Technologies for Future Venus Missions

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Venus Exploration Analysis Group

Overview

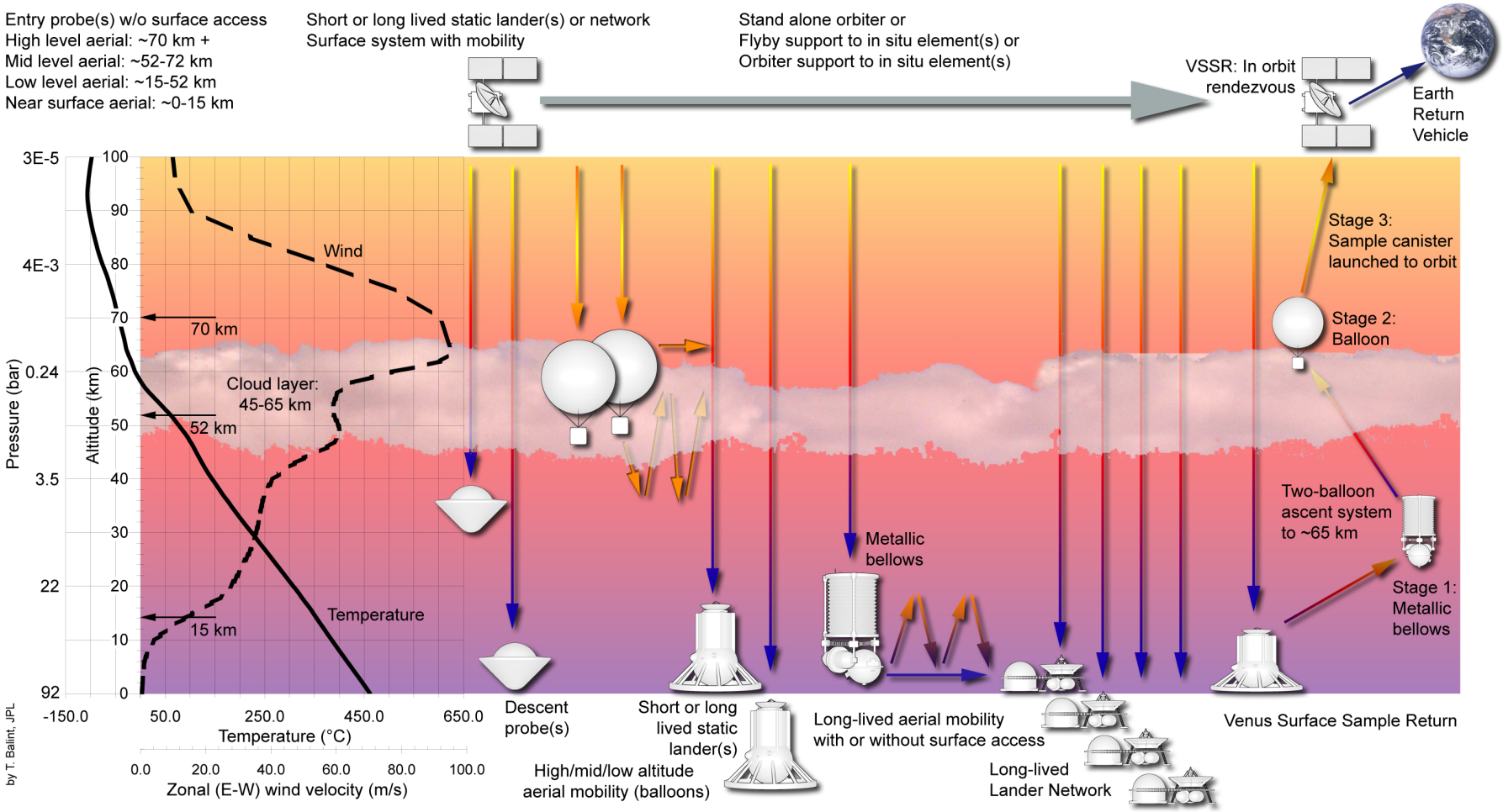
- Introduction
  - Typical Venus Mission Elements and Architectures
  - Extreme Environments
  - Systems Approach for Component Protection

- Technologies for Future Venus Missions
  - High Priority Technologies (VFM)
  - Technologies for Short Lived Mission (presented by T. Balint)
  - Technologies for Long Lived Missions (presented by G. Hunter)

