**Introduction:** Drilling the Martian subsurface are motivated by different scientific and engineering interests associated with the geologic, hydrologic, and climatic history of the planet, the search for life and the identification of potential hazards and resources for future robotic and human exploration. The main objectives of a drilling program for Mars are:

- to understand the distribution and state of subsurface water and other volatiles
- to understand the geology and evolution of the upper crust and regolith
- to determine the nature and distribution of oxidants as function of depth
- to search for organic molecules and other potential indicators of past or present life
- to characterize the geophysical properties, including heat flow, stress and strain
- to characterize volatile-bearing mineralogy with depth.

Drilling into the near-surface crust will provide an opportunity to assess variations in composition, texture, stratification, unconformity, etc. that will help define lithology and structure, and provide important clues regarding origin and subsequent modification. Mineralogical analysis is required to identify and quantify the mineralogical constituents with respect to water content. Mineralogical and chemical compositions, texture, and primary structure are important parameters for identifying igneous, metamorphic and sedimentary rocks. These parameters are best characterized in context by drilling into Mars. The composition of the Martian crust (elemental, chemical and mineralogical) is the single most important parameter that can be measured as a function of depth. The composition of the regolith and crustal rocks provides important information about the geologic evolution of the near-surface crust, the evolution of the atmosphere and climate, the existence of past or present life, and the presence of potential resources and hazardous materials for both human explorations and advanced robotic missions.

Down-hole science can determine the composition and granularity of different layers, and identify the mineralogy of individual grains through dedicated miniaturized instruments, that can be allocated into the drill. Furthermore, temperature and thermal diffusivity sensors, radioactivity dosimeters and spectrometers, resistivity and/or dielectric constant sensors can be allocated in the drill.

The drilling program for Mars's exploration developed by MEPAG foresees to reach different depths in successive mission. There are three primary breakpoints in the issue of science return vs. depth of drilling: 1-5 m, 10-20 m, 50-150 m. Investigations extending to depths of 1-5 meters would provide key information regarding regolith physical properties, petrology, and volatile transport. Depth of 10-20 m is so that there is a chance of penetrating below the surface oxidized layer (estimated to range from ~1 - 10 m), which would enable critical studies of organic geochemistry and astrobiology. This depth is additionally needed to measure the heat flow, and it may also be sufficient to reach ice-saturated frozen ground (depending on the latitude of the landing site). Accessing bedrock is possible in a 10-20 m hole, but it is much more likely in a 50-150 m hole. Depending on the landing site, a 50-150 m hole may reach segregated bodies of massive ground ice, and it would likely access a significant region of ice-saturated frozen ground.

With present technology, investigations to depths of as little as a few meters would provide significant opportunities for improving our knowledge of Mars, proving data that are critically needed to plan future investigations.

**Description of the Italian Proposal:** The proposed solutions here reported have been identified according the possible allocated resource of mass, energy and time, and the time constraint for the 2007 mission. These constraints ask for not only deep miniaturization as well as low power but also for sufficiently mature technological developments.

The development of different instruments is strongly dependent on the Drill configuration considered. In fact, a drill able to collect and distribute samples will be associated with both in situ experiments and with a small micro-laboratory able to perform detailed analyses on the collected samples. In what follow, we report, as an example, the instrument package selected for the 2003 NASA lander mission. Obviously other suites of experiments can be added depending on the lander resources and sharing between partners.

The instruments here described, as well as the concept of the shallow drill have been already studied, not only at laboratory level, but also with selected Industrial Prime Contractors. The Phase A of the drill, mini-lab and experiments has been already concluded, therefore the breadboard of them can surely be ready in less than two years.
Tecnospazio has studied the Drill Sampler Tool (DST) concept under direct guidance of the Italian Space Agency (ASI), as a multi-purpose tool to be used in different space missions. In fact a similar sampler device has been already developed for the lander of the Rosetta mission. The original Drill Sampler Tool, during the assessment and the Phase A, was modified in order to be used as a real scientific system. Moreover it was also foreseen to calibrate the drill torque/force in order to use it as a tool to characterize soil mechanical properties. The scientific team, therefore, was also involved in the definition of the new drill configuration. ASI has proposed this concept to JPL for the missions in 2003 and 2005; in that occasion the system was named DeeDri.

