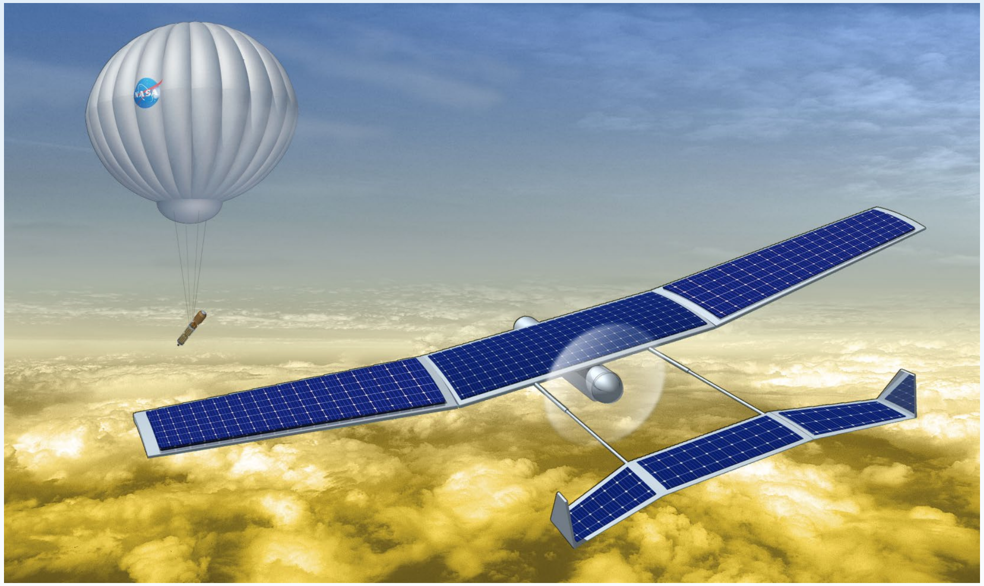
New Concepts for Venus Surface Sample Return



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Acknowledgement

This presentation represents a work in progress; stay tuned for further details

The work was done with the assistance of a great number of collaborators on the NASA Glenn Compass Engineering team, most significantly:

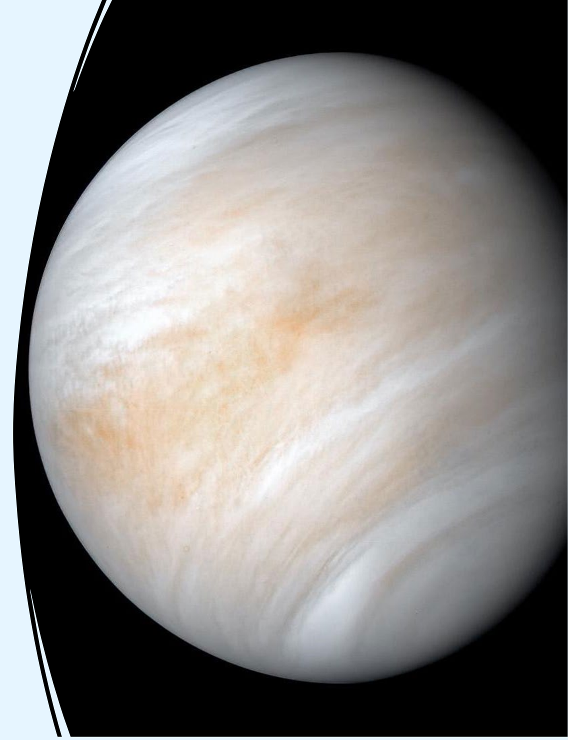
- Compass Lead – Steven Oleson

- System Integration, MEL – Tim Gray, Betsy Turnbull
- Mission: David Smith
- Propulsion Systems – Jim Fittje, Arland Zatania Lojo
- Structures and Mechanisms – John Gyekenyesi
- Environmental/Thermal Control – Anthony Colozza
- High-temperature subsystems – Gary Hunter
- C&DH/Software – Shadi Zogheib, Lucas Shalkhauser

- Science: Noam Izenberg
- Communications – Katelyn Crockett
- Power –Anthony Colozza
- Cryo Fluid Management: Jason Hartwig
- AD&C: Brent Faller
- ISRU: Leslie Gertsch
- Configuration - Tom Packard

Why Venus?

- Venus is Earth's evil twin: nearly the same size at Earth, yet in many ways very different.



