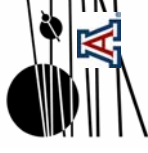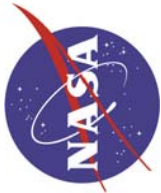# Overview of the Phoenix Entry, Descent and Landing System

Rob Grover

Jet Propulsion Lab
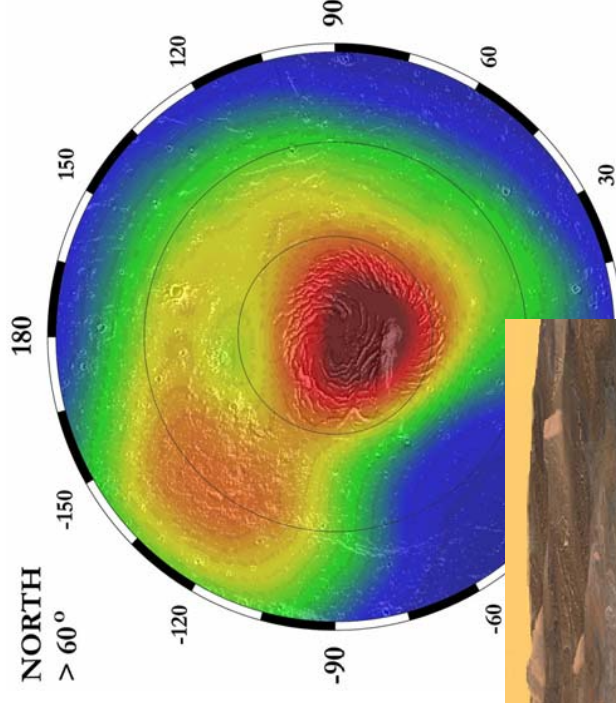
Phoenix Mission Goals

Rebirth of the Mars 2001 Lander

- Study the history of water in Mars' arctic region.
- Search for habitable zones in Mars' arctic.
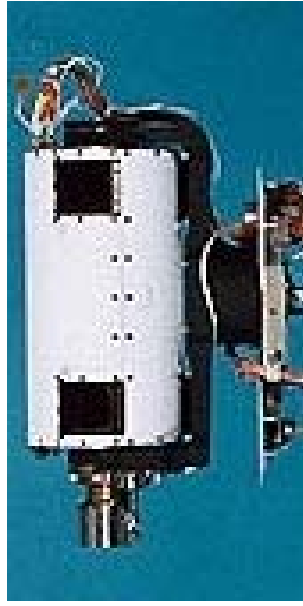- Develop a robotic system to explore Mars.

Phoenix

NORTH
> 60°

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2nd IPPW
August 23rd, 2004

Phoenix
Payload

Microscopy, Electrochemistry & Conductivity Analyzer (MECA)

JPL

Mars Descent Imager (MARDI)

MSSS

Robotic Arm (RA)

JPL

Robotic Arm Camera (RAC)

Max Plank Aeronomie

Meteorological Package with scanning LIDAR

Canadian Space Agency

Surface Stereo Imager (SSI)

University of Arizona
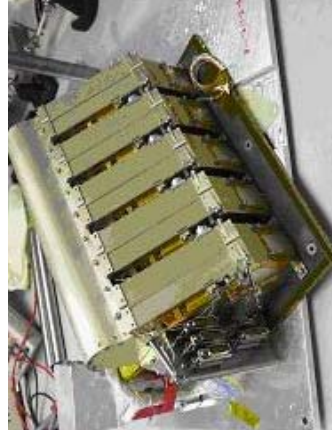
Thermal Evolved Gas Analyzer (TEGA)

