UK Centre for Astrobiology

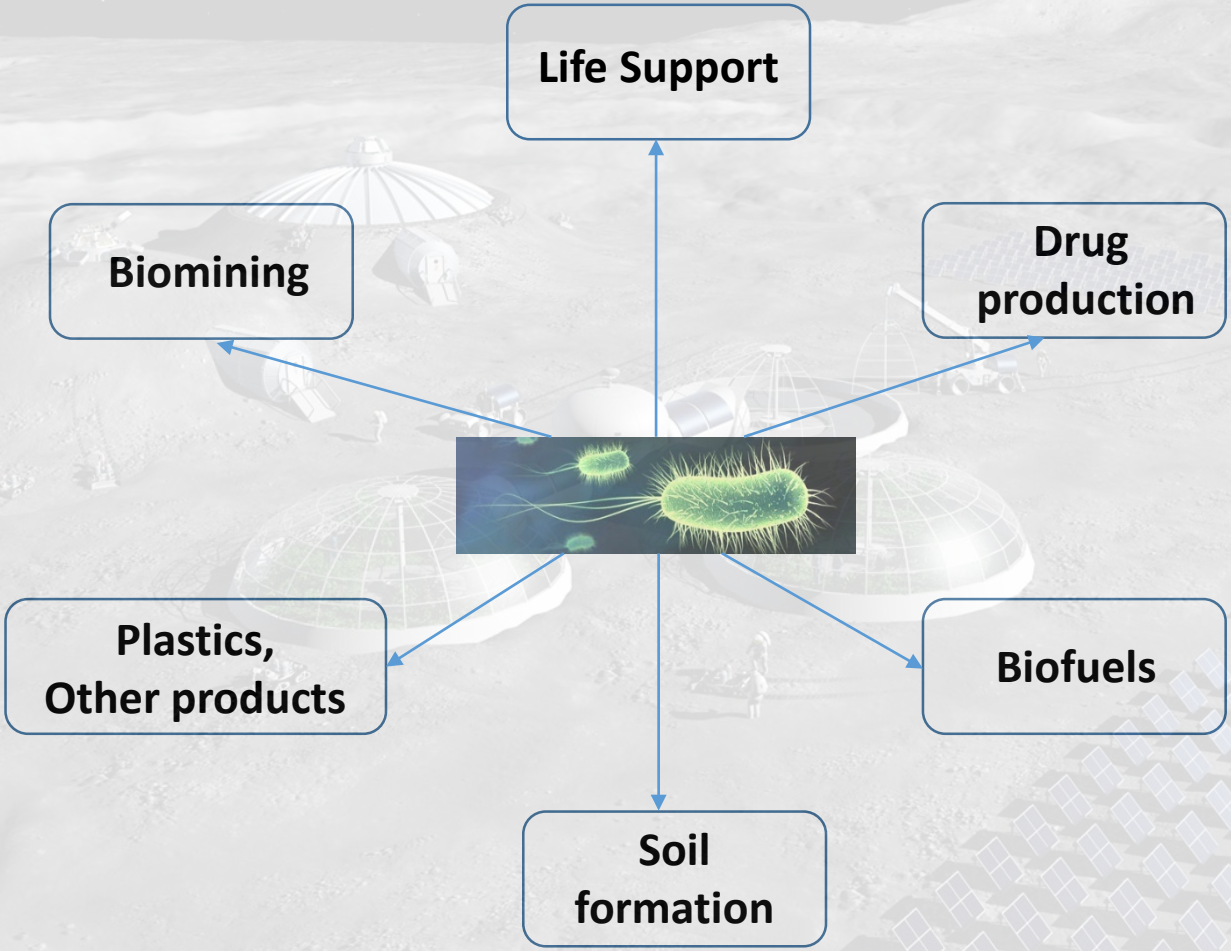
THE UNIVERSITY of EDINBURGH

Mobilizing microbes for the Moon

Charles Cockell
UK Centre for Astrobiology, University of Edinburgh

Why microbes on the Moon?