- Conclusions and Recommendations

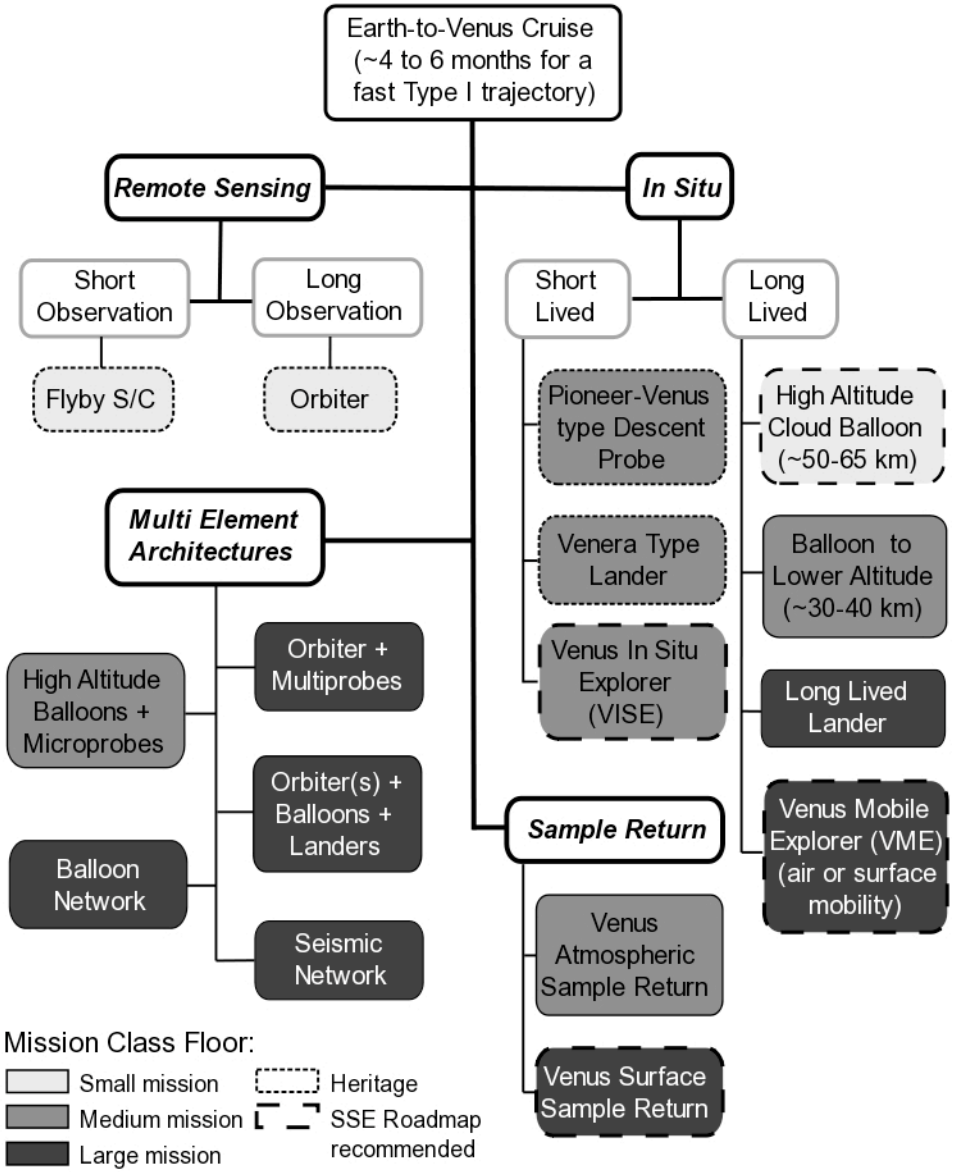
INTRODUCTION

Introduction: Typical Mission Elements



The Venus Flagship study included 13 mission elements

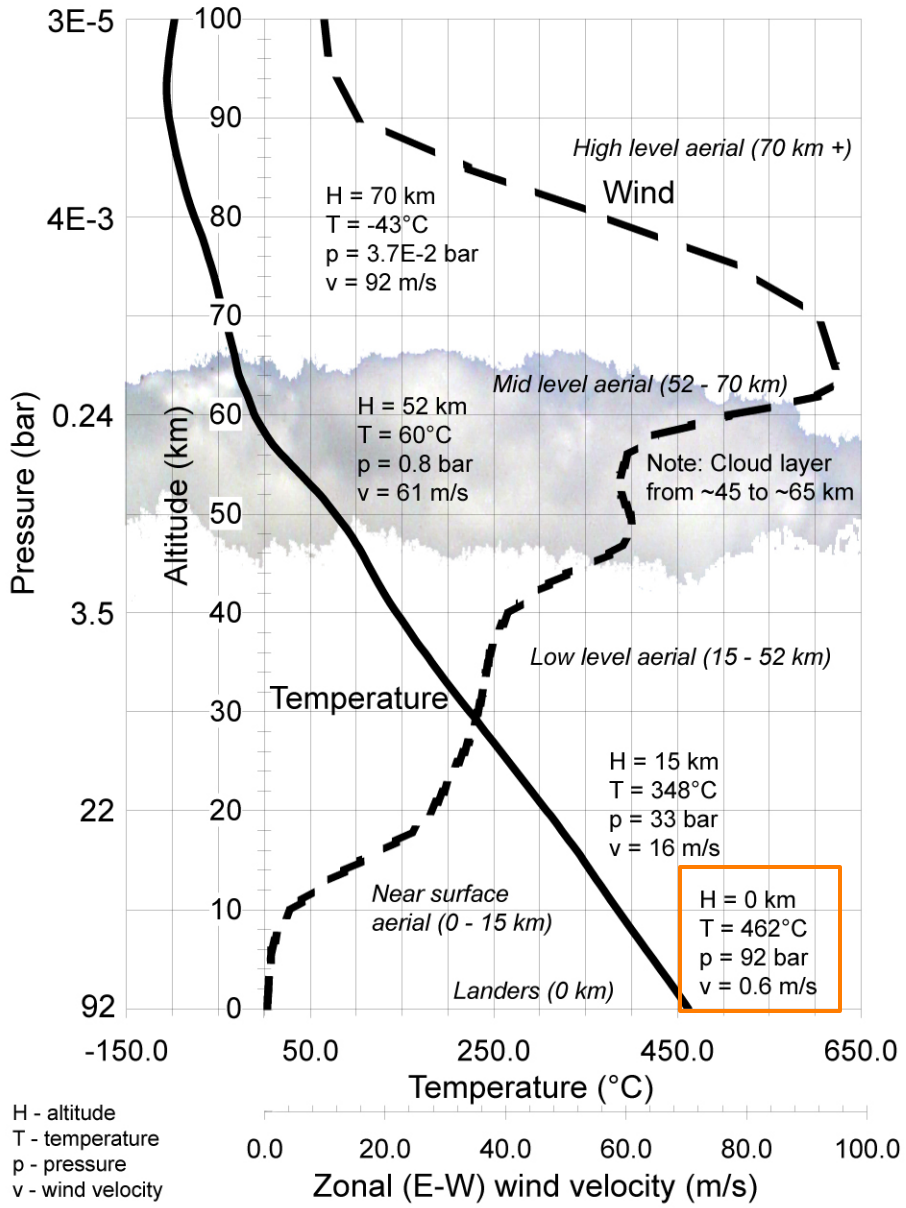
Introduction: Mission Architecture Examples



VDRM – Venus Design Reference Mission

- The Venus Flagship study included 17 candidate mission architectures
- Venus Flagship DRM
  - Multi-element architecture with short lived *in situ* elements
    - 1 orbiter (2 years)
    - 2 short lived landers (5 hours)
    - 2 short lived balloons (30 days)
- Enhanced mission
  - Increased lifetime
    - Hours
    - Days

Introduction: Extreme Environments on Venus

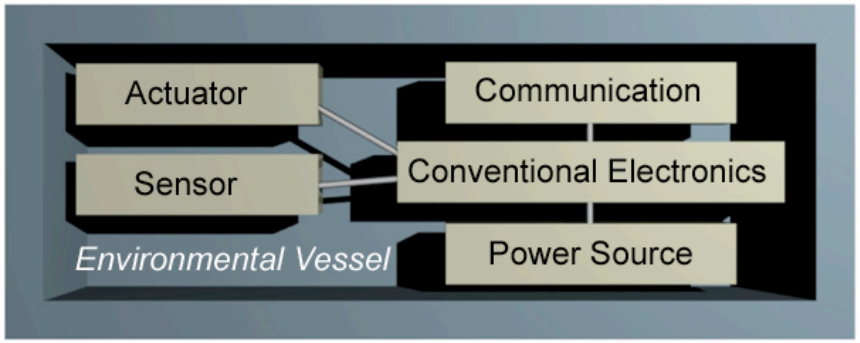


- Temperature and pressure increase towards the surface
- Sulfuric acid droplets in clouds
- Supercritical CO_2 near surface (12.5 km anomaly)
- Additional factors:
  - Mission lifetime
  - Interface with environment
  - Operations
  - Protection methods

Introduction: Systems Approach

Protection Systems

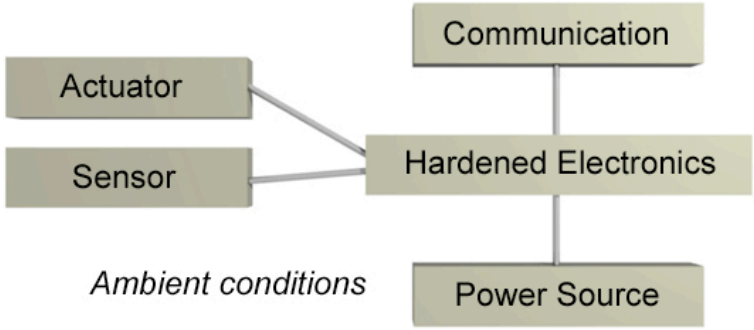
Use conventional components; Develop protection systems (Thermal vessel; pressure vessel, radiation shielding etc.)



