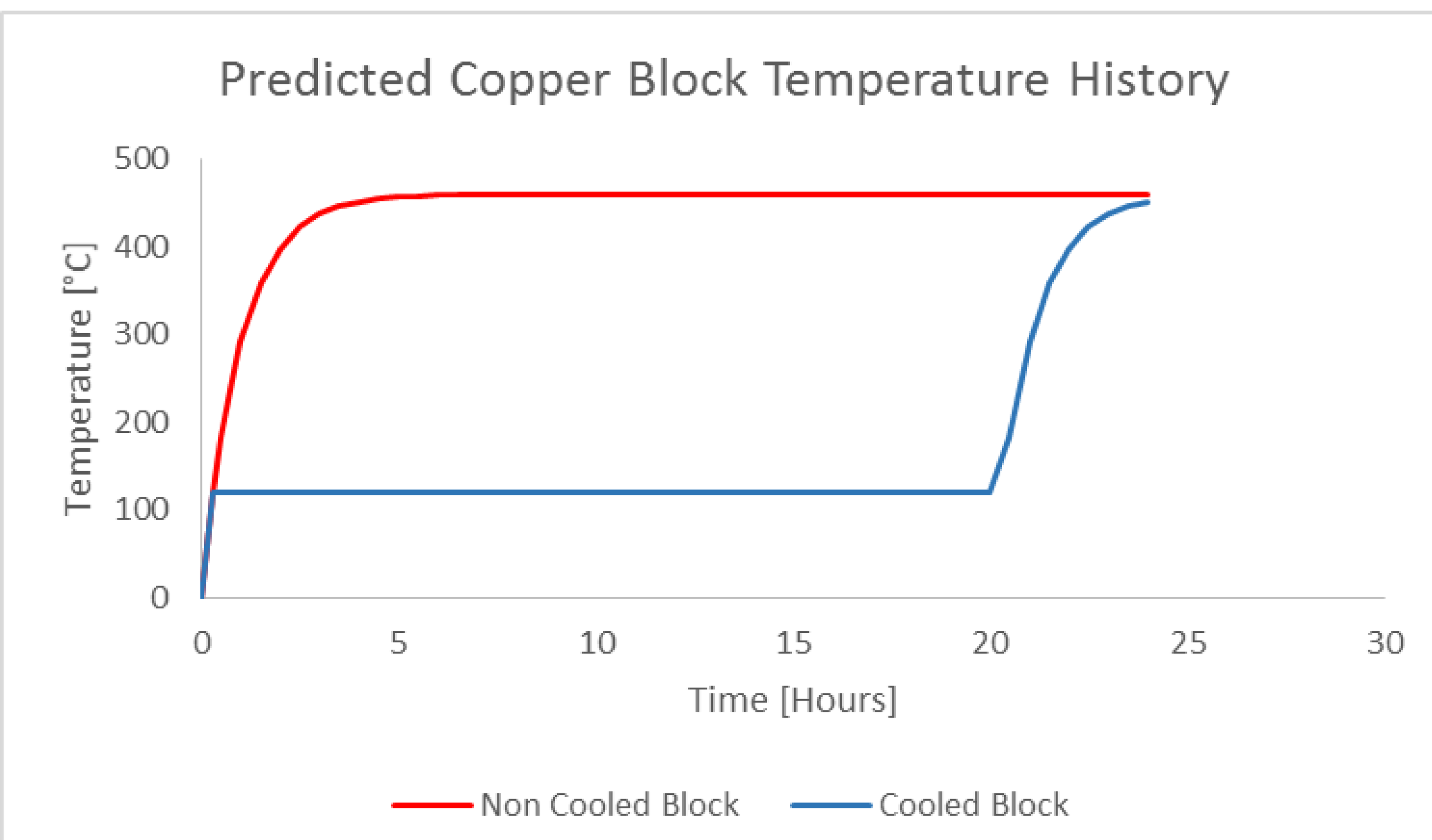
Thermal Control of a Venus Lander: Evaporation of Ammonia

