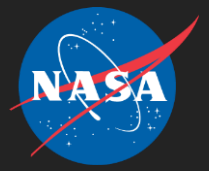
National Aeronautics and Space Administration



DEPLOYTECH

Mars Sample Return Concept Study

Delta Results

www.nasa.gov

Agenda

- Exhaust options to reduce the launch numbers from 3 to 2
  - Mass Reduction of Max-C Rover, ACO Orbiter, and or ACO ERS
  - Eliminate Max-C Rover
  - Launch vehicle options
  - Solar Sail for all interplanetary propulsion, chemical for maneuvering
- Goal would be to
  - Brainstorm any other alternatives we have not considered
  - Eliminate any of the options listed above
  - Go forward with a possible viable option that is identified

Launch Mass Comparison

- Primary objective to reduce baseline mission from three to two launches
- Originally required to maintain baseline mission objectives for all three elements, only redesigning the Earth return propulsion system
- ACO MSR Orbiter and ERS had a launch mass too large to be packaged on the Max-C Rover or Lander launch vehicles

	Predicted Launch Mass (kg)	Launch Vehicle	Launch Capability (kg)	Contingency (kg)
Max-C Rover	4457.4*	Atlas V 531	4980	522.6
MSR Orbiter and ERS	3270	Atlas V 551	4770	1500
Lander and Ascent Vehicle	4668	Atlas V 551	5130	462
ACO MSR Orbiter and ERS	1947.49	--	--	--

*** 300kg was bookmarked in the baseline architecture as a placeholder for ExoMars**

Launch Vehicle Options

- Baselined the launch mass capabilities provided by the Launch Services Program Contract from KSC
- Atlas V 551 Series launching in 2026 and 2028 projected the highest launch mass capability

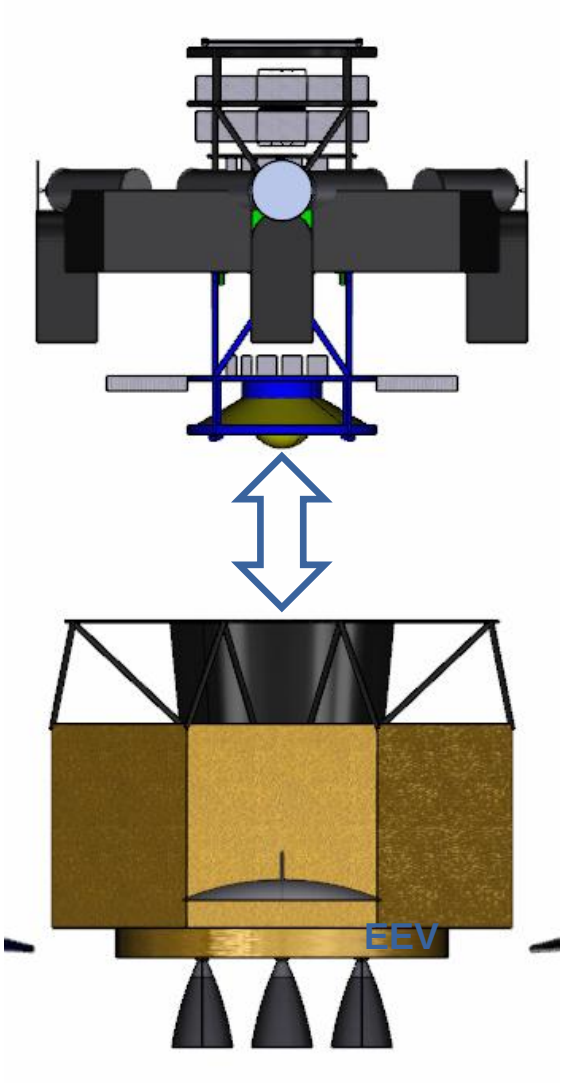
Launch Vehicle Options	Series Option	2024 Launch (kg)	2026 Launch (kg)	2028 Launch (kg)	2035 Launch (kg)
Atlas V	531	3950	4130	4135	4030
Atlas V	541	4495	4695	4705	4585
Atlas V	551	4925	5140	5150	5020
Falcon 9	v1.0	1240	1370	1380	1300
Falcon 9	v1.1	2495	2695	2705	2585

