ESSC-ESF study on the
Definition of a science-driven European scenario for space exploration

ESF-ESA Athens Workshop
Final Declaration

88 scientists and national representatives from ESA Member States met in Athens on 15-16 May 2007 in a workshop organised by ESF and sponsored by ESA, with the aim of establishing recommendations to ESA Human Spaceflight, Microgravity and Exploration Directorate on a science-driven scenario for EEP.

The discussion was initiated by a draft report on this subject prepared by an ad hoc group set up by the European Space Sciences Committee of the European Science Foundation (ESSC-ESF). The report establishes a framework for the definition of Europe's Exploration Programme (EEP), based on an overarching science goal: "Emergence and Evolution of Life with its Planetary Environment", and five sub-themes –or targets: Mars (robotic and human exploration), the Moon (robotic and human exploration) and Near-Earth Objects sample return (robotic exploration). Series of science goals and mission concepts were proposed for the short-term (up to 2020), medium-term (2020-2030), and long-term (after 2030).

The workshop participants met in plenary and splinter sessions to refine the findings of the ad hoc group report for the three target bodies Mars, Moon and NEOs. The workshop participants agreed on a set of recommendations and findings, which form the core of this Athens declaration.

Commonalities

- The overarching scientific goal of EEP should be called: "Emergence and co-evolution of life with its planetary environments", with two sub-themes pertaining to the emergence of life, and to the co-evolution of life with their environments.
- EEP should focus on targets that can ultimately be reached by humans.
- Mars is recognised as the focus of EEP, with Mars Sample Return as the driving programme; furthermore Europe should position itself as a major actor in defining and driving Mars Sample Return missions.
- There is unique science to be done on, of and from the Moon and on Near-Earth Objects or Asteroids (NEOs or NEAs). Hence if these bodies are to be used as a component of EEP, further science should be pursued; the Moon could thus be used as a component of a robust exploration programme, including among others: geological exploration, sample return and low-frequency radio-astronomy.
- The first steps of EEP should be done robotically.
- Since EEP's ultimate goal is to send humans to Mars in the longer-term, research for humans in a space environment must be strengthened. Beyond the necessary ongoing and planned biological research and human presence on, e.g. the ISS or Antarctica, opportunities to this end might also arise in the context of an international lunar exploration programme.
- The role of humans as a unique tool in conducting research on the Moon and on Mars must be assessed in further detail.
- Europe should develop a sample reception and curation facility, of joint interest for ESA's science and exploration programmes.
- Understanding the processes involved in the emergence of life in the solar system, e.g. through in-depth exploration of Mars, is crucial to understanding the habitability of exoplanets.

- International cooperation among agencies engaged in planetary exploration should be a major feature of EEP, materialised by concrete joint ventures.
- Once EEP is funded and running it is further suggested to set up in the near future a series of international science and technology exploration workshops, which for Europe could be organised by ESF with the science community and co-sponsored by ESA, in order to better define the mission concepts and technological choices relevant to the above goals as this multi-decadal programme develops.

1. Robotic exploration of Mars

Mars is recognised as the focus of EEP which should first be led robotically, with sample return from the red planet as its driving series of programmes; furthermore Europe should position itself as a major actor in defining and driving Mars sample return missions.

Beyond the experience gained with Mars Express a roadmap for EEP should articulate the following steps:

- Step 1: ExoMars will be the first and therefore critical step in EEP; it will offer the European community a leading position, by exploring Mars with scientific objectives as diverse as exobiology, geology, environment and geophysics. Securing this mission for a 2013 launch must therefore be the top priority of Europe's robotic exploration programme
- Step 2: Mars Sample Return programme
- Step 3: Human mission programme, for which Europe needs to prepare itself to be a major partner

An essential goal is to understand the details of planetary evolution: why did the Earth become so unique, as compared to Mars or Venus? Understanding the issue of habitability of planets (Mars in particular) and the co-evolution of life within its planetary environments is thus our major goal. This in turn is crucial to understanding the habitability of exoplanets.

Another essential aspect is to continue relevant research on Earth to enable the determination of possible habitats, the mode of preservation of expected bio-signatures (differentiate traces of life from abiotic processes) in these habitats, and the unambiguous recognition of life beyond Earth. Indeed, characterising bio-signatures involves studies of early traces of life in the Precambrian Earth and taphonomy[1] of cells in various preservational environments of present Earth.

To participate in this endeavour with a major role, Europe has a number of assets but needs to develop or improve them, or identify those assets that international partners could contribute to its programme, such as:

- maintaining Europe's world–class instrumentation capability
- Europe's industrial capability to build an infrastructure at Mars
- International collaboration history of Europe
- the development in Europe of 5-10 Watts radioisotope-based devices would open new opportunities to European-led international collaboration

2. Robotic exploration of the Moon

The main objective would be the discovery, exploration, and use of the "8th continent", and the harvesting of unique information from the Moon as an archive of the formation and evolution of Solar System. Furthermore EEP should consider the use of the Moon as a large laboratory in free space.

