National Aeronautics and Space Administration

NASA BPS

Space Biology Program Update

Precision Health Goal Update

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October 8th, 2024

Biological & Physical Sciences

Agenda

1 Program Update
- Solicitations
- Science Highlights
- Publications

2 Precision Health Roadmap Update

Program Update

- Solicitations

Solicitations: Space Biology

1. ROSES Program Element E.11 Consortium in Biological Sciences (NNH24ZDA001N-CIBS)

- Released in response to language in the Joint Explanatory Statement (page 67) accompanying the FY 2024 Consolidated Appropriations Act (P.L. 118-42)

- Emphasis:
  - From a consortium with biological sciences expertise
  - Carry out research investigations and/or conduct activities for the BPS Space Biology Program
  - Ground-based research
  - Address NASA's established space-relevant science interests: Human Health-relevant Science, Animal Science, Cellular Science, Plant Science
- Released: May 17th, 2024, Mandatory NOI: June 17th, 2024, Final Proposals: July 26th, 2024
- Selection will be announced in the near future.
- Award - $2.5 M total cost

2. ROSES 2024 Program Element E.9

Developed and in final revision stages.

Solicitations: BPS Collaborations

1. ISSNL and BPS:

Igniting Innovations: Science in Space to Cure Disease on Earth

- NLRA 2023-10 (Science in Space to Advance Cancer Research (issnationallab.org))
  - 5 awards: 4 awards studying cancer therapeutics, 1 award studying cardiovascular disease
- NLRA 2024-09 announced August 15th, 2024 (Science in Space to Cure Disease on Earth (issnationallab.org))
  - Emphases: Enhanced Models to Study Disease Mechanisms, Population and Disease Heterogeneity, Drug Screening and Development, Drug Delivery, Drug Resistance and Toxicity

2. Research Initiation Awards (with Science Mission Directorate)

- Reviews underway. Organized by SMD but selection of panel chairs and reviewers, and HQ person running the panel performed by Division personnel.
- Award: 2 years, total cost $300,000.
- Eligibility: Non-R1 institution, PI no federal funding in past 5 yrs, undergraduate research required.

Program Update

- Science Highlights
- Publications

FY24 Flight Mission Summary

Completed

- **Rodent Research-20**
  - Female Reproductive Health: Space Flight Induced Ovarian and Estrogen Signaling Dysfunction, Adaptation, and Recovery.
  - **PI:** Lane Christenson; University of Kansas Medical Center.
  - **Launch:** SpX-29 (Nov 10, 23). **Return:** SpX-29 (Dec 22, 23; Live animals), SpX-30 (Apr 30, 24; Frozen samples).

- **MVP-Cell-2A**
  - Experimental Evolution of *Bacillus subtilis* Populations in Space: Mutation, Selection and Population Dynamics.
  - **PI:** Craig Everroad; NASA Ames Research Center.
  - **Launch**: NG-19 (Aug 02, 23). **Return:** SpX-29 (Dec 22, 23).

- **MABL-A**
  - Role of Mesenchymal Stem Cells in Microgravity Induced Bone Loss.
  - **PI**: Abba Zubair; Mayo Clinic, Jacksonville.
  - **Launch:** NG-20 (Jan 30, 24). **Return:** SpX-30 (Apr 30, 24).

- **GEARS – 1st Flight**
  - Genomic Enumeration of Antibiotic Resistance in Space.
  - **PI:** Christopher Carr; Georgia Institute of Technology.
  - **Launch:** SpX-30 (Mar 21, 24). **Return:** SpX-30 (Apr 30, 24).

Upcoming

- **MeF1**
  - Megakaryocytes Orbiting in Outer Space and Near Earth.
  - **PI:** Hansjorg (Hans) Schwertz; University of Utah, Salt Lake City.
  - **Launch:** SpX-31 (NET Oct 30, 24). **Return:** SpX-31 (NET Nov 30, 24).

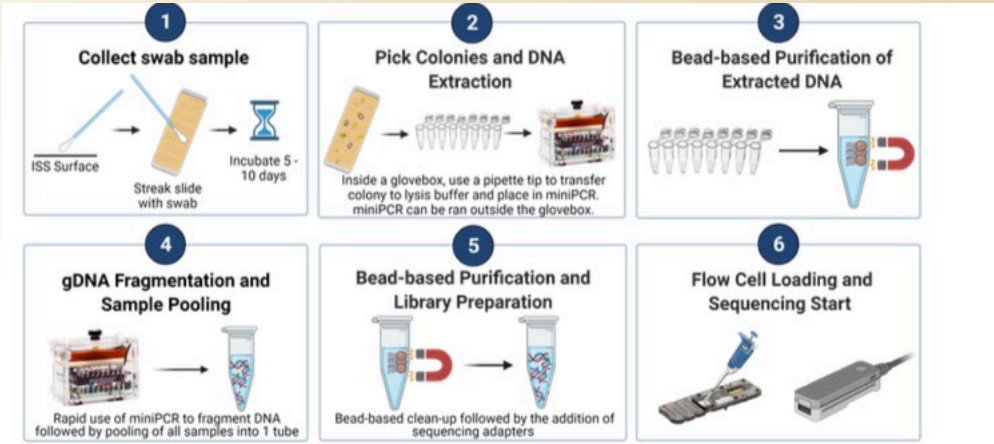
- **GEARS – 2nd Flight**
  - Genomic Enumeration of Antibiotic Resistance in Space.
  - **PI:** Christopher Carr; Georgia Institute of Technology.
  - **Launch:** SpX-31 (NET Oct 30, 24). **Return:** SpX-31 (NET Nov 30, 24).