University of Arizona

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RG 3

Aeroshell/Entry Comparison
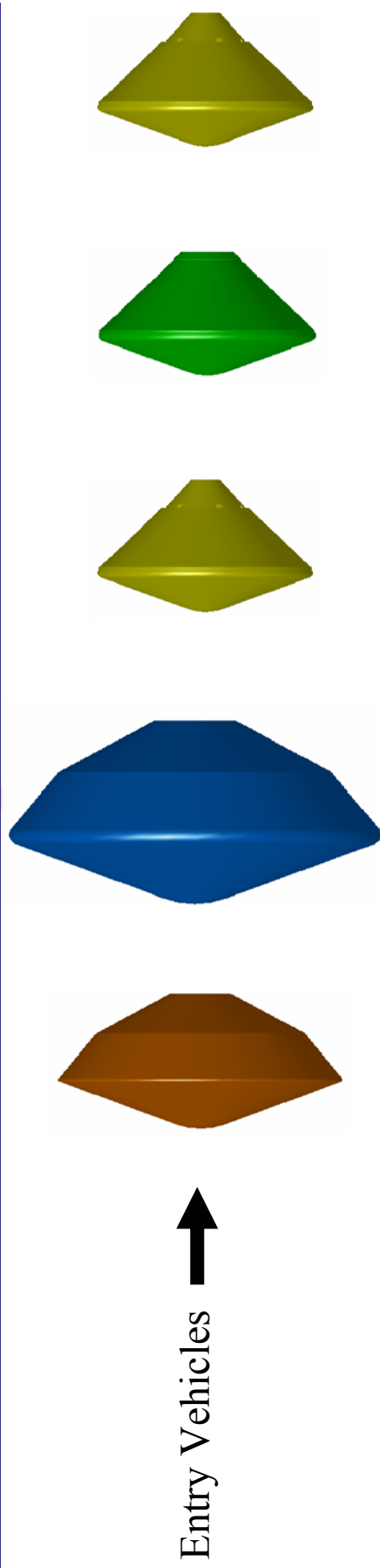
Phoenix

Entry Vehicles

	Viking I, II	MSL	'01 Lander	MPF/MER	Phoenix
Diameter, m	3.505	4.572	2.65	2.65	2.65
Rel. Entry Velocity, km/s	4.5, 4.42	5.2 to 6.8	6.5	7.6/5.5	5.7
Rel. Entry FPA, deg	-17.6	-15.63 to -13.68	-12	-13.8/-11.5	-12.5
Entry Mass, kg	930	2400	588	585/840	602
$m/(C_D A)$, kg/m^2	63.7	94	62.9	62.3/89.8	69.3
X_{CG}/D reference	0.221	0.27, TBD	0.25	0.27/0.26	0.25
Nominal α, deg	-11.1	-11	-3.5	0	-3.5
Nominal L/D	0.18	0.18	0.06	0	0.06

