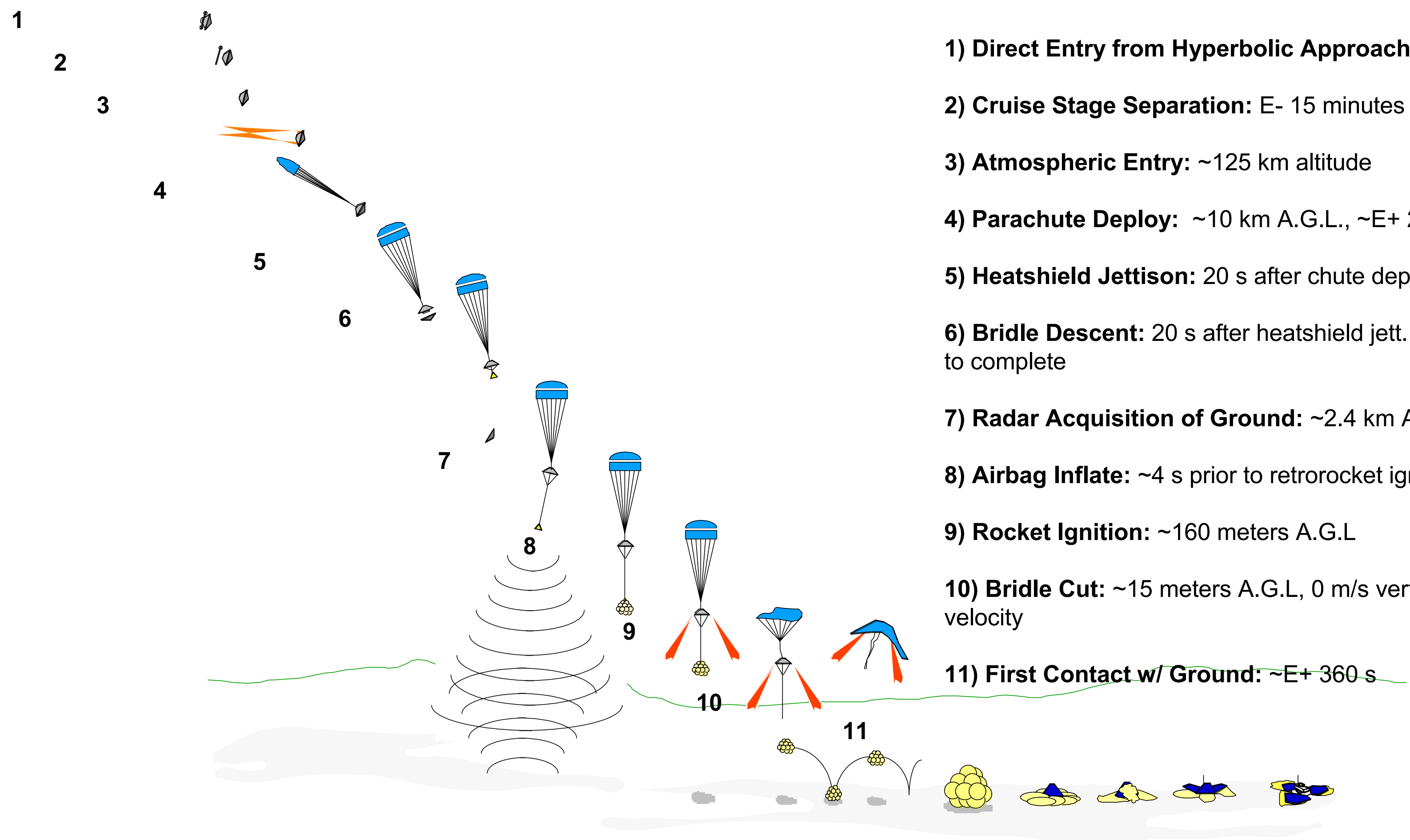
MER Parachute Decelerator System

Program Objectives

- MER Parachute Deceleration Subsystem (PDS) is to deliver the landing vehicle, in the atmosphere of Mars, to a point and flight condition where Rocket Assisted Descent and Airbag Impact Attenuation Systems can complete the descent to the surface
- Resultant design should retain as much heritage as possible with previous Mars programs *(MPF / MPL / MSP01 / Viking)*

Operational Sequence

Mars Exploration Rover



1) Direct Entry from Hyperbolic Approach

2) Cruise Stage Separation: E- 15 minutes

3) Atmospheric Entry: ~125 km altitude

4) Parachute Deploy: ~10 km A.G.L., ~E+ 240 s

5) Heatshield Jettison: 20 s after chute deploy

6) Bridle Descent: 20 s after heatshield jett., 10 s to complete

7) Radar Acquisition of Ground: ~2.4 km A.G.L

8) Airbag Inflate: ~4 s prior to retrorocket ignition

9) Rocket Ignition: ~160 meters A.G.L

10) Bridle Cut: ~15 meters A.G.L, 0 m/s vertical velocity

11) First Contact w/ Ground: ~E+ 360 s

General Design Requirements

Mars Exploration Rover

- Parachute Assembly
  - Decelerates the Entry Vehicle from supersonic flight conditions
  - Establishes stable vertical trajectory to permit Heat Shield jettison and Lander deployment
  - Provides final descent velocity and stability for Rocket Assisted Descent and Airbag Impact Attenuation Systems

