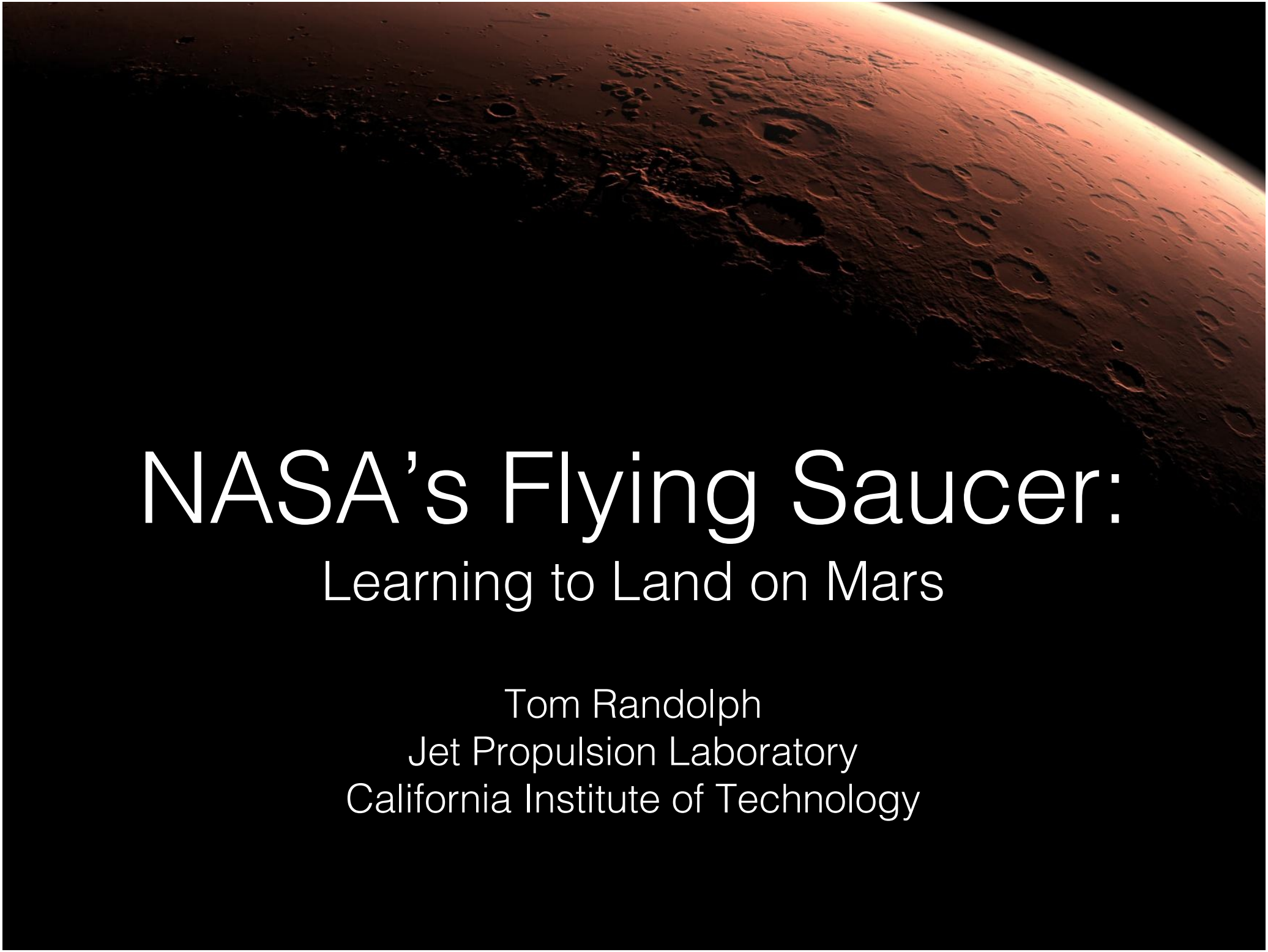
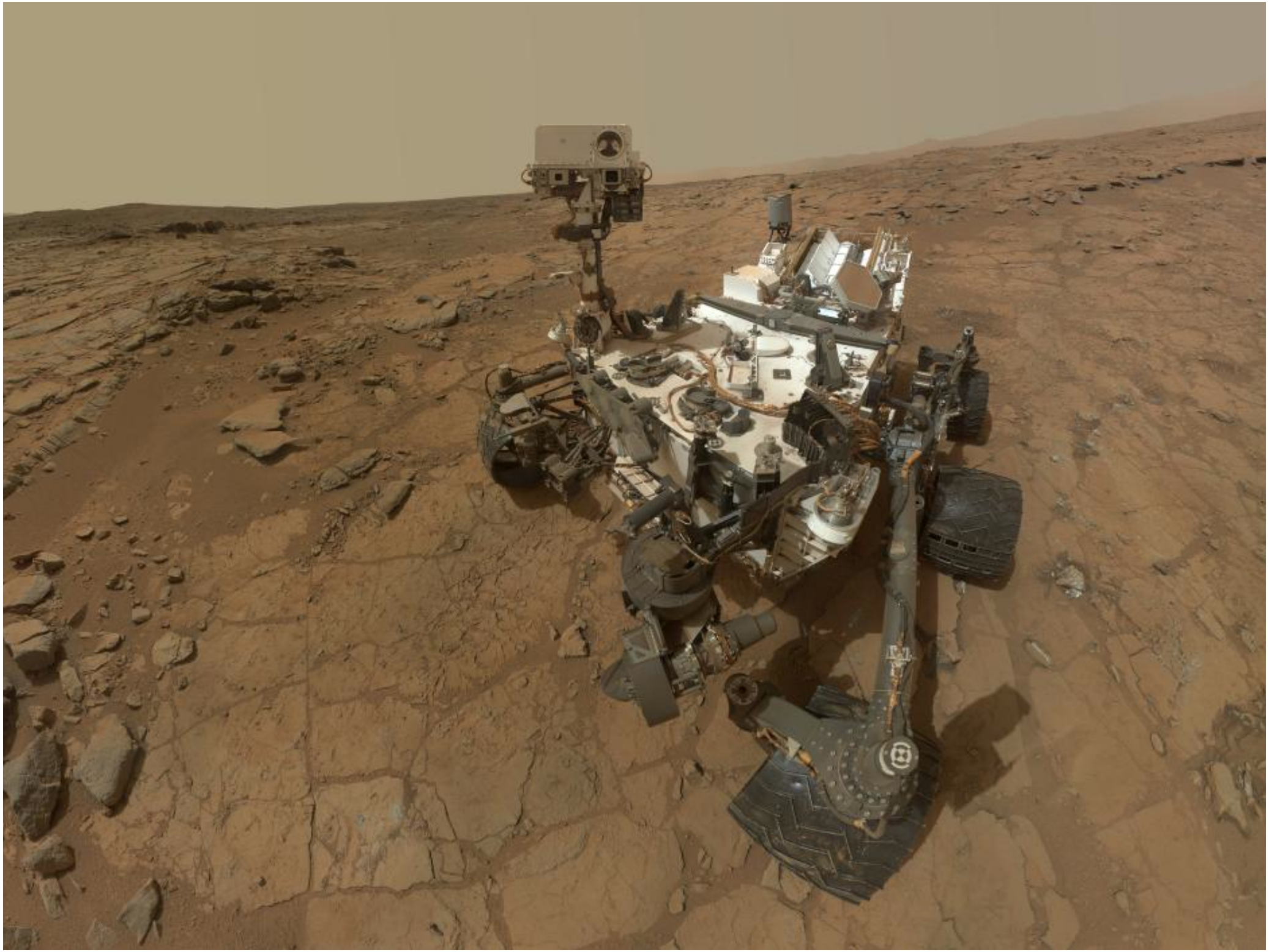


NASA’s Flying Saucer:

