AI-ASSISTED ROBOTIC FARMING ON MARS CAN GROW AND STORE FIVE YEARS OF FOOD FOR A SCIENCE BASE AT MILANKOVIČ CRATER.

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Introduction: For Mars exploration, the need to establish a base near thick, extensive ice deposits is well known and accepted.[1,2,3] Given dual solar and nuclear power sources, the ice could furnish *all* the water, oxygen, and hydrogen fuel that even a large base would need, and could also be excavated to make shelters.[4] But food is another issue – it must be carried to or grown on Mars. Just as robots are exploring the geology and atmosphere of Mars, robotic food production can begin years before humans arrive. This would provide robust safety margins of a large native food supply and a fully functioning and tested biosphere.

Extensive experimental work has been done on Earth and the Space Station to develop methods to grow foodstuffs for extended space missions.[5,6] Bioregenerative life support systems will be needed for self-sufficient food production for lunar and Martian bases; otherwise they will be temporary outposts of limited value, exorbitant to maintain, and requiring unnecessary interplanetary trips with associated risks. Maintaining crops requires intensive hands-on work by humans, reducing time for exploration. However, robotic food production is now occurring on Earth and, given the power of AI, can be adapted to maintain farming modules on Mars. Rovers can gather ice and soil at the landing site. Robotic arms traversing moveable rails can plant, grow, and harvest foodstuffs that can be packaged and frozen, storing years of supplies before humans land. Robots can be quasi-independent or remotely controlled, with arm sockets that can easily detach to connect replacement arms as needed.

Special Conditions on Mars: To ensure success, redundant growth systems can be established, including vertical aeroponic, hydroponic, direct planting in dry soil beds brought from Earth (enriched in organics), use of modified Martian soil, and hybrids of these to reduce soil needs. Excessive perchlorates and other harmful salts would need to be leached from in situ soils, to which can be added initial stimuli of carried organic material, fertilizers to enrich K, P, and N, and feedstock of favorable bacteria and fungi for optimal growth. Terrestrial parasites and plant pathogens of all types would be excluded, much easier to achieve in the initial absence of humans. Controlled composting of inedible plant parts would yield needed soil additives.

The plant habitats would require essential levels of humidity and warmth, but would also have to be monitored to prevent excessive O_2 levels. Martian CO_2 enrichment would enhance plant growth, so long as air pressures would be maintained above ~5-6 psi. At lower pressures, growth rates and productivity are diminished. Research has revealed idealized light wavelengths sourced from LEDs to illuminate plants and enhance growth during hours of darkness.

Oxygen-Nitrogen Storage: O_2 would have to be scavenged from the agricultural modules to prevent levels of buildup toxic to plants. Rather than waste this human resource to the atmosphere, it can be converted and stored in tanks. Liquid O_2 cannot easily be kept in that phase for years. However, gaseous O_2 is readily converted and stored as another compound, nitrogen dioxide (NO_2), which is a common waste gas from combustion engines. Nitrogen extracted[7] from the air can be combined with scavenged oxygen to form NO_2, which becomes a yellowish-brown liquid at mild temperatures below 21°C (294K) and further converts to N_2O_4 below 262K. This N_2O_4 (NTO or amyl) is a powerful oxidizer used with hydrazine as rocket fuel. It reverts to stable NO_2 at higher temperatures, but will evolve to nitrous and nitric acid in the presence of water. NO_2 and N_2O_4 are very toxic, the latter in 1975 sickening three Apollo astronauts (one lost consciousness) as it seeped into their cabin on final descent via a pressure relief valve.[8] With precautions, liquefied and solidified NO_2 provide plausible means of *long-term low-pressure* storage of O_2 and N_2 for use after humans arrive, and can also help formulate N_2-rich fertilizers.

Where to Build a Mars Base: Along with a previous analysis of southern hemisphere landing sites,[4] Milankovič Crater in the northern lowlands (Fig. 1) holds massive ice deposits[9] in shaded areas inside its rim (Fig. 2). Access to this water is critical for a base.

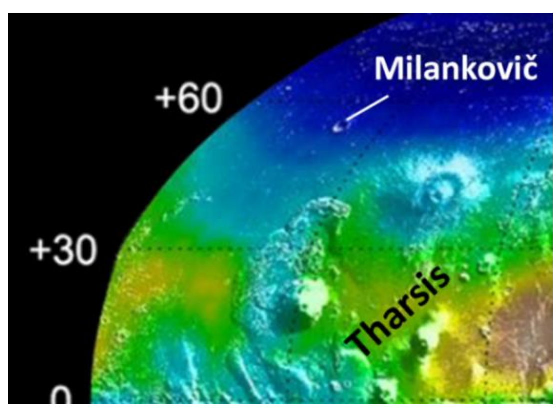

Fig. 1. Location of Milankovič Crater in lowlands NW of the Tharsis volcanic region. Blue areas on this epithermal neutron map are ice-enriched surfaces and shallow soils [**10**].

Milanković Crater lies in a region where the northern hemisphere ice fields reach farthest south. This may not be mere coincidence. Tharsis volcanism extended up through Amazonian time, and associated water runoff toward Milanković may have deposited the observed ice pattern. Milanković is downslope from big outflow channels on the NW flank of Tharsis.

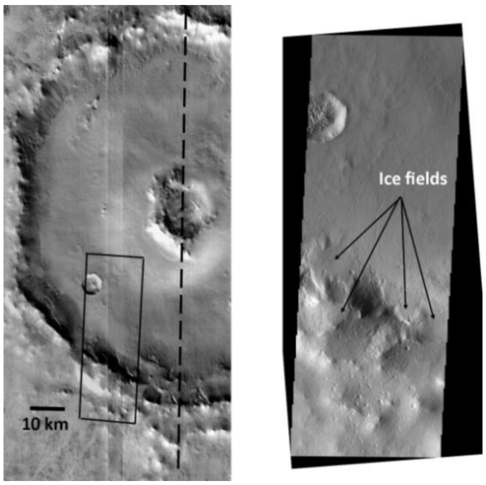

Fig. 2. THEMIS composite image (left) of Milanković Crater. Dashed line is trace of MOLA pass 1598 (Fig 3). Right panel: THEMIS V05373018 reveals ice deposits inside southern rim of Milanković.

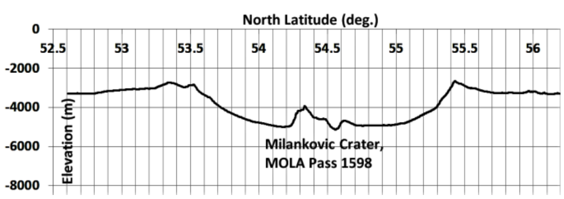

Fig. 3. MOLA profile N-S across Milanković Crater.

Fig. 4. MRO HiRISE image ESP_071573_2350-2 (IR- red-blue) revealing thick, ablated ice deposits inside western rim of Milanković Crater. Frame is at center of image PIA25088.

Crop Selection: Foods to be grown must include a useful balance of proteins and carbohydrates. Crops should be self-pollinating or nearly so, not requiring insects for that purpose although air movement is needed. Small fans can ensure adequate air flows for effective self-pollination. Plants that appear productive and adaptable based on prior research include dwarf wheat and oats, sweet potatoes, eggplants, cucumbers, tomatoes, peas, radishes, strawberries, and many varieties of leafy vegetables and herbs. Cucumbers are monoecious and thus need artificial pollination to fruit heavily, but AI-backed robotics can achieve that as the male and female flowers are relatively large. Tomatillos, rice, beet, and bean varieties can be adapted as crops. Heirloom varieties can be grown because they would no longer host terrestrial parasites and pathogens. It is important to have sustainable communities of plants with compatible environmental needs. The strange plant morphology issues seen in Space Station microgravity would not arise on Mars.

Genetics can play a key role in adaptation. For example, cultivated tomatoes cannot tolerate excessive hours of light. But in 2014 a gene was found in wild tomatoes that gives them tolerance of near-24 hr light cycles, with 20% improvement in yield.[11]

Conclusions: Robotic explorers on Mars have achieved far more geoscience goals than were envisioned even 20 years ago. Likewise, food production by semi-autonomous robots in farming modules can make great strides, planting, growing, harvesting, packaging, and storing years of foodstuffs in advance of human arrival. Such modules will of necessity become key components of self-sustaining plant-human biospheres for permanent bases. Virtually unlimited water ice resources, coupled with permanent and redundant power supplies (solar plus nuclear) and years of preserved Mars-grown food, would ensure large margins of safety for the first humans to reach Mars.

Milanković Crater, 110 km wide, with its large water ice inventory, low floor elevation (-4.5 km) favorable for landing, and temperate latitude (54°N) is a prime candidate for a self-sustaining, permanent base in the northern lowlands of Mars. That ancient ocean basin is itself a region of compelling scientific interest.

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