



ANTENNAS and PROPAGATION
SOCIETY
LOS ANGELES CHAPTER



INSTITUTE OF
ELECTRICAL AND
ELECTRONICS
ENGINEERS

Antenna Designs for the Mars Exploration Rover (MER) Spacecraft, Lander, & Rover

Joseph Vacchione – Lead Antenna Engineer

Michael Thelen – Lead Mechanical Engineer

Paula Brown – Medium/Low Gain Horn Antenna Engineer

John Huang – Microstrip Patch Antenna Engineer

Ken Kelly – UHF Antenna Engineer

Vaughn Cable – Test Engineer

Satish Krishnan – High Gain Antenna Actuator Lead Engineer

Ball Aerospace & Technologies Corp. – High Gain Antenna Contractor

Kevlin Corp. – Rotary Joint Contractor

Atlantic Microwave Corp. – Septum Polarizer Contractor



Presentation Outline

JPL



Mars Exploration Rovers

1. Mission Overview
2. MER Spacecraft Architecture
3. Evolution of an Antenna System
4. MER Cruise Stage Antennas
5. The Antenna Stack
6. Heat-shield / Back Shell Antenna
7. Lander Antennas
8. Rover Antennas



Mission Overview



Mars Exploration Rovers

- **MER-A**
 - **Launch on a Delta II 7925 Launch Window: May 30 to June 16, 2003**
 - **Arrive January 4, 2004**
 - **Latitude band 15°S to 5°N**
- **MER-B**
 - **Launch on a Delta II 7925H Launch Window: June 25 to July 12, 2003**
 - **Arrive January 25, 2004**
 - **Latitude band 10°S to 10°N**
- **Mass (each)**
 - **Launch 1063 kg, Rover 185 kg, Payload 15 kg (not including arm, mobility)**
- **Capability per mission**
 - **90 sols of science operations (after landing sol)**
 - **600 meter odometer traverse (system qualified to 1000 meters)**
 - **~ 4 distinct locations (including landing location)**
 - **~ 6 targets: one soil, five rock—one of which is abraded**
 - **~ 3 Gbits total data return (more for MER-A)**
 - **Your mileage may vary**



Science Objectives



Mars Exploration Rovers

- Search for and characterize a diversity of rocks and soils that hold clues to past water activity
- Investigate landing sites which have a high probability of containing physical and/or chemical evidence of the action of liquid water
- Determine the distribution and composition of minerals, rocks, and soils
- Determine the nature of local surface geologic processes
- Calibrate and validate orbital remote sensing data and assess the heterogeneity
- Identify and quantify iron-bearing minerals indicating aqueous processes
- Characterize mineral assemblages and textures in the geologic context
- Extract clues related to past environmental conditions and assess whether past environments were conducive for life



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Mars Exploration Rovers

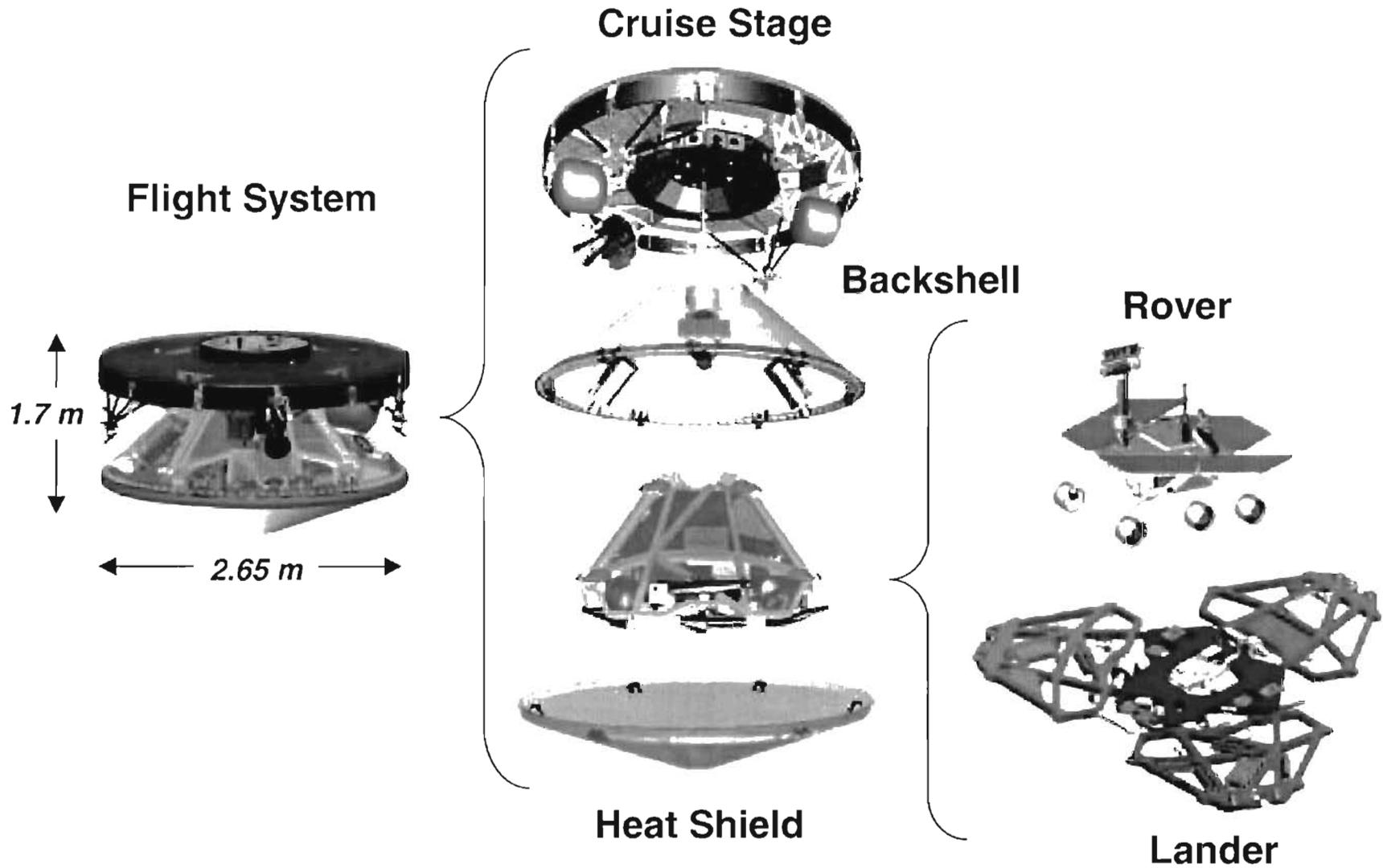
MER Spacecraft Architecture



MER Spacecraft Assembly



Mars Exploration Rovers

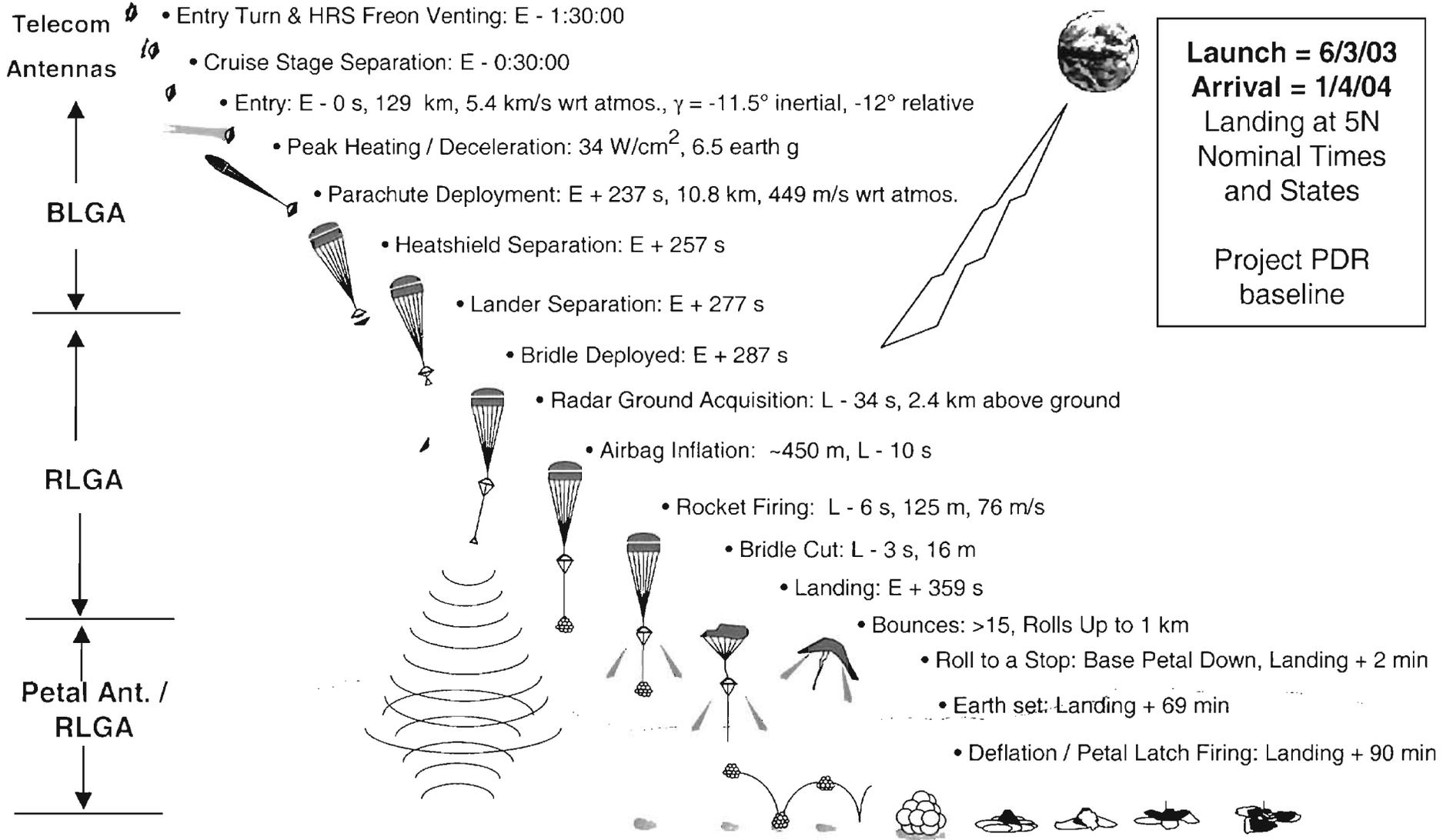




Nominal MER-A EDL Sequence



Mars Exploration Rovers



Launch = 6/3/03
Arrival = 1/4/04
 Landing at 5N
 Nominal Times
 and States

Project PDR
 baseline



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Mars Exploration Rovers

Evolution of an Antenna System

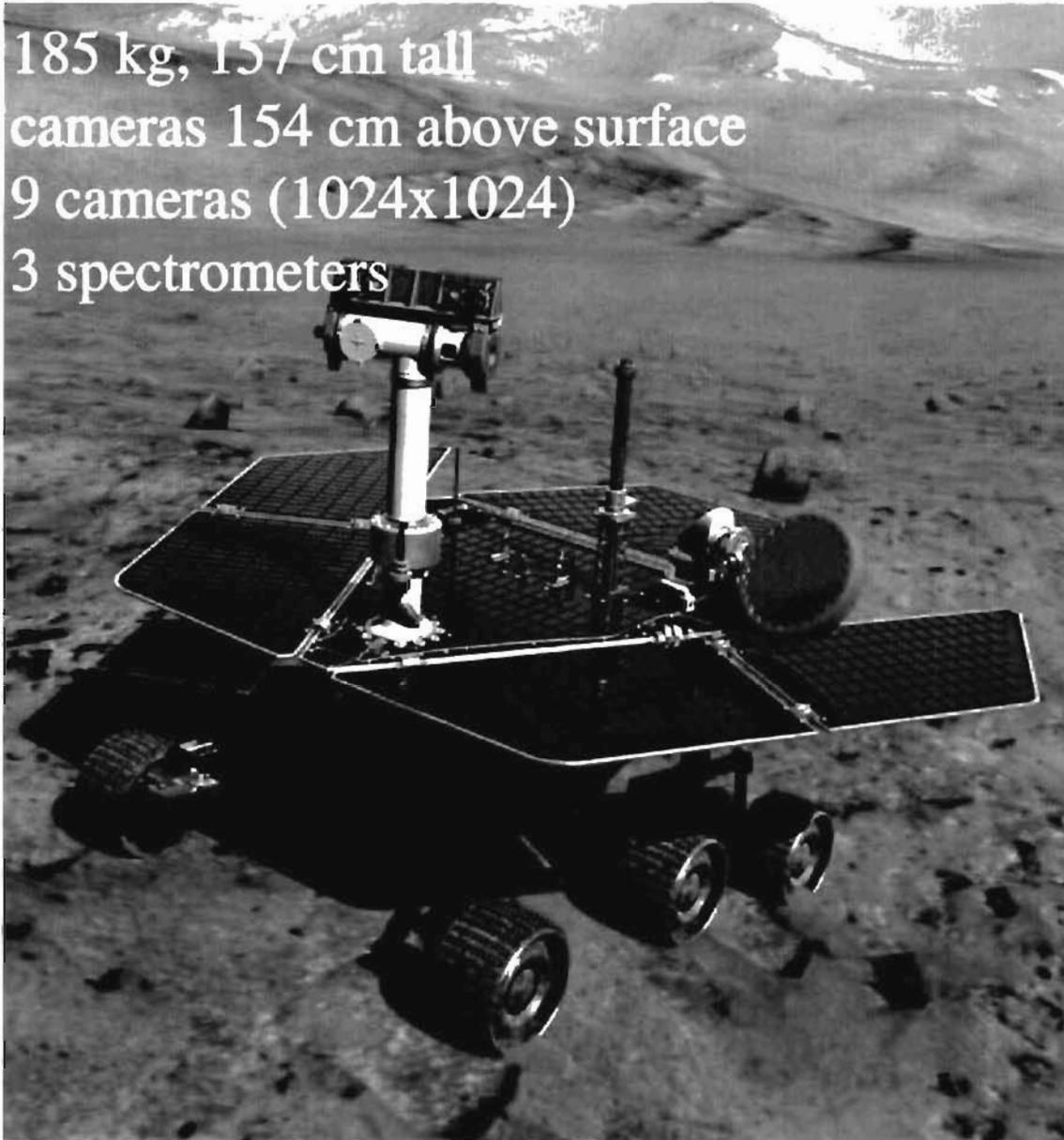


Comparison: MER Rover and Pathfinder Sojourner Rover

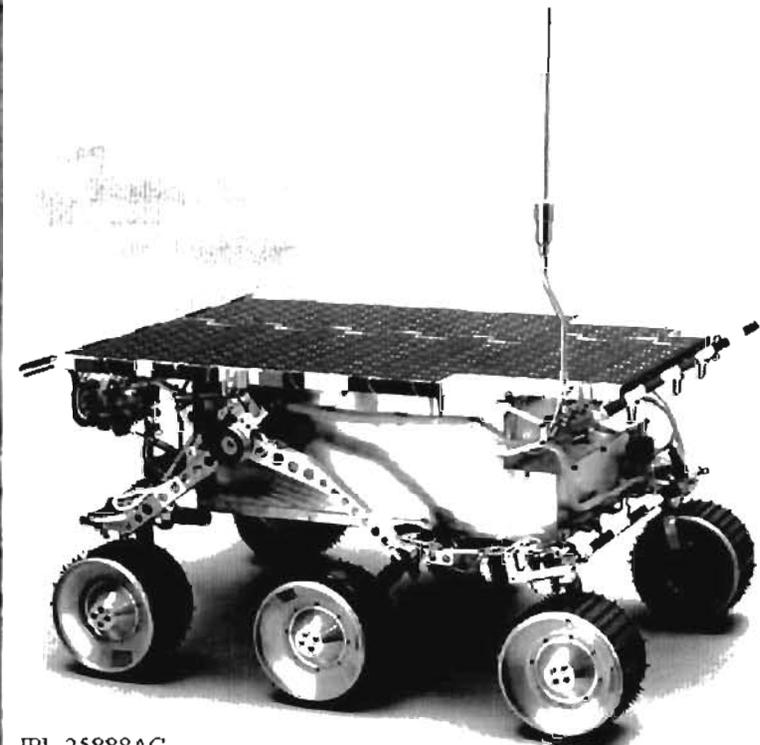


Mars Exploration Rovers

185 kg, 157 cm tall
cameras 154 cm above surface
9 cameras (1024x1024)
3 spectrometers



11 kg, 32 cm tall
cameras 25 cm above the ground
3 cameras (768 x 484)
1 spectrometer



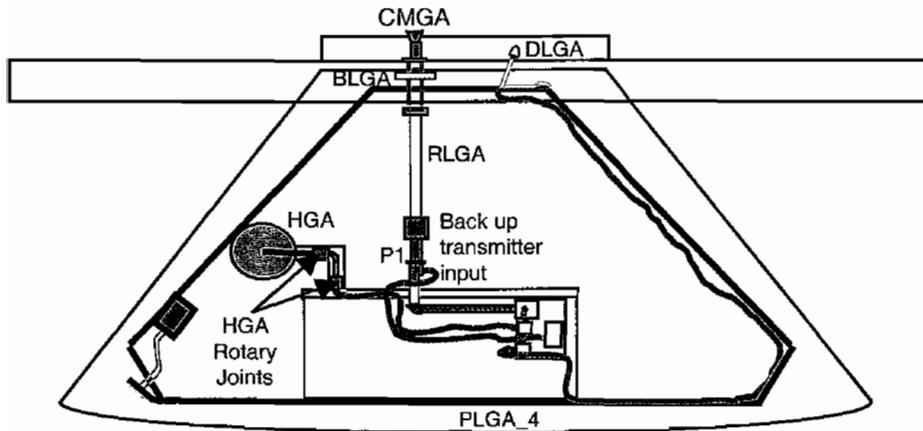
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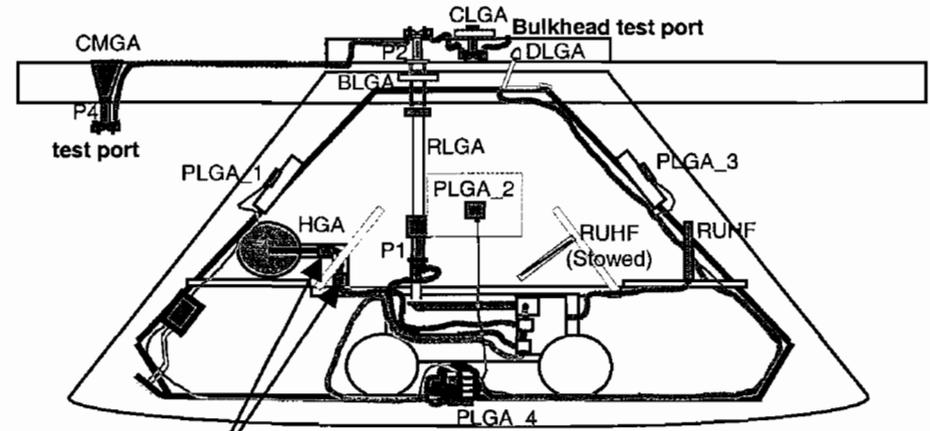
Antenna Evolution



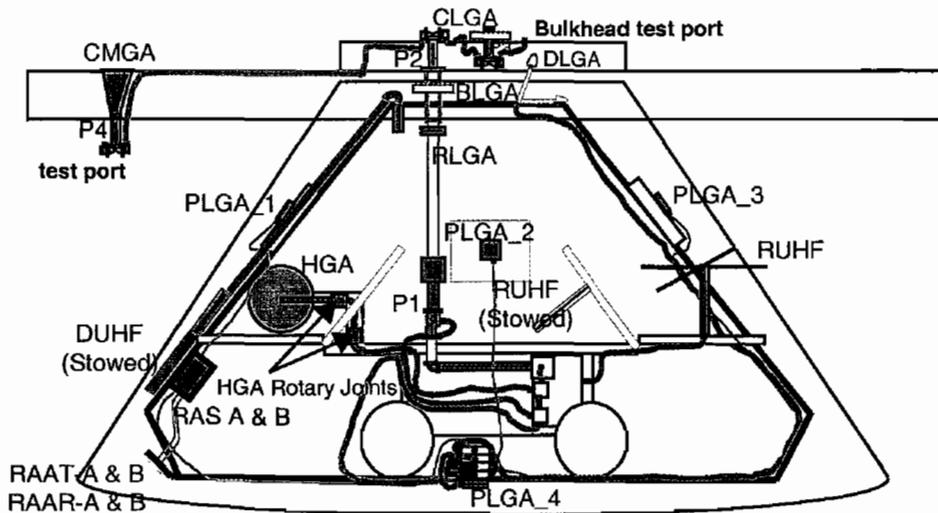
Mars Exploration Rovers



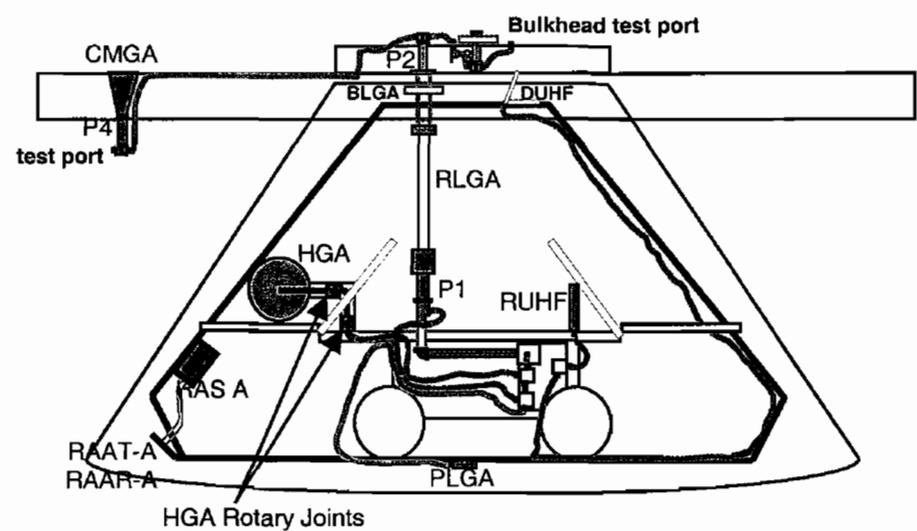
**Pathfinder Architecture – Starting point
October 2000**