Values from NLSII performance values

Delta Assumptions

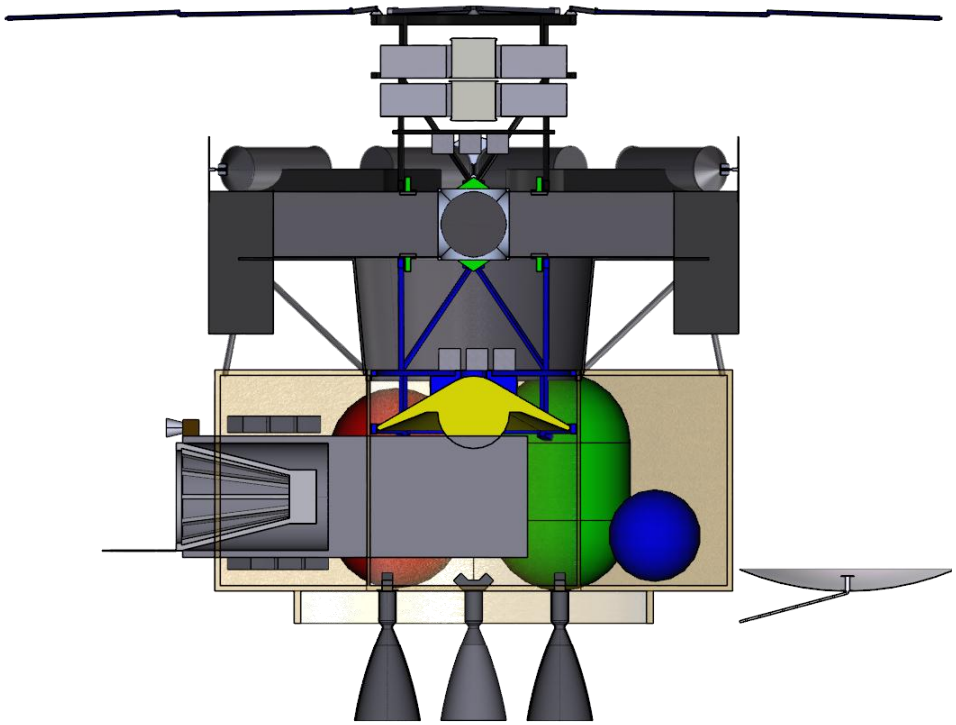
- Repackage the ACO Orbiter and ERS to minimize mass and redundancy
- Launch with Max-C rover on Atlas V 551 in 2028
- Eliminate ExoMars
- Use solar sail as main interplanetary propulsion system
- Limited RCS for course correction and sample rendezvous procedures
- Orbiter and ERS separate at Mars, ERS only returns to Earth with sample