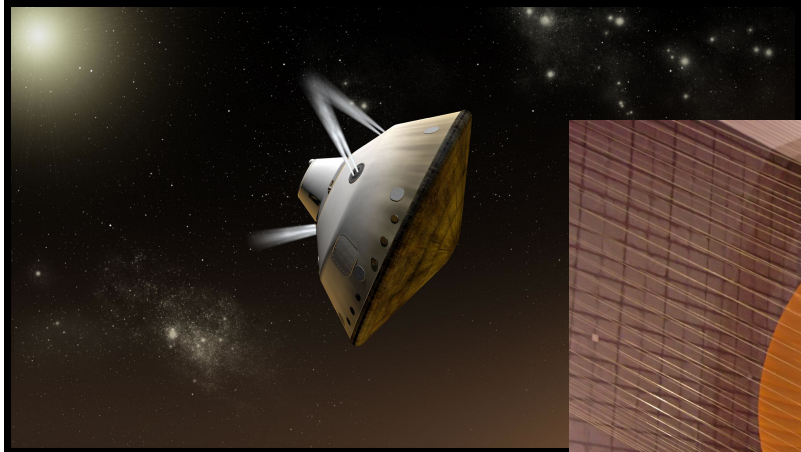
Learning to Land on Mars

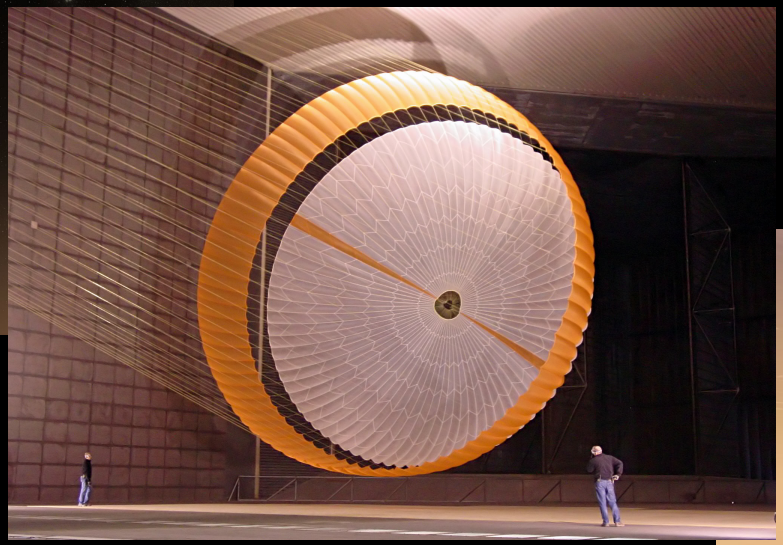
Tom Randolph
Jet Propulsion Laboratory
California Institute of Technology

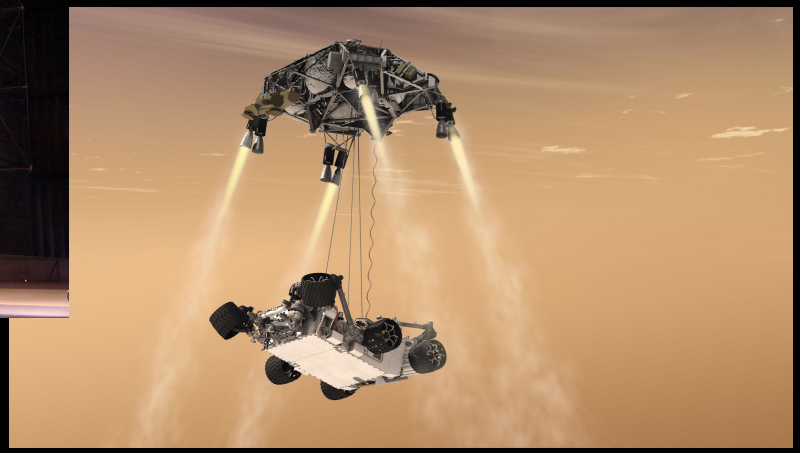


How We Get to Mars Now

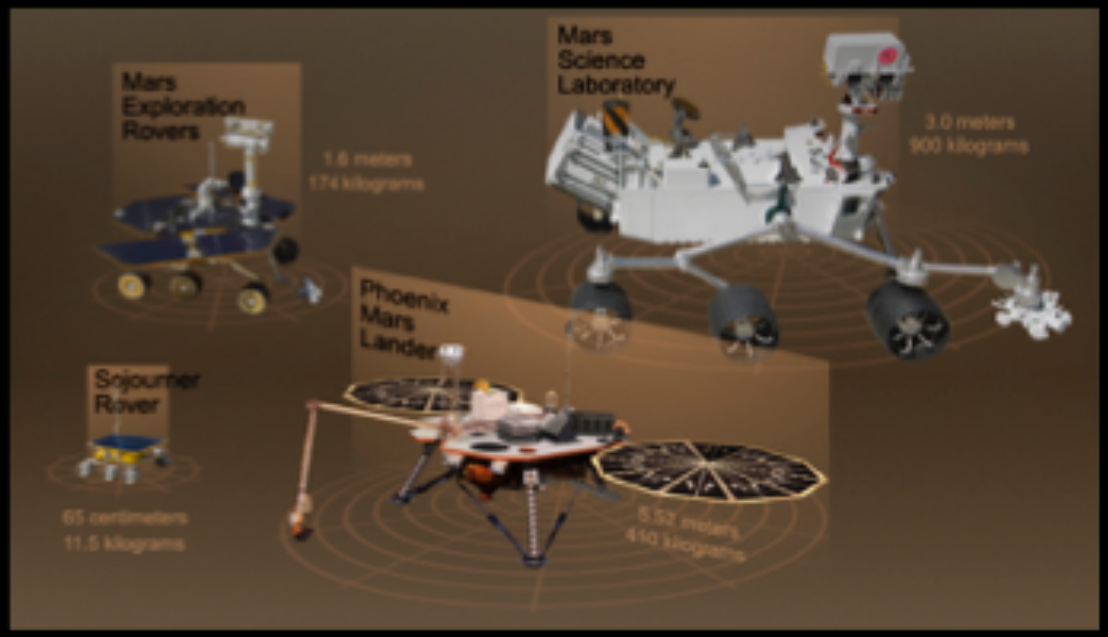
Mars Entry, Descent, and Landing Technology SOA