TITLE	DOCUMENT NO.
MER PDS Performance Requirements Specification	TBD
MER PDS Interface Control Drawing	TBD
MER PDS Environmental Requirements Document	PD-420-1-139 (preliminary) (Embedded in Perf. Spec.)
MER PDS Statement of Work (SOW)	TBD

General Design Requirements

- Mortar Deployment Assembly
  - Interfaces with Backshell structure
  - Provides deceleration parachute structural attachment points
  - Packages and protects the Deceleration Parachute Assembly
  - Ejects the packed parachute from the stowed configuration
  - Accelerates parachute beyond the recirculating wake for controlled and reliable inflation

Design Requirements (Level 3)

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Mars Exploration Rover

Requirement	Assessment
PDS shall ensure parachute deployment at a maximum Mach number of 2.23 and a minimum Mach number of 1.40.	Within Viking heritage
EDL shall ensure that the parachute is deployed at a dynamic pressure of at least 500 Pa and no greater than 830 Pa	Determined as low risk (Workshop)
PDS shall ensure that the nominal ref area (S_0) of the full open parachute with suspended payload is $\geq$ 178.48 m^2 at Mach number 0.3 in the Martian atmosphere	Baseline: 140% MPF chute size, 1.6 Viking Band under consideration
PDS shall ensure parachute deployment at a maximum Angle of attack of 10 degrees.	Viking, MPF, MSP01 limit 15 degrees
PDS shall tolerate a maximum payload spin rate of 4 RPM during descent.	Same as MPF

Driving Level 4 Requirements

Requirement
The PDS shall meet the configuration and interface requirements specified in MICD drawing no. 10205261
Peak inflation loads imparted to the BIP carried on one bridle leg shall not exceed 15,600 lbs.
Peak mortar reaction loads imparted to the BIP shall not exceed 12.5 g's.
Parachute packing density shall not exceed 47 lb/ft^3
Parachute Decelerator System mass shall not exceed 28 kg
The PDS shall apply the factors of safety defined in [the ERD] to all metal components
The PDS shall apply a factor of safety of 1.5 to all textile components
The PDS shall apply a factor of safefy of 1.25 times the peak operating pressure at ambient for proof pressure
The PDS shall apply a factor of safety of 1.5 times the peak operating pressure at ambient for burst pressure.
The PDS shall be designed to function properly after 10 seconds of exposure to the static acceleration loads [defined in the ERD]

Deployment Assembly

- Estimated MER Design Loads
  - Loads have increased because of increase in chute area and deployment conditions.
  - Preliminary Estimates:
    - Mortar Reaction Load: 17,000 lb
      (MPF = 11,000 lb)
    - Peak Inflation Load: 12,500 lb
      (MPF = 7,904 lb)

(@ maximum dynamic pressure condition of 783 Pa,
M = 1.9, 825 kg entry vehicle)

