Sustaining Life on Mars: An Agricultural Strategy for a 5,000-Person Colony

Controlled-Environment Agriculture System for Martian Habitat Alpha
(Rev. 1.0)

I. Overview

NASA will deploy eight prefabricated, oxygenated domes to form the foundation of a self-sustaining agricultural ecosystem on Mars to nourish 5,000 colonists (See **Figure 1** for early renders). This system must balance reliable food production, colonist well-being, and ecological resilience while operating under extreme limits of water, power, and soil resources.

This proposal outlines a modular, dome-based agricultural system designed to produce a balanced and flavorful diet for 5,000 colonists without relying on imports from Earth. Fourteen primary and four secondary crop species are distributed across eight domes, each calibrated to a distinct microclimate based on water and nutrient requirements.

The Temperate, Arid, and Humid domes operate as an interconnected ecosystem, leveraging waste recycling, hydroponic and aeroponic systems, and strict biosecurity to sustain colonists efficiently while maintaining morale, meal variety, and long-term soil health.

Figure 1: Mars pre-fabricated dome designs. Drones began assembly on January 19th, 2031.

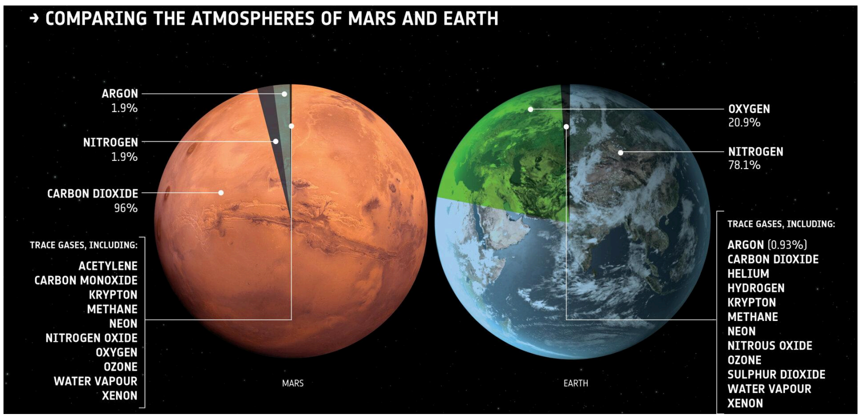
Key Outcomes:

- Achieves near-total dietary coverage (macronutrients, vitamins, minerals) using locally grown crops.
- Reduces water consumption through zone-specific irrigation.
- Balances sustainability and psychology, providing familiar, flavorful foods while minimizing redundancy and resource strain.
- Provides a scalable model adaptable for Phase II expansion to 10,000+ colonists.

As the saying goes: "*The first Martian harvest will not be measured only in calories, but in proof that human life can adapt, thrive, and taste joy even 140 million miles from Earth."*

II. Environmental Factors

Martian agriculture faces four fundamental challenges: **radiation, atmosphere, soil, and water**. Mars's regolith contains perchlorates toxic to humans, lacks organic matter, and has poor water retention. Atmospheric pressure averages less than 1% of Earth's, with CO_2 at ~95% — useful for photosynthesis but hostile to unprotected life. See **Figure 2.**



Sunlight intensity averages 590 W/m^2 (compared to Earth's 1,000 W/m^2), necessitating supplemental LED lighting in most domes. Water must be extracted from ice deposits or recycled from habitation systems, making every liter of irrigation a closed-loop resource.

Figure 2: Mars atmospheric makeup compared to Earth's requires climate controlled conditions until subsequent testing and genetic manipulation allows for surface agriculture.

III. Engineering Constraints

Each dome operates as a semi-autonomous biosphere, with temperature, humidity, and CO_2 controlled through a shared air and nutrient reclamation network. Energy budgets per dome are capped at **250 kW** to maintain equilibrium with the colony's solar and nuclear generation infrastructure. To minimize transport costs, soil analogs will be manufactured from sterilized regolith enriched with composted waste and nitrogen-fixing crops. Where possible, hydroponic or aeroponic systems will replace soil cultivation for water-intensive or short-cycle plants like tomatoes and leafy greens.

IV. Human Considerations

Agriculture supports not only survival but psychological health. **See Figure 3**. Greenery and flavor diversity mitigate isolation stress and "monotony fatigue." For this reason, certain "nonessential" crops, like herbs, citrus, and flowering species, are deliberately included to maintain morale and smell variety.