Microorganisms are nature's engineers and factories



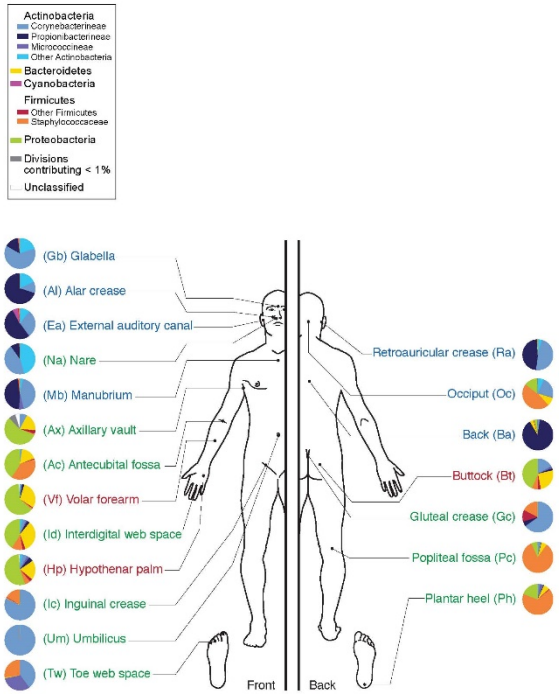
- These capacities can be augmented by synthetic biology/genetic modification

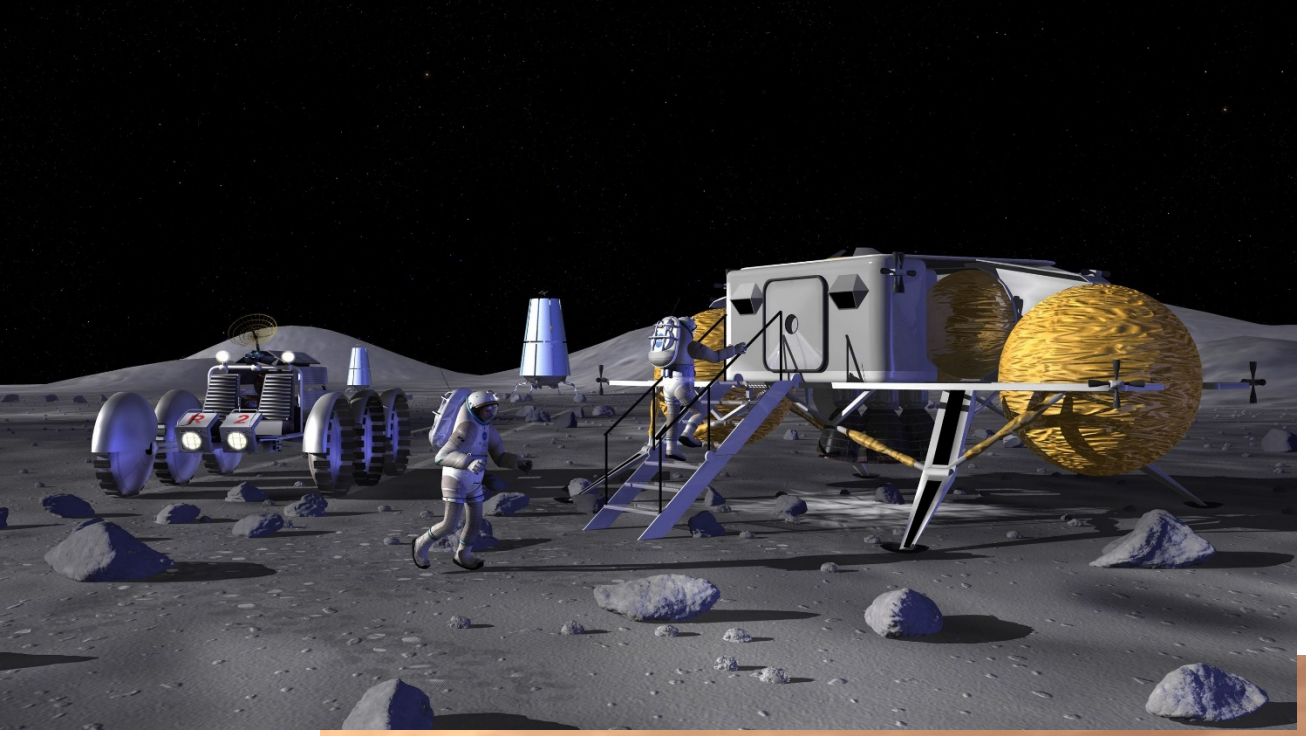
Microorganisms are an integral part of human existence

Human beings are mammal-microbe hybrids

(Weird thought of the day – humans are exoskeleton mobility suits for microbes)

- Humans are about 50% mammal cells/50% microbial cells.
- Rather than view microbes as ‘hitch-hikers’ we should view them as an inseparable part of the biota.
- ‘Mobilize microbes’ to establish a permanent human presence beyond Earth.