Deployment Assembly

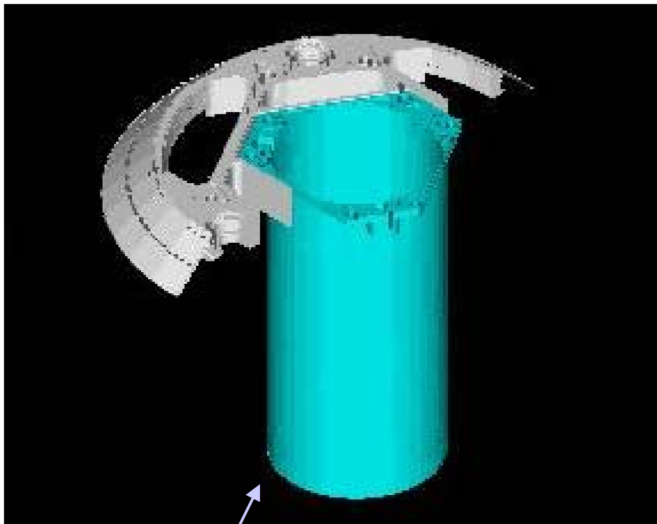
JPL

Mars Exploration Rover

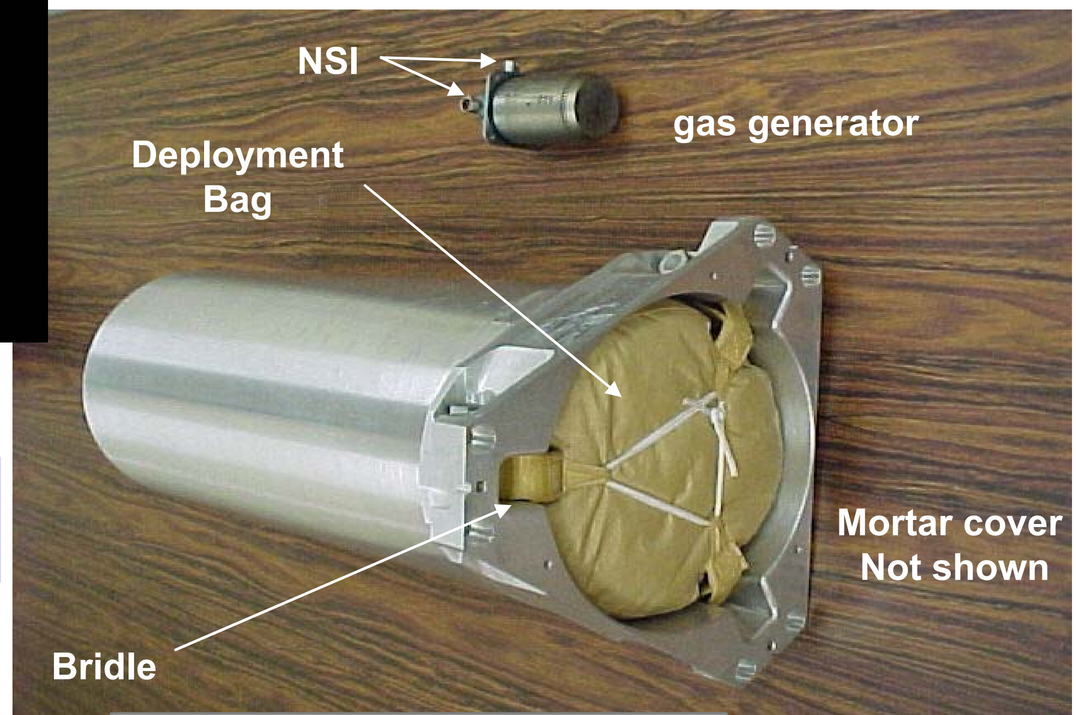
- Mortar System - Introduction
  - Design Heritage
    - Mars Explorer Rover (MER) Mortar Deployer Subsystem (MDS) design will be based on the successful Mars Pathfinder Mortar Deployer System (MDS) developed by General Dynamics (formerly Primex/Olin) as part of the Pioneer Aerospace team
  - Major Requirements Summary
    - 100 ft/s < muzzle exit velocity < 130 ft/s (Mars)
    - Dual initiators for gas generator
    - Operational temperature range: -35C $\pm$ 10C
    - Ejection mass of 34.5 lbm (37 lbm max)
    - Max parachute opening load 15,000 lbf

- Mortar System - Introduction (cont'd)
  - Principal Similarities - Pathfinder vs. MER
    - Same propellant, initiators and design approach
    - Very similar parachute deployment velocity
    - Development, LAT and qualification approach
  - Principal Differences - Pathfinder vs. MER
    - Deployment mass (34.5 lbm vs. 21.5 lbm)
    - Parachute volume (1620 $in.^3$ vs. 953 in^3)
    - Larger parachute inflation load (15,000 lbf vs. 12,000 lbf - MSP01)