Science Highlight

GEARS

Genomic Enumeration of Antibiotic Resistance in Space

- The first of up to 4 GEARS missions launched (Mar 21) and returned on SpX-30 (Apr 30).
- GEARS is quantifying the abundance of antibiotic resistant bacteria strains on ISS surfaces.
- GEARS leverages on-orbit genomic sequencing and complementary ground analyses.
- Subsequent GEARS missions will enable longitudinal analyses of antibiotic resistance (Next iterations on SpX-31 and SpX-32).



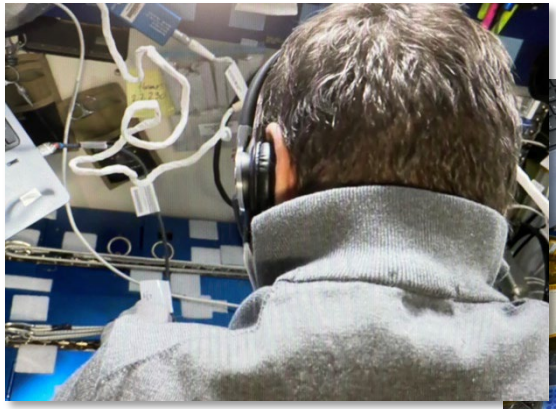
Flight Ops Requirements: Four sessions approximately 3 months apart in one year

MinION Sequencing data downlink from ISS to PI

Cold samples returned from ISS and transferring to the PI

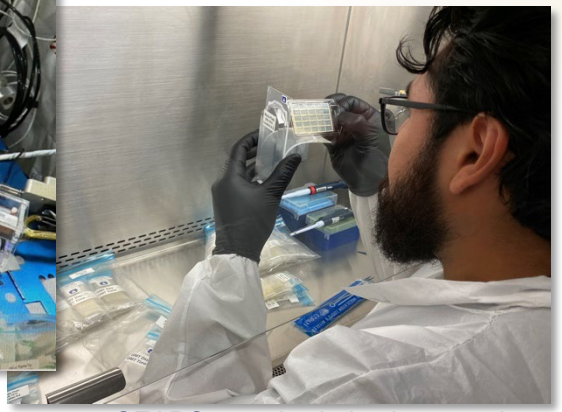
PI: Christopher Carr, Ph.D.
Georgia Tech

Co-PI: Sarah Wallace, Ph.D.
NASA JSC



Astronaut Dr. Michael Barrett preparing sequencing libraries

GEARS samples being sequenced on-orbit



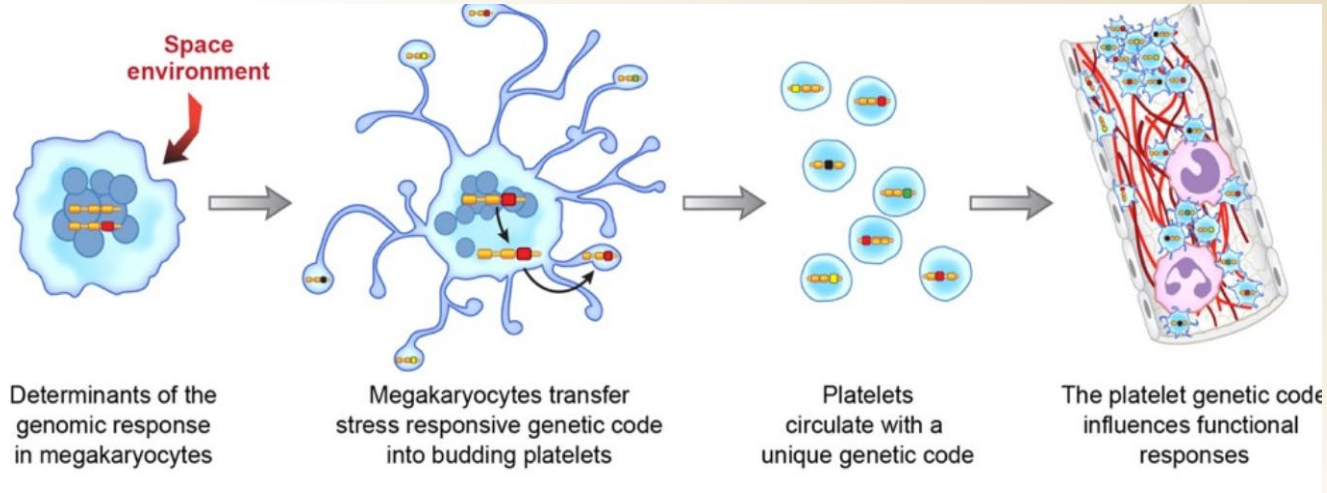
GEARS samples being inspected by Christian Mena after return

Images courtesy of Dr. Susan Wallace (NASA) and Dr. Christopher Carr (Georgia Tech)

Science Highlight

MeF1 – Megakaryocytes Orbiting in Outer Space and Near Earth: The Moon Study

- Megakaryocytes (MKs) and their progeny, platelets (PLTs), are dynamic effector cells which bridge the inflammatory, immune, and hemostatic continuum.
- Astronauts experience unexpected clot formation[1,2,] and dysregulated systemic inflammation[3] potentially caused by altered PLT function.



PI: Dr. Schwertz

Ground-based Specific Aim 1
Determine changes in human Megakaryocyte (MK) transcriptome, proteome, functionality and Platelet (PLT) production under exposure to ***simulated spaceflight conditions*** (microgravity simulation and/or simulated galactic cosmic rays (GCR)).

Flight-based Specific Aim 2
Identify how megakaryopoiesis and thrombopoiesis are altered in spaceflight in Low-Earth orbit (LEO), including gene expression, cell morphology, and function, under microgravitational and GCR conditions ***onboard the International Space Station (ISS). Launching on SpX-31 (Oct 31, 2024).***

Flight-based Specific Aim 3
Determine how spaceflight alters PLT gene expression, number, and function using ***isolated PLTs from astronauts (pre- and post-ISS flight).***

Image from Task Book: https://taskbook.nasaprs.com/tbp/index.cfm?action=public_query_taskbook_content&TASKID=16112.

