MELiSSA

esa BUSINESS INCUBATION CENTRE Baden-Württemberg

2025 MELiSSA Conference

Technology transfer for terrestrial applications

NEW SPACE ECONOMY:

Value Creation avenues for the Agri-food industry

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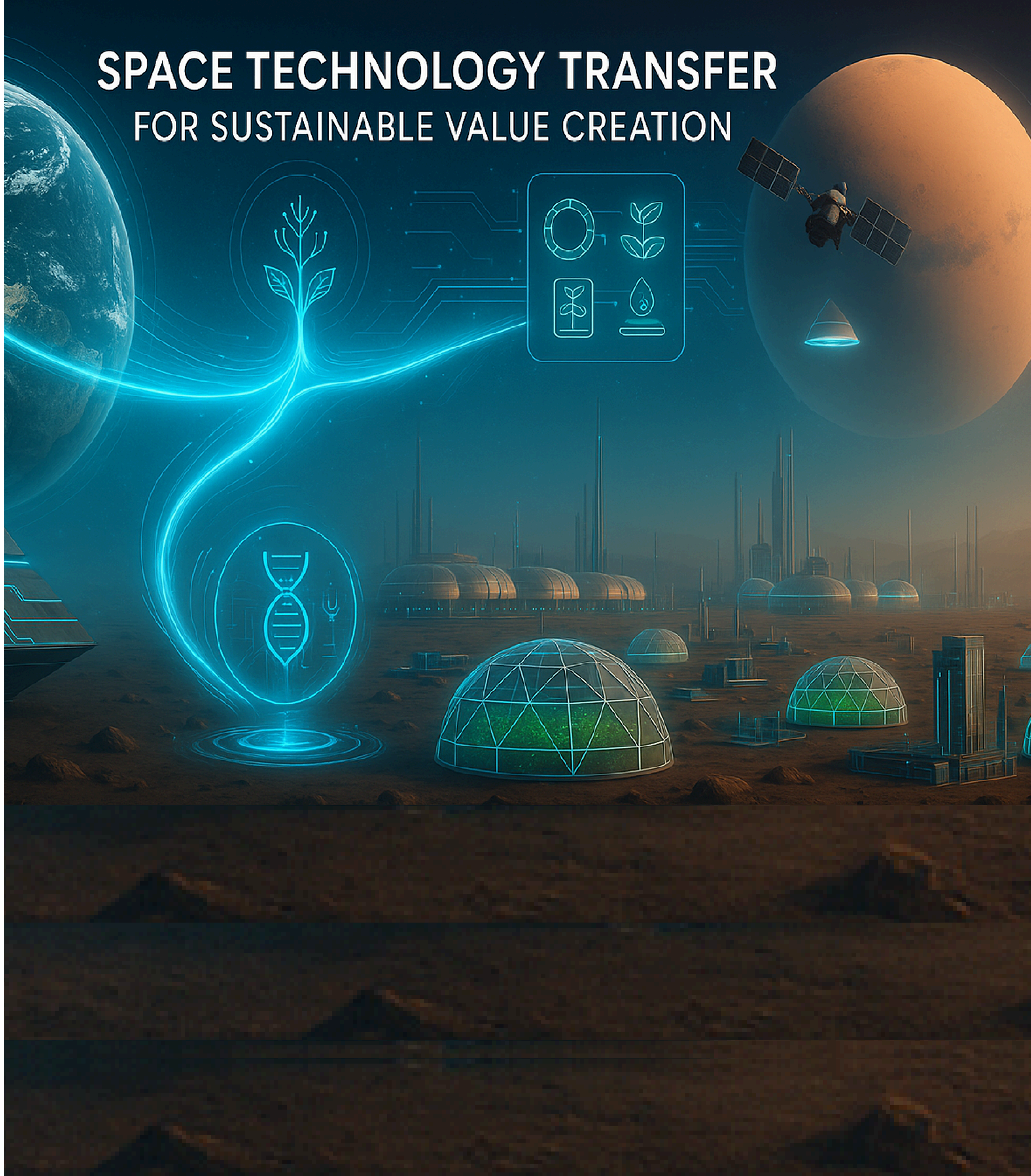


