National Aeronautics and Space Administration

Physical Sciences Status

Biological and Physical Sciences Advisory Committee

April 25, 2024

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Biological & **P**hysical **S**ciences

Overview

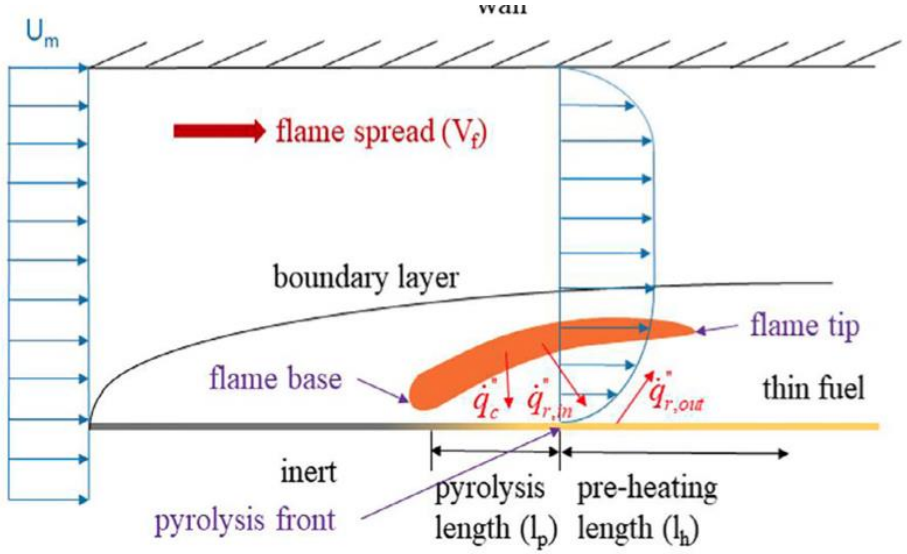
1 Science Highlights

2 Flight Project Status

3 Next Steps

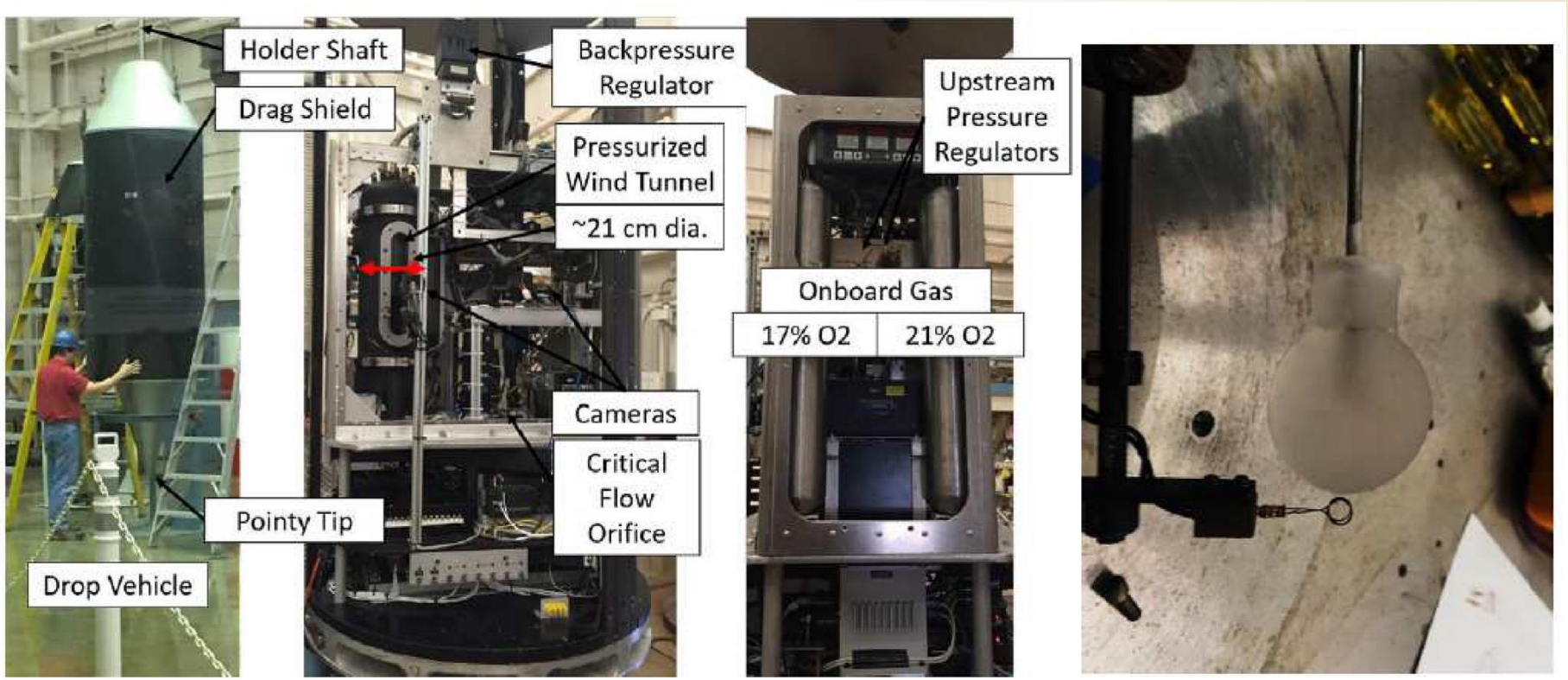
Science Highlight – Fire Safety

- Quenching extinction of solid sphere diffusion flames induced by a sudden removal of gravity
  - Michael c. Johnston, James S. T'ien, Sheng-Yen Hsu, Ching-Wei Wu, Sandra L. Olson, Paul V. Ferkul
  - Fire Safety Journal 2024 https://doi.org/10.1016/j.firesaf.2024.104137



