The ISS as an Earth observation platform

Attitude stability, data rates, constraints and example international partner Earth observation payloads

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ISS as a space based observation platform

- 300km-460km, 51.6° inclination orbit
  - Covers ~85% of earth surface & ~95% population
- Infrastructure for instrument operation:
  - Power, data downlink, command uplink
- External instrument accommodations
  - Platforms on Truss & exterior of modules including Columbus
  - Connection to ISS power & data systems
- Internal instrument accommodations
  - Multiple Windows,
    - Nadir, limb & zenith
    - Variable quality, some optical quality & quartz (UV) transparent
  - Shirt sleeve environment
  - Connection to ISS power & data systems
ISS orbital characteristics for earth observation

- 51.6° Inclination Orbit
- 300km – 460km altitude
  - Distance to earth limb ~ 2300km
  - 16 orbits / day
  - Each successive orbit crosses equator 22.5° to west of preceding orbit
  - Nodal regression ~ 5° west/day
  - Solar Beta angle between 0° and ±75°

- ISS Attitude
  - Torque Equilibrium Attitude during normal operation
    - ~ 10° nose down & few degrees nose left, no role WRT LVLH
  - Local Vertical / Local Horizontal (LVLH) during docking operations & manouvers
ISS orbital characteristics for earth observation

Example of 24h coverage (16 orbits) of a 70km wide nadir swath instrument field of view

Procession of local time of daily ISS orbit passes over a selected location on the ground
ISS orbital characteristics for earth observation

Variation of solar beta angle for the ISS (when assembly complete) during 1 year

Note:
1. Assume the ISS nominal altitude of 407 km and inclination of 51.6 degrees.
2. Assume Vernal Equinox Day of 0th and right ascension of 0 degree.
3. Considering perturbation for aspherical earth only.

Figure1.1.1-3 An Example of The Annual Solar Beta Angle Variation for ISS Orbit
ISS orbital characteristics for earth observation

Variation of orbital altitude with time
Local Vertical Local Horizontal Attitude (LVLH)
Attitude stability, variability & predictability

• Measured Attitude
  – Determined from JAXA startracker & rate gyro
  – Normal operations
    • Approx 1° periodicity (+/-0.5°) in each axis over one orbit (smooth sinusoidal variation)
    • Attitude can be predicted up with accuracy of approx 0.2° for up to 4 days
  – Docking / manouevres
    • Attitude variations of several degrees possible during docking operations
    • Manouevres (reeboosts) approx 2-3° variation during a short period (1-2 orbits)
Attitude stability, variability & predictability

Microgravity environment

Quasi-steady Accelerations

Vibratory Accelerations
ISS External Instrument Accommodations

- JEM Exposed Facility
- Columbus External Payloads Facility
- US Truss (Port & Starboard attachment sites)
- Zvezda URM
- Columbus External Payloads Facility

[Image of the International Space Station with labeled features]
Columbus External Instruments Accommodation

- Columbus External Payload Facility (CEPF)
  - Platforms on exterior of Columbus for instruments
  - EUTEF platform carries EXPOSE, SOLAR & other experiments
  - 4x Express Pallet Adaptors
    - Up to 226kg payload per carrier
    - Up to 1.2kw power per carrier / 2.5kw max all carriers
    - 32Mbit/s data rate
**Kibo Exposed Facility**

Initial instrument configuration

- JEM Experiment Logistics Module - Pressurised Section (ELM-PS)
- JEM Remote Manipulator System (RMS)
- JEM Pressurised Module "KIBO"
- JEM Exposed Facility (EF)
- JEM Experiment Logistics Module - Exposed Section (ELM-ES)

**Directional Labels**

- STARBOARD
- AFT
- FORWARD
- PORT

**Instruments**

- HICO/RAIDS
- SMILE
- MAXI
- ICS
- SEDA-AP
There are two Science Sites on each ELC to accommodate external payloads.

Each Science Site Employs an Express Payload Adapter (ExPA) to accommodate payloads.

- 28 VDC and 120 VDC power
- 1553, Ethernet Data, Digital and Analog Discretes
- Each Logistics site only provides 120V Heater power
Accommodation of External Payloads on the Russian ISS Segment

- BioRisk
- IMPULS
- BTN
- Platan
- VSPLESK
Zvezda Portable Multipurpose Workstation (URM-D)

External Instruments Accommodation

Payload at nadir site
Payload at port site
Payload at zenith site
Passive adapter
Active adapter (part of URM-D)
Frame connector for Electrical interface
Base plate
Platform

Y axis
Z axis
Example External Instrument FOV: Columbus CEPF

Orbit Sunrise

Orbit Noon
Example External Instrument FOV: Columbus CEPF
Internal Instrument Accommodations

- **Cupola location** (to be installed in 2010)
- **Zvezda module Nadir Window**
- **Destiny Nadir Window**
- **Kibo Module (Including EF)**
- **Columbus Module**
- **P3**
- **S3**
ISS Windows: ESA Cupola

• Seven multipane windows
• Borosilicate glass
• Limb & downward viewing possible
ISS Windows: Destiny Module Window
Observation Research Facility (WORF)

- Dedicated Earth Observation Window
  - 50cm diameter optical quality
  - Nadir pointing
  - +/-30° zone of visibility

- Optical quality
  - Near UV, visible & near-IR transmission

- Integrated in rack facility:
  - Mechanical, electrical & data interfaces
ISS Windows: Zvezda Windows

