National Aeronautics and Space Administration

NASA BIOLOGICAL AND PHYSICAL SCIENCES (BPS) DIVISION

Decadal Science Road Map

Interactive Version 1.2 | Sept 15, 2025

In response to the National Academies of Sciences, Engineering, and Medicine's *Thriving in Space: Ensuring the Future of Biological and Physical Sciences Research: A Decadal Survey for 2023-2032*

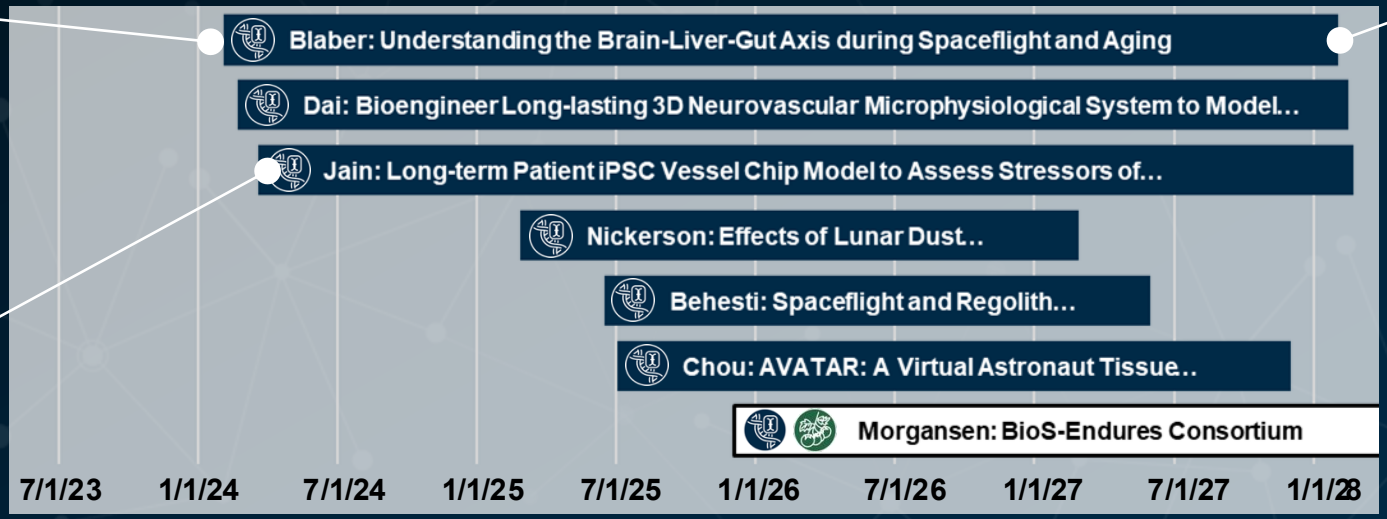
Tips for Reading this Interactive Road Map

Legend
- Ground
- Flight
- Consortium

Click on Decadal Goal and Theme titles and icons to navigate to related pages in the Road Map. Click on items in the Table of Contents (next slide) to navigate to the desired slide.

Legend shows Ground and Flight investigations and other activities, such as Consortia

Each box represents an investigation or set of activities, and the length of the box shows the duration of the activity. Data is updated periodically from The NASA Task Book.



The color of each box and the circular icon in the left side of the box represent the Decadal Science Goal the investigation supports. Some investigations support more than one Decadal Goal or Theme.

The title of each investigation appears in the box. Click on the Goal icon in each bar to be taken to the full activity record in The NASA Task Book online in your web browser.

Click the "back" arrow to return to the last slide you were on

Legend shows meaning of BPS Science Goal icons

Click here to email the Road Map Point-of-Contact for more information or troubleshooting

Precision Health | Space Crops | Quantum Leaps | Foundations | Space Labs

Need Help?

Table of Contents

*Themes marked with an asterisk will link to funded projects in future

Need Help?

Key Science Questions (KSQs) from the 2023 Decadal Survey

KSQ 01	How does the space environment influence biological mechanisms required for organisms to survive the transitions to and from space, and thrive while off Earth?
KSQ 02	How do genetic diversity and life history influence physiological adaptation to the space environment?
KSQ 03	How does the space environment alter interactions between organisms?
KSQ 04	What are the important multi generational effects of the space environment on growth, development, and reproduction?
KSQ 05	What principles guide the integration of biological and abiotic systems to create sustainable and functional extraterrestrial habitats?
KSQ 06	What principles enable identification, extraction, processing, and use of materials found in extraterrestrial environments to enable long-term, sustained human and robotic space exploration?
KSQ 07	What are the relevant chemical and physical properties and phenomena that govern the behavior of fluids in space environments?
KSQ 08	What are the mechanisms by which organisms sense and respond to physical properties of surroundings and to applied mechanical forces, including gravitational force?
KSQ 09	What are the fundamental principles that organize the structure and functionality of materials, including but not limited to soft and active matter?
KSQ 10	What are the fundamental laws that govern the behavior of systems that are far from equilibrium?
KSQ 11	What new physics, including particle physics, general relativity, and quantum mechanics, can be discovered with experiments that can only be carried out in space?

