Outline

• ISS Research facilities and laboratory configuration
• Resources for research: upmass, downmass, crewtime
• Organization of ISS Program to provide Multi-user Support
• Overview of early utilization during assembly
• Resources for more information
ESA and JAXA Research Outfitting

**ESA**
- Biolab
- European Drawer Rack (EDR)
- European Physiology Module (EPM)
- European Transport Carrier (ETC)
- Fluid Science Lab (FSL)

**JAXA**
- EuTEF
- Solar
- Ryutai (Fluids)
- Saibo (Cell Biology)

**Timeline**
- 2008: Ryutai (Fluids)
- 2010: Kobairo (Gradient Heating Furnace)
- 2020: Multi-Purpose Small Payload Rack
COLUMBUS MODULE RESEARCH RACK TOPOLOGY

Configured at Pre-Launch -- Flight STS-119 / Stage 15A

AVCO = Air Volume Closeout
Bio Lab = ESA Biolab Facility
EDR = European Drawer Rack
EPM = European Physiology Module
ETC = European Transport Carrier
EXPR-# (ARIS) = EXPRESS Rack-number (Active Rack Isolation System)
FSL = Fluid Science Laboratory
HRF-# = Human Research Facility-number
MSG = Microgravity Science Glovebox
ZSR = Zero-Gravity Stowage Rack

Note: Following 15A, additional flights/stages planned with rack launches and moves will evolve to final configuration (full utilization-ready) as depicted below

Configured at Assembly Complete -- Flight STS-130 / Stage 19A

Bio Lab = ESA Biolab Facility
EDR = European Drawer Rack
EPM = European Physiology Module
ETC = European Transport Carrier
EXPR-# (ARIS) = EXPRESS Rack Number (Active Rack Isolation System)
FSL = Fluid Science Laboratory
HRF-# = Human Research Facility-Number
MARES = Muscle Atrophy Resistive Exercise System
MSG = Microgravity Science Glovebox
ZSR = Zero-Gravity Stowage Rack

5 NASA Utilization Rack Locations
5 ESA Utilization Rack Locations

Reference sources:
(1) Future ISS Topology Plans, Jay Weber and Tony Sapp, Internal Volume Configuration; (2) ISS Internal Volume Configuration Document, SSP 50564 Revision D (April 2008); (3) Updates made to these charts on 2/4/09 from http://saber.jsc.nasa.gov/team_ivc/topologies.php. “These topologies are options under consideration, used for illustrating configuration scenarios. For approved Strategic Planning purposes, the Program-approved topologies as incorporated into most current MIM, Integrated Flight Schedule, and SSP 50564, Internal Volume Configuration documents, are found returning to SSP 50564 page.”
DESTINY MODULE RESEARCH RACK TOPOLOGY

Configured at Pre-Launch -- Flight STS-119 / Stage 15A

ARS = Air Revitalization Subsystem
AVCO = Air Volume Closeout
RSR (CHeCS) = Resupply Stowage Rack
(Crew Health Care Systems)
CIR (PaRIS) = Combustion Integration Rack
(Passive Rack Isolation System)
DDCU-# = Direct Current-to-Direct Current / Converter Unit
EXPR-# (ARIS) = EXPRESS Rack-number
(Active Rack Isolation System)
FIR = Fluids Integration Rack
HRF-# = Human Research Facility
MELFI-# = Minus Eighty Degrees Laboratory Freezer
for ISS
MSG = Microgravity Glovebox System
MSS / AV = Mobile Servicer System / Avionics
OGS = Oxygen Generation Subsystem
TCS = Thermal Control System
TeSS = Temporary Sleep Station
WHC = Waste and Hygiene Compartment
WRS-# = Water Recovery System-number
ZSR = Zero-Gravity Stowage Rack

Note: Following 15A, additional flights/stages planned with rack launches and moves will evolve to final configuration (full utilization-ready) as depicted below

Configured at Assembly Complete -- Flight STS-130 / Stage 19A

ARS = Air Revitalization Subsystem
CHeCS = Crew Health Care Systems
CIR (PaRIS) = Combustion Integration Rack
(Passive Rack Isolation System)
DDCU-# = Direct Current-to-Direct Current / Converter Unit
EXPR-# (ARIS) = EXPRESS Rack-number
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KIBO MODULE RESEARCH RACK TOPOLOGY

