National Aeronautics and Space Administration

ISS L.A.B.S. Educator Resource Guide

International Space Station
Learning, Achieving, Believing, and Succeeding

International Space Station L.A.B.S.

The International Space Station (ISS) is the unique blend of unified and diversified goals among the world's space agencies that will lead to improvements in life on Earth for all people of all nations. While the various space agency partners may emphasize different aspects of research to achieve their goals in the use of the ISS, they are unified in several important overarching goals.

All of the agencies recognize the importance of leveraging the ISS as an education platform to encourage and motivate today's youth to pursue careers in Science, Technology, Engineering, and Math (STEM): *educating the children of today to be the leaders and space explorers of tomorrow.*

Advancing our knowledge in the areas of human physiology, biology, and material and physical sciences and translating that knowledge to health, socioeconomic, and environmental benefits on Earth is another common goal of the agencies: *returning the knowledge gained in space research for the benefit of society.*

Finally, all the agencies are unified in their goals to apply knowledge gained through ISS research in human physiology, radiation, materials science, engineering, biology, fluid physics, and technology: *enabling future space exploration missions.*

*Information provided courtesy of Reference Guide to the International Space Station, Assembly Complete Edition, November 2010.

Acknowledgments

Many educators, scientists, and engineers have contributed ideas and content directly and indirectly to this revision. Their assistance is gratefully appreciated.

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NASA Foundations of Influence, Relationships, Success and Teamwork (FIRST) - Johnson Space Center (JSC) Class of 2010

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Special Thanks To:

Faculty and Staff of Pilot Testing Schools:

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Goal

To encourage, inspire, and motivate students to enter Science, Technology, Engineering, and Math (STEM) related fields by first encouraging students' interest in STEM activities during the latter grade levels of elementary school, during the middle school years, and throughout high school; subsequently, pursuing STEM related disciplines in colleges, universities, trade schools, and other educational institutions.

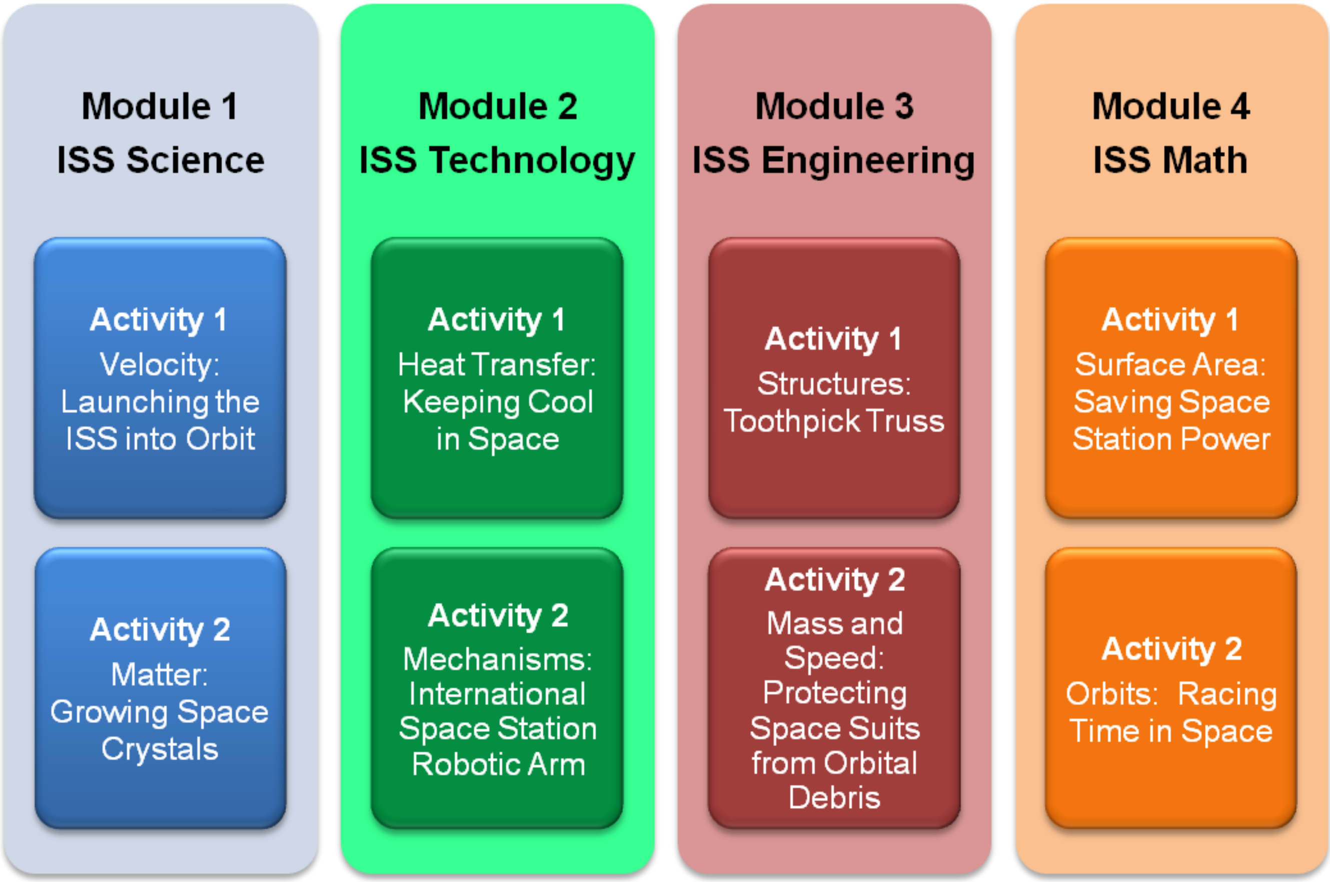
Target Audience

Target audience includes 5^{th} – 8^{th} graders who are the future generation of scientists, engineers, technologist, and mission support personnel.

Structure of Educator's Resource Guide

The ISS Learning, Achieving, Believing, and Succeeding (L.A.B.S.) Educator's Resource Guide consists of eight (8) guided educational learning activities. The activities provided details targeted skill sets, workshop instructions, listings of materials needs to complete activities, and other useful background information.

There are four separate modules contained in the Educator's Resource Guide with each containing two (2) activities relevant to a specific STEM field.



Target Education Standards

The eight (8) guided educational learning activities consist of targeted educational standards. The standards for each module have been taken from the following education entities: National Science Teachers Association (NSTA) standards guide, International Technology Engineering Educators Association (ITEEA) standards guide, and National Council for Teachers of Mathematics (NCTM) *Principles and Standards for School Mathematics.*

Standards	Module 1: Science		Module 2: Technology		Module 3: Engineering		Module 4: Math	
	Activity 1: Velocity	Activity 2: Crystal Growth	Activity 1: Heat Transfer	Activity 2: Robotic Arm	Activity 1: Toothpick Truss	Activity 2: High Velocity Debris	Activity 1: Space Station Power	Activity 2: Racing Time
NSTA Standards								
Science as Inquiry								
Abilities necessary to do scientific inquiry	✓	✓	✓	✓	✓			
Understanding about scientific inquiry		✓						
Physical Science								
Transfer of Energy	✓		✓					
Structure and properties of matter		✓						
Motion and forces						✓		
Position and Motion of Objects								✓
Science and Technology								
Abilities of Technological Design	✓		✓			✓		
Science in Personal and Social Perspectives								
Personal Health			✓			✓		
ITEEA Standards								
Exploring Technology			✓	✓	✓			
Invention and Innovation			✓	✓	✓			
Technological Systems			✓	✓	✓			
Technological Design			✓	✓	✓			
Engineering Design			✓	✓	✓			
Integrated Concepts			✓	✓	✓			
NCTM Standards								
Measurement	✓							
Apply appropriate techniques, tools, and formulas						✓		

Standards	Module 1: Science		Module 2: Technology		Module 3: Engineering		Module 4: Math	
	Activity 1: Velocity	Activity 2: Crystal Growth	Activity 1: Heat Transfer	Activity 2: Robotic Arm	Activity 1: Toothpick Truss	Activity 2: High Velocity Debris	Activity 1: Space Station Power	Activity 2: Racing Time
Data Analysis	✓							
Develop and evaluate inferences and predictions based on data						✓		
Problem Solving						✓		
Connections						✓		
Geometry				✓	✓			
Representations						✓		
Work flexibly with fractions, decimals, and percents to solve problems							✓	
Recognize and generate equivalent forms for simple algebraic expressions and solve linear equations							✓	✓
Model and solve contextualized problems using various representations							✓	✓
Understand relationships among units and convert							✓	
Understand relationships among angles, side lengths, perimeters, areas, and volumes of similar objects							✓	✓
Build new mathematics knowledge through problem solving							✓	✓
Solve problems that arise in mathematics and in other contexts							✓	✓
Apply and adapt a variety of appropriate strategies to solve problems							✓	✓
Recognize and apply mathematics in contexts outside of mathematics							✓	✓
Solve simple problems involving rates and derived measurements for such attributes as velocity and density								✓

International Cooperation and the International Space Station (ISS)

The International Space Station (ISS) Program's greatest accomplishment is as much a human achievement as it is a technological one—how best to plan, coordinate, and monitor the varied activities of the Program's many organizations.

An international partnership of space agencies provides and operates the elements of the ISS. The principals are the space agencies of the United States, Russia, Europe, Japan, and Canada. The ISS has been the most politically complex space exploration program ever undertaken.

The International Space Station Program brings together international flight crews, multiple launch vehicles, globally distributed launch, operations, training, engineering, and development facilities; communications networks, and the international scientific research community.

Elements launched from different countries and continents are not mated together until they reach orbit, and some elements that have been launched later in the assembly sequence were not yet built when the first elements were placed in orbit.

Operating the space station is even more complicated than other space flight endeavors because it is an international program. Each partner has the primary responsibility to manage and run the hardware it provides.

Construction, assembly and operation of the International Space Station requires the support of facilities on the Earth managed by all of the international partner agencies and countries involved in the program.

These include construction facilities, launch support and processing facilities, mission operations support facilities, research and technology development facilities and communications facilities.

National Aeronautics and Space Administration (NASA)
NASA headquarters, in Washington, D.C., exercises management over the NASA field Centers, establishes management policies, and analyzes all phases of the space station program. The Mission Control Center at the Johnson Space Center in Houston, Texas, the Payload Operations and Integration Center at the Marshall Space Flight Center in Huntsville, Alabama, and the Kennedy Space Center are NASA's primary ISS facilities with science development and support centers located at other NASA centers and around the country.

Roscosmos, the Russian Federal Space Agency
Roscosmos oversees all Russian human space flight activities. Moscow Mission Control in Korolev, outside of Moscow, and the Baikonur Cosmodrome are Roscosmos' primary ISS facilities.

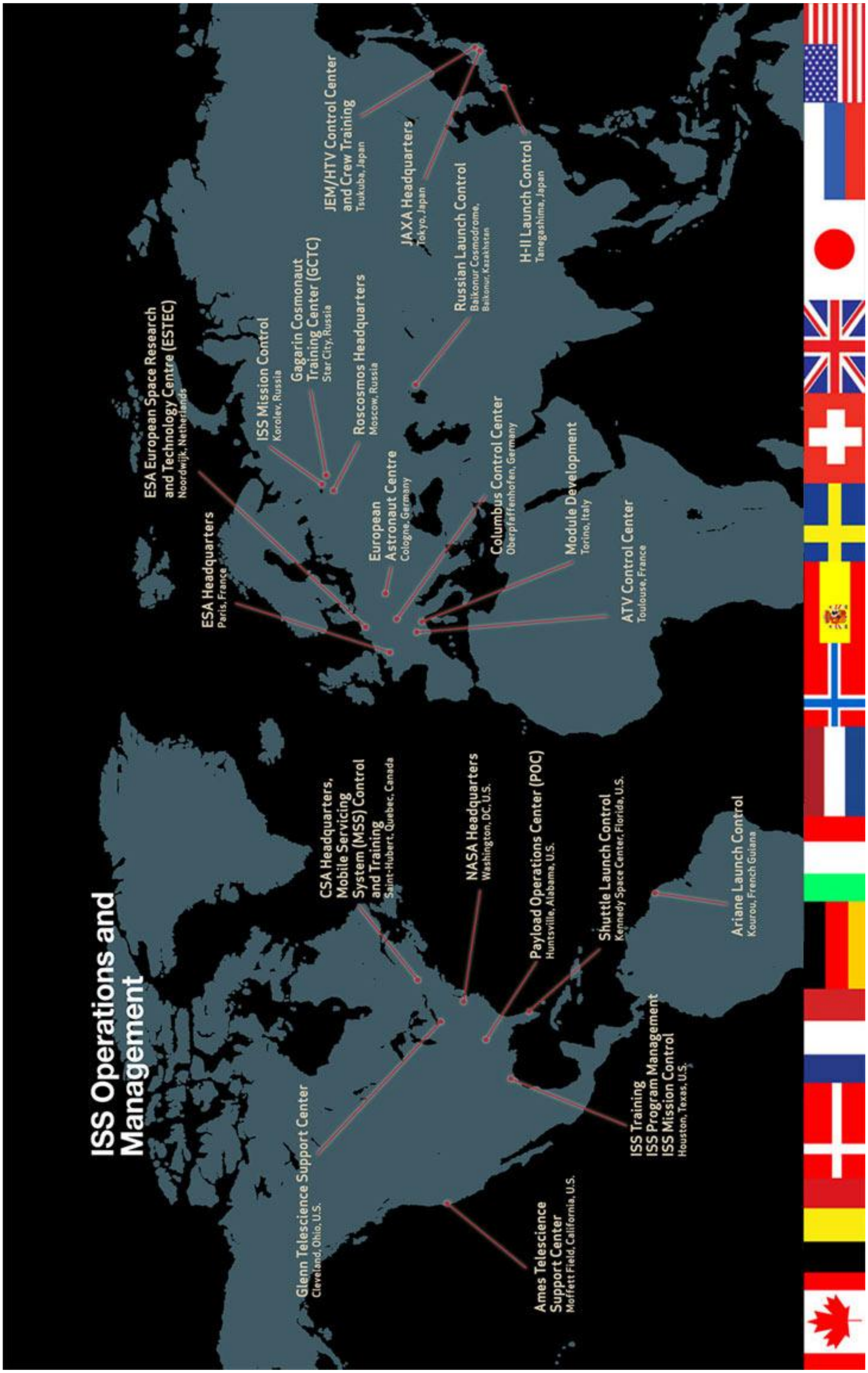
Canadian Space Agency (CSA)
The MSS Operations Complex in Saint-Hubert, Quebec, Canada provides the resources, equipment, and expertise needed for the engineering and monitoring of the Mobile Servicing System as well as for crew training.

European Space Agency (ESA)
The European Space Research and Technology Centre, the largest site and the technical heart of ESA, is in Noordwijk, The Netherlands. Most ESA projects are developed here. The Columbus Control Center outside Munich, Germany, the Automated Transfer Vehicle (ATV) Control Center in Toulouse, France, and the Ariane Launch complex in French Guiana are ESA's primary ISS facilities.

Japan Aerospace Exploration Agency (JAXA)
In addition to the JAXA headquarters in Tokyo and other field centers throughout the country, Tsukuba Space Center and Tanegashima launch Facility are JAXA's primary ISS facilities.

*Information provided courtesy of **http://www.nasa.gov/mission_pages/station/cooperation/index.html**

See the pictorial display, on the next page, of the ISS Operations and Management support from around the world, including a listing of International Partners by their country's flag.

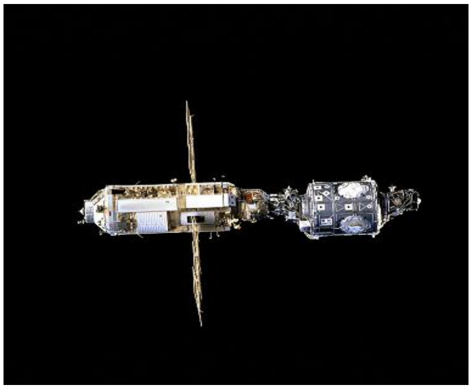

ISS Operations and Management
Glenn Telescience Support Center
Cleveland, Ohio, U.S.
Ames Telescience Support Center
Moffett Field, California, U.S.
CSA Headquarters, Mobile Servicing System (MSS) Control and Training
Saint-Hubert, Quebec, Canada
NASA Headquarters
Washington, DC, U.S.
Payload Operations Center (POC)
Huntsville, Alabama, U.S.
Shuttle Launch Control
Kennedy Space Center, Florida, U.S.
ISS Training
ISS Program Management
ISS Mission Control
Houston, Texas, U.S.
Ariane Launch Control
Kourou, French Guiana
ESA Headquarters
Paris, France
ESA European Space Research and Technology Centre (ESTEC)
Noordwijk, Netherlands
European Astronaut Centre
Cologne, Germany
Columbus Control Center
Oberpfaffenhofen, Germany
Module Development
Torino, Italy
ATV Control Center
Toulouse, France
ISS Mission Control
Korolev, Russia
Gagarin Cosmonaut Training Center (GCTC)
Star City, Russia
Roscosmos Headquarters
Moscow, Russia
Russian Launch Control
Baikonur Cosmodrome, Baikonur, Kazakhstan
JEM/HTV Control Center and Crew Training
Tsukuba, Japan
JAXA Headquarters
Tokyo, Japan
H-II Launch Control
Tanegashima, Japan

Overview of International Space Station Construction

Note: This timeline is not comprehensive of all missions to ISS.

ISS Assembly Mission 1 A/R

November 20, 1998 --- Zarya Control Module was launched atop a Russian Proton rocket from Baikonur Cosmodrome, Kazakhstan. Zarya provides battery power, fuel storage and rendezvous and docking capability for Soyuz and Progress space vehicles.



ISS Assembly Mission 2A
Space Shuttle Mission STS-88

December 4-15, 1998 --- Space Shuttle Endeavour delivered the Unity Node with two pressurized mating adapters. On Dec. 6, 1998, the STS-88 crew captured the Zarya Control Module and mated it with the Unity Node inside the Shuttle's payload bay. On Sunday, Dec. 13, Space Shuttle Endeavour undocked from the young International Space Station for the return to Earth.

ISS Assembly Mission 2A.1
Space Shuttle Mission STS-96

May 27-June 6, 1999 --- Space Shuttle Discovery with the STS-96 crew delivered and outfitted the International Space Station with logistics and supplies. A Russian cargo crane was mounted outside the Station for future spacewalking maintenance activities.

ISS Assembly Mission 2A.2a
Space Shuttle Mission STS-101

May 19-29, 2000 --- The STS-101 crew readied the International Space Station for the arrival of the Zvezda Service Module. Four new batteries, 10 new smoke detectors and four new cooling fans were installed in the Zarya Control Module. Handrails were installed on the Unity Node for future spacewalks.

