14th International Planetary Probes Workshop

Overview of the ASPIRE Project

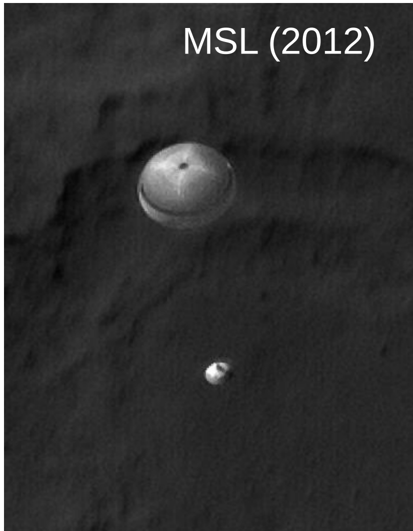
June 12-16, 2017 - The Hague, NL.

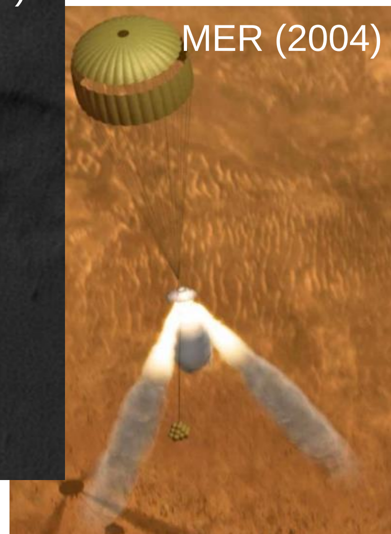
Clara O'Farrell, Ian Clark & Mark Adler
Jet Propulsion Laboratory, California Institute of Technology

© 2017 California Institute of Technology. Government Sponsorship Acknowledged.

Jet Propulsion Laboratory
California Institute of Technology

Disk-Gap-Band (DGB) Parachute Heritage



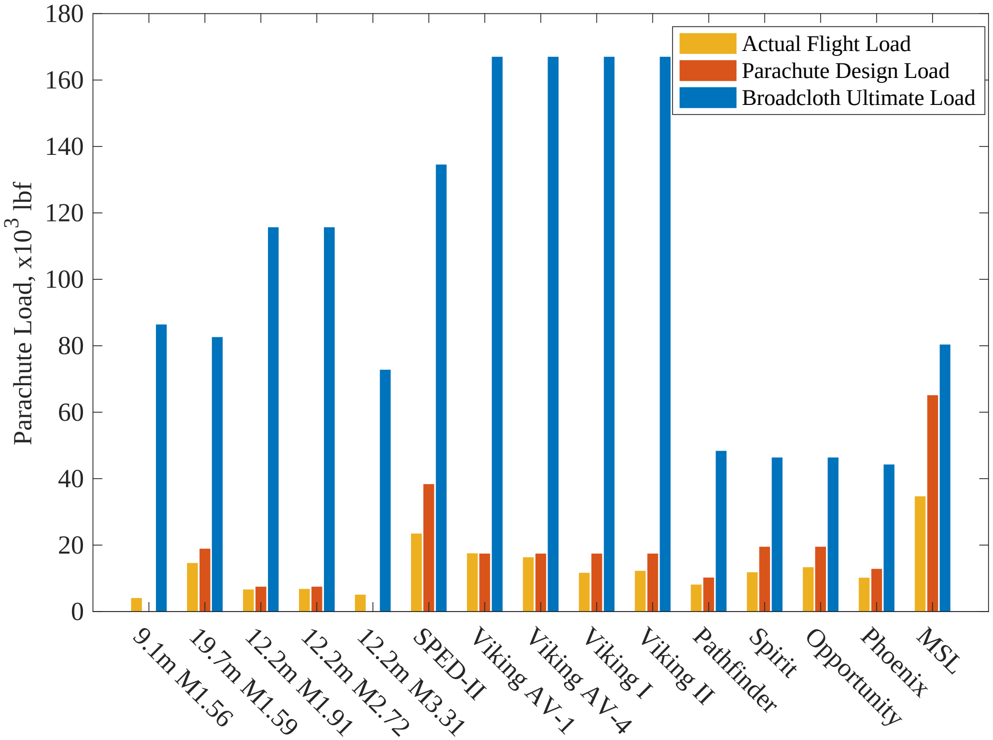


- Developed in the 60s & 70s for Viking
  - High Altitude Testing
  - Wind Tunnel Testing
  - Low Altitude Drop
- Successfully used on 5 Mars missions
  - Leveraged Viking development

