Overview of the NASA Microgravity Biomaterials Program

by

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Microgravity Biomaterials Sponsor

Microgravity Biomaterials Sponsor: The microgravity research program is sponsored by the Space Life and Physical Sciences Division of the Human Exploration and Operations Directorate at NASA Headquarters

- Director: Marshall Porterfield
- Program Executive for Physical Sciences: Fran Chiaramonte
- Biomaterials research project management is delegated to MSFC

Six areas of microgravity research are supported

- Biophysics
- Combustion
- Complex Fluids
- Fluids
- Fundamental Physics
- Materials

Reasons for Performing Microgravity Studies

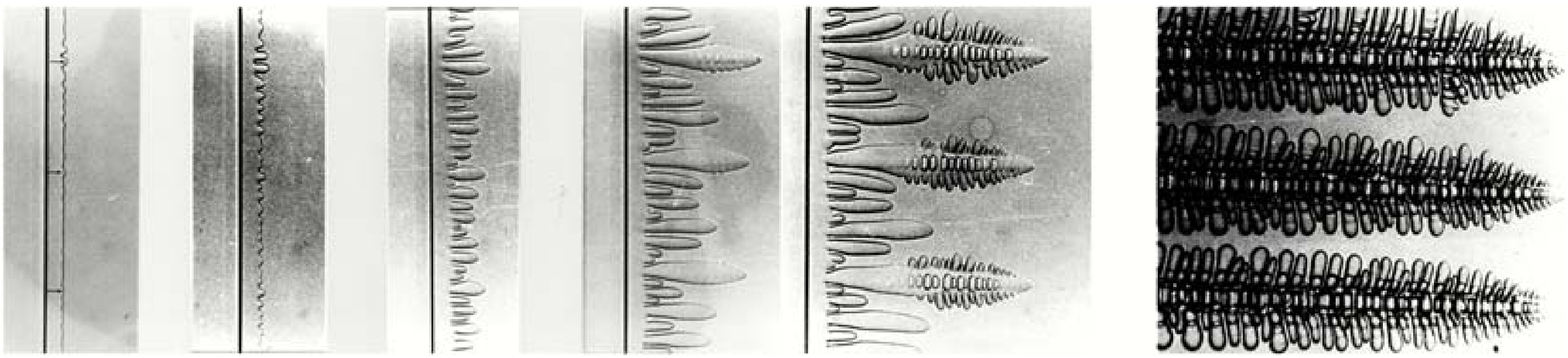
Microgravity is a unique environment for laboratory studies

- A lab experiment on the International Space Station is in a state of nearly perfect ballistic freefall
- Note: slight atmospheric resistance and the offset of the location of the attachment of the experiment from the ISS center of mass prevent a perfect ballistic freefall

Reasons for Performing Microgravity Studies

Near elimination of buoyancy driven convection

- e.g. Diffusion dominated growth in directional Solidification experiments on crystalline and dendrite formation – Studies by Dr. Trivedi of Iowa State University



