ISS OPERATIONS & PLANNING FOR HUMAN SPACEFLIGHT

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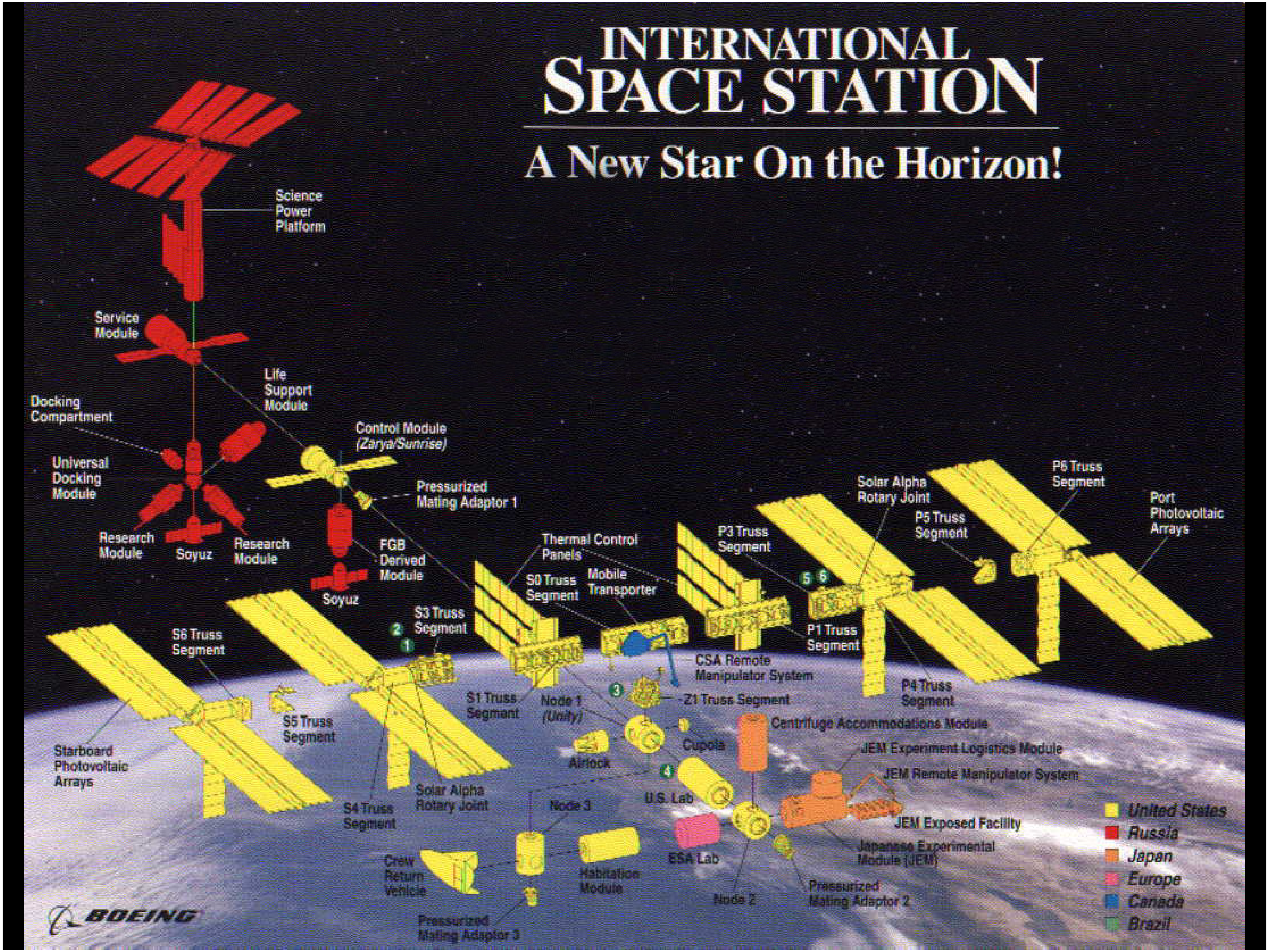
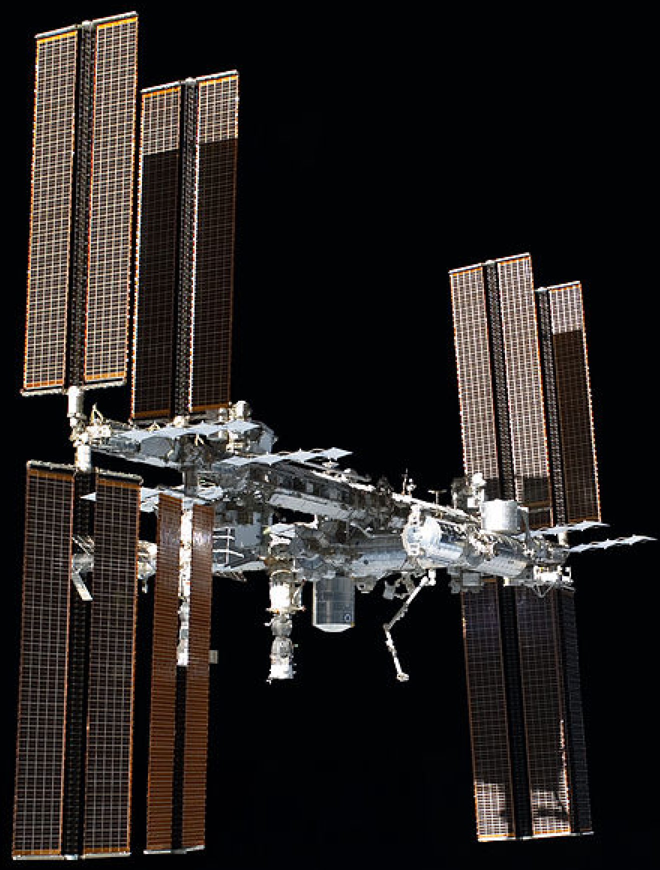
Overview

- What is the International Space Station
- What is life like on the ISS
- What is Mission Control and how do we operate and control ISS operations
- What are considerations for human spaceflight



INTERNATIONAL
SPACE STATION
A New Star On the Horizon!
Science Power Platform
Service Module
Life Support Module
Docking Compartment
Control Module (Zarya/Sunrise)
Universal Docking Module
Pressurized Mating Adaptor 1
Research Module
Soyuz
Research Module
FGB Derived Module
Soyuz
Thermal Control Panels
S0 Truss Segment
Mobile Transporter
P3 Truss Segment
Solar Alpha Rotary Joint
P5 Truss Segment
P6 Truss Segment
Port Photovoltaic Arrays
S3 Truss Segment
S6 Truss Segment
P1 Truss Segment
CSA Remote Manipulator System
P4 Truss Segment
S1 Truss Segment
Node 1 (Unity)
Z1 Truss Segment
S5 Truss Segment
Centrifuge Accommodations Module
Cupola
Starboard Photovoltaic Arrays
Airlock
JEM Experiment Logistics Module
JEM Remote Manipulator System
Solar Alpha Rotary Joint
U.S. Lab
S4 Truss Segment
Node 3
JEM Exposed Facility
Japanese Experimental Module (JEM)
ESA Lab
Crew Return Vehicle
Habitation Module
Node 2
Pressurized Mating Adaptor 2
Pressurized Mating Adaptor 3
BOEING
United States
Russia
Japan
Europe
Canada
Brazil

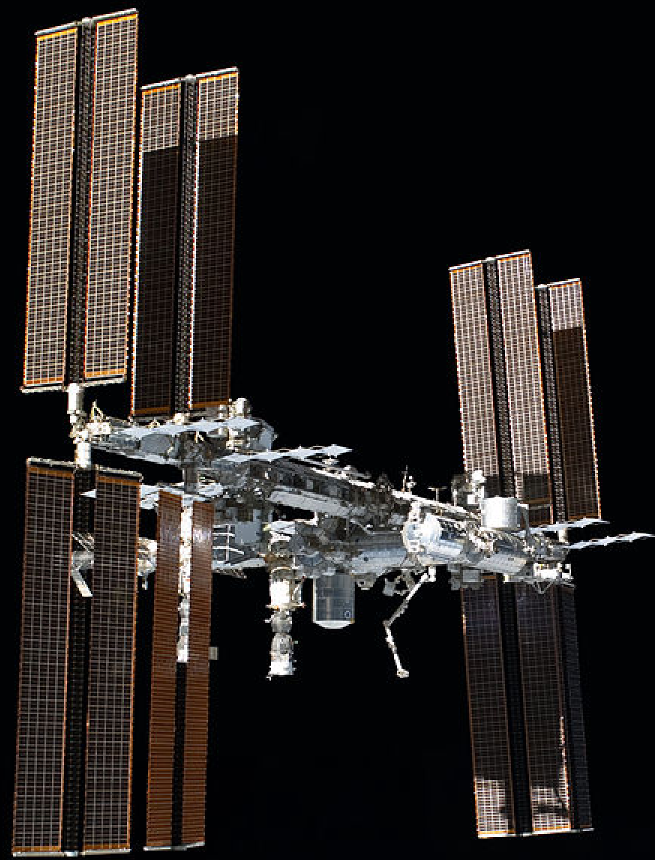
International Space Station



Space Station -

- Assembled in orbit between 1998-2011, manned continuously since 2000
- Components built by hundreds of companies across 16 nations. 100+ launches from Florida, Russia, Japan, and French Guiana
- Research crew of 6 astronauts and cosmonauts serve 6 month stays, rotating 3 at a time from Earth by a Russian Soyuz spacecraft.

