



Simulating the Surface of Venus on Earth

**Briefing by Tibor Kremic
NASA Glenn Research Center**

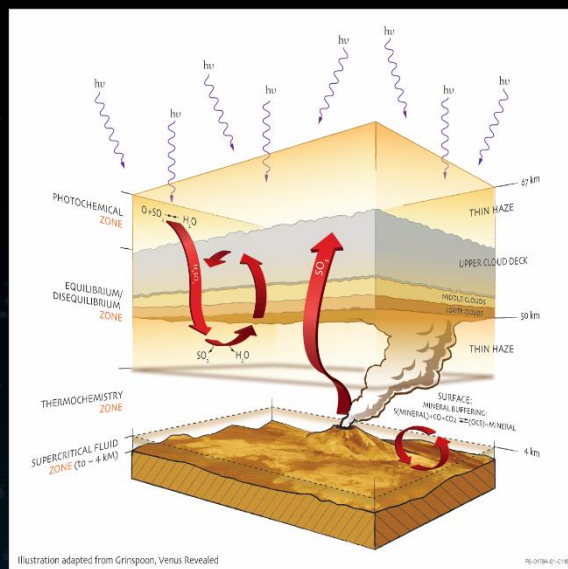
Earth's Twin Planet – Not So Nice



Surface Conditions

- Temperature: approx. 460 degree C
- Pressure: Over 90 bar
- Complex and challenging chemistry
- Relatively dark - covered by thick clouds containing sulfuric acid
- Vastly different physical characteristics possible - Super critical fluids

Why is our twin so different?



What must we learn about Venus today?



Super-Earth exoplanet GJ 1214b

(Image from ESA VLT)

Gas
CO2
N2
SO2
HCl
HF
OCS
CO
& H2O

Venus has a great deal to teach us about other planets and most importantly - Earth

Simulating Venus on Earth



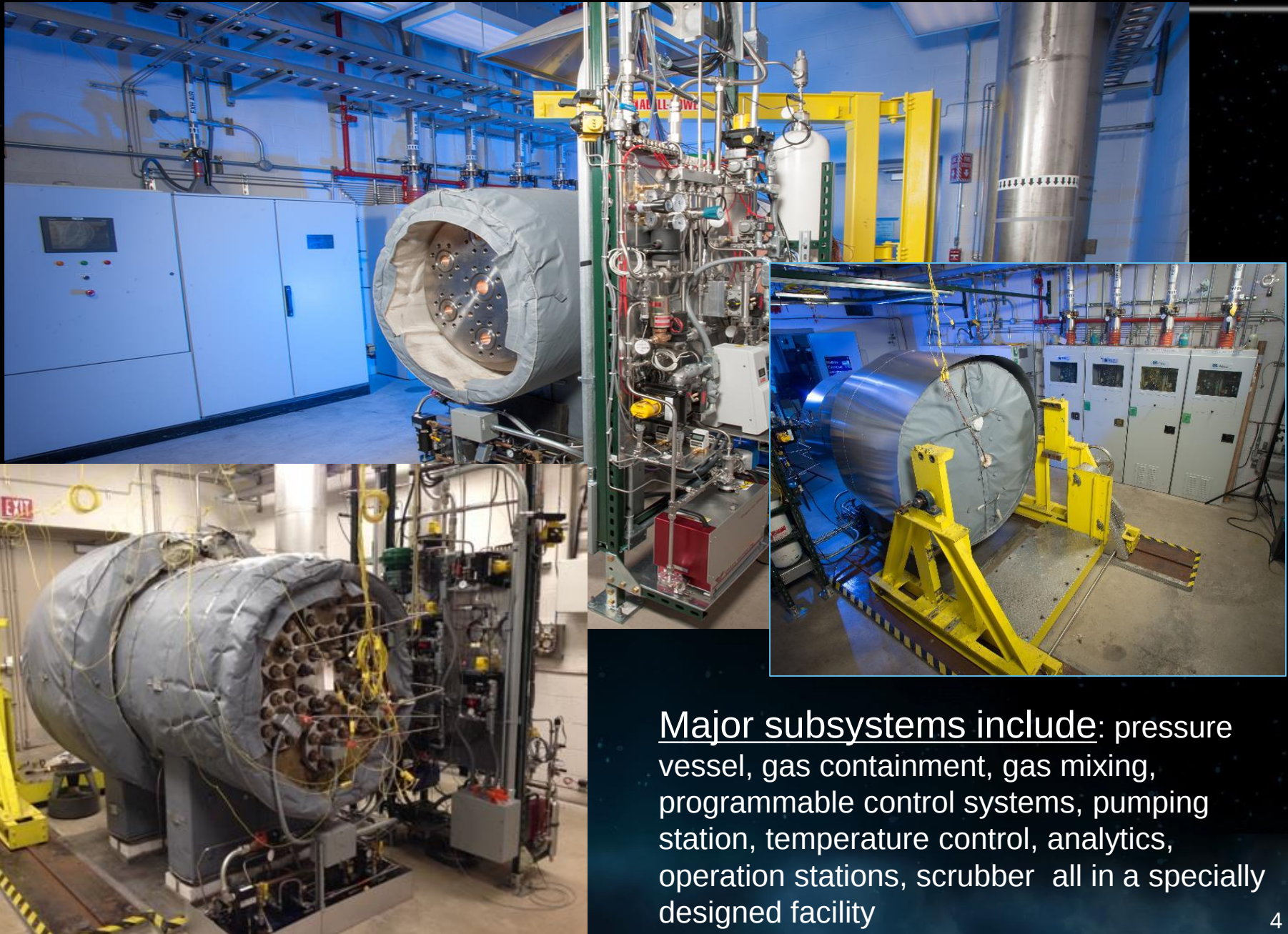
NASA Glenn (Cleveland, Ohio) recently developed Venus simulation capability

