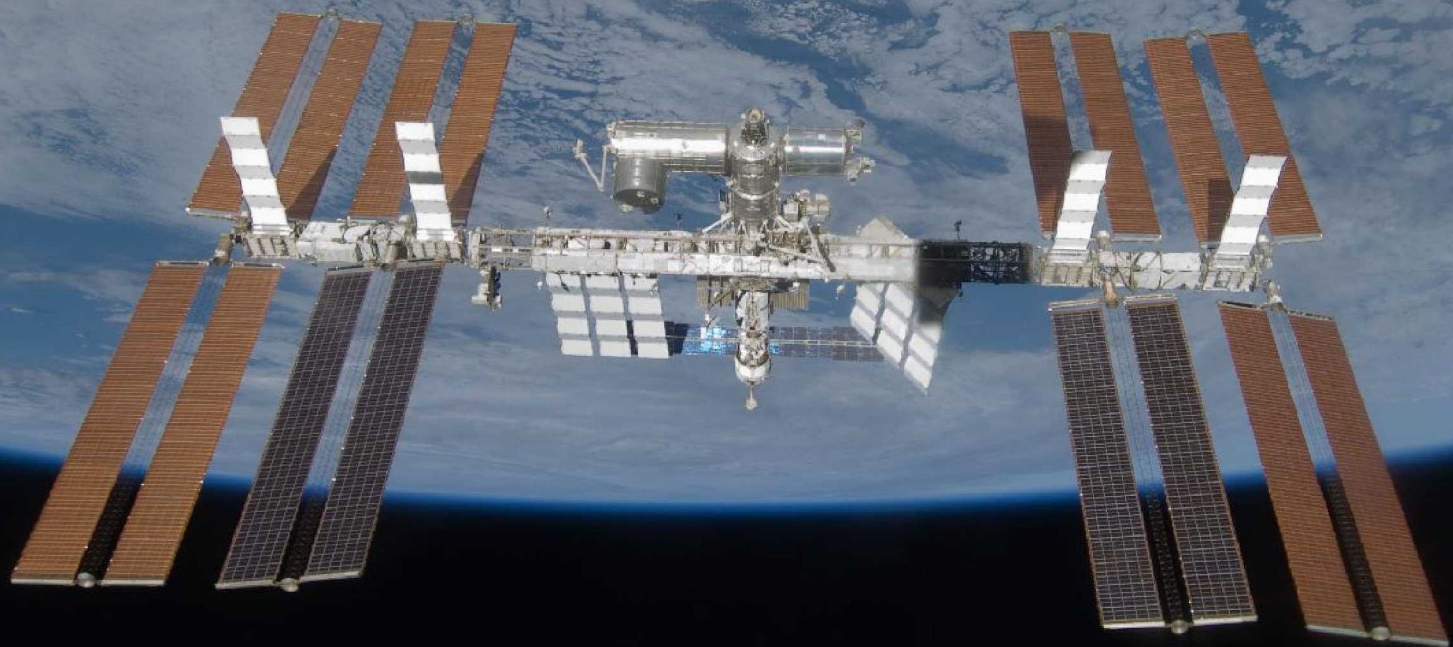
The International Space Station: Systems & Science



Timothy W. Giblin
United Space Alliance
NASA Johnson Space Center

Outline

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

ISS Program Mission

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

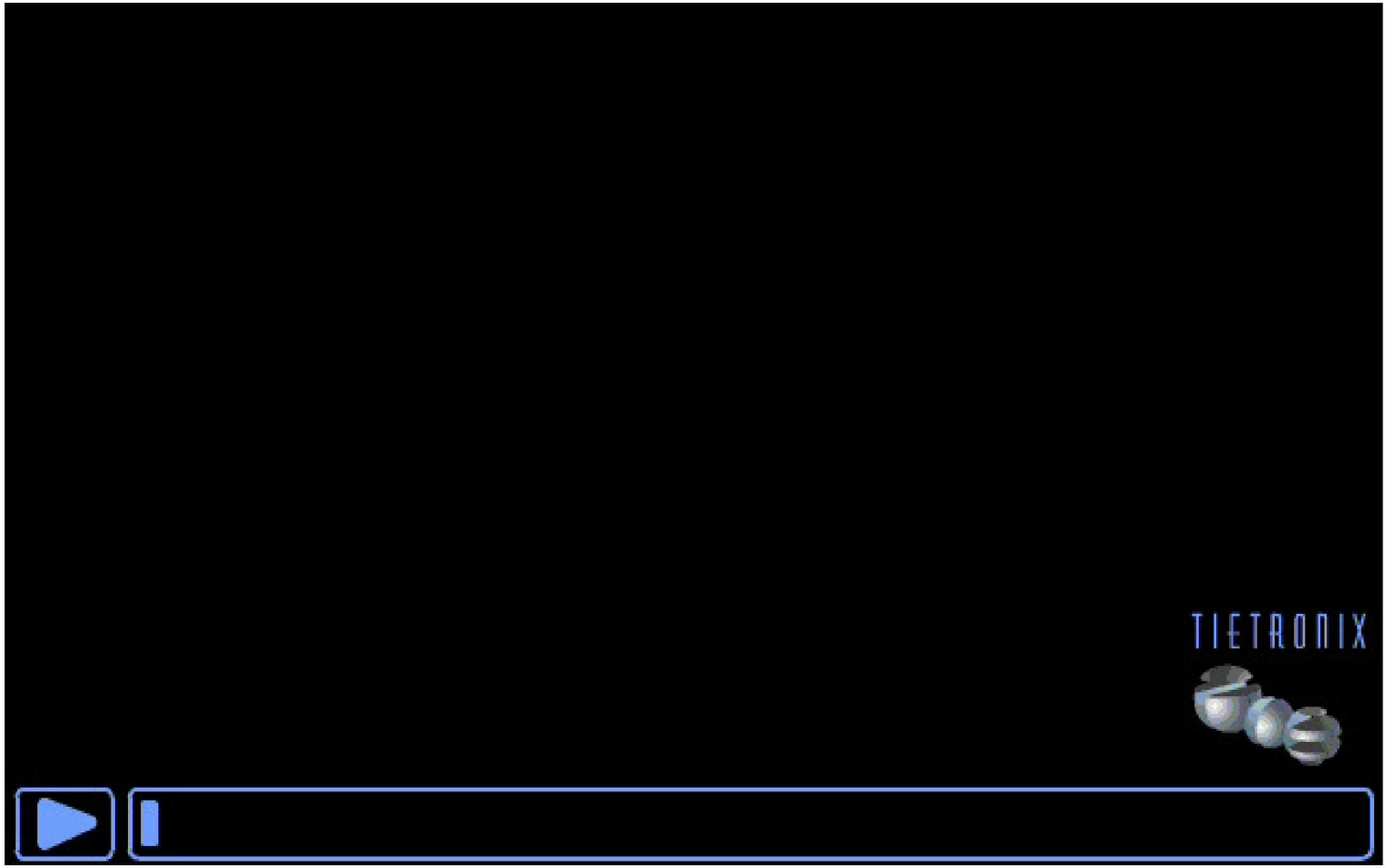
- International collaboration for the long-term exploration of space

United States **Russia** **Canada** **Japan** **Europe**

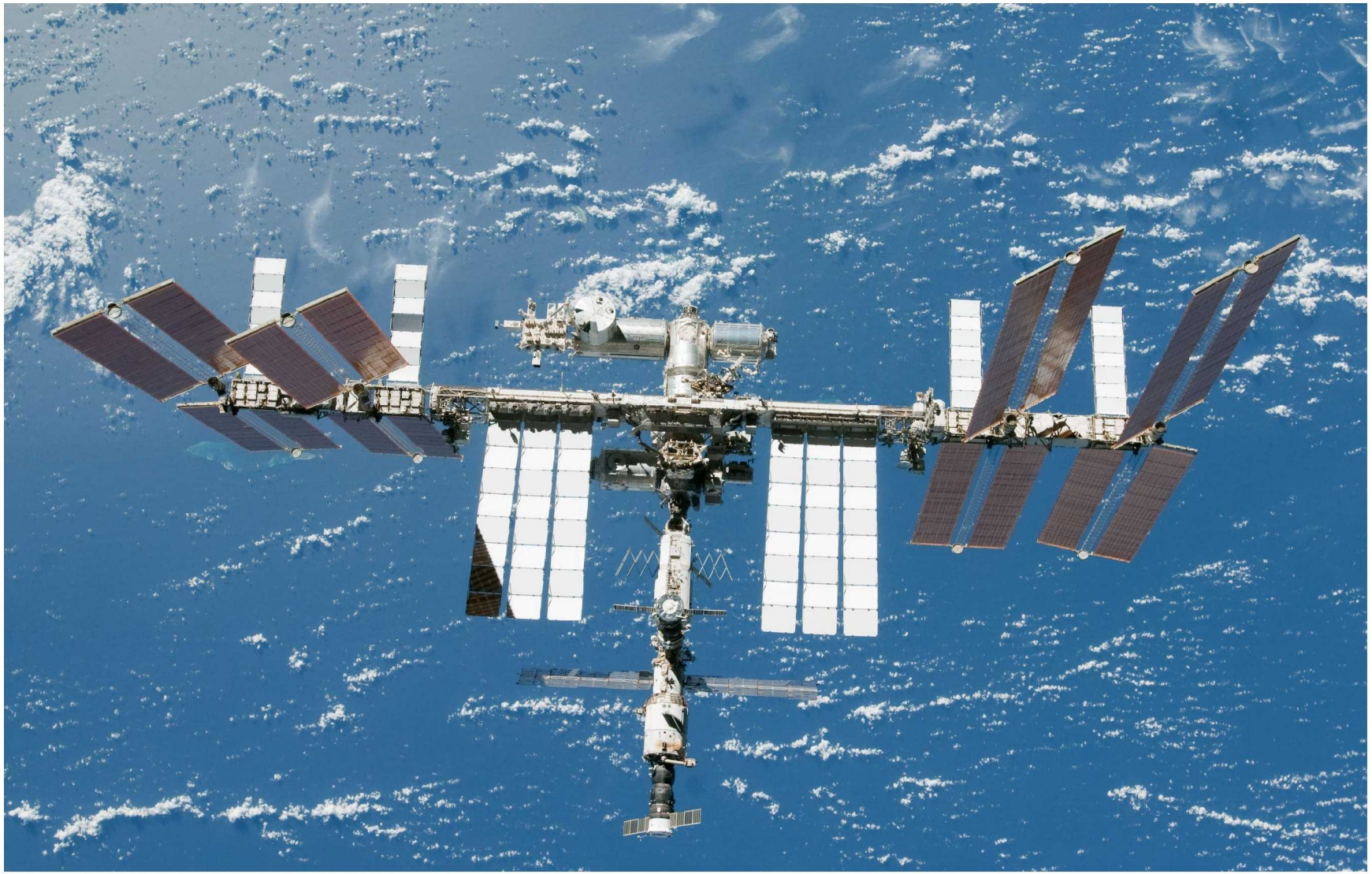
- Orbital inclination 51.6°
- Orbital altitude 370-460 km
- Mass ~419,000 kg
- 1200 m^3
- 108.4 m (truss) × 74 m
- 110 kW power output, (30 kW payload)

Assembly Complete Configuration

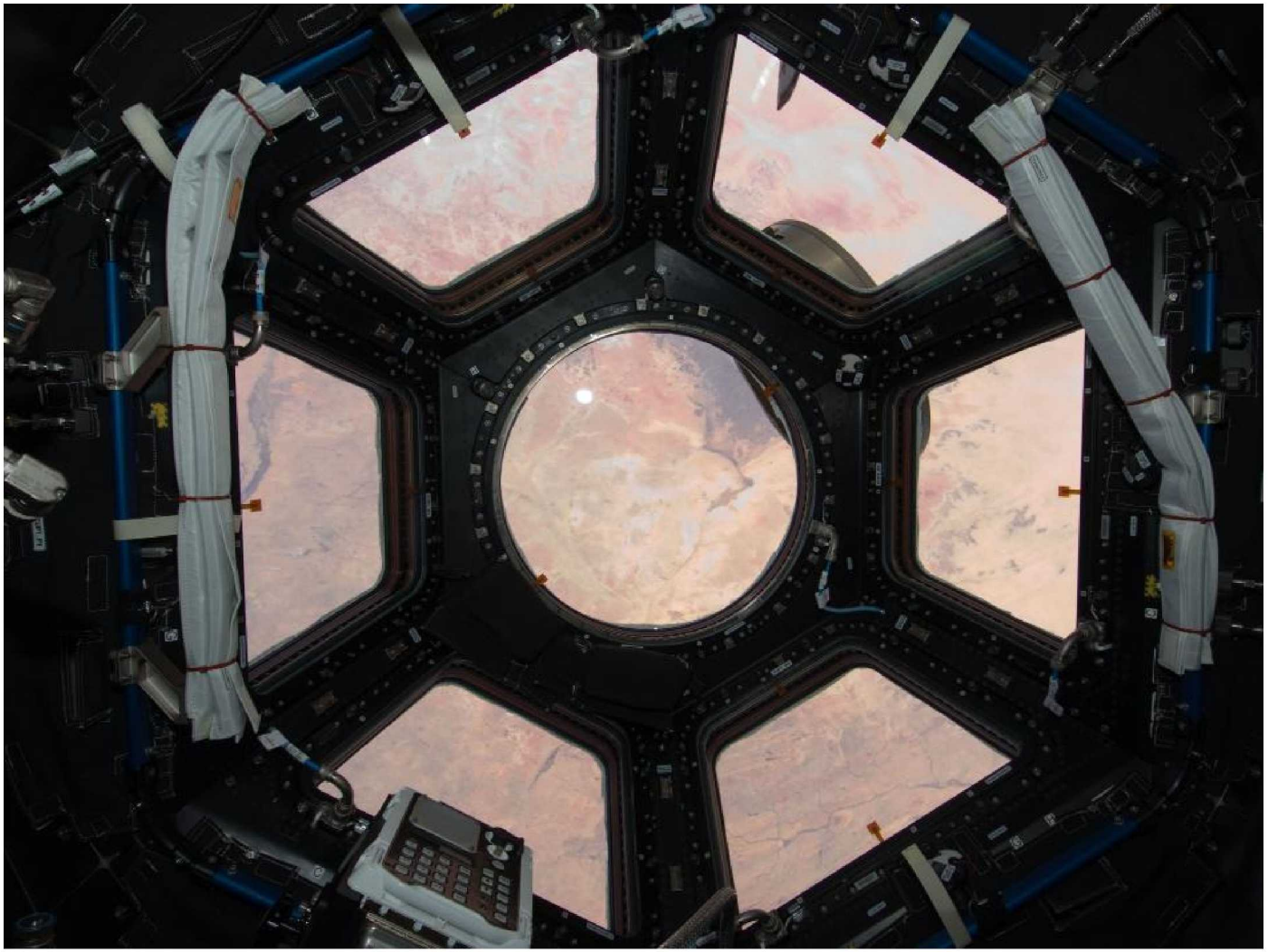
10+ yrs Assembly Timeline



Post Node-3 & Cupola Install Configuration



ISS Cupola Install

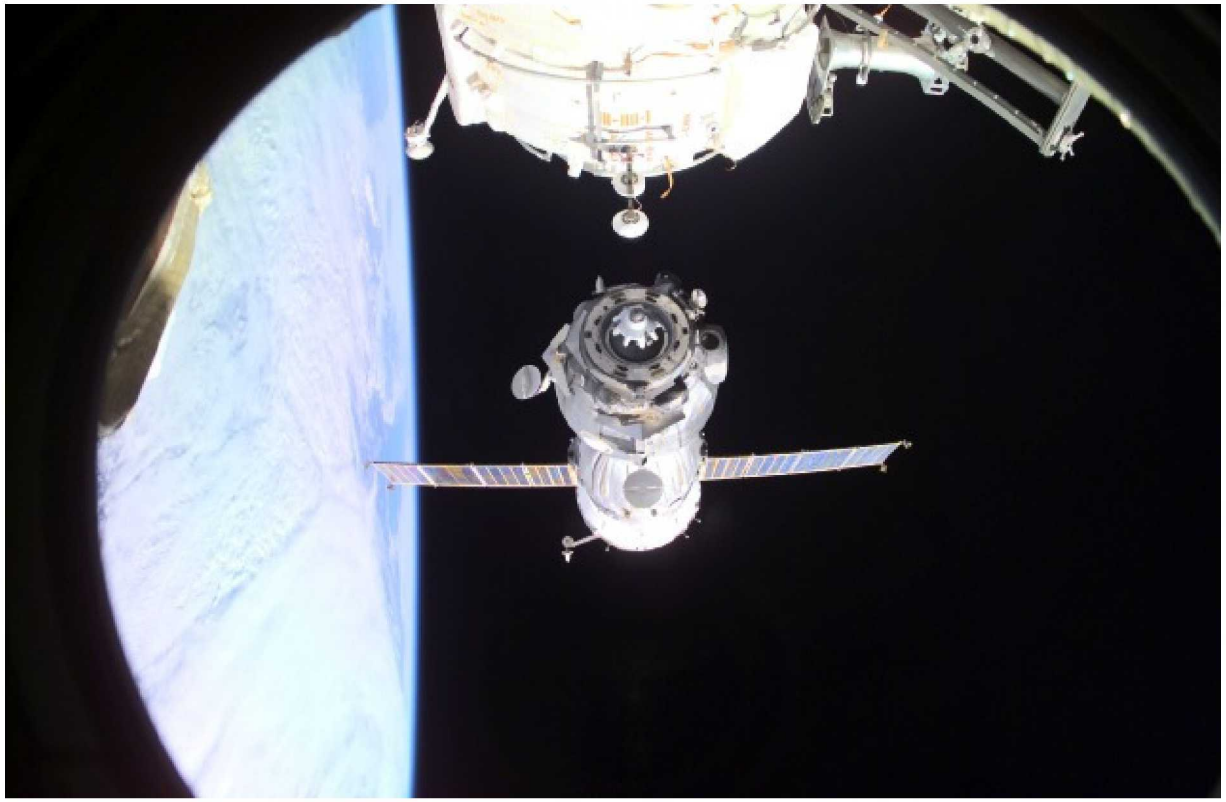


Crew of 6

Current crew onboard ISS

Visiting Vehicles

Soyuz – crew
Progress - cargo



Operations

Mission Control Center – NASA Johnson Space Center, Houston, TX

FCR-1
24/7

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

Command & Data Handling System

Avionics System

- Provides hardware and software used to collect data from onboard core systems and payloads.
- Command and control to onboard core systems.