Deployment Assembly



2.5 “ diam. increase from MPF for 40% area growth

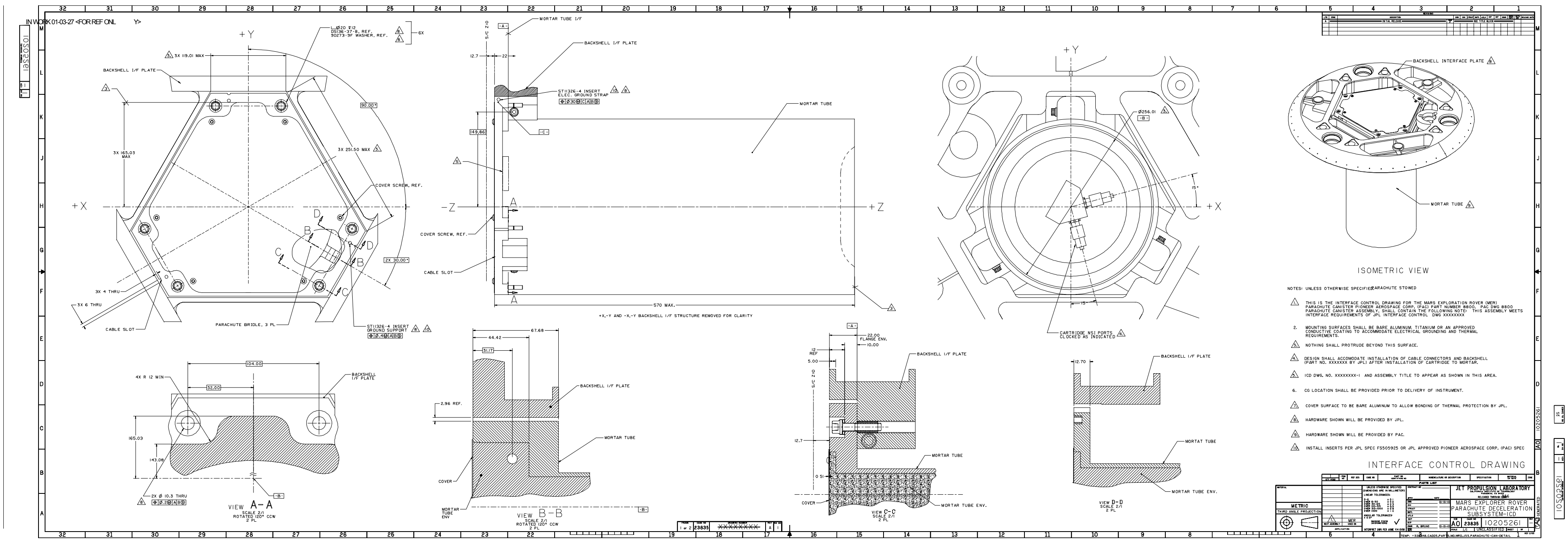


Mars Pathfinder PDS Shown

Deployment Assembly

Mars Exploration Rover

- MER Mortar Deployer Subsystem ICD



Deployment Assembly

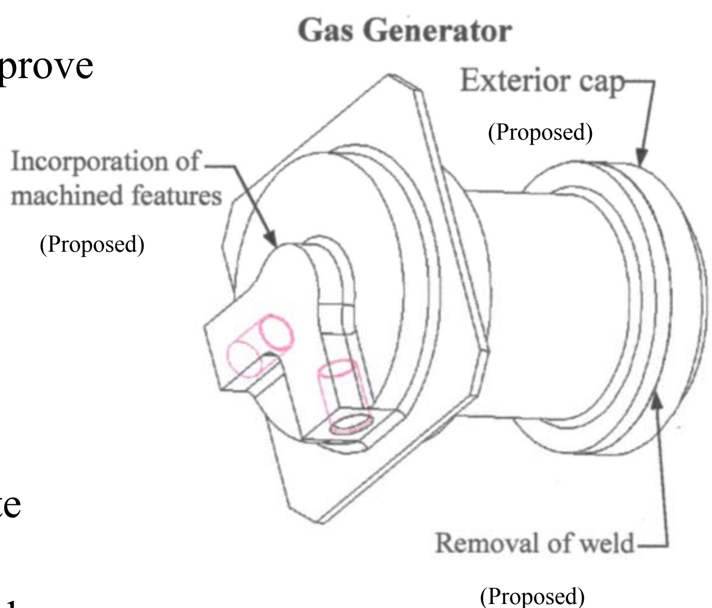
- GD will actively identify, prioritize and manage risk to ensure development and qualification are successful.
- Potential risk items:

Item	Severity	Probability
Design does not scale	Medium	Low
Reduced development cycle time	Low	High
Requirements are not well defined or understood or continue to change	Low-High	Low

- Risk Mitigation Plan
  - Issue: Design Does Not Scale
    - Approach – early system level demonstration to correlate proven performance models
  - Issue: Reduced Development Cycle Time
    - Approach – develop program plan as soon as possible
  - Issue: Requirements Uncertainty
    - Approach – formalize spec and ICD as soon as possible

Deployment Assembly

- Mortar Subsystem – Design
  - Mortar System
    - OD increase from 8.4" to 10.9" (nominal)
  - Gas Generator
    - 12 grams of WC230 (same as previous)
    - Design change to improve manufacturabili proposed - exterior cap configuration to improve access for burst shim braze
    - 2 Each NSI (CFE)
  - Cover
    - Same design approach
  - Mortar Tube
    - Same design approach
    - Will interface with Backshell Interface Plate (changes identified)
    - Structural evaluation will result in increased load/pressure capability for some features



Deployment Assembly

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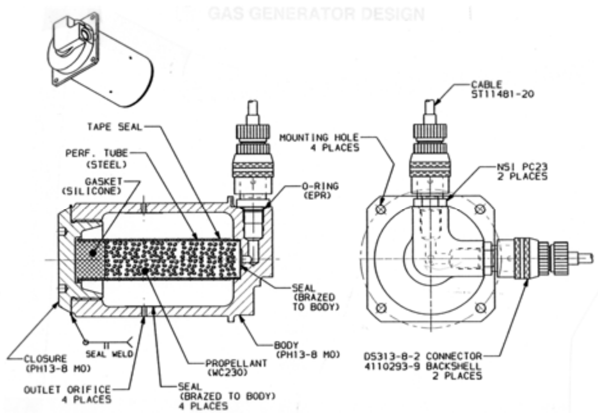
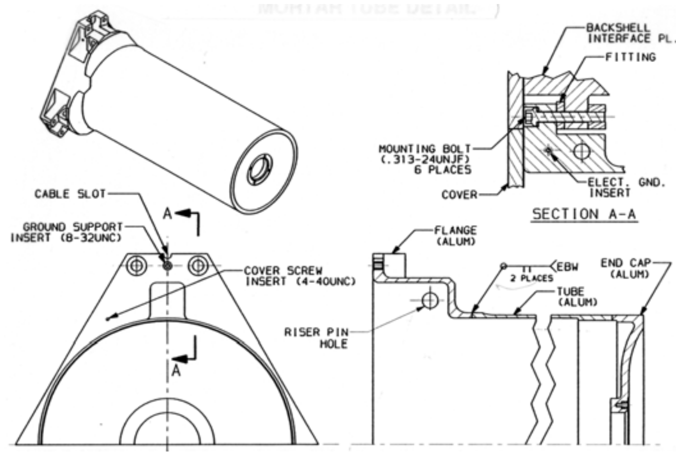
Mars Exploration Rover

