The International Space Station: a National Laboratory

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After more than a decade of assembly missions and the end of the space shuttle program, the International Space Station (ISS) has reached assembly completion. With other visiting spacecraft now docking with the ISS on a regular basis, the orbiting outpost now serves as a National Laboratory to scientists back on Earth. The ISS has the ability to strengthen relationships between NASA, other Federal entities, higher educational institutions, and the private sector in the pursuit of national priorities for the advancement of science, technology, engineering, and mathematics. The ISS National Laboratory also opens new paths for the exploration and economic development of space. In this presentation we will explore the operation of the ISS and the realm of scientific research onboard that includes: (1) Human Research, (2) Biology & Biotechnology, (3) Physical & Material Sciences, (4) Technology, and (5) Earth & Space Science.

The International Space Station: a National Science Laboratory

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NASA – Lyndon B. Johnson Space Center

Outline

I. Introduction to ISS (2 slides)
   1.) ISS Program Mission Statement (NASA)
   2.) ISS Program Office
   3.) International Partners
   4.) ISS parameters (orbit, size, mass, etc)

II. ISS Assembly (2 slides)
   1.) Assembly Complete Overview
   2.) Video: Assembly Complete Mission timeline

III. Visiting Vehicles (4-5 slides)
   1.) Soyuz (properties – crew members)
   2.) Progress (properties – cargo)
   3.) ATV – ESA (properties – cargo)
   4.) HTV – JAXA (properties – cargo)
   5.) Commercial (crew members/cargo)

IV. Communication & Tracking – getting data to the ground (~3 slides)
   1.) ISS – TDRSS – White Sands – MCC (Data path)
   2.) Mission Operations Centers
      a. MCC – Houston
      b. MCC – Moscow
      c. Tskuba - JAXA
      d. Munich -ESA

V. Scientific Research onboard ISS (~8 slides)
   1.) ISS USOS National Laboratory
   2.) Research Overview video (slide #17)
   3.) Current statistics of published research from ISS
   4.) Facilities & Payloads:
      a. Payload Racks
      b. Express Racks
      c. External payloads
   5.) Weekly Research Highlights – current update

VI. Research Disciplines
   1.) Human Research (~3 slides)
      a. Integrated Physiology
   2.) Biology & Biotechnology (~3 slides)
      b. Cellular Biology
      c. Macromolecular Crystal Growth
      d. Microbiology
   3.) Physical & Materials Science (~4 slides)
      a. Microgravity Acceleration Measurement System (MAMS)
      b. Space Acceleration Measurement System (SAMS)
      c. MISSE (updated on ULF6 EVA)

d. Combustion science (BASS/COSMIC)
e. Fluid mechanics & surface tension studies (CCF, FASTER, Marangoni Convection)
f. Fundamental Physics (Heat, Thebas)

4.) Technology (~3 slides)
   a. Robonaut (STS133/ULF5)

5.) Earth & Space Science (~10 slides)
   a. Crew Earth Observation (CEO)
   b. WORF & EarthKAM
   c. HREP-HICO & HREP-RAIDS
   d. Solar – SOLSPEC, SOVIM (Solar Variable & Irradiance Monitor), and SOLACES
   e. SAGE III
   f. MAXI (JEF/JAXA)
   g. Alpha Magnetic Spectrometer (AMS) (~3 slides + video, http://ams-02project.jsc.nasa.gov/index.htm)

VII. Opportunities for Research Onboard ISS

1.) Outline basic process
2.) Provide documentation links via http://www.nasa.gov

References: published Journal papers, articles, and www.nasa.gov (all material is public domain)

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The International Space Station: a National Science Laboratory

"Spreading out into space will have an even greater effect. It will completely change the future of the human race and maybe determine if we have any future at all."

- Prof. Stephen Hawking

Outline

- Introduction to the International Space Station (ISS)
- ISS Operations
- Scientific Research onboard ISS

ISS Program Mission Statement

Safely build, operate, and utilize a permanent human outpost in space through an international partnership of government, industry, and academia to advance exploration of the solar system, conduct scientific research, and enable commerce in space.

ISS Introduction

- International collaboration for the long-term exploration of space

United States

Russia

Canada

Japan

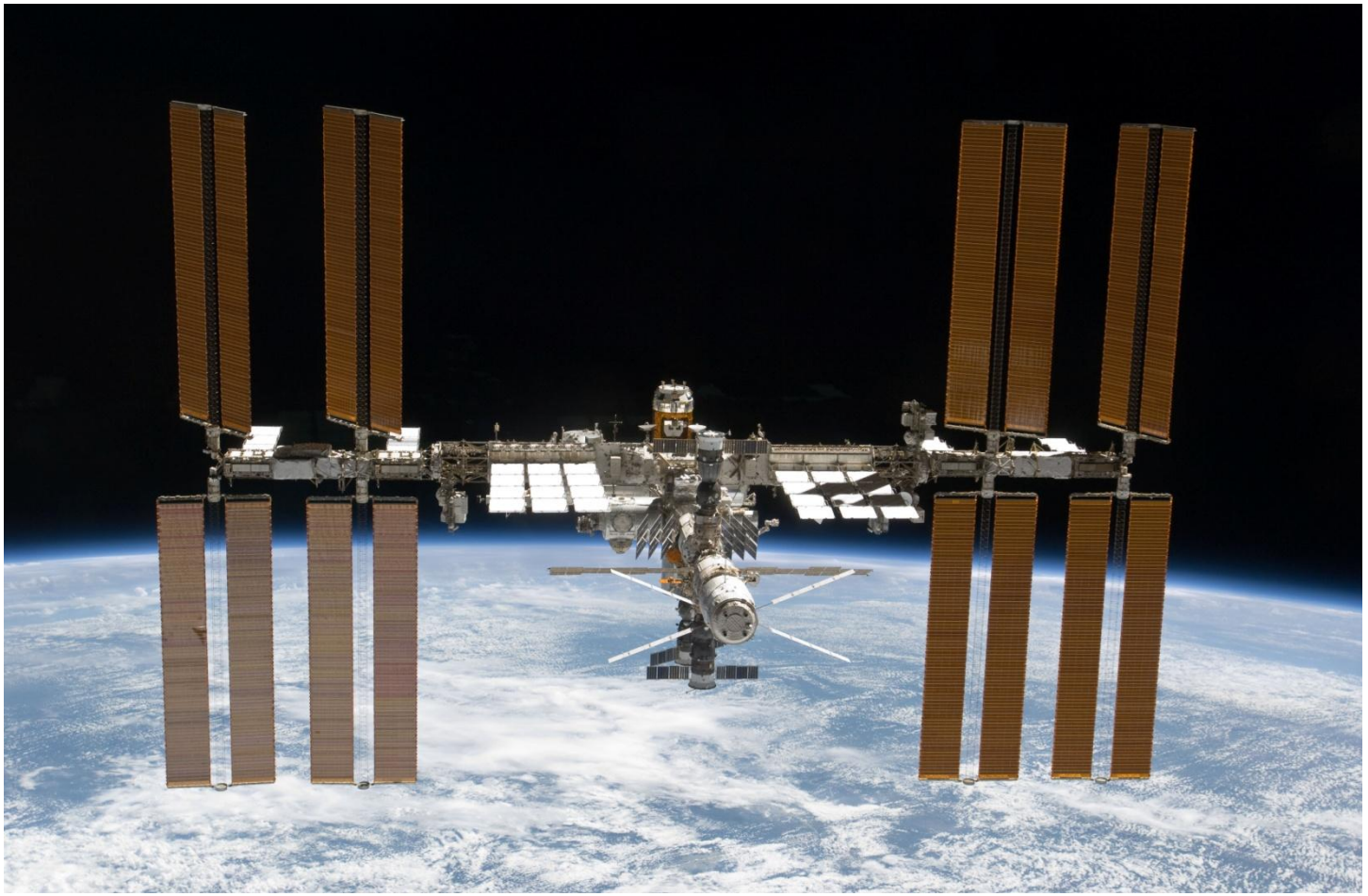
Europe

- Orbital inclination 51.6
- Orbital altitude 370-460 km
- Mass ~419,000 kg
- ~1200 m^3
- 108.4 m (truss) 74 m
- 110 kW power output, (30 kW payload)

Assembly Complete Configuration

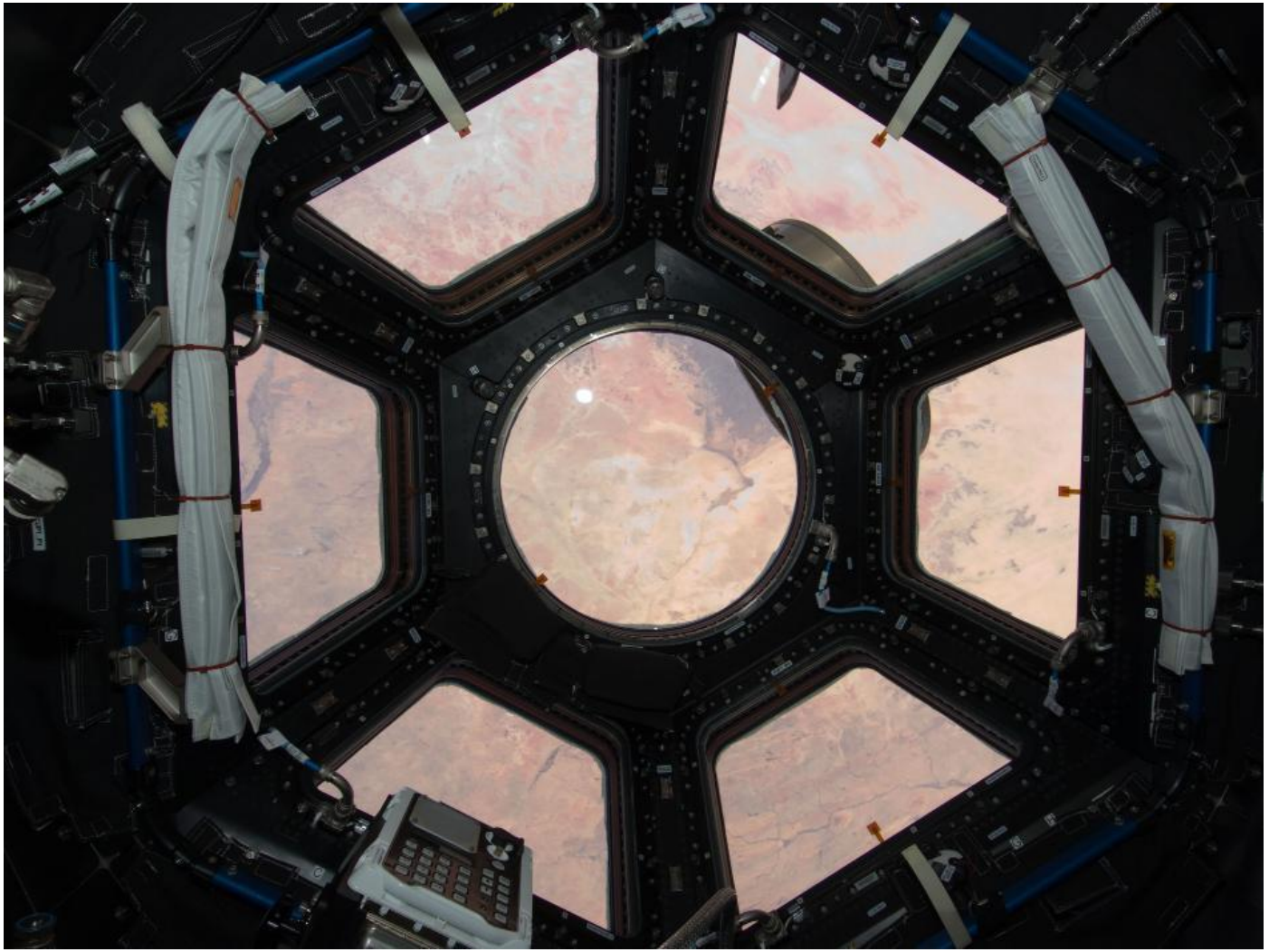
10+ yrs Assembly Timeline

ISS Assembly Complete in 2011



March 2011 STS-133 Delivers final pressurized module (**MPLM – *Leonardo***)