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JPL

Entry Trajectory Comparison
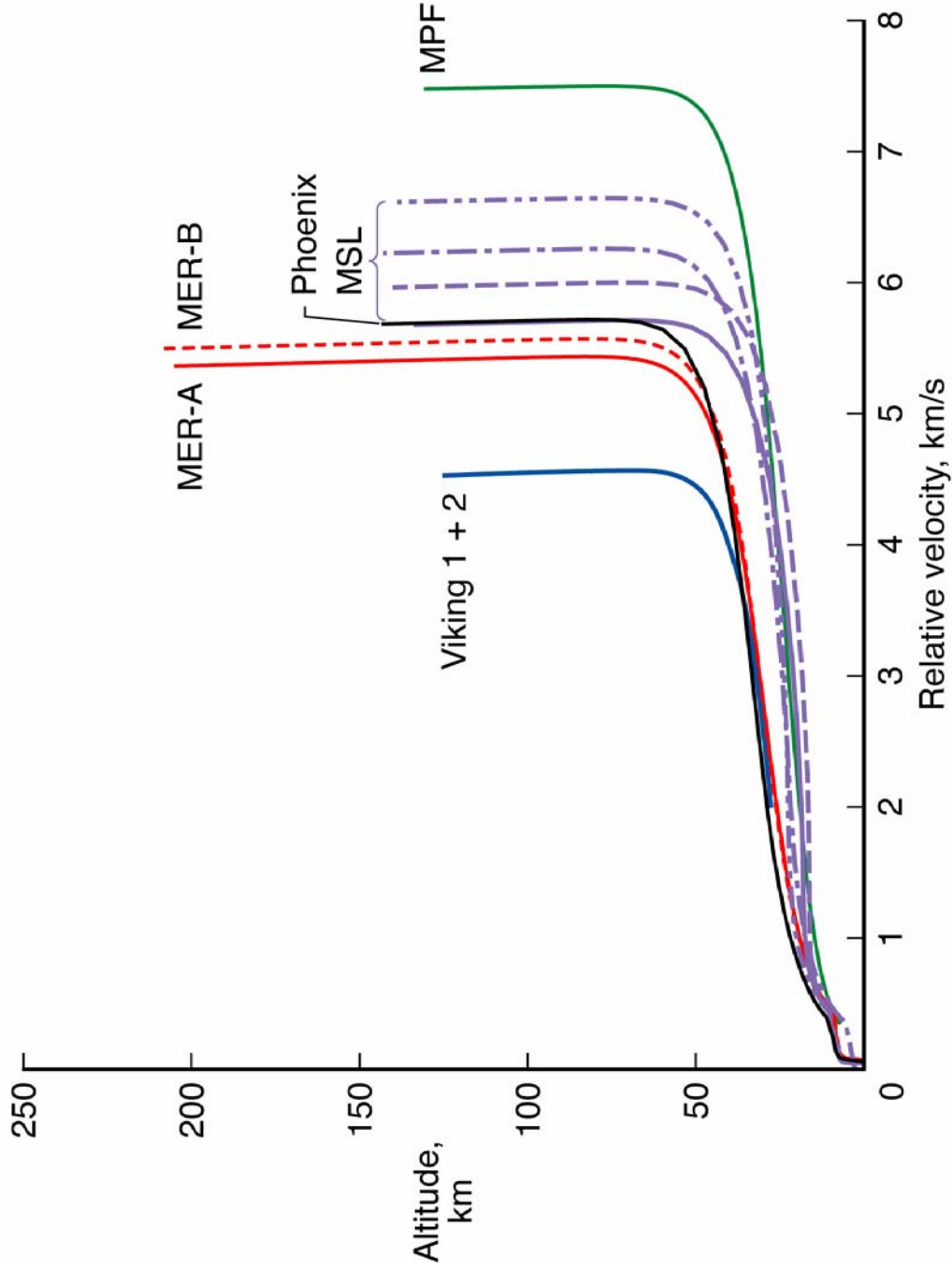
Phoenix

Phoenix EDL Timeline

Phoenix

X-band DTE Closed / Open Loop UHF-band to Orbiter

- Entry Turn Starts: E-6.3 min. Turn completed by E-5min.
- Cruise Stage Separation: E-5min
- Entry: E-0s, L-470s, 125 km*, 5.7 km/s, γ = -12.5°
- Peak Heating: E+99s, L-301s, 45 km, Peak Deceleration: E+117s, L-353s, 7g
- Parachute Deployment: E+250s, L-150s, 10 km, < 350 m/s (Mach 1.45)
- Heat Shield Jettison: E+260s, L-140s, 9 km
- Radar Activated: E+263s, L-137s, 8 km
- Leg Deployments: E+293s, L-107s, 6.5 km

X-band DTE Open-Loop UHF-band to Orbiter

- Lander Separation: E+371s, L-29s, 0.74 km
- Throttle Up: E+374s, L-26s, 0.57 km
- Constant Velocity Achieved: E+393s, L-7s, 0.012 km, 1.6 m/s
- Radar cutoff: E+395s, L-5s, 0.010 km, 1.6 m/s

X-band DTE UHF-band to Orbiter

- **Touchdown**: E+400s, L-0s, **0 km**, 1.6 m/s
- Dust Settling: L+0 to L+15 min
- Fire Pyros for Deployments: L+7sec
- Solar Array Deploy: L+25min
- Begin Gyro-Compassing: L+100min