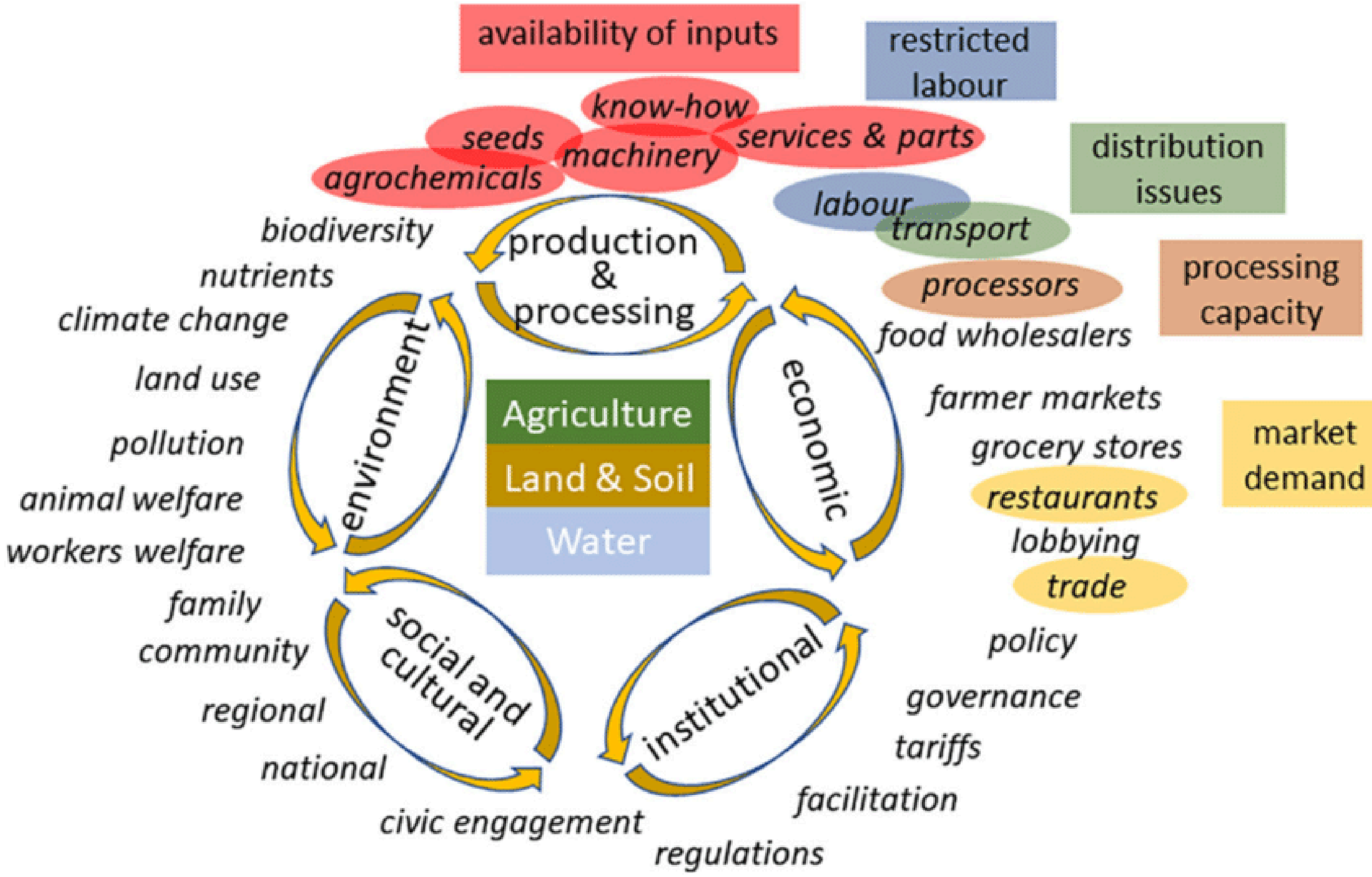
From Global crisis to transformational Agri-food solutions