- 1553B communications protocol
- Total of 44 MDMs onboard
- Tiered architecture

Tier 1 – Command & Control (C&C) MDM

Tier 2 – 6 system-specific MDMs

Tier 3 – subsystem MDMs connect to sensors & effectors

Command & Data Handling System (con't)

Emergency, Warning & Caution system (EWC)

- managed by the Primary C&C MDM
- bits set at subsystem level for trigger criteria
- alarm annunciation throughout ISS
- Caution & Warning Panels

Payload Network (PL)

- Tier 2 Payload MDMs
- Fiber-optic network
- Ethernet network

CDH interfaces with the Russian Segment & IP modules

Communication & Tracking System

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

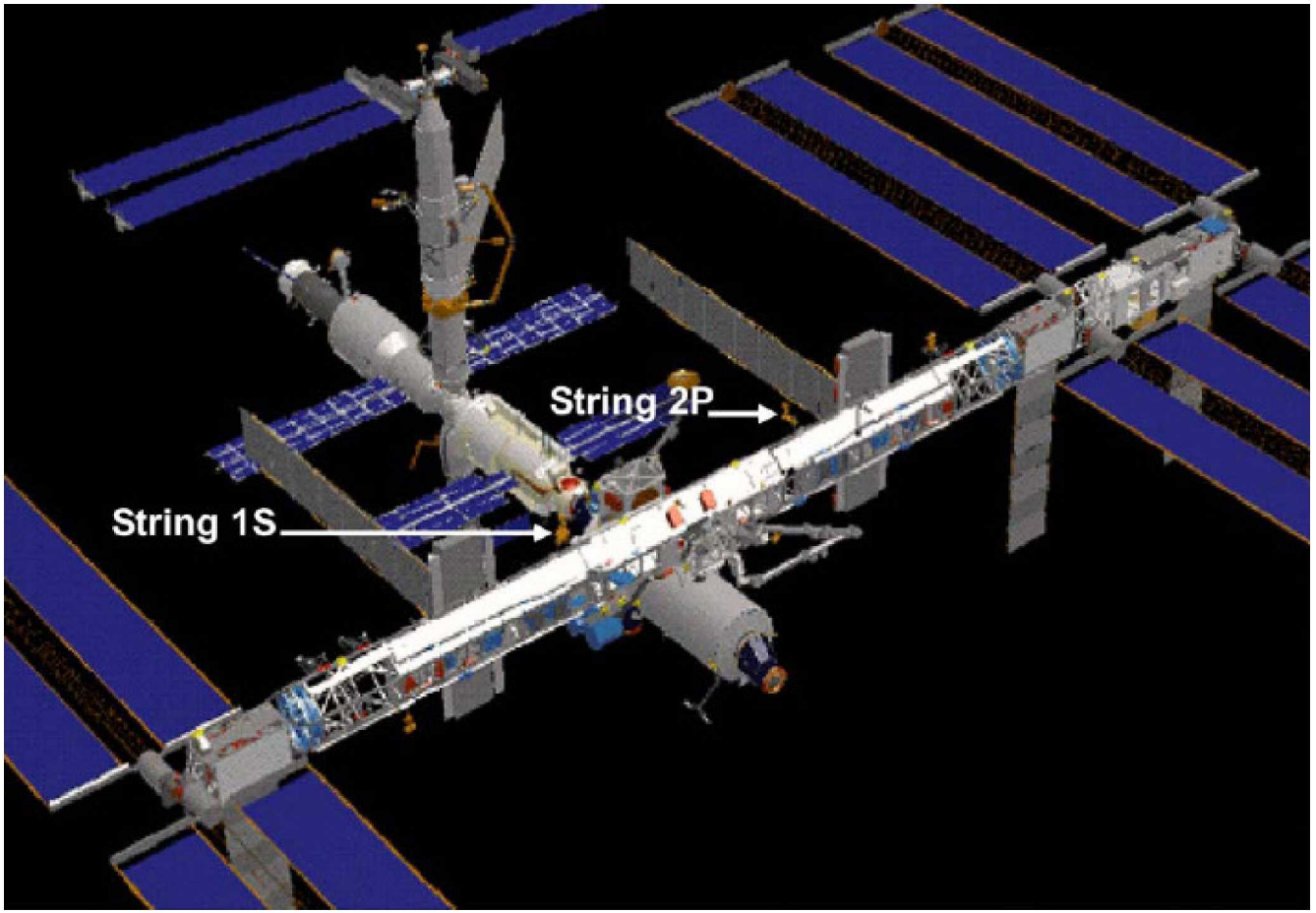
S-Band

- voice, commands, telemetry, & files
- 2.025-2.2110 GHz downlink
- 2.2-2.29 GHz uplink
- 2 strings (S1 truss, P1 truss)

Baseband Signal Processor — Transponder — Radio Frequency Group

Communication & Tracking System (con't)

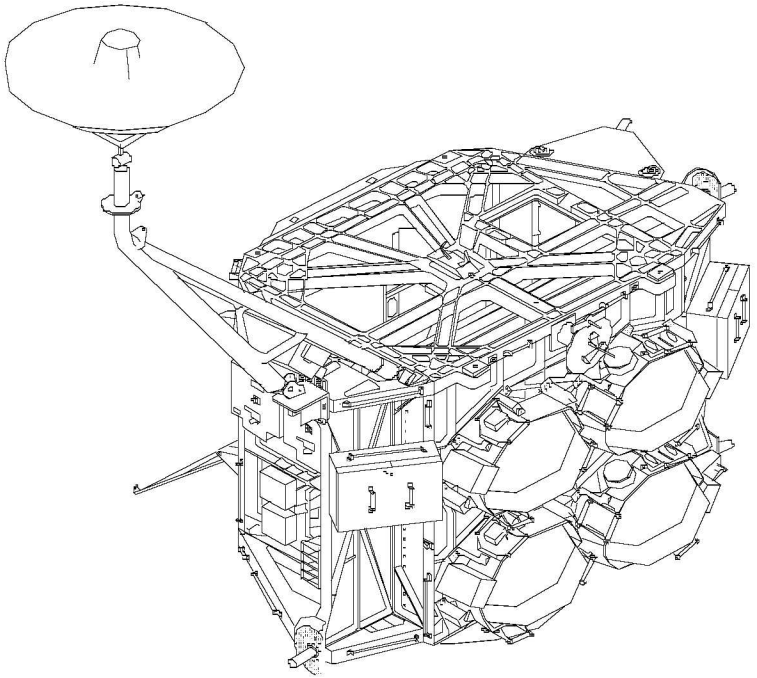
Redundant S-Band strings



Communication & Tracking System (con't)

Ku-Band

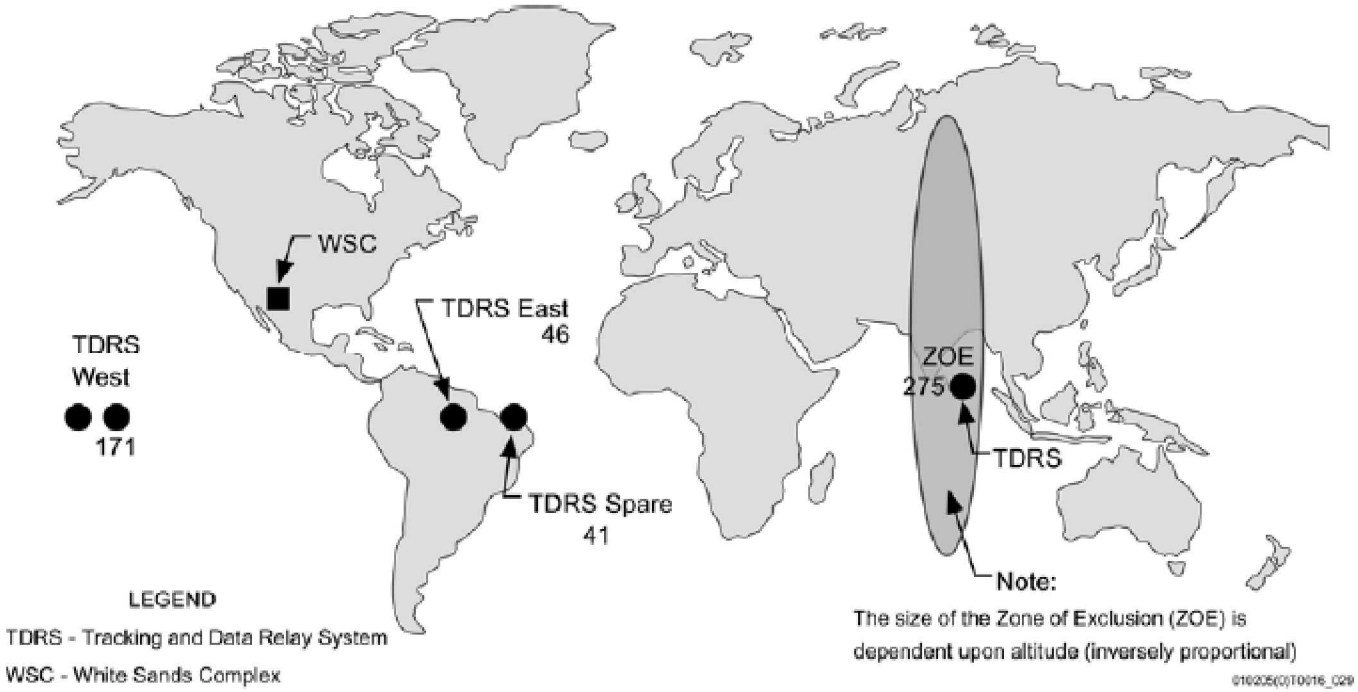
- payload data, video downlink, 2-way telecon
- 10.7-12.2 GHz downlink
- 14.0-14.5 uplink



Z1 truss & Ku-Band antenna

Communication & Tracking System (con't)

TDRSS

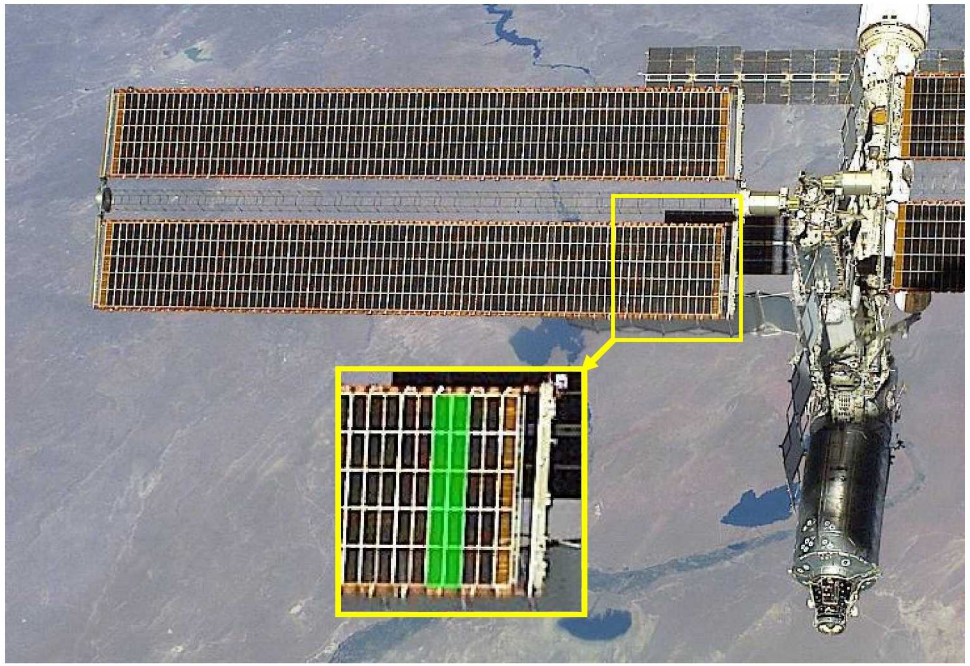


Electrical Power System

Solar Energy (photons) ⟶ Electrical Energy

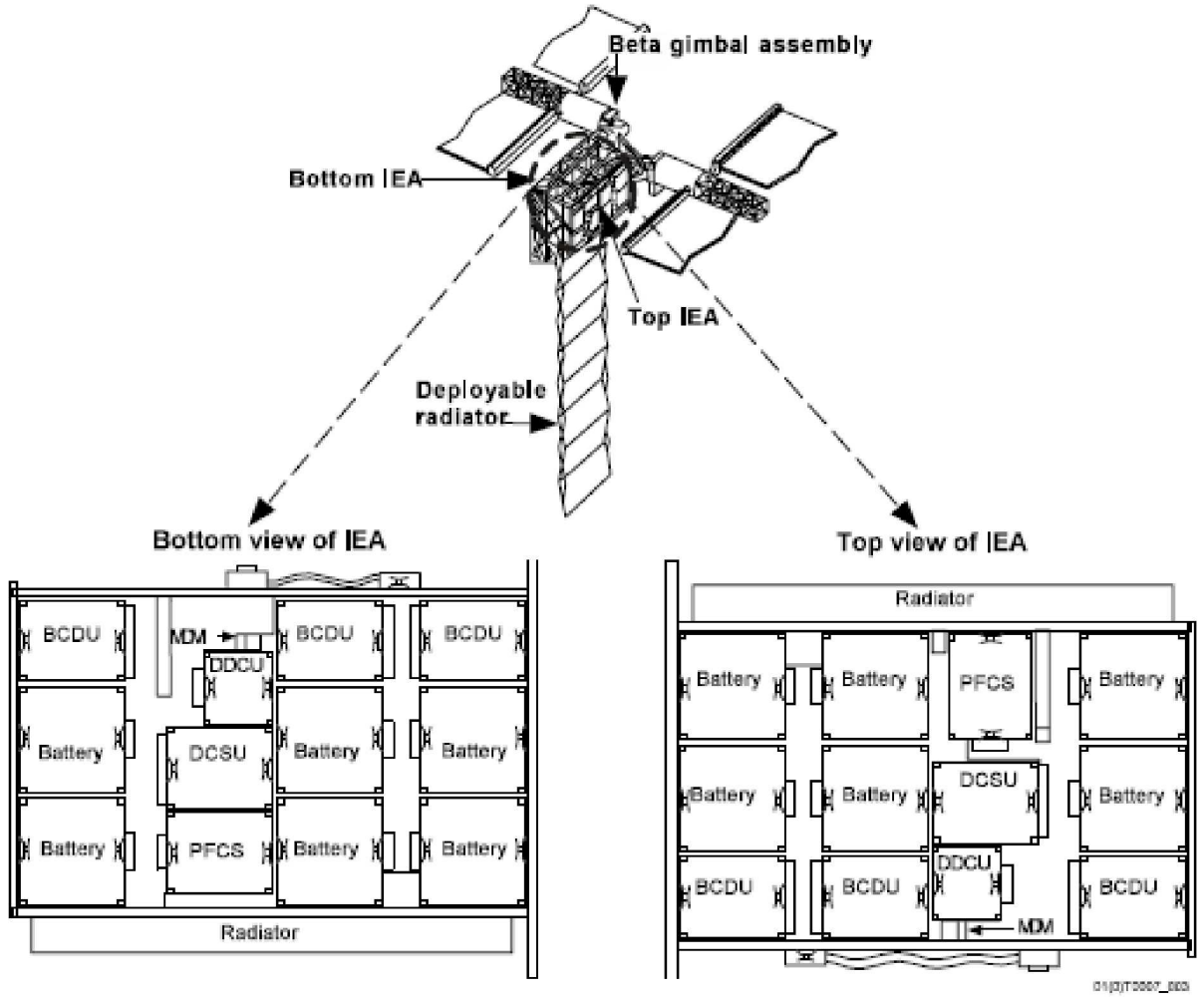
- Provide continuous power to ISS during insolation and eclipse

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

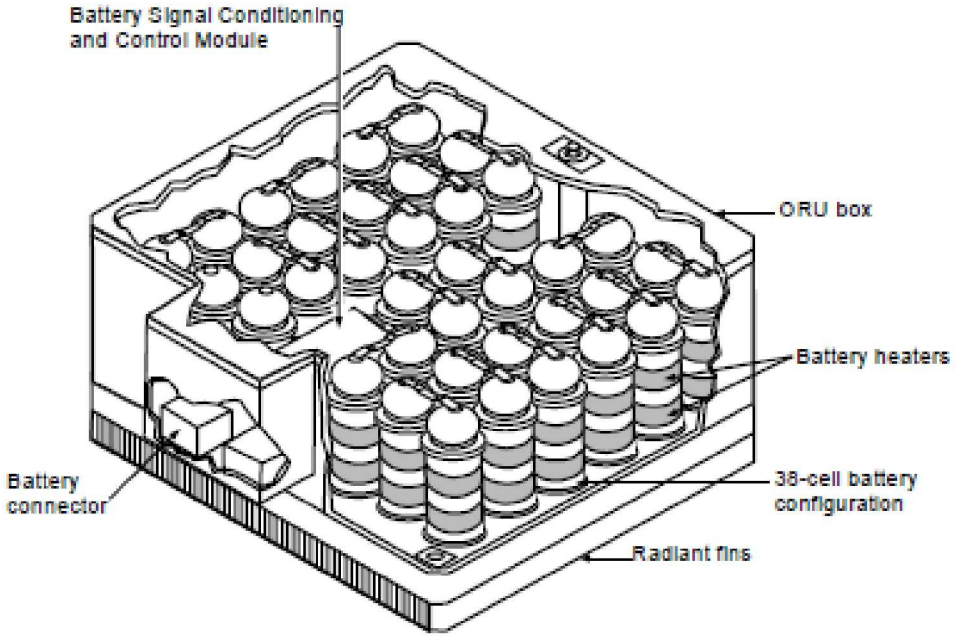
Electrical Power System (con't)



Electrical Power System (con't)

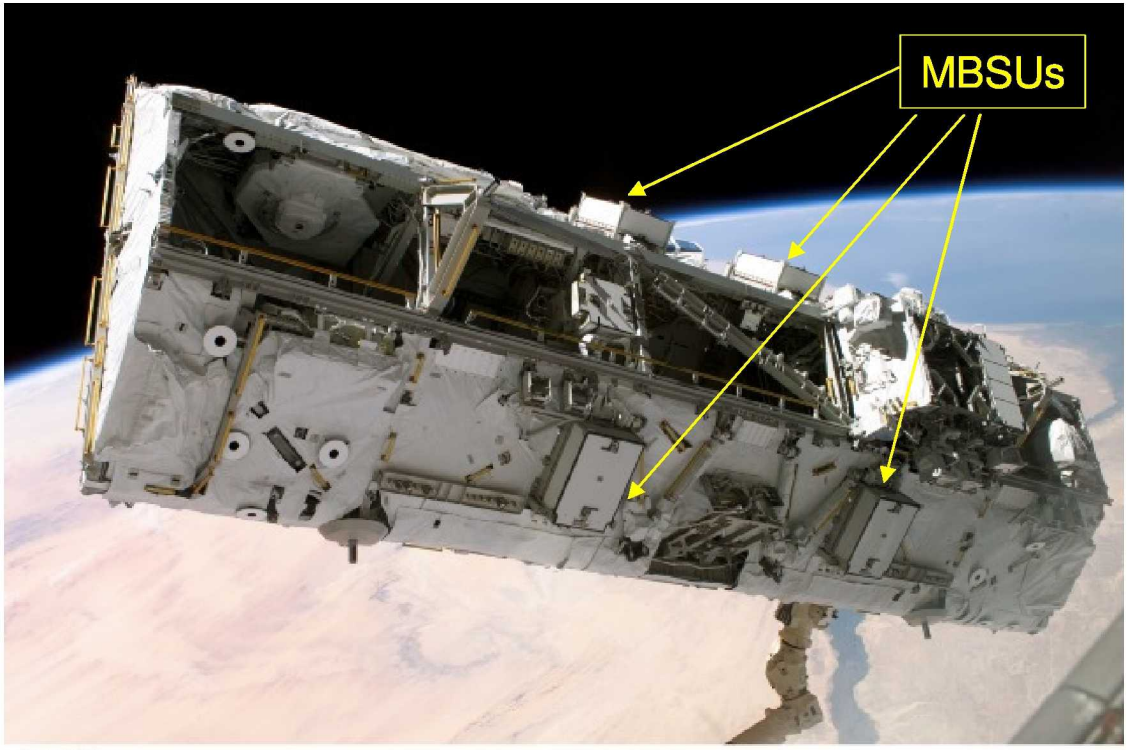
Primary power storage – NiH_2 batteries (0-10° C)

- 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.

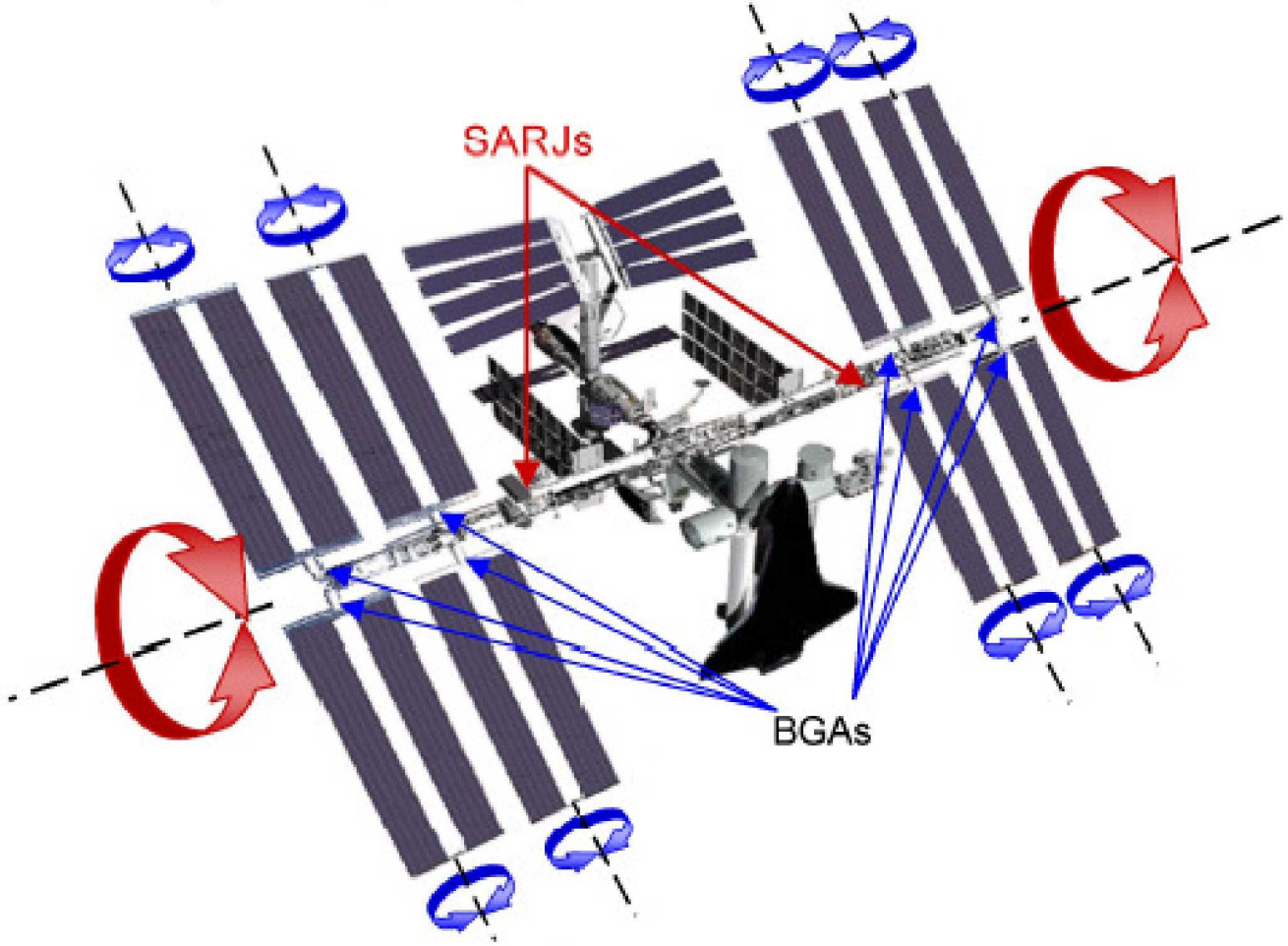


S110E5173

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)



