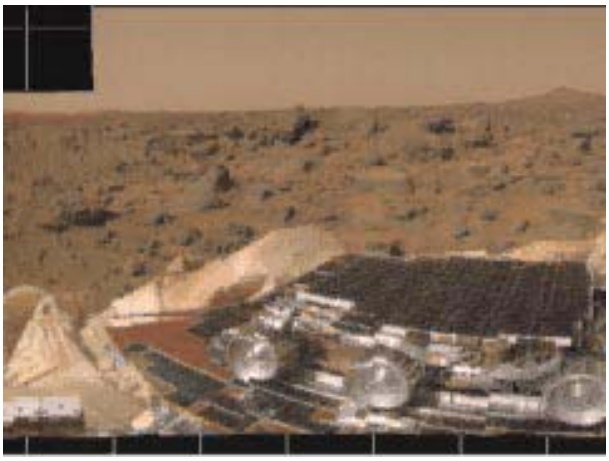
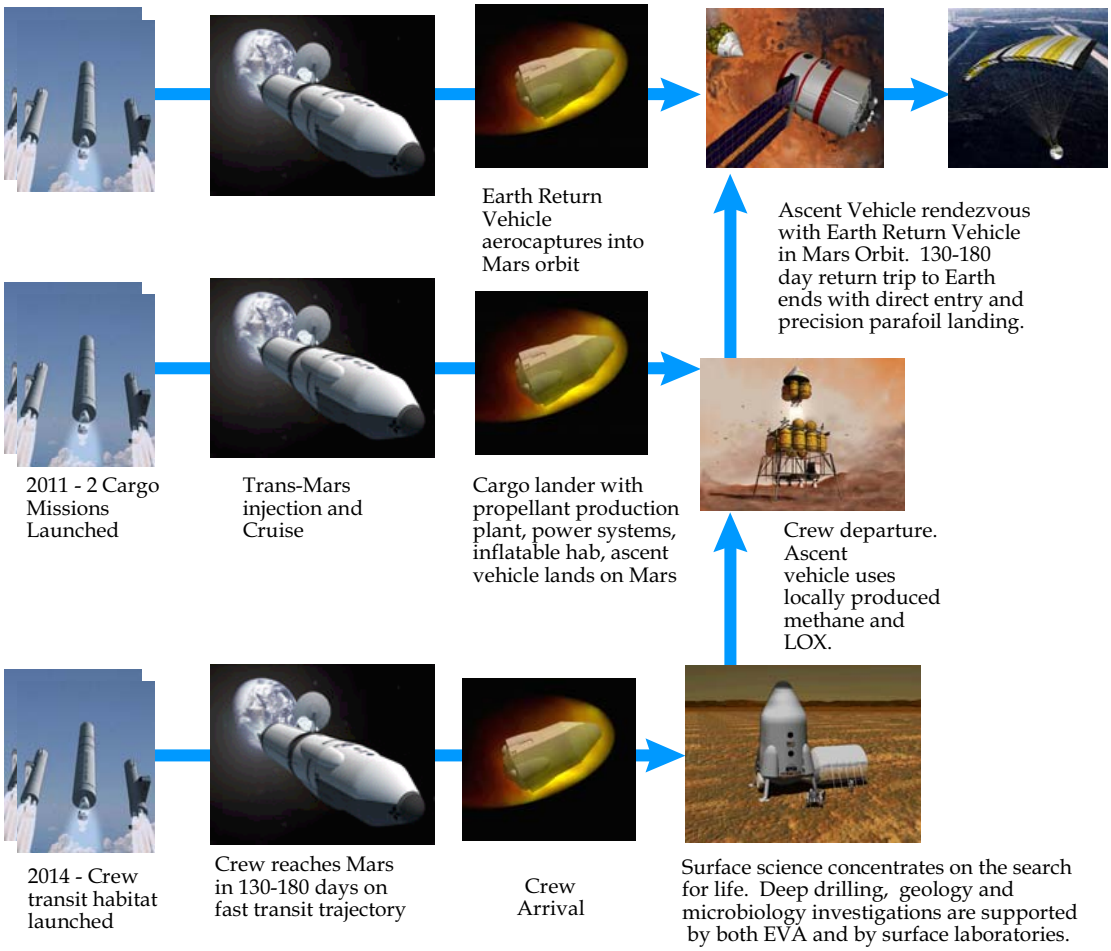
Human To Mars?