Reasons for Performing Microgravity Studies

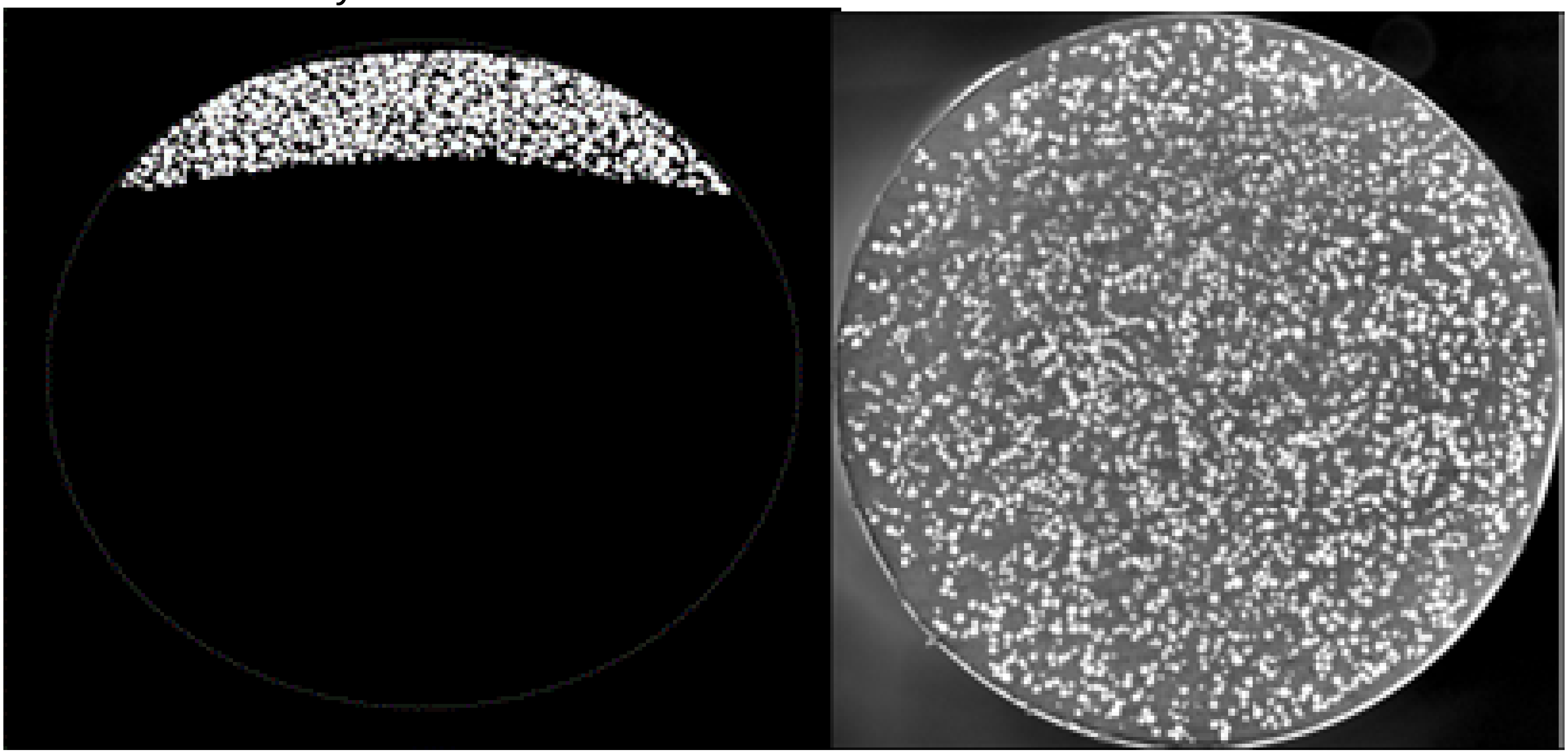
Near elimination of pressure head effects

- e.g. Stress-strain studies of granular samples at low-confining pressures – The Mechanics of Granular Materials investigations by Stein Sture of the University of Colorado

Reasons for Performing Microgravity Studies

Near elimination of sedimentation

- e.g. Coarsening of spherical droplets (molten Sn in Pb) via Ostwald Ripening – Microgravity Studies by Dr. Peter Voorhees of Northwestern University



Reasons for Performing Microgravity Studies

Note: Studies of molecular level interactions are typically not a reason for performing microgravity experiments

- Gravity is so weak that electrostatic interactions between molecules overwhelm any gravitational effects

Microgravity Biomaterials Science Selection

SLPS Science Selection Process:

Traditionally projects are selected from proposals submitted in response to a NASA Research Announcement soliciting response in a defined area of interest

- An NRA soliciting proposals to “mine” data from previous spaceflight experiments is planned in this year.
- Data from previous microgravity physical sciences experiments sponsored by SLPS and conducted on the ISS is being collected for a database accessible to the user community
    - POC: Ben.Henrie@NASA.Gov, 256-544-2446.

Alternatively scientific project requirements may be determined by a Science Definition Team with post-flight analysis of results conducted by a research group to be determined near or after the flight.

Microgravity Biomaterials History

The precursor to the current biomaterials program was a series of experiments in which protein crystals, crystals of viruses, and nucleic acid crystals were grown in microgravity conditions by a variety of methods