Impractical for planned missions

Component Hardening

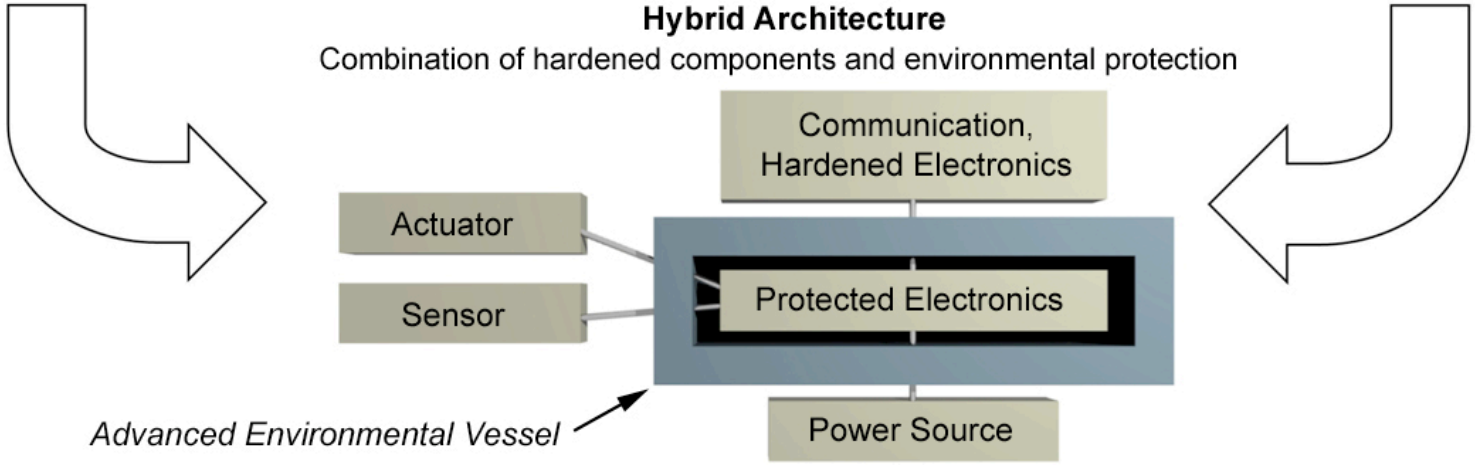
Develop technologies tolerant of extreme environments



Prohibitively expensive for some technologies

Hybrid Architecture

Combination of hardened components and environmental protection

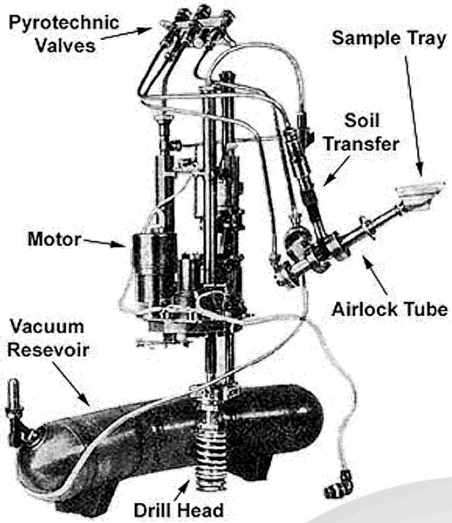


Requires development of innovative architectures

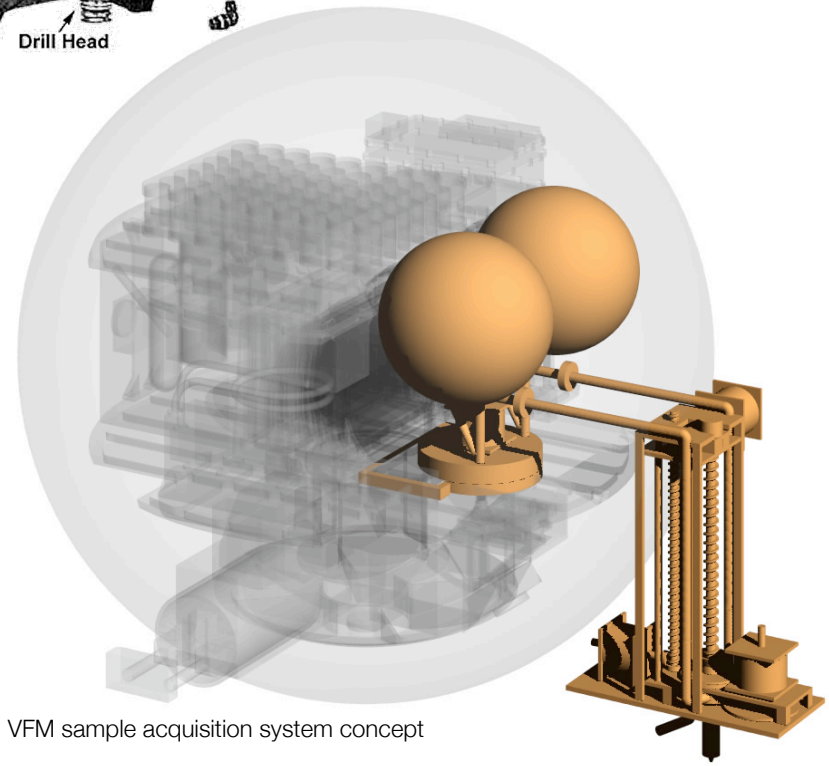
TECHNOLOGIES FOR FUTURE VENUS MISSIONS

HIGH PRIORITY TECHNOLOGIES

Surface Sample Acquisition & Handling (VDRM)



Venera's sample acquisition system



VFM sample acquisition system concept

Current State of the Art (SOA)

- vacuum-driven sampling was demonstrated on Venera
- not available off the shelf

Technology Development Needs

- surface sample acquisition system at high temperatures and pressures
- requires development for NASA

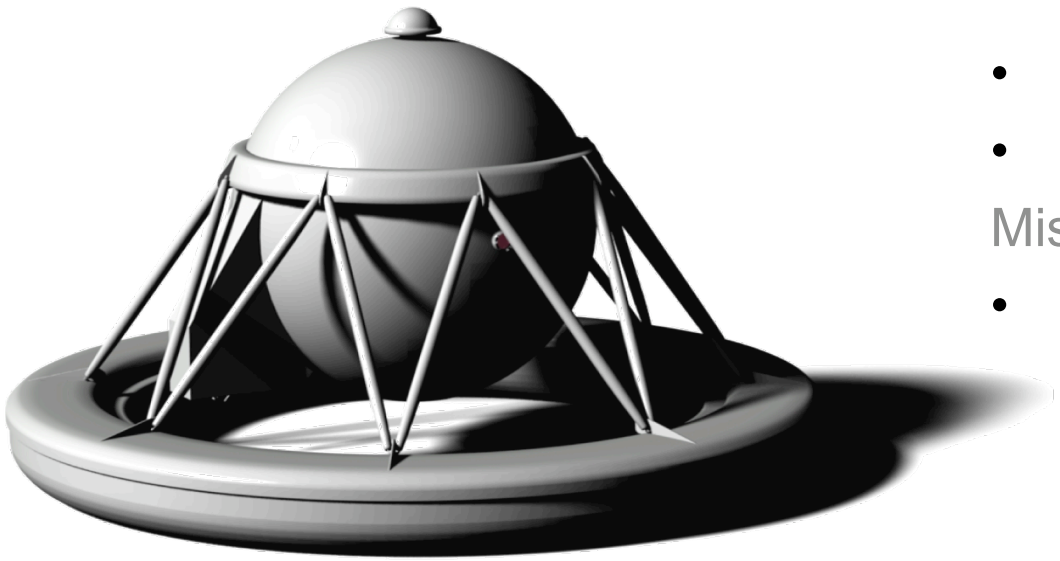
Mission Benefits

- drilling, sample collection and sample handling are enabling

TRL 2 to 3

Priority HIGH

Rotating Pressure Vessel (VDRM)