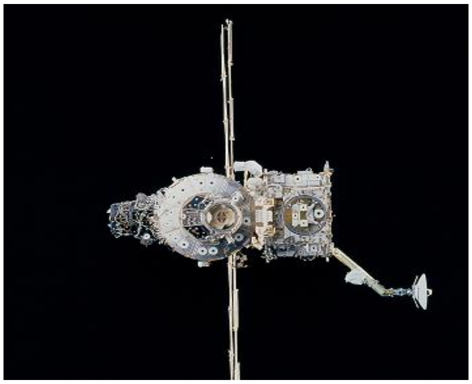
ISS Assembly Mission 1R

July 12, 2000 --- Zvezda Service Module was launched atop a Russian Proton rocket from Baikonur Cosmodrome, Kazakhstan. The Zvezda provides living quarters and performs some life support system functions to the International Space Station.

ISS Assembly Mission 2A.2b
Space Shuttle Mission STS-106

September 8-20, 2000 --- The STS-106 crew on Space Shuttle Atlantis delivered supplies and performed maintenance on the International Space Station.

ISS Assembly Mission 3A
Space Shuttle Mission STS-92



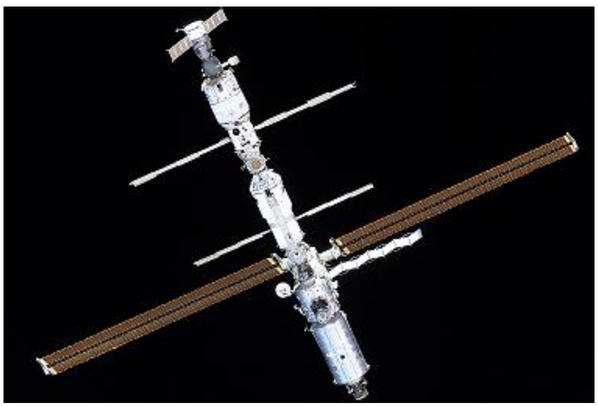
October 11-24, 2000 --- Arriving aboard Space Shuttle Discovery, the STS-92 crew installed the Z1-Truss. Inside the Z1 are four Control Moment Gyroscopes (CMGs) that provide the International Space Station's attitude control. The CMGs were later activated on ISS Assembly Mission 5A. A third pressurized mating adapter was installed on the Unity Node, providing an additional Shuttle docking port. A Ku-band antenna provides television capability.

ISS Assembly Mission 2R
Expedition 1 (Russian Soyuz Flight)

October 30, 2000 – March 21, 2001 --- The International Space Station's first resident crew, Expedition One, launched from Baikonur Cosmodrome, Kazakhstan on October 30, 2000, on a Soyuz rocket. The docked Soyuz provides Russian assured crew return capability without the Space Shuttle present. The first resident crew of Expedition One was ISS Commander, William (Bill) Shepherd; Soyuz Commander, Yuri Pavolich Gidzenko; and Flight Engineer, Sergei K. Krikalev.

ISS Assembly Mission 4A
Space Shuttle Mission STS-97

November 30-December 11, 2000 --- The STS-97 crew delivered and installed the P6 Truss, which contains the first U.S. solar arrays. The P6 was temporarily installed on top of the Z1 Truss. The P6 provides solar power with solar arrays and batteries, called the photovoltaic modules.



ISS Assembly Mission 5A
Space Shuttle Mission STS-98

February 7-20, 2001 --- The STS-98 crew installed the new Destiny Laboratory Module after removing it from Space Shuttle Atlantis' payload bay. Control Moment Gyroscopes were activated with delivery of electronics in the lab, providing electrically powered attitude control.

ISS Assembly Mission 5A.1
Space Shuttle Mission STS-102

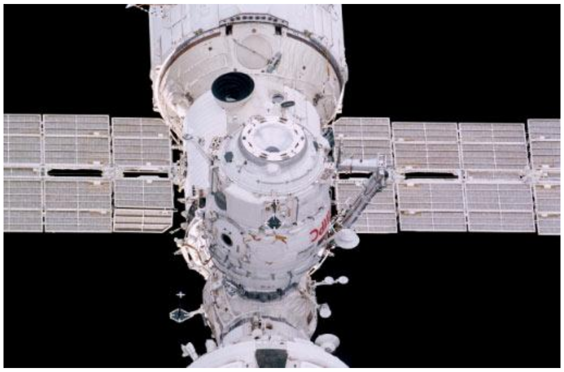
March 8, 2001-March 21, 2001 --- Space Shuttle Discovery resupplied the Station with the Italian-built Leonardo Multi-Purpose Logistics Module. Expedition Two crew arrived with the Shuttle. Expedition Two crew included ISS Commander, Yury Usachev; Flight Engineer, James Voss; and Flight Engineer, Susan Helms. Expedition One crew returned home.

ISS Assembly Mission 6A
Space Shuttle Mission STS-100

April 19-May1, 2001 --- Space Shuttle Endeavour delivered racks inside the Raffaello Multi-Purpose Logistics Module to the Destiny Laboratory. Canadarm2, the Station's robotic arm, walked off the Shuttle to its new home on the International Space Station. A UHF antenna that provides space-to-space communications capability for U.S.-based spacewalks was installed on the Station.

ISS Assembly Mission 7A
Space Shuttle Mission STS-104

July 12, 2001 --- The STS-104 crew used the Space Shuttle Atlantis' robotic arm to install the new Joint Airlock from which both Russian and American spacewalks may take place. The high pressure gas assembly supports spacewalk operations and augments the Zvezda Service Module gas resupply system.

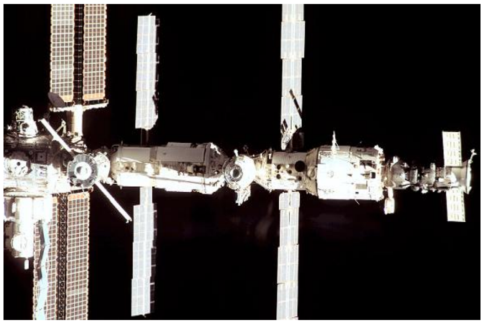


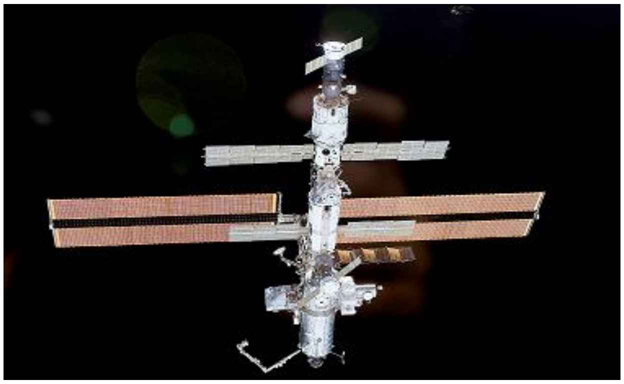
ISS Assembly Mission 4R

September 14, 2001 --- A Soyuz rocket launched from Baikonur Cosmodrome, Kazakhstan with the new Pirs Docking Compartment and a crane called the Strela Boom. Pirs docked automatically to the Earth-facing, forward end of the Zvezda Service Module. The Docking Compartment provides an additional egress and ingress location for Russian-based spacewalks and a Soyuz docking port.

ISS Assembly Mission UF-1
Space Shuttle Mission STS-108

December 5-17, 2001 --- Space Shuttle Endeavour on mission STS-108 delivered experiment racks inside the Multi-Purpose Logistics Module that were installed inside the Destiny Laboratory. Also, the STS-108 crew swapped International Space Station crews, delivering Expedition Four and returning Expedition Three.





ISS Assembly Mission 8A
Space Shuttle Mission STS-110

April 8-19, 2002 --- Space Shuttle Atlantis delivered the S0 Truss Structure, which the STS-110 crew installed on top of the Destiny Laboratory module. The Mobile Transporter, a movable base for the Canadarm2 to move along the Integrated Truss Structure, was also delivered and installed.

ISS Assembly Mission UF-2
Space Shuttle Mission STS-111

June 5-19, 2002 --- Space Shuttle Endeavour, with the Multi-Purpose Logistics Module inside its payload bay, delivered more payload and experiment racks to the Destiny Laboratory. The Mobile Base System was also installed completing the Station's Mobile Servicing System, which includes the Canadarm2 and the Mobile Transporter. The STS-111 crew also delivered the Expedition Five crew for its resident stay and returned home the Expedition Four crew after 196 days in space.

ISS Assembly Mission 9A
Space Shuttle Mission STS-112

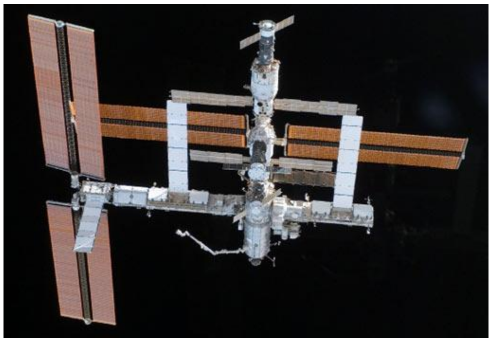
October 7-8, 2002 --- Space Shuttle Atlantis delivered the first starboard truss segment, the S1 Truss, which the STS-112 crew installed. The S1 was attached to the central truss segment, the S0 Truss. Additional cooling radiators were delivered but remained stowed until ISS Assembly Mission 12A.1. A cart, known as the Crew and Equipment Translation Aid, was delivered to help spacewalkers move equipment along the Integrated Truss Structure.

ISS Assembly Mission 11A
Space Shuttle Mission STS-113

November 23, 2002 --- Space Shuttle Endeavour delivered the first port truss segment, P1 Truss, which was attached to the central truss segment, S0 Truss. Additional cooling radiators were delivered but remained stowed until ISS Assembly Mission 12A.1. A cart, known as the Crew and Equipment Translation Aid, was delivered to help spacewalkers move equipment along the Integrated Truss Structure.

ISS Assembly Mission LF1
Space Shuttle Mission STS-114

July 26-August 9, 2005 --- STS-114, the Space Shuttle's Return to Flight mission, delivered supplies and equipment to the International Space Station. An External Stowage Platform was installed with the assistance of Space Shuttle Discovery's robotic arm and two space-walkers. Also, spacewalkers restored power to a failed Control Moment Gyroscope and installed a new one.



ISS Assembly Mission 12A
Space Shuttle Mission STS-115

September 9, 2006 --- The STS-115 crew delivered and installed the second port truss segment, the P3/P4 Truss, to the P1 Truss. Solar arrays and a radiator were also deployed.

ISS Assembly Mission 12A.1
Space Shuttle Mission STS-116

December 9-22, 2006 --- The STS-116 crew delivered and installed the third port truss segment, the P5 Truss, and attached it to the second port truss segment, the P3/P4 Truss. The Space Shuttle Discovery delivered logistics and supplies inside a SPACEHAB single cargo module.

ISS Assembly Mission 13A
Space Shuttle Mission STS-117

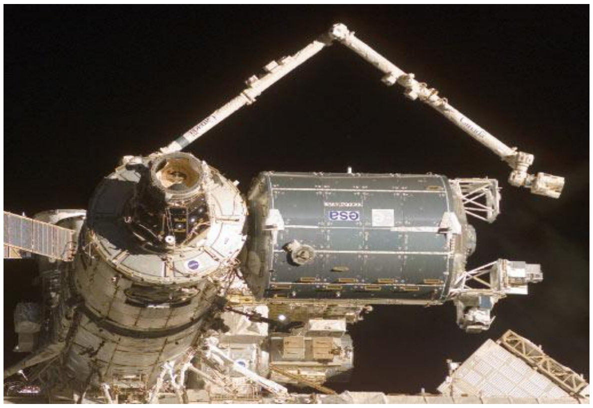
June 8-22, 2007 --- The STS-117 crew delivered the second and third starboard truss segments (S3/S4) and another pair of solar arrays to the space station. STS-117 also carried Expedition 15 Flight Engineer Clayton C. Anderson to the station and returned Expedition 15 Flight Engineer Sunita L. Williams to Earth.

ISS Assembly Mission 13A.1
Space Shuttle Mission STS-118

August 8, 2007 --- The STS-118 crew delivered and installed the third starboard truss segment, the ITS S5 Truss. A SPACEHAB single cargo module delivered supplies and equipment to the International Space Station.

ISS Assembly Mission 10A
Space Shuttle Mission STS-120

October 23-November 7, 2007 --- STS-120 delivered the Harmony Node 2 which was later installed to the forward end of the Destiny Laboratory. The Node 2 provides attach points for the European Columbus laboratory and the Japanese Kibo laboratory. The Port 6 truss structure was also moved from atop the International Space Station's Z1 truss to the end of the Port 5 truss structure.

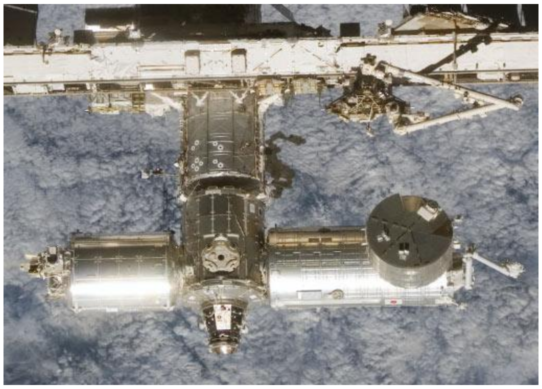


ISS Assembly Mission 1E
Space Shuttle Mission STS-122

Feb. 7, 2008 --- The STS-122 crew delivered and installed the European Space Agency's Columbus laboratory. Atlantis also carried European Space Agency astronaut Léopold Eyharts to the complex and returned Expedition 16 Flight Engineer Dan Tani to Earth.

ISS Assembly Mission 1J/A
Space Shuttle Mission STS-123

March 11, 2008 --- Endeavour delivered the first pressurized component of the Japanese Kibo laboratory, the Experiment Logistics Module - Pressurized Section, to the station. The mission also delivered NASA astronaut Garrett Reisman to the station and returned European Space Agency astronaut Léopold Eyharts to Earth. In addition, the STS-123 crew delivered a Canadian robotic device called Dextre to the complex.



ISS Assembly Mission 1J
Space Shuttle Mission STS-124

May 31, 2008 --- The STS-124 crew delivered the Pressurized Module and robotic arm of the Japanese Kibo laboratory, to the International Space Station. The mission also performed an exchange of station crew members. Astronaut Greg Chamitoff flew to the station as a mission specialist on STS-124. He took astronaut Garrett Reisman's place as an Expedition 17 flight engineer.

ISS Assembly Mission ULF2
Space Shuttle Mission STS-126

November 14-30, 2008 --- Space shuttle Endeavour delivered supplies and equipment, including additional crew quarters, exercise equipment, equipment for the regenerative life support system and spare hardware, inside the Leonardo Multi-Purpose Logistics Module. While at the station, Endeavour's crew repaired and serviced crucial rotating joints for the station's giant solar arrays. The STS-126 mission also carried astronaut Sandra Magnus to the complex and returned astronaut Gregory Chamitoff to Earth.

ISS Assembly Mission 15A
Space Shuttle Mission STS-119

March 15-28, 2009 --- The STS-119 crew of space shuttle Discovery delivered and installed the International Space Station's final, major U.S. truss segment, Starboard 6 (S6), and its final pair of power-generating solar array wings. STS-119 also carried Japan Aerospace Exploration Agency astronaut Koichi Wakata to the station and returned NASA astronaut Sandra Magnus to Earth.

ISS Assembly Mission 2J/A
Space Shuttle Mission STS-127

July 15-31, 2009 --- Endeavour set sail on its 23rd mission with the Kibo Japanese Experiment Module Exposed Facility and Experiment Logistics Module Exposed Section. The facility provides a type of "front porch" for experiments in the exposed environment, and a robotic arm that is attached to the Kibo Pressurized Module and is used to position experiments outside the station. The mission included five spacewalks.

ISS Assembly Mission 5R

November 10, 2009 --- The Mini-Research Module-2 (MRM2) launched Nov. 10, 2009, atop a Soyuz booster rocket from the Baikonur Cosmodrome in Kazakhstan and docked to the station's Zvezda service module Nov. 12. Also known as Poisk, which means "explore" in Russian, MRM2 serves as an additional docking port for Russian vehicles, as an airlock for Russian-based spacewalks and as a platform for external science experiments.

ISS Assembly Mission 20A
Space Shuttle Mission STS-130

February 8, 2010 --- During the STS-130 mission, space shuttle Endeavour delivered Node 3, named Tranquility, to the International Space Station. Tranquility is a pressurized module that will provide room for many of the space station's life support systems. Attached to the node is a cupola, which is a unique work station with six windows on the sides and one on top.

ISS Assembly Mission 19A
Space Shuttle Mission STS-131

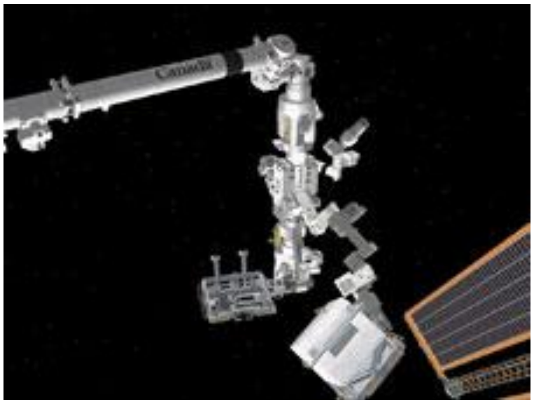
April 5-20, 2010 --- Space shuttle Discovery delivered the Leonardo Multi-Purpose Logistics Module filled with science racks that were transferred to laboratories on the International Space Station during the STS-131 mission. Discovery's crew conducted three spacewalks to replace an ammonia tank assembly, retrieve a Japanese experiment from the station’s exterior and switch out a rate gyro assembly on the S0 element of the station's truss.

ISS Assembly Mission ULF4
Space Shuttle Mission STS-132

May 14-26, 2010 --- Space shuttle Atlantis launched on its final planned mission to deliver an Integrated Cargo Carrier and the Russian-built Mini-Research Module-1 (MRM1) to the International Space Station. The 19.7-foot Russian module was installed on the Earth-facing port of the station’s Zarya module. Known as Rassvet, Russian for "dawn," MRM1 provides cargo storage and an additional docking port to the station. STS-132 spacewalkers installed a spare antenna, replaced batteries on the P6 truss and retrieved a power data grapple fixture.