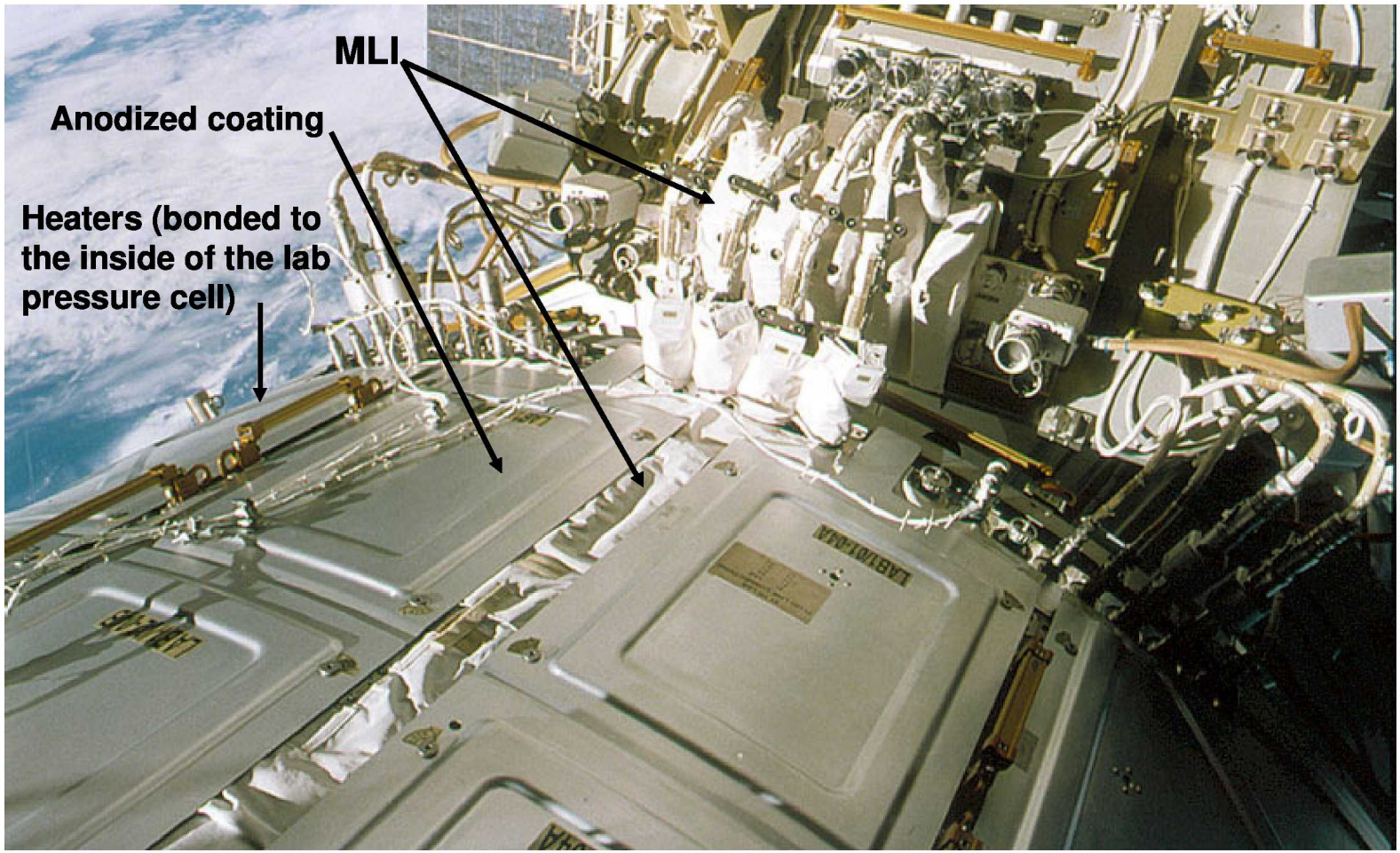
Thermal Control System

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))

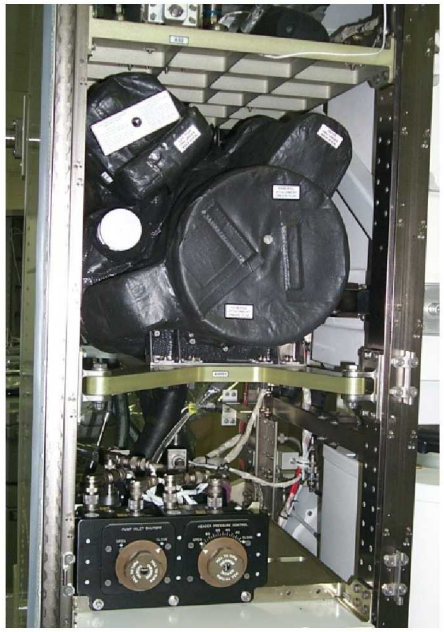
Thermal Control System (con't)



Thermal Control System (con't)

Active thermal control

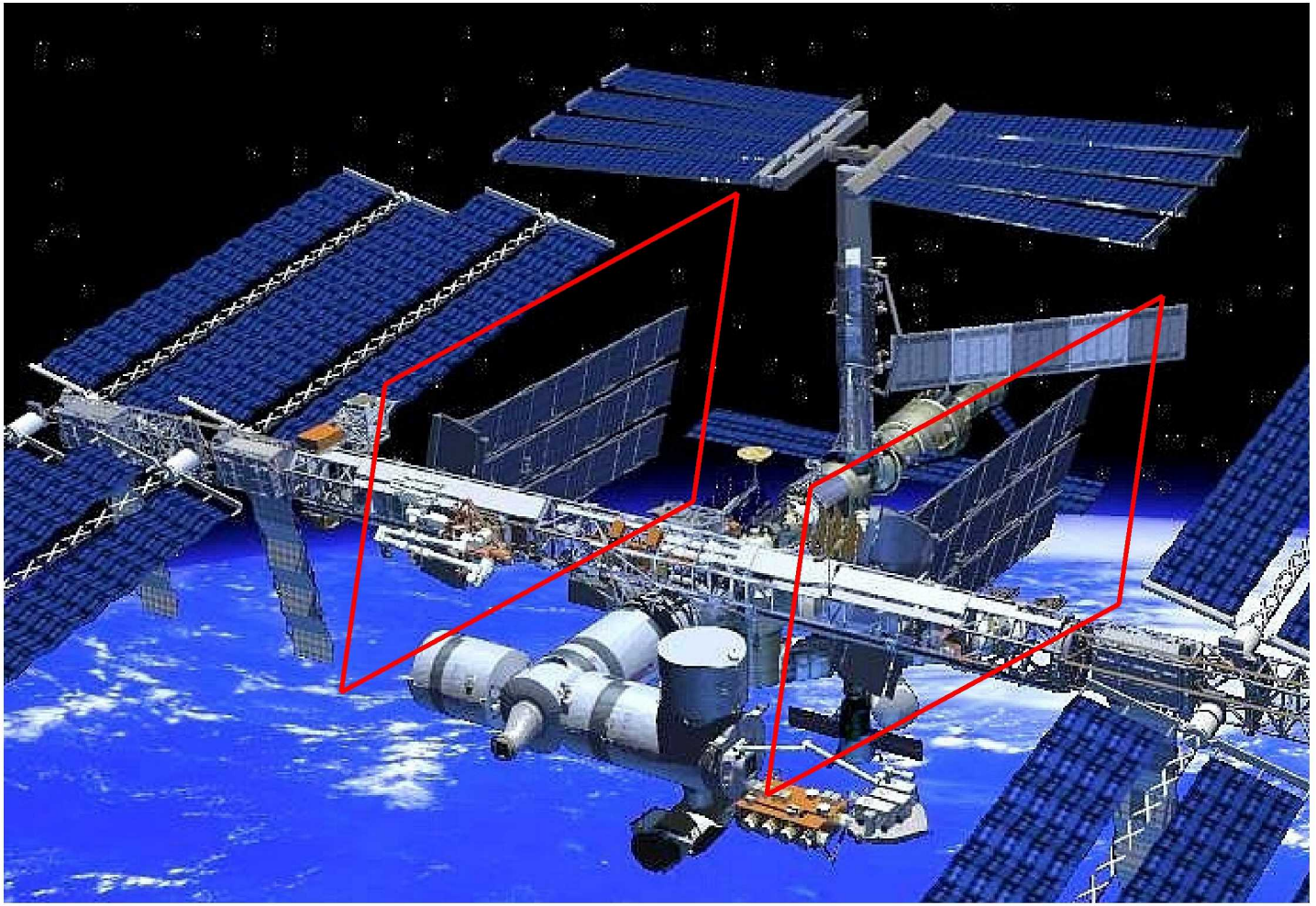
- Internal Thermal Cooling System (ITCS)
  - Working fluid = H_2O with teflon/Ti lines
  - Heat collection: cold plates & heat exchangers
  - Pump Package Assembly
  - Moderate Temperature Loop (MTL): 17° C
  - Low Temperature Loop (LTL): 4° C



- 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

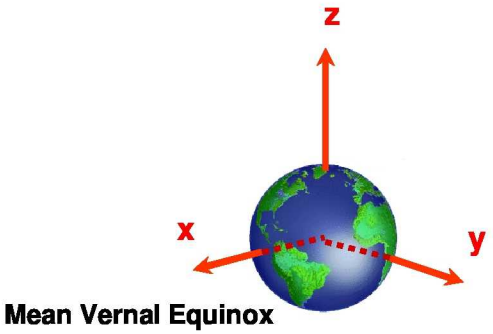
Thermal Control System (con't)

TRRJ

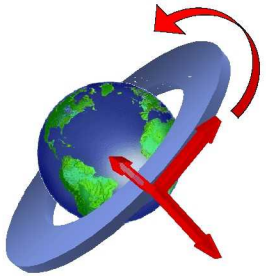


Motion Control System

- 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 reboosts via SM or Progress
- Provides state vector and attitude information to other ISS core systems



Mean Vernal Equinox
J2000



LVLH

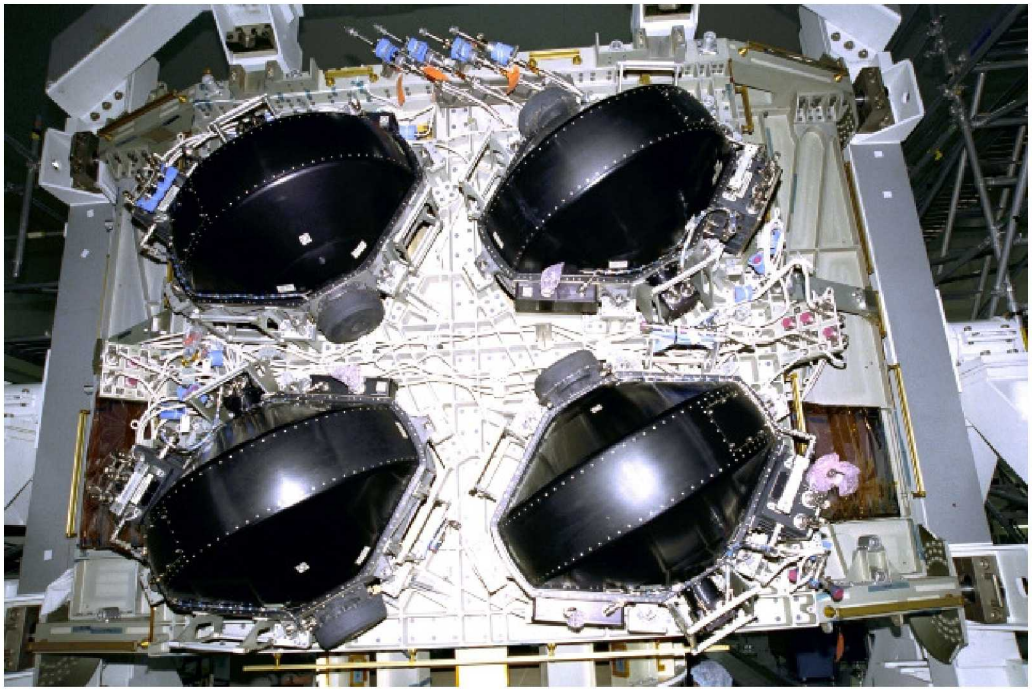
Motion Control System (con't)

USOS Attitude Control

Control Moment Gyros (CMGs)

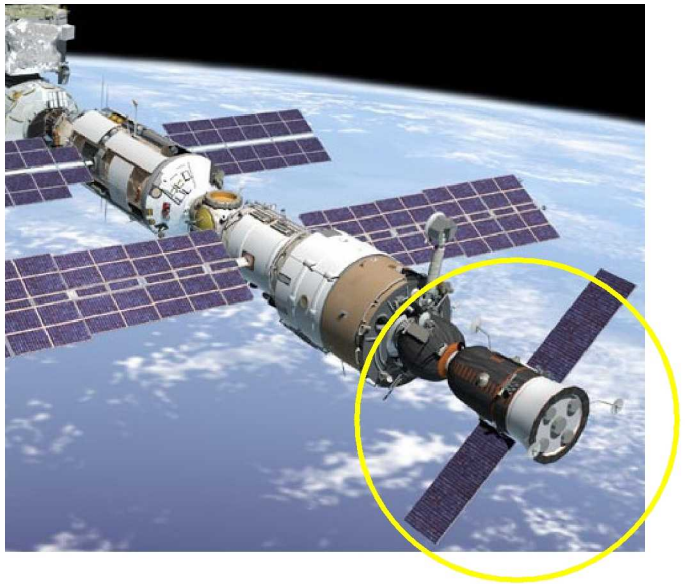
- 600 lbs each
- 6600 rpm
- 4880 N-m-s

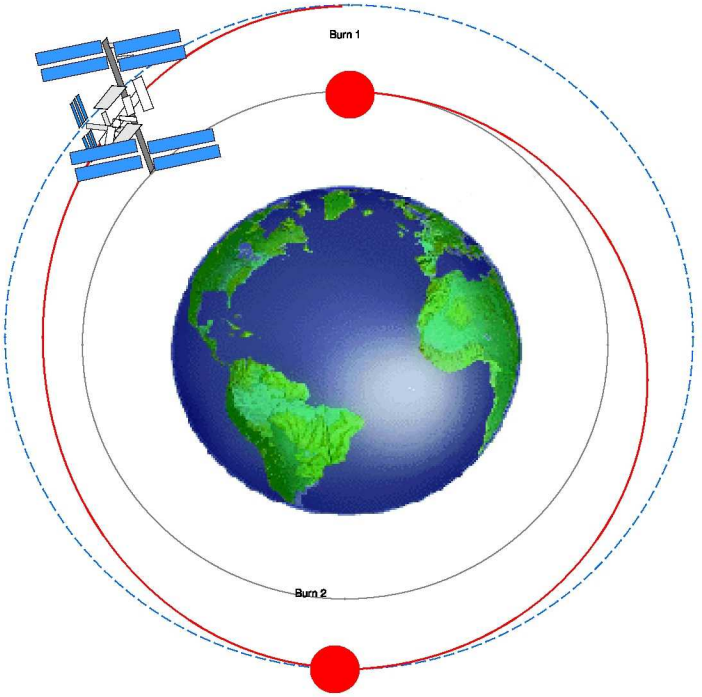
CMGs (Z1 truss)



Motion Control System (con't)

Translational Control (Reboost)





Robotics System

International collaboration:

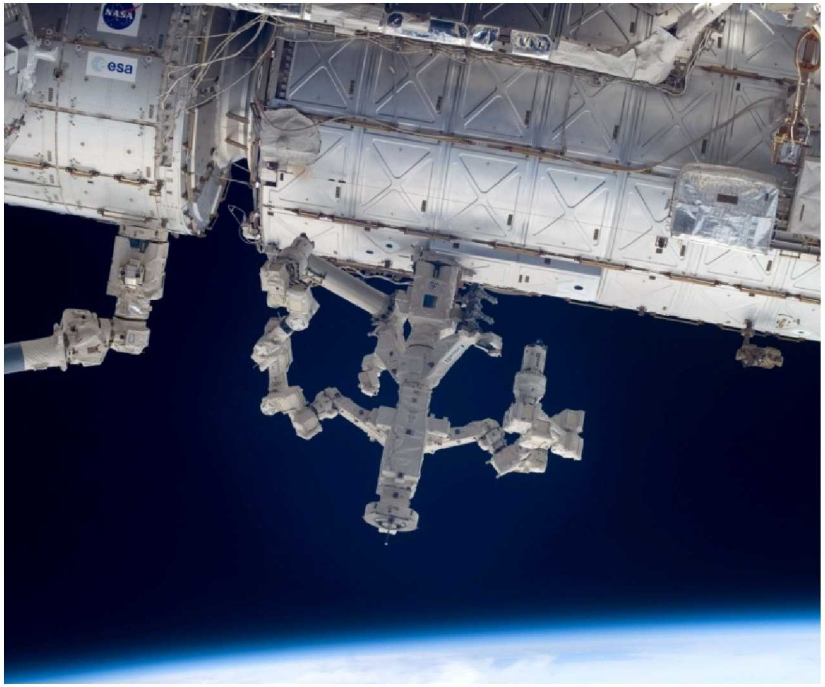
NASA, CSA, & JAXA

Functions:

- ISS assembly and maintenance
- EVA support and payload handling

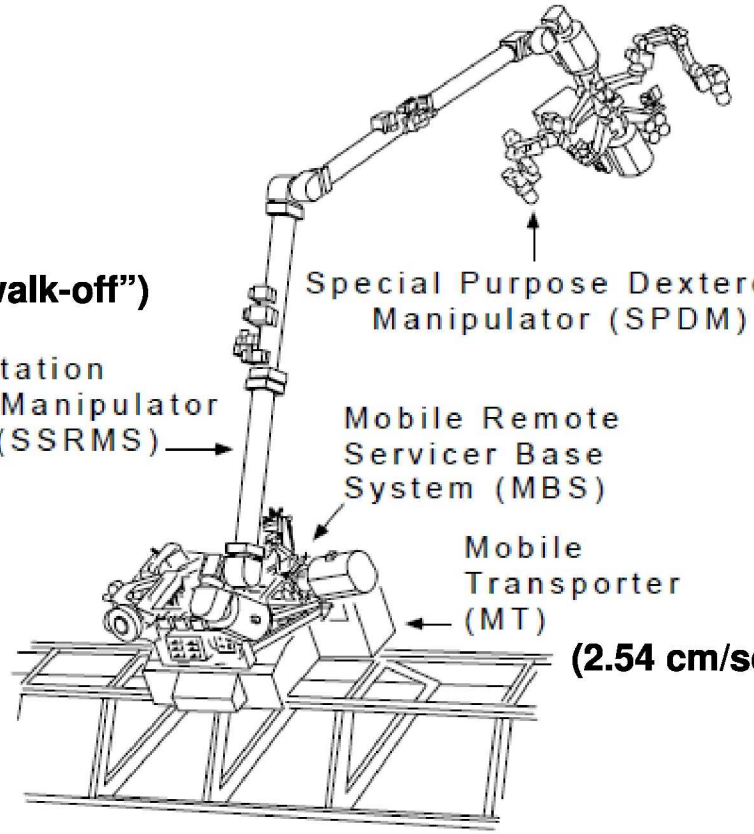
Systems:

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

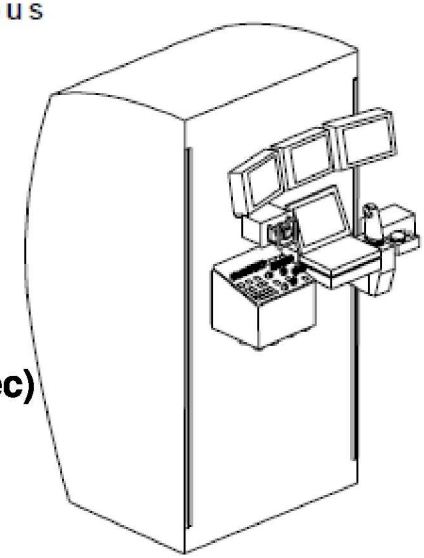


Robotics System (con't)

Mobile Servicing System (MSS)

