Microgravity Issues in Spaceflight Engineering Systems

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- 2.2 million ft^2 / 204,400 m^2 of laboratories & offices
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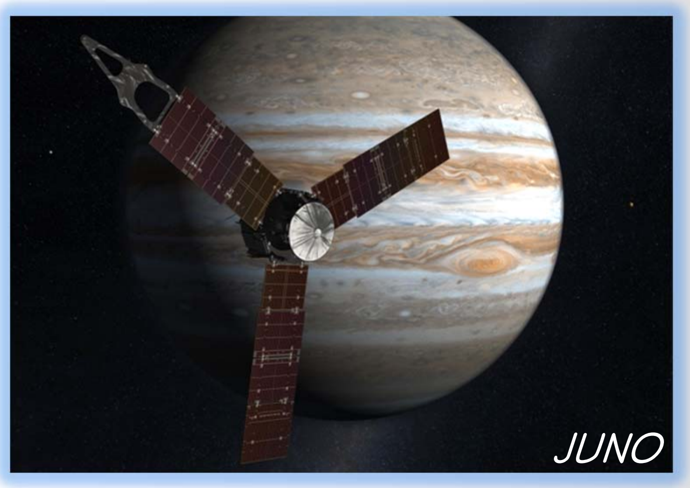
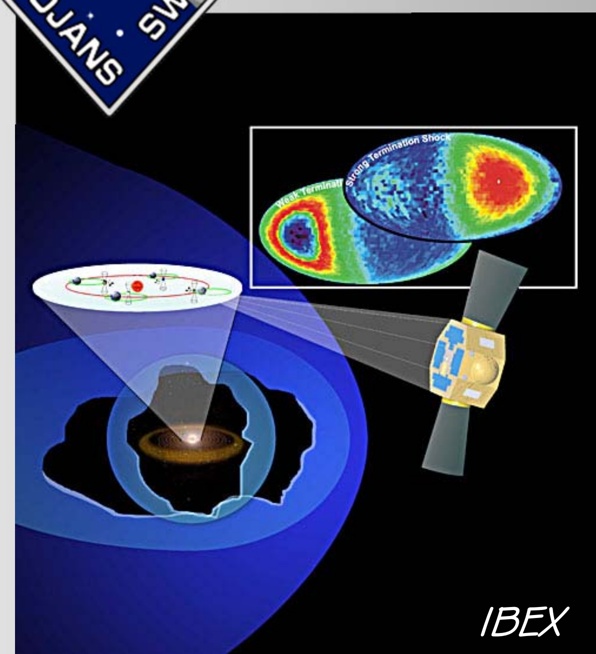
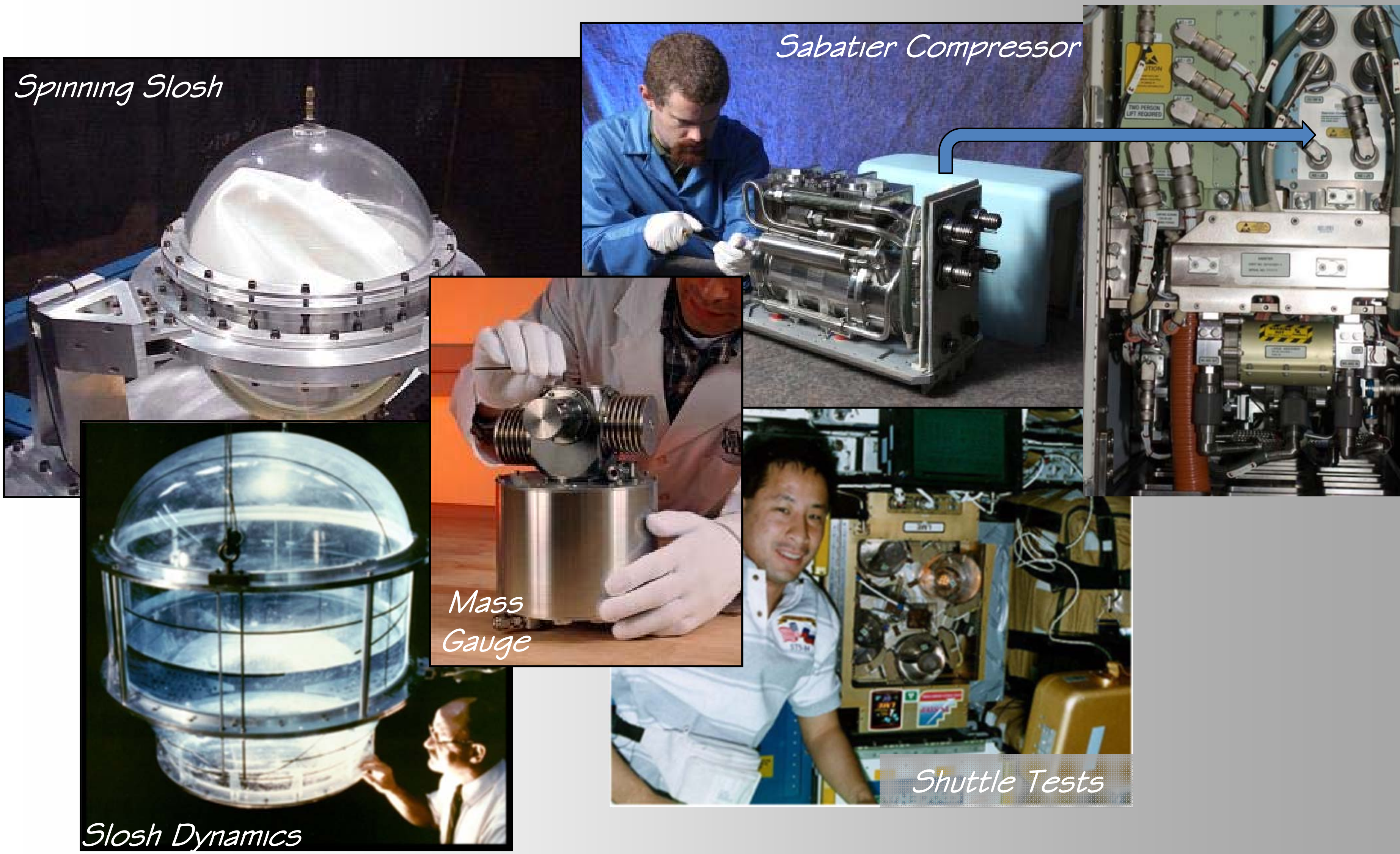
SwRI Space Science Missions





