

RAMS | MARS TO TABLE CHALLENGE

RAMS: HABITAT METABOLISM FOR MARTIAN FOOD ECOLOGY

Solution Summary | 15-person, 500-sol operations within a five-year ecological succession

Abstract

RAMS approaches the Mars mission as the commissioning phase of a food ecology designed to mature over five years. Humans will not physiologically adapt to Mars on a mission timescale; the system therefore reconstructs Earth-like ecological relationships while using daily food and plant materia medica to support the physical stresses that cannot be engineered away.

The habitat operates as a circular metabolism of Martian and Earth provisioned materials, foods, energy, and other inputs. Polar ice enters segregated water loops; irrigation cascades down pyramidal shape through to plant guilds and wetlands; transpired water is condensed and recirculated. A passive-first thermal architecture uses vertical climatic bands, solar aspect, Martian day-night temperature differences, heat recovery, shaded radiators, and cold subsurface or ice reservoirs to reduce active cooling. Beneath cultivation, on the lowest floor, a raised brownfield refinery separates the biome from raw regolith while capturing regolith and reducing perchlorates, collecting chloride, recovering oxygen-bearing coproducts, concentrating iron-bearing minerals, and producing glass, ceramics, construction feedstock, and mineral scaffold for living soil.

Food production is organized as ecological conversation between a variety of plants, microorganisms, fungi, humans, and eventually animals. Nitrogen fixers, mineral accumulators, canopy species, wetland plants, fungi, microbes, fermenters, aquaculture, and later ruminants exchange nutrients and convert residues into food, fodder, fiber, soil carbon, dairy, and growing media, pursuing zero unmanaged biological waste. A modular 14-sol menu evolves with this succession while preserving nutrition, sensory pleasure, cultural identity, and choice.

Medicinal plants drawn from Andean, Himalayan, Ayurvedic, Traditional Chinese Medicine, and Sowa Rigpa knowledge form a renewable pre-pharmaceutical layer for respiratory dryness, fluid regulation, digestion, inflammation, wound care, sleep, and recovery, conserving finite manufactured medicines. RAMS considers food production as also a water, waste, health, and materials processing system.

Design thesis *Earth-independence is not achieved by maximizing the yield of isolated food machines. It is achieved when the same local water, minerals, organisms, residues, and thermal gradients repeatedly perform food, health, waste-treatment, material, and habitat work.*

Challenge design basis

Crew and mission	Food sourcing	Dedicated labor	Habitat design point
15 people; 500 sols within a five-year succession horizon	Majority of calories produced, grown, processed and prepared on Mars	Food systems engineer plus nutrition/meal-prep specialist; 45 hours per five sols each	3.71 m/s ² ; 56.5 kPa; 34% O ₂ ; 18 to 27 C

TEAM AND AFFILIATIONS

A two-person independent design team developing RAMS as one integrated food-system proposal

Team composition and project roles

Pragya Saxena | Team Lead and Systems Architect

Affiliations: Columbia University, M.S. Sustainability Management (2026).

Contributions: origin and architecture of RAMS; long-duration settlement premise; brownfield-refinery strategy; closed-loop ecology; plant, fungal, fiber, fodder, and medicinal guilds; food-culture and sensory framework; traditional-knowledge integration; herbal use system, proposal narrative and system visualization.

Alexa Der (Lexi) | RAMS Team Member

Affiliations: University of California, San Diego, B.S. Cognitive Science, Design and Interaction, Minor in Computational Social Science, RAMS independent design team.

Contributions: co-development of the RAMS proposal; food-system and challenge research; meal-plan and operational development; integration across submission deliverables; review of mission requirements, crew experience, and concept communication.

Working method

RAMS uses iterative systems review: every proposed crop, organism, process, or meal must be identified according to its inputs, outputs, dependencies, ecological services, human value, operational burden, and failure/recovery pathways.

PROPOSED TECHNOLOGY

A food system designed as the metabolism of a long-duration settlement

1. Raised brownfield refinery and local materials

RAMS treats Mars as a brownfield: a hazardous mineral environment that must be isolated, characterized, refined, and gradually recruited into the habitat's material economy.

The pyramidal (or other shape based on atmospheric pressure needs) does not contact Mars-native regolith directly. A raised, inspectable foundation features a vitrified or sintered liner, monitored interstitial drainage, replaceable reactive media, and modular soil cassettes with independent sampling and isolation. Regolith batches are assayed for soluble salts, perchlorate/chloride, particle size, mineralogy, and metals before routing.

Mechanical, electrostatic, density, and magnetic beneficiation separate useful fractions; magnetic separation concentrates iron-bearing phases but is not treated as complete detoxification. Contained perchlorate-reducing bioreactors, followed by physicochemical polishing where justified, convert perchlorates into a managed chloride stream and oxygen-bearing coproducts. Chloride is concentrated, separated, crystallized, or routed to industrial chemistry so it can be used for later applications. Washed and mineral-balanced silicates become construction aggregate, glass/glass-ceramic feedstock, and the mineral scaffold of soil; iron-rich concentrates enter reduction, smelting, and alloy-development trades. Early local products are non-pressure tiles, pipes, thermal mass, drainage media, tools, and repair stock. [6-8]

2. Water, atmosphere, and passive-first thermal control

An accessible polar or subsurface ice deposit supplies Martian water into the system to help create Earth independence. Ice is extracted in closed equipment, assayed, filtered, disinfected, mineral-balanced, and assigned to segregated potable, crop, animal, wetland, and industrial loops. Irrigation pumps water to upper beds from where water naturally cascades down through root zones and constructed wetlands, and is then centrally collected. Nutrient-rich drainage, saline water, contaminated process water, and clean condensate are kept in separate systems or pipes until defined release criterion is confirmed. Plant transpiration and crew humidity are condensed, treated, and returned to the system; latent heat is recovered for roots, fermentation, mushrooms, domestic hot water, or ice processing. [3-5]

The thermal architecture is passive-first but not passive-only. It uses the enclosure's elevation and aspect to establish controlled warm, humid, cool, and dry bands; heat pipes and thermosiphons move heat toward shaded high-emissivity radiators; sunshades, selective coatings, louvers, thermal mass, phase-change storage, Martian day-night temperature swings, and cold subsurface or ice reservoirs reduce compressor load. Because the Martian atmosphere is thin and convective rejection is limited, radiative and conductive pathways carry the main design claim; active fans, pumps, valves, and trim cooling retain environmental precision. [5,9-10]

3. Ecological process train

RAMS closes mass balances while maintaining separated circular streams that mix at defined gates. Human wastes, animal manure, kitchen residues, crop biomass, pharmacy residues, industrial brines, and pathogen-risk material remain distinct until digestion, composting, filtration, disinfection, deactivation, or chemical separation produces a characterized output.

Ecological engine	Primary work in the system
Microbial and fungal consortia	Mineralize nutrients; decompose lignocellulose; support mycorrhizal exchange; produce edible fungi; treat selected waters and residues.
Plant and wetland guilds	Produce food, medicine, fodder and fiber; fix nitrogen; lift and capture minerals; manage shade, humidity and evaporation; polish water.
Fermentation and trophic conversion	Preserve harvests; improve flavor and digestibility; convert by-products through koji, bread, pickles, vinegar, aquaculture, and later ruminants.
Controls and monitoring	Track carbon, nitrogen, phosphorus, potassium, sulfur, salts, water, oxygen, contaminants, labor and inventory; isolate modules and preserve manual safe states.

4. Habitat and ECLSS interfaces

Isolatable interfaces exchange CO₂, oxygen, water, nutrients, heat, and treated residues. Pressure districts, stored reserves, seed/culture banks, redundant equipment, and deterministic safe states permit ecological modules to be reset without threatening the crew.

FOOD ECOLOGY, HEALTH, AND FIVE-YEAR SUCCESSION

The menu is the visible expression of the ecology

Plants in ecological conversation

Crops are selected as functional guilds, not as isolated yield units. Each species participates in an ecological conversation: root exudates feed microbes; fungi redistribute nutrients; nitrogen-fixing partners provision demanding crops; deep roots mobilize minerals; canopies shape light and humidity; groundcovers reduce evaporation; wetland roots intercept runoff; and prunings become fungal substrate, feed, fiber, mulch, or compost.

The first-wave portfolio combines annual staples and pulses with sea buckthorn/*Frankia*, sainfoin and alfalfa for nitrogen and fodder; mulberry and willow for canopy, fruit/browse, fiber and fungal substrate; flax, hemp, ramie and Himalayan nettle/*allo* for seed, oil, clothing and bedding; Coix, Plantago, Centella/*Brahmi*, horsetail and other controlled wetland candidates for food, materia medica, fiber and water polishing. Edible mushrooms, mycorrhizae, bacterial/archaeal communities, fermentation cultures, aquaculture, and later small ruminants extend the material cascade. The target is zero unmanaged biological waste: unavoidable losses are measured, treated, and routed; saline, toxic, pharmaceutical, and pathogen-risk streams remain isolated.

A pre-pharmaceutical physiological support layer

Mars will be medically resource-scarce. RAMS therefore grows a locally renewable materia medica intended to provide food-based physiological support and a governed layer of care before escalation to finite manufactured pharmaceuticals, while preserving those medicines for conditions that require them. This is plant-derived pharmacology organized through long Andean, Himalayan, Ayurvedic, TCM, and Sowa Rigpa use. There is an open question about whether plant adaptations to Martian conditions will in turn help support human adaptation to the same conditions as is seen in many indigenous traditions.

Five-year food-system succession

Pre-arrival	Commission barrier, ice extraction, water treatment, refinery and simple crop modules; stage stored foods and seed/culture banks.
Year 1	Stabilize annual crops, microbes, fungi, fermentation and sanitation; produce staples, pulses, greens, mushrooms, breads and sauces.
Years 2-3	Build living soil, wetlands, perennials, aquaculture and fiber; add fruit, oils, fish/invertebrates, cloth, paper and soil carbon.
Years 4-5	Mature canopy and fodder reserves; permit small-ruminant milk, dairy, wool and manure only after welfare, veterinary and closure gates pass.

A tall terraced enclosure - potentially pyramidal - may organize elevation, aspect and gravity-assisted water niches, but remains a pressure-architecture trade. A later rotating zone is optional for mammalian breeding and crew research; neither pyramidal geometry, gravity, nor artificial gravity is required for initial food production.

NOVELTY, EARTH-INDEPENDENCE, EARTH VALUE, AND IP

Why the integrated system matters

RAMS does not claim that wetlands, heat pipes, fermentation, regolith processing, medicinal plants, or controlled-environment agriculture are individually new. The innovation is our five-year integration into one phase-responsive habitat metabolism in which local hazards and mission residues become inputs to food, health, water, soil, and repair-material systems.

Brownfield-to-biome conversion couples contaminant isolation and perchlorate/chloride management to ISRU materials and living-soil succession.

Ecological conversation replaces crop monoculture with complementary guilds designed around nutrient exchange, microclimate, water polishing, fiber, fodder, medicine, decomposition and resilience.

Pre-pharmaceutical capacity treats renewable materia medica as health infrastructure in a resupply-constrained settlement, with identity, interaction and residue controls.

Modular cuisine connects system performance to actual human appetite - crunchy, salty, creamy, sour, spicy, fruity, fresh and familiar - while preserving nutrition and cultural agency.

Progress toward Earth-independence

The 500-sol meal plan will source a majority of calories from Martian production, meeting the Challenge's less-than-half Earth-provisioned limit, while the five-year sequence reduces dependence on imported water, substrate, fertilizer, bulk structural mass, replacement media, medicines, textiles, and animal products. Earth cargo shifts toward precision items that Mars cannot yet reproduce: electronics, membranes, catalysts, reference cultures, pharmaceuticals, genetic diversity, seals, bearings, sensors, and selected cultural ingredients. Redundant routes – crops, fungi, fermentation, aquaculture, stored foods and later dairy – prevent one failed crop or reactor from collapsing nutrition. [1-4,8]

Food security on Earth

RAMS translates directly to places where clean land, water, supply chains, or specialized labor are scarce. Its raised barrier and refinery logic applies to brownfields, mine-affected land and saline or contaminated sites; its closed water and nutrient loops apply to arid settlements, islands, remote research stations, refugee and disaster infrastructure, and controlled-environment farms; its local glass, ceramic, fiber, soil and repair pathways reduce dependence on distant industrial supply. The modular menu and culturally governed medicinal gardens preserve food choice and locally held knowledge instead of imposing a single emergency ration. NASA-derived closed-loop water and plant-monitoring technologies have already produced terrestrial wastewater and agriculture applications, demonstrating the two-way value of space food research. [3-5]

Intellectual property and permissions

RAMS does not claim ownership of underlying public-domain scientific principles or third-party technologies. Candidate subsystems include off-the-shelf pumps, sensors, heat exchangers, heat pipes, radiators, membrane and biological water treatment, anaerobic digestion, controlled-environment agriculture, mineral separation, fermentation, aquaculture, and materials-processing equipment. Commercial components should be procured under ordinary purchase or license terms; patented or proprietary implementations would be licensed, substituted, or redesigned before use.

AI-use disclosure

Generative AI assisted drafting various ideas and providing base language which was then edited and corrected by team members for accuracy and articulation. It also assisted in image production and concept visualization. The Team originated RAMS and the combination of system and food solutions recommended for Mars, including the unique approach to circular material systems, herb growth and use, and modular flexible recipes.

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