



Mars Deep Drill -- A Mission Concept for the Next Decade

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Introduction

- Mars science groups repeatedly have concluded that scientific analyses of samples from significant depths below the surface are important for understanding Mars in general and for searching for evidence of past or present life in particular.
- In February 2001 the Mars Program Office held an international workshop in Houston, concluding:
 - Science justification exists for early access to at least 10 m in depth
 - Drilling technology could be ready to support such a mission by the latter part of the current decade
- “Deep Drill” appears in discovery-responsive exploration pathways developed in 2003 at NASA’s request, with leadership of Mars Science Planning Synthesis Group

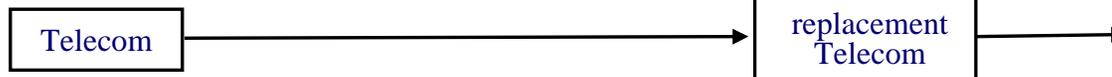
Mars Exploration Pathways Missions

2009 - 2020



Mars Deep Drill

Pathway	2009	2011	2013	2016	2018	2020	NOTES
Search for Evidence of Past Life	MSL to Low Lat.	Scout	Ground-Breaking MSR	Scout	Astrobiology Field Lab or Deep Drill	Scout	All core missions to mid-latitudes. Mission in '18 driven by MSL results and budget.
Explore Hydrothermal Habitats	MSL to Hydrothermal Deposit	Scout	Astrobiology Field Laboratory	Scout	Deep Drill	Scout	All core missions sent to active or extinct hydrothermal deposits.
Search for Present Life	MSL to N. Pole or Active Vent	Scout	Scout	MSR with Rover	Scout	Deep Drill	Missions to modern habitat. Path has highest risk.
Explore Evolution of Mars	MSL to Low Lat.	Scout	Ground-Breaking MSR	Aeronomy	Network	Scout	Path rests on proof that Mars was never wet.





Deep Drill Key Level 1 Requirements (Preliminary)

- Launch an *in situ* surface mission to Mars in the 2018 launch opportunity
- Science
 - Characterize the geology (stratigraphy, structure, chemistry) and geophysics of the uppermost Martian crust at one site, particularly as it relates to interpreting past and/or present habitability
 - Search for past and/or present life in the subsurface at one site
 - Obtain a meteorological record at one site
- Using a drill, bring tens of samples to the surface from various depths, down to at least TBD (10-50) m
- Landing site specifications
 - Between 60°S and 60°N latitude (launch opportunity dependent)
 - Altitudes up to TBD (0 to +2.5) km MOLA reference
 - Pinpoint landing (10 to 100 m landing accuracy) for very localized targets, otherwise Precision landing (10 km)
- Planetary Protection category IVc or IVb

Placeholder Science Instrument Types for Mars Deep Drill



- Organics and Evolved Gas Analyzer
- Life-Detection Suite
- Mineralogy and Chemistry Lab
- Microimager
- Stereo Panoramic Camera with Point Spectrometer
- Meteorology Station
- Ice/Water Detector (downhole?)
- Heat Flow with Thermal Experiments (downhole)
- Borehole Camera (downhole)



Interplanetary Trajectory

- Launch
 - May 12, 2018 (opening of 20-day launch period)
 - Max C_3 : $9.7 \text{ km}^2/\text{s}^2$ (relatively low launch energy)
 - Launch vehicle class: Medium Delta or Atlas
- Arrival
 - January 8, 2019 (8 month cruise)
 - Southern hemisphere summer ($L_s = 320^\circ$)
 - V_{inf} : 3.3 km/s
 - Inertial entry speed: 5.9 km/s
 - Sun range: 1.46 AU
 - Earth range: 1.33 AU
 - For landing site at 60° S latitude
 - Sun elevation: 42.7°
 - Earth elevation: 34.2°
- Total interplanetary Delta V: $< 40 \text{ m/s}$