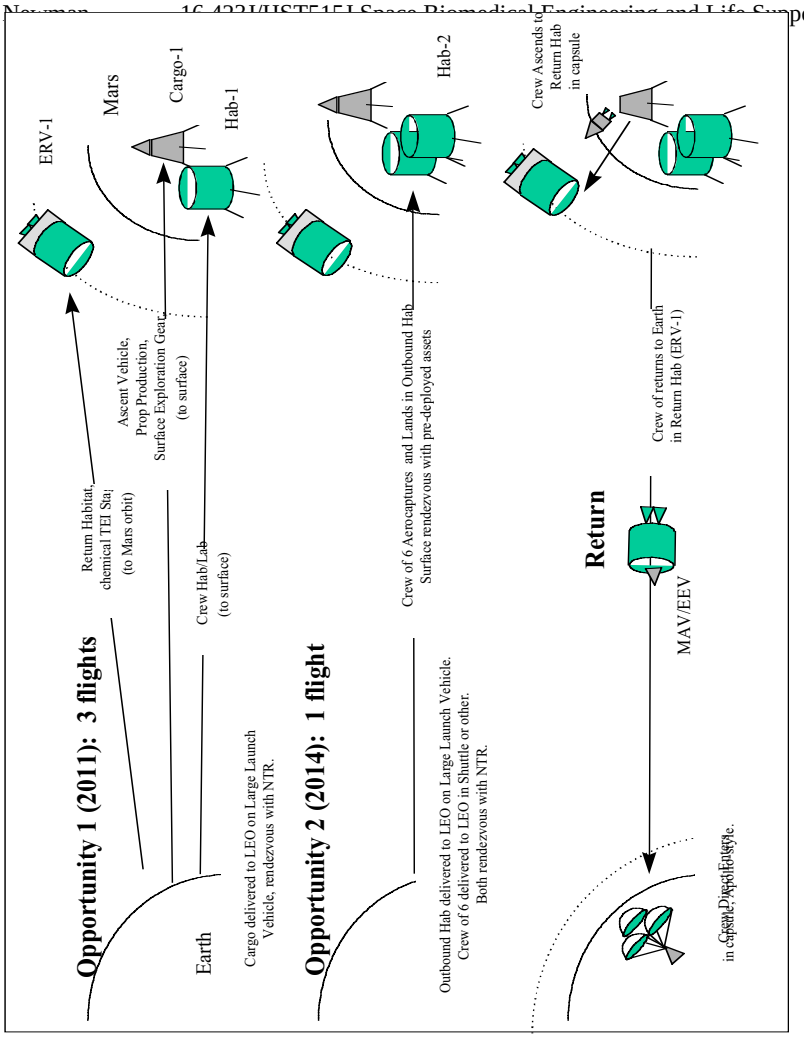
- It’s Expensive!



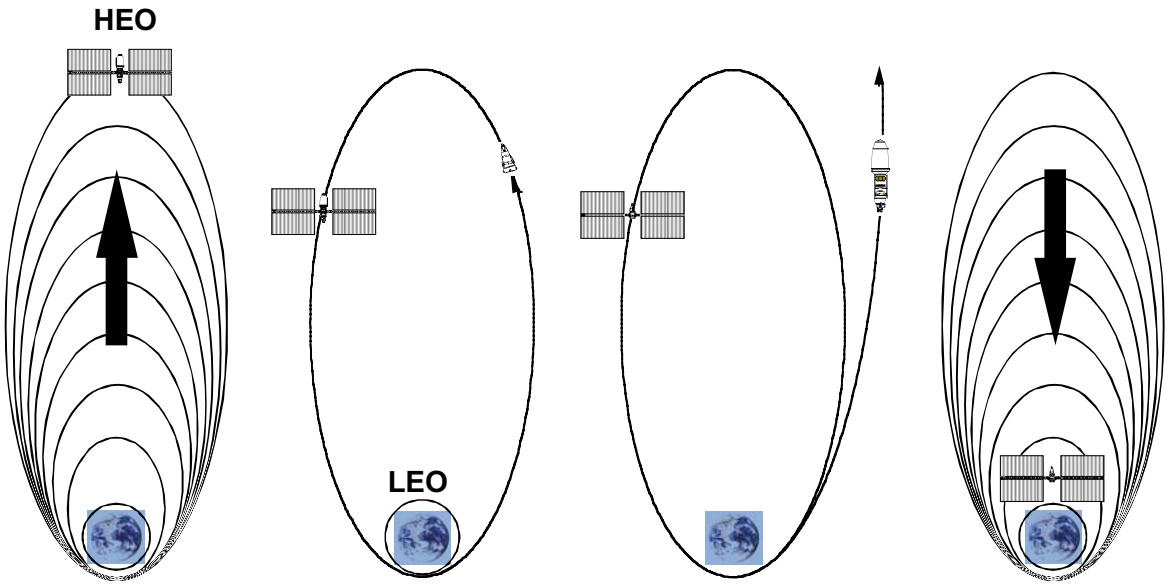
- Global Cooperation
- Human Spirit
- Science and Engineering
- $20 Billion ‘Mars Direct Mission’ - Zubrin

Mars Reference Mission




Opportunity 1 (2011): 3 flights
Earth
Mars
ERV-1
Cargo-1
Hab-1
Hab-2
Return Habitat, chemical TEI Stage (to Mars orbit)
Ascent Vehicle, Prop Production, Surface Exploration Gear (to surface)
Crew Hab/Lab (to surface)
Cargo delivered to LEO on Large Launch Vehicle, rendezvous with NTR.
Opportunity 2 (2014): 1 flight
Crew of 6 Aerocaptures and Lands in Outbound Hab Surface rendezvous with pre-deployed assets
Outbound Hab delivered to LEO on Large Launch Vehicle. Crew of 6 delivered to LEO in Shuttle or other. Both rendezvous with NTR.
Crew Ascends to Return Hab in capsule
Crew of returns to Earth in Return Hab (ERV-1)
Return
MAV/EEV
Crew Descends in Capsule, Aperobrake.

Solar Electric Propulsion Mission Concept



Electric Propulsion (EP) space tug performs low-thrust transfer for Mars-bound cargo to High Earth Orbit (many months transfer)

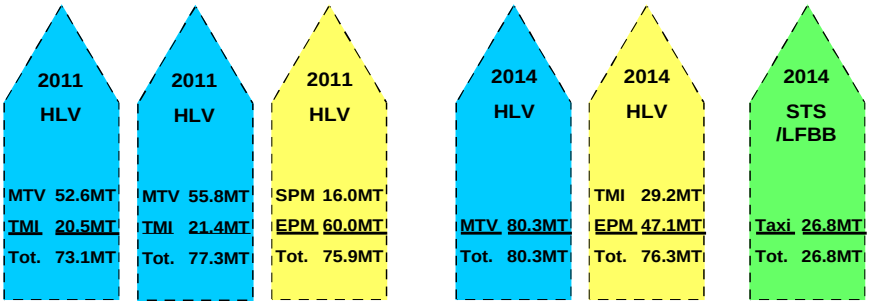
Crew delivered in “small” chemically-propelled transfer vehicle - X-38 derived (few days rendezvous time)

Remainder of trans-Mars injection performed by chemically-propelled system

Space tug returns for refueling and next assignment (faster or more efficient return since no payload present)

2011: One SEP stage delivers two Cargo MTV/TMI's to 39,709 x 800 km @ 51.6 deg.