Planetary stressors

- Accelerated climate change
- Rising sea levels
- Extreme weather events
- Biodiversity loss
- Economic impacts

Planetary stressors meet the PLATE

Climate-driven crop failures	→	volatile yields and unstable supply chains
Urban encroachment	→	shrinking arable land
Resource depletion	→	degraded soil and water scarcity
Rising population	→	pressure on global food security



Systemic pressures on global agriculture

Space exploration and Food production

- Long-duration space missions require **self-sustaining food systems**
- Development of **Bioregenerative Life Support Systems (BLSS)**

What is **BLSS**?

- Closed-loop ecosystems for human survival in space

BLSS structure:

- Producer: Plants
- Consumer: Humans/Animals
- Decomposer: Microorganisms

- Artificial ecosystems designed to support human life in space by recycling resources like oxygen, water, and food, minimizing reliance on Earth supplies and preventing pollution on extraterrestrial bodies.

"Earth is the cradle of humanity, but one cannot live in a cradle forever (Tsiolkovsky, 1912)."

- FOOD SECURITY CHALLENGES
- SPACE EXPLORATION AND FOOD PRODUCTION
- **BLSS MODELS**
- RESEARCH QUESTION
- RESEARCH APPROACH
- PRELIMINARY RESULTS
- FINAL THOUGHTS

Global BLSS initiatives

- NASA's **CELSS** (Controlled Ecological Life Support Systems)
- ESA's **MELiSSA** (Micro-Ecological Life Support System Alternative)
- Italian Space Agency- CAB (Controllo Ambientale Biorigenerativo)
- China's **Lunar Palace 1**
- Russia's **BIOS-3**
- Japan's **CEEF** (Closed Ecological Experimental Facility)
- U.S.-based **Biosphere 2**

BLSS applications on Earth

BLSS principles **for food security in extreme environments**:

- Arid deserts
- Polar regions
- Disaster-stricken areas
- Urban & resource-limited zones
- Drought-prone agriculture
- Extreme soil restoration
- Remote island/Off-grid communities
- Space-to-Earth transfer demonstrations

CLIMATE RESILIENT TERRESTRIAL TRANSFER MODELS

Small scale remote markets
- Off-shore structures
- Extreme environmental habitats
- Research vessels/ Oil tankers
- Remote military camps, summit camps, and work sites

Medium scale specialised markets
- Waste treatment chamber
- Desalination plants
- Refugee camps

Large scale vertical farming markets
- Mega cities
- Abandoned buildings
- Desert companies

Medium scale research oriented markets
- Plant research
- Pharmaceuticals
- Seed companies
- Molecular farming

Micro scale commercial markets
- Schools
- Restaurants
- Hospitals
- Prisons
- Recreational exhibits
- Submarines
- Home farming

Research Question

How can space-derived technologies be seamlessly translated into terrestrial agri-food systems to drive multi-sectoral value creation?