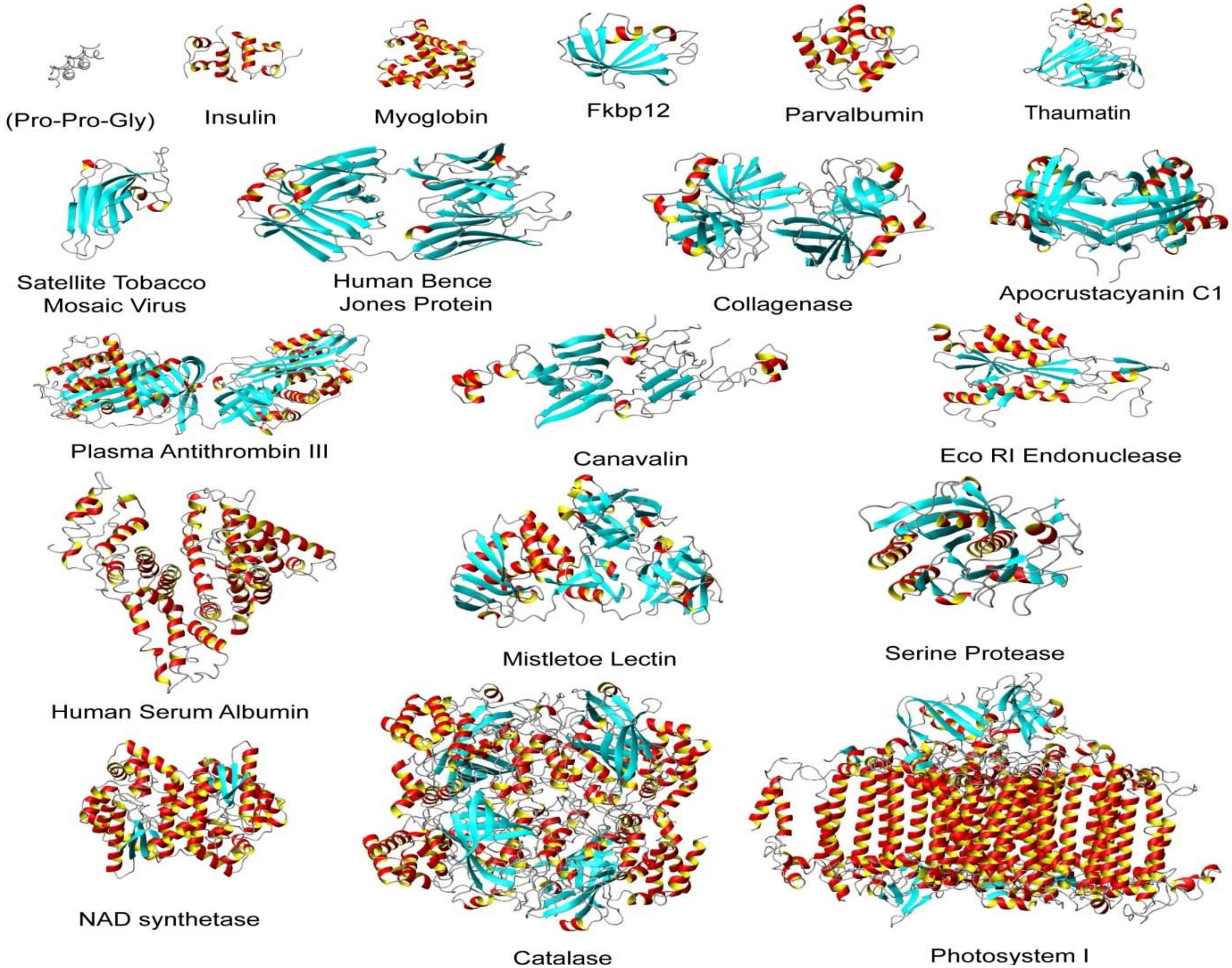
The investigations were largely conducted by Drs. Alexander McPherson, Larry Delucas, and Daniel Carter with associated colleagues

Improved crystalline order from a number of samples such as insulin complexes, satellite tobacco mosaic virus, etc. allowed more detailed structural data from diffraction patterns to be obtained.

In a number of cases crystals large enough for neutron diffraction studies were obtained.

Reasons for the improvement attributed to factors such as slower growth, coarsening/annealing, and/or improved partitioning of large impurities from the growing crystal surface.

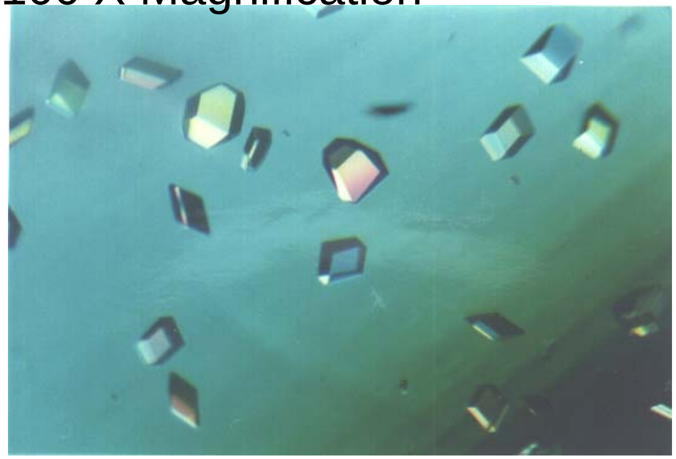
New and Improved Published Macromolecular Structures Resulting from Microgravity Research