ISS Cupola



Crew of 6

Current crew – Expedition 32

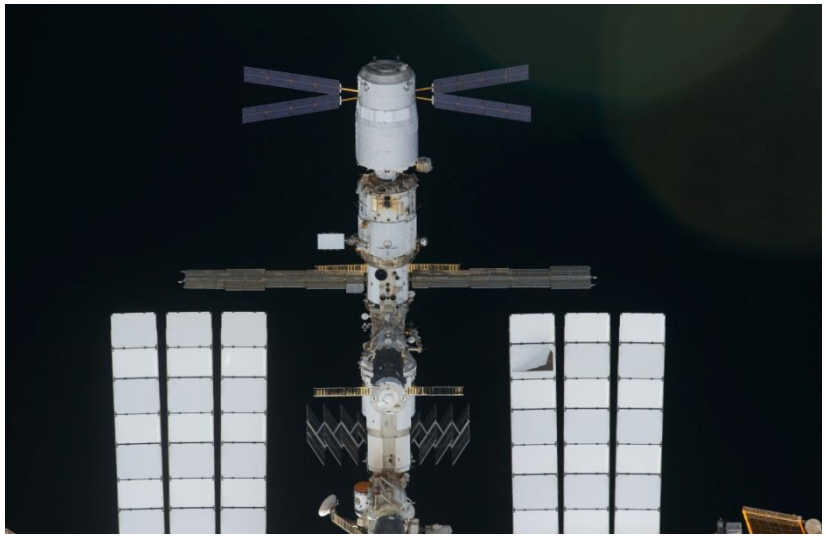
Visiting Vehicles

Soyuz – crew
Progress - cargo

Baikonur
Cosmodrome

Visiting Vehicles

Automated Transfer Vehicle
(ATV)



ATV-2 *Johannes Kepler* (credit ESA)

- Aianne-5 launch vehicle
- French Guiana
- 6.6 tons cargo

H-II Transfer Vehicle
(HTV)

HTV-2 *KOUNOTORI-2 (credit JAXA)*

- H-IIB launch vehicle
- Tanegashima Space Center
- ~6 tons cargo
- trash removal

Communication & Tracking System

- Provides near continuous communication with the ground (MCC-H)
- Crew & vehicle safety, disseminate science data
- Flight controller commanding from the ground

TDRSS

S-Band
Ku-Band

White Sands
Ground Station

MCC-H

Mission Operations

Mission Operations

Mission Control Center (MCC-H) – NASA Johnson Space Center, Houston, TX

FCR-1
24/7

Mission Operations - Russia

MCC-Moscow

(credit *Roscosmos*)

IP Mission Operations

ESA – Columbus Control Center (Munich)

(credit *ESA*)

JAXA – Japanese Experiment Module (Tsukuba)

(credit *JAXA*)

Scientific Research Onboard ISS

ISS USOS National Laboratory

2005 NASA Authorization Act designated the U.S segment of the ISS as a national laboratory and directed NASA to develop a plan to "increase the utilization of the ISS by other Federal entities and the private sector…"

- Technology Development
- Physical Sciences
- Materials Sciences
- Biological Sciences
- Human Sciences
- Earth Observation
- Space Science

Scientific Research Onboard ISS

(courtesy *NASA*)

Scientific Research Onboard ISS

Publication statistics

- 28 published *review papers* on ISS results
- 20 publications on ISS and future exploration technologies
- 216 *results publications (e.g. scientific journals)* from specific payloads or projects

First Decade: more than 400 research experiments & 70 educational projects

(source: www.nasa.gov)

Payloads

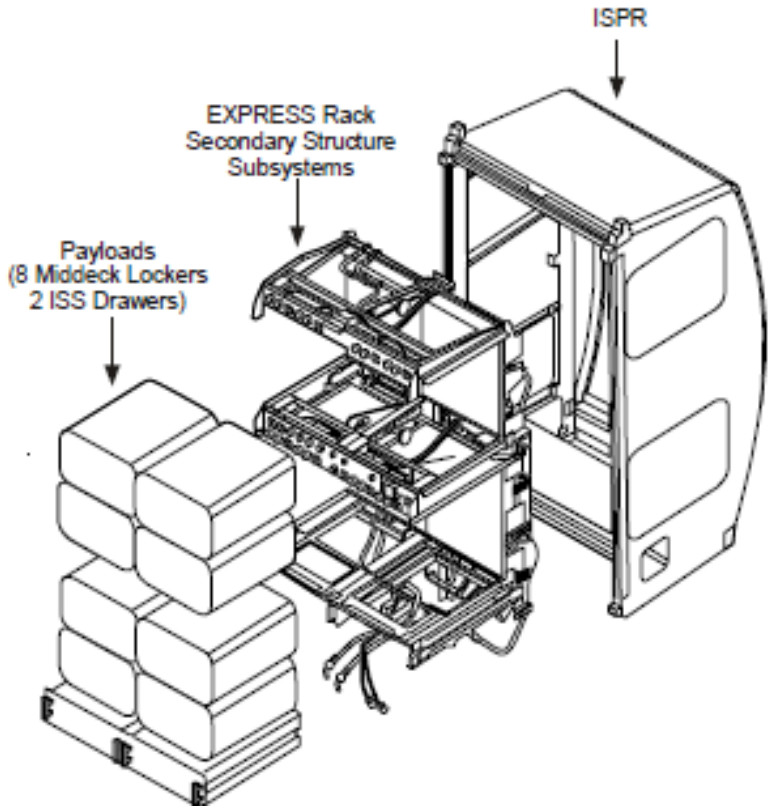
Payload operations: Marshall Space Flight Center, Huntsville, AL

Payload components onboard ISS:

- U. S. Laboratory (“Destiny” Lab) – 24 rack locations
- Facility Class payloads – long-term or permanent payloads

- EXPRESS RACK System
- Advanced Human Support Technology (AHST)
- Human Research Facility (HRF)
- Minus Eighty Degree Laboratory Freezer ISS (MELFI)
- Materials Science Research Facility
- Microgravity Science Glove box
- Fluids and Combustion Facility
- X-Ray Crystallography Facility
- Biotechnology Facility

Payloads

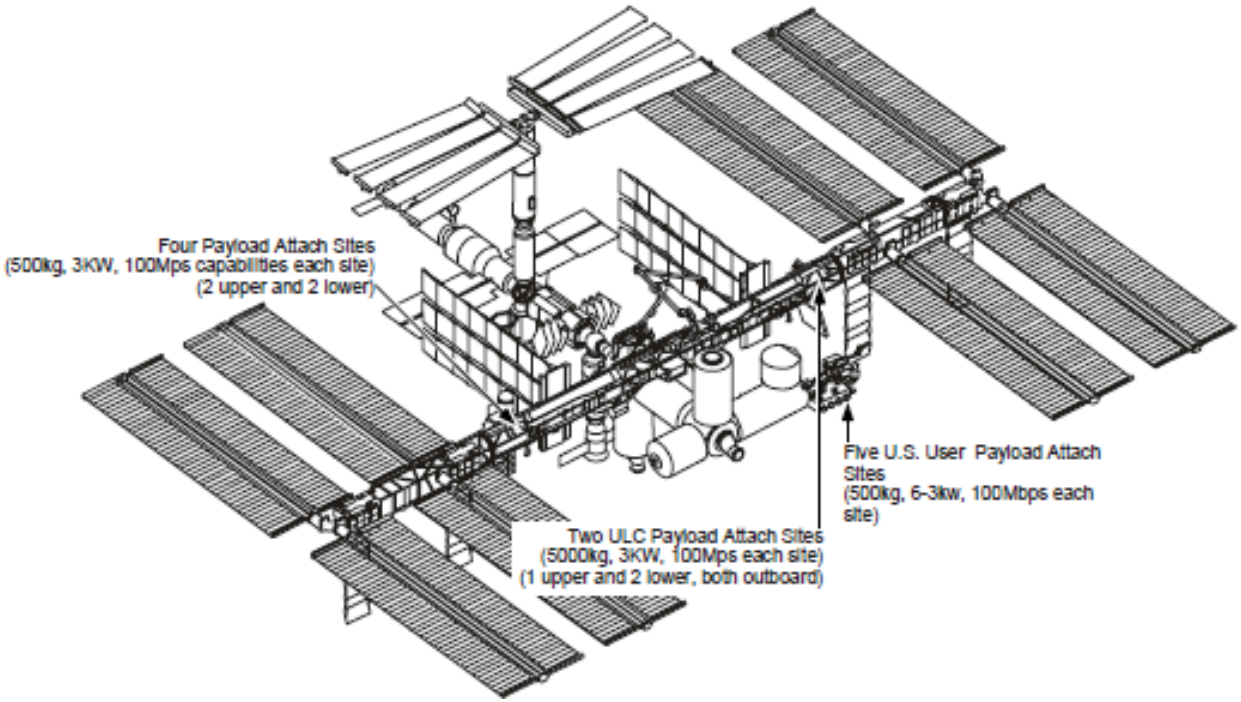


Express Rack

Payloads

- Attached payloads – located externally on the truss or the JEM Exposed Facility

4 locations on S3 truss segment
2 locations on P3 truss segment
10 locations on the JEM EF



Human Research

Integrated Physiology

- bone density loss
- muscle tissue deterioration
- cardiovascular performance
- immune system & neurological changes
- psychological changes

National Aeronautics and Space Administration Biological Specimen Repository (Repository) - MELFI

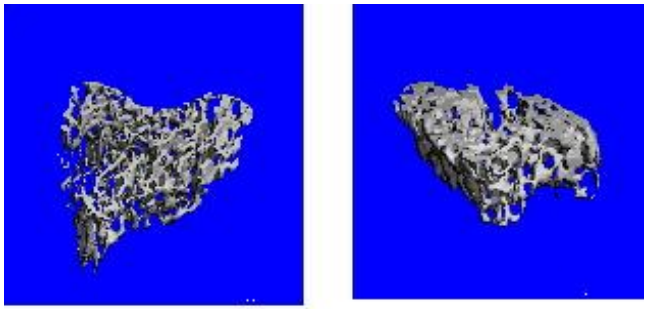
Advanced Diagnostic Ultrasound in Microgravity (ADUM)

Human Research

Commercial Biomedical Testing Module (CBTM) :
Effects of Osteoprotegerin (OPG) on Bone Maintenance in Microgravity

- determine effectiveness of OPG in treating bone loss
- space mouse vs. ground mouse bone tissue

(Clemson Univ.)



(*courtesy NASA/MSFC*)

Dietary Intake Can Predict and Protect Against Changes in Bone Metabolism during Spaceflight and Recovery (**Pro K**)

(Johnson Space Center)

Hypothesis: a diet with a decreased ratio of animal protein to potassium will lead to decreased loss of bone mineral during flight

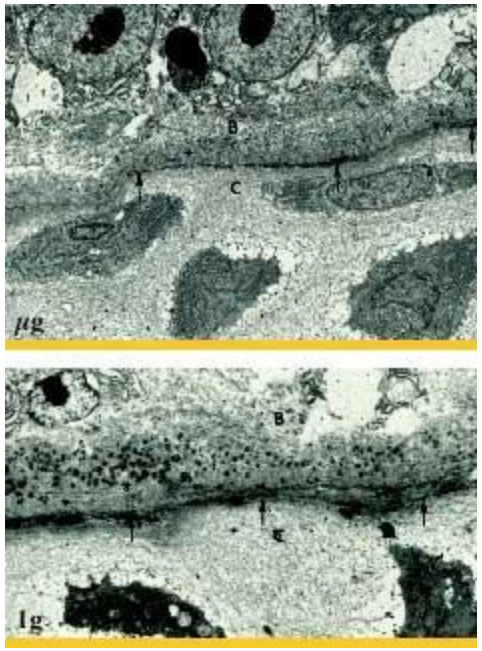
A growing body of data suggests a direct relationship between nutrition and the effects of space.

Biology & Biological Sciences

Cellular Biology

Avian Development Facility - Skeletal Development in Embryonic Quail (**ADF-Skeletal**)

(Doty, Hospital for Special Surgery, NY)



Mechanism of bone formation during development of the limbs in quail embryos could provide basic information to help prevent bone loss in astronauts during long duration missions.

Biology & Biological Sciences

Cellular Biotechnology Operations Support Systems: Human Renal Cortical Cell Differentiation and Hormone Production
(**CBOSS-01-02-Renal**) (NASA)

- one of 7 CBOSS experiments
- stable cell growth environment

Cell Growth in microgravity:

Microgravity allows the cells to grow in three-dimensional structures which are similar to how they grow in the human body. The cells were returned to Earth and were used in studies of several kidney disorders.