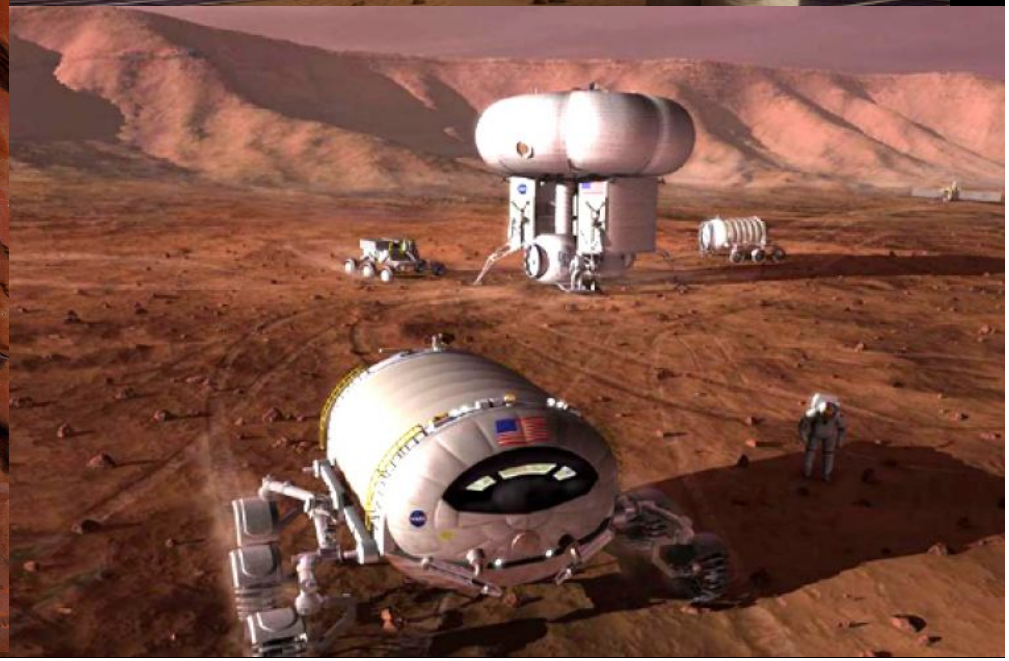




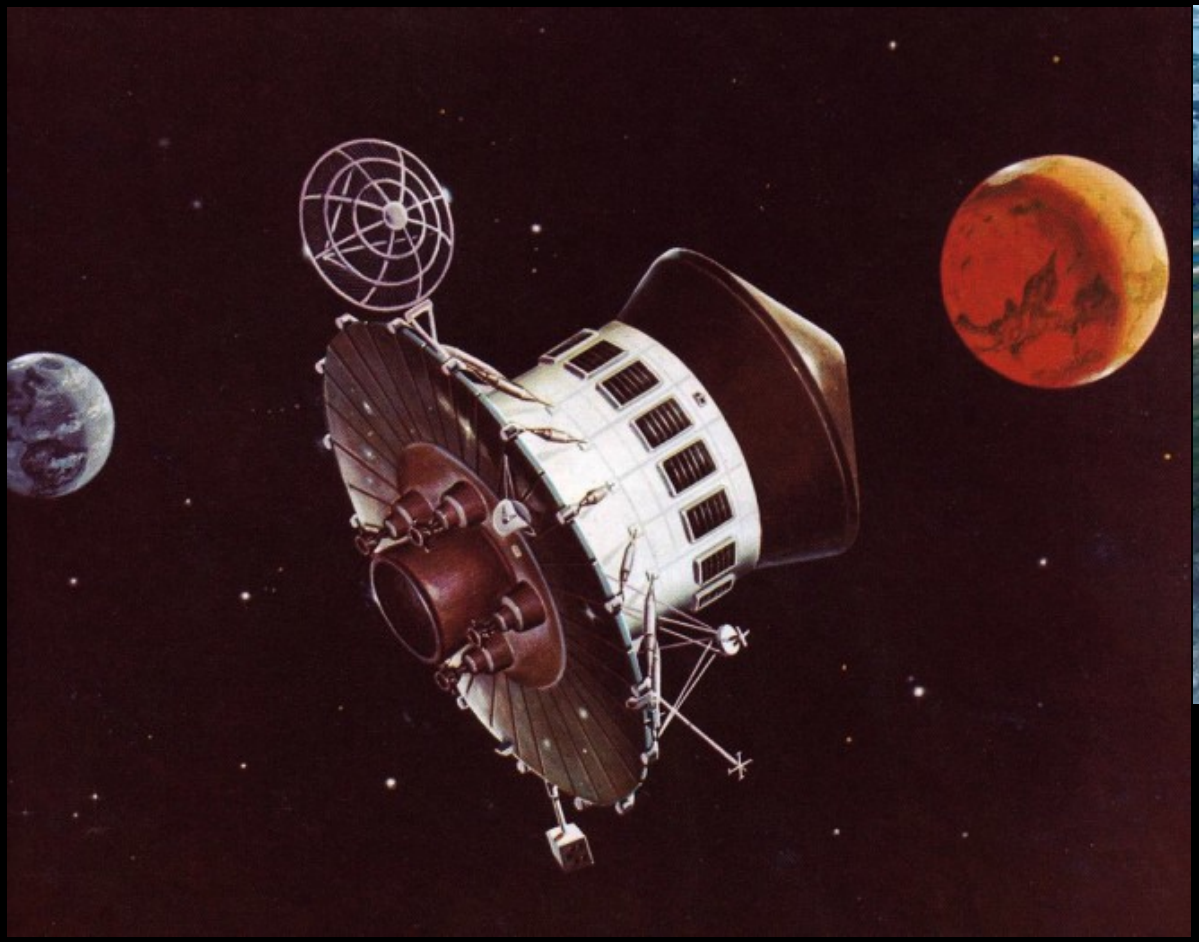
Square-Cube Law



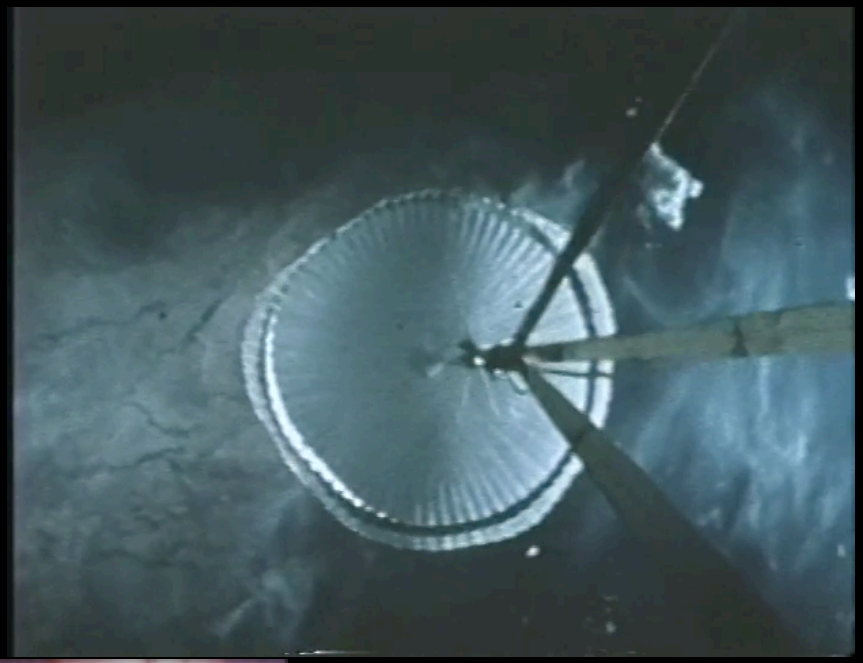
The Future

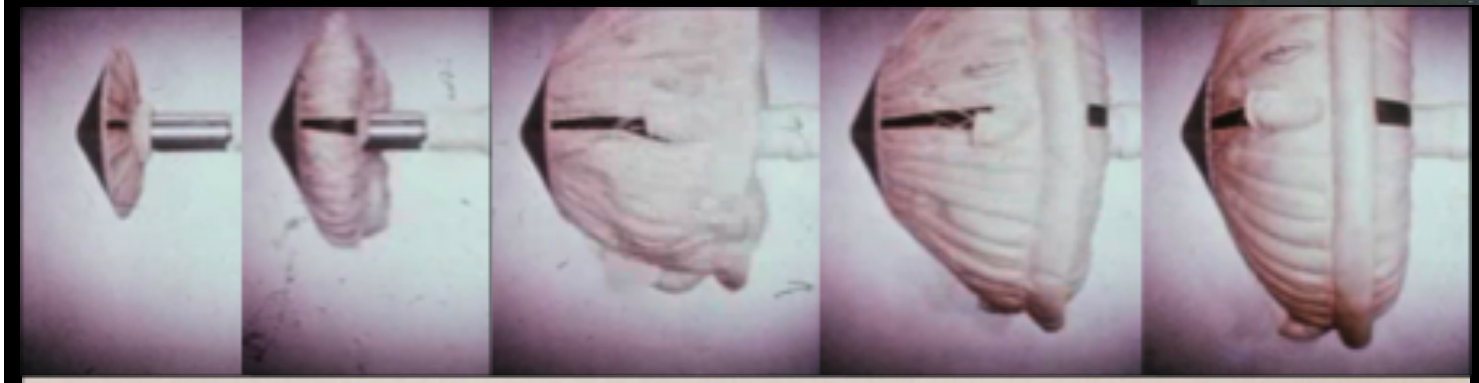


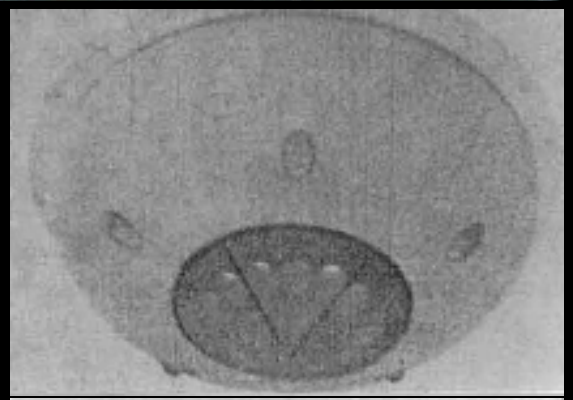
Mars Voyager



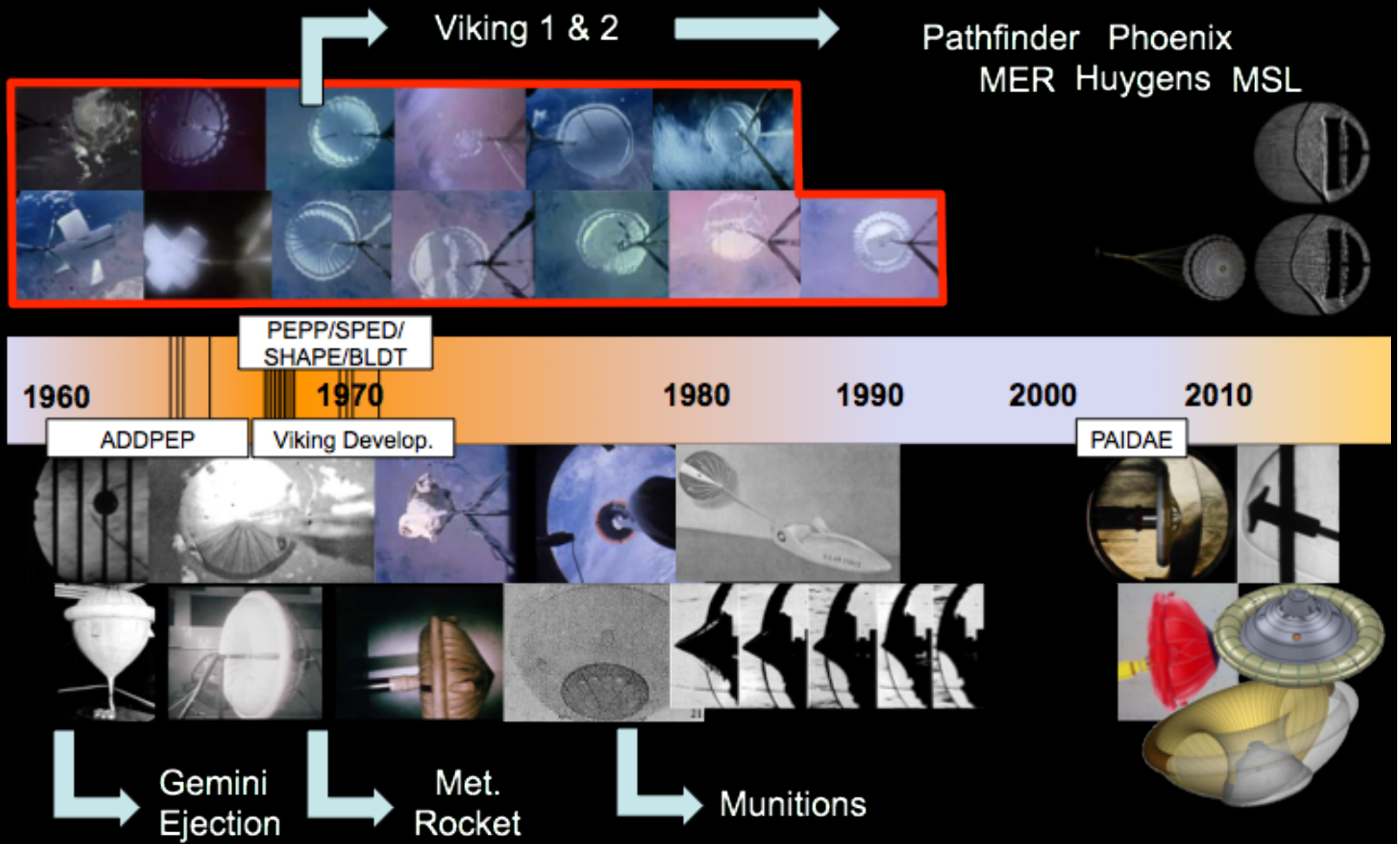
Mars Voyager: Decelerator Development







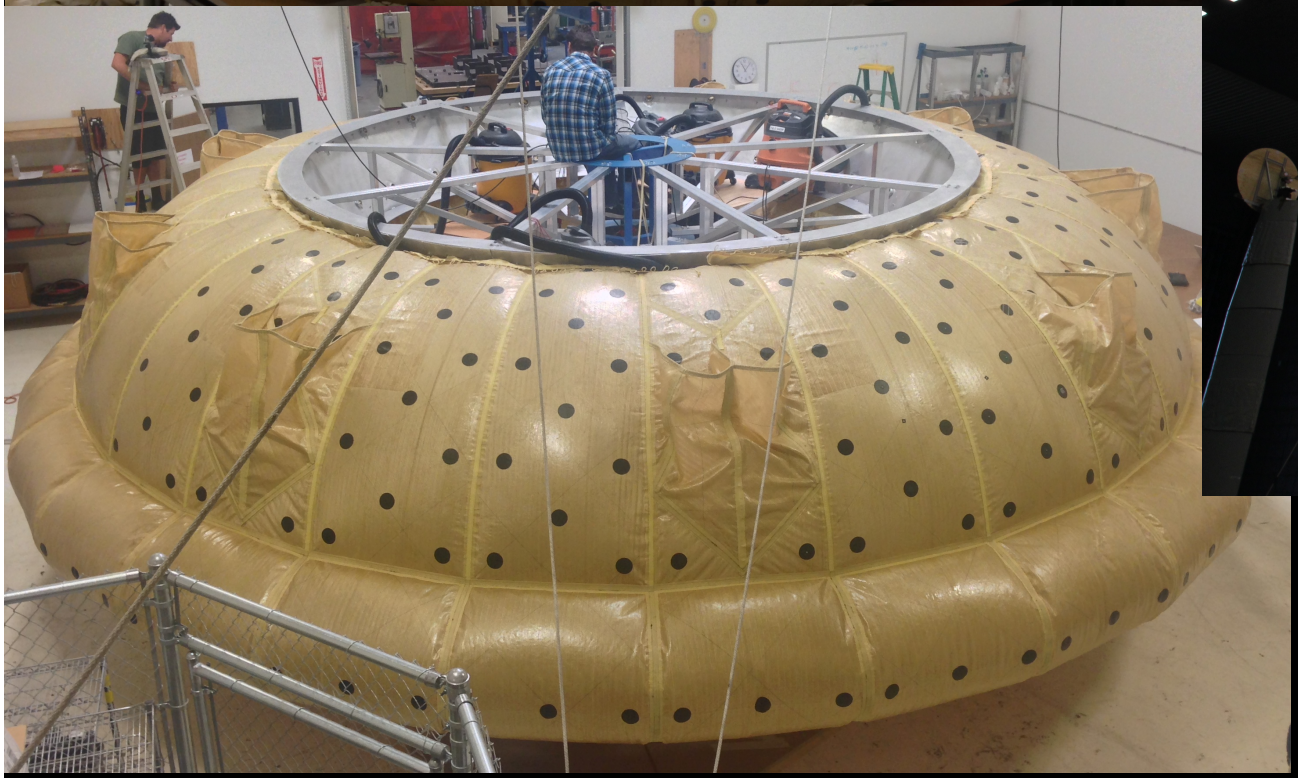
Square-Cube Law

