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Innovate. Integrate. Inspire

Understanding the Challenges of Low Gravity Fluids and Sample Management in Space Biological Research System Design

National Academies of Sciences, Engineering, and Medicine
Committee on Biological and Physical Sciences in Space Symposium

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Exploration Park, FL

29 March 2017

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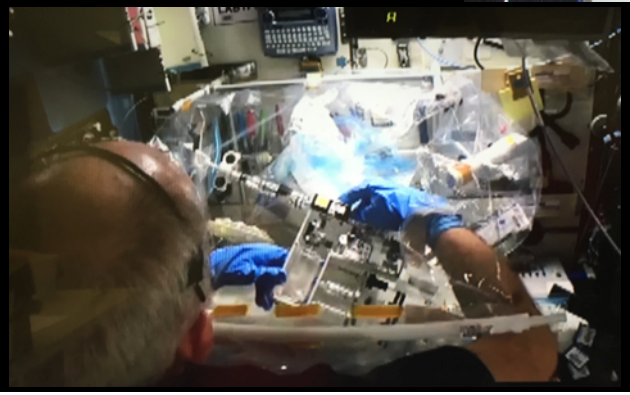
25+ years of experience with life & physical science research in space









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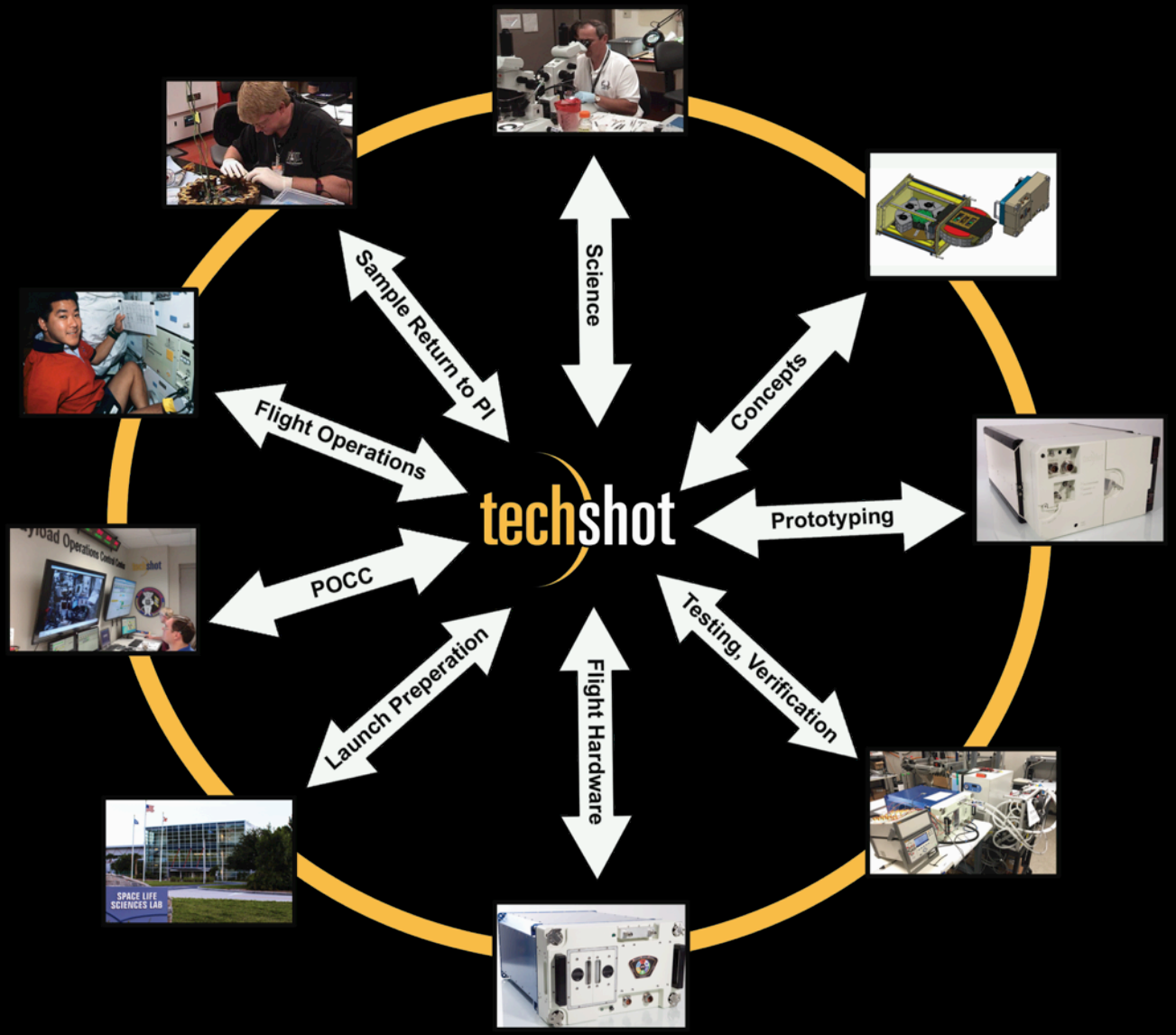
Continuum of Service