- Motivation – understanding flame spread on solid fuels
  - Sketch from Urban, et al. *Combustion and Flame* 109 (2019)

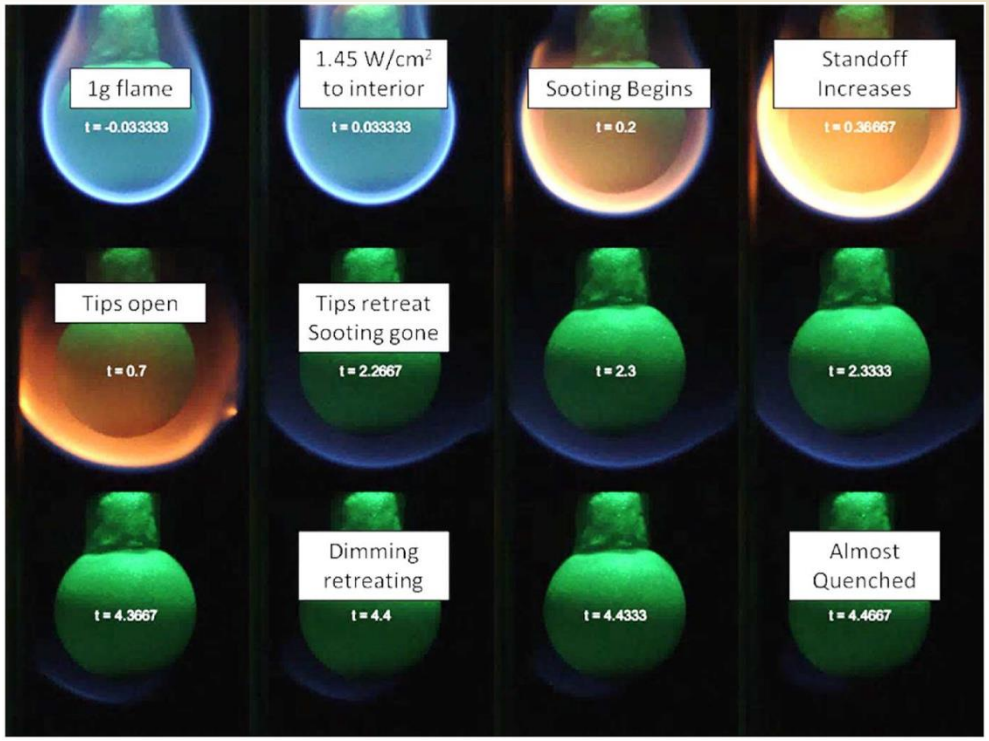
Experiment and drop rig at Glenn Research Center



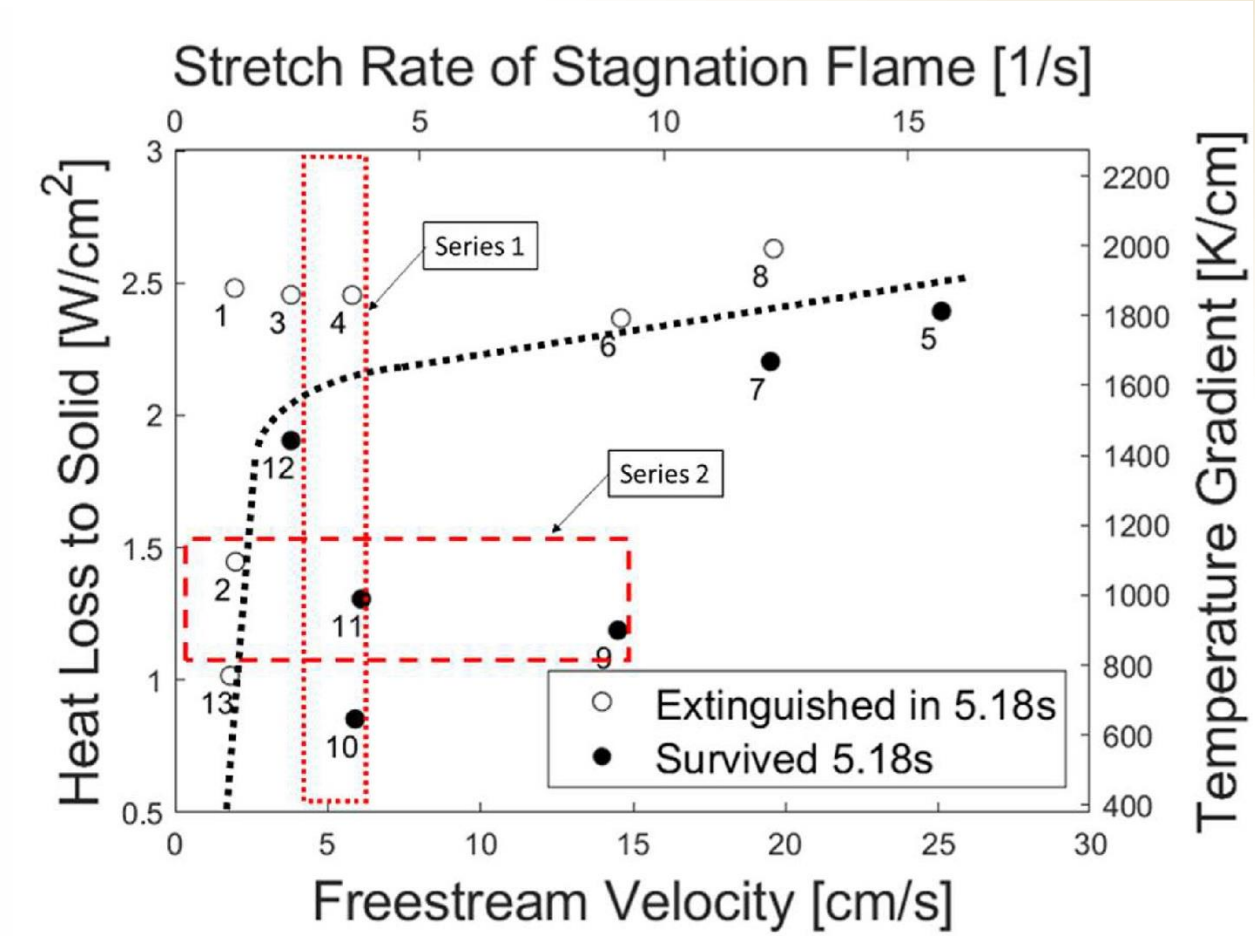
Polymethylmethacrylate sphere is ignited with a heated wire

Typical run

- Flames are ignited at the bottom of the sphere and allowed to burn for a set time before the experiment is dropped. Forced flow is from below. Heat transfer to the solid is calculated from internal temperature gradient.