Publications

OSDR Database Increases Publications From Past Awards

506
Studies

970
Datasets

45
Species

>80
Assays

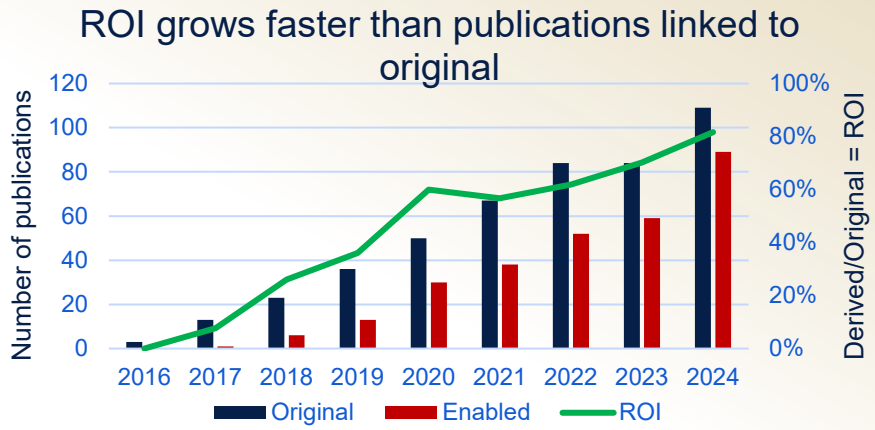
>160TB
Data

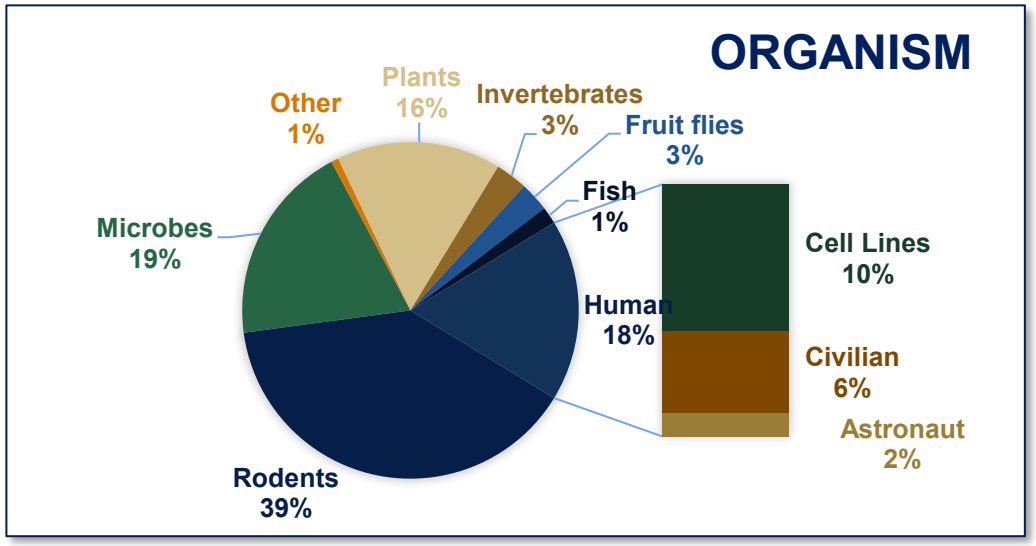
109
Original Publication linked to OSDR

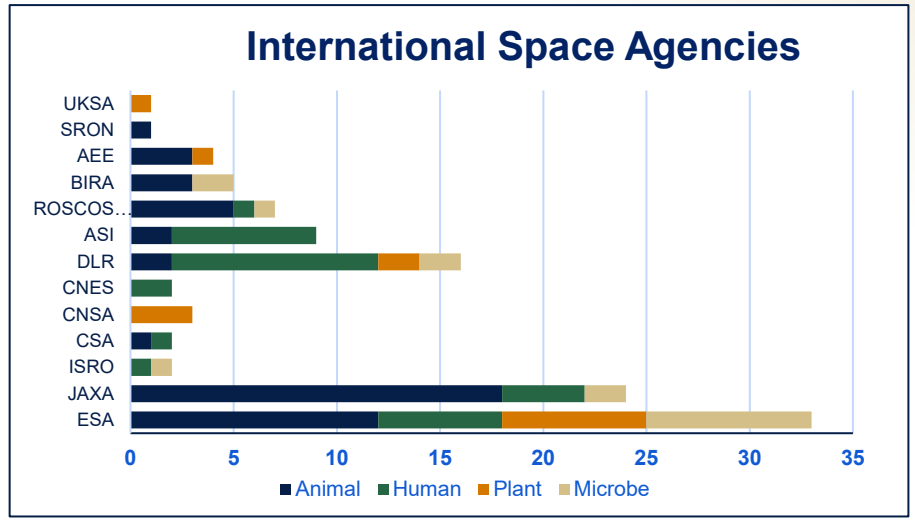
89
Enabled Publication linked to OSDR

80+
Presentations linked to OSDR

150+
Datasets used in enabled publications







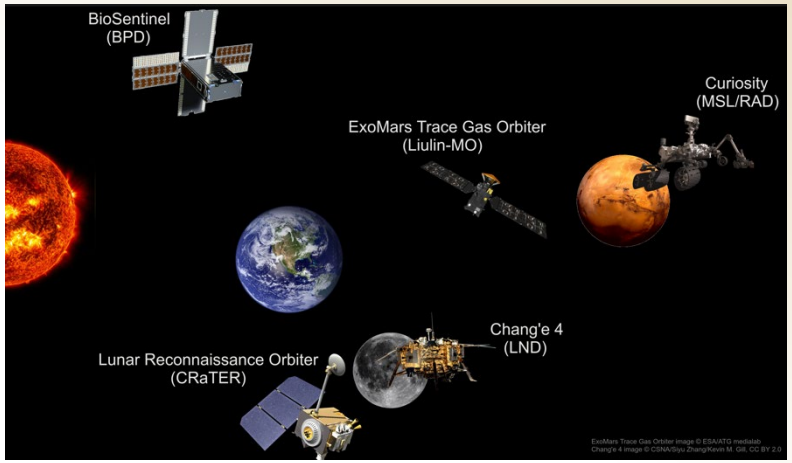
Open Science Highlight

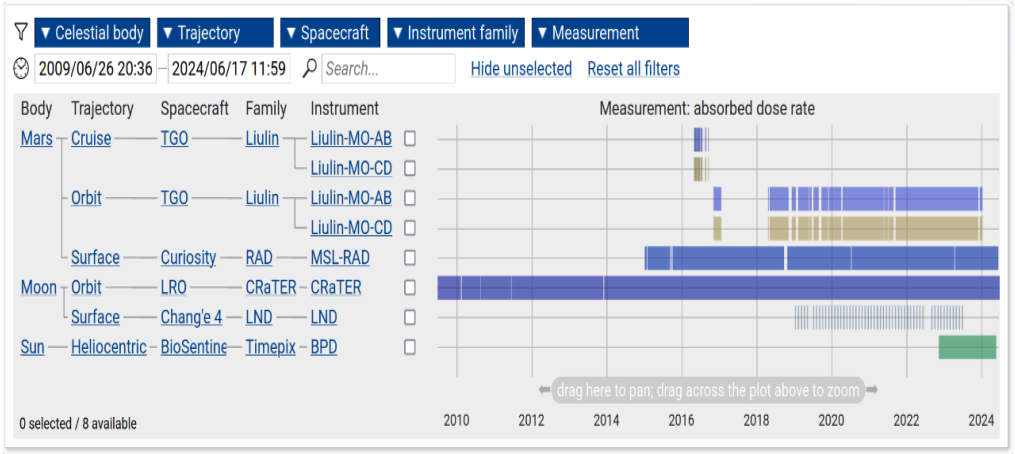
OSDR's RadLab Portal: New Instruments and Data Propel Open Space Radiation Research Beyond Low Earth Orbit

Repository Visualization team unveiled the latest updates to the RadLab Portal. This latest update introduces new instruments, data, and significant performance improvements. Notably, it now incorporates a range of instruments from various space missions, including

- -BioSentinel CubeSat in heliocentric orbit is Earth-trailing, currently ~50 million km from Earth (deep space)