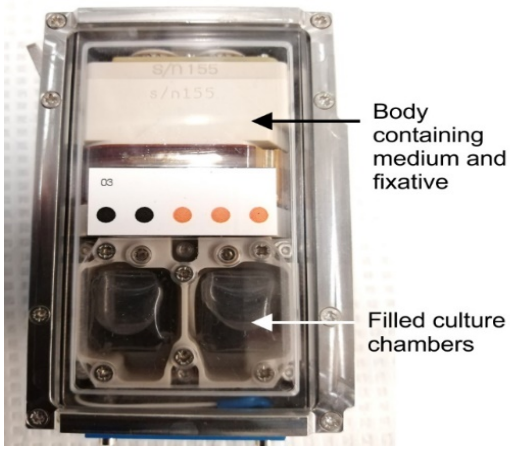

HABITAT
01

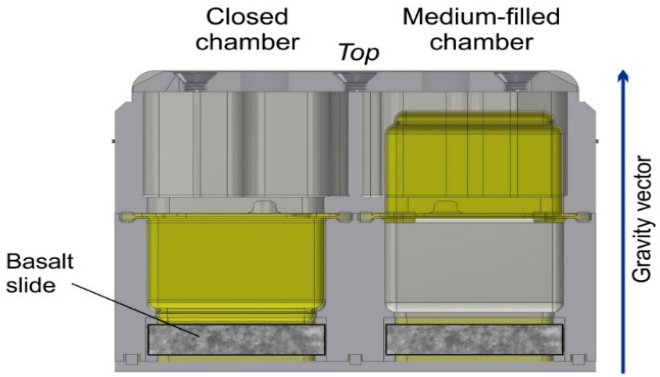

BIOROCK

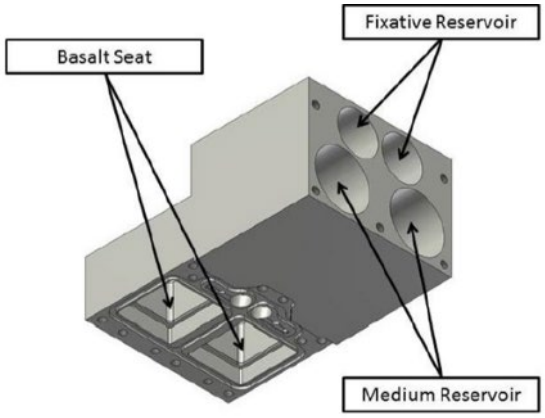

BIOASTEROID
UK SPACE AGENCY

Mining in space
Using “biomining” – microbes doing mining
A Biomining Reactor

BioRock involved development of new hardware that can be used to study **microbe-mineral interactions** and biofilm **formation in space**.







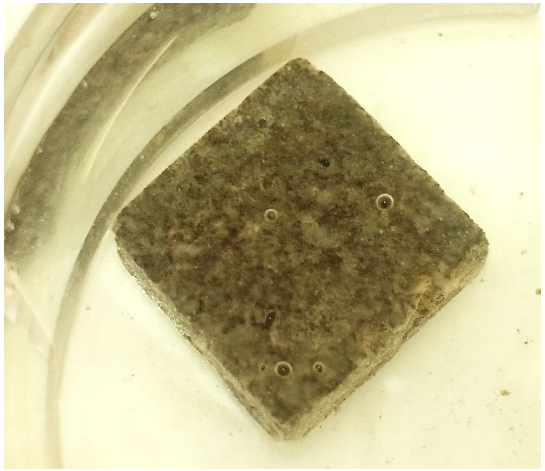
with our microbes…..


