Observations of Thermosyphon Flooding in Reduced Gravity Environments

Donald A. Jaworske, Marc A. Gibson, James L. Sanzi

Interagency Advanced Power Group

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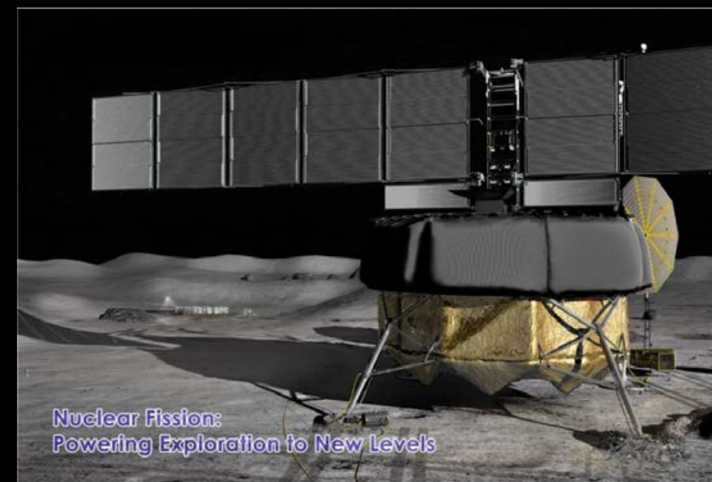
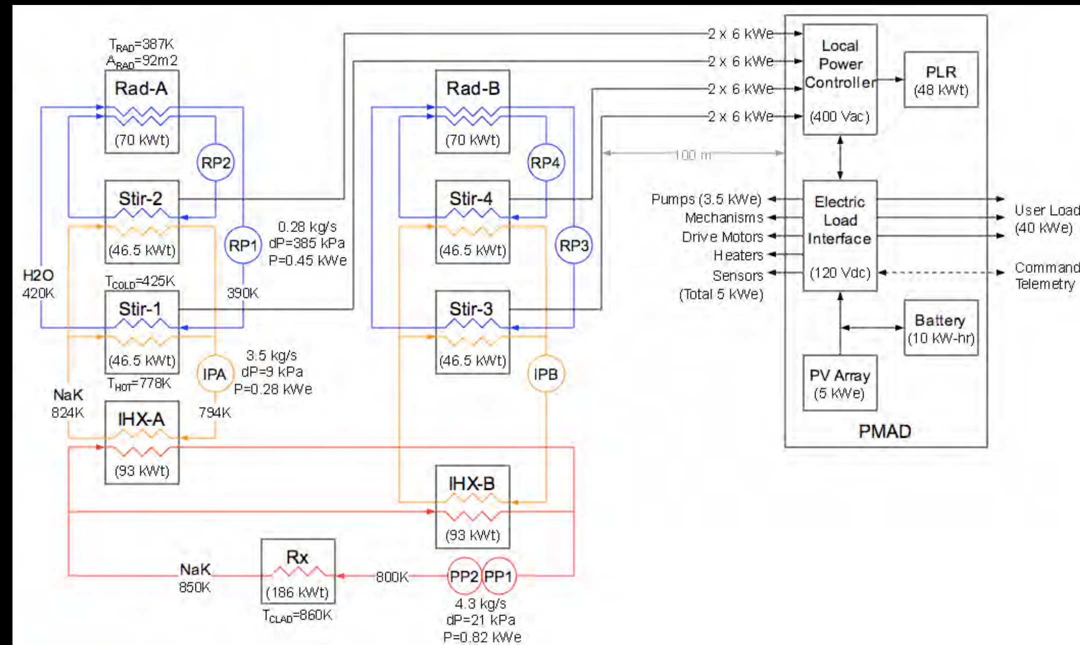
Planetary Applications of Fission Power