Space Tissue Loss - Microbial Immunity
(**STL-Microbial_Immunity**)

(Arizona State University/NASA)

- How human cell culture responds to infection by bacteria in the microgravity environment in comparison to Earth normal gravity
- Vaccine development and other therapeutics for treatment, prevention and control of infectious diseases on Earth.

Biology & Biological Sciences

Macromolecular Biology – Protein Crystal Growth

- ISS is relatively free from the effects of sedimentation and convection
- provides an exceptional environment for crystal growth

Crystals grown in microgravity could help scientists gain detailed knowledge of the atomic, three-dimensional structure of many important protein molecules used in pharmaceutical research for cancer treatments, stroke prevention and other diseases.

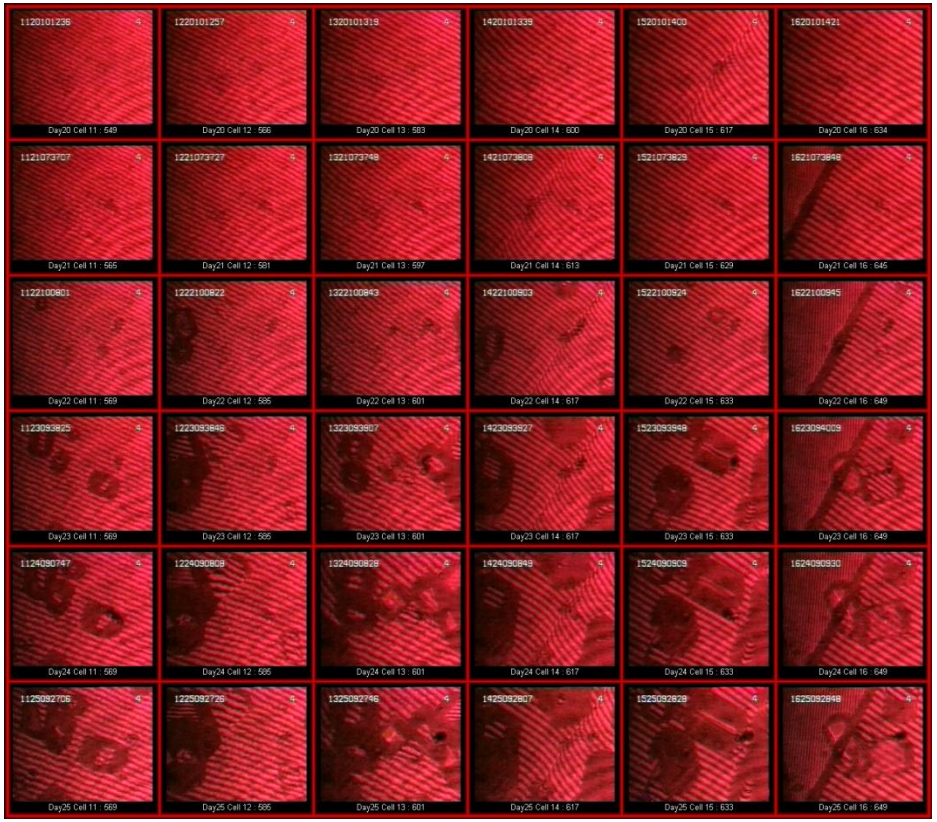
The knowledge gained could be instrumental in the design and testing of new drugs.

Biology & Biological Sciences

Protein Crystal Growth Monitoring by Digital Holographic Microscope for the International Space Station
(**PromISS**)

(ESA)

- microscope that will allow for the visualization of the protein crystal growth process
- produces protein crystals for ground-based X-ray diffraction studies
- role of the proteins in diseases?



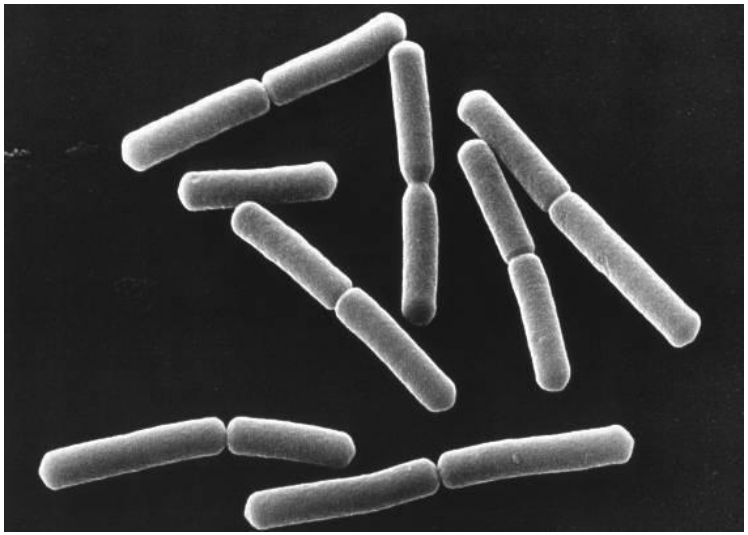
Biology & Biological Sciences (con't)

Microbiology

Passive Observatories for Experimental Microbial Systems (**POEMS**)

(NASA)

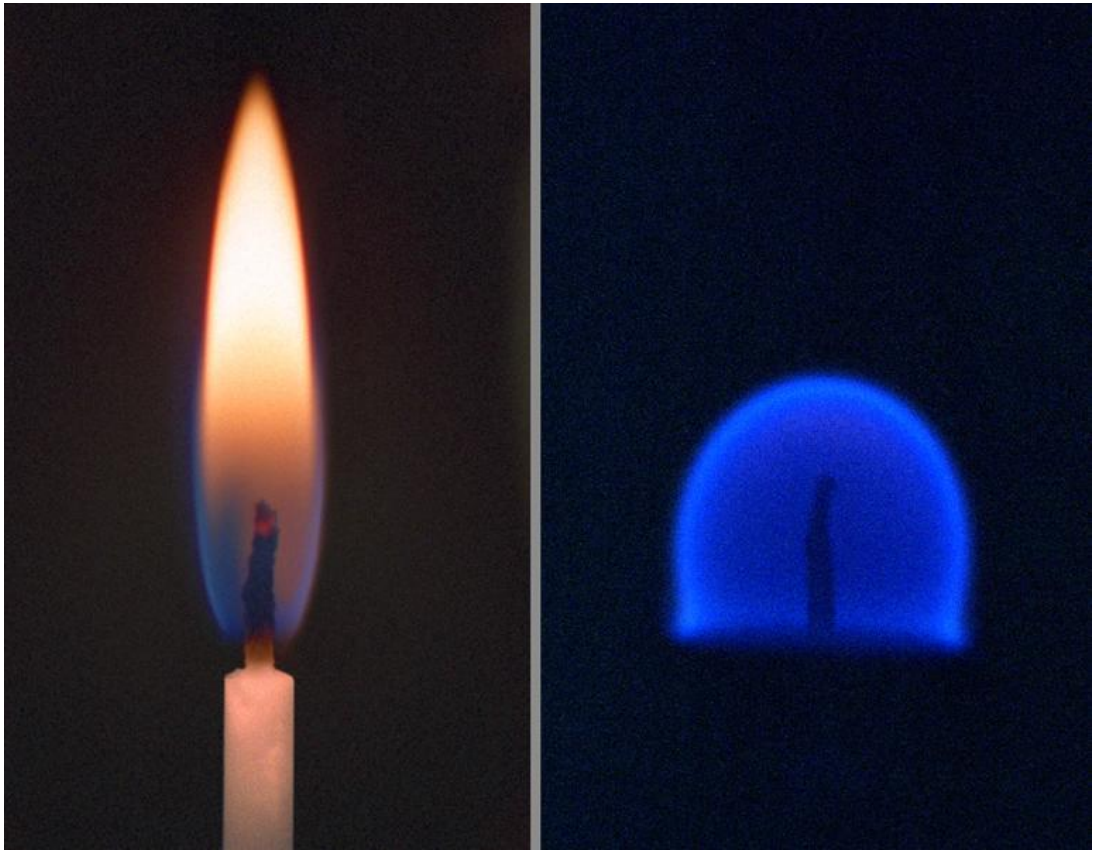
Demonstration of a passive system for growing microbial cultures in space and to observe genetic changes that occur in them as a result of living and growing in the space environment



Physical & Materials Science

Combustion Science

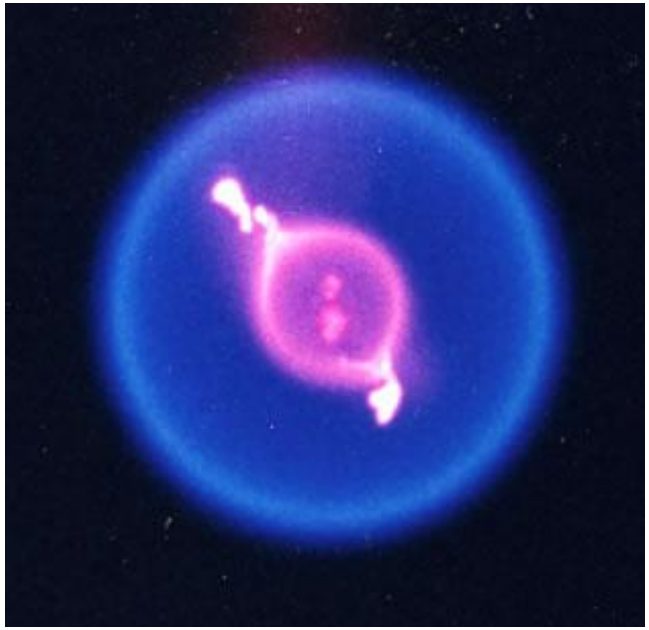
- Burning and Suppression of Solids (BASS)
- Combustion Synthesis Under Microgravity Conditions (COSMIC)



Physical & Materials Science

Multi-User Droplet Combustion Apparatus - Flame Extinguishment Experiment (**MDCA-FLEX**)

(UCSD, Princeton, Drexel, Glenn Research Center)



Quantitative measure of the effectiveness of various suppression agents and more importantly a set of predictive tools that will allow the effective, efficient design of future spacecraft fire suppression systems.

Physical & Materials Science

Chaos, Turbulence and its Transition Process in Marangoni Convection (**Marangoni**)

(JAXA)

Experiment to fully understand a surface-tension-driven flow in microgravity

Marangoni convection is the tendency for heat and mass to travel to areas of higher surface tension within a liquid.

Physical & Materials Science

Materials on the ISS Experiment
(MISSE) (NRL, NL DoD)

http://issresearchproject.grc.nasa.gov/MISSE/

Technology

Robonaut
(**Robonaut**)

(NASA/JSC & GM)

Demonstrate that a dexterous robot can:

- launch and operate in a space vehicle
- manipulate mechanisms in a microgravity environment
- operate for an extended duration within the space environment
- assist with tasks
- interact with the crewmembers.