Goal: To develop a Strategic Roadmap for BLSS Integration

Explored across five key dimensions

Sustainability & Ethics

Ecosystem Governance

Technology & Integration

Economic Value Creation

Regulatory & Legal Frameworks

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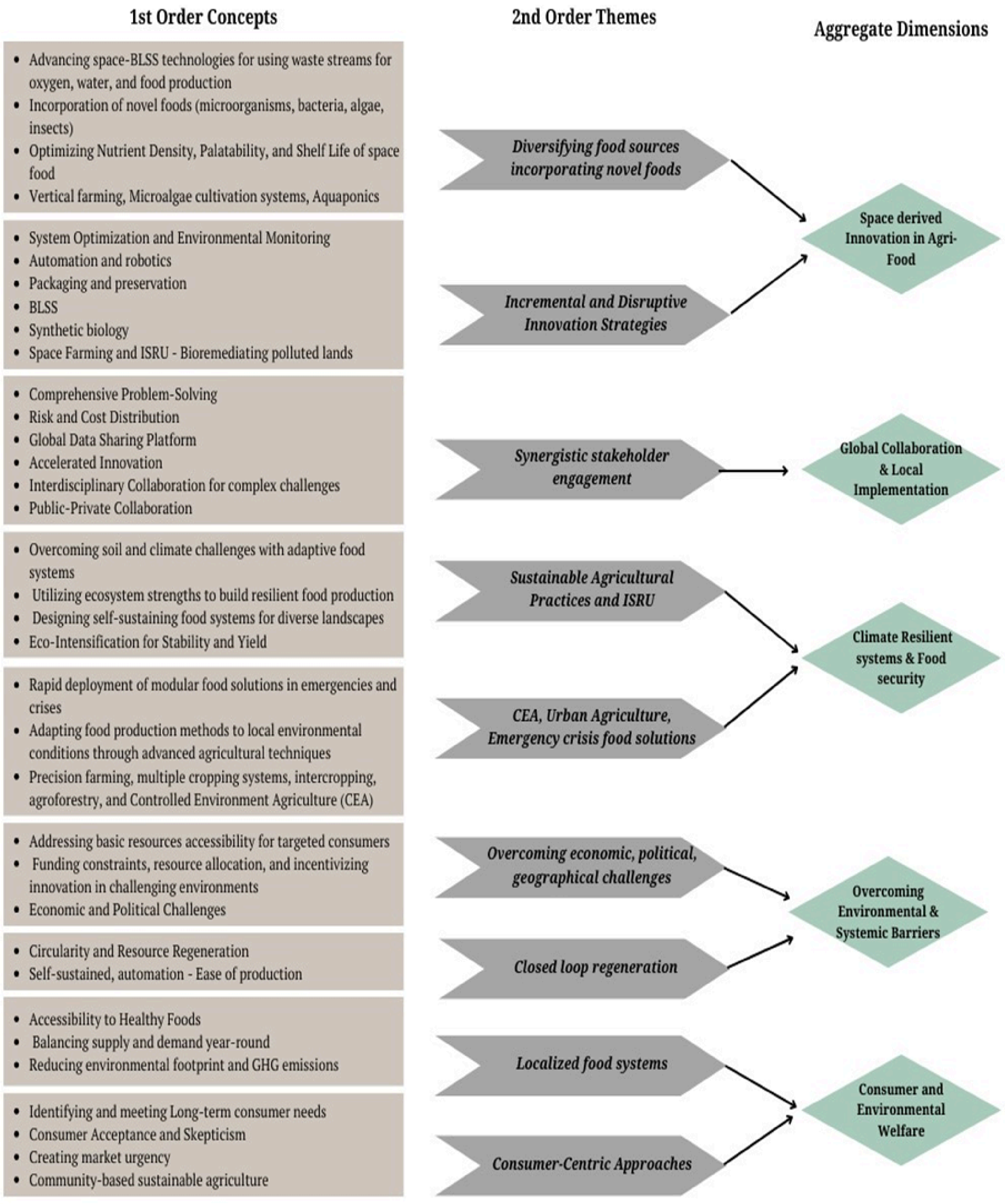
Research Approach – Data Structure

