Sample Acquisition and Management Systems for Missions to Mars

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General issues on sampling requirements

The collection and subsequent analysis of soil sample materials is of great importance in the exploration of planets and comets.

**Surface samples:** their constituents can potentially represent the different parts of a planet surface and of the surface environment. They can provide insight into surface processes.

**Subsurface samples:** they provide insight into the geological history of the landing site region, including stratigraphic information. These samples are shielded from the upper surface environmental conditions and therefore contain pristine information.

**Atmospheric samples:** they can provide understanding of early history of water on the planet and on early evolution of life.

Examples of sampling requirements for missions to Mars

**MARS SAMPLE RETURN (ESA):**
- surface, subsurface and atmosphere samples
- deepest subsurface sample collected at 1.5 metres
- sample mass: 0.5 kg (250 cm³, assuming a soil density of 2 g/cm³)

**EXOMARS MISSION, PASTUER PACKAGE (ESA):**
- subsurface samples at a depth of 2 meters
- samples from surface rocks (beyond weathering ring, c.a. 10 mm)
- sample size 4 cm in length, 1 cm in diameter

**MARS SCIENCE LABORATORY (NASA):**
- surface samples down to 120 mm depth
- sample size 10-12 cm in length, 0.8 to 1.2 cm in diameter
- 3.5 cm in diameter abraded spots on rocks
Types of Drill Systems

Different types of Drill Systems can be adopted depending on mission and resource requirements:

- Single Rod Drill: for depth of penetration of about 1 meter
- Multi Rod Drill: for depth of penetration of 2-5 meters
- Coiled Tube Drill: for depth of penetration > 5 meters

Single Rod Drill System

- The single rod drill makes use of a single drill tool whose length is sufficient for the drilling depth
- This drill is relatively long and requires an appropriate volume on the lander or rover for its accommodation
- It basically has only two mechanisms: drill rotation and drill translation
- It is a simple equipment, very reliable
- It cannot be used in application where the volume available for stowage is limited
The multi rod drill makes use of a drill tool and a number of extension rods which are “summed” to obtain the required drilling depth.

The number of rods and their length depend on the available volume for accommodation and penetration depth.

The extension rods are accommodated on a dedicated carousel and must be assembled during drilling and disassembled to recover the drill tool and discharge the collected samples.

Example of multi rod drill system for 5 m depth

This concept uses 10 pipes to reach 5 meters penetration depth.

The mandrel is placed external to the rods’ carousel and the collection and deposition of each of the rods requires a translational displacement of the whole carousel.

The drill mass is about 11 kg and its dimensions c.a. 265x215x860.

Drill rotation motor power: 60W.

The drill tool is a corer 17 mm diameter working at 100-200 rpm.

Drilling speed in travertine-like material 1 mm/minute.
Coiled Tube Drill system

CTD has an excavating head mounted at the end tip of a flexible rigid or semi-rigid guiding tube.

- the tube can transmit a pushing force from the surface unit to the drilling head;
- possibility to implement the chip transportation to the surface by means of fluids;
- deployable probes can be used to collect samples or to conduct down-hole scientific experiments.

Example of CTD developed by Los Alamos Laboratory

Example of CTD for Mars exploration (ASI DeeDri program)

Prototype developed and tested (ASI DeeDri program)

- External diameter 35 mm
- Core diameter 14 mm

Sampling procedure

Samples collected by drill tool with shutters: gas concrete, dry sand, travertine, tuff
**Concept of corer tool**

Prototype developed and tested (ASI DeeDri program)
- External diameter 17 mm
- Core diameter 10 mm

**Sampling procedure**

Drilling to reach Sampling Depth
Central Piston in upper position
Core Forming
Continuation of Core Forming up to thrust > TBD N (core root detachment)
Drill uplift
Sample Discharge

Samples collected by drill tool with shutters in travertine, marble

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**Concept of Rothal tool**

Rothal concept (developed in ASI DeeDri programme) is based on a front transversal cutting disc

The main advantage of this approach is the suppression of the zero-speed zone
The cutting action results from the combination of two rotary motions:
- a fast one for the rotary disc
- a lower one of the main tool body for hole formation and chip uplifting.
Some tool performances

During tool prototype developments (in the frame of asi DeeDri program) extensive testing activities have been carried out in different types of materials.

<table>
<thead>
<tr>
<th>Material</th>
<th>Compressive strength $\sigma_R$ (MPa)</th>
<th>Density g/cm$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Concrete</td>
<td>1-3</td>
<td>0.46</td>
</tr>
<tr>
<td>Travertine</td>
<td>20-60</td>
<td>2.44</td>
</tr>
<tr>
<td>Tuff</td>
<td>1-2 matrix + hard inclusions</td>
<td>1.01</td>
</tr>
<tr>
<td>Marble</td>
<td>70-150</td>
<td>2.67</td>
</tr>
<tr>
<td>Granite</td>
<td>100-200</td>
<td>2.73</td>
</tr>
</tbody>
</table>

Some of the results showing performances in terms of vertical thrust vs. penetration speed are reported in the next charts.

Test results in gas concrete

Test results in tuff

Test (N) Vs. penetration speed (mm/min)
**Some tool performances**

![Thrust (N) Vs. penetration speed (mm/min)](image1)

**Test results in travertine**

**Test results in marble (granite for Rothal)**

*(from DeeDri program)*

**Sample preparation and distribution**

The collected samples are subject to an on-board processing which is heavily dependant on the type of the serviced instrumentation:

- sample storage in dedicated vessels and container for earth re-entry
- sample preparation for analysis by the on-board scientific instrumentation

being the latter the most demanding in terms of handling problematics.

Some of the on board instrumentation may require samples “as collected” (e.g. core solid type, if available, or fragmented) for part of their analysis process.

In most of the cases the samples need be powdered to a suitable degree of finesse.

The processing facilities includes specific devices like polishing station, grinding station, containment vessels, distribution lines (e.g. carousel).

The degree of complexity of the processing facility is strongly related to the configuration and number of the on-board apparatus to be served.
Devices for sample preparation

Schematics of Polishing station

Schematics of Grinding station

Schematics of sample processing system

Schematic of an integrated sample processing system (shown at its top level capability)
Sample distribution by means of carousel and “ovens”

- 10 Medium Temperature Ovens for presentation of samples to the microscopes and to interface the tapping stations of the GC/MS
- 16 High Temperature Ovens to interface the tapping station of the GC/MS

Example of sample distribution system: SD2 for Rosetta mission

Detail of Carousel

SD2 ovens and discharged sample

(ASI program)