Examples of Microgravity Grown Crystals

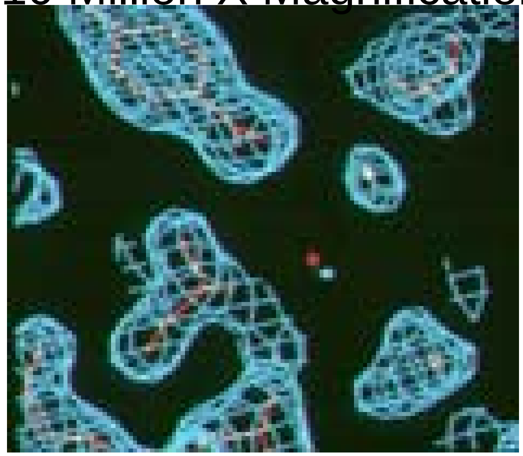
Recombinant Human Insulin

100 X Magnification

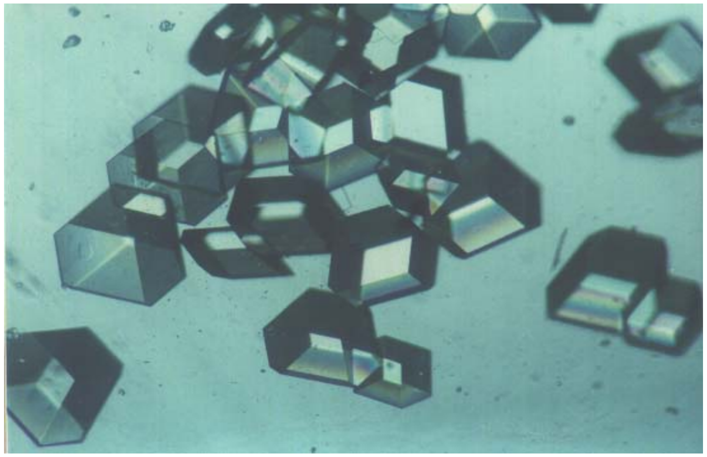


Earth-Grown Insulin

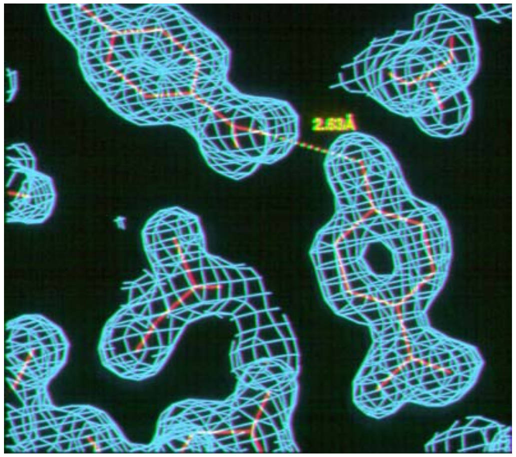
10 Million X Magnification



Earth-Grown Insulin



Space-Grown Insulin



Space-Grown Insulin

Courtesy University of Alabama at Birmingham

Microgravity Biomaterials Recent Selections

Biophysics/Biomaterials currently has 4 investigations selected from proposals received in response to a 2014 NASA Research Announcement

“Solution Convection and the Nucleation Precursors in Protein Crystallization” by Dr. Peter Vekilov of the University of Houston

“Growth Rate Dispersion as a Predictive Indicator for Biological Crystal Samples Where Quality Can be Improved with Microgravity Growth” by Dr. Edward Snell of the Hauptmann Woodward Medical Institute

“The Effect of Macromolecular Transport on Microgravity Protein Crystallization” by Dr. Lawrence Delucas of the University of Alabama at Birmingham

“Amyloid Fibril Formation in Microgravity: Distinguishing Interfacial and Flow Effects” by Dr. Amir Hirsa of Rensselaer Polytechnic Institute

Note that the Center for the Advancement of Science in Space (CASIS) is also funding ISS researchers in this area

Microgravity Biomaterials Workshop

Future: To determine the level of interest in new areas of microgravity biomaterials research a Request for Information was released by NASA

- 23 responses

In addition, a workshop was held on December 3 at the recent 2014 Fall Materials Research Society Meeting and Exhibition in Boston entitled, "NASA Biological Materials, Biomaterials and Biomimetics Workshop" to further evaluate the level of interest in conducting biomaterials research on ISS.

- Approximately 50 Attendees

Microgravity Biomaterials RFI Requested Data

What best describes your area of expertise?

What category is your employer?

Please describe at a high level the materials experiment or set of closely related experiments which you believe would be the highest scientific quality and the widest impact to the research community that require the use of the International Space Station.

Please describe the equipment, hardware, facilities, etc. that would be necessary to perform the experiment(s) which you described above on the ISS.
What is the application and broader impact of this research to life on earth and/or space exploration?

Which (if any) other government agencies or commercial entities would you anticipate partnering with NASA in support of performing the experiment(s) you described above?

What types of experimental data and approximately how much data, e.g. megabytes, gigabytes, etc. would be generated by the experiment(s) which you describe above?