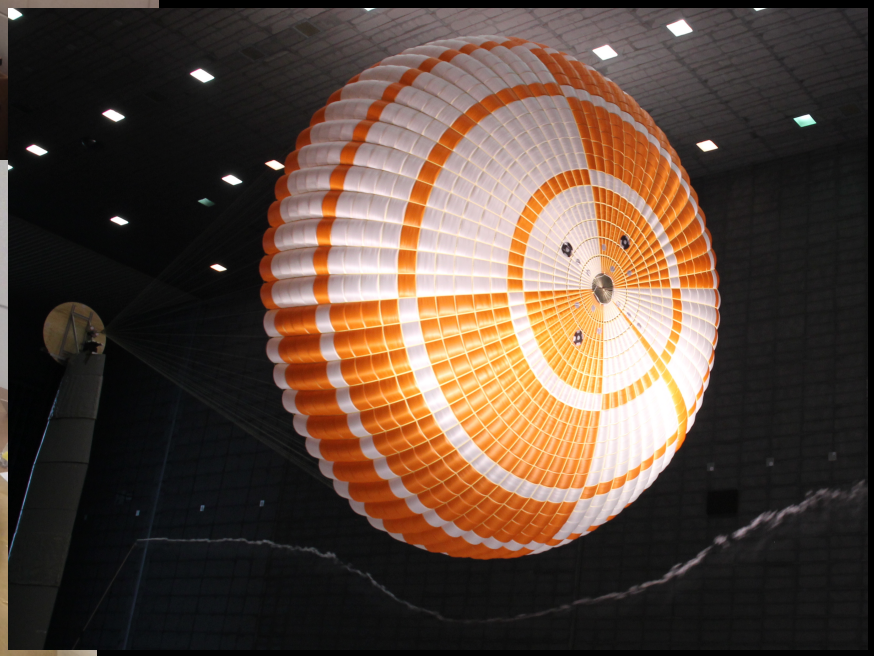


Disk-Gap-Band (DGB) Parachute Heritage

- Developed in the 60s & 70s for Viking
  - High Altitude Testing
  - Wind Tunnel Testing
  - Low Altitude Drop
- Successfully used on 6 Mars missions
  - Leveraged Viking development

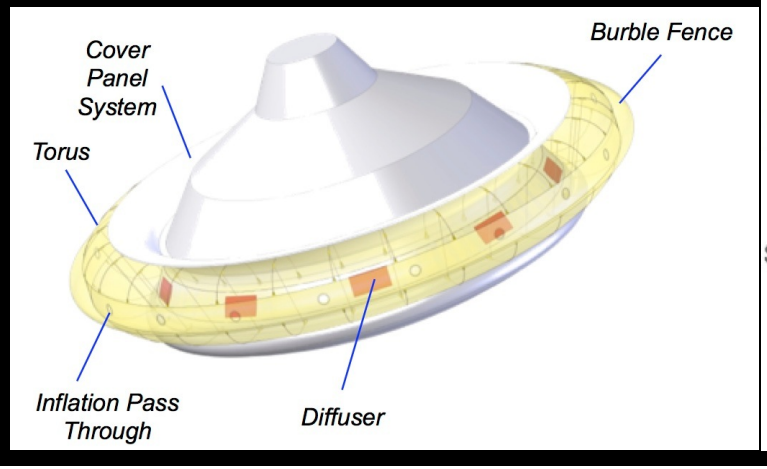
LDSD: Low-Density Supersonic Decelerator

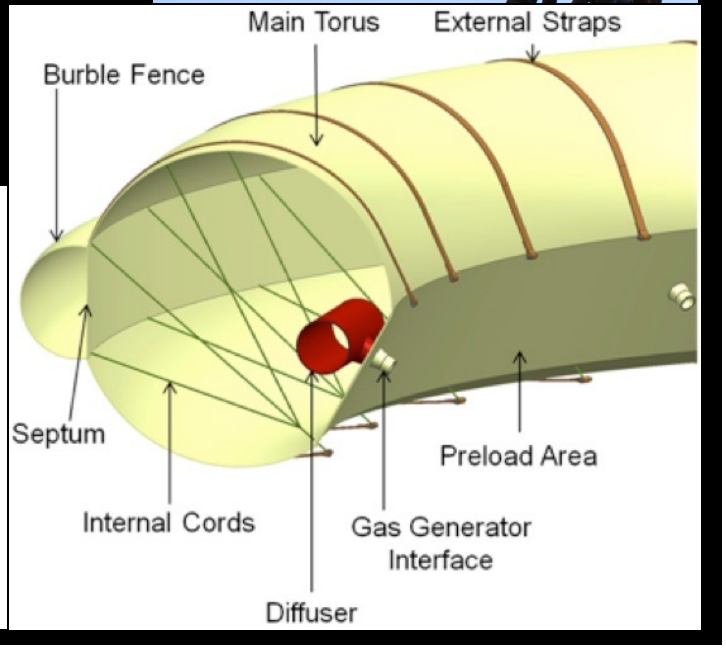




6m Attached Torus Overview