Landing at -3.5 km elevation above MOLA
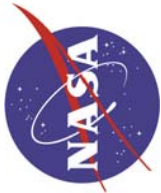
* Altitude referenced to equatorial radius

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RG 6

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Hypersonic Phase

Phoenix

- Hypersonic Guidance will be Demonstrated by Using a Modified Version of the Apollo Earth-entry Guidance
  - Terminal Point Range Control with Gain Matrix From Trajectory Perturbations
  - Nominal Vehicle L/D = 0.06 (Alpha=3.5 deg)
  - Utilizes Bank Control to Steer to Target at Chute Deploy
  - Operates at 10 Hz

Apollo Guidance Crossrange Performance

Position at Parachute Deploy
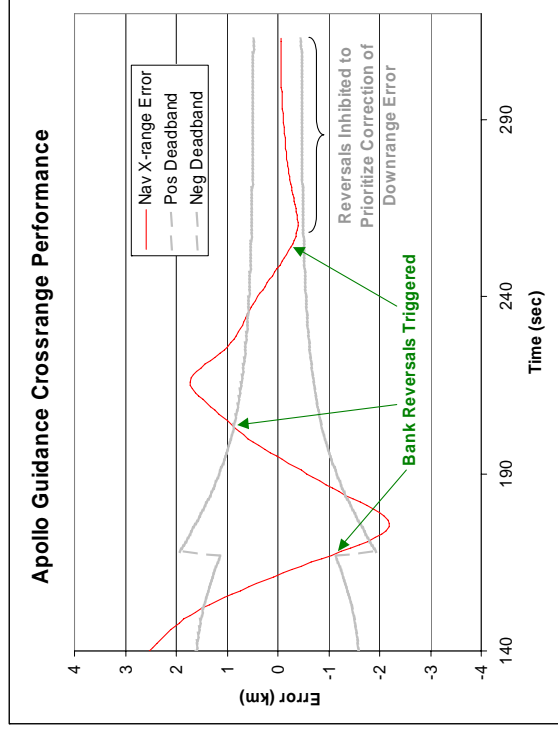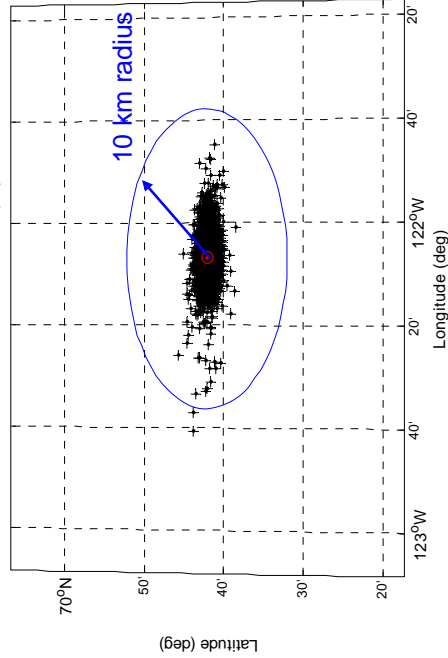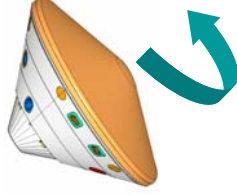
- No Requirement on Guidance Accuracy
- Performance will be Characterized by End-to-End Monte Carlos
- "Break-it" Testing Will Help Define Capability Limits
- Full "Lift Up"/"Lift Down" Does Not Impact Landed Success, Just Accuracy

Hypersonic Phase

Phoenix

- Begins with Entry Interface at 125 km Reference Altitude
- Dominated by Entry Heating
- *All Key Parameters Within Mars 2001 Design Envelope*