2014: Same SEP Stage is refueled and delivers piloted MTV/TMI to 70,761 x 800 km @ 51.6 deg.

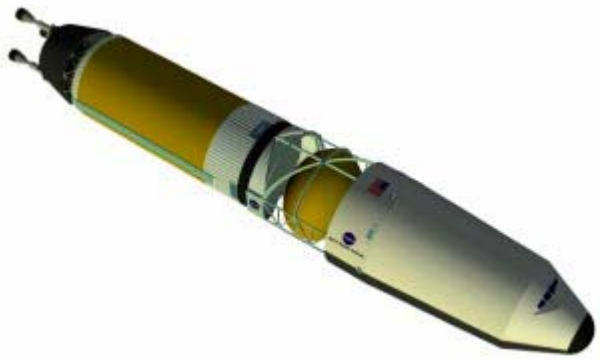


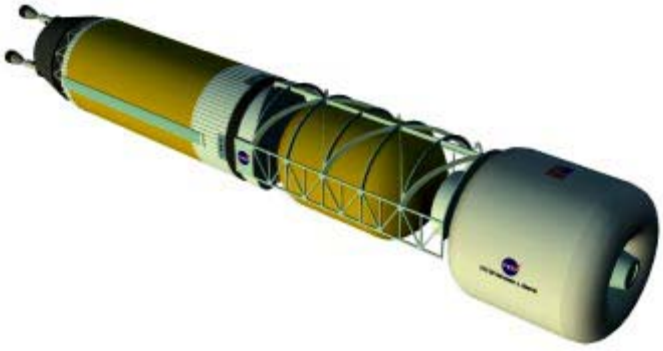
MTV - (Injected) Mars Transfer Vehicle
TMI - Trans Mars Injection Stage/Propellant
SPM - Solar Power/Bus Module
EPM - Electric Propulsion Module (wet)
Taxi - LEO to HEO Crew Taxi

Total Launches:
5 HLV
1 STS

IMLEO:
382.9 MT (HLV)
26.8 MT (STS)