Current State of the Art (SOA)

- powerful concept
- but technologically immature

Technology Development Needs

- full scale design and testing needed
- with a driver motor and
- mounted sampling system

Mission Benefits

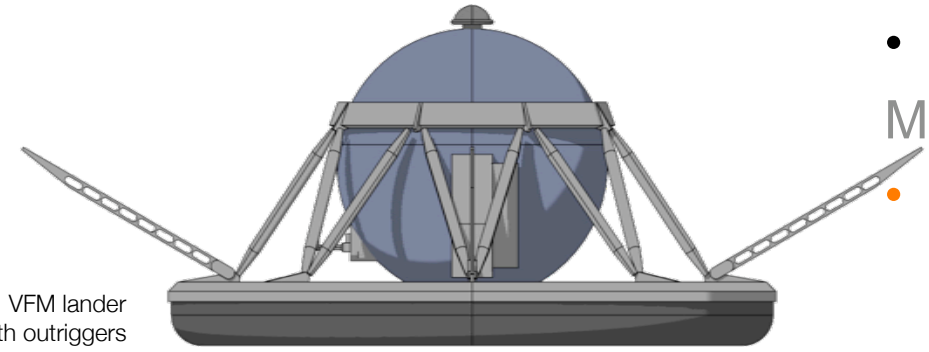
- minimizes the external components (e.g., drill arms, actuators, motors, sampling systems)
- minimizes penetrations, thus
- minimizes heat leakage

TRL 2

Priority HIGH

Rugged-Terrain Landing (VDRM)

Venera 13 lander



VFM lander
with outriggers

Current State of the Art (SOA)

- proof of concept by Russian landers
- all Veneras landed at benign surfaces
- used a drag plate instead of parachutes

Technology Development Needs

- design and test a landing system
- accounting for a large variety of unknown landing hazards
- using parachutes

Mission Benefits

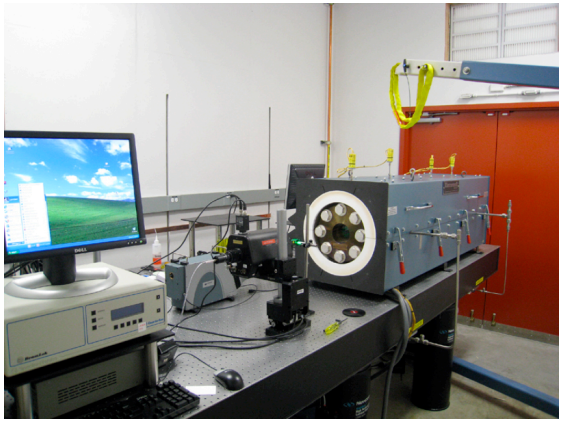
- reliable access to Tessera and other rugged areas on Venus

TRL 2

Priority HIGH

Venus Test Facility (VDRM)

Small JPL Venus environmental chamber for testing materials and components (with window and electrical ports)



Small JPL Venus environmental chamber with windows placed at either end to enable the testing of optical instruments

Current State of the Art (SOA)

- small operating Venus test chambers (GSFC, JPL)
- proof of concept, decommissioned Russian chamber

Technology Development Needs

- large test chamber doesn't exist
- full scale *in situ* elements testing (probe/ lander)
- transient conditions and composition

Mission Benefits

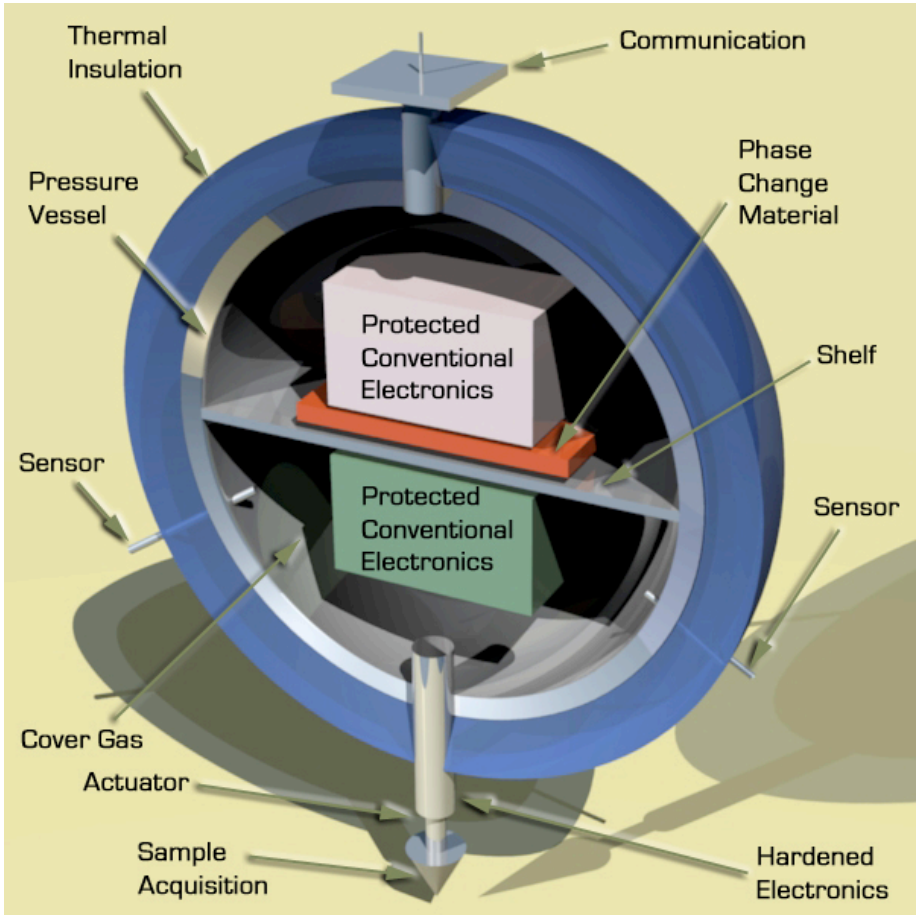
- test, validate, calibrate
  - spacecraft components and science instruments
- test operating scenarios under realistic conditions
- lessons learned from 12.5 km anomaly

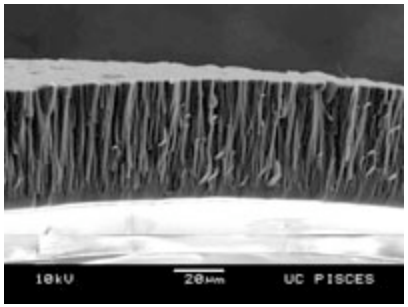
TRL 2 to 6

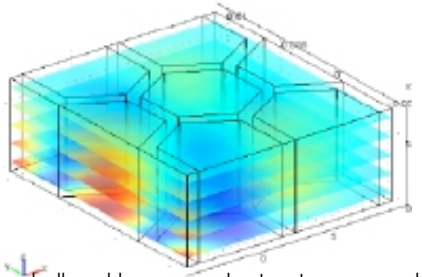
TECHNOLOGIES FOR FUTURE VENUS MISSIONS

FOR SHORT LIVED *IN SITU* MISSIONS

Pressure Control







Beryllium shell and honeycomb structure examples

Current State of the Art (SOA)