Earth & Space Science

Crew Earth Observations
(**CEO**)

(NASA/JSC)

Photograph natural and human-made changes on Earth

Window Observational Research Facility (WORF)
US Laboratory (nadir)

Earth Viewing Camera (EVC)

Earth & Space Science

Sun Monitoring on the External Payload Facility of Columbus (**Solar**)

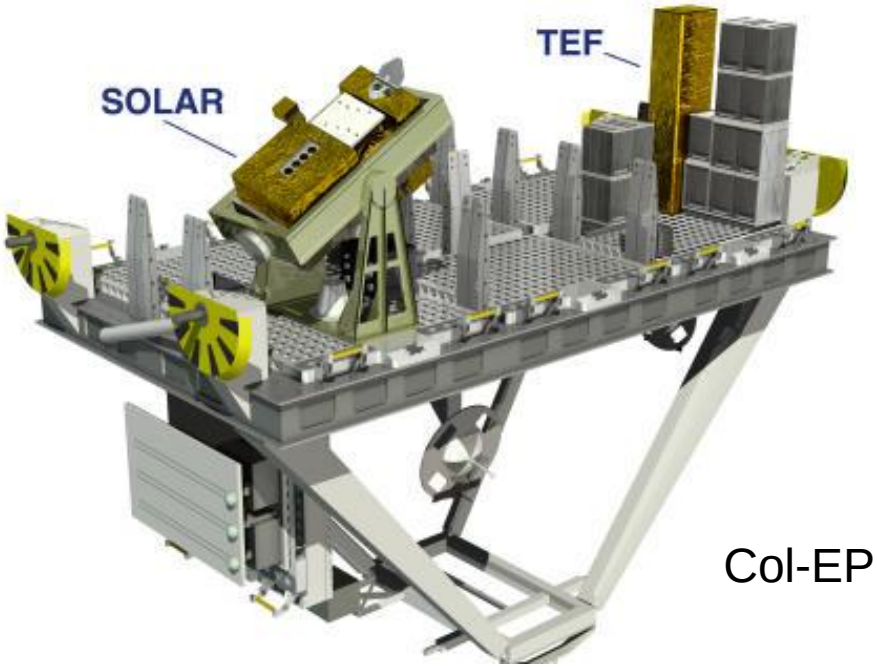
(ESA)

SOLSPEC – Solar

SOVIM – Solar Variable and Irradiance Monitor

- 180-3000 nm
- 2 % in UV
- 1 % visible/IR

Solar Cycle #23



Col-EPF

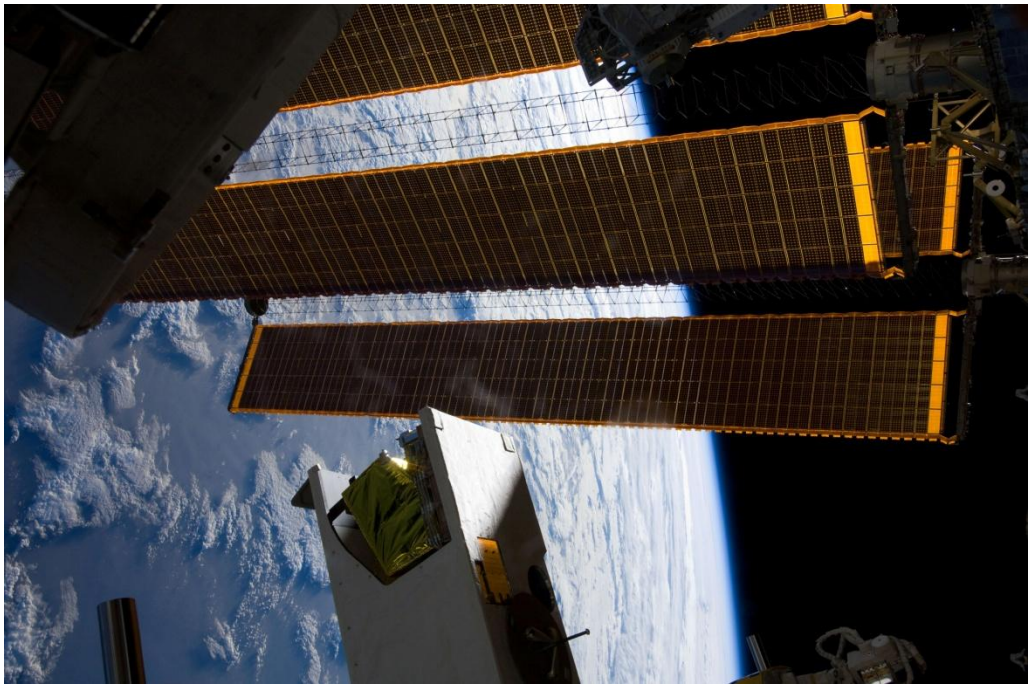
→ Earth Climatology

Earth & Space Science

HICO and RAIDS Experiment Payload - Remote Atmospheric and Ionospheric Detection System (RAIDS)
(**HREP-RAIDS**) (NRL/NASA)

UV and visible remote sensing instrument that views the limb of the Earth to measure vertical composition and temperature of the atmosphere above 95 km.

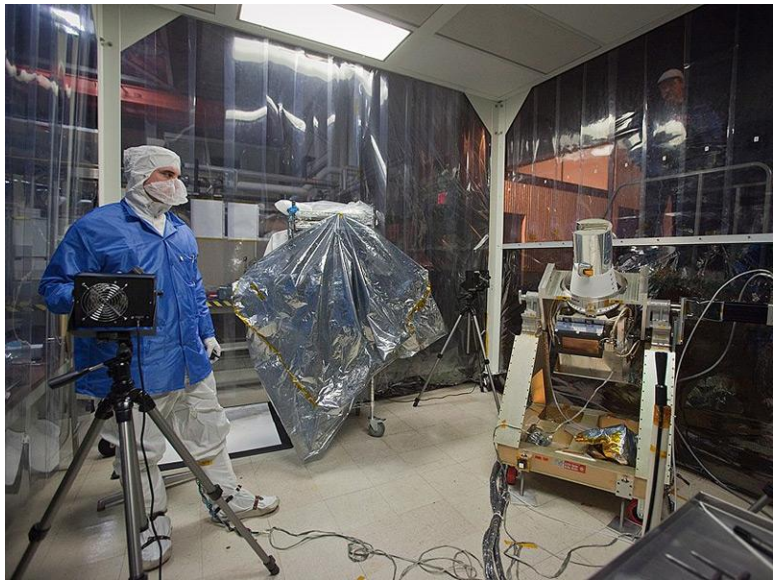
Hyperspectral Imager for the Coastal Ocean (HICO)



Earth & Space Science

SAGE III

NASA's Stratospheric Aerosol and Gas Experiment III-ISS (SAGE III-ISS) will measure ozone, water vapor and aerosols in the atmosphere.



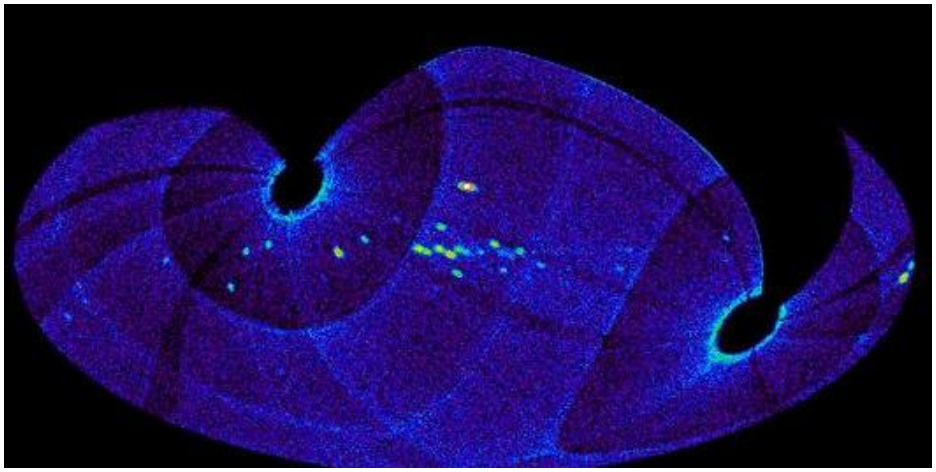
- 2014 attachment to ISS
- measure composition of middle + lower atm

1st Payload scheduled to be delivered by COTS Dragon

MAXI – Monitor All-sky X-Ray Imager

JAXA

- 2-30 keV Gas Slit X-Ray Camera for all-sky survey
- no Earth blockage
- X-ray transients, AGN, GRB afterglows
- JEM Exposed Facility



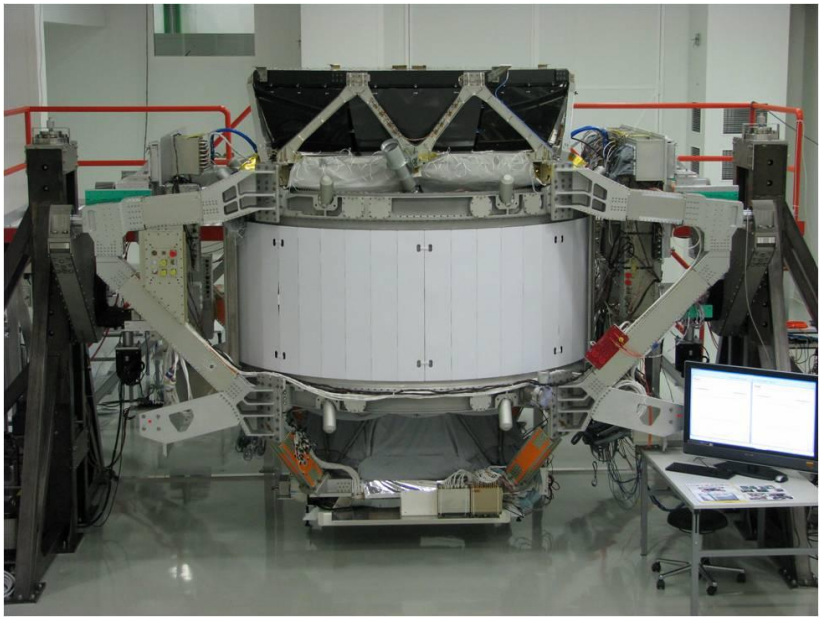
http://www.nasa.gov/mission_pages/station/science/experiments/MAXI.html#images

Alpha Magnetic Spectrometer

- High-energy particle physics detector under DOE sponsorship
- International partnerships: 16 countries & 56 institutions
- Led by Nobel Laureate Samuel Ting (MIT)

Alpha Magnetic Spectrometer

- Specifically searching for detection of Anti-Matter & Dark Matter (TeV energies)

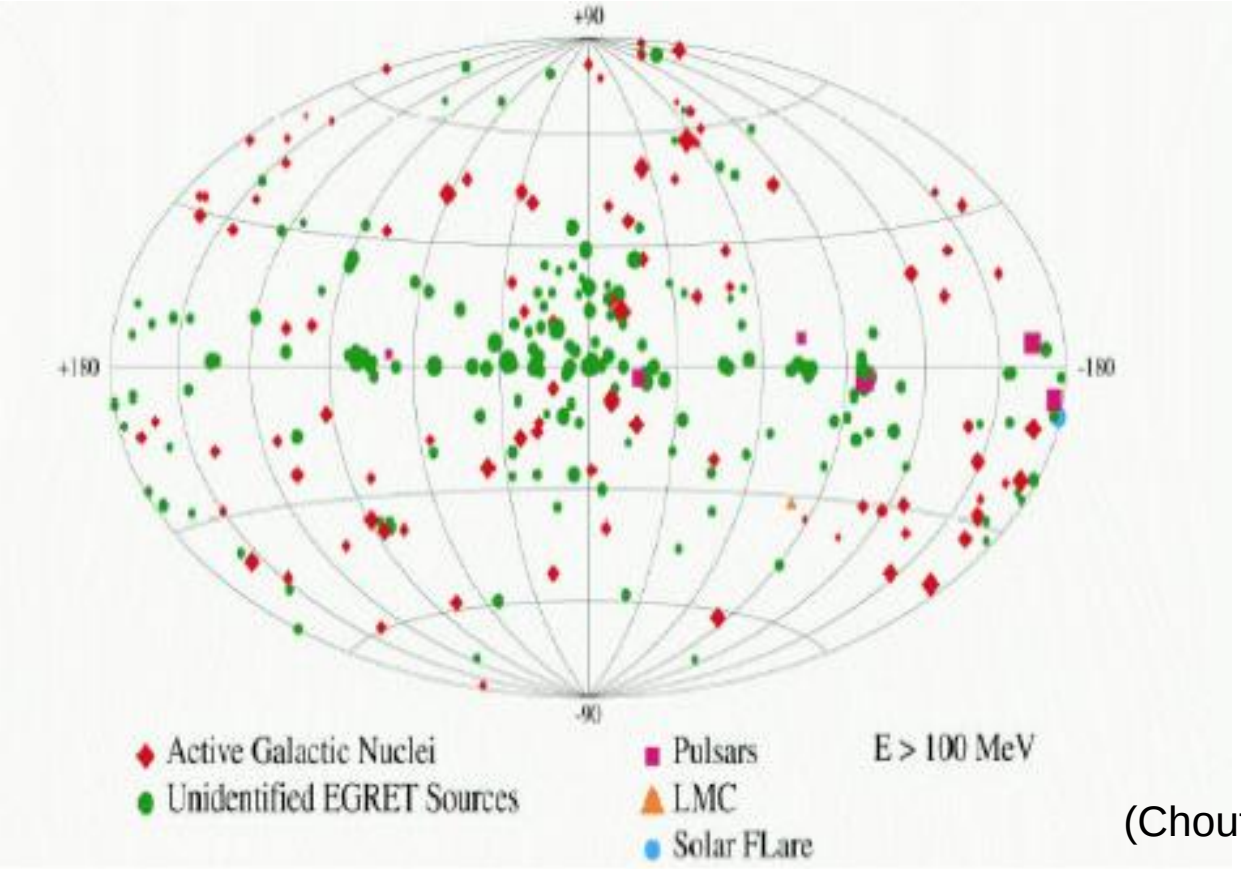


08. T superconducting magnet, 4 layers of scintillators, 8 layers of Silicon detectors

http://www.nasa.gov/mission_pages/station/science/experiments/AMS-02.html

Alpha Magnetic Spectrometer

- 2-10 GRB detections per year
- ~100 new AGN per year



(Choutko 2004)

Research Opportunities

http://www.nasa.gov/mission_pages/station/research/opportunities.html

Scientists: Become a Researcher

- Partner with academia, industry
- ISS Payloads Office (jsc-iss-payloads-helpline@mail.nasa.gov)

Students:

- Talk with astronauts from space
- EarthKAM

Educators: Teaching from Space (TFS)

Teaching From Space Office NASA Johnson Space Center, Houston, TX

E-mail: JSC-Teaching-From-Space@mail.nasa.gov

http://www.nasa.gov/audience/foreducators/teachingfromspace/home/index.html

Questions?

