Testing of Exomars Drill Tool EM
in Mars Analogous Materials

A. Fumagalli, P. Magnani, E. Re, S. Senese (Selex Galileo)
G.G. Ori (IRSPS)
P. Baglioni (ESA)

ASTRA-2011, April 12-14, ESTEC
✓ Exomars Drill Unit – Recalls

✓ Mars Analogous Materials
  ✓ Mechanical characterization

✓ Drilling Tests (on the Mars Analogous)

✓ Sampling Tests (on the Mars Analogous)

✓ Conclusions and future activities
The ExoMars Drill and Sampling system is composed of three main elements:

- **Drill Unit**
- **Positioner Unit** (rotation and translation)
- **Control Unit** (Electronics and Software)

The Drill Unit and Positioner Unit are installed on the front panel of the Rover.

The Electronics is split in two parts: a Central Electronics Unit located inside the Rover and a Local Electronics located at the Drill Box.

**Deployment sequence**

**Roving configuration**

**Sample discharge configuration**
Multi-rod DRILL concept

- Multi-rod device allows a 2 m depth sampling
- Achieved by assembling a drill string composed of:
  - 1 drill tool (+1 spare)
  - 3 extension rods
- Drill tool:
  - hollow tube with auger thread,
  - drill tip with PCD cutting head
  - internal mechanism for sample formation chamber with shutter at the lower end.
- 3 extension rods with electrical and optical fibres contacts
- Clamps systems for mounting and dismounting extension rods
Several BB parts have been manufactured and tested progressively till the development of a full model inclusive of all key items:

- Drill tool
- Extension rods
- Roto-translation group
- Rods magazine
- Mandrel clamp and lower clamp
- Two d.o.f. positioner

Integration of a pre-EQM model is in progress, inclusive of all the items and mechanism of the Drill Unit (no Positioner).
The ExoMars Drill Tool is in charge of:
- providing cutting/perforation capabilities
- Provide a Sample Acquisition System
- Host the Ma_Miss instrument for Down-Hole Science

The Drill Tool is composed by:
- An external Tube
- A cutting Head
- The sampling mechanism, including:
  - A retractable central piston (to be retracted for coring)
  - A sample chamber
  - A shutter mechanism

All the mechanisms are actuated by a single motor hosted inside the drill tool.
Down hole science is implemented by incorporating the Ma_Miss (MArs Multispectral Imager for Subsurface Studies) spectrometer.

- The spectrometer is capable to perform soil stratigraphy in both visible and infrared spectrum.

- Optical head is incorporated into the Drill Tool.

- The spectrometer images (both visible and infrared) are conveyed to the surface via an optical link system composed of optical fibers connected by optical joints.

- The illumination lamp is provided locally down stream via a dedicated lamp.
The Engineering Model of the Drill Tool (incorporating MaMiss spectrometer) has been developed and is the subject of this test campaign.
In December 2009, a dedicated ESA Working Group on Mars Soil Characterization proposed a new reference set of lithologies to be used in the next test campaigns foreseen on the ExoMars Drill Unit.

This set of lithologies encompasses materials that could be found on the Mars soil or, in general, materials that are of interest from an exobiology point of view.

Prior being used for Drill Testing activities, such materials have been mechanically characterized in terms of:
- Uniaxial Compressive strength
- Knoop micro-hardness
- Cerchar Abrasivity Index
• **Stromatolites:** lithology consists of red limestone Precambrian in age (Morocco South of Ouerzazate)

• **Sandstone High Quartz Content (HQC):** this lithologies is collected in the Marnoso Arenacea

• **Sandstone Low Quartz Content (LQC):** collected in the slabs of the Argille Scaglieose of the Val Marecchia

• **Claystone High Calcium Content (HCC):** clay with a percentage of calcareous material that hardens the rock

• **Claystone Low Calcium Content (LCC):** selected from the same family, with a lower amount of calcium content

• **Gypsum (Micro-Crystalline):** Samples are provided from the Vena del Gesso, Italy

• **Hydrothermal Deposits (Geyserites):** collected samples are from the Solfatara at Pozzuoli (Italy)

• **Basaltic Lava:** Samples from Mount Etna (Sicily)

• **Strongly Weathered Lava:** This lithology has been collected on the east slope of Mount Etna
Uniaxial Compressive Strength

Test setup

Failure mode of Claystone HCC

Compressive strength – Summary of results
Laboratory Characterization of the Mars Analogous Materials

Knoop micro hardness

Rhombic-based pyramidal indenter

Micro-hardness Tester

Knoop Hardness – Summary of results
Laboratory Characterization of the Mars Analogous Materials

**Cerchar Abrasivity Index:**

- Scratch the sample material with a sharpened stylus
- Measure the length of the “flat” on the stylus

### Cerchar Test Apparatus

Stylus after scratching “Abrasive” and non-Abrasive samples

### Cerchar Abrasivity – Summary of results
• Purpose was to verify the capability of the Drill to perforate the new materials

• On each material:
  ✓ Drill at 3 different thrust levels: 250N - 350N - 450N
  ✓ Measure advancing speed

• Plot “Advancing Speed vs Thrust” curve

• Expected behaviour reflected on all the materials

Materials of “Easy” drillability

Materials of “Medium” drillability

Materials of “Hard” drillability
• Purpose was to verify the capability of the Drill to collect samples of the new materials

• Collect 5 samples of each material, by performing the following steps:
Sampling Tests on the Mars Analogous Materials

- More than 40 samples have been collected.
- The acquired samples are always “satisfactory” in terms of mass.
- No sample has ever been “lost” during the test campaign.
- Surprisingly, the most challenging materials to collect were found to be Gypsum and Geyserite:
  - Despite their poor mechanical characteristics, these materials tend to stick against the walls of the sampling chamber.
  - Require higher current from the sampling mechanism motor to be discharged.
Conclusions and future activities

The ExoMars drill and sampling system has so far been tested in a variety of conditions, including laboratory tests in Mars-analogous materials.

Achieved results are in line with the expected drill overall performances in terms of key issues, such as: thrust, torques, advancing speed during drilling, amount of sample material collected, …

Further testing in Mars-like environment (in terms of temperature range, pressure, CO2 atmosphere) are about to start and will be completed by June this year.

The overall results so far achieved confirm the effectiveness of the Drill and Sample Acquisition approach followed for the ExoMars Drill.