From the National Academies of Sciences, Engineering, and Medicine's *Thriving in Space: Ensuring the Future of Biological and Physical Sciences Research: A Decadal Survey for 2023-2032*

BPS Decadal Science Goals

- Thriving in Space: Revolutionary research in extraordinary places

Precision Health

Leveraging space to unlock the secrets of aging and disease

Space Crops

Boldly growing where no one has grown before

Quantum Leaps

Unraveling mysteries of the universe

Foundations

Revealing the novel behaviors of fluids, fire, and materials in space

Space Labs

Advancing research in space, on any platform, anywhere

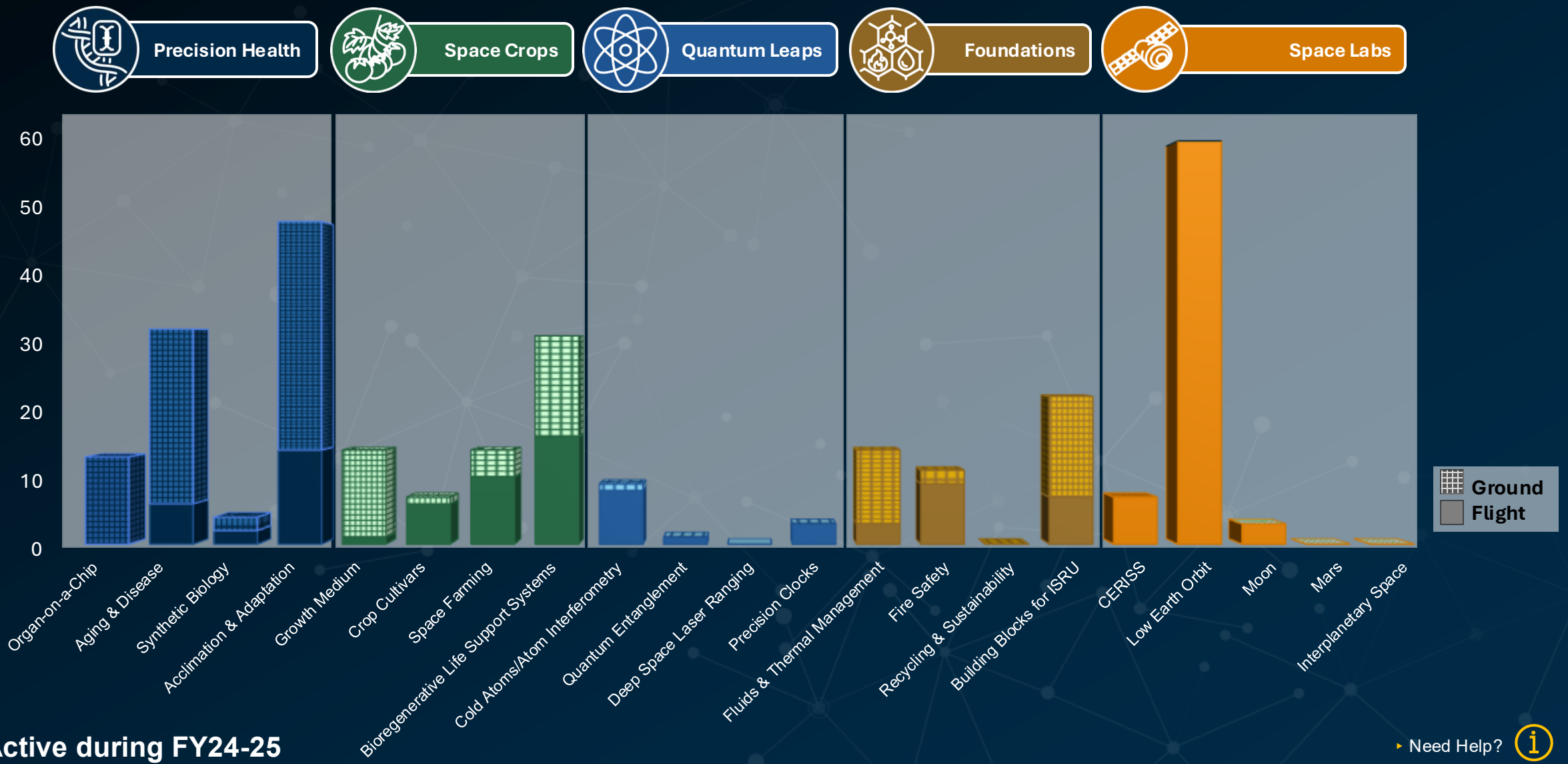
BPS Road Map FY25 Framework

BPS Program	Exploration Science				
Key Science Questions Addressed	1,2,3,4,5,8	1,2,3,4,5,8	9,10,11	5,6,7,8,9,10	ALL
Goal	Precision Health	Space Crops	Quantum Leaps	Foundations	Space Labs
Theme	Organ-on-a-Chip	Growth Medium	Cold Atoms/Atom Interferometry	Fluids & Thermal Management	Commercially Enabled Rapid Space Science (CERISS)
	Aging & Disease	Crop Cultivars	Quantum Entanglement	Fire Safety	Low Earth Orbit (LEO)
	Synthetic Biology	Space Farming	Deep Space Laser Ranging*	Recycling & Sustainability*	Moon
	Acclimation & Adaptation	Bioregenerative Life Support Systems	Precision Clocks	Building Blocks for ISRU	Mars*
					Interplanetary Space*

*Themes marked with an asterisk will link to funded projects in future

Need Help?

BPS Ground and Flight Research*



* Active during FY24-25

Need Help?

Sunsetting and Emerging Science

Goal	Sunsetting	Timeframe	Emerging Science	Space Labs (CERISS, LEO, Moon, Mars, Interplanetary Space)
