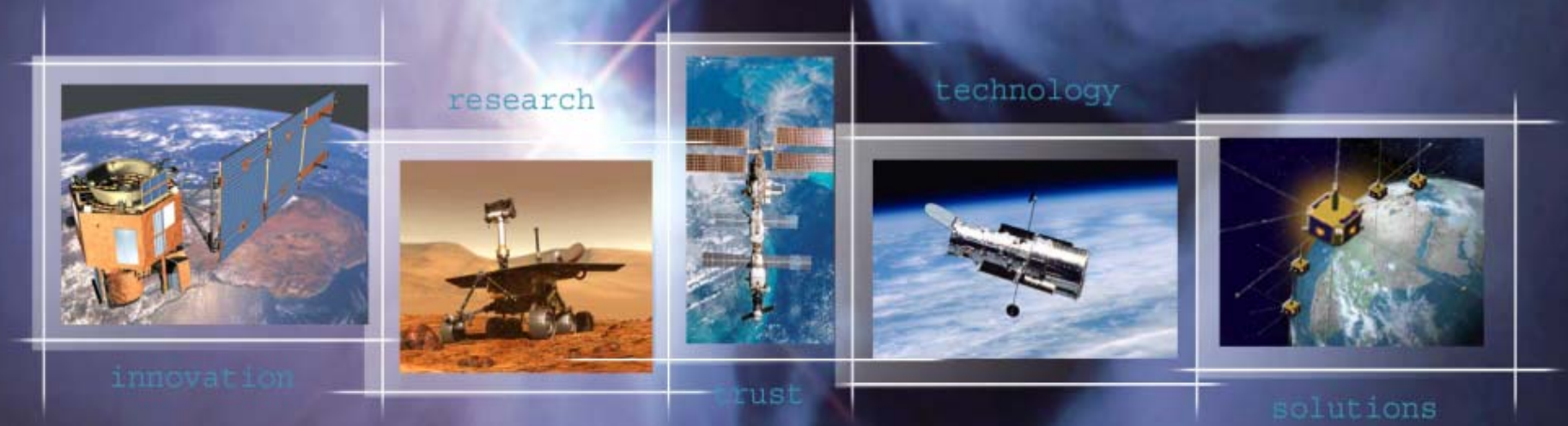
SWALES AEROSPACE



Planetary Drill Technology and Applications to Future Space Missions

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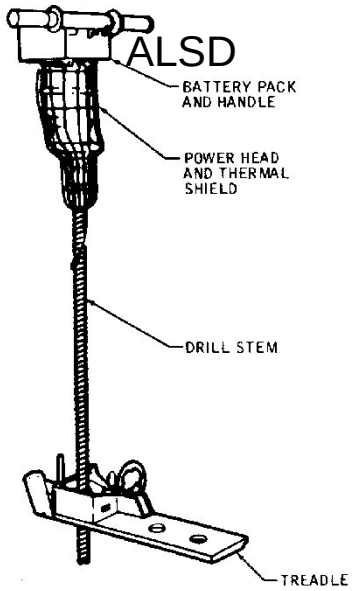
Presentation Outline

- Past Drill Missions
- Future Drill Mission Objectives
- Future Drill Mission Technology Needs
- Swales Planetary Drilling Technology
- Swales Drill Technology – Features
- 2-5m Drill System on Lander Platform
- 2-4m Drill on Large (Mega) Rover Platform
- Planetary Drilling: Ongoing Efforts

Past Drill Missions

- In 1972, Apollo 16 Mission used the first Lunar drill system called the Apollo Lunar Surface Drill (ALSD).
- Apollo 17 mission drilled to 2m and obtained core rock samples.
- Manual operations – astronauts conducted drilling and sampling operations.
- Sample cross-contamination was not actively prevented.