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Spaceflight Research Hardware

- Bone densitometry
- Rodents
- Cells/stem cells
- Protein crystal growth
- *C. elegans* roundworms
- Bacteria
- Biofilms
- *Drosophila* fruit flies
- *Arabidopsis* plants
- Colloids
- Light microscopy
- Avian development
- 3D organ and tissue printing

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Challenges Designing for Spaceflight

- Overlapping and conflicting requirements come from safety, vehicle interfaces, and mission success sources
- Containment designs must be robust and fault tolerant
- Fluids and biology must not contaminate the habitable environment nor shall the environment contaminate the experiment
- Liquids and gases must both be considered, particularly when mixing or separating in an enclosed volume
- Physical phenomena affect living systems at the microscopic and macroscopic level: buoyancy, convection, heat and mass transport, boundary layer effects

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ADvanced Space Experiment Processor

ADSEP

Cell culturing, rotating bioreactor

C. elegans, Fluid Processing, etc.

Protein Crystal Growth

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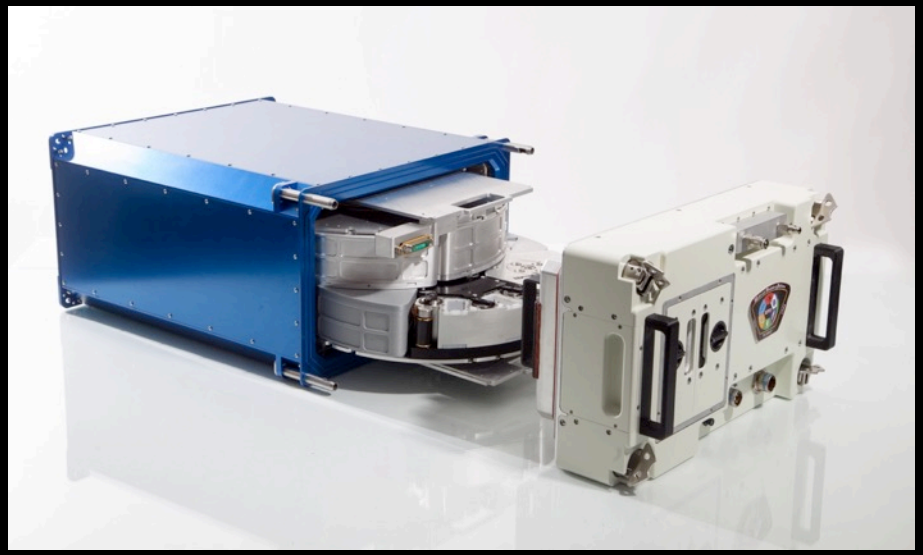
Multi-use Variable-g Platform