ISS Assembly Mission ULF5
Space Shuttle Mission STS-133

Feb. 24, 2011 --- Space shuttle Discovery launched on its final mission to deliver the Permanent Multipurpose Module Leonardo, and the EXPRESS Logistics Carrier 4 external stowage platform to the ISS, along with other equipment and supplies. Leonardo had visited the station seven times before as a cargo carrier before being refurbished to serve as a permanent addition to the orbiting laboratory. Also launched was Robonaut 2, a human upper torso-like robot that could be a precursor of devices to help during spacewalks.

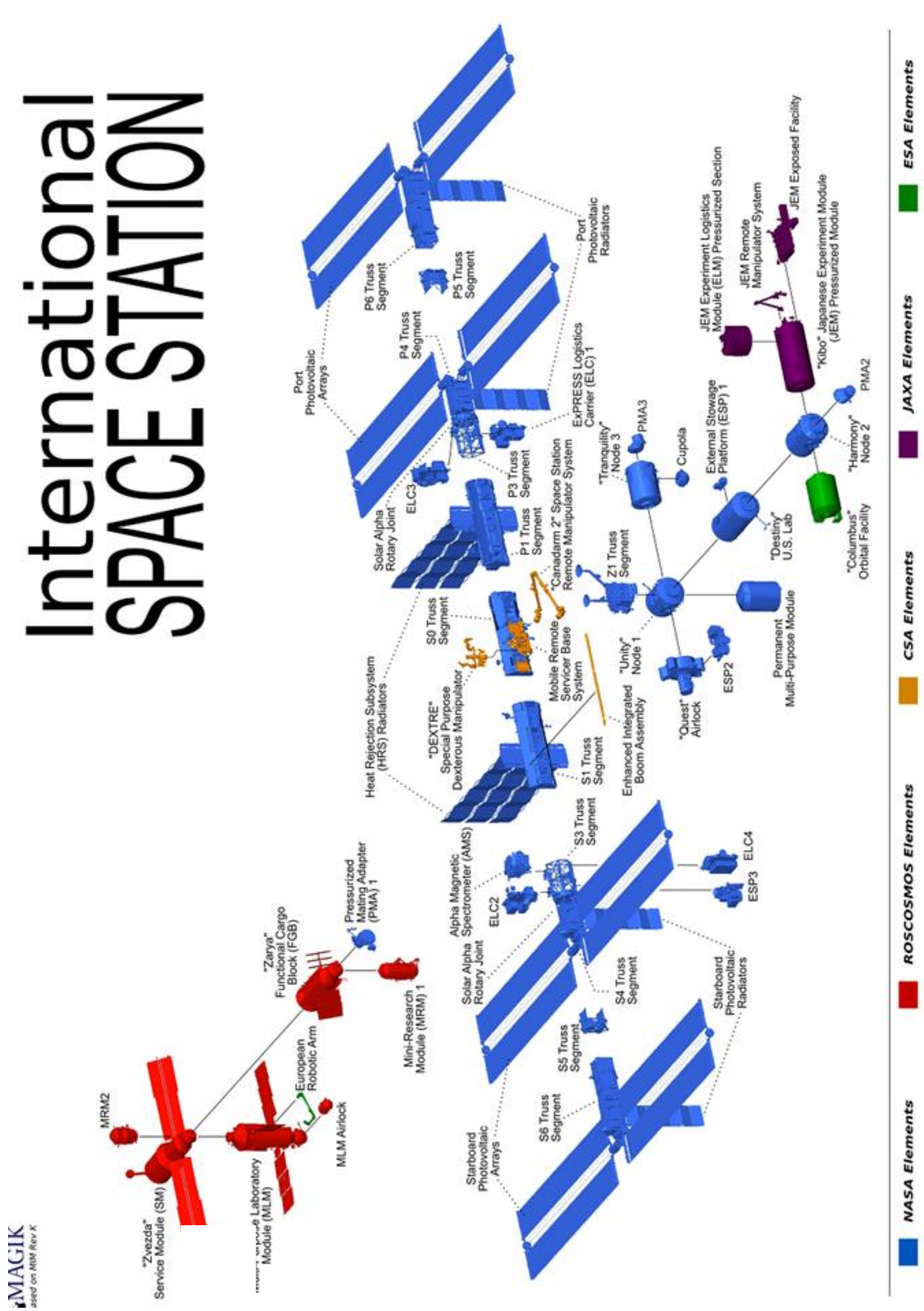


ISS Assembly Mission ULF6
Space Shuttle Mission STS-134

May 16, 2011 --- During the 14-day mission, Endeavour delivered the Alpha Magnetic Spectrometer (AMS) and spare parts including two S-band communications antennas, a high-pressure gas tank and additional spare parts for Dextre – Special Purpose Dexterous Manipulator. This was the 36th shuttle mission to the International Space Station. The STS-134 crew members are Commander Mark Kelly, Pilot Gregory H. Johnson and Mission Specialists Michael Fincke, Greg Chamitoff, Andrew Feustel and European Space Agency astronaut Roberto Vittori.

ISS Assembly Mission ULF7
Space Shuttle Mission STS-135

The NASA Authorization Act of 2010 directs NASA to conduct the STS-135 mission. Atlantis will carry the Raffaello multipurpose logistics module to deliver supplies, logistics and spare parts to the International Space Station. The mission also will fly a system to investigate the potential for robotically refueling existing spacecraft and return a failed ammonia pump module to help NASA better understand the failure mechanism and improve pump designs for future systems.


International SPACE STATION
MAGIK
Based on MSM Rev K
"Zvezda" Service Module (SM)
MRM2
Multi-Purpose Laboratory Module (MLM)
MLM Airlock
European Robotic Arm
"Zarya" Functional Cargo Block (FGB)
Mini-Research Module (MRM) 1
Pressurized Mating Adapter (PMA) 1
Starboard Photovoltaic Arrays
S6 Truss Segment
S5 Truss Segment
Solar Alpha Rotary Joint
S4 Truss Segment
Starboard Photovoltaic Radiators
Alpha Magnetic Spectrometer (AMS)
ELC2
S3 Truss Segment
ESP3
ELC4
Heat Rejection Subsystem (HRS) Radiators
"DEXTRE" Special Purpose Dexterous Manipulator
S1 Truss Segment
Enhanced Integrated Boom Assembly
Mobile Remote Servicer Base System
S0 Truss Segment
"Quest" Airlock
ESP2
"Unity" Node 1
Permanent Multi-Purpose Module
"Canadarm 2" Space Station Remote Manipulator System
Z1 Truss Segment
Solar Alpha Rotary Joint
ELC3
P1 Truss Segment
P3 Truss Segment
"Tranquility" Node 3
PMA3
Cupola
"Destiny" U.S. Lab
"Columbus" Orbital Facility
External Stowage Platform (ESP) 1
"Harmony" Node 2
PMA2
Port Photovoltaic Arrays
P4 Truss Segment
EXPRESS Logistics Carrier (ELC) 1
P6 Truss Segment
P5 Truss Segment
Port Photovoltaic Radiators
JEM Experiment Logistics Module (ELM) Pressurized Section
JEM Remote Manipulator System
JEM Exposed Facility
"Kibo" Japanese Experiment Module (JEM) Pressurized Module
NASA Elements
ROSCOSMOS Elements
CSA Elements
JAXA Elements
ESA Elements

Research Aboard the International Space Station (ISS)

The ISS is an unprecedented technological and political achievement in global human endeavors to conceive, plan, build, operate, and utilize a research platform in space. It is the latest step in humankind's quest to explore and live in space. As on-orbit assembly of the ISS is completed-including all international partners laboratories and elements-it has developed into a unique research facility capable of unraveling the mysteries of life on Earth. We can use the ISS as a human-tended laboratory in low-Earth orbit to conduct multidiscipline research in biology and biotechnology, materials and physical science, technology advancement and development, and research on the effects of long-duration space flight on the human body. The results of the research completed on the ISS may be applied to various areas of science, enabling us to improve life on this planet and giving us the experience and increased understanding to journey to other worlds.

Some examples of research capabilities aboard the ISS are as follows:

Biological Research

Biological Laboratory (BioLab) [ESA] is used to perform space biology experiments on microorganisms, cells, tissue cultures, small plants and small invertebrates, and it will allow a better understanding of the effects of microgravity and space radiation on biological organisms. BioLab includes an incubator with a microscope, spectrophotometer, and two centrifuges to provide artificial gravity. It also has a glovebox and two cooler/freezer units.

Mice Drawer System (MDS) [NASA, ASI] is hardware provided by the Italian Space Agency (ASI) that uses a validated mouse model to investigate the generic mechanisms underlying bone mass loss in microgravity. MDS is multifunctional and multiuser system that allows experiments in various areas of biomedicine, from research on organ function to the study of the embryonic development of small mammals under microgravity conditions. Research conducted with the MDS is an analog to the human research program, which has the objective to extend the human presence safely beyond low-Earth orbit.

Human Physiology Research

Human Research Facility (HRF-1 and HRF-2) [NASA] enables human life science researchers to study and evaluate the physiological, behavioral, and chemical changes induced by long-duration space flight. HRF-1 houses medical equipment including a **Clinical Ultrasound**, the **Space Linear Acceleration Mass Measurement Device (SLAMMD)** for measuring on-orbit crewmember mass, devices for measuring blood pressure and heart function, and a **Refrigerated Centrifuge** for processing blood samples. The equipment is being used to study the effects of long-duration space flight on the human body. Researchers will use the ISS to understand the physiology and to test countermeasures that will prevent negative effects of space travel, and enable humans to travel beyond Earth orbit. Techniques developed for using ultrasound technology on the ISS are now being used in trauma facilities to more rapidly assess serious patient injuries.

The **Combined Operational Load Bearing External Resistive Exercise Treadmill (COLBERT) [NASA]** can collect data such as body loading, duration of session, and speed for each crewmember.

The **Advance Resistive Exercise Device (ARED) [NASA]** is systems hardware that provides exercise capabilities to crewmembers on the ISS. The ARED also collects data regarding parameters (loads, repetitions, stroke, etc.) associated with crew exercise and transmits it to the ground.

The **Cycle Ergometer with Vibration Isolation System (CEVIS) [NASA]** provides the ability for recumbent cycling to provide aerobic exercise as a countermeasure to cardiovascular deconditioning on orbit. The second generation of exercise equipment used for daily exercise on board the ISS collects information on protocols and forces that are used as supplemental data for studies of muscle and bone loss and cardiovascular health during long-duration space flight.

Physical Science and Materials Research

Fluid Science Laboratory (FSL) [ESA] is a multi-user facility for conducting fluid physics research in microgravity conditions. The FSL provides a central location to perform fluid physics experiments on board the ISS that will give insights into the physics of fluids in space, including aqueous foams, emulsions, convention, and fluid motions. Understanding how fluids behave in microgravity will lead to the development of new fluid delivery systems in future spacecraft design and development.

Combustion Integrated Rack (CIR) [NASA] is used to perform sustained, systematic combustion experiments in microgravity. It consists of an optics bench, a combustion chamber, a fuel and oxidizer management system, environmental management systems, and interfaces for science diagnostics and experiments-specific equipment, as well as five different cameras to observe the patterns of combustion in microgravity for a wide variety of gases and materials.

Earth and Space Science

JEM Exposed Facility (JEM-EF) [JAXA] is an unpressurized pallet structure attached to the Japanese Experiment Module (JEM), Kibo. This external platform will be used for research in areas such as communications, space science, engineering, materials processing, and Earth observation. The **ICS** (Inter-Orbit Communication System) is used to downlink data to Earth. The first JAXA experiments for the JEM-EF are **SEDA-AP** (Space Environment Data Acquisition equipment-Attached Payload), which measures the space environment around the ISS, **MAXI** (Monitor of All-sky X-ray Image), an instrument to monitor the X-ray sources in space, and **SMILES** (Superconducting Submillimeter-wave Limb emission Sounder), which enables global observation of trace gases in the stratosphere.

These are just a few of the dozens of research facilities and experiments onboard the International Space Station, so the above is not an exhaustive list. Additional information can be found at http://www.nasa.gov/mission_pages/station/research/index.html.

*Information provided courtesy of Reference Guide to the International Space Station, Assembly Complete Edition, November 2010.

8 "Did You Know?" Facts About The International Space Station (ISS)

1. The space station, including its large solar arrays, spans the area of a U.S. football field, including the end zones.

Image above: The International Space Station's length and width is about the size of a football field. Credit: NASA

2. The ISS will weigh almost one million pounds (925,627 lbs. or 419,857 kilograms). That's the equivalent of more than 320 automobiles.
3. The U.S. solar array surface area is 38,400 square feet (0.88 acre or 3567 square meters) – large enough to cover eight basketball courts.
4. Crews have eaten about 22,000 meals since the first Expedition in 2000. Approximately four (4) tons or 4000 kilograms of supplies are required to support a crew of three for about six months.
5. The ISS travels an equivalent distance to the Moon and back in about a day.
6. The International Space Station marks its 10th anniversary of continuous human occupation on Nov. 2, 2010. Since Expedition 1, which launched Oct. 31, 2000, and docked Nov. 2, the space station has been visited by 196 individuals from eight different countries.
7. As of November 2, 2010, the International Space Station's odometer read more than 1.5 billion statute miles (the equivalent of eight round trips to the Sun).
8. The station's Water Recovery System reduces crew dependence on "delivered" water by 65 percent – from 1 gallon or 3.8 liters a day to 0.34 gallon or 1.3 liters.

Module 1
ISS Science

- **Activity 1**
  Velocity: Launching the ISS into Orbit
- **Activity 2**
  Matter: Growing Space Crystals

ISS L.A.B.S. Educator's Resource Guide

International Space Station: Learning, Achieving, Believing, Succeeding

Science Activity 1

Velocity:
Launching the ISS into Orbit

Figure 1. View of the launch of STS-120 *Discovery* from launch from Pad 39A at the Kennedy Space Center, Florida.

Objective
To investigate the speed required to launch the International Space Station (ISS) into a circularized orbit. To introduce the concept of lateral velocity, and investigate how changes in a spacecraft's lateral velocity affect its orbit.

NASA Challenge
You are a NASA Rocket Scientist, and you need to find a way to launch sections of the International Space Station (ISS) into orbit at just the right speed to keep the orbit from going too high or too low.

Background
The International Space Station (ISS) orbits at about 400 kilometers (250 miles) above the surface of the earth, at an average speed of about 7.7 kilometers per second (17,240 miles per hour) or about eight times the speed of a bullet! Each module (section) of the ISS was launched from Earth using rockets to get them to exactly the right speed to maintain a circularized orbit.

All orbits are elliptical, but most spacecraft orbiting the Earth travel in 'circularized' orbits, to maintain a more constant altitude (height) above the surface. A circularized orbit is an elliptical orbit that is made as circular as possible.

Grade Level: 5th, 6th, 7th, 8th

Key Topic: Orbits and lateral velocity

Prep Time: 1 hour

Class Time: 50 minutes

Materials per Group

- 1 globe (or large ball on a stable platform)
- 1 large pencil eraser
- 1 length of String (about 4 feet long)
- 1 stopwatch

National Science Content Standards:

- Science as Inquiry
  - Abilities necessary to do scientific inquiry
- Physical Science
  - Transfer of Energy
- Science and Technology
  - Abilities of technological design

National Mathematics Content Standards:

- Measurements
- Data Analysis

Vocabulary:

- Acceleration
- Circle
- Orbit
- Space Station
- Speed
- Lateral Velocity

Velocity defines the speed and direction in which an object is traveling.

When a rocket first lifts off the launch pad, it is traveling straight up, so all of its velocity is vertical. The rocket then begins to tilt so that some of its speed is pointed laterally (to the side), so that it begins to travel around the Earth instead of continuing to travel away from it. This is called lateral velocity (seen in Figure 2), and it is the key to reaching orbit.

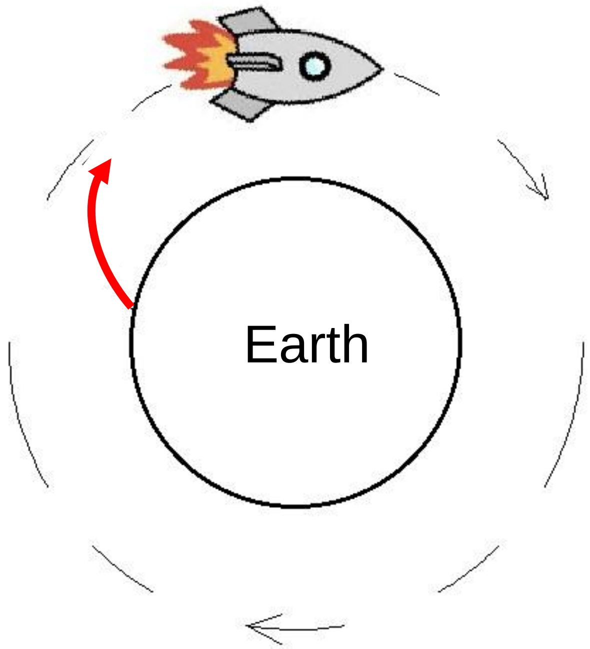


Figure 2. A rocket orbiting around the Earth, showing vertical velocity during launch, and the transition to lateral velocity in orbit.

Figure 3. Aerial view of the second Shuttle launch from Kennedy Space Center, Florida, showing vertical and lateral velocity.

Setting up the Rocket Launch

1. Tie one end of the string around the eraser.
2. Set the globe on the floor, or place the ball in a stable position close to the floor.
3. Hold the other end of the string about 2 - 4 feet above the globe. The eraser should rest against the side of the globe, at the equator, as seen in Figure 4. You can tie the string up or have a fellow Rocket Scientist hold it.

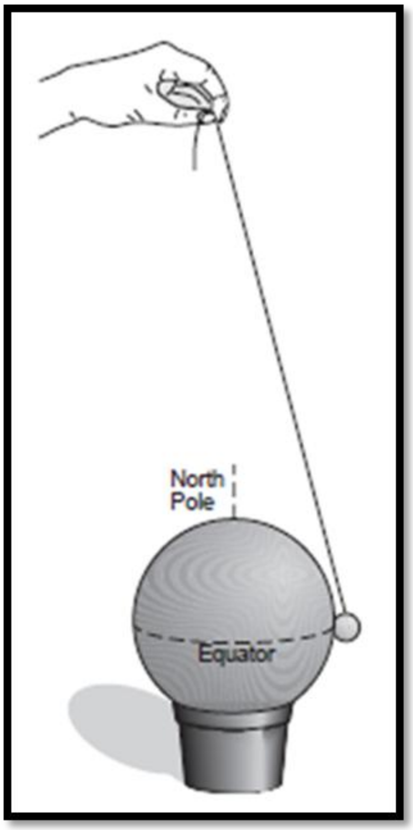


Figure 4. Looking from the side - method for holding the rocket (eraser) against the equator of the Earth (ball), using the string.