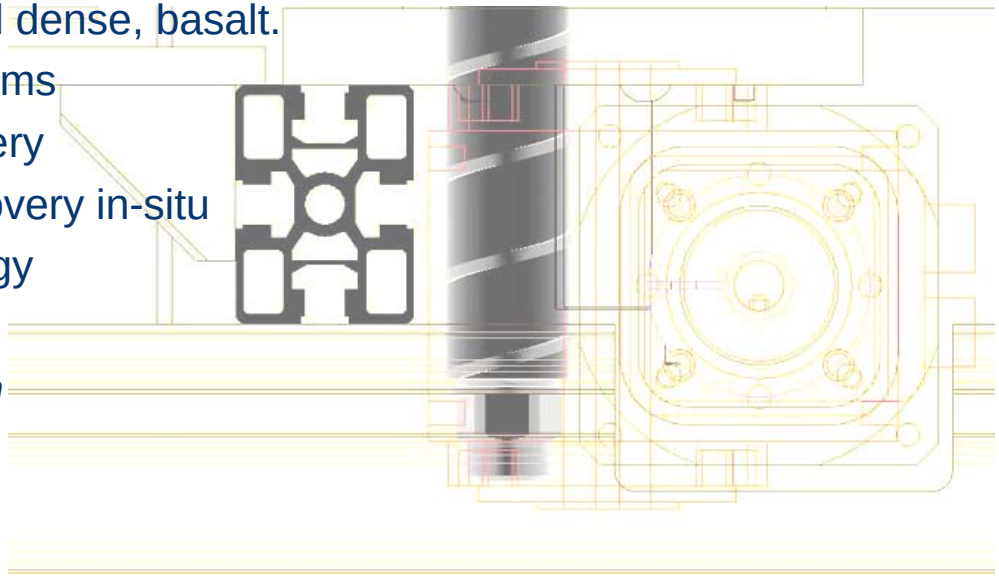
- First successful automated lunar soil sample return was Luna 16 on September 20, 1970.
  - Designed to extract 100 grams of rock and soil to a depth of 35 cm.
- Deep soil sample return was attempt in Luna 20.
- In 1976 Luna 24, drilled 2 meters and deep soil sample return was successful.
- Mission objective was to collect only one continuous sample.

Future Drill Mission Objectives

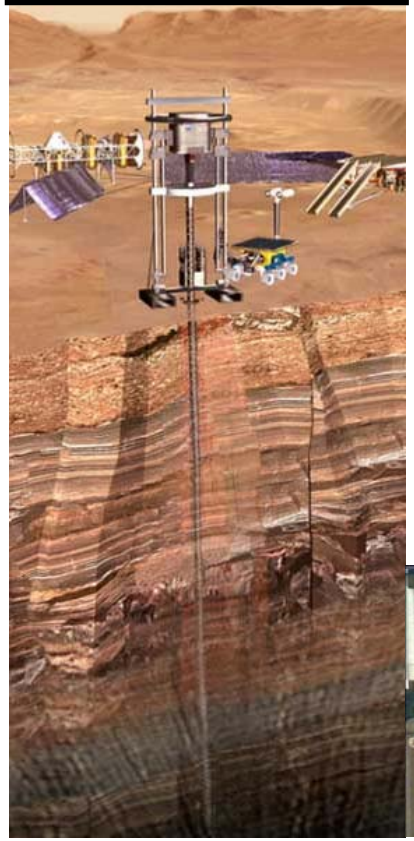
- **Drilling Technology facilitates the following Lunar and Mars Investigation Goals In support of Human Exploration**
  - Soil Engineering Measurements:
    - Characterize surface soil
    - Soil samples from different locations
    - Vertical soil density profile
    - Soil Cohesion
  - ISRU Water Measurements:
    - Water ground truth
    - Ice deposits in Lunar Polar Craters and Mars Polar regions
    - Survey locations and depths for water/ice deposits

