Mars Agriculture: Feeding Exploration and Enabling Earth Independence

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The Food Production Vision

Ensure Food System Security on Long Duration Missions Beyond Low Earth Orbit*

- ***Proper nutrition is critical to crew health and performance***
- **Provide safe, nutritious, and acceptable fresh food**
- **Add variety to crew diet**
- **Enhance morale**

* *Food security* = continuous access to sufficient safe and nutritious food which meets crew dietary needs and food preferences to maintain peak health and performance.

Near Term Goal

Nutrient Supplementation of the Prepackaged Food System

- **Fresh produce may supplement key vitamins (B_1, K, C) and bioactive compounds that may degrade in the stored food system on multi-year exploration missions that cannot be resupplied.**

- **"Pick-and-Eat" crops that require no processing and minimal preparation will provide variety, customization, and psychological appeal without adding food security risk or high resource demand.**

- **Enable testing and demonstration of dependable crop production before reliance on system.**

- **Limiting factors are vehicle resources mass, power, volume, water, air, crew time**

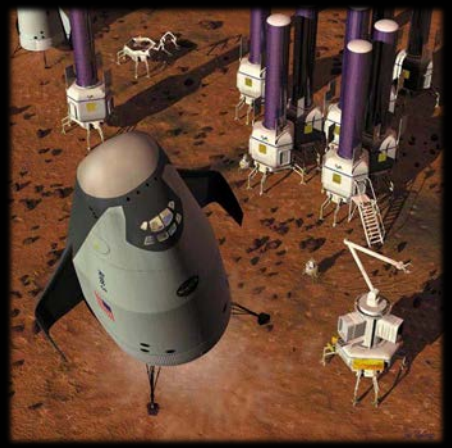
Needed for:
Deep Space Transport

Long Term Goal

Caloric Replacement to Facilitate Earth Independence

- **Reduce up-mass associated with pre-packaged food**
- **In addition to “pick and eat” crops, include staple crops that require processing and preparation**
- **Bioregenerative capability will be required for long duration surface missions**