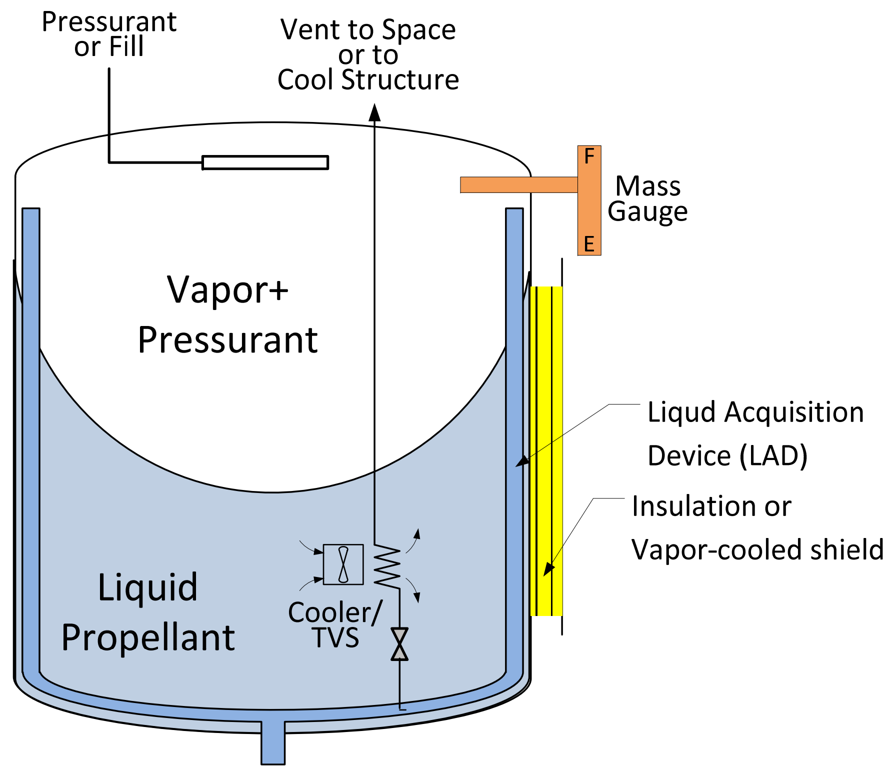
…….and many more.