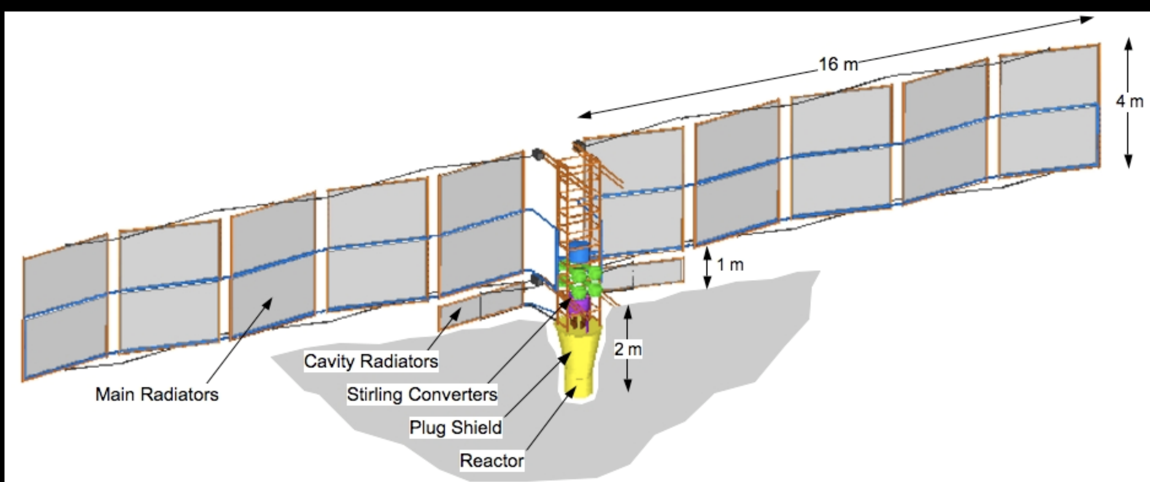
- Several architecture studies have examined the use of Fission Power Systems (FPS) for the human exploration of the moon and Mars.
- For a 40 kW_e installation, radiators would be needed to dissipate approximately 140 kW_t of waste heat.
- A 180 m^2 radiator panel over 10 years would have 3.6 hits of sufficient kinetic energy to damage fluid flow.
- The design solution to mitigate the risk of rupturing a fluid line is to utilize multiple heat pipes.
  - In the event of a micrometeoroid hit to a single heat pipe, only the fluid in the heat pipe is lost.
- The design solution also includes high thermal conductivity composite facesheets to distribute heat across the radiator panel.

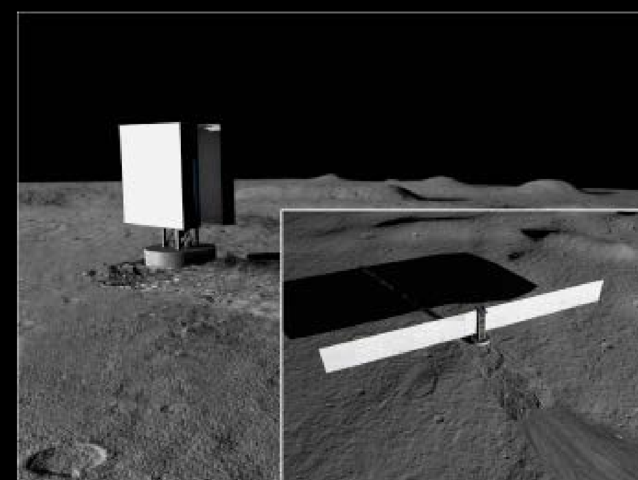


FPS Preliminary Reference Concept

- A guide for technology development.
- Power levels, temperatures, pressures, flow rates, and efficiencies become notional requirements.

