National Aeronautics and Space Administation

Glenn Extreme Environment Rig (GEER)

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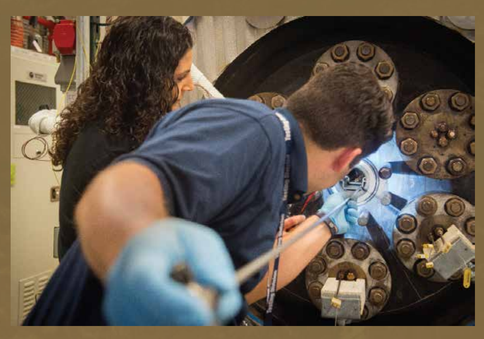
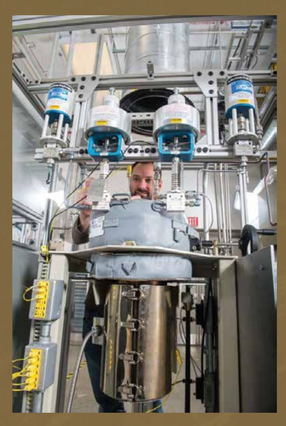
INTRODUCTION

Visions and Voyages for Planetary Science in the Decade 2013-2022[1] identified the goal of understanding the origin, evolution, and processes that control climate on terrestrial planets, with direct interest in Venus. The Glenn Extreme Environment Rig (GEER), located at NASA Glenn Research Center, was developed to address a community need for a facility which could simulate the extreme environments, complex, and often hostile atmospheres, notably including Venus' surface conditions. It actively supports science investigations and technical development activities of research institutions and industry partners. It is uniquely suited for studying the interactions between Venus' substantial atmosphere, its surface, and exploration components. Ongoing facility enhancements will provide significant additional value to the research community and maintain GEERs status as a world-class Venus simulation facility.

CAPABILITIES



Glenn's Extreme Environment Rig (GEER)
- 811L volume
- 94 bar pressure
- 538ºC operating temperature
- 8 gas streams

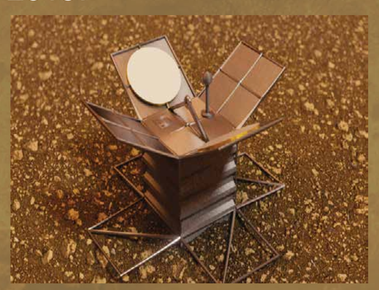


miniGEER
- 4L volume
- 186 bar pressure
- 510ºC operating temperature
- 3 gas streams
- Rapid cycling times

VENUS CONFIGURATION
- Achieving pressures ranging from <1 psi to 1350 psi
- PPB level control of CO2, N2, SO2, HF, HCl, CO, OCS, H2S, and H2O
- Ability to change gas mixtures during operation
- Static testing configurations include Venus lowland and highland environments

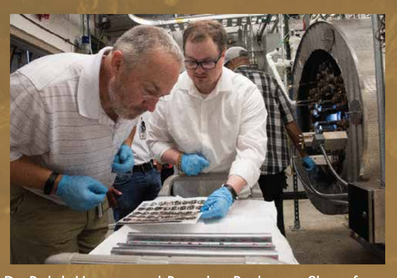
2019 RESEARCH AND EXPERIMENTS

GEER has successfully operated at Venus conditions for a total of 274.5 Earth Days, which converts to over one year of Venus time. This capability served multiple researchers exploring atmospheric Venus conditions for gas-solid and weathering relationships. The following is an example of three GEER facility select users in 2019:



- **Federal:** Long-Lived In-Situ Solar System Explorer (LLISSE) Project (NASA).This project is developing sensors, systems, proof of concept prototypes, and an engineering model that will be tested to demonstrate performance at Venus conditions. [2]

- **Academia:** Multiple investigations into atmospheric physics and surface-atmospheric interactions. These studies include analyses of reaction products, rates, and textural changes of geological materials after long-duration exposure to the surface environment. [3] [4]

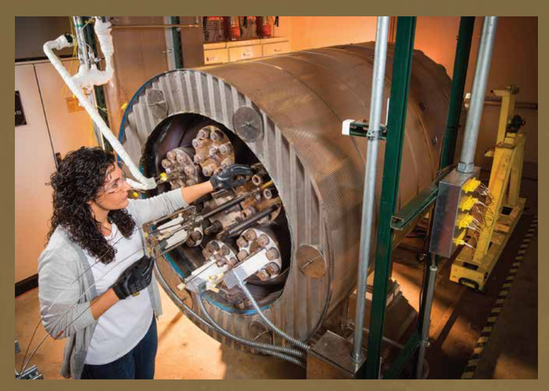


Dr. Ralph Harvey and Brandon Radoman-Shaw from Case Western Reserve University inspect samples after removing them from GEER.

- **Industry:** Stability and functionality verification in the Venus environment. Test articles include structural materials and engineering components, surface and coatings analyses were completed before and after exposure testing.

ANALYTICAL CAPABILITIES

GEER currently verifies target test conditions through a combination of approaches that include engineering controls and analytics. Multiple temperature/pressure transducers provide real-time data at various locations within the vessel. Sensitive gas flow meters provide 8 stream mixing controlled to < 1 ppm per stream. An automated, in-line gas chromatograph provides compositional information for targeted reactive species. Finally, a standalone mass spectrometer is used to verify gas chromatograph (GC) measurements and investigate possible reaction products by scanning between 1-500 amu. Custom power and data feedthroughs allows for additional in situ sensing capabilities.



Installation of monitoring equipment in GEER user port.

PLANNED ANALYTICAL ENHANCEMENTS

- **Low-Pressure Optical Reactor Cell** – This apparatus will augment the high pressure GEER cell with a 1-2 bar glass reactor that is designed to replicate the physical conditions and chemistry of Venus' intermediate cloud layers.

- **Dynamic Temperature Control** – Due to the thermal mass of the GEER vessel, temperature changes are relatively slow. The addition of supplementary cooling and heating apparatus will allow for the simulation of notional descent profiles through the atmospheric column.

- **Mass Spectrometer Molecular Beam** – A supersonic expansion sampling system allows for nearly instantaneous quenching of the high pressure gases from inside GEER. This ensures that the chemical species sensed in the low pressure, low temperature environment of the quadrupole mass analyzer, are the same as those inside the GEER vessel at the sample point.

- **Optical Analytics** – A high pressure optical chamber connected to the GEER vessel would allow for in-situ analysis of gas composition. The optical cell will allow for visual observations during testing for increased understanding of the relationship between time and gas-solid reactions.

- **Four column GC** – The addition of a four column GC will allow for precise real-time tracking of all minor reactive species.

REFERENCES

[1] Vision and Voyages for Planetary Science in the Decade 2013–2022,National Academy of Sciences, National Academies Press, 2011. Retrieved from https://www.nap.edu/catalog/13117/vision-and-voyages-for-planetary-science-in-the-decade-2013-2022.

[2] Kremic, T., et al. (2019). Preparing for Venus Surface Exploration. 2019 International Venus Conference. Niseko, Japan.

[3] Lebonnois, S., et al. (2019). An Experiment to Investigate Venus' Deep Atmosphere. 2019 International Venus Conference. Niseko, JP.

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