orientation problems encountered in space, and by monitoring the experiments performed by astronauts. *Cantelade de Cestas School, Gironde, France; Jaunay Clan High School, Poitiers, France; Laboratory of Physiology and Perception of Action, Collège de France.*

IMEDIAS JEUNES (IMEDIAS YOUTH AND THE EFFECTS OF CLIMATE CHANGE), ANDROMÈDE MISSION

As part of the IMEDIAS [Immedias Jeunes] scientific experiment, photographs of two selected regions (Rhône delta and Gironde river estuary) taken from ISS were correlated with other satellite data of the same regions together with data collected in the field. *École du Parc, Lunel, Gard, France; Cantelade de Cestas School, Gironde, France; Eiffel High School, Bordeaux, Gironde, France; Médias France.*

EDUCATIONAL DEMONSTRATIONS—ISS DVD LESSONS

Three DVD lessons—20 minutes each and filmed onboard the ISS, on the ground, and in schools, with 10,000 copies distributed across member states—were produced. The DVD lessons produced to date are “Newton in Space” (Cervantes Mission), “Body Space” (Delta Mission), and “Space Matters” (Eneide Mission). Additional DVDs are planned. The Delta Researchers School Program provides an interface for Dutch educators and students linked and modeled on the NASA Explorer Schools program.

SCIENCES DESSUS-DESSUS (SCIENCE UPSIDE-DOWN), ANDROMÈDE MISSION

Very young schoolchildren were introduced to the environment around them, including space, through study of images taken at different altitudes and scales. Scientific and imaging concepts features included distance, points of view, and “zooming.” *Buthegnemont Preschool and Primary School, Nancy, France.*

A DEMONSTRATION OF PHYSICAL PHENOMENA IN SPACE (VIDEO), ODISSEA MISSION

This experiment provides video of five different physical phenomena demonstrated onboard ISS. These demonstrations show air bubbles in water, motion trajectories, a free-floating paper ball, water drops on a solid surface, and a balsa glider. *U. Merbold (ESA).*

A DEMONSTRATION OF NEWTON’S THREE LAWS OF MOTION (VIDEO-2), CERVANTES MISSION

The objective of the experiment was to demonstrate Newton’s Three Laws of Motion by filming five demonstrations under weightless conditions aboard ISS. Three schools in France, Ireland, and Spain participated in filming ground demonstrations. The video was used to produce the second ISS DVD Lesson “Newton in Space.” The DVD is distributed in 12 languages to secondary school teachers in ESA Member States. *M. Paiva (Belgium., http://www.esa.int/esaED/SEMXTV0XDYD_index_0.html)*



European Space Agency (ESA) astronaut Pedro Duque demonstrates Newton's Three Laws of Motion on ISS as part of the VIDEO-2 activity. He is floating three balls in front of him, one of which has been filled with liquid to provide additional mass.

STUDY OF THE BEHAVIOR OF A RIGID BODY ROTATING AROUND ITS CENTRE OF MASS (APIS), CERVANTES MISSION

The APIS experiment focused on the behavior of a rigid body rotating around its centre of mass, simulating a rotating spacecraft. The objective was to prepare a videotape for educational purposes to demonstrate the dynamics of solid body rotation and how the distribution of mass can change the axis of rotation of a spacecraft. This student experiment was selected by a Spanish committee for inclusion in the Cervantes mission. Experimental video material was prepared for educational purposes and is being used at the University of Madrid in mechanics courses. *A. Laverón-Simavilla, V. Lapuerta, M. Higuera, Instituto Universitario Ignacio da Riva, Universidad Politécnica de Madrid (Spain).*

A TEST OF THE BASIC PRINCIPLES OF MECHANICS (THEBAS), CERVANTES MISSION

Using relatively simple hardware, the THEBAS experiment illustrated the principles of dynamics, ranging from the classical rational mechanics of solid bodies to the continuous media mechanics. The behavior of transparent closed containers (having the same size and total mass) filled with solid bodies (spheres) of different radii was analyzed. This student experiment was selected by a Spanish committee for inclusion in the Cervantes mission. Experimental video material was prepared for educational purposes and is being used at the University of Madrid in mechanics courses. *A. Laverón-Simavilla and V. Lapuerta, Instituto Universitario Ignacio da Riva, Universidad Politécnica de Madrid (Spain).*