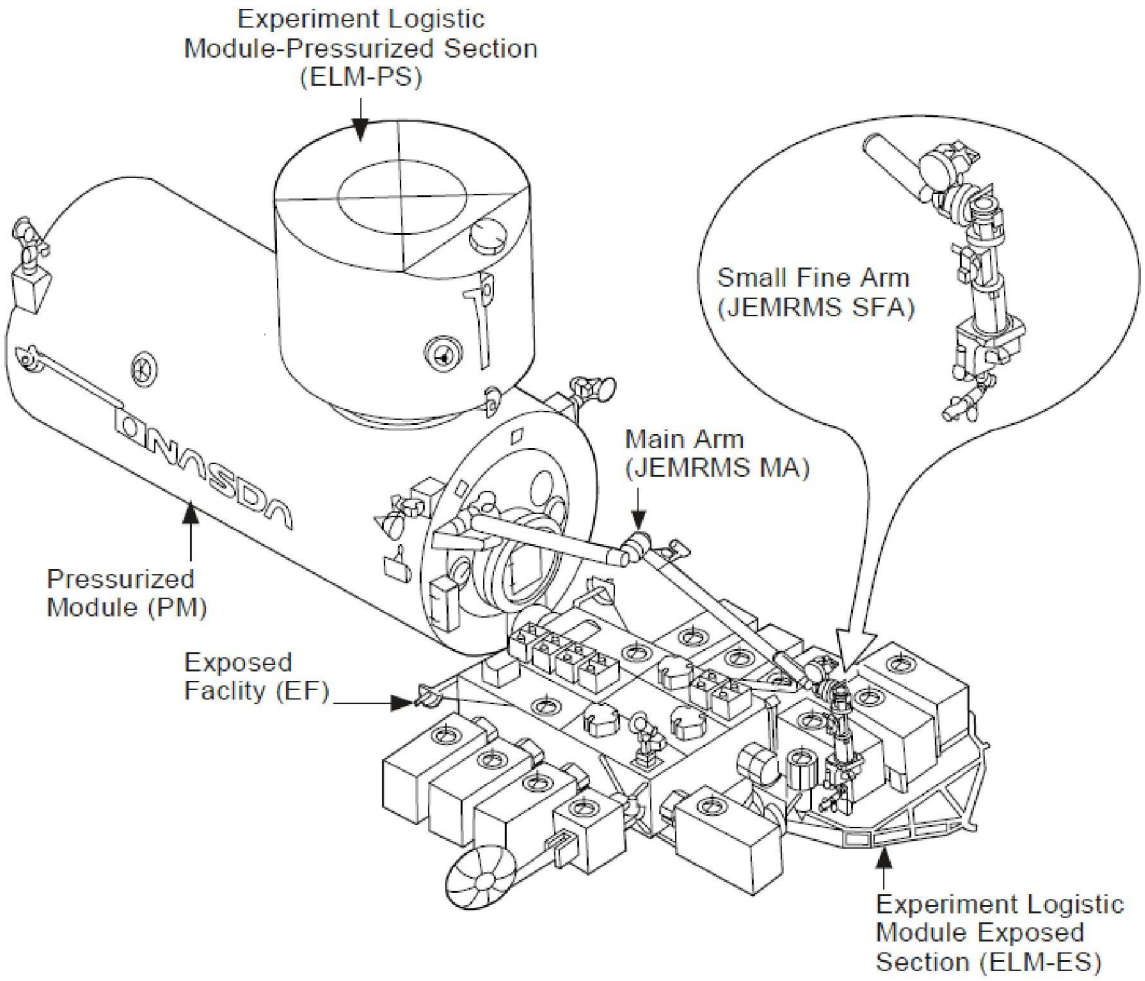


MSS External Components



Robotic Workstation (RWS)

Robotics System (con't)



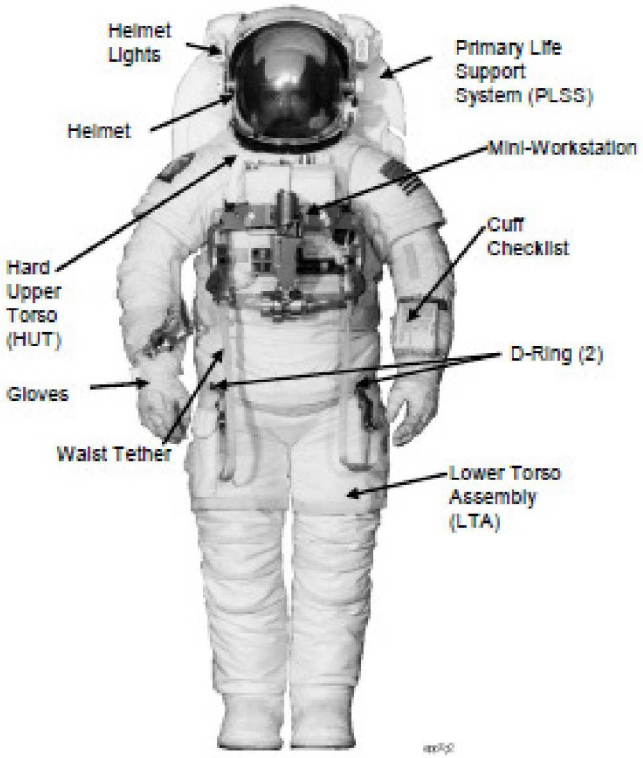
Robotics System (con't)

Robonaut (R2)

http://robonaut.jsc.nasa.gov/

Extravehicular Activity

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

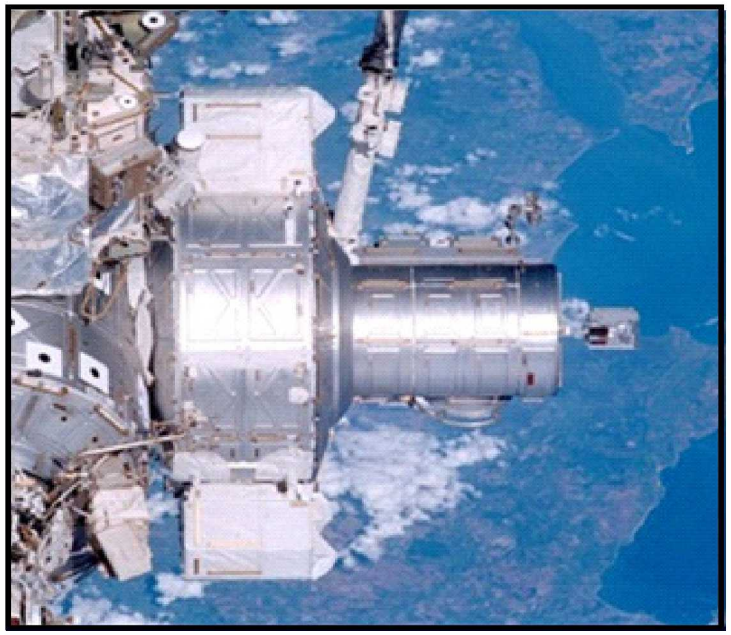


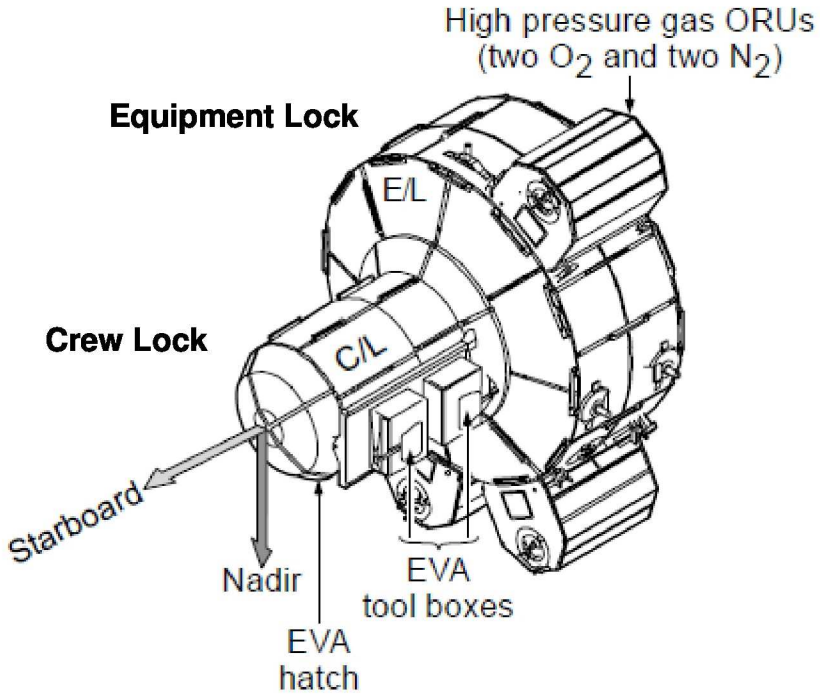
Extravehicular Mobility Unit (EMU)

- 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)

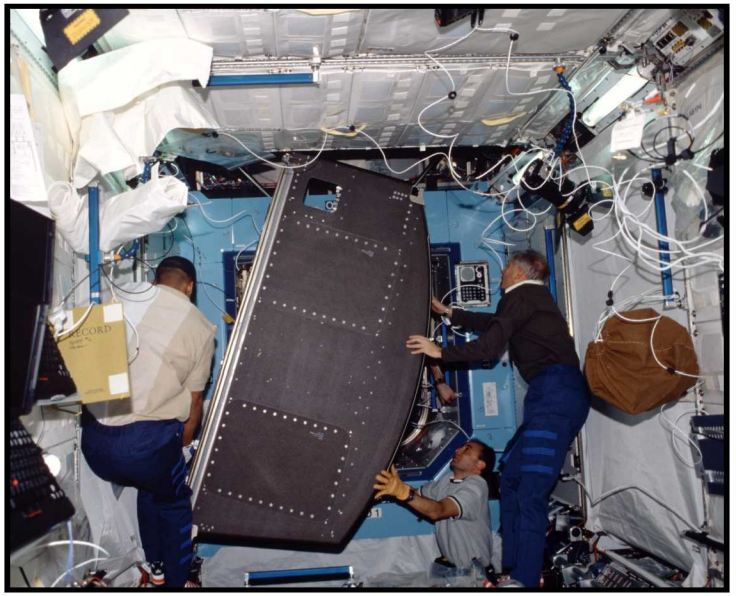
Payloads

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 Glovebox
- Fluids and Combustion Facility
- X-Ray Crystallography Facility
- Biotechnology Facility



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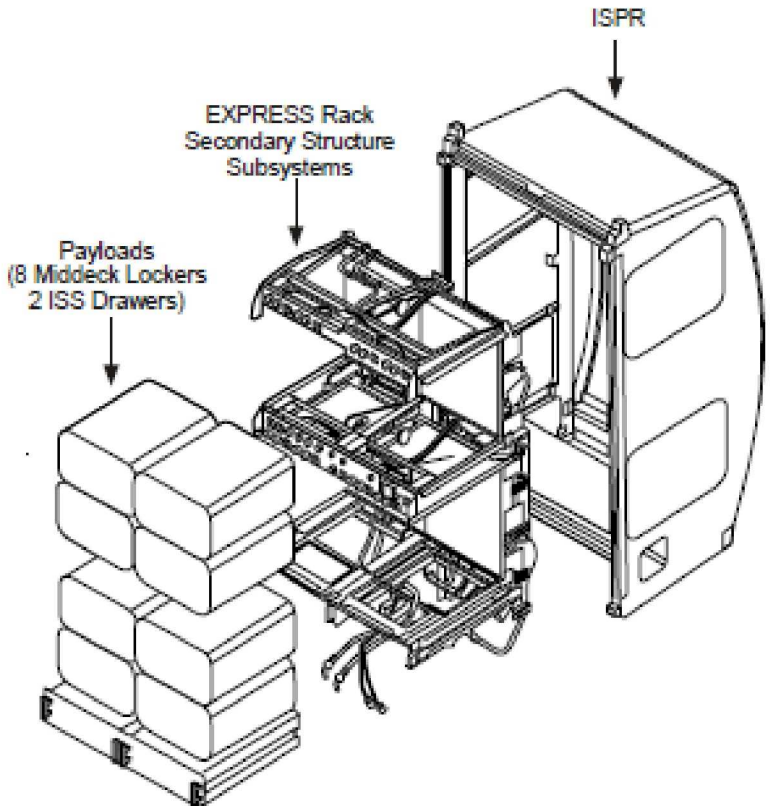
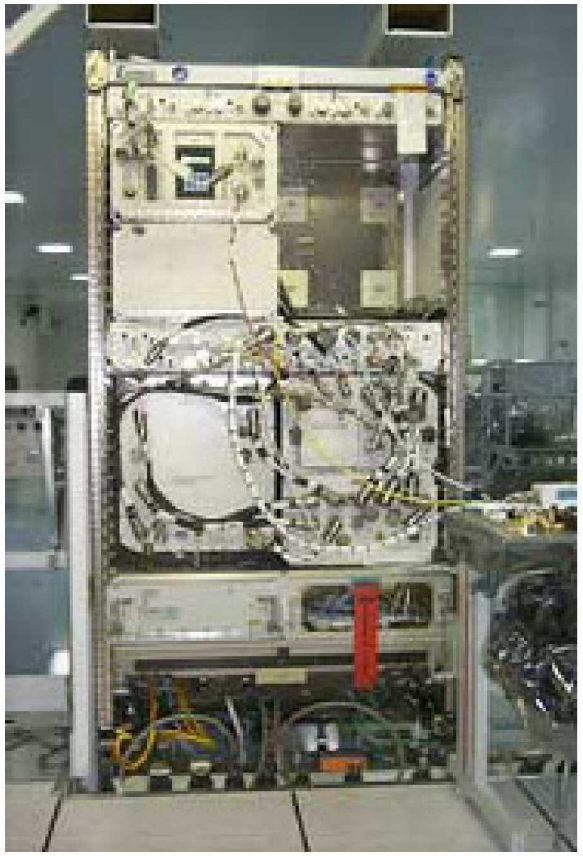


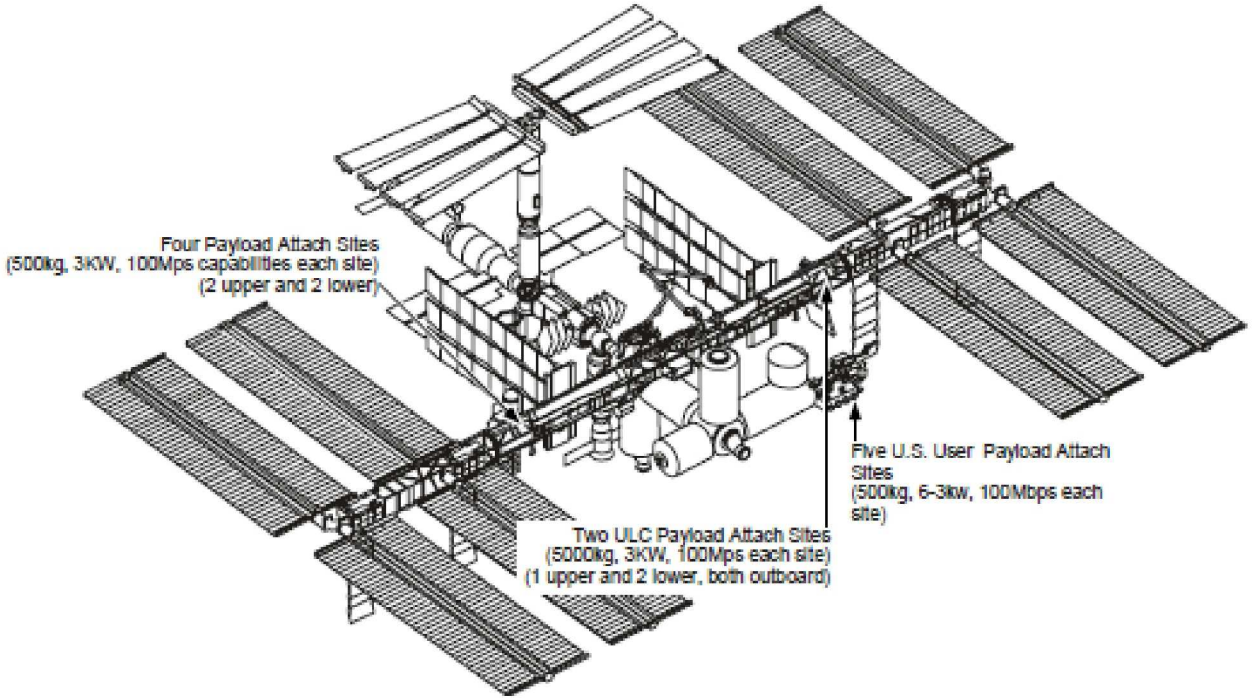


Express Rack

Payloads (con't)

- 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



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
- Biological Sciences
- Human Sciences
- Earth Observation
- Space Science

Earth & Space Science

EVC – Earth Viewing Camera

http://www.nasa.gov/mission_pages/station/science/experiments/EVC.html

CEO – Crew Earth Observations

http://www.nasa.gov/mission_pages/station/science/experiments/CEO.html

HREP-RAIDS – Remote Atmospheric and Ionic Detection System

http://www.nasa.gov/mission_pages/station/science/experiments/HREP-RAIDS.html#images

SOLSPEC – Solar

http://www.nasa.gov/mission_pages/station/science/experiments/SOLSPEC.html

SOVIM – Solar Variable and Irradiance Monitor

http://www.nasa.gov/mission_pages/station/science/experiments/SOVIM.html

MAXI – Monitor of All-sky X-Ray image

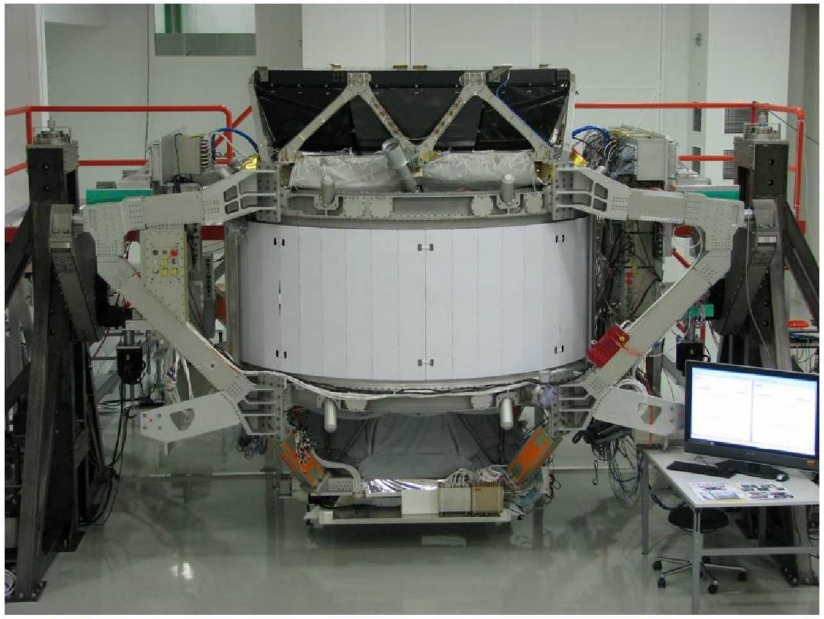
http://www.nasa.gov/mission_pages/station/science/experiments/MAXI.html#images

Alpha Magnetic Spectrometer

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

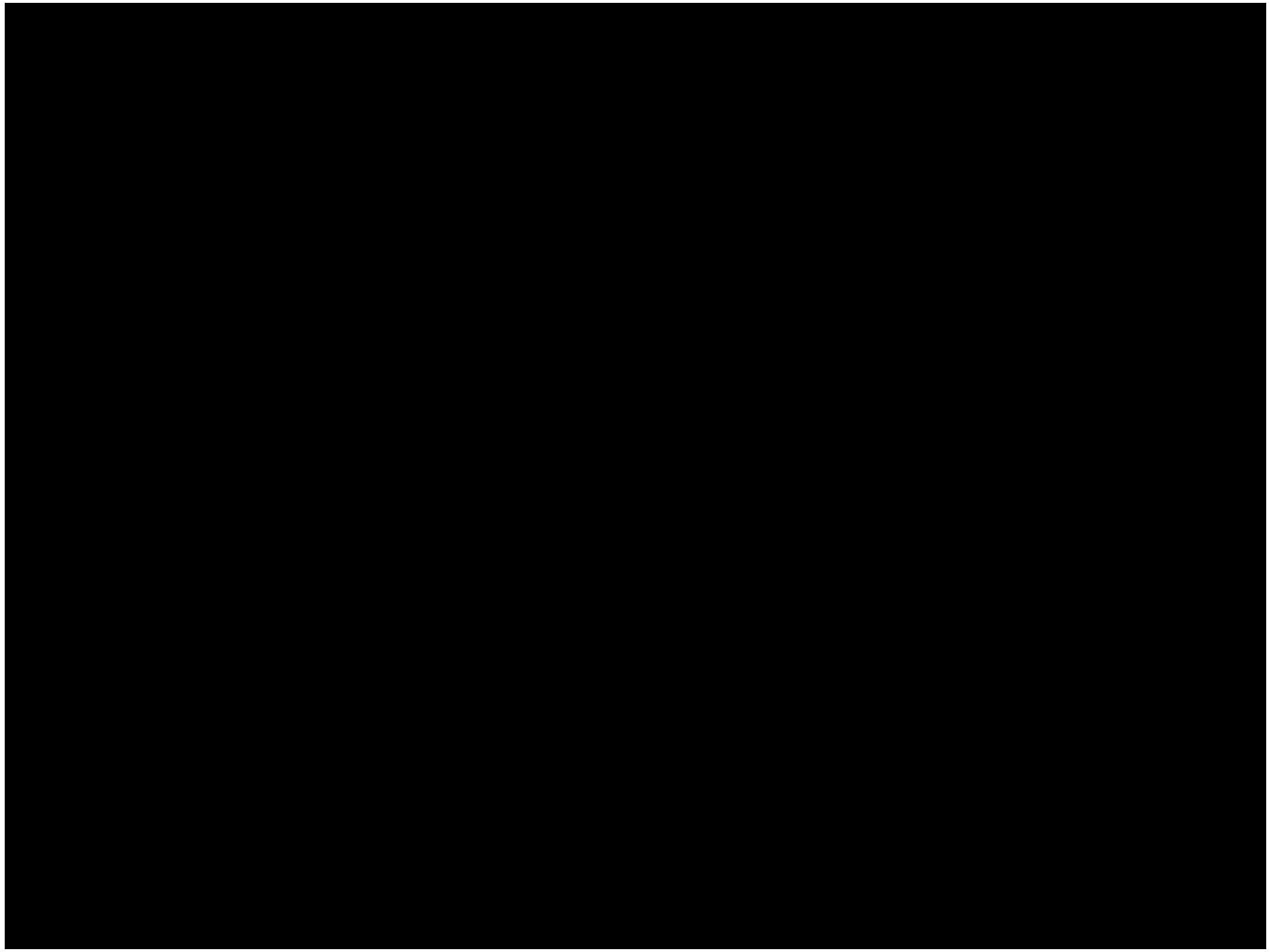
Alpha Magnetic Spectrometer (con't)