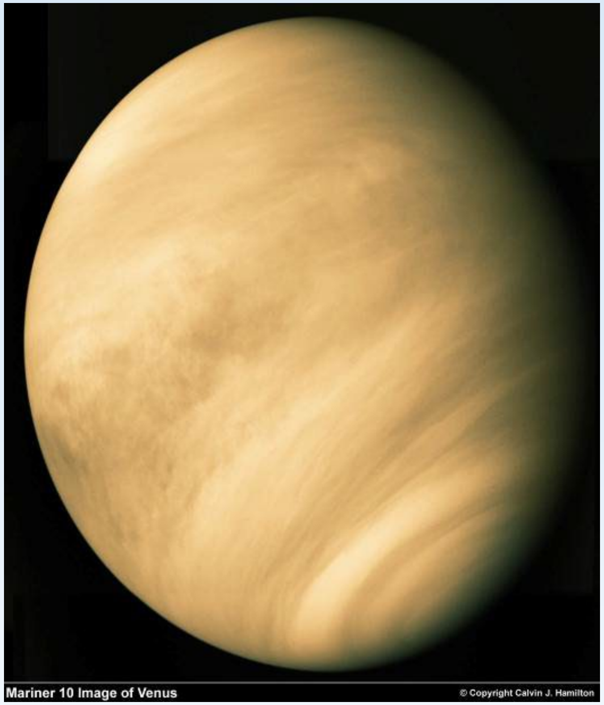
Our knowledge of the geology and mineralogy of surface of Venus is very slight.

- Only one NASA mission has even entered the atmosphere. One of the Pioneer probes continued to transmit for an hour after reaching the surface, but made measurements only of the atmosphere, not of the surface.
- The Soviet Venera and VeGa missions did slightly better, with the longest-lived Venera lander transmitting for two hours from the surface, but made only relatively crude measurements of mineralogy, since sophisticated instruments were not available that could operate at Venus conditions.

Beneath the clouds, the surface of Venus is mostly unknown.

Missions to Venus are Hard!

- Solar day 117 days
- Surface temperature 452 C (850F)
- Surface pressure 92 bars (equals pressure 1-km under the ocean) carbon dioxide
- Clouds are concentrated sulfuric acid droplets



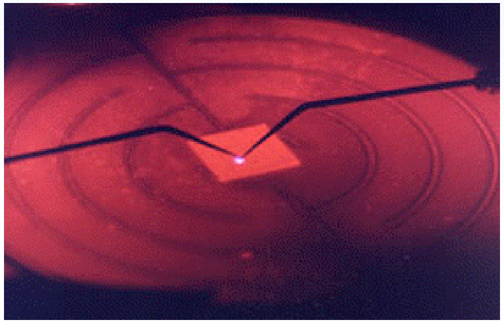
Venus in the UV (viewed from the Mariner 13 Venus mission)

At 450° C and 90 bars of atmospheric pressure, the surface of Venus is possibly the most hostile surface environment in the solar system….

Venus surface missions are hard.
Returning a sample is even harder!

NASA Glenn is the champion at technology for Venus

- NASA Glenn's Silicon Carbide high-temperature electronics (LSC) have been tested to work at Venus conditions
- Batteries for Venus being developed led by LEX
- GEER chamber simulates conditions at the surface of Venus
  - Developed a long list of what materials can be used on the surface… and which can't
- The Compass concurrent-engineering team has done many studies of Venus missions
- Proposed and developed concepts for atmospheric flight on Venus
- Developed LLISSE small mission as a technology-demonstration of long-lived operation on the surface



NASA Glenn SiC devices have repeatedly demonstrated proper operation at temperatures as high as 650 C.

Two hard problems:

- Collecting a sample from the surface of Venus
  - Get to the surface
  - operate on the surface of Venus to collect a sample
  - rise off the surface

- Launching a sample from Venus into orbit
  - Since Venus is almost as large as Earth, the ΔV to launch from Venus into orbit is nearly as high as a launch from Earth
    - That means a **big** rocket
  - But even harder, because of the thick atmosphere

Approach

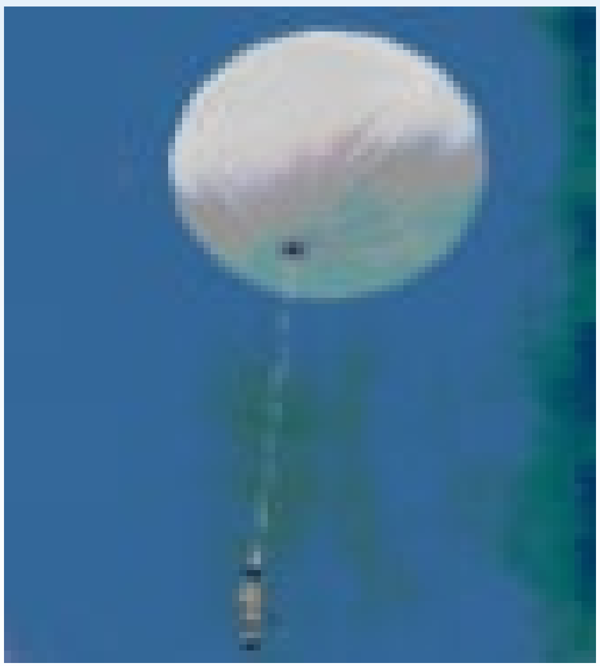
• Launching a sample from Venus into orbit