Microgravity Biomaterials Areas of Interest

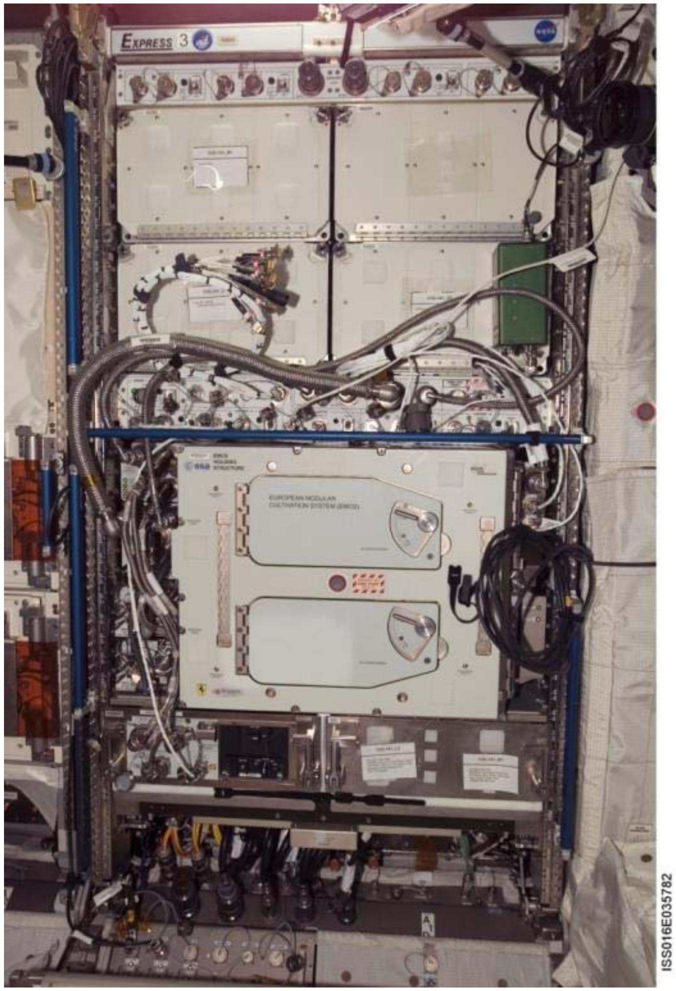
Freeze casting of bioscaffolds from aqueous solutions

Electro-spinning of fibers to be used in patterned bioscaffolds

Ordered biomaterials structured from acoustic fields

Bioscaffolds constructed by sol-gel transitions

Available Hardware: EXPRESS Rack



EXPRESS Rack 3 with European Modular Cultivation System operating in Columbus Module

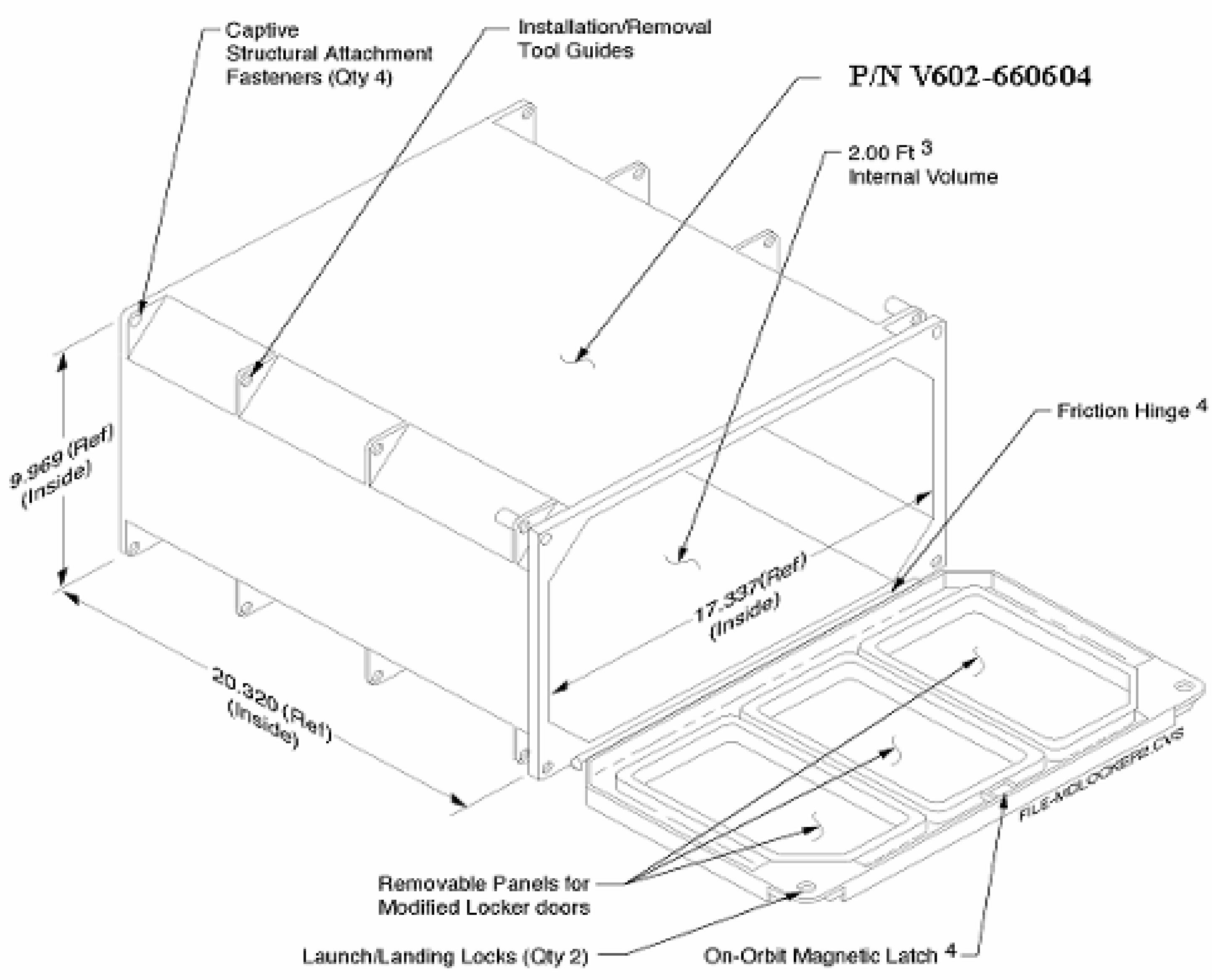
- EXpedite the PRocessing of Experiments to Space Station (EXPRESS) rack is a multi-use facility which provides standard interfaces and resources for Middeck Locker-type and International Subrack Interface Standard (ISIS)Payloads
    - 28Vdc power
    - Ethernet, RS422 , Analog, Discrete
    - Air and Water (2 locations per rack) Cooling
    - NTSC Video
    - Vacuum Exhaust (1 location per rack)
    - Nitrogen Supply (1 location per rack)
- Eight flight racks
- Trainer Racks at JSC and MSFC to support crew and ground training
- Functional Checkout Unit (FCU) to support payload testing at MSFC

