National Aeronautics and Space Administration

CHANGING ENTRY, DESCENT, AND LANDING PARADIGMS FOR HUMAN MARS LANDER

Alicia Dwyer Cianciolo
NASA Langley Research Center

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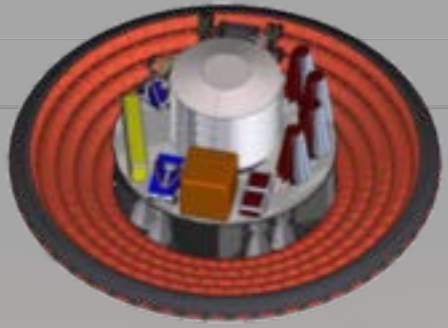
Introduction

The electric light did not come from the continuous improvement of candles.

-Oren Harari

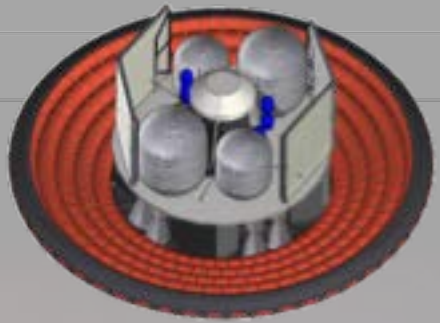
Cargo Elements for Long Duration Surface Stay

10 m diameter SLS fairing; 300 day stay; Crew of 4; Four 20 t payloads



Lander 1

- Surface Power Units
- Unpressurized Rovers
- Cargo Off-loading
- Logistics Module
- Science Payloads



Lander 2

- Mars Ascent Vehicle
- Atmosphere ISRU
- Crew Access Tunnel

Lander 3

- Pressurized Rover
- Logistics module
  - Crew consumables
  - Fixed system spares
  - Mobile system spares
  - EVA spares
- Surface Mobility

Lander 4

- Habitation

Sequence is repeated 3x for surface build up

Implication: Many landers delivered to same site; now have CG location + inertias

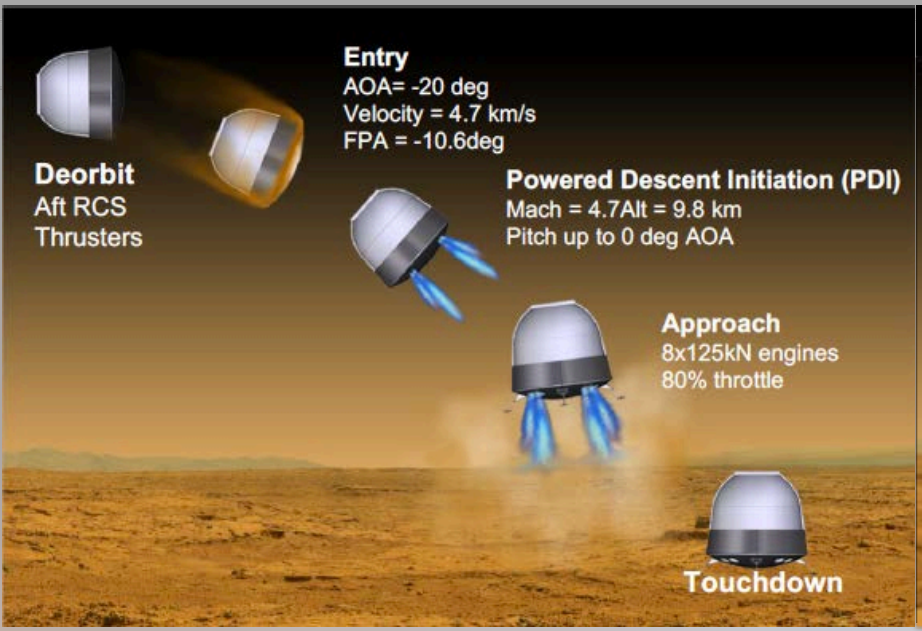
EDL Vehicle Designs: 20 t Payload Capability