Gas Generator

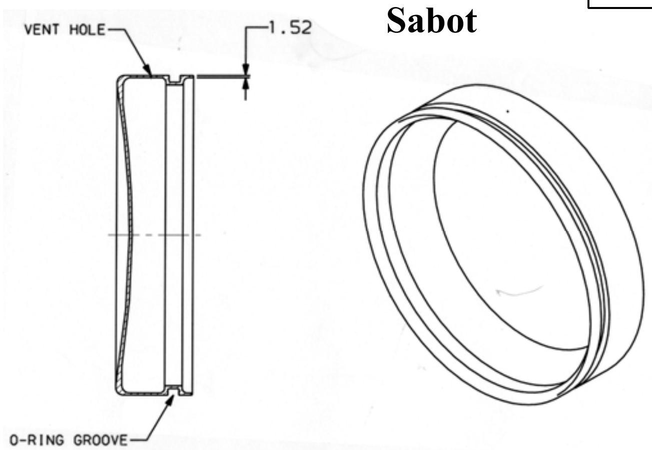


Mortar Tube

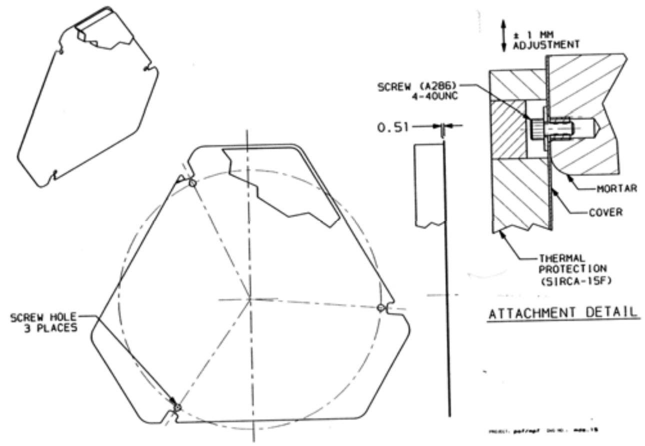


MPF shown

Sabot



Cover



Deployment Assembly

- Mortar Subsystem - Materials and Processes List (MPF shown)