Habitability studies (Biosphere 2, HI-SEAS, and Antarctic bases) show that fresh produce correlates directly with crew cohesion and overall mission performance. A thriving greenhouse is a mental health need as much as a logistical one.

Figure 3. Martian Crew Captain Lt. Col. Dan Myers and Sgt. Katie Walker tend to budding tomato crops, a hands-on effort that creates for the colony and unites.

V. Crop Proposals

Selecting the right crops for Mars agriculture is a matter of both biology and psychology. On Mars, we don’t ask "*can* we grow it?" We ask *"is growing it better than shipping it* once you factor mass, power, water, crew time, and morale?"

Each species must feed the body, sustain the mind, while accounting for the treacherous environment and 9-month travel time from Earth to Mars. Our extensive research in the Earth-side, simulated Martian soil domes indicates that only a narrow range of terrestrial crops can thrive under these conditions, which we have categorized into two groups via tested criteria (**see Figure 4**): fourteen essentials and four nice-to-haves.

CROP SELECTION CRITERIA

CRITERION	DESCRIPTION
Nutrition	Provides necessary calories, protein, fats, and an array of vitamins and minerals
Resource Efficiency	Requires minimal water, energy, and substrate to grow, with manageable labor demands
Resilience	Tolerant to variations in light, humidity, and temperature within controlled environments
Growth Suitability	Adapted to soilless cultivation or nutrient-poor Martian regolith
Psychological Benefits	Supports crew morale by enhancing meal quality and providing sensory variety

Figure 4. Crop selection criteria includes nutrition, resilience, and psychological benefits.

> **Note**: This proposal does not include algae (spirulina) or mushrooms, as those will be handled by the pre-fab microalgae farms and subsurface caverns respectively.

Primary Crops

Crop	**Function / Key Benefit**	**Notes**
Wheat	High-calorie staple; primary carbohydrate base	Easy to store and mill; adaptable to hydroponics or aeroponics
Quinoa	Complete amino acid profile; nutrient-dense grain	Salt-tolerant and thrives in lower humidity environments
Lentils	Major plant protein source; nitrogen fixer	Balances soil fertility and reduces need for artificial fertilizers
Sweet Potatoes	High-yield starch with vitamins A & C	Excellent calorie-to-area ratio; strong candidate for humid domes
Broccoli	High in calcium and vitamins K & C	Compact yield; excellent nutrient density
Kale	Continuous leaf harvest; iron and folate	Resilient to moderate temperature swings
Cabbage	Compact growth; bulk leafy green	Long storage life and minimal pest issues in closed systems
Carrots	Root crop; rich in beta carotene	Aerates soil and stores well after harvest
Onions	Base flavor and antimicrobial compounds	Long shelf life; enhances meal diversity
Garlic	Flavor enhancer; natural antibiotic	Low resource footprint; easy companion crop to onions
Green Beans	Protein and fiber; nitrogen fixer	Grows well in trellised hydroponic systems
Tomatoes	Vitamin C; high morale and menu variety	Resource-intensive but justifiable for crew satisfaction
Peppers	Vitamin C and flavor diversity	Moderate yield; compatible with tomato climate settings
Strawberries	Antioxidants and strong psychological benefit	Small area cultivation; symbolic "taste of home" crop

Additionally, we found the following crops to have low energy costs yet high psychological benefits. While not mandatory for nutrition, these crops are nice to have.

Secondary Crops

Crop	Function / Key Benefit	Notes
Basil	Culinary flavor; antimicrobial oils	Grown in small beds; main bulk can be shipped dried
Oregano	Culinary seasoning; preservative properties	Hardy and compact; minimal water needs
Thyme	Medicinal and aromatic herb	High essential oil yield per plant; low energy demand
Aloe Vera	Medicinal, hydration, emergency use	Best maintained as a small medicinal plot; low maintenance

VI. Dome Layout

To optimize energy efficiency across lighting, irrigation, and thermal regulation, the colony's agricultural system groups crops into three distinct microclimates. Each dome set maintains consistent humidity, light intensity, and temperature parameters to conserve power and water but also simplify nutrient management and pollination logistics.

Temperate Domes (Domes 1–3)

Focus: Supports core caloric and protein intake; legumes fix nitrogen for soil health.