Nuclear Thermal Propulsion

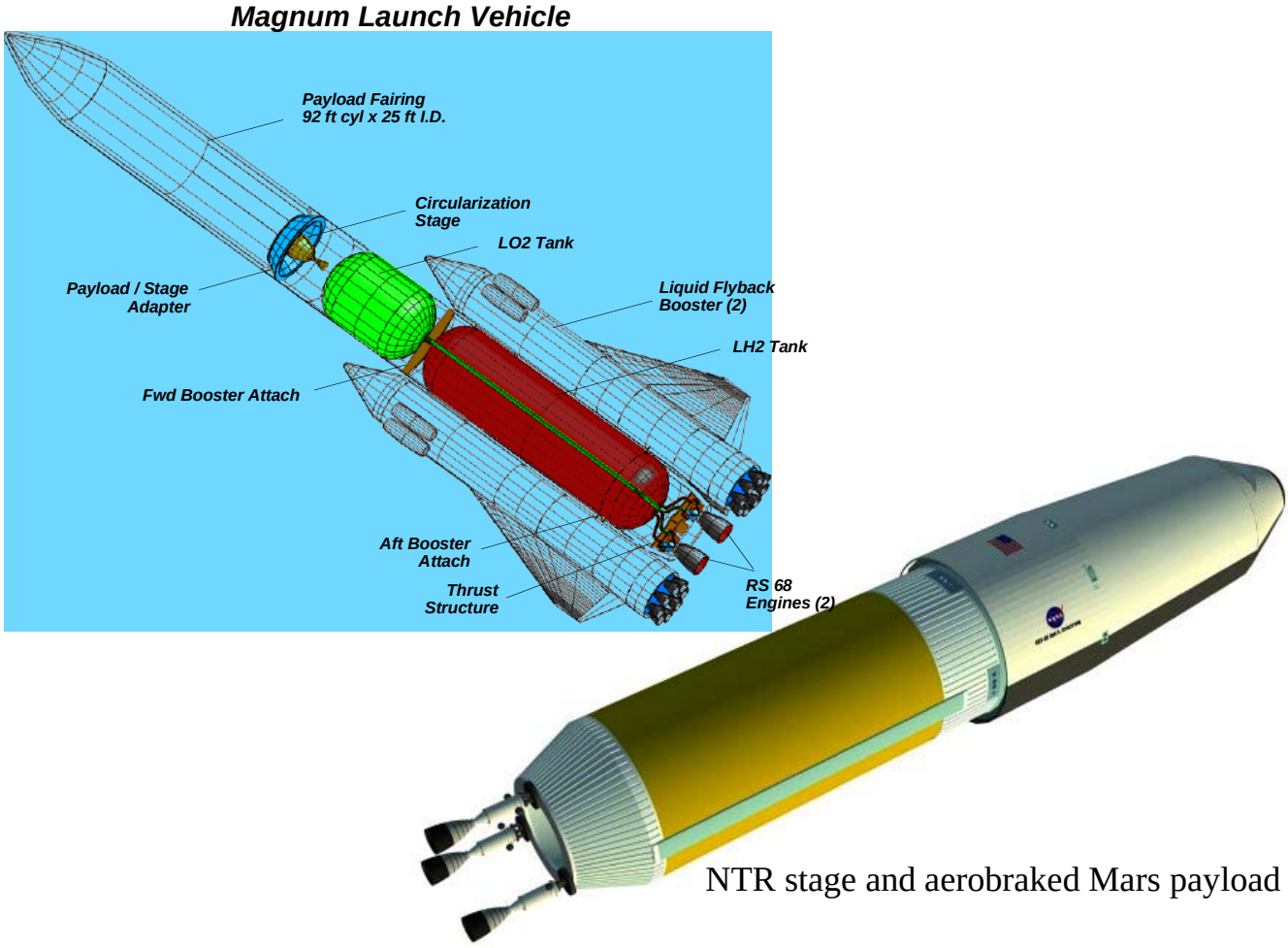




Magnum Launch	Flight Element	2011 Cargo Lander		2011 ERV *		2014 Crew Lander		Totals	
	Mission Type	DRM	Bimodal	DRM	Bimodal	DRM	Bimodal	DRM	Bimodal
#1	Payload	66.0	65.0	74.1	25.5	60.8	56.4	200.9	146.9
	- Surface/"In-Space"	- 40.2	- 40.2	- 29.1	- 25.5	- 30.9	- 28.4	- 100.2	- 94.1
	- Transportation	- 25.8	- 24.8	- 45.0		- 29.9	- 28.0	- 100.7	- 52.8
	"In - Line" Propellant/Tankage (**LH_2** &/or LOX)	-	-	-	20.1	-	5.3	-	25.4
#2	NTR TMI stage ("Modified" DRM uses "bimodal" NTRs)	68.6	73.6	73.4	79.0	76.6	79.0	218.7	231.6
	Total :	134.6	138.6	147.5	124.6	137.5	140.7	419.6	403.9
	# Magnums	2	2	2	2	2	2	6	6

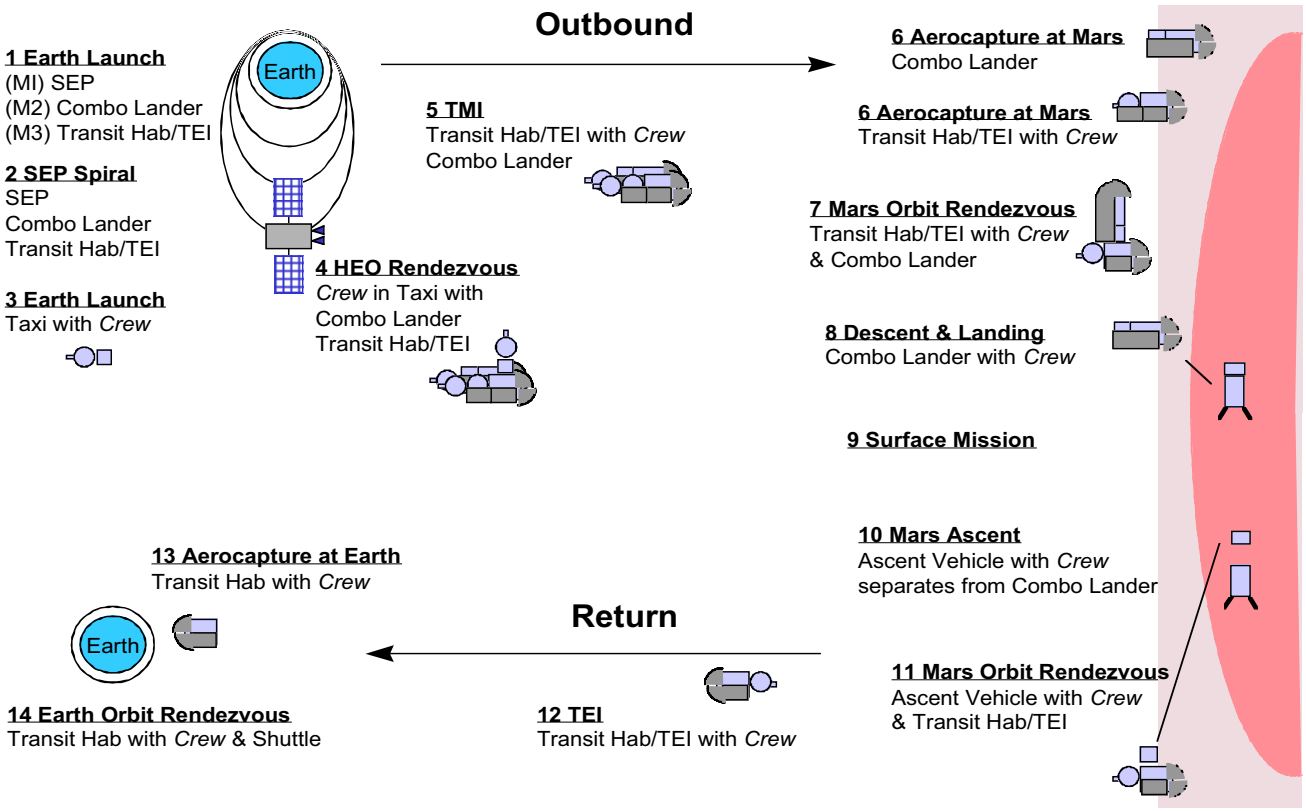
* 2011 ERV mission using "bimodal" NTRs for MOC and TEI is lighter than DRM by ~23 t and eliminates DDT&E and recurring costs for LOX/CH_4 TEI stage, also recurring cost for 30 kWe PVA and aerobrake.

** Common "Bimodal" NTR TMI stage provides 50 kWe power capability to the ERV, Crew and Cargo lander missions. Also supplies MCC burns for these missions. For cargo lander, the "Bimodal" stage refrigeration/heat rejection systems can be used to cryocool 4.5 t of "seed" LH_2 and dump "waste heat" from 15 kWe DIPS power cart.