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



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

Alpha Magnetic Spectrometer (con't)



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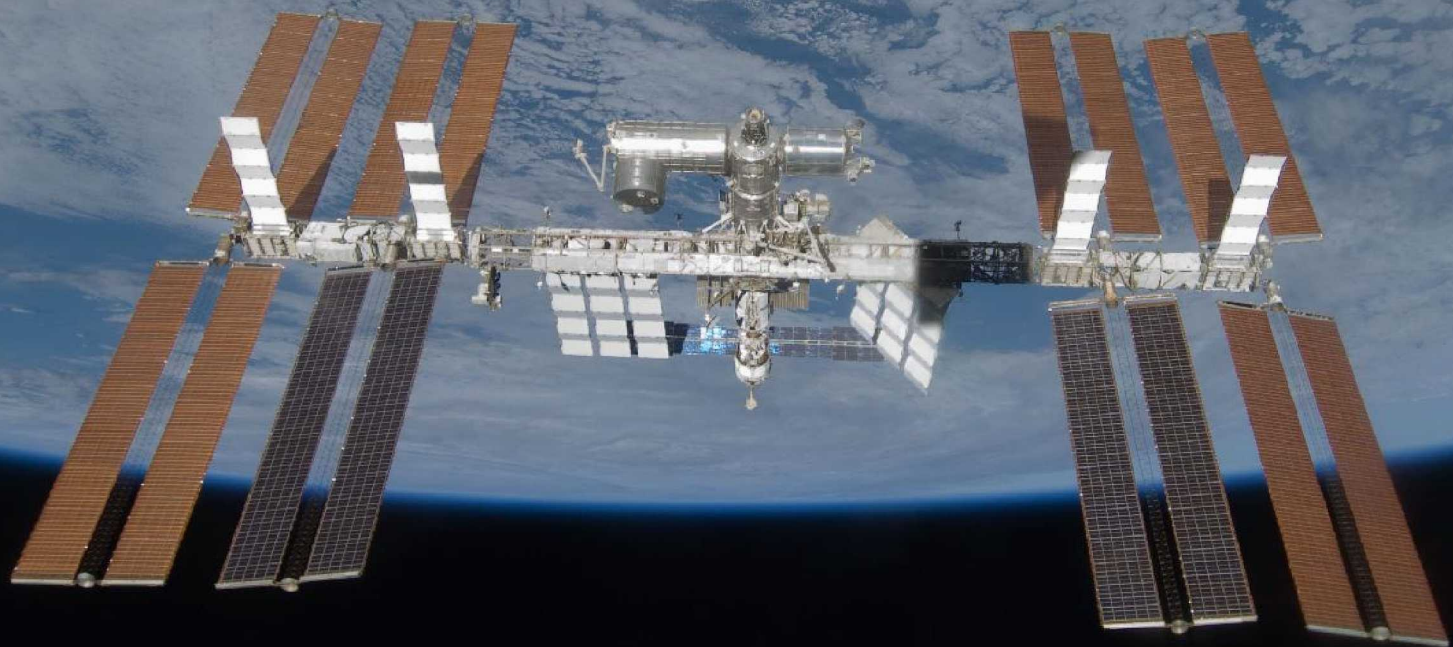

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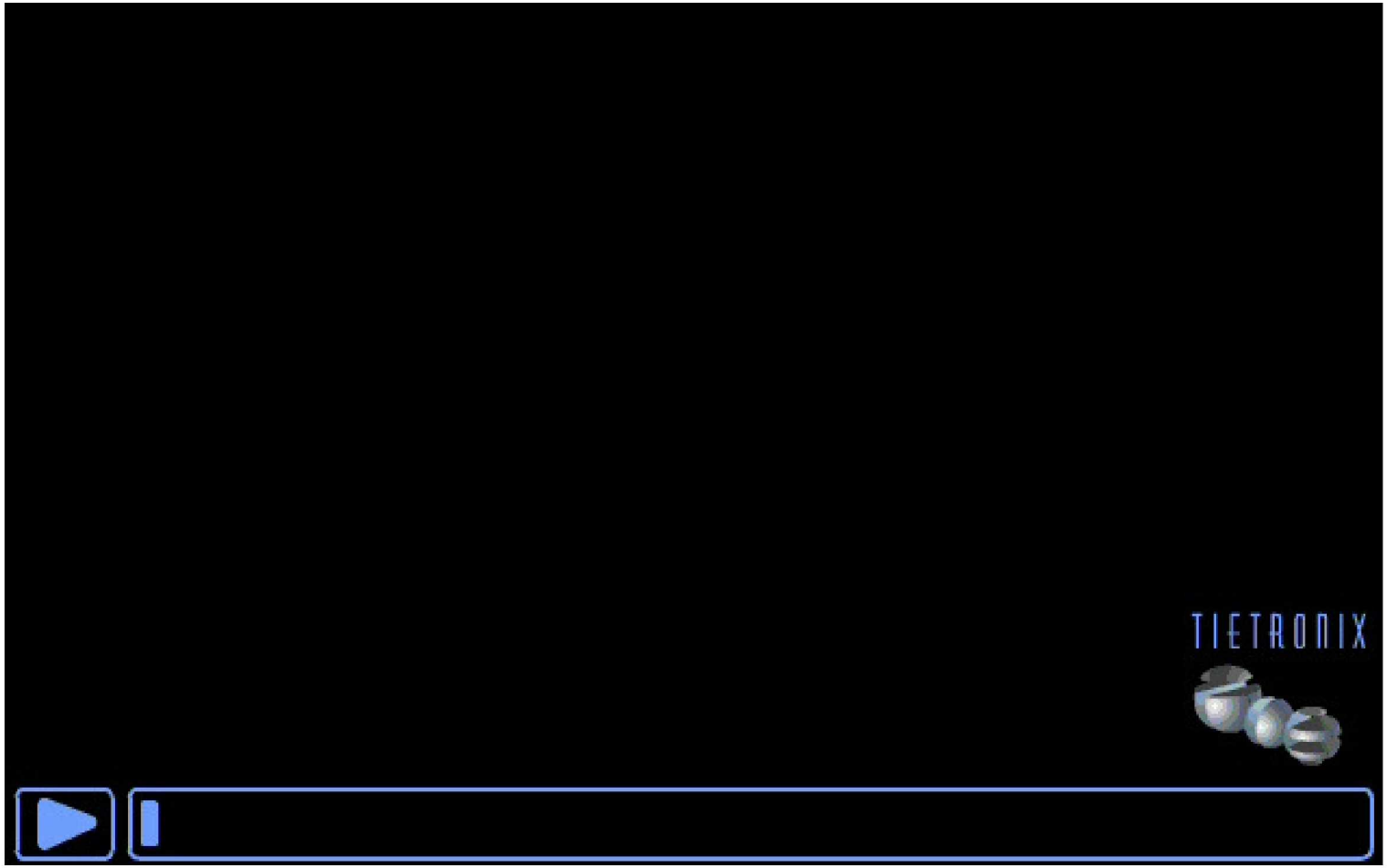

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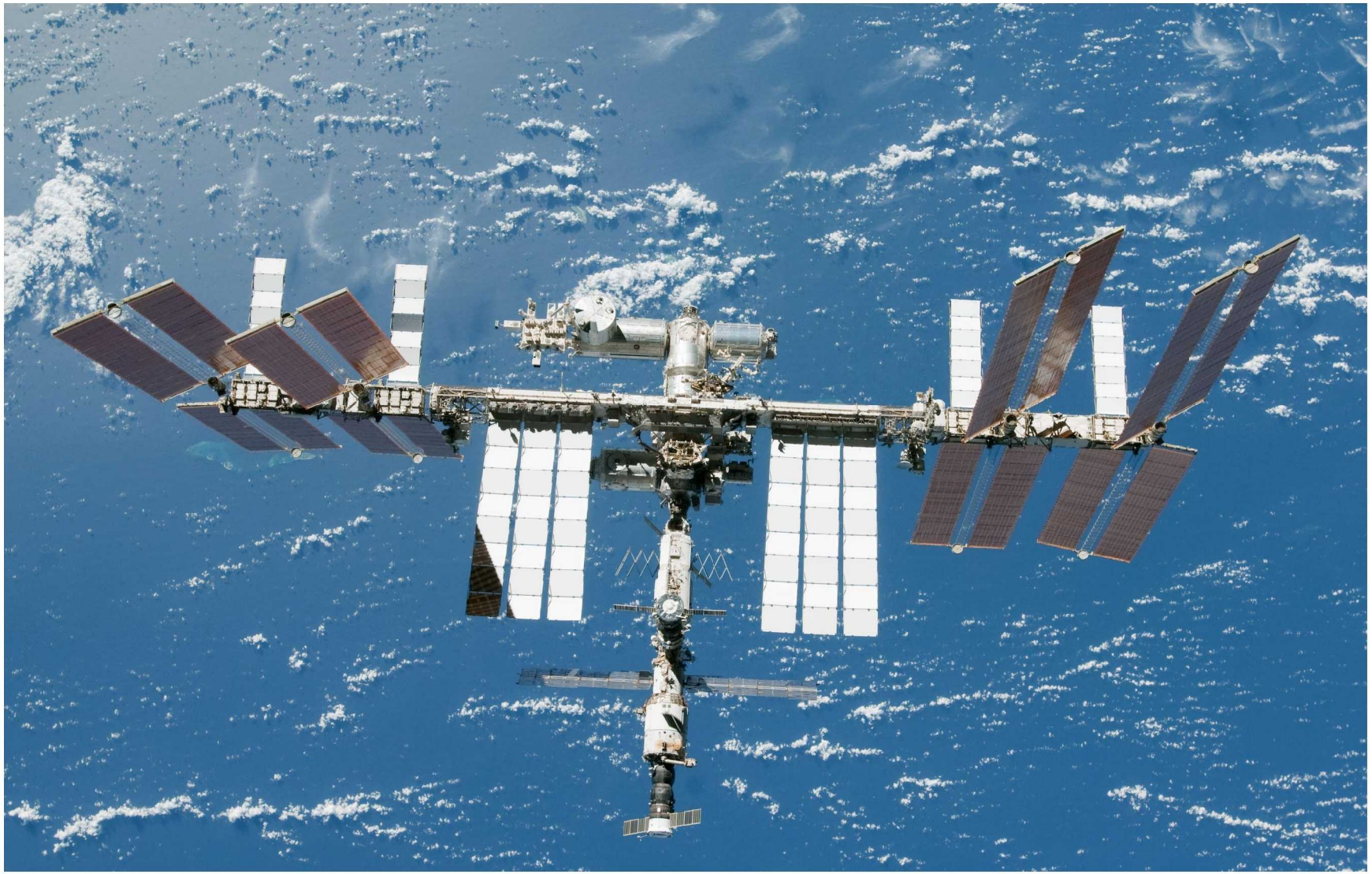

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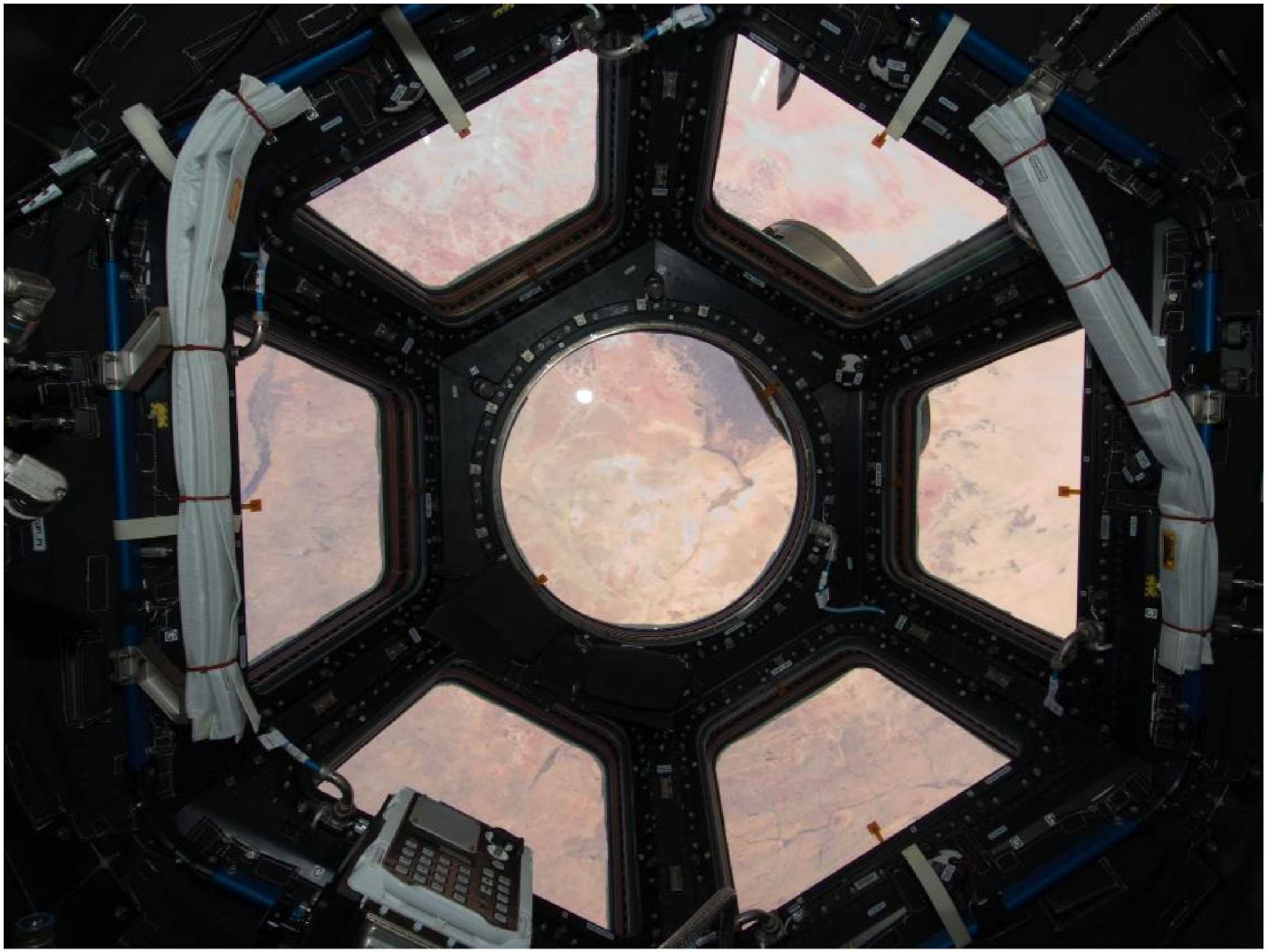

Crew of 6

Current crew onboard ISS

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Soyuz – crew
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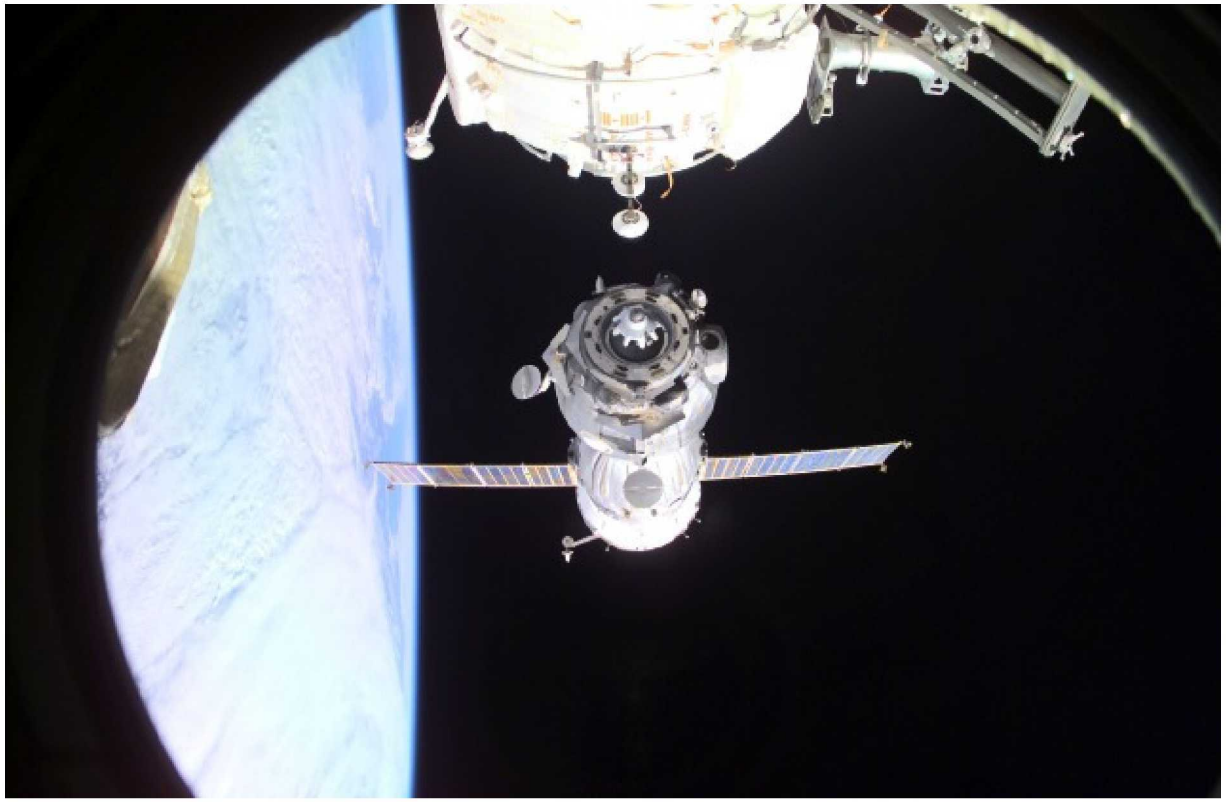

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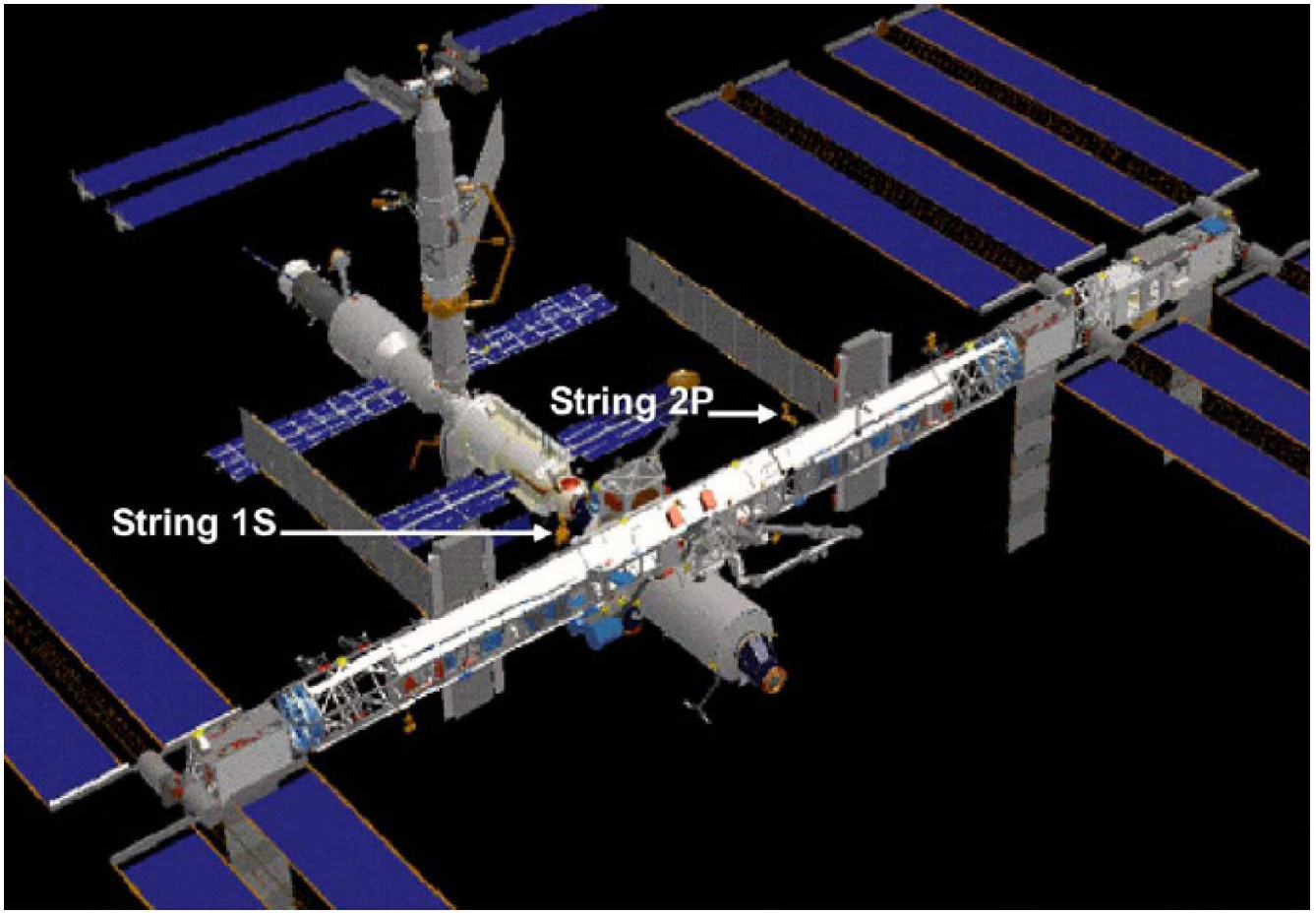
- 2.2-2.29 GHz uplink
- 2 strings (S1 truss, P1 truss)