- CRaTER instrument on the Lunar Reconnaissance Orbiter (LRO) in Moon orbit
- Liulin-MO instrument aboard the ExoMars Trace Gas Orbiter (TGO), operational during Mars cruise and in Mars orbit
- MSL/RAD instrument aboard the Curiosity rover on the surface of Mars

Through its web interface, users can query, visualize, inspect, and download data, enabling analyses such as time series plots of radiation readings, pairwise comparisons of detector outputs, and geospatial visualizations of radiation dose and flux as recorded by different detectors, while its API enables sophisticated programmatic analyses of various combinations of these data.



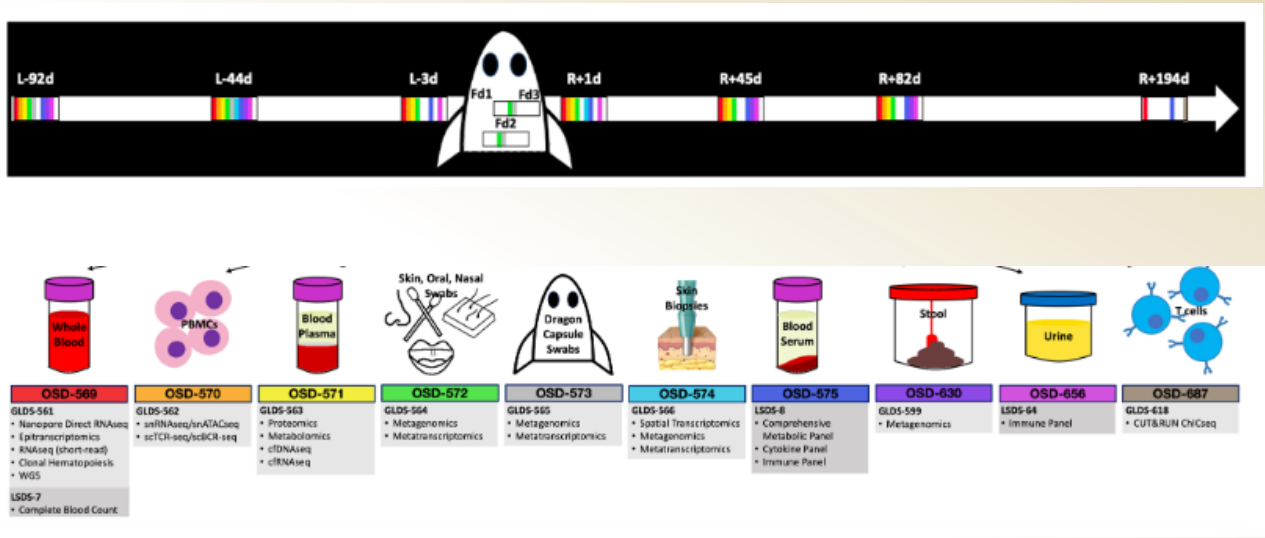


Images from OSDR (NASA). The top image used images from: ExoMars TGO image by @esa/ATG medialab (http://tinyurl.com/4hrn87wf). Chang'e 4 image by CSNA/Siyu Zhang/Kevin M. Gill, licensed CC-BY 2.0 (http://tinyurl.com/5d36rt4p).

