

Exporting terrestrial life to the Moon - a bottom-up, risk-minimizing approach (ET-BURMA)

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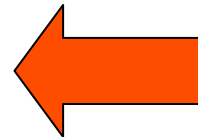
Alcatel Alenia Space Italia – Vimodrone (MILAN), Italy

Moon Fact Sheet

Moon/Earth Comparison

Bulk parameters

<u>(Moon/Earth)</u>	<u>Moon</u>	<u>Earth</u>	<u>Ratio</u>
Mass (10^{24} kg)	0.07349	5.9736	0.0123
Volume (10^{10} km ³)	2.1958	108.321	0.0203
Equatorial radius (km)	1738.1	6378.1	0.2725
Polar radius (km)	1736.0	6356.8	0.2731
Volumetric mean radius (km)	1737.1	6371.0	0.2727
Ellipticity (Flattening)	0.0012	0.00335	0.36
Mean density (kg/m ³)	3350	5515	0.607
Surface gravity (m/s²)	1.62	9.80	0.165
Escape velocity (km/s)	2.38	11.2	0.213



...but, it is not only a Gravity issue !

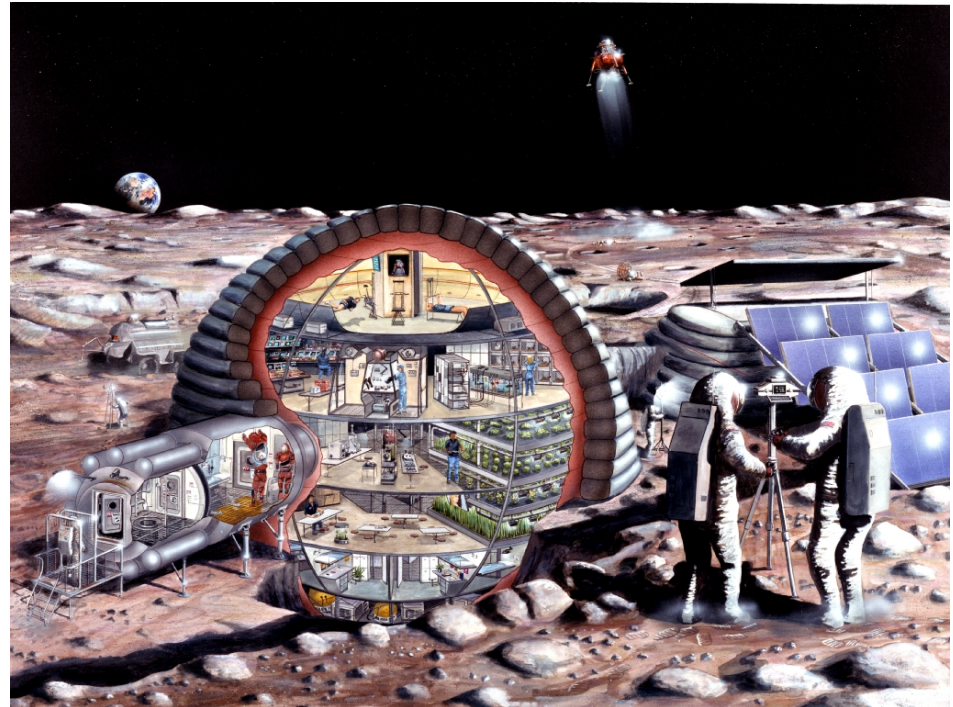
A Flash back of the Lunar perspectives (from NASA)



September 1976--- An artist's concept of an Orbiting Lunar Station (OLS), one of the potential options for space activity being studied. The picture appeared in a September 1977 publication from the NASA-JSC Program Planning Office entitled A Compendium of Future Space Activities.

The systems elements associated with the OLS concept include a space station, a lunar transport vehicle (LTV), re supply modules (RM), fluid module (FM), and crew transfer vehicles (CTV). Nine modules are required to provide ample space for a crew of eight.

(July 1989)--- A new evaluation and study at NASA JSC by the Man Systems Division and Johnson Engineering personnel. A sixteen-meter diameter inflatable habitat such as the one depicted here could accommodate the needs of a dozen astronauts living and working on the surface of the Moon.



Depicted are astronauts exercising, a base operations center, a pressurized lunar rover, a small clean room, a fully equipped life sciences lab, a lunar lander, selenological work, hydroponic gardens, a wardroom, private crew quarters, dust-removing devices for lunar surface work and an airlock.

...and now why ET-BURMA?