Configuration



Sail with EEV

Orbiter



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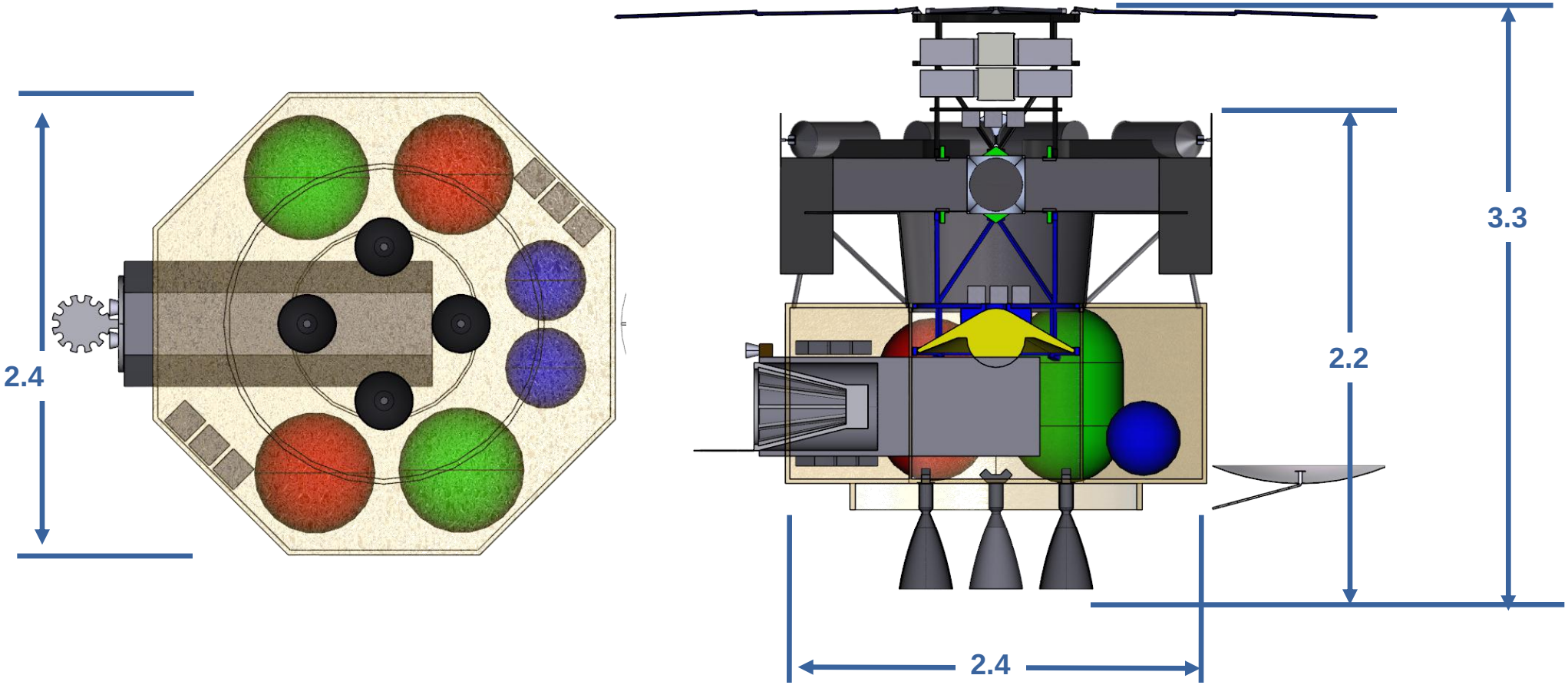
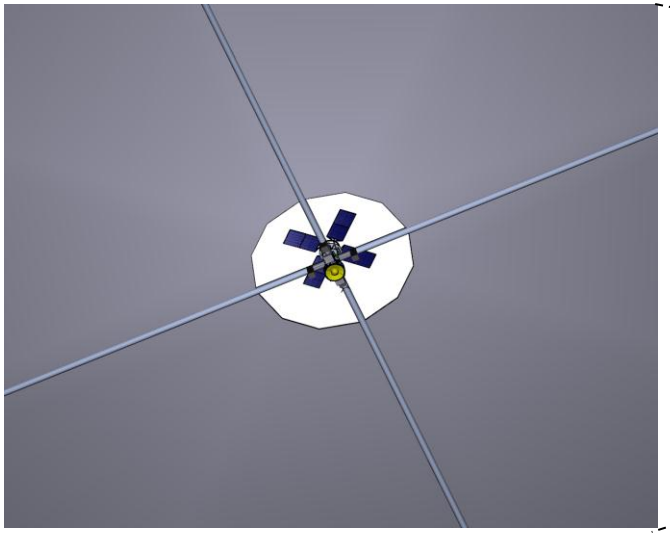
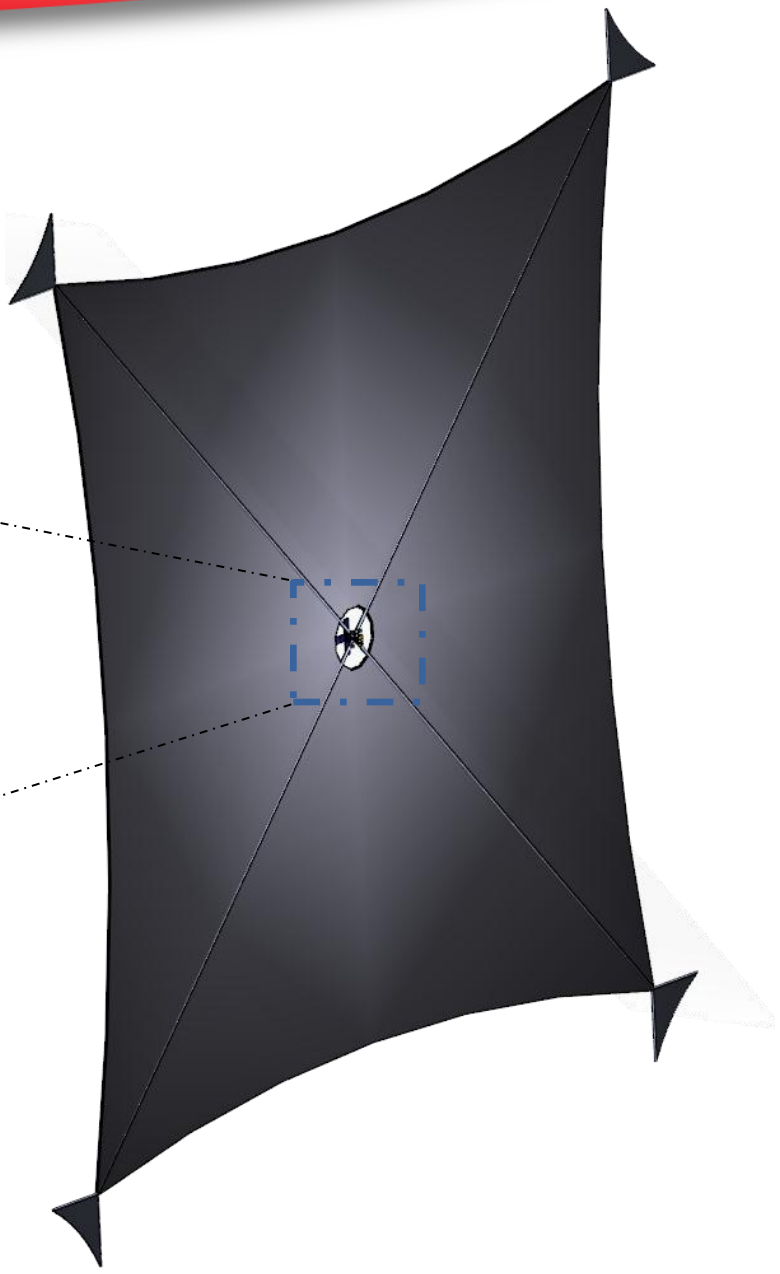