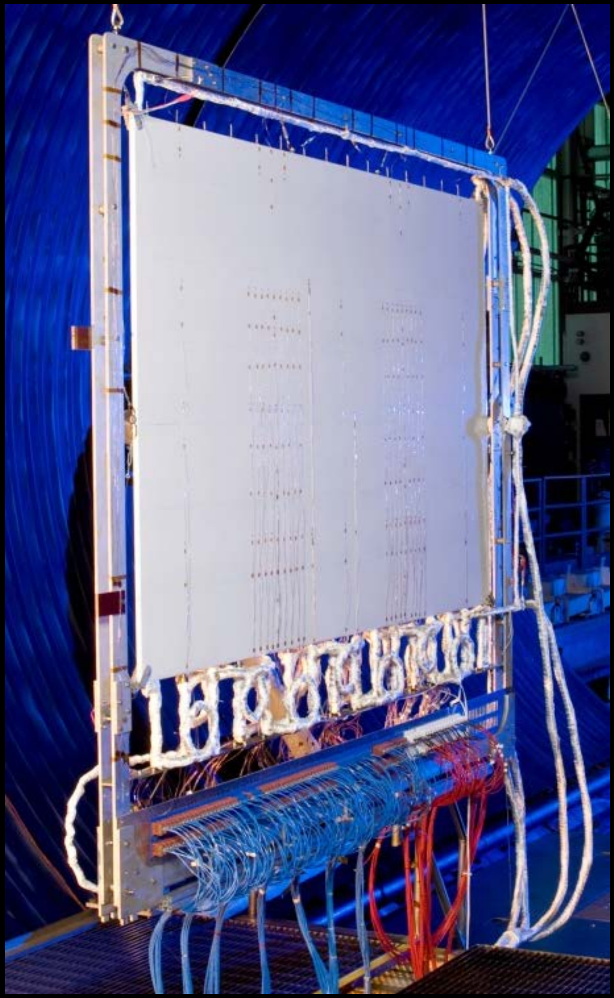






Heat Pipes Operating as Thermosyphons

- Radiators equipped with thermosyphons spread and reject waste heat effectively.
- With the aid of gravity, thermosyphons can be used within appropriate heat transfer limits.
  - The limit of most concern is the flooding limit.
- Understanding these limits requires testing of thermosyphons in Reduced Gravity Environments (RGEs).
  - Drop towers
  - Parabolic flights
  - Sounding rockets
- Parabolic flights provide the opportunity to achieve both lunar and Martian gravity environments.

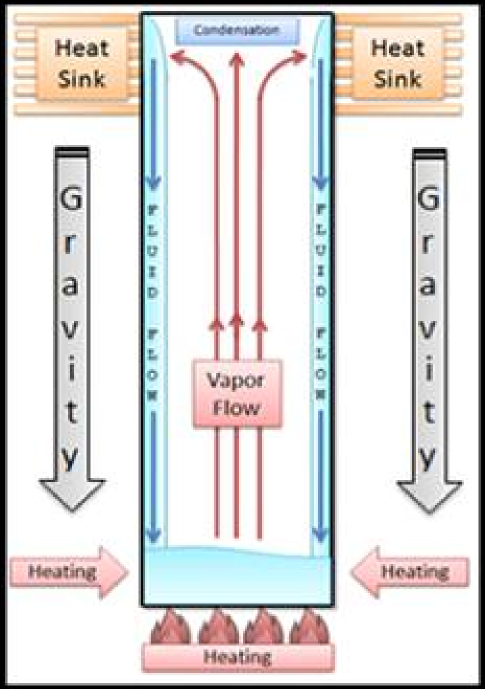


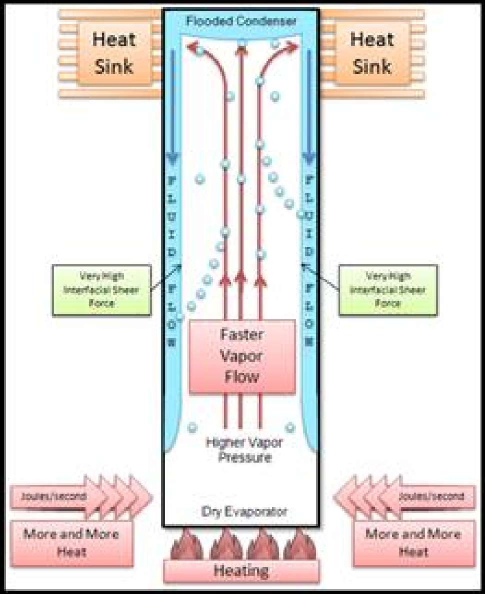
Experiment Justification

- In the literature, it was found that the flooding limits of thermosyphons have never been tested in RGEs.
- If existing flooding models were incorrect then the heat rejection system could be under-designed, leaving significant risk that the thermosyphons could reach their flooding limit.
- Upon flooding, the reactor and power converters would have to be powered down.
  - A decrease in temperature would allow thermosyphon recovery.
- After recovery, the fission power system may have to operate at a lower power level.