A European roadmap for lunar exploration would thus include:

- SMART 1 exploitation and orbiter follow-up
- Surface missions– mobile laboratory
- Sample return
- Contribution to human-tended science laboratory
- Low-frequency radio-astronomy, especially from the far side

[1] study of a decaying organism over time

Sample return missions can in particular address samples from South Pole Aitken Basin (window to lunar interior), from Procellarum (youngest volcanism), from poles, from paleo-regolith, extraterrestrial samples, regolith samples of the solar wind history, samples of ice cometary deposits in the last billion years, samples from Mars and asteroids (and Venus?), and lunar samples of the Early Earth.

Prototype radio-astronomy experiments could initially be realised at one of the poles with the desire to move towards the far side thereafter. The usefulness of the Moon as a potential site for telescopes at other wavelengths needs to be further assessed by in-situ exploration.

There are a number of enabling technologies to realise this roadmap, such as: air-less entry and descent, hazard avoidance control, precise point landing, generic soft landing platform, instrument development, context and environment characterisation, sample acquisition and screening (robotics), intelligent rover sample fetcher and permanent robotic assets deployment, planetary protection demonstration, lunar ascent rocket, rendezvous, Earth re-entry, Earth descent and landing, sample curation, radioisotope power sources development.

3. Near-Earth Object sample return

On the short-term, and after flyby and landing missions on NEOs (ca. 2014), the next goal should be sample return, enabling a detailed investigation of primitive and organic matter from one selected, small body. Priority shall be given to pristine small bodies, e.g. C or D-type asteroids or comets.

At a later stage, the diversity of objects should be investigated by missions to different types of objects. Finally characterisation of potentially hazardous objects is considered vital. The following relevant technologies should start to be developed by Europe:

- precision landing
- autonomous sampling (sample transfer; containment; drilling)
- advanced propulsion
- Earth re-entry
- in-orbit docking
- sample treatment on Earth

Europe should implement a technological demonstration mission, which could be fairly cheaper than Mars or Moon sample return missions, and where the cosmogonical and exobiological contexts would be explored.

Characterisation of multiple small bodies is important in that context for threat evaluation, mitigation and, potentially in the longer-term, for identification of resources.

In the context of the preparation of Mars Sample Return the development of technologies for NEO sample environment monitoring and control during cruise, and sample storage on the ground, are relevant to address planetary protection issues for future Martian missions.

4. Human exploration of Mars and the Moon

A driver of exploration programmes is to advance human presence in space. Future manned missions should make use of humans as intelligent tools in the exploration initiative, with the following specific scientific goals:

- reach a better understanding of the role of gravity in biological processes and in the evolution of organisms at large
- determine the physical and chemical limits of life (from micro-organisms to humans)
- determine the strategies of life adaptation to extreme environments
- acquire the knowledge required for a safe and efficient human presence in outer space (from the International Space Station via Moon to Mars)

Specifically, human exploration would have the following scientific advantages:

- Much more efficient collection of a more diverse range of samples from larger geographical areas than is possible robotically
- Facilitation of large-scale exploratory activities such as deep (ca. 100m) drilling to determine geological details of the surface of the Moon (e. g. paleo-regolith deposits) or to seek possible habitable environments in Martian aquifers

- Facilitation of landing much more complex geophysical and other equipment than is likely to be feasible robotically
- Increase of opportunities for serendipitous discoveries
- Facilitation of a number of other, non-planetary, science activities on the Moon such as (i) life sciences investigations under reduced gravity conditions, and (ii) maintenance and upgrading of astronomical instruments placed on the lunar surface

In terms of the enabling science and technology needed to reach these goals, further knowledge is required to enable a safe and efficient human presence in outer space:

- responses of the human body to parameters of spaceflight (weightlessness, radiation, isolation, etc) and development of countermeasures
- responses of the human body to surface conditions on Mars and on the Moon, and protection measures
- development of efficient life support systems including bio-regenerative systems which can be done on Earth conditions, to be further adapted to specific mission conditions; in this context support to a Moon mission as an intermediate step towards a Mars mission could become relevant
- development of a habitat providing a living and working area on Mars and the Moon

To reach these goals experiments must be supported to better understand the role of gravity on biological processes on the International Space Station (multi-generation experiments in microgravity and long-term adaptation of humans to microgravity), on the Moon (multi-generation experiments at 0.17 g and long-term adaptation of humans to low gravity), and on Earth (multi-generation experiments under hypo- and hyper-gravity).

Furthermore the limits of life and its strategies of adaptation to extreme environments must be further studied through experiments on the International Space Station, the Moon and on Earth. More specifically the programme should aim at determining the climate and environmental parameters of potential hazard to humans, i.e. on the Moon: dust, radiation, 0.17 g, seismic activities, and micro-meteorites; on Mars: dust, radiation, atmospheric traces, temperature variation, seasons, 0.38g.

Knowledge acquired by the above mentioned experiments will enable human health and working efficiency in space and planetary environments. It is a sine qua non before the involvement of humans in exploratory missions to Moon and Mars, which then will benefit significantly from their presence.

Finally guidelines for planetary protection need to be elaborated with international partners concerning forward and backward contamination, and Europe must play an influential role in that context, by continuing the development and adoption of its own planetary protection policy, in compliance with the COSPAR guidelines.

Concluding summary

These four components of EEP illustrate the overarching science goal “Emergence and co-evolution of life with its planetary environments” which should structure Europe’s approach, along with the framework recommendations presented in the commonalities section. This declaration is a complement to the more detailed report of the ESSC Ad Hoc Group, which took into account and incorporated the discussions led during the Athens workshop.