The National Academies of Sciences, Engineering and Medicine's Committee on Biological and Physical Sciences in Space: Issues Relevant to NASA's Planning for Human Exploration and Low Gravity Research

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October 31, 2017

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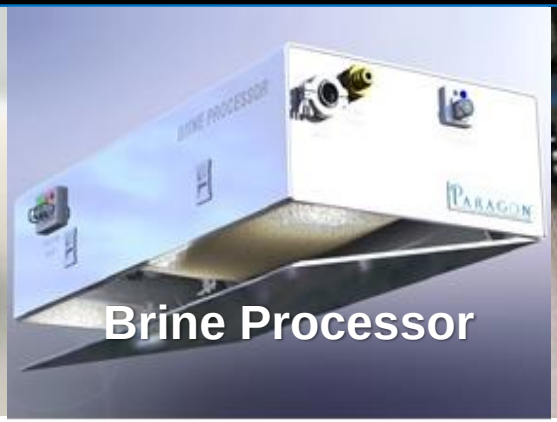
Background - Paragon

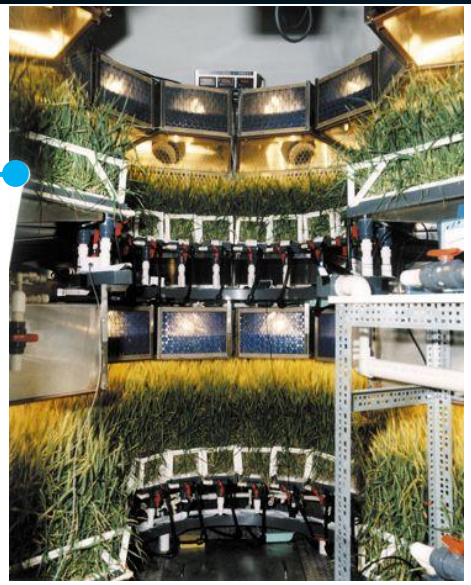
Air Revitalization	Thermal Control	Water Recovery	Analysis, Specialty Manufacturing & Instrumentation

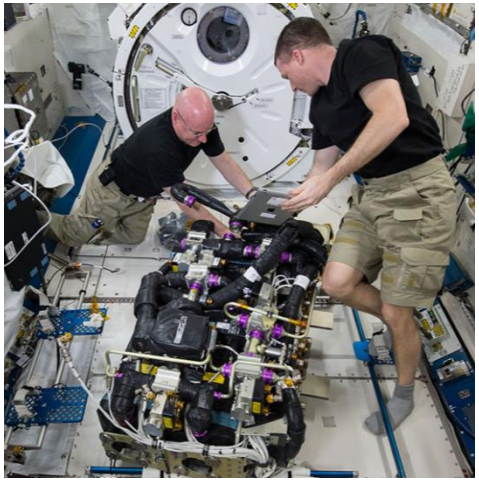
A world leader in the design and manufacture of life support and thermal control systems and hardware for extreme environments in aerospace, defense and commercial markets



Background - Me

- 1987-1992 University of Florida, BS & MS in Aerospace Engineering
- 1992-1997 – KSC Controlled Ecological Life Support System (CELSS) Engineer
- 1997-2004 – JSC / Honeywell ISS Sustaining Engineering and Life Support Technology Development
- 2004-2005 – JSC / United Technologies Life Support Technology Development
- 2005-2006 Bigelow Aerospace ECLSS Manager
- 2006-Present – Paragon, Chief Engineer





Framing My Thoughts and Observations

Committee on Biological and Physical Sciences in Space

http://sites.nationalacademies.org/SSB/SSB_145312#SOT

- The overarching purpose of the committee is to support scientific progress in space research in the biological, medical, and physical sciences and assist the federal government in integrating and planning programs in these fields.
- The scope for CBPSS spans:
  - plant and microbial biology
  - animal and human physiology
  - basic and applied physical sciences, in the context of understanding the role of gravity in living and physical systems in order to develop capabilities required for space exploration
  - using the space environment as a tool of science to advance knowledge.