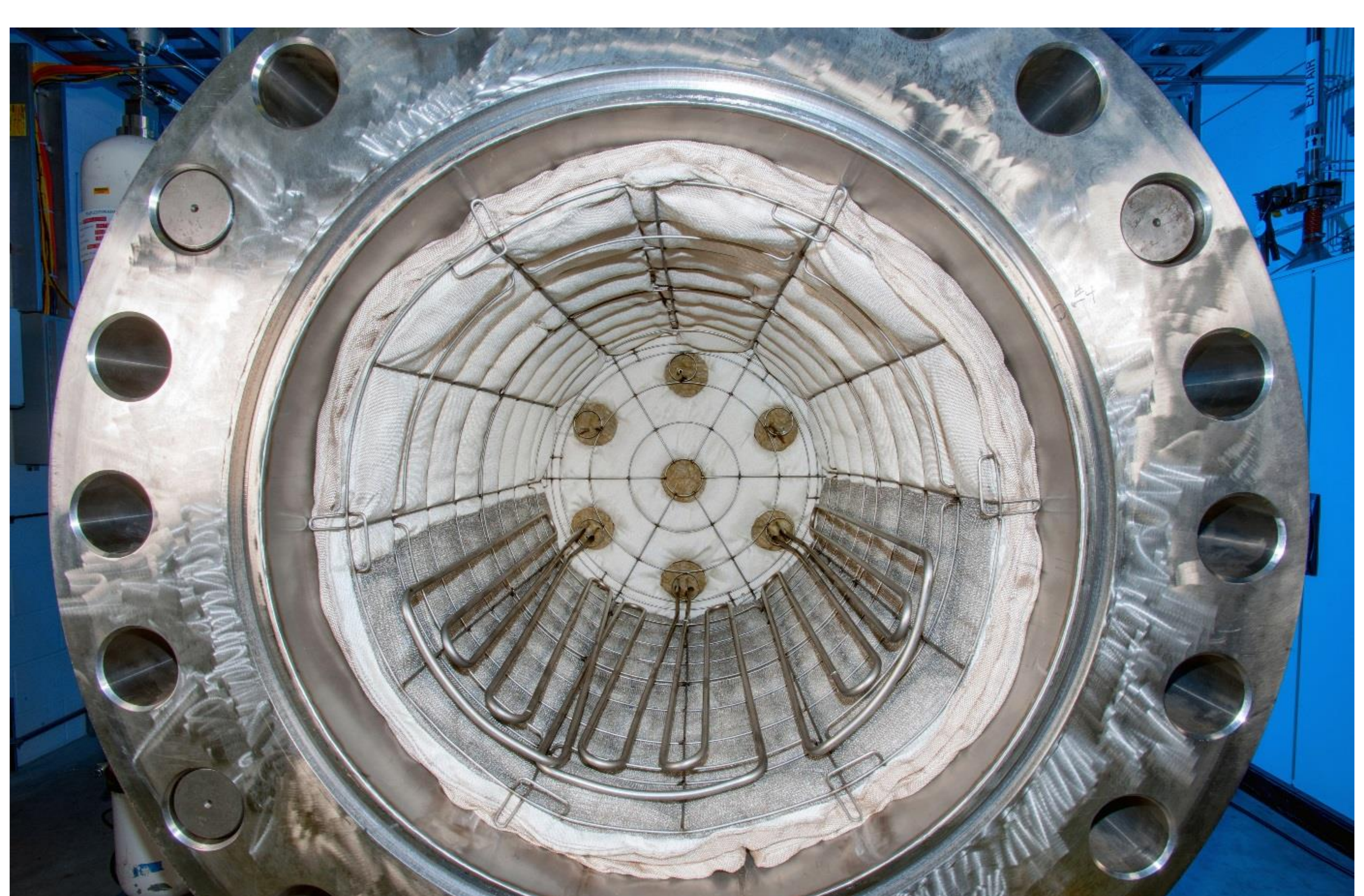
Dr. Eric Golliher[1], Dr. Michael Pauken[2]

[1] NASA Glenn Research Center, Cleveland OH; [2] NASA- Jet Propulsion Laboratory, Pasadena, CA