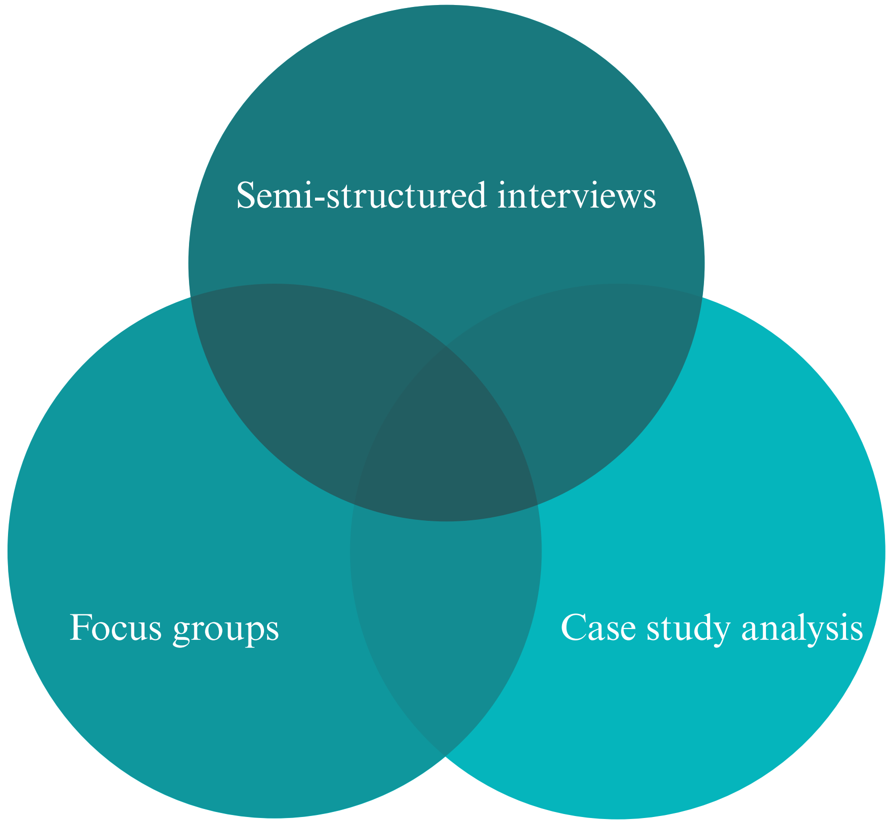


Research Approach – Data Collection

- **Semi-structured interviews with stakeholders (13, approx. 60 min. each)** with:
  - Experts from NASA, ESA, DLR, and leading agritech startups, e.g.
    - MEPA project head, DLR German Aerospace Center
    - CEO semilla - Think Like An Astronaut
    - SEMiLLA Sanitation head
    - CEO & Chief Scientist ASTRO FOOD
    - Controlled Environmental Systems expert
    - Space Exploration & Science Innovation Lead and Senior Expert Life Support & Habitability at THALES ALENIA SPACE

- **Focus group** (on space-inspired spin-off potential to address global challenges) with:
  - Analog astronauts of the Asclepios IV mission (Asclepios is a student-led community simulating space analog mission)

- **Case study analysis** of terrestrial applications of space agriculture:
  - **MEPA** (Mobile Emergency Plant-Growing Application) – Germany
  - **Enhancing Food Security in Canada's North with the AgNorth Modular Farm Concept**
  - **Abu Dhabi Controlled-Environment Horticulture Project** – UAE
  - **SEMiLLA by MELiSSA** – Sustainable space-inspired agriculture