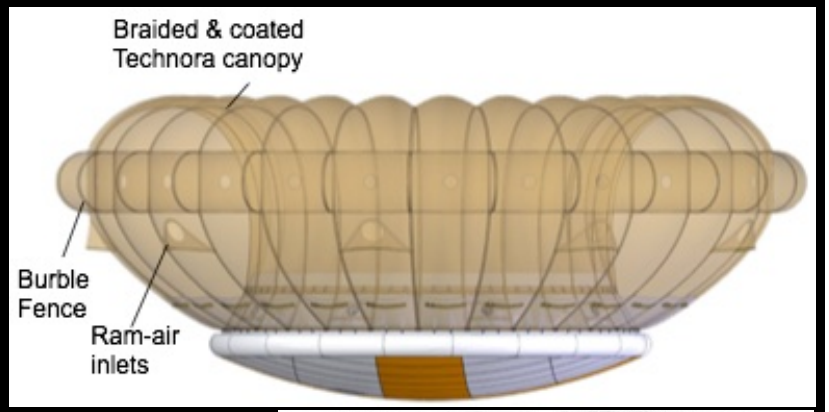
- Single pressurized torus with a burble fence for stability
- Simple, low-mass design to provide a ~50 - 70% increase in drag over an MSL aeroshell
- Internal pressure produces a rigid shape absent of aeroelastic deformations
- Allows for rapid inflation in <1 sec, minimizing vehicle disturbances
- Designed for deployment and operation at up to Mach 4