MARS MORTAR PARACHUTE DEPLOYMENT ASSEMBLY PARTS, MATERIALS & PROCESSES

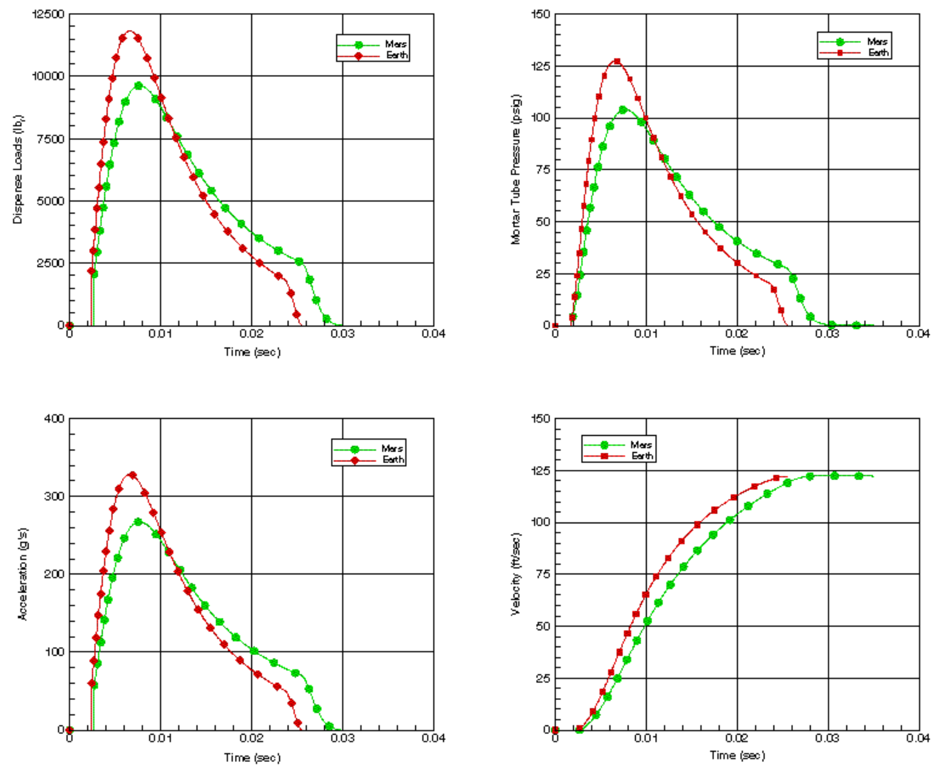
PART NAME	PART NO.	QTY	MATERIAL	PROCESS	SOURCE	NONSTANDARD ITEM STATUS
O-RING, GG/END CAP	2-033-E515-80	1	EPR		PARKER	N/A
O-RING, SABOT	2-368-E515-80	1	EPR		PARKER	N/A
O-RING, NSI/GG	3-903-E515-80	2	EPR		PARKER	N/A
SABOT	32683-101	1	AL 6061-T651		OAC	N/A
COVER	32684-101	1	AL 5052-H32		OAC	N/A
TUBE, MORTAR	32687-101	1	AL 6061-T6511	EB WELD	OAC	N/A
FLANGE	32688-101	1	AL 6061-T651	EB WELD	OAC	N/A
END CAP	32689-101	1	AL 6061-T651	EB WELD	OAC	N/A
BODY, GG	32692-101	1	CRES PH 13-8 Mo, H1050	GTA WELD, BRAZE	OAC	N/A
CLOSURE	32693-101	1	CRES PH 13-8 Mo, H1050	GTA WELD	OAC	N/A
PROPELLANT TUBE	32694-101	1	STEEL, ASTM A 366M	GTA WELD	OAC	N/A
SPACER	32695-101	1	SILICONE FOAM, BF1000		BISCO	N/A
SEAL	32696-101	5	CRES 304L	BRAZE	OAC	N/A
SLEEVE	32698-101	1	CRES PH13-8 Mo, H1050		OAC	N/A
WASHER	5710-268-30	3	CRES 300 series		SEASTROM	N/A
BRAZING MATERIAL	90007-607	AR	BRAZE MAT'L, NIORO	BRAZE		N/A
LUBRICANT	90011-631	AR	BRAYCOTE 601 EF		CASTROL	N/A
TAPE, SEAL	90013-619	AR	ALUMINUM / MYLAR		3M	N/A
LACQUER	90020-689	AR	TT-L-50, TYPE II			N/A
INK	90080-601	AR	A-A-208, TYPE I			N/A
WASHER, FLAT	AN960C816	3	CRES per MIL-S-5059, AMS5510 or AMS5512			N/A
FILLER ALLOY	AWS 4047	AR	AL 4047	WELD		N/A
INSERT, GROUND SUPPORT (CFE)	KNCA0832J	4	CRES 303		JPL	N/A
INSERT, COVER	MS51830-102	3	CRES 303			N/A
INSERT, GG MOUNT	MS51830-103L	4	CRES 303			N/A
NUT, SELF-LOCKING	NAS1291C8M	3	CRES A-286			N/A
SCREW, COVER	NAS1352NO4LE4	3	A-286			N/A
SCREW, GG	NAS1352NO6-6	4	CRES A-286			N/A
WASHER	NAS1587-8C	3	CRES peR MIL-S-6721 or QQ-S-763			N/A
WASHER	NAS620C6	4	CRES 300 series			N/A
BOLT, HEX HD, CLOSE TOL.	NAS6308U38	3	A-286			N/A
NSI (CFE)	SEB26100001-258	2			JPL	N/A
PROPELLANT	WC230	12gm			Olin Ord.	N/A

Expect M&P to be very similar for MER

Deployment Assembly

- Mortar Subsystem
  - Earth/Mars Performance
- Deployment subsystem performance will be different in Earth and Mars environments
- Primary performance effects due to
  - Atmospheric backpressure (1 atm vs. 0.03 atm)
    - Work delta = 2.94 kj (2169 ft-lbs)
- Earth environment system performance reduction offset by system operating characteristics
  - Backpressure results in higher pressure under sabot
  - Presence of air behind sabot causes higher tube delta p

MER MDS Predicted Performance
(12 grams WC-231, Maximum Payload, -35 °C)



Deployment Assembly

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Mars Exploration Rover

- Mortar Subsystem
  - System Performance
    - Initial sizing analysis conducted
  - Structural Analysis
    - Loads of similar magnitude
    - FEA to be conducted when authorized
  - Reliability Analysis/Hazard Analysis
    - Expected to be similar to Pathfinder
    - To be conducted when authorized