Publication Highlight

The Space Omics and Medical Atlas (SOMA)

The Space Omics and Medical Atlas (SOMA) package is comprised of manuscripts, data, protocols, and code from I4 mission and space biology experiments. This collaboration with over **100 institutions from >25 countries worked together to release 40+ publications in Nature Press.**



- OSDR AWGs, OSDR Team members, and Ames scientists contributed to **17 papers** across six Nature Journals

- Data generated from I4 mission, **10 studies with 25 total datasets**, is available in OSDR. Processed data made publicly available, while private raw data will require an application process with board approval to gain access

Image credit: https://www.nature.com/articles/s41526-024-00393-5

Publication Highlight

Proteomic and phosphoproteomic characterization of cardiovascular tissues after long term exposure to simulated space radiation (Kidane et al. 2024)

- Bishawi et al. (2022) showed that mice exposed GCR develop cardiovascular dysfunction by 12 months post-radiation (changes in arterial elastance and elastin fragmentation in the aorta)
- This study measured protein levels in hearts and blood plasma at 8 months to better understand mechanism
- Pathways related to inflammation were the most highly perturbed in the heart and plasma. Most differentially expressed proteins were reduced after GCR suggesting reduced protein synthesis.
- Neutrophil extracellular traps (NETs) were demonstrated to be increased in GCR5-ion irradiated hearts at 12-month post irradiation.
- NETs play a fundamental role in combating bacterial pathogens, modulating inflammatory responses, inflicting damage on healthy tissues, and escalating vascular thrombosis
- Findings suggest that a single exposure to GCR5-ion results in long-lasting changes in the proteome and that these proteomic changes can potentiate acute and chronic health issues for astronauts.

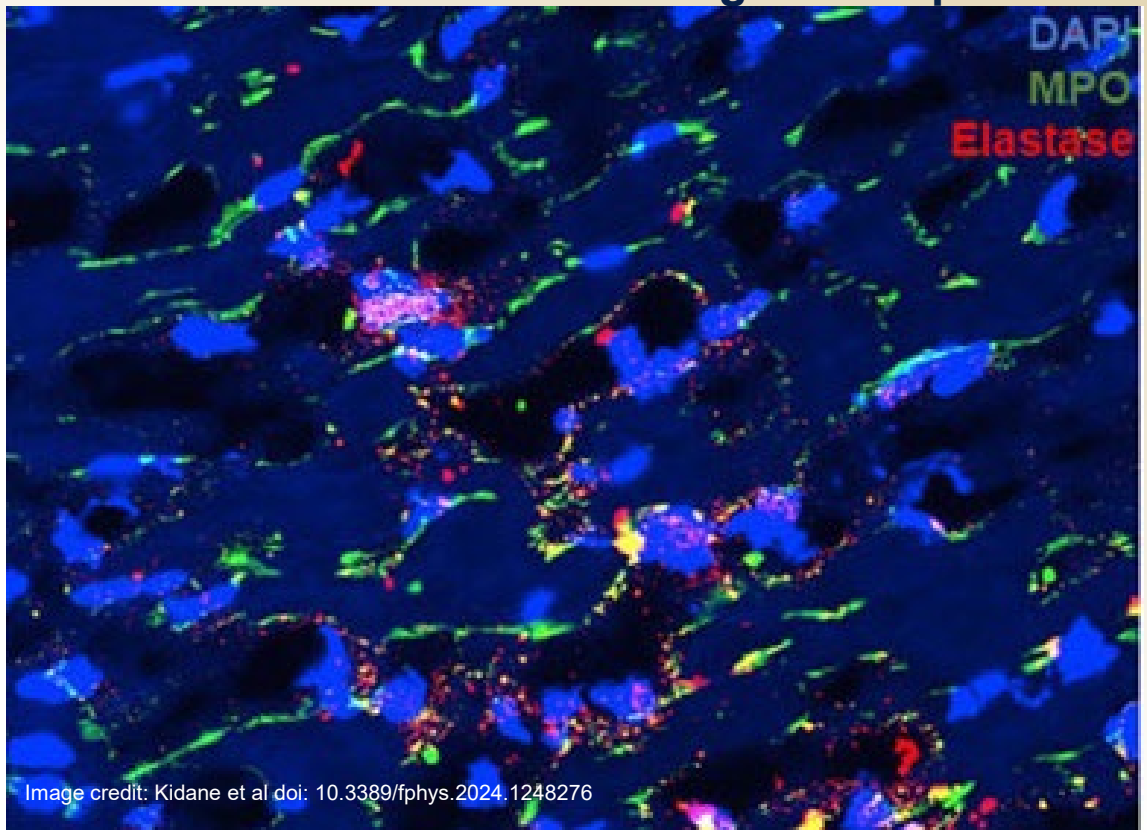


Image credit: Kidane et al doi: 10.3389/fphys.2024.1248276

Neutrophil extracellular traps (NETs) were increased at 12-months post irradiation. NETs are characterized by the colocalization of extracellular DNA (blue) and neutrophil granule proteins such as MPO (green) and elastase (red).