The Flooding Limit

- Heating in the evaporator vaporizes fluid which travels upward into the condenser.
- Vapor condenses on the condenser wall and travels back down to the evaporator with the aid of gravity.
- As heating increases, more vapor is formed and travels at a higher velocity up the pipe.
- As more vapor condenses, the fluid thickness on the wall increases.
- The increasing mass flow and shrinking vapor throat area create high shear between the vapor and the fluid.
- This shear force overcomes the gravity force and the condenser floods.

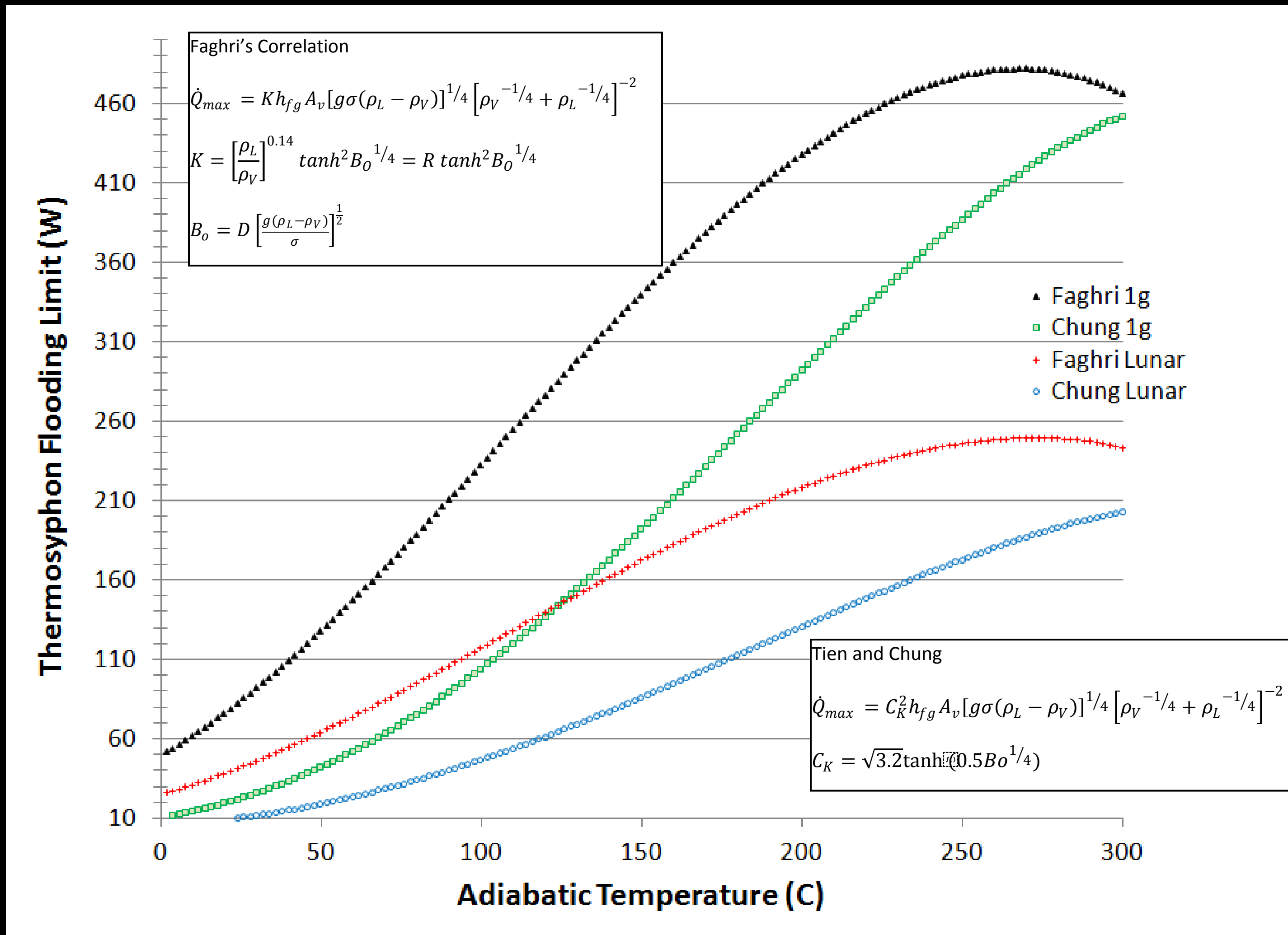




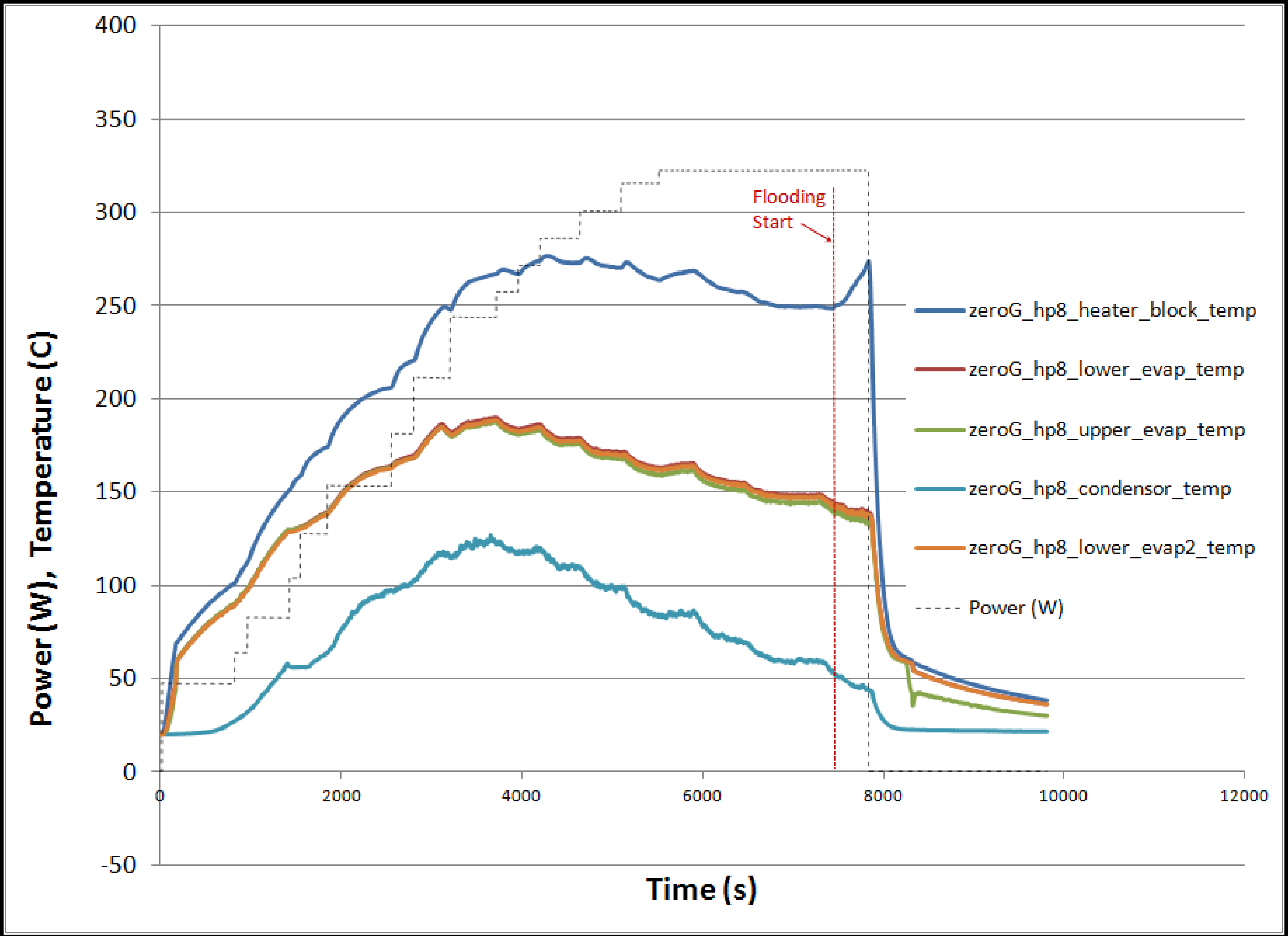
Experiment Setup

- Twelve 0.25” O.D. x 0.035” wall Ti/H_2O thermosyphons
- Individual evaporators heated electrically
- Maximum heat input: 350 W/each
- Forced air cooling w/aluminum-finned condensers
- National Instruments PXI realtime DAC system
- Labview programming
- Laptop computer control