Flight System Overview

- Consists of 5 Primary Systems:

- *Cruise Stage*

- Provides launch vehicle interface and delivers to Entry target position

- *Entry Vehicle*

- Steers and protects S/C during hypersonic entry

- *Parachute*

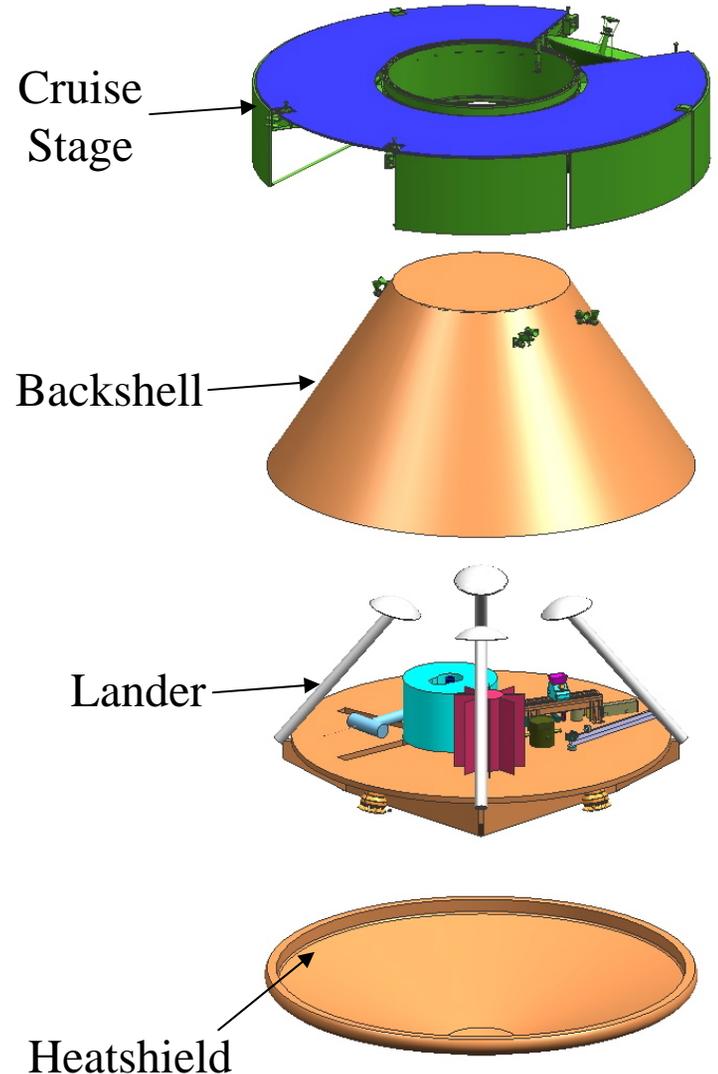
- Decelerates S/C to terminal velocity for powered descent

- *Powered Descent*

- Reduces S/C to landing velocities & guides S/C to landing target

- *Lander*

- Carries scientific & engineering payload and provides services to meet mission objectives





Flight System Details (1 of 2)

- Cruise Stage System
 - Solar array for primary power
 - 3-axis, stabilized control provided by thrusters & GN&C algorithms
 - Optical Navigation with Phobos & Deimos for approach to Mars
 - Improves delivery error to < 2km (necessary for pinpoint landing)
 - Waste heat managed with active thermal control -- pumped liquid-cooled
- Entry Vehicle & Parachute System (combined for simplicity)
 - Heatshield and Backshell protect S/C from harsh entry conditions during hypersonic phase
 - Guided entry used to steer out delivery errors using GN&C algorithms, thrusters, and an increased lift-to-drag ratio over ballistic landers (MER, MPF) achieved via a center-of-mass offset



Flight System Details (2 of 2)