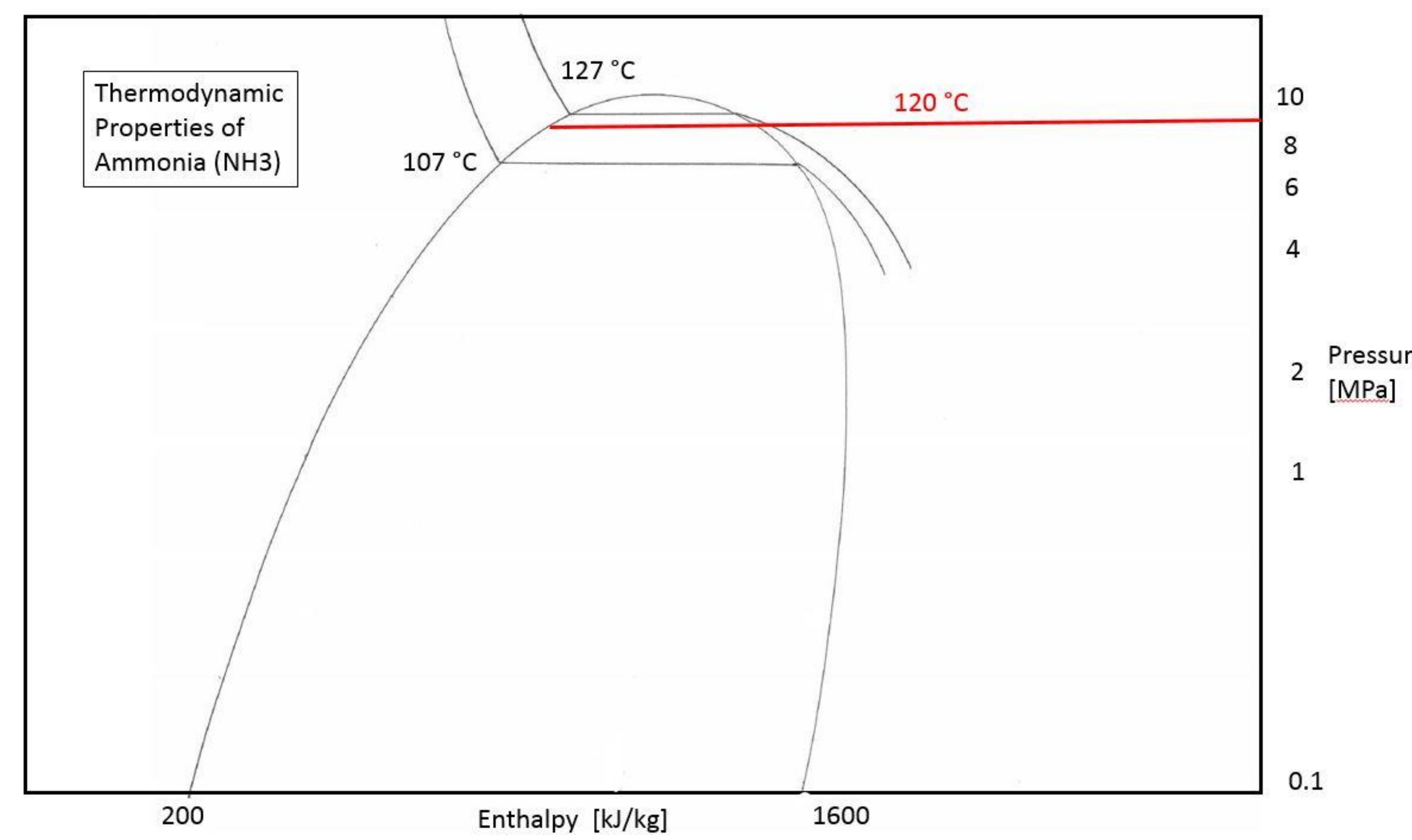
Near-Term Concept: During the liquid-vapor phase change process, the large latent heat of evaporation of ammonia allows heat to be removed from the electronics and absorbed by the evaporating ammonia, while little temperature change occurs. Thus, for the duration of the evaporation or boiling process, until all the liquid is boiled away, the temperature is constant at the saturation temperature corresponding to the environmental pressure and temperature of Venus' surface.



