NASA High Operating Temperature Technology Program Overview, Quang-Viet Nguyen[1], Gary W. Hunter[2], [1]NASA Headquarters, Washington DC, [2]NASA Glenn Research Center, Cleveland OH

Mission concepts that require operation on the Venus surface for more than a couple hours have proven challenging. Recent progress in high temperature electronics [1] and other system elements are making possible realistic concepts for small landers with relatively simple instruments. LLISSE [2] is one such prototype development project that takes advantage of these new capabilities with new mission approaches. These innovative ideas however cannot address all the science desired and technology development of high temperature/pressure systems will be required. For example, generation of long duration power, in sufficient capacity to cool a pressure vessel and then also power science instruments that are inoperable in Venus ambient conditions, will be required for some instruments such as imagers. Eventually science will demand mobility, which again will likely require significant power capability. These and other challenges have been noted in the Venus Exploration Analysis Group documents such as the Technology Plan [3], the Planetary Decadal Survey Report, and other documents.

NASA's Planetary Science Division (PSD) has begun a structured approach to addressing Venus surface technology challenges by beginning to invest in new technology development efforts. The program initiated is called **H**igh **O**perating **T**emperature **Tech**nology (HOTTech). The HOTTech program supports the advanced development of technologies for the robotic exploration of high-temperature environments such as the Venus surface, Mercury, or the deep atmosphere of Gas Giants. The goal of the program is to develop and mature technologies that will enable, significantly enhance, or reduce technical risk for in situ missions to high-temperature environments with temperatures approaching 500 degrees Celsius or higher. It is a priority for NASA to invest in technology developments that mitigate the risks of mission concepts proposed in response to upcoming Announcements of Opportunity (AO) and expand the range of science that might be achieved with future missions. HOTTech does not soliciting hardware for a flight opportunity and is limited to high temperature electrical and electronic systems that could be needed for potentially extended in situ missions to such environments.

Ultimately NASA funded 12 awards in the recent call. Selected 1-3year development projects include technology topics ranging from high temperature batteries, solar cells and power generation technologies, various electronics (processors, memory, different approaches to electronic devices, and a high temperature motor. Table 1 lists the selected projects including the Principle Investigator (PI) and home institution. As one reviews the list of selected projects, one can envision these components as potential complementary elements of a future high temperature "system".

NASA is taking the development investment one step further. In order to increase the maturation potential of the individual investments, maximize the potential for infusion, and to begin to address integration level challenges, NASA has initiated a new approach that will explore the potential path to integration of these individual developments into a "system". PI's of the HOTTech awards have an opportunity, if desired, to plug into a system level development and test effort, The details of this system level development/test are still in development, but it is expected that this new approach will produce a number of advantages.

This briefing will describe the HOTTech program, summarize the development efforts and describe, to the degree known, the integration/system level opportunity that is being made available to the PI's.

P.I.	Title
Simon Ang, / Univ. of Arkansas	500°C Capable, Weather-Resistant Electronics Packaging for Extreme Environment Exploration
Kris Zacny / Honeybee Robotics Corp.	Development of a TRL6 Electric Motor and Position Sensor for Venus
Debbie Senesky / Stanford Univ.	Passively Compensated Low-Power Chip-Scale Clocks for Wireless Communication in Harsh Environments
Jonathan Grandidier /JPL	Low Intensity High Temperature (LIHT) Solar Cells for Venus Exploration Mission
Michael Paul / JHUAPL	Hot Operating Temperature Lithium combustion IN situ Energy and Power System (HOTLINE Power System)
Robert Nemanich/ Arizona State Univ.	High Temperature Diamond Electronics for Actuators and Sensors
Leora Peltz/ Boeing Corp.	Field Emission Vacuum Electronic Devices for Operation above 500 degrees Celsius
Darby Makel / Makel Engr. Inc.	SiC Electronics To Enable Long-Lived Chemical Sensor Measurements at the Venus Surface
Ratnakumar Bugga / JPL	High Temperature-resilient and Long Life (HiTALL) Primary Batteries for Venus and Mercury Surface Missions
Phil Neudeck / NASA GRC	High Temperature Memory Electronics for Long-Lived Venus Missions
Jitendra Kumar / Univ. of Dayton	Higher Energy, Long Cycle Life, and Extreme Temperature Lithium Sulfur Battery for Venus Missions
Yuji Zhao / Univ. of Arizona	High Temperature GaN Microprocessor for Space Applications

Table 1. Selected HOTTech projects and Principle Investigators

References:

[1] P. G. Neudeck, R. D. Meredith, L. Chen, D. J. Spry, L. M. Nakley, and G. W. Hunter, AIP Advances **6**, 125119 (2016). [2] T. Kremic, G. W. Hunter, P. G. Neudeck, D. J. Spry, G. E. Ponchak, G. M. Beheim, R. Okojie, M. C. Scardelletti, J. D. Wrbanek, D. M. Vento, L. M. Nakley, and J. Balcerski, "Long-Lived In-Situ Solar System Explorer (LLISSE) Probe Concept And Enabling High Temperature Electronics", 48th Lunar and Planetary Science Conference, The Woodlands, Texas, March 20–24, 2017. [3] http://www.lpi.usra.edu/vexag/reports/Venus-Technology-Plan-140617.pdf.