Glenn Extreme Environment Rig (GEER)

- Atmosphere replication capability with precise chemistry at a range of temperatures and pressures
 - Encompasses Venus surface – virtually any chemistry
- GEER officially “opened” about 1 year ago - with basic functionality
- “Basic” relative to what is ultimately desired – Already believed to be a unique capability in the world
 - Today can create precise chemistry and create and maintain desired temperature and pressure and chemical conditions indefinitely – *no lightning yet*

GEER accurately replicates extreme atmospheres – even at Venus surface conditions

GEER Basics



Major subsystems include: pressure vessel, gas containment, gas mixing, programmable control systems, pumping station, temperature control, analytics, operation stations, scrubber all in a specially designed facility

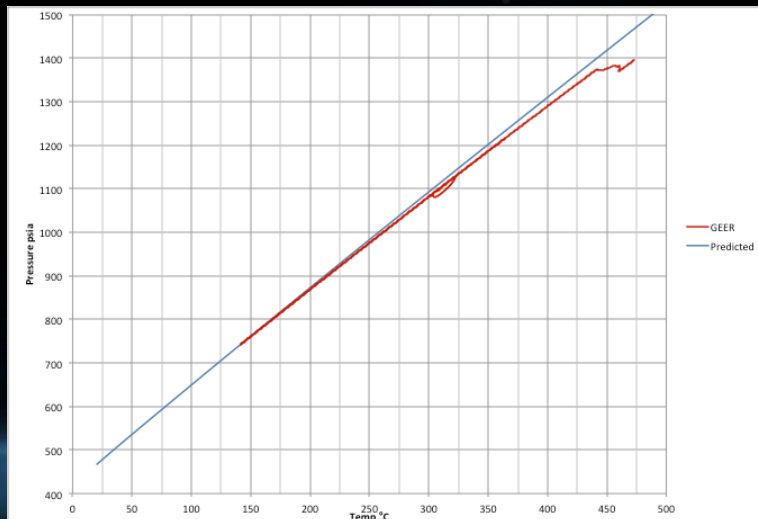
Glenn Extreme Environment Rig (GEER) Specs



- 304SS vessel - 3' dia x 4' long inside dimensions (28.3 ft³ or .8 m³)
- Max conditions pressure 103 bar at 500 degree C
- Eight ports - including a couple at opposing ends
- Nine separate gas streams
 - Each of these can handle pure or mixed gases
 - Ppm accuracy or better
- Re-boost pumping system
- Supporting infrastructure sized to handle multiple or a much larger chamber if ever needed
- Currently verify chemistry through mass spectroscopy (regular sample)

Gas	Moles	Grams
CO2	1237.1107	54445.24191
N2	44.8693	1256.96857
SO2	0.2307564	14.782255
HCl	0.00051279	0.0186954
HF	0.00006409	0.001282
OCS	0.00564071	0.338843
CO	0.02948554	0.825919
H2O	0.0384594	0.692885

Tested with predicted chemistry near Venus surface



Early test run

Operating Details

- Temperature ramp rate 7 degree C /hour
- Average temperature controlled to 1 degree C
- Pressure can be boosted
- Large volume may offer opportunity to explore stratification

GEER User accommodations



- Operating practices continue to evolve and improve
 - E.g. avoid condensation
- Small scale hardware & materials inserted through small ports - larger items can be installed through main door
- Electrical feed-throughs available for power, signal etc..
- Notional cycle takes about a week for leak check, heat up and cool down plus whatever time desired at conditions
- Testing approach and details worked case by case with customer specifically designed for user needs
- Remote users can be accommodated



Electrical feed-throughs

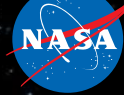
- Signal, power, etc.



Sample holders using the GEER center port



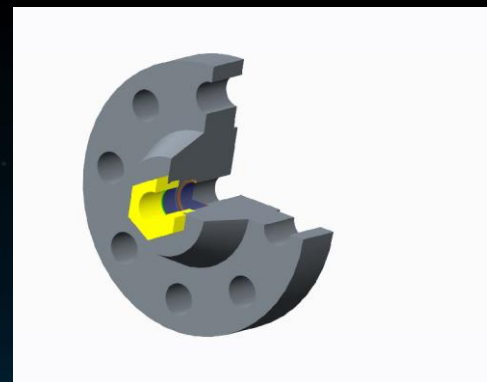
GEER Capabilities That Are Still in Work



- Configured and currently calibrating Raman system
 - Expected to provide real time compositional readings
- Optical window(s) in work
 - Enable real time compositional measurements
 - Test various instruments designed to study Venus atmosphere or surface
- Fast / fine temperature control designs in work
 - Vessel in vessel approach
 - Useful for cooling portions of experiment, dynamic testing (E.g. descent profile for pressure and temperature), corrosive tests, or constant precise chemistry
- Small vessels added for quick and/or small scale tests



Small Parr vessels
being added



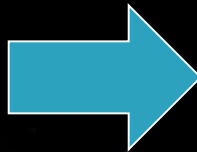
Optical port being
added

Some Exciting First Results Coming

Venus weathering experiment with CWRU/GRC



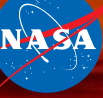
Removing sample holder from vessel



Post test with predicted chemistry near Venus surface



and the results
ARE ?



GEER Welcomes all Users

- **Science**
 - Planetary atmospheres, weathering, physical properties of supercritical fluids, emissivity, propagation, ...
- **Technology**
 - Instruments, probe systems, chemical sensors, ...
- **Mission implementing, planning teams**

Website: <https://geer.nasa.gov>

This project was possible through support by NASA's Planetary Science Division