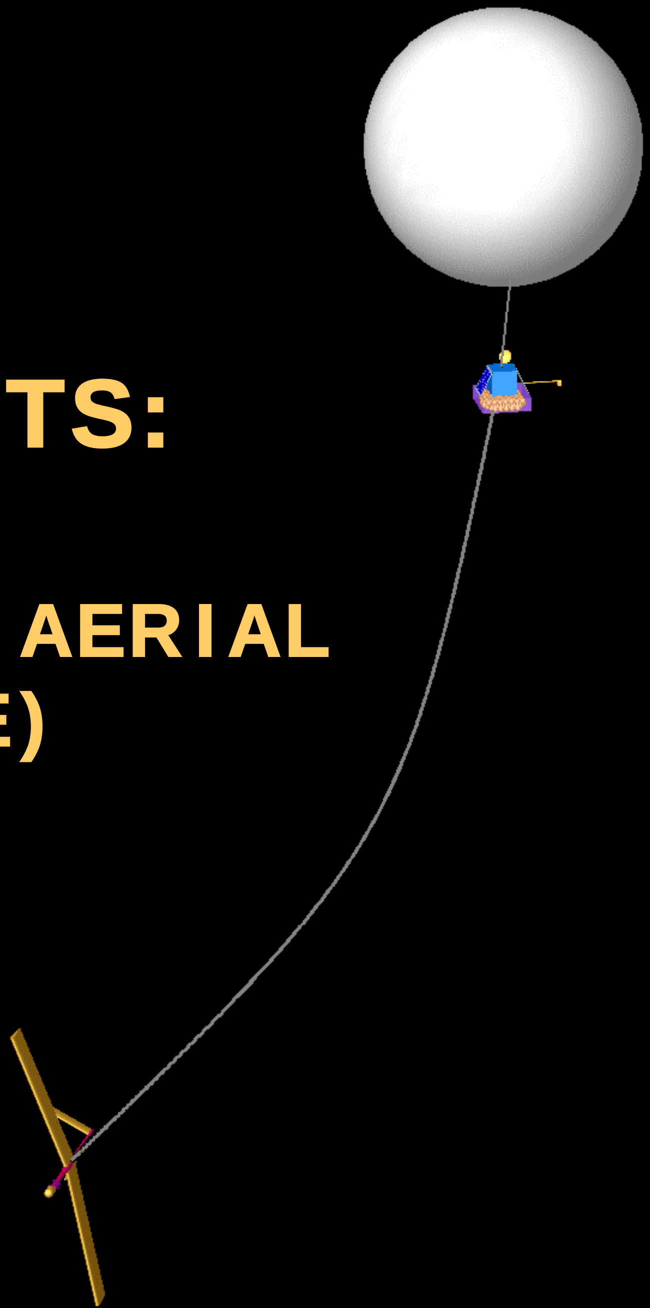
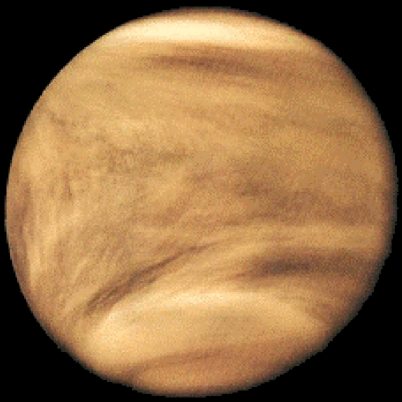
SAILING THE PLANETS:

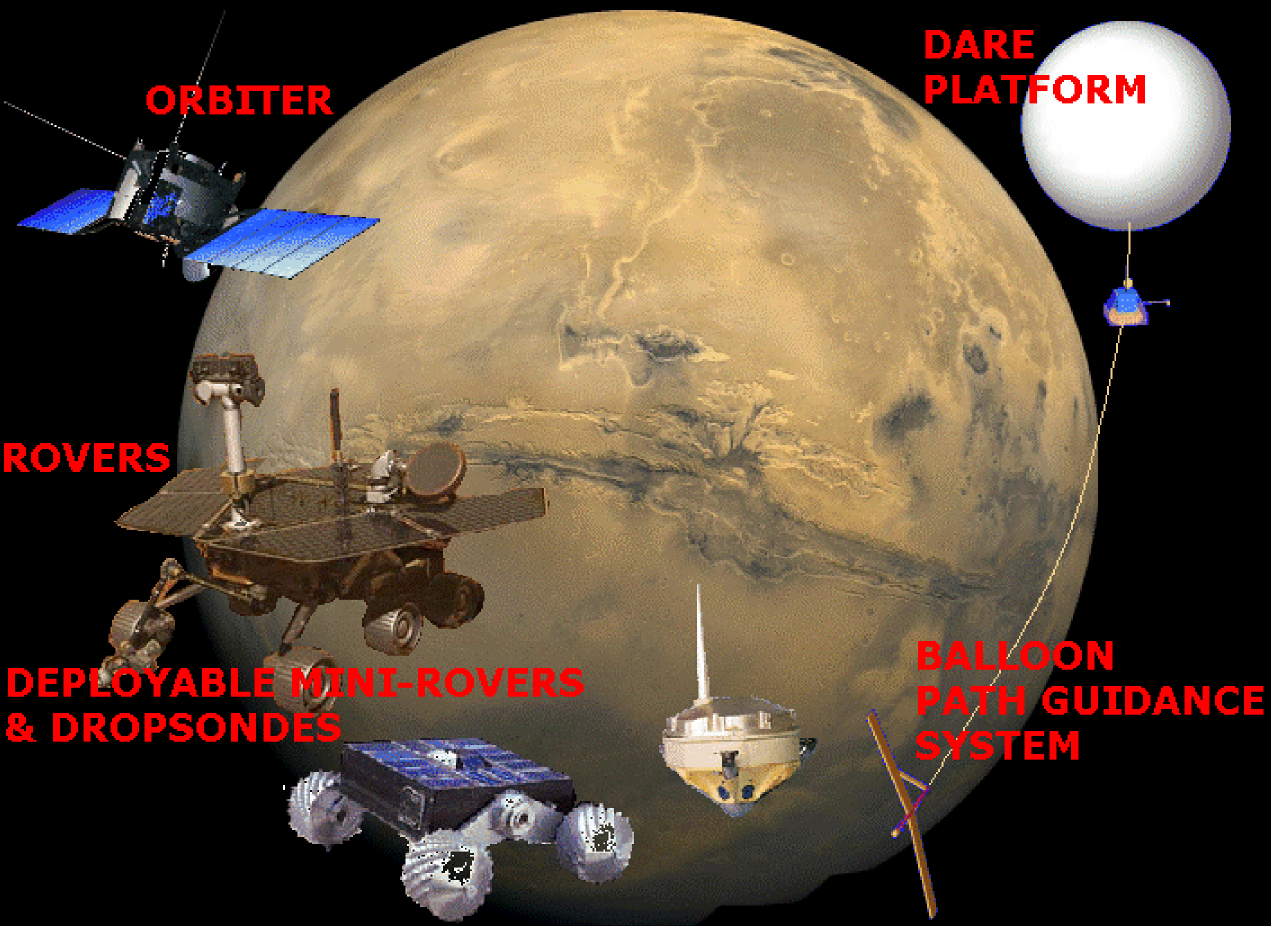


SCIENCE WITH DIRECTED AERIAL ROBOT EXPLORERS (DARE)

DR. ALEXEY PANKINE
GLOBAL AEROSPACE CORPORATION



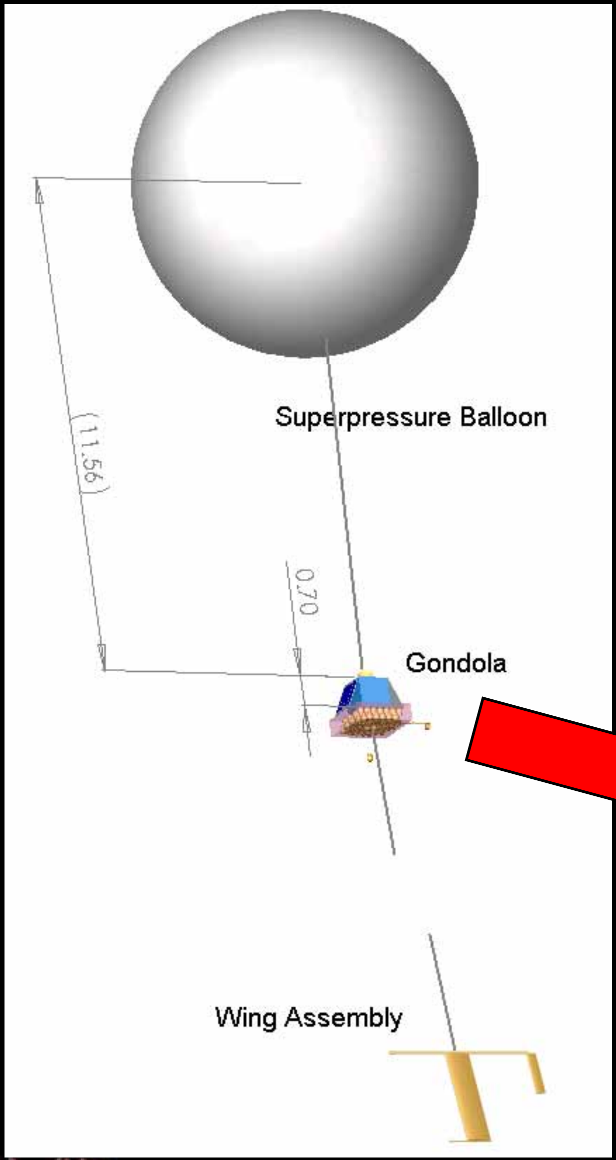
NEW ARCHITECTURE FOR PLANETARY EXPLORATION



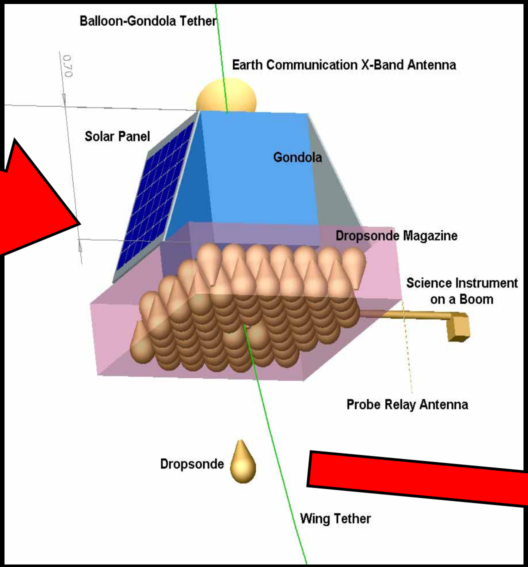
KEY ELEMENTS:

- Long-Duration Planetary Balloon Platforms
- Balloon Flight Path Guidance
- Autonomous Navigation & Control
- Lightweight Power Generation & Energy Storage
- Miniaturized Science Sensors
- Small Deployable Science Packages
- Communication Relay Orbiter
- Synergy Between Platforms Comprising Architecture

DARE PLATFORM SCHEMATICS



- Superpressure balloon
- Gondola
- Solar panels, antennas, batteries, computers, science instruments
- Dropsonde magazine
- Tether
- Balloon Guidance System (BGS)



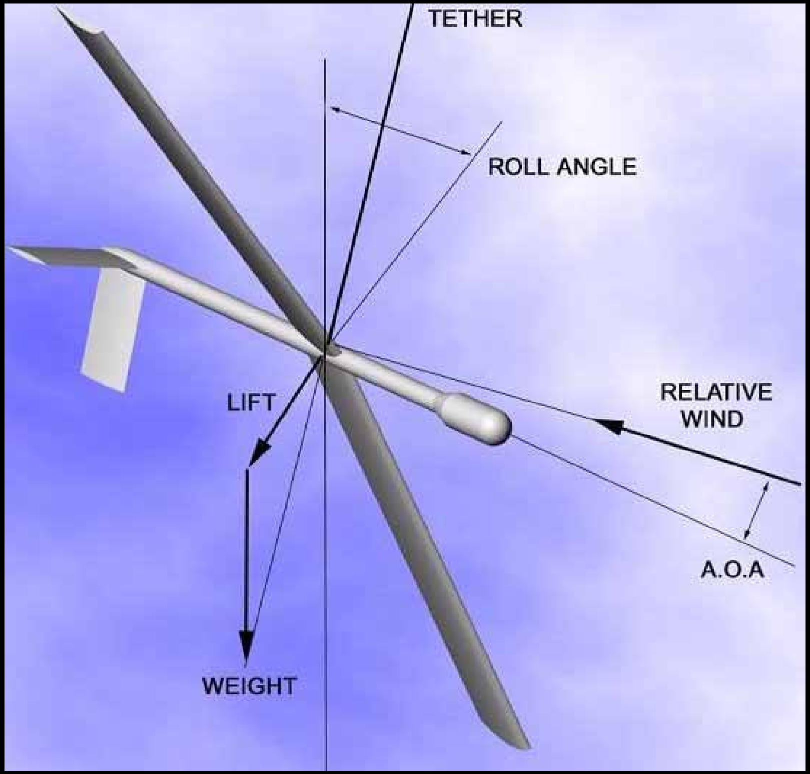
NASA

BALLOON GUIDANCE SYSTEM (BGS)

- Aerodynamic surface on a tether several km below the balloon
- Variation in atmospheric wind and density with altitude result in a sideways lifting force

Single-wing BGS

- Dual-wing BGS is more complex, but also is more efficient in strong winds
- Creates control velocity of 1-2 m/s

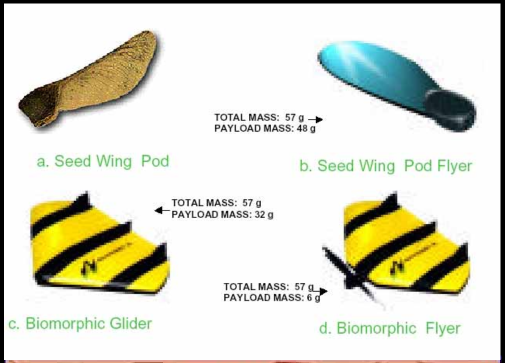


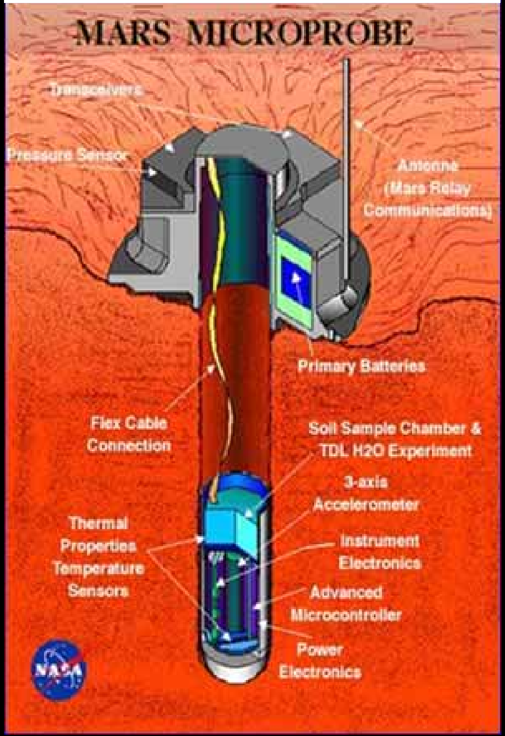
Dual-wing BGS

MICROPROBES

- Microprobes enable surface exploration on a global scale with a single DARE platform
- Single DARE platform can carry several (tens) deployable probes
- Lightweight probes - no entry protection and delivery system
- Targeted delivery to surface sites
- Emplacement of networks of meteorological or seismological stations
- High-resolution (1 cm) imaging, *in-situ* and remote analysis of selected sites

Biomorphic flight systems (JPL NASA)





NASA

Mini-rover (NASA)

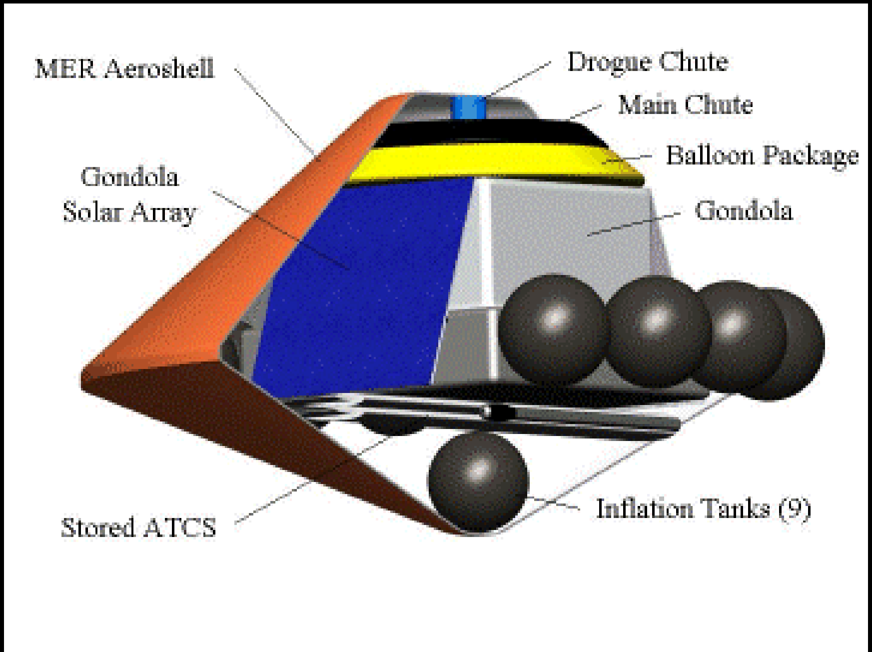
Mars Microprobe (NASA)

DARE PLANETARY SCIENCE CAPABILITIES

- Global planetary coverage
- Long flight duration: ~100 days
- Targeted overflight of surface sites and precise delivery of science probes
- Proximity to surface enables high-resolution imaging, elemental, magnetic and gravity surveys not possible or challenging from orbit
- Longer dwell time over a target enables:
  - Continuous target observations - not a “snapshot”
  - Use of short-lived microprobes