- ❑ In the permanent Moon Base scenario, to assess on a statistically significant base the short- and long-term health risks, it is imperative to conduct preliminary yet extensive and long-duration experiments.
- ❑ Prior to expose large numbers of complex organisms, and certainly prior to expose large numbers of Human individuals to the unknown risks of the Moon environment for long periods of time.
- ❑ All of which clearly will become routine, once the permanent Moon Base will become operative, presumably within 10-15 years from now.
- ❑ Such experiments will require the exposure of living organisms of **increasing complexity** to long periods of time to the Moon environment.
- ❑ It is not early to start as soon as possible with those experiments. It is essential to take advantage of the Precursor Flights which will take place prior to the Moon Base construction and prior to the manned phase of the Moon Base scenario.

ET-BURMA Proposed strategy

A. *Test organisms of increasing complexity:*

- Bacteria (i.e.: E. Coli, Salmonella)
- Yeasts
- Amebae
- Cultured mammalian cells (i.e.: FRTL-5, a normal and differentiated thyroid cell strain)
 - Nematodes
 - Small mammals (i.e.: mice, rats)
 - Larger mammals will be used if and when hardware/facilities will permit such studies.

It is anticipated that genetic/biochemical/physiological studies will be then performed by the scientific community on human subjects (astronauts, Moon Base staff) in the Moon Base scenario, as already routine in the present phases of Space research.

ET-BURMA Proposed strategy

B. *Test conditions:*

- Freeze-dried: simpler living organisms will be deposited in special containers on the Moon surface in the early phases of the Precursor Flights.
- Frozen microorganisms and cultured cells: when such condition could be assured during the Earth to the Moon flight and, with the use of solar batteries and Peltier elements, on the Moon surface, it will be possible to leave test organisms on the Moon surface for years.
- Cultured cells: such as FRTL-5, in dormant, non-proliferative state capable of surviving for several months without medium changes, in a Hormone/Growth Factors-deprived state.

ET-BURMA Proposed strategy

C. Testing strategies:

- Test microorganisms and cells will be left on the Moon surface for years (months in the latest missions) in the above described Test condition, to be later recovered during the Moon Base assembly phase. The effects of several years exposure to the Moon environment could then be evaluated upon revitalization and subsequent in vitro culture (on Earth and/or in the Moon Base) of the test microorganisms.
- Test microorganisms and cells will be examined by means of Biosensors and miniaturized, automatic analytical instruments embedded in the culture chambers and hardware.
- Acquired data will be transmitted on Earth by telemetry.

Precursor Flight ET- BURMA mission scenario

Two different Mission scenario must be considered:

- ❑ ET-BURMA Mission without the return to Earth of the biological samples
- ❑ ET-BURMA Mission with the return to Earth of the biological samples

A third “mixed” scenario could be envisaged:

- ❑ ET-BURMA Mission without the return to Earth of the biological samples but where a later astronaut presence could be foreseen to analyze the samples or to complete a more sophisticated section of the experiment protocol

In these three scenarios all the industrial aspects (complexity, requested level of automation and relevant costs must be assessed).

Precursor Flight ET- BURMA basic questions

The Moon Base ET-BURMA will address more basic and simple questions concerning:

1. the impact of the Moon environment on the biological samples
2. discrimination between effects of gravity and radiation

To achieve this, the envisaged experiments on ET-BURMA will include:

FIRST: a set of gravity related experiments.

- 1g reference experiments in centrifuges, and
- experiments either in local gravity or on programmable centrifuges which will allow exposing samples to various gravitational stresses, modulated both in time and magnitude

In this way, ET-BURMA will help to determine parameters like gravity perception application times or gravity perception threshold levels on the biological samples.

SECOND: the assessment of the the impacts of local radiation environment in the “ET- BURMA” precursor flight

The discrimination and the impacts of local radiation environment shall be investigated starting from the multi-level “BURMA approach” described here above.

Precursor Flight ET- BURMA involved technologies (examples)

It is requested an effort to develop bio-systems with a technology flexible to be adapted in this hostile environment. Some examples:

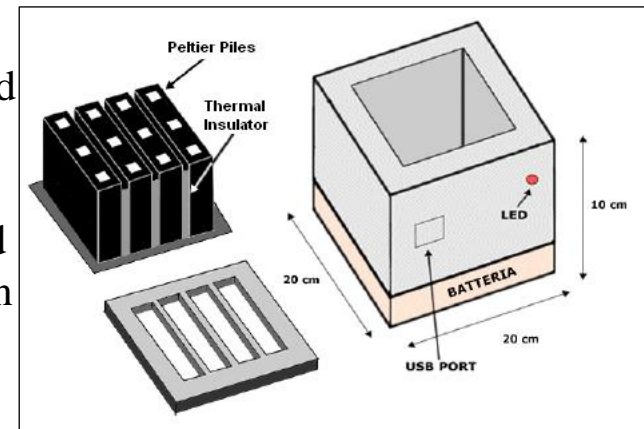
- ❑ Optical biosensors can provide a rapid and efficient detection technique: pathogenic microorganisms in biochemical tests can be identified in a lunar outposts by employing Fourier transform Infrared (FTIR) spectroscopy and Surface Plasmon Resonance (SPR) based sensors.
- ❑ instrument based on a simple photodiode measurement of the fluorescence emission from a Photosystem II biomediator, located into a closed dark cell and excited by a blue LED Cosmic radiation changes the living cells metabolism and inhibits the photosynthesis process, thus producing variations in fluorescence re-emission. The biomediator is kept alive by a survival white LED, mounted close to the exciting one. The photodiode generated current is amplified and converted into a voltage signal, while a timer controls the fluorescence process by turning the LED on at fixed intervals. The system must be equipped with a electronic control board and a flash memory to store data during autonomous operations.

