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Equivalent system mass of cyanobacterium production from Martian resources

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Bioproduction systems that rely on diazotrophic, rock-weathering cyanobacteria for in situ resource utilization have been described as potential ways of increasing the sustainability of crewed missions to Mars. According to this concept, cyanobacteria would be fed with water mined from the ground; carbon and nitrogen sourced from the atmosphere; and the local regolith, from which it has been argued that they could extract the other necessary nutrients. They could then produce various consumables directly, such as dioxygen and dietary supplements, but also support the growth of secondary producers (plants or microorganisms) which could, in turn, generate a wide range of critical consumables.

While a fast-increasing body of work suggests that such systems could function, no thorough assessment of their cost-efficiency has so far been presented. This can be attributed to the paucity of data related to the physiological responses of cyanobacteria to factors which are critical to their cultivation on site, including: low total pressure; non-ambient partial pressures of carbon dioxide and nitrogen; and interactions with regolith, a source of both nutrients and toxic compounds. In this talk, we will present work performed toward such an assessment. We will give an overview of data collected for that purpose, including the effects on growth rates of changes in key atmospheric parameters or in the concentrations of regolith components; describe a mechanistic mathematical model that, relying (among others) on this data, can predict productivity and equivalent system mass (ESM) of cyanobacterium cultivation on Mars; and present ESM estimates for several cultivation scenarios.

These estimates are not definitive: we were limited by the many uncertainties that remain, notably on technologies that will become available and on specific mission parameters. However, they already provide insights that can guide development efforts: they underline areas where improvements would most improve cost-efficiency, such as that of the cultivation system's water efficiency; point out to adaptations of existing technology that are required for the system to be operated, aimed for instance at providing regolith-handling capabilities; and underline gaps in knowledge whose filling-in would enable much refined predictions, critical ones among which pertain to cyanobacterium-regolith interactions. Most notable may be the suggestion that development efforts are warranted: a breakeven can be reached, it seems, after only a few years of operation.

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