- Powered Descent & Lander System (combined for simplicity)
 - Viking-style throttled engines and GN&C algorithms used for “soft” touchdown (~1-2 m/sec)
 - Also used for pitch and yaw control while roll control relies on thrusters
 - Engines used for translation (parachute drift error removal) for pinpoint
 - MMRTG-powered with rechargeable battery augmentation
 - X-Band relay with orbiting asset (primary) & direct-to-earth (secondary) telecommunications
- Scientific & Engineering Payload
 - Science payload consisting of instrument types as outlined in earlier slide
 - Engineering payload consisting of: drill, sample preparation & distribution (SPAD), robotic arm (surface sample collection and sample transfer to/from drill and SPAD), remote sensing mast (pancam & meteorology station) & drill camera



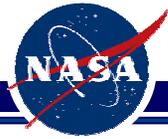
Flight System Mass Estimates

“Precision” landing case

	Mass (kg) with Margin
Powered Descent & Lander -- Dry Mass	842
Lander Propellant	85
Powered Descent & Lander Total	<u>927</u>
Entry Vehicle & Parachute -- Dry Mass	708
Entry Propellant	0
Entry Vehicle & Parachute Total	<u>708</u>
Cruise Stage -- Dry Mass	298
Cruise Propellant	42
Cruise Stage Total	<u>340</u>
Total Launch Mass	<u>1975</u>

“Pinpoint” landing case

	Mass (kg) with Margin
Powered Descent & Lander -- Dry Mass	886
Lander Propellant	232
Powered Descent & Lander Total	<u>1118</u>
Entry Vehicle & Parachute -- Dry Mass	769
Entry Propellant	0
Entry Vehicle & Parachute Total	<u>769</u>
Cruise Stage -- Dry Mass	300
Cruise Propellant	58
Cruise Stage Total	<u>357</u>
Total Launch Mass	<u>2244</u>

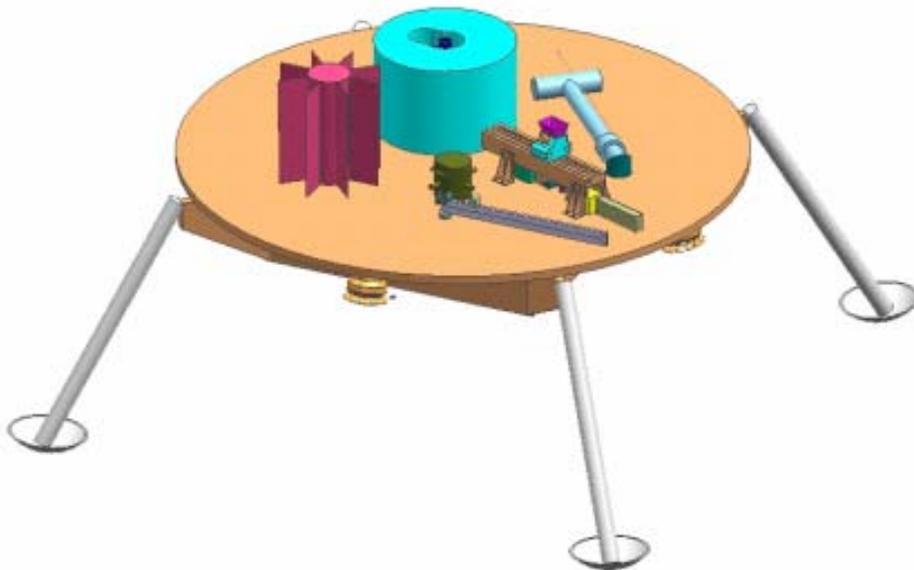


Scientific & Engineering Payload

- Engineering Payload Details:

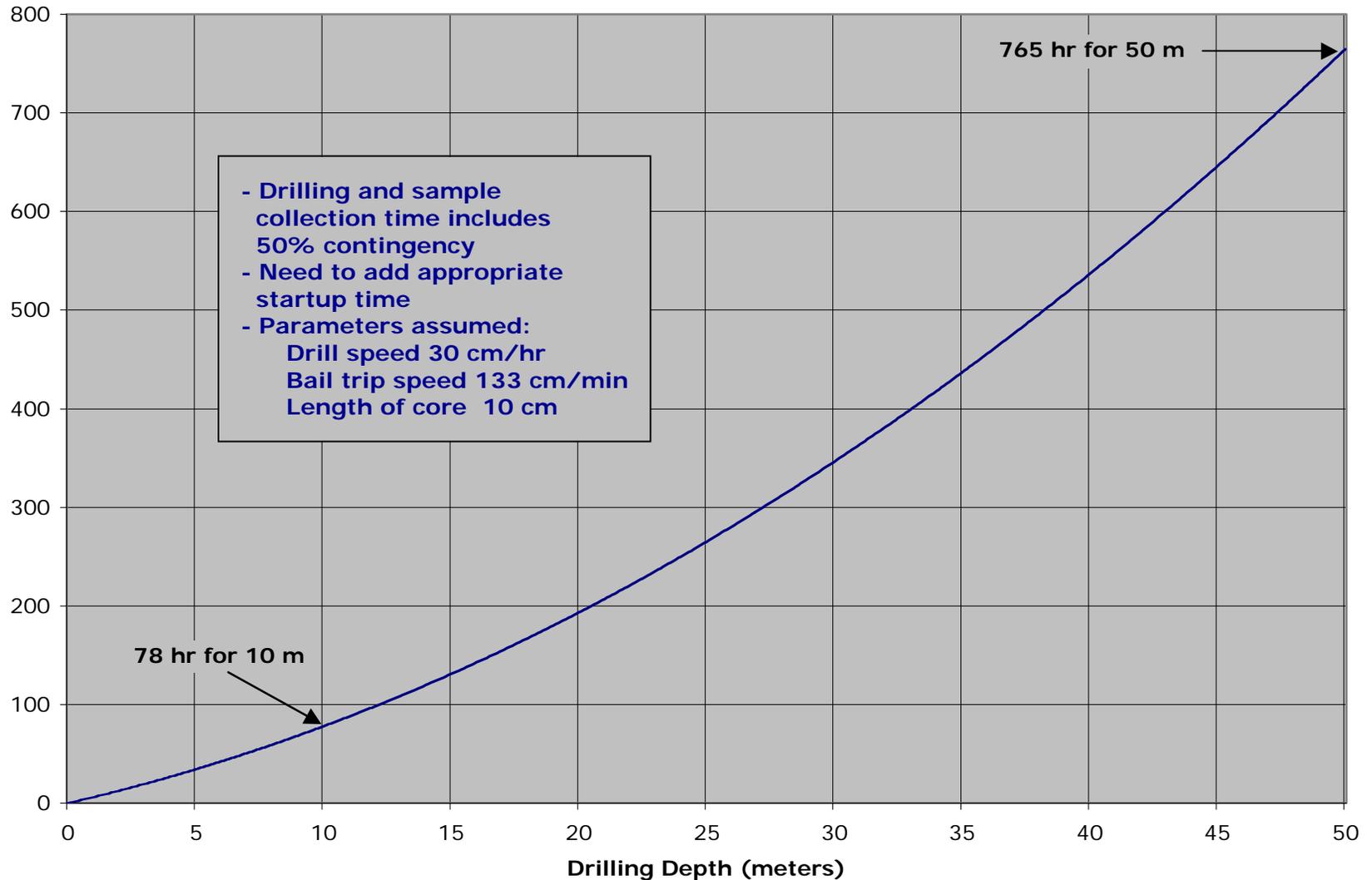
Component	Mass (kg)	Contingency	CBE + Contingency (kg)
SPAD	38.5	30%	50.0
Robotic Arm	12.1	30%	15.0
Drill	80.0	30%	104.0
Remote Sensing Mast	13.1	30%	17.0
Drill Camera	1.2	30%	1.6
Science Payload	38.9	30%	50.6