Future Drill Mission Technology Needs

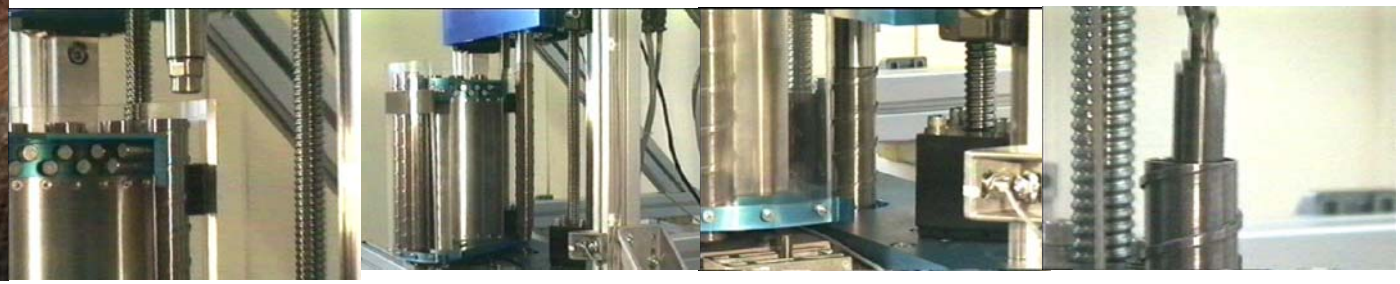
- **Technology Needs**
  - Ability to operated in extreme Lunar and Martian environments
    - Lunar Temperature range -200 to 150 C
    - Mars Temperature range -120 to 20 C
    - Extreme cold level and vacuum (Lunar Polar Craters)
    - Lunar debris concern with mechanical joints
  - Ability to operate with 200W-hr/sol
    - Low power levels below 80-100W
  - High durability and reliability of drilling components
  - Drilling several boreholes/multiple locations
  - Drilling greater depths in hard dense, basalt.
  - 10cm to 20m depth drill systems
  - Maximize sample core recovery
  - Enable intact ice-sample recovery in-situ
  - Drilling Automation Technology
  - Low mass: 5 to 50 Kg
  - *Sample Management System*



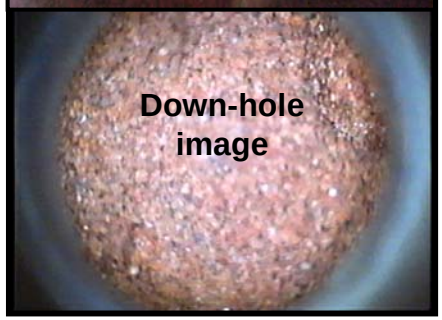
Swales Planetary Drill Technology



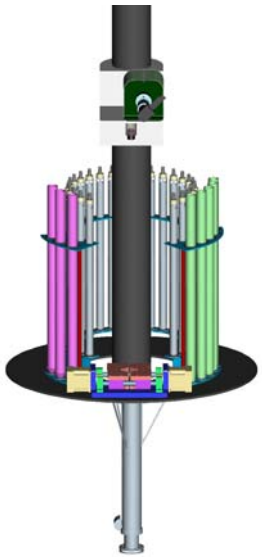
- 1998 NASA Mars/Comet Drill Study
- 1999 (TRL-2) 1-meter Segmented Coring Auger Drill (SCAD) demonstration, dry drilling method verified.
- 2001 (TRL-3) SCAD complete 2m and rock hardness lab tests.
- 2002 (TRL-4) Subsurface Planetary Exploration Core Extracting System (SPECES) drill developed and NASA field-proven to 10-meters using less than 100W.
- 2003 NASA Astrobiology Mission - 2.5m Rover Drill System Study
- 2003 NASA Mars Deep Drill Mission Study – 50m Drill System
- 2004 NASA Lunar Precursor Mission - 2.5m Drill System Study
- 2004 NASA Contract Award to develop Modular Planetary Drill Systems (MPDS), capable of 0.5 to 20 meters (TRL-5 & 6).
- 2005 NASA Mars Very Deep Drill Study to evaluate drilling technologies and develop drill concepts for 100 to 1000 meter depths.



Swales Drill Technology - Features



- Field-Proven Low-Power Dry Drill Technology
- Core samples are continuously collected during drilling operations.
- Samples are maintained in separate containers.
- Cuttings and cores are collected for review and scientific evaluation.
- Obtained core samples while drilling rock with hardness from 1-6.
- Technology supports down-hole and surface platform instruments.
- Down-hole logging shows minimal temperature effects during drilling.
- Proven record of continuous cuttings removal.
- Successful, field proven borehole stabilization method.
- Automated multi-stem assembly.
- Operational Drill Research Laboratory.