Deployed Sail

Deployed Sail





Delta Mass Summary

	Delta Orbiter and ERS	Basic Mass (kg)	Contingency (%)	Predicted Mass (kg)
1.0	Structures	48.8	30	63.4
2.0	Chemical Propulsion	40	30	52
3.0	Solar Sail	125	12	140
4.0	Power	68	10	74.8
5.0	Avionics	71.5	6	75.79
6.0	Thermal	39	30	50.7
7.0	Payload	52.05	0	52.05
	Total	**443.4**		**508.8**

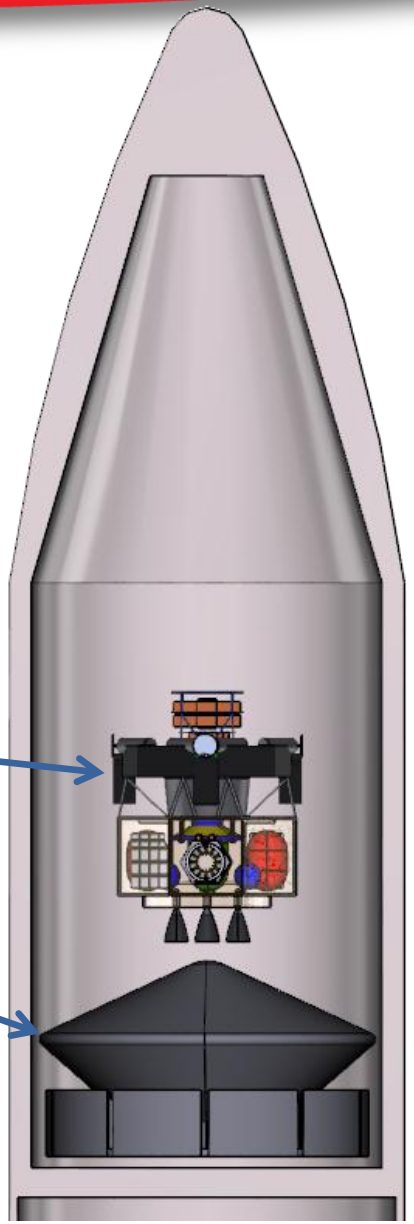
Mass Comparison

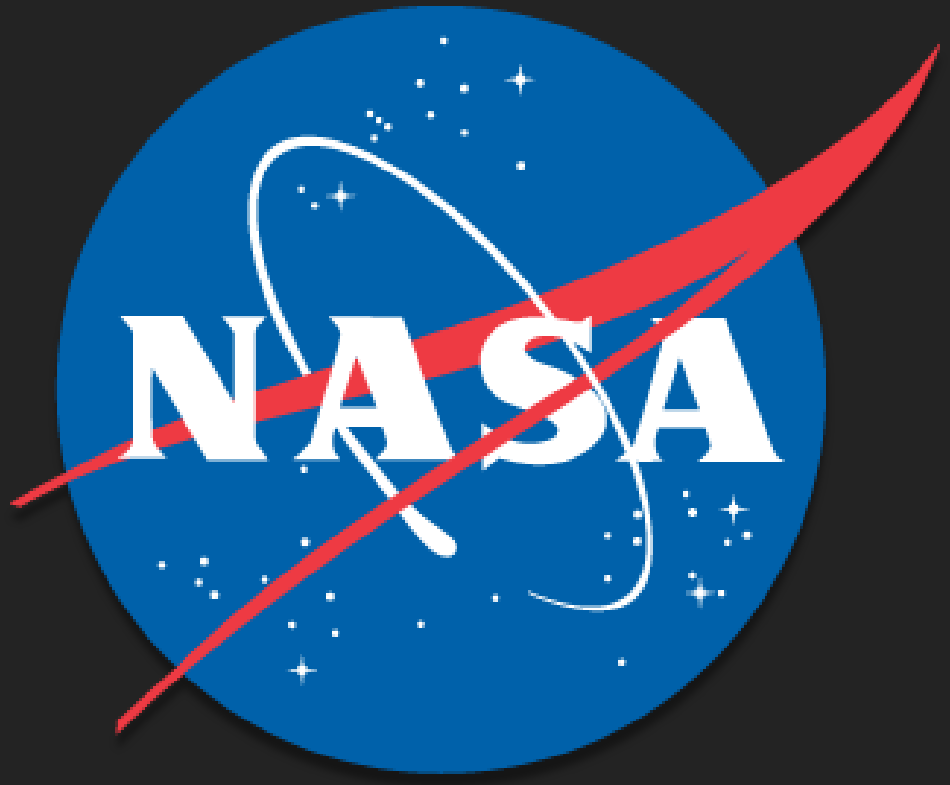
ACO Concept Study	Predicted Mass (kg)
Max-C Entry System	1550.7
Descent Stage	1313.1
Pallet	327.5
Max-C Rover	364.5
ACO Orb+ERS	1947.5
Total	**5503.3**

Delta	Predicted Mass (kg)
Max-C Entry System	1550.7
Descent Stage	1313.1
Pallet	327.5
Max-C Rover	364.5
ACO Delta Orb+ERS	508.8
Total	**4064.6**

Delta Launch Summary	
2028 Atlas V 551 Mass (kg)	5150
Delta Mass (kg)	4064.6
Launch Contingency:	**21%**