- titanium pressure vessel is space qualified

Technology Development Needs

- new lightweight materials
- advanced materials (e.g., beryllium, honeycomb structures)

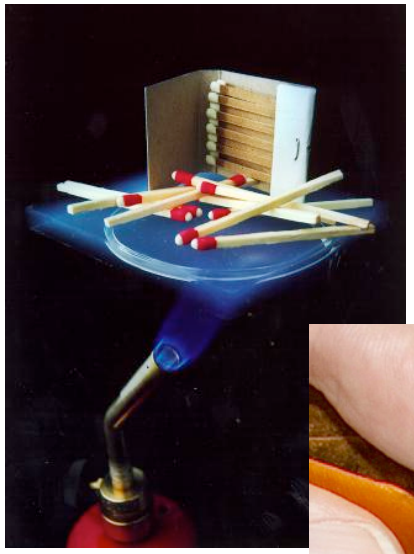
Mission Benefits

- mass saving
- translates to higher payload mass fraction for the same entry mass

TRL 4 to 9

Priority medium

Temperature Control (Passive)



Aerogel

Multi-layer Insulation (MLI)

Phase Change Materials (PCM)

Current State of the Art (SOA)

- aerogels, MLI, PCM are space qualified
- not for high g–load Venus entries

Technology Development Needs

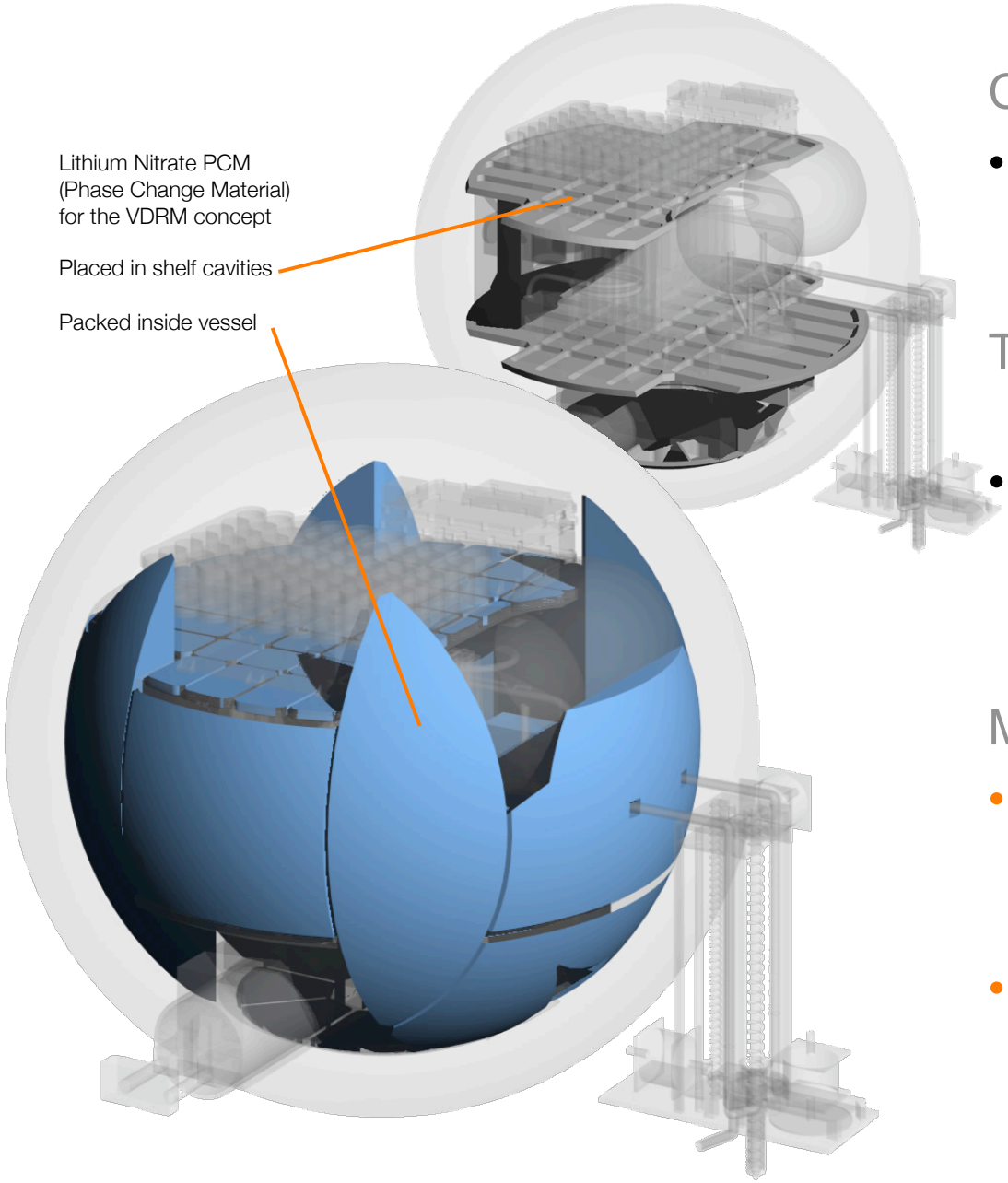
- high performance thermal insulation for Venus environment

Mission Benefits

- extend lifetimes beyond 2 hours, demonstrated by Venera 13
- VDRM considered 5 hours,
- desire for extending to ~24 hours

TRL 4 to 9

Advanced Passive Thermal Control



Current State of the Art (SOA)

- Venera and P-V era insulation and PCM are mostly available

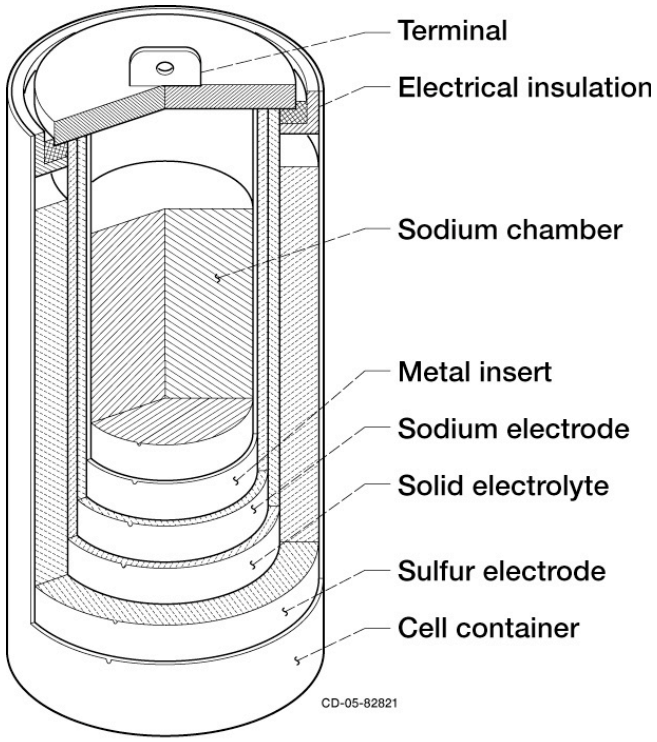
Technology Development Needs

- alternate insulation and PCM needed to increase lander lifetimes beyond 2–5 hour