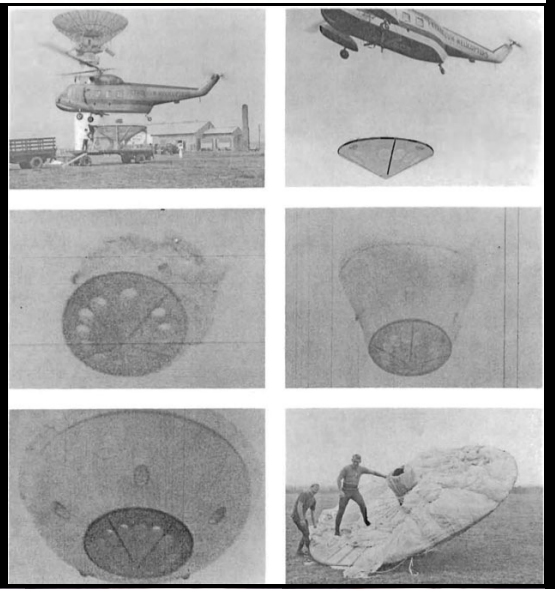


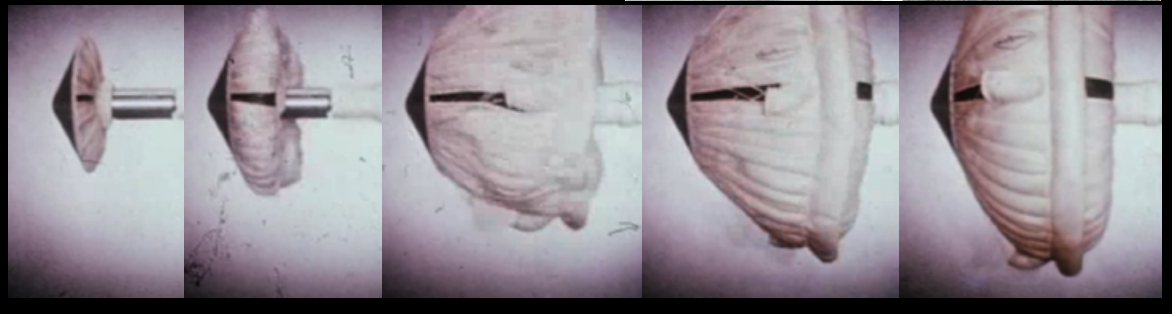


8m Attached Isotensoid Overview

- Represents first forays into understanding nature of highly flexible attached decelerator systems
- Structurally favorable design allows for minimal inflation pressure
  - Low-stresses => reduced canopy mass
  - Design allows for ram-air inflation (reduced inflation system mass)
- Subject of considerable subscale testing prior to Mars Viking program
  - More recently tested at sub/transonic conditions by NASA
- Will be largest non-parachute decelerator ever tested at supersonic conditions
- Designed for deployment and operation at up to Mach 4

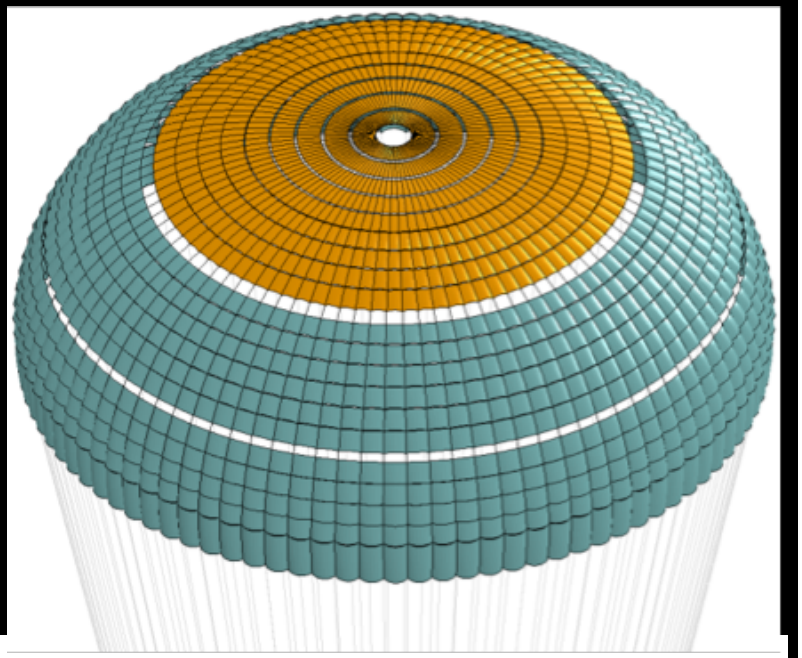


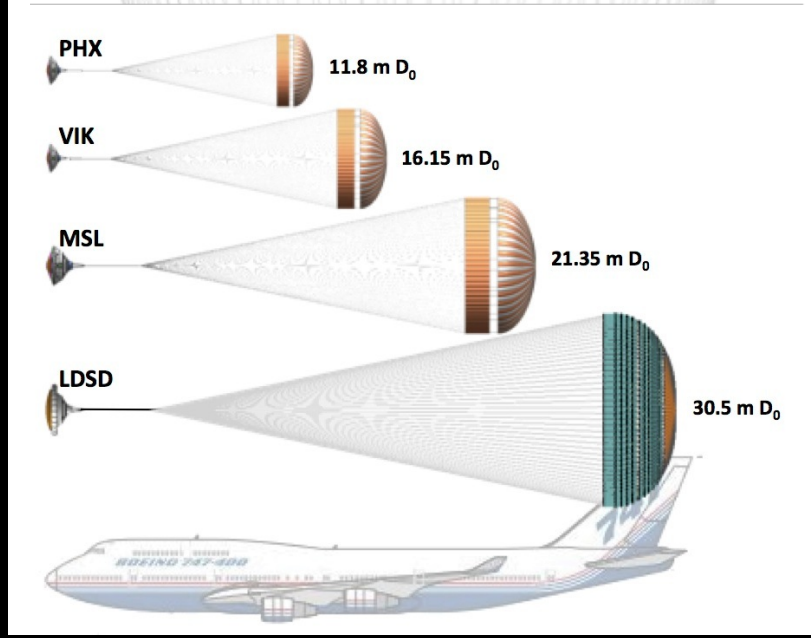




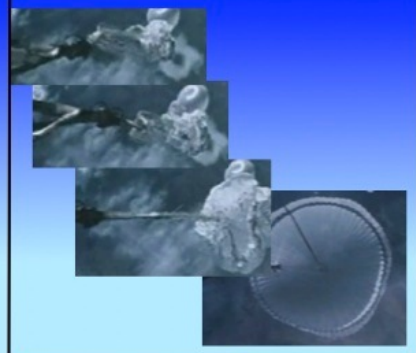
30.5m Supersonic Parachute Overview

- Ringsail configuration originally tested in conjunction with the Disk-Gap-Band for supersonic use on Viking missions
- Performance very similar to DGB, though DGB selected for simplicity of configuration
- Recent Ringsails have shown continued improvements in drag and stability
- Modifications still necessary for supersonic use
- Design features allow for improved opening reliability and ability to mitigate inflation loads via reefing (in theory)





Aerodecelerator Qualification Summary

Phase 1: Initial Deployment	Phase 2: Inflation Dynamics	Phase 3: Peak Strength	Phase 4: Supersonic Performance	Phase 5: Subsonic Performance
				
Driving Physics: Applied deployment forces much greater than aero forces. **Relevant Test Parameters** Hardware designs and deployment forces. Scale	**Driving Physics:** Transition from fabric inertial forces dominating to aero forces dominating. **Relevant Test Parameters** Mach Number Wake Structure Scale	**Driving Physics:** Stress and Strain state of the aero-decelerator. **Relevant Test Parameters** Dynamic pressure [Temperature] Scale	**Driving Physics:** Aerodynamics Aerothermodynamics **Relevant Test Parameters** Mach number Atm. density	**Driving Physics:** Aerodynamics **Relevant Test Parameters** Mach number Atm. density

Test Approach

High-altitude flight testing (SFDT)

Full-scale struct. test (SDV/PDV)