Name	Shape	Vehicle Dimensions	Launch Mass	Entry Mass	Ballistic Number	L/D
Capsule Low L/D		10 m (h) x 10 m (w)	68t	63t	500 kg/m^2	0.3
Cobra MRV Mid L/D		22m (l) x 7.3m (h) x 8.8m (w)	66t	62t	380 kg/m^2	0.55
ADEPT Low L/D		4.3m (h) x 18m diameter	60t	55t	155 kg/m^2	0.2
HIAD Low L/D		4.3m (h) x 16.4m diameter	57t	49t	155 kg/m^2	0.2

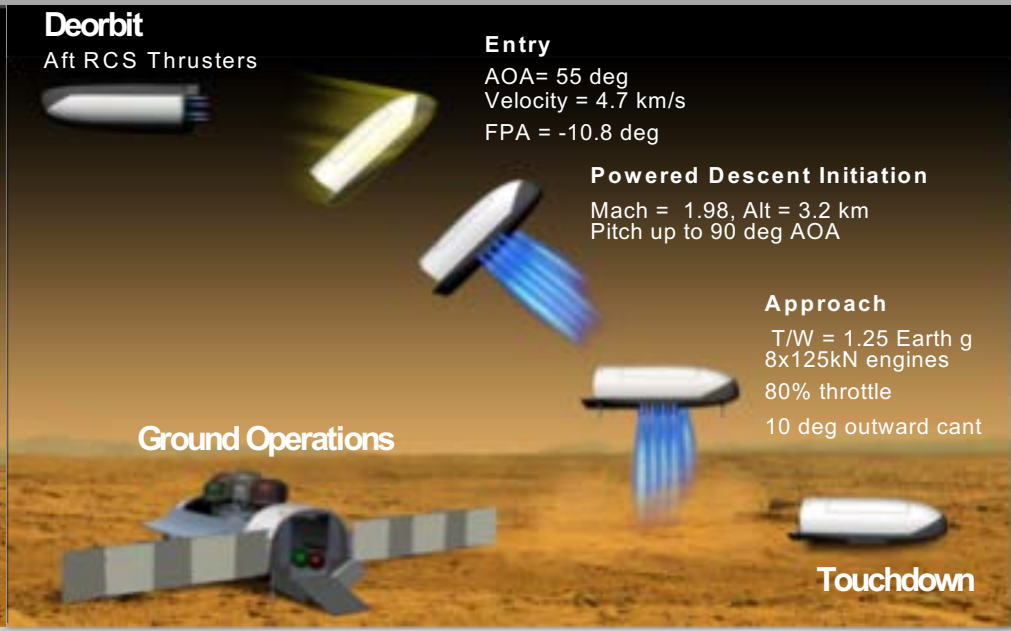
ADEPT = Adaptable Deployable Entry Placement Technology
HIAD = Hypersonic Inflatable Aerodynamic Decelerator
Cobra MRV = Mid-L/D Rigid Vehicle