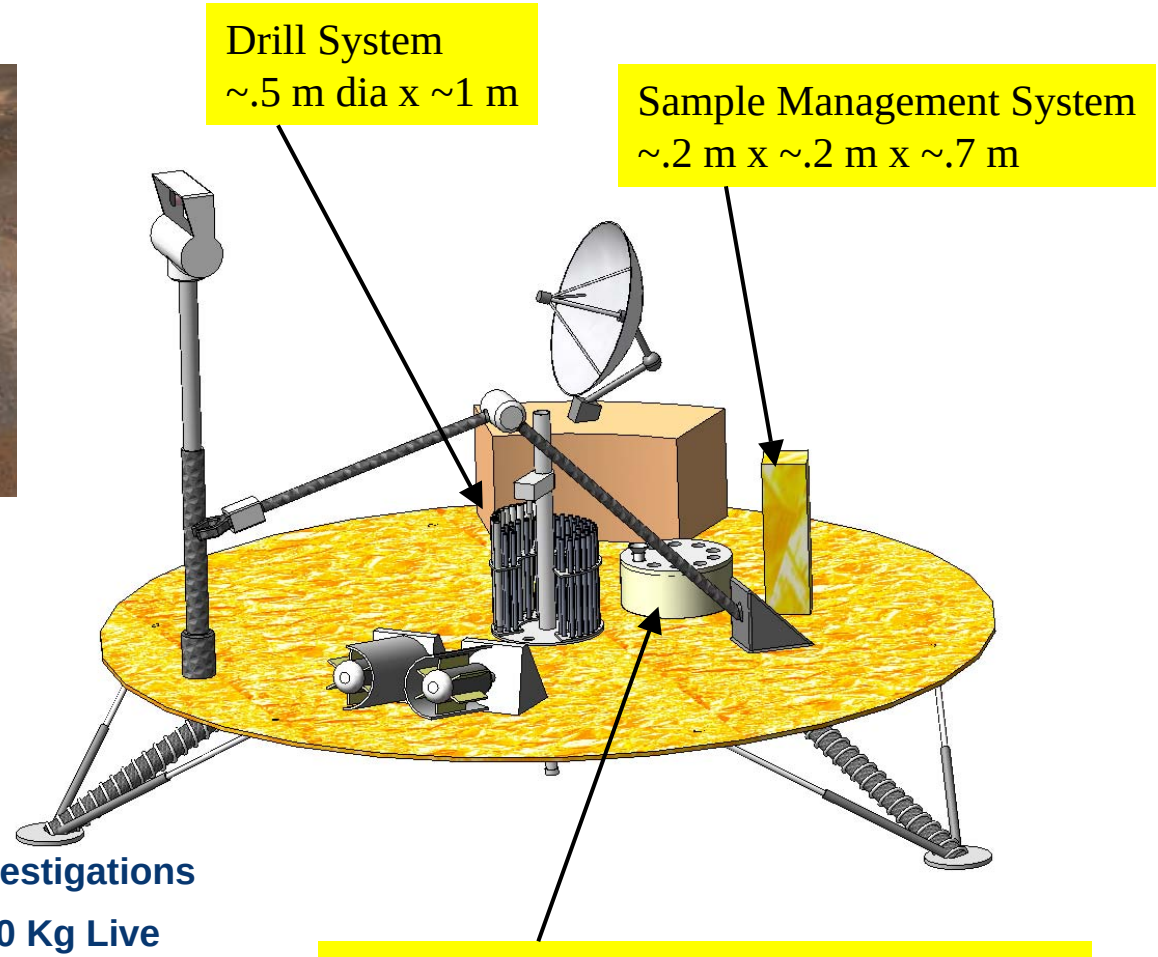


George M. Low Award

10m Field Test Data/Results

Depth (m)	Power (W) Actual Drill	Power (W) Total System	Core (°F) Ave(Tcore-Tamb)	Drill Rate m/sol	Images Cores	Images Cuttings
1	8	82	1.1	0.5		
2	17	91	-1.1	1		
3	18	92	6.4	1		
4	13	87	9.0	1.5		
5	13	87	4.1	2		
6	23	97	8.5	4		
7	22	96	1.7	4		
8	27	101	1.6	5		
9	36	110	8.3	5		
10	31	105	9.9	5		