BIOBOCK

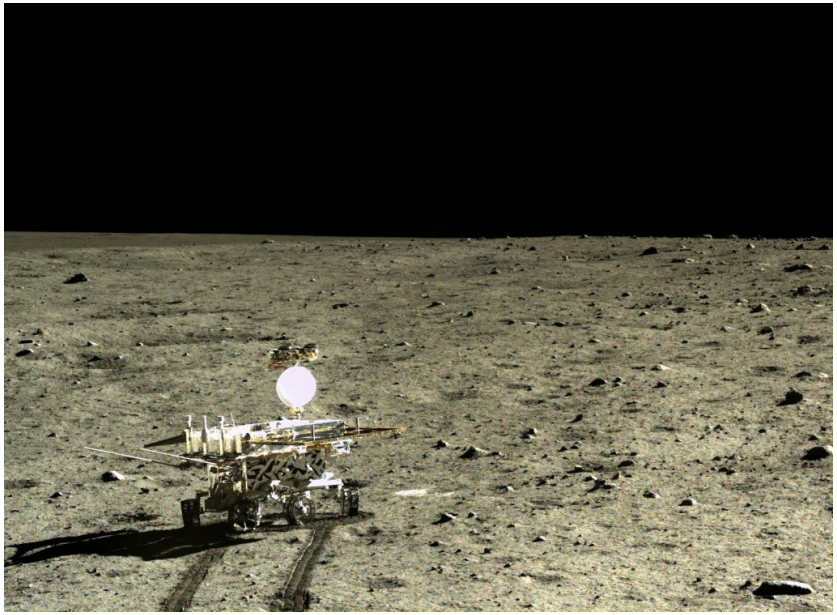

SPACEX

Experiment uses basalt rock as a mining substrate

- Lots of it on the Moon and Mars

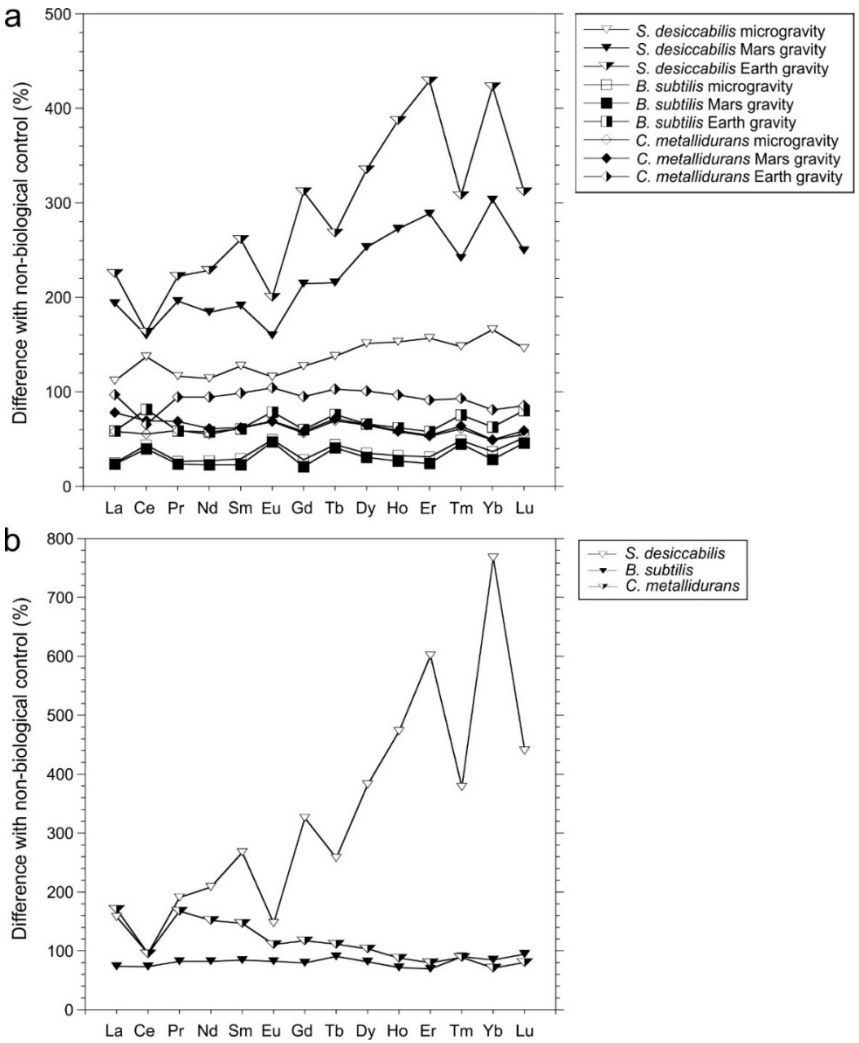


Symbol	Element	Concentration (%)
Na_2O	Sodium	1.92
MgO	Magnesium	10.00
Al_2O_3	Aluminium	15.35
SiO_2	Silicon	47.48
P_2O_5	Phosphorus	0.128
K_2O	Potassium	0.162
CaO	Calcium	11.69
TiO_2	Titanium	1.344
MnO	Manganese	0.186
Fe_2O_3	Iron	12.12