Human Mars EDL Concept of Operations

Capsule

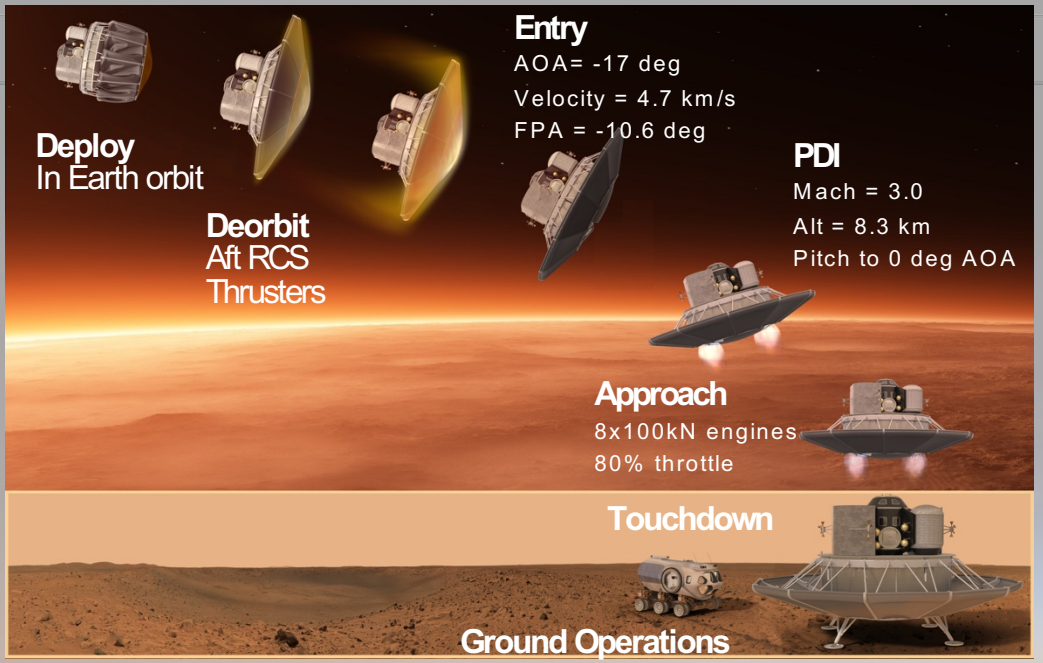


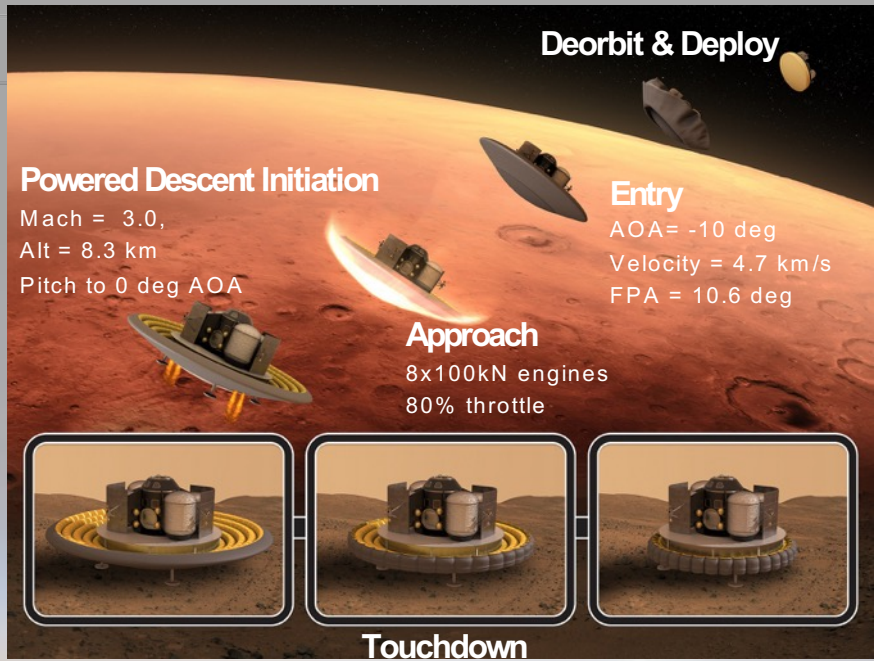
Cobra MRV



Human Mars EDL Concept of Operations

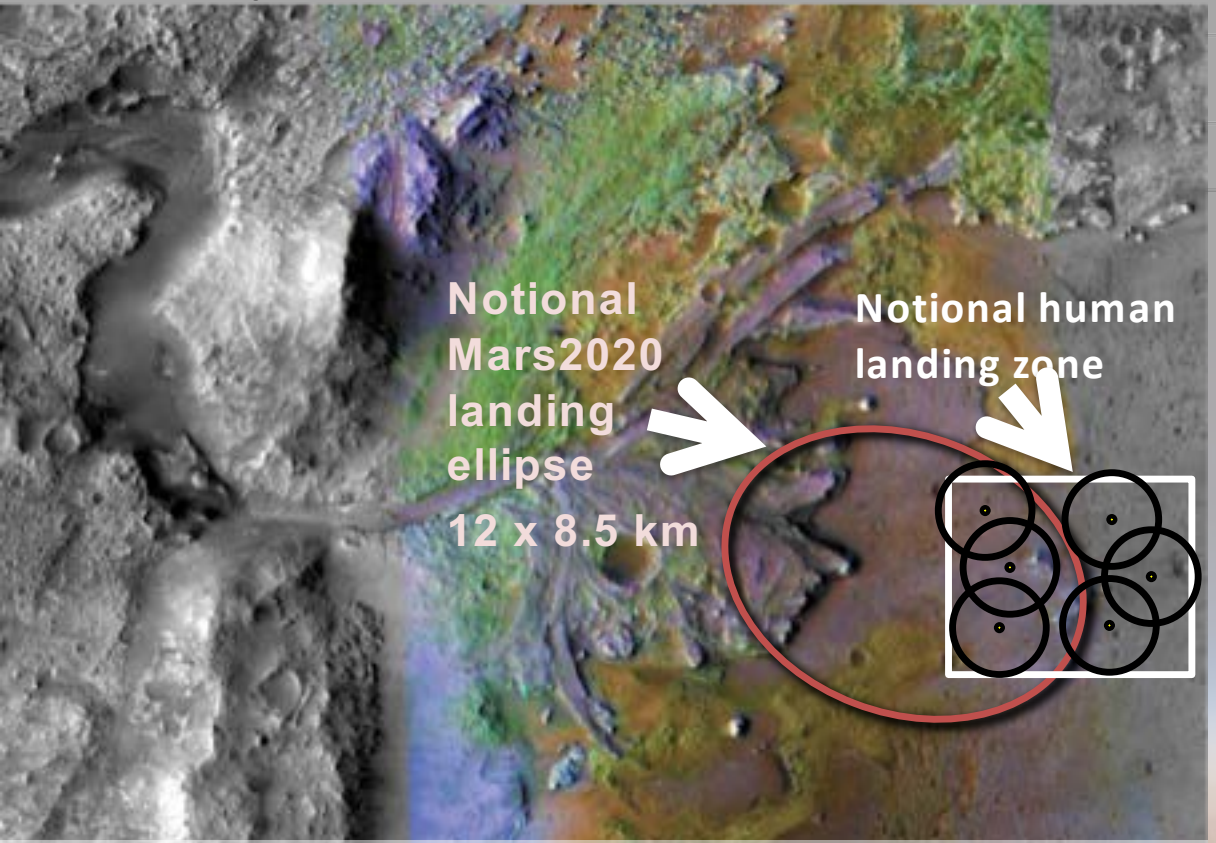
Low L/D





Landing Considerations

Sample Site: Jezero Crater (#1 Mars 2020 site)