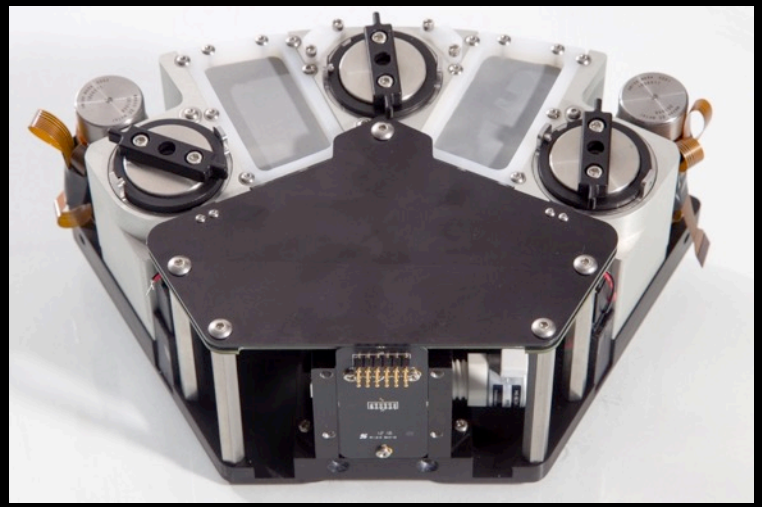
MVP



- Dual independent rotors
- Microgravity
- Lunar (1/6 g)
- Martian (1/3 g)
- True 1-g reference control

Adherent or suspended cell culture

Drosophila fruit flies



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Analytical Containment Transfer Tool

ACT^2

- Safe doubly-contained sample transfers to orbit, from orbit, and between equipment in space
- Freezable down to -80 °C
- Standard Luer connector

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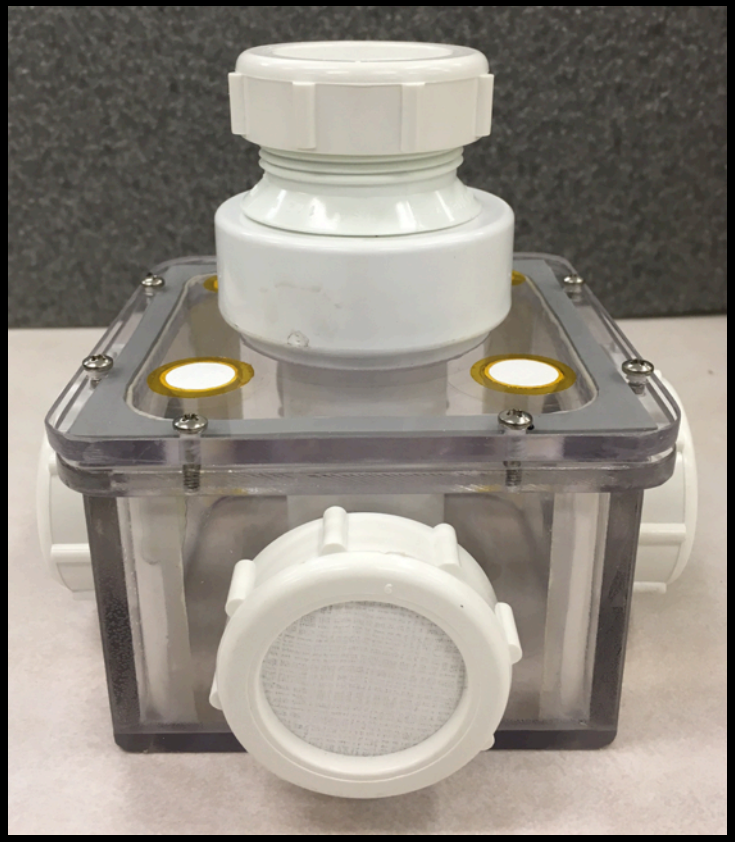
Passive Orbital Nutrient Delivery System

PONDS - In Development

Lettuce



NASA-developed prototype

Cabbage

Tomato

Arabidopsis

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Space 3D Bioprinter

In Development

3D printed neonatal heart ventricle

Parabolic flight demonstration

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Additional Spaceflight Hardware Information