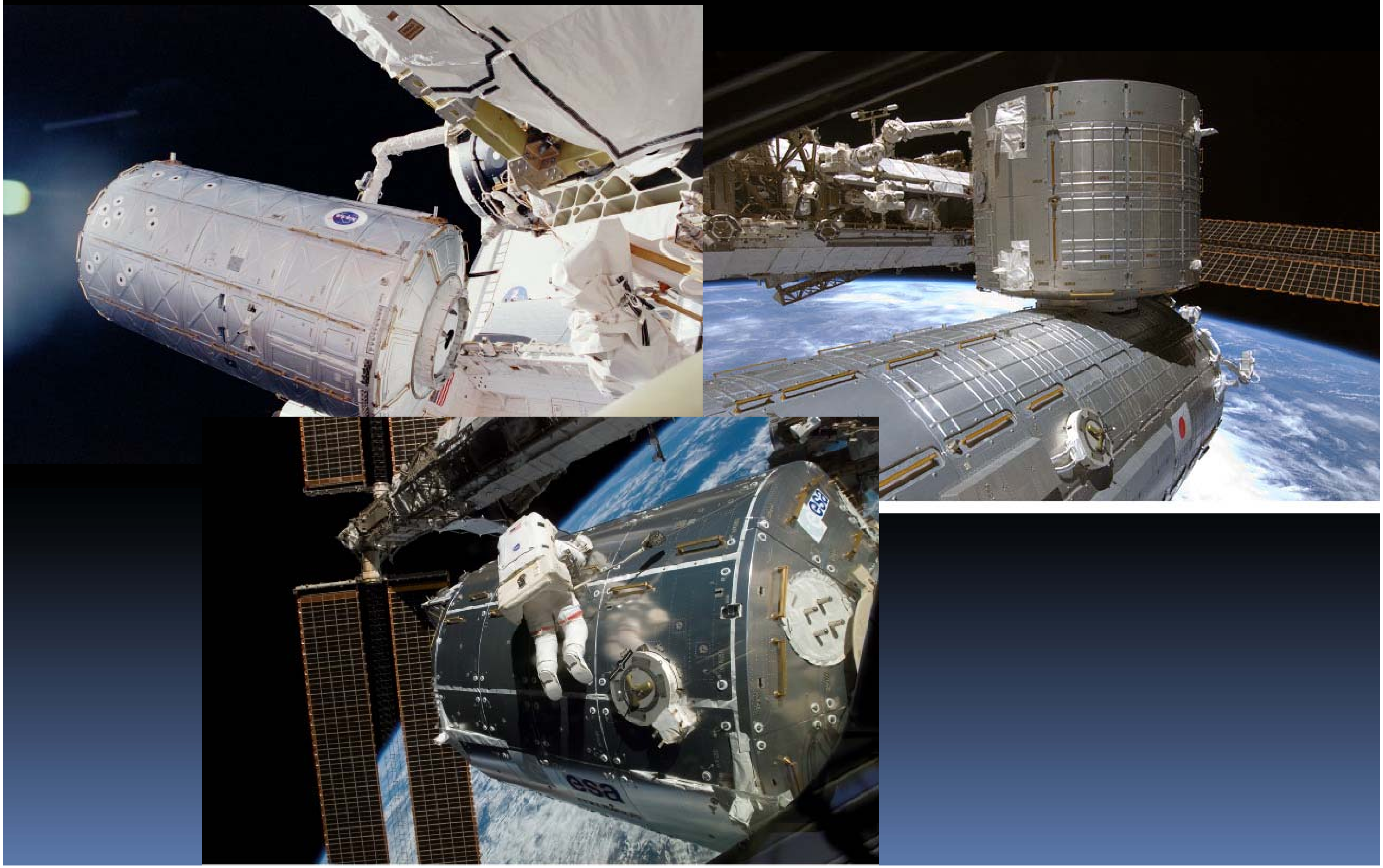
International Space Station



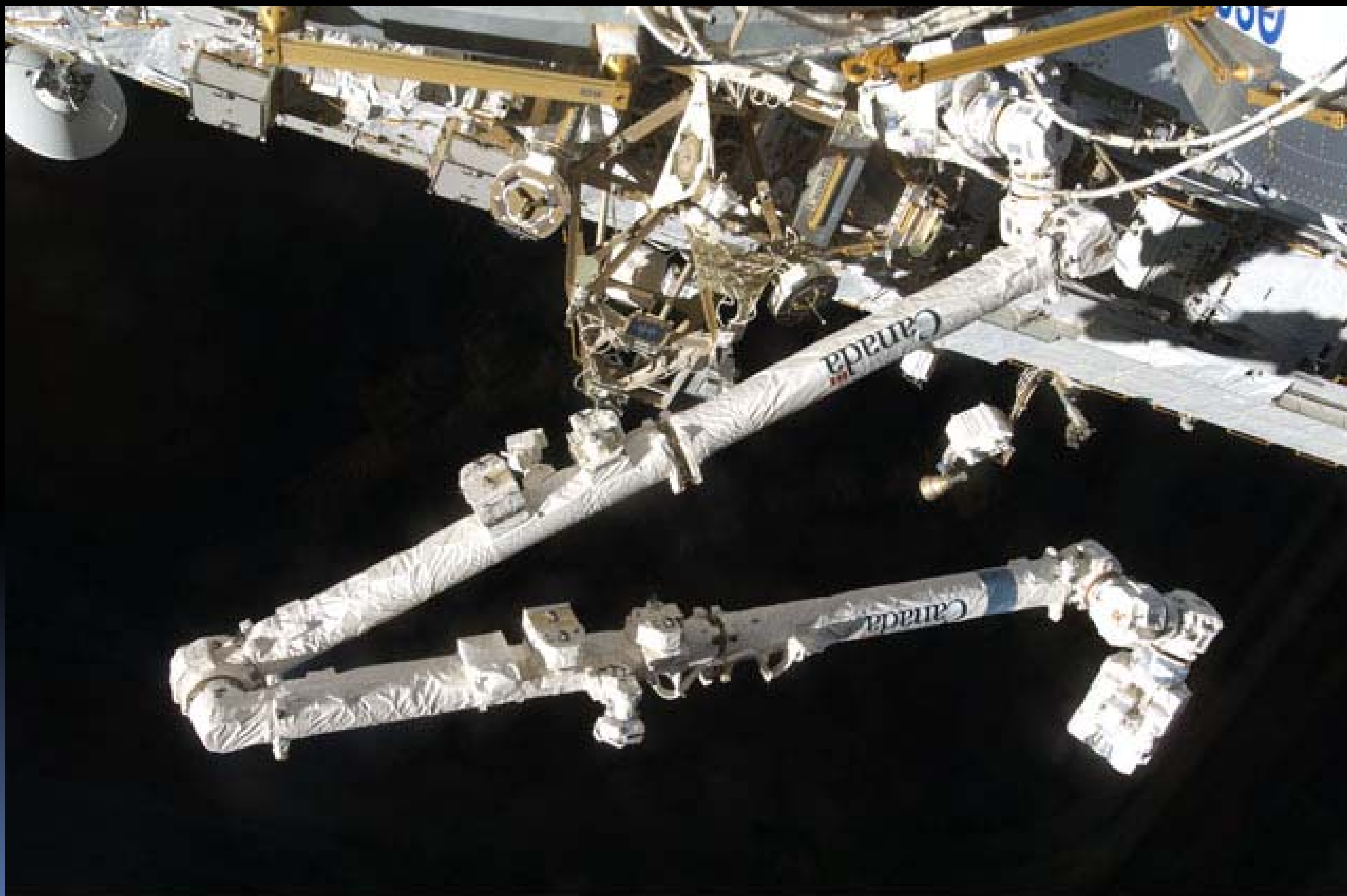
- Power provided by 4 pairs of Solar Arrays (.88 acres)
- Attitude maintained by gyros (US) and thrusters (Russian)
- Communications:
  - S-bd: Audio and cmd/tlm
  - Ku-bd: video, audio, data transfer
  - Ground sites: audio, cmd/tlm
- Truss and Solar Arrays measure 357ft end-to-end
- Internal volume equal to a 5 bedroom house

International Crew Complement

International Science Modules



Space Station Robotics – Canada and Japan



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Russian Soyuz Crew Transport

Cargo Delivery to ISS

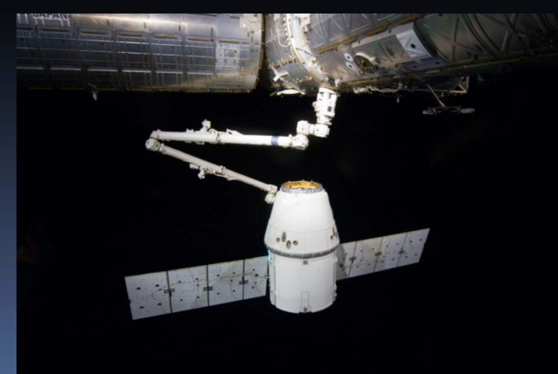
HTV one of 4 vehicles currently launching cargo to ISS.

The HTV is built , launched, and controlled from Japan.

Other cargo vehicles:

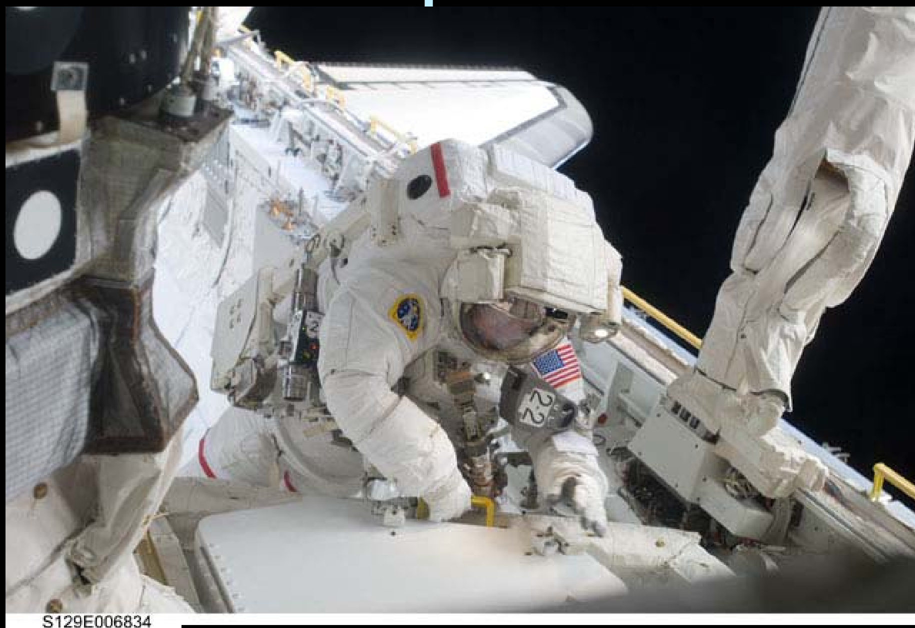
ATV - Europe

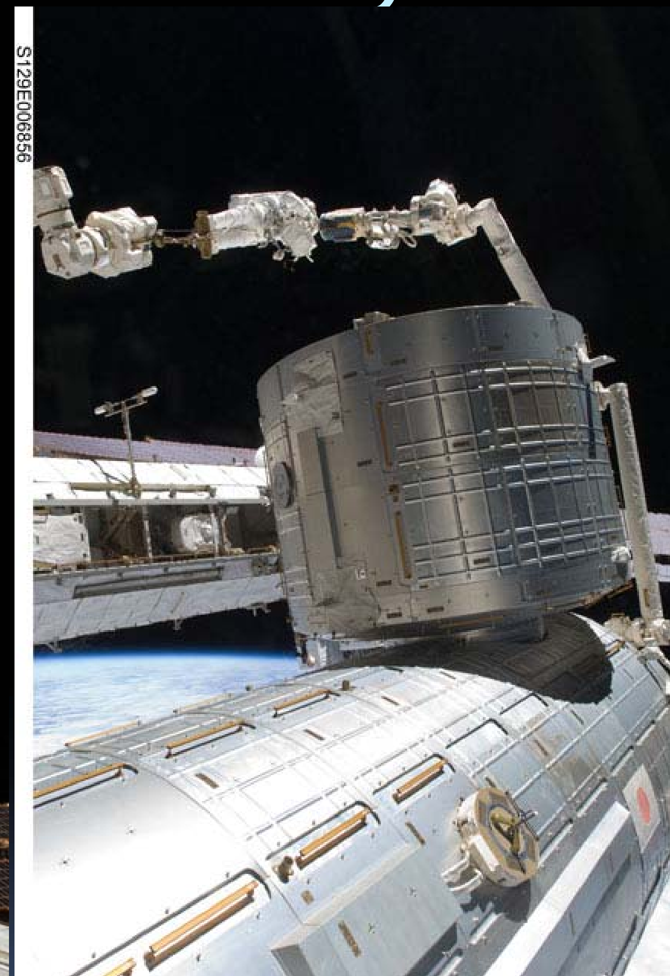
Progress - Russia

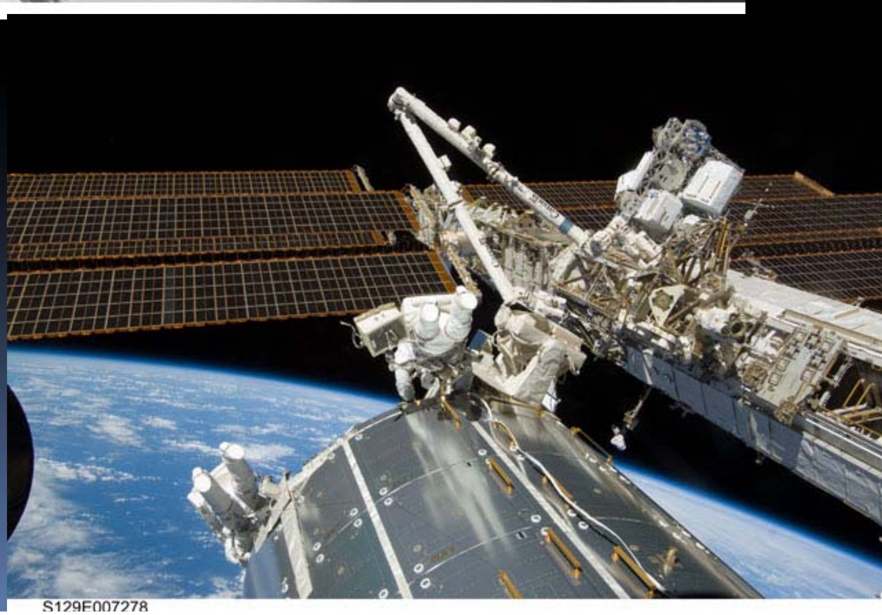


Dragon – United States

Space Station Assembly

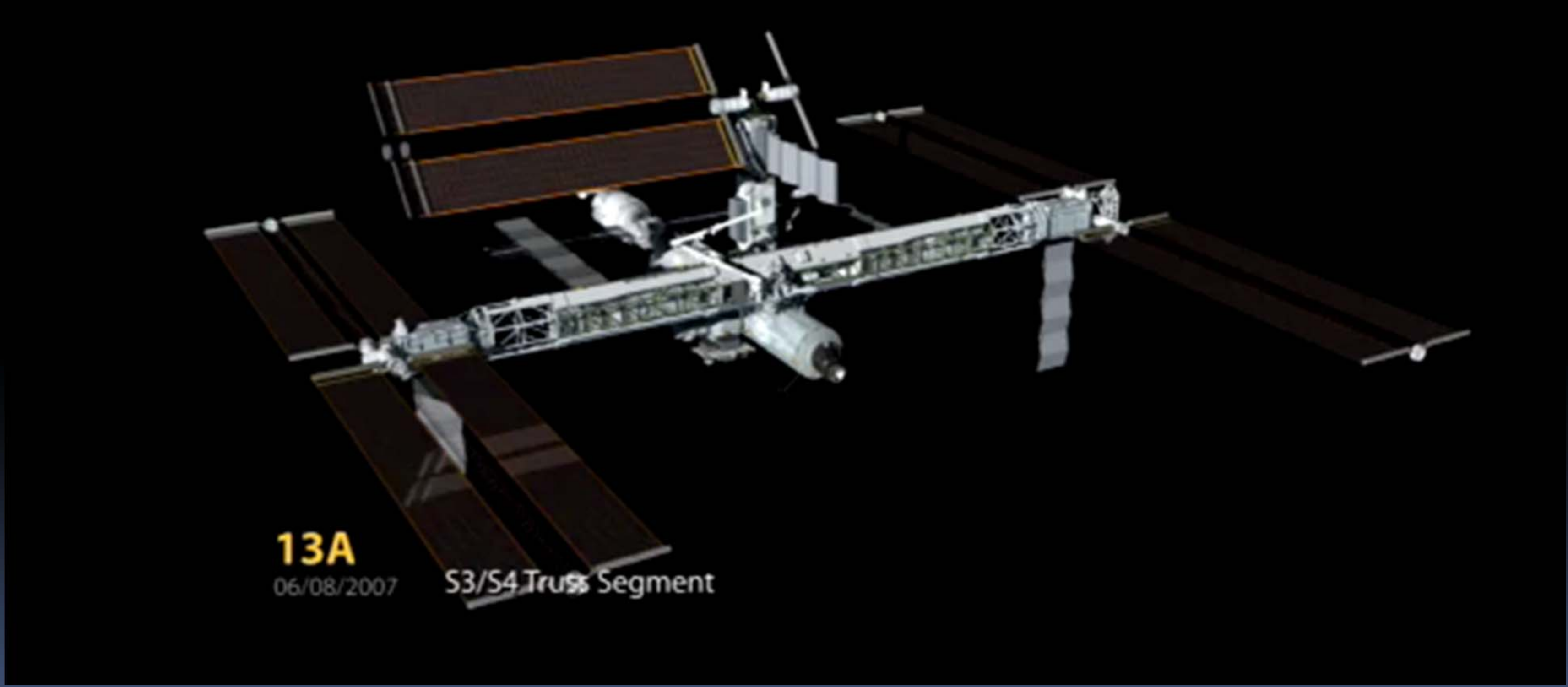




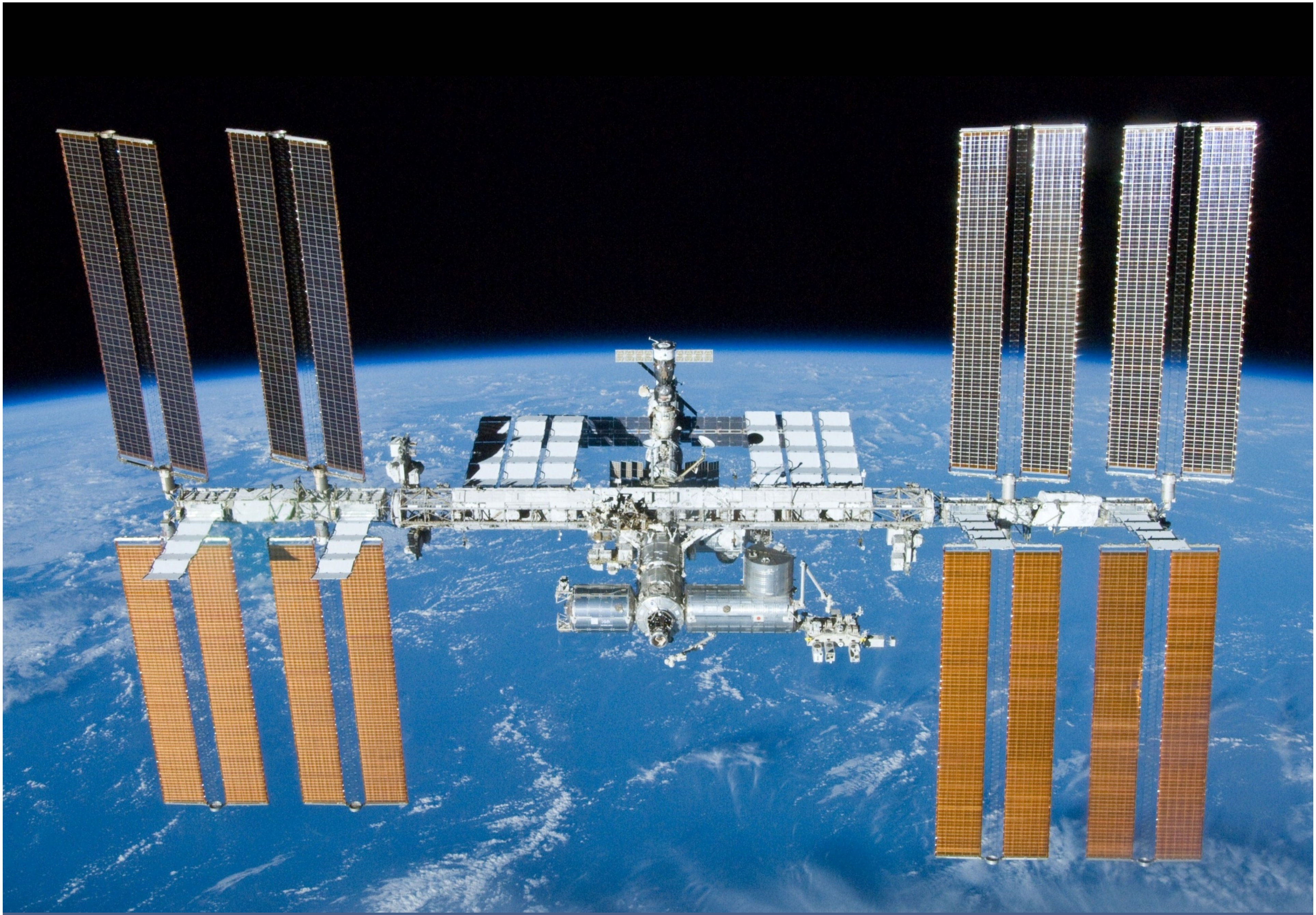


ISS Assembly Sequence

13A – ULF4



ULF4 – Assembly Complete



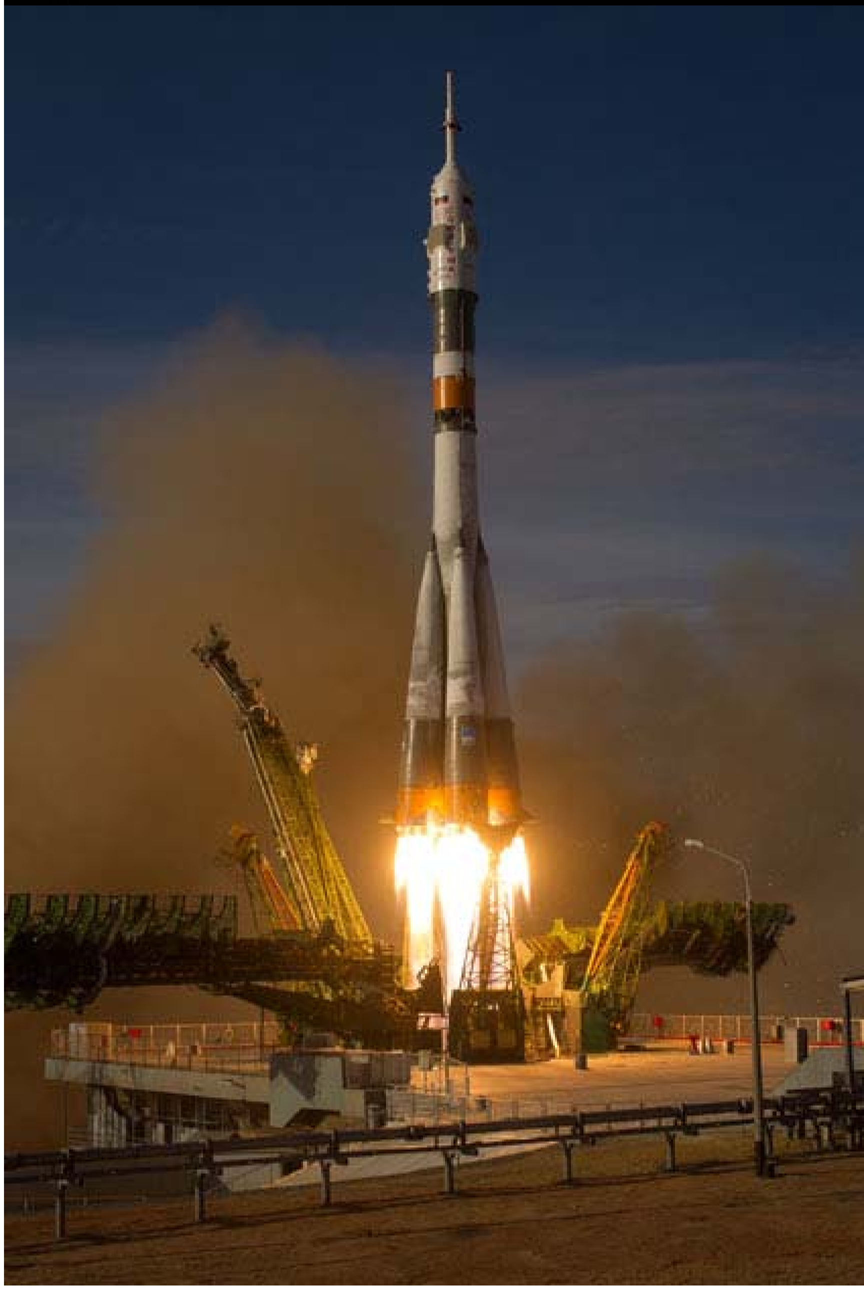
Considerations for Human Operations

- Design:
  - Hazard Causes and Controls
  - Dispersions and Margins
  - Systems and Integrated Design
  - Operational Concepts (Comm and Automation)
  - Crew Size and Complement - Variable
- Testing:
  - Hardware Interfaces and Fit Checks
  - Software Interfaces, Fault, Detection, Isolation & Recovery and Software Changes
  - MCC and Interfaces with On-board Software
  - Crew Interfaces (Displays and Controls) - Subjective
- Launch and Assembly:
  - Shelf-life and on-orbit life limits
  - Robotics and/or spacewalk capabilities

So how does the crew fit into all of this?

Mission Preparation

Getting to Space



Welcome to ISS

ISS025E006731

ISS017E021295