Precursor Flight ET- BURMA involved technologies (examples)

It is envisaged to take advantages also from electrochemical processes to develop systems based on amperometric and potentiometric detection.

❑ For example from biosensors made up by an isolated Reaction Center (RC) used as biomediator able to activate an electron transport when exposed to environmental pollutants. The RC is attached to a screen-printed electrode which measures the amount of current generated by the pollutant interaction. Each cell hosting the biological material allows a flow of liquid (e.g. recycled water) with the employment of micropumps and valves.

❑ The Multi Bio Freeze (MBF, built by BIOSENSOR-Rome and CARSO -Trieste) is an engineered model to sample, freeze and store blood and skin cells cultures in microgravity conditions. It's made up by 12 independent cells able to be automatically and separately frozen, thanks to a stack of isolated Peltier elements, in order to study the radiation exposure during time. It is protected by an insulated box and equipped with a timer and a USB port.



Precursor Flight ET- BURMA involved technologies (examples)

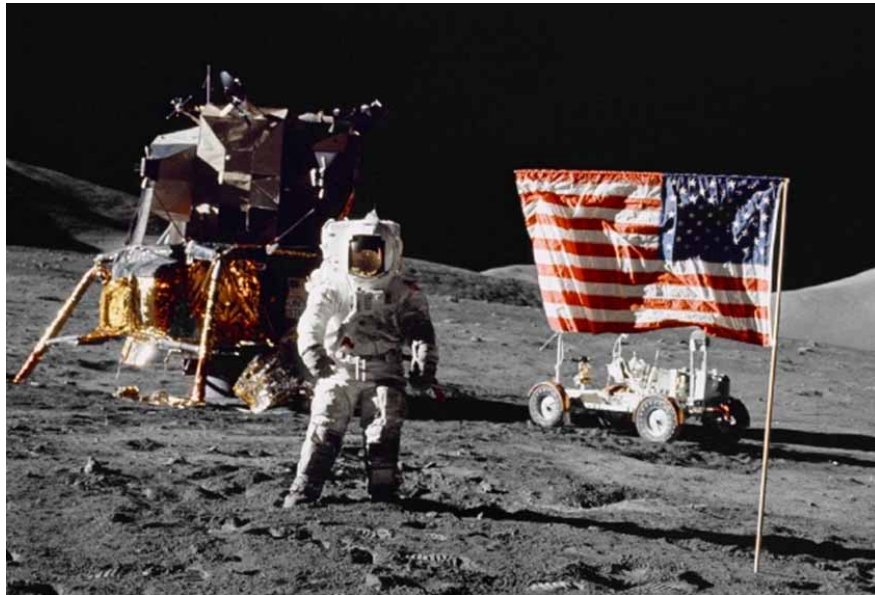
- ❑ Exposure to radiation can be studied by monitoring the fluorescence emission of an excited biomediator (such a technique must be accomplished by a multispectral analysis for signal interpretation).
- ❑ Others candidates in the ET-BURMA involved technology are :
 - FUD- miniaturized Fluorescence Device (FUD) that will analyze marked proteins to determine DNA molecular damages. It's composed by an amplified photodiode, leds drivers and a timer.
 - MPM -A device is aimed at Measuring the electrical Potential of a cell Membrane (MPM) (e.g. in thyroid cells) through an array/matrix of screen-printed or planar microelectrodes on which the cells cultures are attached.

Preliminary conclusions on ET- BURMA

□ The envisaged ET-BURMA precursor flight is a valuable test bench for producing biosensors and instruments that open the way to more complicated measurement configurations and systems, where:

- MEMS,
- multiple sensors,
- improved cells matrix and
- flow enabling pumps and valves

can lead to a complete automatic **biorobot** for growing, storing and monitoring cells activity under extreme conditions during space flights.



Preparing the 7° Human Lunar Landing.....



K-10 D-RATS (desert research and technology studies),

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