Thank you

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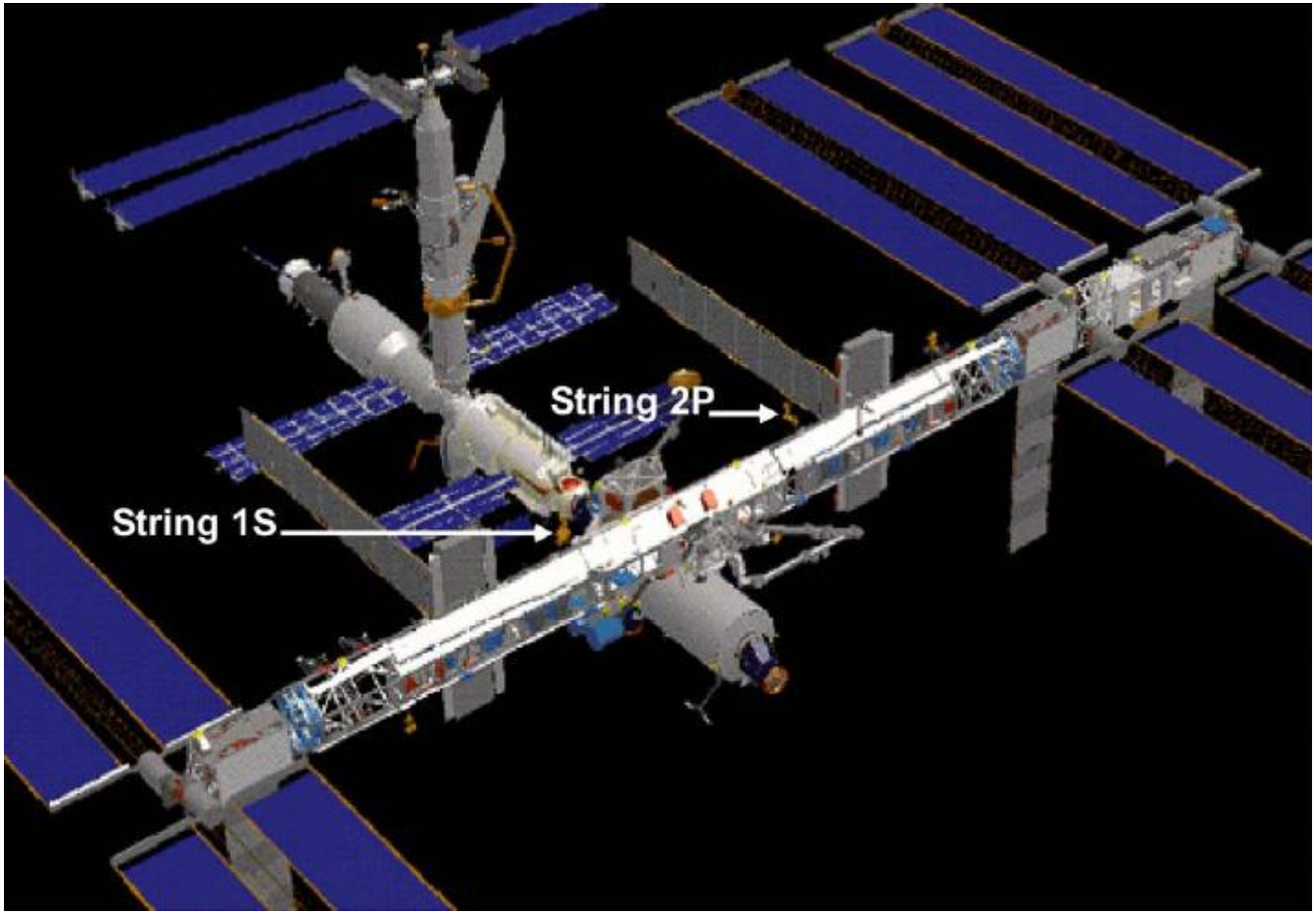
Backup Slides

ISS Core Systems

- Command & Data Handling (CDH)
- Communication & Tracking (C&T)
- Electrical Power System (EPS)
- Thermal Control System (TCS)
- Motion Control System (MCS)
- Environmental Control & Life Support System (ECLSS)
- Robotics
- Extravehicular Activity (EVA)
- Payload Systems

Communication & Tracking System (con't)

Redundant S-Band strings

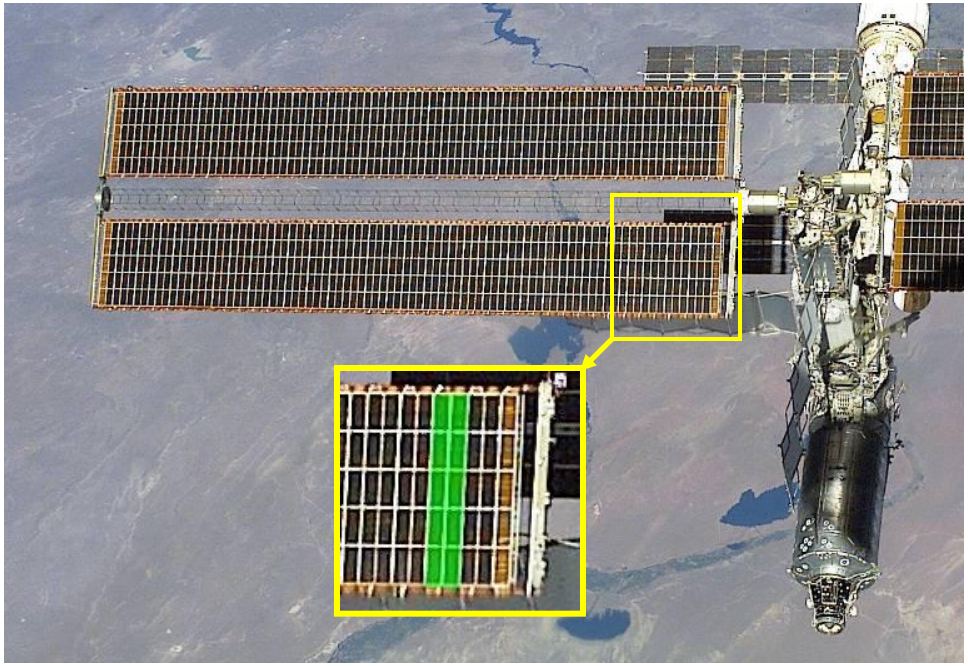


Electrical Power System

Solar Energy (photons) ⟶ Electrical Energy

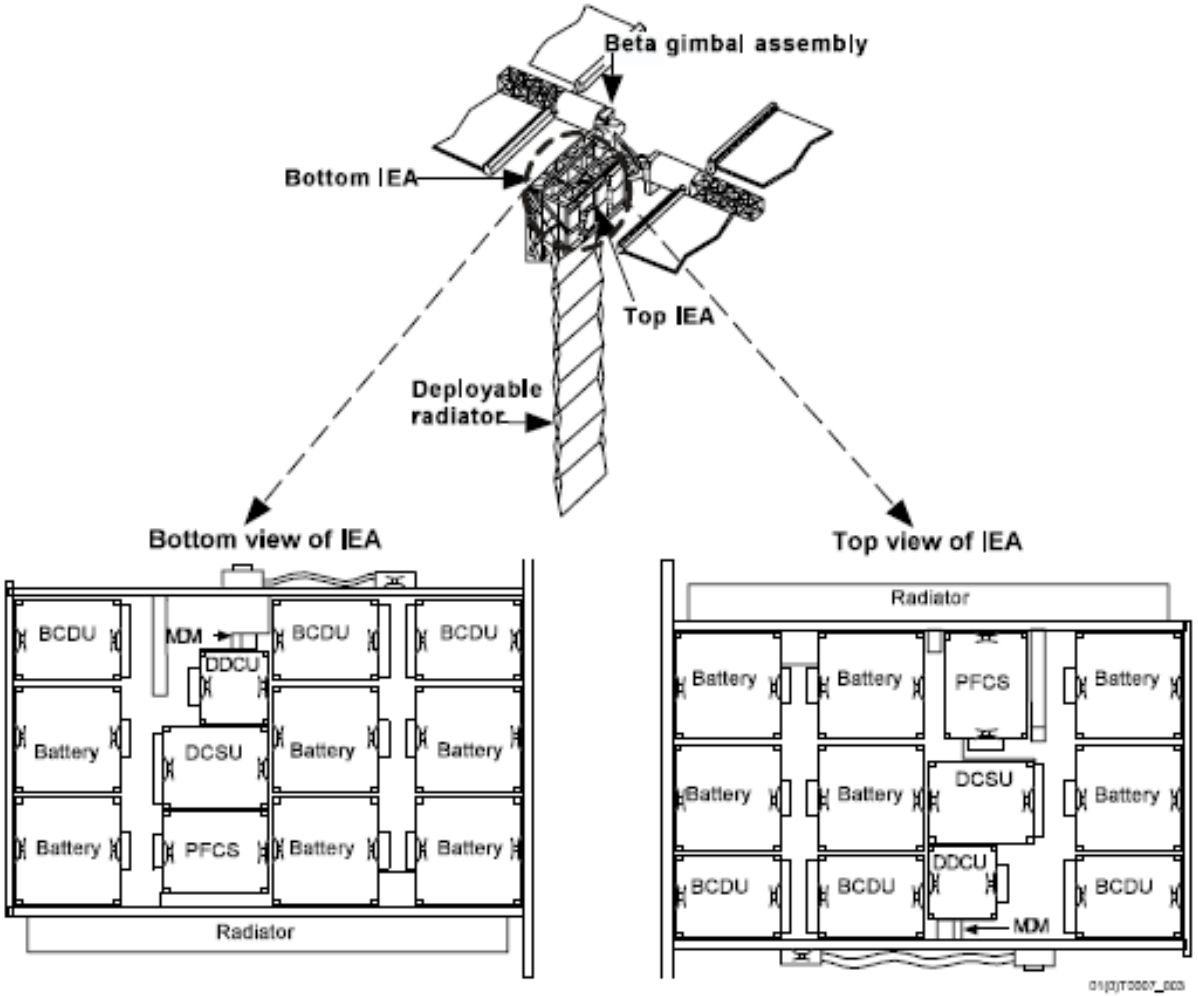
- Provide continuous power to ISS during insolation and eclipse

Photovoltaic Modules (PVM)



- 2 power channels
- generate primary power (150-160 V DC)
- Si solar cells series (81 panels/blanket)
  (~262,000 cells)
- sequential shunt unit – set pt voltage 160 V

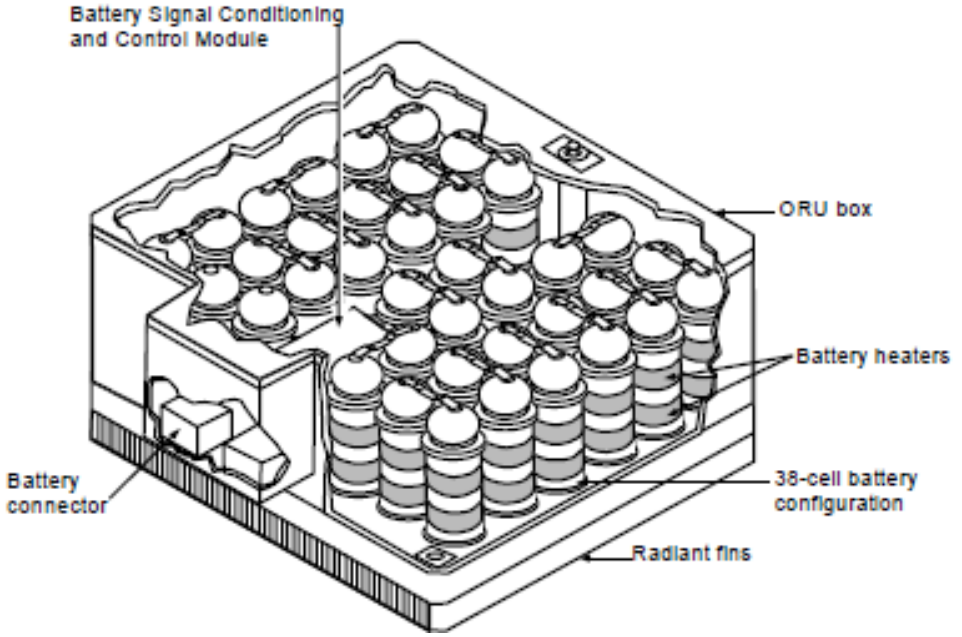
Electrical Power System (con't)