AMS-02
esa

We were able to demonstrate for the first time the principles of biomining in space by mining rare earth elements from basalt rocks



Scandium	Aerospace components, aluminum alloys
Yttrium	Lasers, TV and computer displays, microwave filters
Lanthanum	Oil refining, hybrid-car batteries, camera lenses
Cerium	Catalytic converters, oil refining, glass-lens production
Praseodymium	Aircraft engines, carbon arc lights
Neodymium	Computer hard drives, cell phones, high-power magnets
Promethium	Portable x-ray machines, nuclear batteries
Samarium	High-power magnets, ethanol, PCB cleansers
Europium	TV and computer displays, lasers, optical electronics
Gadolinium	Cancer therapy, MRI contrast agent
Terbium	Solid-state electronics, sonar systems
Dysprosium	Lasers, nuclear-reactor control rods, high-power magnets
Holmium	High-power magnets, lasers
Erbium	Fiber optics, nuclear-reactor control rods
Thulium	X-ray machines, superconductors
Ytterbium	Portable x-ray machines, lasers
Lutetium	Chemical processing, LED lightbulbs

nature COMMUNICATIONS

ARTICLE

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Check for updates

Space station biomining experiment demonstrates rare earth element extraction in microgravity and Mars gravity

Charles S. Cockell[1,11✉], Rosa Santomartino[1,11], Kai Finster[2], Annemiek C. Waajen[1], Lorna J. Eades[3], Ralf Moeller[4], Petra Rettberg[4], Felix M. Fuchs[4,5], Rob Van Houdt[6], Natalie Leys[6], Ilse Coninx[6], Jason Hatton[7], Luca Parmitano[7], Jutta Krause[7], Andrea Koehler[7], Nicol Caplin[7], Lobke Zuijderduijn[7], Alessandro Mariani[8], Stefano S. Pellari[8], Fabrizio Carubia[8], Giacomo Luciani[8], Michele Balsamo[8], Valfredo Zolesi[8], Natasha Nicholson[1], Claire-Marie Loudon[1], Jeannine Doswald-Winkler[9], Magdalena Herová[9], Bernd Rattenbacher[9], Jennifer Wadsworth[10], R. Craig Everroad[10] & René Demets[7]

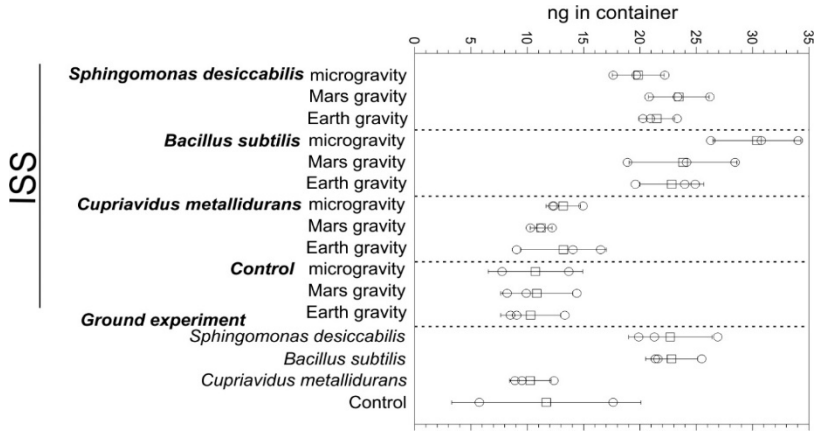
Rare Earth Elements on the Moon

Lunar KREEP terrain

- The Oceanus Procellarum region, including Imbrium Basin contains KREEP rocks [Potassium (K), Rare Earth Element (REE), Phosphorus (P)].
- Up to ten times higher REEs than other rocks, but still 10-100 times less than REEs ores on Earth.
- Could be higher concentrations at sub-km scales.