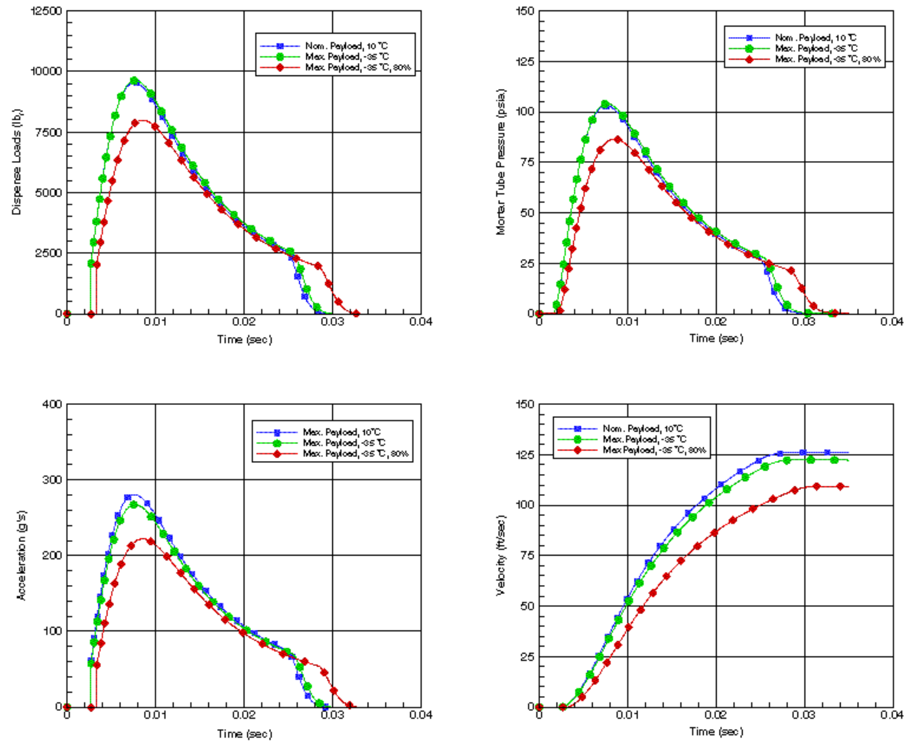
Deployment Assembly

Mars Exploration Rover

- Mortar Subsystem
  - Anticipated gas generator performance
  - Anticipated mortar tube pressure
  - Anticipated reaction load

Loads and velocity expected meet requirements

MER MDS Predicted Performance
(12 grams WC-231, Martian Environment)



Mass Properties

- Parachute Assembly Mass Properties
  - Current Best Estimates, requirement ≤ 28 kg

Component	Weight (lb)	Weight (kg)
PARACHUTE ASSY	**34.5**	**15.6**
Disk	8.23	3.73
Band	10.51	4.77
Tape	3.44	1.56
Thread	1.33	0.60
Susp Lines	8.44	3.83
Riser	0.74	0.34
Bridle	0.62	0.28
Bag	0.19	0.09
Misc Hardware	0.56	0.25
Sabot Bag	0.40	0.18
DEPLOYMENT ASSY		
Mortar	**24.2**	**11**
TOTAL	**58.7**	**26.6**

Development Testing - Aerial

Mars Exploration Rover

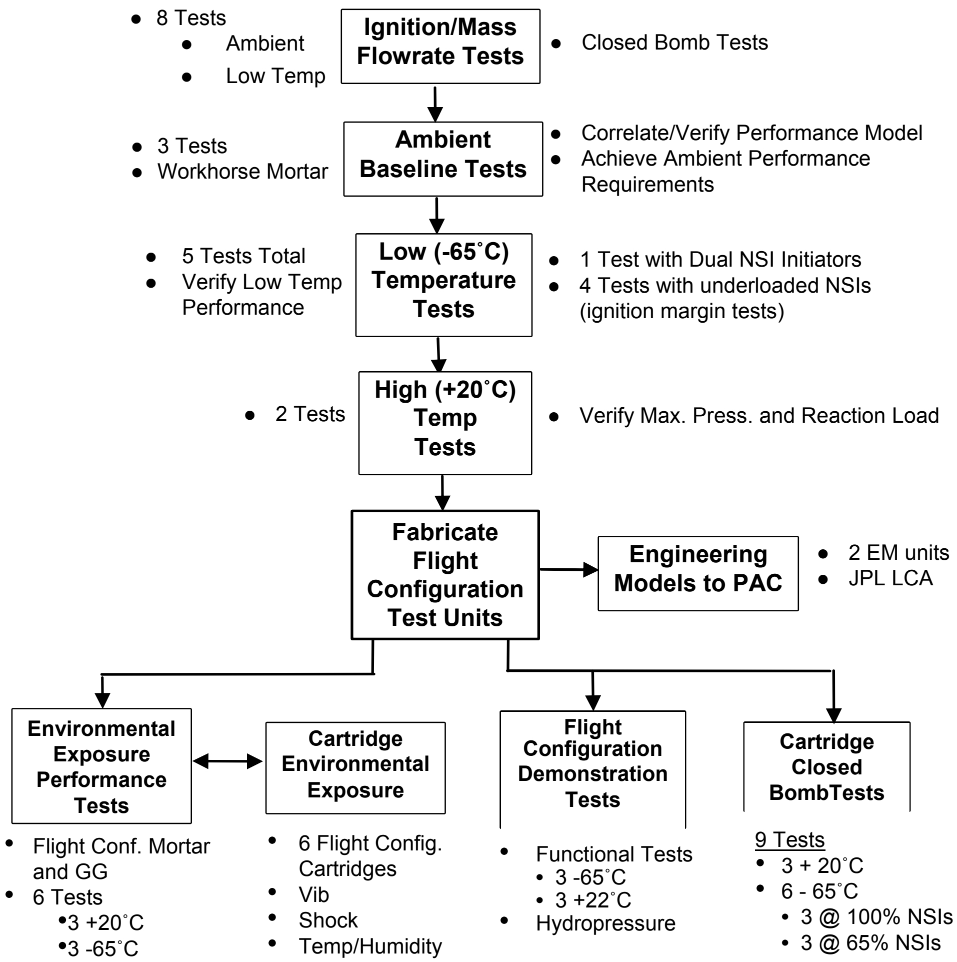
- Phase 2: Aerial Testing:
  - Divided into 3 parts, conducted after design "quantified"
    - Part 1   Rate of Descent/Stability Testing
    - Part 2   Structural Testing 1& 2