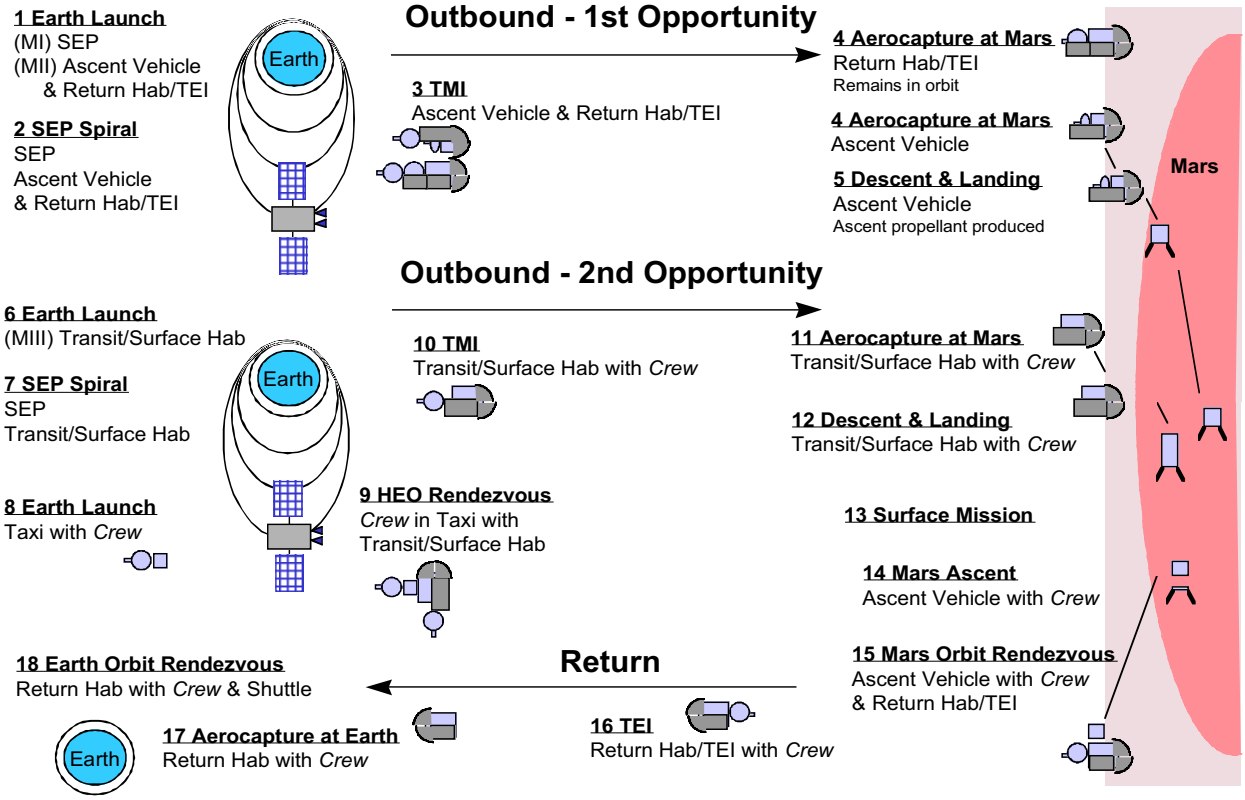


NTR stage and aerobraked Mars payload

Three-Magnum Combination Lander Scenario

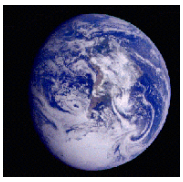


Three-Magnum Split Mission Scenario

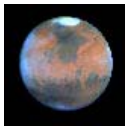


Temperature

Earth



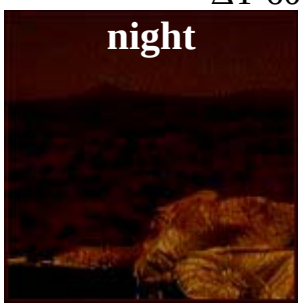
Mars

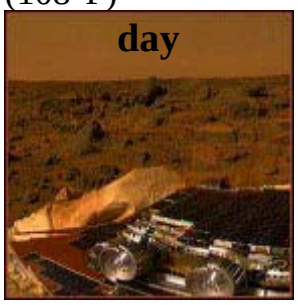


15°C 288°K (55°F)

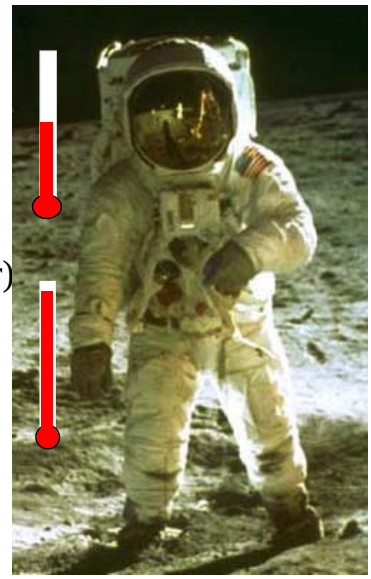
-55°C 218°K (-67°F)

ΔT 60°K (108°F)





- ~10°K (18°F) between
  Over 0.75 m (30 in) height
  0.65 m (knee) & 1.4 m (shoulder)



- Noon: vertical temperature variation highest
- Night: vertical temperatures are very similar
- Expansion and contraction of materials, resulting in great stresses

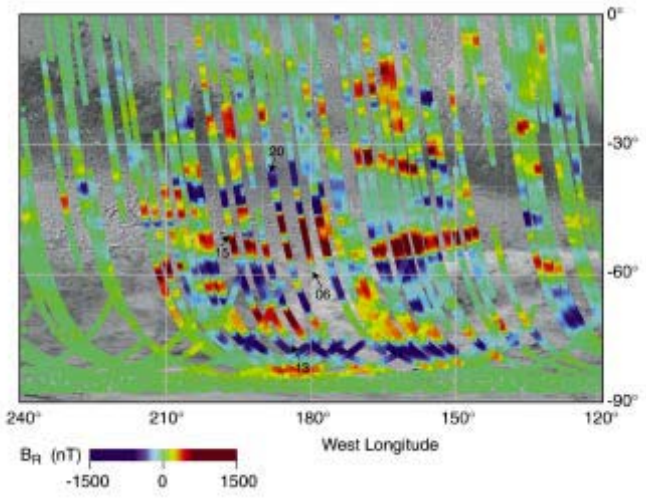
Life?