Test matrix summary with extinction boundary

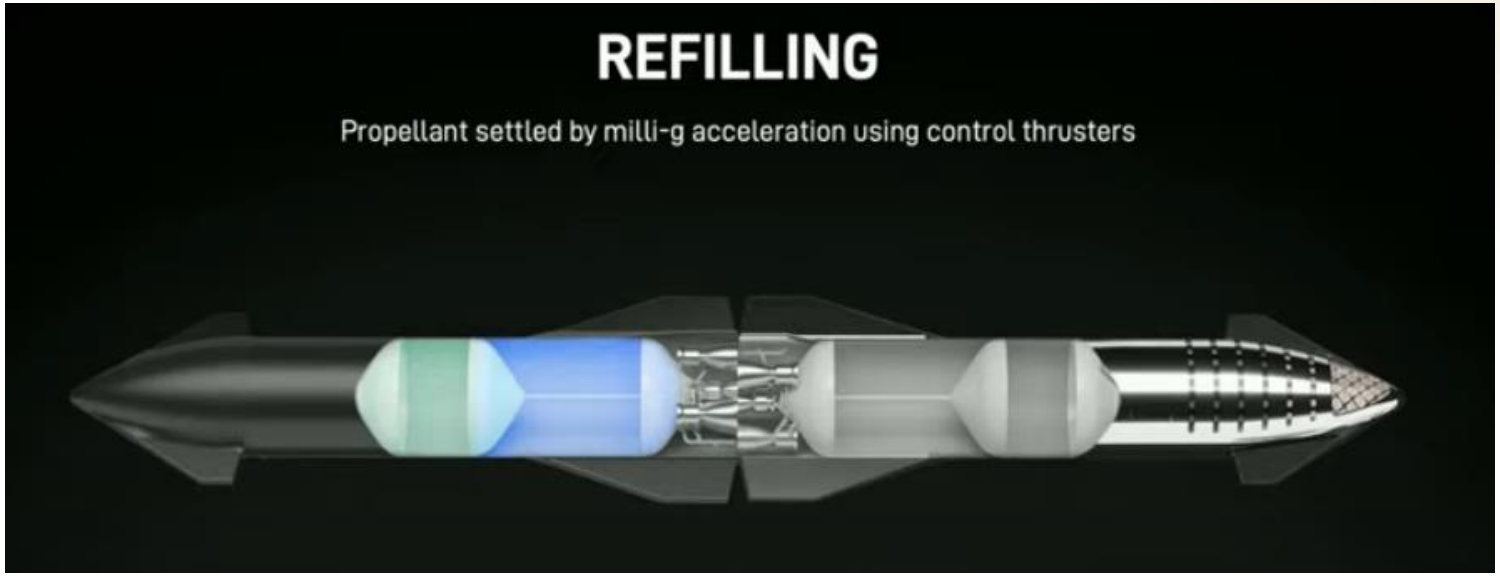


Conclusions

- External flow and heat transfer to the solid are both important factors in flame quenching
- Current numerical models can’t predict extinction limits. More detailed reaction kinetics and inclusion of radiation effects will be required