Topic Areas

- Exploiting and Working With (not Against) the Space Environment
- Reducing the Cycle Time from Scientific Discovery to Engineered Solution
- The Application of Biology to Engineered Systems for Space Exploration

PARAGON

Exploiting and Working With (not Against) the Space Environment

- From the Preliminary Panel Questions:

"Multiphase flows in life support systems are one example of how reduced gravity can alter a physical behavior in [a] way that is highly detrimental to space technology performance. What kinds of similar issues do you see as being most important in the development of future space systems? "

- I suggest that changing the frame of reference can lead to new questions:

Multiphase flows in life support systems are one example of how reduced gravity can alter a physical behavior in [a] way that is fundamentally different than would occur in a 1-g environment. If properly understood, these differences can be exploited to radically enhance space technology performance. What kinds of similar opportunities do you see as being most important in the development of future space systems?

It's been 56 years since Yuri Gagarin traveled into space and it's time to fully embrace and exploit the local environment

Exploiting and Working With (not Against) the Space Environment

What kinds of similar opportunities do you see as being most important in the development of future space systems?

- How can the emergence of capillary and surface tension forces be exploited to radically improve "interface intensive" processes (e.g. gas exchange between liquid and gas phases)?
- How can the absence of buoyancy driven convection be exploited to improve thermodynamic processes?
- Particularly for deep space and transit spacecraft:
  - How can essentially unlimited solar radiation (across all wavelengths) be exploited to directly perform useful work (e.g. visible for photosynthesis & illumination, UV for sterilization/disinfection, IR for direct heating)?
  - How can we directly utilize the essentially unlimited sink temperature of the Cosmic Microwave Background Radiation (2.7K) to do more than just radiate heat to it?

Significant science remains to be done as these basic physical processes and space resources are not utilized by existing exploration systems

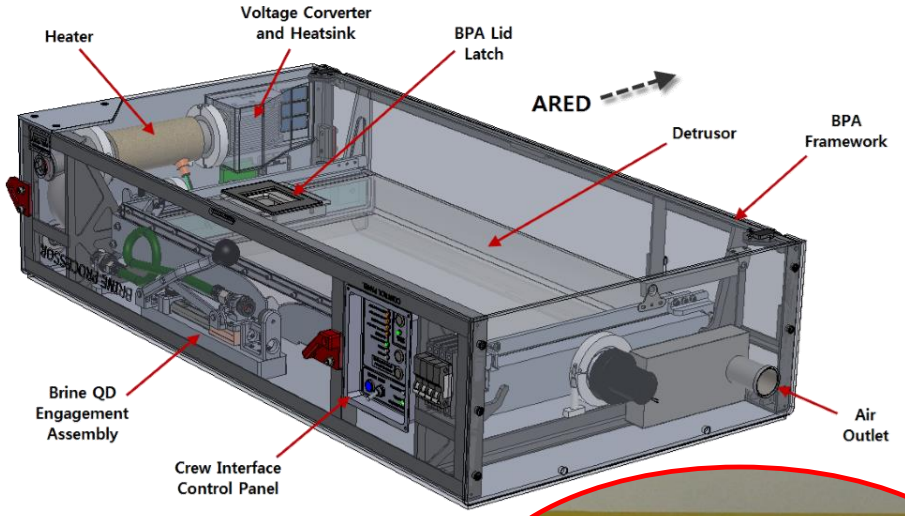
Reducing the Cycle Time from Scientific Discovery to Engineering Solution