**HGA Rotary Joints
December 2000**



May 2001



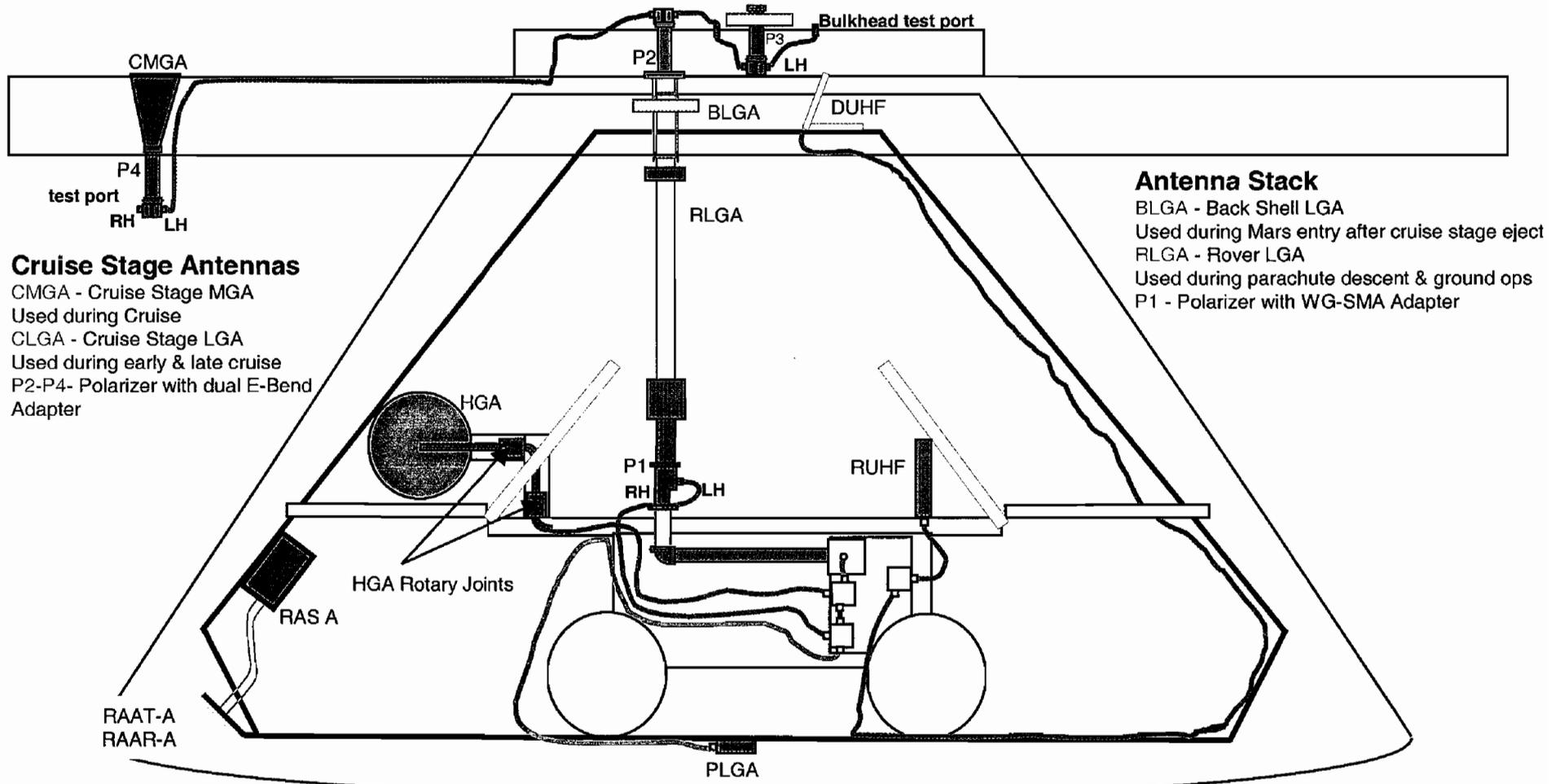
**HGA Rotary Joints
October 2001**



Current Antenna Baseline



Mars Exploration Rovers



Cruise Stage Antennas

CMGA - Cruise Stage MGA
 Used during Cruise
 CLGA - Cruise Stage LGA
 Used during early & late cruise
 P2-P4- Polarizer with dual E-Bend
 Adapter

Antenna Stack

BLGA - Back Shell LGA
 Used during Mars entry after cruise stage eject
 RLGA - Rover LGA
 Used during parachute descent & ground ops
 P1 - Polarizer with WG-SMA Adapter

RAS Antennas

RAAT - Transmit
 RAAR - Receive
 Used during final descent

Descent & Landing Antennas

PLGA - Petal LGA
 Used just after landing
 DUHF - UHF Descent Antenna
 Used during parachute descent

Ground Ops Prime Data Link Antennas

RUHF - Rover UHF LGA
 Used during ground ops for link with orbiter
 HGA - High Gain Antenna
 Used during ground ops as prime data link

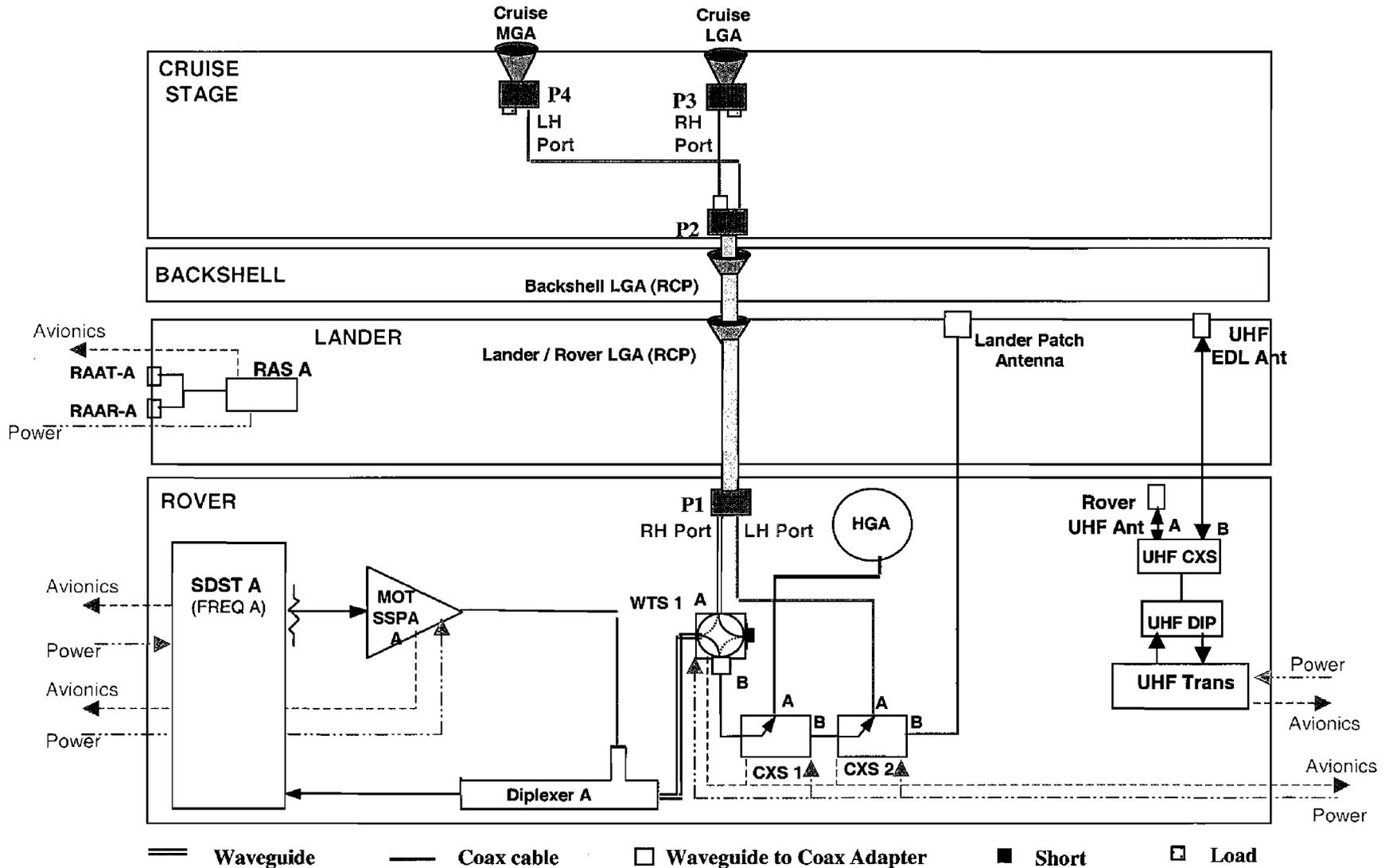


Overview

MER Telecom Block Diagram



Mars Exploration Rovers





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Mars Exploration Rovers

MER Cruise Stage Antennas

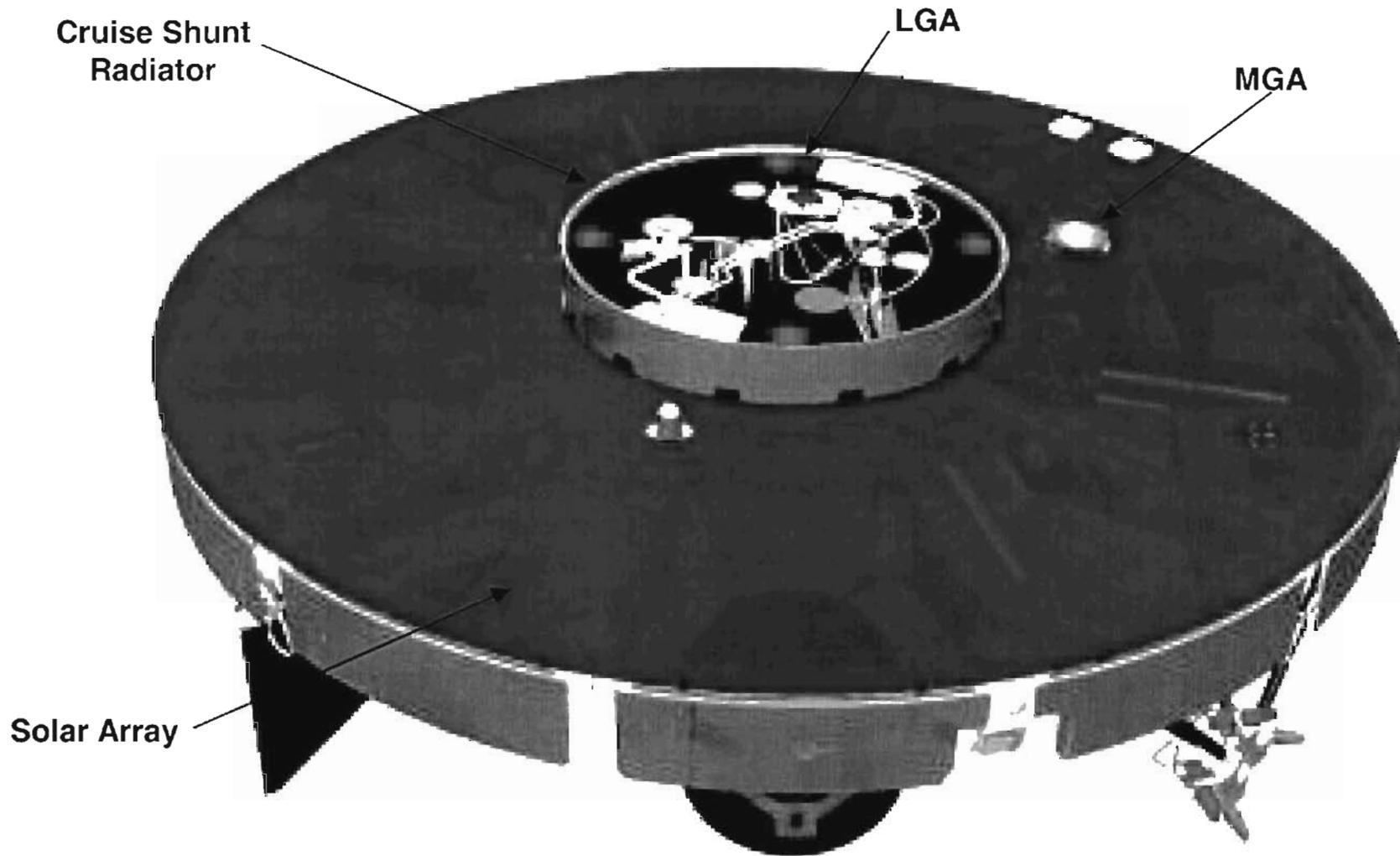


Top View of MER Cruise Stage

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Mars Exploration Rovers

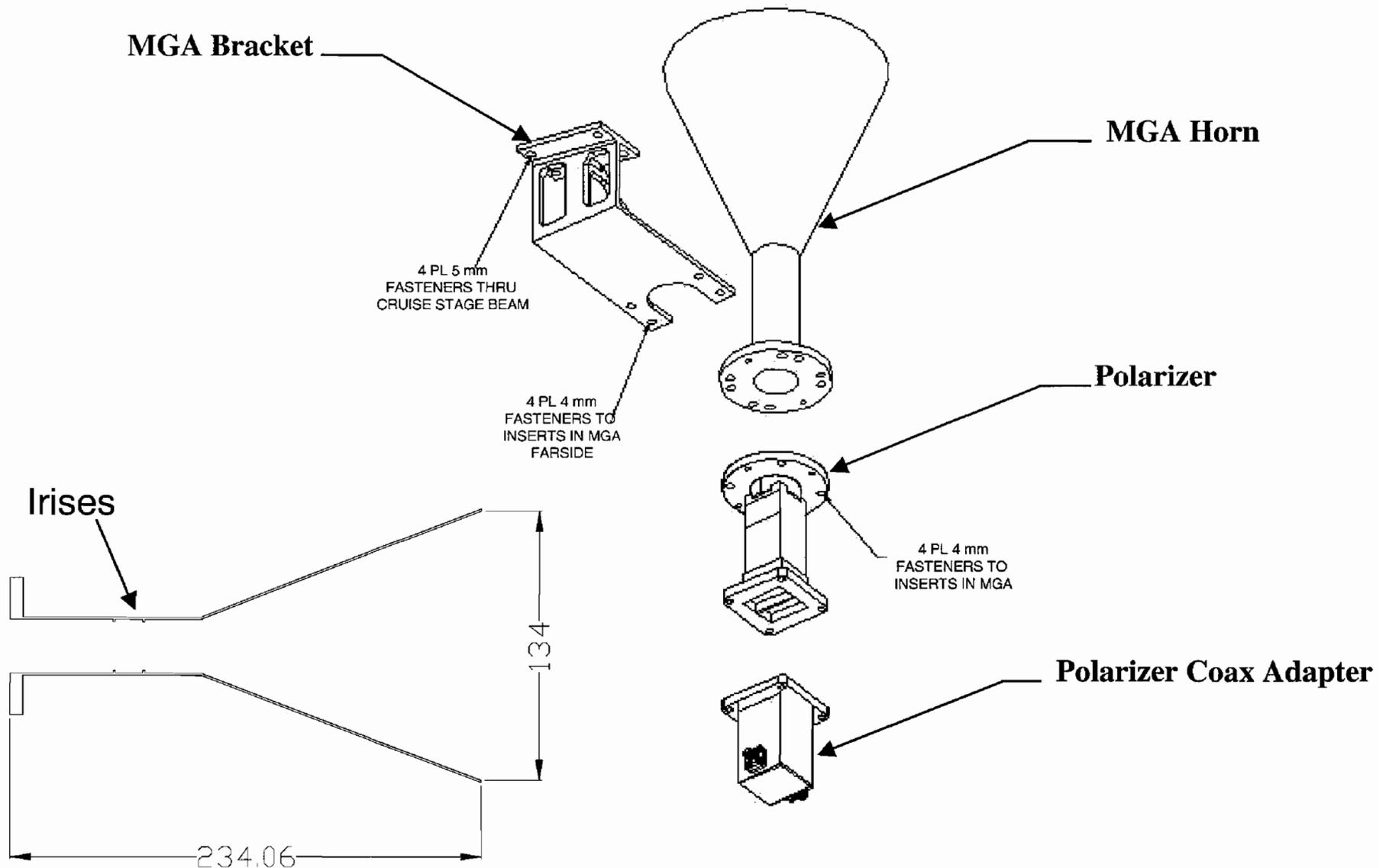




Medium Gain Antenna Design



Mars Exploration Rovers



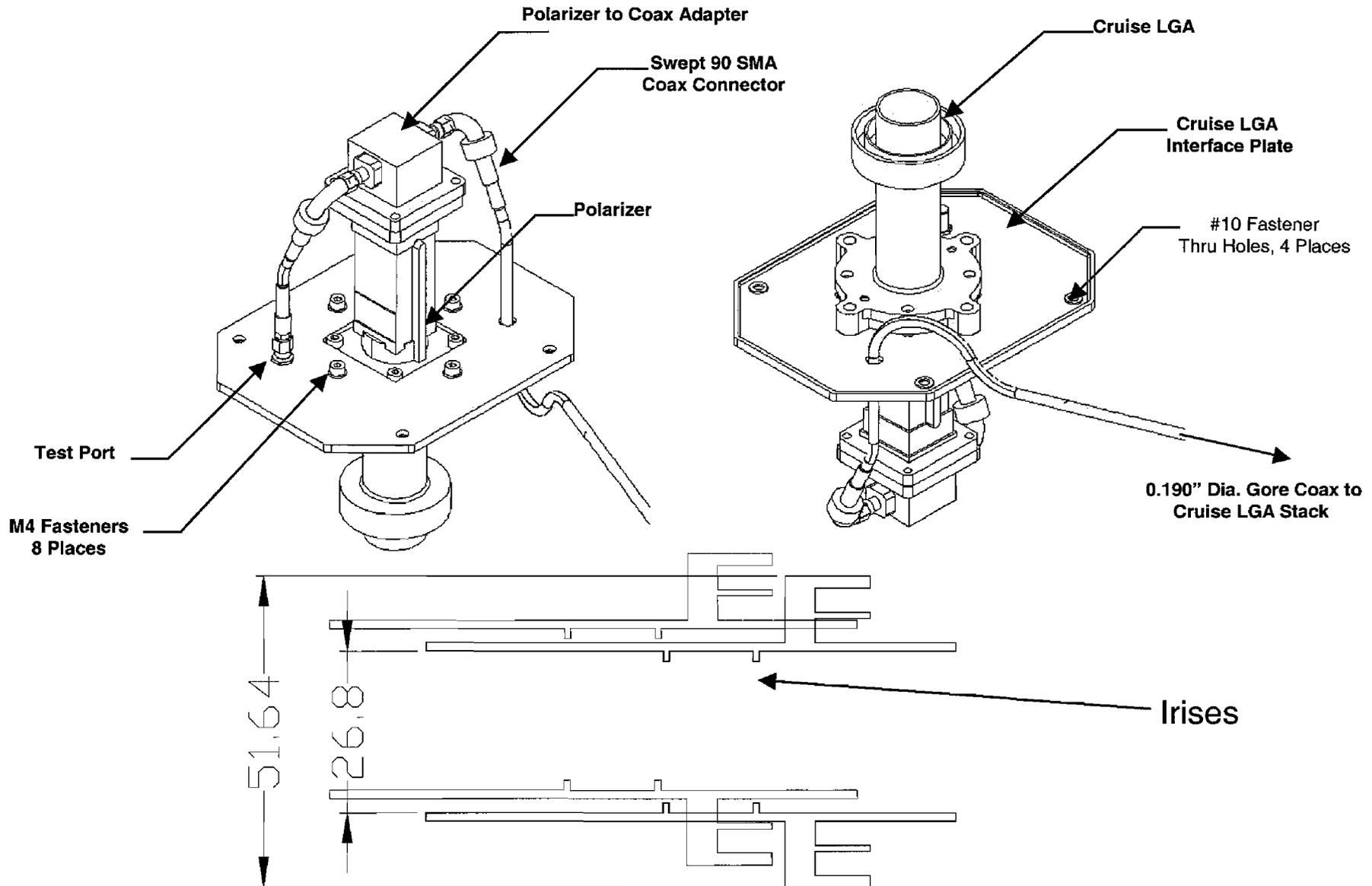


Cruise LGA Sub Assembly

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Mars Exploration Rovers



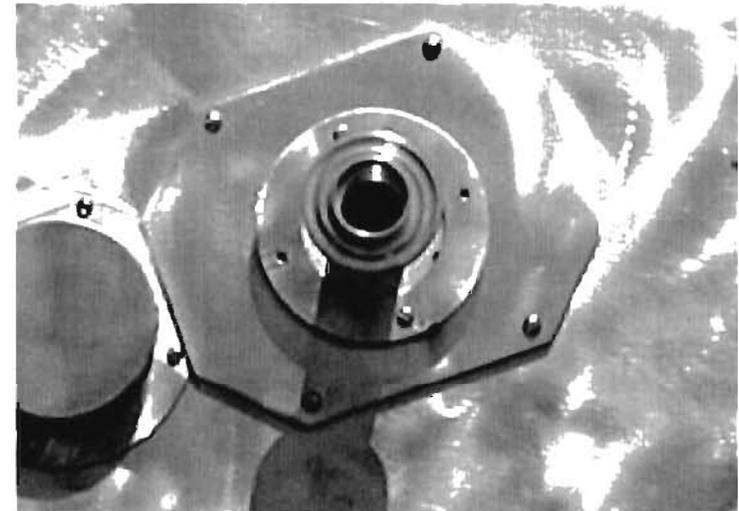
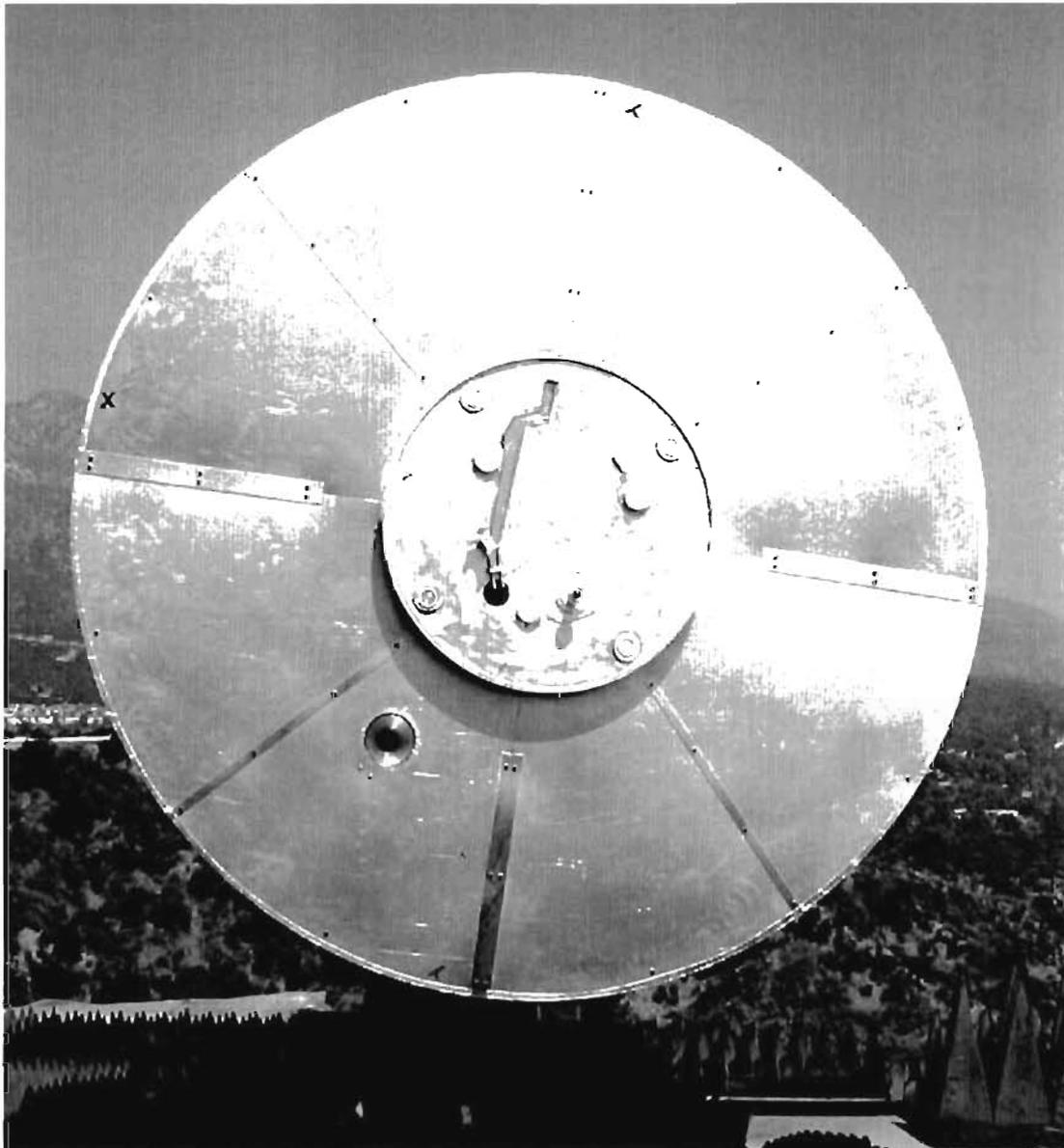