Image credit: mars.nasa.gov

DGB Heritage & Design Margins

- Strength margins may have been eroding in recent DGB designs:



Clark & Tanner, IEEE Aerospace Conference Paper 2466 (2017):

Broadcloth ultimate load estimated by treating the disk as a pressure vessel:

$$F_{ultimate} = \pi D_{disk} \sigma t$$

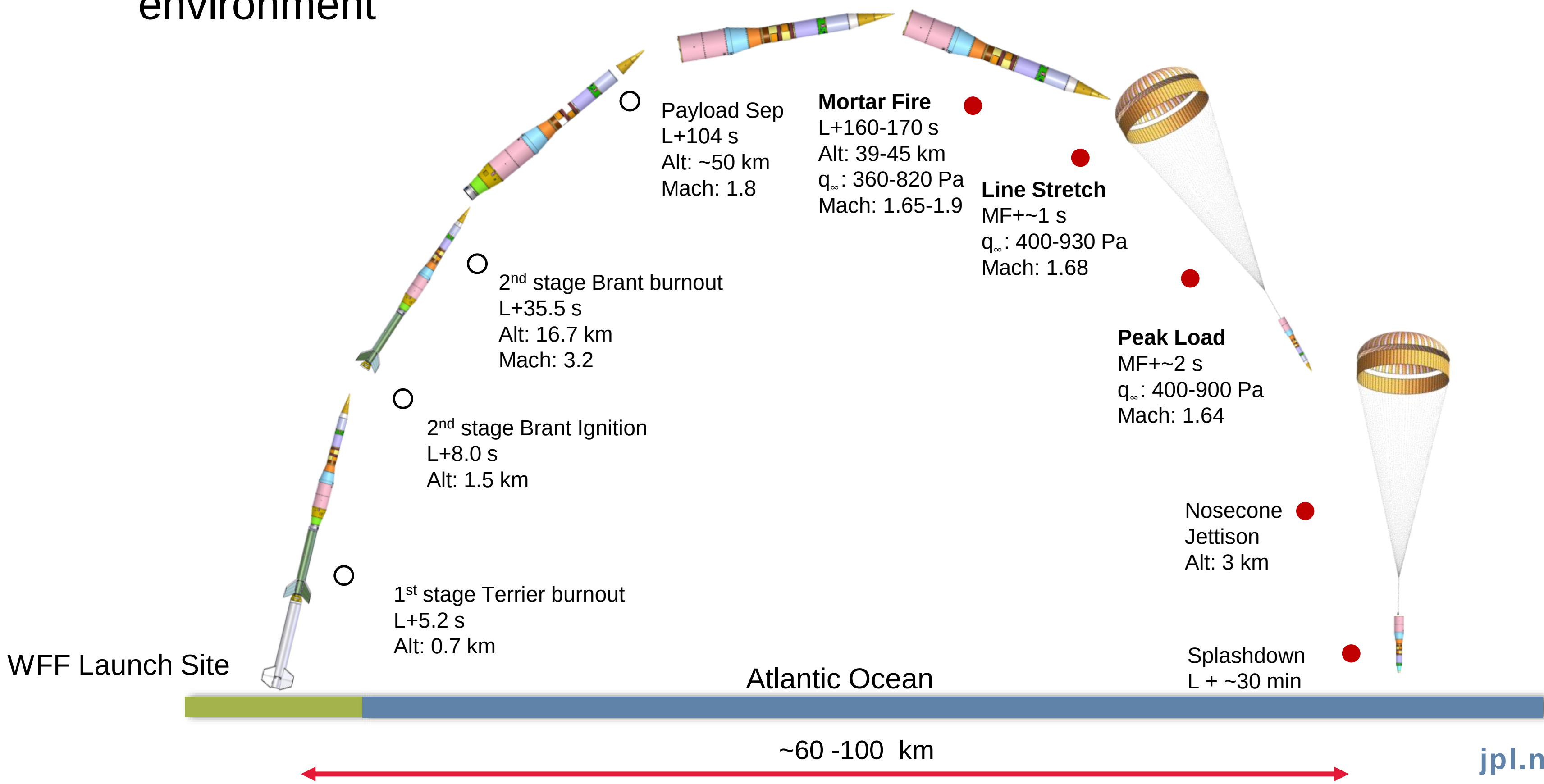
Disk diameter

Broadcloth stress (per unit length)

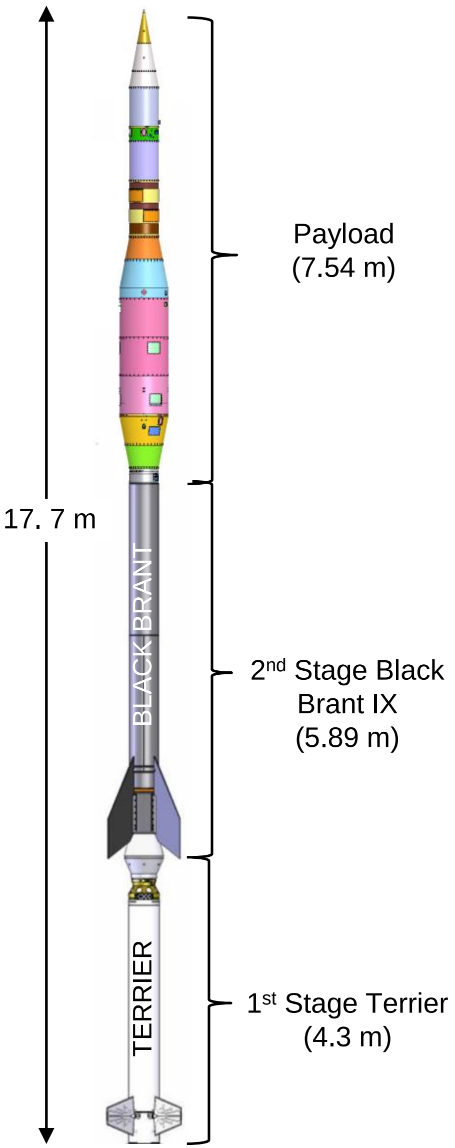
- The Low-Density Supersonic Decelerators Project saw failures of two supersonic ringsail parachutes well below those achieved in supersonic tests