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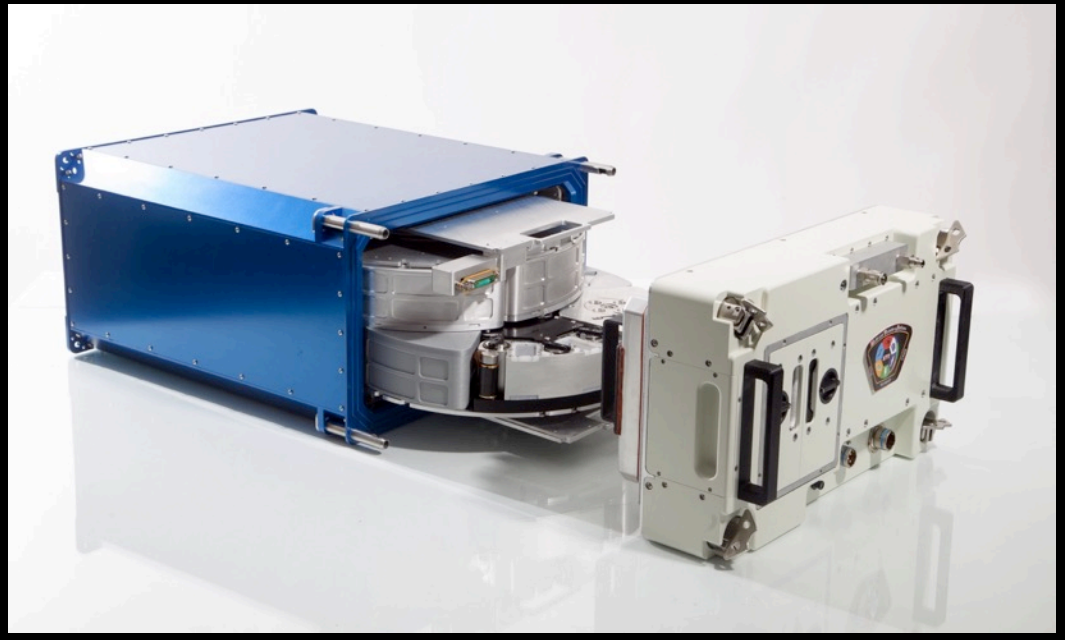
Multi-use Variable-g Platform

MVP



- Dual 390 mm rotors, simultaneous 0-2g
- Thermal control
- 12 sample modules, each with video capability
  - Cell culturing (adherent and suspended)
  - *Drosophila*
- Rotors and sample modules removable on orbit.

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Multi-use Variable-g Platform

Cell Culturing Sample Module

- Cell culturing (adherent and suspended)
- Fully Automated: feed, sampling, waste, fixation
- Microscopy optics
- Three levels of containment
- Can add and/or remove fluids with ACT^2