FILMED DEMONSTRATIONS OF THE EFFECTS OF WEIGHTLESSNESS ON THE HUMAN BODY (VIDEO-3), DELTA MISSION

The main objectives of this experiment was to demonstrate some of the effects of weightlessness on the human body (e.g., blood pressure and circulation, fluid shift, orientation awareness, etc.) by means of

videotaping four basic physiology experiments under weightless conditions onboard ISS. Four schools in Belgium, Denmark, Germany, and the Netherlands participated in filming ground demonstrations. The video was used to produce the second ISS DVD Lesson “Mission 2: Body Space,” which is distributed in 12 languages to secondary school teachers in ESA member states. *S. Ijsselstein (Netherlands), J. van Loon (Netherlands) and M. Paiva (Belgium).* http://www.esa.int/esaED/SEM3F86Y3EE_teachers_2.html

ELECTROSTATIC SELF-ASSEMBLY DEMONSTRATION (ESD), ENEIDE MISSION

The ESD experiment involves filming two sets of small spheres composed of different materials that charge with opposite polarities to each other. These spheres are contained within a polycarbonate cube container. Once charged, the spheres will assemble themselves into ordered structures. For all demonstrations, comparable on-ground experiments were performed and filmed to familiarize students with the differences between the Earth and space environments. Four schools in Italy, Norway, Portugal, and Greece participated in filming ground demonstrations. Video footage of the demonstrations was used to develop the third ISS DVD Lesson, “Space Matters.” The DVD is distributed in 12 languages to secondary school teachers in ESA Member States. *W. Carey, S. Ijsselstein (ESA).*

ROBOTICS, ASTROLAB (PLANNED)

The upcoming Astrolab mission (planned for 2006) will feature a long-term stay on ISS for ESA astronaut Thomas Reiter. Reiter will complete a set of robotics-themed demonstrations to be used as part of the fourth ISS DVD Lesson. Demonstrations will include operation of the SPHERES experiment (also see previous section on NASA student involvement in the development of the experiment) that will involve a free-flying mini-spacecraft within the station. This video will then go into one of the next ESA educational DVDs that will focus on robotics on ISS, which is targeted at K–12 students. Four schools in Austria, Switzerland, Sweden, and the United Kingdom will participate in the filming of the on-ground demonstrations. *S. Ijsselstein (ESA).*

EDUCATIONAL ACTIVITIES—COMMUNICATIONS WITH ASTRONAUTS

AMATEUR RADIO ON THE INTERNATIONAL SPACE STATION (ARISS)

Amateur radio has been a feature of nearly all taxi flights. On his two missions, Roberto Vittori spoke with Italian students; Frank De Winne spoke with Belgian and other students. After a competition called *Habla ISS* (ISS speaks) during the Cervantes Mission, approximately 5,000 Spanish and Portuguese children submitted drawings and essays, and were selected to speak to astronaut Pedro Duque via live radio. During the DELTA Mission, André Kuipers on the ISS spoke to selected children from Dutch and Belgian schools to allow them to have the experience of interacting with someone in orbit around the Earth. *G. Bertels (Belgium) and E. Grifoni (ESA).*

EARTH CALLING SPACE, ANDROMÈDE MISSION

This is a project for schoolchildren interested in space communications. *Charvonnex School, Haute Savoie, France.*

CONVERSING WITH THE UNIVERSE, ANDROMÈDE MISSION

Contact was made between French, British, Italian, and Belgian students and the ISS using Short Message Service (the technology used for cell phone text messages). *CNES; Freeve, France.*

Japanese Aerospace Exploration Agency



Kansai Soka Schools in Japan (Oct. 27–30, 2004) participated in the 14th EarthKAM session. At the time of this session, the Kansai Soka Schools held the record for the most time accumulated participating in the student space program.