2-5m Drill System on Lander Platform



•Mission Type 1:

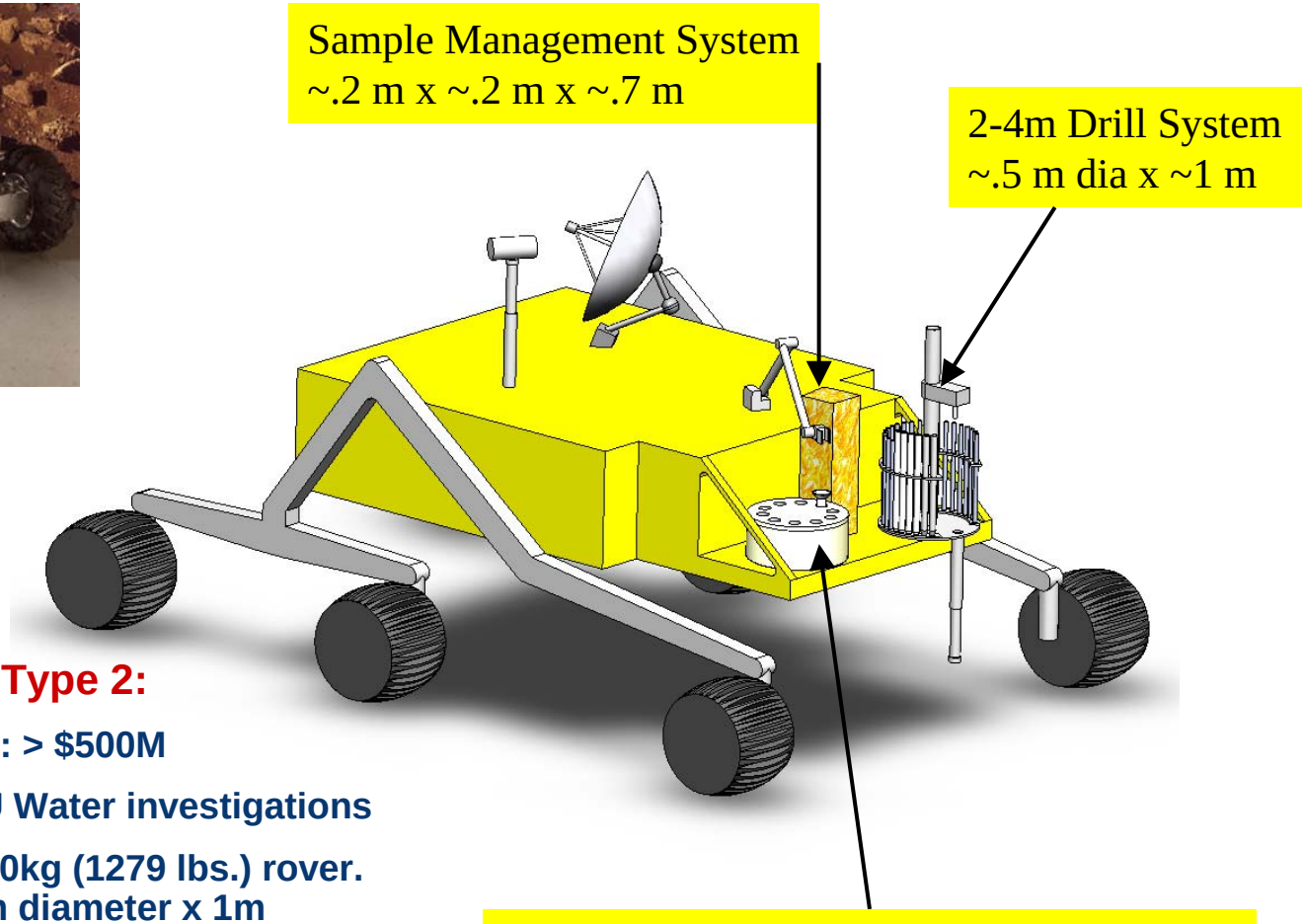
-Estimated Mission Budget: < $500M

-Supports ground truth data

-Soil Engineering and ISRU Water investigations

- Precision Soft landing approach, 760 Kg Live Lander. The drill system 30-50kg, 0.5m diameter by 1m. in stowed position, will be mounted on the static Lander, and drill 2-5m boreholes within lander access. The drill system may be given 10-15 sols and a 200 W-hr/sol power budget. Down-hole science instruments may be considered for long-term data collection.

2-4m Drill on Large (Mega) Rover Platform



•Mission Type 2:

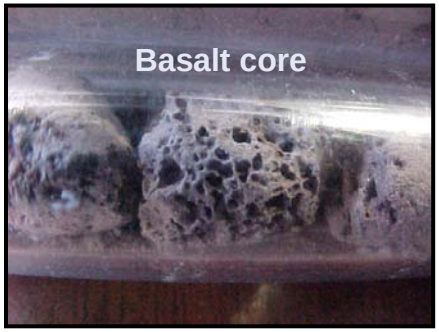
-Estimated Mission Budget: > $500M

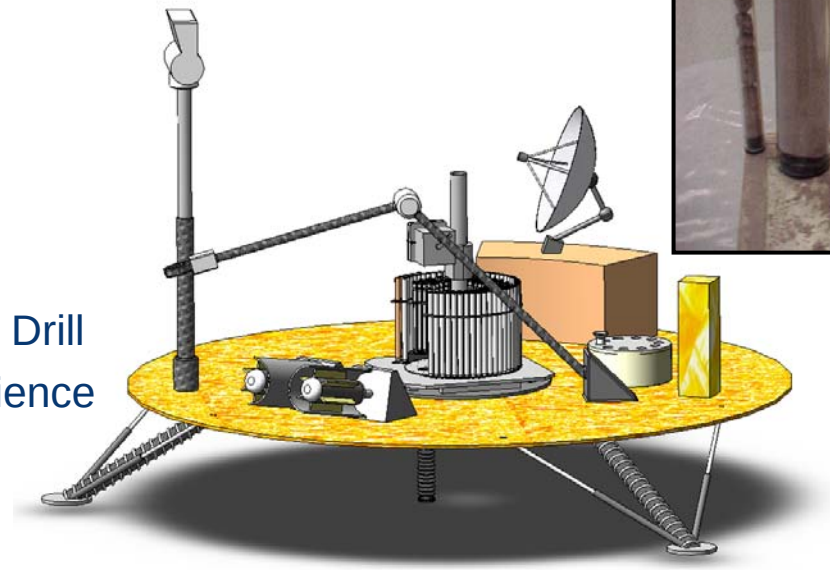
-Soil Engineering and ISRU Water investigations

- Soft landing approach, 580kg (1279 lbs.) rover. The drill system 30kg (0.5m diameter x 1m envelope) will be mounted on a Mega rover and drill 1-3m depths (three to ten boreholes). The drilling operations (including sample analysis) may be given 5-10 sols per 1m drilled and a 200 w-hr/sol power budget.

Planetary Drilling: Ongoing Efforts

- **Define Initial Drill Mission Goals**
  - Allowable Sample Contamination (5% or <0.5%?)
  - Sample core/fines volume Goals
  - Time to Depth
  - Mission Operational Duration Goals
  - Sample Management Process
  - Science Mission Objectives and Priorities
  - Instrument Interfaces
- **Collaboration to develop Mission System Concepts**
  - Mission objectives
  - Roadmap
  - Evaluate Mission Risk
  - Power and mass envelopes
- **Establish team field tests**
  - Integration of Instruments & Drill
  - Increase Operational Experience
  - System Validation





20-50m Drill System on Lander Platform