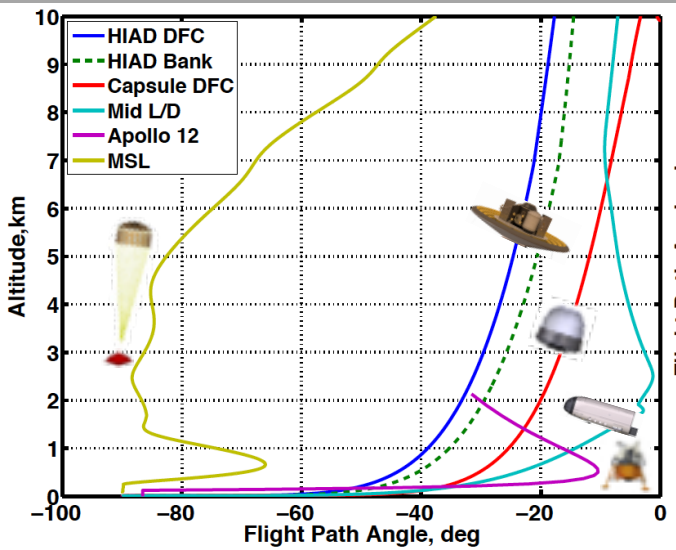


Jezero contains Fe-Mg smectite clay indicative of multiple episodes of fluvial/aqueous activity on ancient Mars, elevating the potential for preservation of organic material.(Green = phyllosilicates, orange = olivine, purple = neutral/weak bands.)