Needed for: Long duration Surface missions on the Moon and Mars



Candidate Plants

Salad
Leafy Greens
Tomato
Pepper
Radish
Strawberry
Green Onion
Pea
Carrot

Lettuce, Chinese cabbage, Swiss chard, Mizuna, Spinach

CONSUMED FRESH WITHOUT PROCESSING

Spice
Basil
Mint
Chives
Dill

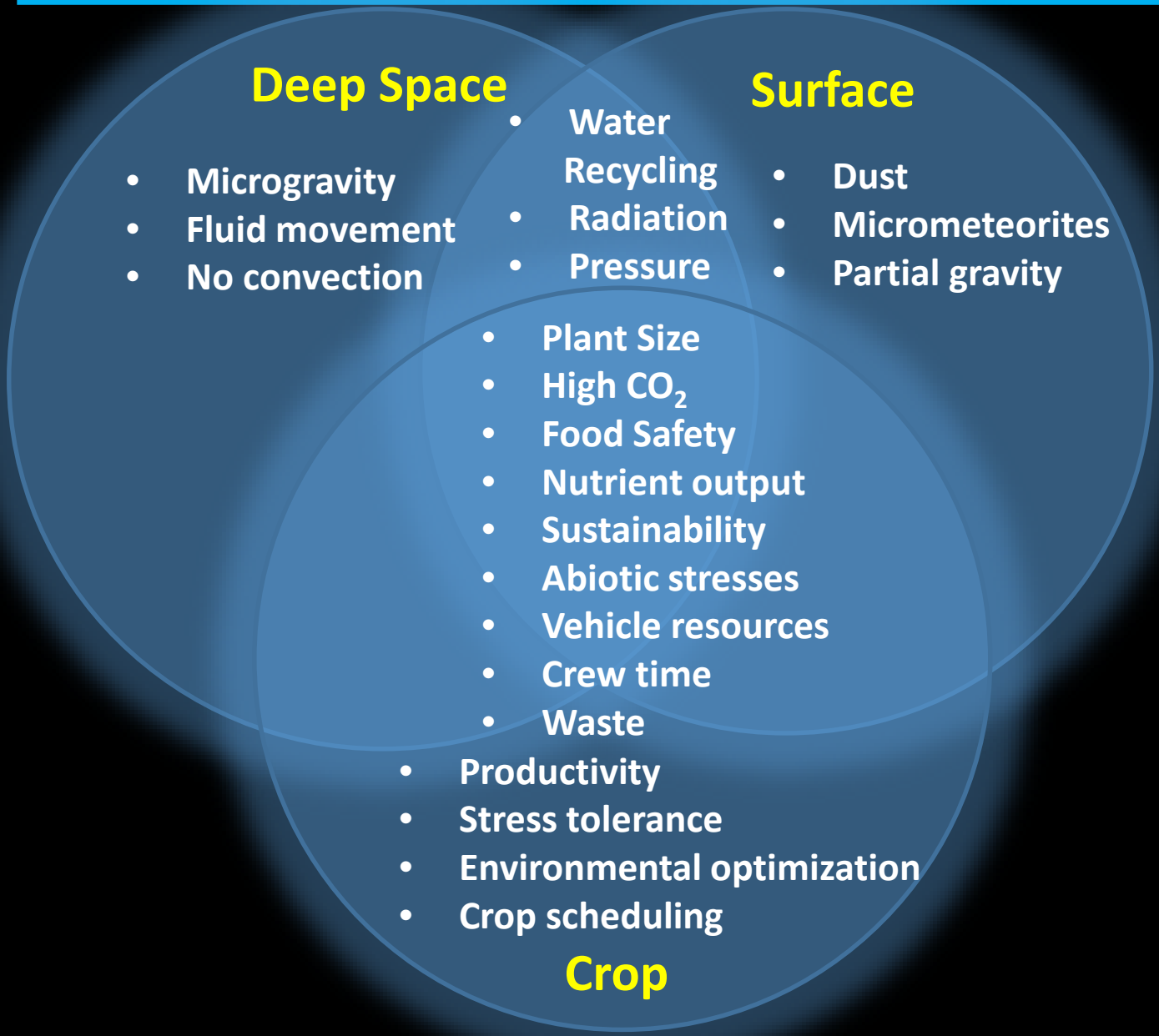
Staple Crops
White Potato
Sweet Potato

MINIMAL PREPARATION / COOKING

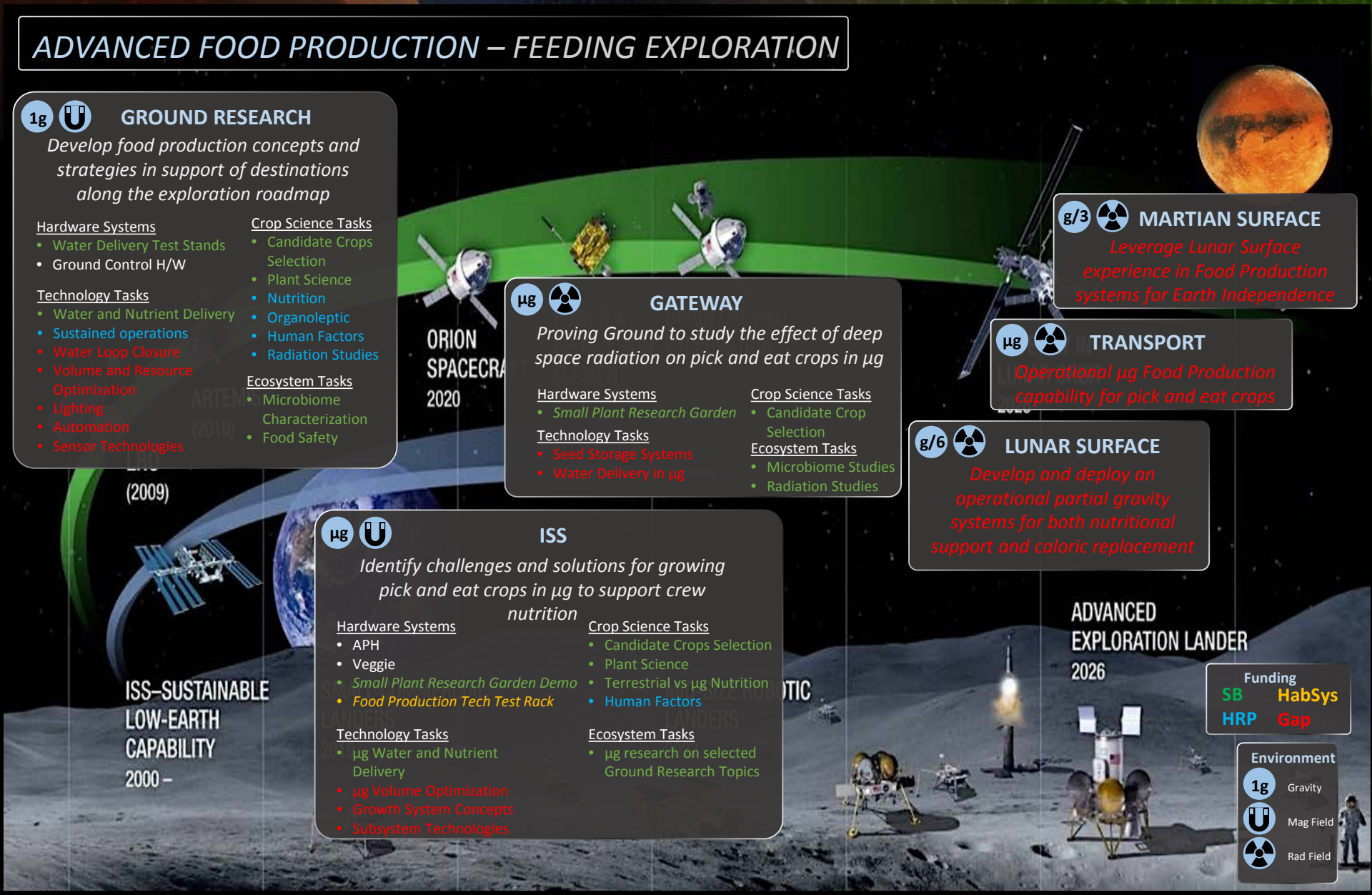
Rice
Wheat
Dried Bean
Soybean
Peanut

SIGNIFICANT PREPARATION / COOKING

Space Food Production Challenges



ADVANCED FOOD PRODUCTION – FEEDING EXPLORATION



1g GROUND RESEARCH

Develop food production concepts and strategies in support of destinations along the exploration roadmap

Hardware Systems
- Water Delivery Test Stands
- Ground Control H/W

Technology Tasks
- Water and Nutrient Delivery
- Sustained operations
- Water Loop Closure
- Volume and Resource Optimization
- Lighting
- Automation
- Sensor Technologies

Crop Science Tasks
- Candidate Crops Selection
- Plant Science
- Nutrition
- Organoleptic
- Human Factors
- Radiation Studies

Ecosystem Tasks
- Microbiome Characterization
- Food Safety

µg GATEWAY

Proving Ground to study the effect of deep space radiation on pick and eat crops in µg

Hardware Systems