- LDSD experience stresses seen in subsonic testing may not bound the stresses seen in supersonic testing, at least for some parachutes

The ASPIRE Project

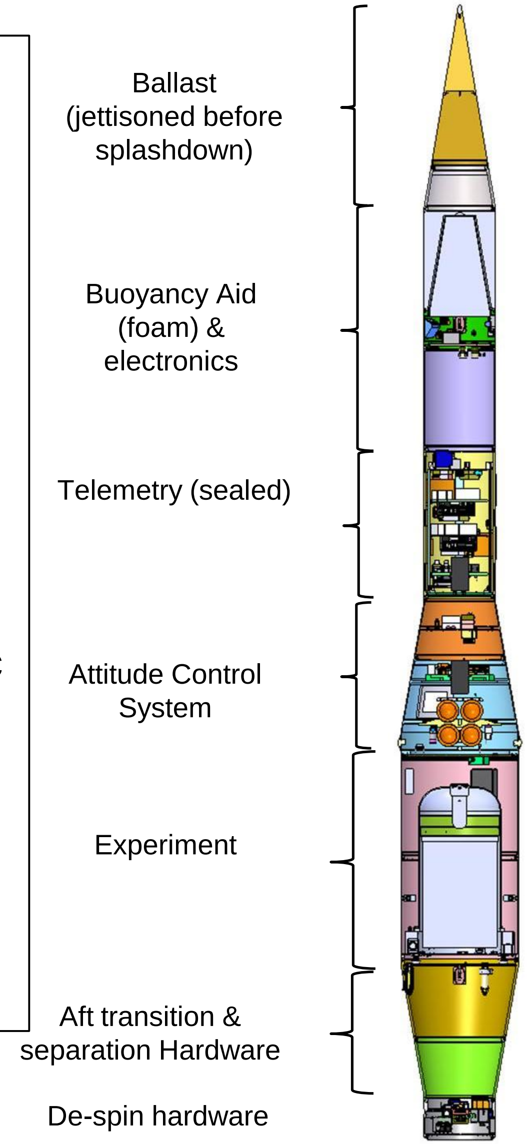
- **A**dvanced **S**upersonic **P**arachute **I**nflation **R**esearch **E**xperiments Project established to investigate the physics of supersonic DGB inflation
- DGBs to be tested on sounding rocket flights out of Wallops Flight Facility (WFF) starting summer 2017
- Expose two candidate M2020 parachute designs to a supersonic inflation environment