We did not identify specific student experiments or educational activities sponsored by the Japanese Aerospace Exploration Agency (JAXA) and completed onboard ISS to date. Educational activities and communications with students were an important part of astronaut Soichi Noguchi’s shuttle mission to ISS (STS-114/LF1, July–August 2005). Japanese schools have been active participants in both the student Earth observation experiment EarthKAM and the amateur radio experiment ARISS. A total of 27 schools from Japan have participated in 16 of the 19 EarthKAM sessions conducted between Expeditions 2–13. For example: during Expedition 12, 25 students from Meikei Junior High School in Tsukuba Ibaraki, north of Tokyo, were studying the environment by focusing on seashores, coastlines, rivers, and wetlands. Recently during the Expedition 13 mission, 100 students from Kansai Soka Jr. and Sr. High School in Osaka studied changes in the environment in place where the Ramsar

Convention is located. In addition, students from 19 schools across Japan have had the opportunity to talk directly with ISS crewmembers via amateur radio with the ARISS program.

Russian Federal Space Agency

KOLIBRY

The goal of the launch of the Kolibri microsatellite was to allow pupils to operate microsatellites under the direct guidance of scientists. Students were responsible for the implementation of projects dealing with ballistics, radio engineering, computer science, and thermal physics. They also analyzed and observed the satellite manufacturing processes, and analyzed the scientific information transmitted from the space satellite. The operations will contribute to the further improvement of the secondary and higher education system, and will make it possible to find the best solutions to the problems of training future specialists for the space industry.

KONSTRUKTOR

The Konstruktor experiment involved filming the actions of space robot “Jitter,” which had been assembled from LEGO Mindstorms components. Jitter was developed by a father-and-son team that won a contest sponsored by LEGO, Siemens, and Hitachi in the summer of 2001 using only LEGO components. In November 2001 Jitter was sent to ISS. The robot was successfully tested on station in December 2001 and January 2002. Jitter is able to act independently inside of the ISS, performing its duty of collecting small stray parts throughout the station.

RADIOSKAF (SUIT SATELLITE)

Expedition(s): 12, tentatively scheduled again for Expedition 14 or 15
Grade Level(s): K–12
Impact: Hundreds of schools worldwide attempted to make contact with SuitSat; nearly 300 schools and student groups from around the world participated in the “School Spacewalk” project that flew inside SuitSat.

EXPERIMENT DESCRIPTION

A decommissioned Russian Orlan suit (used in EVAs (spacewalks)) was outfitted with an amateur radio and was released into a retrograde orbit from the ISS by the Expedition 12 crew during an EVA on Feb. 3, 2006. Various known as SuitSat-1 (Suit Satellite-1) or Radio Sputnik, the radio continued transmitting prerecorded messages and images for approximately two weeks before the radio batteries expired. SuitSat-1 was able to downlink various images using a series of audio tones, similar to that on a computer modem, using the ham radio picture standard of Slow Scan Television to downlink images of similar quality as received on cell phones. Students, teachers, scout troops, ham radio operators, and the general public were able to track the signals from SuitSat-1 and listen to the messages.

STUDENT ACTIVITY

The voices and images coming from SuitSat-1 were collected from students around the world. As SuitSat-1 floated in space, it transmitted voice messages from students in Russian, Japanese, Spanish, German, French, and English. These messages contained a “hidden” special word that the students needed to identify. Students were able to copy these special words in the different languages and submit them to the ARISS Team for special educational award recognition.

Students submitted their data on when they heard the SuitSat transmission and suit temperature, battery power, and mission elapsed time that were continually being transmitted by SuitSat. These data were then posted on a Web site and were used to track the radio status and orbit and decay of the SuitSat. Students received certificates for making contact with SuitSat, plus a special endorsement on the certificate if they were able to identify the “hidden” words in the transmissions.

Placed inside the Orlan spacesuit was a special student CD called “School Spacewalk” that contained images of student artwork, signatures, poems, class pictures, and scout logos.

STUDENT PARTICIPATION

Hundreds of schools from all over the world were represented on the “School Spacewalk” CD including images from the United States, Japan, Europe, Russia, South America, and Africa. A number of schools around Moscow and across Russia, which were sponsored by the Russian Space Agency, also participated. Two identical CDs were flown. One was placed inside the suit, and the other remained inside station for the Expedition12 crew to review. Approximately 300 items were on the CD including student artwork, school and educational organization logos, student signatures, and student and school pictures.