Mock-up of Cruise Stage for Antenna Measurements

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Mars Exploration Rovers



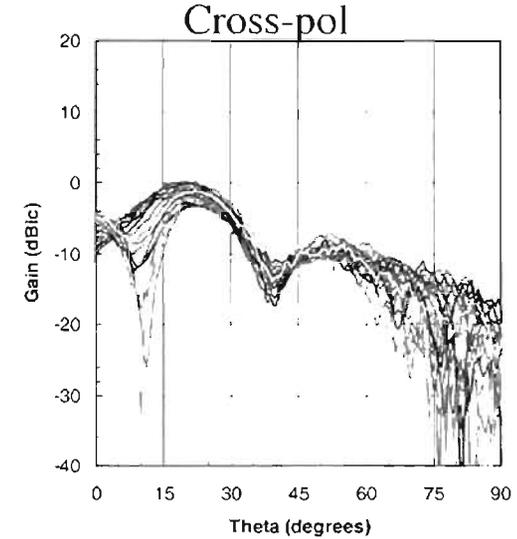
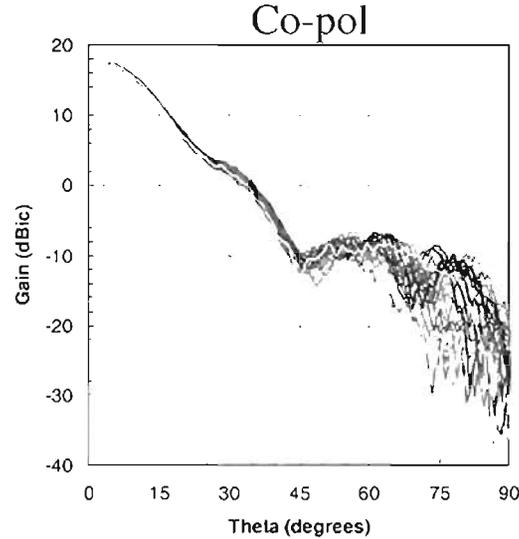
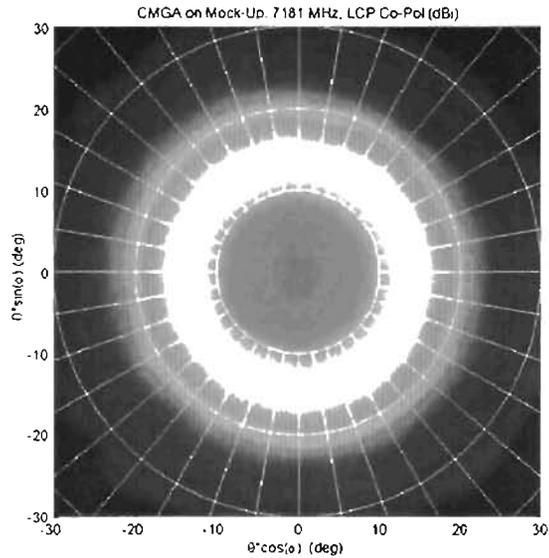


CMGA Radiation Patterns on Cruise Mock-up

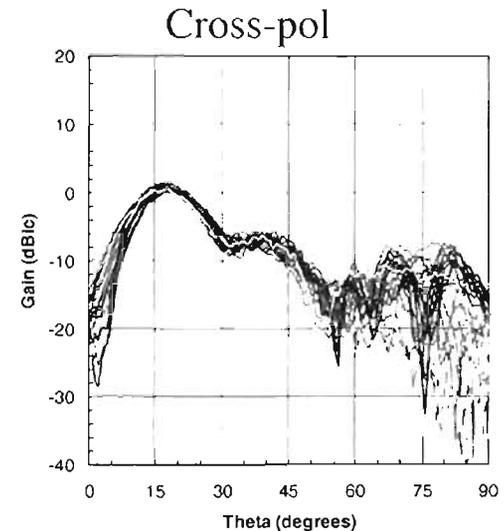
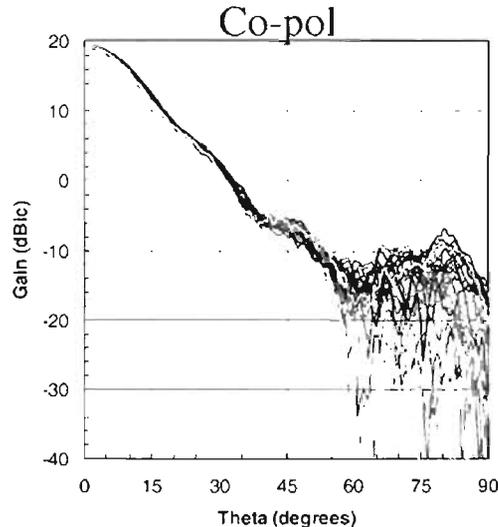
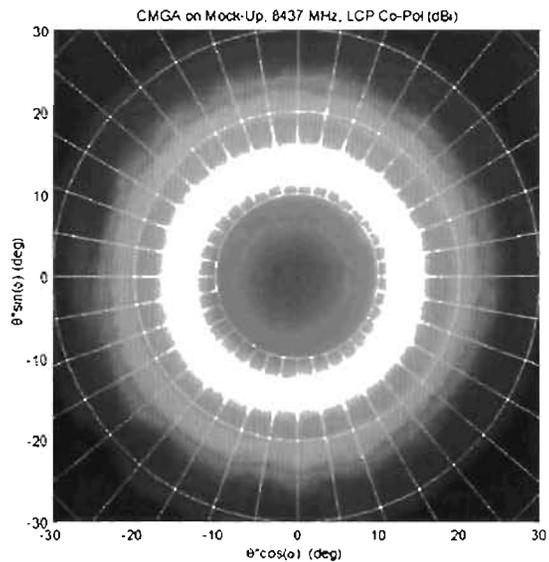


Mars Exploration Rovers

7181 MHz - Measured Boresight Gain: 18.10 dBic



8437 MHz - Measured Boresight Gain: 19.34 dBic

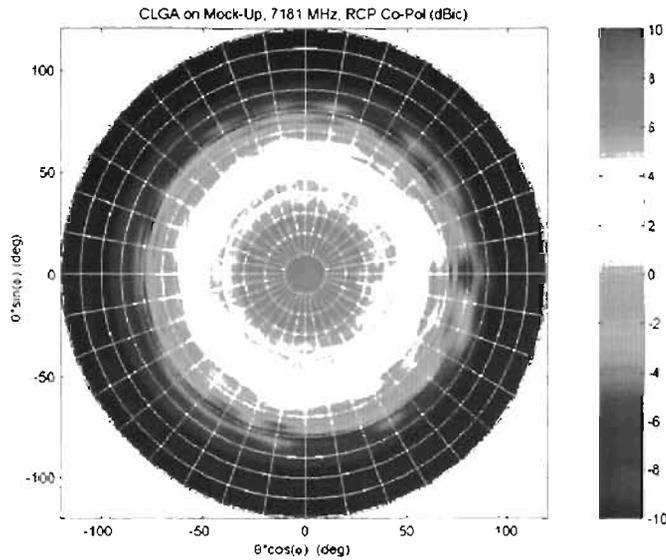




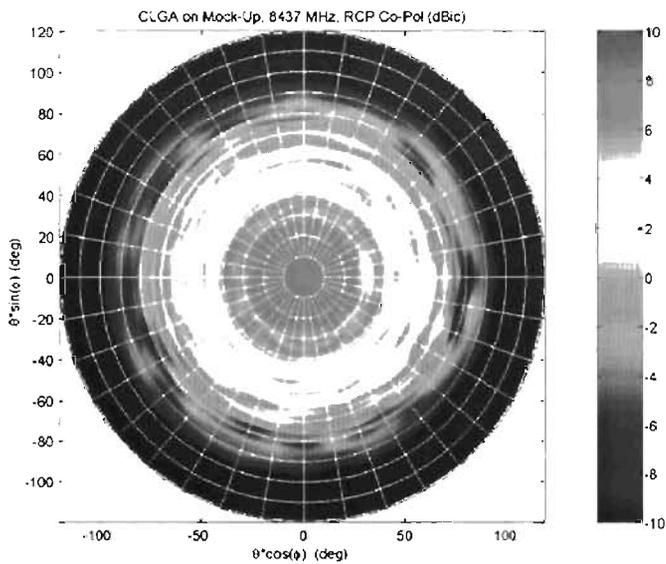
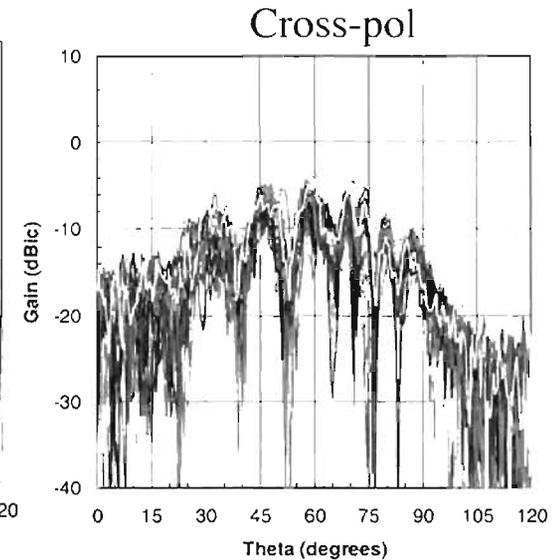
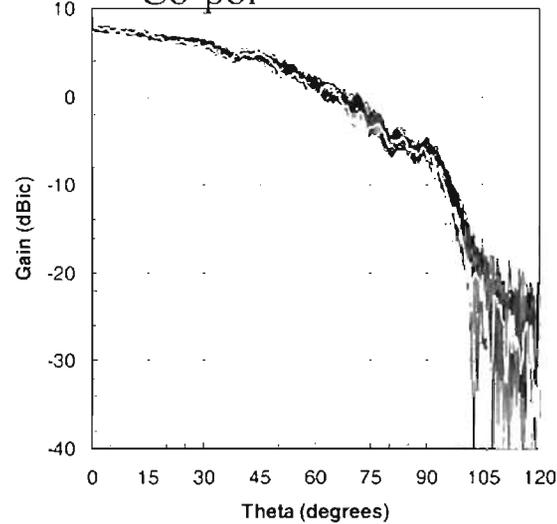
CLGA Radiation Patterns on Cruise Mock-up



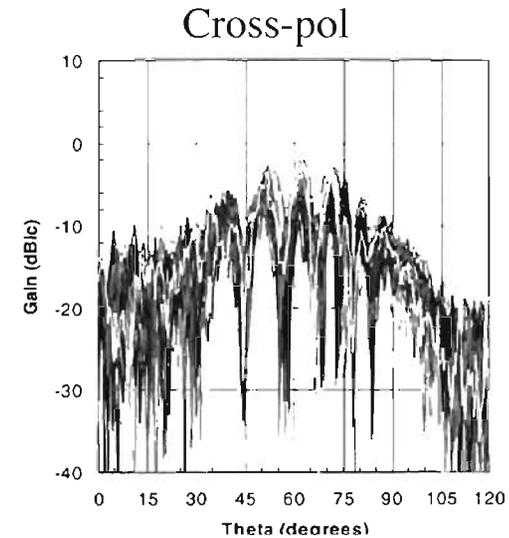
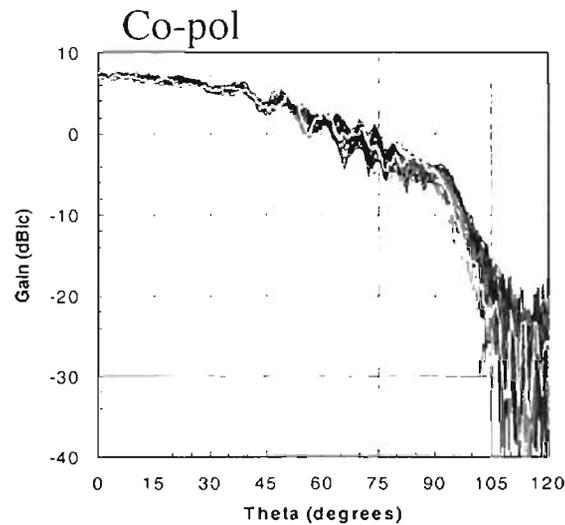
Mars Exploration Rovers



7181 MHz - Measured Boresight Gain: 7.84 dBic



8437 MHz Measured Boresight Gain: 7.14 dBic





Mars Exploration Rovers

The Antenna Stack

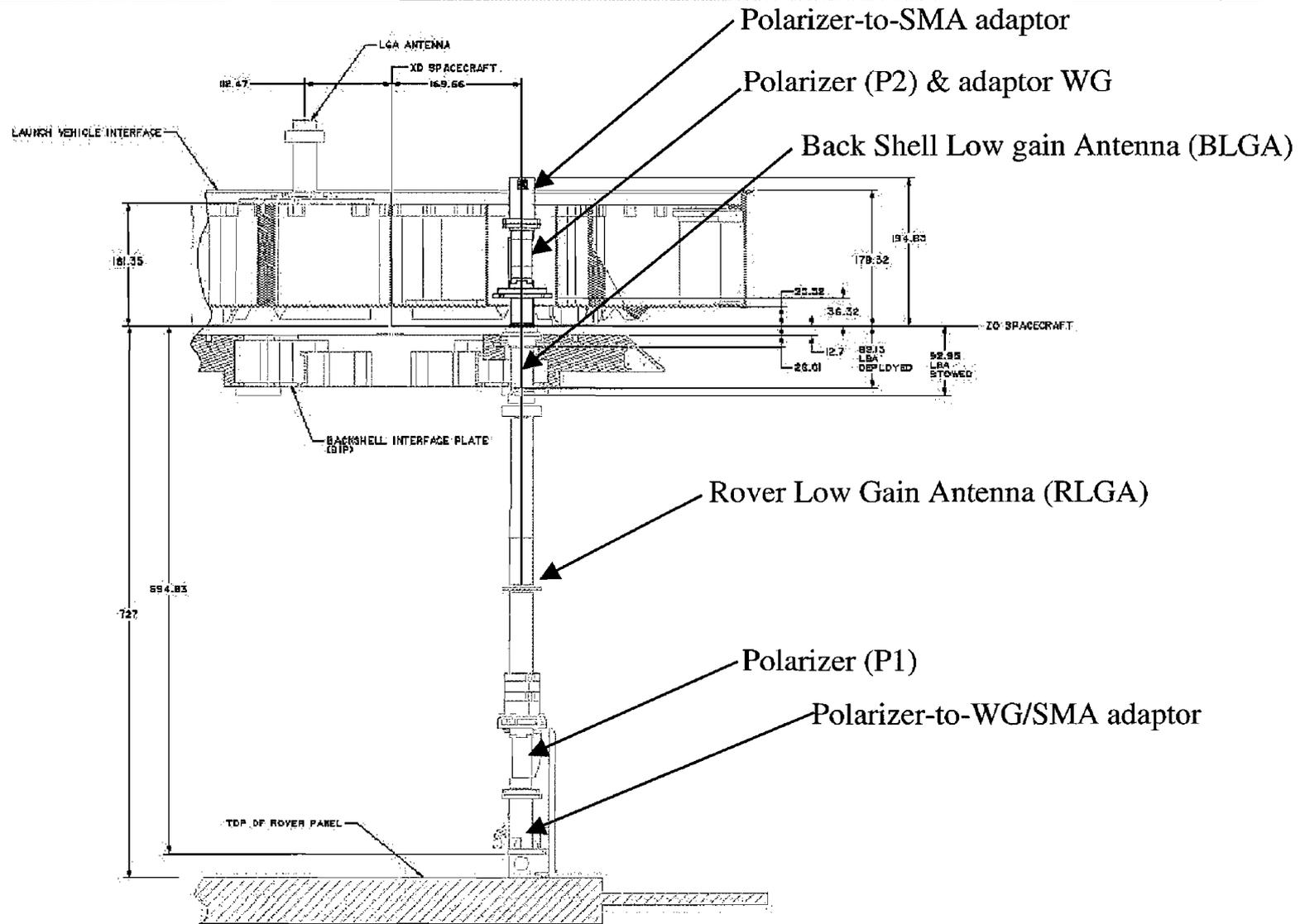


LGA Stack

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Mars Exploration Rovers





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Mars Exploration Rovers

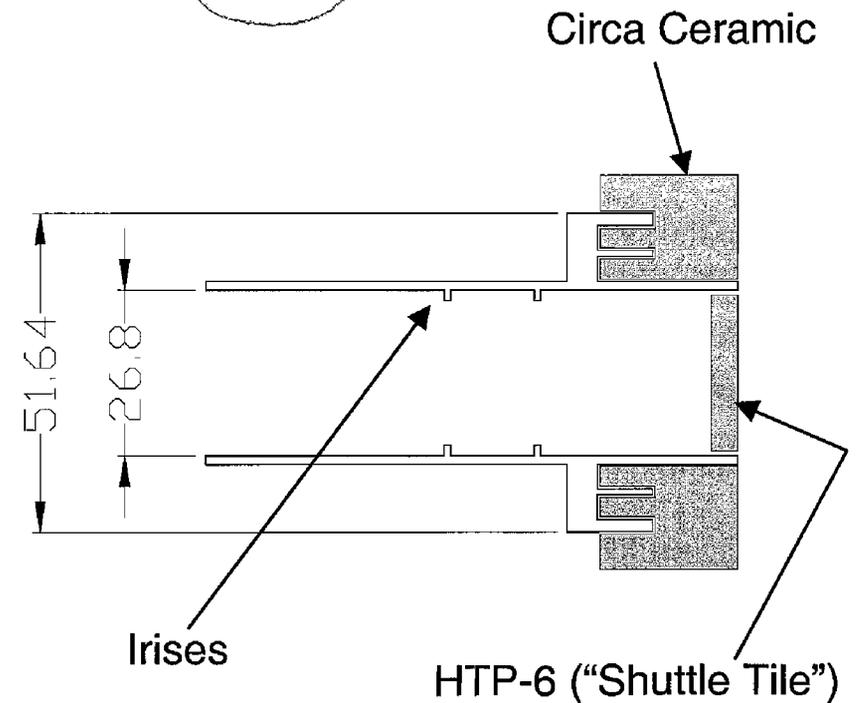
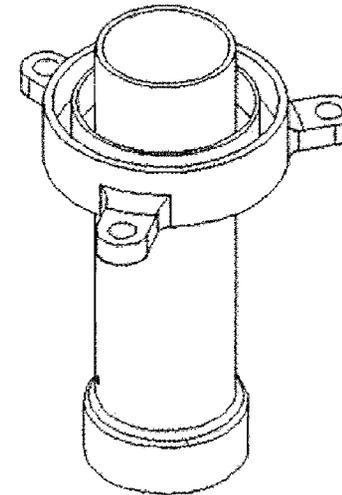
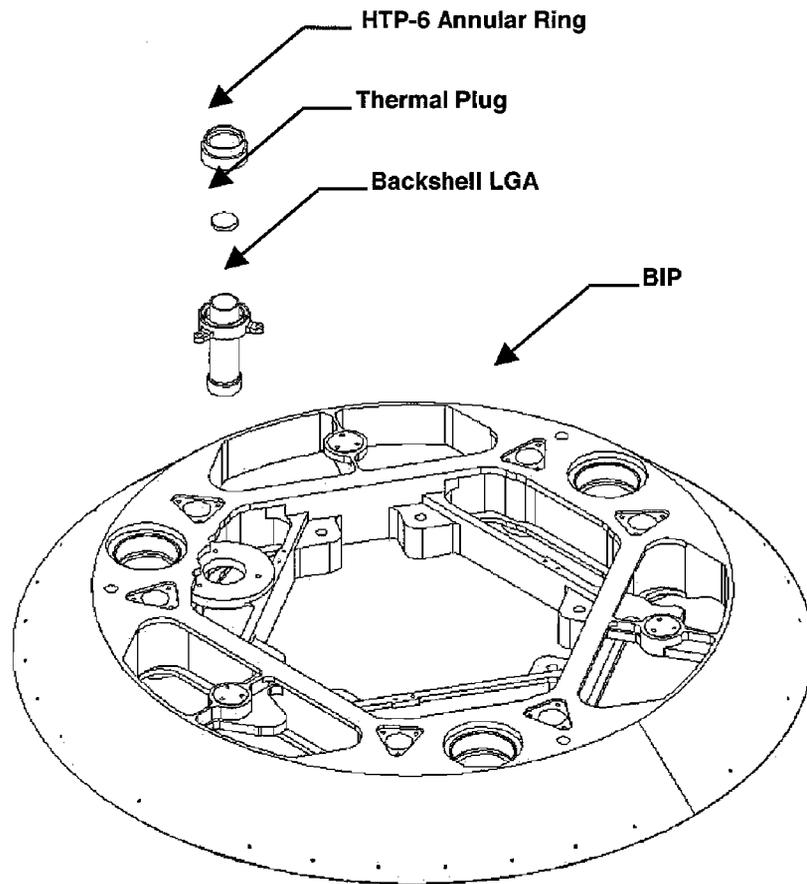
Heat-shield / Back Shell Antenna