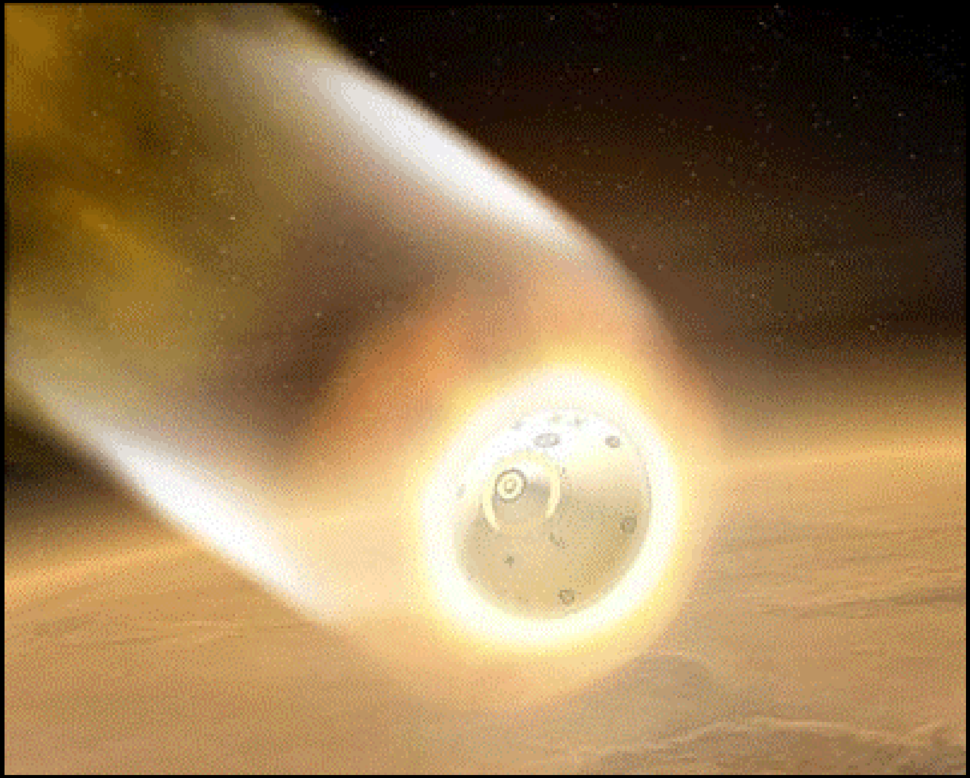
CONCEPTUAL MARS MISSION OVERVIEW

LAUNCH, CRUSE & ARRIVAL



Schematics of the entry vehicle packaging

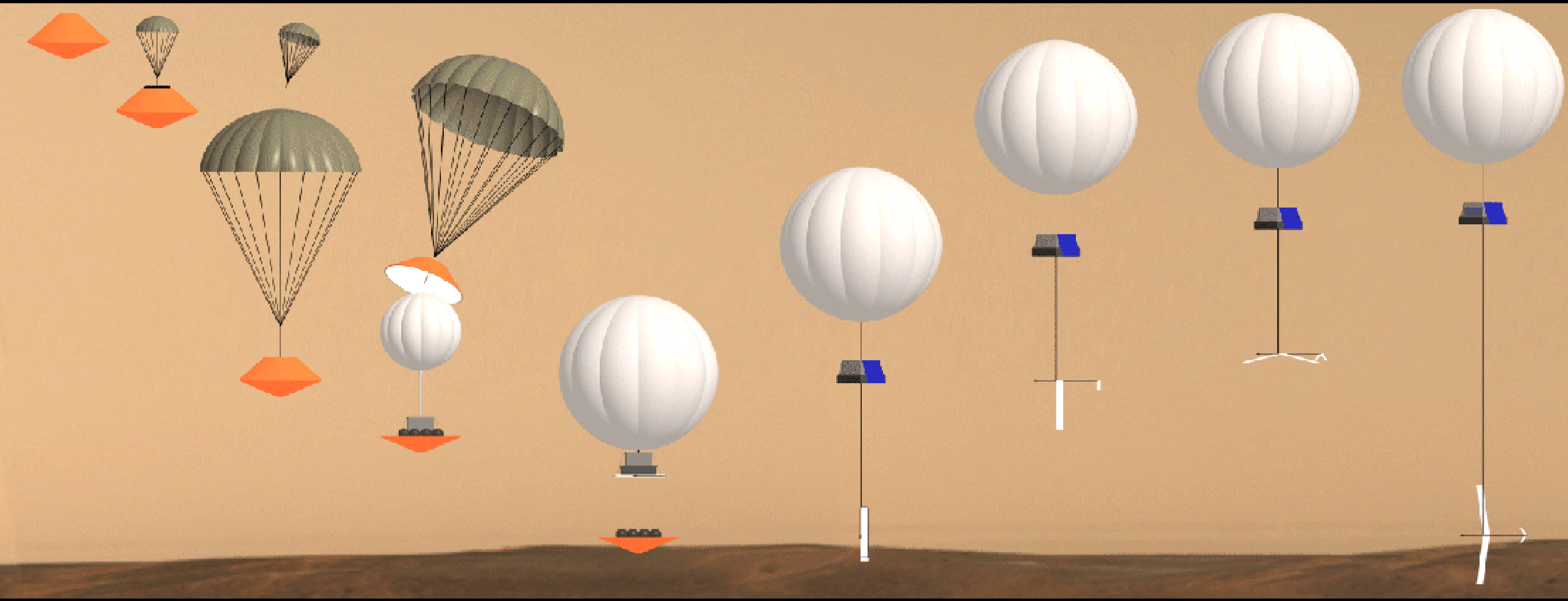
- Delta launch vehicle
- Pathfinder-type entry vehicle
- Ballistic atmospheric entry



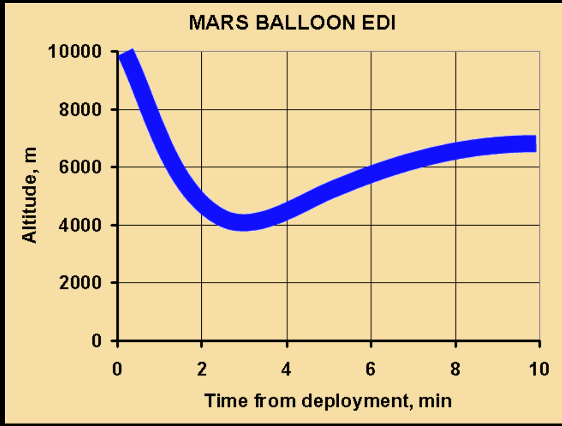
Aeroshell entry

- Heat shield protects the entry vehicle during short entry phase

ENTRY, DESCENT & INFLATION (EDI)



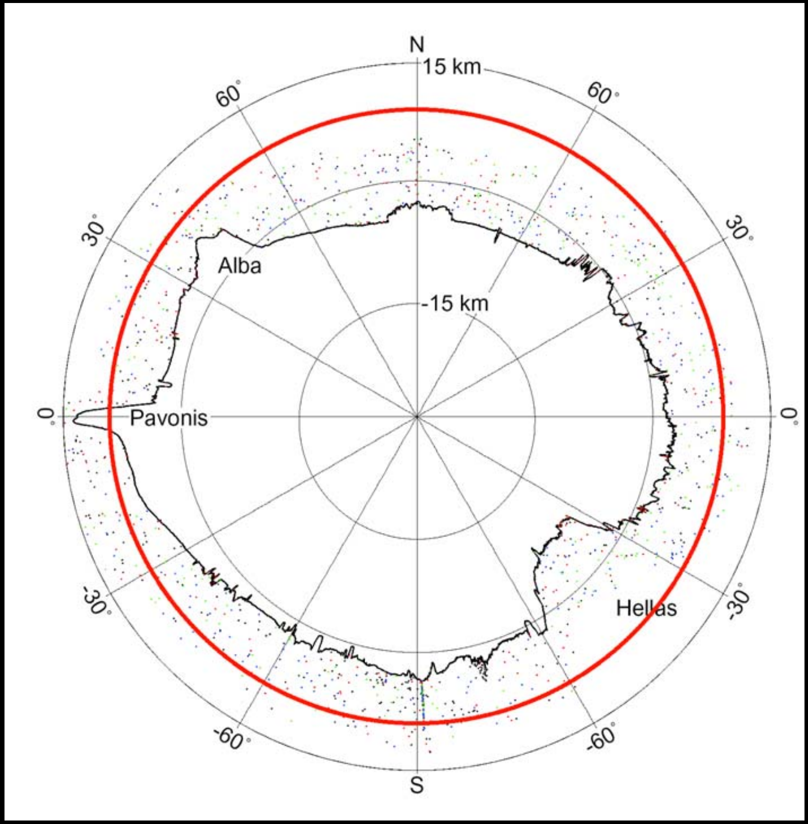
- Parachute deploys
- Inflation commences
- Parachute cut-off
- Inflation equipment jettisoned
- System ascends to floating altitude
- The BGS is deployed



Altitude profile

MARS BALLOON ENVIRONMENT

- Low density cold atmosphere (like Earth's stratosphere)
- High topography obstacles (Tharsis volcanoes, Southern highlands)
- Ever-present atmospheric dust
- Turbulent lower atmosphere (dust devils)
- Strong zonal winds during summer and winter seasons



A single Mars Orbital Laser Altimeter (MOLA) topography profile (NASA) and Mars balloon float level

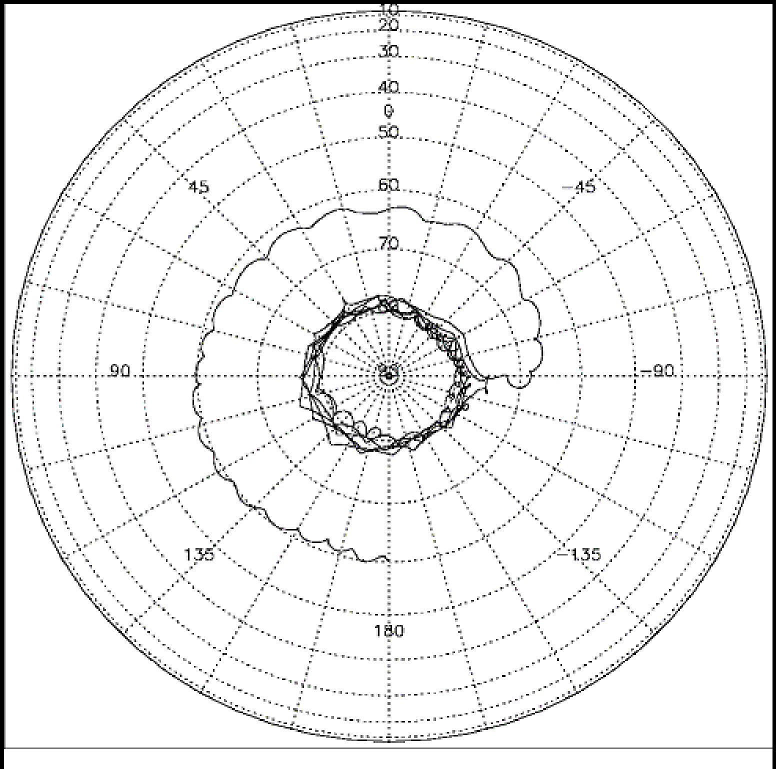
TRAJECTORIES AND OBSERVATIONS

SUMMARY OF APPLICATIONS

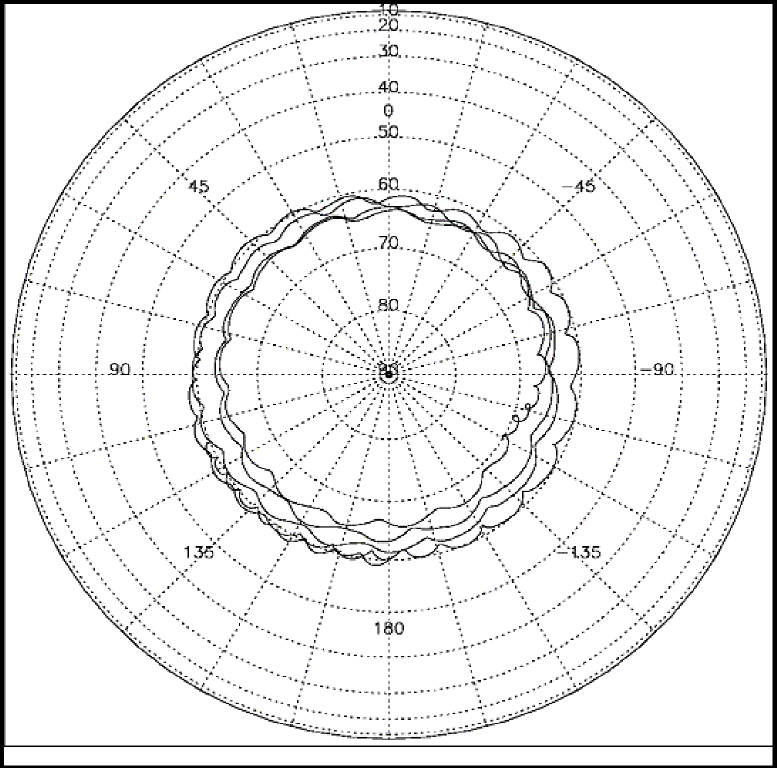
- Global high-resolution imaging
- *In situ* atmospheric winds, constituents, global search for biomarkers
- Targeted delivery of surface bio-chemical labs
- Emplacement of networks of surface stations
- Landing sites reconnaissance
- Navigation beacons placement