Atlas Shroud



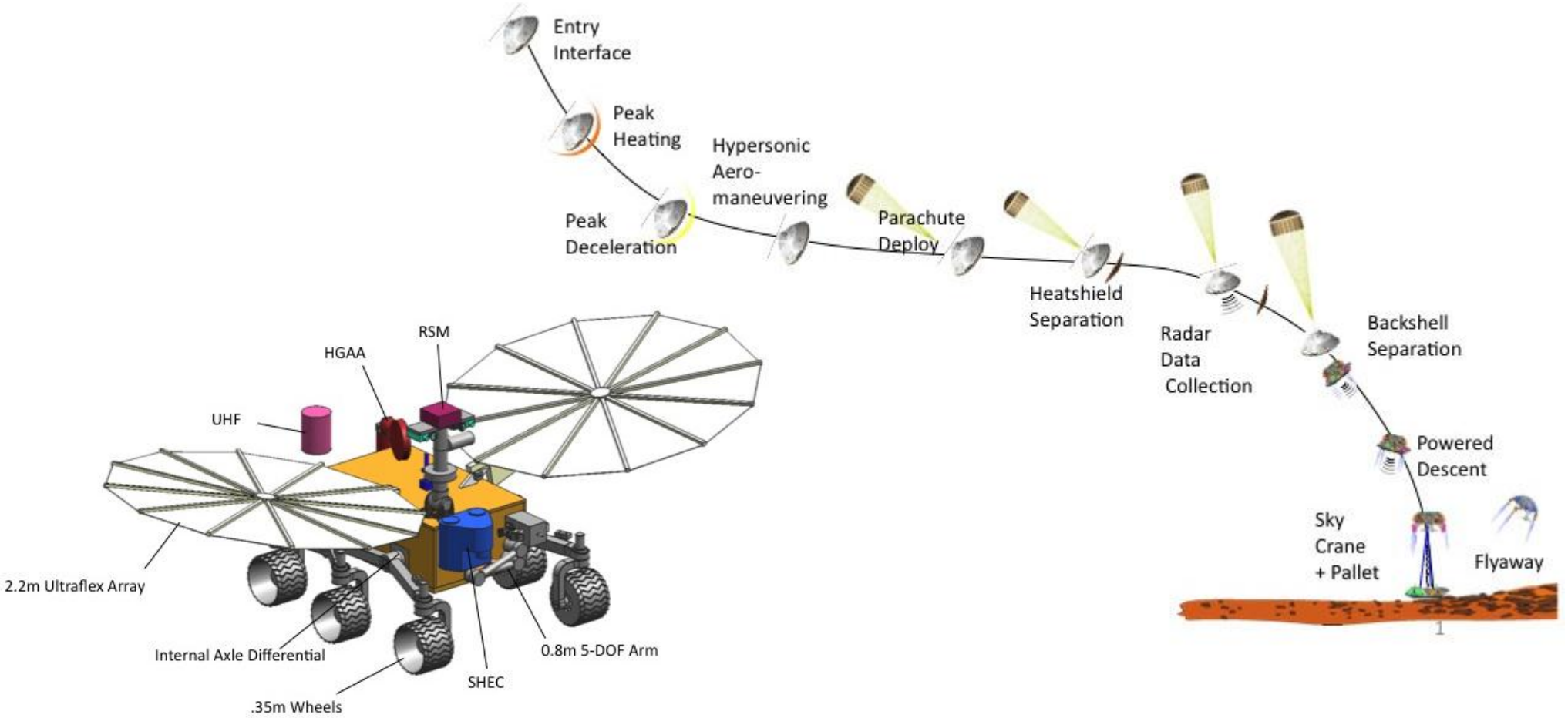

NASA

Delta Roster

- Les Johnson
- Roy Young
- Tiffany Russell
- Leo Fabisinski
- Tom Percy
- Dan Thomas