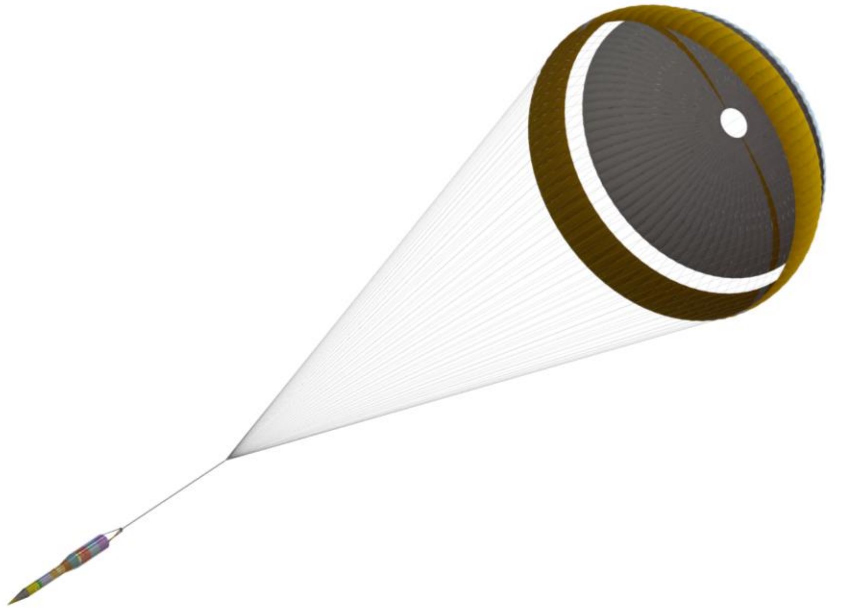
Test Architecture



- Rail-launched Terrier Black Brant
- Spin-stabilized at 4 Hz
- Yo-yo de-spin after 2nd stage burnout
- Mortar-deployed full-scale DGB
- Cold gas ACS active from payload separation to before mortar fire
- Recovery aids:
  - Foam provides buoyancy
  - Nosecone ballast (for aerodynamic stability) is jettisoned before splashdown
- Payload mass:
  - Launch: 1268 kg
  - Post-separation: 1157 kg
  - Splashdown: 128 kg



Parachutes



Test two full-scale mortar-deployed DGBs:

- MSL built-to-print
- Strengthened version of MSL DGB with a stronger broadcloth

	MSL built-to-print	Strengthened
D_0	21.35 m	21.45 m
SL length	37.0 m (1.73 D_0)	36.44 m (1.70 D_0)
Riser length	7.05 m	7.78 m
Geometric Porosity	12.5%	12.5%
No. of gores	80	80
SL line material	2100 lb Technora	3500 lb Technora
Band fabric	PIA-C-7020 Type I	Custom nylon Heathcoat Ltd. (1.86 yd/oz, 100 lbf/in)
Disk fabric	PIA-C-7020 Type I (skirt)/Polyester 8860 (crown)	
Radials	2100 lb Technora	3500 lb Technora
Mass	49.8 kg	75.4 kg
Fabric permeability	100 cfm	90 cfm