Antenna on Backshell Interface Plate



Mars Exploration Rovers



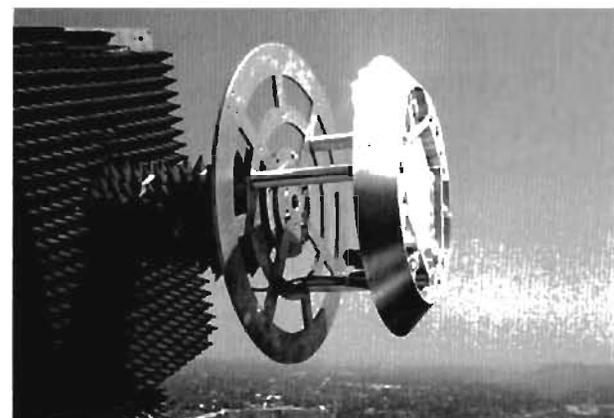
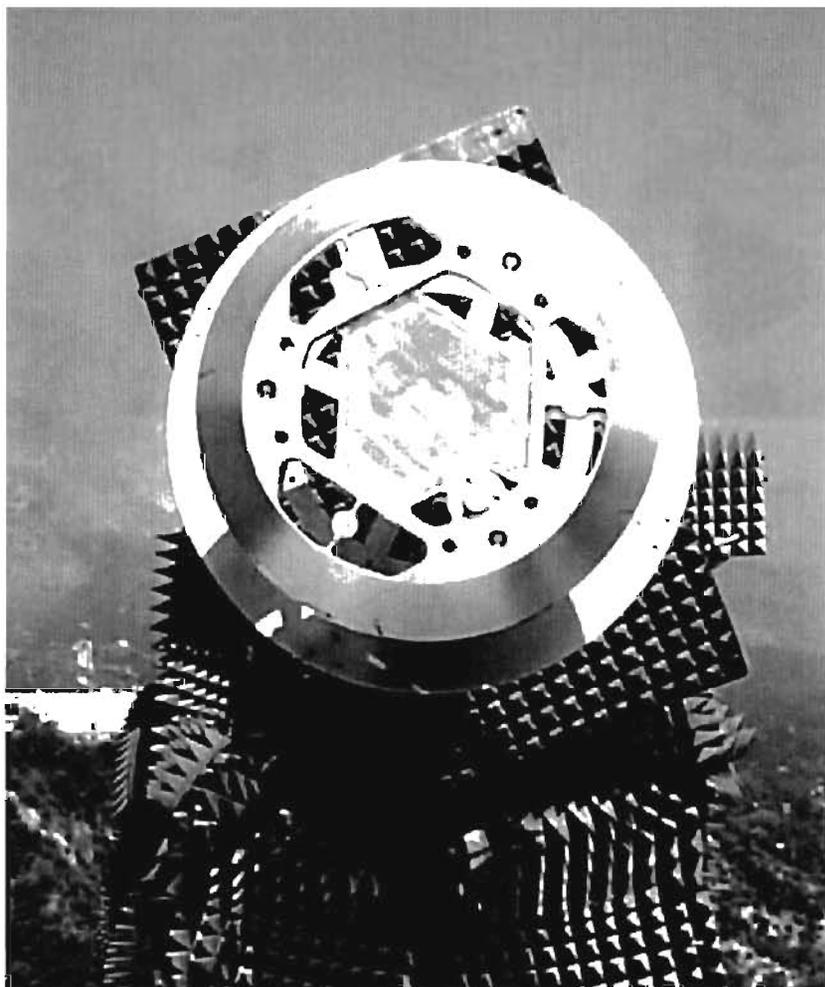


Mock-up of Backshell Interface Plate for Antenna Measurements

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Mars Exploration Rovers



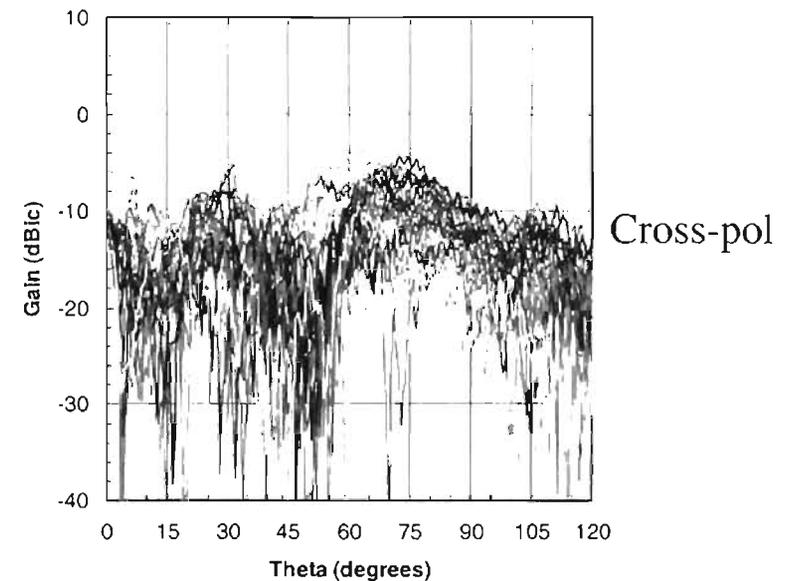
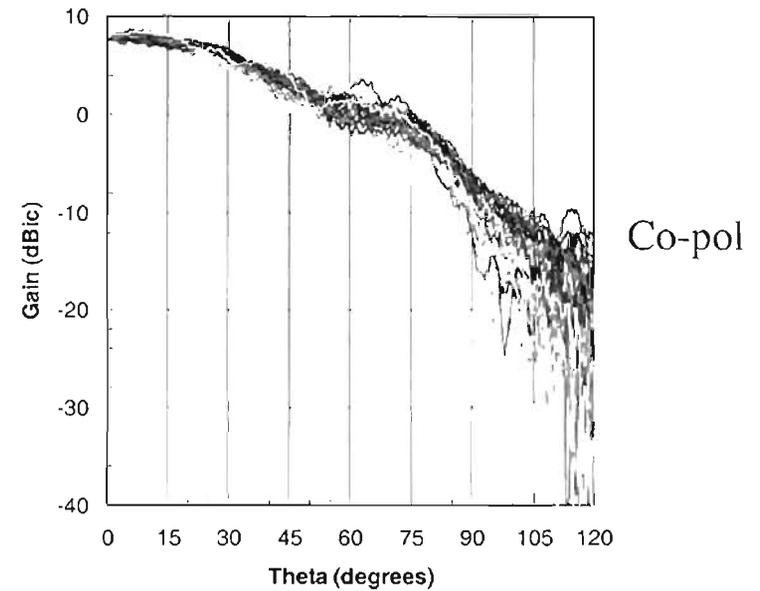
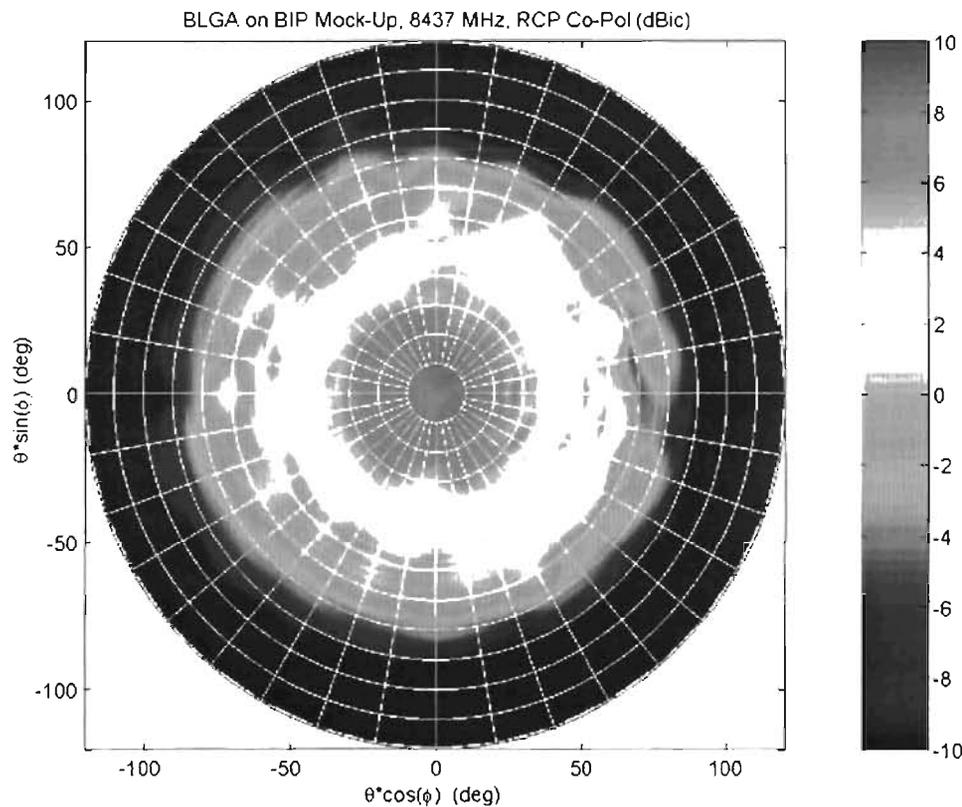


BLGA Radiation Patterns on BIP Mock-up



Mars Exploration Rovers

8437 MHz - Measured Boresight Gain: 7.84 dBic





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Mars Exploration Rovers

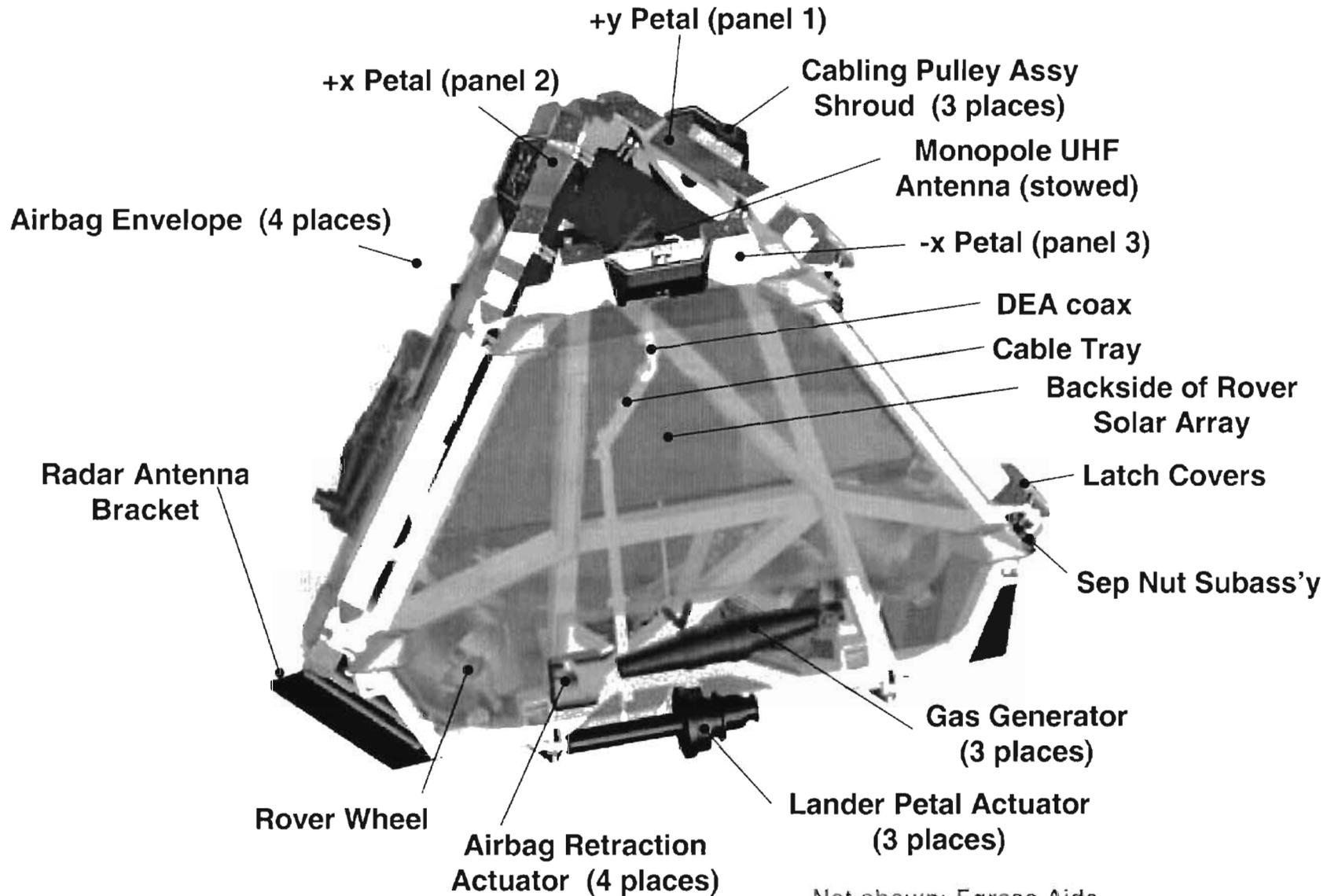
Lander Antennas



Lander Assembly - Stowed



Mars Exploration Rovers

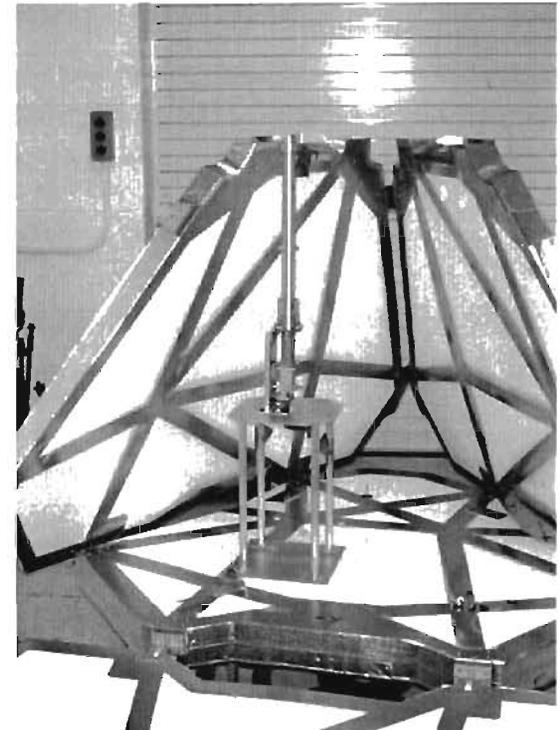
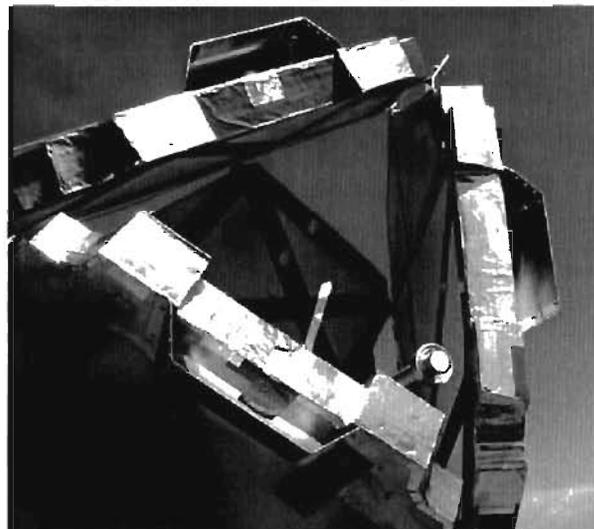
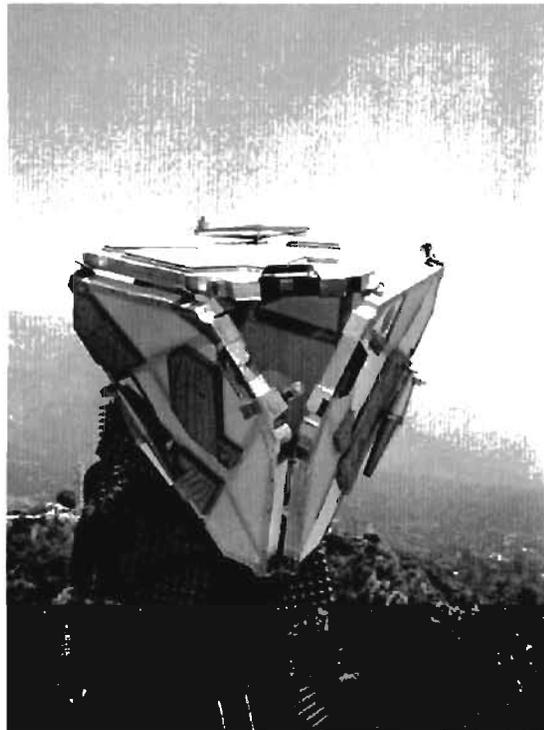




RLGA Measurements on Lander Mock-up



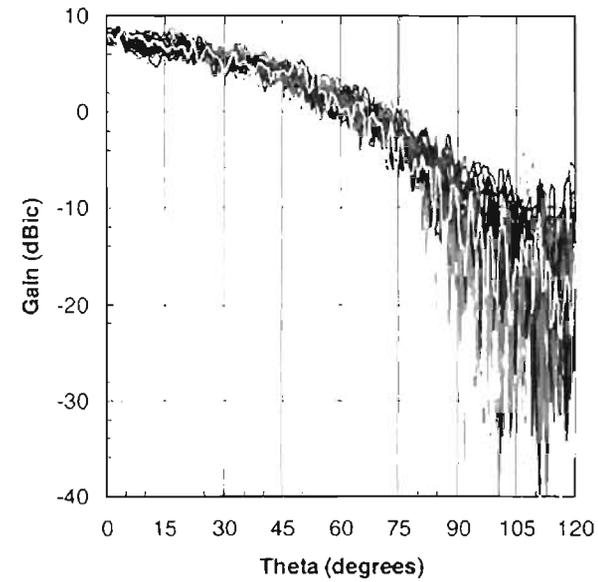
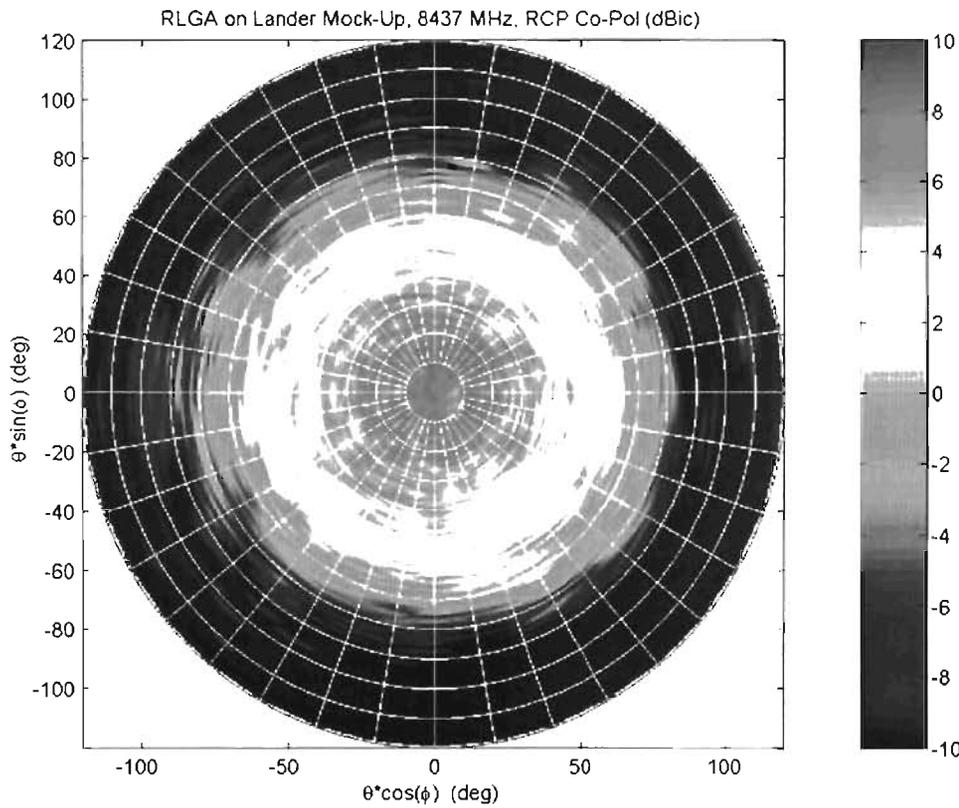
Mars Exploration Rovers