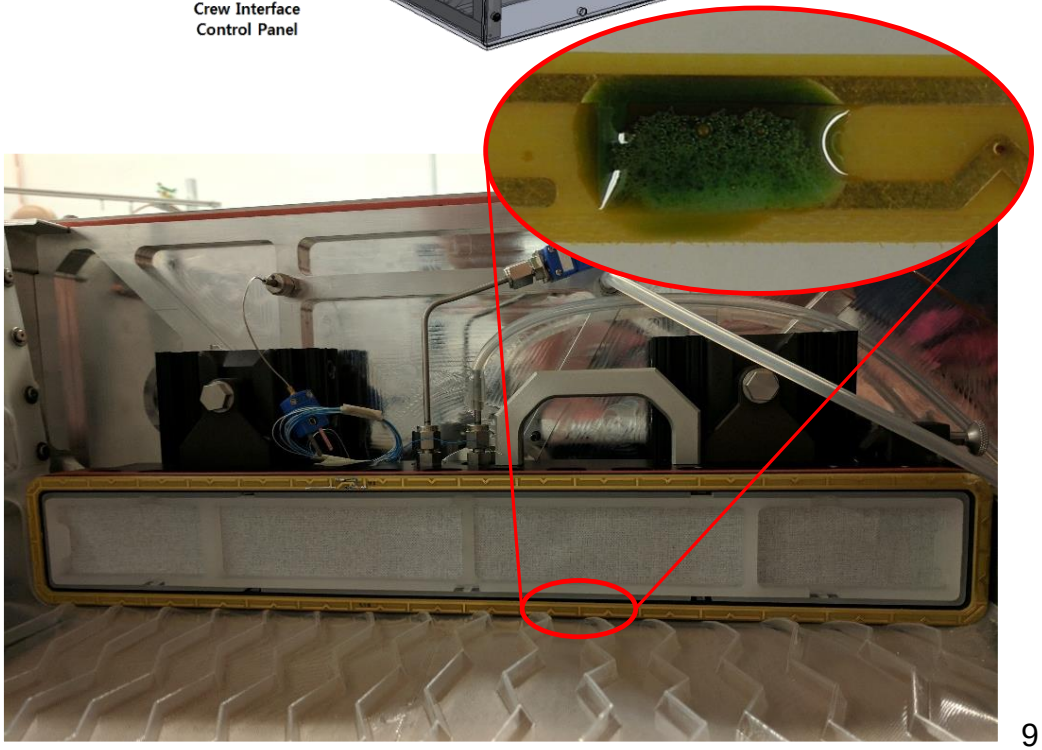
- Linking these three Preliminary Panel Questions:
  - *"When looking at future questions on how physical behaviors in low gravity might affect technology development or systems performance in space, do you think your organization would be likely to pursue these through in-house research, contract out investigations to smaller technology companies, or use some other approach?"*
  - *"Do you currently utilize NASA data and studies on how low gravity alters physical (and biological) processes? Would you anticipate using such data in the future? To what extent?"*
  - *Can you talk about how you have, or would expect to, partner with NASA on answering questions about how physical (and biological) processes affect space technologies and systems?*

How do you currently answer questions on physical and biological processes in space, and how do you plan to do so in the future?

Reducing the Cycle Time from Scientific Discovery to Engineering Solution

- Life Support Technology Maturation Example – Paragon's Brine Processor Assembly
  - Increases water closure to >98%
  - Launches to ISS in 2019
  - NASA and University expertise in surface tension and capillary fluid behavior directly applied to development of sensor wetting solution
- The short answers to the previous questions:
  - Partnering with universities and/or NASA to answer questions on low gravity is the way to go
  - Yes we currently use NASA data on how low gravity alters physical processes. (see above)
  - We are strong proponents of partnering with NASA to answer similar questions





Application of Biology to Engineered Systems for Space Exploration

- Preliminary Panel Question:
  - *"Can you give us a picture of the demand that you see in your organization or in the larger aerospace community for knowledge about biological and physical behaviors in space over the next 10 years?"*
- After 50+ years of life support technology development, there is still no operational implementation of fundamental biological processes (e.g. photosynthesis for food production or bioremediation for waste processing and resource recovery)
  - Are the correct scientific questions not being asked/answered?
  - Or are the program manages and engineers just not listening?

Either way, these mature terrestrial technologies are not utilized by existing exploration systems nor is there any expectation that they will be over the next 10 years unless something changes.

Final Thoughts

- Focused application of the biological and physical sciences on the development of spaceflight systems can lead to transformative changes in the human exploration of space
  - The “mystery” of emergent physical forces such as surface tension and capillary forces must be eliminated and their use brought into the mainstream aerospace “toolbox”
  - The same goes for biological processes
- Finally, an emphasis on bridging the gap between pure science and applied engineering is wise giving the cost-constrained environment we currently work under and in all likelihood will continue to do for the foreseeable future

Cutting edge applied science = next generation engineering.