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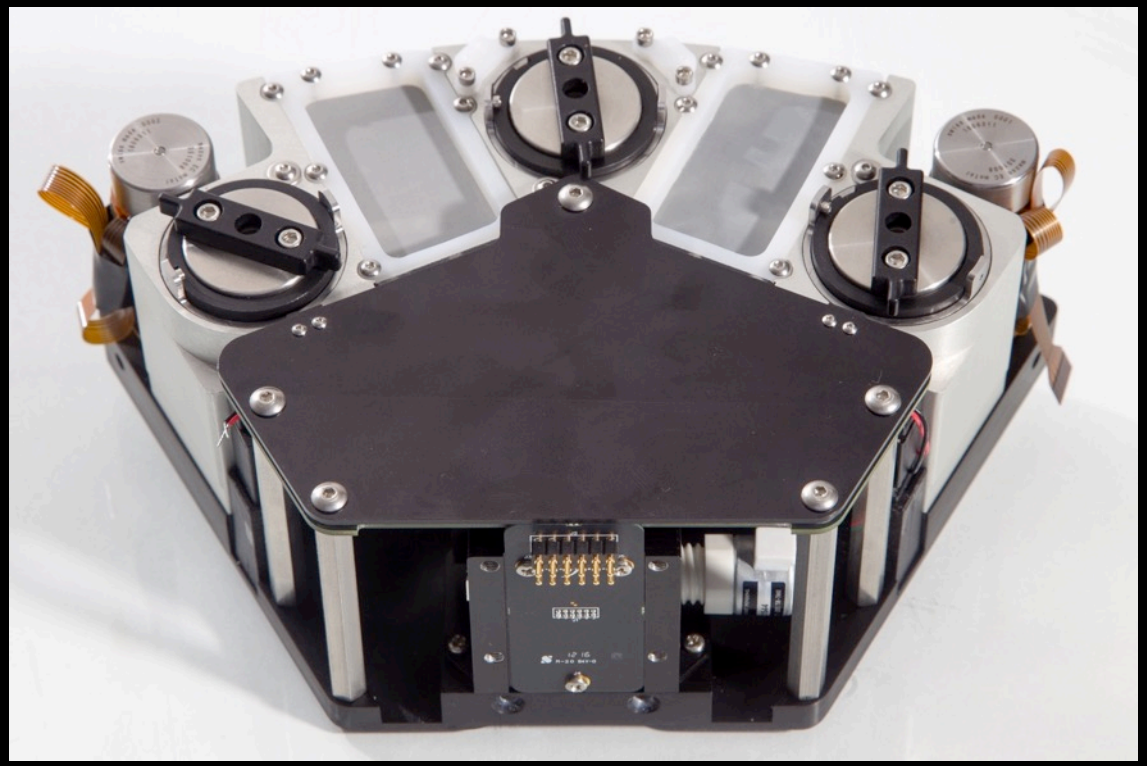
Multi-use Variable-g Platform

Drosophila Sample Module



- Accommodates multiple generations
- Food cylinders
- Lighting control
- Color and IR Video
- Humidity, thermal and gravity control provided by MVP locker

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CellCult

- **Rotating wall bioreactor**
- **Fully automated: feed, sampling, waste, fixation**
- **Three levels of containment**
- **Can add and/or remove fluids with ACT^2**

techshot ADvanced Space Experiment Processor (ADSEP)

Fluid Processing Cassette

- Pumps and valves move fluids
- Fluoropolymer bags
  - Medium
  - Waste
  - Samples
- Three levels of containment
- Can add and/or remove fluids with ACT^2

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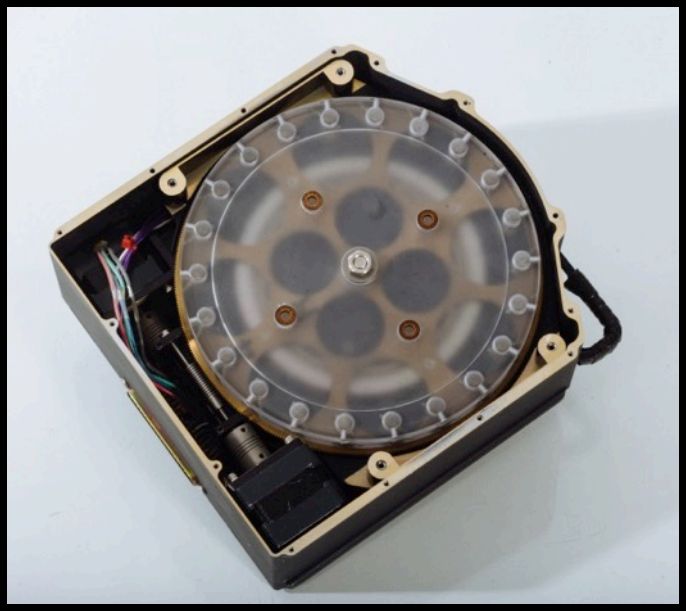
BiSep



- **Good for protein crystal growth**
- **Two pairs of moveable plates.**
- **Each pair of plates has 22 pairs of 0.5 ml sample cavities**
- **Mixing via programmable electromagnetic stirring.**
- **Separates and purifies living cells, cell particles and proteins.**
- **Non-toxic, Aqueous Two-Phase Partitioning (ATPP) separation technique.**
- **ATPP preferentially separates various sized cells and cellular particles, using immiscible aqueous-based polymers (typically PEG and Dextran).**