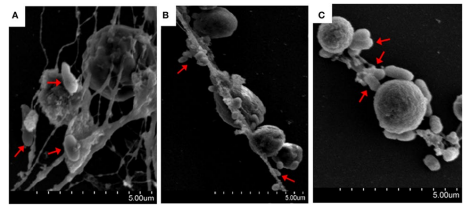


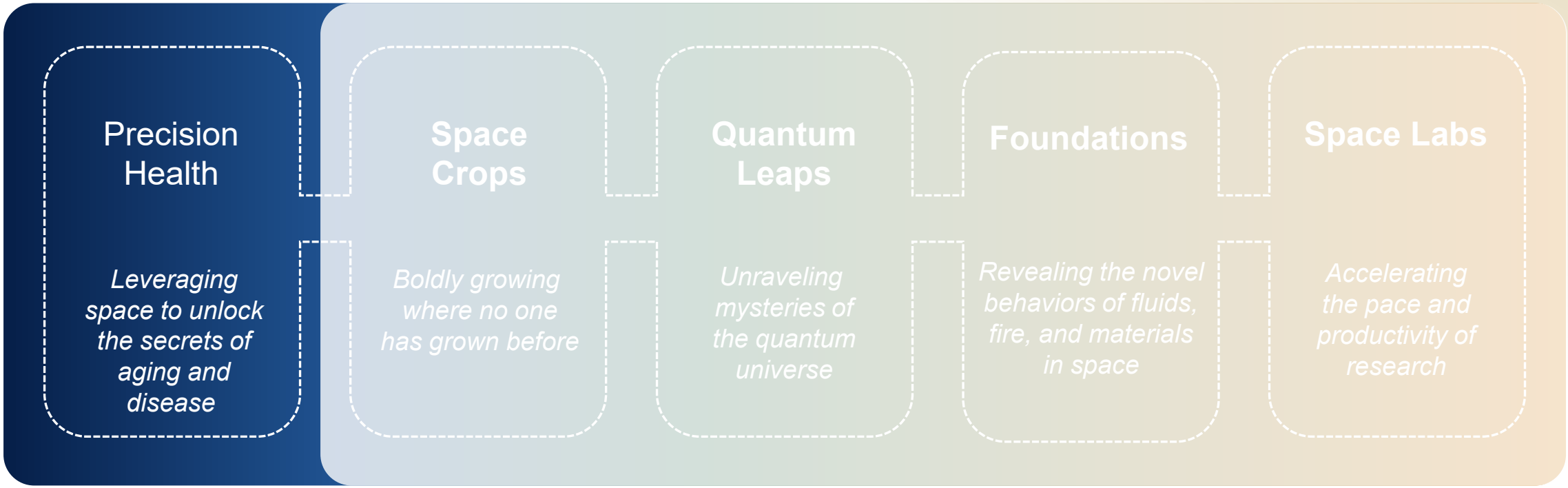
Image credit: Zhao et al doi: 10.3389/fimmu.2017.00290

Funding: 80NSSC22K0253, A Multi-Omics and Multi-Species Examination of Combined Environmental Stressors of Space Exploration to Dr. Dawn Bowles. 2020 Space Biology NNH20ZDA001N-SB E.12

Roadmap Update

Thriving in Space

Revolutionary research in extraordinary places.



Precision Health

Leveraging space to unlock the secrets of aging and disease

- **Investigate at a fundamental level how and by what mechanisms physiological/biological systems change due to space-relevant stressors**

- **Provide fundamental knowledge to:**
  - understand the onset and progression of disease/aging.
  - advance new disease treatments.
  - advance countermeasure development.
  - improve microbial control in the space vehicle environment.

Decadal Alignment: Precision Health

Adapting to Space (Theme 1)

- Transition to/from space (KSQ1)
- Genetic diversity & life history (KSQ2)
- Interactions between organisms (KSQ3)

Living and Traveling in Space (Theme 2)

- Multigenerational effects (KSQ4)

Probing Phenomena Hidden by Gravity or Terrestrial Limitations

- Mechanisms for sensing and responding (KSQ8)

Research Campaign: Advances BLiSS objectives

Notional Concept: Polar Radiation of Model Organisms (PROMO)

Science Goal: Precision Health

Themes:

- Tissue Chips
- Accelerated Aging and Disease
- Microbiology
- Systems Biology

Disciplines:

- Open Science
- Integrative Physiology
- Microbiome
- Synthetic Biology

Multidisciplinary Elements:

Space-Relevant Stressors

- Altered Gravity
- Space Radiation
- Altered Day and Night Cycle
- Lunar and Martian Regolith
- Altered Magnetic Field
- Altered Atmospheric Pressure
- Altered Partial Pressure of Gases