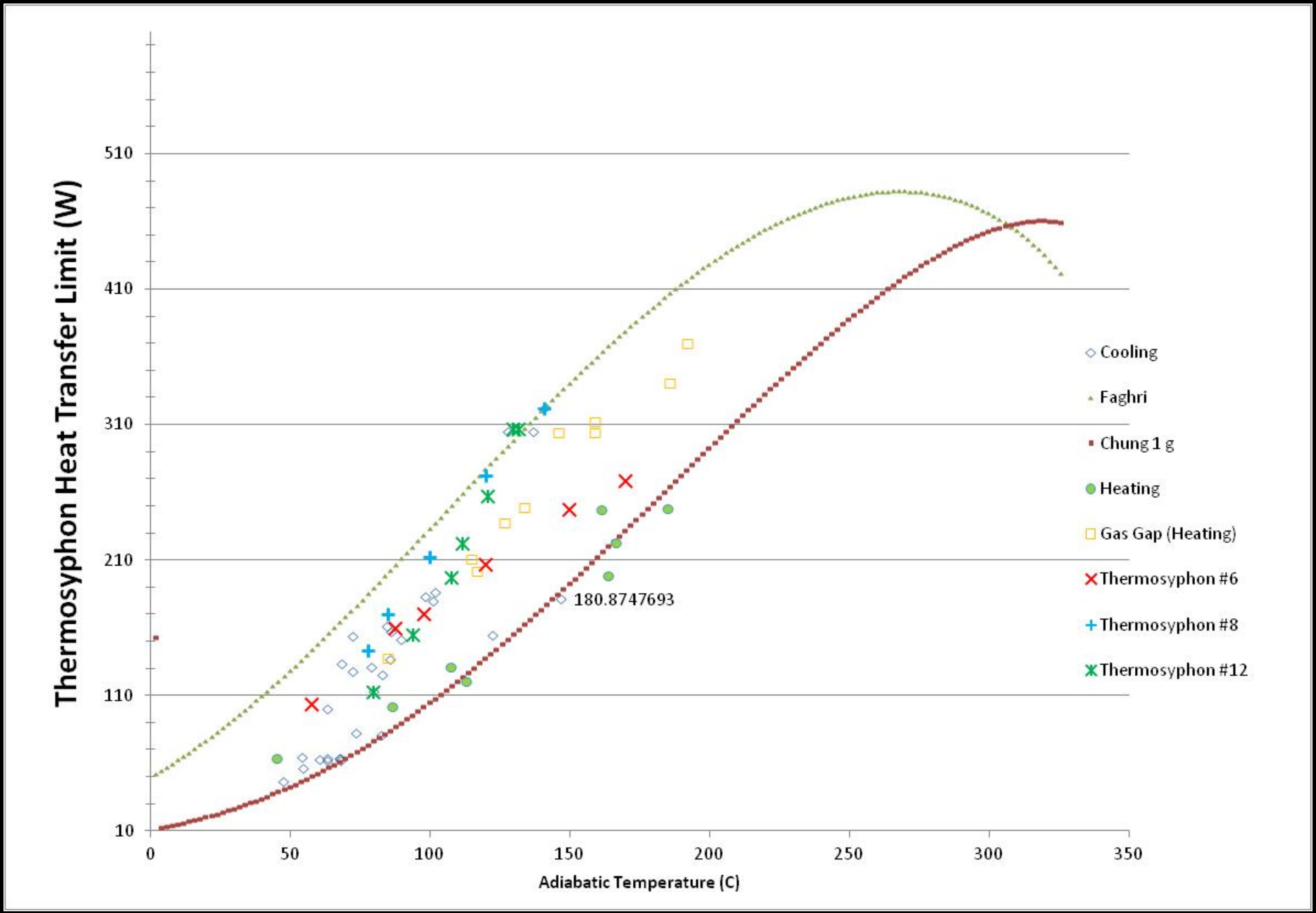
Predictions via the Bond Number



Establishing the Flooding Limit (1g)