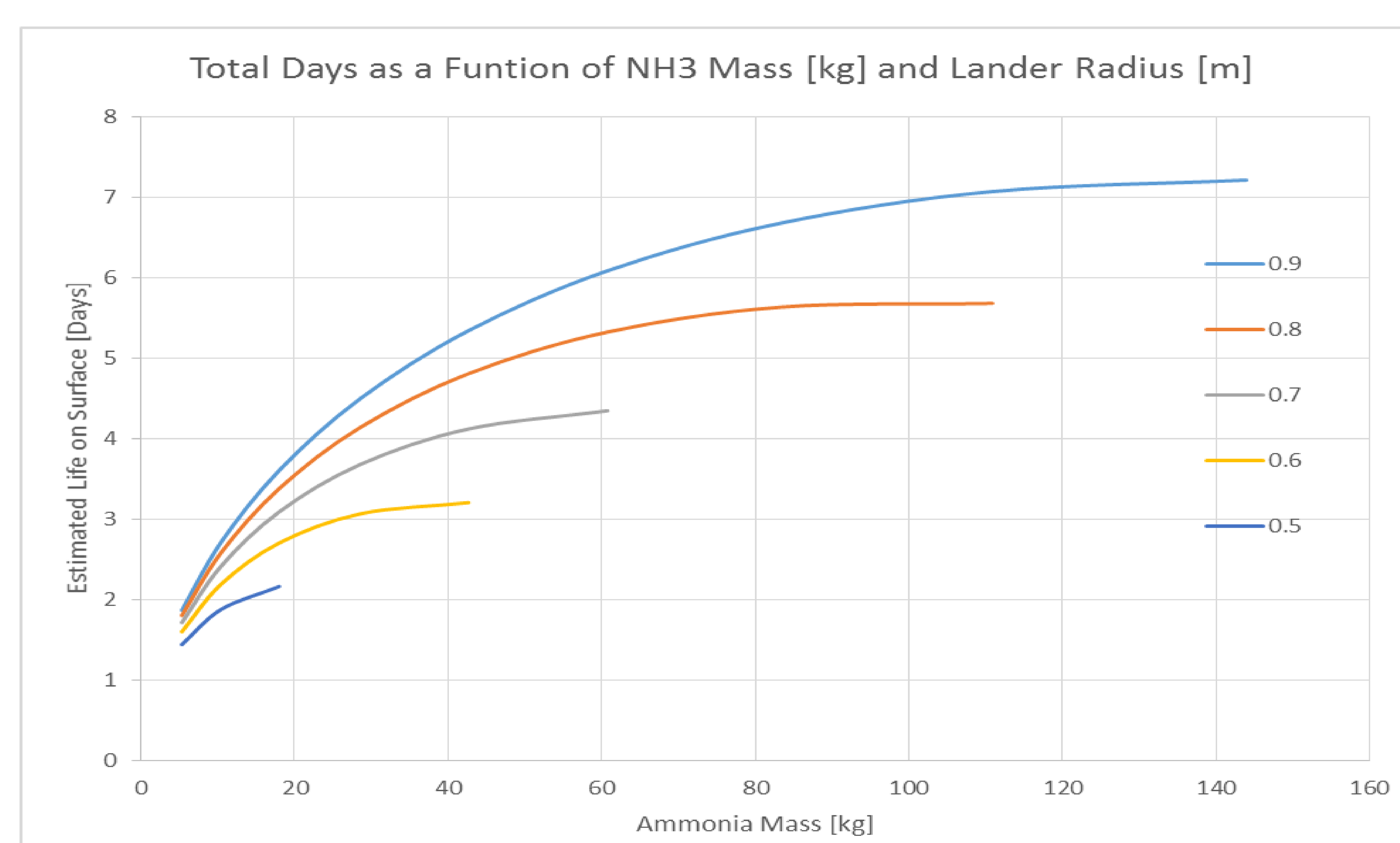
The Boiling Process. Boiling ammonia (NH3) at high pressure is well understood. Testing in the Glenn Extreme Environments Chamber (GEER) (below) would verify the results of the thermal model shown above. Two copper blocks, one cooled by evaporating ammonia and the other without cooling (as a control) would be exposed to Venus surface pressure and temperature inside the GEER.



Thermodynamic Diagram for Ammonia. The boiling process takes place near saturation conditions, 86 Bar to 94 Bar is 117 C to 122 C. Thus, if instruments' baseplates can survive these temperatures, the limiting factors become 1) the amount of ammonia that can be carried aboard, and 2) the communications link constraints. On earth, some types of off-the-shelf electronics such as downhole seismometers, can withstand these temperatures for a limited time.



Estimate Life of the Lander as a Function of Ammonia and Lander Size. The assumption of insulation conductivity of 0.06 W/mK and a spherically-shaped lander leads to the chart data in the plot below. A system level trade between science goals and lander life is needed to refine this concept.



References:
1. GSFC, et. al, "*Venus Mobile Explorer Concept*", 2009
2. Pauken, et. al., "*Expendable Cooling for a One-Day Venus Lander Concept*", 2014

Additional Flagship Concept: The evaporated ammonia would also disassociate to hydrogen to supply buoyancy and power from a solid oxide fuel cell operating at ~ 800 C. Oxygen would be carried along to supply the fuel cell. The water produced by the solid oxide fuel cell could be used for additional cooling. This would provide Thermal Control, Power, & Mobility in one package.