- 14 Windows
  - Nadir, limb & zenith pointing
  - Varying optical quality
- Quartz Optical Window
  - Nadir pointing
  - UV, visible & near-IR transmission
  - Used for ATV-1 reentry observation (UV & visible imaging & spectroscopy)
Airborne observation campaign instruments:
Analogue concept to internal ISS optical instruments
Actual Data Rates: First 18 months of Columbus operation

• Data communication types
  – Payload 1553B interface Bus: low data rate and housekeeping telemetry (all payloads must use this interface) via analogue, discrete and serial connections to the payload control unit
  – Medium data rate: Standard Ethernet LAN, limited to 10Mb/s (currently restricted 3Mbps). Future evolution may permit data rates up 100Mb/s
  – High data rate: Fibre optic line Up to 32Mb/s/channel to be expanded to 120Mb/s/channel

• Examples of actual data rates
  – ESA EDR Facility: ~2Mb/s near continuously for an operating run of 120 days total duration (During LOS data dumped to HCOR)
  – ESA EVC experiment externally attached to CEPF: ~2Mb/s for 6-8h once per week, supplemented with ~2Mb/s for 1h each day.
  – ESA FSL facility: 8Mb/s for 6-8h period once per week
  – JAXA MAXI Instrument (on Kibo-EF): 0.6Mb/s continuous
  – JAXA SMILES Instrument (on Kibo-EF): 0.2Mb/s continuous
Examples of International Partner Earth Science Instruments on ISS

NASA, JAXA & RSA Instruments
Configuration of JEM-EF

- JEM-EF can accommodate 10 experiment payloads
- 5 ports for JAXA, 5 ports for NASA
- JEM-EF can provide following accommodation:
  1. Electrical Power
  2. Communication
  3. Exhaust Heat (using cooling medium)
1st phase utilization of JEM Exposed Facility

Launch schedule

Superconducting Sub millimeter-wave Limb-Emission Sounder (SMILES)

SMILES will be launched by HTV in 2009

Space Environment Data Acquisition (SEDA)

Solar flare induced neutron detected by BBN in US Lab "Destiny"

MAXI will be launched by Shuttle 2J/A

SEDA-AP will be launched by Shuttle 2J/A

Monitor of All-sky X-ray Image (MAXI)

Engineering Model

Thermal & Structure Model

Flight Model
Not only in the polar latitudes, but also in the mid- and lower latitudes, ozone depletion is critical whole the globe. The recovery is estimated around 2060–2070, but there is very big uncertainty in association with the Cl and Br chemistries (WMO, 2006)

Model results for the future Antarctic ozone amount calculated from chemistry–climate models (WMO, 2006)
**JAXA SMILES**

*Submillimeter limb–emission sounding and global observation*

- High sensitivity in detecting atmospheric limb emission of the submillimeter wave range (640GHz)
- Vertical profiling (~3km) from JEM/ISS with latitudinal coverage of 65N to 38S

→ Measurements on several radical species crucial to the ozone chemistry (normal O₃, isotope O₃, ClO, HCl, HOCl, BrO, HO₂, H₂O₂)
JEM/SMILES Payload

- Attitude Reference: Star Tracker + Rate Gyro
- Attitude Data accurate to better than 1’ (arc seconds)
- Antenna scanning through predicted attitude range (parameters calculated & uplinked)

Overview

Flight Model

Major Design Parameters

- RF: 640 GHz band
- Spectral Coverage: 1200 MHz x 2
- Antenna: 40 cm x 20 cm
- Weight: < 500 kg
- Mission Life: 1 year
JAXA SMILES

JEM/SMILES observation performance

Error estimation for the mid-latitude case based on the single scan measurement
The HREP payload hosts two experiments, the Remote Atmospheric and Ionospheric Detection System (RAIDS) and the Hyperspectral Imager For The Coastal Ocean (HICO).

RAIDS will provide atmospheric scientists with a complete description of the major constituents of the thermosphere and ionosphere, global electron density profiles at altitudes between 200–750 km.

HICO will launch and operate a rapid-development, cost-constrained Visible and Near-Infrared (VNIR) Maritime Hyperspectral Imaging (MHSI) system, to detect, identify and quantify of coastal geophysical features.
RUSSIAN ISS Earth Observation Projects:

Environment-1

Experiment “Diatomia”: Detection and study of ocean bioproductivity

Experiment “Seiner”: Space fish finding

Geographical location and shape of high-productive water area of Canary upwelling in intensification 06.01.2008 г. (A) and relaxation 12.06.2005 г. (B) periods.

The area of Magdalena river run-off in 04.01.2004 г. (A) and 06.01.2008 г. (B)
Experiment “Vsplesk”: study of the origin of seismo–magnetosphere phenomena and development of earthquake forecast methods with the precursor-bursts of high-energy charged particles in the near-Earth space.

Experiment “Seismoprognoz”: study of ionospheric earthquake precursors (electron concentration altitude profiles in seismic areas)

Experiment “Relaxation”: Study of atmospheric optical phenomena on the orbital altitudes

Experiment “Hydroxyl”: Upper atmosphere monitoring for the geophysical disasters forecasting, including global warming effects.

“Rusalka” experiment: Development of methods of CO₂ and methane content determination in Earth atmosphere from ISS board for climate change modelling.
Serendipitous earth observations from ISS: Eruption of Sarychev peak, Kuril Islands

- Sarychev peak in the Kuril Islands erupted on the 12th June
- ISS passed over the volcano minutes after the start of the eruption
- 19 photographs were obtained by a crew member using a digital stills camera which provide a unique record of the early events in a volcanic eruption

15th June MODIS image for comparison
Candidate earth sciences related ESA education activities

- Candidate education activities use digital stills photography & video from ISS
- Noctilucent clouds
- Stratospheric volcanic dust
- Imaging of ozone layer