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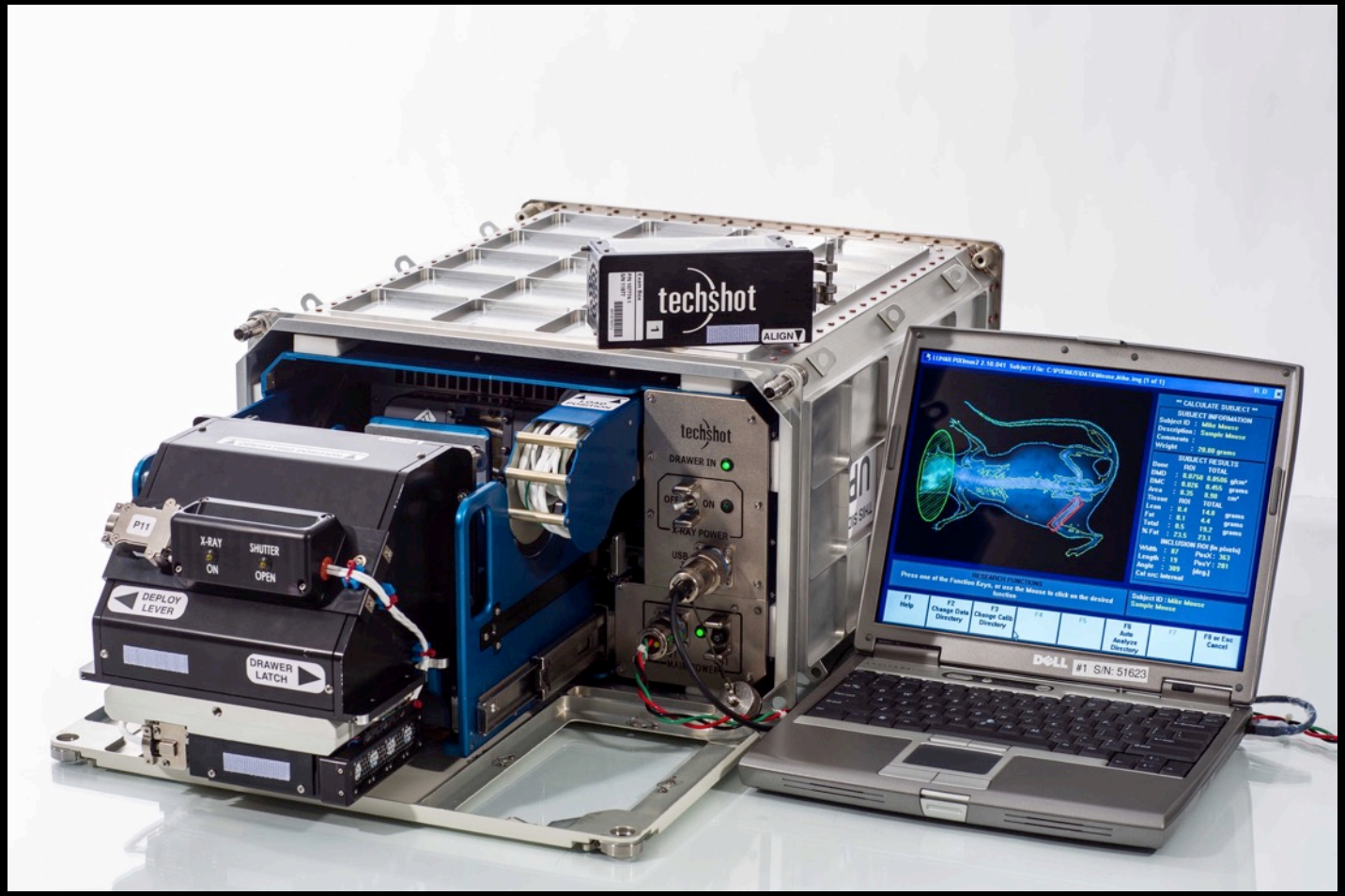
Bone Densitometer



- **Osteoporosis, muscle wasting diseases**
- **Commercial customers: Eli Lilly, Novartis**