Configured at Pre-Launch -- Flight STS-119 / Stage 15A

- DMS-2
- AVCO
- JRSR-1
- ICS / PROX
- DMS-1
- RMS
- AVCO
- EPS-1
- EPS-2
- ECLSS / TCS-1
- AVCO
- Crew Quarters
- W / S
- EXPR-4 (NASA)
- ZSR (NASA)

Note: Following 15A additional flights/stages planned with rack launches and moves will evolve to final configuration (full utilization-ready) as depicted below

Configured at Assembly Complete -- Flight STS-130 / Stage 19A

- DMS-2
- AVCO
- JRSR-1
- ICS / PROX
- DMS-1
- RMS
- AVCO
- EPS-1
- EPS-2
- ECLSS / TCS-1
- AVCO
- Crew Quarters
- W / S
- EXPR-4 (NASA)
- ZSR (NASA)

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Human Research Facility (2 + racks)

• HRF-1 and HRF-2 support wide range of physiological investigations
  - Clinical ultrasound
  - Body mass measurement
  - Metabolic gas analysis
  - Pulmonary monitoring
  - Blood pressure measurement
  - Holter monitor
  - Refrigerated centrifuge
  - Range of experiment unique hardware

Muscle Atrophy Research Exercise System (MARES) 2010 Launch

- Facility for musculoskeletal, biomechanical, neuromuscular and neurological physiology measurements
Multi-user EXPRESS Racks

- Middeck locker scale instruments in various research disciplines such as biotechnology and plant research
  - Sub-rack class payloads and facilities
- At this time the NASA funded science program is projected to utilize only approximately 50% of the U.S. internal payload accommodations
  - The remaining 50% is available for National Lab investigations or an expanded number of NASA-supported investigations
- 7 Express Racks physical capacity
  - 59 Lockers total, 25 have planned use, 34 available
  - 13 Drawers total, 7 have planned use, 6 available

Expedition 3 crewmember Frank Culbertson conducting cell culture experiment in CBOSS in EXPRESS Rack 4

Expedition 14 crewmember Mike Lopez-Alegria conducting TROPI plant growth experiment in EMCS in EXPRESS Rack 3

European Space Agency Astronaut Thomas Reiter, Expedition 13 Flight Engineer, installing the EMCS facility into the EXPRESS Rack 3A.
Microgravity Sciences Glovebox (MSG)

- Provides multiple levels of containment for a variety of experiments
  - Combustion
  - Physical processes
  - Materials
  - IV Fluid Generation
- Provides 2 levels of containment

Astronaut Garrett Reisman during a training session at JSC harvests plants from the CWRW investigation inside the MSG.

European Space Agency (ESA) Astronaut Pedro Duque as he works at the Microgravity Science Glovebox for the Cervantes mission experiment PromISS 2.

Expedition 13 crewmember Jeff Williams performing the PFMI experiment in the Microgravity Science Glovebox.
# MSG Investigations, 2007-2008

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<tr>
<td>Smoke and Aerosol Measurement Experiment PI: D. Urban</td>
<td>Cell Wall/Resist Wall (Plant harvesting) PIs: R. Yokoyama, K. Wakabayshi et al</td>
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<td><strong>CSLM-2</strong> Coarsening in Solid-Liquid Mixtures-2 PI: P. Voorhees</td>
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<td><strong>InSPACE-2</strong> Investigating the Structure of Paramagnetic Aggregates from Colloidal Emulsions PI: E. Furst</td>
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<td><strong>Properties of particle growth in liquid metal mixture</strong></td>
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## MSG Investigations, 2008-2009

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<td></td>
<td>- SODI - Advanced Photonic Devices</td>
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<td>in Microgravity, PI: G. Wegdam</td>
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<td>PI: J. McQuillen</td>
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<td>Testing a method of generating IV fluids on</td>
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**Freezers and Incubators**

- **Minus Eighty-degree Laboratory Freezer for ISS (MELFI)**
  - Provides thermal conditioning at +4°C, -26°C and -80°C
  - 1 unit currently on orbit
  - 1 will launch in 2009, and 1 more in 2010

