Agenzia Spaziale Italiana

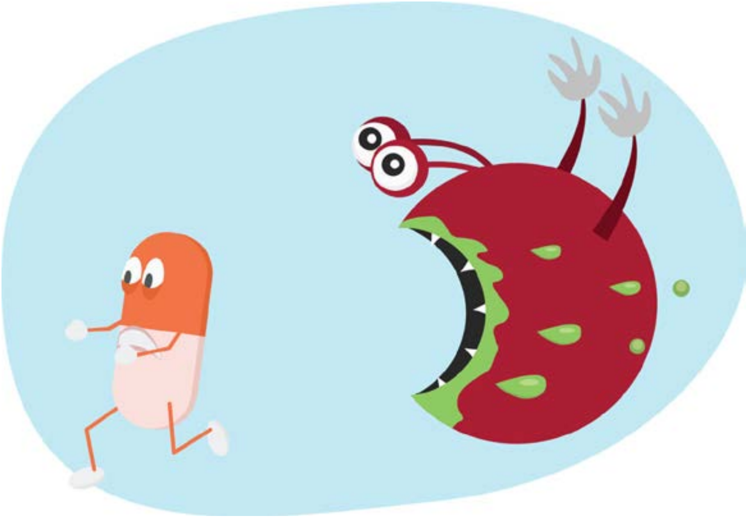
Antibiotic Resistance in Space: a threat for human long-term missions

Ferranti, Pacelli, Del Bianco

BACKGROUND

The last decade of microbiological studies associated with the International Space Station has revealed that microbes can not only withstand low orbit conditions, but thrive, reproduce and form corrosive biofilms, posing potential threats to the safety of the astronauts, in particular in interaction with the impaired immune system.

Antibiotics are medicines used to prevent and treat bacterial infections. Bacteria become antibiotic-resistant. These bacteria may infect humans and animals, and the infections they cause are harder to treat than those caused by non-resistant bacteria.



Tackling antibiotic resistance is a high priority to ensure the safety and success of future long-term manned missions.

EDUCATIONAL OBJECTIVES

High-schoolers (3rd-4th year) will perform their own ground-based experiment by growing the bacteria on agar plates. To do this, they will have to learn how to prepare the growth medium and to plate bacteria. Then, they will execute the antibiogram experiment and compare the results to the inflight experiments.

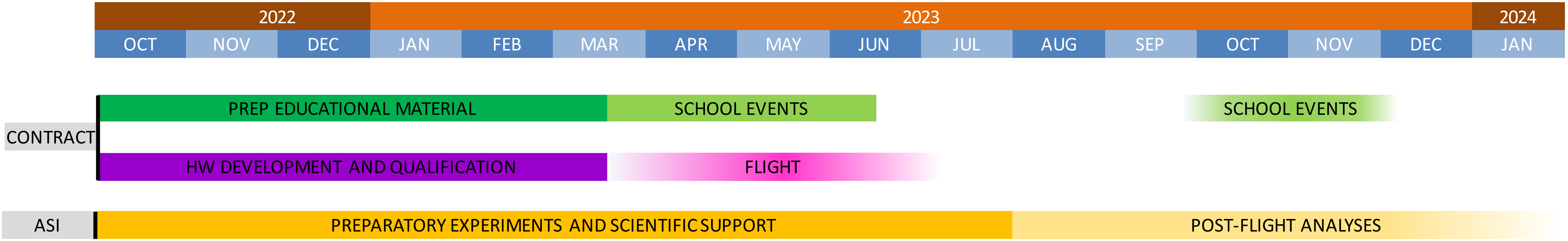
1. Learn the bases of the scientific method (observation, hypotheses, test)
2. Lab techniques (handling bacteria: growth medium preparation and plating)
3. Learn about antibiotic resistance
4. Learn and perform an **antibiogram** test

SCIENTIFIC OBJECTIVES

Microgravity conditions may affect the capacity of bacteria to resist to antibiotics and their pathogenicity.
Antibiogram test is a simple method to investigate the antibiotic resistance.

1. Study the microbial grow in microgravity condition
2. Investigate the **microbe antibiotic resistance through the antibiogram method**
3. Assess changes in pathogenicity through -omic approaches (genes, proteins, etc)

Operational Overview



Dates are still TBD and will depend on HW development and flight availability.

Hardware Requirements

This experiment could use the SPACE SLIME hardware with minor modifications (i.e. temperature control (TBD), etc.).

Bacteria will be grown on agar plates with spot of antibiotics (TBD).