Precision Health	▸ Research on individual systems	▸ 1-5 years	▸ Systems biology ▸ Integrated physiological systems	▸ LEO ▸ Partial gravity ▸ Interplanetary space
Space Crops	▸ Gene expression in whole plants (transcriptomics) studies in 1g & ISS microgravity	▸ 1 year	▸ Cell-type specific 'omics' in space environments ▸ Genes relevant for Earth-to-Space transitions	▸ Partial gravity ▸ Suborbital flights
Quantum Leaps	▸ Cold Atom Lab (CAL)	▸ 5 years	▸ Bose-Einstein Condensate and Cold Atom Lab (BECCAL)	▸ LEO
Foundations	▸ ISS Combustion Integrated Rack	▸ 1-3 years	▸ Flammability of Materials on the Moon (FM2)	▸ Partial gravity

The NASA BPS Director presented these examples to the Committee on Biological and Physical Sciences in Space on April 2, 2025

PRECISION HEALTH

Leveraging space to unlock the secrets of aging and disease

Stressors encountered during space travel can affect human health, including bone and muscle loss, immune system function, microbes, and other biological responses. NASA research could provide vital information needed to help protect astronauts during future deep-space missions and advance the prevention and treatment of disease for people on Earth.

BPS Precision Health Themes

GOAL:

Precision Health

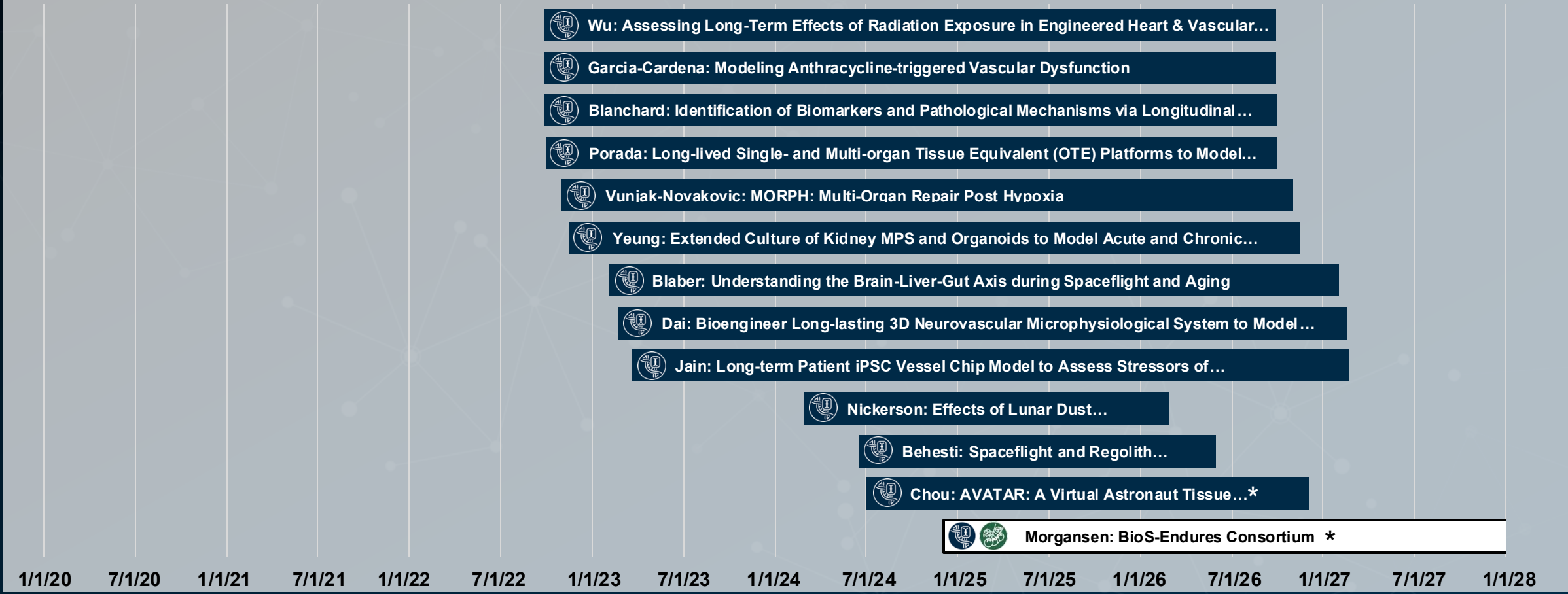
Human exploration exposes astronauts and their microbiomes to spaceflight stressors. The four themes of Precision Health will provide a mechanistic understanding of the physiological, cellular, and genetic alterations that occur during space travel. NASA will expand knowledge of the short- and long-term risks of prolonged deep-space exploration, as well as the onset and progression of disease and dysfunction that could affect astronauts beyond low Earth orbit.