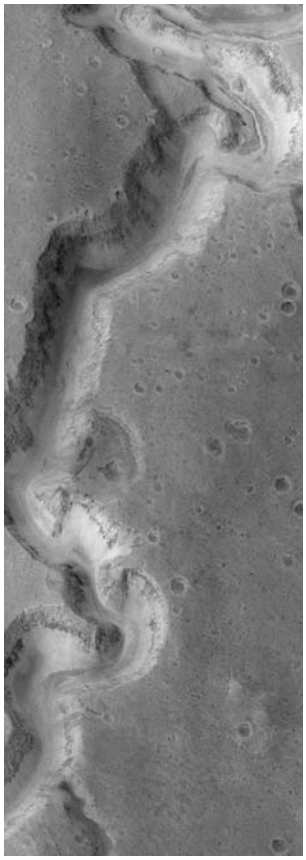
Mars Observer Camera Images

• High resolution images identify interesting places for exploration.

Magnetic Stripes

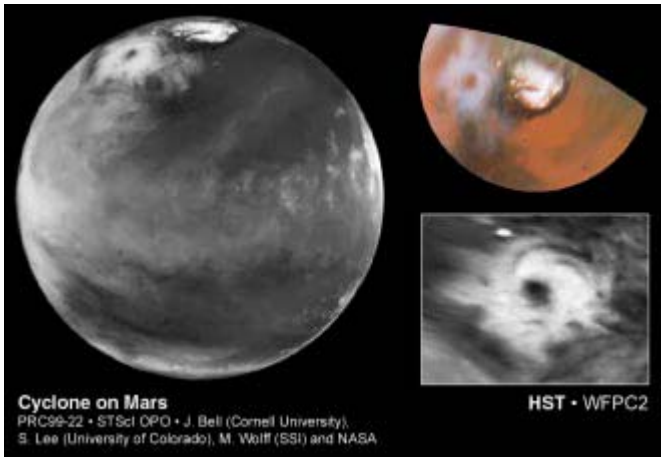
• Oldest place on Mars identified using magnetic stripes
• South polar cap may have preserved organic material

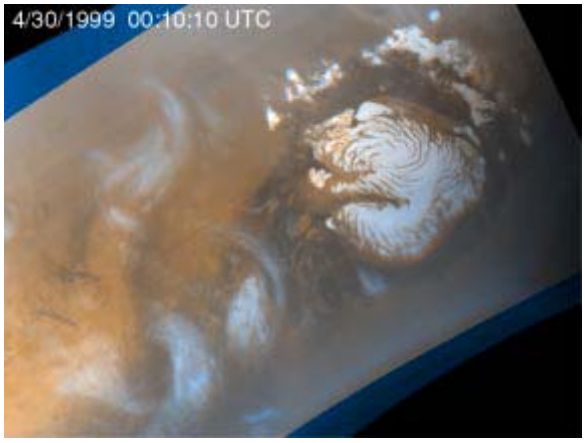




Wind

- Wind direction – blows from all directions within one day
- Daily repeating wind direction and wind speed pattern.



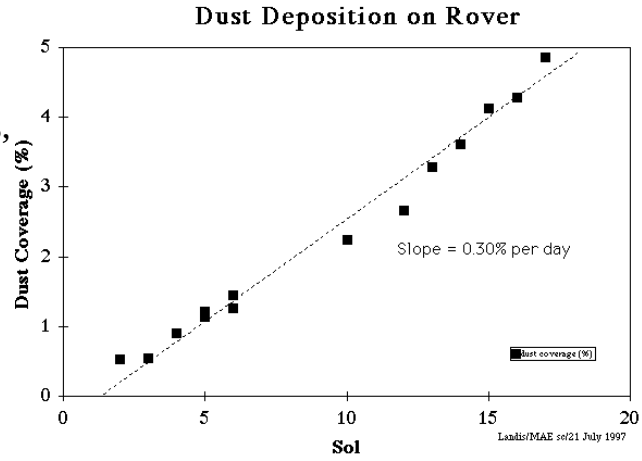


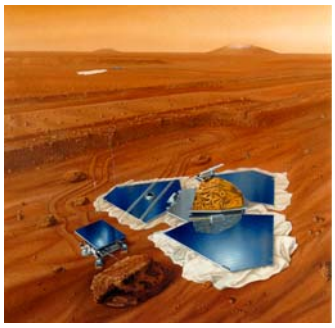
- Highest turbulence in the morning
- Greatest wind speeds early morning and around noon
- Numerous dust devils each day