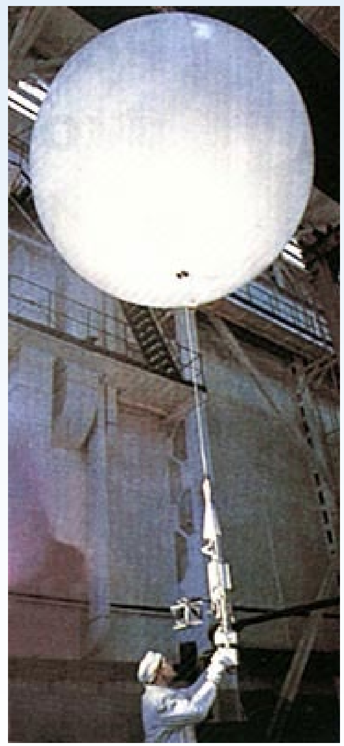
- At a temperature of 450° C, we don't want to land the fully-fueled sample return rocket on the surface!
- Solution: Float the rocket high above the surface in a balloon

One conceptual design of the balloon platform shown here with the launch vehicle suspended beneath, ready for launch.

Previous Missions: VEGA Venus balloons (Russia):

ballooning in the Venus atmosphere
2 balloons floated for 48 hours at 54 km altitude
delivered by probe during Venus swingby



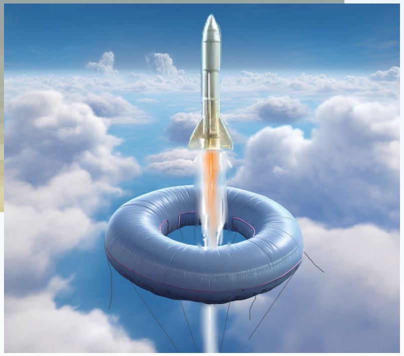


VEGA gas envelopes coated with a polytetra-fluorethylene (PTFE, "Teflon") surface
PTFE is robust against attack by sulfuric acid.

Approach

Early concept looked at a toroidal balloon

- Rocket was to be suspended below and launched vertically through the hole



After analysis, toroidal envelope was (reluctantly) abandoned

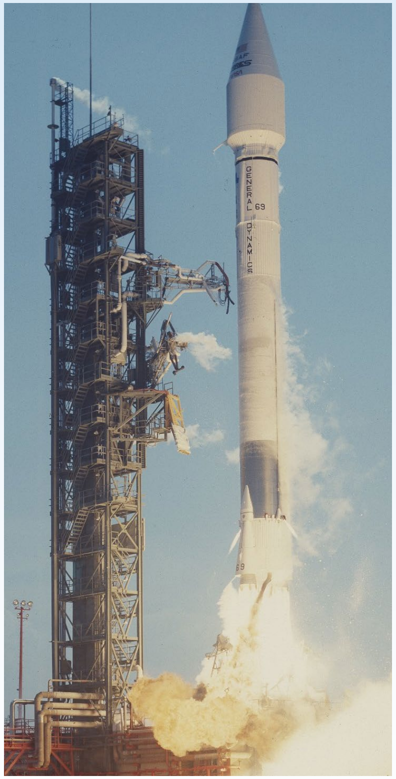
- Envelope mass increase
- Vertical launch is unnecessary; angled launch is preferred
- Makes increase in lifting gas volume as propellant is manufactured more difficult
- Launch through center makes it difficult to re-use propellant manufacturing plant for later sample return missions

Approach

- Launching a sample from Venus into orbit

- Need a big (and heavy!) rocket.