Science Highlight – Thermal Fluids

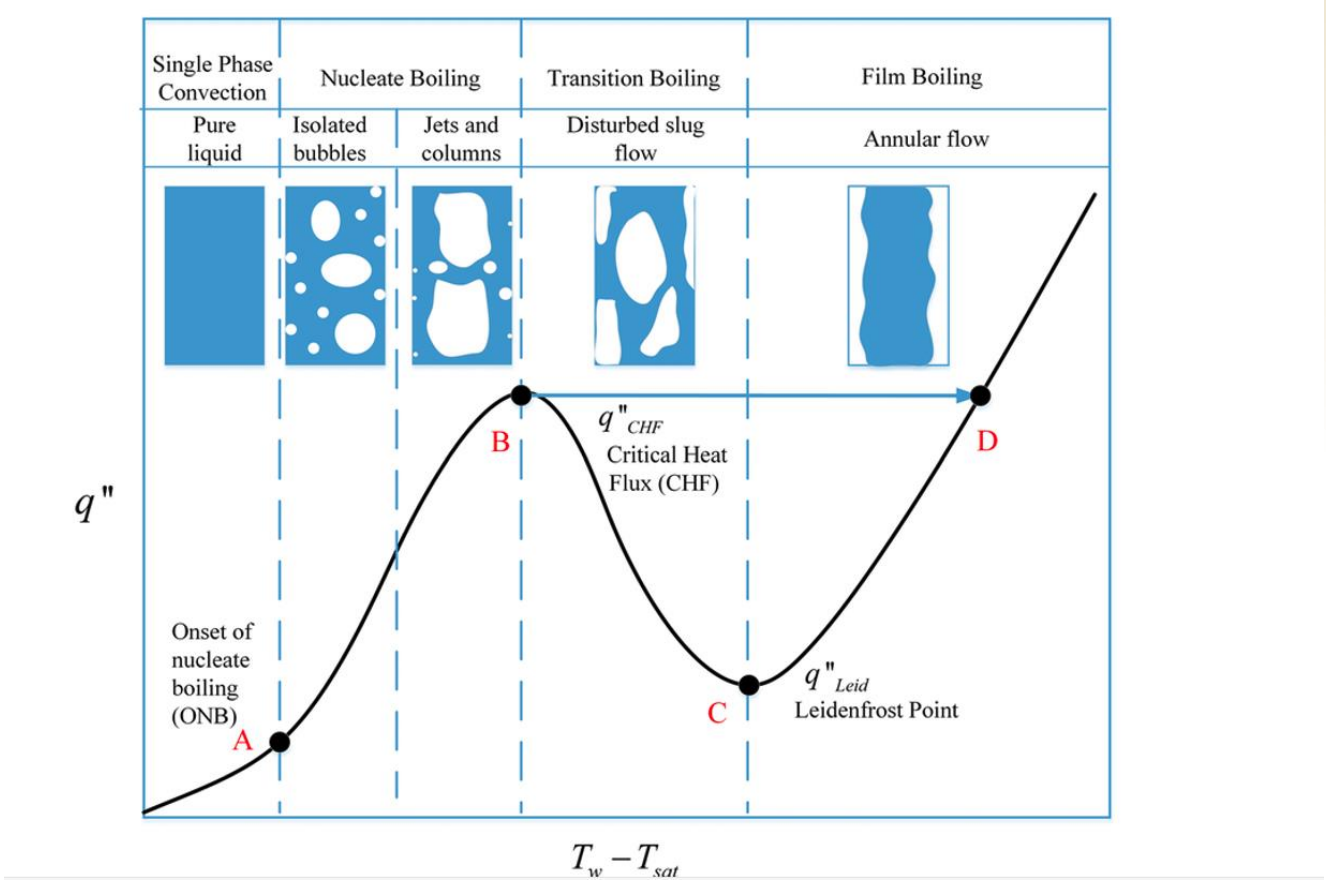
- Flow Boiling and Convection Experiment – Transfer Line
  - Flight project currently in development



From: https://www.youtube.com/watch?v=Oee66sAXGtc

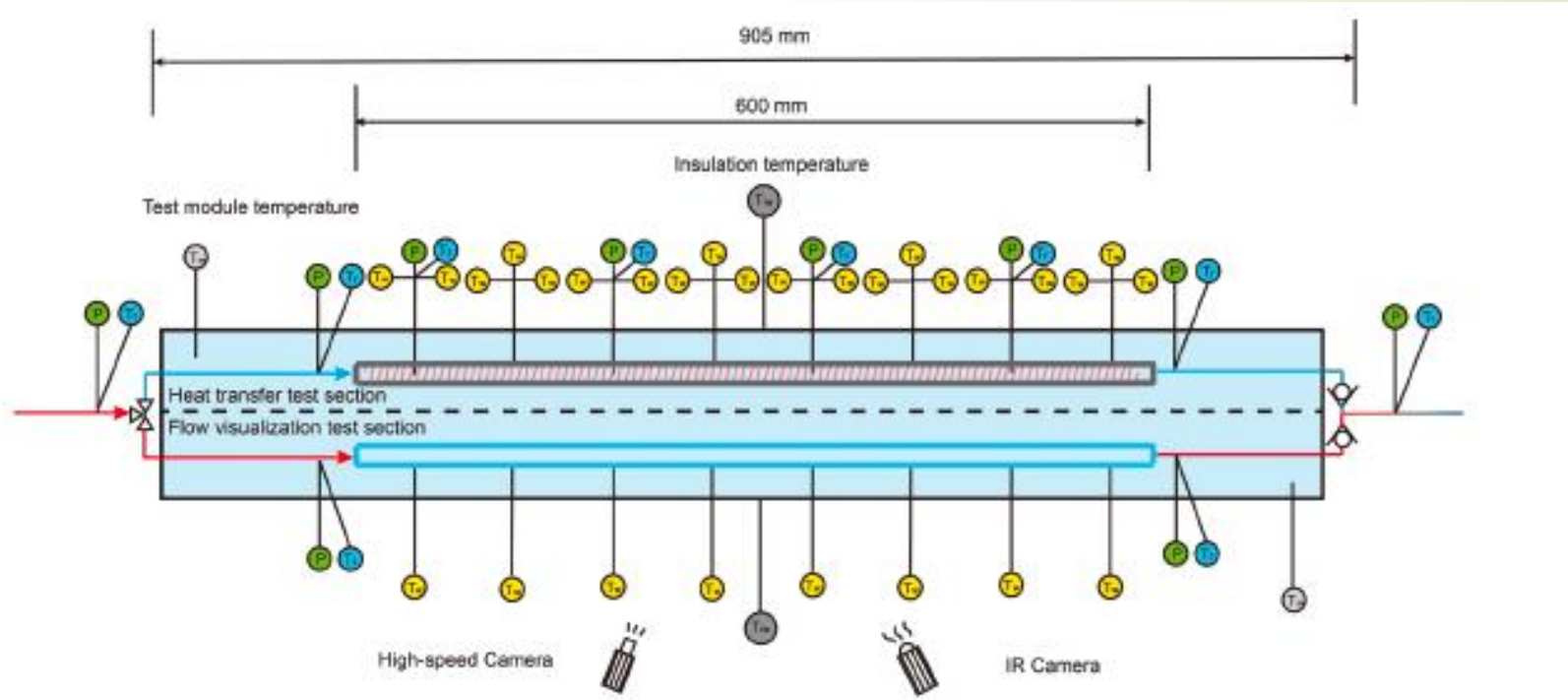
- Transfer of cryogenic fuels between vehicles is a critical capability for exploration missions. The density difference between liquid and gaseous fuels is O(1000-100), so vapor generation can have serious operational consequences