EXPRESS Payload Resources

Resource	Amount per Payload Position	
	Locker	ISIS Drawer
Structural Attachment	Attachment to Rack per IDD •Mass constraint launch vehicle dependent	Attachment to Rack per ISIS Spec •64 lb within cg constraints
Power	5, 10, 15, or 20 Amp at 28 VDC	5, 10, 15, or 20 Amp at 28 VDC
Thermal Control Air	Nominal 150 W (1200 W rack maximum)	Nominal 150 W (1200 W rack maximum)
Thermal Control Water	500 W Heat Rejection per position (2 positions per rack)	500 W Heat Rejection per position (2 positions per rack)
Data	•1 - RS-422 •2 - +/- 5 Vdc Analog •1 - Ethernet •3 - 5 Vdc Discrete (bi-dir)	•1 - RS- 422 •1 - +/- 5 Vdc Analog •1 - Ethernet •2 - 5 Vdc Discrete (bi-dir)
Video	NTSC/RS 170A feed from payload source (Shared)	NTSC/RS 170A feed from payload source (Shared)
Venting	1 payload interface per rack (Shared)	1 payload interface per rack (Shared)
Nitrogen	1 payload interface per rack (Shared, 12 lbm/hr)	1 payload interface per rack (Shared, 12 lbm/hr)

Reference: EXPRESS Rack Payloads Interface Definition Document, SSP 52000-IDD-ERP

EXPRESS Rack Drawer



Available Hardware: Microgravity Science Glovebox

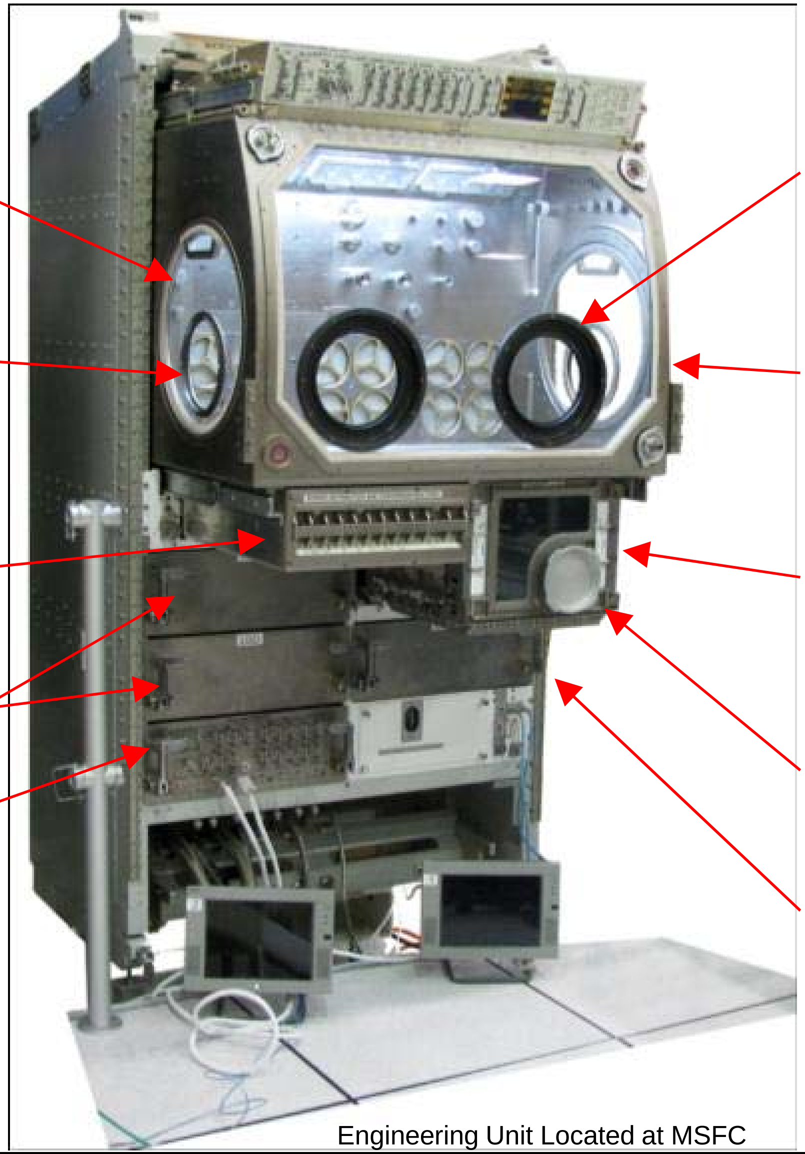
Removable Side Ports
16” diameter on both Left and Right sides for setting up hardware in Work Volume