Triangulated qualitative methods

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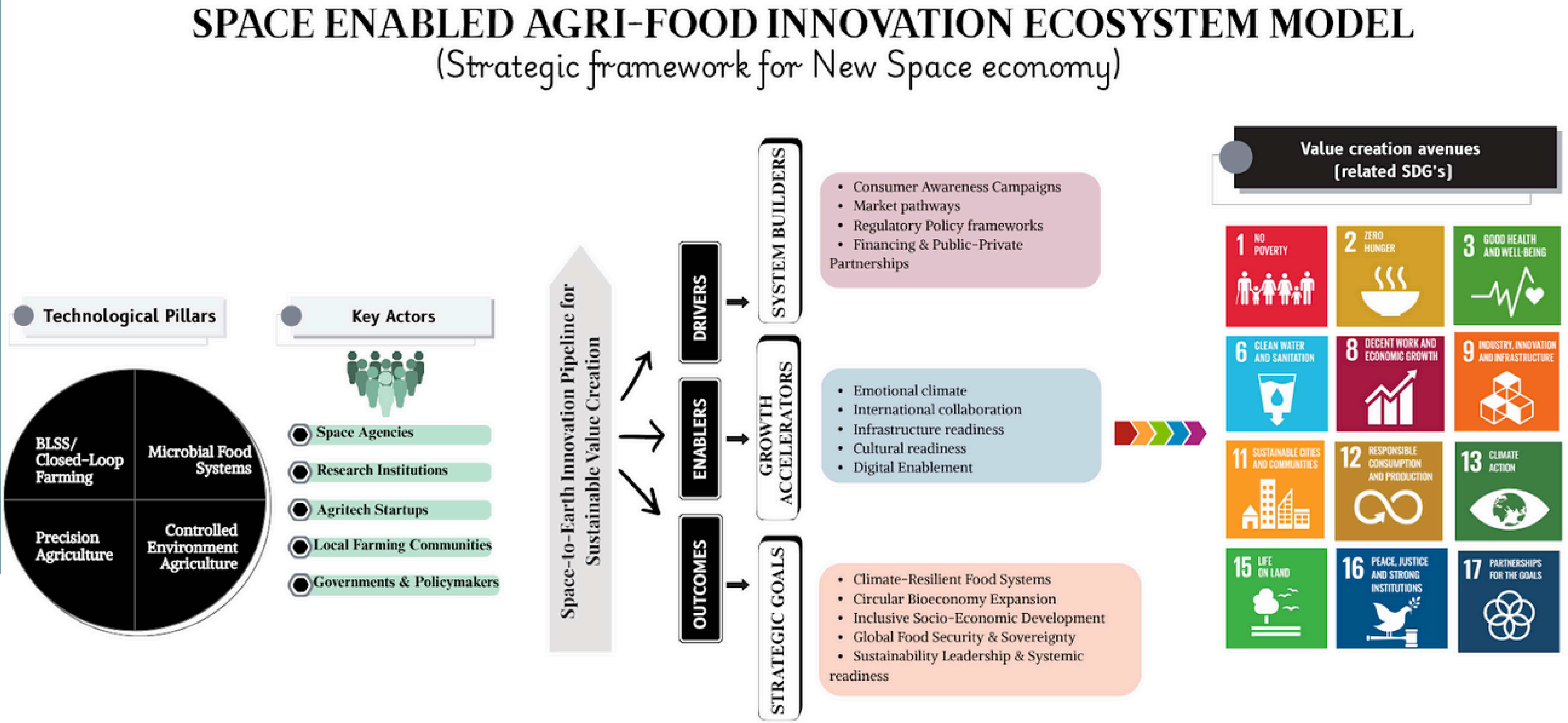
Research Approach- Ecosystem Model

- Exploring intersection of space technology, food systems sustainability, and innovation management



Preliminary findings: Key innovations from BLSS for Earth

Innovation	Terrestrial Potential
Closed-Loop Nutrient & Water Recycling	Transforms waste into safe irrigation and fertilizer inputs; cuts chemical use; closes nutrient loops for circular agriculture.
Controlled Environment Agriculture (CEA) Modules	Recipe-driven growth chambers adaptable to deserts, megacities, and disaster zones; ensures year-round, reliable harvests.
Photobioreactors & Algal Biofactories	Provide food, biofertilizer, oxygen, and carbon capture in one system; offer scalable solutions for climate mitigation and sustainable protein.
Microbial & Mycelium Processing	Converts organic waste into food, feed, biomaterials, and soil enhancers; supports ecosystem restoration in degraded lands.
3D Food Printing & Fabrication	Creates personalized nutrition and compact rations from side streams; vital for malnutrition relief and rapid crisis deployment.
Autonomous Environmental Control Systems	AI- and sensor-driven platforms to regulate crops, optimize inputs, and reduce labor intensity; enhances resilience in fragile supply chains.
Advanced Genomics & Crop Breeding	Develops stress-tolerant, nutrient-dense cultivars; addresses hidden hunger and climate-driven yield loss.
Ecosystem Monitoring & Biosensors	Real-time monitoring of soil, water, air, and microbiome health; ensures system safety, scalability, and traceability.
Modular & Deployable Habitat Units	Rugged BLSS-inspired pods for fast deployment in polar regions, deserts, refugee camps, or post-war landscapes; enable self-sustaining food systems.