Test 1: Vertical Launch with Zero Lateral Velocity

1. Pull the eraser a few inches directly away from the side of the globe, but let the string hold the weight of the eraser.
2. Let it go and watch it fall right back to the surface of the globe, where it was before. This shows how gravity pulls us back to the surface of the Earth when we jump up in the air. This would also happen if a rocket kept going straight up (vertical velocity) during launch, and never turned to go around the Earth (lateral velocity).

Test 2: Launch with Low Lateral Velocity

1. Pull the eraser a few inches directly away from the surface of the globe, while still letting the string hold the weight of the eraser.
2. Gently swing the eraser to the side, parallel with the Earth's equator, and let go. If you do this very gently, the eraser will travel partway around the Earth, and then fall back to the surface at a different point around the equator.

Test 3: Launch with Orbital Velocity

1. Keep trying until you find just the right speed where the eraser circles around the ball without touching the surface, as seen in Figure 5. Try to make the orbit as circular as possible.
2. Once you have found the speed where the eraser comes back to the starting position at the same height where it started, you have reached orbit!
3. Use the stopwatch to measure the time it takes for the eraser to go around the globe in one orbit. Measure this a few times and then calculate the average.
4. Compare your time with the other teams - did you all get the same answer? Why or why not?

Figure 5. The rocket (eraser) orbiting around the Earth (ball), with the string being held at a point above the ball.

Extension

Advanced students can use the following equation to calculate the lateral velocity that the International Space Station must maintain in order to remain in orbit at 402 km (250 miles) above the surface of the Earth.

$$v = \sqrt{\frac{GM}{r}}$$

v = velocity of the ISS, in meters/sec (this is what we are calculating)

GM = Gravitational Constant times Earth's mass (value: 3.99×10^{14} meters^3/sec^2)

r = Radius of ISS orbit (Radius of the Earth plus altitude of ISS orbit)

6,378 km + 402 km = 6.78×10^6 m

Discussion and Answers

1. This experiment is focused on the qualitative lesson, and giving the students a sense of what it means to be in orbit.
2. The orbital time measured by the students in Test 3 will vary according to the radius of the orbit, and the height at which the string is held (the angle the string makes with the ground). Therefore the specific orbital time (and therefore, orbital velocity) that they measure is not as important as the fact that they should all come up with the same number, within a margin of error taking these factors into account.
3. For the extension question, the calculation should result in an answer of 7.67 km/sec (17,160 miles/hour). The same calculation will not apply directly to the ball and eraser (i.e. the parameters G and M cannot be used for the experiment setup), because the experiment uses the tension in the string to simulate the effects of gravity on the eraser's orbit.
4. Discussion Questions for students: How could you make the experiment more reliable? Explain what 'orbit' means to you. How are our lives impacted by things in orbit?

Assessment

- Have students compare their orbital times.
- Review students' time measurements and their conclusions with the class

Science Activity 2

Matter:
Growing Space Crystals

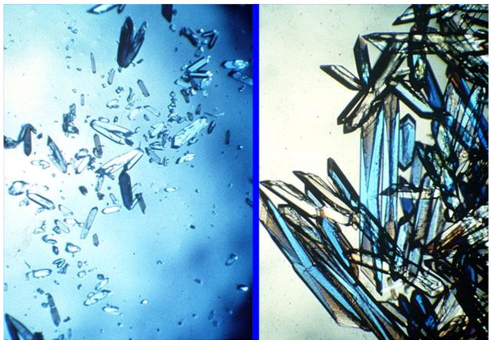



Figure 1. Insulin protein crystals grown (a) on earth and (b) on the ISS Laboratory. (c) Crystals grown in the classroom.

Objective
Investigate how crystals form when materials change from their liquid to their solid state

NASA Challenge
You are a scientist astronaut working in the laboratory of the International Space Station (ISS). Use the materials below to grow the largest crystal you can, to help scientists on earth design a new medicine!

Background
Astronauts on the ISS get to do a lot of science experiments growing crystals. When certain materials 'freeze' from a liquid to a solid, their special growth patterns appear. These materials that group together in a repeated pattern are called crystals. You see crystals every day such as in salt, sugar, gemstones, and medicine!

Most new medicines are designed by scientists using special crystals called proteins. Proteins play a key role in the living world around us. They are important building blocks that are used by human and animal cells. Knowing exactly how these protein crystals are shaped helps scientists design new medicines to combat diseases.

Growing some protein crystals here on earth can be extremely difficult, or even impossible, because gravity causes the delicate crystals to grow with imperfections (defects). Studying crystals in space, where gravity doesn't get in the way, allows space scientists to grow big, almost perfect crystals! Space scientists on the space station are helping find out how to grow the best quality crystals with proteins crystals, like insulin (used to help people with diabetes). Bigger and better protein crystals made in space are a fantastic opportunity to design new medicines in the future!

Grade Level: 5^{th}, 6^{th}, 7^{th}, 8^{th}

Key Topic: States of matter

Prep Time: 15 minutes

Class Time: Two class periods; one 50 minute laboratory and one 40 minute evaluation

Materials per Lab Group:
- 1 small glass jar
  - About 250 ml
- 1 pencil or stick
- 1 cotton or wool string
- 1 bowl
- 1 spoon
- Hot water
- Table salt (see Table 1)
- Optional: safety goggles, paper towels, food coloring, tape, coffee filter

Materials for Evaluation:
- Table salt
- White sugar
- 1 magnifying glass
- Black construction paper
- Optional: grown sugar crystal (rock candy)

National Science Content Standards:
- Science as Inquiry
  - Abilities necessary to do scientific inquiry
  - Understanding about scientific inquiry
- Physical Science
  - Structure and Properties of Matter

Vocabulary:
- Gas
- Liquid
- Solid
- Crystal
- Dissolve
- Saturated solution
- Protein

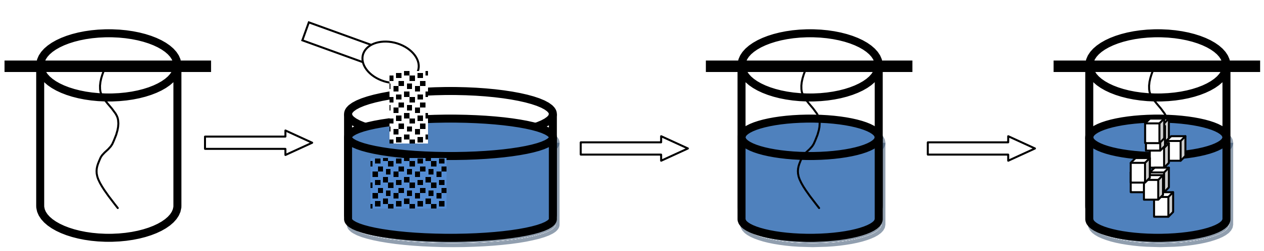
Science Activity 2 – Lab Procedure

Growing Space Crystals

Management
This activity can be done alone or in teams of three (3) students: the chemist (mixer), the engineer (string designer), and the safety watcher. Teachers can prompt students to come up with procedure on their own, before showing them full instructions.

Lab Day Procedure

1. Break off into teams and gather your materials.
2. Engineer: Tie the string to a pencil or stick. Make sure you are using a fuzzy string or yarn.
3. Engineer: Set the pencil or stick across the top of the glass jar and make sure that the string will hang into the jar without touching its sides or bottom. You want the string to almost hang to the bottom. Cut the length of the string, if necessary.
4. Safety: Pour hot water into bowls (boil in a tea kettle or in the microwave). Be very careful to avoid getting splashed! The teacher may want to pour for the students.
5. Mixer: Stir in the salt, 4 teaspoonfuls at a time. Keep adding salt until it starts to collect at the bottom of the jar and won't dissolve (melt) even with more stirring.
6. **Note:** This means the solution is saturated (full). If you don't use a saturated solution, then your crystals won't grow quickly. On the other hand, if you add too much salt, the crystals will grow on the salt at the bottom of the jar and not on your string!
7. Safety: Dip the string into the solution so that half of the string is wet. Take the string out and lay it on a paper towel.
8. If you want colored crystals, stir in a few drops of food coloring.
9. Safety: Pour your solution into the clear glass jar. If you have undissolved salt at the bottom of your container, pour very slowly to avoid getting solid salt in the jar. Fill the glass about 2/3 full. The teacher may want to pour the solutions.
10. Engineer: Place the pencil over the jar and let the string dangle into the liquid. Make sure the string does not touch the jar. **Optional:** You can tape the pencil/stick to the jar to keep it from moving.
11. Set the jar somewhere where it can stay warm and untouched. You can also put a loose coffee filter over the jar to prevent dust from falling in.
12. Finish lab for the day.



Step 2 and 3 | Step 4 | Step 8 | Salt Crystal!

Science Activity 2 – Evaluation and Discussion

Growing Space Crystals

Crystal Evaluation

The teacher may lead a discussion on crystal evaluation using the student worksheet. The evaluation may include comparisons between the table salt and sugar, comparisons between the grown salt and sugar crystals, and understanding crystal growth lab concepts (ideas).

Beware that salt crystals make take 1 to 2 weeks to reach a good size or stop growing. Sugar crystals can take 2 to 4 weeks or longer. To speed evaporation and growth, put the jar under a warm lamp. Once grown, pull out the string crystal, empty out the solution, and hang the crystal to dry in the jar. Optional: A comparison sugar crystal (rock candy) can be bought if time is limited.

A. Put the table salt and table sugar over black paper, to help see them better. Use a magnifying glass (or microscope) to closely look at the crystal grains and compare.

B. Now repeat comparison with magnifying glass using grown salt and sugar crystals

C. Discuss the similarities and differences between sugar and salt crystals color, transparency, and shape.
Hint: Since crystals grow in patterns, each type of crystal grows to always have the same shape.

D. Discuss crystals in daily life and crystal growth concepts from laboratory.

Photos: ISS insulin crystals

For high resolution photos, see Website section of Educator Guide.

Additional Lab Discussion Information

Material phases

Mention 3 items: water, ice cubes, and steam. Ask the students what the water, ice, and steam have in common (they are all forms of water). Explain that these 3 forms of water are examples of the three states of matter: liquid, solid, and gas.

What are crystals?

Crystals are materials that solidify together into an ordered and repeated pattern. For example, water can freeze into ice (a solid) with a pattern making snowflakes! Sugar and salt are also crystals and you can grow these patterned materials in class!

Why hot water?

In step 5 and 6 you made a saturated solution. The salt dissolved or 'melted' into the water at first. When the salt started appearing at the bottom of the bowl, it meant that the water could not hold any more salt. The water did not have room to dissolve anymore. We used hot water because hot liquids can hold/dissolve much more than cold liquids, and doing this is called super-saturation!

Growing the crystal

In step 7 you dipped the string into the solution. Dipping the string helped some of the dissolved salt stick to the string, making a seed salt crystal. Once the solution in the jar started to cool off, the salt in the water started to join the seed crystal on the string. When the water started to dry up into the air (evaporate), salt was also left behind. All these little salt crystals started to join and stick together to grow the string crystal! Because the jar only has salt, all the salt grows in the same pattern and shape.

Teacher Answer Key

Activity

A. Draw the shape of the table salt and table sugar crystals

B. Draw the shape of the grown salt crystal and sugar crystals

Discussion Questions

1. What Are Crystals?

   Answer: Crystals are materials that group together in a repeated pattern.

2. How are salt and sugar crystals alike?

   Answer: Both materials are crystals and they look very similar – they are both white colored with small grains.

3. How are the salt and sugar crystal shapes different?

   Answer: The salt crystals are cube shaped (like dice) and have six sides. The sugar crystals are rectangle shaped with rough pointed ends.

4. Why do the sugar and salt crystals that you made look different than the table sugar and salt crystals?

   Answer: The string crystals are actually just a bunch of the little cubes or rectangles stuck together! Some crystals might also look different because pieces have broken.

5. Is a rough or smooth surface better for growing crystals?

   Answer: A rough surface tends to be better for growing crystals. Notice that the crystal grow on the fuzzy piece of string and not on the smooth sides of the glass

6. Can you identify other crystals you see every day?

   Answer: Snowflakes, ice, baking soda, baking powder, geodes, etc.

7. Is glass a crystal?

   Answer: No, glass doesn't freeze in any specific pattern, it has no order.

8. How would the protein crystals you grow on the ISS be different than ones you grow on Earth? What can protein crystals be used for?

   Answer: The ISS crystals are much bigger and have fewer imperfections.

   Answer: Making new medicines!

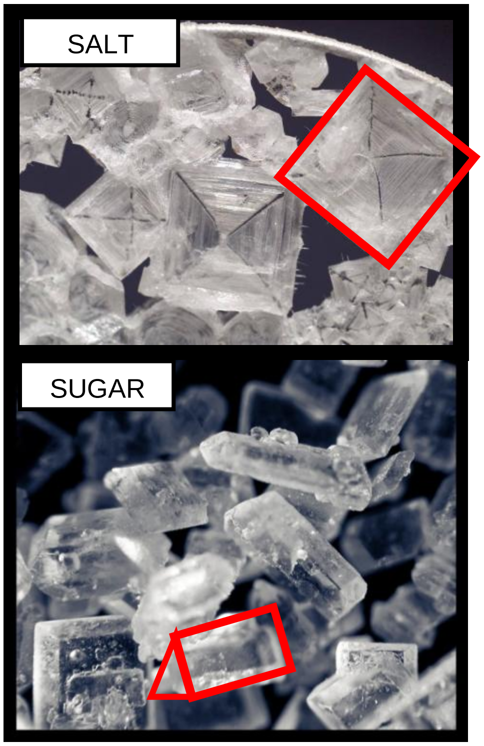


Figure 2. Example images of salt and sugar crystal shapes.

Table 1. Crystal Growing Options

Jar	Ingredients	Observation
#1	1 3/4 cups regular salt 4 cups hot water	Eye: Fuzzy, white crystals Magnifying glass: squares stuck together
#2	1 3/4 cups sugar 1 cup hot water	Eye: frost like crystals Magnifying glass: sharp rectangles stuck together

Name:______________________________

Science Activity 2 – Student Worksheet

Growing Space Crystals

International Space Station L.A.B.S. Team:
Chemist: ______________
String Engineer: ______________
Safety Watcher:__________________

Draw the shape of the table salt crystals	Draw the shape of the table sugar crystals

Draw the shape of the grown salt crystal	Draw the shape of the grown sugar crystal

1. What Are Crystals?

2. How are sugar and salt crystals alike?

3. How are the salt and sugar crystal shapes different?

4. Why do the grown sugar and salt crystals look different than the table sugar and salt?

5. Is a rough or smooth surface better for growing crystals?

6. Can you identify other crystals you see every day?

7. Is glass a crystal?

8. How would protein crystals you grow on the ISS be different than ones you grow on Earth? What can protein crystals be used for?

Module 2
ISS Technology

- **Activity 1**
  Heat Transfer: Keeping Cool in Space
- **Activity 2**
  Mechanisms: International Space Station Robotic Arm

ISS L.A.B.S. Educator's Resource Guide

International Space Station: Learning, Achieving, Believing, Succeeding

Technology Activity 1

Heat Transfer:
Keeping Cool in Space

Figure 1. Liquid Cooling and Ventilation Garment

Objective
Investigate two of the three types of heat transfer. The three types of heat transfer are conduction, convection, and radiation. This activity will focus on conduction and convection.

NASA Challenge
You are an astronaut about to go on a spacewalk outside of the International Space Station. You have to wear a space suit to protect you from the space environment. Once you reach your worksite, you notice you are getting hot in your space suit. Find a way to cool yourself while you are in the space suit.

Background
Regardless of what type of suit is made, NASA Suit Engineers will always have to make sure the astronauts do not get too hot in the space suits. NASA space suit engineers have looked at various methods to help keep astronauts cool. Some of these methods include air and water cooling.

Grade Level: 5th, 6th, 7th, 8th
Key Topic: Heat Transfer
Prep Time: 30 minutes
Class Time: 60 minutes

Materials per Group

- 1 small funnel
- 3-4 feet of clear tubing that fits funnel
- 1 bottle of water
- 1 bucket
- 1 foot of cellophane tape
- 1 thermometer
- 1 roll of paper towels
- 1 timer/clock

National Science Content Standards

- Science as Inquiry
  - Abilities necessary to do scientific inquiry
- Physical Science
  - Transfer of energy
- Science and Technology
  - Abilities of technological design
- Science in Personal and Social Perspectives
  - Personal Health

National Technology and Engineering Content Standards

- Exploring Technology
- Invention and Innovation
- Technological Systems
- Technological Design
- Engineering Design
- Integrated Concepts

Vocabulary:

- Conduction
- Convection
- Radiation

Sometimes the astronauts need to go outside of the International Space Station (ISS) in order to perform inspections, make repairs, conduct experiments, and add modules (sections) onto the ISS.

When the astronauts go outside the ISS, they need to wear a space suit called an Extravehicular Mobility Unit (EMU). Extravehicular is anything that happens outside of the vehicle (e.g. the ISS). The inspections, repairs, experiments, and additions to ISS are all called extravehicular activities (EVAs) because they are activities that happen outside of the ISS.

The space suit is protected by many layers of material with each layer serving a particular function. The inside layer of the EMU (space suit) is called the **pressure garment bladder**. This layer keeps the breathing air inside the space suit. However, since the pressure garment bladder does not breathe (allow air in or out), the astronauts get hot when they are doing EVAs (work outside of the ISS).

Engineers explored different ways of cooling astronauts in the space suit. Water cooling is currently the primary method used to cool astronauts in their space suits. This is done by running cool water through about 91.4 meters (300 feet) of small plastic tubing in the Liquid Cooling and Ventilation Garment (LCVG). The plastic tubing is woven through the spandex outer layer of the LCVG. The spandex makes the plastic tubing fit tight to the body so that the garment and tubing makes contact with the skin.

The heat transfer properties of water work more efficiently than gas cooling which is why it is used.

This activity illustrates the same technology NASA uses to cool down the astronauts.

Management

This activity needs a team of at least two (2) students

Teachers should either refrigerate the bottled water or put the water in a cooler with ice prior to giving it to the students. Colder water will give better results.

The funnels and clear plastic tubing can be found in a home improvement store. Get the smallest funnels available. Make sure the clear plastic tubing can fit snugly around the small end of the funnel. Tape may be required to better secure the funnel to the tubing. The thinner the wall of the clear plastic tubing, the more cooling the students will feel. Thinner walls and a small diameter will also make it easier to wrap the clear plastic tubing around the arm of the students.

When wrapping the clear plastic tubing around the arm, make sure the tubing is in direct contact with the skin.

While pouring the water into the funnel, air bubbles may develop. This is ok.

Figure 2. Cooling Loop made of clear plastic tubing and funnel.