	Phoenix	Mars '01 Requirement
Entry Velocity	5.76 kps	~6.5 kps
Entry Errors, Delivery	0.20 deg	0.27 deg
Entry Errors, Nav	0.15 deg	0.15 deg
Max Heating	62 W/cm2	72 W/cm2
Max Loads	9.5 g's	16 g's
Max Bondline Temp	150 C	250 C
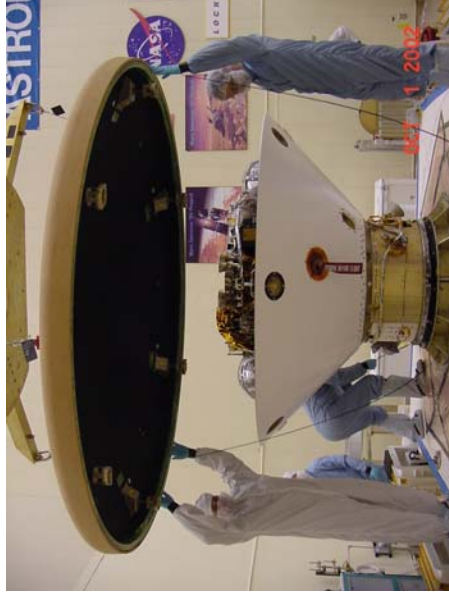
- Exist Hardware: Heatshield / Backshell Structure & TPS
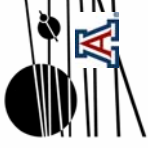- New Hardware: EDL Antennas & Assoc. TPS

Parachute Phase

Phoenix

Phoenix Parachute

- Viking Design Disc Gap Band (DGB)

- Mars 2001 Parachute: 13.4m Viking disc gap band
- Phoenix Currently 12.4m Viking Disc Gap Band
- Phase Begins with Parachute Mortar Firing
- Mars–01 Deploy Pushed to Viking Limit for Site Performance
- Current Lander Loads Capability Requires a Deploy Below 500 Pa

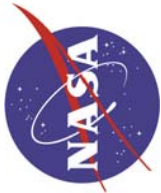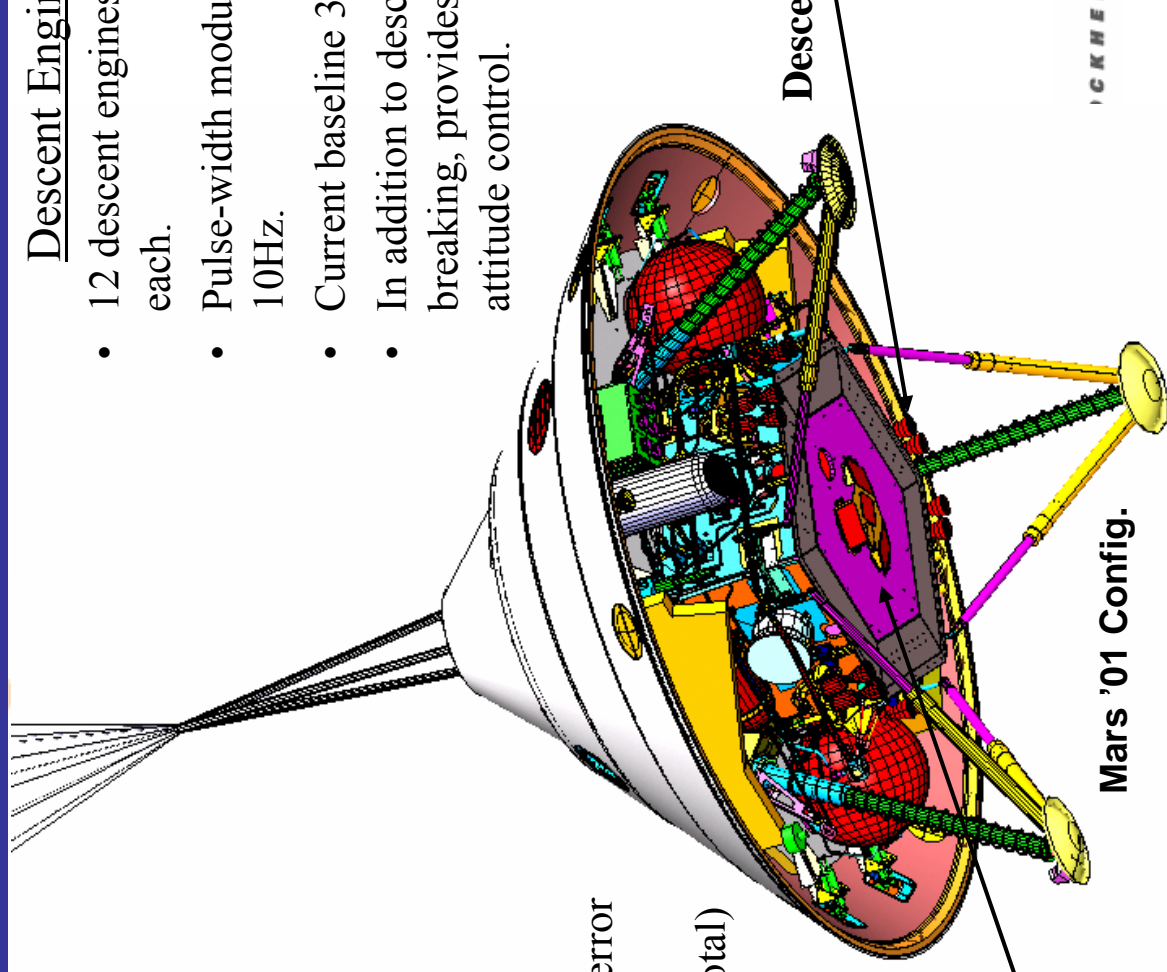|	Phoenix	Mars '01Requirement
Max Deploy Mach	1.7	2.25
Max Deploy Qbar	485 Pa	1100 Pa