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Preliminary findings: Challenges in BLSS Adoption

Challenge Area	Description (Space → Earth relevance)
Energy Intensity	High power demand for lighting, HVAC, and bioreactors; must be balanced with renewables for Earth-scale deployment.
System Complexity & Stability	Multi-compartment ecosystems require fine-tuned balance; risk of cascading failures if microbial/plant dynamics destabilize.
Scaling from Lab to Field	Proven at pilot/analogue scale (e.g., EDEN ISS), but still costly and logistically complex for large terrestrial applications.
Water & Waste Regulations	Wastewater recycling and microbial proteins face strict food safety and regulatory hurdles; sandbox frameworks are lacking.
Technology Readiness Gaps (TRL 4–6)	Many subsystems (e.g., bioreactors, waste-to-protein) are still mid-TRL; integration into commercial ecosystems remains limited.
Cultural & Social Acceptance	Algae-based foods, insect proteins, or 3D-printed meals may face resistance; palatability and cultural fit are critical.
Maintenance & Labor Burden	BLSS modules need trained operators and frequent monitoring; automation and AI are not yet fully autonomous.
Economic Viability	High CAPEX/OPEX relative to conventional farming; lack of established business models or financing instruments (impact bonds, nutrient credits).
Policy & Legal Frameworks	Unclear IP rights, dual-use controls, and absence of terrestrial "BLSS standards" slow down adoption.
Integration with Local Environments	Need for tailoring to diverse climates — e.g., desert, polar, urban slums — requires modular flexibility.

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Preliminary findings: Economic & Environmental Benefits

Economic Benefits	**Environmental Benefits**
Localized Production – Cuts logistics costs, reduces spoilage, boosts food sovereignty.	Resource Circularity – Recycles water, air, and nutrients; minimizes waste and pollution.
Reduced Input Costs – Lowers fertilizer, irrigation, and waste management expenses.	Reduced Transport Emissions – Shrinks food miles and CO_2 from global supply chains.
New Markets & Industries – Unlocks alt-proteins, biofactories, CEA, and bioplastics.	Carbon Capture – Algae/bioreactors scrub CO_2 and enable large-scale sequestration.
Innovation Spillovers – Dual-use AI, robotics, and biotech boost cross-sector efficiency.	Soil & Ecosystem Restoration – Microbial/mycelial cycles detoxify and restore soils.
Risk Diversification & Crisis Value – Ensures autonomy, lowers supply shock risks, aids disaster response.	Food Security & Nutrition – Stress-resilient, nutrient-dense crops fight malnutrition.