Biomining can help us achieve a self-sustaining presence in space and learn how to do mining on Earth without environmental destruction

We also demonstrated vanadium biomining



Vanadium has uses in:

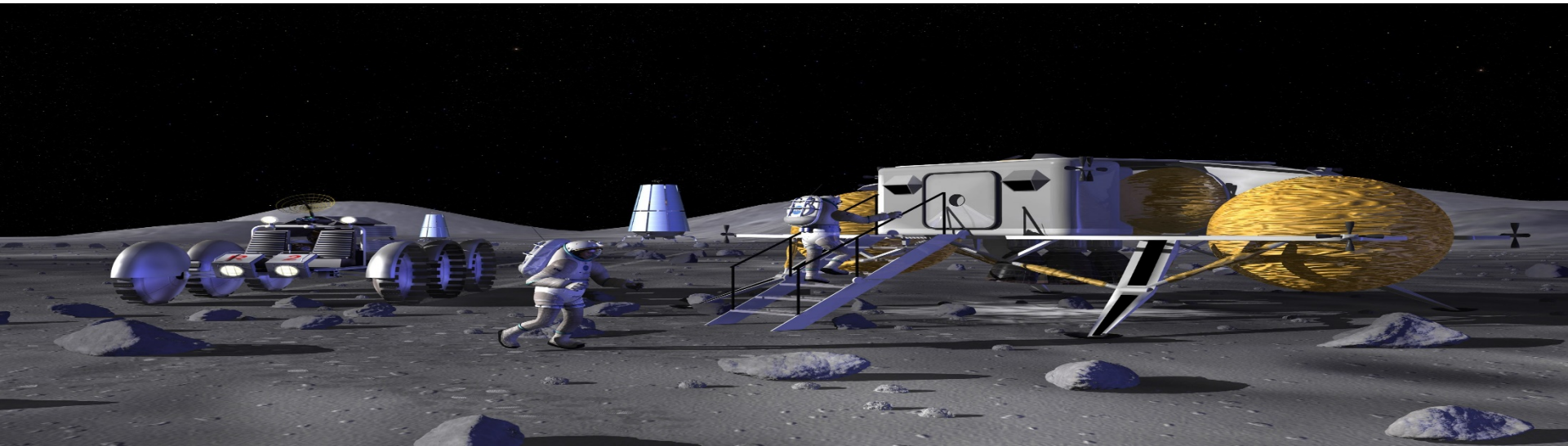
- High strength steel alloys
- Abrasion and thermal fluctuation resistant steel
- Neutron absorption in reactor metals
- Batteries
- etc

		1	2	3	4
		Concentration (ng)	Percentage above control (%)	Percentage of basalt (%) x 10^5	Percentage in cell pellet (%)
S. desiccabilis	Microgravity	19.84±2.29	184.92±75.33	8.62±1.00	1.39±0.51
	Mars gravity	23.45±2.70	216.32±68.43	10.19±1.17	1.69±0.40
	Earth gravity	21.50±1.59	208.70±55.85	9.34±0.69	0.96±0.23
B. subtilis	Microgravity	30.38±3.90	283.22±116.44	13.20±1.69	0.96±0.36
	Mars gravity	23.83±4.78	219.78±78.37	10.35±2.08	1.86±0.53
	Earth gravity	22.83±2.84	221.59±63.30	9.91±1.23	1.74±0.85
C. metallidurans	Microgravity	13.19±1.53	122.97±50.10	5.73±0.66	2.67±1.05
	Mars gravity	11.23±0.96	103.54±31.78	4.88±0.42	4.20±1.73
	Earth gravity	10.26±1.85	128.21±49.47	5.74±1.65	1.67±0.35
Non-biological control	Microgravity	10.73±4.19	-	4.66±1.82	-
	Mars gravity	10.84±3.19	-	4.71±1.39	-
	Earth gravity	10.30±2.65	-	4.47±1.15	-
Ground 1 *g* experiment	*S. desiccabilis*	22.69±3.72	194.13±143.11	9.86±1.61	2.46±1.31
	B. subtilis	22.81±2.31	195.12±141.63	9.91±1.00	1.41±0.31
	C. metallidurans	10.26±1.85	87.78±65.04	4.46±0.08	2.73±1.06
	Control (non-biology)	11.69±8.40	-	5.08±3.65	-

Cockell CS *et al* (2020) Microbially-enhanced vanadium mining and bioremediation under micro- and Mars gravity on the International Space Station. *Frontiers Microbiol.* (in press).