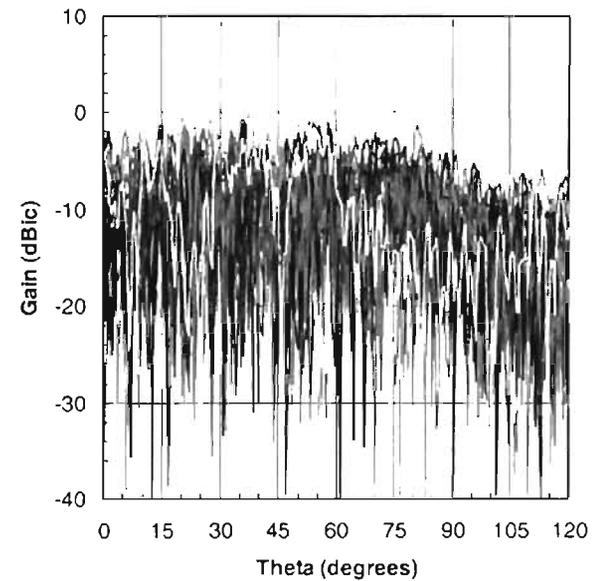


Mars Exploration Rovers

8437 MHz Measured Boresight Gain: 7.87 dBic



Co-pol



Cross-pol

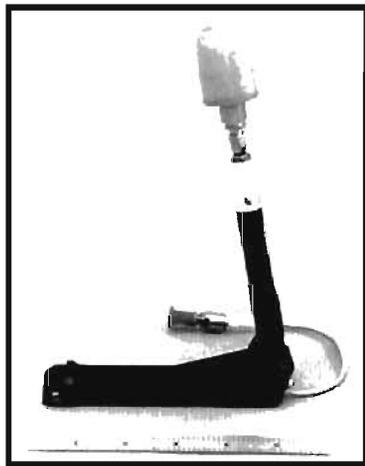


UHF Deployable Decent Entry Antenna

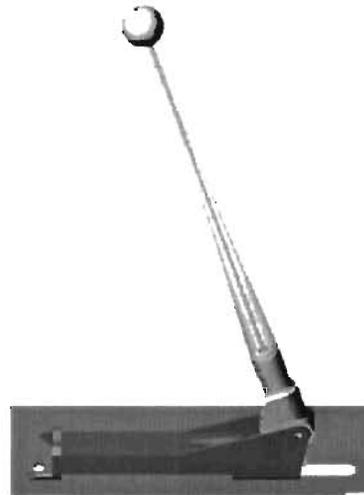


Mars Exploration Rovers

- Based on MPF Deployable X-Band DEA Design
- Converted antenna from X-Band to UHF



Mars Pathfinder X-band Monopole



MER UHF Monopole design



FIG1. MPF X-Band DEA

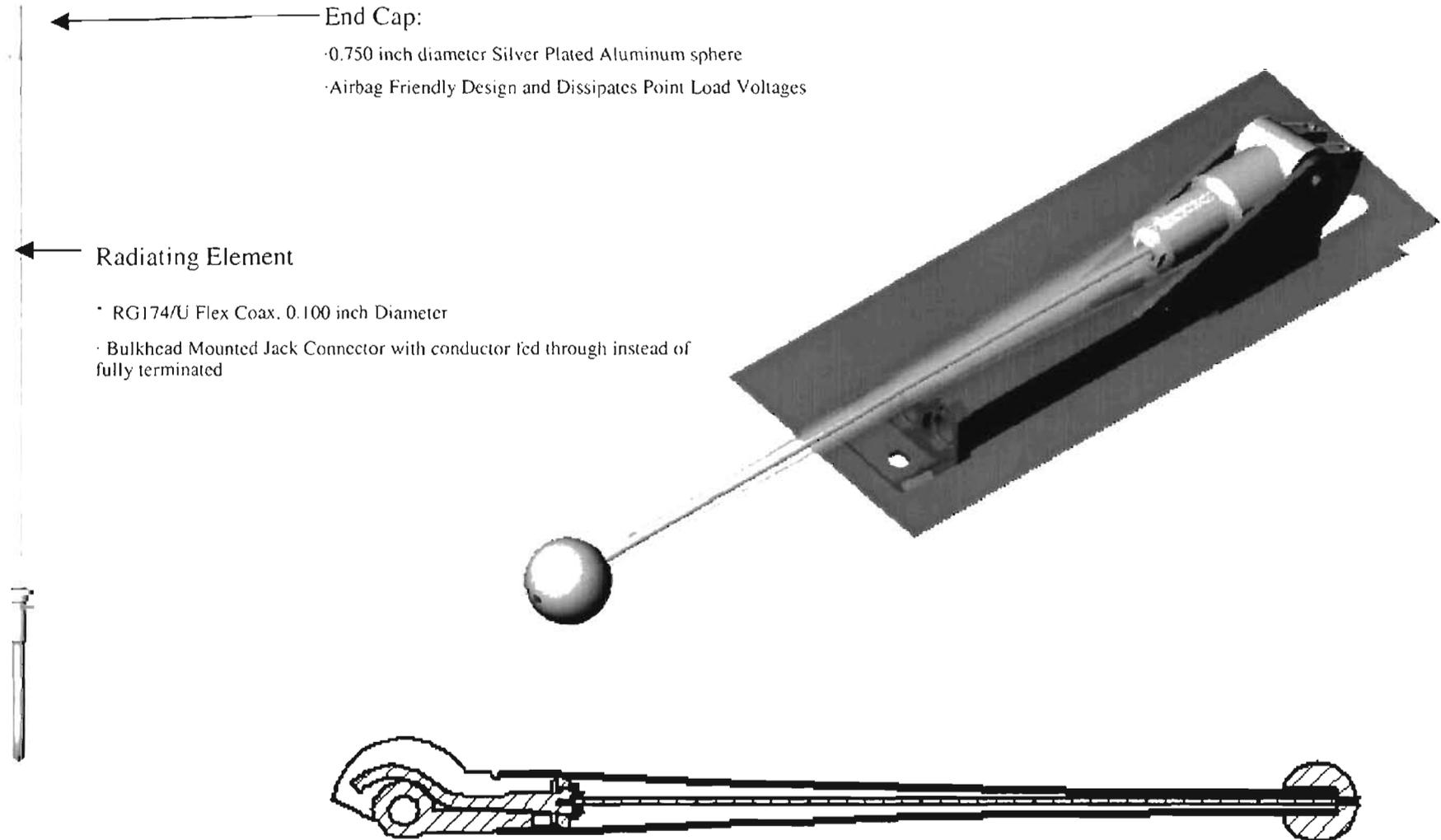


UHF Deployable Decent Entry Antenna

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Mars Exploration Rovers



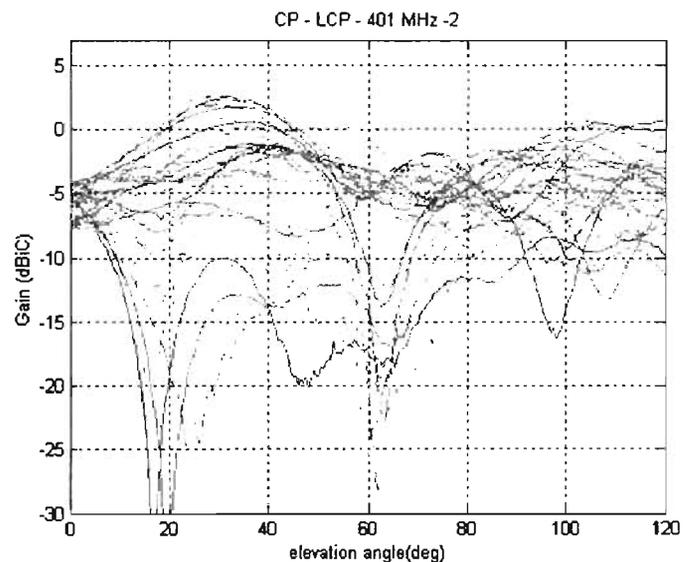
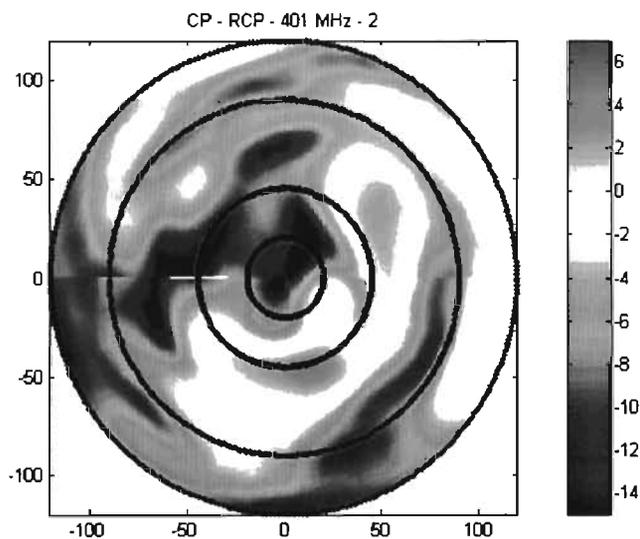
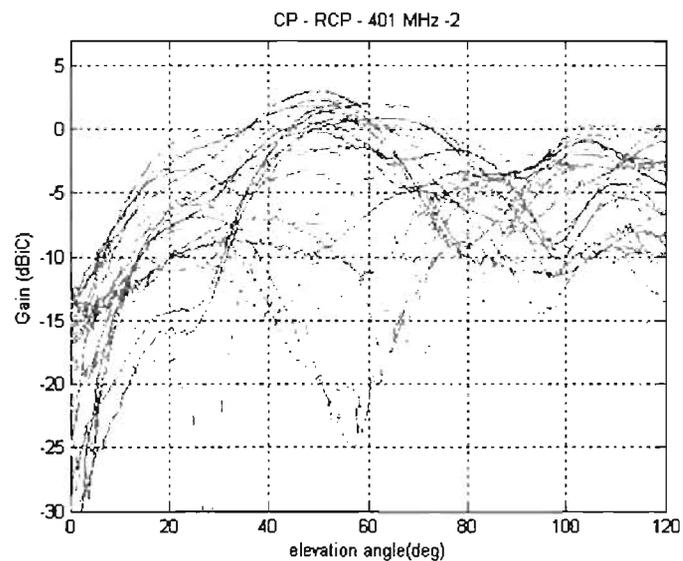
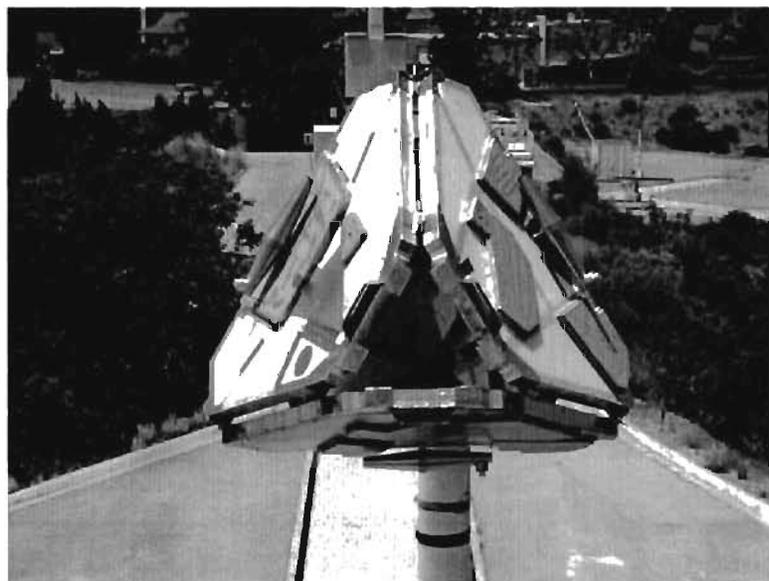


Descent Antenna Radiation Patterns on Lander Mock-up

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Mars Exploration Rovers

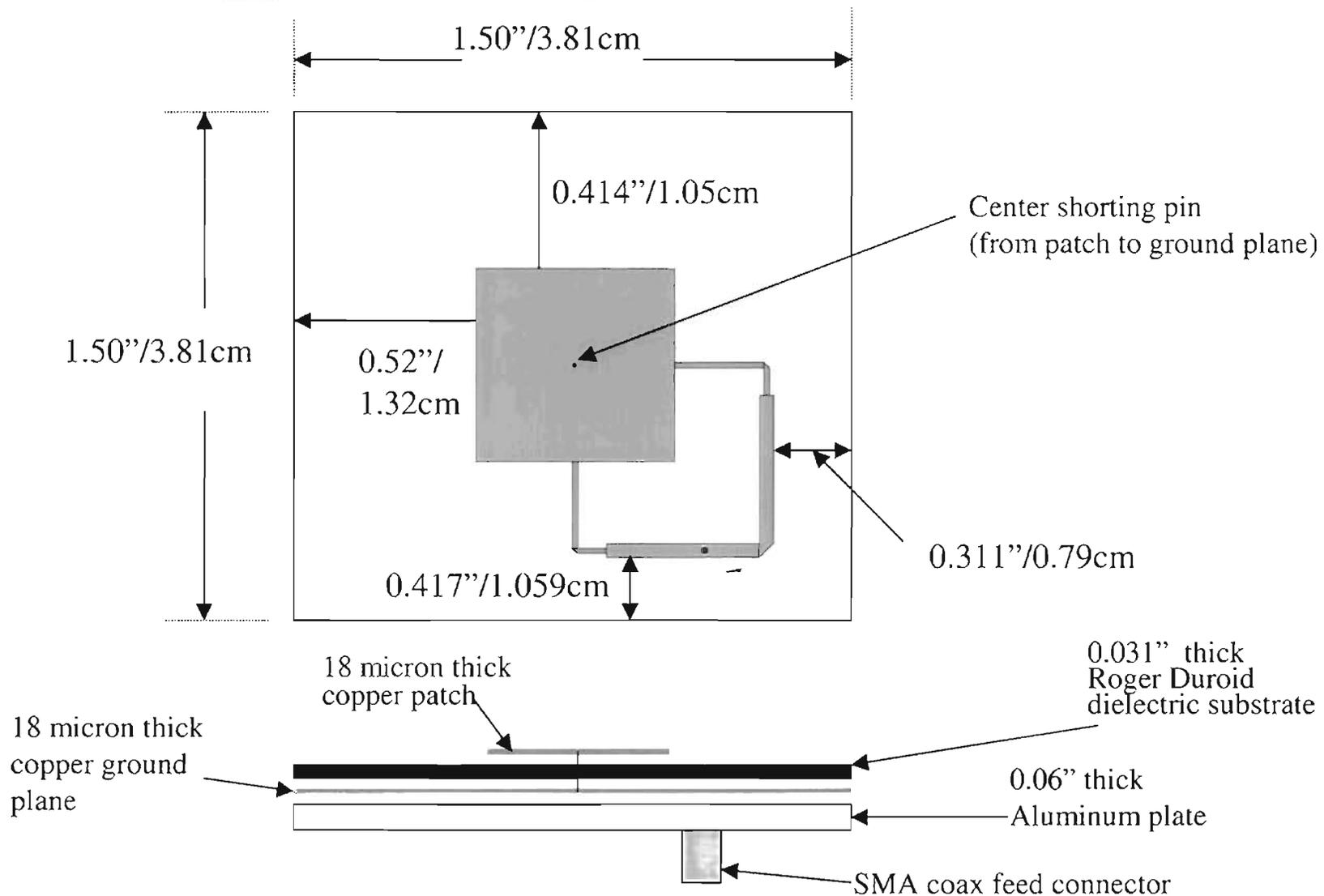




Base Petal Petal Low Gain Antennas, (PLGAs)



Mars Exploration Rovers



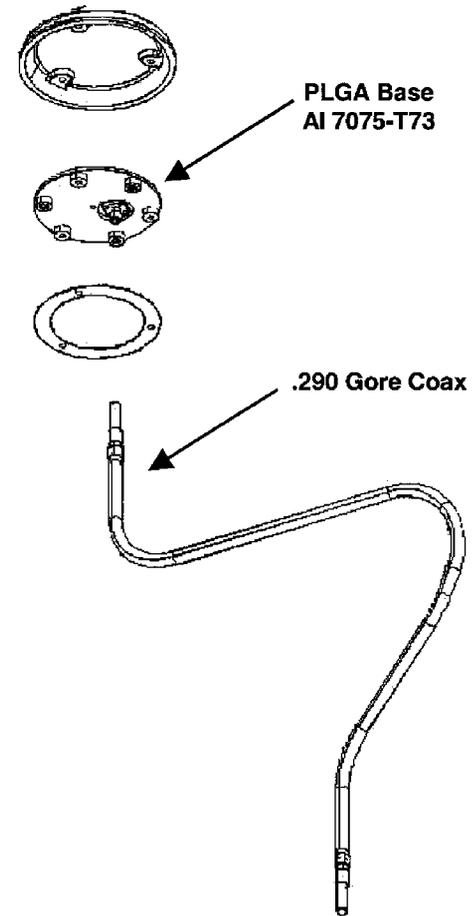
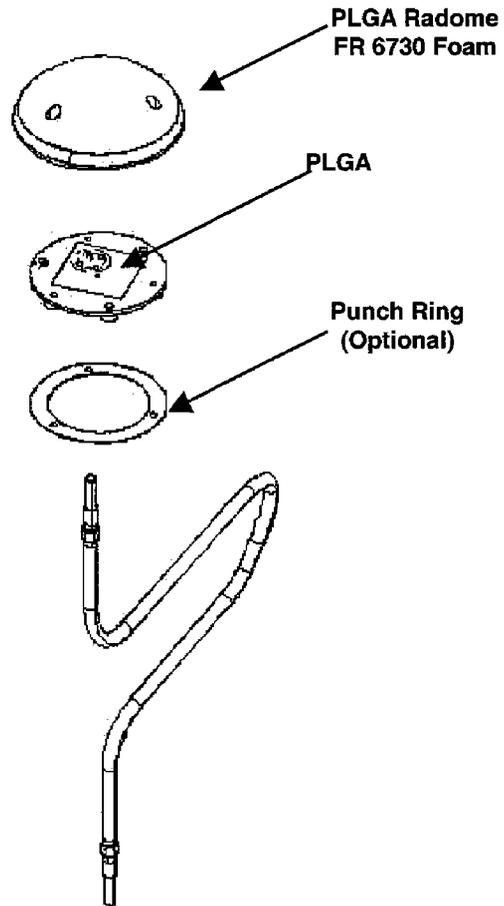


Base Petal Petal Low Gain Antennas, (PLGA)

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Mars Exploration Rovers





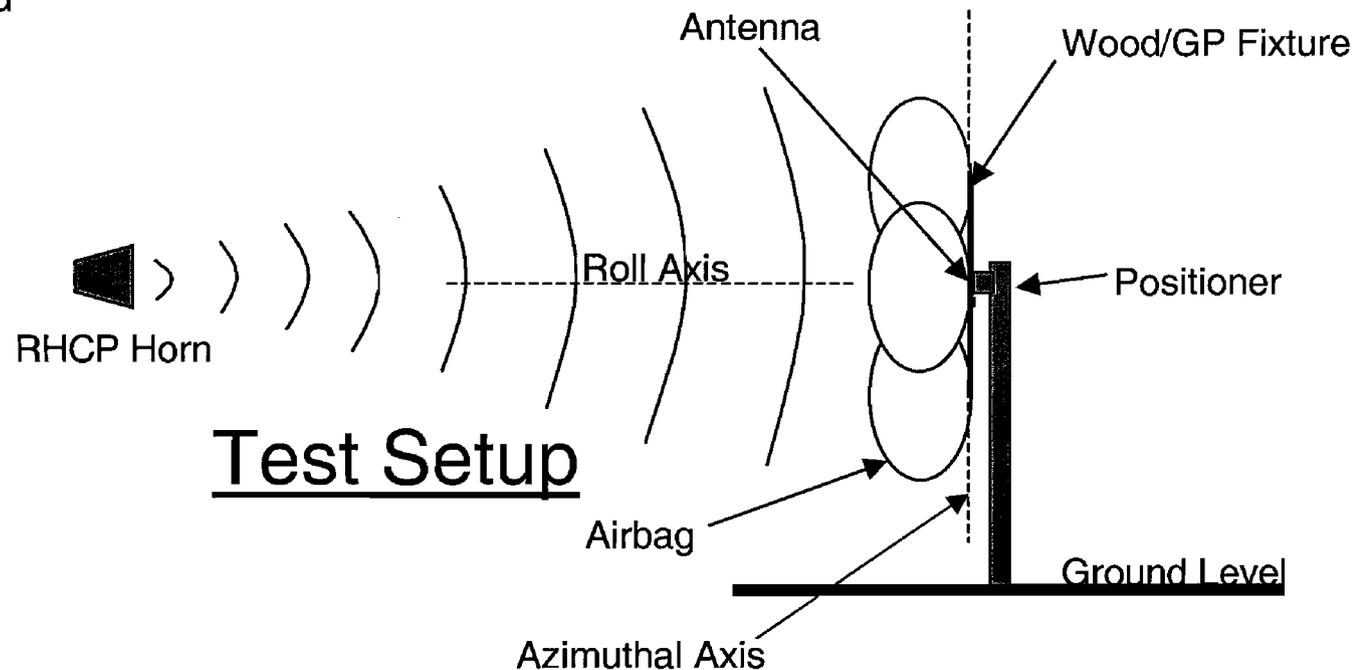
Test Data - Antenna Gain & Pattern

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Mars Exploration Rovers

- Antenna gain is measured on boresight.
 - Without Airbag
 - Airbag stowed
 - Inflated
 - Deflated
- Antenna radiation patterns are measured over +/- 90 degrees Az
 - Without Airbag
 - Airbag stowed
 - Inflated
 - Deflated