Science Highlight – Thermal Fluids



The chilldown path for a cryogen transfer line

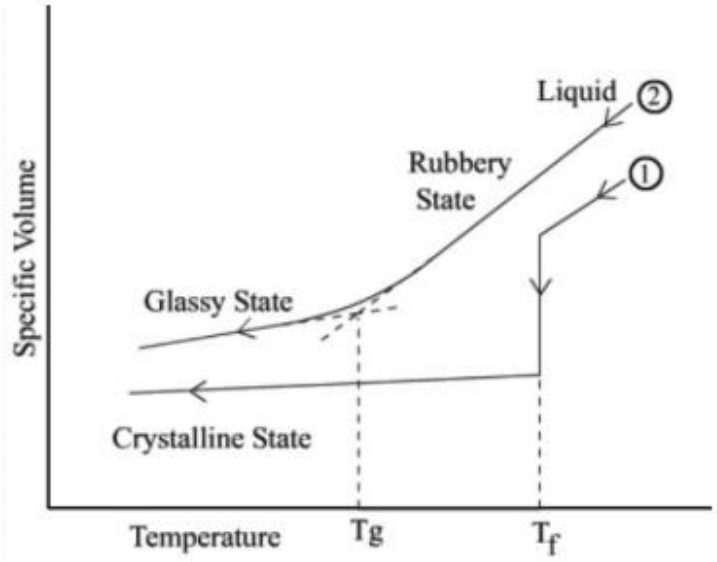
Science Highlight – Thermal Fluids



FBCE-FT heat transfer and flow visualization test sections

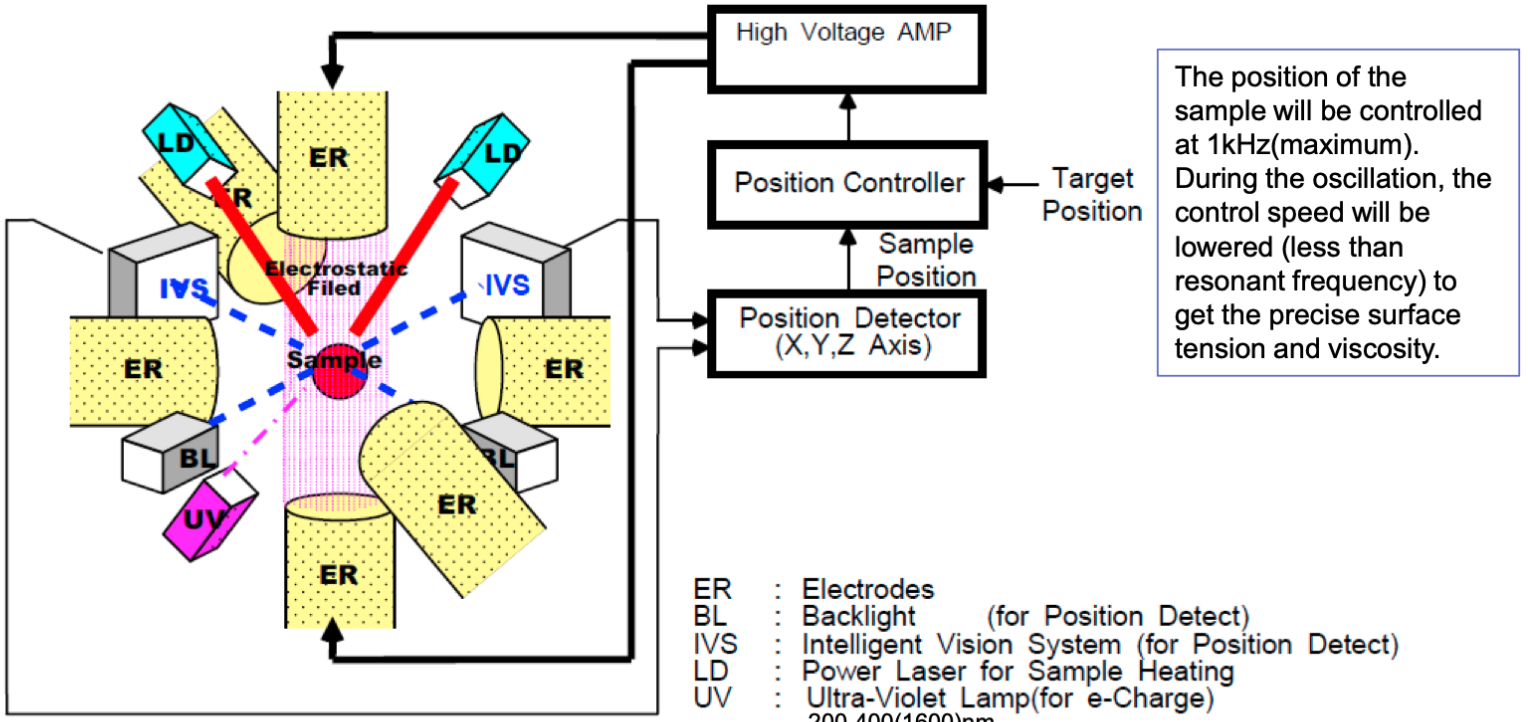
Science Highlight – Microgravity Effects in Glass Formation

- Microgravity effects on nonequilibrium melt processing of neodymium titanate: thermophysical properties, atomic structure, glass formation and crystallization
  - Wilke, et al., *npj Microgravity* https://doi.org/10.1038/s41526-024-00371-x