Crew Routine

- Expedition:
  - 6 months long (1 yr coming soon!)
  - 4 holidays/expedition
  - Lots of visiting vehicles
- Work week:
  - 5 work days
  - 1.5 off duty days (1/2 day cleaning)
- Work day
  - 2.5hrs exercise daily
  - 8.5hrs rest daily
  - 6.5hrs scheduled time each workday
  - Focus on science time
- Routine Conferences:
  - Medical
  - Planning and stowage
  - Operations Coordination
  - Family and friends

Crew Health

ISS021E007807

Public Relations Events

Stowage – Where's my stuff?

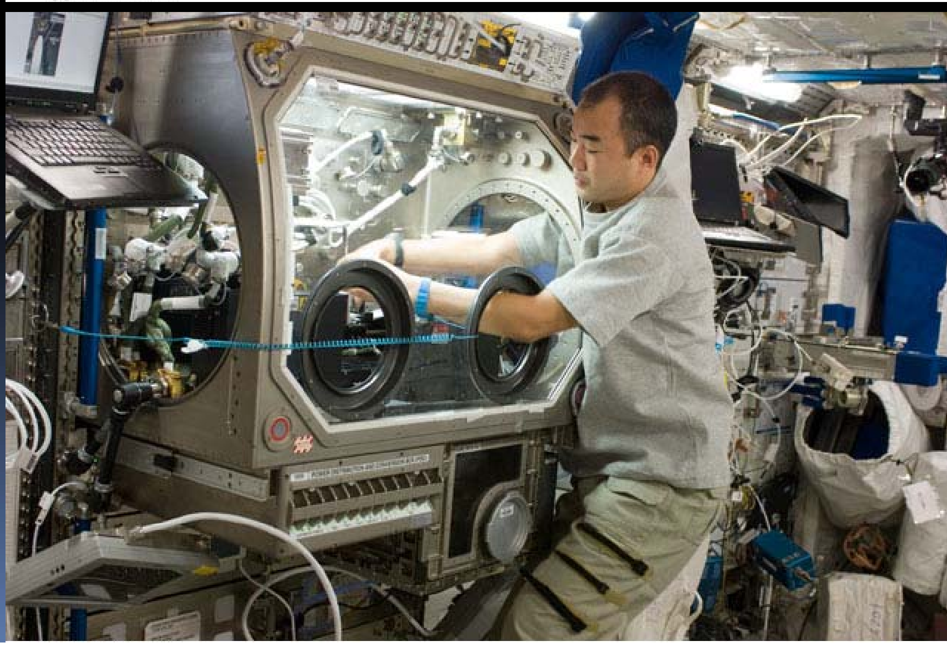
E018550

In Flight Maintenance

Science

ISS022E011879

ISS021E006289



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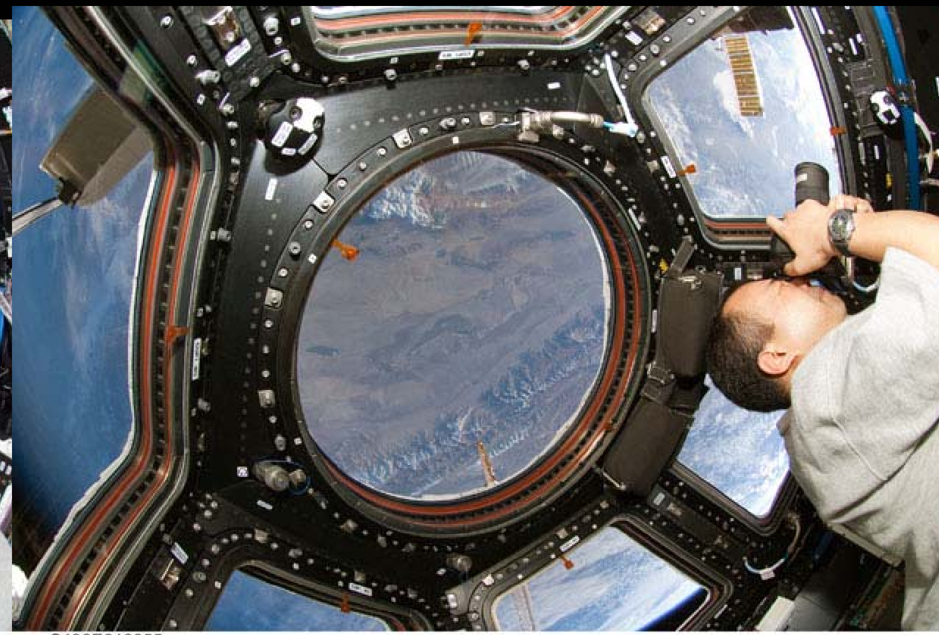
Earth Observations

Cupola

S130E010380

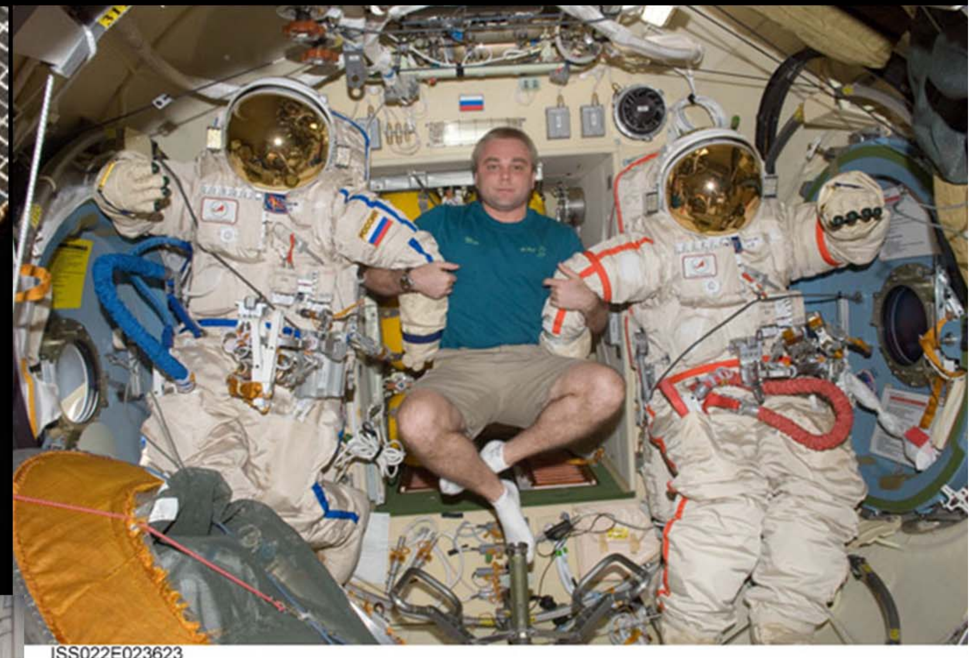


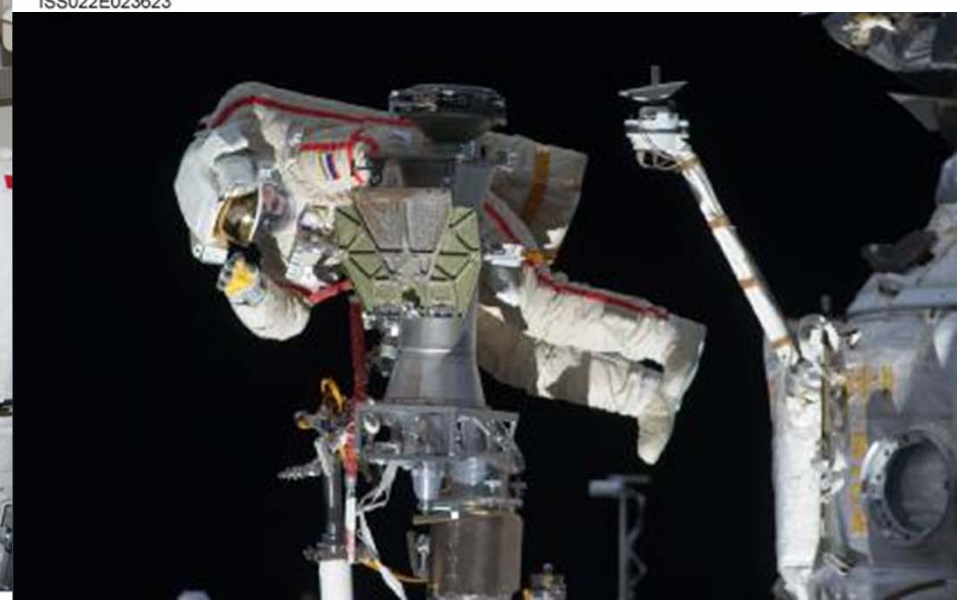
S130E010355

S130E010367

ISS022E068726

Extra Vehicular Activity (EVA)

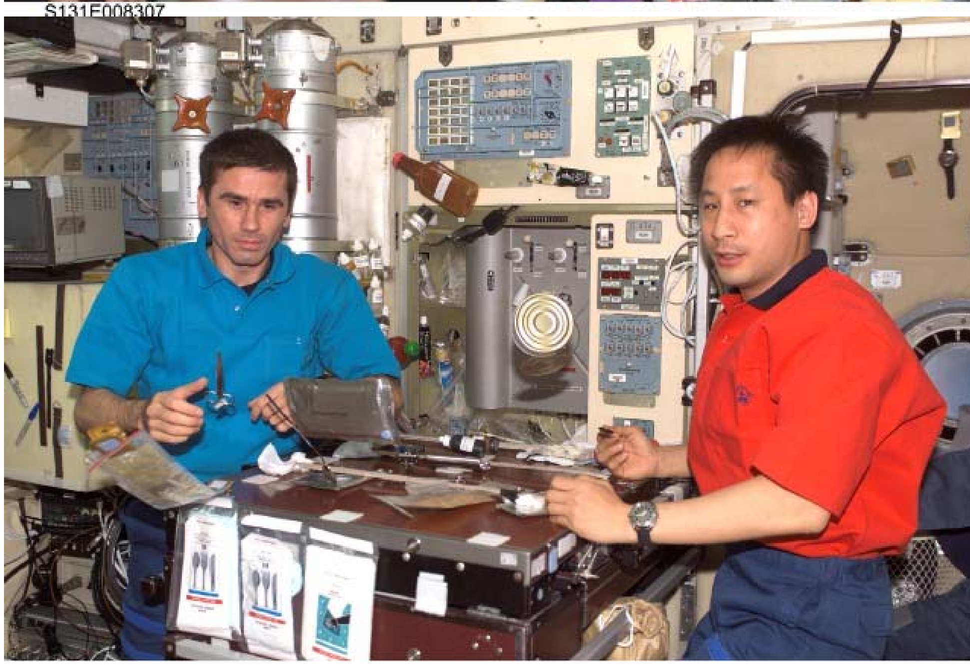




Meal Time

S131E008307

ISS020E005082



ISS020E046953

Relaxing after a hard day’s work

Friday night movies

Enjoying time off!