DARE AT MARS

CONTROLLED BALLOON FLIGHT AT MARS



Free-floating Mars balloon trajectory

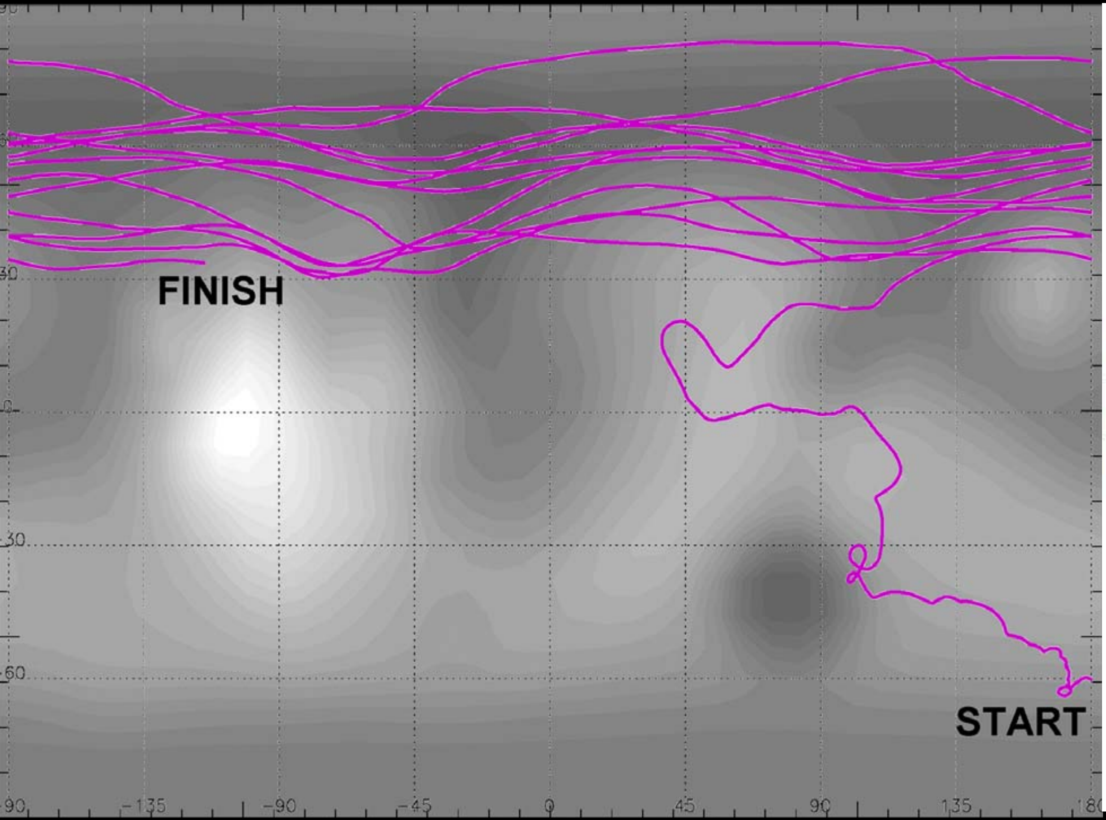


DARE platform trajectory

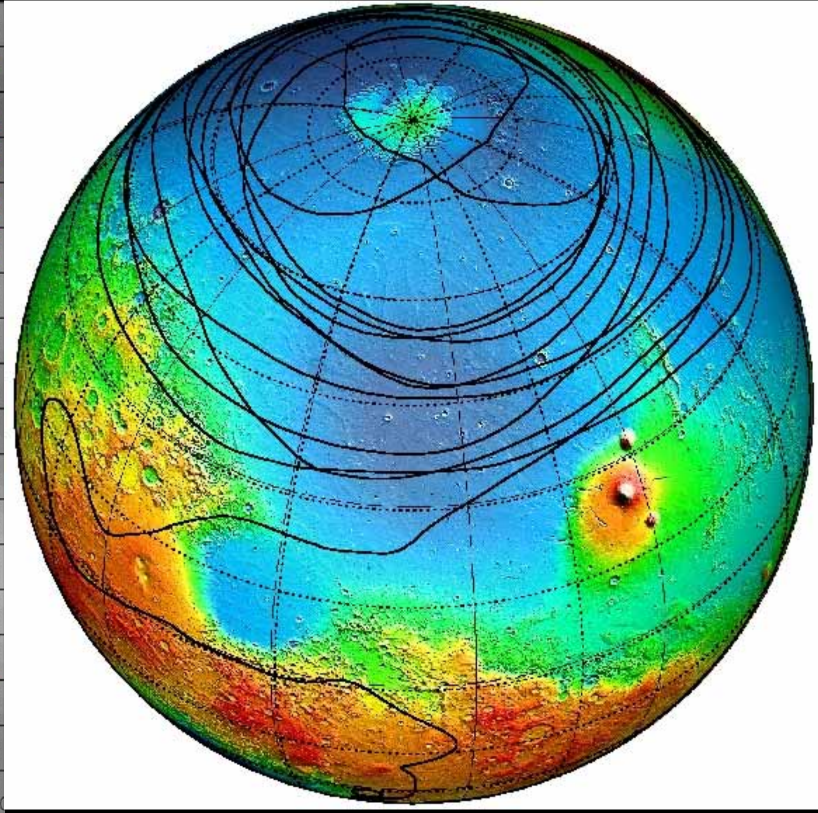
- Northern Polar summer, 0.1 m/s control velocity
- Trajectory objective: maintain 60N latitude

SAILING ACROSS MARTIAN EQUATOR

Simulated DARE trajectory over elevation map



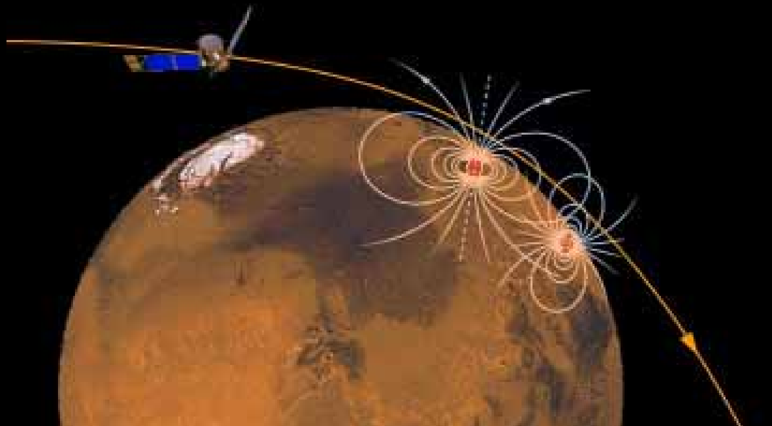
DARE trajectory over MOLA topography (NASA)



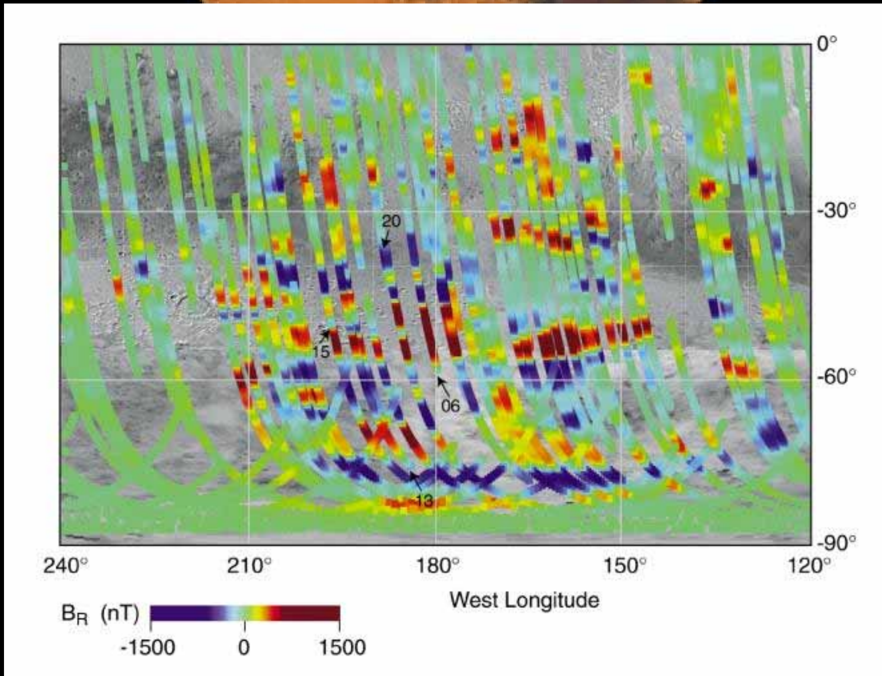
- 90-day late Southern spring, 1 m/s control velocity
- Objective: navigate from Southern to Northern midlatitudes

CRUSTAL MAGNETIC ANOMALIES ON MARS

- MGS discovered strong crustal magnetic anomalies during aerobraking phase
- Orbital measurements lack resolution to study the anomalies
- DARE platform with a vertical array of magnetometers along the tether can
  - Enable high-resolution observation
  - Enable detection of weak anomalies via gradient measurements



Mars Global Surveyor (MGS) observing crustal magnetic sources (GSFC NASA)