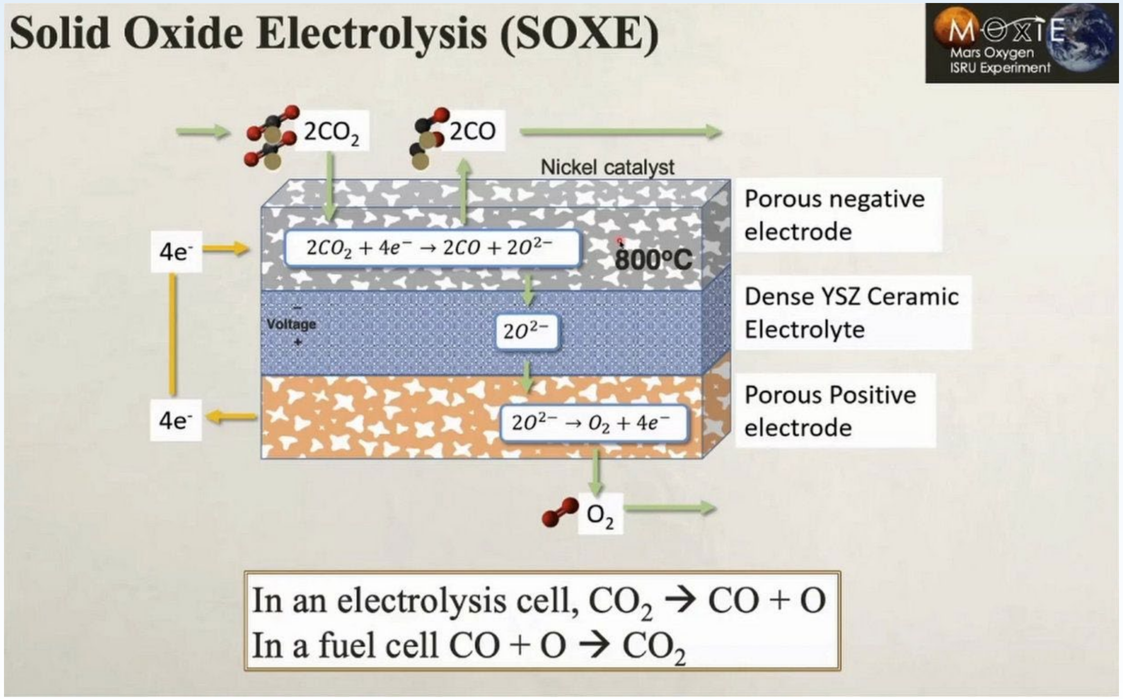
- To reduce the amount of mass we have to carry to Venus, we are looking at **in-situ propellant production** to make rocket propellant from the Venus atmosphere



Trade study: is the mass we save by not bringing the propellant from Earth overweigh the mass required for the propellant manufacturing and power supply?

Approach: ISRU from atmospheric carbon dioxide

- Solid Oxide Electrolysis technology to make oxygen from carbon dioxide
- $2\ CO_2 \rightarrow 2\ CO + O_2$



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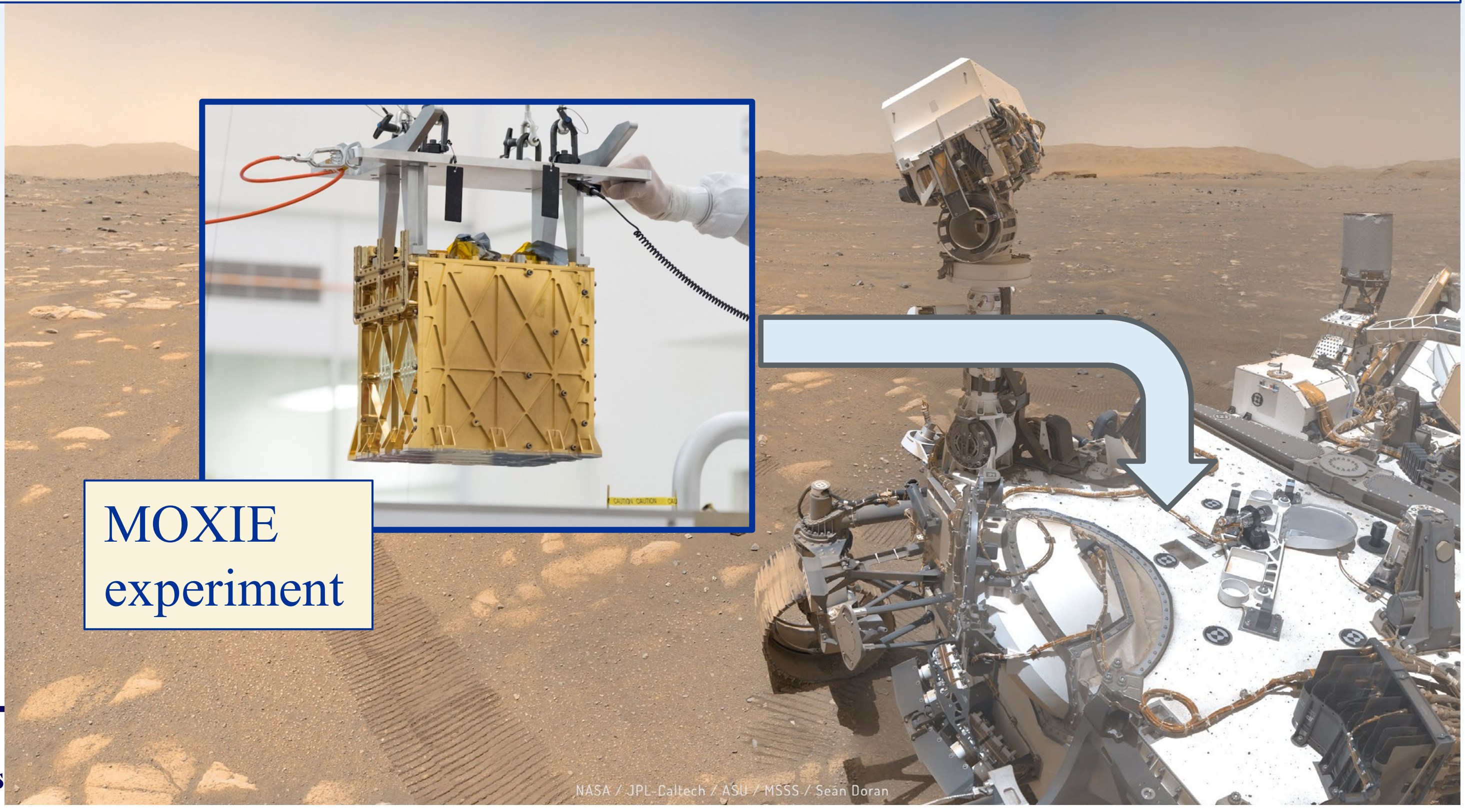
Approach: ISRU