End of mission

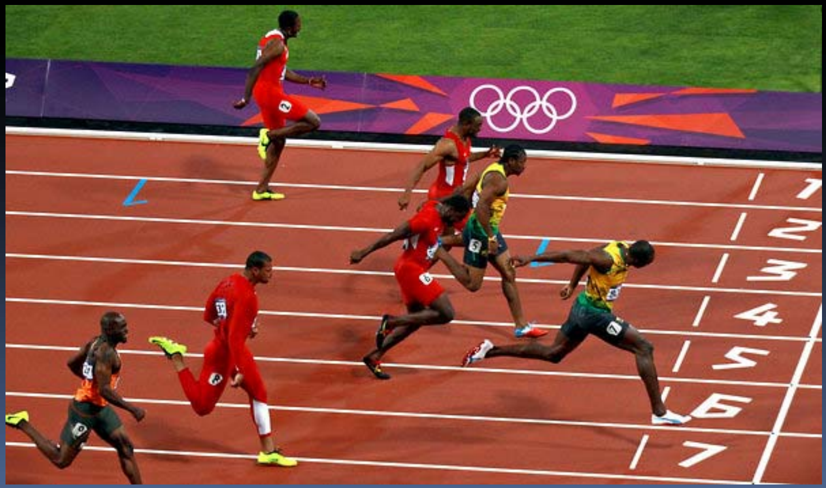
Considerations for Human Operations

- Training:
  - Emergency Response (Rapid Depress, Fire, Tox release)
  - Maintenance skills, science experiments, skill proficiency
  - Mission planning and procedures
- Systems Design:
  - CO_2 removal, O_2 supply, water, food
  - Ability to repair and/or replace
- Human behavior and health:
  - Psychological support (family conferences and e-mail)
  - Living space (private crew quarters)
  - Galley (2), toilet (2), exercise equipment (5 devices)
  - Plans and procedures
- Logistics: Stowage and resupply
  - Trash management
  - Resupply planning (spares, food, clothing, water, air, prop)
  - Stowage and equipment access

So How is this complex program controlled?

The Ground Teams

ISS is a marathon, not a sprint



Josh Haner/The New York Times

Photograph: David Levene/Guardian

What is Mission Control?

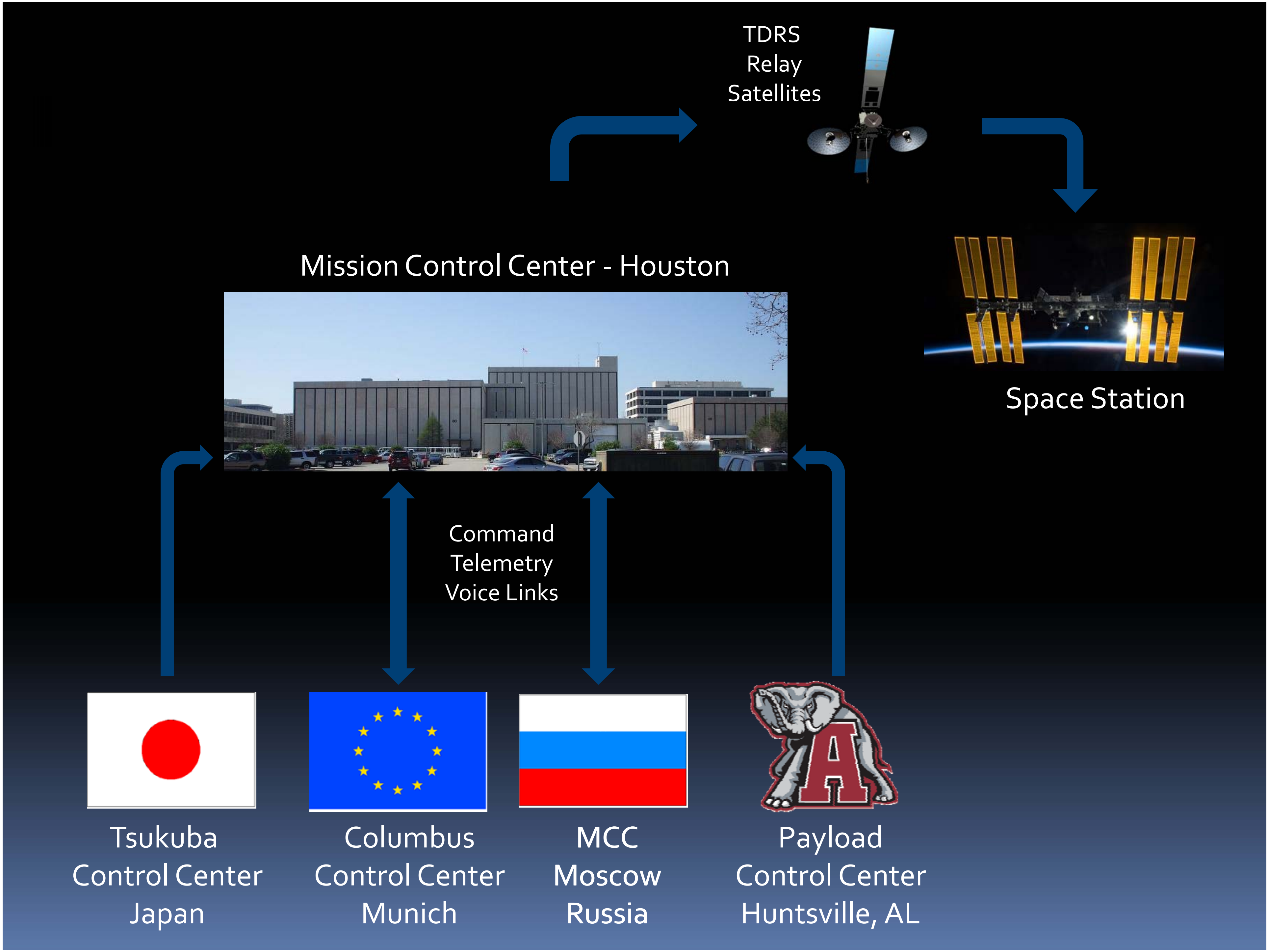
ISS is "flown " by the ground to free up crew time for science

System experts (flight controllers) organized by console to manage one or more subsystem (guidance, electrical, life support, timeline…)

Each controller monitors ISS system performance and health and issues commands to control vehicle operations (~3000/day!)

Each engineer divides time between office and console

Each engineer has completed a documented training and evaluation plan for MCC ops, most including computer driven simulation



TDRS
Relay
Satellites
Mission Control Center - Houston
Space Station
Command
Telemetry
Voice Links
Tsukuba
Control Center
Japan
Columbus
Control Center
Munich
MCC
Moscow
Russia
Payload
Control Center
Huntsville, AL

