International Space Station
Research Progress during Assembly

Julie A. Robinson, Ph.D., ISS Program Scientist (acting)
AIAA Aerospace Sciences Meeting
January 2007
Themes

- Provide an overview of the multidisciplinary accomplishments on ISS
  - Assembly period limitations (transportation, crew time, sample return)
- Demonstrate the capabilities of a growing suite of laboratory facilities on ISS
- Early ISS science serves as a pathfinder for potential future research in many disciplines
13 ISS Expeditions Completed

Over 6 years of active human presence

Nov 2000 – Mar 2001
Mar 2001 – Aug 2001
Dec 2001 – June 2002
June 2002 – Nov 2002
Nov 2002 – Mar 2003
Apr 2003 – Oct 2003
Oct 2003 – Apr 2004
Apr 2004 – Oct 2004
Oct 2004 – Apr 2005
Apr 2005 – Oct 2005
Oct 2005 – Apr 2006
Apr 2006 – Sept 2006

Lopez-Alegria, Williams, Tyurin

EXPEDITION 14
U.S. Investigations on ISS

Outside U.S.: 39
International Research Accomplishments

Total # of ESA Experiments 2001-2006

- Human Physiology: 29%
- Psychology: 17%
- Biology: 19%
- Microbiology: 3%
- Plasma Physics: 4%
- Material Sciences: 3%
- Fluid Physics: 6%
- Radiation Physics: 1%
- Earth Observation: 1%
- Education: 15%
- Technology: 3%

Russian Space Agency/
Energia Talley
331 Experiments through 2006
Igor Sorokin, October 2006

European Space Agency Talley
183 Experiments on ISS 2001-2006
Marc Heppener, October 2006
Current U.S. Outfitting—9 racks + optical window

Human Research Facility Rack 1 (March 2001)

EXPRESS Rack 1 (April 2001)

EXPRESS Rack 2A (April 2001)

EXPRESS Rack 4 (August 2001)

EXPRESS Rack 5 (August 2001)

Euro. Modular Cultivation System (EMCS) (June 2002)

EXPRESS Rack 3A (July 2006)

Microgravity Sciences GloveBox (June 2002)

Human Research Facility Rack 2 (July 2005)

MELFI Freezer (July 2006)
2006 Science Outfitting

Storage of Blood and other samples
Card (ESA) —
Mechanisms of activation of sympathoadrenal activity in humans during spaceflight and
A model for investigating the mechanisms of heart disease

Microgravity and Partial Gravity Growth Chambers

Tropi—Analysis of a Novel Sensory Mechanism in Root Phototropism
Gravi-1(ESA)—Threshold Acceleration for Gravisensing
Multigen (ESA)—Microgravity Effects on Multigeneration Studies of Arabidopsis thaliana (2007)

Nutrition Status Assessment—
Key bone loss biomarkers:
Hormone indicators of stress
Vitamin status related to metabolic function
Markers of oxidative stress

Minus Eighty Degree C Freezer (MELFI)

European Modular Cultivation System (EMCS)
Next Steps in Science Outfitting 2008

Combustion Integrated Rack (CIR)

Space Dynamically Responding Ultrasonic Matrix System (SpaceDRUMS)

Window Observational Research Facility (WORF)

Materials Science Research Rack (MSRR)
Disciplines Represented in early ISS Research

- Cell Biology and Biotechnology
- Plant Biology
- Human Research
- Physical Sciences
- Technology Development
- Environmental Monitoring
- Earth Observation
- Education
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Examples from 3 areas
Biotechnology

Cell Culture
Bacterial Growth, Virulence, and Antibiotic Production on ISS
CGBA
(Commercial Generic Bioprocessing Apparatus)

- Proven multipurpose incubator that can culture a variety of organisms
  - Bacteria, cells, plants, *Drosophila*, to *C. elegans*
  - First studies were on ISS prior to permanent human occupation
  - Currently a unit is on ISS culturing both seedlings and *C. elegans* for a combination of research and educational activities

- Commercially developed and operated via Bioserve Space Technologies, Boulder, CO

CGBA-APS Results
(Antibiotic Production in Space)

- Used *Streptomyces plicatus* to produce actinomycin-D for 72 days on orbit
- Early antibiotic production in space greater than ground controls
  - Day 8: 15.6% higher
  - Day 12: 28.5% higher
  - After Day 12: ground production > orbit production
- Mechanism under investigation

Ongoing work on Microbial Growth and Virulence: Yeast-GAP, Microbe, POEMS

- Suite of different investigations using microbe culture on ISS
  - Saccharomyces, Candida, Salmonella, Pseudomonas, Bacillus subtilis