Ma_Miss (Mars Multispectral Imager for Subsurface Studies) is a miniaturized imaging spectrometer designed to provide imaging and spectra in VIS/NIR for studies of Martian subsurface layers. The instrument can be integrated into the drill and will be able to provide an image of a “ring”, to determine the composition and granularity of different layers, and to identify the mineralogy of individual grains. Ma_Miss main objectives are to detect the presence of layers containing clays, carbonates and alteration products, to identify the grain size distribution and grain structure at different depths along the walls of the hole, and to study the mineralogy of single grains through their spectrum.

IPSE (Italian Package for Science Experiments) is a scientific autonomous micro-laboratory for Mars’s soil and environment analysis providing the capability to serve, handle and manage scientific miniaturized instruments accommodated inside its envelope. The IPSE concept has been developed by the CISAS group of the Padua University, in strict co-operation with the prime contractor Tecnospazio. A small robotic arm is stowed inside the envelope and provides the capability to deliver soil samples to the instruments from the Drill. Its general configuration is based on a structure with an external envelope to fit also the small lander. IPSE is designed to operate in Martian environmental conditions and for a lifetime of one Earth year with the aim to be upgraded at each launch opportunity. A modular philosophy has been implemented to allow the maximum level of de-coupling between IPSE and the experiments. IPSE includes the four scientific instruments here after described (IRMA, MA-FLUX, MAGO, MARE-DOSE)

IRMA (Infra-Red Microscope Analysis) is a hyperspectral microscope for the in-situ mineralogical analysis of Martian samples. It works in the 1-5 µm spectral range, with a spectral resolution of 8 nm. Its spatial resolution is 38 µm and the overall field of view is compatible with the sample dimension collected from the DEEDRI drill (12-mm diameter). The investigation carried out by IRMA has the goal to quantitatively characterize the mineral and the micro-physical properties of Martian subsurface samples.

MA-FLUX (Mars X FLUorescent Experiment) will investigate the Martian surface using the X-ray fluorescence technique, thus allowing the detection of the major and trace chemical elements in the Martian soil, down to a few ppm, using simultaneously the gamma scattering method and the X-ray fluorescence technique. This instrument investigates the interior of samples to a depth ranging between one mm and one cm.

MAGO (Martian Atmospheric Grain Observer) measures cumulative dust mass flux and dynamical properties of single intercepted particles as a function of time. It allows determination of grain mass, size and shape distribution, and dynamic behavior of airborne dust. It is a single instrument including three different detection sub-systems: three micro-balances as detectors of mass deposition, a grain detection system, and an impact sensor.

MARE-DOSE (Mars Radioactivity Experiment-DOSimeter Experiment) is an experiment for monitoring the β and the γ radioactivity during the Earth to Mars cruise phase and at the surface of Mars, in the range 30-300 keV. It consists of lithium-fluoride doped pills which can be exposed to the radiation, reset and readout by heating the pills within a thermoluminescent process during heating cycle and the emission of an optical signal flux proportional to the absorbed dose.

Deep drill concepts could probably not allow the sample delivery due to the complexity of such an operation; nevertheless deep drill concepts can include the Ma_Miss and the already mentioned temperature, thermal flux, diffusivity and radioactivity sensors. The selection of the solution will be tied to the specific depth objectives of the drilling activity, the risks that are willing to be taken, and the geologic material of the drill site. Generally the solutions range from the low risks of the DST that can attain depths of 2 metres, to the higher risk drilling technologies, currently under study at Tecnospazio, that can reach a few tens of metres of depth, or, in the case of the innovative worm concept, even hundreds of metres.