Mission Control Center - Houston

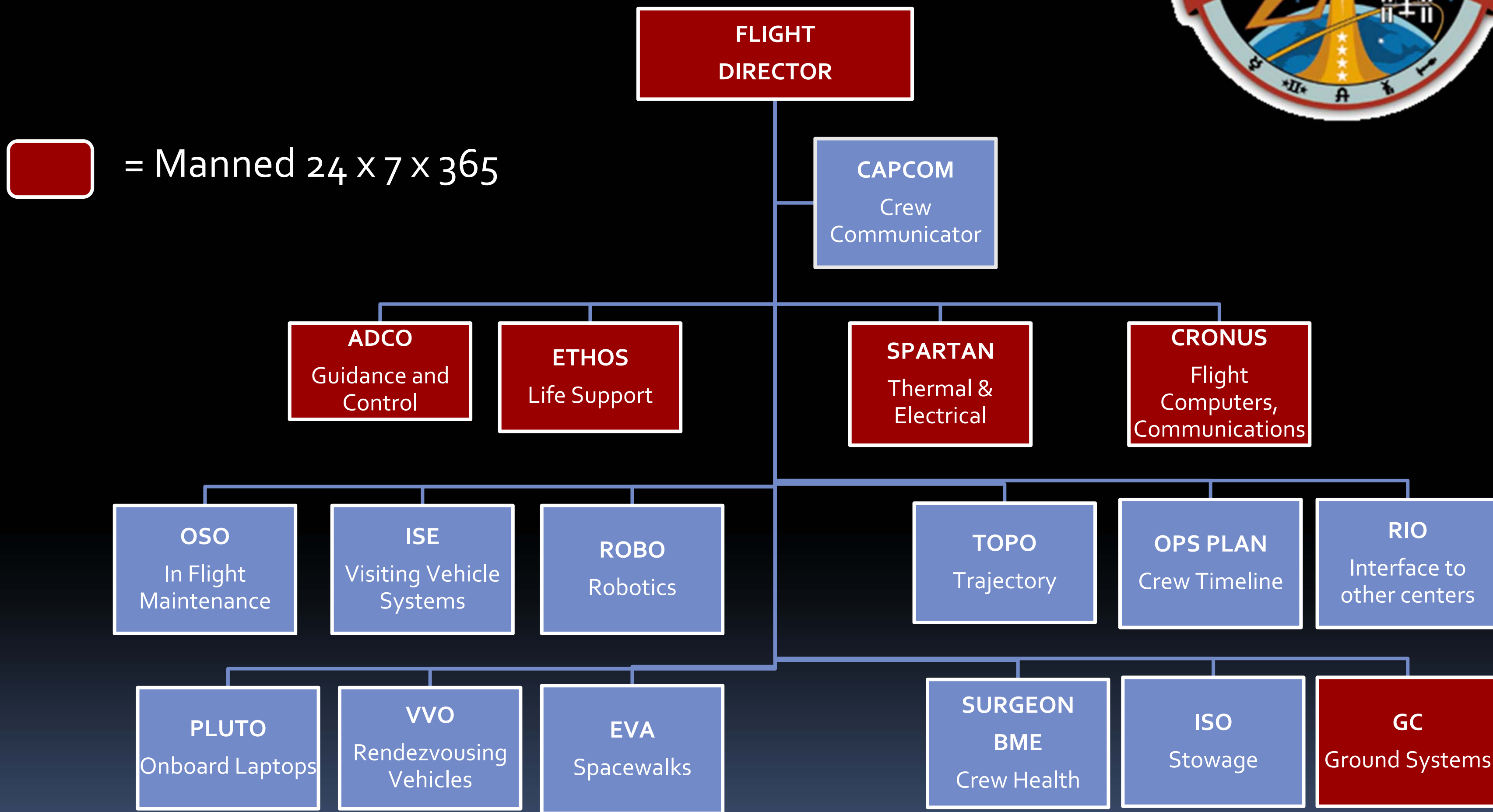
Mission Control Center - Moscow

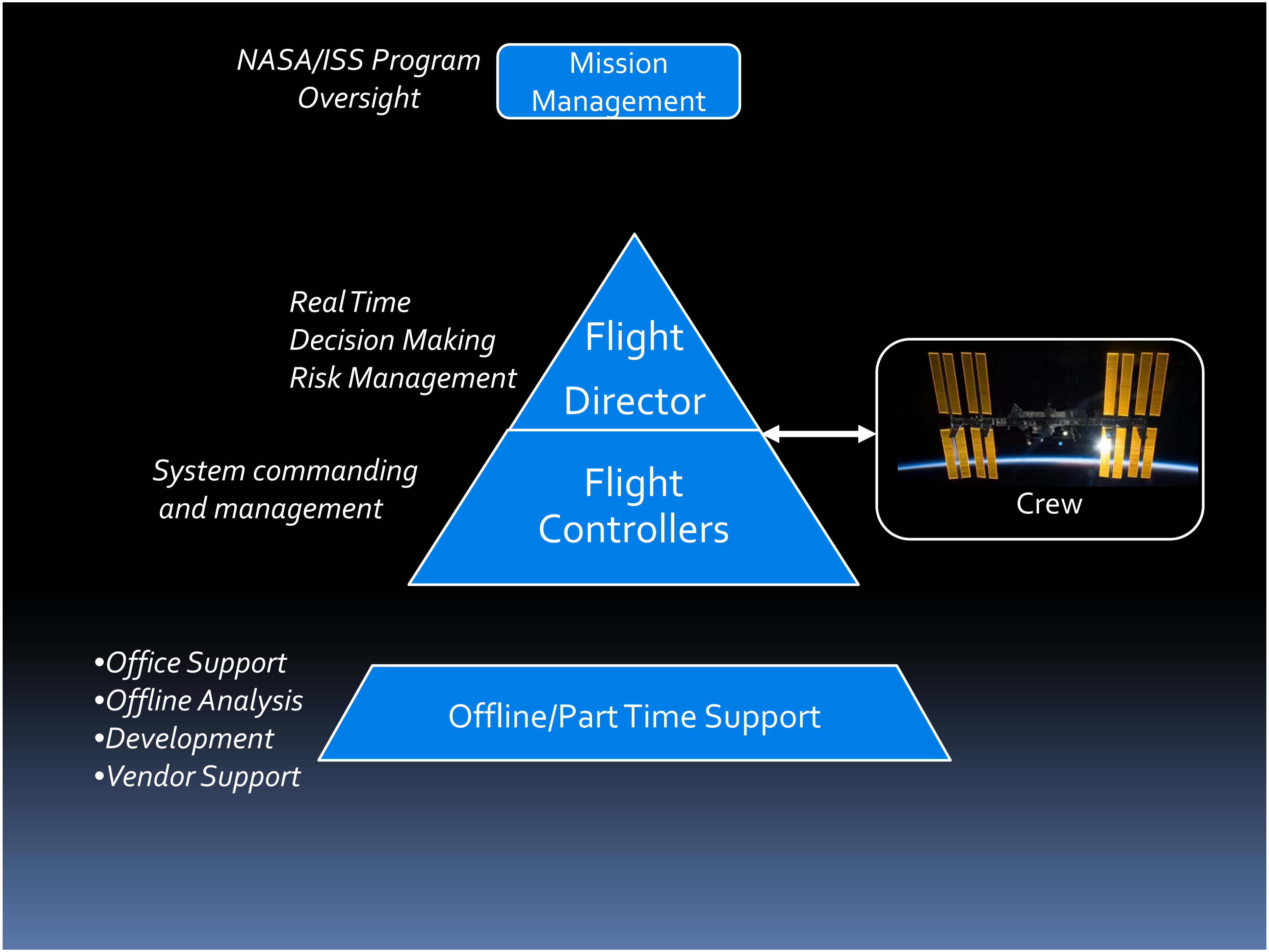
Columbus Misison Control Center - **Oberpfaffenhofen, Germany**

Space Station Integration and Promotion Center (SSIPC) - Tsukuba Space Center (TKSC), Ibaraki prefecture,Japan

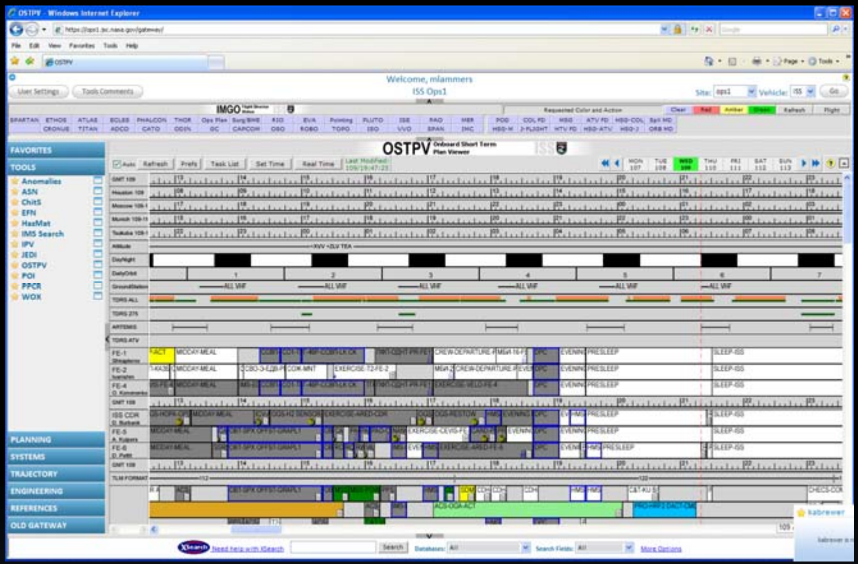
Marshall Spaceflight Center (MSFC) – Huntsville, Alabama

Operational Hierarchy



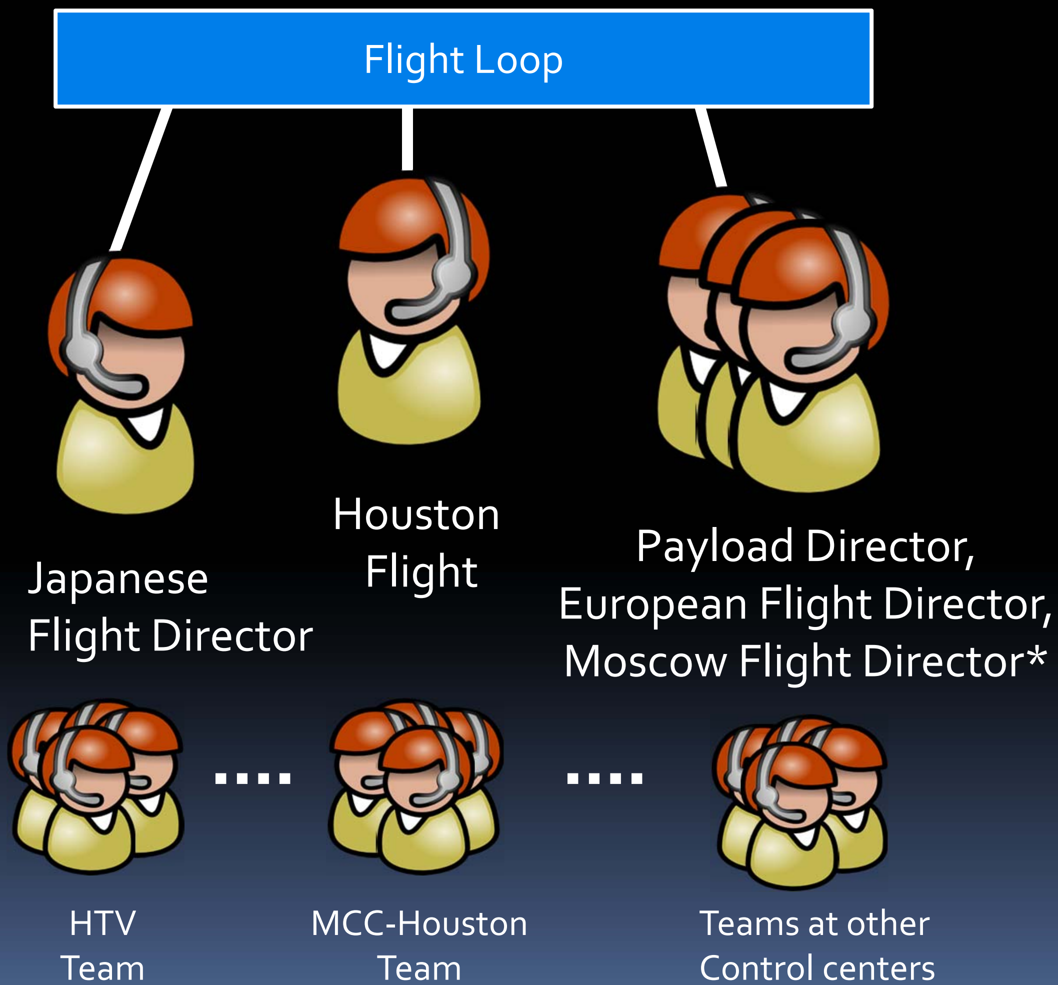

NASA/ISS Program Oversight
Mission Management
Real Time
Decision Making
Risk Management
Flight Director
System commanding and management
Flight Controllers
Crew
•Office Support
•Offline Analysis
•Development
•Vendor Support
Offline/Part Time Support

Timeline - Keys



- Crew, Houston, other centers execute from *a common timeline.*
- Delays to critical events are *reported on the Flight Loop* - everyone hears them so they can work up a recovery plan
- Changes/deviations to the timeline are approved only by Flight

Voice Discussion - Intercenter



- Teams in Houston and remote centers share some voice loops
- Big picture status and go's on Flight Loop
- Decisions made on Flight Loop
- Unambiguous final authority is Houston Flight

Execution Phases

How we get ready for a major operation, and how we learn from it.

Execution Phases

Pre-Flight

- Build Procedures & Flight Rules
- Build Timelines
- Train crew and MCC controllers

Real Time

- Execute Procedures
- Respond to anomalies and other surprises

Post-Flight

- Investigate/close Anomalies
- Document Lessons Learned

~ 1 year

Pre-Flight

- Flight Procedures and Flight Rules developed & approved
  - In office in Houston and at interchange meetings with engineering and international partners
- Timelines developed for critical events
  - Iterative process, but big ticket days like rendezvous/grapple are carefully planned.