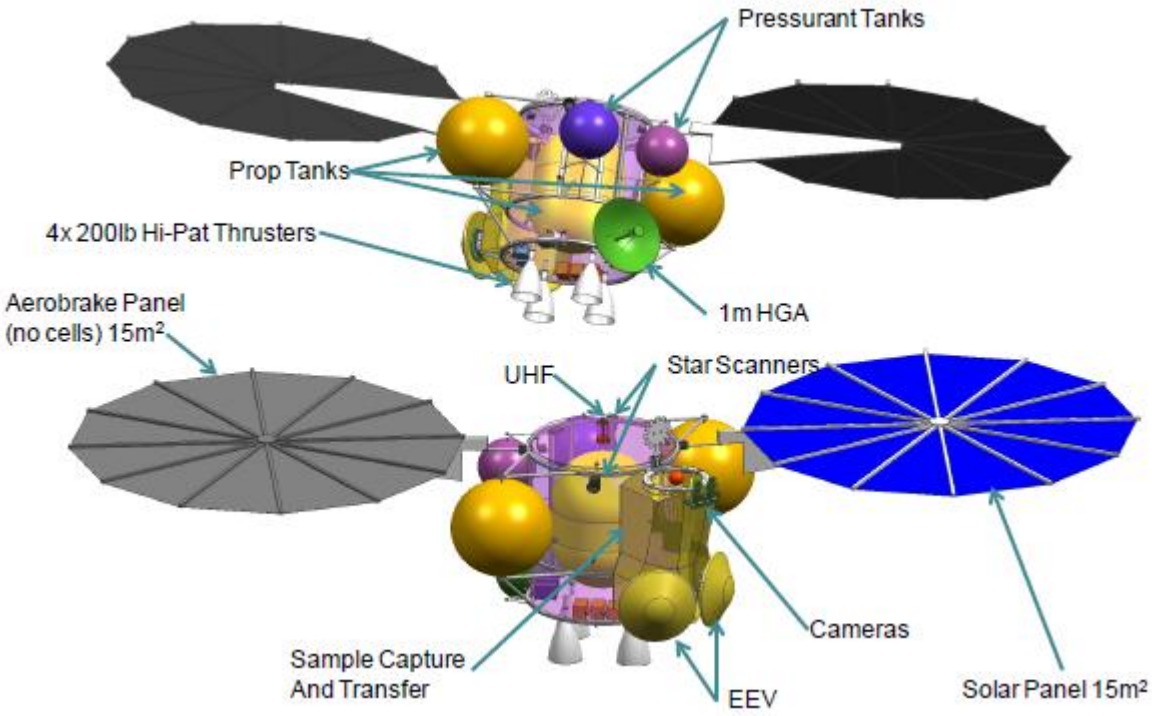
Mission Overview

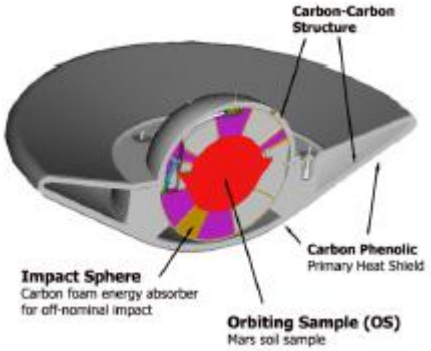
- Astrobiology Explorer (Rover)
  - Launch = mid 2018



Mission Overview

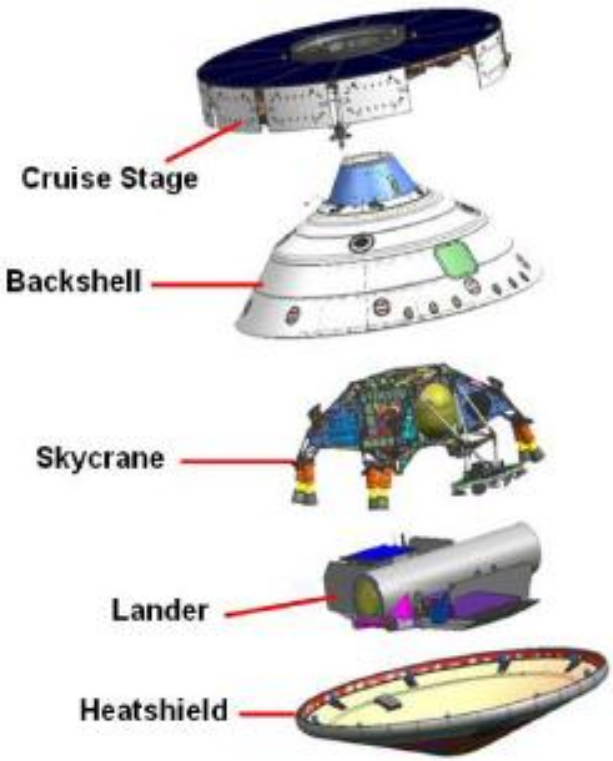
- Sample Return Orbiter (with EEV)
  - Launch = 2022