Glove Ports
Four identical glove ports are located on the left and right side loading ports and the front window

DC Power Switching And Circuit Breakers

Stowage Drawers

Video System Drawer



Engineering Unit Located at MSFC

Front Window Glove Ports
Four 6” diameter glove ports can be fitted with any of three different sized gloves or blanks

Core Facility
Retractable Core Facility includes the Work Volume, Airlock, Power Distribution & Switching Box, and the Command and Monitoring Panel

Airlock
Provides a “Pass Through” for hardware to enter the Work Volume without breaking Containment. The lid of the Air Lock opens up into the floor of the Work Volume

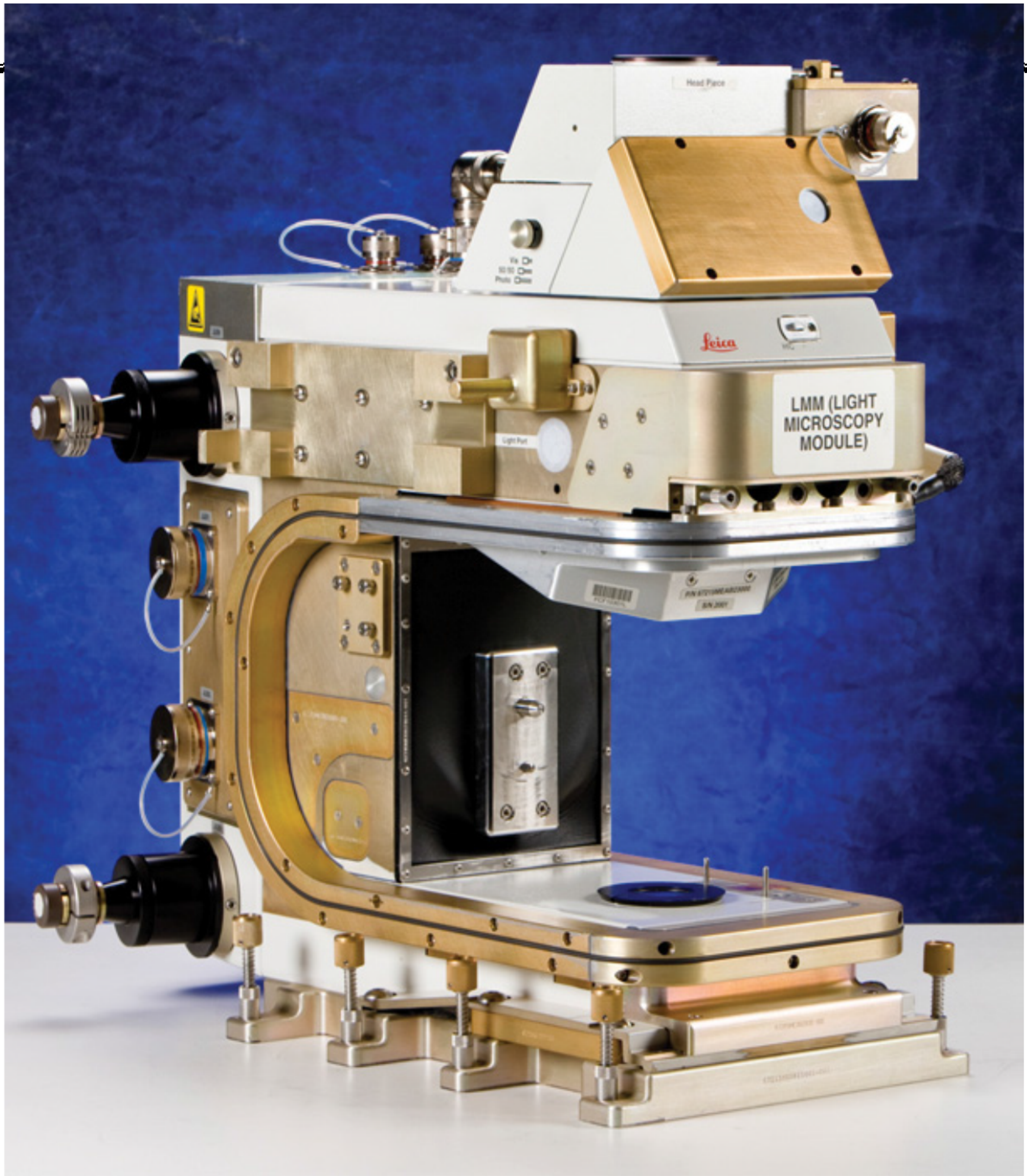
Airlock Glove Port with Blank
A Single 4” diameter glove port can also be fitted with any of three different sized gloves or a blank