Surface Materials

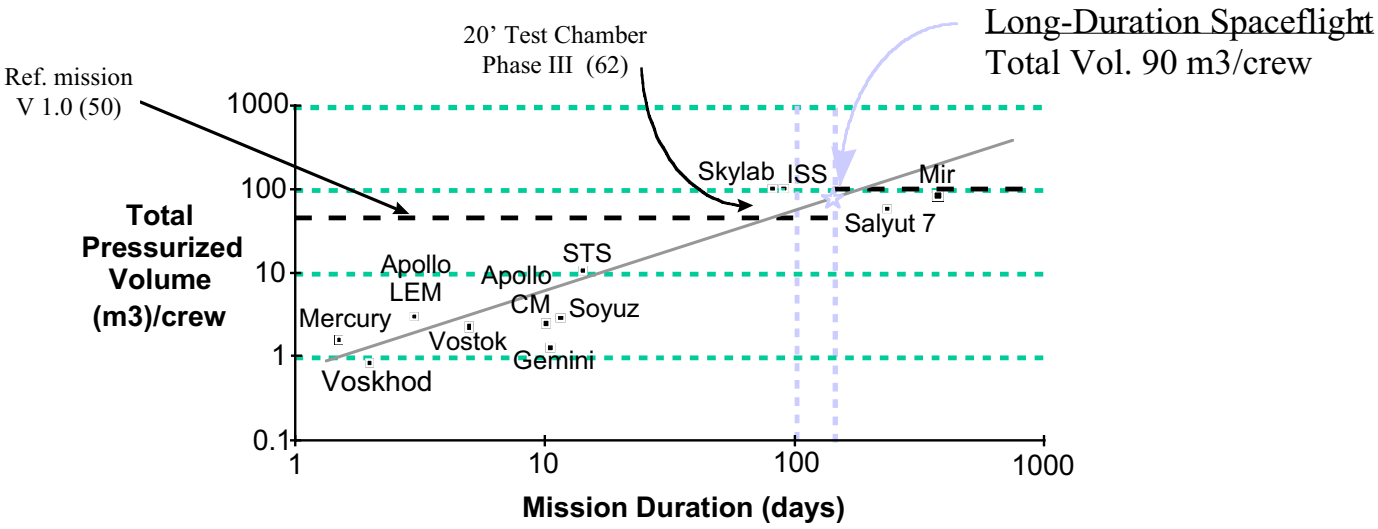
1 Sol = 1 Mars day = 24 h 37 min 22.66 s

- Regolith
- Dust: 40μm–large boulders several m in diameter
- Harder than Aluminum & softer than Nickel
- Abrasion: blowing dust will wear down solar panels, other equipment
- Dust adheres to solar panels, 0.28% per Sol
  - decreases efficiency of solar panels
- Dust is magnetic
  - sticks to everything
  - charges equipment and produces electrical discharges which interfere with operations





System Mass Design



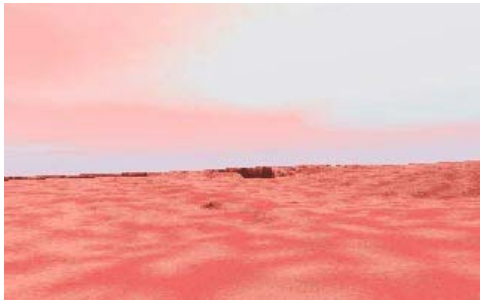
Science Manifest

Surface Science Equipment*	DRM 1.0	DRM 3.0	
Field Geology Package	335 kg	300 kg	35 kg not accounted for
Geoscienc Laboratory Eq.	125 kg	110 kg	15 kg not accounted for
Exobiology Laboratory	50 kg	50 kg	No change
Traverse Geophysical Inst.	400 kg	275 kg	125 kg discretionary margin removed
Geophysical/Meterology Inst.	200 kg	75 kg	125 kg discretionary margin removed
10-Meter Drill	260 kg	260 kg	No change
Meterology Balloons	200 kg	200 kg	Needs better definition
Biomedical/Bioscience Lab	500 kg	500 kg	Needs better definition
Discretionary Science	300 kg	0 kg	Removed
Total	2370 kg	1770 kg	
Cruise Science Equipment*			
Particles & Fields Science	100 kg	100 kg	No change
Astronomy Instruments	200 kg	200 kg	Estimate only
Small Solar Telescope	100 kg	100 kg	No change
Biomedical Instruments	200 kg	200 kg	Needs better definition
Total	600 kg	600 kg	

* NASA Reference Publication 1345

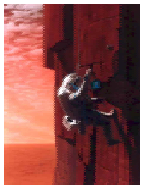
Martian Space Walks

- Beyond ISS humans will go to Mars
- EVA primary activity to search for life
- Revolutionary technologies/methodologies needed
  - Optimize human performance in partial gravity
- Promise of engineering analyses and design

