The International Space Station: Systems & Science

Timothy W. Giblin
United Space Alliance
NASA Johnson Space Center
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

<table>
<thead>
<tr>
<th>United States</th>
<th>Russia</th>
<th>Canada</th>
<th>Japan</th>
<th>Europe</th>
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</table>

- Orbital inclination 51.6°
- Orbital altitude 370-460 km
- Mass ~419,000 kg
- 1200 m³
- 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
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
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)
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

LEGEND
TDRS - Tracking and Data Relay System
WSC - White Sands Complex

Note:
The size of the Zone of Exclusion (ZOE) is dependant upon altitude (inversely proportional)
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/blacket) (~262,000 cells)
• sequential shunt unit – set pt voltage 160 V
Electrical Power System (con’t)
Primary power storage – NiH₂ 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).
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 (O₂ & MMOD protection)
- surface coatings – anodized coatings & paint w/varing emissivity and absorbtivity
- heaters – electrically powered (>300 on ISS)
- heat pipes – latent heat of vaporization (NH₃ fluid)
Thermal Control System (con’t)
Active thermal control

- **Internal Thermal Cooling System (ITCS)**
  - Working fluid = H₂O 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 – NH₃
  - Heat collection: interface heat exchangers
  - Two loops: Loop A (S1 truss) & Loop B (P1 truss)
  - Heat rejection: Thermal Radiators
Thermal Control System (con’t)
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
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)

(17 m, 7 joints, “walk-off”)

Special Purpose Dextereous Manipulator (SPDM)

Space Station Remote Manipulator System (SSRMS)

Mobile Remote Servicer Base System (MBS)

Mobile Transporter (MT)

MSS External Components

Robotic Workstation (RWS)

(2.54 cm/sec)
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

High pressure gas ORUs (two O₂ and two N₂)

Equipment Lock

Crew Lock

Starboard

Nadir

EVA hatch

EVA tool boxes
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)
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
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
EVC – Earth Viewing Camera

CEO – Crew Earth Observations

HREP-RAIDS – Remote Atmospheric and Ionic Detection System
http://www.nasa.gov/mission_pages/station/science/experiments/HREP-RAIDS.html#images

SOLSPEC – Solar

SOVIM – Solar Variable and Irradiance Monitor

MAXI – Monitor of All-sky X-Ray image
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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)

Questions?

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- heaters – electrically powered (>300 on ISS)
- heat pipes – latent heat of vaporization (NH₃ fluid)
Thermal Control System (con’t)

- MLI
- Anodized coating
- Heaters (bonded to the inside of the lab pressure cell)
Active thermal control

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Mean Vernal Equinox J2000

LVLH
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Payloads (con’t)

Express Rack

Payloads (8 Middeck Lockers, 2 ISS Drawers)

EXPRESS Rack Secondary Structure Subsystems

ISPR
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