- Drill
 - Segmented drill strings
 - Up to 50 m deep (+ contingency 25 m with redundant bit string)
- SPAD
 - Sample storage, “preparation” & distribution
 - System cleaning to prevent cross-contamination
- Robotic Arm
 - Transfer of samples between drill & SPAD
 - Surface sampling using scoop
- Remote Sensing Mast
 - Az/EI articulation for panoramas
- Drill Camera
 - Verify alignment & monitor progress
 - Asses drill bit wear and assist in fault diagnosis



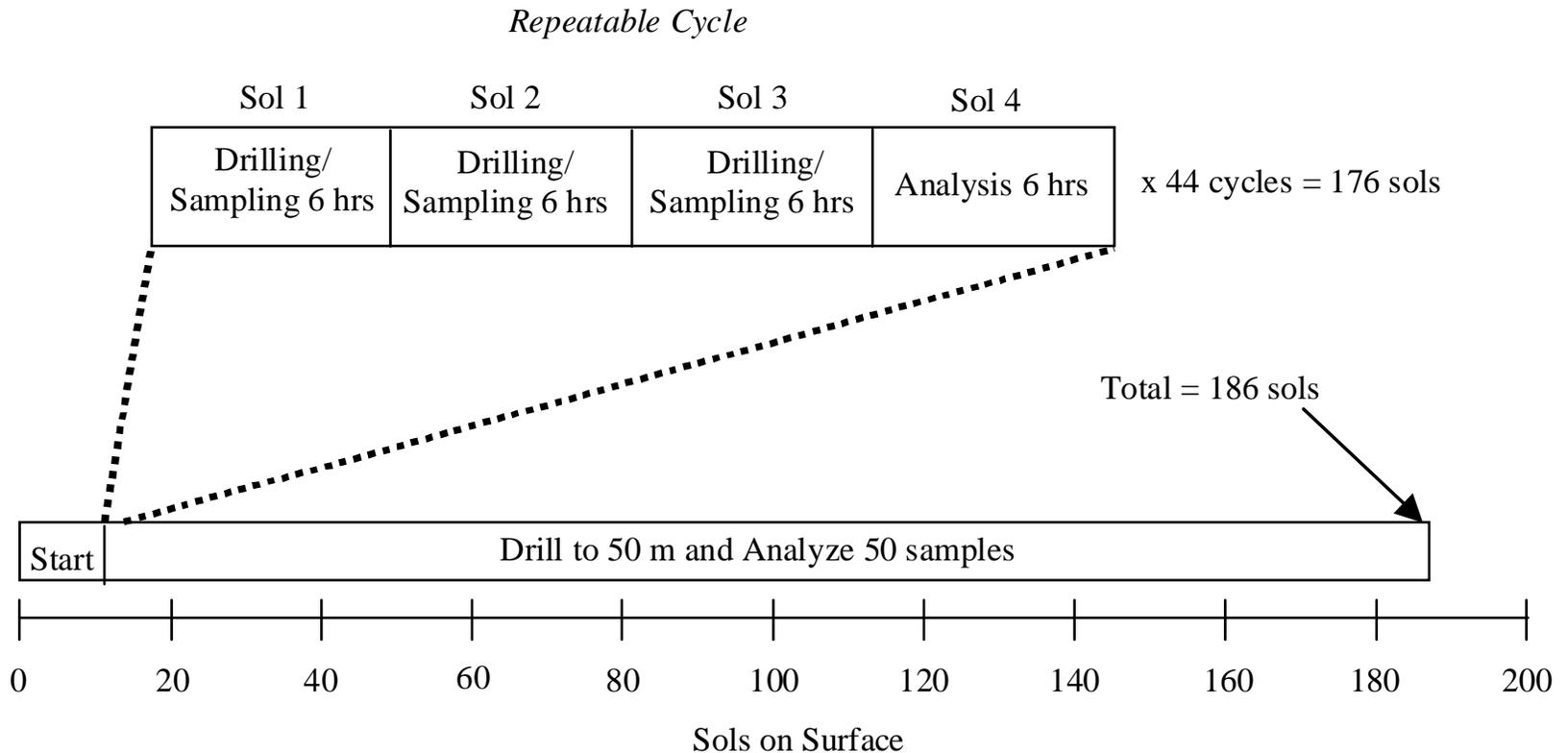


Drilling & Sampling Time vs. Depth



Drilling Mission Scenario (example)