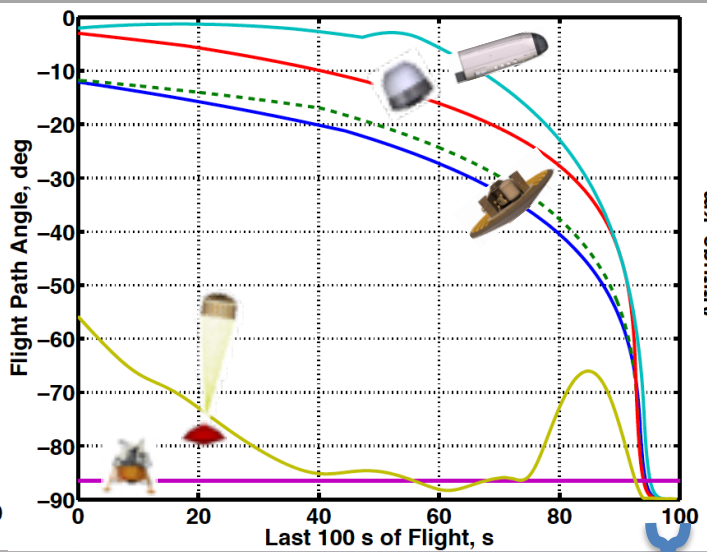
- **No jettison events**
- **Must land within 50 m of target**
- **Land at 0 km MOLA**
- **Hold constant velocity 2.5 m/s for 5 s prior to landing**
- **Cannot land closer than 1 km to any other landed asset due to surface plume interactions**

Trajectory Geometry

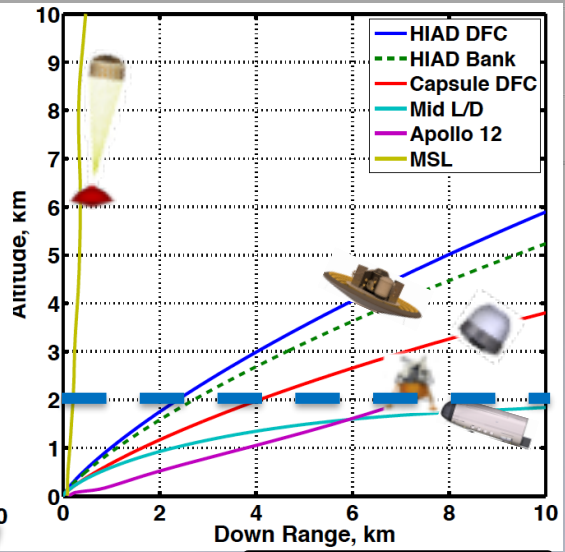
Altitude vs. Flight Path Angle



FPA vs. Time



Altitude vs. Down Range



- -90 deg FPA = Vertical flight (straight down)
- DFC = Direct Force Control
- Bank = Bank angle modulation
- **Apollo FPA is really pitch angle

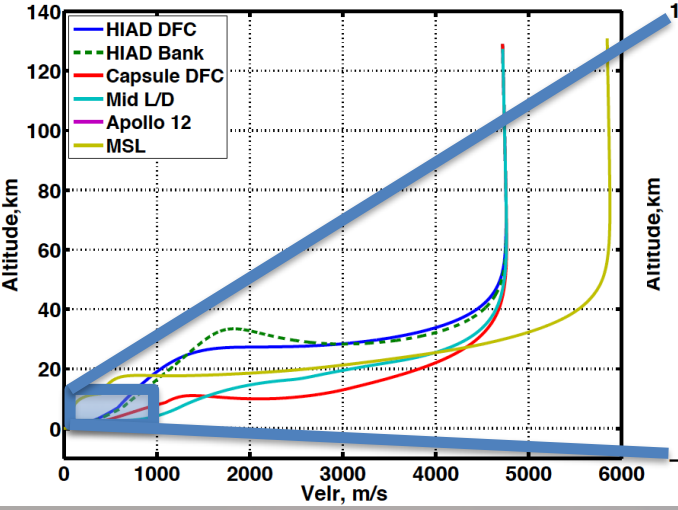
Less than 10 s of flight with less than -60 deg FPA