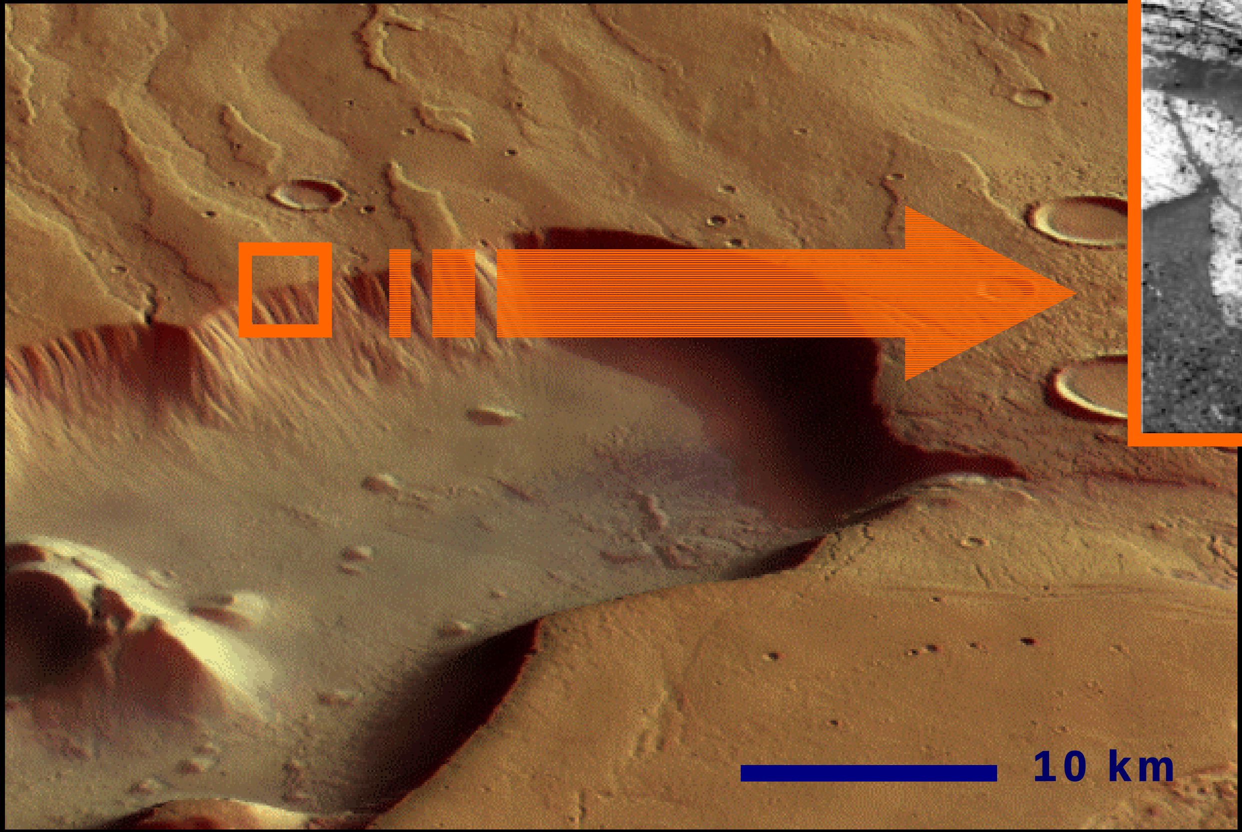


Map of crustal magnetic anomalies on Mars (GSFC NASA)

HIGH-RESOLUTION IMAGING OF MARS

- Canyon/crater walls
- Polar layered terrain
- Surface topography

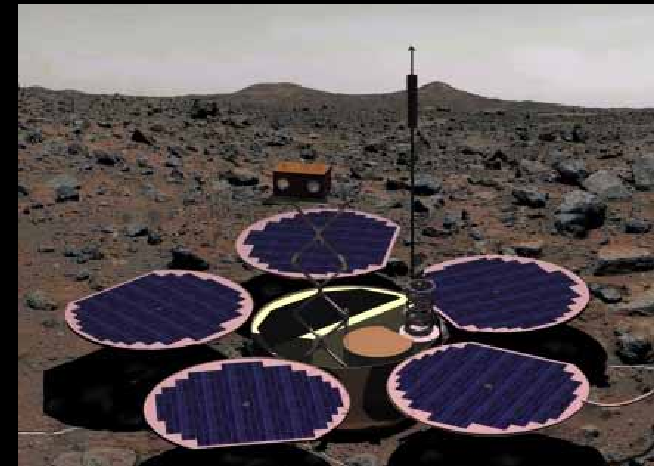
MER Opportunity Pancam image (JPL NASA)



Dao Valles and Niger Valles (Mars Express, ESA)

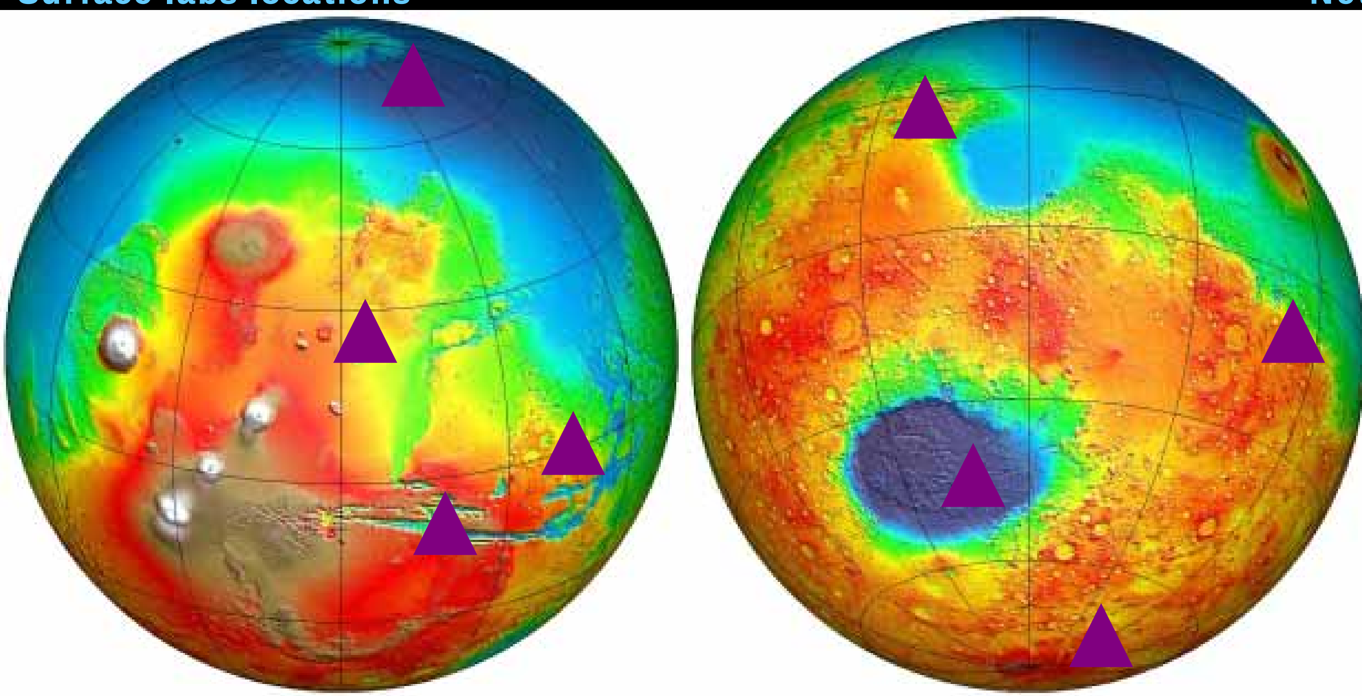
EMPLACEMENT OF SURFACE NETWORKS ON MARS

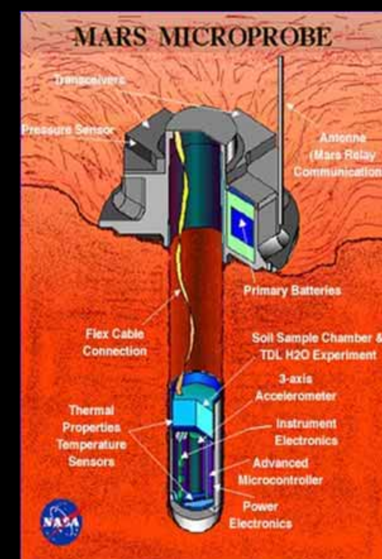
- Single DARE platform can carry tens of mini-labs
- Meteorological & seismological networks
- Surface mini-labs – chemistry, mineralogy



NetLander Surface Module (ESA)

Surface labs locations

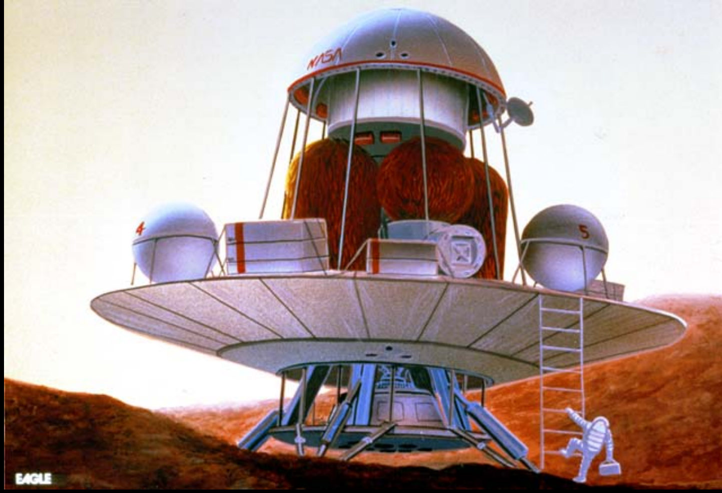


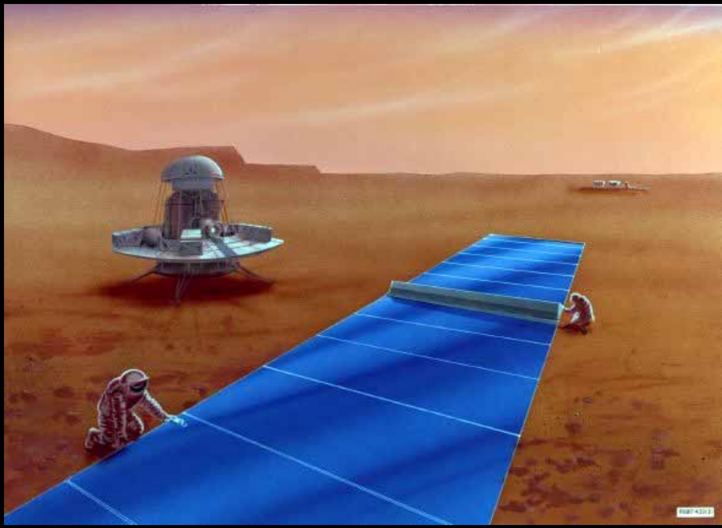


Mars Microprobe (NASA) as an example of a mini-lab

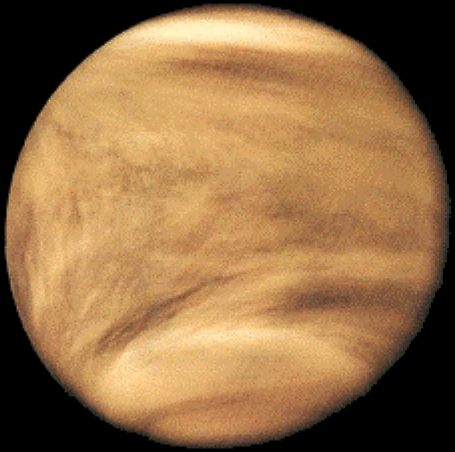
DARE AND HUMAN EXPLORATION OF MARS

- ***In-situ*, high-resolution search for usable resources:**
    - **Delivery of miniature geochemical laboratories**
    - **Sounding radars**
    - **Gas abundances (H_20)**
- **Precise delivery of navigation beacons for future robotic and human exploration landing sites**
- **Detailed multispectral reconnaissance of the potential landing sites**
- **Monitoring atmospheric conditions to improve accuracy of aerobraking and landing**