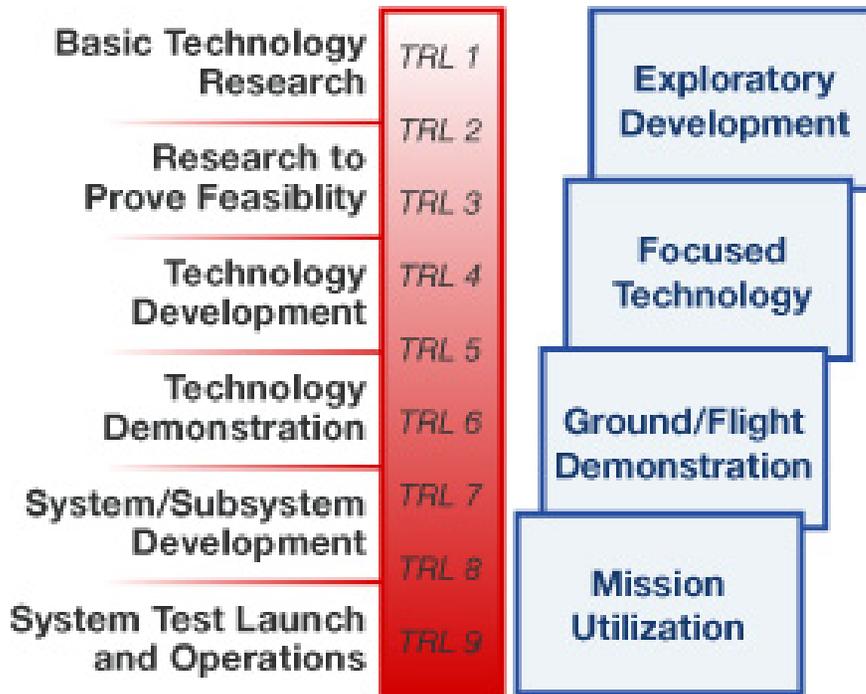
50 m Depth



- Consistent with both power system and temporal requirements



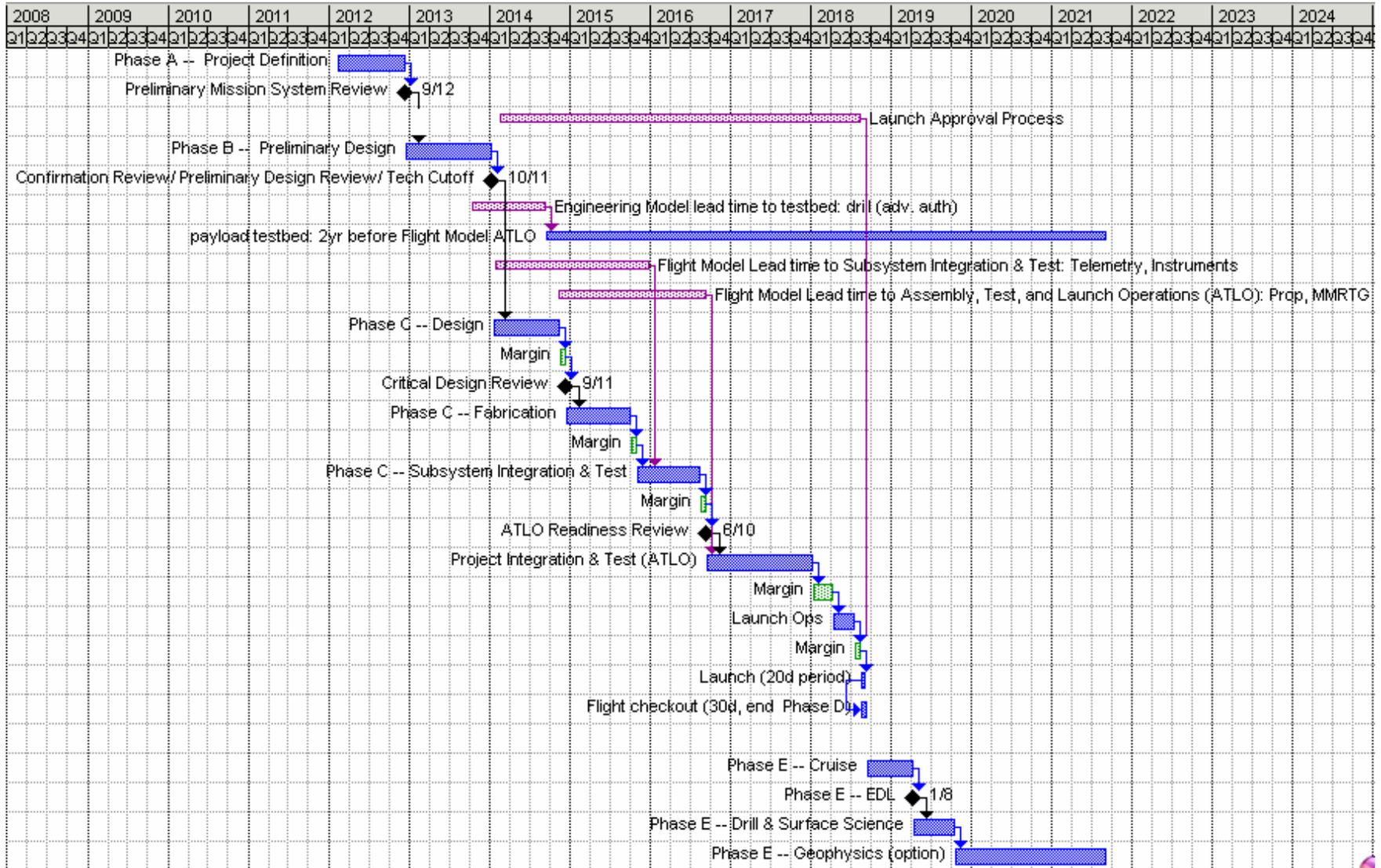
Technology Development



- All new technology required to reach TRL 6 by project PDR
- New technologies needed:
 - Subsurface access (up to 50 m)
 - Pinpoint Landing
 - Forward Planetary Protection (Category IVb or IVc)
 - *In situ* science instruments (surface analysis & downhole)
 - SPAD systems including:
 - Icy sample preparation
 - Storage for up to 50 samples
- Inherited technologies (from planned missions)
 - Next-generation power systems (MSL)
 - Long-term surface survivability (MSL)
 - Telecom network data rates (MSL)
 - Impact attenuation and landing survivability (Phoenix)
 - Precision Landing (Phoenix & MSL)



Development Schedule





Costs, Conclusions, & Future Work

- A Deep Drill mission, with preliminary assumptions, appears to be feasible for launch in the next decade.
 - \$1.5B class mission
- Concept will evolve, but this example may prove useful for program planning
- Future Work
 - Engage science community
 - Explore Entry, Descent, and Landing strategies in more detail
 - Investigate launch/arrival date space more fully
 - Monitor developing capabilities for precision guided entry
 - Phoenix and Mars Science Laboratory
 - Develop and test options for autonomy
 - Monitor ongoing technology developments