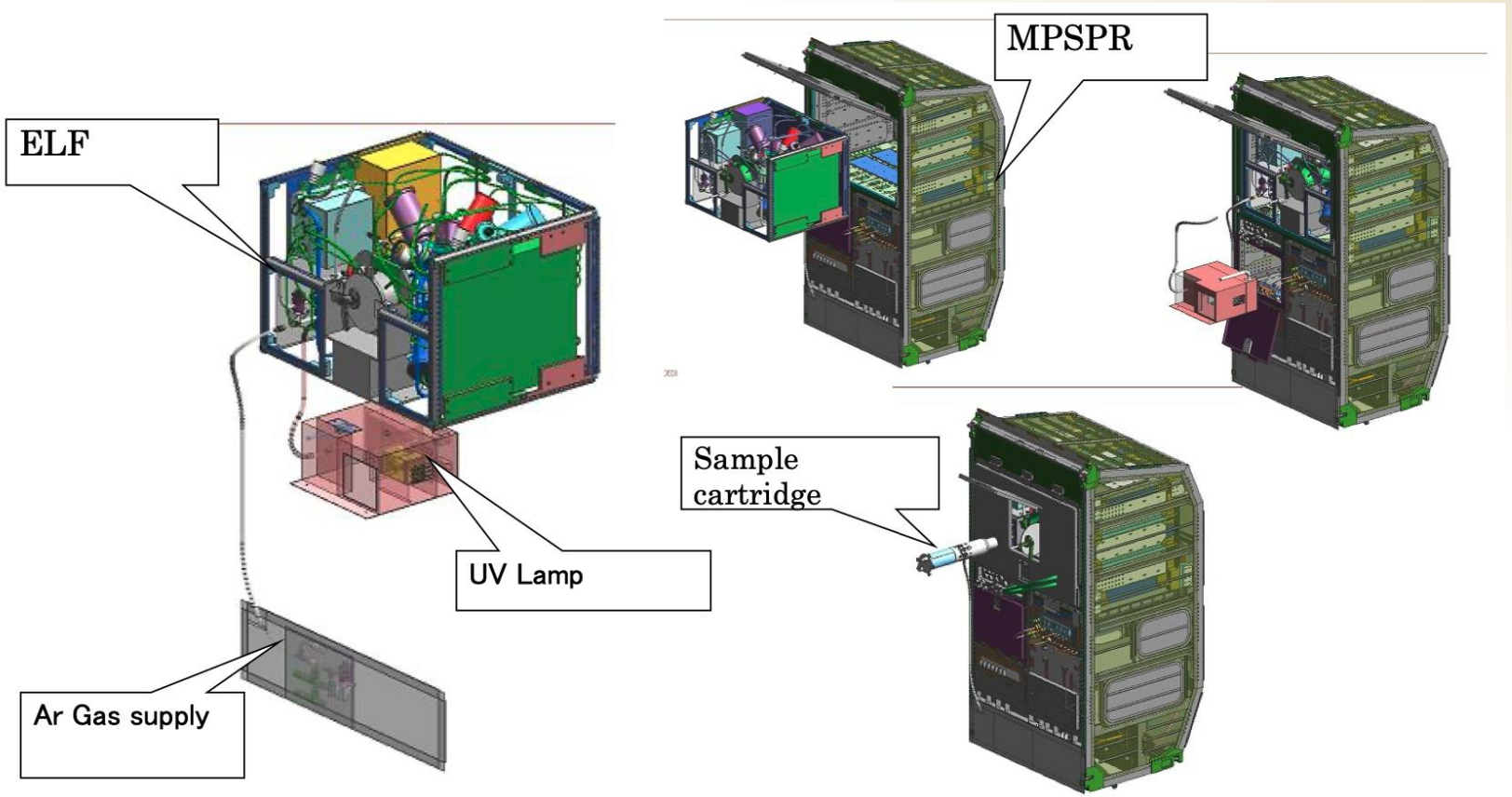
Glass and Crystal Phase Transitions

Electrostatic levitation in the JAXA ELF on ISS

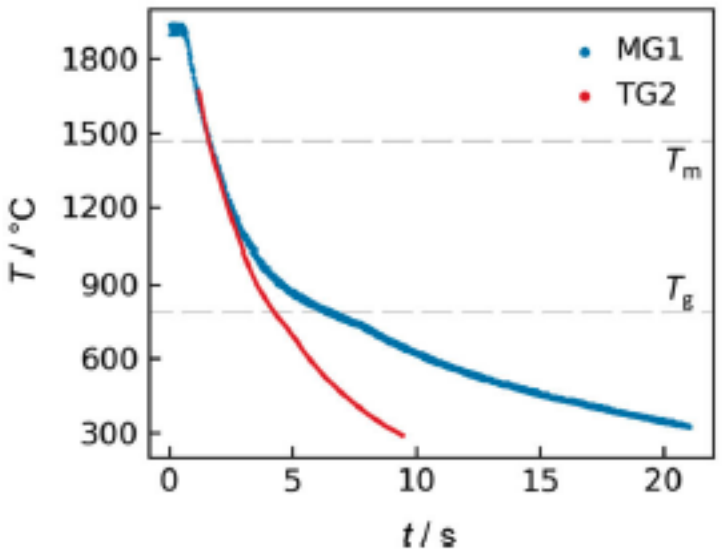


ELF Principle Concept

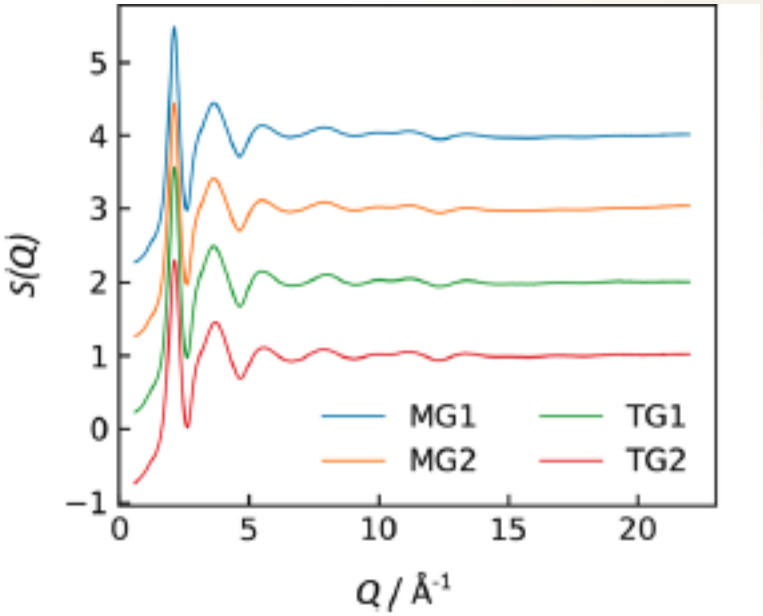
ELF Instrument in its rack



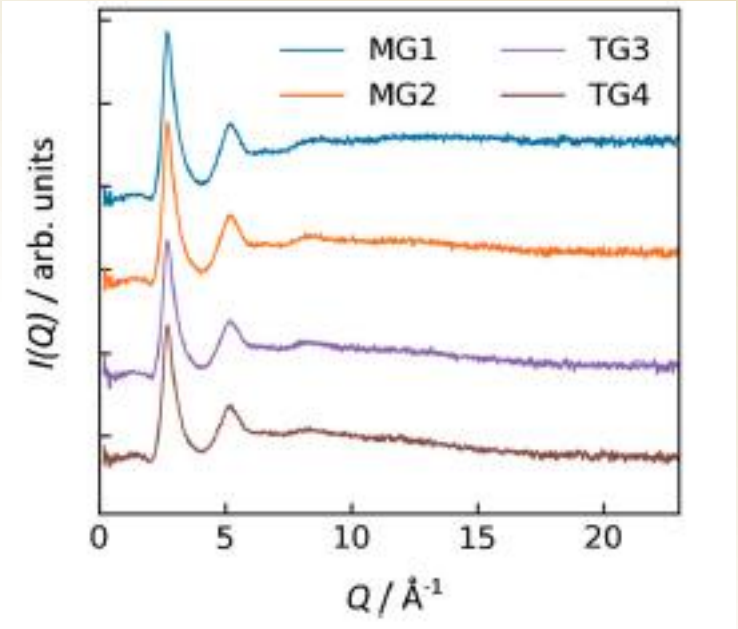
Experimental Results



Terrestrial and microgravity sample cooling



X-ray scattering results for terrestrial and microgravity processed samples (curves offset)



Neutron diffraction results for terrestrial and microgravity processed samples (curves offset)

- Authors' conclusion:
  - *The atomic structures of glasses were nearly identical for the Earth and microgravity processing conditions, except for subtle differences that could be explained by compositional variations of ~2 mol. % Nd2O3. This comparison provides validation, at least for rare-earth titanates, that the same glass can be manufactured in space as on Earth, aside from differences in thermal history.*