Model Systems

- Tissue Chips/ Organoids
- Invertebrate
- Vertebrate
- Microbes

Identifying Gaps : Precision Health

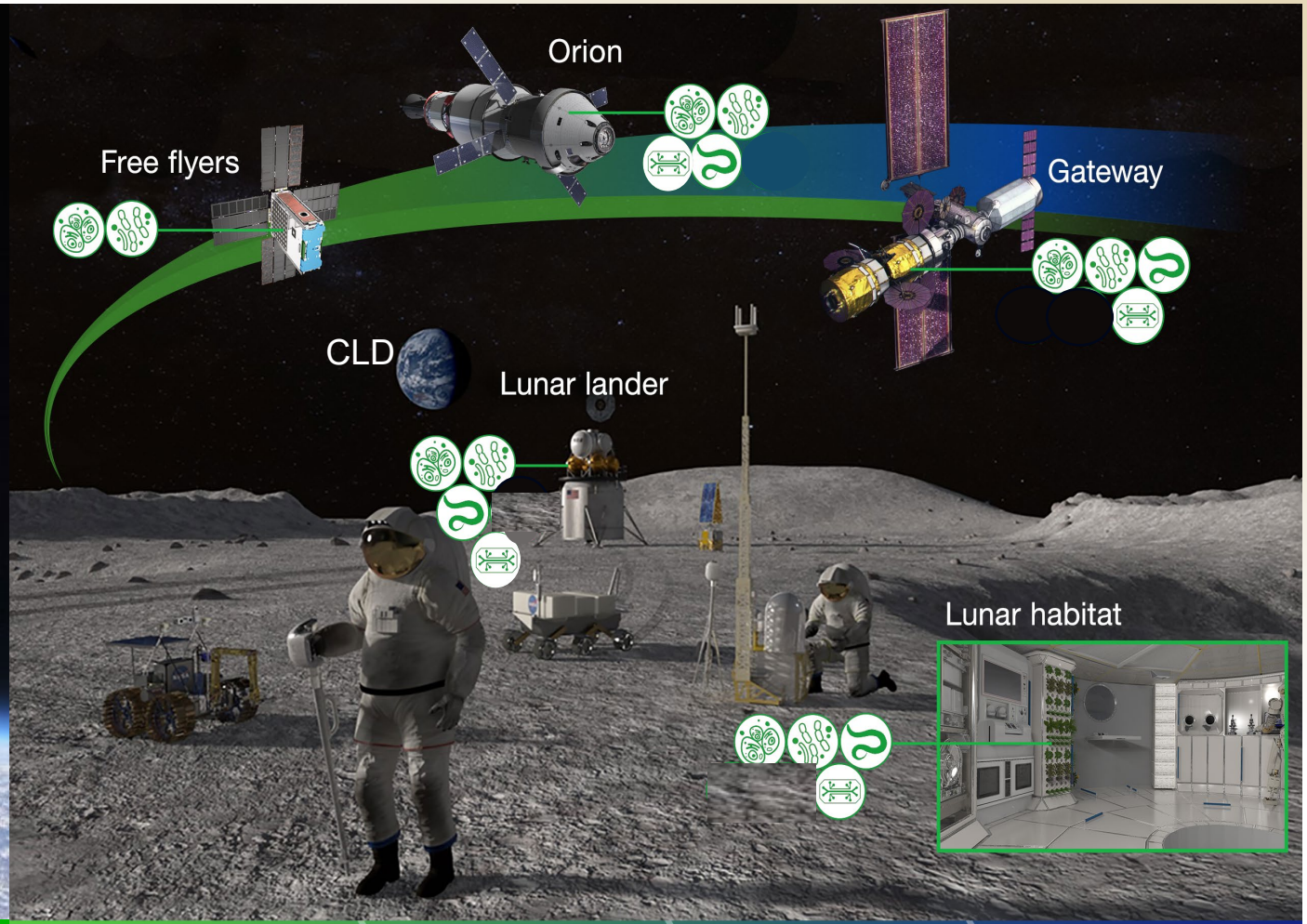
Science: 82 active grants

Transition to/from space (KSQ1)
Genetic diversity & life history (KSQ2)
Interactions between organisms (KSQ3)
Multigenerational effects (KSQ4)
Mechanisms for sensing and responding (KSQ8)

Discipline	Number of Active Grants (Flight , Ground)				
	KSQ1	KSQ2	KSQ3	KSQ4	KSQ8
Cardiovascular	15	0	0	2	10
Pulmonary	0	0	0	0	0
Neural Systems	15	3	1	2	11
Integrated Systems	12	1	0	1	7
Musculoskeletal	18	3	0	3	18
Immune System	8	2	3	2	4
Microbiome	23	17	14	19	13
Reproduction	2	0	0	2	0

Discipline	Number of Active Grants (Flight , Ground)							
	Gravity	Radiation	Regolith	Atmospheric Pressure	Day/ Night	Magnetic Field	Gas Pressure	Space flight
Cardiovascular	5	2	0	0	0	0	1	6
Pulmonary	0	0	0	0	0	0	0	0
Neural Systems	7	7	0	0	1	0	1	3
Integrated Systems	4	3	1	0	0	0	1	6
Musculoskeletal	8	1	0	0	1	0	0	9
Immune System	1	0	0	0	0	0	0	5
Microbiome	5	2	1	0	0	0	0	19
Reproduction	0	1	0	0	0	0	0	2

Opportunities: Multiple Platforms



Current situation | Near Term | Long Term

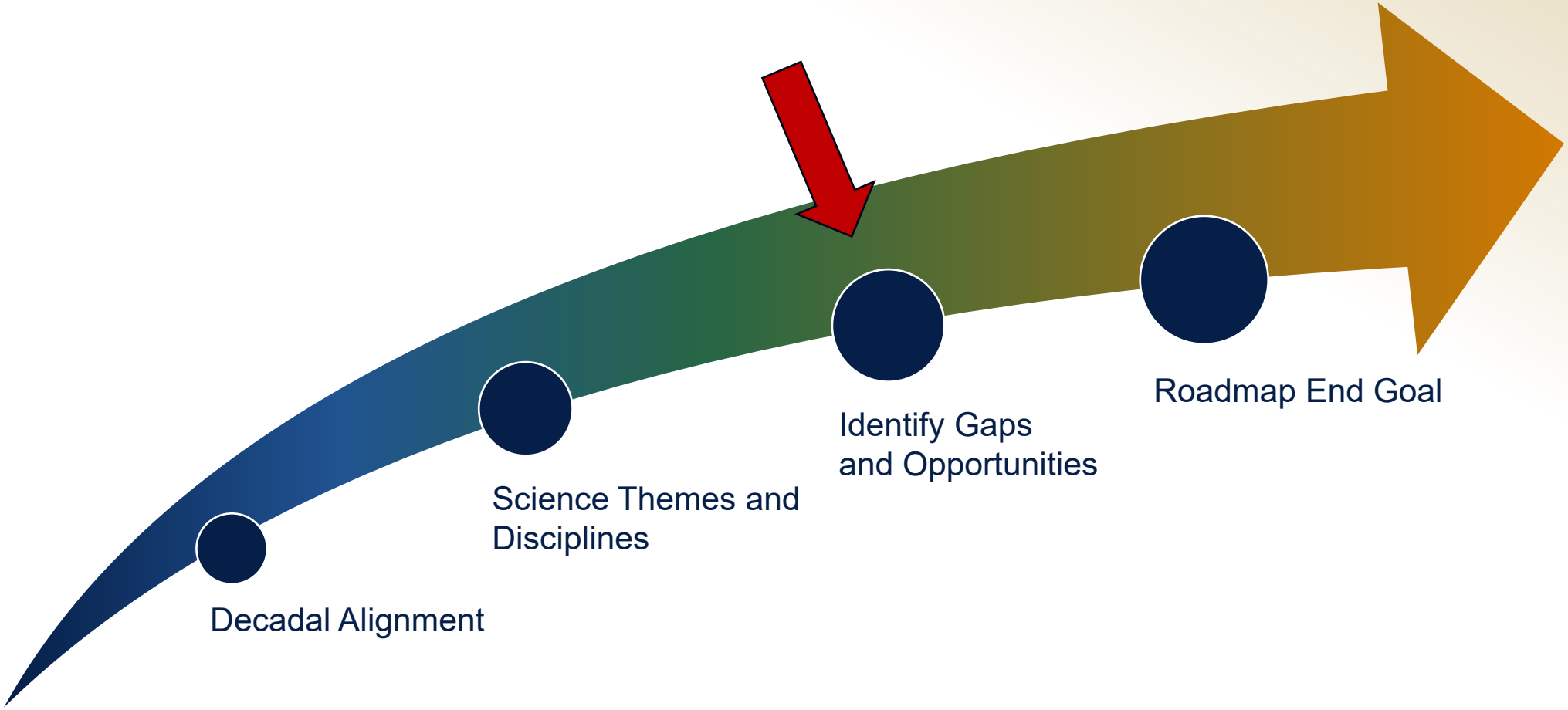
Images: Credit NASA (modified from https://www.nasa.gov/reference/international-space-station/) and modified from doi: 10.2478/gsr-2024-0001