Electrical Power System (con't)

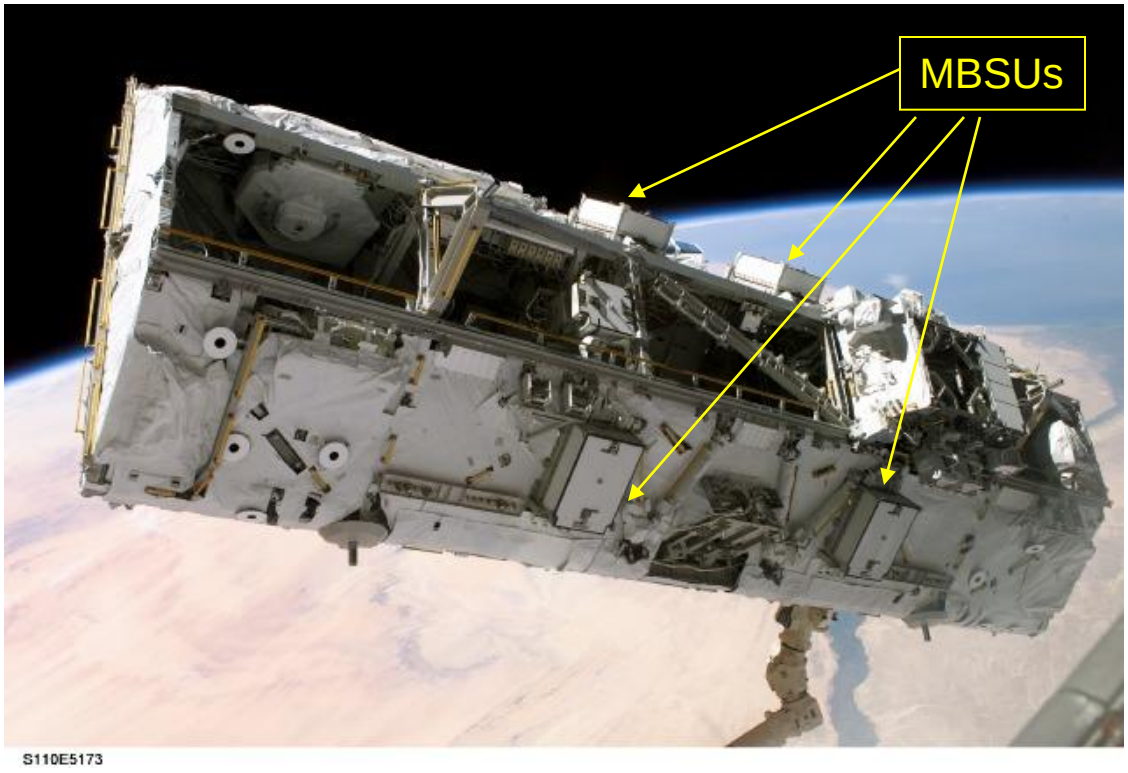
Primary power storage – NiH_2 batteries (0-10 C)

- 3 pairs per power channel
- each pair controlled by a Battery Charge-Discharge Unit (BCDU)



Electrical Power System (con't)

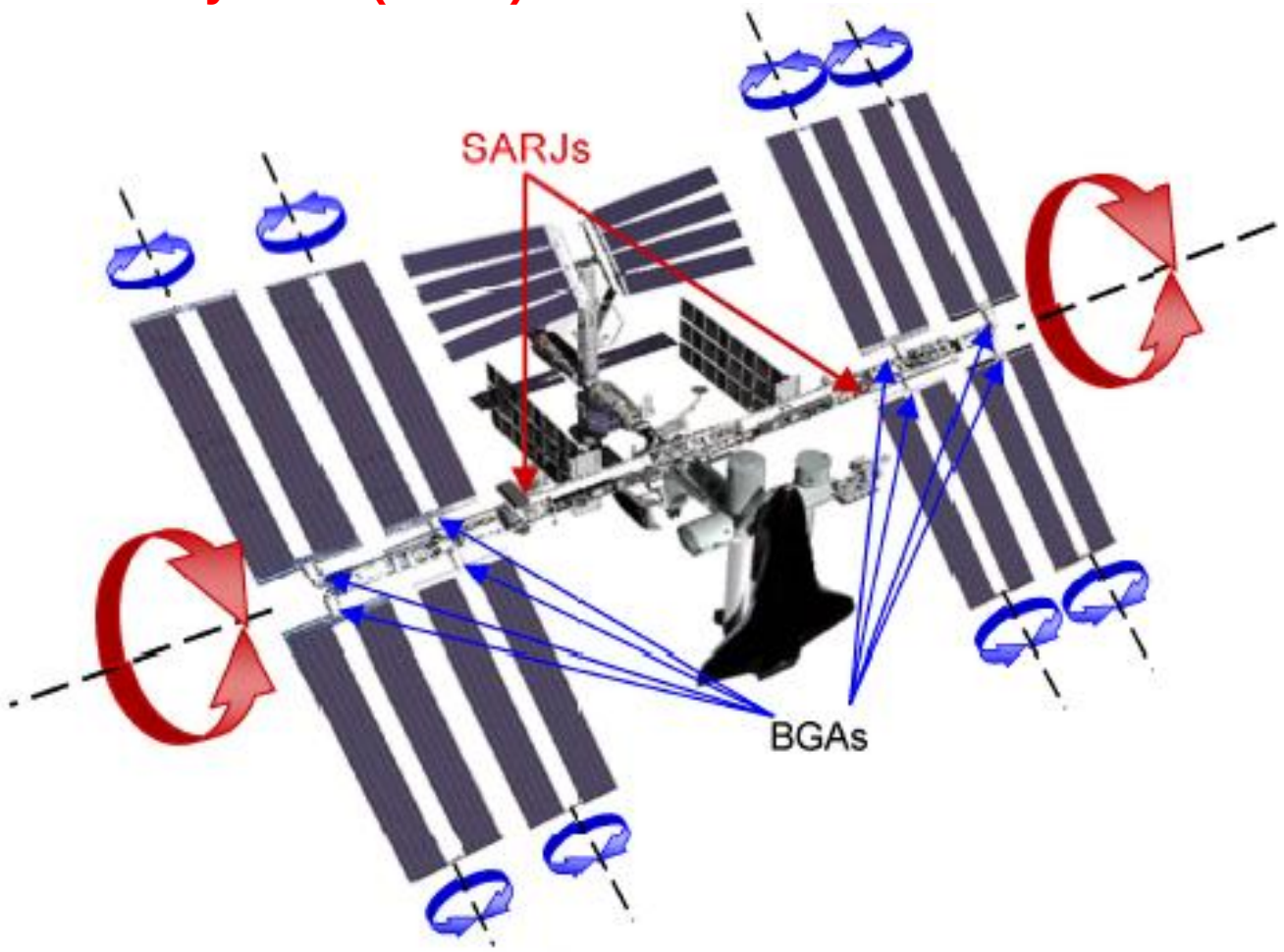
Direct Current Switching Unit – routes power to one of 4 Main Bus Switching Units (MBSUs) located on the S0 truss.



Direct Current Direct Current Control Units (DDCUs) – step down transformer (~124 V DC) routes secondary power to downstream user loads (called Remote Power Control Modules).

Electrical Power System (con't)

Solar Alpha Rotary Joint (SARJ)



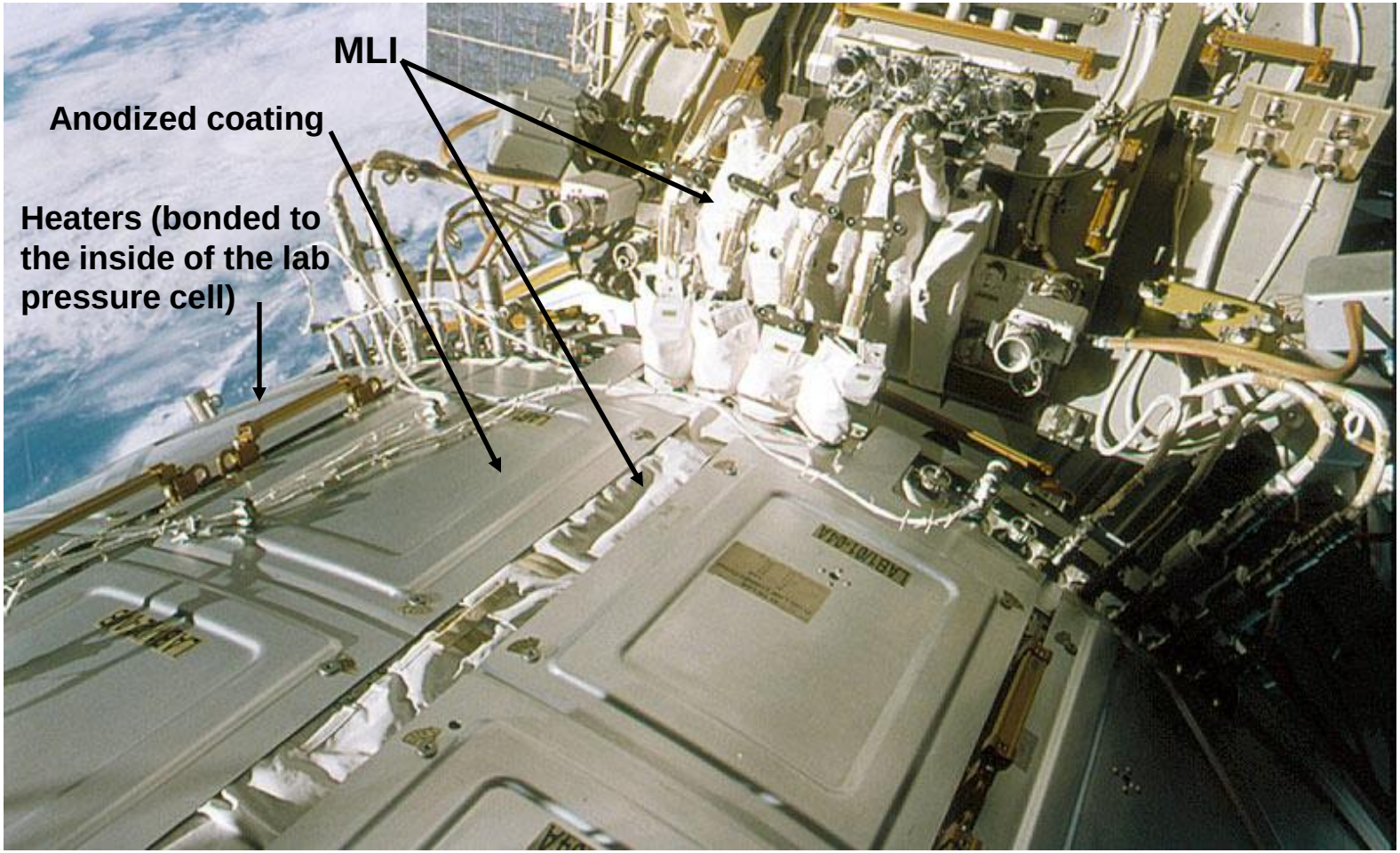
Thermal Control System

Maintain ISS equipment & payloads at optimum nominal operating temperature range

Passive thermal control

- MLI (Multi-Layer Insulation) blanket
  - 3.2-6.4 mm
  - single aluminized outer layer (O_2 & MMOD protection)
- surface coatings – anodized coatings & paint w/varying emissivity and absorbtivity
- heaters – electrically powered (>300 on ISS)
- heat pipes – latent heat of vaporization (NH_3 fluid))