Additional Information for Teachers
Thermodynamics is a part of physics that deals with the energy and work of a system.

Heat is a form of energy. Heat always goes from a hotter place (higher energy molecules) to a cooler place (lower energy molecules). There are three types of heat transfer (movement).

Conduction
Heat is transferred by conduction when it flows through a solid material or when heat flows from one object to another through direct contact. For example, when you touch something cold like ice, the heat from your hand flows from your hand to the ice by conduction.

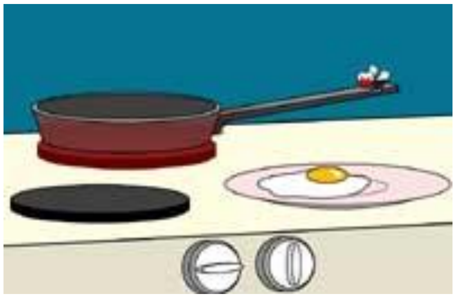


Figure 3. An example of conduction.

Convection
Heat is transferred by convection when it is being moved from one point to another by the movement of fluid (movement of the gas or liquid particles). For example, when you feel a cold wind in the winter, you are feeling a convection current of air.

Figure 4. An example of convection.

Radiation
Heat is transferred by radiation when it flows through empty space without heating the space. For example, heat reaches earth from the sun by radiation. Radiated heat travels as electromagnetic waves.

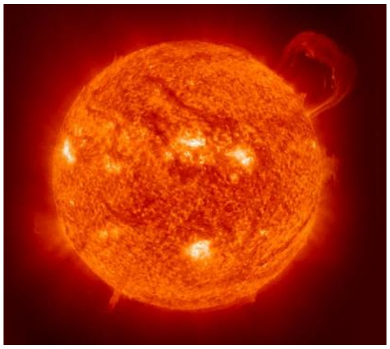


Figure 5. Image of the Sun.

Can you make a space suit that cools and warms you up?
For the EMU, which is used when the astronauts have to go outside of the space station or space shuttle, it is much more common for astronauts to get too warm in their space suits rather than too cold.

However, the fingertips of the astronauts were getting too cold while they were in the space suits. For this reason, the NASA space suit engineers installed heaters in the fingertips of the gloves.

For future space suits that will be used on planetary surfaces like the Moon or Mars, NASA may have to make space suits that provide both cooling and heating to the entire body of the astronauts.

Websites
Links to more information on types of heat transfer, space suits, and the International Space Station can be found at the end of this educator’s guide.

Answer Key

Discussion

1. What did you notice as the ice water flowed through the cooling loop around your arm? Why?

   The engineer wearing the cooling loop should have felt their arm get cooler because the plastic tubing in contact with the skin was picking up heat from their arm and moving it away through conduction.

   Conduction is a type of heat transfer where energy is transferred from one object to another by direct contact.

   The flow of energy, otherwise known as heat, passes from the higher energy molecules to the lower energy ones. A high temperature area has higher energy molecules whereas a lower temperature area has lower energy ones.

2. How did the plastic tubing get cold?

   Convection and conduction. Convection is a type of heat transfer depends on energy being moved from one point to another by the movement of fluid. In the case of this activity, ice cold water was the fluid used to transport energy from one point to another.

   While the energy is being transferred from one end of the tube to another, the ice cold water is in direct contact with the clear plastic tubing. This direct contact causes the ice cold water to transfer energy to the clear plastic tubing through conduction. This transfer causes the clear plastic tubing to cool down and the water to heat up.

3. What are other examples of heat transfer due to conduction and convection?

   Conduction: When you touch a cold object like a cold glass, heat flows from your hand to the cold glass.

   Convection: When you see "heat" rising over a hot stove, you are seeing a convective current of warm air.

4. Why does an astronaut need to be cooled while they are in a space suit?

   The space suit is protected by many layers of material with each layer serving a particular function. The inside layer of the EMU (space suit) is called the pressure garment bladder. However, since the pressure garment bladder does not breathe (allow air in or out), the astronauts get hot when they are doing EVAs (work outside of the ISS). It is like running in a raincoat.

Name: ______________________________

Technology Activity 1

Heat Transfer: Keeping Cool in Space

Engineering Team Members:

- Space Suit Engineer #1 :___________________________
- Space Suit Engineer #2: ___________________________
- Space Suit Engineer #3: ___________________________

I. Objective

Investigate two of the three types of heat transfer. The three types of heat transfer are conduction, convection, and radiation. This activity will focus on conduction and convection.

II. NASA Challenge

You are an astronaut about to go on a spacewalk outside of the International Space Station. You have to wear a space suit to protect you from the space environment. Once you reach your worksite, you notice you are getting hot in your space suit. Find a way to cool yourself while you are in the space suit.

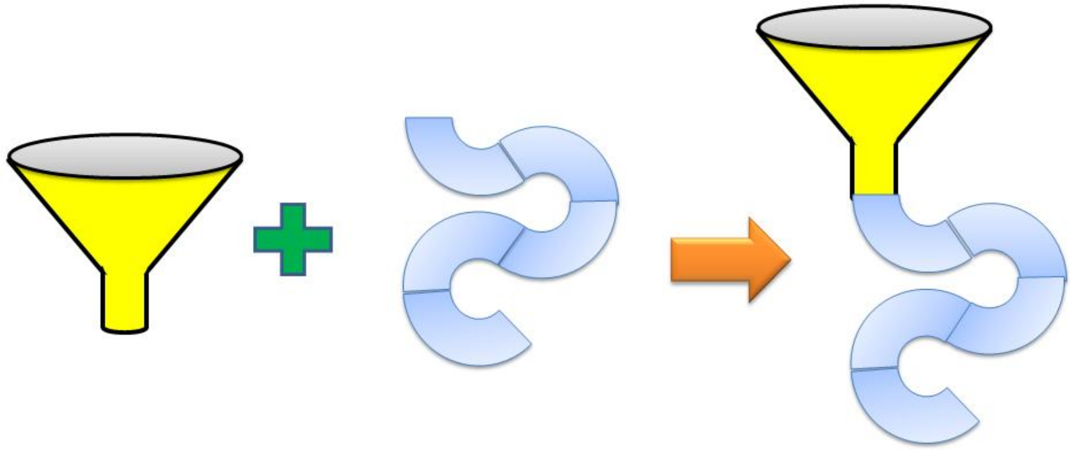
III. Materials

- 1 small funnel
- 3-4 feet of clear tubing
- 1 ice cold bottle of water
- 1 bucket
- 1 foot of cellophane tape
- 1 thermometer
- 1 roll of paper towels
- 1 timer/clock

Figure 1. Astronaut Jim Reilly on a space walk outside of the International Space Station.

IV. Procedure A: Making the Cooling Loop

1. Insert the small end of the funnel into one side of the clear plastic tubing.
2. If needed, the funnel may be further secured to the clear plastic tubing by wrapping tape around the area where the funnel interfaces with the tubing.



V. Procedure B: Using the Cooling Loop

3. Suit Engineer #1: Open the ice cold bottle of water.
4. Suit Engineer #1: Using the thermometer, measure the temperature of the water in the water bottle.
5. Suit Engineer #2: Record starting temperature of water in bottle.

   Starting Temperature of Water: ________________°C

6. Suit Engineer#3: Wrap the clear plastic tubing around your arm with the funnel up and near your shoulder. You may need help from your teammates. Make sure the funnel can be pointed upward.
7. Suit Engineer #2: Place the bucket on side of Suit Engineer #3 with the cooling loop.
8. Suit Engineer #3: Direct the end of the cooling loop in your hand toward the bucket for the water.
9. Suit Engineer #2: Hold the funnel end up for the duration of the activity.
10. Suit Engineer #1: Pour ice cold water into the funnel making sure not to spill the water on Suit Engineers #2 and #3.
11. Suit Engineer #3: Keep water in the clear plastic tubing for 5 minutes by temporarily blocking (with thumb) the drainage end of the tube.
12. Suit Engineer #3: Report what you are feeling to your teammates.
13. Suit Engineer #3: Pour water in the clear plastic tubing into the bucket.
14. Suit Engineer #1: Using the thermometer, measure the temperature of the water in the bucket.

    Ending Temperature of Water:___________________ °C

15. Repeat Steps 1 through 12 until everyone has worn the cooling loop.

Discussion

1. What did you notice as the ice cold water flowed through the cooling loop around your arm? Why?

____
____
____

2. How did the plastic tubing get cold?

____
____
____

3. What are other examples of heat transfer due to conduction and convection?

____
____
____

4. Why does an astronaut need to be cooled while they are inside a space suit?

____
____
____

Technology Activity 2

Mechanisms:
International Space Station Robotic Arm

Figure 1. A photograph from a window of the International Space Station, showing the Robotic Arm grappling onto an 'H-2 Transfer Vehicle' or HTV.

Figure 2. A close-up photograph of the Robotic Arm after it has grappled onto the HTV.

Objective
To understand how an engineer designs a mechanism (simple machine) that will allow the International Space Station Robot Arm to grapple (grab onto) a spacecraft.

NASA Challenge
You are a NASA Robotics Engineer, and you need to find a way for the International Space Station (ISS) Robotic Arm to grapple (grab onto) a spacecraft called the 'H-2 Transfer Vehicle' or HTV. The HTV is used to carry supplies and tools to the ISS.

Grade Level: 5th, 6th, 7th, 8th

Key Topic: Mechanisms

Prep Time: 30 minutes

Class Time: 50 minutes

Materials per Group

- 2 styrofoam coffee cups
- 3 lengths of string (12 cm each)
- 1 lollipop
- Cellophane tape
- Scissors or knife

National Science Content Standards:

- Science as Inquiry
  - Abilities necessary to do scientific inquiry

National Technology and Engineering Content Standards:

- Exploring Technology
- Invention and Innovation
- Technological Systems
- Technological Design
- Engineering Design
- Integrated Concepts

National Mathematics Content Standards:

- Geometry

Vocabulary:

- Mechanism
- Robotics
- Grapple

Background

A new spacecraft called the 'H-2 Transfer Vehicle' or HTV, is flying up to dock (connect) with the International Space Station (ISS). To accomplish the docking, astronauts will operate the ISS Robotic Arm to grapple the HTV as it is flying nearby and then carefully connect it to ISS.

The part on the end of the ISS Robot Arm, which does the grappling, is called the End Effector. For this activity, we will call it the Grappler. The goal of today's activity is to build a Grappler that is similar to the one on the ISS Robotic Arm, and use it to grapple different objects in the classroom.

On the ISS, the way that the Robotic Arm holds onto objects is by using three 'snares' on its Grappler, which tighten around an object to keep it from moving, as in Figure 3.

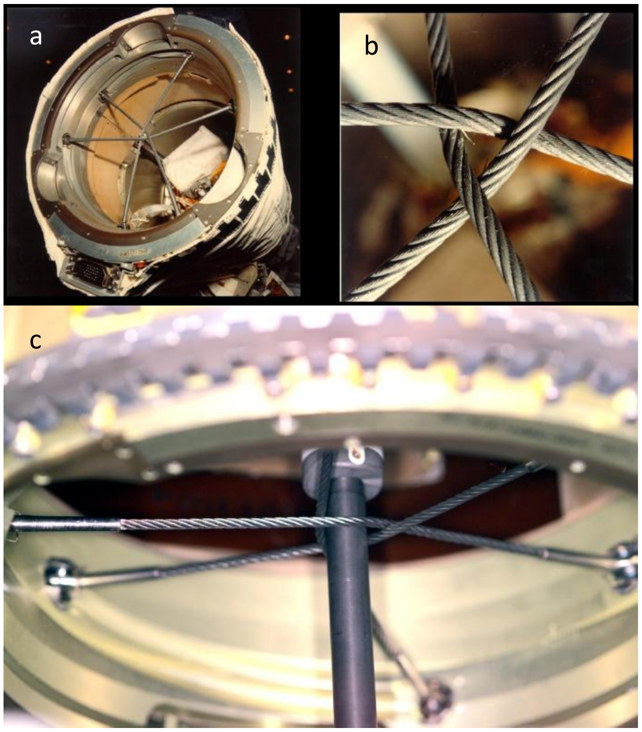


Figure 3. (a) The end of the real ISS Robotic Arm Grappler, (b) A close-up of the Snares inside the real ISS Grappler, (c) The ISS Grappler with Snares closed around the bar of a Fixture

Any object that the Robotic Arm is going to grab needs to have something to hold onto called a Fixture, like the one in Figure 4. The HTV has one of these Fixtures. The Fixture has a metal bar with a ball on the end of it. The Grappler Snares tighten around the bar, and the ball at the end prevents them from sliding off the end. In today's activity we will create a Fixture by using a lollipop.

Figure 4. A Fixture like this is attached to the HTV, so it can be grappled by the Space Station Robot Arm. Note the bar (painted black) and the ball at the end (painted white).

When the three Snares tighten around the bar, it looks like the diagram in Figure 5. We are going to create the same motion by attaching strings to two styrofoam cups, and then twisting the cups to tighten the strings around a lollipop.

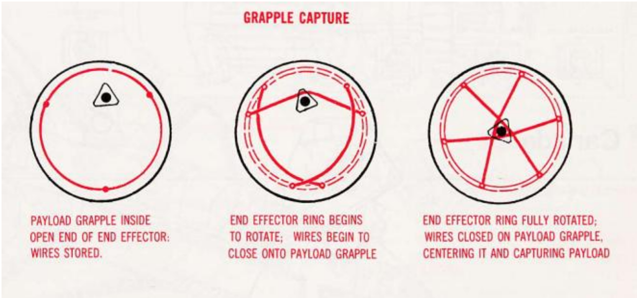


Figure 5. This diagram shows Snares from a Grappler tightening around a Fixture bar, and bringing it towards the center.

Procedure: Make the Grappler

1. Have the robotics engineers work in pairs or small groups.
2. Nest (or 'stack') the two cups together and cut through both cups where indicated in the diagram by the dashed line - about halfway up, as shown in Figure 6. The diagram shows a knife but this can also be done with scissors. Note: keep cups together while cutting.

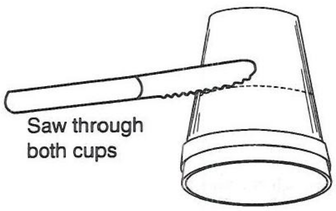


Figure 6. Two styrofoam cups being cut together

3. Cut three 12-centimeter lengths of string.
4. Tape the end of the first string to the side of the inner cut just below the cut edge.
5. Tape the other end of the string outside of the cup, but do not press this piece of tape tightly yet.
6. Repeat Steps 4 and 5 twice more, but place the strings about a third of the way (120 degrees) around the cup from the first string. When you are done your cups should look like Figure 7.

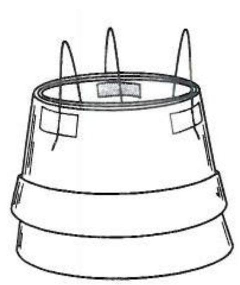


Figure 7. The Grappler with the strings attached

7. While holding the rim of the inner cup, rotate the outer cup until the three strings cross each other. The strings will have some slack. Pull the end of the strings on the outside until they are straight and intersect exactly in the middle of the opening, as seen in Figure 8. Press the tape on the outside to hold the strings.

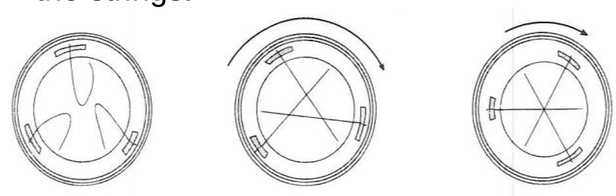


Figure 8. String placement

8. You have now finished the Grappler! When the outer cup is turned it should look like the photos in Figure 9.

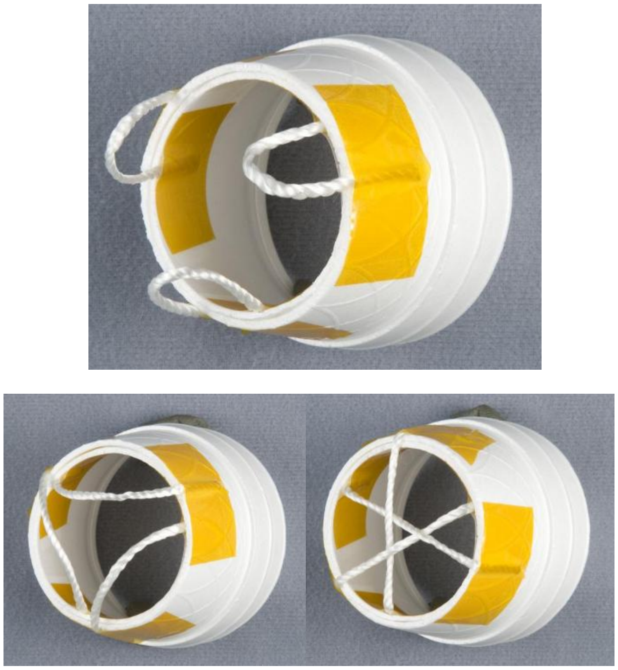


Figure 9. Strings tightening when the outer cup is turned

Procedure: Use the Grappler to grapple the HTV Fixture

9. Have someone hold a lollipop upright. This is the HTV Fixture.

10. Open the Grappler by turning the outer cup, so that the strings are not crossing each other.

11. Slip the Grappler over the lollipop so that it is in the middle, and does not go through the loops, as shown in Figure 10.

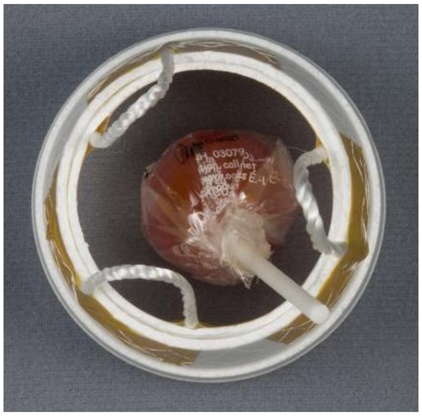


Figure 10. Grappler position before grappling the lollipop

12. Rotate the outer cup until the strings tighten around the lollipop. Congratulations! You have successfully grappled the HTV.

Figure 11. Grappler position after grappling the lollipop (or 'HTV')

13. Now, see if you can grapple a pen. How about a water bottle?

Extension:

1. Can you think of any other objects to grapple?

2. How could the Grappler be improved to hold on to heavier objects?

3. Figure 12 shows a photograph of the ISS Robotic Arm grappling an astronaut in a space suit. This is done so that the astronauts can get to hard-to-reach parts of the ISS more quickly during spacewalks. Can you think of a safe way to use your Grappler to hold on to an astronaut?