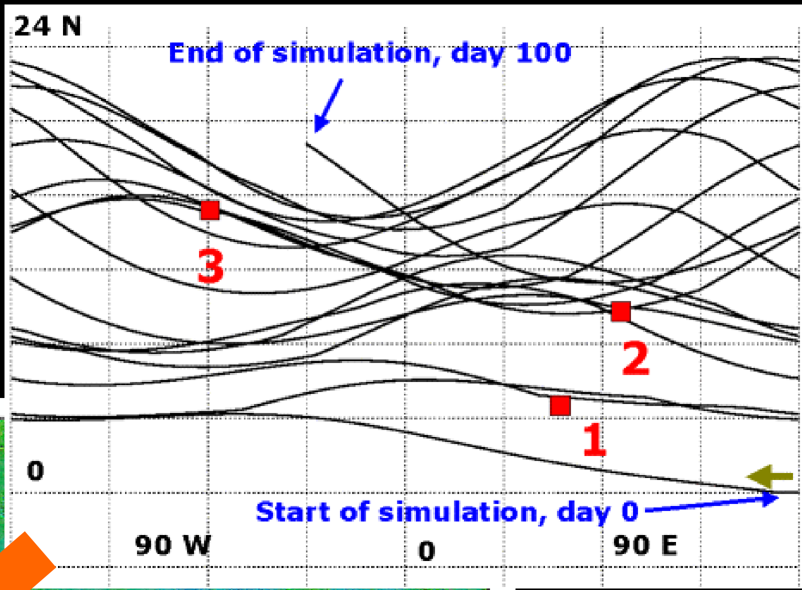
DARE AT VENUS

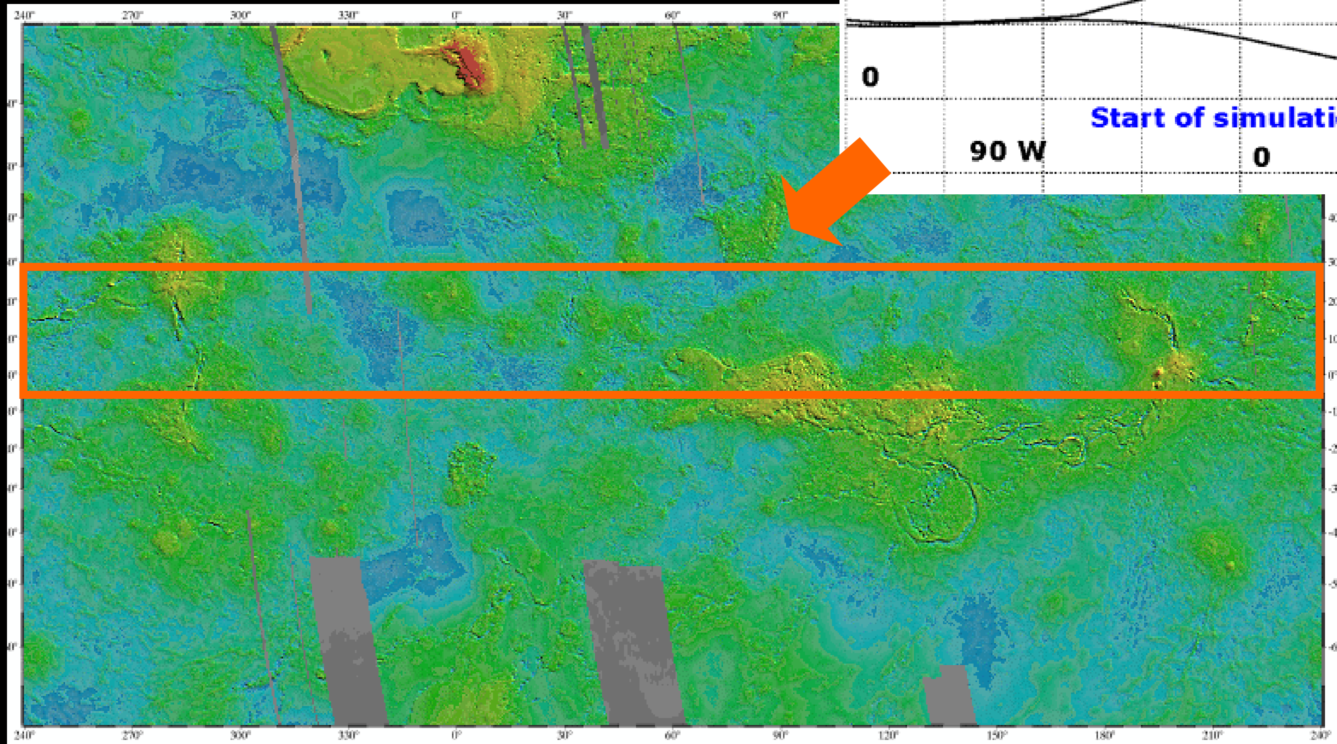


MULTIPLE TARGET OVERFLIGHT AT VENUS

- Targeted overflight of surface sites and precise delivery of geophysical probes
- Wind profiles and atmospheric composition at multiple locations

Lon-lat plot of Venus DARE trajectories relative to 3 overflight targets



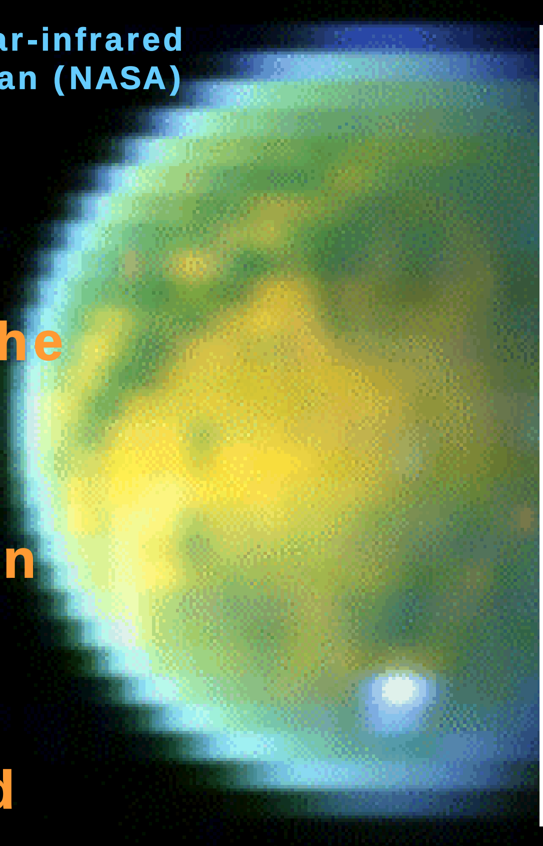


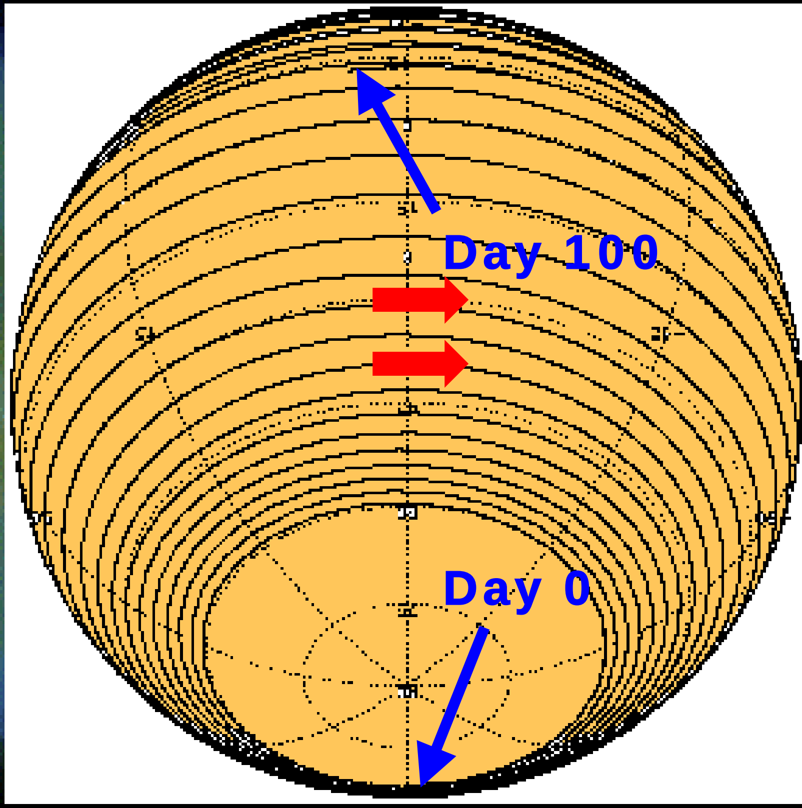
Global Aerospace Corporation

DARE AT TITAN

GLOBAL COVERAGE OF TITAN

Cassini near-infrared image of Titan (NASA)