Mission Benefits

- 12 to 24 hour lifetime could enable humans–in–the–loop
- decrease refrigeration requirements for truly long–lived lander missions

Power Storage



Sodium sulfur battery schematic

Current State of the Art (SOA)

- high TRL primary batteries for short missions
- demonstrated LiAl– FeS2, Na–S, and Na–metal chloride secondary batteries

Technology Development Needs

- adapt high T cell & battery designs for space
- address stability of seals and terminals
- minimize current collector corrosion at high T
- optimize the electrolyte composition to improve performance and reliability

Mission Benefits

- high T batteries on the surface could be placed outside, reducing volume and thermal requirements for the pressure vessel

TRL 4

Atmospheric Entry at Venus

Pioneer-Venus probes

Thermal Protection Systems (TPS) with
P-V heritage 45-degree cone angle

Current State of the Art (SOA)

- carbon-phenolic (CP) on P–V, Galileo
- special rayon for CP is out of production
- current arc jet capabilities are limited
- CP for steep EFPA, low density TPS could be used for shallow EFPA entry

Technology Development Needs

- re-establish test capabilities
- remanufacture heritage CP;
- establish alternate to heritage CP TPS
- assess lower density TPS for Venus entry

Mission Benefits

- TPS is essential and enabler

Upper Atmosphere Balloons

A 5.5-m diameter Venus cloud level test balloon was developed and successfully tested at JPL

Current State of the Art (SOA)

- Russian VeGa balloons in 1984 (for 48 hrs)
- JPL and CNES built and tested large super–pressure balloons, considered mature
- JAXA is developing a mid–altitude balloon

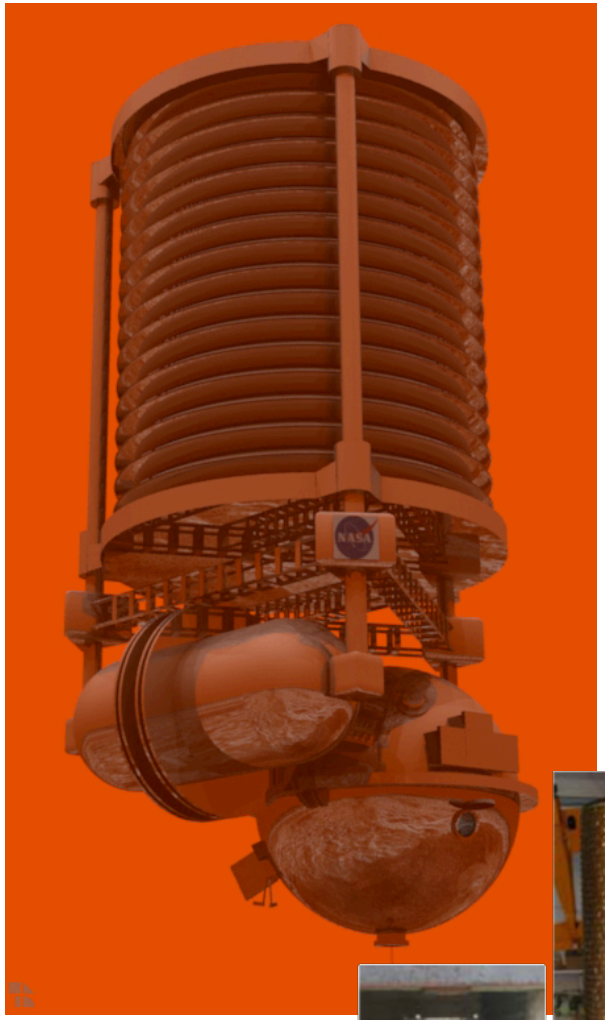
Technology Development Needs

- development, testing, verification and validation to address lifetime & reliability
- materials must tolerate high T, corrosive environment (H_2SO_4 droplets in clouds).

Mission Benefits

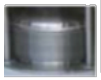
- Enables VFM balloons for 30–days lifetime
- ASRG powered balloons could go

Near Surface Bellows



Venus Mobile Explorer using a bellows system (artist's concept)

A metallic bellows system was successfully tested at JPL at Venus relevant temperatures



Current State of the Art (SOA)

- metallic bellows proof– of–concept was built at JPL and tested at high temperatures

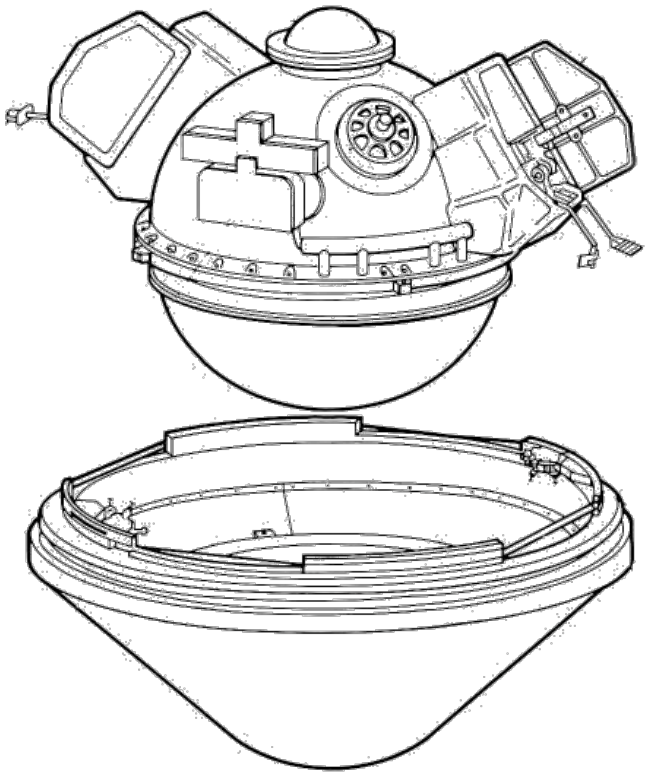
Technology Development Needs

- build and test a metallic bellows system
- test it under Venus surface p/T conditions
- near surface operation must address altitude change and surface access
- requires other connected technologies

Mission Benefits

- could traverse 100s of km's over 90–days
- image the surface at high resolution
- periodically access the surface for sampling

Descent Probes



Pioneer-Venus small probe

Current State of the Art (SOA)

- P–V probe heritage for large probes
- Microprobes have been designed, not tested

Technology Development Needs

- Develop small drop sondes that could be released from a balloon platform (also work as ballast)