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Terminal Descent Phase

Doppler Radar

- Altitude
  – Op. Range: 40-2400 m
  – Error: ≤5%
- Velocity
  – Op. Range: 40-1400 m
  – Error: ≤4% (> 1m/s)
  – Quantization: 0.82 m/s
- Phoenix Upgrade
  – Mitigates horizontal vel. error due to slopes
  – Extra set of antennas (8 total)
  – Alt. Range: 1-3700 m
  – Vel. Range: 10-2150 m
  – Quantization.: 0.40 m/s
  – Same error specs

Descent Engines

- 12 descent engines, ~300N each.
- Pulse-width modulated at 10Hz.
- Current baseline 3 full on.
- In addition to descent breaking, provides 3-axis attitude control.

Descent Engine (12)

Radar Antennas

Mars '01 Config.

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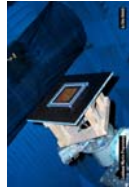
Phoenix

EDL Communications

Signal to Noise Ratio during entry

Nominal

Acquisition

Realtime

Worst Case No swing,

Worst Case w/ 25 deg swing

Parachute Deploy

Entry Interface

Post-realtime Processing

Time (seconds)

Pt/No (dB-Hz)

25.00 23.00 21.00 19.00 17.00 15.00 13.00 11.00 9.00 7.00 5.00

0 50 100 150 200 250 300 350 400 450

Margin for 8 kbps

Power (dBm)

35 30 25 20 15 10 5 0 -5 -10

Cruise Stage Jettison

Entry interface 125 km

Chute Deploy

Lander separation (helix antenna)