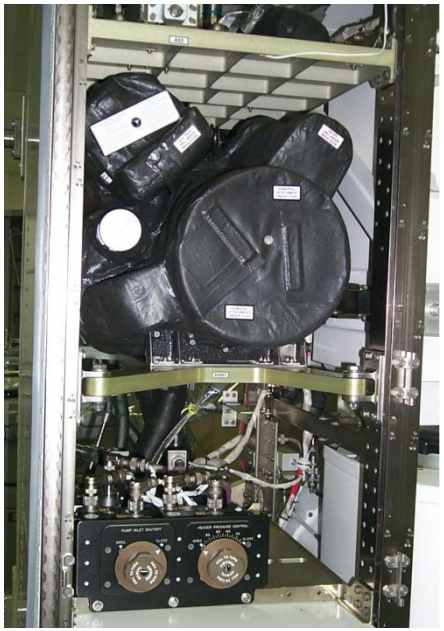
Thermal Control System (con't)



Thermal Control System (con't)

Active thermal control

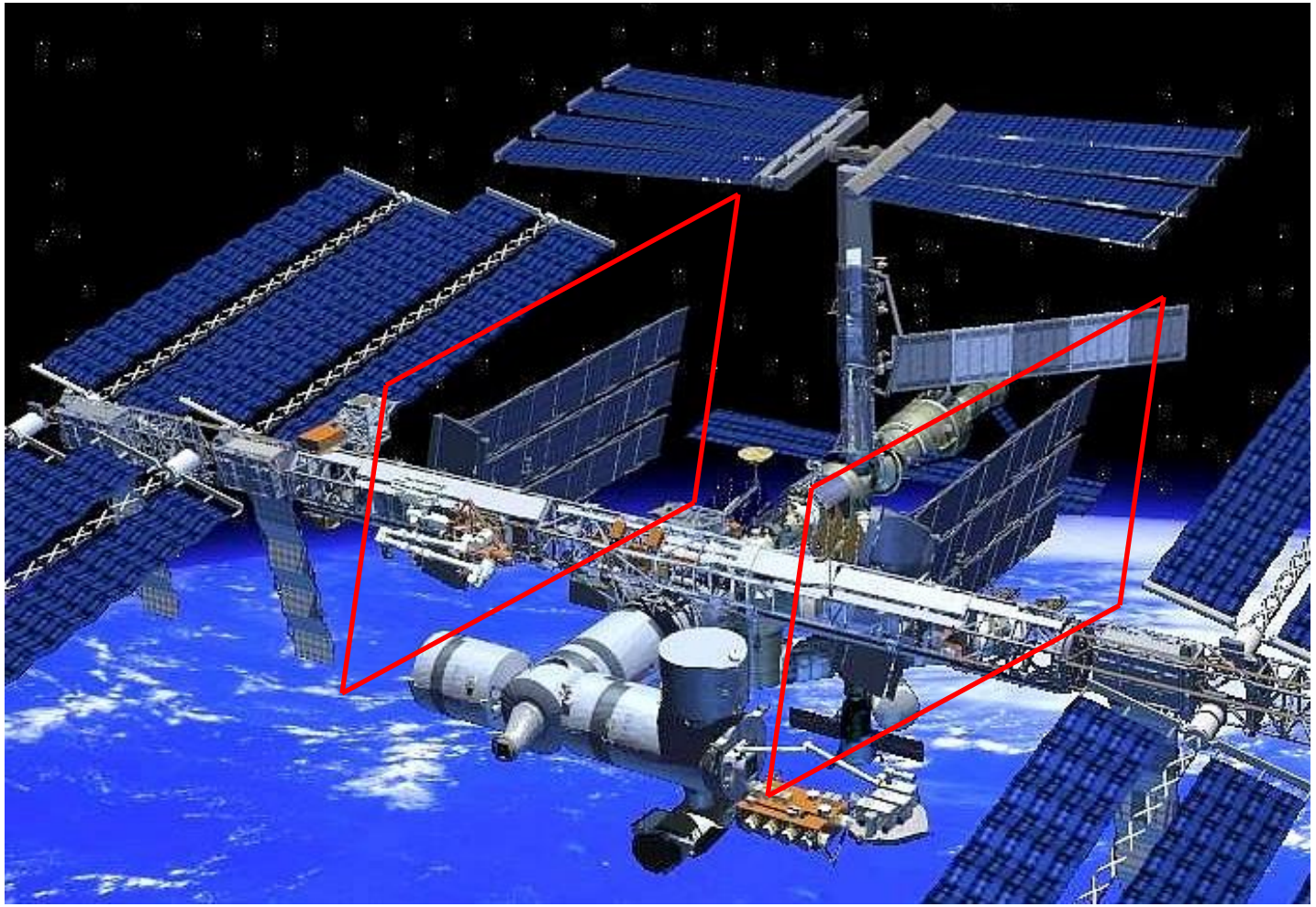
- Internal Thermal Cooling System (ITCS)
  - **Working fluid = H_2O with Teflon/Ti lines**
  - **Heat collection: cold plates & heat exchangers**
  - **Pump Package Assembly**
  - **Moderate Temperature Loop (MTL): 17 C**
  - **Low Temperature Loop (LTL): 4 C**



- External Thermal Cooling System (ETCS)
  - **Working fluid – NH_3**
  - **Heat collection: interface heat exchangers**
  - **Two loops: Loop A (S1 truss) & Loop B (P1 truss**
  - **Heat rejection: Thermal Radiators**

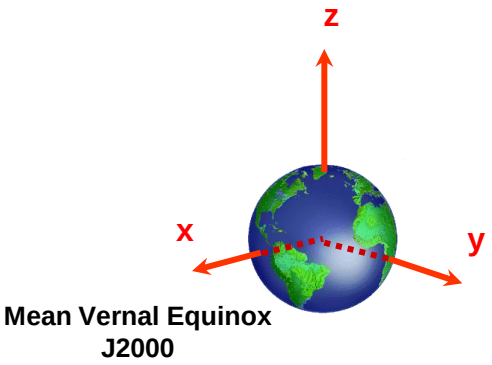
Thermal Control System (con't)

TRRJ



Motion Control System

- Determines ISS state vector
  - Position (x, y, z) and velocity (v_x, v_y, v_z) at a given time
- Determines ISS attitude
  - Rotational angles (yaw, pitch, roll) and the rate at which these angles are changing
- Provides attitude and translation control
  - Provides attitude hold
  - Maintains a microgravity environment
  - Performs reboot via SM or Progress
- Provides state vector and attitude information to other ISS core systems

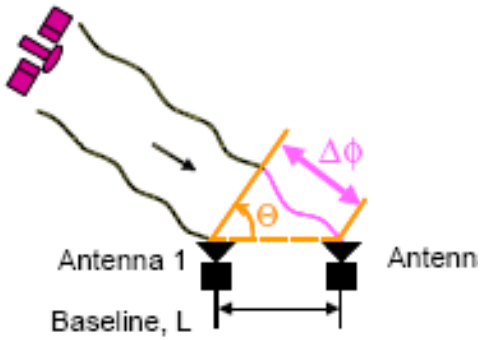


Motion Control System (con't)

USOS Attitude Control

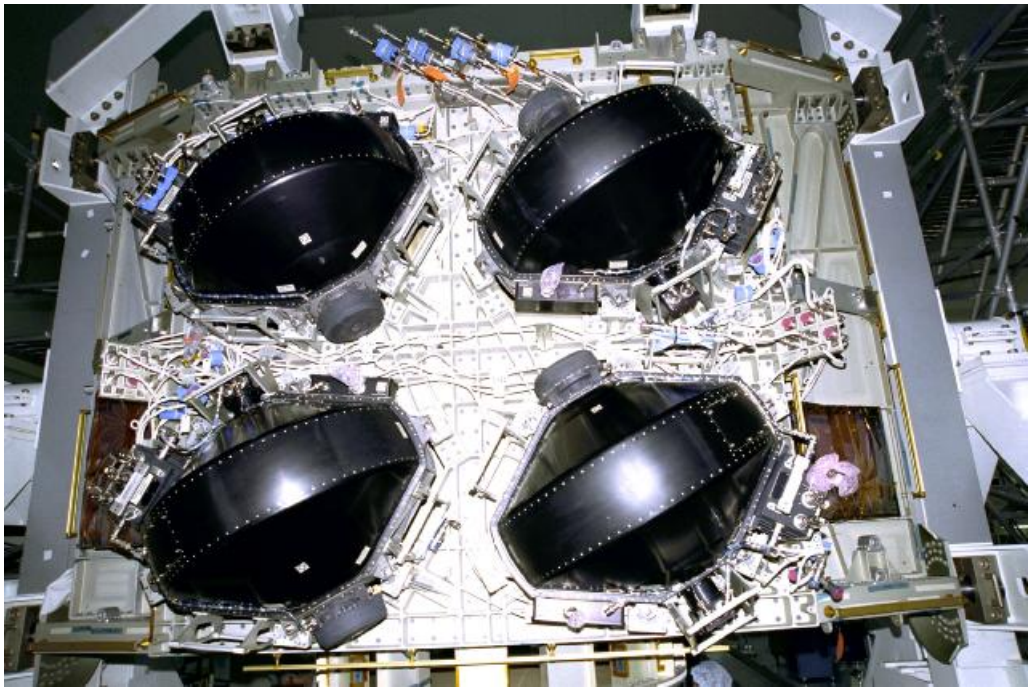
Control Moment Gyros

- **600 lbs each**
- **6600 rpm**
- **4880 N-m-s**



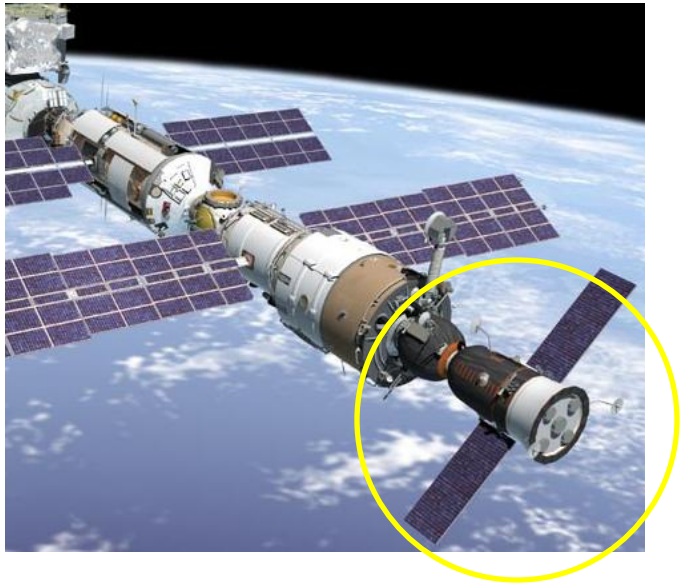
GPS

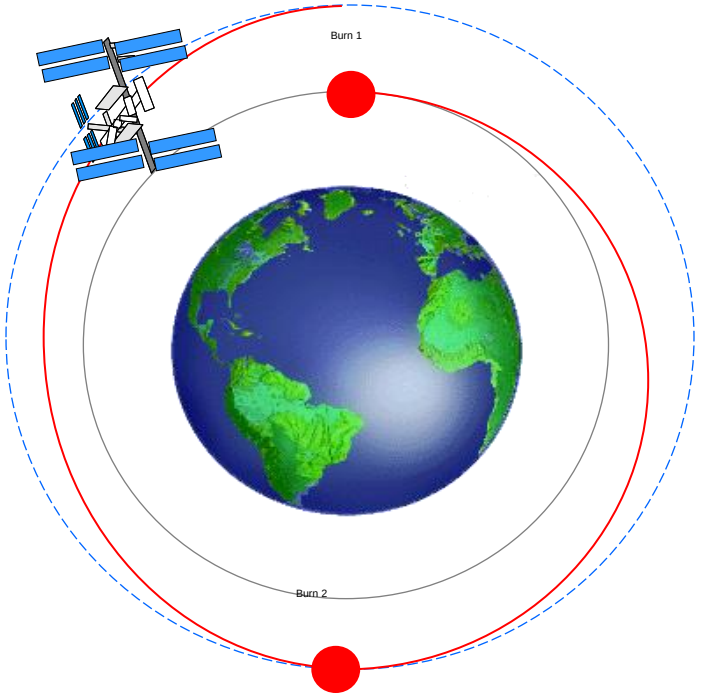
CMGs (Z1 truss)



Motion Control System (con't)

Translational Control (Reboost)