HIAD DFC
HIAD Bank
Capsule DFC
Mid L/D
Apollo 12
MSL

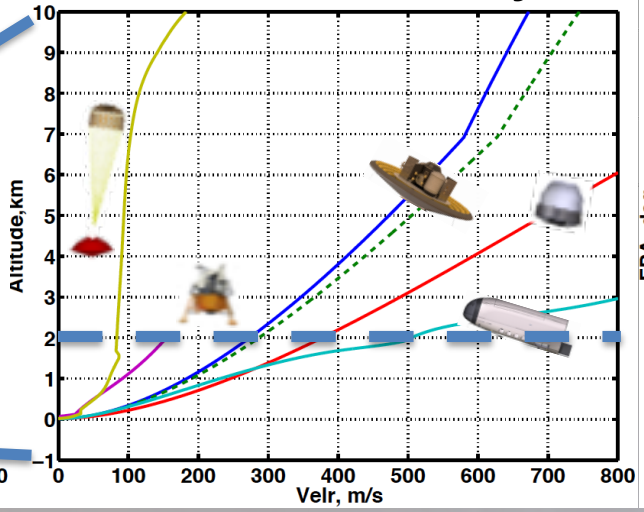
Geometry and attitude affect sensor location, shutter speeds, view angles, number of sensors, data processing requirements, vehicle accommodation, etc.

Trajectory Geometry

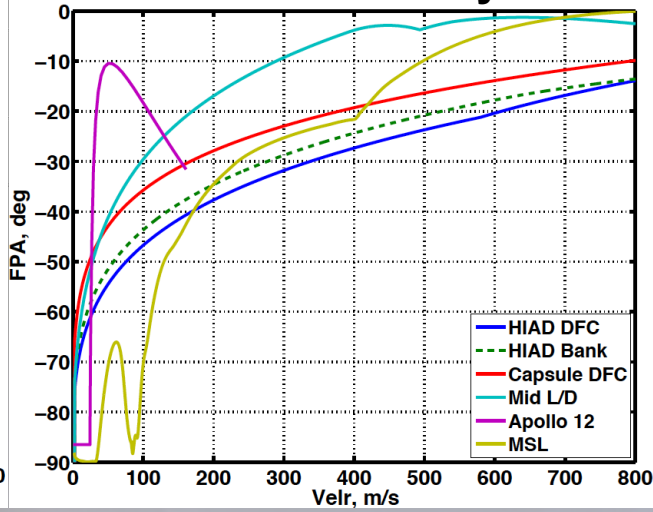
Altitude vs. Velocity



Altitude vs. Velocity



FPA vs. Velocity



Summary: At 2 km above the surface

Vehicle	Downrange (km)	Velocity (m/s)	FPA (deg)	Time to landing (s)
MSL	0.2	90	-86	30
Mid L/D	10	500	-5	50
Capsule	4	375	-20	30
HIAD	2.5	300	-30	30

Landing paradigms change for human scale landers using SRP.

Summary

- **Still much to learn about EDL using supersonic retropropulsion**
  - Entry and Descent Guidance and Control
    - How and when to hand off
    - How to transition vehicle angle of attack
  - Engines
    - Effect on vehicle stability
    - Impact of plumes on instrument views and surface
    - Performance, transients, keep out zones
  - Navigation
    - Which and how many navigation instruments are needed
    - Their performance and accuracies
    - Vehicle locations and accommodation
    - Software requirements
    - Preplaced infrastructure (orbiters or surface beacons)
- **Do know**
  - Engine performance drives the design
  - Guidance, Navigation and Control is specific to each vehicle configuration
  - All configurations will have vehicle and surface interactions with the SRP plume
  - Regardless of EDL details, the system can not be designed independent of the overall Mars architecture