The ARISS Team is planning to develop numerous science lessons plans for schools based on SuitSat. For example, one plan involves having students use the recorded audio together with the video of the suit right after deployment to study the spin rates to see whether they slowed down or speeded up as SuitSat-1’s orbit decayed.

FUTURE PROJECTS: RADIOSKAF-2 (SUITSAT-2)

ARISS has been presented with an opportunity to participate in a second SuitSat project. SuitSat-2 would be launched in 2007 to celebrate the 50th anniversary of the launch of Sputnik, the 100th anniversary of Sergei Korolev’s birthday (he was the chief designer of the early Russian spacecraft), and the 150th anniversary of Konstantin Tsiolkovsky’s birthday (considered the Father of Space Travel in Russia).

The Russians are designing a new Orlan MK spacesuit, and it is expected that the suits currently on-board the ISS will be available for ARISS's use once the new spacesuits are made available to the ISS crew. SuitSat-2 is expected to have greater capabilities than its predecessor, and may be equipped with solar panels—increasing its expected lifespan.

Principal Investigator(s): Frank Bauer, NASA GSFC, Greenbelt, Md., and Alexander Alexandrov, Russian Space Agency
Education Lead(s): Rosalie White, American Radio Relay League
Education Web Site(s): <http://www.suitsat.org>

AMATEUR RADIO ON ISS

Expedition(s): 1–12 (ongoing investigation)
Grade Level(s): K–12
Impact: Seven Russian schools have participated in ARISS.

EXPERIMENT DESCRIPTION

Ever since the ARISS hardware was first launched onboard the shuttle *Atlantis* on the STS-106 mission and transferred to the ISS during Expedition 1, it has been regularly used to perform school contacts. With the help of amateur radio clubs and ham radio operators, the astronauts and cosmonauts aboard the ISS have been speaking directly with large groups of the general public, showing teachers, students, parents, and communities how amateur radio energizes youngsters about science, technology, and learning. The overall goal of ARISS is to get students interested in mathematics and science by allowing them to talk directly with the crews living and working aboard the ISS.

STUDENT ACTIVITY

As the ISS passes over a school or another location that receives the signal from ISS and relays it on to a participating school, there is typically a 5- to 8-minute window for students to make contact with the station crews. In preparation, students research ISS and learn about radio waves and amateur radio among other topics. Before their scheduled contact with ISS, they prepare a list of questions on topics they have researched, many of which have to do with career choices and science activities aboard station. Depending on the amount of time and complexity of the questions, between 10 and 20 questions can be asked during one session. While typically only a handful of students is able to ask questions due to the limited time available, hundreds of other students usually are listening in to the school event from their school classrooms or auditorium, so that each of these events reaches hundreds of students.

Principal Investigator(s): Frank Bauer, NASA GSFC, Greenbelt, Md.
Education Lead(s): Rosalie White, American Radio Relay League
Education Web Site(s): <http://www.arrl.org/ARISS/>



Cosmonaut Sergei Y. Treschev, Expedition 5 flight engineer, uses an amateur radio in the functional cargo block (FGB)/Zarya on station.

South Africa

Mark Shuttleworth generated great interest among African students when he visited ISS as a space tourist in April–May 2002 (at the same time at which Roberto Vittori completed the Marco Polo taxi flight mission for ESA). Prior to his flight, a conference was held for mathematics and science teachers from 102 South African schools. During the mission, Shuttleworth used ARISS to pique interest in science and mathematics and to discuss zero-gravity effects with schoolchildren and teachers throughout South Africa. Four ham radio sessions with more than 1,000 students and teachers from over 30 schools throughout South Africa were conducted. Some questions asked by students were:

- How does zero gravity affect your body?
- At present, how do you prevent muscle wastage in the space station?
- How do they keep a continuous supply of oxygen to the space station?

Additional information is available on the following Web site: <http://www.africaninspace.com>.

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