- *Small Plant Research Garden*

Technology Tasks
- Seed Storage Systems
- Water Delivery in µg

Crop Science Tasks
- Candidate Crop Selection

Ecosystem Tasks
- Microbiome Studies
- Radiation Studies

µg ISS

Identify challenges and solutions for growing pick and eat crops in µg to support crew nutrition

Hardware Systems
- APH
- Veggie
- *Small Plant Research Garden Demo*
- *Food Production Tech Test Rack*

Technology Tasks
- µg Water and Nutrient Delivery
- µg Volume Optimization
- Growth System Concepts
- Subsystem Technologies

Crop Science Tasks
- Candidate Crops Selection
- Plant Science
- Terrestrial vs µg Nutrition
- Human Factors

Ecosystem Tasks
- µg research on selected Ground Research Topics

g/3 MARTIAN SURFACE

Leverage Lunar Surface experience in Food Production systems for Earth Independence

µg TRANSPORT

Operational µg Food Production capability for pick and eat crops

g/6 LUNAR SURFACE

Develop and deploy an operational partial gravity systems for both nutritional support and caloric replacement

ORION SPACECRA 2020

(2009)

ISS–SUSTAINABLE LOW-EARTH CAPABILITY 2000 –

ADVANCED EXPLORATION LANDER 2026

Funding
SB HabSys
HRP Gap

Environment
1g Gravity
Mag Field
Rad Field

The Vegetable Production System (Veggie)