- **GLACIER Freezer**
  - +4°C to -185°C

- **CGBA (Commercial Generic Bioprocessing Apparatus)**
  - -10°C to +37°C

- **ABRS (Advanced Biological Resarch System)**
  - Includes imaging of green fluorescent protein

- **EMCS (European Modular Cultivation System)**
  - Two centrifuges for plants and small animals spin from 0 to 2 G

**Images**:
- General Laboratory Active Cryogenic ISS Experiment Refrigerator (GLACIER)
- Centrifuges of EMCS
- Expedition 19 crewmember Michael Barratt inserts samples into the MELFI
- Commercial Generic Bioprocessing Apparatus (CGBA)
Fluid Physics and Combustion

Combustion Integrated Rack (CIR)
- Facility dedicated to research in combustion science
- First investigation: FLEX (Flame Extinguishment Experiment / Multi-user Droplet Combustion Apparatus)

Fluids Integrated Rack (FIR) 2009 Launch
- Facility dedicated to fluid physics research, with Light Microscope Module
- First Experiment CVB (Constrained Vapor Bubble)

Astronaut Sandra Magnus working with the CIR.
Materials Science

- **Space Dynamically Responding Ultrasound Matrix System (SpaceDRUMS) (2008)**
  - EXPRESS-based containerless (ultrasound) processing facility
  - Sintering furnace

- **Microgravity Science Research Rack (MSRR) 2009 Launch**
  - Facility to support ESA Microgravity Science Lab furnace
  - NASA Cooperative use of the furnace and quenching facility insert
Research racks launched in Columbus

- **European Physiology Module**
  - Facility for human physiology research in neurosciences, cardiology, bone and muscle metabolism

- **Fluid Science Lab**
  - Multi-user facility for fluid physics research

- **Biolab**
  - Facility for cell culture, tissue, microorganisms, small plants and animals research, includes glovebox, incubator, microscope

- **European Drawer Rack**
  - Provide for middeck-class experiments and stowage

- **European Transport Carrier**
  - Stowage and transportation rack for experiments
External facilities launched with Columbus

- **European Technology Exposure Facility (EuTEF)**
  - Provides a platform for investigators to gather science data on the ISS space environment
  - Nine experiment modules will support research in Earth and space science and materials exposure to the space environment

- **SOLAR**
  - Observatory that measures solar spectral irradiance.
  - Three science instruments which monitor the solar flux in different wavelengths varying between 17 nanometers and 100 micrometers.
  - Data will be used for atmospheric modeling, atmospheric chemistry and climate research, as well as solar physics studies
Research racks launched with pressurized elements or later on HTV

- **Ryutai**
  - Fluid physics and solution/crystal growth research, including image processing unit

- **Saibo**
  - Cell biology facility, contains Clean Bench and Cell Biology Experiment Facility, including glovebox, incubator, microscope, centrifuge

- **Kobairo (HTV 2009)**
  - Gradient Heating Furnace for materials processing research
On-orbit resources
Overview Resource Constraints for Science on ISS

- General constraints (roughly in the order most likely to be limiting, post-assembly complete)
  - Upmass
  - Downmass
  - Crew time
  - Thermal
  - Facility throughput
  - Power
  - Data downlink

- Constraints unique to human research
  - Maintaining experimental controls for multiple human subject experiments (some experiments with conflicting requirements cannot use the same crewmember as a subject), approximate limit is 6 experiments per subject
  - Postflight baseline data collection during the 1st 7 days
  - Limits on blood collections (volume, frequency)
  - Informed consent requirements
Program Planning to minimize Resource Constraints for Science on ISS

• **Upmass**
  - Planned upmass capabilities meet projected NASA requirements at current budget levels (but not National Lab users or any additional NASA use)
  - CRS (Orbital, SpaceX) vehicles a key part of plan
  - Contingency planning to defer some maintenance activities if CRS vehicles delayed to insure ongoing science
  - Additional CRS capability could be purchased to support a larger science program than currently planned (budget based)

• **Downmass**
  - SpaceX vehicle will have downmass capability that fits projected requirements after Shuttle retirement
  - Three on-orbit MELFI freezers (compared to originally planned single freezer) provides a storage capability that can insure continued life science experiments if there is a CRS delay. All freezers empty when last Shuttle undocks.