- NASA has demonstrated on Mars technology to make oxygen from carbon dioxide on Mars
- MOXIE (Mars Oxygen In-Situ Resource Utilization Experiment) experiment demonstrated on Perseverance Rover
- Byproduct of oxygen generation is carbon monoxide



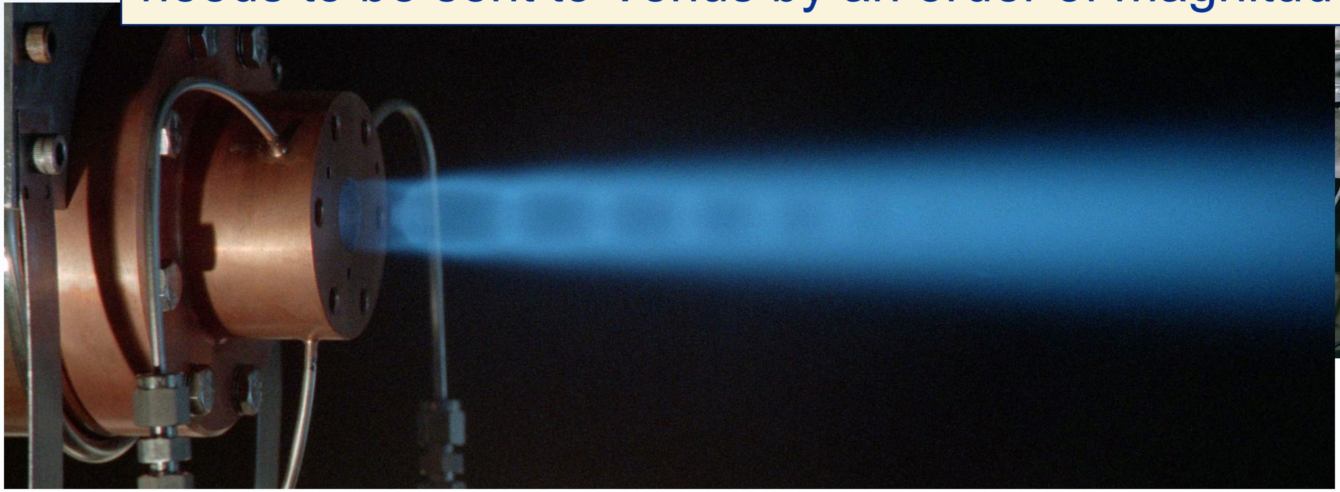
Proposed Approach:

can we make both fuel and oxidizer?

- The major weight of rocket propellant is the oxidizer. But… can we make the fuel as well?
- Carbon monoxide can be used as rocket fuel!
- We look at the possibility of using technology developed by Dianne Linne at NASA Glenn to make carbon monoxide and oxygen from the Venus atmosphere, and use it as a rocket fuel

If we can make our fuel when we get there, we can possibly reduce the mass of the return rocket that needs to be sent to Venus by an order of magnitude!