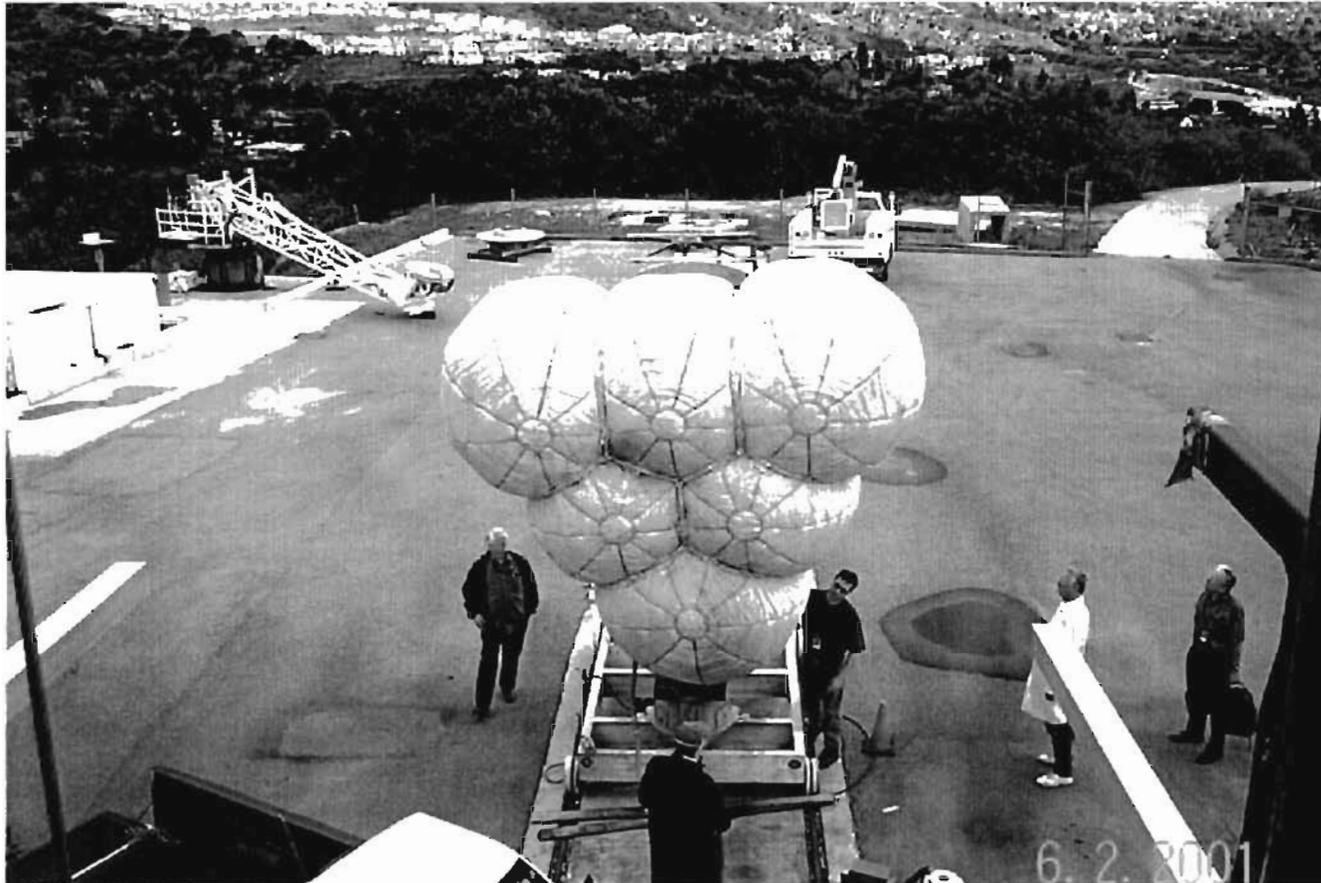




Test Article - Airbag



Mars Exploration Rovers

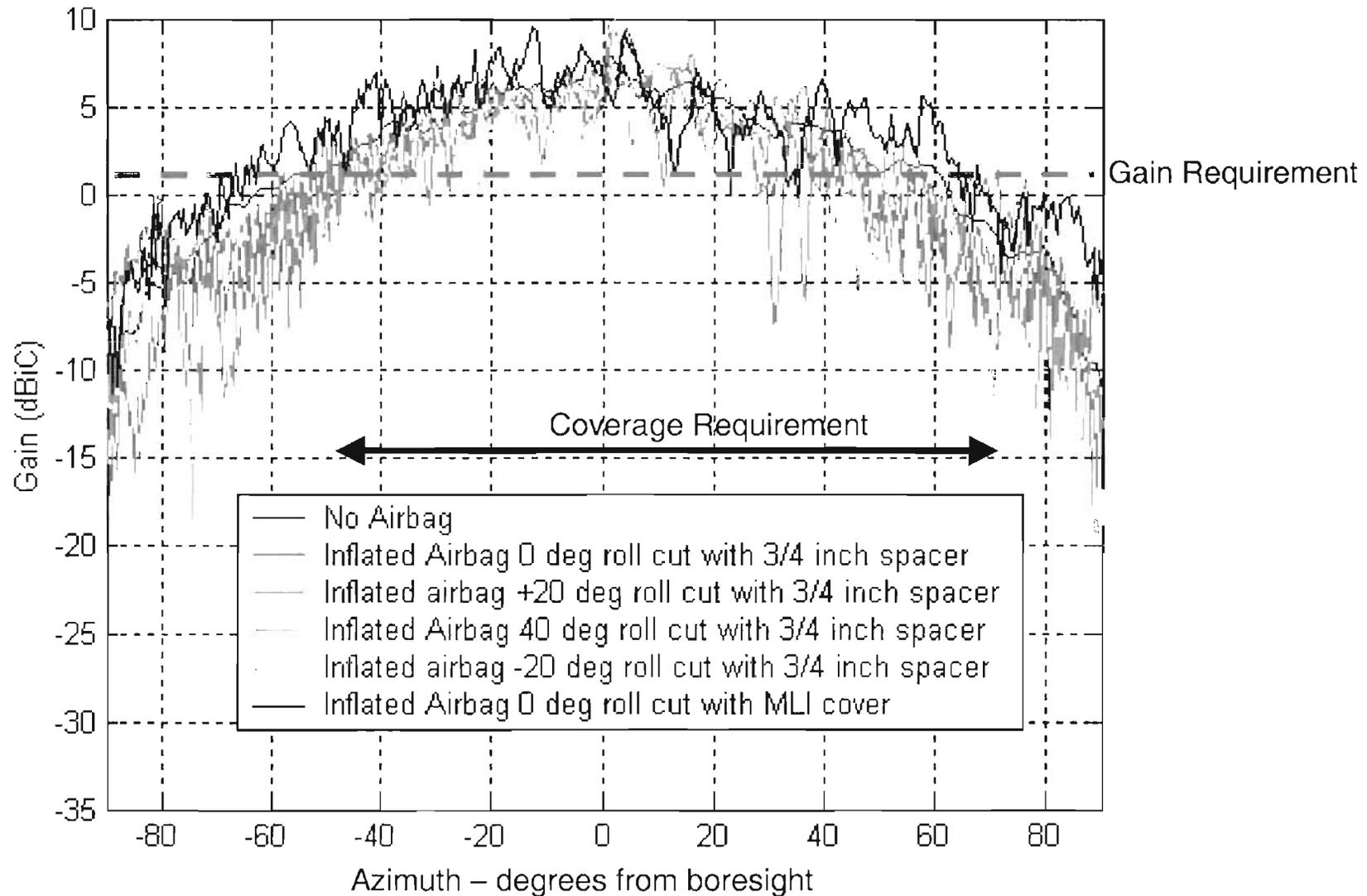




Measured Pattern/Gain Data Inflated Airbag



Mars Exploration Rovers





Deflated Airbag Over Antenna

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Mars Exploration Rovers



2 Folds



4 Folds



5+ Folds



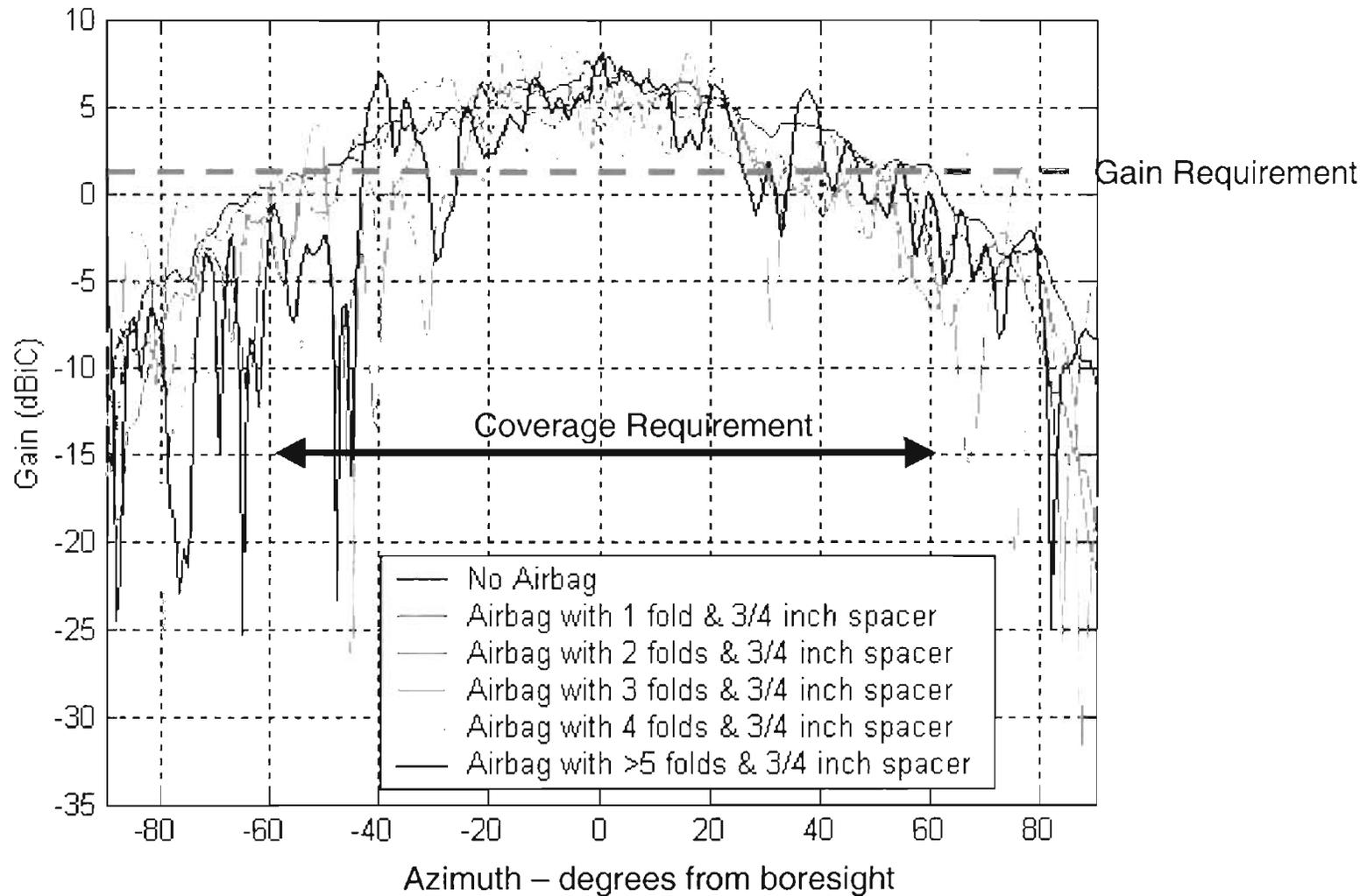
Packed w/ MLI Cover



Measured Pattern/Gain Data Deflated Airbag



Mars Exploration Rovers

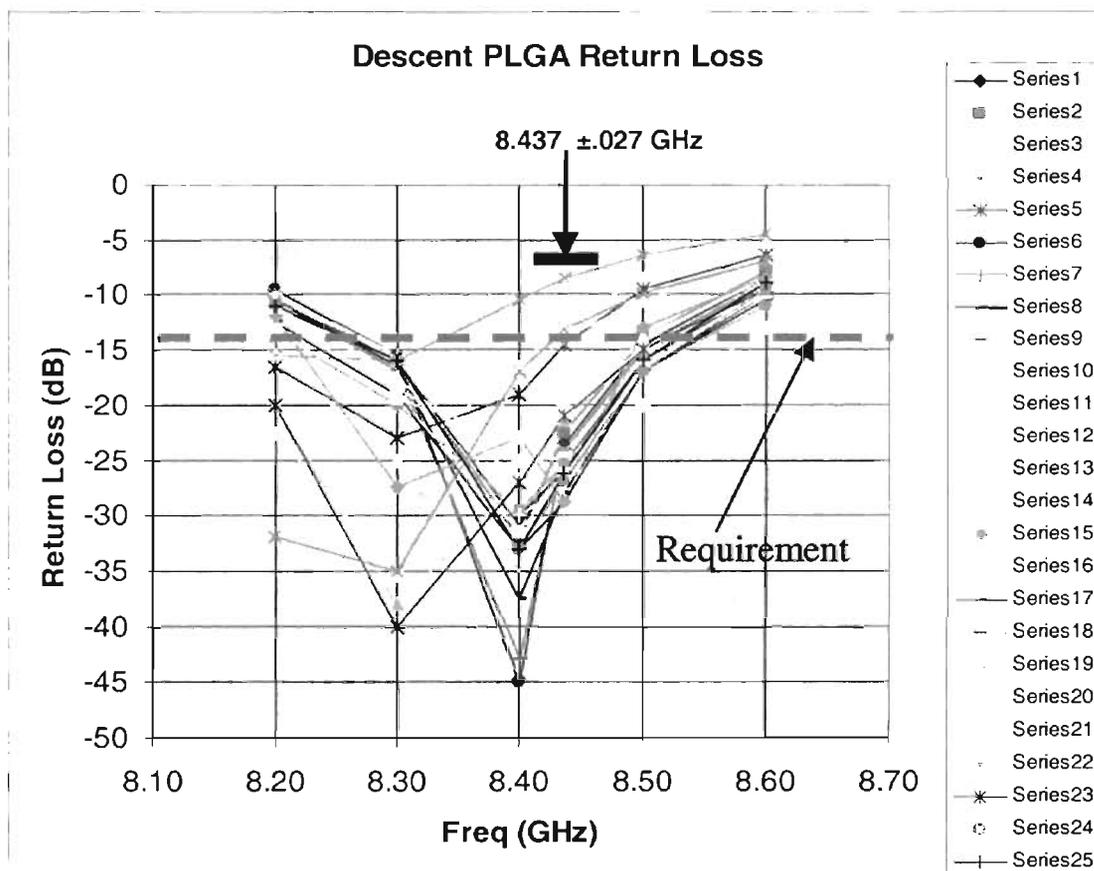




Return Loss w/ & w/o Airbag



Mars Exploration Rovers



Data Series	Bag	Configuration
1	None	
2		w/ 3" Spacer & Cover
3	Inflated	
4		
5		
6		w/ 3" Spacer
7	Deflated	1 Fold
8		1 Fold w/ 3" Spacer & Cover
9		1 Fold w/ 3" Spacer & Cover
10		2 Folds
11		2 Folds w/ Cover
12		
13		2 Folds w/ 3" Spacer
14		3 Folds
15		
16		3 Folds w/ 3" Spacer
17		3 Folds w/ Cover
18		3 Folds w/ 3" Spacer & Cover
19		Packed
20		
21		
22		Packed w/ Cover
23		
24		Packed w/ 3" Spacer & Cover
25		Packed w/ 3" Spacer



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Mars Exploration Rovers

Rover Antennas

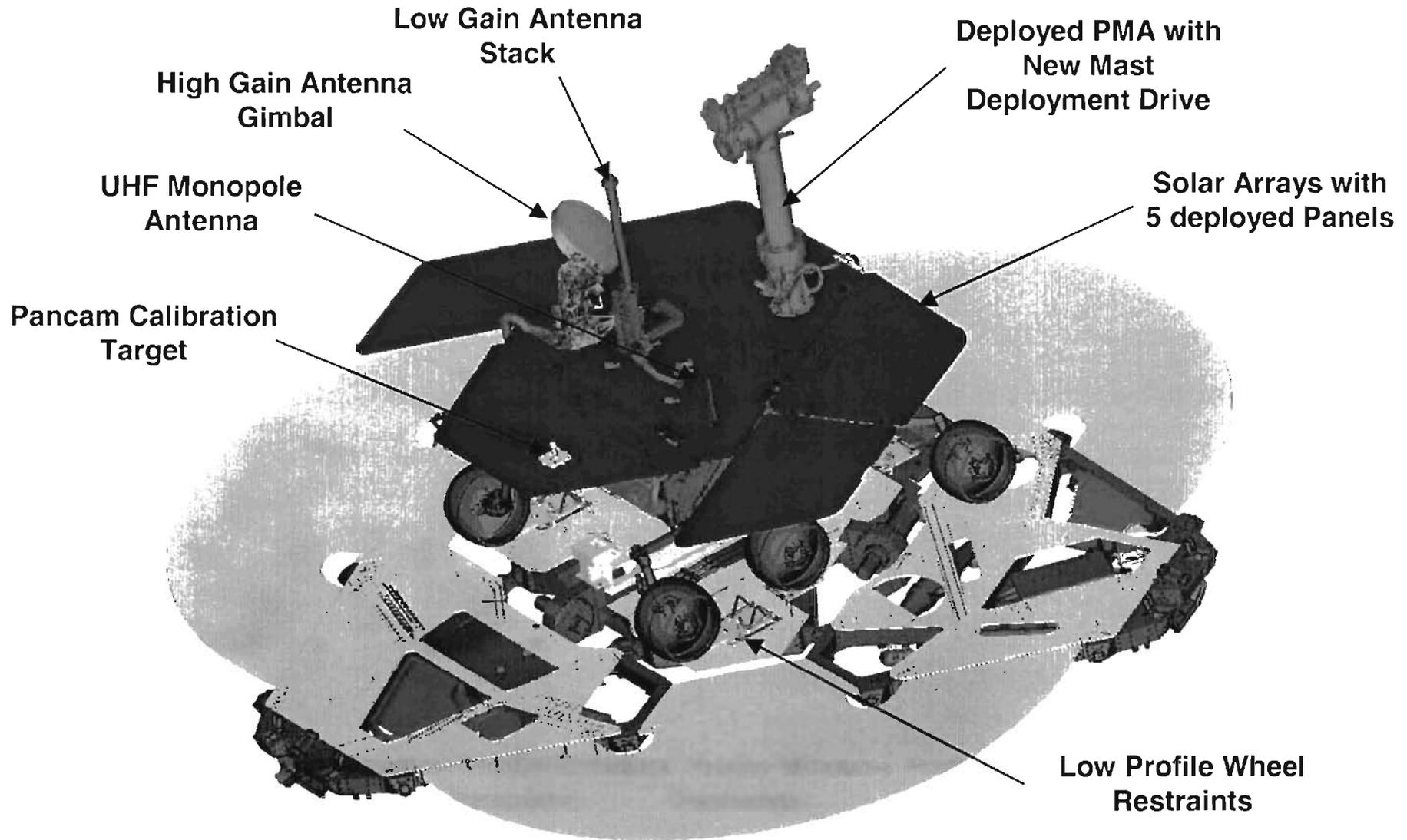


Deployed Rover on the Lander

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Mars Exploration Rovers



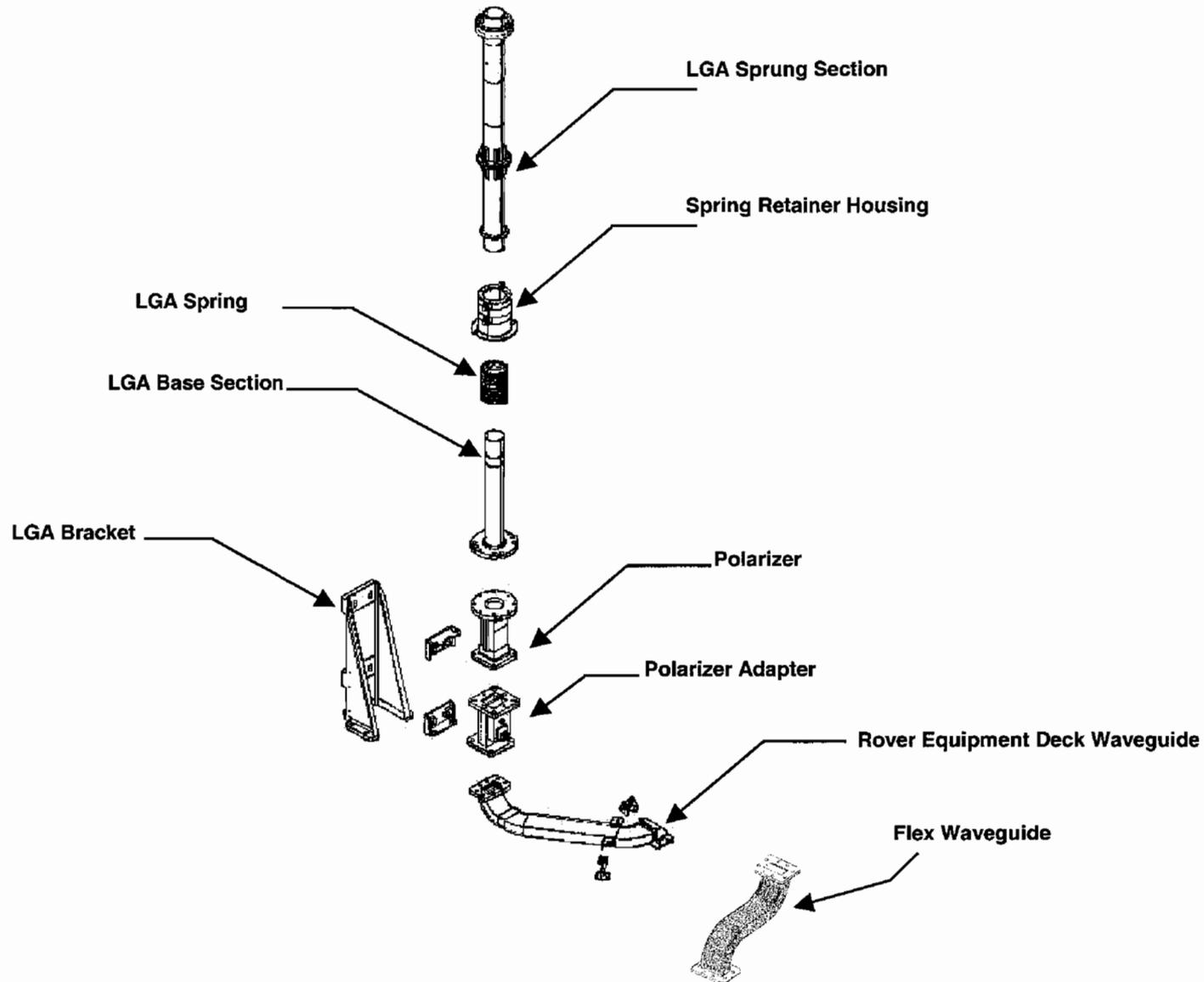


Rover Low Gain Antenna (RLGA)