Figure 12. The Space Station Robotic Arm Grappler can also hold on to astronauts, using a different attachment

Module 3
ISS Engineering

- **Activity 1**
  Structures: Toothpick Truss
- **Activity 2**
  Mass and Speed: Protecting Space Suits from Orbital Debris

ISS L.A.B.S. Educator's Resource Guide

International Space Station: Learning, Achieving, Believing, Succeeding

Engineering Activity 1

Structures:
Toothpick Truss

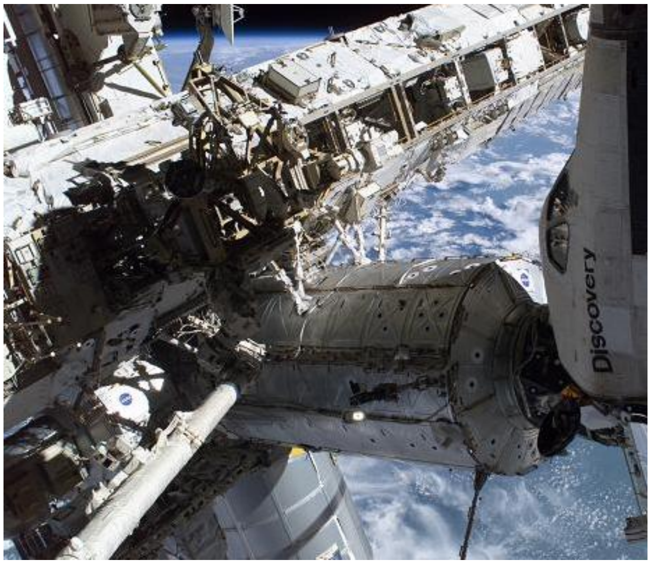


Figure 1. International Space Station Truss Segment

Figure 2. International Space Station Truss Segment cross section

Objective
To develop an understanding of engineering design for truss structures, and the role of shapes in the strength of structures.

NASA Challenge
You are a NASA Structural Engineer, and you need to find a way to build a structure that the International Space Station can use to hold the Laboratory and modules (sections) together with the solar arrays and radiators.

Grade Level: 5th, 6th, 7th, 8th

Key Topic: Structures

Prep Time: 30 minutes

Class Time: Three class periods of 30 minutes, 30 minutes, and 50 minutes

Materials per Group

- 78 toothpicks
- 1 bottle of white glue
- 2 sheets of wax paper
- 8 small alligator clips
- 1 strip of felt or cloth approximately 10”x1”, with small holes at the ends
- 1 hook
- Set of weights in 1/2 kg and 1 kg sizes
  - Or a bag and 15-20 rolls of pennies
  - Total available weight should be about 8 kg

National Science Content Standards:

- Science as Inquiry
  - Abilities necessary to do scientific inquiry

National Technology and Engineering Content Standards:

- Exploring Technology
- Invention and Innovation
- Technological Systems
- Technological Design
- Engineering Design
- Integrated Concepts
- Science as Inquiry

National Mathematics Content Standards:

- Geometry

Vocabulary:

- Truss
- Solar Array
- Radiator

Background

When building a structure that needs to hold its own weight along with other loads, whether it is for a bridge or a truss used to secure equipment in place, you must take into account how the forces or 'loads' that push against a structure are diverted (shifted) by the structure. The way these forces are diverted determines whether the structure is strong enough to hold its shape.

In this exercise you will use toothpicks and glue to build two truss segments, one using squares as the basic shape, and one using triangles, and then determine through testing which structure is able to withstand (hold) more weight.

As shown in Figure 3, a truss with a triangular cross-section will resist external forces more effectively than one with a square cross-section. As a force is applied against one side of a triangle, the force will be re-directed along the length of the adjacent side and transferred into a compression force.

Most materials have a strong resistance to compression force. However, when a force is applied to the edge of a square, the force is re-directed to the corners where the force tries to bend the corners away from their 90 degree angle. Without any reinforcement, it is very hard for a corner to resist this force, and it will buckle more easily. For this reason, most trusses, including bridges, cranes, and the truss on the International Space Station, are built using triangular shaped cross-sections.

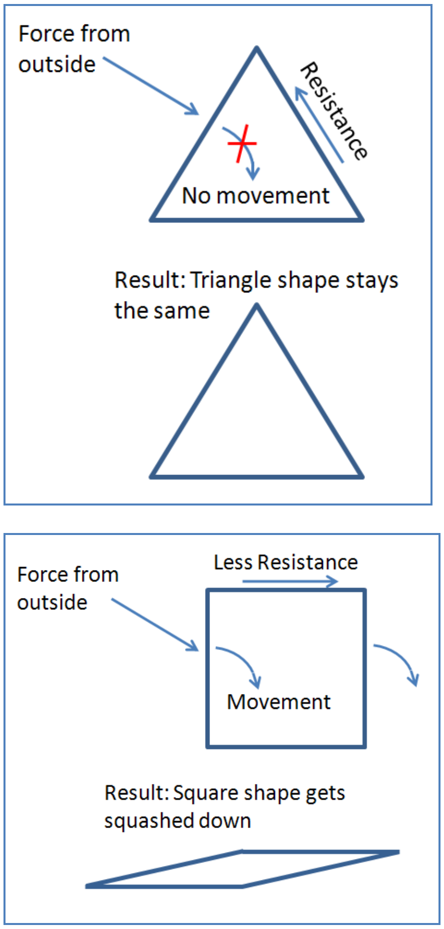


Figure 3. Comparison of triangular shapes to square shapes in resisting external forces.

Management

This activity can be done at home or in a classroom, by individuals or in teams.

It is best to do this activity in three sessions (or class periods) at least 8 hours apart. In the first session, toothpicks are arranged and glued into a pattern to create both the square and triangular truss. After the glue dries, in the second session, both of these patterns are folded and glued into a truss shape. After the glue dries, in the third session, both of these structures are tested to see how much weight they can hold.

Procedure: Make the Square Truss

Class period 1 (30 min)

1. Each Square truss will need a sheet of wax paper, 40 toothpicks and a bottle of white glue
2. Glue the toothpicks together into a square pattern as shown in Figure 4. The glue will stick to the wax paper as well, but this is ok since it will peel off after drying.

Figure 4. Toothpicks glued together on wax paper into a square pattern.

3. Allow the glue to dry for at least 8 hours.

Class period 2 (30 min)

4. Peel the pattern off of the wax paper (some of the glue might not be completely dry - this is ok), and fold it together into a square tube shape, as shown in Figure 5.
5. Clamp the sides together where they meet, using small alligator clips.
6. Glue along this edge to hold the tube together.

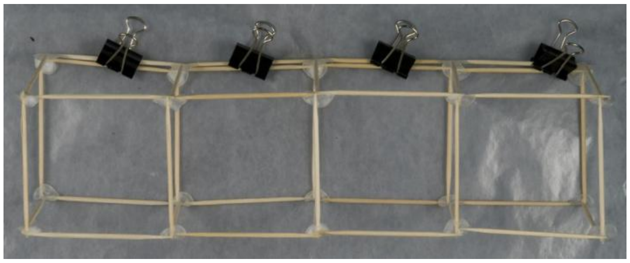


Figure 5. Square toothpick pattern folded into a square tube shape to form the truss structure.

7. Allow the square truss segment to dry overnight for optimum (best) strength.

Procedure: Make the Triangular Truss

Class period 1 (30 min)

1. Each Triangle truss will need a sheet of wax paper, 38 toothpicks and a bottle of white glue
2. Glue the toothpicks together into a triangular pattern as shown in Figure 6. The glue will stick to the wax paper as well but this is ok, it will peel off after drying.

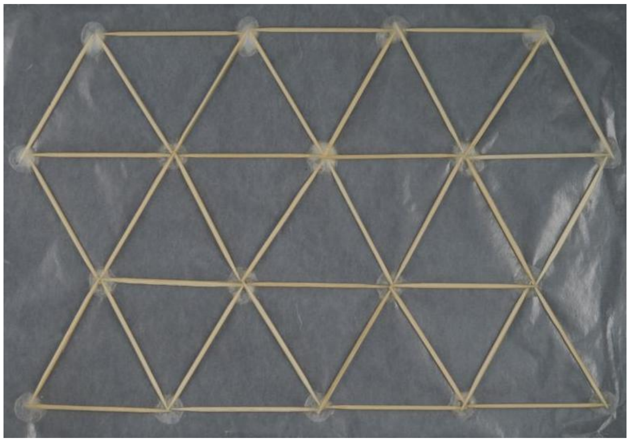


Figure 6. Toothpicks glued together on wax paper into a triangular pattern.

3. Allow the glue to dry for at least 8 hours.

Class period 2 (30 min)

1. Peel the pattern off of the wax paper (some of the glue might not be completely dry - this is ok), and fold it together into a triangular tube shape, as shown in Figure 7.
2. Clamp the sides together where they meet, using small alligator clips.
3. Glue along this edge to hold the tube together.

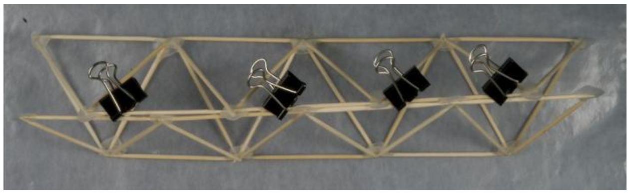


Figure 7. Triangular toothpick pattern folded into a triangular tube shape to form the truss.

4. Allow the triangular truss segment to dry overnight for optimum (best) strength.

Comparison of the Square and Triangular Trusses

Class period 3 (50 min)

1. Place the ends of each of the truss segments on tables or desks so that the center is not supported, as shown in Figures 8 and 9.
2. The tables or desks should only support 1 inch of each end of the truss.
3. Wrap the strip of felt or cloth around the top of the truss and make a hole for the weight hook, as shown in Figures 8 and 9.
4. Place about 1/2 kg weight on the hook and observe any change in the truss segment.
5. Add increasing weights about 1/2 kg at a time, until the truss buckles and gives way. Failure is when the truss can no longer hold up the weight.
6. Record the weight that caused each truss to fail.
7. What part of the truss broke first [toothpick or glue joint]?

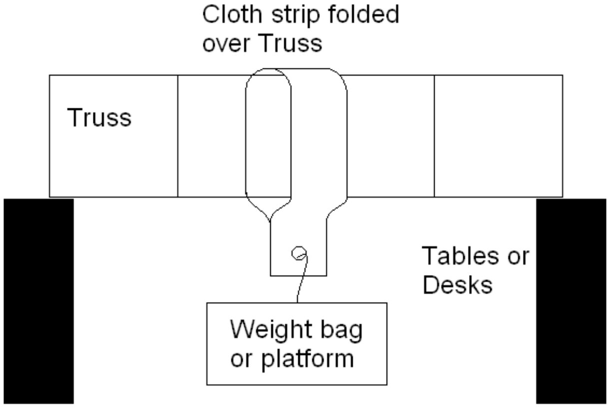


Figure 8. Hanging weight from the square truss

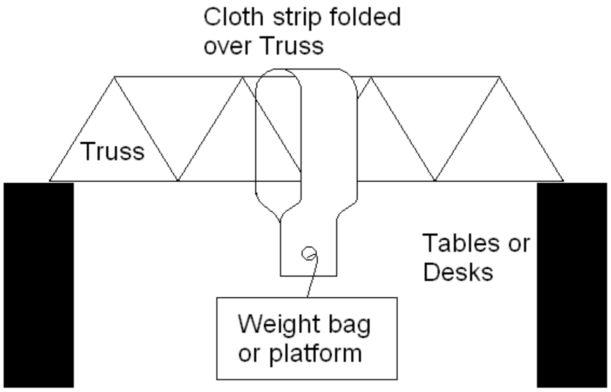


Figure 9. Hanging weight from the triangular truss

Assessment

- Write down and compare the data on the weights at which each of the trusses buckled or failed.
- Was there a clear winner? [Teacher discussion: results should show the triangular truss segment can hold significantly more weight than the square truss segment before buckling.]
- Discuss that the winning structure also used 2 fewer toothpicks. So it is possible to create a structure that is both lighter and stronger, if the right shapes are used in the design.

Extension

- What else would you do to the current design to make it hold even more weight

Name:_______________________

NASA Challenge:

Toothpick Truss Worksheet

Where are some places you see the Square or Triangle Truss shape used?

____

Hypothesis: I think the _______________ Truss will hold more weight, because

____

Team	Square Truss Weight	Triangle Truss Weight	Which Truss held the most weight? Square or Triangle
1			
2			
3			
4			
5			

Based on my research, the _____________ Truss holds more weight

How could you improve the current design to make it hold more weight?

____

Engineering Activity 2

Mass and Speed:
Protecting Space Suits from Orbital Debris

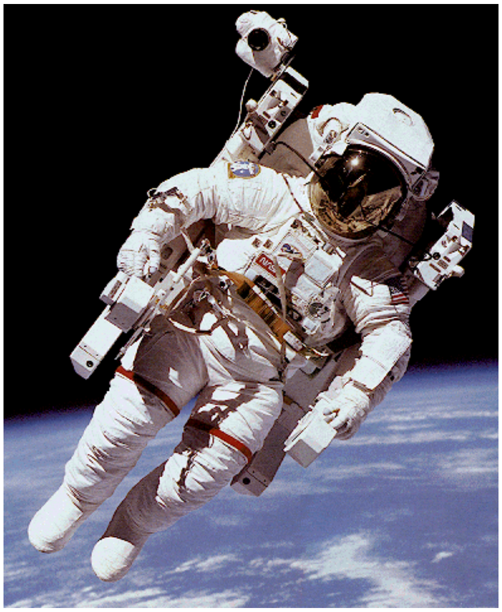


Figure 1. Extravehicular Mobility Unit (EMU) outside of the International Space Station.

Objective
To investigate the relationship between mass, speed, velocity, and kinetic energy. To apply an engineering design test procedure to determine impact strength of various materials.

NASA Challenge
You are a NASA Space Suit Engineer and you need to select the best material to be used on your space suit. You need to pick a material that can survive an impact (hit) by a piece of space debris the size of a marble traveling at different speeds.

Background
The International Space Station (ISS) orbits about 400 kilometers (250 miles) above the surface of the earth. The ISS is surrounded by human-made debris (trash) which can impact (hit) the ISS or the astronauts in space suits outside of the ISS at speeds up to about 7 kilometers per second (16000 miles per hour). Debris traveling at high speeds can cause life threatening damage to the ISS the space suits. Data collected by the International Space Station helps to track these objects.

Grade Level: 5^{th}, 6^{th}, 7^{th}, 8^{th}

Key Topic: Mass and Speed

Prep Time: 1 hour

Class Time: 50 minutes

Materials per Group

- 1 empty tissue box
- 1 pair of scissors
- 1 roll of cellophane tape
- 10 napkins
- 10 paper towels
- 1 small marble
- 1 large marble
- 1 meter stick

National Science Content Standards:

- Physical Science
  - Motion and Forces
- Science and Technology
  - Abilities of Technological Design
- Science in Personal and Social Perspectives
  - Personal Health

National Mathematics Content Standards:

- Measurement
  - Apply appropriate techniques, tools, and formulas
- Data Analysis
  - Develop and evaluate inferences and predictions based on data
- Problem Solving
- Connections
- Representations

Vocabulary:

- Debris
- Force
- Kinetic Energy
- Mass
- Speed
- Velocity

Management
This activity can be conducted in a classroom environment. Ideally, have three (3) students per team.

Other materials like tissues, aluminum foil, etc. may be used in the place of the napkins and paper towels. Marbles can be replaced with other objects if desired. A student handout with answer key is provided.

Additional Information for Teachers

Types of Orbital Debris

1. **Natural Debris.** This comes from asteroids and comets that pass near Earth. It is usually smaller and harder to observe than human-made debris.
2. **Orbital Debris.** This means all human-made space objects that aren't being used. These are caused by pieces from rockets and satellites.

Both types of debris are called Micrometeoroid and Orbital Debris (MMOD).

How much orbital debris is in Earth orbit?
In Earth orbit there are about 19,000 objects bigger than 10 cm, about 500,000 objects between 1 and 10 cm, and millions of objects smaller than 1 cm.

How is the International Space Station protected from orbital debris?
The ISS is the most heavily shielded space craft ever flown. Important areas like the modules (sections) where the astronauts live can survive hits from orbital debris less than 1 cm in diameter. The ISS can also move to avoid larger objects.

How are astronauts protected when they need to go outside of the ISS?
Astronauts sometimes need to go outside of the ISS to do repairs and inspections. These are called Extravehicular Activities (EVAs). The astronauts use a space suit to protect them, called the EVA Mobility Unit (EMU).

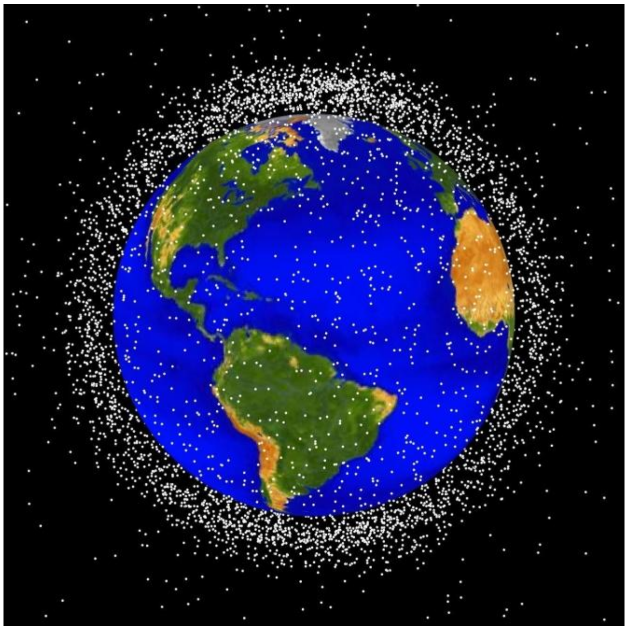


Figure 2. The white dots in this image show the orbital debris that is currently circling the Earth.

Space Suit Layers
This activity focuses on the engineering design and testing process used to select the best materials to protect the astronauts while they are in their space suits. The space suit is protected by multiple layers of materials with each layer serving a different function. The layers of the suit from inside to outside are:

1. **Pressure garment bladder**. This is a urethane coated nylon oxford material (kind of like a rubber balloon) which keeps all the breathing air inside the space suit.

2. **Pressure garment restraint layer.** This layer is made of Dacron (a material commonly found in tents). This gives the pressure garment bladder a human shape and holds it close to the body of the astronaut.

The next layers of the suit are called the Thermal Micrometeoroid Garment (TMG).