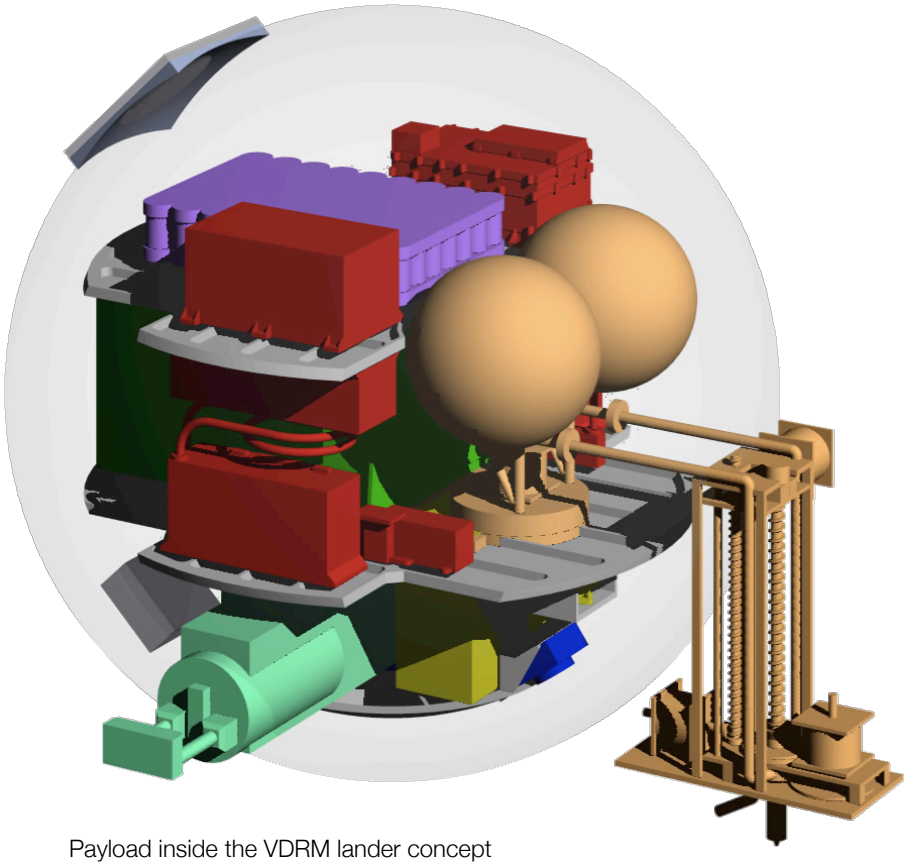
Mission Benefits

- Drop sondes can enhance science by providing vertical slice measurements to complement balloon constant altitude measurements of the atmosphere

TRL 2 to 9

Priority medium

In Situ Instruments for the VDRM



Payload inside the VDRM lander concept

Current State of the Art (SOA)

- P-V probe instrument heritage

Technology Development Needs

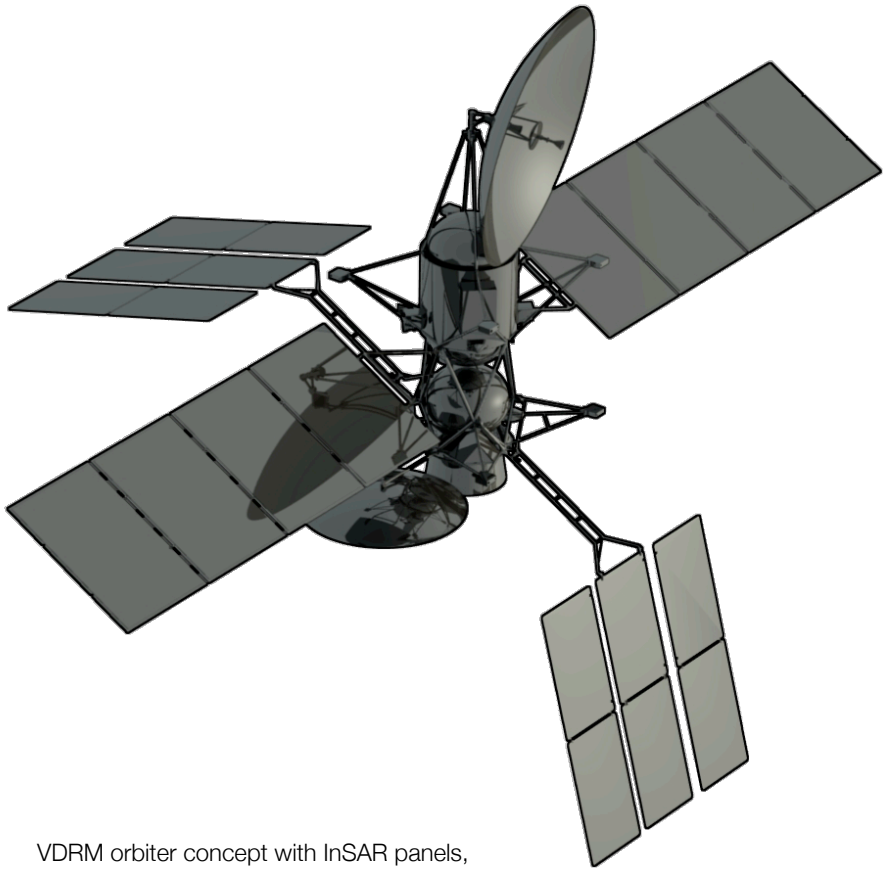
- nor new *in situ* contact instruments
- several VFM instruments, e.g., heat flux plate, XRD/XRF, are at medium TRL
- high–T seismometry and high–T meteorology are at low TRL
- g–load tolerance during atmospheric entry should also be addressed

Mission Benefits

- *In situ* instruments are key drivers for Venus missions and are required for mission success

TRL 2 to 9

Orbiter Instruments and Telecom for the VDRM



VDRM orbiter concept with InSAR panels, high and medium gain antennas and solar panels

Current State of the Art (SOA)

- Magellan, Venus Express, P-V heritage

Technology Development Needs

- InSAR
- passive IR & millimeter spectroscopy
- cloud LIDAR

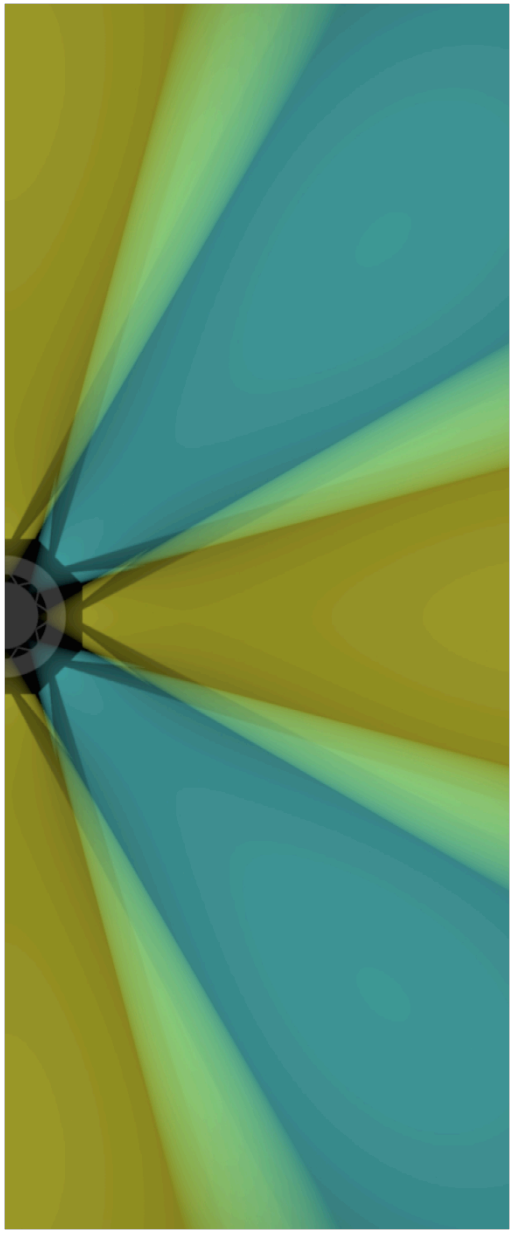
Mission Benefits

- InSAR is a key instruments on the VFM
- Ultra–fine resolution radar mapping and cloud LIDAR could provide high resolution science data on the surface and clouds, and highly desirable by science