After activation, the experiment runs for around 2-4 days: the bacteria would be let to grow and imaged regularly. The experiment is stopped by fixation (RNAlater). Fixed samples are stable at 4°C, but lower temperatures would be preferable.

Requirements

For school activity phase:

- In flight: - message from astronauts (if possible)

For payload phase:

- Upload: - up-mass TBD
  - late access
- In flight: - minimal handling
  - power supply (if possible)
  - 4°C stowage after fixation (or lower, if possible)
- Download: - down-mass: same as up-mass, TBD
  - 4°C stowage (or lower, if possible)
  - early retrieval

Space Biomining: harnessing the power of microbes for space exploration

Pacelli, Ferranti, Del Bianco

BACKGROUND

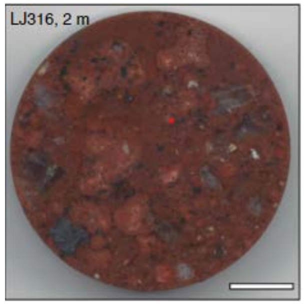
Colonization of Moon and Mars can become stable and sustainable only with in situ resource utilization (ISRU), i.e. using waste and native materials as primary resources. Biomining is a technique of extracting economically important elements from ores and other solid materials using bacteria, fungi or plants.
This technique, already in use on Earth, could one day be regularly applied in space as well.

Biomining is one of the key points for the implementation of the next human space programs.

EDUCATIONAL OBJECTIVES

High-schoolers (3rd-4th year) will perform their own ground-based experiment by growing biomining microbes on Martian and Lunar regolith pellet and agar plates. Students will assess if biomining activities is present by detecting a change in pH values.

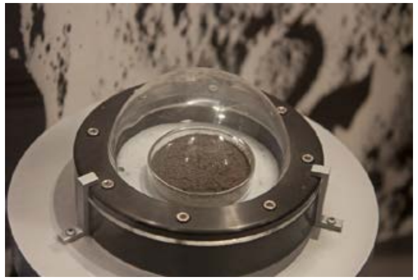
1. Learn the bases of the scientific method (observation, hypotheses, test)
2. Lab techniques (handling microbes: regolith pellet and grow medium preparation, microbes plating)
3. Learn about extraterrestrial regolith composition and biomining
4. Learn about pH and test pH values using paper strips.



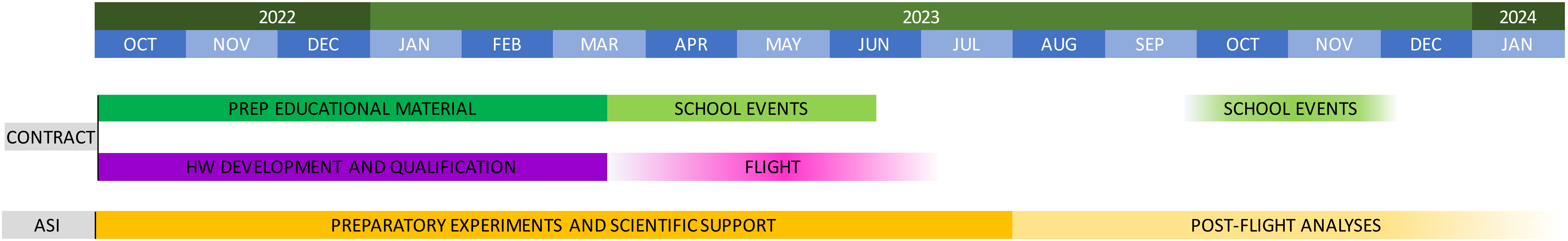

SCIENTIFIC OBJECTIVES

Biomining is a process that uses microorganisms to extract metals from rocks or mining waste.
The biomining capability of selected microbes will be tested on Martian and Lunar regolith simulants onboard the International Space Station.

1. Study the **microbial biomining activity** in microgravity condition
2. Investigate pH changes during biomining
3. Investigate the mineral extraction through ICP-MS approach
4. Assess the adaptation of microbial biomining machinery through –omic approaches (genes, proteins, etc)



Operational Overview



Dates are still TBD and will depend on HW development and flight availability.

Hardware Requirements

The hardware would substain microbial growth on Martian and Lunar regolith pellets. Ideally, the hardware would be compatible with onboard facilities for simulated Martian and Lunar gravity.

After activation (addition of water), the experiment runs for minimum 10 days.

The experiment is stopped by fixation (RNAlater). Fixed samples are stable at 4°C, but lower temperatures would be preferable.

Temperature control is TBD.