SwRI Space Fluids Engineering



Challenges for Cryogenic Propellants On Long Missions

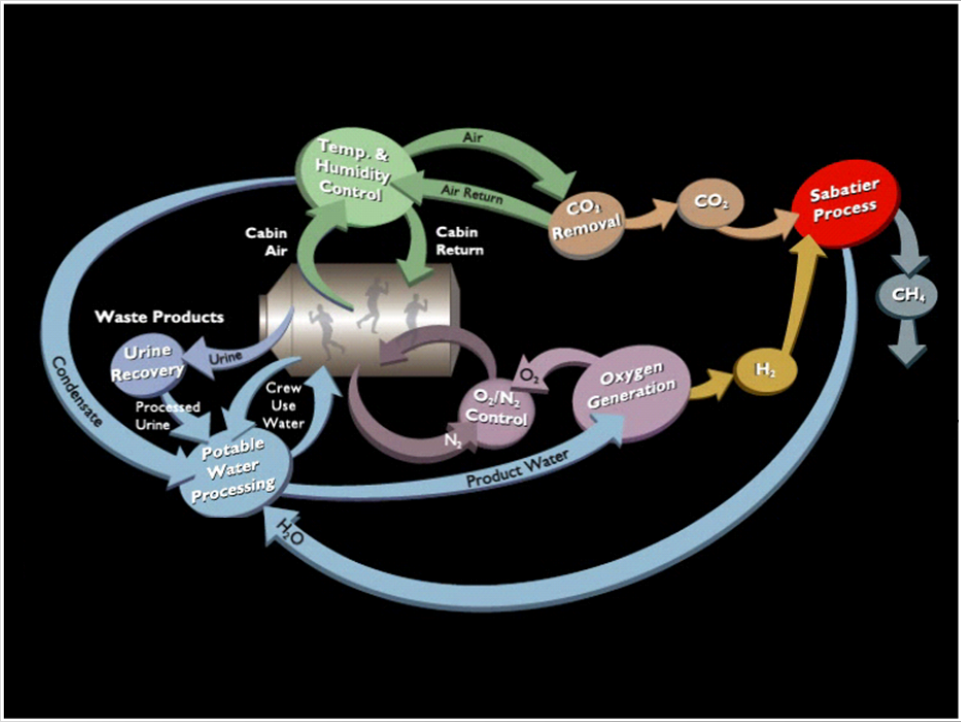
- Fluid Management
  - Vapor-free delivery is required for engines.
  - Microgravity hinders liquid acquisition/retention.
- Thermal Management
  - Heat leak reduction is key to conserving propellant.
  - In-tank cooling will be required for long missions.
- Mass Gauging
  - Standard methods (Bookkeeping, PVT) are well proven for non-cryogens.
  - PVT with periodic settling may work for cryogens in 0-g.
  - Advanced 0-g methods require more development (optical, acoustic, radio).



- *Much of the physics is understood.*
- *Engineered <u>systems</u> still need development and in-space testing.*

Life Support Systems

- Closed loop air systems will be key to the success of long missions.
  - Several processes are identified for CO_2 removal.
    - Candidates are based on Zeolites, Amines, and <???>
    - Flight demonstrations are planned.
  - Hardware issues uncovered in ISS Sabatier
    - Mechanical life
    - Water breakthrough effects on CO_2 pump and CO_2 storage
- Fluid Separation
  - Gas/Liquid separation is a problem in 0-g
  - Long-life, low-maintenance hardware requires development.
    - Mechanical devices?
    - Surface tension devices?



Closed-Loop CO_2 Processing for O_2 Recovery

- *The chemistry/physics is known for most processes.*
- *Engineered systems still need development and in-space testing.*

In-Situ Resource Utilization for Mars and Moon

- The discovery of water on Mars (at least at high latitudes) has changed the outlook for ISRU processes there.
- All the basic components for fuel feedstock and oxygen production are potentially in place.
- There is ongoing research in scaled analog missions on Earth of moderate duration.
- Any system will be required to operate in the reduced gravity of Mars/Moon for long life.
- *These are harsh environments that will require engineering solutions for*

Filtration | *Gas Compression*
Gas Liquefaction | *Cryogenic Storage*
Mechanical Life | *Repair/Replacements*
etc., etc., etc.

$$2CO_2 \rightarrow 2CO + O_2$$

Reduction
Solid Oxide Electrolysis

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

Methanation
Sabatier

$$CO_2 + H_2 \rightarrow CO + H_2O$$

Reduction
Reverse Water Gas Shift

Three of the candidate processes for fuel and oxygen production for Mars ISRU systems.

Concluding Remarks

- The ISS and its Microgravity Science laboratory provide unique facilities for scientific studies of microgravity effects in fluid mechanics, materials processing, and biological systems.

- Large scales and long-duration tests are needed to validate fluid and gas processing systems for human exploration beyond Earth orbit.
  - ISS can be used for at least some ECLSS system testing.
  - Single purpose flight tests may be needed for cryogenic propellant technology demonstrations.
  - High fidelity testing (low pressure, dust, thermal cycle, etc.) is required to qualify ISRU systems.