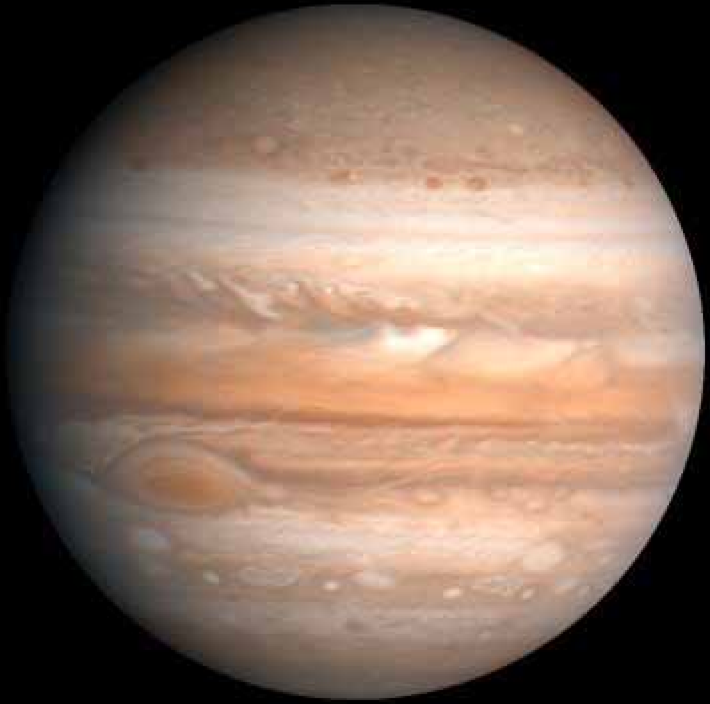




Titan DARE trajectory simulation

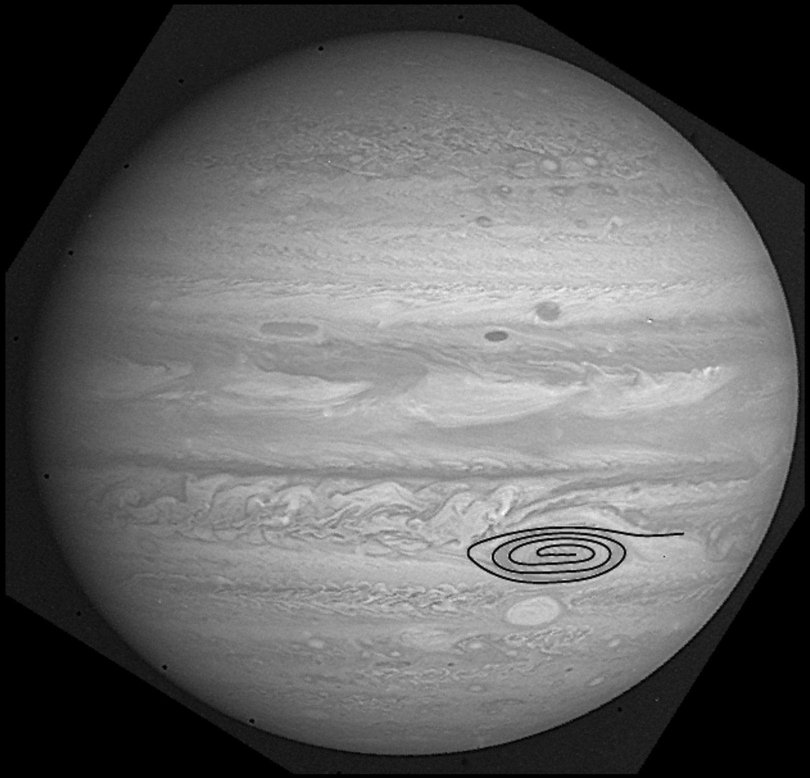
- Balloon can be the next step after Cassini
- 50-80 km balloon altitude (below haze)
- ~100 kg payload
- 1 m/s control velocity
- Global measurements of winds, gas abundances, surface chemistry with probes

DARE AT JUPITER

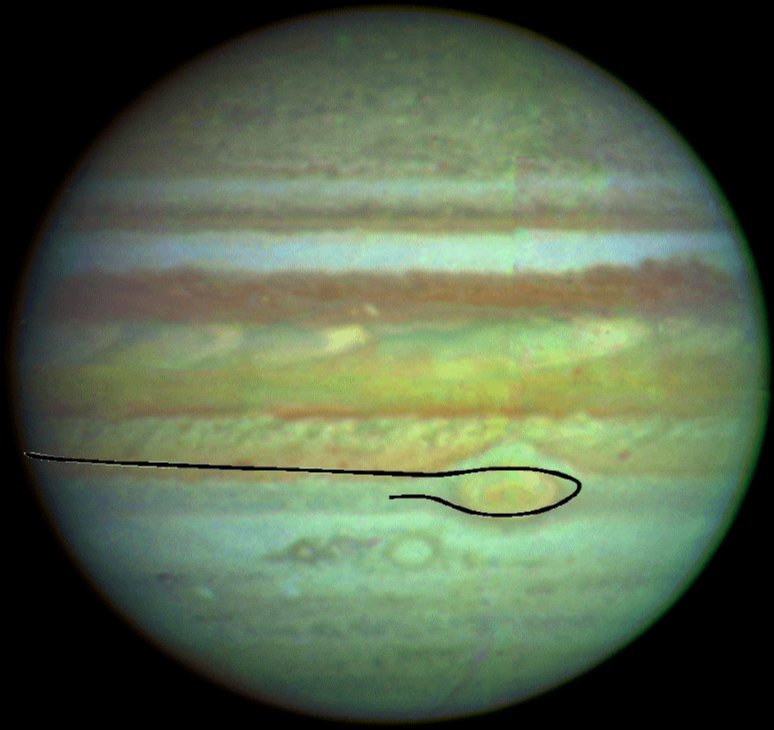


TARGETED SCIENCE AT JUPITER

- **Sample with probes distinct regions of the atmosphere (Great Red Spot, belt/zone) over a 100-day mission**



Spiraling into the GRS



“Trajectory assist” using GRS winds

SAILNG THE PLANETS: NIAC PHASE II

PHASE II OBJECTIVES

- Further develop the concept … in the context of a Mars mission
- Identify enabling technologies
- Balloon guidance research
- Cost and Performance benefit analysis
- Pathways to architecture realization

CONCEPT DEVELOPMENT

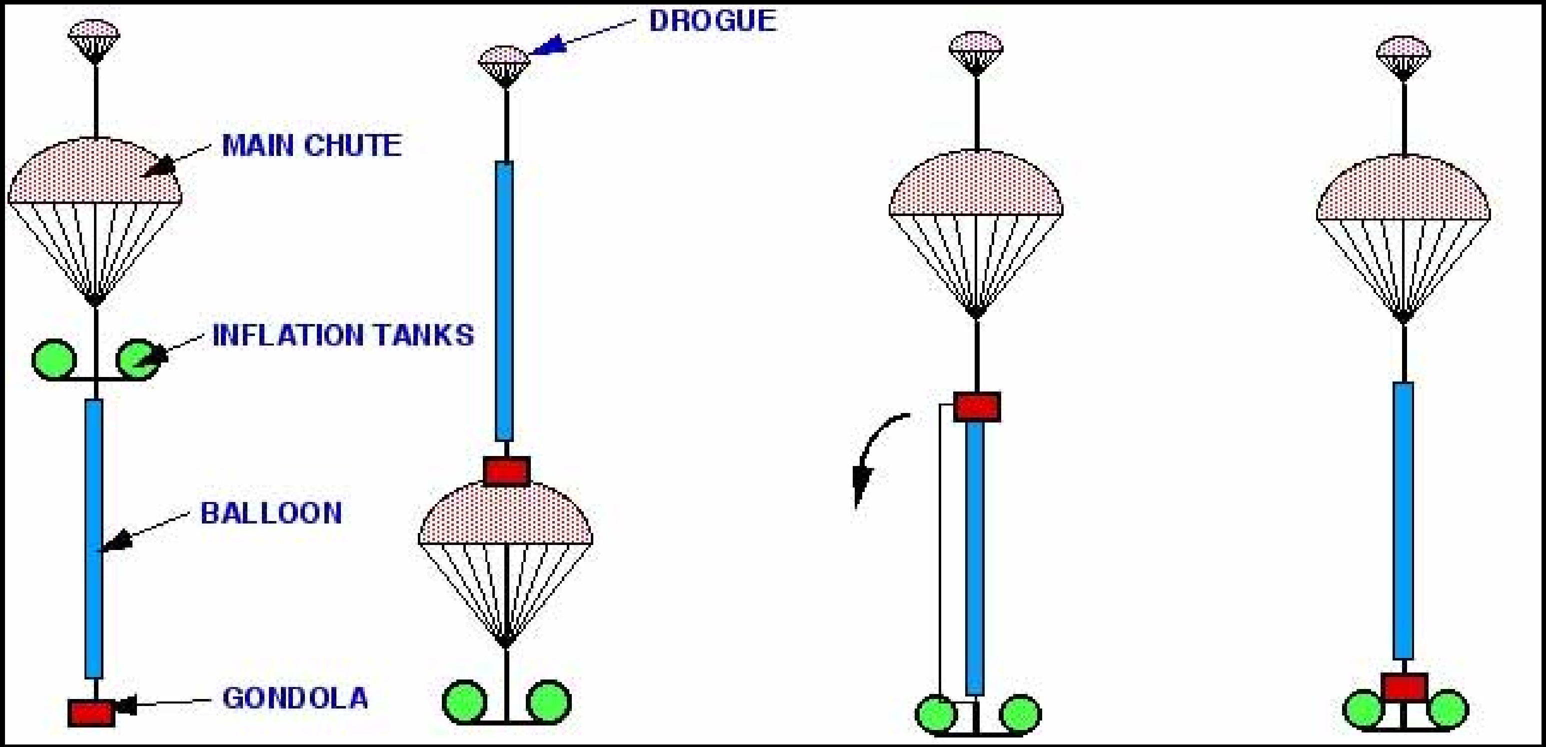
- Mission scenarios
- Targets for observations
- Novel innovative observation techniques
- Exploit synergy between different platforms
- Conceptual design