Baseband Signal Processor — Transponder — Radio Frequency Group

Communication & Tracking System (con't)

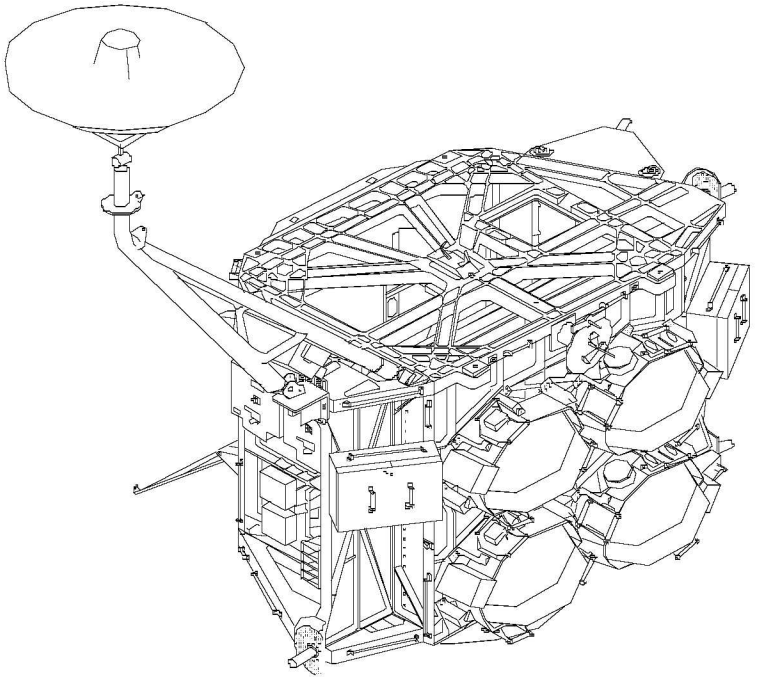
Redundant S-Band strings



Communication & Tracking System (con't)

Ku-Band

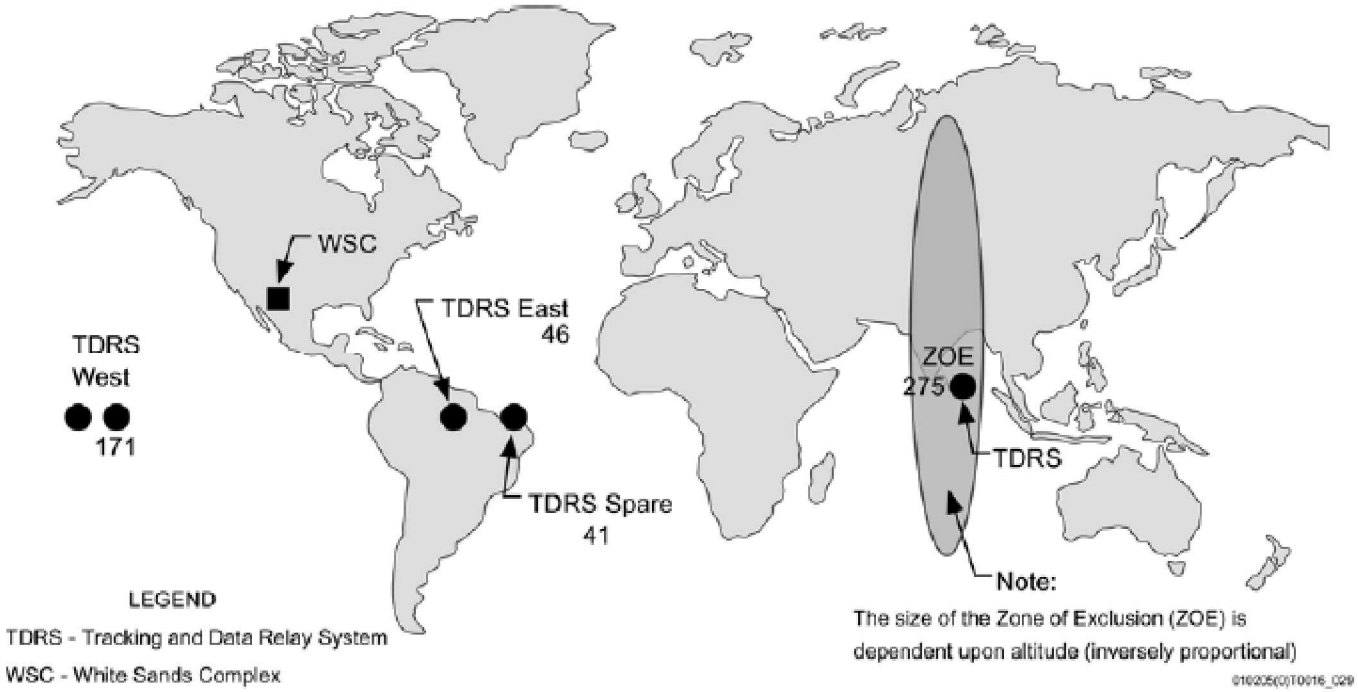
- payload data, video downlink, 2-way telecon
- 10.7-12.2 GHz downlink
- 14.0-14.5 uplink



Z1 truss & Ku-Band antenna

Communication & Tracking System (con't)

TDRSS

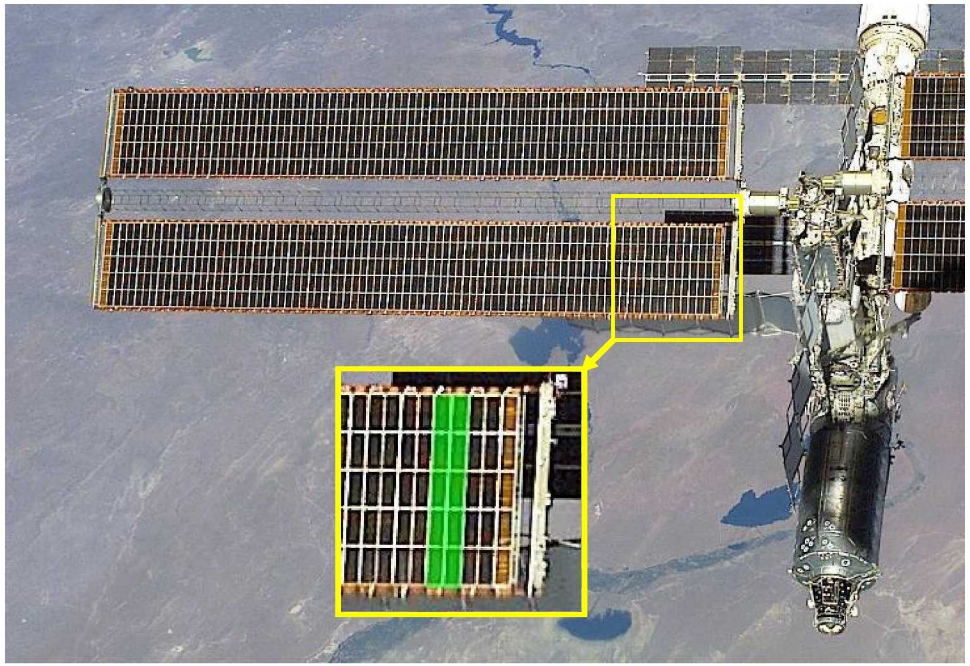


Electrical Power System

Solar Energy (photons) ⟶ Electrical Energy

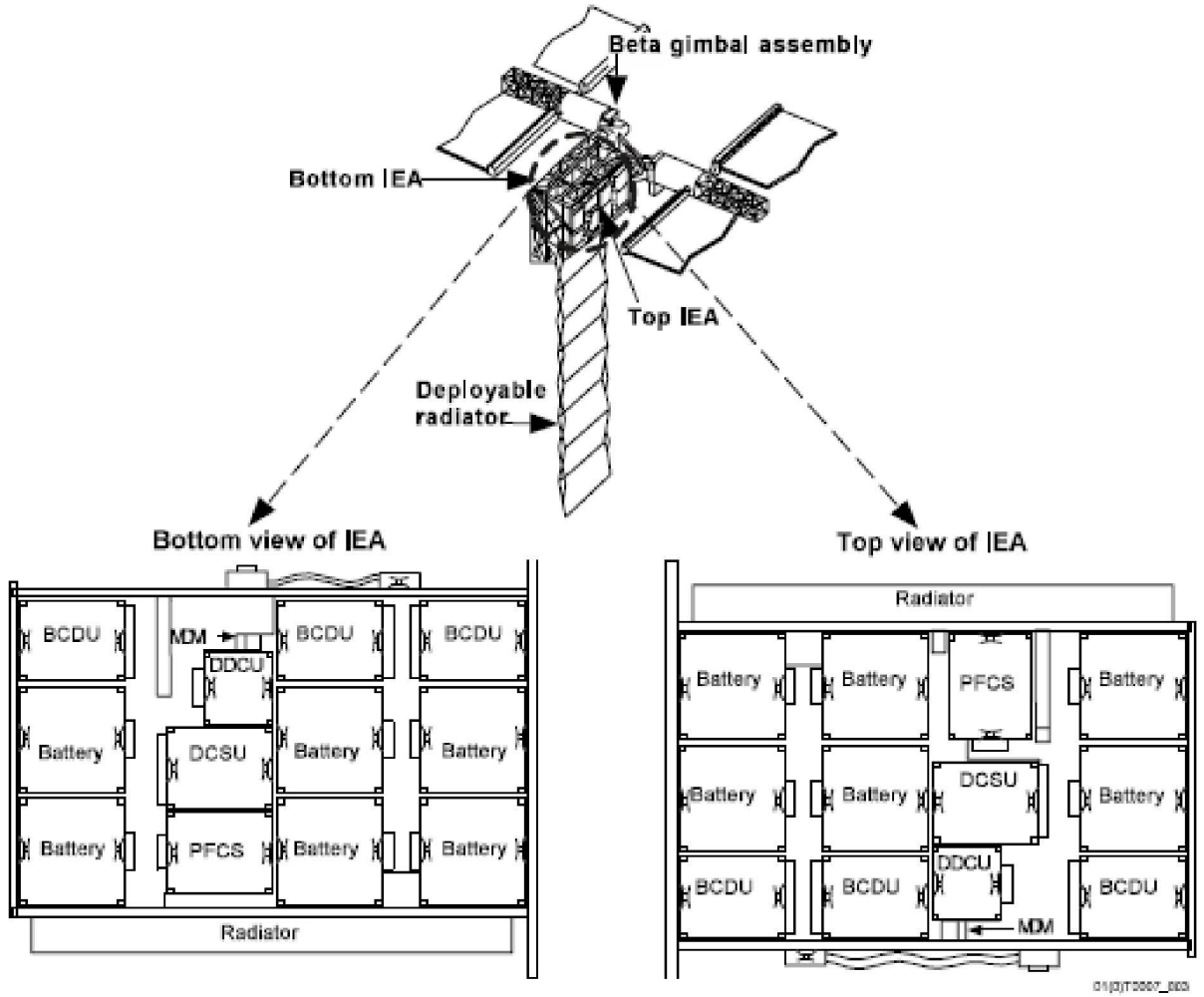
- Provide continuous power to ISS during insolation and eclipse

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

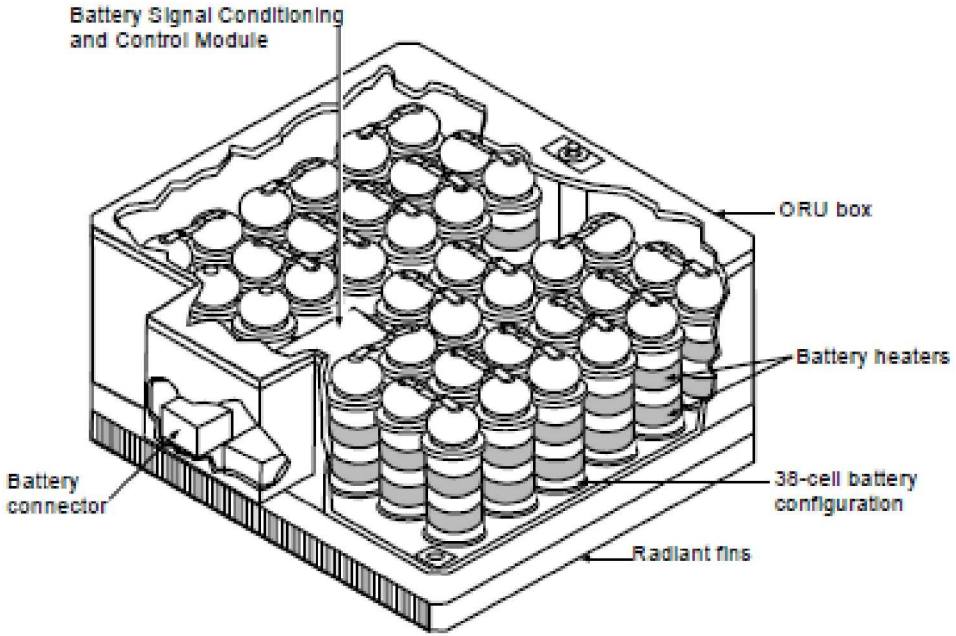
Electrical Power System (con't)



Electrical Power System (con't)

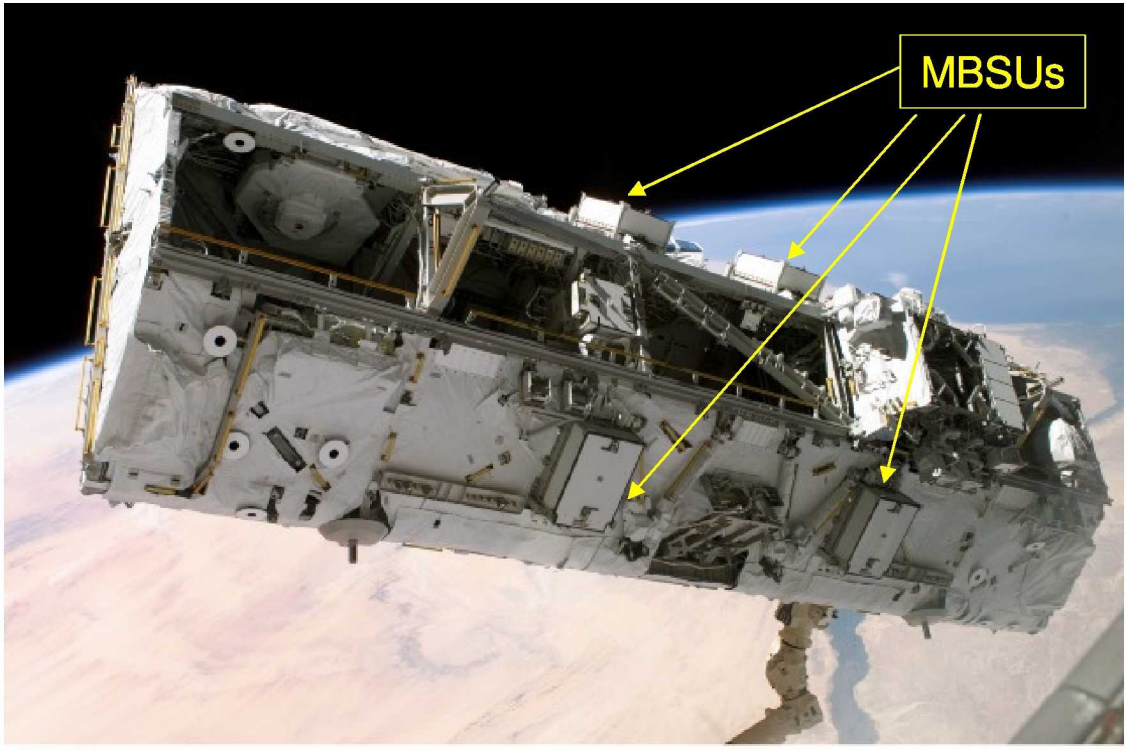
Primary power storage – NiH_2 batteries (0-10° C)

- 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.

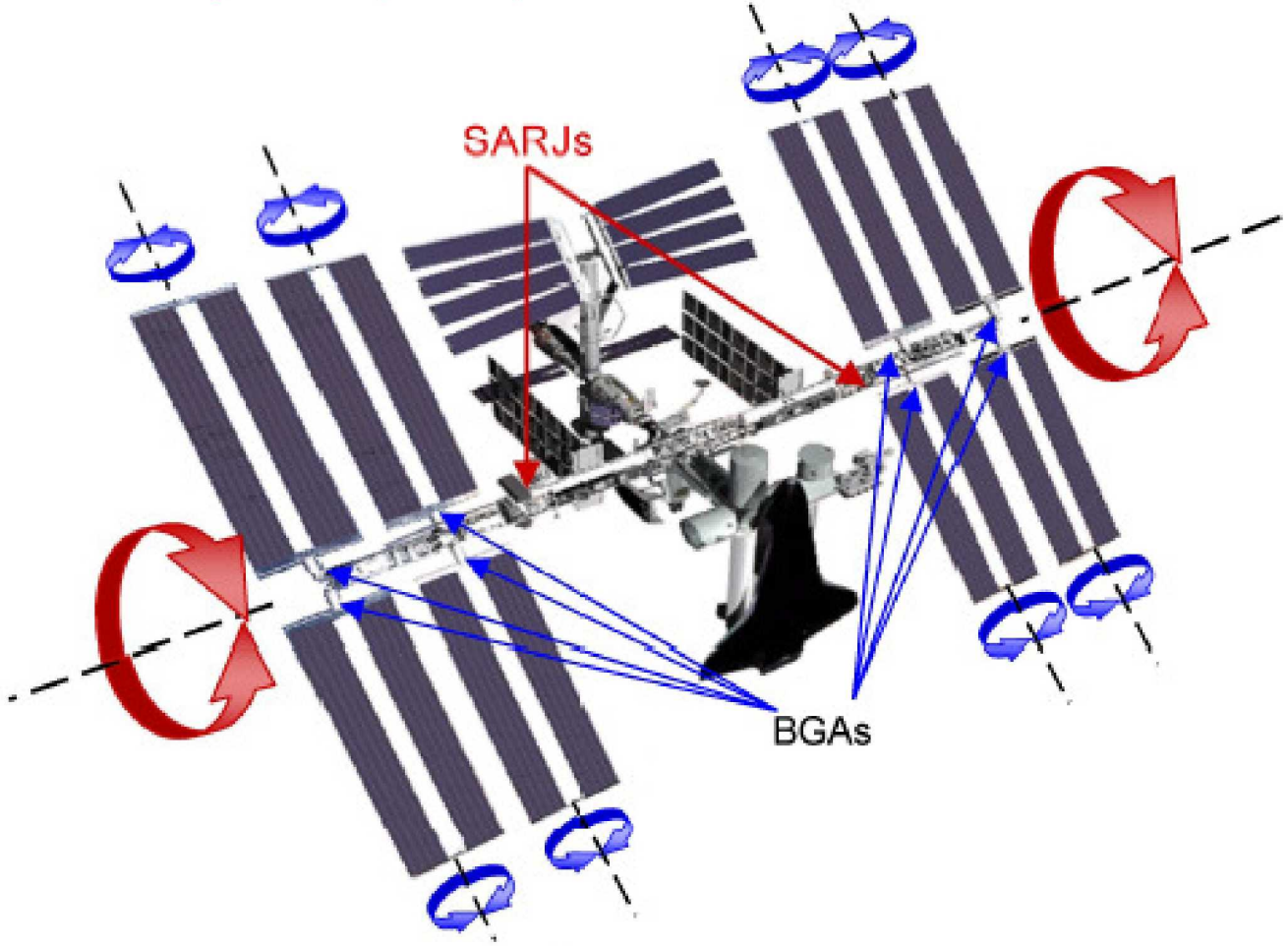


S110E5173

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)