- Simulations test the result….
  - “Stress test” Procedures, Flight Rules, and timelines to validate them and find weak points so they are corrected before we fly.

Pre-Flight

- Procedures = Specific instructions used by the crew and MCC
  - Send these commands to order an approaching vehicle to abort
  - Timeline and audio calls between crew and MCC used to synch procedure execution
- Flight Rules = Higher level guidance
  - Example – how low can pressure drop in a leak before evacuating crew
- Both Procedures and Rules carefully configuration managed
  - Maintained electronically onboard and MCC
  - Electronic approval process, signoff by all parties
    - Other flight control disciplines (including astronaut office)
    - Engineering (both NASA and contractor), Program Management
    - International partners when appropriate

Pre-Flight

Typical Weak Points uncovered in simulations and debriefings:

- **We didn’t think of that!**

  Realistic failure scenarios that do not have documented Flight Rules or procedures

- **We didn’t mean to do that!**

  Flight Rule or Procedure that works for one partner impacts someone else when working together

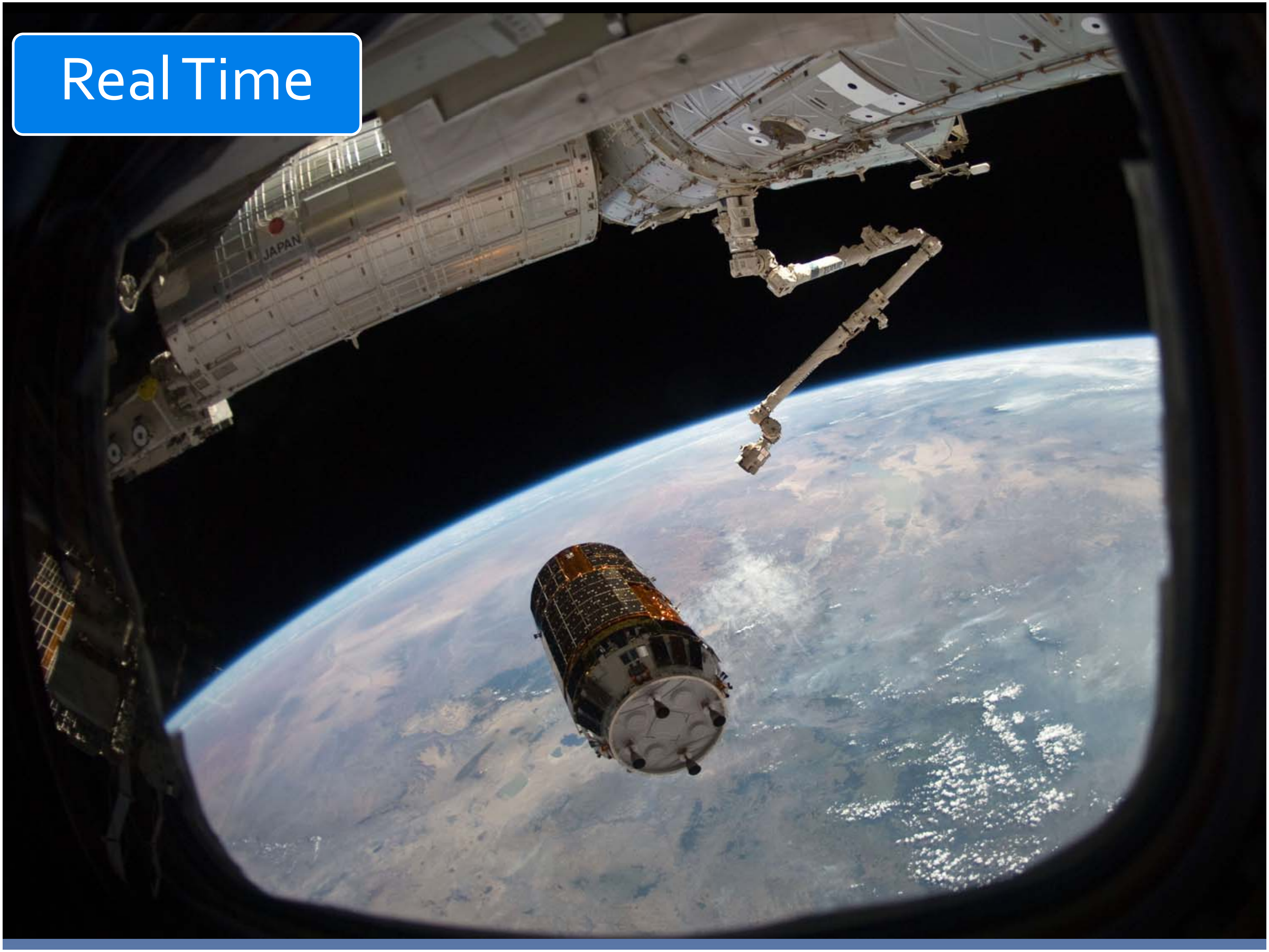
- **We’re not giving ourselves enough time here…**

  Insufficient time reserved to do something critical

- **We’re not communicating well here….**

  Missing or poorly placed synch point between crew and/or control centers on the timeline, miscommunication

Real Time



Real Time

Execute	• Crew, MCC-H, SSIPC-Japan run documented procedures according to the timeline
Respond	• To anomalies using the guidance in Flight Rules
Deviate	• From procedures and Flight Rules only with sufficient rationale, analysis of risk, and approval from Flight
Document	• What went right and wrong • If you deviated from procedures/rules and why

Post-Flight

Formally review what you did

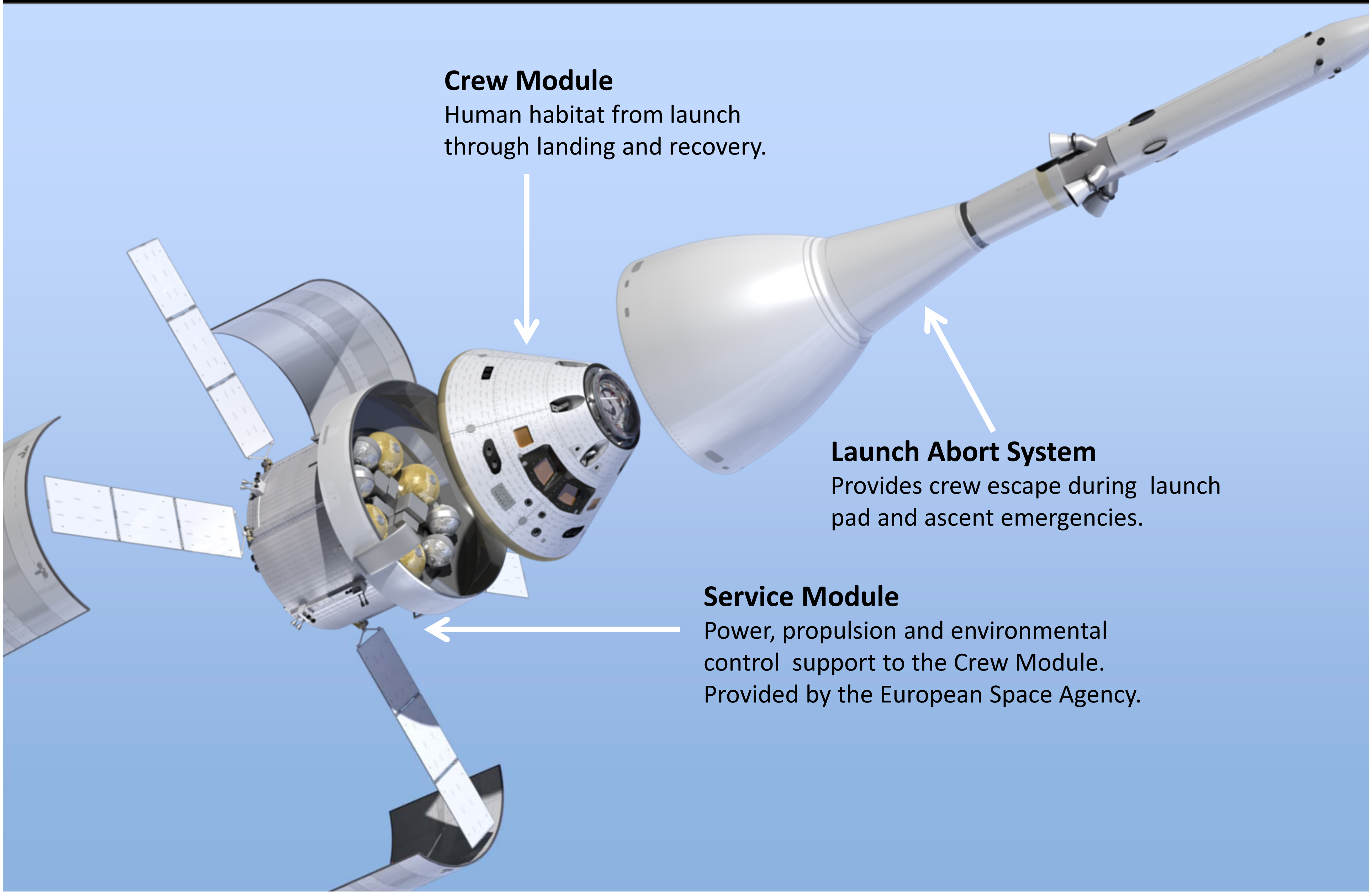
- **Investigate Anomalies**
  - *Engineering investigation of hardware failures*
- **Debrief Crew**
  - *Done both on orbit immediately following event and after return to earth.*
- **Document Lessons Learned**
  - *Solicit honest written feedback from system disciplines, contractor organizations, and International Partners on what worked well and what didn't.*