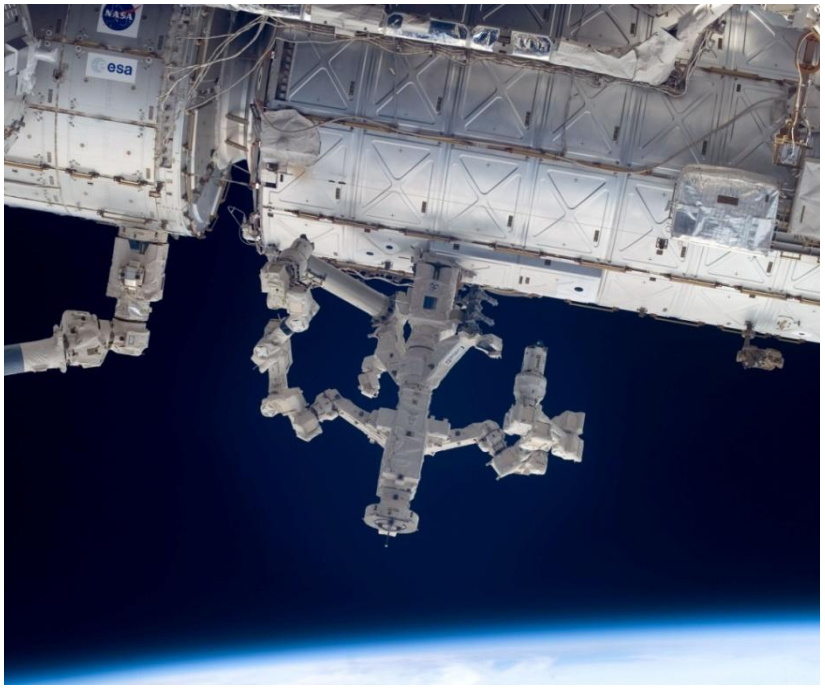




Robotics System

International collaboration:

NASA, CSA, & JAXA



Functions:

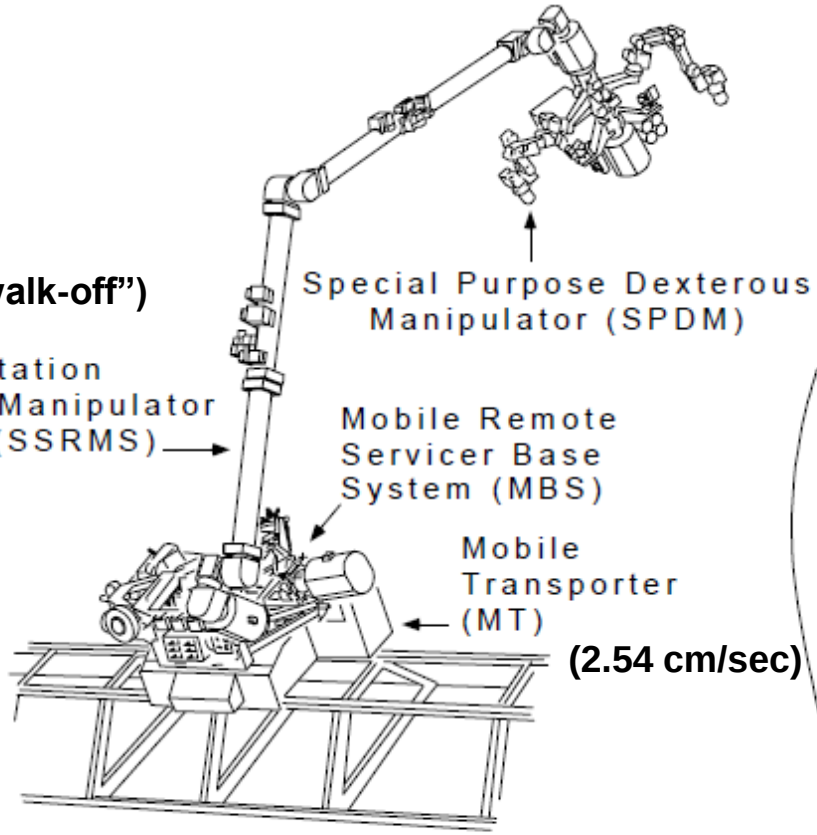
- ISS assembly and maintenance
- EVA support and payload handling

Systems:

- Mobile Servicing System (MSS)
- Japanese Experiment Module Remote Manipulator System (JEM-RMS)

Robotics System (con't)

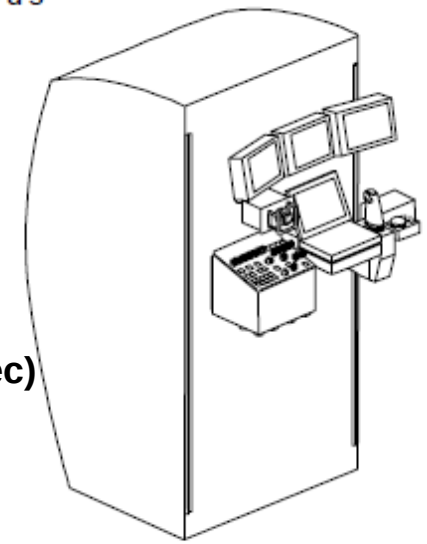
Mobile Servicing System (MSS)



(17 m, 7 joints, "walk-off")

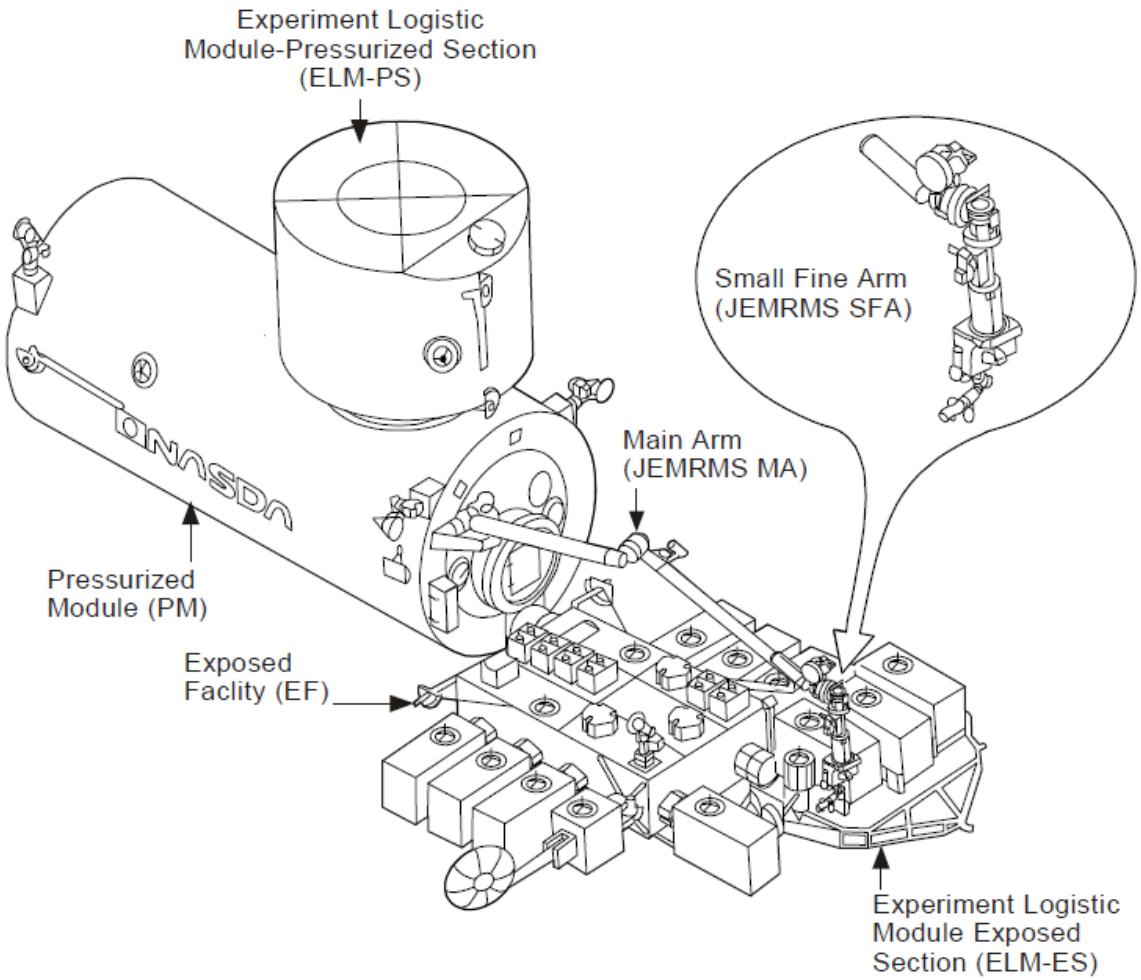
(2.54 cm/sec)

MSS External Components



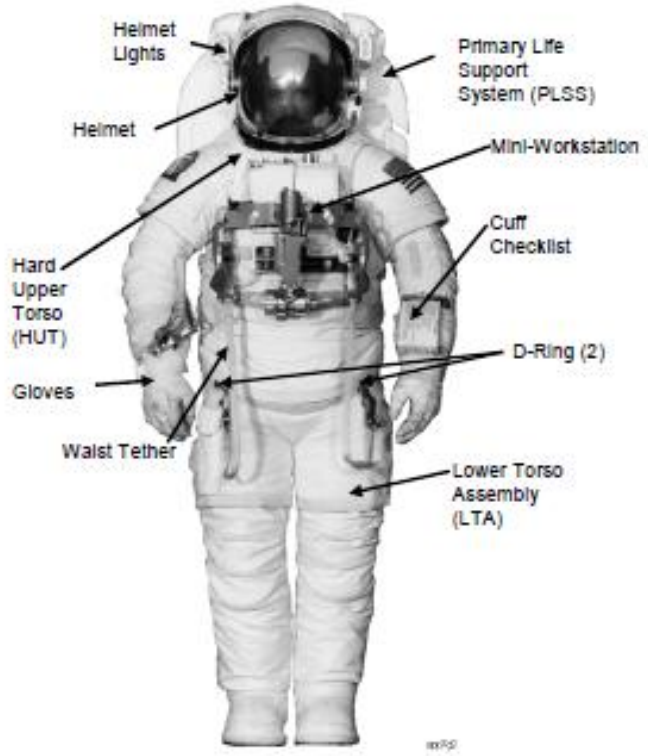
Robotic Workstation (RWS)

Robotics System (con't)



Extravehicular Activity

Over 600 tasks must be successfully completed for ISS assembly, requiring more than **540** hours of EVA.

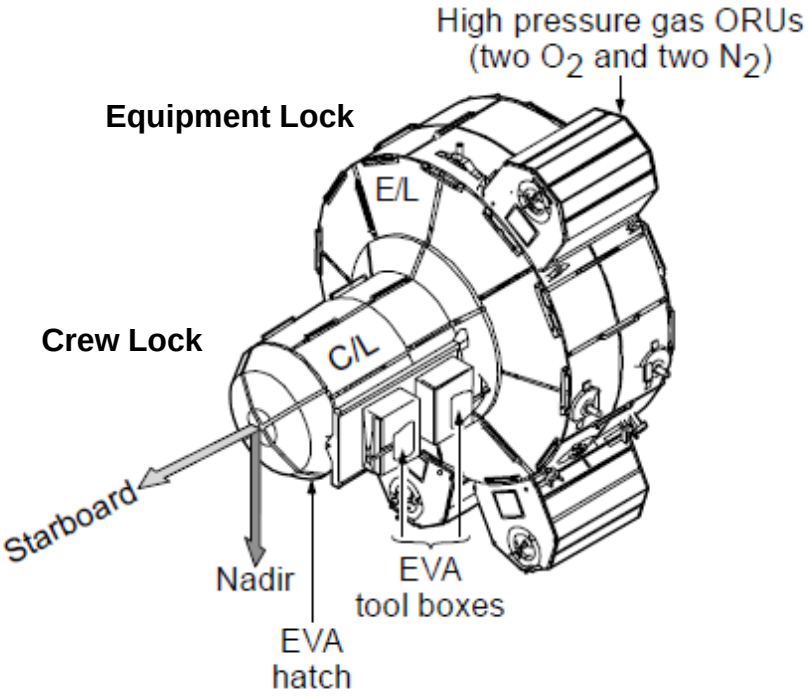


Extravehicular Mobility Unit (EMU)

- pressurized to 4.3 psid
- 7 hrs (15 min to egress A/L, 30 min to ingress A/L, 30 min reserve)
- secondary oxygen pack (30 min)
- UHF comm

Extravehicular Activity (con't)

"Quest" Joint Airlock



Extravehicular Activity (con't)