More on the Decadal…

Some key takeaways for Physical Sciences

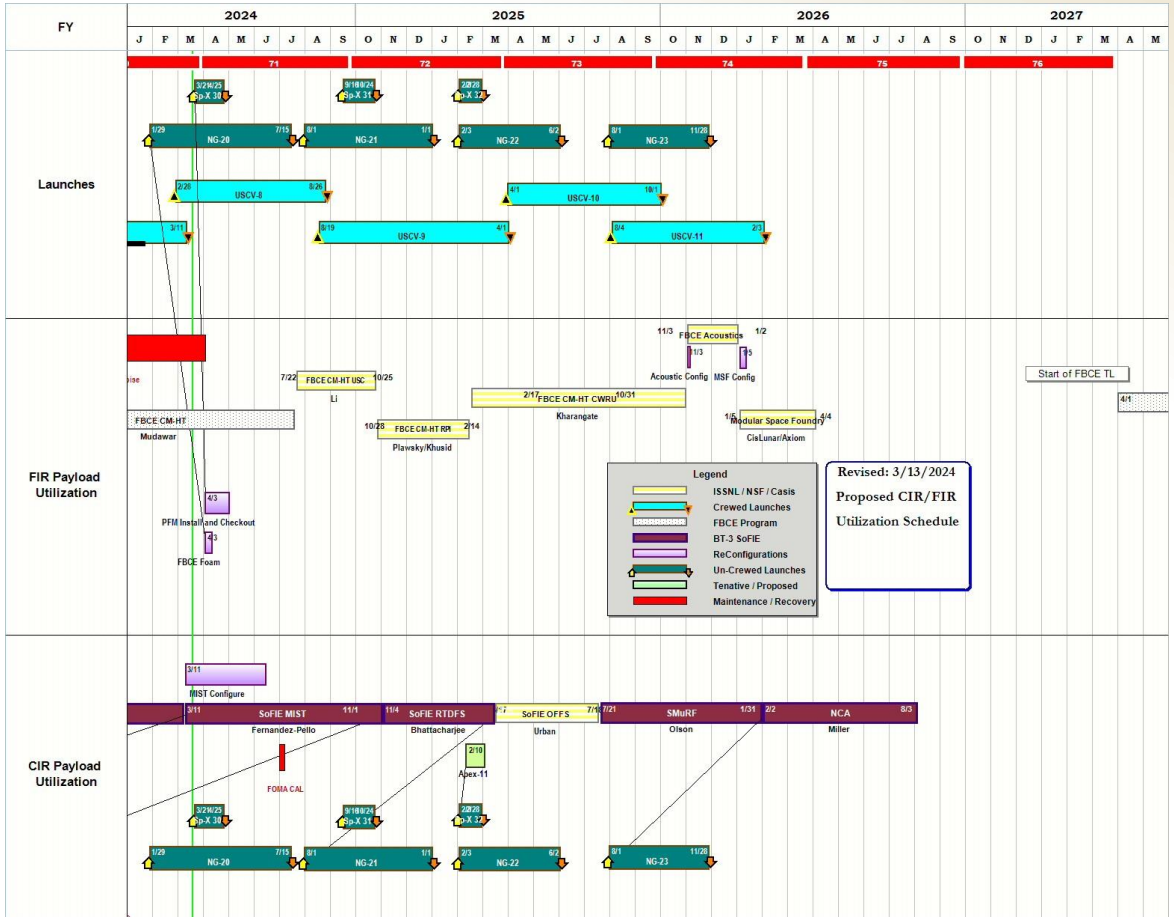
- We have compelling Key Scientific Questions
  - What principles enable identification, extraction, processing, and use of materials found in extraterrestrial environments to enable long-term, sustained human and robotic space exploration?
  - What are the relevant chemical and physical properties and phenomena that govern the behavior of fluids in space environments?
  - What are the mechanisms by which organisms sense and respond to physical properties of surroundings and to applied mechanical forces, including gravitational force?
  - What are the fundamental principles that organize the structure and functionality of materials, including but not limited to soft and active matter?
  - What are the fundamental laws that govern the behavior of systems that are far from equilibrium?