Requirements

For school activity phase:

- In flight: - message from astronauts (if possible)

For payload phase:

- Upload: - up-mass TBD
  - late access (if possible)
- In flight: - minimal handling
  - power supply (if possible)
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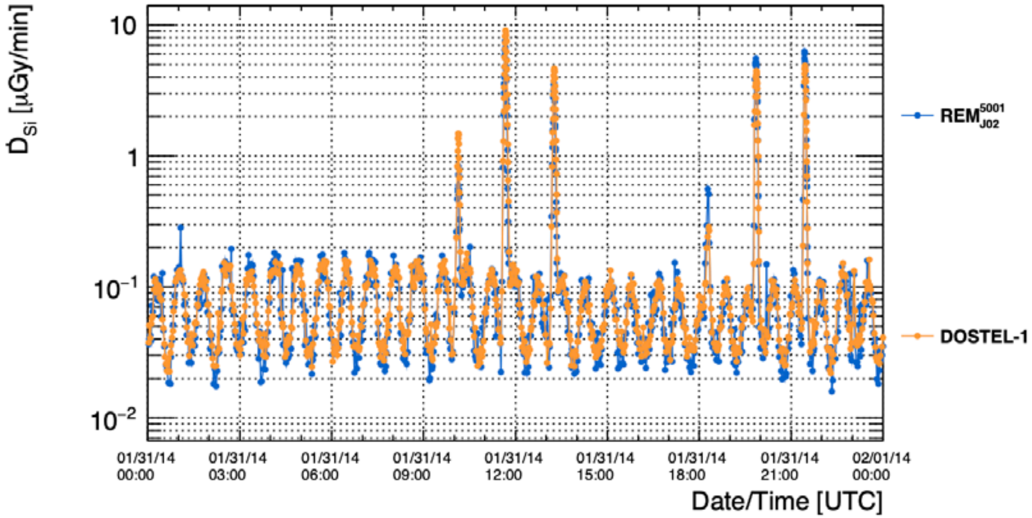
Cosmic ray measurement: educational proposal

Valerio Vagelli

Detection of cosmic rays on ISS and at ground: comparisons and differences

- Intense flux, especially outside of ISS
  - The detection rate depends on the detector that will be used
- Primary cosmic rays, from protons to heavy nuclei (Fe)
  - May be able to see different signatures using a track imaging detector (more complexity required w.r.t. count rate detectors)
- The detection rate depends on orbit due to geomagnetic field
  - Modulation of ~90 mins on the detected rate



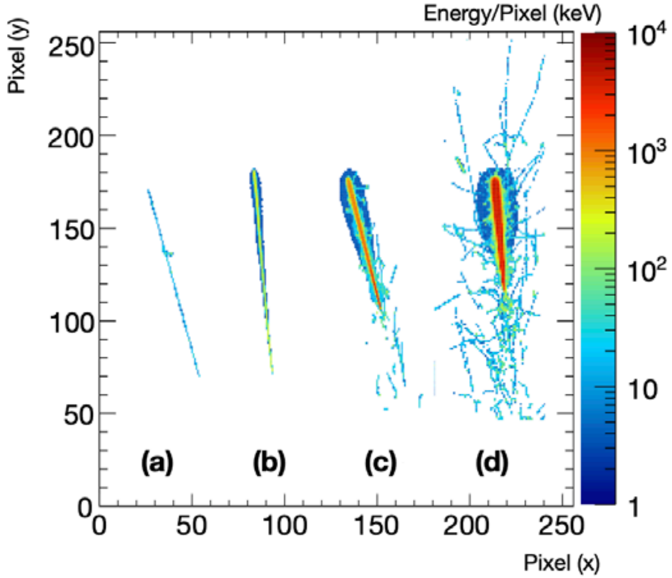


Figure 1. Four tracks of increasing LET with similar azimuth angle θ and polar angle ϕ:

(a)	$LET_{Si} = 0.52\,keV\,\mu m^{-1}$	$\theta = 71.0°$	$\phi = 84.6°$
(b)	$LET_{Si} = 5.45\,keV\,\mu m^{-1}$	$\theta = 82.0°$	$\phi = 84.0°$
(c)	$LET_{Si} = 54.8\,keV\,\mu m^{-1}$	$\theta = 66.7°$	$\phi = 81.4°$
(d)	$LET_{Si} = 233\,keV\,\mu m^{-1}$	$\theta = 84.2°$	$\phi = 81.1°$