ENABLING TECHNOLOGIES

- Three technological time horizons: current (0-3 years), near (3-10 years), far (beyond 25)
- Entry, Descent and Inflation (EDI)
- Balloons
- Balloon path guidance system (BGS)
- Navigation & guidance
- Low mass power generation & energy storage
- Miniaturization of instruments (sensors)
- Microprobes
- Communications (with the elements of the architecture and/or Earth)

ENTRY, DESCENT AND INFLATION

- Analysis of entry velocities
- Analysis of entry locations and seasons
- Analysis of deployment and inflation options



Deployment & inflation options

PLANETARY BALLOONS

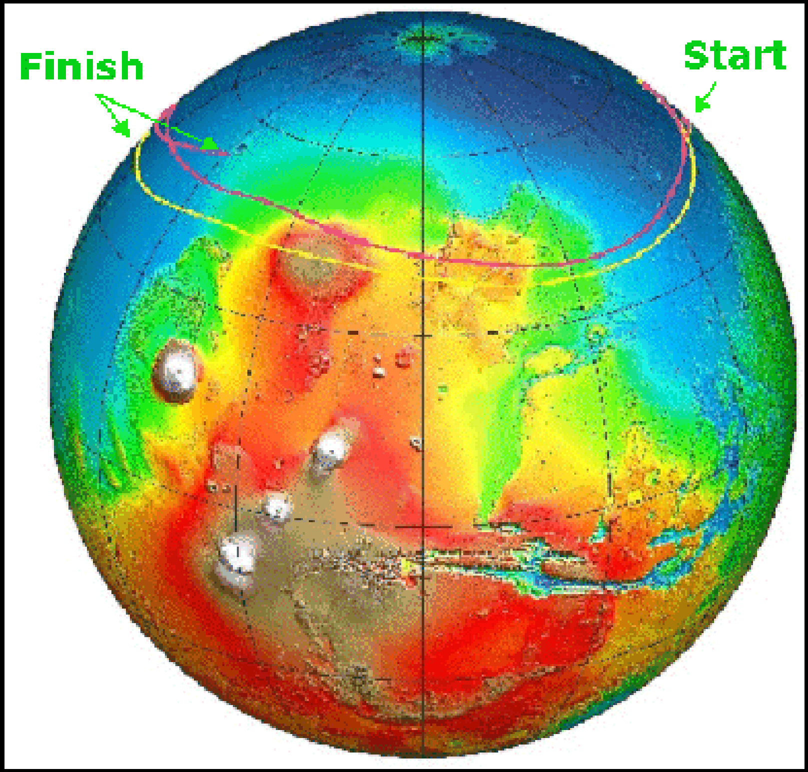
- Low-mass high-strength materials
  - Nano-tubes?
  - Composite materials
- Design
  - Superpressure
  - Solar & Infrared Montgolfiere (Jupiter)
- Shapes
  - Sphere
  - Cylinder
  - Pumpkin
- Resistance to environment
  - UV degradation
  - Acid (on Venus)
  - Extreme cold (Titan)
- Gas replenishment
- Altitude control

Venera / VEGA balloon, 1984

Composite Mars balloon material

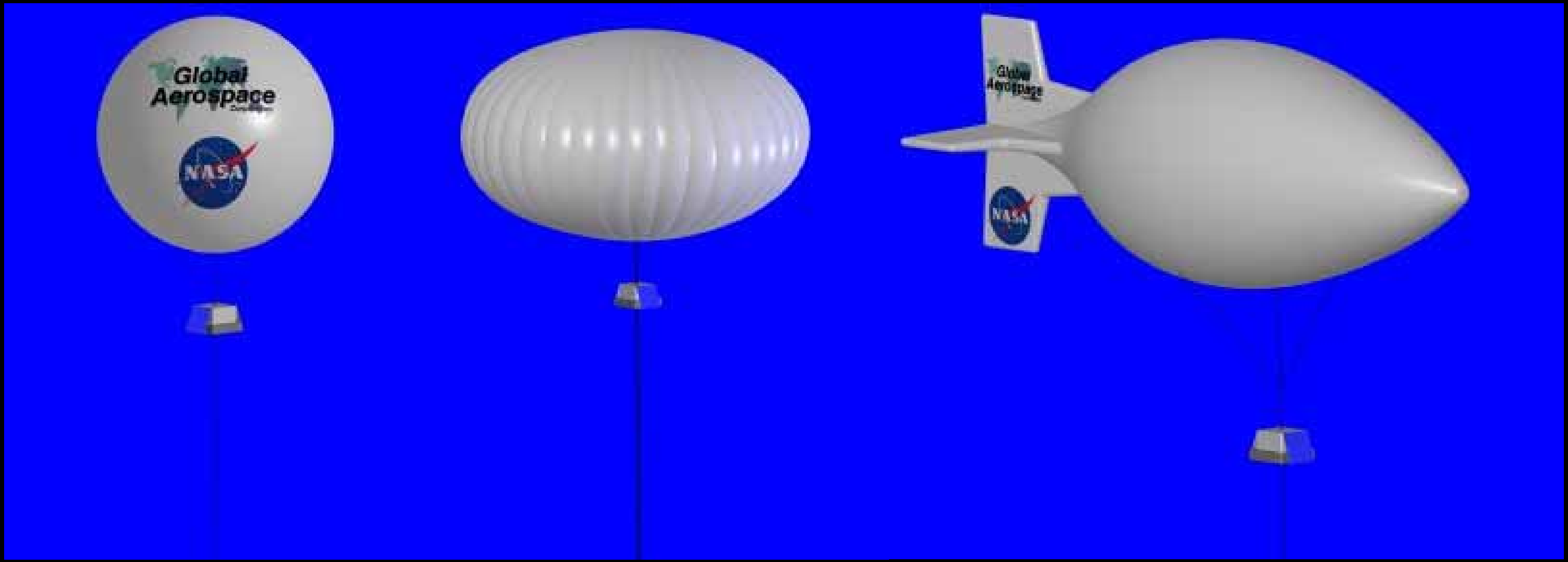
BGS ANALYSIS

- Lightweight design
  - Inflated wing?
  - High-strength tethers
- Performance modeling
  - Balloon shapes
  - Single- or dual wing BGS
- Winds analysis
  - MARS-GRAM
  - MARS MM5
- Trajectory simulations
- Control strategies and methodologies



Simulated trajectories

BALLOON SHAPES & BGS PERFORMANCE

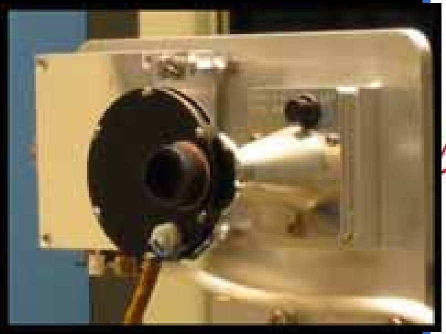


Spherical balloon | Pumpkin balloon | Aerodynamically-shaped balloon

- Pumpkin balloon can use thinner film and be lighter than a spherical balloon
- Aerodynamically-shaped balloon improves BGS performance by generating lift

MINIATURIZATION OF INSTRUMENTS

- MER Pancam cameras are 270 grams or about 9 ounces
- Generates panoramic image mosaic as large as 4,000 pixels high and 24,000 pixels around
- MER Mini-TES weighs just 2.1 kg
- Mini-TES is an infrared spectrometer that can remotely determine the mineralogy of rocks and soils



MER Pancam

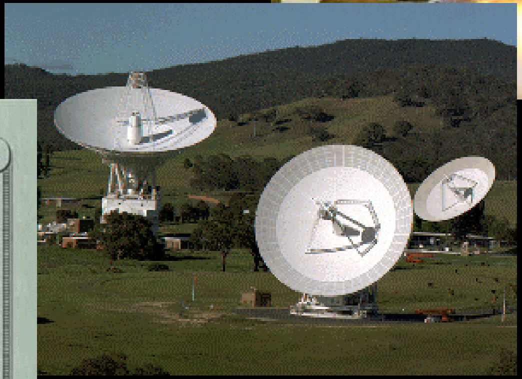
COST AND PERFORMANCE BENEFIT ANALYSIS

- Generate ROM mass estimates of the DARE architecture in the context of a Mars mission based on near-term technology

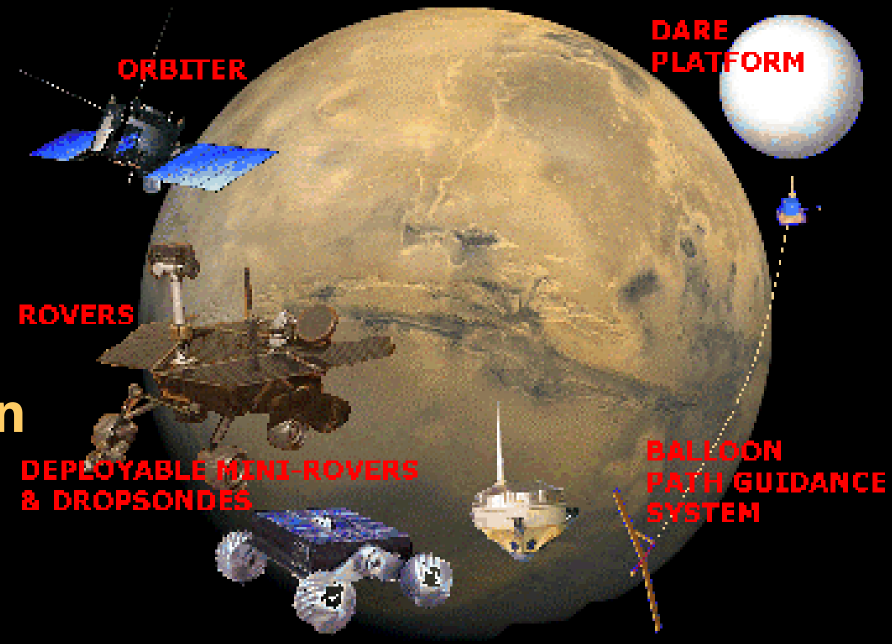
- Use traditional mass-based cost estimating techniques to estimate system costs

- Base cost estimates on analogy with recent missions of similar complexity

- Compare the cost of a DARE implementation to a conventional implementation which meet similar science requirements



CONCLUSIONS



- New architecture centered around guided balloons enables global high-resolution observations of planetary atmospheres and surfaces.
- The architecture facilitates search for and reconnaissance of future robotic and human landing sites.
- Innovative balloon path guidance system enables steering of balloons in the atmospheres of Mars, Titan, Venus and Jupiter.