More on the Decadal…

Some key takeaways for Physical Sciences

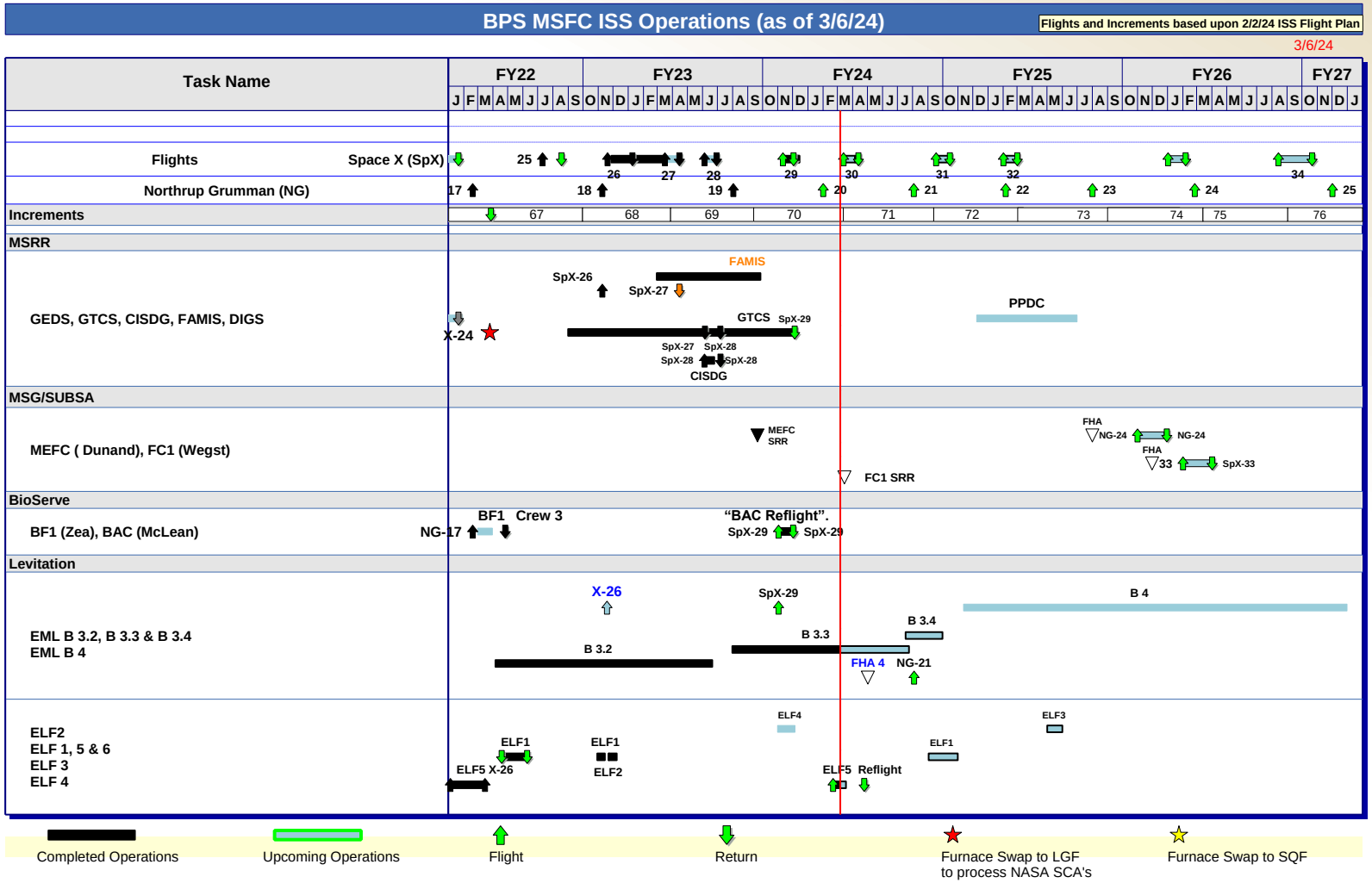
- We have compelling Key Scientific Questions, … and we should retune to be our best
  - Regular solicitations to re-engage with the research community
  - Plan our research for alignment with the space program- begin research for sustainable exploration
  - Look for deeper collaborations with the biological sciences

Current Status- our ISS research is drawing down



Research operations planned in the fluids and combustion racks

Our ISS research is drawing down



Research operations planned for materials science and biophysics

A new plan is in development

- FM2 – Flammability of Materials on the Moon
  - Experiment payload aboard a lunar lander, conducting flammability tests of material in lunar gravity and 37% O_2
- Regular research solicitations
  - Funding to begin in 2025-2026
- Big, Hairy, Audacious Goals