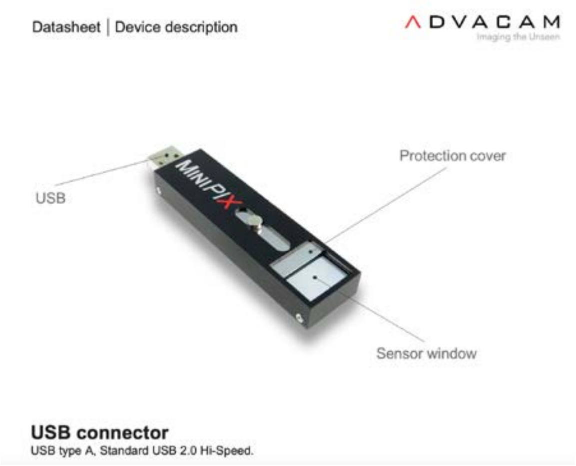
Detection of cosmic rays on ISS and at ground: comparisons and differences

- Faint flux, only muons from energetic air showers reach ground
  - ~ 1 muon / cm^2 / minute → requires large area detectors
  - a track imaging detector could visualize differences between heavy ions on ISS (very rare) and muon charge at ground
- The detection rate does not depend on time (as in ISS)
- The detection rate depends on polar angle

- Detection of cosmic rays at ground is already sponsored during the International Cosmic Days (ICD, https://icd.desy.de/), an event in which the students join the laboratories equipped with cosmic ray detectors and do a measurement of the cosmic flux at ground with the help of the researchers. From Italy, INFN is a sponsor of ICD
- The instrumentation requires a large area detector, which is usually developed custom by the laboratories and is not commercially available. It is not viable to equip each school with a similar instrument
- Commercially available kits for radiation measurement have small areas, so the experiment cannot be done in a small time. See for example https://advacam.com/minipix. The cost for unit amounts to approx. 3 k€ / unit.

Example of Imaging detector: MiniPIX (ADVACAM)

- compact
- educational suite commercially available
- small detection area (few cm^2)
- one declination of the MiniPIX family already used in ISS



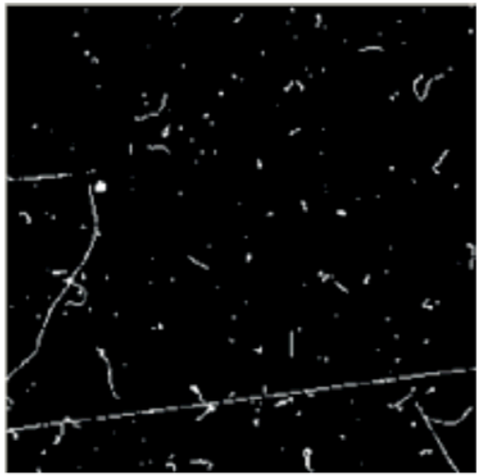


Illustration of single particle sensitivity of Timepix device. The tracks of different particles of normal radiation background were recorded in 10 minutes. No noise (clean zero) is seen in dark regions.

Example of Large area detector: Cosmic Ray Cube (INFN-GSSI)

- large area, well suits for measurements at ground
- developed for educational purposes
- small detection area (few cm^2)
- cannot be used on ISS
- cannot be easily equipped in all school laboratories
- not commercially available, probably requires an agreement with INFN

Cosmic ray cube ospitato nella stazione metro di Toledo, Napoli

- Proposal n.1
  - Students measure the flux of cosmic rays at ground with a commercial suite and compare with the results obtained from ISS from the same instrument, that must be deployed on the ISS. This requires the access to a detector on ISS that could be operated by the astronaut and that should be identified. The REM instrument could be a possibility. On ISS solar energetic particle events could also be measured, but these cannot be forecast so that would be an unexpected event. The feasibility of measurements at ground must be verified.

- Proposal n.2
  - Students measure the flux of cosmic rays at ground with a large area detector hosted in a laboratory and compare with the results obtained from a commercial suite (see proposal n.1). This requires an agreement with laboratories of INFN and universities that could host the students. Or the instrument could be the output of the hardware deliverable by the industry, but many replications will be required, one for each school. This may result quite expensive.

Disclaimer: there is no "scientific innovation" in this approach. Measurements of cosmic rays in space require complicated detectors that require a huge international effort to which ASI already participates and which are already operated in space or inside/outside ISS (CALET, AMS, ALTEA/LIDAL, …) to achieve scientific relevant results. These proposals are merely intended to be purely educational.

It should also be checked if the industry could be able to deliver an educational cosmic ray detector in reasonable time (< 2 years), verify the feasibility of measurements in space and test it for operations in space.