- Investigating
  - Reproductive changes
  - Acquisition of antibiotic resistance
  - Changes in virulence
  - Gene activation (microarray analysis)

- Flight components complete

Yeast-Group Activation Packs and Microbe: Cheryl Nickerson, Arizona State University, Tempe, AZ
Passive Observatories for Experimental Microbial Systems, Michael Roberts, Dynamac Corporation, FL
Advanced Astroculture (ADVASC)

- Long-duration plant growth chamber
  - Seed-to-seed life cycle
  - Effect of microgravity on gene expression
  - Chemical characteristics of seeds produced on the ISS

- Arabidopsis thaliana successfully grown from seed to seed on ISS.
  - 90% of the seeds germinated in space
  - 70% of the plants grew to maturity.

- 2nd-generation seeds produced
  - Tissues were harvested and preserved for RNA and cDNA analysis.

- Soybeans grown from seed to seed (95 days), for the first time in space.
  - Biomass production ~ 4% larger than ground controls.

- AiroCide TiO$_2$ developed for maintaining air quality in the hardware applied to air purification by KES Science & Technology

Biomass Production System (BPS) and Photosynthesis Experiment and System Testing and Operation (PESTO)

- Plant growth hardware test for regenerative life support system investigations
  - *Brassica rapa* (field mustard plant) in microgravity for technology validation
  - *Triticum aestivum* (common bread wheat plant) was grown (photosynthesis, metabolism, renewable food)

- BPS results
  - *Brassica rapa* grown over two growth cycles on ISS.
  - Tissue analyzed for general morphology, seed anatomy and storage reserves, foliar carbohydrates, and chlorophyll and root zone hypoxia analysis.
  - Hardware proven for future use

- PESTO results
  - Grew 32 plants for 73 days inside the plant growth chambers
  - Microgravity did not affect either the transpiration or the photosynthesis processes of the plants.

EMCS Facility

- Controlled growth facility for small organisms (plants, microbes, insects, amphibians)
- Variable gravity conditions (0.001G to 2.0G) using a rotating centrifuge
- Multi-generation experiments and studies on gravity effects on early development and growth
- For plant studies, EMCS facilitates
  - long-term growth studies, including multi-generation studies (seed to seed),
  - early development events in plants,
  - gravity influence on early development and growth (g-level threshold research) and
  - studies of how plants perceive and respond to gravity when they grow.
- U.S./ESA Shared equipment

Thomas Reiter installing EMCS, Expedition 13
Analysis of a Novel Sensory Mechanism in Root Phototropism (Tropi)--ongoing

- *Arabidopsis thaliana* (thale cress) response to varying levels of light and gravity.
  - Various gravity conditions (0g to 1.0g) using a rotating centrifuge
  - White light, red light, and blue light treatments to separate phytochrome systems
  - Seedlings frozen in MELFI for future genetic analysis

- 0G and 1 G and partial G operations completed during Expedition 14

- Next experiment (Gravi) planned for next week
  - Threshold for gravisensing by lentil seeds

Tropi: John Kiss, Miami University, Oxford, OH
Gravi (Threshold Acceleration for Gravisensing): Dominique Driss-Ecole, Université Pierre-et-Marie Curie, Paris
Physical Science
Study of the physics of colloids (fluids with dispersed particles)
- On earth, properties dominated by sedimentation and buoyancy
- Crystallize (self-assemble) in microgravity

Results
- Colloid-polymer mixtures of polymers serve as a model for molecular behavior at the critical point (led to development of BCAT follow-on investigation, ongoing)
- Power-law growth behavior in binary crystallization
- Formation of gels with fractal structures

PCS: David Weitz, Harvard, Peter Pusey, Univ. Edinburgh
Binary Colloidal Alloy Test: David Weitz, Peter Lu, Arjun Yodh et al.
Pure material production in microgravity

- Solidification and crystal growth processes (lack of convection and sedimentation in ug)
  - Melt growth to reduce convection in solidifying indium antimonide doped with Te and Zn
  - Zeolite (minteral aluminosilicate) crystallization

- Results
  - Pure semiconductor crystals from InSb
  - Zeolite beta with high degree of crystalline perfection
  - In progress: bulk metallic glasses, magnetorheological fluids, pore formation during molten solidification

Published summary of Results from Expeditions 1-10

NASA/TP-2006-213146

Resources

Space Station Science Webpages (track objectives and results with frequent updates)