Diane Linne in the rocket lab preparing to test an engine (1989)



Carbon monoxide/oxygen rocket engine being tested

Launching to Venus orbit

- Vehicle based on Japanese SS-520 vehicle
- Carried a 9-pound cubesat into Earth orbit
- Use of ISRU fuel production means we need to transport to Venus only the empty weight of the launch vehicle, 250 kg, rather than the fully-fueled weight of the rocket.

Once the sample is launched into orbit, a separate in-space vehicle picks it up and transports it to Earth

Trade study: how much power will be required to keep cryogenic liquid propellants cold?

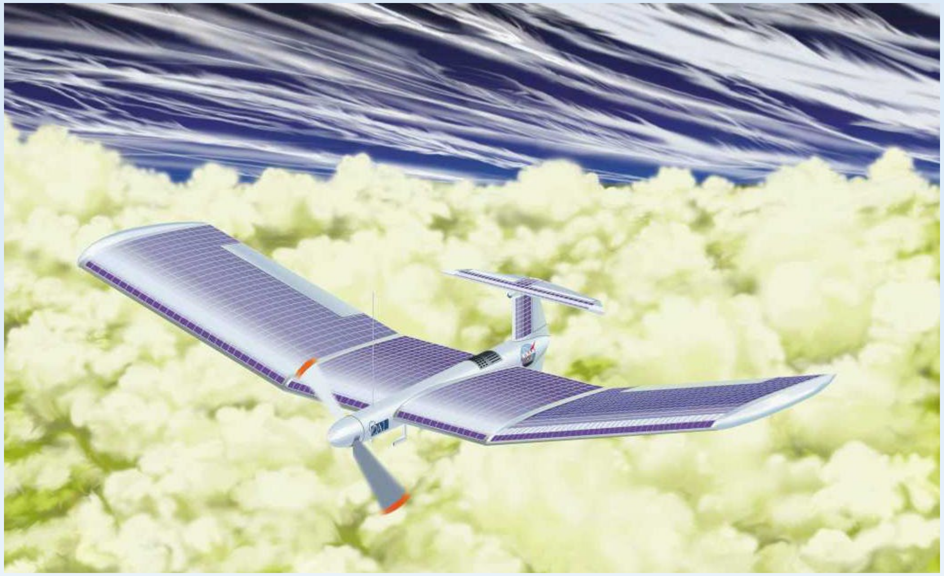
SS-520 orbital booster, the smallest vehicle to ever launch a satellite.

Collecting the sample from the surface of Venus

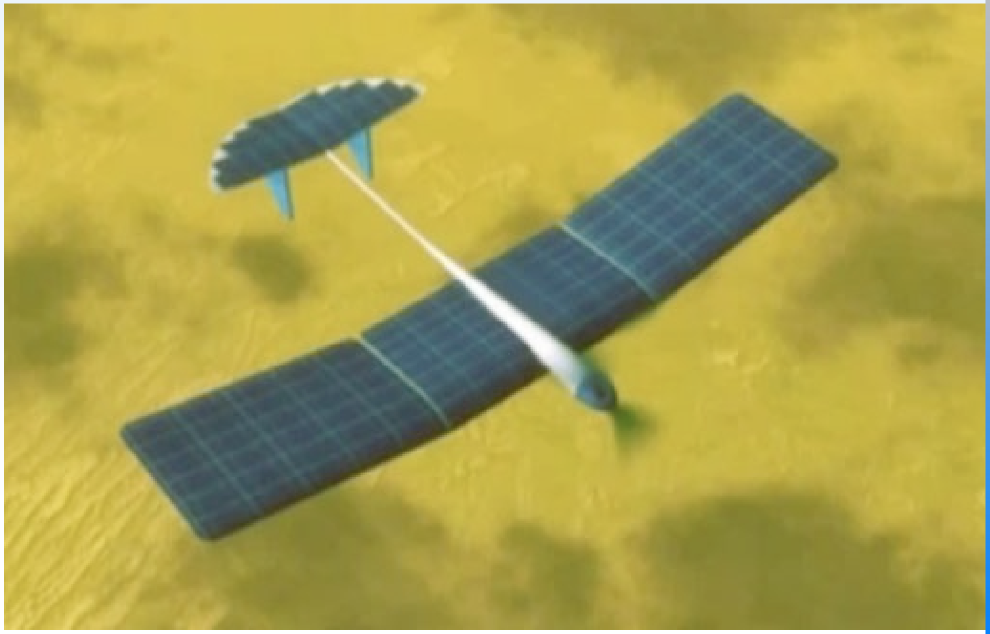
–Get to the surface
–operate on the surface of Venus to collect a sample
–rise off the surface and rendezvous with the balloon carrying the fully-fueled return rocket