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Mars Exploration Rovers





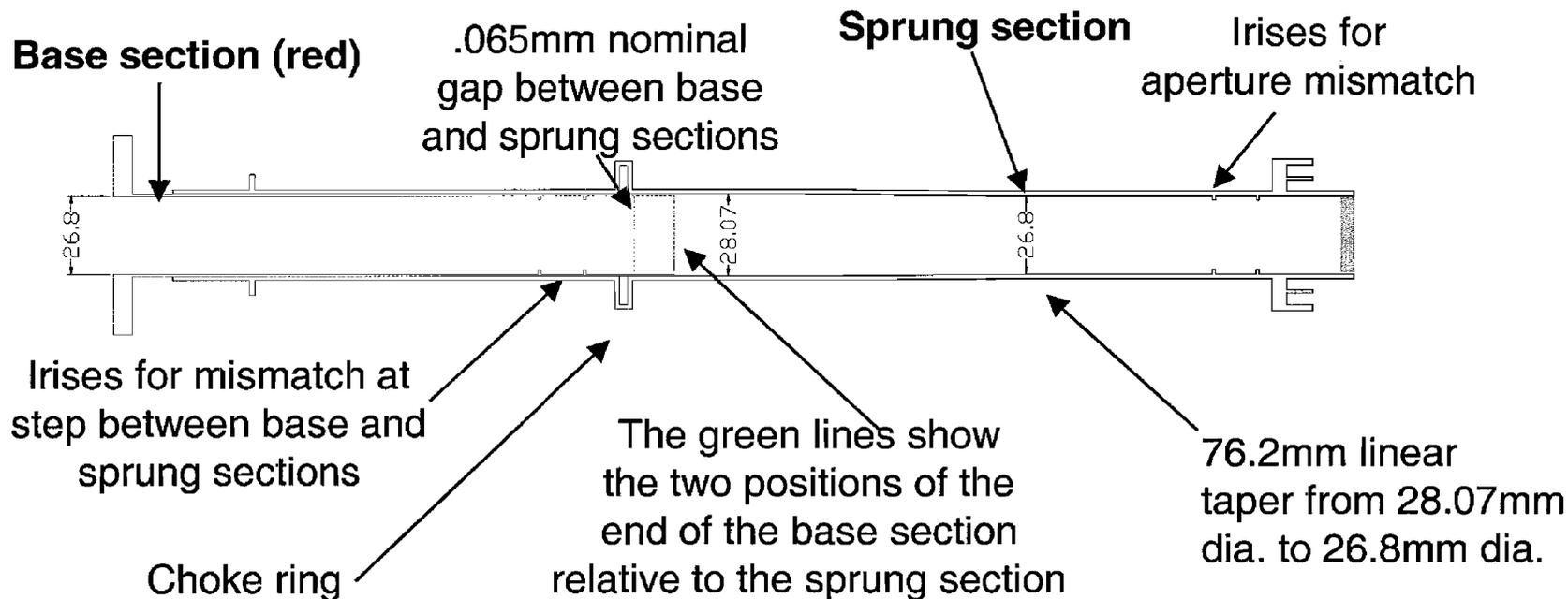
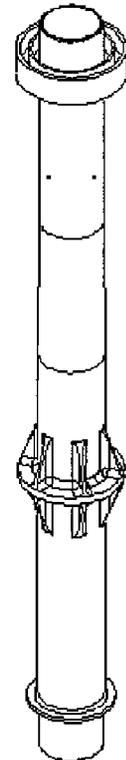
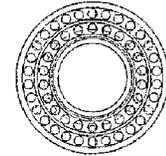
Rover Low Gain Antenna (RLGA)

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Mars Exploration Rovers

- The RLGA consists of a base and a sprung section
 - The sprung section slides over the base section, and has two different positions during operation
- A choke was added to reduce the amount of RF energy that could couple through the gap between the base and sprung sections
- Irises were added to improve the match at the step between the base and sprung sections from -22.5 dB to -40 dB in the low frequency band



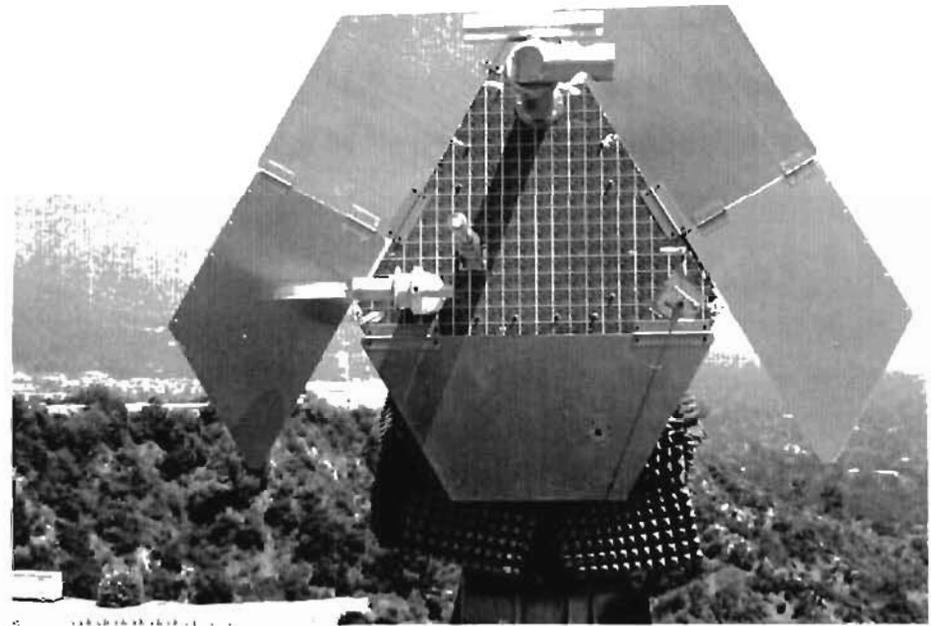
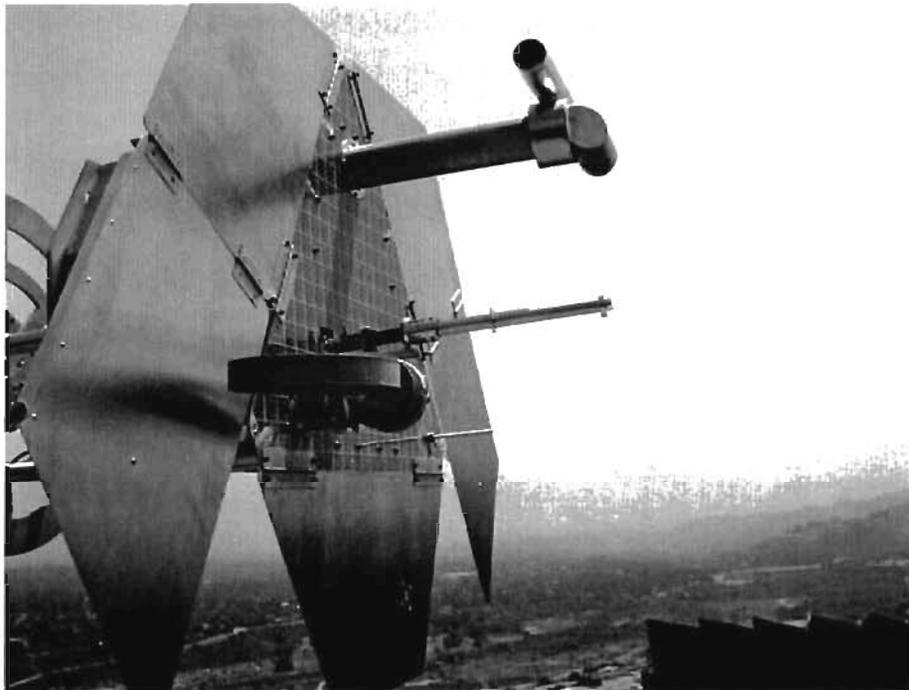


RLGA on Mock-up of Rover

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Mars Exploration Rovers

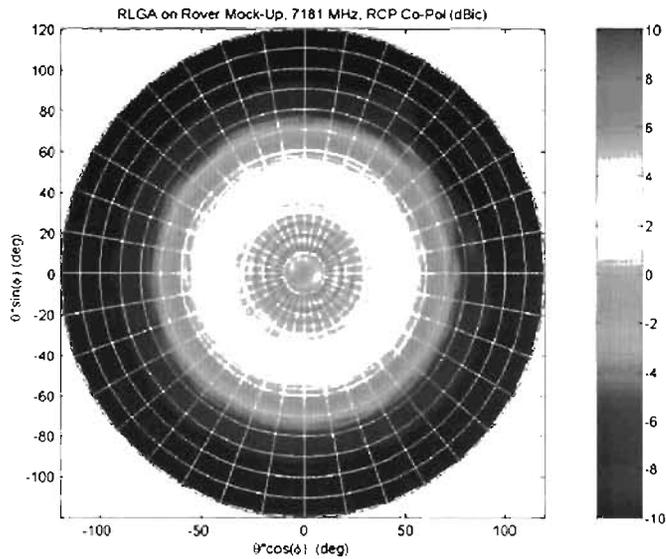




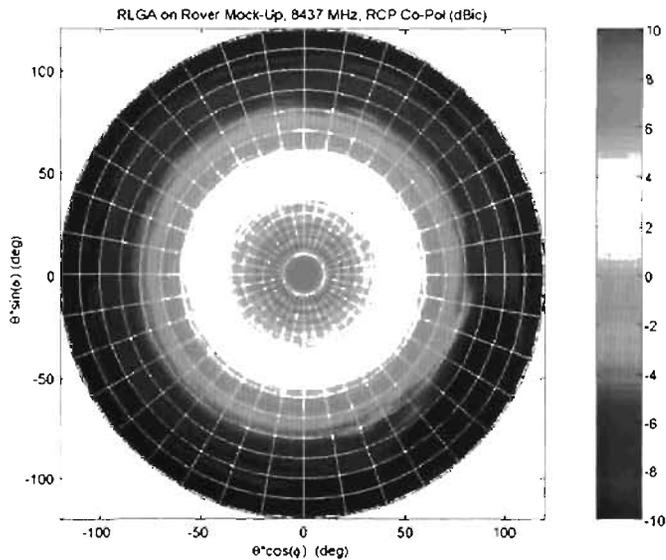
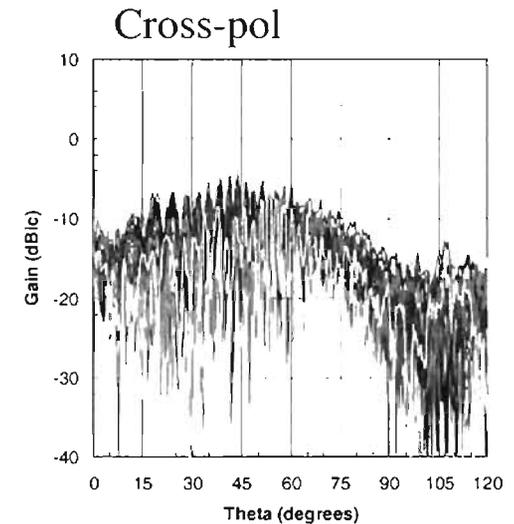
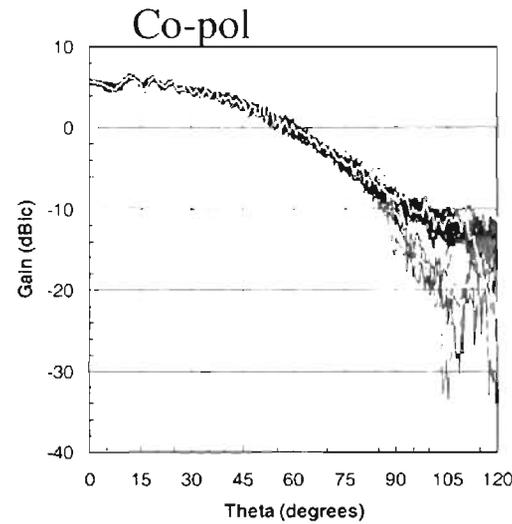
Antenna Patterns for RLGA on Rover Mock-up



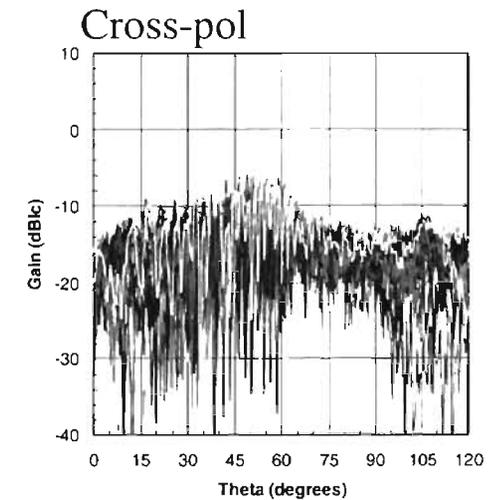
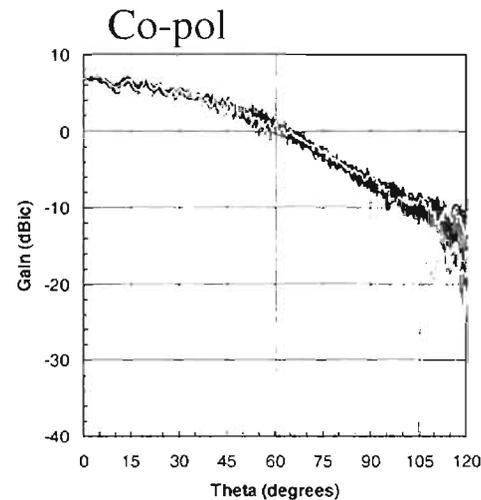
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7181 MHz - Measured Boresight Gain: 5.73 dBic



8437 MHz - Measured Boresight Gain: 6.85 dBic



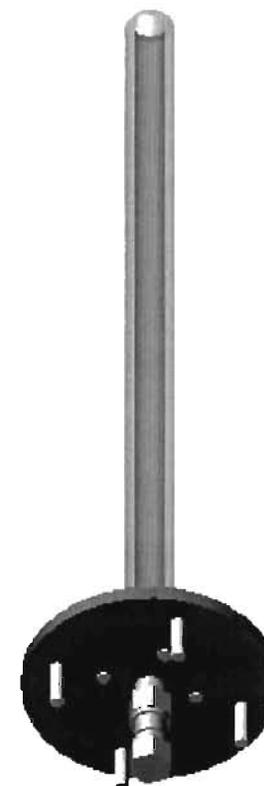
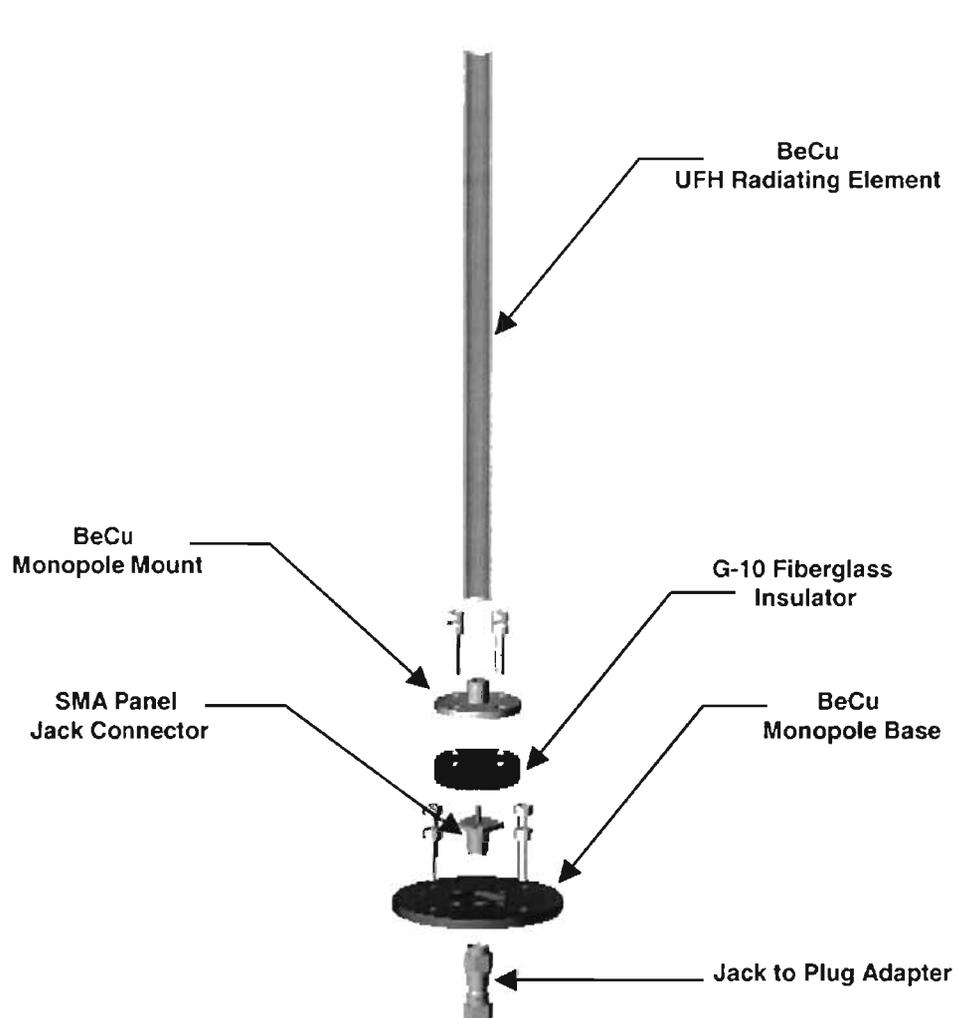


Rover UHF Monopole

JPL



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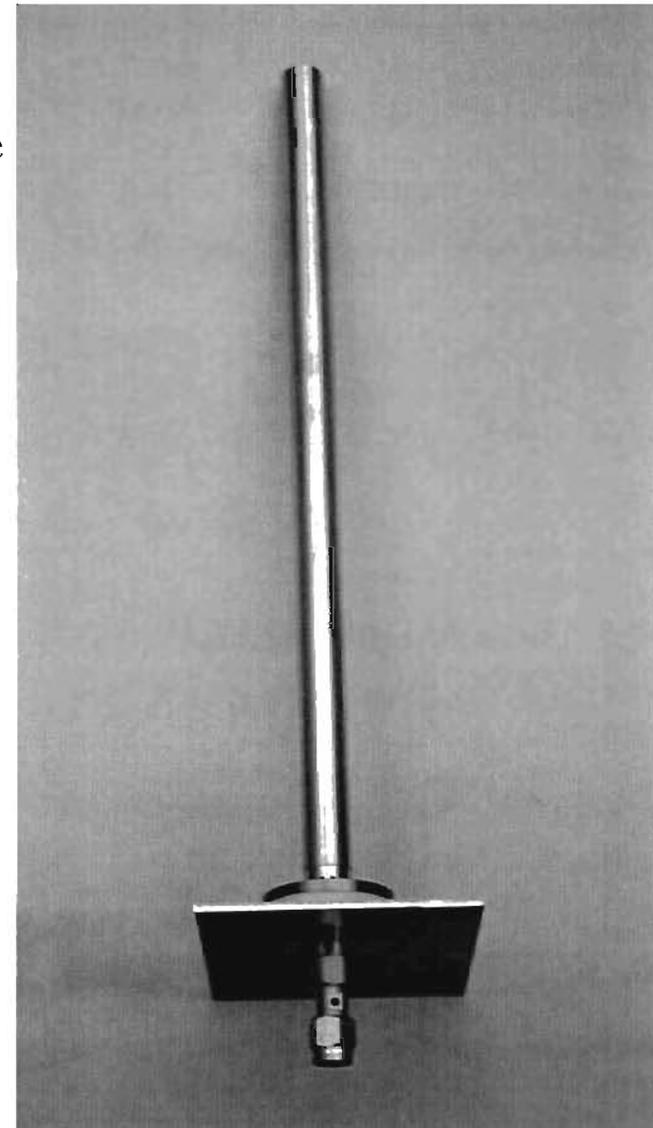
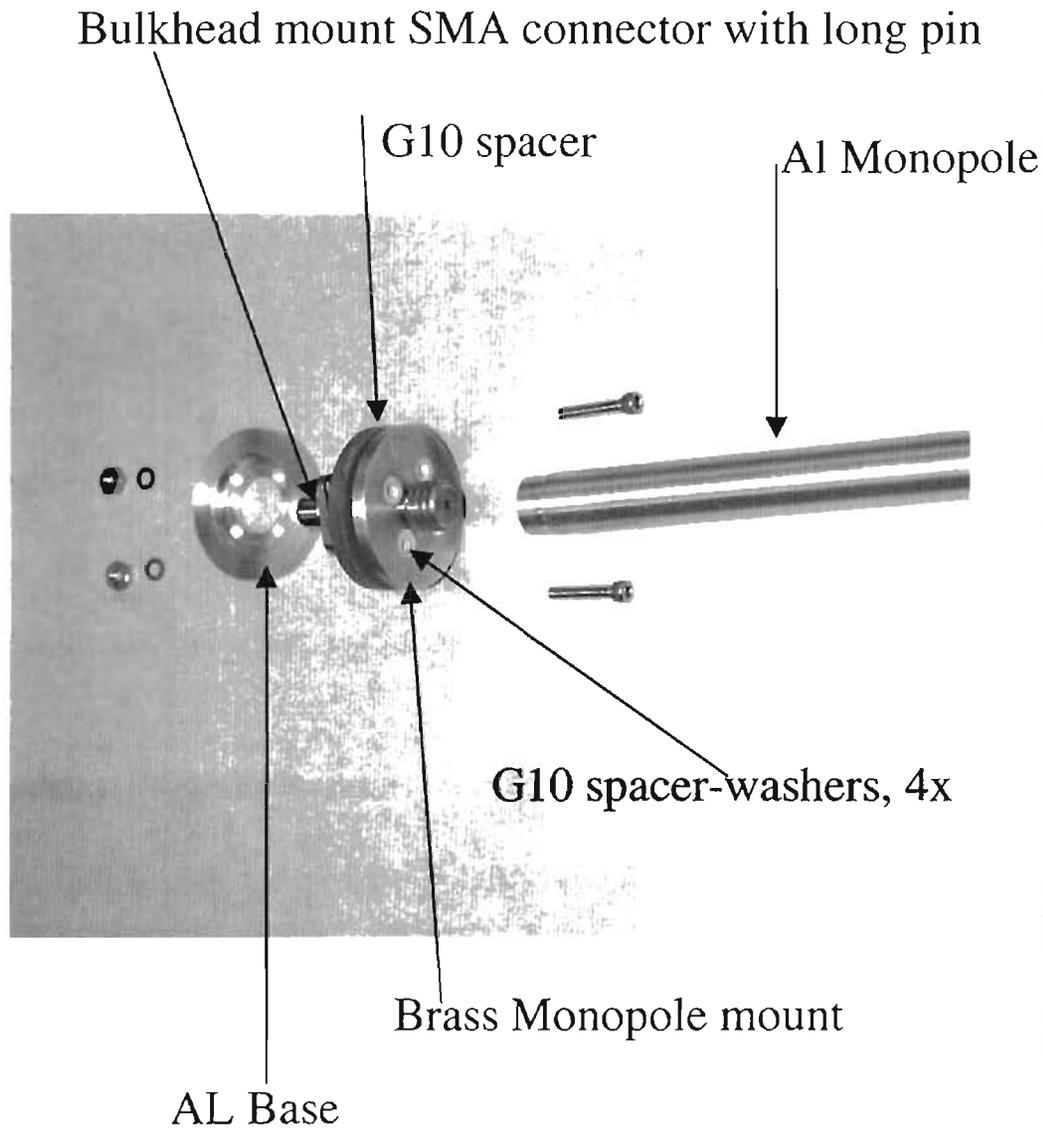