• **Crew time**
  - Six crew meets projected science requirements, possible to select significant additional relatively automated science (National lab or additional NASA use)
  - ISS Program could increase to 7 crew with Orion (launch/return vehicle for 4)

• **Thermal**
  - Occasional limitations during assembly on rack enablement due to life support and research hardware demands on Moderate Temperature Loop. Handled with research scheduling.
  - Once Node 3 is onboard, the limitations are not projected to continue.
Program Planning to minimize Resource Constraints for Science on ISS

• **Facility throughput**
  - MSG is currently the only facility projected to approach throughput limitations.
  - As crewtime becomes less limiting, we have more ability to move experiments through MSG rapidly.
  - Some experiments require significant dwell time in the facility.

• **Power**
  - ISS power system can meet all pressurized facility requirements identified.
  - There is redundant capacity in the system at assembly complete.
  - Only major external facilities such as AMS have the potential to have power demands requiring significant coordination.

• **Data downlink**
  - Current capability of 150mps being upgraded to 300mps. EXPRESS export data rate is limited to 1.8mps and we are investigating upgrading to 100mps.
  - Only projected data downlink limitations are for planned external HDTV and possible external remote sensing payloads which have High-rate Data Loop requirements. Scheduling solutions solve this problem for projected payloads.

• **Human subjects constraints**
  - Shared data collection with medical operations
  - Multilateral planning group works to optimize use of subjects by identifying suites of compatible experiments, and reworking plans following informed consent if needed
  - ISS Program continues to discuss full USOS access to Russian crews as subjects (however, these crews are well-utilized for Russian and collaborative Russian-international investigations)
Partner Utilization Requirements Compared to Utilization Capabilities

**Upmass**

*2008 Signed Consolidated Operations and Utilization Plan. Assembly Sequence Rev J*

<table>
<thead>
<tr>
<th></th>
<th>Capabilities</th>
<th>Requirements met by Allocation</th>
<th>Unused Allocation</th>
<th>Requirements accrued by Allocation</th>
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</table>

**Total Utilization Upmass (Pressurized + Unpressurized) Capabilities, Allocations, and Requirements**

- **Upmass Requirements and Allocations (kg)**
  - Requirements below the line are in excess of Partner Allocations

**Calendar Year**
- **2010**
- **2011**
- **2012**
- **2013**
- **2014**
- **2015**

**Upmass in kg**
- **Press**
  - 2010: 1438
  - 2011: 1438
  - 2012: 1457
  - 2013: 1432
  - 2014: 1415
  - 2015: 1415

- **Unpress**
  - 2010: 543
  - 2011: 543
  - 2012: 555
  - 2013: 540
  - 2014: 536
  - 2015: 535

**Calendar Year**
- **2010**
- **2011**
- **2012**
- **2013**
- **2014**
- **2015**

Requirements below the line are in excess of Partner Allocations.
Pressurized Utilization Downmass Capabilities, Allocations, and Requirements

2008 Signed Consolidated Operations and Utilization Plan. Assembly Sequence Rev J

Note: Unpressurized downmass is not available after Shuttle retirement in 2010
Partner Utilization Requirements Compared to Utilization Capabilities

2008 Signed Consolidated Operations and Utilization Plan. Assembly Sequence Rev J
Cumulative ISS Utilization Crewtime by All Partners
Multi-user Support
Sponsorship of Payloads on ISS

ISS National Laboratory

U.S. Commercial Sector

Human Research Program (ESMD)

NASA Research

Human Research Program

Exploration Technology & Development & Microgravity (ESMD)

Exploration Technology & Development & Microgravity

Astrophysics, Heliophysics, Planetary Science

Earth Science (SMD)

ISS Program Office

ISS Int’l Barter Commitments (SOMD)

International Partners

ISS National Laboratory (SOMD Agreements)

Other U.S. Government Agencies (DoD, NIH…)

NASA Mission Directorates
Manage Agreements:
SOMD – Space Operations
ESMD – Exploration Systems
SMD – Science