- NASA Glenn has done many studies of solar powered aircraft to fly on Venus
- NASA Glenn has developed high-temperature technologies to operate on the surface of Venus
- We will put these technologies together to make a high-temperature airplane to land on the surface, collect a sample, and fly up to the balloon with the return vehicle

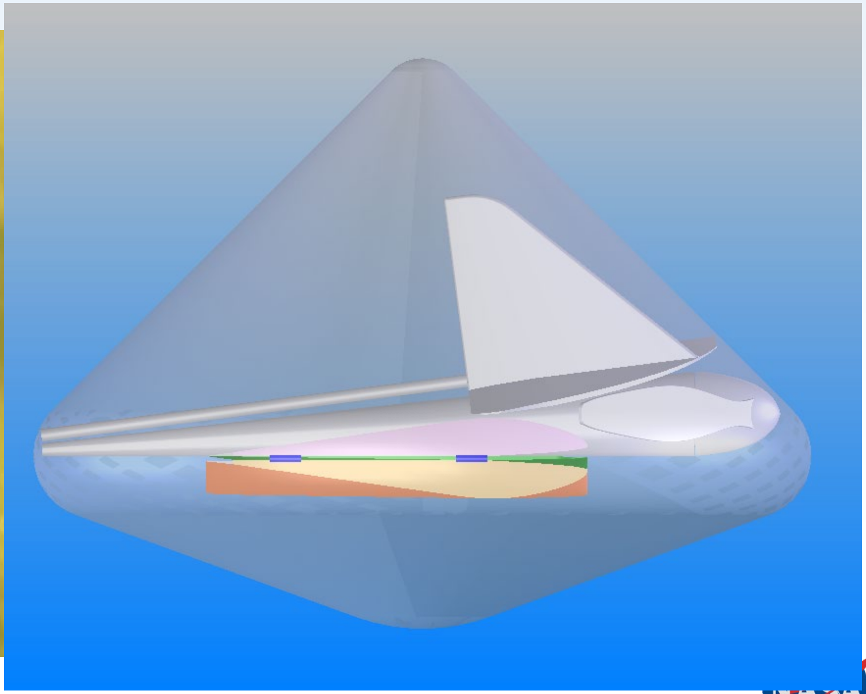
NASA Lewis RASC Venus airplane study (2002-3)



