Dans le champs de l'observation, le hasard ne favorise que les esprits préparés. – Louis Pasteur, 1854

(Where observation is concerned, chance only favours the prepared mind.)

J. L. Vago, A. Santovincenzo, B. Gardini & CDF Study Team

Exobiology in ESA

In the late 80’s ESA identified Exobiology as an important scientific discipline in its microgravity programme.

**Goal:** To study the persistence and survival of life in vacuum, microgravity, and radiation in Low Earth Orbit (LEO).

- **1989 –** 3 experiments in the Exobiology and Radiation Assembly (ERA), on board Eureca.
- **1994 – 2002** Tenths of exposure experiments on Biopan, externally attached to Russian Foton capsules.
- **1998 – 2002** Stone experiments to quantify the survivability of microorganisms and organics trapped in model meteorites to planetary reentry.
- **2003 –** Expose facility on ISS. For vacuum and simulated planetary conditions.
Exobiological Exploration

- A subject of growing scientific interest, complementary to other planetary studies.
- A logical progression from the exobiology experiments in LEO.
- A multidisciplinary discipline: Biochemistry Paleobiology Biogeology Mineralogy
  - Recommended an integrated drilling and analysis package to search for life beneath the Martian surface and inside surface rocks.
- Two parallel Phase A studies performed by industry in 1999 – 2000.

What is Life?

A self-sustained chemical system capable of Darwinian evolution. That is, a system that can transfer its molecular information via self-replication, and evolve through mutations.

**Drawback:** Evolution occurs over thousands of generations, and exchange of molecular information is difficult to verify.

**We need a definition that is useful for our space mission.**
What is Life?

Life is cells. Every living thing is cellular.
- Cells need water (for transport)
- Cells require sugars (as energy source and backbone for nucleic acids)
- Cell membranes are built with phospholipids

Life has homochirality.
Biomolecules exist in 2 mirror forms (enantiomers). Life uses only one enantiomer, and not the other:
- Left-handed (L) aminoacids
- Right-handed (R) sugars

What to Search For?

- **Extant Life**: Biological markers, such as:
  - Sugars
  - Aminoacids
  - Phospholipids
  - Nucleotides (ATP / ADP)

- **Extinct Life**: Organic residuals of biological origin (chirality, chemical, and isotopic information)
  - Images of groups of fossil organisms and their structure.
  - Geochemical and mineralogical biosignatures related to these structures.
Where to Search?

Life relies on the existence of water, above all else.

• Since water is now unstable on the Martian surface, and the solar UV dose is harmful, the search for extant life will focus on the subsurface. Preferably on warm spots with evidence of a water deposits at accessible depths (identified from remote sensing satellites, i.e. Mars Express).

• Also for extinct life, the search strategy points to sites originally occupied by bodies of water over extended time periods:
  • Sedimentary deposits in ancient lake beds,
  • Outflow regions of past water channel systems.
What to Search With?

- **Panoramic Stereo Zoom Camera (on a long mast)**
  - To characterise the landing site and surface environment.
  - To search for large biological and geological features.
  - To identify scientifically interesting targets within the rover’s reach.
  - To complement the rover navigation cameras.
  - 14 color filters for multispectral measurements.
  - Focus range: 1m – infinity.

- **Subsurface Electromagnetic Sounder**
  - The principle is similar to that used by remote, ground-penetrating radars.
  - Measurements of electrical conductivity profiles of Martian subsoil layers.
  - Identification of ground water/ice signatures.
• Drill System
  - To obtain subsurface samples (even on hard rock) down to (minimum) 2-m depth, and on surface rocks.
  - Drill must deliver sample to the sample preparation subsystem.
  - If feasible, miniaturised Opto/spectroscopical instrumentation must be integrated in the drill to characterise borehole’s bio/mineralogical structure.

• Sample Preparation and Handling Subsystem (SPHS)
  - Mill, cut, and polish sample (as required).
  - Present processed sample to appropriate instruments.

• Optical Colour Microscope (low & high resolution)
  - Detection of microorganisms, fossil structures, and mineralogical studies.
  - Resolution: 0.1 mm down to 1 µm.

• Combined Laser Plasma and Raman Spectrometers
  - Provide complementary information, useful for the identification of organics and of the environment where the sample is obtained.
  - The Raman spectrometer detects non-polar (–C–C– and –C=C–) molecular bonds.
  - The LPS characterises the atomic composition of the sample.

• Life Marker Chip
  - New technology instrument based on antibodies and organic molecules attached to well-known locations on a chip matrix.
  - A solution with Mars soil and a chromophore substance is washed over the chip.
  - The chip is illuminated, and chip spots fluoresce where a match exists.
Oxi/Pyr-GCMS …the most versatile instrument

- Oxidant detection
- Gas Chromatography
- Mass Spectroscopy
- Chirality Measurements
- For determining the isotopic, elemental, organic and inorganic molecular compositions, and chirality.
- No instrument with space heritage exactly fits the exobiology scientific requirements.

Instrument Characteristics

- Ability to perform bulk analysis on sample
- Low mass
- No precise temperature conditioning
- Impulsive electrical operation
  - High power for short periods is OK
  - Short integration times
- Data compression with dedicated computer
CDF Study Team


Achievements:

- Integrated all Pasteur instruments into a high-mobility rover (30–50 km on the Martian surface).
- Preserved flexibility in landing sites: Latitudes between 10 and 45°, either N or S.
- Included a data relay satellite to maximise the mission’s scientific return.
Programmatics

• Pasteur Call for Ideas: Release: Early January 2003
  Closure: Early March 2003
  • Request ideas for instruments and investigations addressing the ExoMars mission scientific objectives.
  • Scientists will be informed of the ExoMars mission engineering constraints so they can propose “mission-compatible” experiments.

• Pasteur Phase A2/B1 study kick off: April 2003
  • Adapt “model” Pasteur payload to rover platform, based on the Concurrent Design Facility (CDF) study mission constraints.
  • Include the CDF study results.

Programmatics

• Exobiology workshop: Early May 2003
  • ESA, industry, and selected “Call for Ideas” scientists to meet at ESTEC.
    Goals: 1) Form two working groups of approx. 15 researchers each (plus industry): Search for past life
            Search for present life
    2) Select Pasteur instruments and define their operational scenario on Mars.

• Working Groups Presentation: July 2003
  • Integral payload concept, scientific operations scenario, and list of candidate landing sites.
Programmatics

- Announcement of Opportunity – when ExoMars is approved
- Launch of Pasteur Phase B2 study
  - In parallel, through Aurora, in a joint collaboration between D/MSM, D/SCI, D/TOS and D/SER, ExoMars must be further refined and presented for approval: First Aurora Flagship Class mission.
  - Depending on when approval is granted, 2 launch windows are possible:
    - October 2009
    - November 2011
- ESA provides: launcher, spacecraft + flight instruments, all operations.