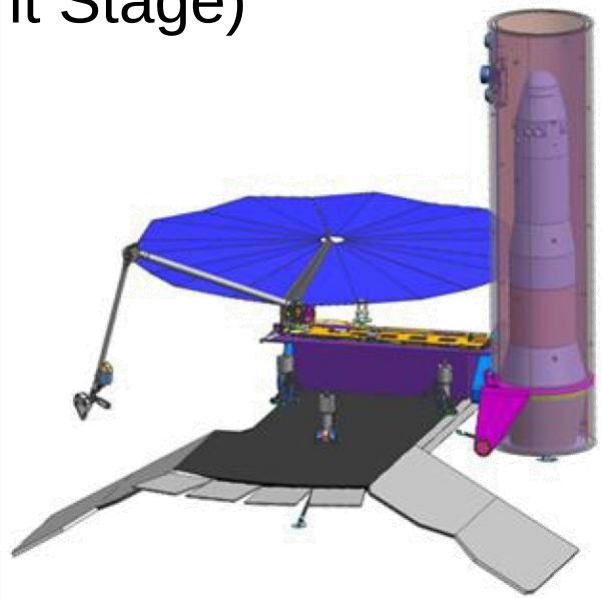


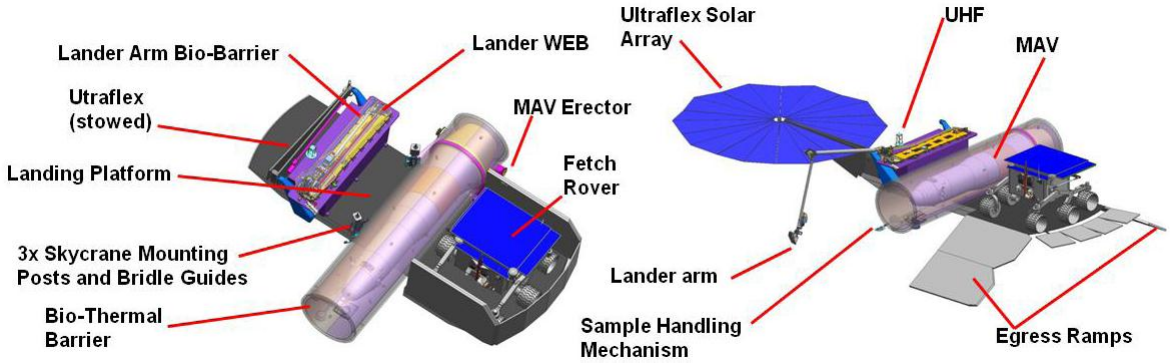


Mission Overview

- Sample Return Lander (with Ascent Stage)
  - Launch 2024







Earth-to-Mars Trajectories

Used MIDAS to generate optimal Earth-to-Mars trajectories

Earth Departure			Outbound		At Mars		
Departure Date	C3 (km^2/s^2)	Launch Declination (deg)	TOF (days)	HCA (deg)	Arrival Date	Vinf (km/s)	MOI ΔV (km/s)
08/30/2022	15.151	3.319	347.024	212.10	08/12/2023	2.604	0.877
09/30/2024	11.369	14.915	332.696	209.17	08/29/2025	2.445	0.804
10/31/2026	9.229	28.746	311.054	205.71	09/07/2027	2.571	0.861
11/23/2028	9.116	28.696	300.113	212.83	09/19/2029	2.970	1.059
12/24/2030	*10.794*	*14.994*	*283.084*	*216.15*	*10/03/2031*	*3.480*	*1.342*
04/17/2033	*9.086*	***-55.268***	*199.722*	*148.44*	*11/02/2033*	*3.317*	*1.248*
02/21/2033	*13.646*	*7.369*	*260.000*	*206.40*	*11/08/2033*	*3.934*	***1.617***
06/27/2035	10.372	8.822	201.889	148.63	01/15/2036	2.630	0.889

For now, assumed an MOI ΔV = 1.1 km/s in the propellant estimations, which was used by JPL design. Therefore, orbiter will be unable to accomplish 2030 and 2033 opportunities.

Mission ΔVs and Maneuver Propellants

- Launch mass (first estimate) ~ 2110 kg

  Includes:

  - Launch vehicle adapter ~ 30 kg
  - Orbiter + Sail burnout ~ 1300 kg
  - Orbiter propellant (see below)

Event	System	Mass (kg)	ΔV (m/s)	Isp (s)	Propellant Used (kg)	
					MPS	ACS
TCMs	MPS	2080.0	30.0	326	19.4	0.1
Max. MOI (with gravity losses)	MPS	2060.5	1100.0	326	599.8	3.7
Walk-in	ACS	1456.9	7.2	209	0.0	5.1
Aerobrake ACS	ACS	1451.8	9.0	209	0.0	6.4
Walk-out	MPS	1445.4	84.9	326	37.9	0.2
Sample Rendezvous and Margin	MPS	1407.3	250.0	326	105.9	0.7
				Total Propellants:	**763.0**	**16.2**

Orbiter Propulsion System Masses

Item	Qty	Unit Mass (kg)	Basic Mass (kg)	MGA	Predicted Mass (kg)
Main Engine	4	5.2	20.8	25%	26.0
ACS Two-thruster Module	8	1.3	10.2	25%	12.7
Fuel Tanks	2	10.8	21.6	25%	27.0
Oxidizer Tanks	2	6.5	13.0	25%	16.2
Pressurant Tanks	2	5.5	11.0	25%	13.8
Propulsion Feed Components (valves, etc.)	1	26.0	26.0	25%	32.5
Lines and Fittings	1	4.5	4.5	25%	5.6
Structural Mounts	1	10.7	10.7	25%	13.4

Total Dry Mass: 147.1

Loaded Propellant (with residuals)	
Hydrazine	441.5
NTO	361.1

Total Propellant: 802.6

Pressurant	
Gaseous Helium	3.1

Total Wet Mass: 952.8 kg