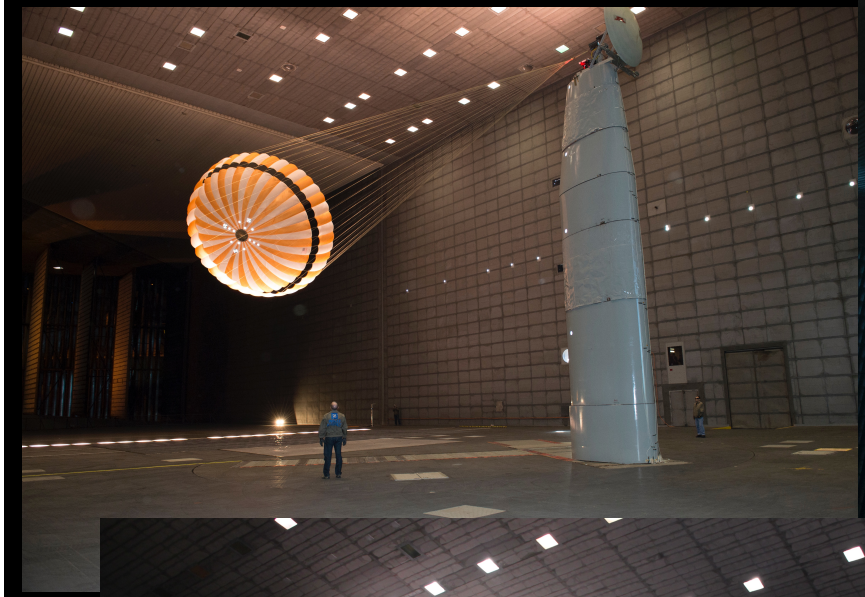
High-altitude flight testing (SFDT)

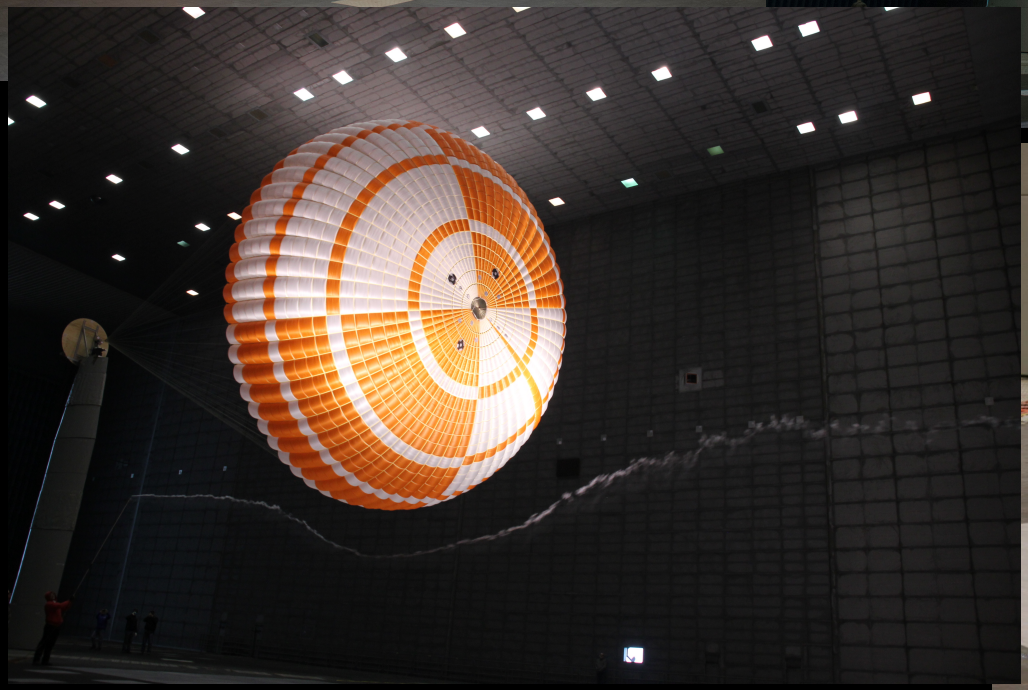
Testing: SIAD

Testing: SIAD

Testing

Testing: Parachute

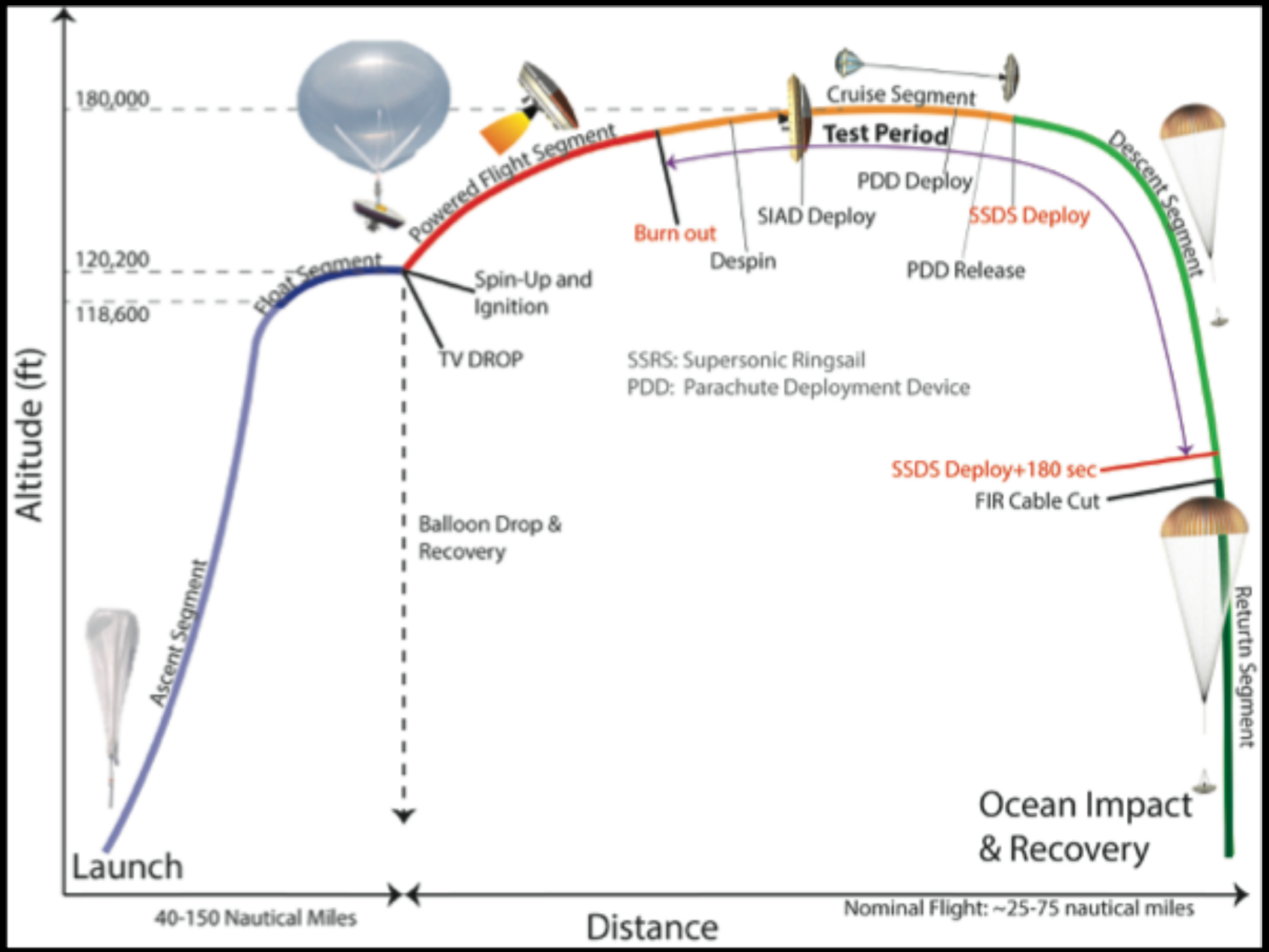




Testing: Parachute

Testing: Parachute

Testing: Supersonic Flight Dynamics Test



Testing: High Altitude

Testing: High Altitude

Testing: Accomplishments

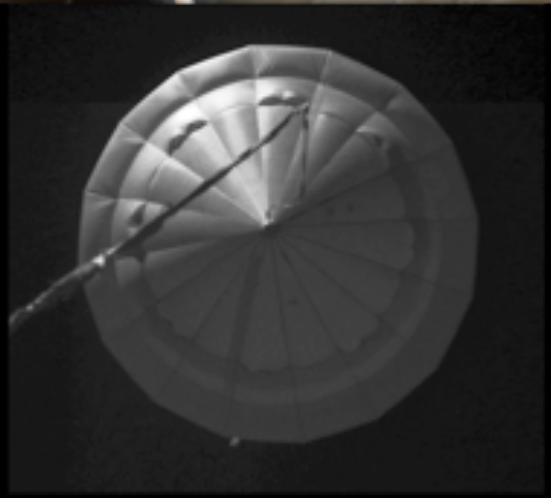
Largest inflatable aerodynamic decelerator *ever* deployed and tested at supersonic conditions