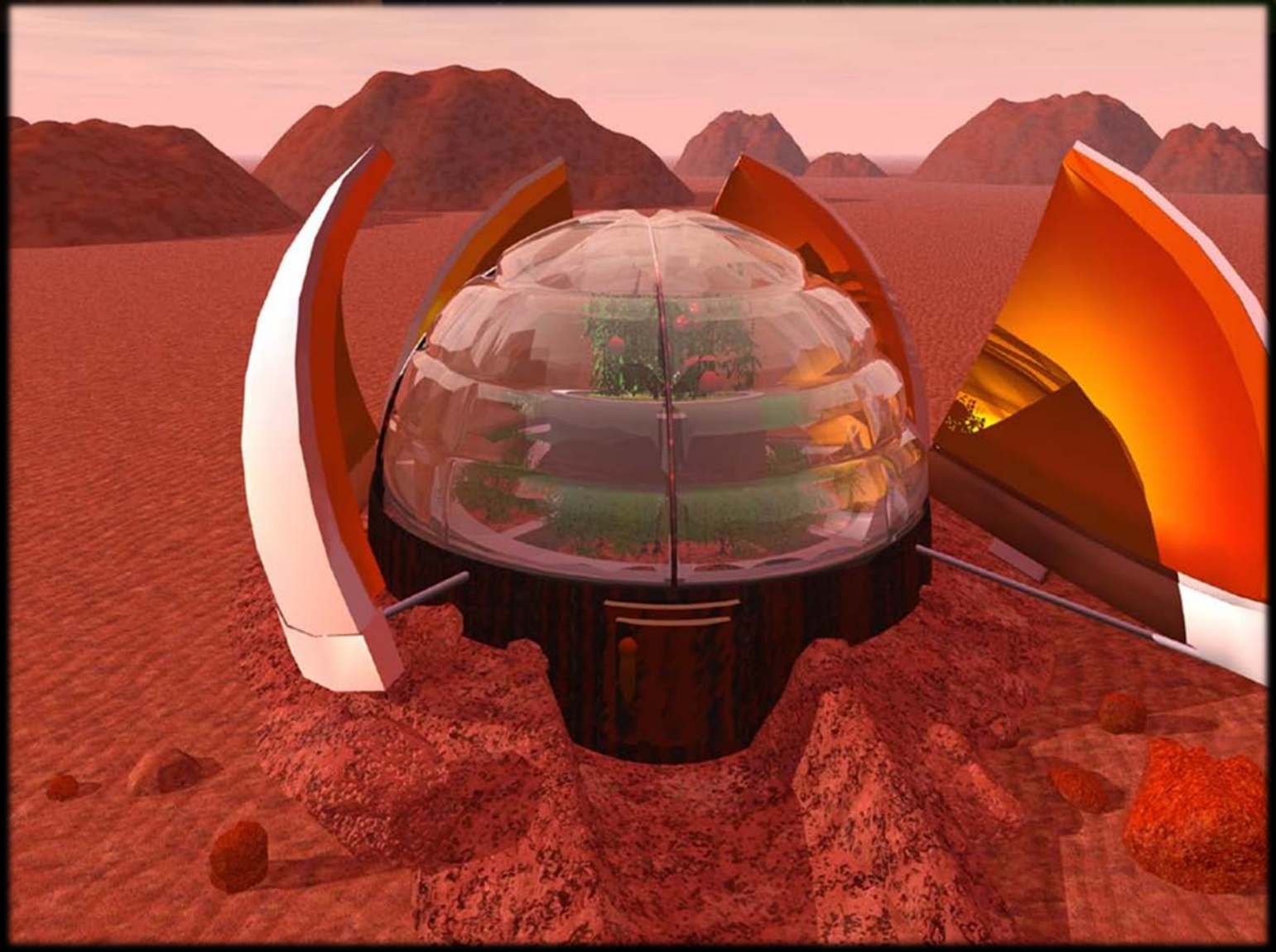
Astronaut Comments

- **Scott Kelly**
  - the logistical complexity of having people live and work in space for long periods
  - the supply chain that is required
  - For Mars, need a space craft that is more self-sustainable with regards to its food supply
- **Kjell Lindgren**
  - benefit of eating the fresh food
  - contribution that plants have to the ISS ecosystem
  - psychological benefit - it's really fun to see green growing things in the sterile environment of the ISS

Advanced Plant Habitat (APH)

Mars Surface Operations

Deployable Surface Greenhouse



Thank You!