ISS Program Office
Plans, Integrates and Operates

CSA

ESA

ASI

JAXA
ISS Payload Integration Timeline

Strategic

- L-X months
- Requirements Definition (Design, Development, Test, Safety, and Verification)
  - PDR
  - CDR
- Manifest Approved

Tactical

- L-X months
- Mission Integration (Increment Planning)
  - ISS Crew Rotation
- ~L-1m
- ~6 months
- Real Time Operations (Research)

Operations

Post-flight

- Crew Return
- Post Flight Ops (H/W, Data Return)

Increment

- Stage
- Launch

Hardware development time varies per payload
36 months to days
Research Sponsor initially responds to the RPWG “Call for Payloads” with a list of candidate payloads and resource requirements for consideration. This action starts the manifesting process.

Payload-specific Resource Definition and Two-pagers

ISS Payloads Office Feasibility Assessments (Integration Organizations)

Payload-prioritization

Research Planning Working Group

Increment-specific Research Plan

Flight & Increment-specific Utilization Allocations (ISS Program Office)

(Up/down-mass, Crew time, Power, etc)

Launch Schedules (Shuttle, Russians, ESA, JAXA, ISS Program Office)
Payloads Mission Integration Process

**Increment-specific Research Plan**

*Research Directive*

**Increment Management**
- Payload Tactical Plan
- Flight and Stage Priorities
- ISS Mission Management Team
- Weekly Planning
- Safety Process
- Certificate of Flight Readiness

**Mission Integration**

**Launch Package Management**
- Manifest and Stowage
- Flight Priorities
- Shuttle Crew Time Schedules
- Safety Process
- Certificate of Flight Readiness

**Payload Integration Manager (PIM)**
- Primary interface to ISS for the Payload Developer
- Function as payload advocate at ISS Program meetings
- PIM schedule for major ISS integration milestones and hardware deliveries
- Coordinate ISS Program Support for PDRs/CDRs
- Negotiate and coordinate Payload Developer requirements and service needs
Early Utilization Overview
ISS Research Accomplishments
(Expeditions 0-18, September 2000 – April 2009, data as of April 21, 2009)

- Expedition 18 (Oct 2008-Apr 2009)
  - 77 U.S.O.S.-integrated investigations
    - 27 new investigations
    - 10 completed investigations
    - 34 International investigations (CSA, ESA, JAXA)
  - > 340 scientists

- Expeditions 0-18 (Sept 2000-Apr 2009)
  - 197 U.S.-integrated investigations
    - 115 completed investigations
    - 43 International Partner investigations
  - > 600 scientists

Disciplines for U.S. Science
- Human Research for Exploration
- Technology Development
- Physical Sciences
- Biological Sciences
- Earth Observation & Education
- Integrated Immune
- Ice Crystal
- 3D-Space
- Marangoni
- SPICE
- NLP-Vaccine
- SHERE
Current Research
Expedition 19/20, April 2009 – October 2009, data as of Feb 17, 2009

- Expedition 19/20
  - 98 U.S.O.S.-integrated investigations
    - 39 new investigations
    - 49 International Partner investigations
      - 5 CSA
      - 28 ESA
      - 16 JAXA
  - > 400 scientists

Disciplines for U.S. Science

- Human Research for Exploration
- Technology Development
- Physical Sciences
- Biological Sciences
- Earth Observation & Education
Expedition 21/22 Research Plans
(October 2009 – April 2010, data as of Feb 17, 2009)

- Expedition 21/22
  - 104 U.S.-integrated investigations
    - 39 new investigations
    - 47 International Partner investigations
      - 3 CSA
      - 25 ESA
      - 19 JAXA
  - > 300 scientists

Disciplines for U.S. Science
- Human Research for Exploration
- Technology Development
- Physical Sciences
- Biological Sciences
- Earth Observation & Education

![Images of research projects: HREP-RAIDS, Reaction Self Test, IVGEN, MDCA-FLEX, BXF-NPBX]
For More Information

ISS Reference Guide
Cumulative Results Reports:
NASA/TP-2006-213146
NASA/TP-2009-213146-REVISION A

Education on ISS 2000-2006:
NASA/TP-2006

Space Station Science Webpages

Facilities Webpages