Initial 1g Flooding Limit Data

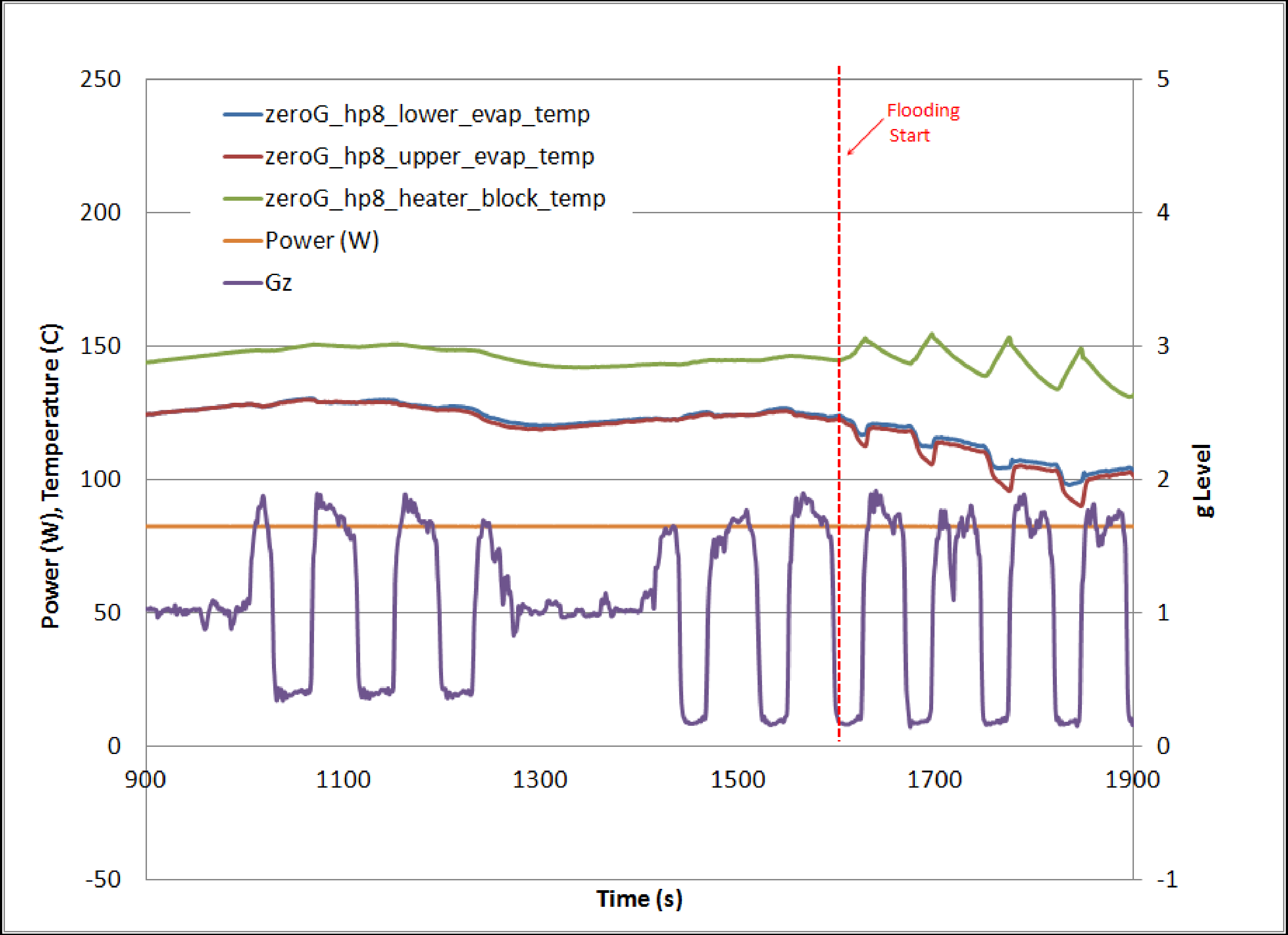


Flight Week 1, September 2011

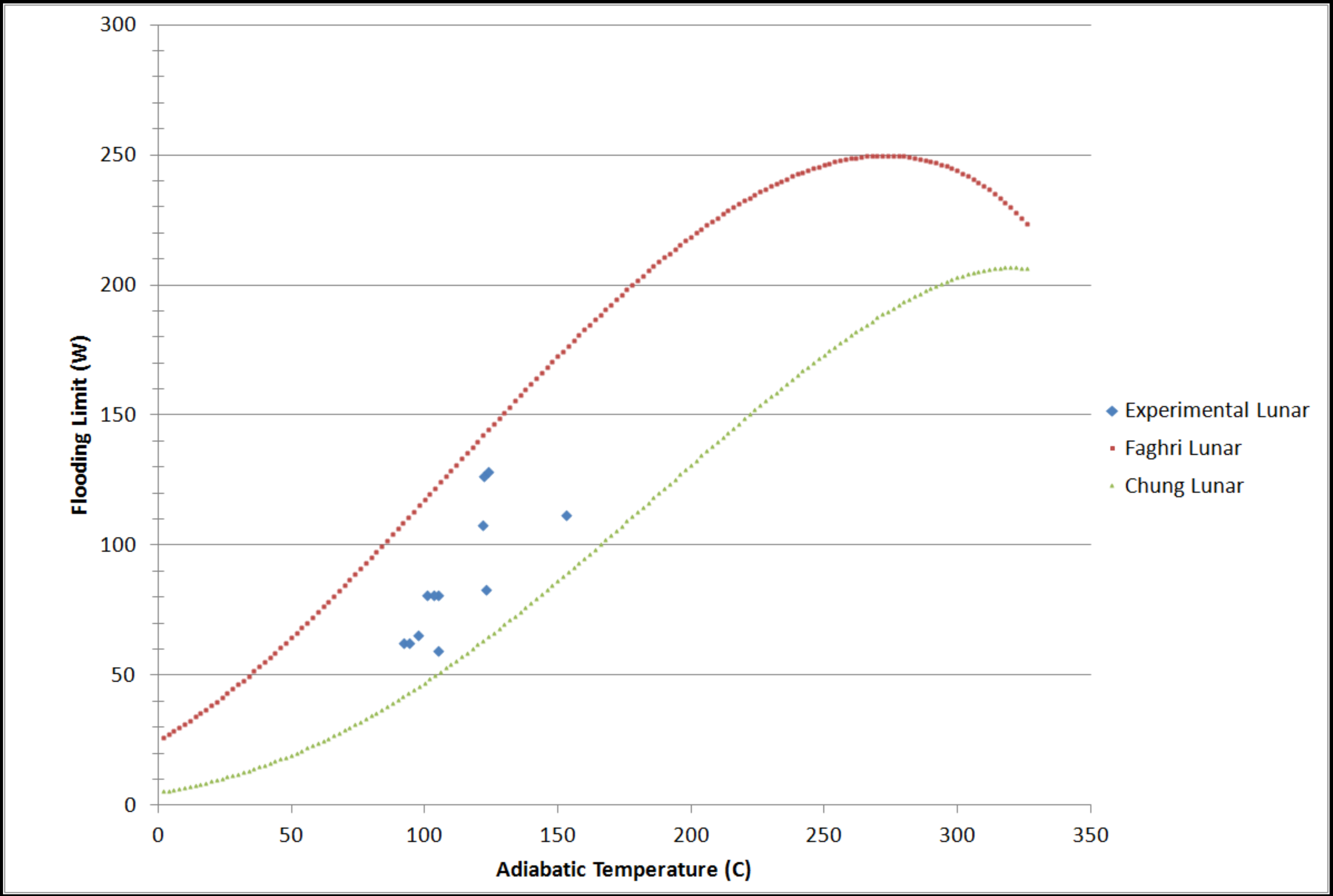
- 40 parabolas per day
- 12 Lunar, 3 Martian, 25 zero
- 4 days totaling 160 parabolas




Data Analysis



Lunar Results



Conclusions

- The observed RGE flooding limit falls between Faghri and Chung’s correlations providing boundaries for analysis.
- Initial results show that correlation models may have discrepancies in the slope at lower temperatures as compared to the test data, both in 1g and reduced g.
- Follow on work is continuing in 2012 to reduce data scatter and provide an improved correlation.