Schedule & Test Matrix

- Top Level Objectives
  - Expose two candidate designs to a supersonic inflation environment
  - Acquire data sufficient to characterize the flight environment, loads, and performance of the parachute

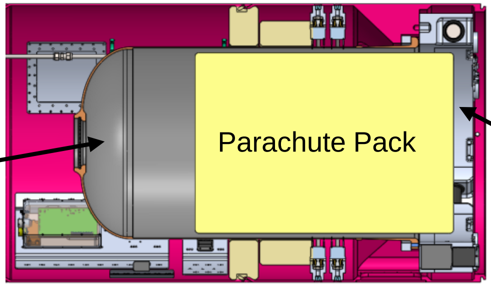
- Baseline strategy requires four successful flights:

	Parachute	Load	Purpose	Target date
SR01	Built-to-print	35 klbf (MSL @ Mars)	Ensure test approach doesn't introduce new parameters.	Sept. 19, 2017
SR02	Strengthened	35 klbf (MSL @ Mars)	Ensure strengthened design survives MSL load; calibrate targeting for next two flights	Nov. 1, 2017
SR03	Strengthened	70 klbf	Strength test of new design	Dec. 19, 2017
SR04	Strengthened	70 klbf	Address testing variability	Feb. 4, 2018
SR05	TBD			
SR06				

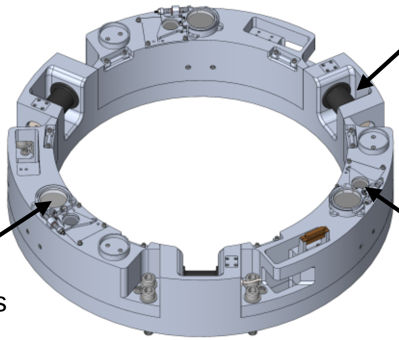
- Six flights planned to provide margin on four required tests

Instrumentation

Experiment section:



Instrument Ring:



- Additional on-board instrumentation:
  - GLN-MAC IMU
  - GPS
  - C-band transponder (radar tracking)
- Meteorological instrumentation:
  - 3x meteorological balloons carrying Radiosondes: temperature, density, winds to 35 km
  - 2x SuperLoki rockets w/inflatable ROBIN spheres: temperature, density, winds for 30 - 60km
- Allow reconstruction of:
  - Parachute loads
  - Conditions at parachute deploy (Mach, dynamic pressure, angle of attack)
  - Parachute shape & position
- See B. Sonneveldt *et al* "Instrumentation and Reconstruction for the ASPIRE Supersonic Parachute Test Campaign" (poster)

ASPIRE Data Products & Success Criteria

- Data products:
  - Payload trajectory from separation until mortar fire + 60 sec: position, velocity, acceleration, attitudes rates
  - Payload aerodynamic states trajectory from separation until mortar fire + 60 sec: Mach, dynamic pressure, angles of attack, sideslip
  - Synchronized parachute load history
  - Synchronized HS/HR camera imagery
  - Parachute inspection report
- Minimum success criteria
  - Deliver the experiment to the required test conditions.
  - Acquire, transmit, and record the required experiment data.
  - Recover the experiment section without recovery induced damage to the data.
  - Recover sufficient data to determine the parachute peak load, assuming proper payload functionality.
- Comprehensives success criteria
  - Recover the parachute assembly (that remains attached to the experiment section) without recovery-induced damage.

Acknowledgments

The authors are grateful for the many contributions from the ASPIRE team.

Project Manager: Tom Randolph
Deputy Project Manager: Mike Hughes
Project Manager Emeritus: Mark Adler
Principal Investigator: Ian Clark
Parachute CogE: Chris Tanner
Flight Performance (JPL): Mark Ivanov
Flight Performance (LaRC): Eric Queen
Aerosciences: Suman Muppidi
Sounding Rocket Lead: Brian Hall
NSROC Mission Manager: Jay Scott
WFF Range Lead: Dave Wilcox

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA.

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov