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A Robotic Deep Driller for Mars Exploration

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Background

The discovery on Earth of **life forms** thriving in **extreme environments** has open the possibility that some sort of life could have possibly also evolved on **Mars** or **Europa**.

The search for possible extinct or extant life is the goal of the **exobiology** investigations to be undertaken during future Mars missions.

As it has been learned from the NASA Viking and Pathfinder missions, sampling of **surface soil** and rocks can gain only **limited scientific information**. In fact, possible organic signatures tend to be erased by surface processes (weathering, oxidation and exposure to UV). The only sensible Martian exobiology investigation must be performed on pristine samples that have never been exposed to the surface environment.

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Robotic Sample Acquisition

Scientists demand two types of samples:

- **Surface samples**: these are extracted from surface stones/rocks by coring at the depth of few centimetres

- **Deep soil samples**: these are extracted vertically from a depth of >1 meters

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Robotic Sample Acquisition (2)

This operation can be divided in 3 actions:

- **accessing** the sampling location
- **sampling**
- **delivering** the samples

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Robotic Sample Acquisition (3)

- **Drilling** is best way for accessing both surface and deep samples
- The requirements related to drilling can be resolved into the tasks to:
  - penetrate **deep** (>1 or even 2 meters)
  - penetrate **non-homogeneous soil** of **unknown hardness** (soft to very hard)
  - allow **multiple drilling** (research nature of deep sampling does not guarantee that anything interesting is found in the first drill hole)
  - operate in unmanned and automatic mode (deployment, drilling and sampling)
  - operate in **low gravity**: the system cannot rely on weight to generate drill thrust

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Robotic Sample Acquisition (4)

Sampling

Requirements:

- acquire a **pristine sample** of unknown hardness (soft to very hard) and consistency (loose to compact)
- **sample at a certain depth**, material of that specific layer (not material carried through from upper layers)
- allow investigation of **several layers**
- **preserve morphology** of the sample

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Robotic Sample Acquisition (5)

Delivering the sample

- Requirements:
  - **transport** the sample to the instruments based on the lander
  - **do not alter sample morphology**
  - **do not pollute** sample with surface material

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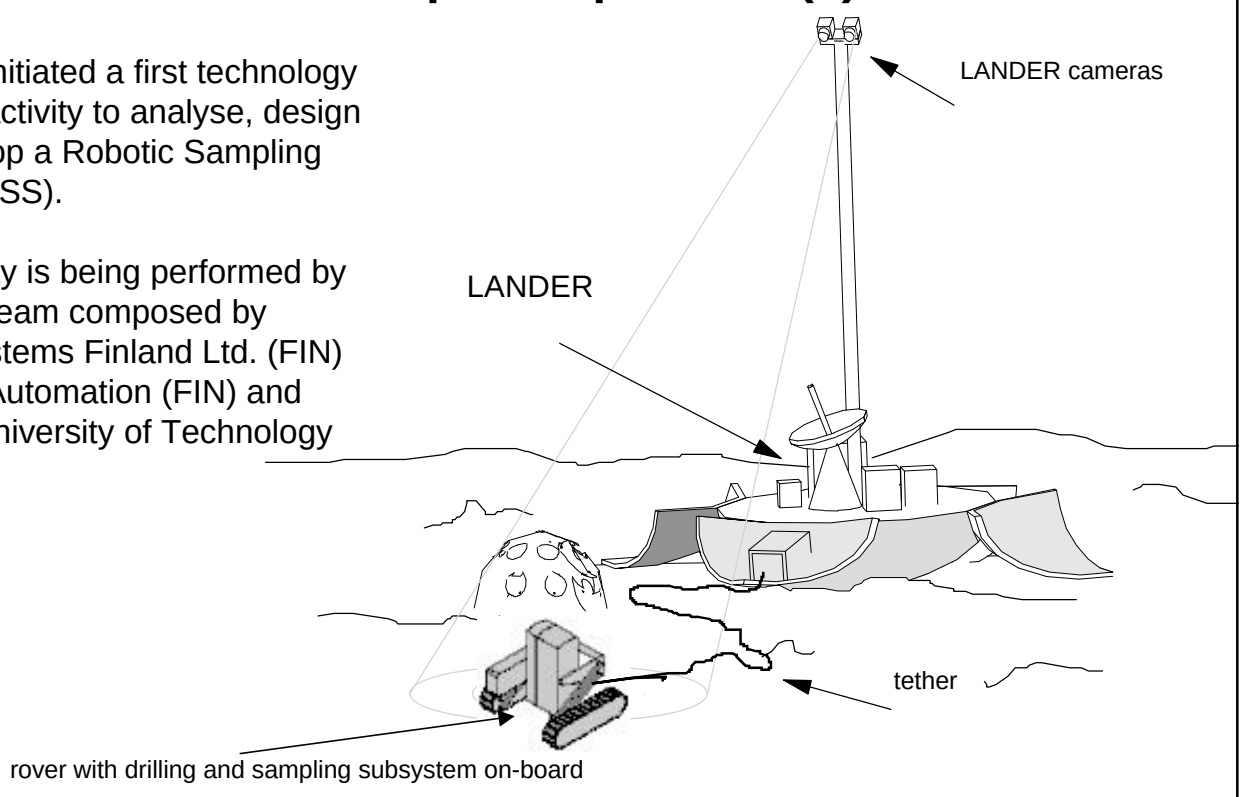
Robotic Sample Acquisition (6)

ESA has initiated a first technology research activity to analyse, design and develop a Robotic Sampling System (RSS).

This activity is being performed by industrial team composed by Space Systems Finland Ltd. (FIN) with VTT Automation (FIN) and Helsinki University of Technology (FIN).



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Robotic Sample Acquisition (7)

The RSS consists of the following components:

- A **Mobile Drilling Platform** (MDP). This is basically a small rover whose function is to house the drilling and sampling subsystem and transport it between the lander and the sample acquisition locations.
- A **Drilling and Sampling Subsystem** (DSS). This is the subsystem that performs the actual sampling. Acquired samples are also stored here prior to their delivery to the Lander.
- A **Docking and Sample Delivery Port** (DSDP). This is the “home base” of the MDP. DSDP is mounted on the Lander. The MDP starts its mission docked to the DSDP and this is where it returns to deliver the acquired samples.

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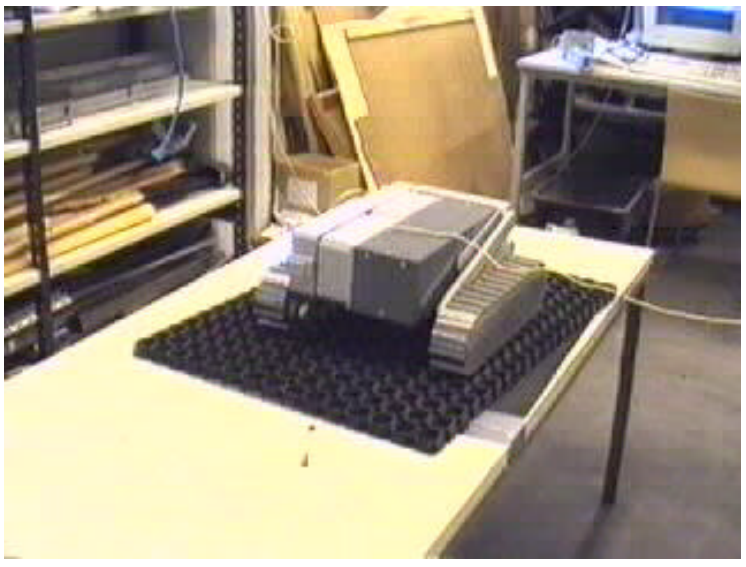
The Mobile Drilling Platform (1)

The Mobile Drilling Platform (MDP) is a tracked tethered vehicle, serving as a platform for the DSS. Its function is to enable the DSS to sample at desired locations and to deliver these samples back to the lander.
The rover is composed by two parallel track-bodies connected by a lifting bridge. An additional body, called payload cab, is connected to the bridge through a rotating axis. The payload cab hosts the DSS.



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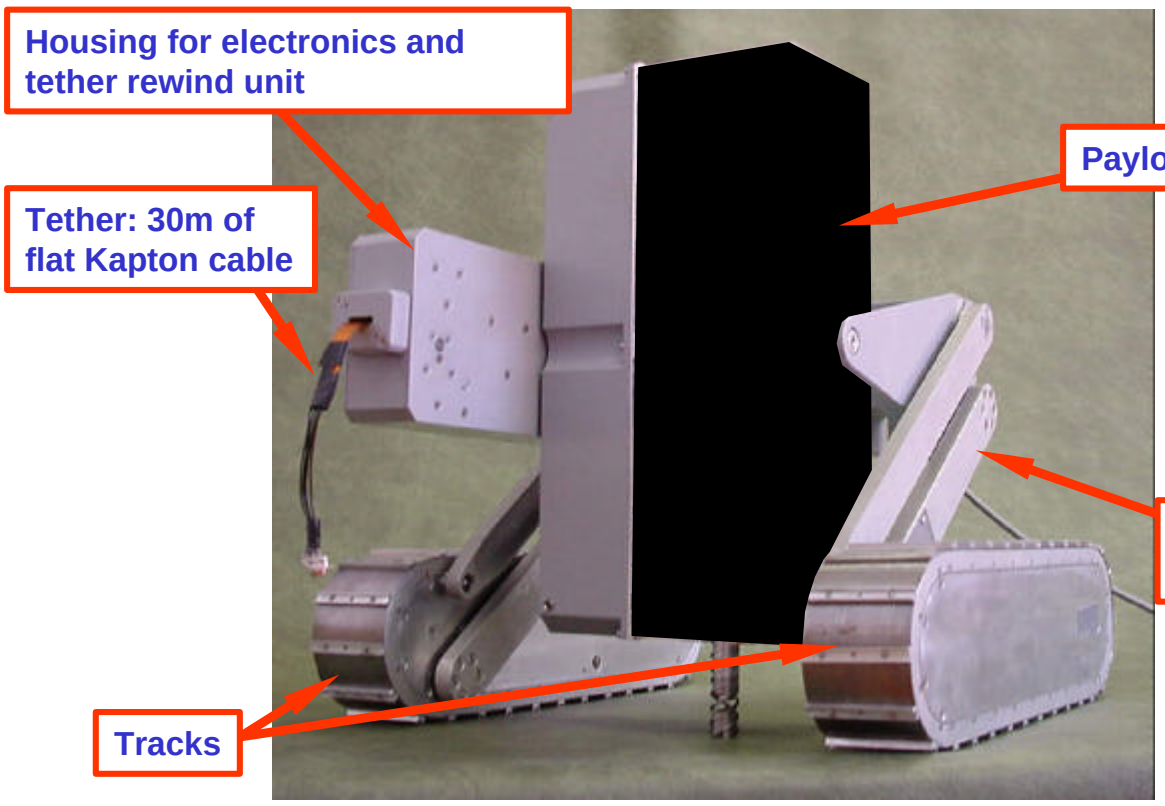
The Mobile Drilling Platform (2)



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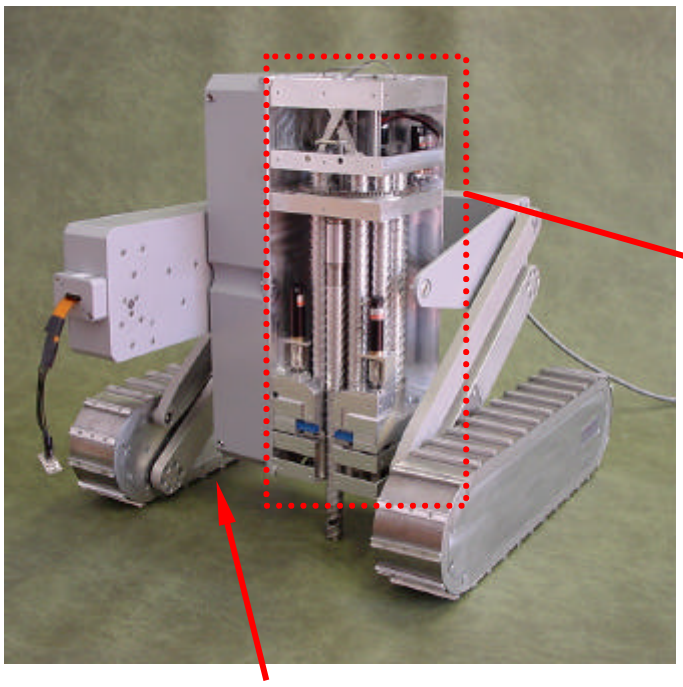
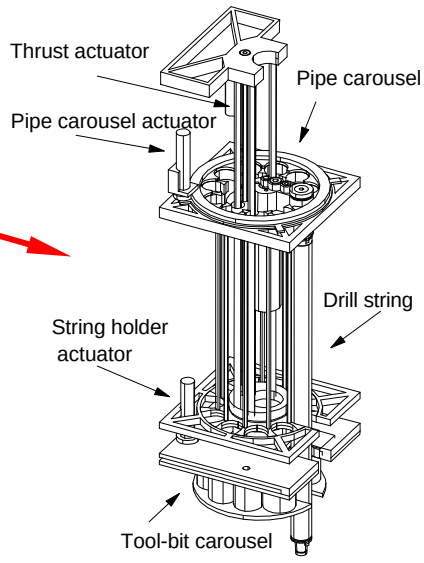
Drilling and Sampling Subsystem (DSS)



Mobile Drilling Platform (MDP).



Drilling and Sampling Subsystem (DSS)

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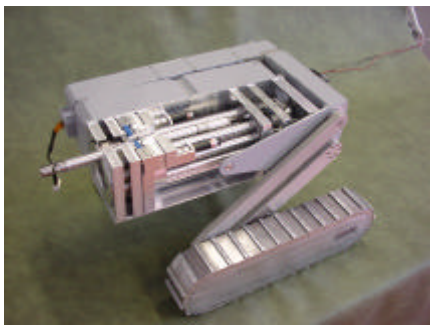
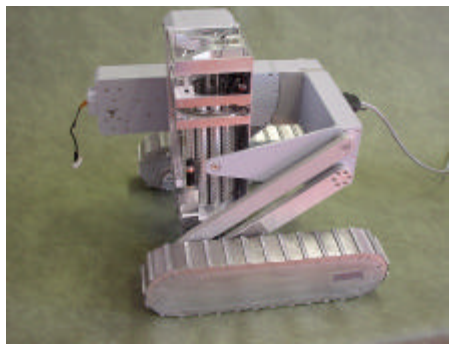
Drilling and Sampling Subsystem (DSS) (2)

Different possible drilling directions



Horizontal Configuration



Vertical Configuration

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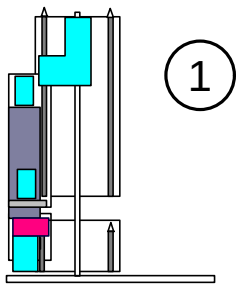
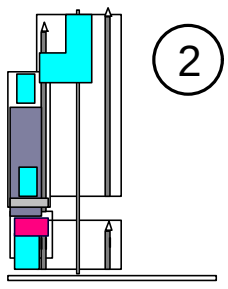
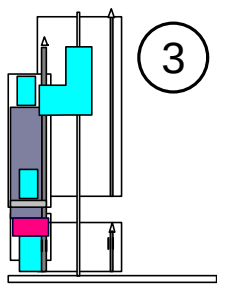
Drill String Assembly Sequence



Drill pipe carousel rotates a drilling pipe into thrust/rotation unit

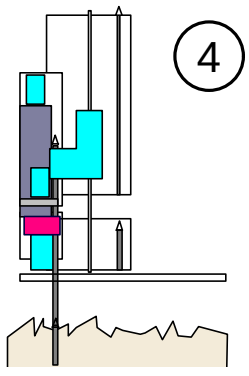


Drill pipe is driven down by the thrust motor

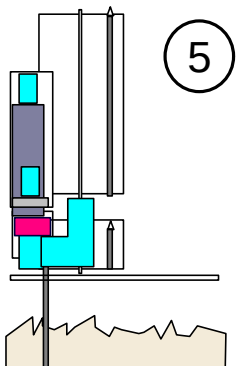


Drill pipe mates the drill string (which intially is only the drill bit)

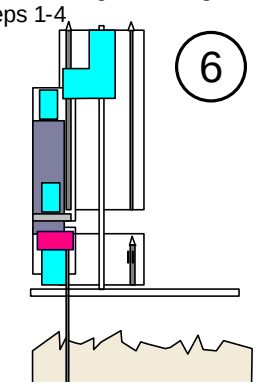
The so-assembled drill string drills into the soil propelled by the thrust and rotation motors



The end of the first drill pipe is reached



A new drill pipe is attached to the drill string according to steps 1-4



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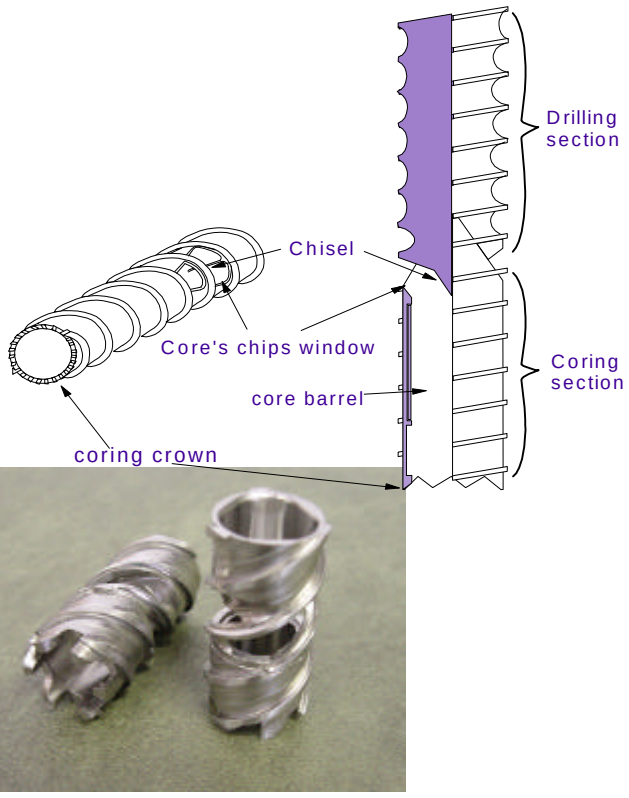
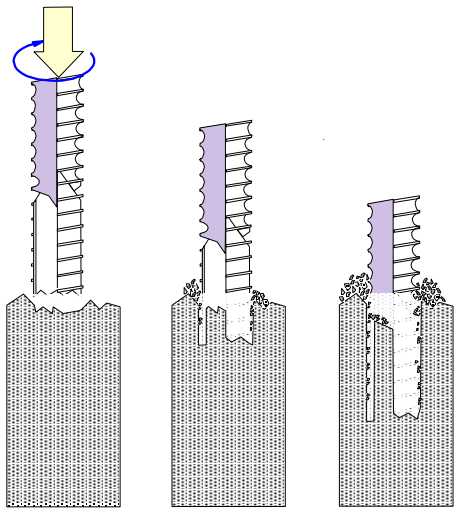
Drill bit and its combined drilling and coring





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The Docking and Sample Delivery Port

The Docking and Sample Delivery Port serves as a “home Base” for the MDP. It is located on the Lander. This is where the rover starts its mission and it also where it delivers the acquired samples.