Gaps & Opportunities: Precision Health

- **Technology:**
  - For in situ analysis on ISS/ CLDs
  - For autonomous experiments on Artemis/ Gateway/ Free flyers
  - For data science and data access

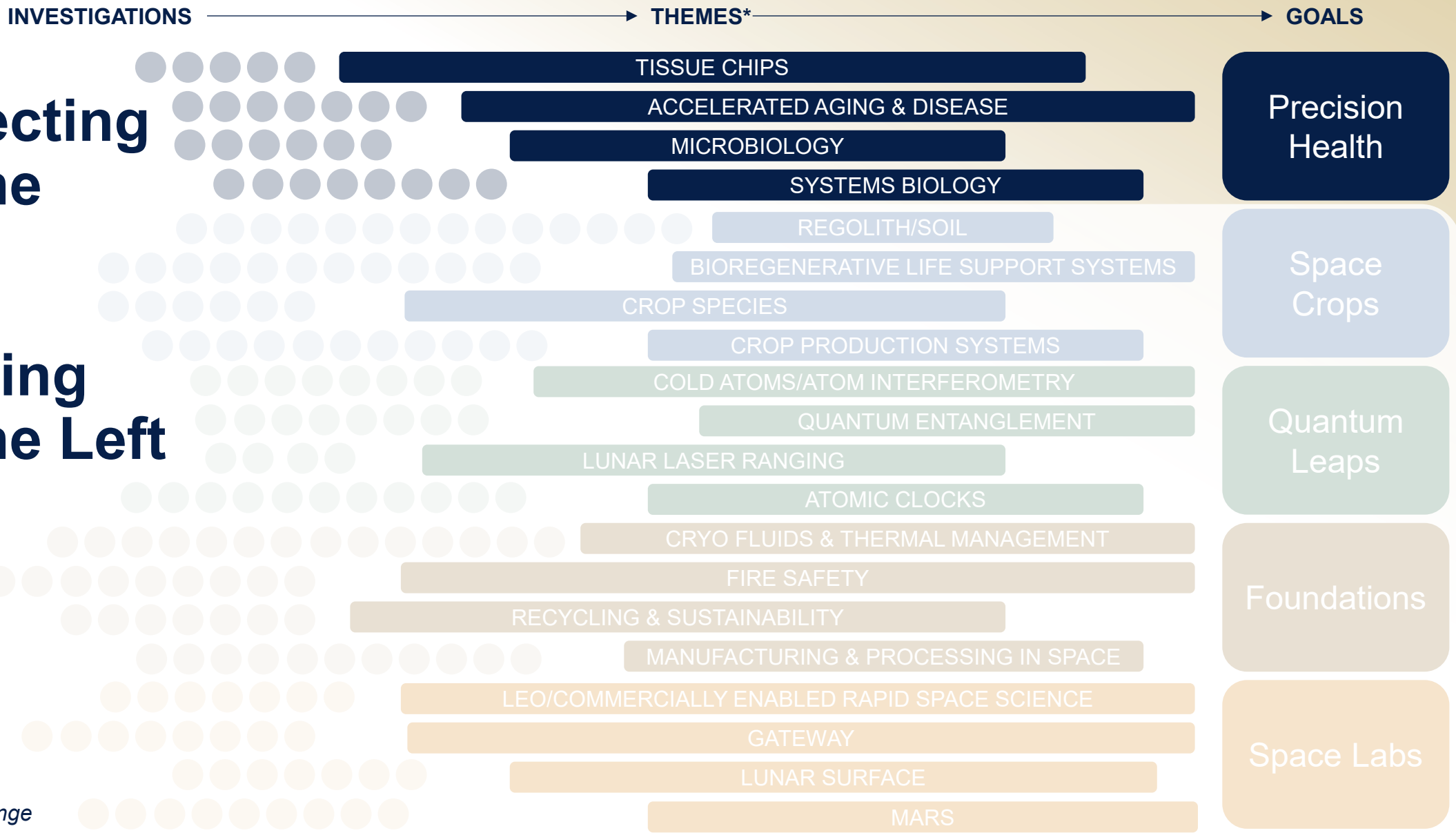
- **Partnerships:**
  - ISSNL (e.g. Igniting Innovation)
  - HRP (e.g. NSRL usage, joint solicitations)
  - InSPA
  - HHS Agencies (e.g. Tissue Chips Longevity Awards)
  - International (e.g. Equipment usage MHU-8, OSDR)

Goal Overview: Precision Health



Architecting from the Right,

Executing from the Left



**Draft – subject to change*