Preliminary findings: Strategic Roadmap for BLSS Integration

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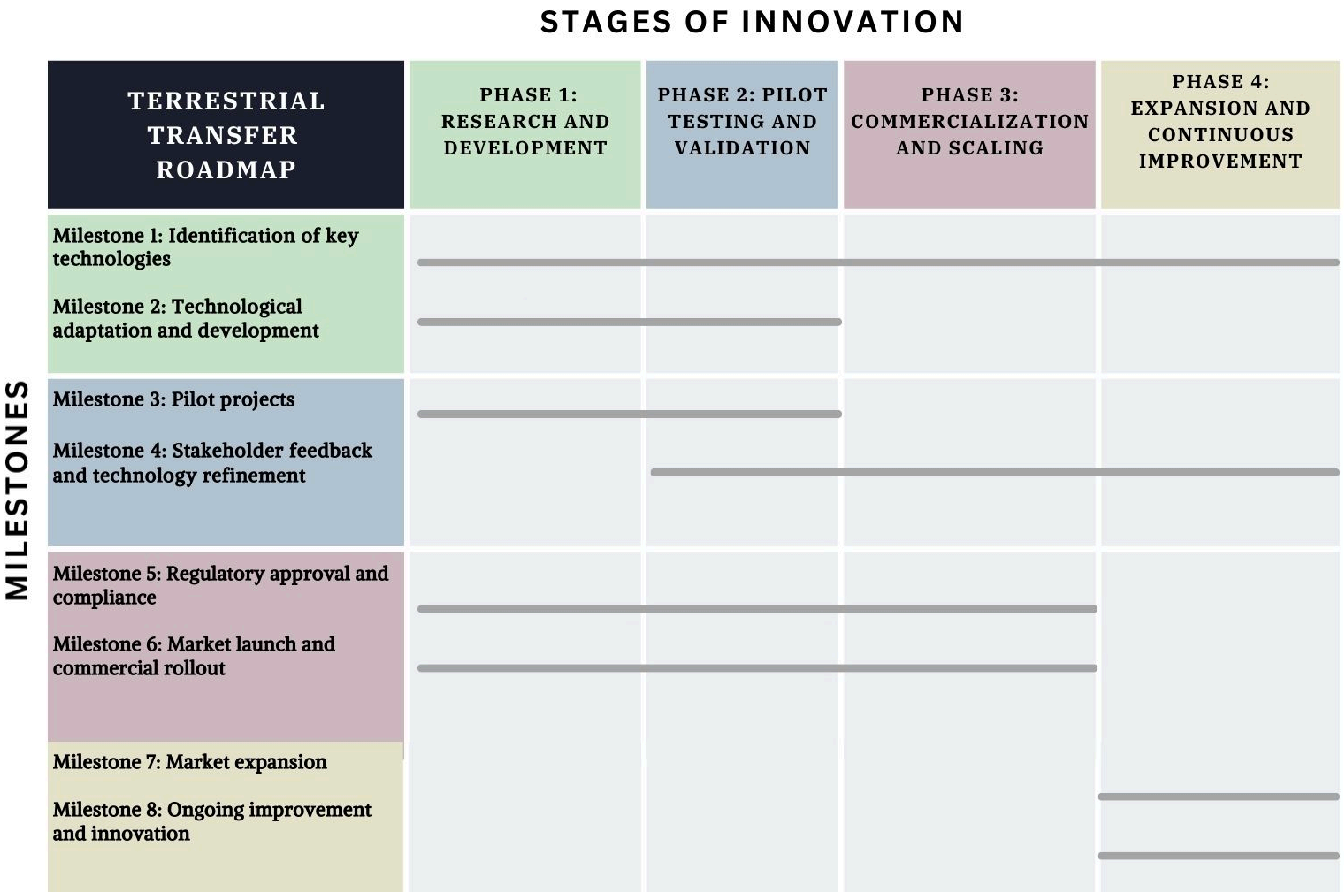

ESA Business Incubation Centres (BICs) — Enabling Space-to-Earth impact

- **Technology Transfer –** Adapt space innovations (EO, GNSS, comms, sensor systems) into sustainable applications.
- **Entrepreneurial Support –** Provide technical expertise, funding, and incubation programs to turn ideas into market-ready solutions
- **Cross-Sector Collaboration** – Foster open innovation networks, connecting startups with industry, research institutions, and investors to co-create and scale solutions.

Agriculture & Forestry

TREEO GmbH	**Removing CO2 and empowering the Global South through our single-tree monitoring technology**
Sam Dimension UG	**Smart Aerial Mapping for every farmer on every field**
Farmblick GmbH	**Digitalising agriculture with the farmers know-how aiming to increasing soil fertility is our central focus.**
Visioverdis GmbH	**Create a multi-layered facade greening system for urban living**
Biomassets GmbH	**Creating a robust ecosystem for biomass utilization linking right actors**
Bettersoil GmbH	**Revitalizing soil and digiliting crop rotation alternatives using satellite and soil data**
Woodkrew UG	**Linking traditional forestry with the space technologies for early detection to bark beetle infestations.**

Final Thoughts

From Space to Soil — Let Space-Born innovation nourish the world

Thank You!

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