Stowage Drawers

Current MSG-Provided Payload Interfaces/Resources

- Work Volume(WV) - Volume
  - 0.255 m^3 = 255 liters
- Work Volume - Dimensions
  - 906mm wide x 637mm high
  - 500mm deep (at the floor)
  - 385mm deep (at the top)
- Maximum size of single piece of equipment in WV (via side access ports)
  - 406mm diameter
- Payload Attachment
  - M6 threaded fasteners in floor, ceiling, & sides
- Power available to investigation
  - +28V DC at useable 7 amps
  - +12V DC at useable 2 amps
  - -12V DC at useable 2 amps
  - +5V DC at useable 4 amps
  - +120V DC at useable 8.3 amps
- Maximum heat dissipation
  - 1000W Total
    - 800W from coldplate
    - 200W from air flow
- General illumination
  - 1000 lux @ 200mm above WV floor
- Video
  - 4 color Hitachi HV-C20 cameras
  - 2 Sony DSRV10 Digital Recorders
  - 2 Sony GV-A500 Analog 8mm Recorders
- Data handling connections
  - Two RS422-to-MSG for investigations
  - One MIL-BUS-1553B-to-MSG for communication via MLC
  - Ethernet LAN 1 and LAN 2 (in US LAB)
  - MSG Laptop Computer (MLC) – IBM T61P
- Filtration
  - 12 HEPA/charcoal/catalyst WV filters
- 1 HEPA/charcoal/catalyst Airlock filter
- Up to Two Levels of Containment
  - Physical barrier of MSG structures, gloves, etc.
  - Negative pressure generated by MSG fans.
- Other resources available
  - Gaseous Nitrogen
  - Vacuum (VRS & VES)

Available Hardware: Light Microscopy Module



Light Microscopy Module

The microscope can house many different lenses corresponding to magnifications of 2.5, 4, 10, 20, 40, 50, 63 (air), 63 and 100 oil-coupled objectives.

Present capabilities include brightfield, fluorescence, and epi-illumination microscopy.

Future planned capabilities include high-resolution color video microscopy, condenser assembly, confocal microscopy, and possibly laser tweezers.

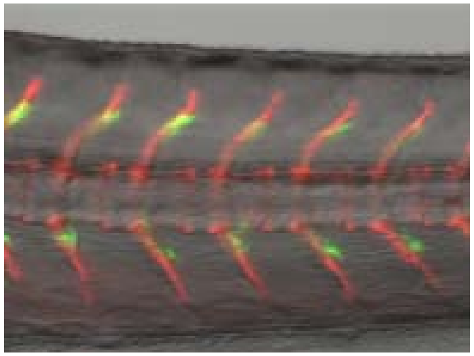
Available Hardware: Fluorescence Microscope

Specifications

- Inverted microscope: Leica DMI 6000B
- Bright field, phase contrast, and fluorescence observations
- Objective lens: x5 (NA 0.12), x10 (NA 0.25), x20 (NA 0.35), x20 (NA 0.70), x40 (NA 0.50), x40 (NA 0.75)
- Monochrome CCD camera: Leica 360FX
- GFP and DsRED observations
- LED illumination (365, 470, 530, 620nm): Leica SFL7000
- Time-lapse videomicroscopy
- Leica micro-titer plate holder (No. 11531434) is set as a standard specimen holder.
- The maximum size of the specimen vessel including frame or holder is 83x127mm (micro-titer plate size)
- Objective lens, CCD camera, fluorescence filter cube, and LED illumination are exchangeable to Leica series

Launched with HTV-3 in 2012, and onboard check out has been completed.

JAXA Microscope in MSPR



Medaka transgenic line

Other Hardware

A number of refrigerators, freezers, incubators, and crystal growth hardware devices also are available.

Microgravity Biomaterials Wrap Up

Next Step: Likely to release an NRA in the next year.

Finally –

Comments, questions, or inputs on the program are welcome

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