BioRock-L and beyond….

- Autonomous BioRock hardware
- Flights to Moon, Mars and beyond
- Currently developing autonomous capability with Kayser and University of Edinburgh



Ultimately we want to build a lab on the Moon…

This is an old paper, but an updated version might include the capacity for molecular biology, synthetic biology, cell biology, human biology etc.

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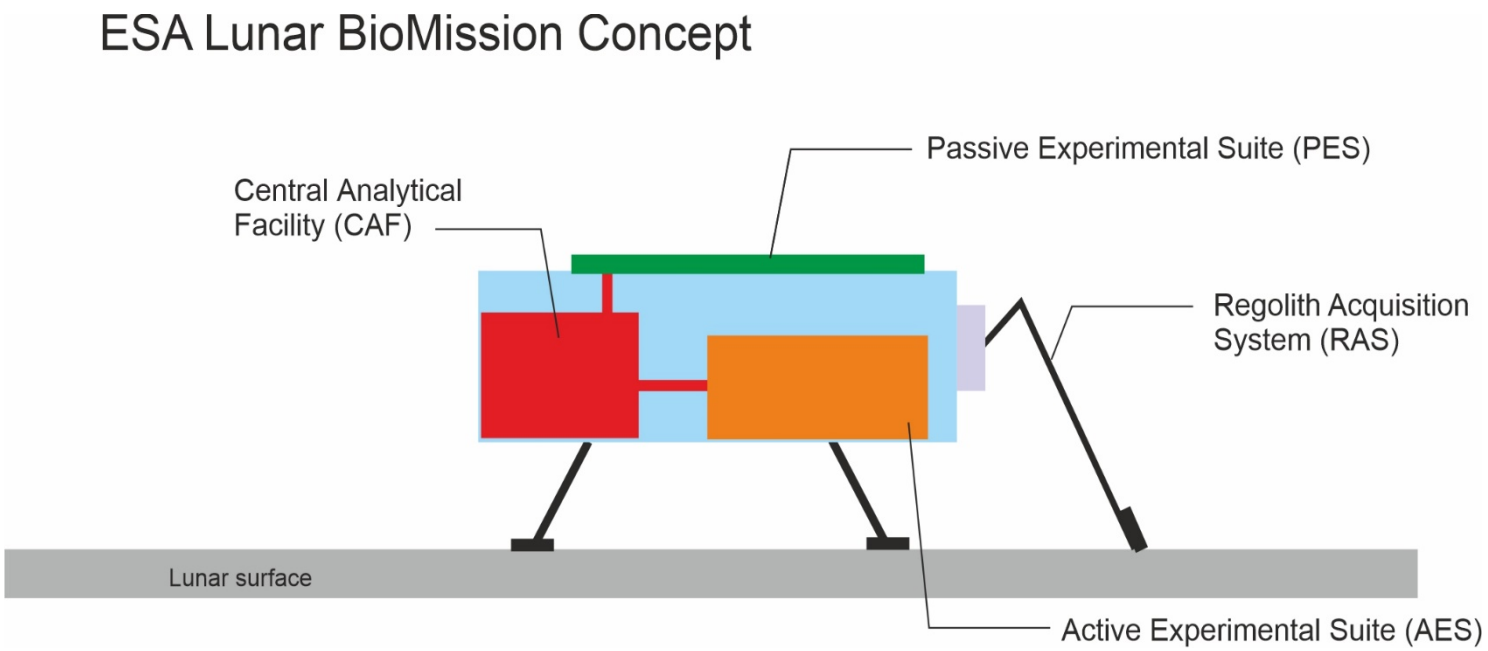
Special Review

Lunar Astrobiology: A Review and Suggested Laboratory Equipment

AARON GRONSTAL,[1] CHARLES S. COCKELL,[1] MARIA ANTONIETTA PERINO,[2] TOBIAS BITTNER,[3] ERIK CLACEY,[4] OLATHE CLARK,[5] OLIVIER INGOLD,[6] CATARINA ALVES DE OLIVEIRA,[7] and STEVEN WATHIONG[6]

We are developing a proposed lunar BioMission concept

- Part of ESA's proposed Large Logistics Lander (EL3) proposed programme
- Passive and active biological analysis with a range of biological models
- Interactions with radiation, regolith etc
- Sophisticated biomolecular/genetic analysis on the lunar surface.



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