Crop	Water Need	Temp (°F)	Light / Climate
Wheat	Moderate	59–77°F	Full light; dry-tolerant
Lentils	Moderate	59–77°F	Moderate light
Green Beans	Moderate	59–77°F	Moderate light
Kale	Moderate	50–68°F	Moderate light
Cabbage	Moderate	50–64°F	Moderate light
Broccoli	Moderate	54–72°F	Moderate light

Subtropical (Domes 4–6)

Focus: High-yield starches and morale crops; flavor and vitamin variety. Crops share irrigation loops; pollination assisted by robotics or vibrational systems. Additional infrastructure within the domes allow for rotational herbs and micro-crops. See **Figure 5.**

Crop	Water Need	Temp (°F)	Light/Climate
Sweet Potatoes	High	68–86°F	High light; humid
Tomatoes	High	68–86°F	High light; humid
Peppers	Moderate	68–86°F	High light
Basil/Rotational Herbs	Moderate	68–86°F	High light
Strawberries	Moderate	59–72°F	Moderate light; humid

Figure 5. Interior greenhouses like this allow for mass cultivation of herbs and spices, as well as micro-climates within the dome's greater ecosystem.

Arid (Domes 7–8)

Focus: Root crops and alliums; low-water efficiency zone. Desert-like conditions maximize water reclamation and reduce fungal risk; minimal irrigation footprint.

Crop	Water Need	Temp (°F)	Light / Climate
Carrots	Low–Moderate	50–68°F	Moderate light
Onions	Low	50–68°F	High light; dry
Garlic	Low	50–68°F	High light; dry

Quinoa	Low–Moderate	50–68°F	High light; low humidity
Thyme / Rotational Herbs	Low	64–77°F	High light; arid
Oregano / Rotational Herbs	Low	64–82°F	High light; arid
Aloe Vera	low	68–86°F	High light; arid

VII. Resource Efficiency Summary

Our estimations put resource consumption per dome at the following:

Dome Group	Average Water Use (m^3/wk)	Power Load (kWh/wk)	Yield (kg/wk)	Efficiency (kg/kWh)
Temperate (1–3)	115	12,600	6,000	0.48
Subtropical (4–6)	130	13,200	6,500	0.49
Arid (7–8)	60	6,000	3,000	0.5

VIII. Operational Plan

Each dome operates on an integrated environmental control system managed by the **Agricultural Command Node (ACN). See figure 6**. Sensors monitor soil moisture, nutrient concentration, light levels, and CO_2. Automated drip lines, misting systems, and light arrays adjust hourly to maintain target parameters. A centralized dashboard tracks:

- Crop yield forecasts
- Water recovery efficiency
- Power draw per zone
- Nutrient depletion rates

Figure 6. Automated arms test soil moisture, monitor light levels, and forecast future crop outputs as part of the Agricultural Command Node system.

Redundancies are built in: if one dome fails, seed reserves and cuttings stored in others allow rapid reseeding of essentials within 15 sols.

Crew Operations

Crew labor is limited to roughly 2.5 hours per person per week, distributed across a 40-person agri-team. Tasks include:

- Harvesting and sorting (twice weekly)
- Pruning and pollination checks
- Nutrient reservoir maintenance
- Pest and microbial monitoring

Hydroponic and soil-based domes alternate harvest cycles to ensure a continuous food supply, not feast/famine bursts. All biomass waste (non-edible plant matter) is composted or fed into the methane generator loop.

IX. Future Expansion

The system described here represents Phase I of Martian agricultural independence. It's a proof of concept that food security and psychological wellness can be achieved off-world with minimal Earth resupply. But true sustainability requires evolution.

Phase II will integrate rotational crop models to prevent nutrient depletion, introduce genetically optimized cultivars for low-pressure and high-CO_2 growth, and refine bioreactor waste-conversion loops to recover every molecule of usable carbon, nitrogen, and water.

Phase III, projected five years after first harvest, expands the agricultural footprint through modular dome replication and vertical stacking to support a population of 10,000+. New dome generations will incorporate transparent graphene glazing for improved solar efficiency and adaptive LED spectrums calibrated to plant circadian rhythms.

Long-term goals include:

- **Seed independence:** establishing a full in-situ seed bank for closed genetic cycles.
- **Microbial soil regeneration:** cultivating beneficial bacteria and fungi to replace imported fertilizers.
- **Genome diversification:** maintaining variant strains to guard against blight, disease, or monoculture collapse.
- **Cross-habitat integration:** linking agricultural domes with habitation modules for direct O_2 and CO_2 exchange, completing the biological loop of the colony.

In short, this system is not just designed to sustain life — it's designed to evolve with it.

X. Conclusion

The success of any Martian colony will depend not on the technology that gets us there, but on the systems that let us stay. This proposal demonstrates that sustainable agriculture on Mars is possible, practical, and essential to long-term human presence.