3. **TMG Liner.** The inside layer is made of Neoprene (a material found in wetsuits). It protects astronauts from the temperature extremes in space.
4. **TMG Insulation.** This is made of about 6 layers of aluminized Mylar (a material commonly found in metallic balloons), and insulates the astronauts to keep them at the tight temperature.
5. **TMG cover.** The outside layer is made of Nomex, Kevlar, and Teflon. These are the same kinds of materials used in a bulletproof vest, even though the space suit is not bulletproof. It protects against micrometeoroid impacts in space. It is also white because white tends to reflect more heat energy than it absorbs which prevents the space suit from getting too hot. The TMG cover layer is the focus of this engineering activity.

How does NASA test space suit materials?

NASA has a Hypervelocity Impact Testing Facility (HITF) located at White Sands Test Facility in New Mexico. The HITF is home of a light gas gun.

NASA has to use a light gas gun in order to accelerate small objects to speeds of up to 7 kilometers per second (16,000 miles per hour) into a space suit material sample.

A failure is defined as an impact that completely penetrates the pressure garment bladder, damages the inner liner of the pressure garment bladder, or causes the bladder to leak air or oxygen.

Websites

Links to more information can be found at the end of this educator guide.

Answer Key

Discussion

1. Speed is defined as the distance an object travels over a certain period of time. As an engineer, how would you calculate the speed the marbles are traveling when they impact (hit) the space suit material sample?

   Answer: Speed is calculated by measuring the distance the marble travels and dividing it by the time it takes the marble to impact the suit material sample.

2. When the same-sized marble was dropped from a different height, did it hit the suit material sample with the same speed? Why or why not?

   Answer: No. Since the marble is constantly accelerating, the further the marble fell, the faster it was going when it hit the test material sample.

3. A force is defined as the push or pull on an object. What two forces are pushing and pulling on the marble as it falls toward the space suit material sample?

   Answer: When the marbles are falling on Earth, they are falling through the atmosphere. An object that is falling through the atmosphere has two external forces acting on it. The first is the gravitational force (weight) and the second is the force due to drag (air resistance) acting on the marble as it falls toward the space suit material sample.

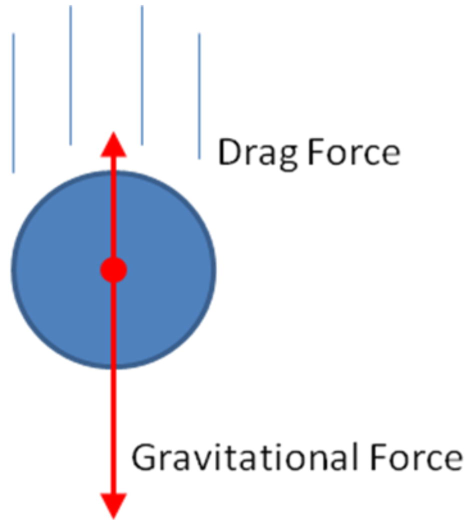


Figure 3. The two forces acting on a falling object.

4. Air resistance increases with speed. When different sized marbles are dropped from the same height, will they hit the suit material sample with the same speed? Explain your answer using your answer from Question 3.

   Answer:
   If you were to compare two objects, the higher velocity occurs for the object of lower frontal area. For this activity the marbles would have drag forces very close to each other due to their similar frontal areas, which lead to similar drag forces.

   If the two marbles were falling in a vacuum (no atmosphere), the only external force acting on them is the force of gravity. Without air resistance, objects fall toward the Earth with the same constant acceleration caused by Earth's gravity. Such objects are said to be free falling. The weight, size, and shape of an object are not a factor during free fall, so both marbles would fall at the same speed and hit the box at the same time.

   During the Apollo 15 mission to the Moon, NASA astronauts proved this by dropping a hammer and a feather at the same time, and they both landed at the same time. On Earth the drag forces would have made the feather hit later, but the Moon has no atmosphere, so gravity was the only force.

   If the marbles were dropped from a much greater height, according to Newton's first and second laws of motion, an object will accelerate if the forces acting on it are unbalanced. The amount of acceleration is proportional to the amount of net force acting upon it.

   Falling objects initially gain speed because there is no force big enough to balance the downward force of gravity. As an object gains speed, the air resistance (drag force) increases. A marble that weighs more will have a greater downward force of gravity. The heavier marble will have to accelerate for a longer period of time before there is enough upward air resistance to balance the larger force of gravity (weight).

   When the upward air resistance equals the downward force of gravity, the object will have reached its terminal velocity. Terminal velocity is the final velocity of the object.

   The heavier marble requires a larger air resistance to reach terminal velocity so it would have to accelerate for a longer period of time.

5. What suit material survived the largest number of impacts? Explain you answer based on your test results.

   Answer: The paper towel should have survived the largest number of impacts. The layered napkins should have performed better than at least the single napkin.

6. Compare the damage done by the two different marbles. What did you observe?

Answer: The larger marble should have done more damage than the small marble.

VI. Extension

1. Velocity is defined as the speed and direction an object travels. Kinetic Energy is defined as the energy due to the motion of an object. Kinetic Energy is defined as the one half of the mass of an object multiplied by the square of the velocity of an object.

$$\textit{Kinetic Energy} = \tfrac{1}{2} \times \textit{mass} \times \textit{velocity}^2$$

If marble A is traveling at the same velocity as marble B, and marble B has more mass, which marble has the larger kinetic energy?

Answer: Marble B will have the larger Kinetic Energy.

Team Name: ____________________________________

Engineering Activity 2

Protecting Space Suits from Orbital Debris

Engineering Team Members:

- Space Suit Engineer #1 :______________
- Space Suit Engineer #2: ______________
- Materials Engineer:__________________

I. Objectives

- To investigate the relationship between mass, speed, velocity, and kinetic energy.
- To apply an engineering design test procedure to determine impact strength of various materials.

Figure 1. Space Suit outside of the International Space Station.

II. NASA Challenge

You are a NASA Space Suit Engineer and you need to select the best material to be used on your space suit. You need to select a material that can survive an impact by a piece of space debris the size of a marble traveling at various speeds.

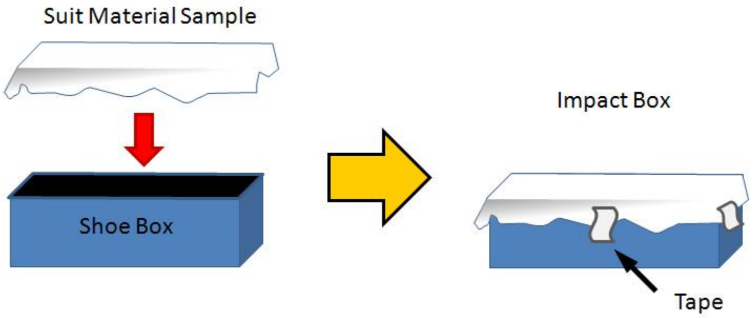
III. Materials

- 1 empty tissue box
- 1 pair of scissors
- 1 roll of cellophane tape
- 10 napkins
- 10 paper towels
- 1 small marble
- 1 large marble
- 1 meter stick

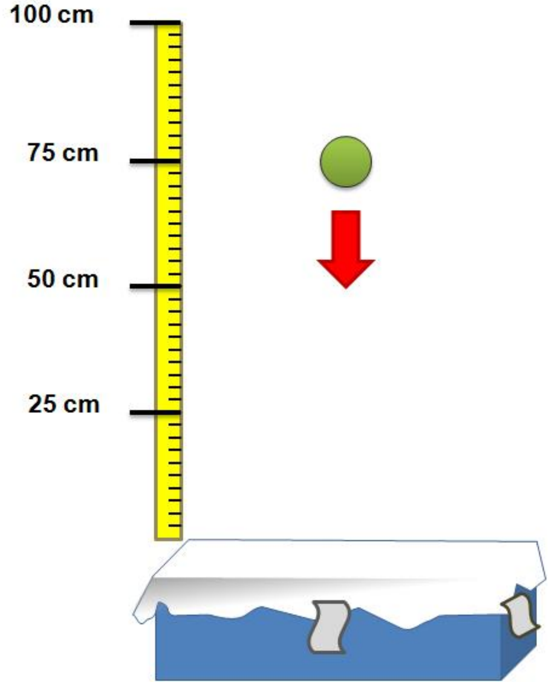
IV. Procedure A: Making the Impact Box

3. Using your scissors, cut the top of the box off (if using a tissue box).
4. Place suit material sample (napkin, paper towel. etc.) on top of shoe box opening.
5. Use tape to attach the paper to the four sides of the box. Make sure the paper is tight over the opening of the tissue box.

IMPORTANT:
To ensure that your results are valid, always attach the materials the same way.



V. Procedure B: Impact Testing



1. Select an open space in the classroom to conduct the test.
2. Make sure the suit material sample is tightly secured over the impact box.
3. Make sure the suit material sample is not torn or damaged.
4. **Suit Engineer #1** will hold a meter stick along the side of the impact box.
5. Using the smallest marble, **Suit Engineer # 2** will drop the marble 25 cm above the top surface of the impact box.
6. **Materials Engineer** will record whether or not the test is a pass/fail.

   Pass means no damage was done to the suit material sample.

   Fail means the marble did damage the suit material sample.
7. Repeat steps # 2 – 6 while steadily increasing the distance the marble is dropped by 25 cm until the marble damages the suit sample material or you reach 100 cm.
8. Repeat steps #1-7 using the larger marble.
9. Repeat steps #1-8 using a different suit material sample and/or multiple layers of one of the two already tested suit materials.

VI. Data

Mass of Marble A: _____________ grams
Mass of Marble B: ______________grams

1. **Napkin**

	25 cm		50 cm		75 cm		100 cm	
	Prediction	Results	Prediction	Results	Prediction	Result	Prediction	Results
Marble A								
Marble B								

2. **Paper Towel**

	25 cm		50 cm		75 cm		100 cm	
	Prediction	Results	Prediction	Results	Prediction	Result	Prediction	Results
Marble A								
Marble B								

3. **3-5 layers of Napkin**

	25 cm		50 cm		75 cm		100 cm	
	Prediction	Results	Prediction	Results	Prediction	Result	Prediction	Results
Marble A								
Marble B								

VII. Discussion

1. Speed is defined as the distance an object travels over a certain period of time. As an engineer, how would you calculate the speed the marbles are traveling when they impact (hit) the space suit material sample?

   ____

   ____

2. When the same-sized marble was dropped from a different height, did it hit the suit material sample with the same speed? Why or why not?

   ____

   ____

3. A force is defined as the push or pull on an object. What two forces are pushing and pulling on the marble as it falls toward the space suit material sample**?**

   ____

   ____

4. Air resistance increases with speed. When different sized marbles are dropped from the same height, will they hit the suit material sample with the same speed? Explain your answer using your answer from Question 3.

   ____

   ____

5. What suit material survived the largest number of impacts and why?

   ____

   ____

6. Compare the damage done by the two different marbles. What did you observe?

   ____

   ____

VIII. Extension

1. Velocity is defined as the speed and direction an object travels. Kinetic Energy is defined as the energy due to the motion of an object. Kinetic Energy is defined as the one half of the mass of an object multiplied by the velocity of an object.

   $$\textit{Kinetic Energy} = \tfrac{1}{2} \times \textit{mass} \times \textit{velocity}^2$$

   If marble A is traveling at the same velocity as marble B, which marble has the larger kinetic energy?

   ____

   ____

Module 4
ISS Math

- **Activity 1**
  Surface Area: Saving Space Station Power
- **Activity 2**
  Orbits: Racing Time in Space

ISS L.A.B.S. Educator's Resource Guide

International Space Station: Learning, Achieving, Believing, Succeeding

Mathematics Activity 1

Grade Level: 5th, 6th, 7th, 8th
Key Topic: Surface Area
Prep Time: 30 minutes
Class Time: 50 minutes

Materials per Group

- 1 sheet of paper
- 1 pencil

National Mathematics Content Standards:

- Work with fractions, decimals and percents
- Solve linear equations
- Model and solve contextualized problems using representations
- Convert units
- Understand relationships among angles, perimeters, lengths, areas and volumes
- Build Math knowledge through problem solving
- Solve problems that arise in Mathematics
- Apply and adapt a variety of strategies to solve problems
- Recognize and apply mathematics in contexts outside mathematics

Vocabulary:

- Debris
- Solar Array
- Space Station

Surface Area:
Saving Space Station Power

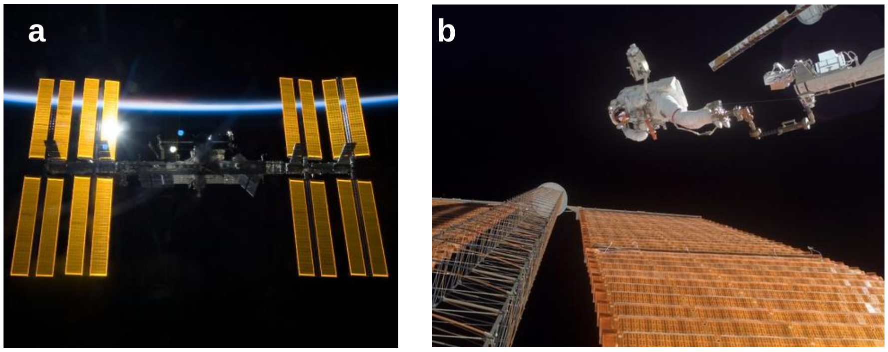


Figure 1. (a) The International Space Station solar arrays lit up by the Sun. (b) Astronaut Scott Parazynski does a spacewalk to repair the damaged solar array

Objective
To calculate surface areas, then use the amount of power or electricity the solar arrays can create. The goal is to apply these calculations to solve a scenario-based challenge.

NASA Challenge

You are in space as the Commander of the International Space Station, and one of your solar arrays has been torn by a piece of space debris. If you cannot provide enough power, you might have to shut down science experiments onboard the International Space Station.

You need to figure out if you can still charge the batteries using this damaged solar array, by calculating how much power it produces.

Background
The International Space Station (ISS) uses 8 large solar arrays similar to the solar arrays used to power small calculators, but on a much larger scale. The area of the ISS is equal to nearly two football fields! They provide the power needed to keep the ISS running, keep the crew comfortable, and operate systems and experiments. They also charge sets of batteries that are used to store extra power. The solar arrays are attached to motors that move them to point at the sun as the ISS orbits around the Earth. When the Earth is between the ISS and the Sun, there is no energy produced by the solar arrays, and all power is provided to ISS by the batteries.

In 2007, one of the solar arrays on the ISS was torn due to an issue with the device that extends it, as shown in Figure 2. When issues like this occur, it is possible that the solar array might not generate as much power as it did prior to the damage. The real solar array on ISS was fixed after this damage happened and is now back up to full power generation. This real-life example is the basis for this activity.

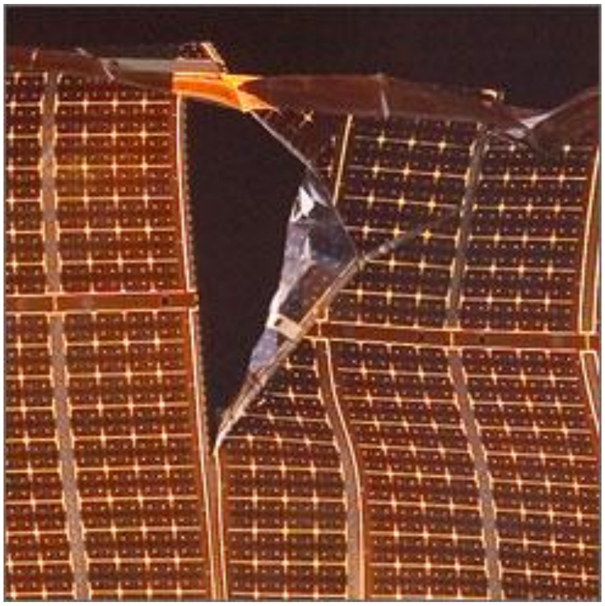


Figure 2. A torn solar array on the International Space Station.

Procedure

1. An undamaged solar array is a rectangle 12 meters wide by 34meters long. Calculate the total area of the solar array.
2. You look out the window of ISS to assess the condition of the solar array. It appears that 10% of it has been damaged and will not produce power. Calculate the remaining usable area of the solar array.
3. If the solar array could produce 40 Watts of electricity per square meter, calculate the total number of Watts the damaged solar array can generate from the Sun. Round your answer to the nearest 100 Watts.
4. Mission Control tells you they need 9 (nine) kilowatts of power from this solar array in order to keep running ISS systems and science experiments. How much power is left to charge the batteries?

Extension

a. If the solar arrays are pointed away from the sun or are shaded, will they generate more or less power than if they were pointed directly at the sun?

b. Assume that the ISS is in eclipse (in the shade of the Earth) 33% of the time during each orbit, and an orbit is 90 minutes long. During eclipse, the batteries do not get charged, and they also have to send out (discharge) 9 kilowatts of power to the science experiments. Do you have enough power to keep all of the science experiments running?

c. One of the motors that moves the solar array breaks, and you can no longer point the solar array directly at the Sun. If the solar array is pointed 45 degrees away from the Sun, how much power will it generate? Round your answer to the nearest 100 Watts. [hint: you will need the Cosine function for this]

d. After this happens, do you still have enough power to keep all of the experiments running?

Discussion and Answers

1. To calculate the total area of the solar array, multiply 12m times 34m.

   Answer: 408 m^2

2. If 10% is damaged, only 90% of the surface area is still usable. Multiply 408 m^2 times 0.9.

   Answer: 367.2 m^2

3. Multiply 367.2 m^2 times 40 Watts/m^2.

   Answer: 14,700 Watts (or 14.7 kilowatts)

4. Subtract 9 Kilowatts from 14.7 Kilowatts.

   Answer: 5.7 Kilowatts

Extensions

a. **Answer: The solar arrays will generate less power if they are pointed away from the sun or are shaded from the sun.**

b. The eclipse pass is 33% of the 90 minute orbit, so 0.33 x 90 = 30 minutes per orbit with no Sun and no battery charging. So the batteries are charged for the remainder of the orbit, 90-30 = 60 minutes, or 1 hour, each orbit.

   So the total amount of charge the batteries receive per orbit is 1 hour of charging times 5.7 kilowatts = 5.7 kilowatt hours.

   During the 30 minutes of eclipse the ISS systems and experiments are drawing 9 kilowatts for 0.5 hours, or a total of 4.5 kilowatt hours.

   Therefore each orbit the batteries are losing receiving 5.7 kilowatt hours of charge, which is more than their expenditure of 4.5 kilowatt hours of charge.

   Answer: Yes, the batteries are still receiving enough power to keep all experiments running

c. If the solar array is pointed 45 degrees away from the Sun, it will generate Cosine 45 times the original level of power generation. Cosine 45 = 0.53, multiplied by 14.7 kilowatts.