Engineering Model of Rover Monopole



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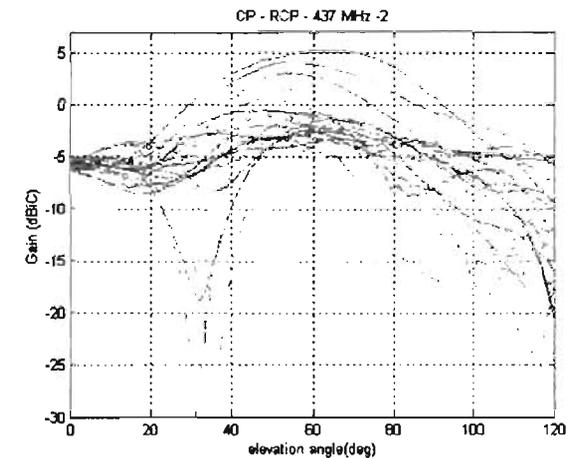
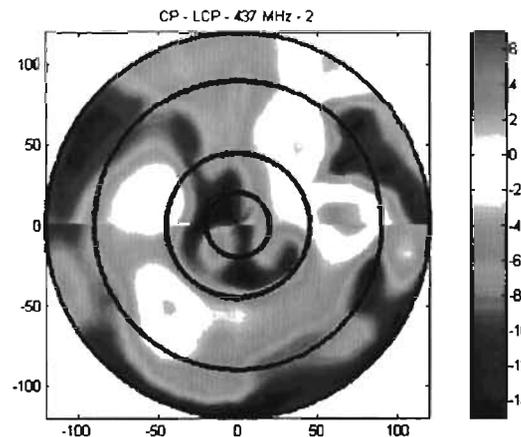
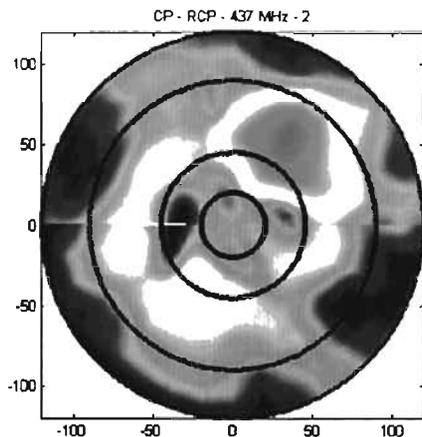
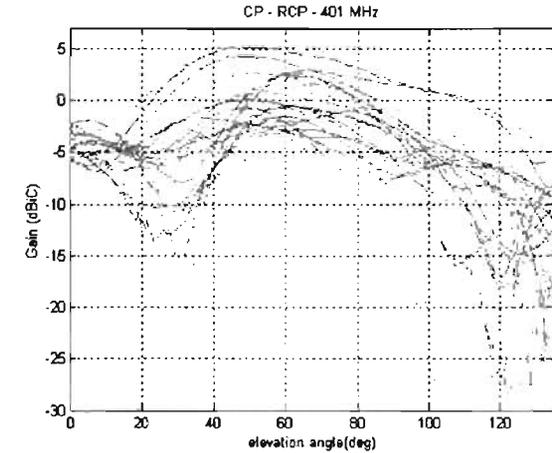
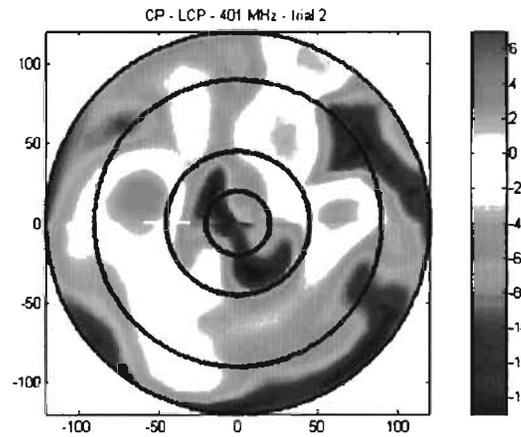
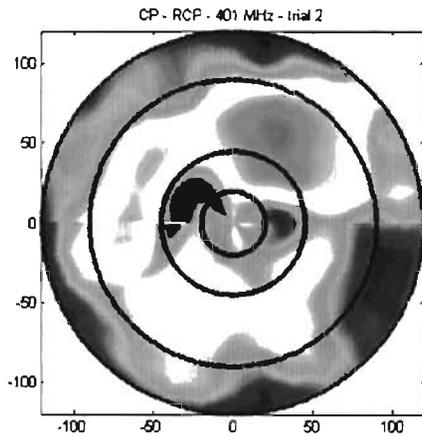


Radiation Patterns of Rover UHF Antenna on Rover Mock-up

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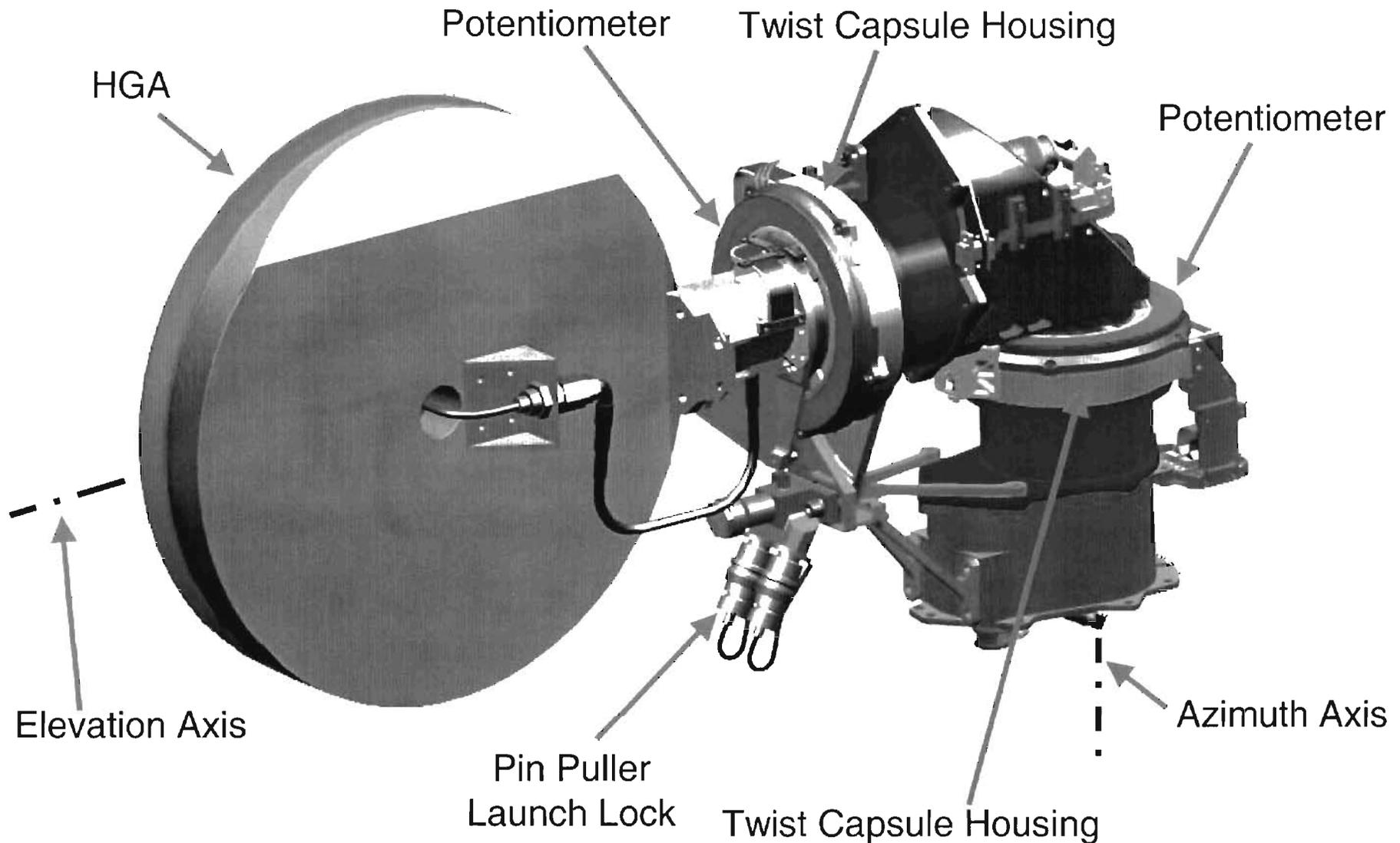




High Gain Antenna Assembly (HGAA) Overview



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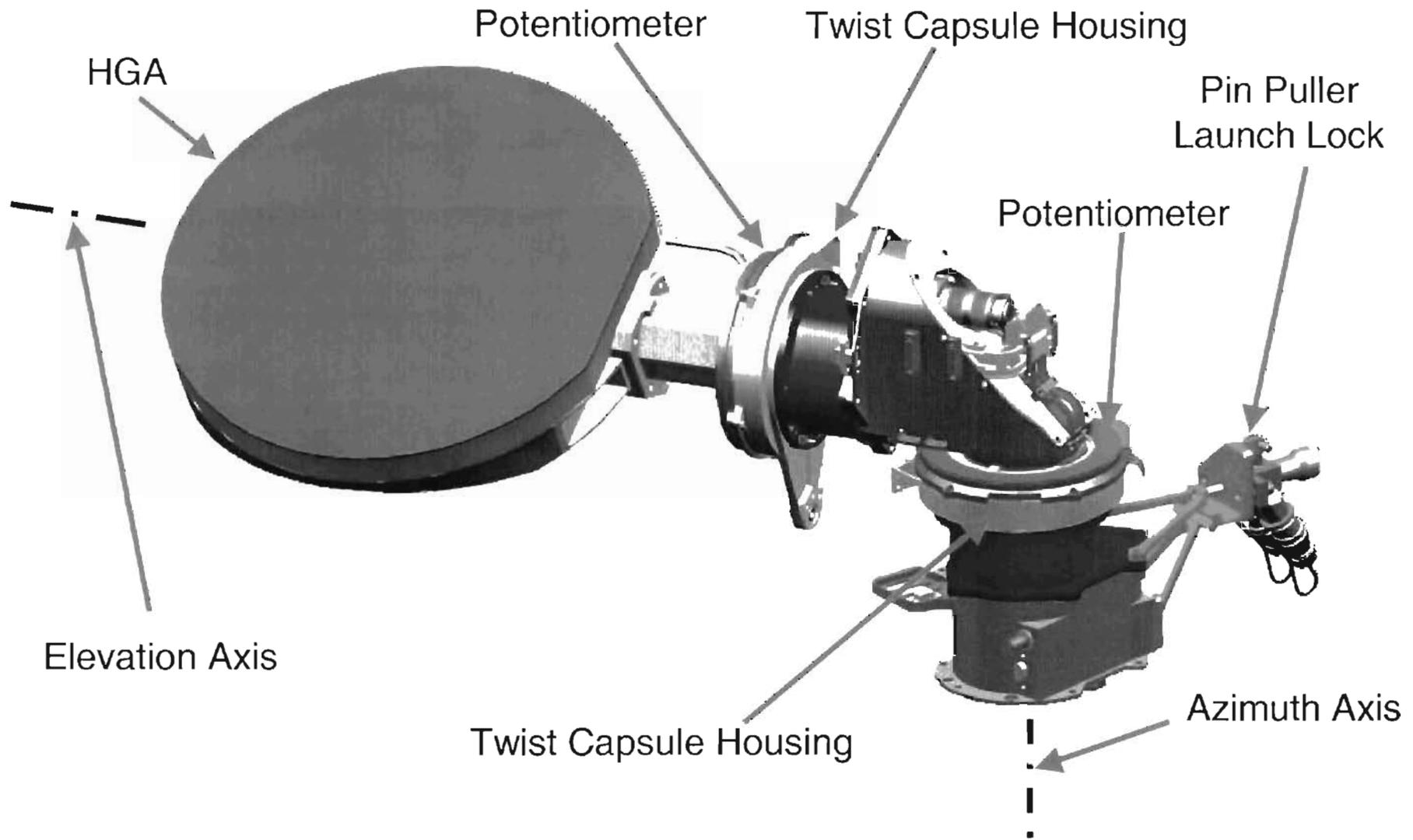




HGAA Overview



Mars Exploration Rovers



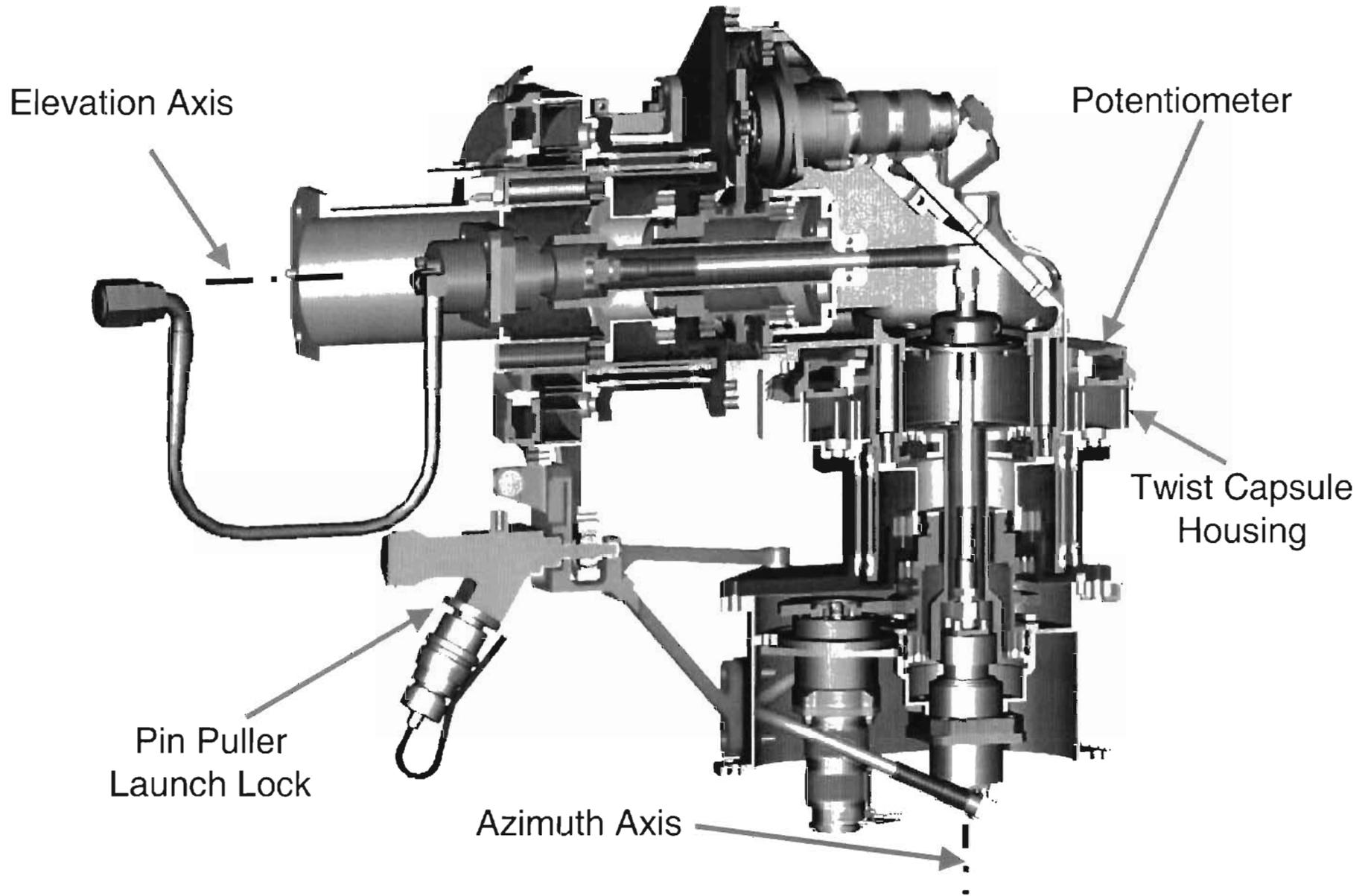


HGAA Overview Cross-Section (HGA Removed)

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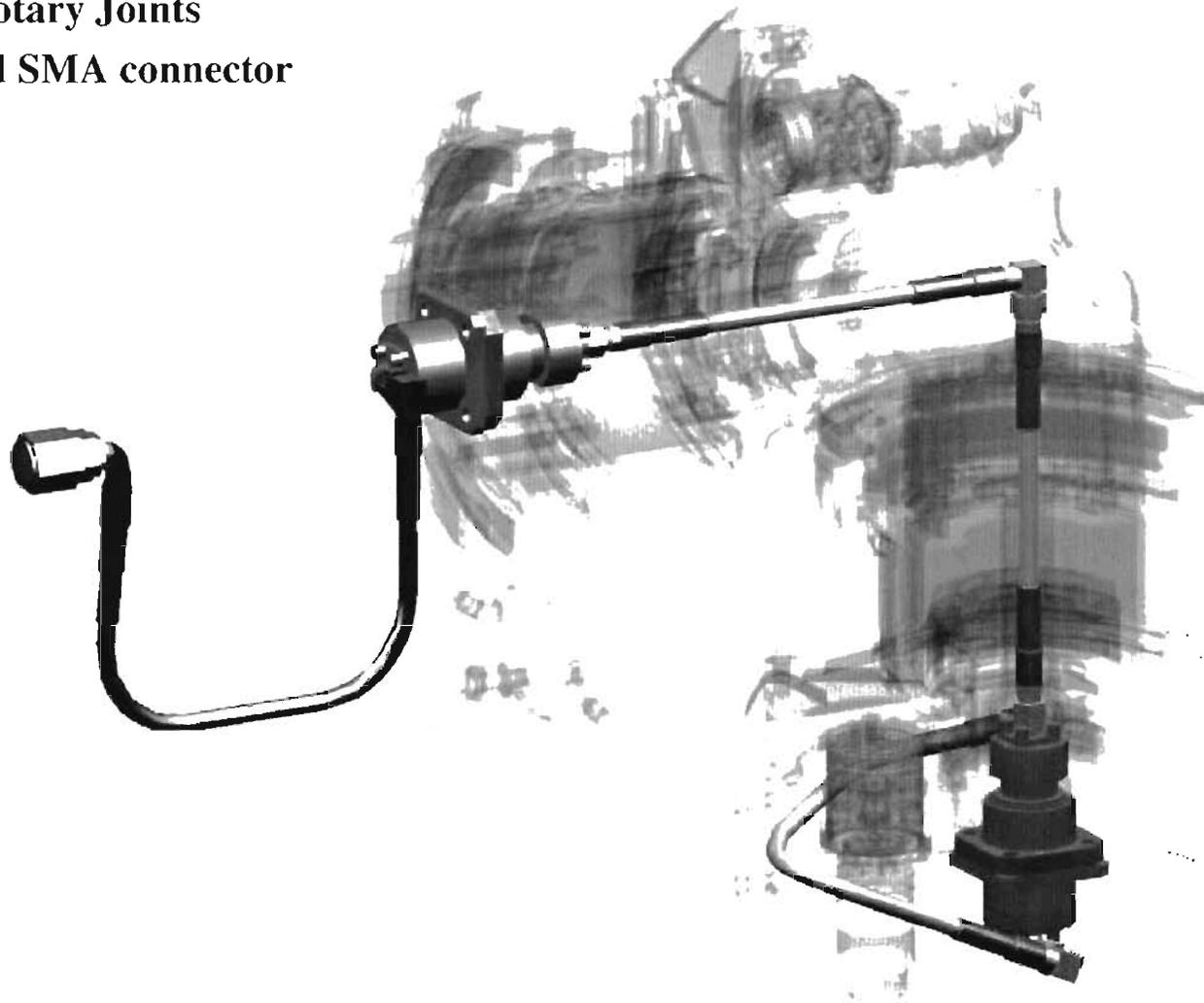


High Gain Antenna Gimbal RF System



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- (4) flex coax lines - .190 inch diameter, SMA and TNC connections
- (2) RF Rotary Joints
- Bulkhead SMA connector





High Gain Antenna & Coaxial Rotary Joint

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Kevlin Corp.

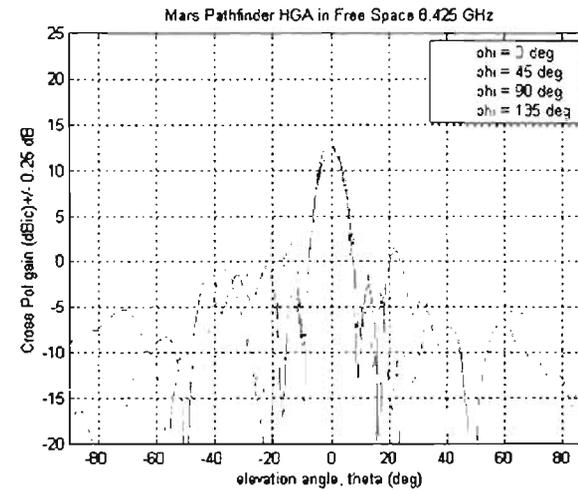
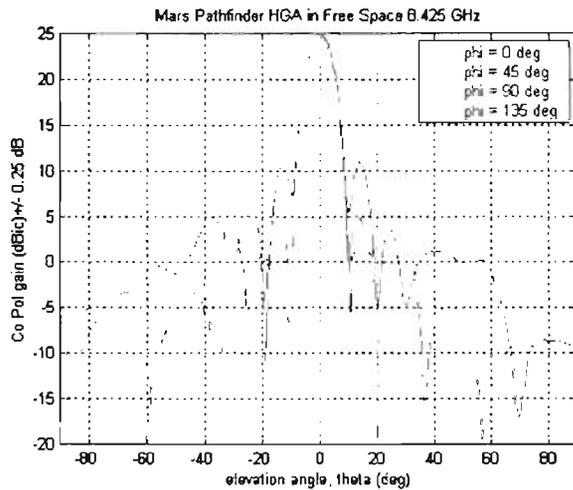


High Gain Antenna Radiation Patterns



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Transmit



Receive