Largest ballute ever successfully flown at supersonic conditions

First ever supersonic pilot deployment of a large parachute

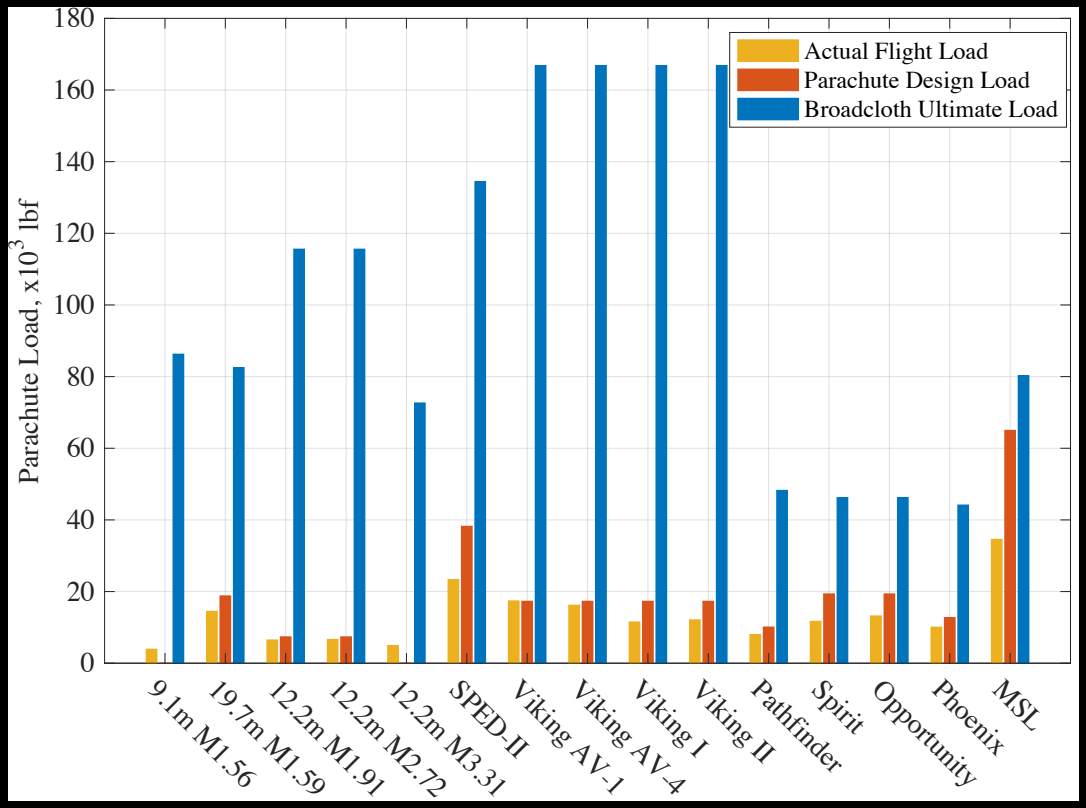
Largest supersonic parachute ever deployed

Unprecedented quantity and quality of data collected



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:

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

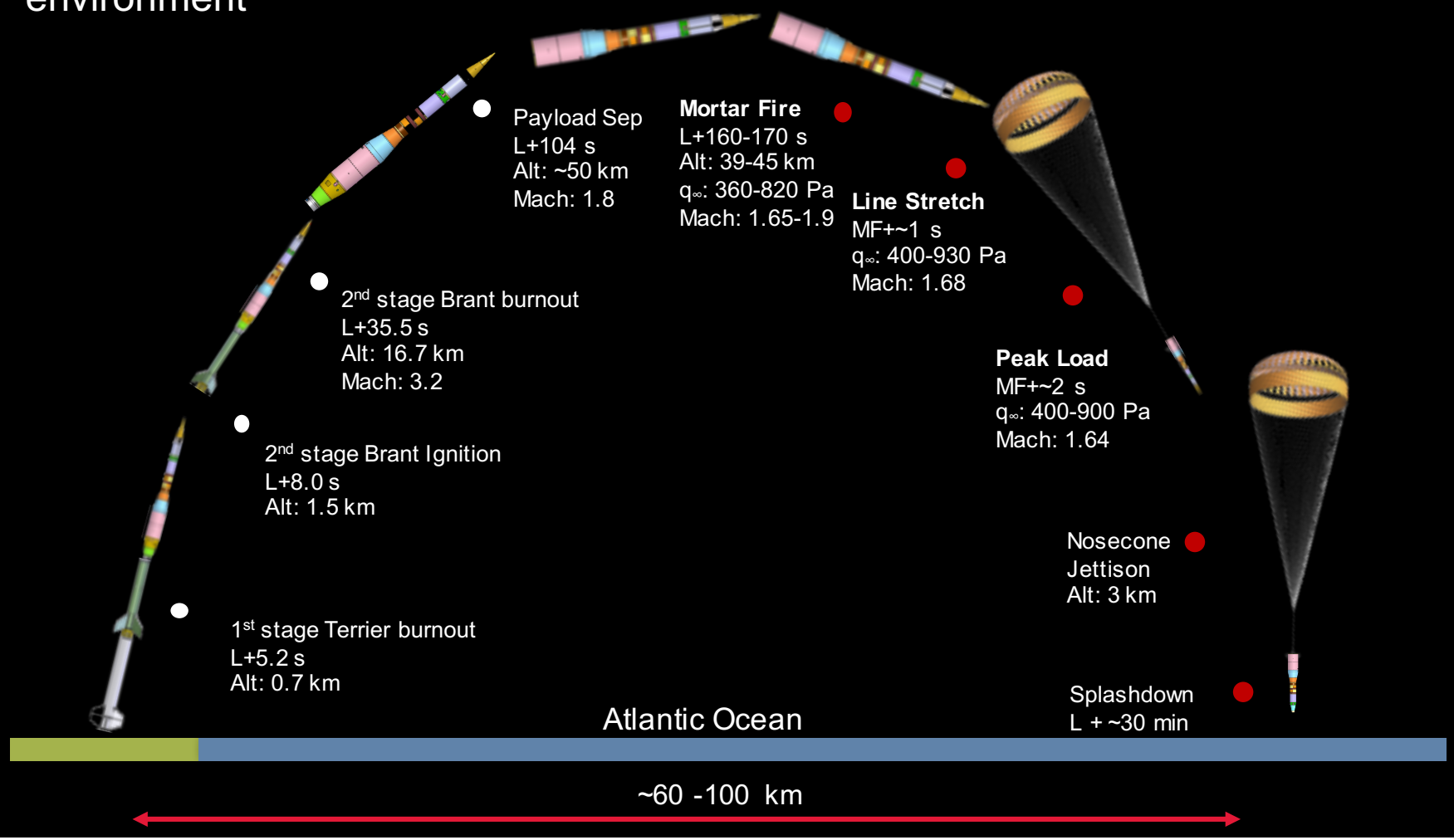
Disk diameter

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



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

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