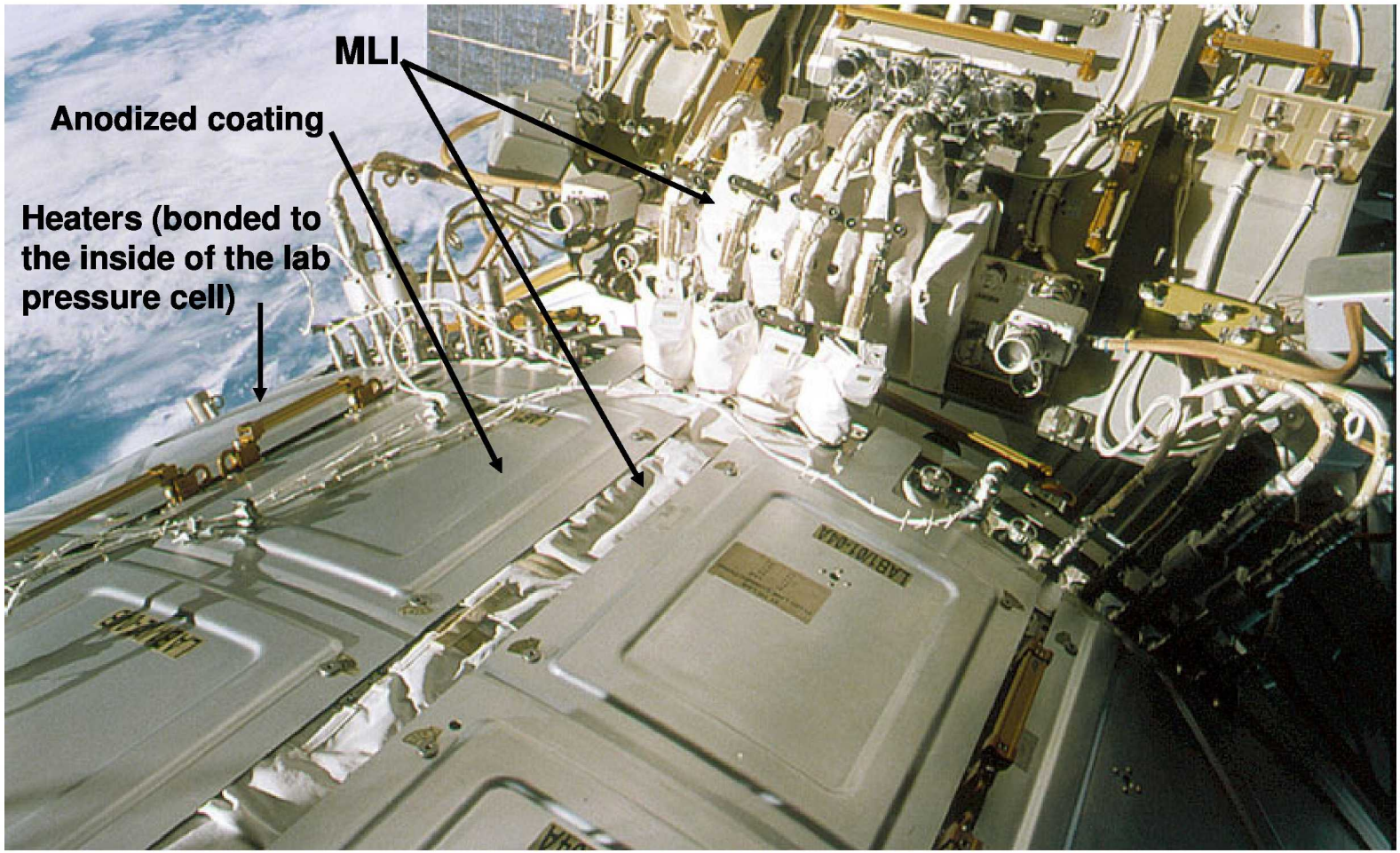
Thermal Control System

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))

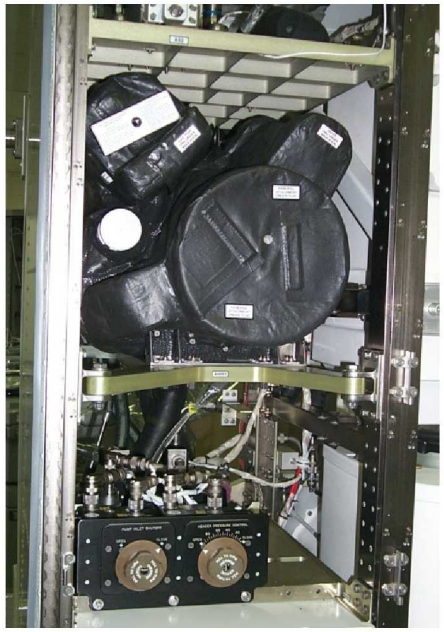
Thermal Control System (con't)



Thermal Control System (con't)

Active thermal control

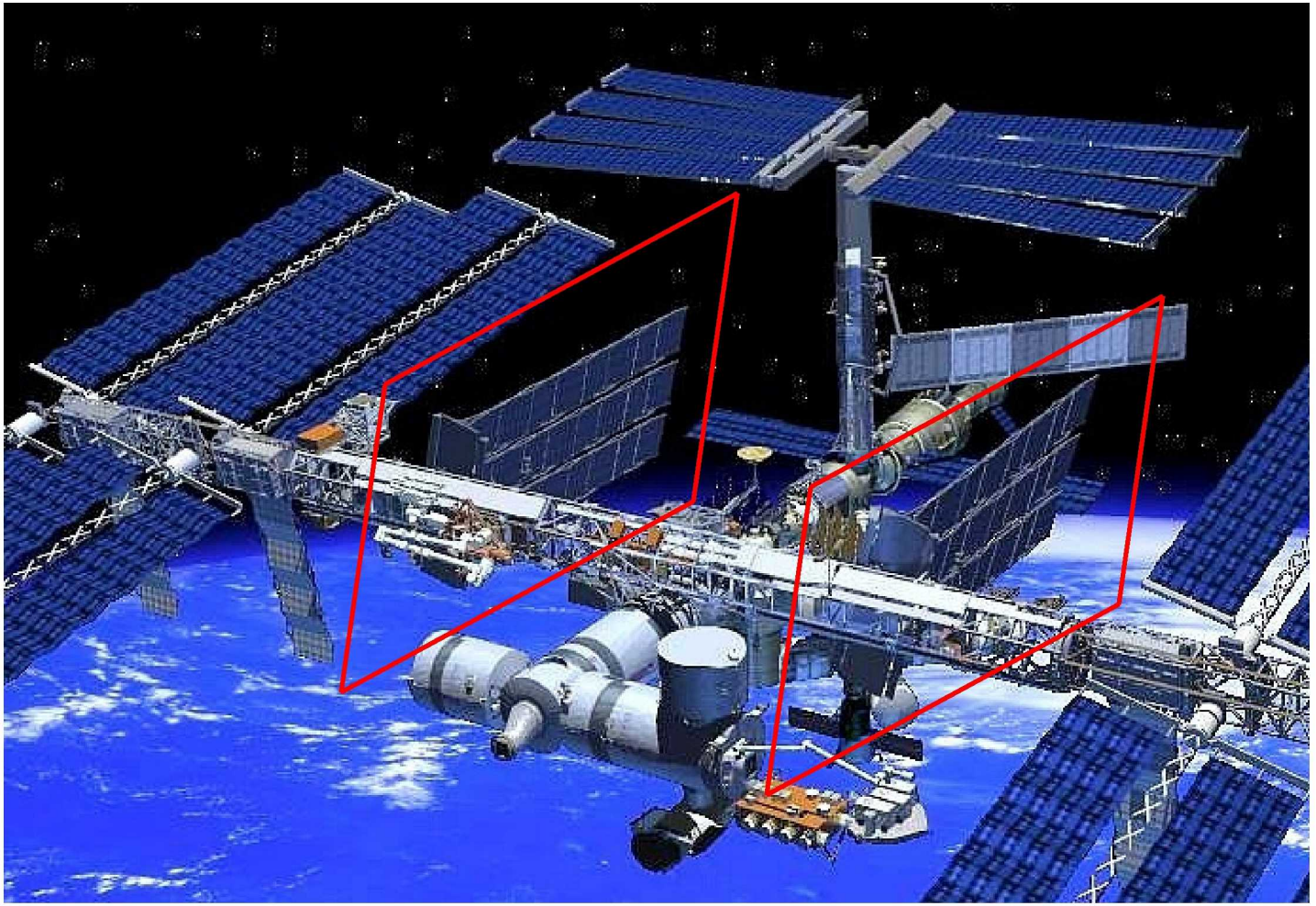
- Internal Thermal Cooling System (ITCS)
  - Working fluid = H_2O with teflon/Ti lines
  - Heat collection: cold plates & heat exchangers
  - Pump Package Assembly
  - Moderate Temperature Loop (MTL): 17° C
  - Low Temperature Loop (LTL): 4° C



- 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

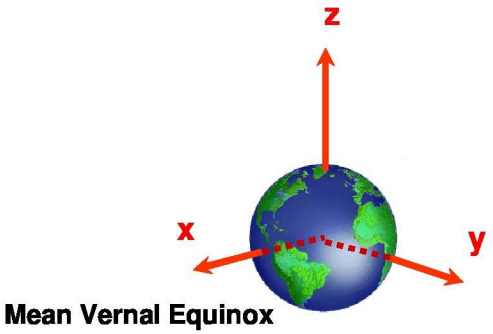
Thermal Control System (con't)

TRRJ

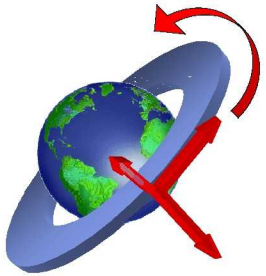


Motion Control System

- 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 reboosts via SM or Progress
- Provides state vector and attitude information to other ISS core systems



Mean Vernal Equinox
J2000



LVLH

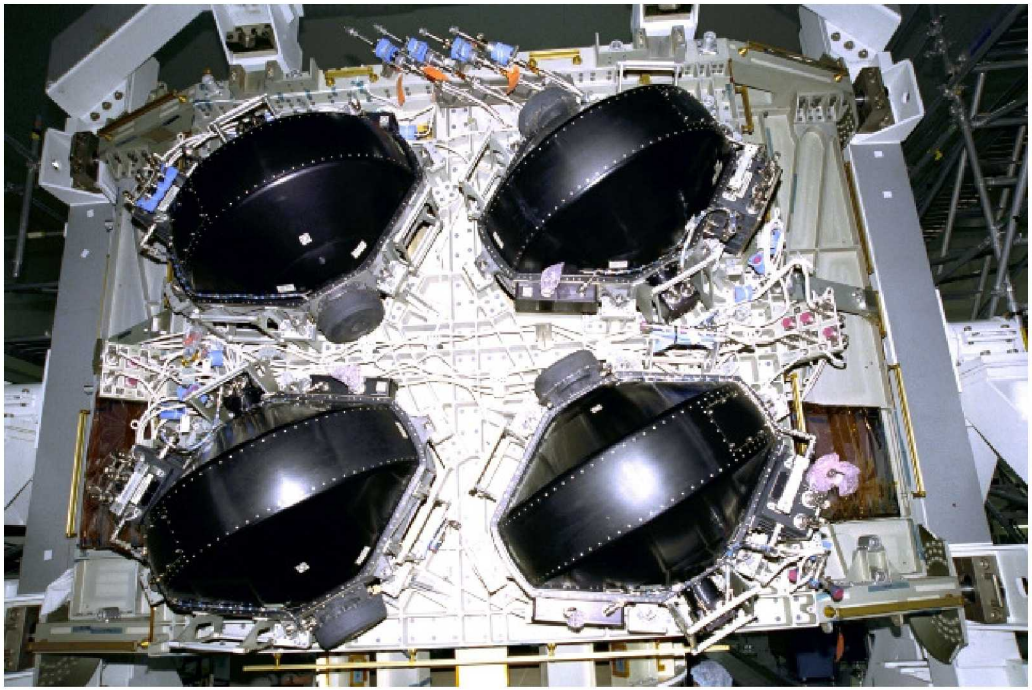
Motion Control System (con't)

USOS Attitude Control

Control Moment Gyros (CMGs)

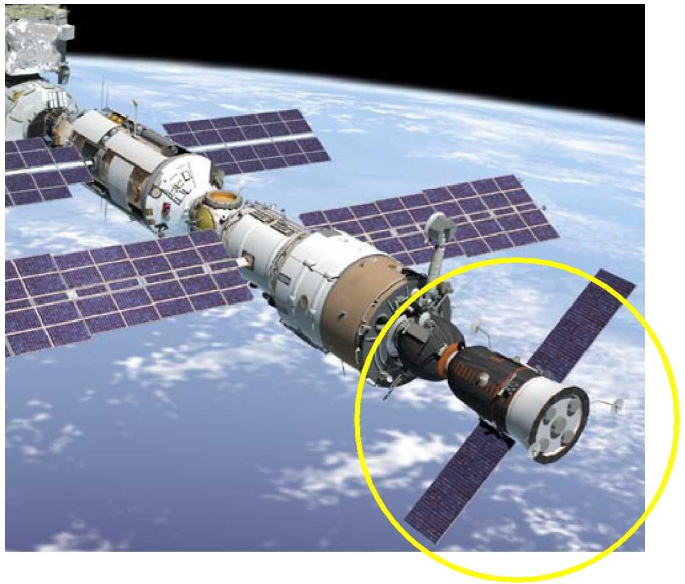
- 600 lbs each
- 6600 rpm
- 4880 N-m-s

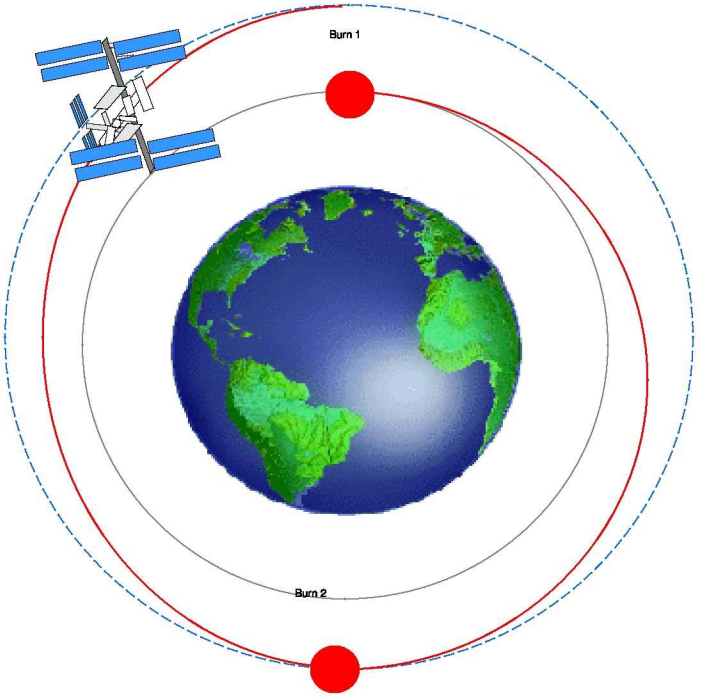
CMGs (Z1 truss)



Motion Control System (con't)

Translational Control (Reboost)





Robotics System

International collaboration:

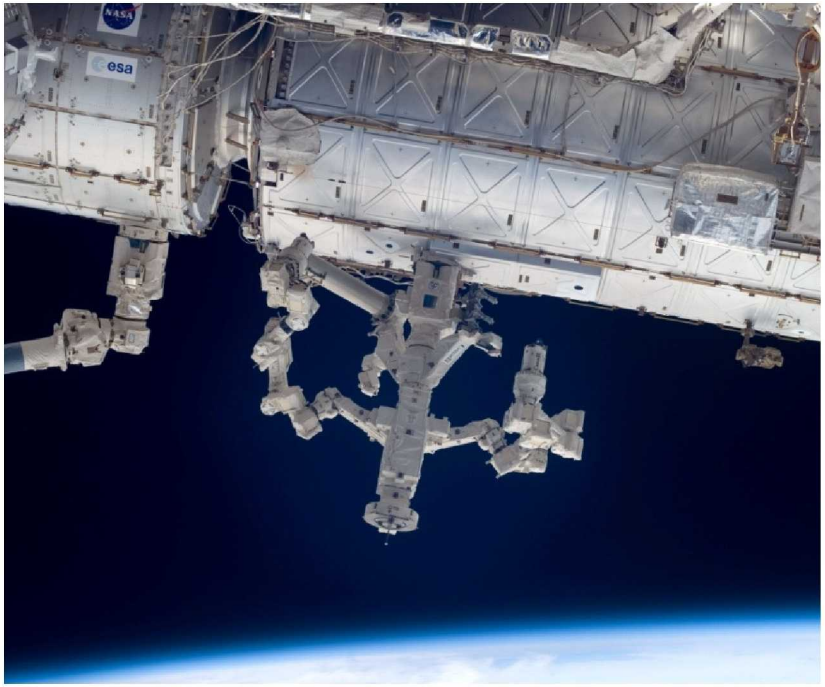
NASA, CSA, & JAXA

Functions:

- ISS assembly and maintenance
- EVA support and payload handling

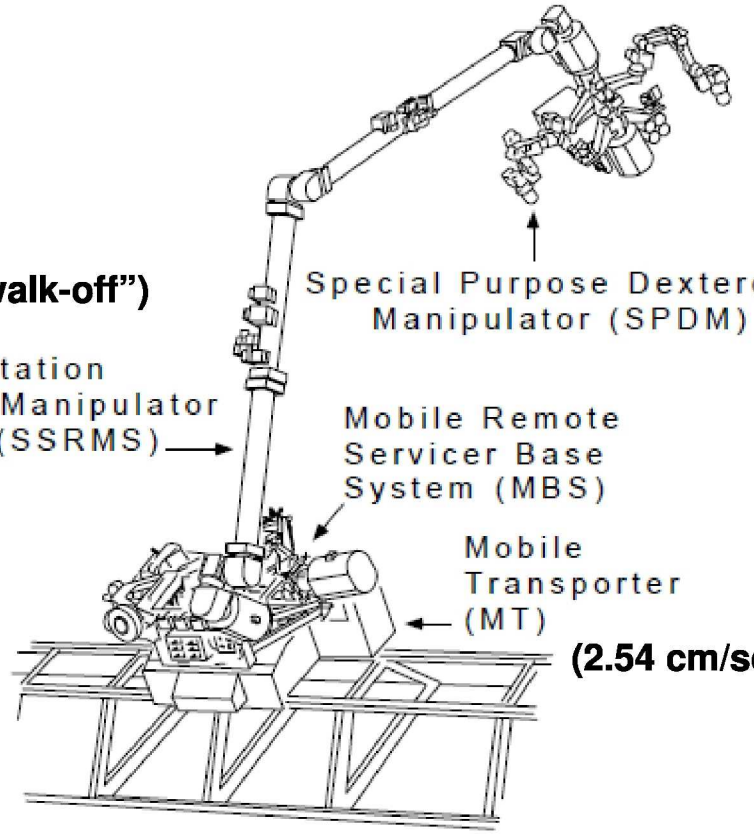
Systems:

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

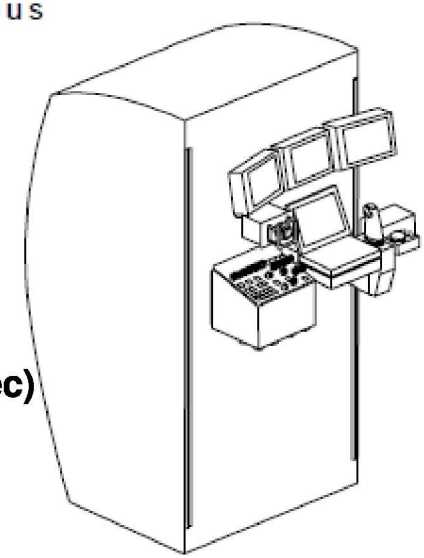


Robotics System (con't)

Mobile Servicing System (MSS)

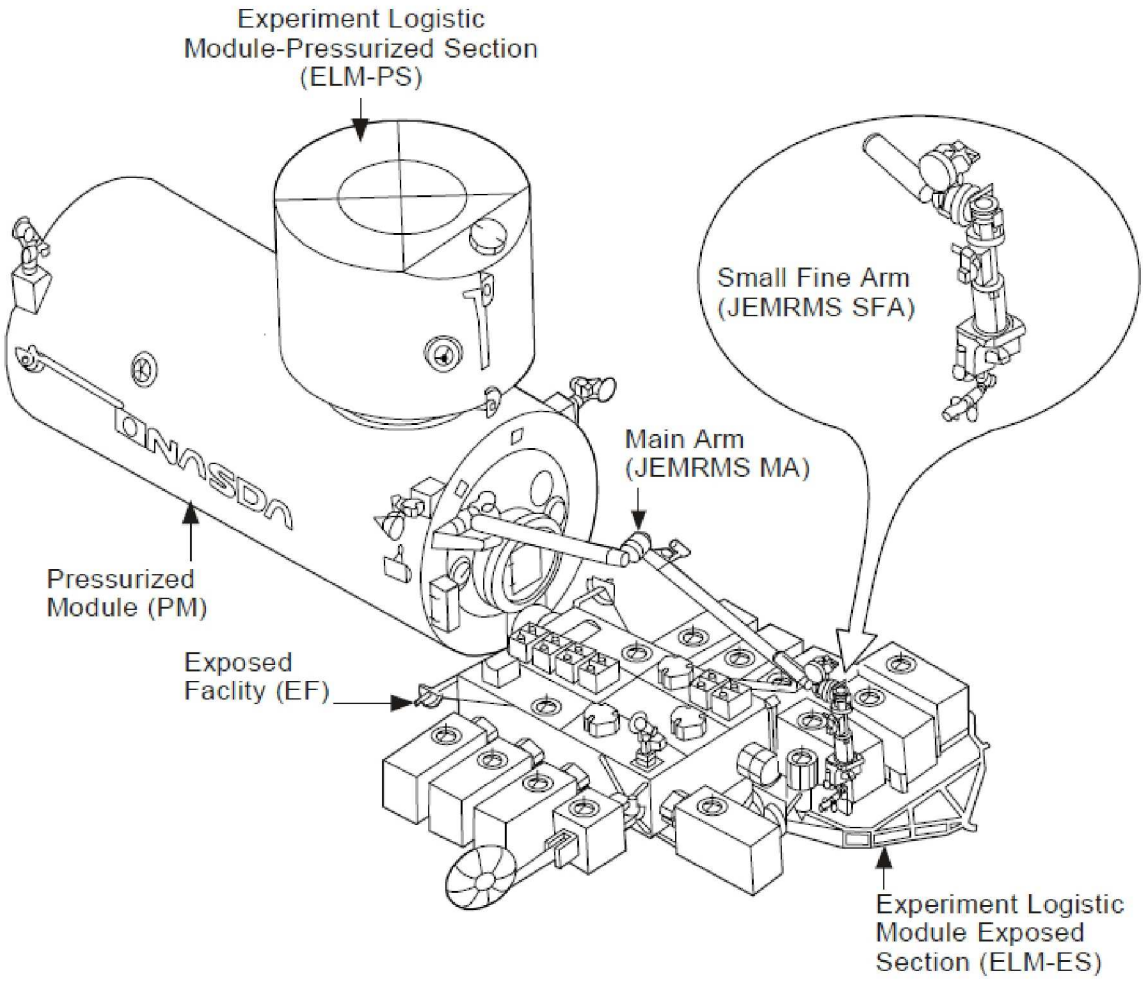


MSS External Components



Robotic Workstation (RWS)

Robotics System (con't)



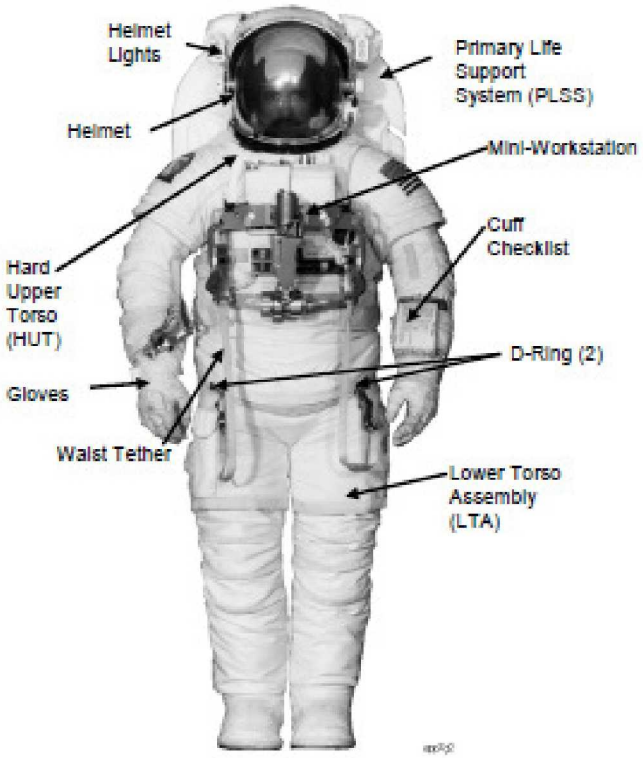
Robotics System (con't)

Robonaut (R2)

http://robonaut.jsc.nasa.gov/

Extravehicular Activity

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

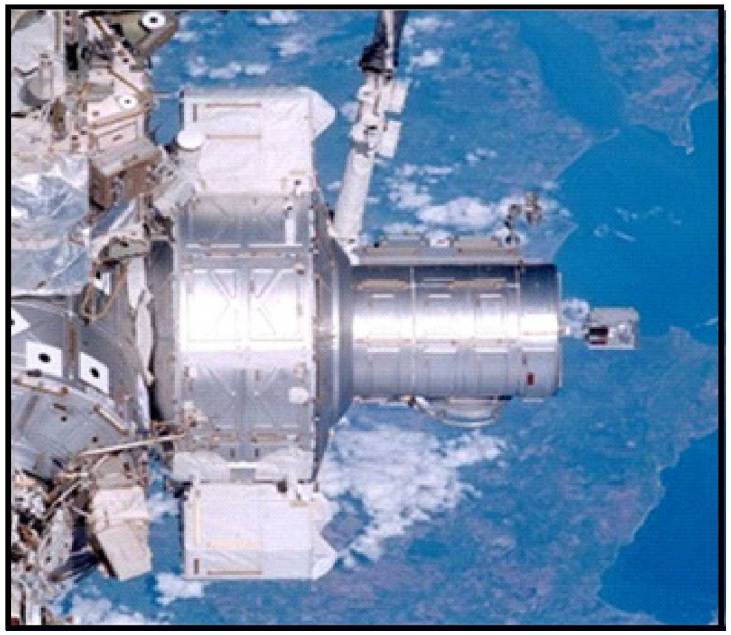


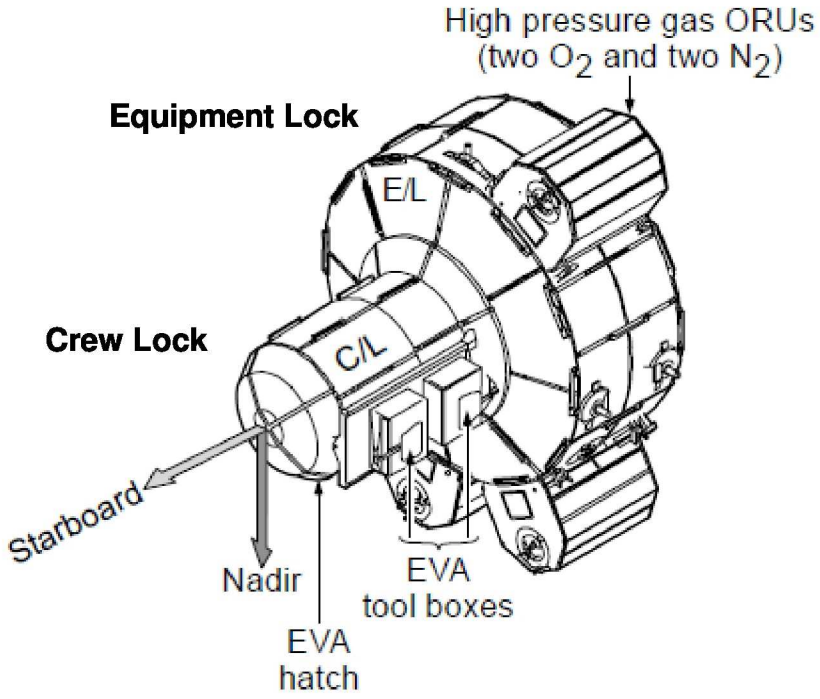
Extravehicular Mobility Unit (EMU)

- 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)

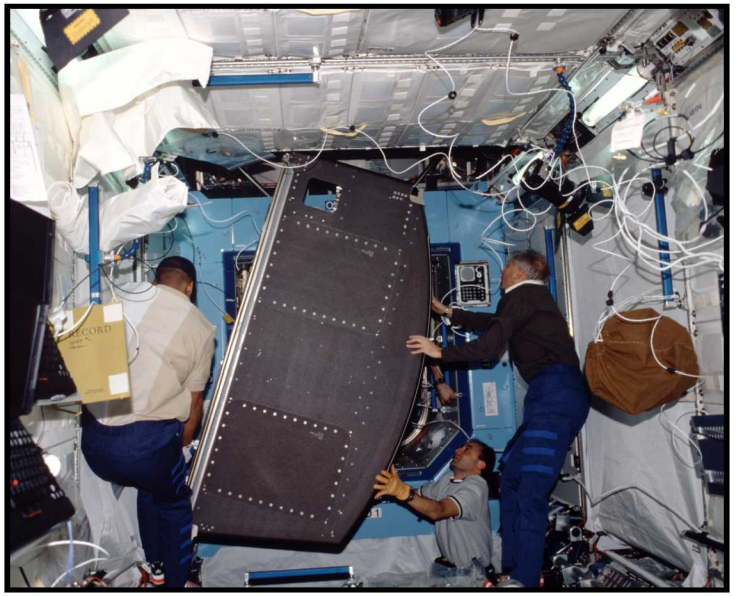
Payloads

Payload operations: Marshall Space Flight Center, Huntsville, AL

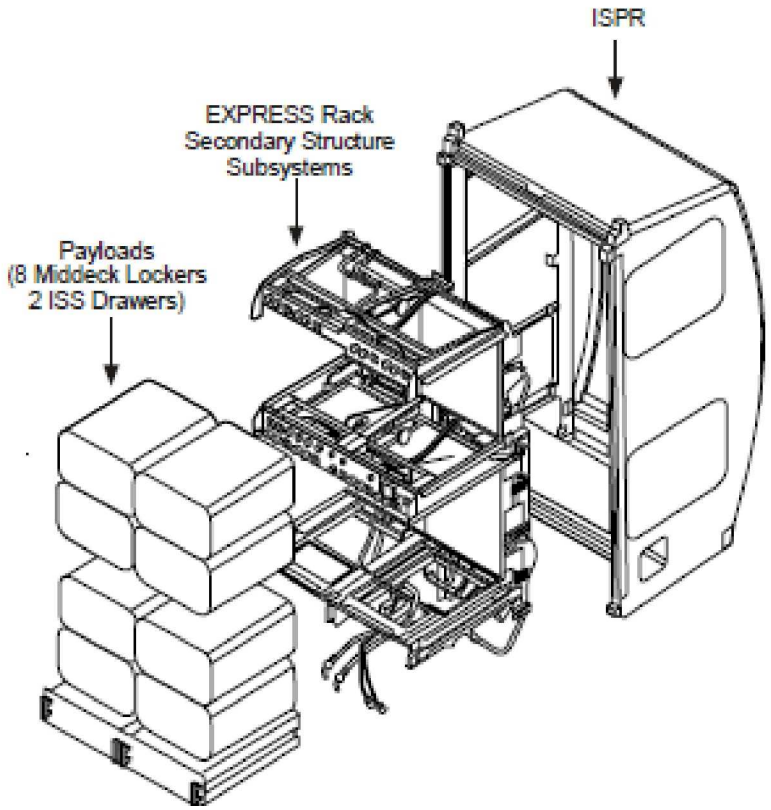
Payload components onboard ISS:

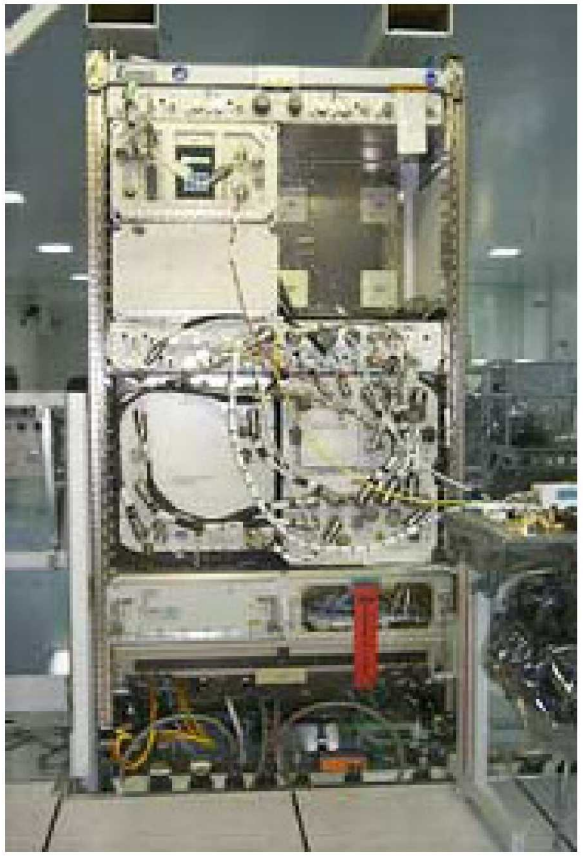
- U. S. Laboratory ("Destiny" Lab) – 24 rack locations
- Facility Class payloads – long-term or permanent payloads

- 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 Glovebox
- Fluids and Combustion Facility
- X-Ray Crystallography Facility
- Biotechnology Facility



Payloads (con't)



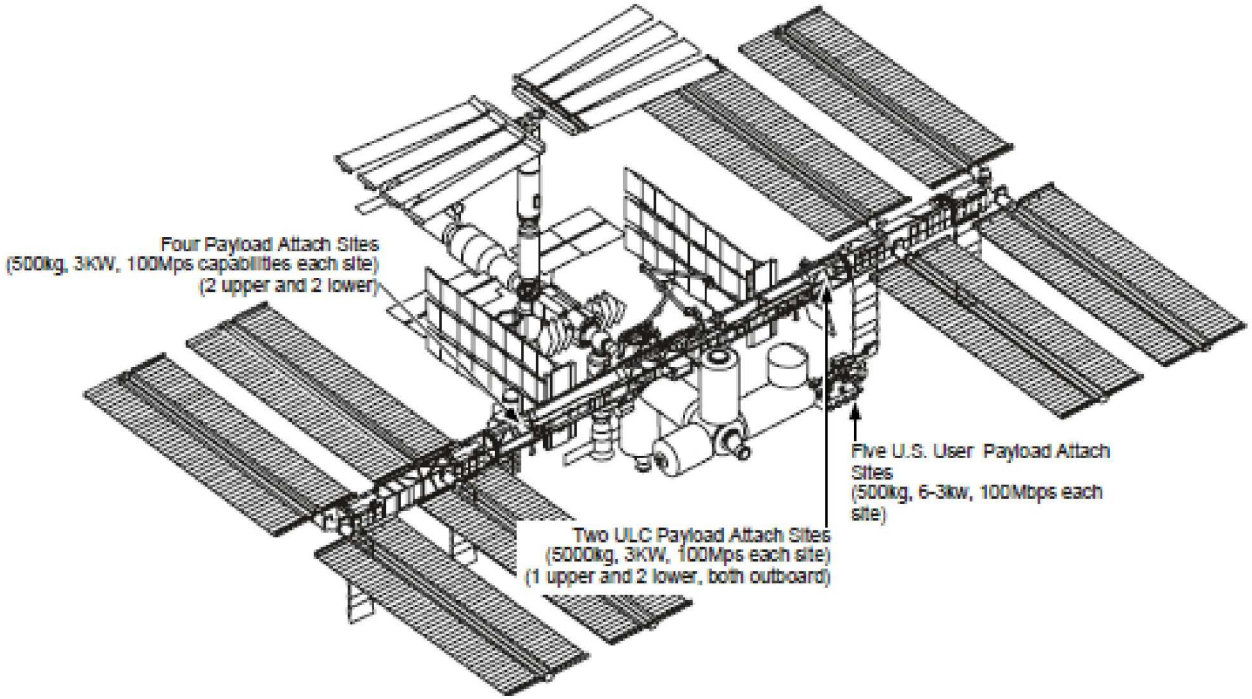


Express Rack

Payloads (con't)

- 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



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
- Biological Sciences
- Human Sciences
- Earth Observation
- Space Science

Earth & Space Science

EVC – Earth Viewing Camera

http://www.nasa.gov/mission_pages/station/science/experiments/EVC.html

CEO – Crew Earth Observations

http://www.nasa.gov/mission_pages/station/science/experiments/CEO.html

HREP-RAIDS – Remote Atmospheric and Ionic Detection System

http://www.nasa.gov/mission_pages/station/science/experiments/HREP-RAIDS.html#images

SOLSPEC – Solar

http://www.nasa.gov/mission_pages/station/science/experiments/SOLSPEC.html

SOVIM – Solar Variable and Irradiance Monitor

http://www.nasa.gov/mission_pages/station/science/experiments/SOVIM.html

MAXI – Monitor of All-sky X-Ray image

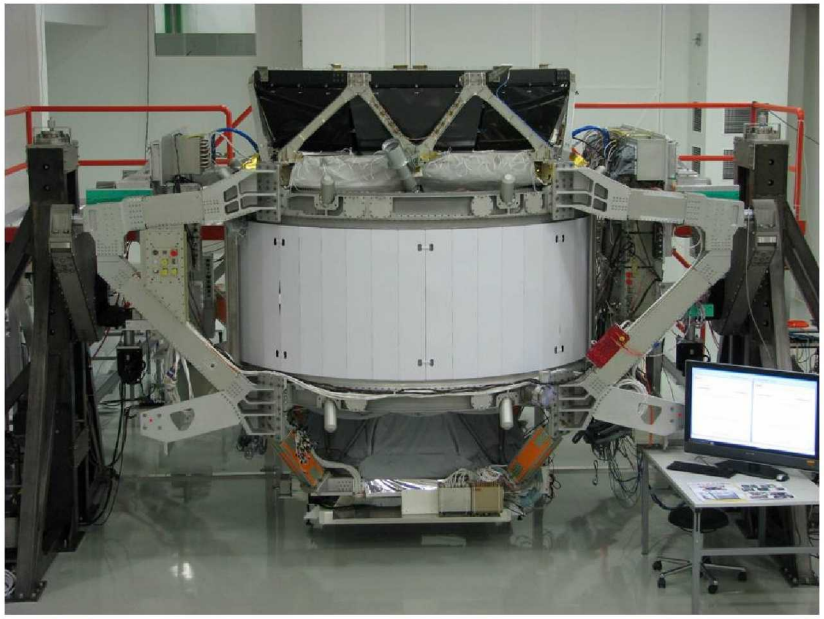
http://www.nasa.gov/mission_pages/station/science/experiments/MAXI.html#images

Alpha Magnetic Spectrometer

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

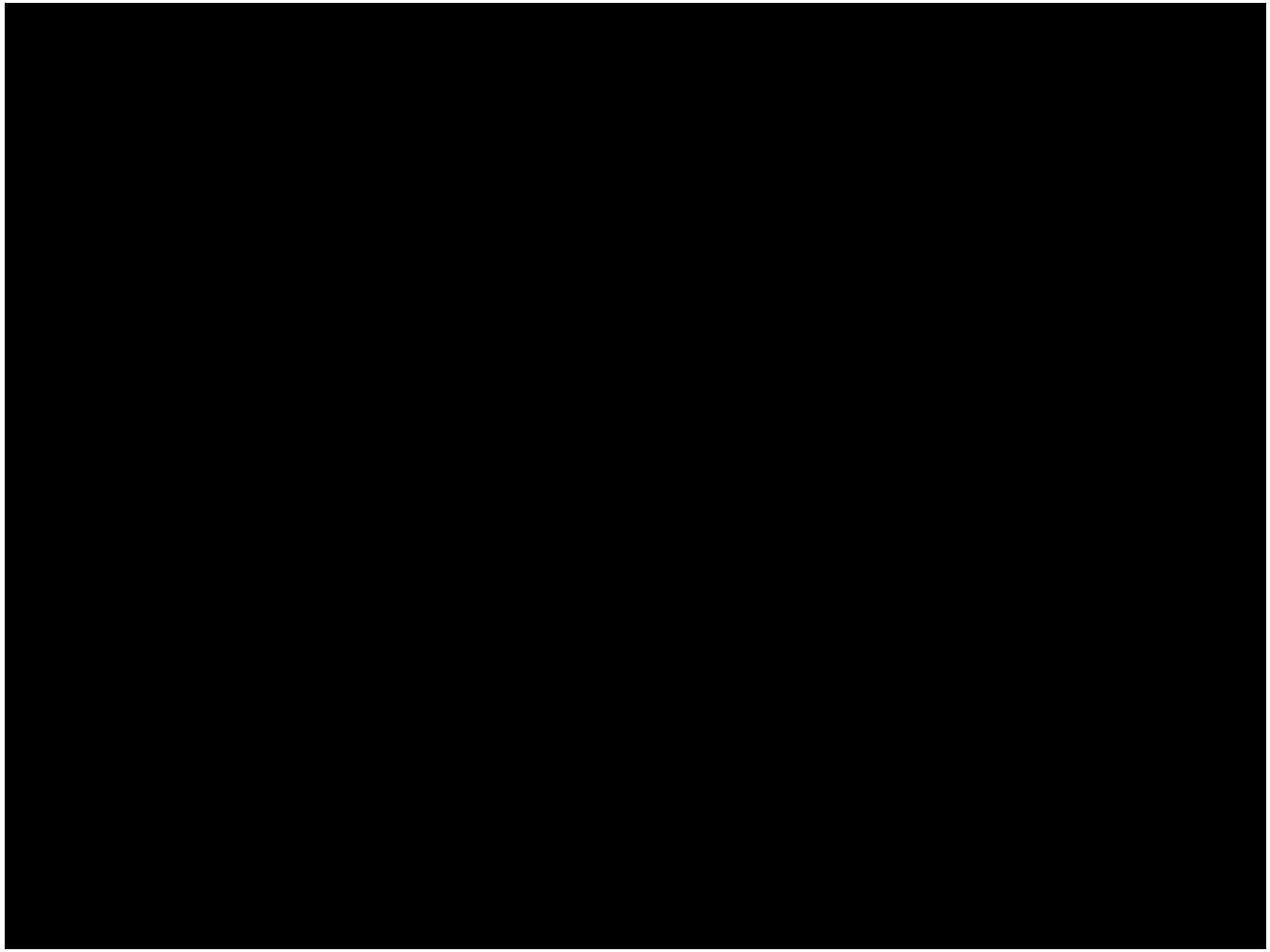
Alpha Magnetic Spectrometer (con't)

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



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

Alpha Magnetic Spectrometer (con't)



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