   Answer: 7.8 kilowatts

d. Similar to question 4, we need to determine how much charge the batteries are receiving if the systems and payloads are using 9 kilowatts of power. In this case, since the payloads are using more than the total amount of power available (7.8 kilowatts), the batteries are not getting charged at all.

   Answer: No, there is not enough power to keep the experiments running. They will have to be turned off.

Mathematics Activity 2

Orbits:
Racing Time in Space

Figure 1. A photo from space of the eruption of Mount Etna, on the east coast of Sicily, Italy

Objective
To investigate the relationship between speed, distance, and orbits.

NASA Challenge
You are an astronaut conducting science experiments on the International Space Station. Suddenly, Mission Control in Houston calls to tell you that there is a volcano erupting on the other side of the world, and they need you to take measurements from space within 1 hour. These measurements will help scientists learn more about the cause of the eruptions so they can warn people about future eruptions.

You have the equipment you need, but you must wait until the ISS passes over the volcano, which is exactly on the other side of the Earth (1/2 orbit away). Will you be able to take measurements within one hour?

Background
The International Space Station (ISS) circles (orbits) the Earth an average of 400 kilometers (248 miles) above the surface at an average of approximately 8 kilometers per second (17,900 miles per hour). The ISS travels at this speed to maintain a circularized orbit around the earth. All orbits are oval in shape (elliptical), but most spacecraft orbiting earth travel in elliptical orbits that are made as circular as possible in order to keep a constant altitude (height) above the Earth.

Grade Level: 5^{th}, 6^{th}, 7^{th}, 8^{th}
Key Topic: Orbits
Prep Time: 20 minutes
Class Time: 50 minutes

Materials per Group

- 1 pencil
- 1 sheet of paper, folded into quarters
- 1 calculator (optional)

National Science Content Standards:

- Physical Science
  - Position and Motion of Objects

National Mathematics Content Standards:

- Solve linear equations
- Model and solve contextualized problems using representations
- Understand relationships among angles, perimeters, lengths, areas and volumes
- Build Math knowledge through problem solving
- Solve problems that arise in Mathematics
- Apply and adapt a variety of strategies to solve problems
- Recognize and apply mathematics in contexts outside mathematics
- Solve simple problems involving rates and derived measurements for such attributes as velocity and density

Vocabulary:

- Circle
- Distance
- Orbit
- Space Station
- Speed
- Velocity

The radius of the Earth is about 6387 kilometers (3963 miles). Sometimes NASA is called to take pictures from space and track natural or unnatural events occurring on the planetary surface. Some examples of natural disasters NASA has taken pictures of are hurricanes, forest fires, oil spills, and volcanic eruptions.

Figure 2. A photo from space of the eruption of Cleveland Volcano, in the Alaskan Aleutian Islands

Kepler's Laws:
Johannes Kepler was a 17th century German mathematician and scientist in the field of astronomy. For a long time, it was thought that the planets or large bodies moved in circular paths or orbits around larger bodies. Using Martian orbital data obtained by Danish scientist Tycho Brahe, Kepler determined that the planets moved in elliptical orbits rather than circular. Kepler's work led him to discover three general laws that govern the motions of planets in their orbits, called Kepler's laws.

First Law: The orbit of each planet is an ellipse, with the sun at a focus.

Second Law: The line joining the planet to the sun sweeps out equal areas in equal times.

Third Law: The squares if the periods of the planets are proportional to the cubes of their semi-major axes.

Kepler's laws described planetary motion. It would not be until later that Isaac Newton would discover the laws explaining planetary motion.

Management:
Have the students take a sheet of paper and divide it into quadrants (fold in half along the length of the paper and then fold in half along the width of the paper). Have the students write each of the four procedures listed below and their answers in each quadrant.

Procedures:

1. Calculate the radius of the circularized orbit the ISS travels on.
2. Using the radius of the circularized orbit of the ISS, calculate the distance that the ISS travels around the earth during one full orbit.
3. If you know the average speed the ISS is traveling and the total distance the ISS travels around the earth, calculate the time it takes the ISS to complete one orbit around the earth. Note: The time it takes for an object to complete one orbit around another object is also known as an Orbital Period.
4. If the volcano is ½ of one orbit away, it will take ½ of one Period to reach the volcano. Calculate the time it takes for the ISS to reach the volcano from its present location.

Extension
Advanced students can use the following equation to calculate the period of the circularized orbit of the ISS. Compare the period obtained with this equation to the period obtained using the previous equations.

$$P = 2\pi\sqrt{\frac{r^3}{\mu}}$$

P = the period of the elliptical orbit

μ = Gravitational Constant times the Earth's mass = 3.99×10^5 km^3/sec^2

r = radius of circularized orbit that the ISS travels on

Teacher Answer Key

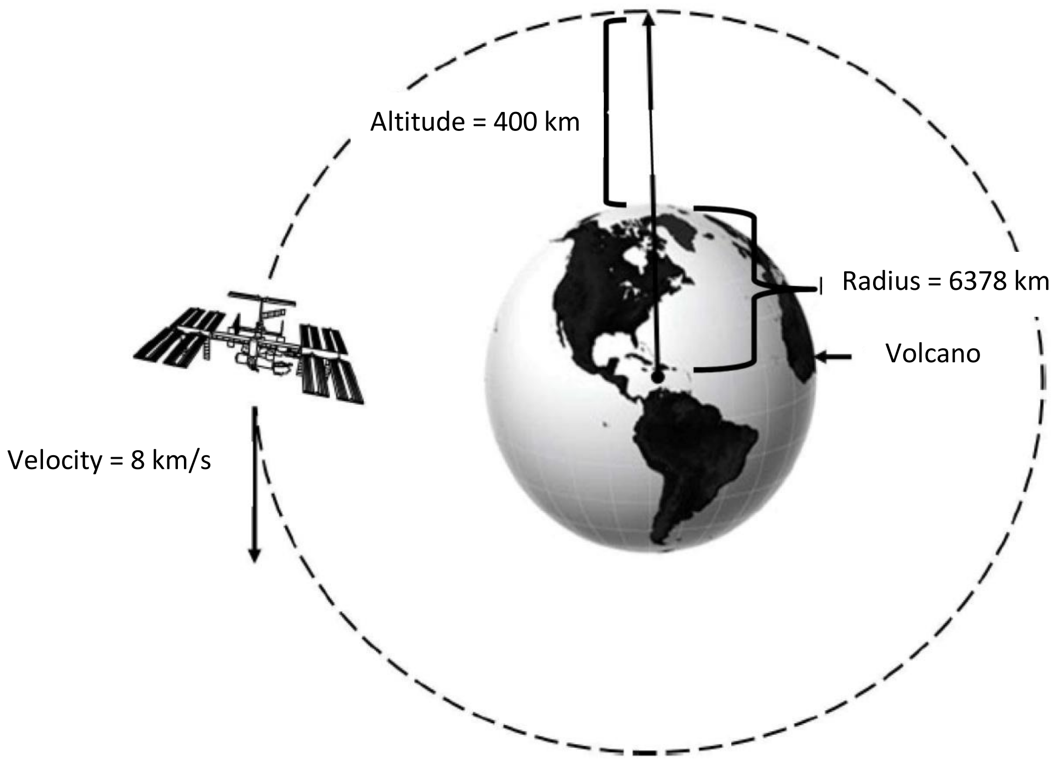


Figure 3. ISS orbit (not to scale)

Formulas:

$$r = radius\ of\ earth + \ distance\ ISS\ is\ from\ earth's\ suface$$

$$C = circumference = \ 2\pi r$$

$$\pi = 3.14$$

$$speed\ of\ ISS = \frac{distance\ ISS\ travels\ in\ one\ orbit}{time}$$

$$Period = time$$

$$Time\ takes\ ISS\ to\ travel\ to\ Volcano\ location = \frac{Period}{2}$$

Answer 1:

The radius of the circularized ISS orbit is equal to the radius of the earth added to the distance from the Earth's surface to the orbit of ISS.

$$r = radius\ of\ earth + \ distance\ ISS\ is\ from\ earth's\ suface$$

$$r = 6378\ km + 400\ km = 6778\ km$$

Answer 2:

Since the ISS travels around the earth in a circular orbit, the distance the ISS travels is equal to the circumference C of its circular orbit.

$$C = 2\pi r = 2\pi(6{,}778\ km) = 42{,}565.84\ km$$

Answer 3:

The ISS travels 42,650 km around earth. The average speed of the ISS is equal to the total distance traveled in a certain period of time. Since we know the velocity of the ISS is 28,165 kilometers per hour (kph), we can solve for the time it takes to reach the volcano.

$$speed\ of\ ISS = \frac{distance\ ISS\ travels\ in\ one\ orbit}{time}$$

$$time\ = \frac{distance\ ISS\ travels\ in\ one\ orbit}{velocity\ of\ ISS} = \frac{42{,}565.84\ km}{8\ km/s}$$

$$Period = time\ = 5320.73\,\text{sec} = 88.68\,\text{min} = 1.48\ hours$$

Answer 4:

The volcano is located ½ an orbit away which is half the Period of the orbit.

$$Time\ takes\ ISS\ to\ travel\ to\ Volcano\ location = \frac{Period}{2} = 0.74\ hours = about\ 44\ minutes$$

Yes. Since it will take you 0.74 hours to reach orbit over the volcano from your current position, you will be able to take measurements within the hour.

Extension Answer:

The more advanced equation should give roughly the same answer as the orbital period calculated in Answer 3 above.

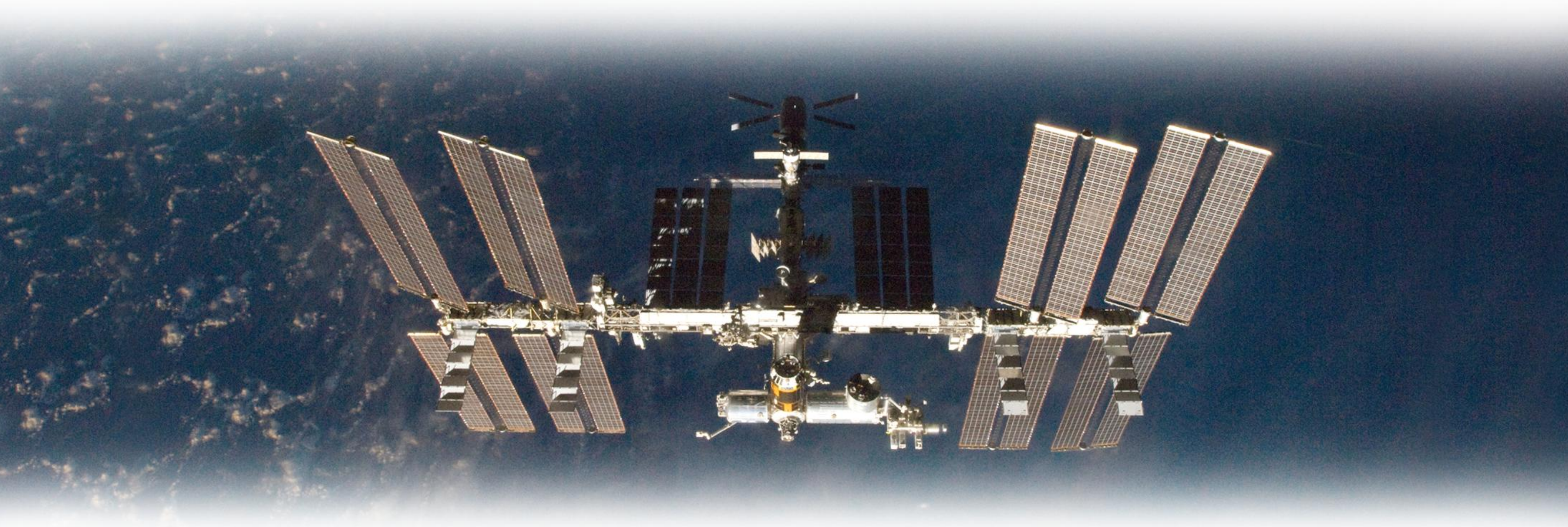
$$P\ = 2\pi\sqrt{\frac{r^3}{\mu}} = 2\pi\sqrt{\frac{(6778\ km)^3}{3.99\ x\ 10^5\ \ km^3/_{sec^2}}} = 2\pi\sqrt{\frac{3.11\ x\ 10^{11}\ km^3}{3.99\ x\ 10^5\ \ km^3/_{sec^2}}}$$

$$P\ = 5551\ seconds = 92.5\ minutes = 1.54\ hours$$

Answer 3 gives a period of 1.48 hours, while the extension answer gives a period of 1.54 hours.

Certificate of Achievement

Be it known that _________________________________ has mastered Science, Technology, Engineering, and Mathematics through completion of the International Space Station L.A.B.S. Education Guide and is prepared to learn, achieve, believe, and succeed at the next level.



International Space Station: Learning, Achieving, Believing, Succeeding

Completed on this _____ day of ______, 20_______

It Takes A Community to Explore Space

Aerospace Engineer **Architect** **Astronaut** **Astronomer** **Biologist** **Chemical Engineer** **Chemist** **Communications Engineer** **Computer Engineer** **Contract Manager** **Dietician**	**Doctor** **Electrical Engineer** **Environmental Scientist** **Geographer** **Geologist** **Materials Engineer** **Mechanical Engineer** **Meteorologist** **Mission Controller** **Nurse** **Oceanographer**	**Physicist** **Public Affairs Specialist** **Robotics Engineer** **Safety and Occupational** **Health Specialist** **Simulation Specialist** **Teacher** **Technician** **Test Pilot** **Wildlife Biologist** **And many more…**

See a job that looks interesting? Want to join the team? All these careers and many more are needed to explore space.

NASA and the companies that work together to build the International Space Station are always looking for scientists, technicians, engineers, and mathematicians. They need people who can plan, design, and fly missions throughout the Solar System. The International Space Station is comprised of many systems working together. People, working together, build the spacesuits, prepare the space food, construct the energy and environmental systems, program the computers, and train the flight crews. Doctors keep the astronauts healthy on the ground and in space. Technicians prepare the launch pads and process the payloads.

Visit **www.nasa.gov** to find more information to help future aerospace workers plan their education that will lead to careers, internships, cooperative education programs, and more.

International Space Station Vocabulary

Acceleration – The change in velocity over a certain period of time.

Action – A force (push or pull) acting on an object. See Reaction.

Circle – A closed round shape where any point on the shape is the same distance from the center.

Conduction – The transfer of thermal energy (heat) from one object to another by direct contact.

Convection – The transfer of thermal energy (heat) from one object to another by the movement of fluid.

Crystal – When a material goes from liquid to solid and grows in a repeated pattern.

Debris - Pieces that are left when something breaks apart.

Dissolve – Is a process where you blend a solid into a liquid, and the solid breaks up in a liquid.

Distance – Measure of separation in space.

Docking - Connecting two spacecraft together in space.

Ellipse – A closed curve of oval shape.

Evaporate – When a liquid turns into a gas.

Force – The push or pull applied to an object.

Grapple - To grab or hold onto something.

Kinetic Energy – Energy of motion.

Lateral Velocity - Speed in a sideways direction.

Liquid – A substance that flows like water and takes the shape of its container.

Mass – The amount of matter. Something with more mass has more weight.

Mechanism - A piece of machinery or a mechanical operation.

Microgravity – An environment where an object's acceleration (change of speed) in any direction is very low in relation to its surrounding.

Motion – Movement of an object in relation to its surroundings.

Newton's Laws of Motion - Laws governing all motion.

Orbit – A path made by one object in its revolution around another.

Proteins – Are the building blocks for humans and other animals.

Radiation – transfer of thermal energy (heat) by waves or rays.

Radiator - a series of tubes used to radiate heat away from the ISS.

Reaction – A movement in the opposite direction from the imposition of an action. See Action.

Robotics - designing and building robots

Saturated – When a liquid solution is full and has dissolved as much solid as possible.

Solar Array – An electrical device that made up of solar cells that change sunlight into electricity.

Solid - An object that has three dimensions (length, width, height) and keeps its shape.

Space Station – An orbiting laboratory with people onboard.

Speed – The distance an object travels over a certain period of time. The magnitude of the velocity.

Truss - A structural frame.

Velocity – The speed and direction an object travels.

NASA Education Resources

The National Aeronautics and Space Administration has an amazing collection of resources for the classroom. Hundreds of educator guides, fact sheets, posters, and lithographs have been developed for the classrooms and are available for electronic downloads. Photo and video collections chronicling NASA's more than 50 years of aerospace research and exploration are also available. Information about current and future programs, including NASA's space exploration policy for the 21st century, can be obtained by electronically stepping through NASA's internet portal. To speed you and your students on your way to your space exploration adventure, some of the links within the NASA portal are highlighted below:

http://www.nasa.gov/audience/forstudents/index.html
http://www.nasa.gov/audience/foreducators/index.html
http://www.nasa.gov/multimedia/index.html

In addition, several websites have been provided that can assist teachers and students in finding additional information on each of the eight (8) activities.

	Activity 1	Activity 2
ISS Science	How the Shuttle Works http://www.nasa.gov/returntoflight/system/system_STS.html Launch Video Archive http://www.nasa.gov/mission_pages/shuttle/launch/MM_collection_archive_1.html	Weightless Research http://spacescience.spaceref.com/newhome/headlines/notebook/msad22jul98_1.htm On Target for a Cure http://science.nasa.gov/science-news/science-at-nasa/1997/msad11jul97_1/ Photos of Crystals http://mix.msfc.nasa.gov/ Search for key words: insulin, crystals
ISS Technology	Heat Transfer http://www.grc.nasa.gov/WWW/K-12/airplane/heat.html Space Suits http://www.nasa.gov/audience/foreducators/spacesuits/home/clickable_suit.html	Canadarm http://www.asc-csa.gc.ca/eng/canadarm/default.asp Space Station http://www.nasa.gov/mission_pages/station/structure/elements/mss.html
ISS Engineering	Integrated Truss Structure http://www.boeing.com/defense-space/space/spacestation/components/integrated_truss.html http://spaceflight.nasa.gov/station/assembly/elements/its/its_structure.html	Orbital Debris http://orbitaldebris.jsc.nasa.gov/index.html NASA orbital debris program office Hypervelocity Impact Technology http://ares.jsc.nasa.gov/ares/hvit/index.cfm (Hypervelocity Impact Test Facility/HITF)
ISS Math	Solar Power on Station http://science.nasa.gov/science-news/science-at-nasa/2001/ast13nov_1/ How Do Solar Cells Work http://science.nasa.gov/science-news/science-at-nasa/2002/solarcells/ Station Spacewalk Game http://www.nasa.gov/multimedia/3d_resources/station_spacewalk_game.html	What is Orbit? http://www.nasa.gov/audience/forstudents/5-8/features/orbit_feature_5-8.html

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