Considerations for Human Operations

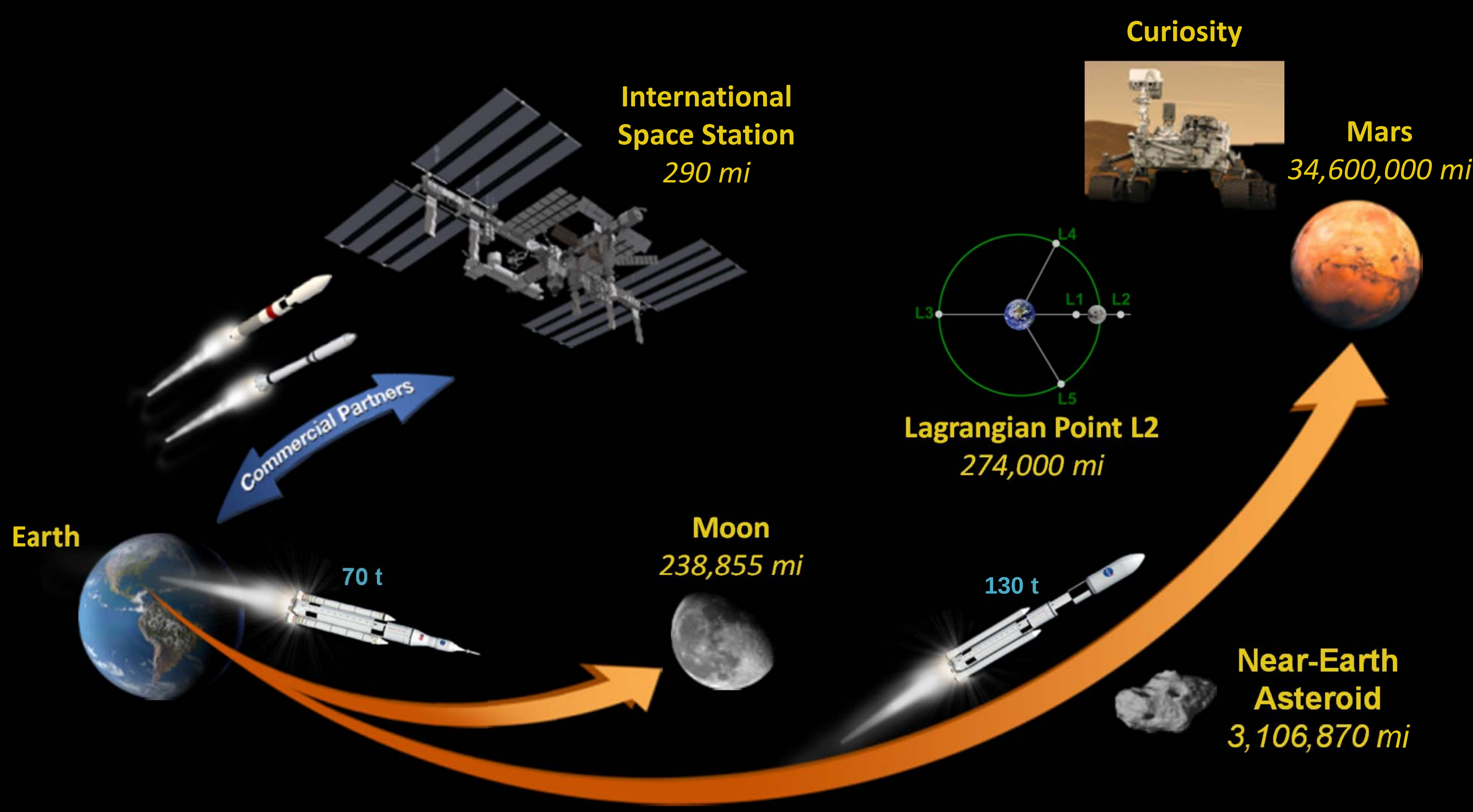
- International and Commercial Cooperation:
  - Agreements and Contributions (financial, government, legal, etc)
  - Partner (Critical Path Participation) vs Procurement
  - Differing engineering philosophies: redundancy run to failure vs load sharing, margins, manual vs automation, etc.
- Planning and Training
  - Planning is extensive (extra time with more partners) – common timelines, procedures and communications
  - Pre activity simulation/practice – culture, locations, communications
  - Post Activity reviews (Open, honest debriefs & lessons learned)
- Command and Control:
  - Decision making authority and process, roles & responsibilities, system and human operability limits – pre-coordinated and written
  - Distributed data, telemetry and command capability


Where do we go from here?

The Orion Spacecraft



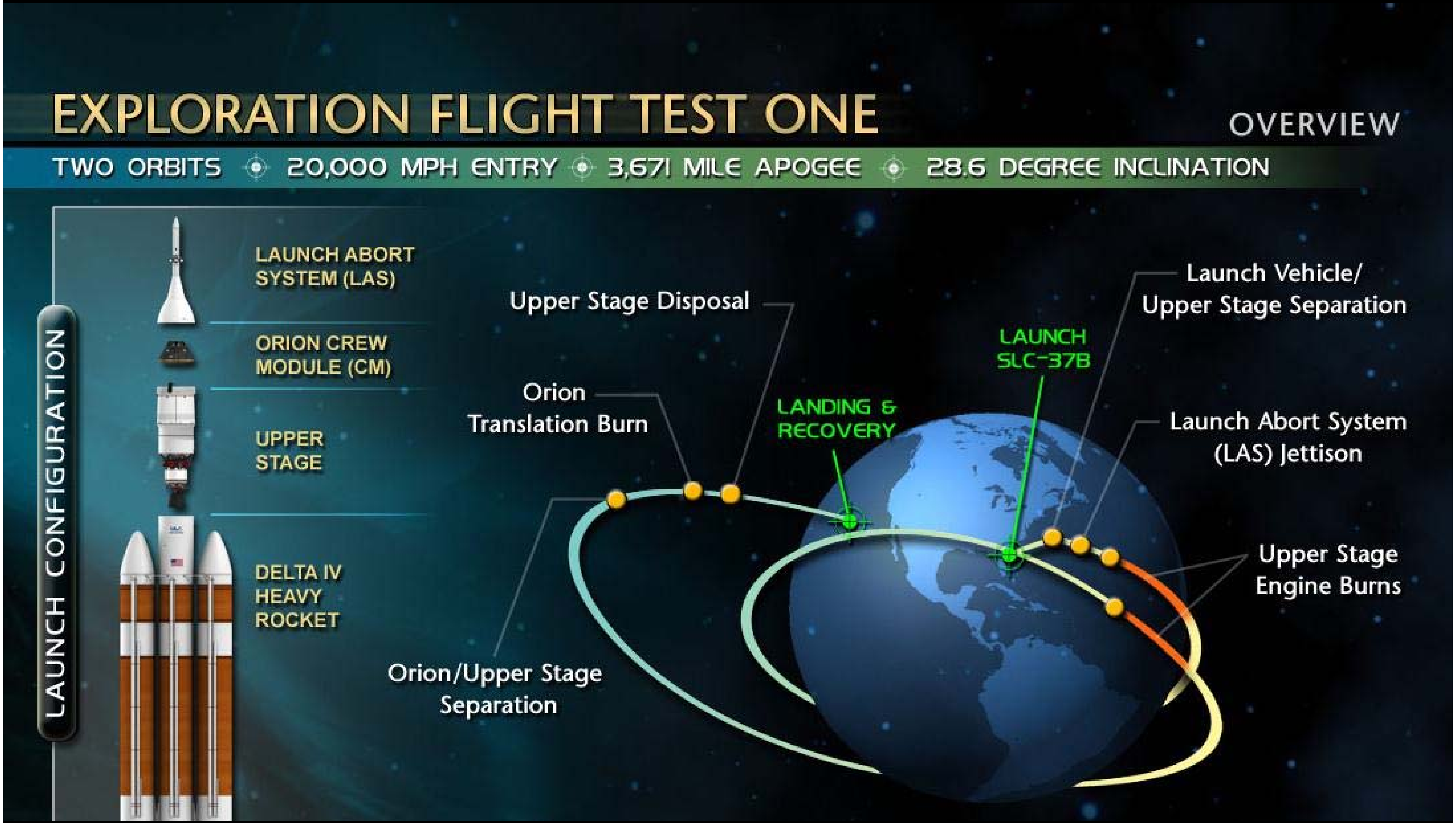
The Future of Exploration



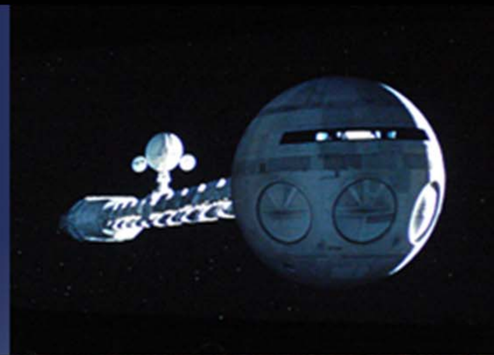
The Space Launch System [will] be the backbone of its manned spaceflight program for decades. It [will] be the most powerful rocket in NASA's history…and puts NASA on a more sustainable path to continue our tradition of innovative space exploration.

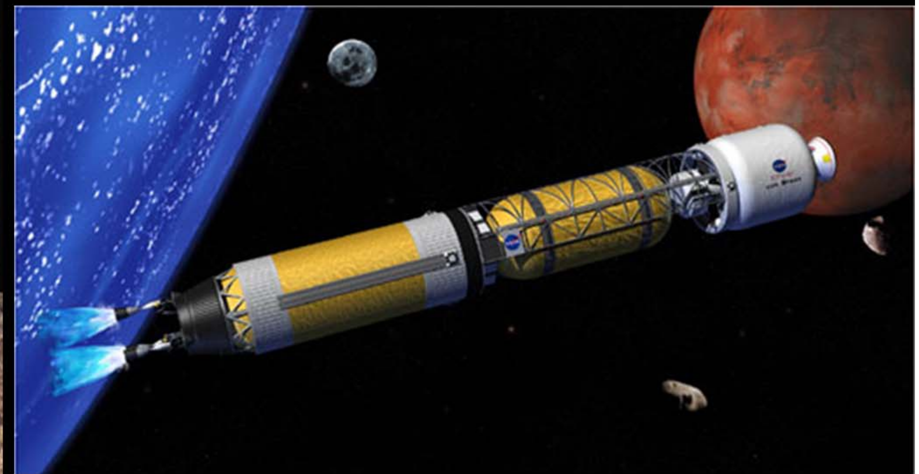
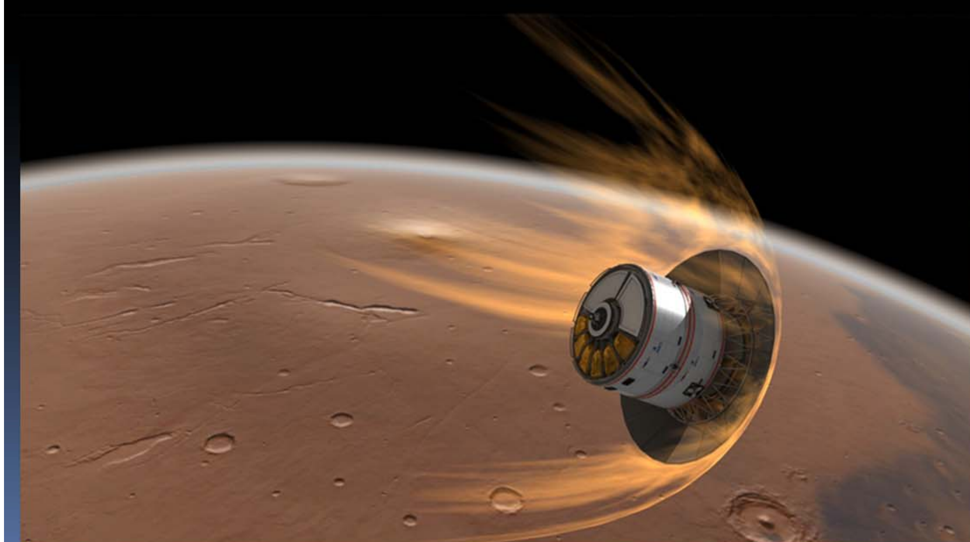
President Obama's Accomplishments for NASA
May 22, 2012

Exploration Flight Test 1 - 2014



A two-orbit, high energy entry test flight that will demonstrate Orion systems associated with 8 of the 11 biggest risk drivers


Considerations for Human Operations beyond Low Earth Orbit

- Radiation prevention
- Autonomy in systems and human operations:
  - Human computer interface
  - Roles of mission control and crews
- Logistics: stowage, resupply, and trash management
- Dealing with time delays
- Crew proficiency training and learning new skills
- Human adjustment to varied gravitational environments
- Emergency Response (no easy way to evacuate)
- Equipment and systems design:
  - Simplified, reliable, redundant, easy to fix
  - How to handle spares


U.S.S. ENTERPRISE
NCC-1701

NASA