Deployment Assembly Testing

- Mortar Development Tests
  - Ignition/mass flowrate
  - Ambient baseline tests
  - Low temperature tests
  - High temperature tests
  - Environmental exposure performance tests
  - Cartridge environmental exposure tests
  - Flight configuration demonstration tests
  - Cartridge closed bomb tests

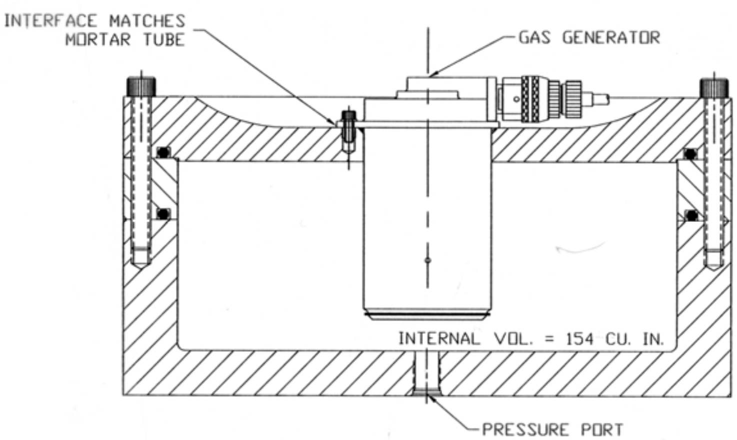
MPF temperatures listed, MER to be verified

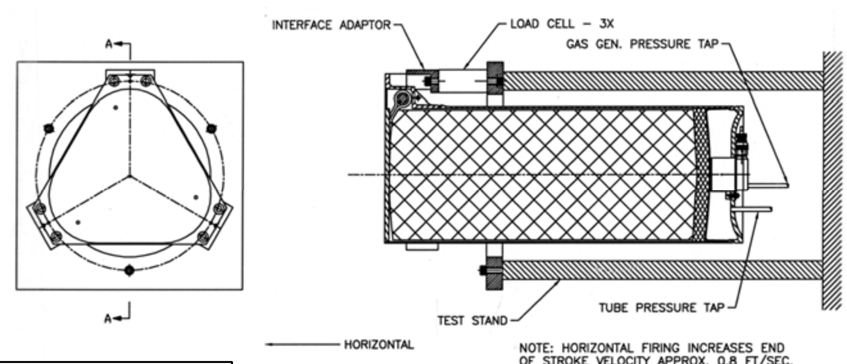
Test Matrix



Deployment Assembly Testing

- Gas Generator Level Test Setup
  - Baseline GG performance
  - Test used to determine effects of Environment on GG performance
  - Establish baseline for LAT
- Mortar Level Test Setup
  - Correlate GG performance to system level
  - Validate performance models



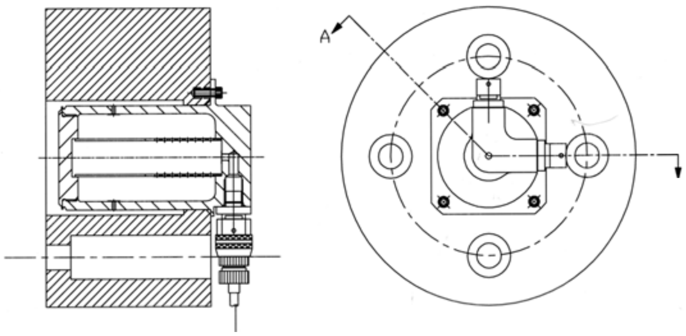


MPF shown

Deployment Assembly Testing

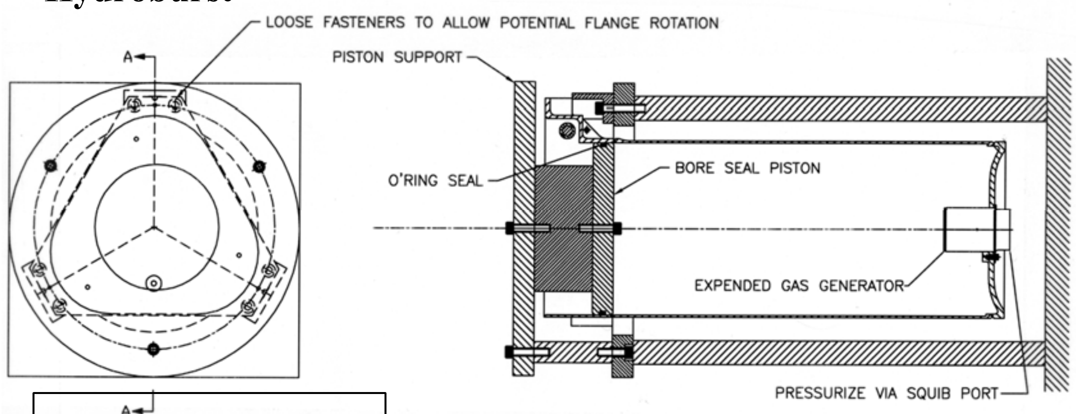
Mars Exploration Rover

Vibration/Shock



Parachute opening load validated in static tensile test

Hydroburst



MPF shown