Seconds from Entry

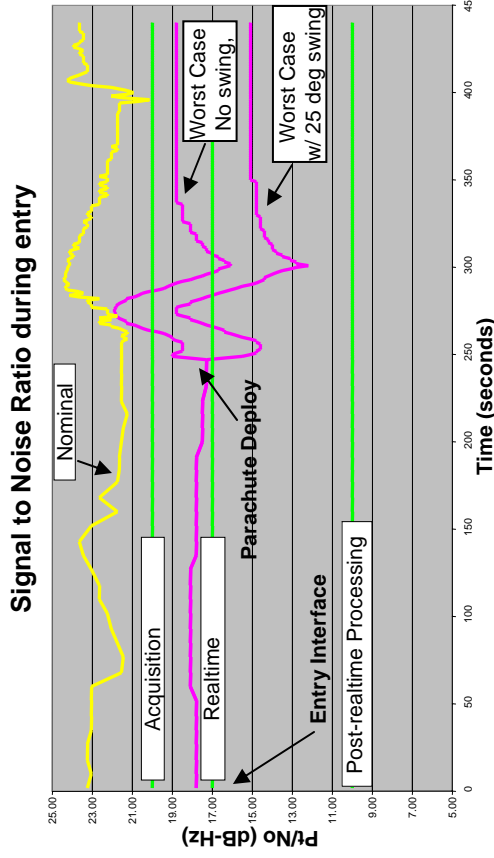-400 -300 -200 -100 0 100 200 300 400 500 600
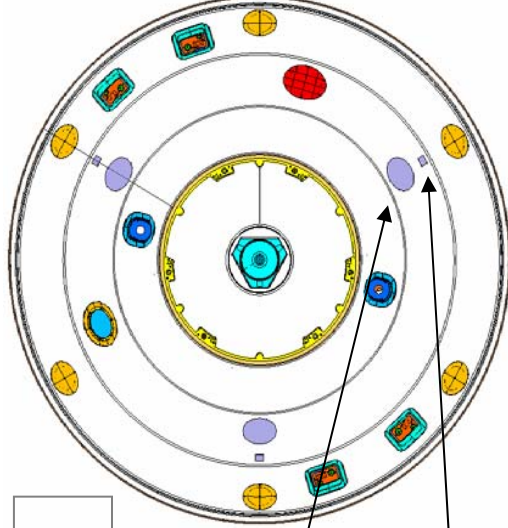
KDR
**3.3.5 Telemetry Durations**

UHF ANTENNA

3 PLCS

LGA
3 PLCS

Data Return

- UHF Comm during all of EDL
  - Direct link to Odyssey or MRO
  - 8 Kb/s Data Rate
  - Concern about Plasma blackout in Hypersonic
- X-Band Semaphores during all of EDL
  - Confirmation of Key Events
  - Capability to produce "fault" semaphores
  - Some level of performance data
- Link analyses to be refined as Mission Design matures

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RG 11

JPL
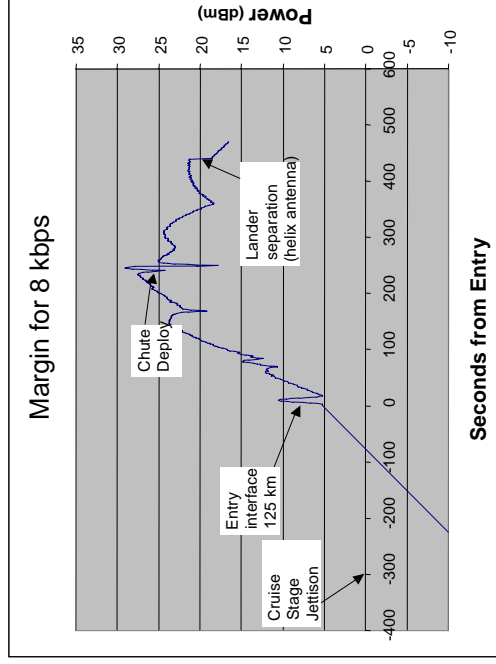
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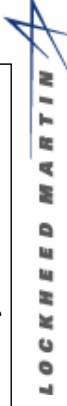
Phoenix

Summary

- Phoenix is a rebirth of the 2001 Lander using the same hardware and many of the same team members.

- Continuation of follow water strategy targeting subsurface ice in the northern polar region.

- First use of hypersonic guidance at Mars.

- Launching in 2007 and landing in 2008, it returns to propulsive soft landing with strong similarity to the Viking landings.

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