Initial Venus airplane concept

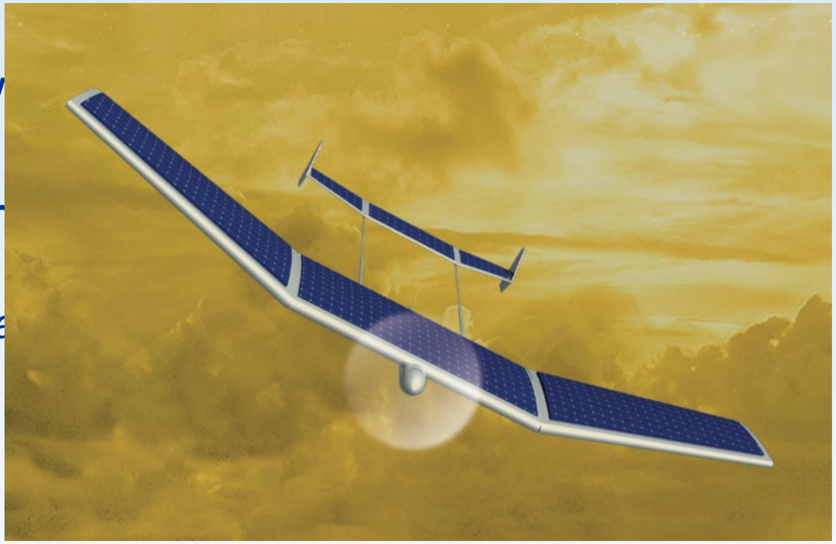


Final RASC design



Folded into aeroshell

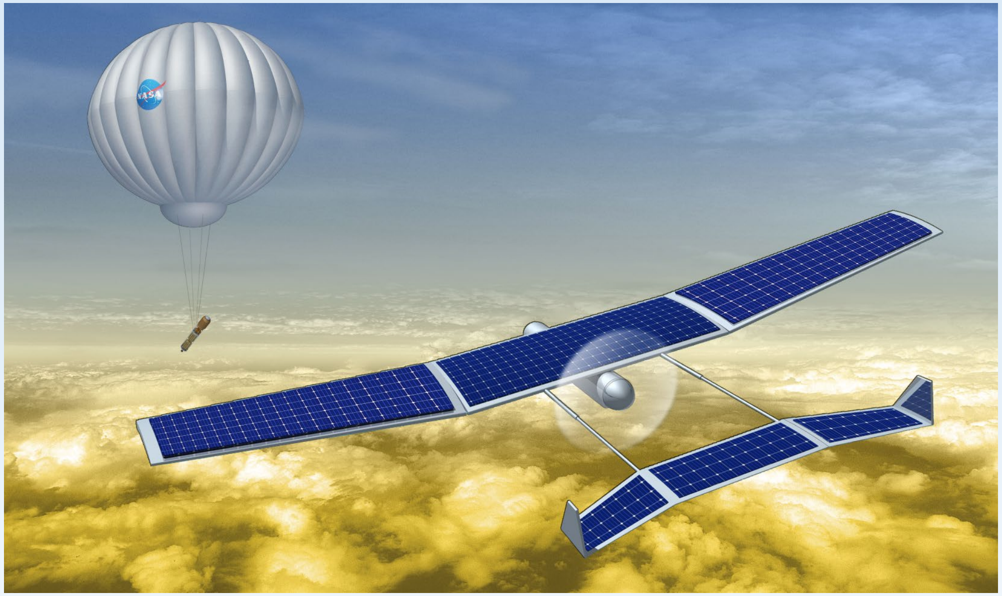
Airplane design requirements



- Capable of both low-altitude/high temperature flight and high-altitude/low temperature flight
- Solar powered when above cloud layer
  - Requires high temperature solar cells
  - Build on prototype cells from Grandidier *et. a*
- Battery powered below clouds
  - Leverage NASA GRC work on high-temperature batteries
  - High-temperature battery dropped when depleted
- Low speed at Venus Surface
  - Due to high atmospheric density, minimum airspeed is low near surface
- High-temperature motor
  - Designs from Honeybee robotics operate at Venus temperatu
- High temperature electronics
  - NASA GRC SiC integrated circuits

Can this even be done?
…we're working on it!
Stay tuned

Summary: Why Venus? Why Sample Return?



Artist's conception by Terrance Condrich, NASA Glenn

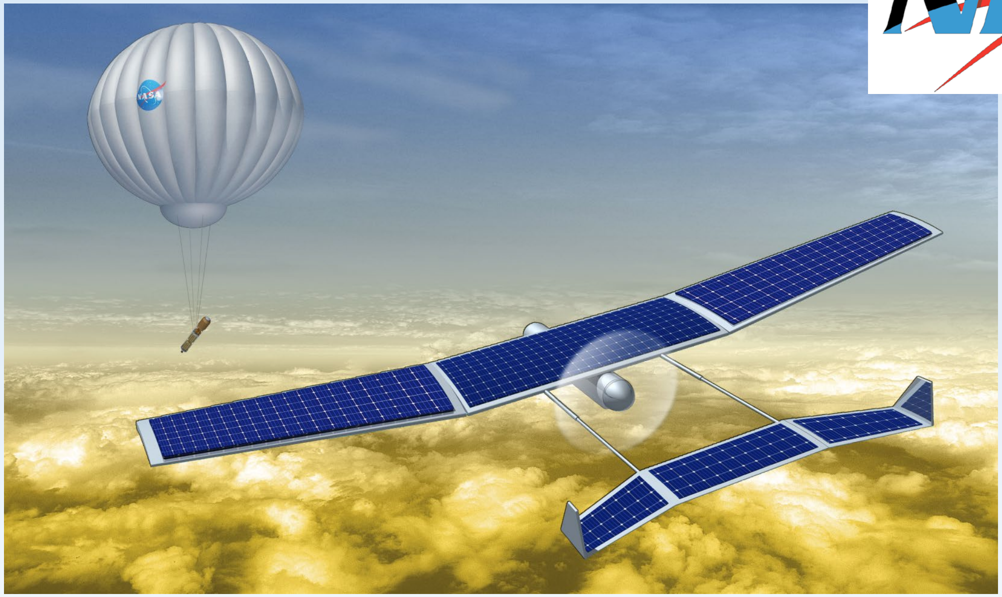
- Because it is hard
  - If it wasn't hard, we wouldn't do it

- Because it applies and showcases NASA interesting new technologies

- Because the technologies we develop will have applications to other missions

- Because it's cool

Acknowledgement



- We would like to thank the NASA Innovative Advanced Concepts (NIAC) program for selecting this concept for a phase-A study