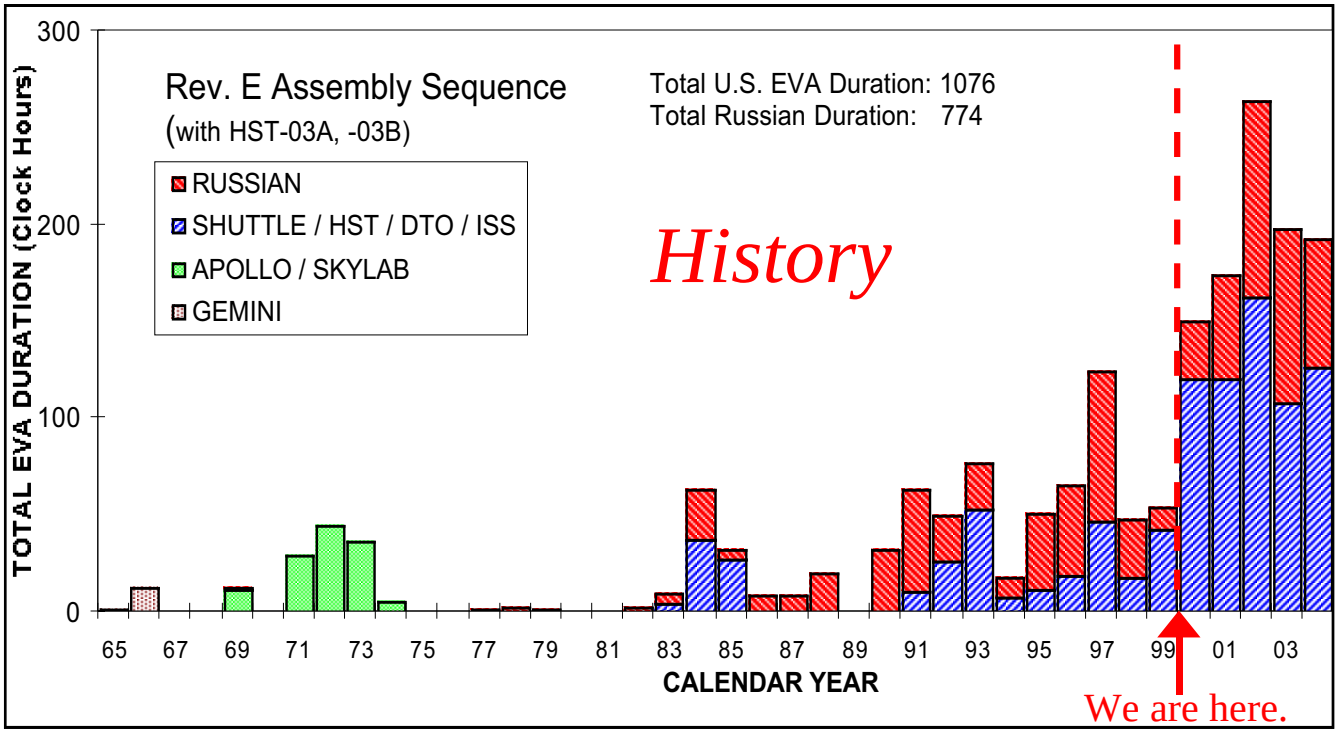


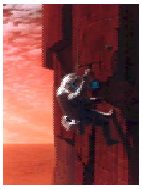
Space Suits

Apollo Shuttle/ISS Mars

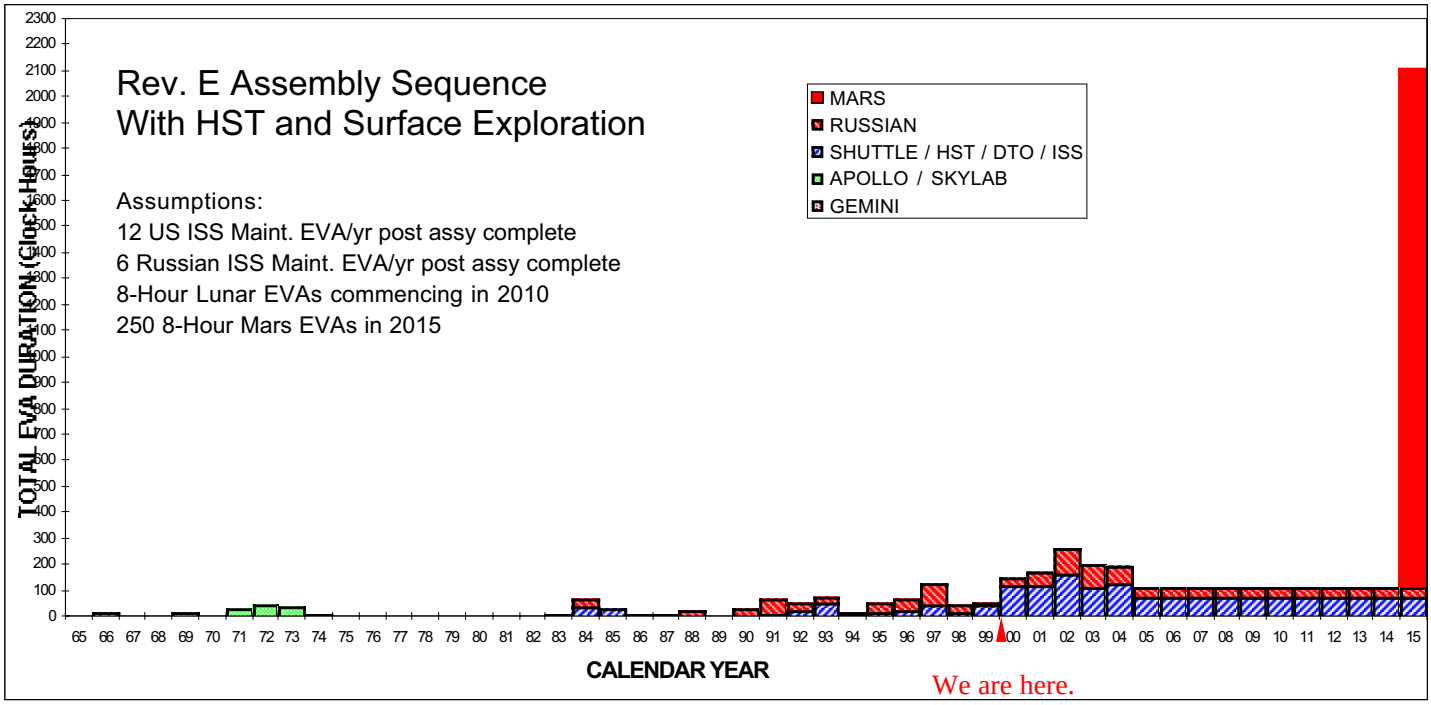


Why?
ISS "The Wall"





Mars: "The Mountain"



NASA Mars Reference Mission

- www_sn.jsc.nasa.gov/marsref/contents.html
- *Launch Strategy*