TRL 3 to 9

Priority medium

Autonomy



VDRM lander concept,
Panoramic images taken autonomously

Current State of the Art (SOA)

- Autonomous operation have been used (e.g., P–V)
- but at a lower complexity than required for a VDRM

Technology Development Needs

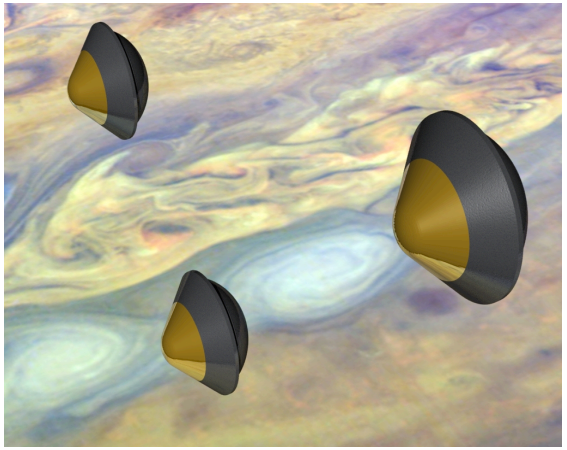
- develop and test reliable autonomous operation for a Venus surface mission, including
- control of the rotating pressure vessel; drill site selection; sample acquisition; instrument operations; telecom

Mission Benefits

- Short lived missions (up to 5 hours) does not support humans-in-the-loop operations
- Autonomous operation is required for all science measurements and subsystem control

TRL 4 to 6

Cross Cutting Technologies



Venus and Giant Planets probes share technologies

Current State of the Art (SOA)

- Pioneer-Venus and Galileo probes

Technology Development Needs

- thermal protection systems
- pressure vessel materials
- passive thermal control (insulation, PCM)
- instrumentation / miniaturization

Mission Benefits

- These technologies can benefit a number of planetary missions, e.g.,
  - probes to Venus and
  - deep probes to the Giant Planets
  - experiencing similarly high p/T

TRL 3 to 9

Priority medium

TECHNOLOGIES FOR FUTURE VENUS MISSIONS

FOR LONG LIVED *IN SITU* MISSIONS

PRESENTED BY GARY HUNTER (NASA GRC)

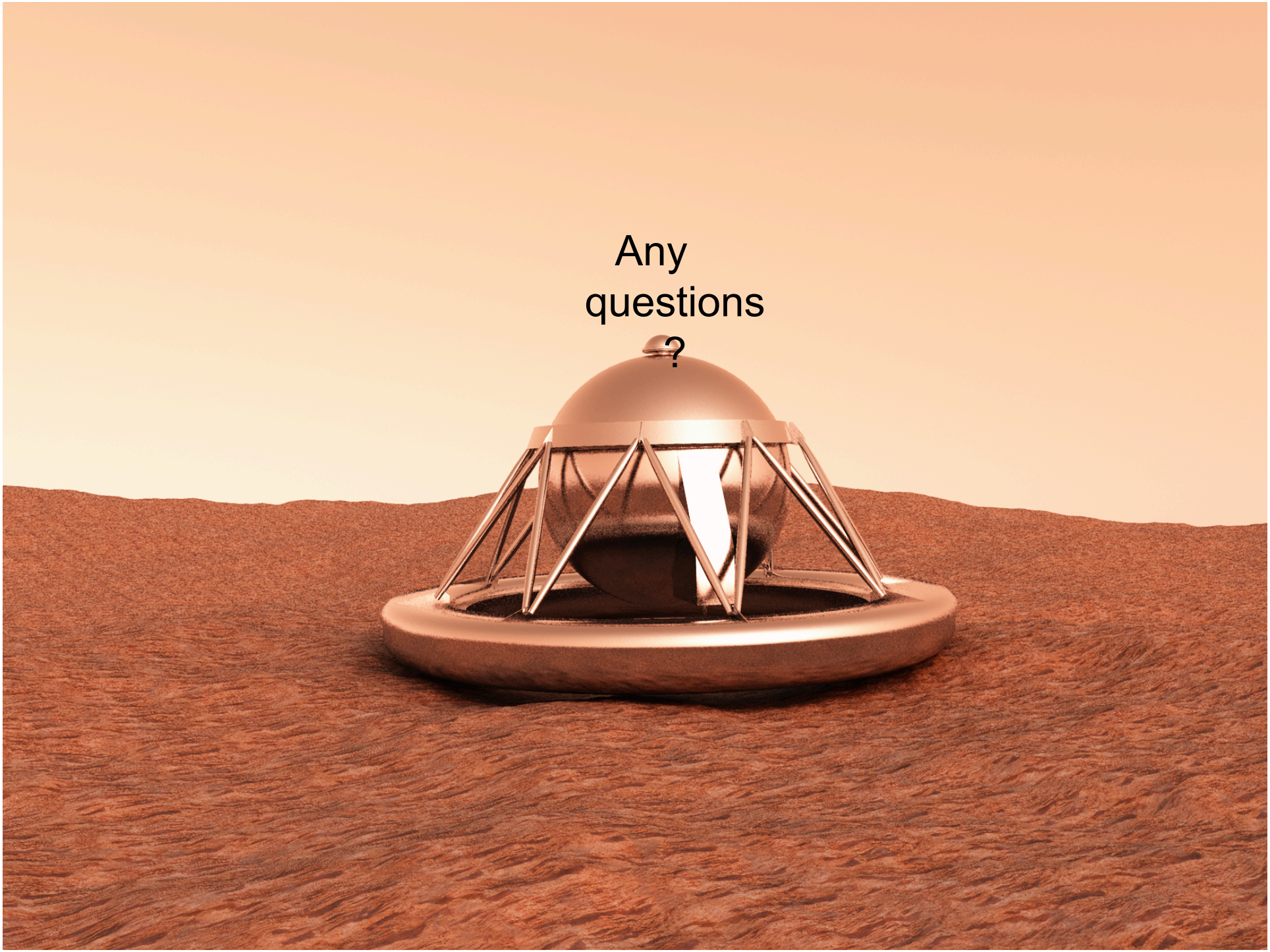
- Switching over to Gary's slides on long lived technologies for in situ missions

- Including:
  - high and medium temperature electronics,
  - high temperature actuators,
  - motors,
  - sensors,
  - power sources with active refrigeration,
  - telecom,
  - sesimometry

CONCLUSIONS & RECOMMENDATIONS

Conclusions & Recommendations

- VEXAG recommends investments in key technologies to enable future Venus missions.
- The highest priority technology items, in line with the VDRM, are:
  - a sample acquisition and handling system,
  - a rotating pressure vessel,
  - a rugged-terrain landing system, and
  - a large scale Venus test chamber facility.
- A future Venus Flagship Mission could be further enhanced by
  - longer operating lifetimes on the surface.
- For this, development of additional technologies are needed, including
  - a Venus specific Radioisotope Power System, coupled with active cooling
  - high temperature tolerant components (e.g., sensors, actuators, and electronics)
- Other mission architectures could be enabled by technologies for
  - Seismometry; metallic bellows for near surface mobility; and a multi-balloon system for a future Venus sample return mission


Any
questions
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