THEME:	Organ-on-a-Chip	Aging & Disease	Synthetic Biology	Acclimation & Adaptation
THEME DEFINITION:	Organ-chips are tiny devices that act like small versions of human organs. Made with human cells, the chips mimic how tissues, such as the brain, heart, liver, or dozens of other organs, work. NASA research will focus on validating and leveraging these models to assess the impacts of deep-space stressors on human health. Insights could advance personalized medicine in space and on Earth.	Research to-date has revealed aging-like phenotypic changes that suggest spaceflight accelerates the onset and progression of age-related disease. NASA research aims to clarify this linkage by using relevant model systems and computational modeling and analyses. Work will focus on identifying the underlying mechanisms of spaceflight aging and disease and understanding if severity is altered by the duration or destination of the mission.	Microbes can be used as tools for protecting human health. NASA will investigate ways to engineer molecules that are beneficial to astronaut health, such as vitamins or pharmaceuticals essential for long-duration missions. This could include developing beneficial bacteria to counteract disease or expanding capabilities such as biosensors for measuring low oxygen. Synthetic biology research could yield advancements benefitting agriculture, medicine, and manufacturing.	Organisms, including humans and microbes, may acclimate and adapt to living in a spaceflight environment. Acclimation is the short-term physiological responses organisms undergo, while adaptation involves permanent genetic changes resulting from exposure to selective environmental pressures. NASA research will focus on understanding the mechanisms of acclimation and adaptation and determining whether changes are beneficial or associated with dysfunction and disease.

Funded Precision Health Research

Legend: Ground, Flight, Consortium

Organ-on-a-Chip



*Task Book link coming soon

Funded Precision Health Research

Legend: Ground, Flight, Consortium

Aging & Disease

- Mao: Space Flight Environment Induces Remodeling of Vascular Network and Glia-vascular Communication in Mouse...
- Christenson: Female Reproductive Health: Space Flight Induced Ovarian and Estrogen Signaling Dysfunction, Adaptation, and Recovery...
- Komatsu: Bone Remodeling under Differential Gravitational Environments
- Narayanan: Simulated Microgravity-Induced Systemic Inflammation and Its Impact on Circulatory Function and Structure
- Lawler: Upstream Regulation of Nox2 and Skeletal Muscle Atrophy During Microgravity and Countermeasure Development
- Delp: Radiation, Simulated Weightlessness and Countermeasures: Effects on Cerebral and Coronary...
- Blaber: The Role of the Hematopoietic Stem Cell in the Hepatic Response to Simulated Spaceflight
- Fuller: Adaptation of Mouse Systems Physiology to Artificial Gravity via Centripetal Acceleration: Timing, ...
- Lu: Develop a Novel Single-Cell Biodosimetry for Brain Genomic Instability and Neurodegeneration...
- McGee-Lawrence: Osteocyte Plasma Membrane Disruptions
- Ramasubramanian: Thrombosis in Microgravity
- Zubair: Role of Mesenchymal Stem Cells in Microgravity Induced Bone Loss, Part A (MABL-A and MABL-B)

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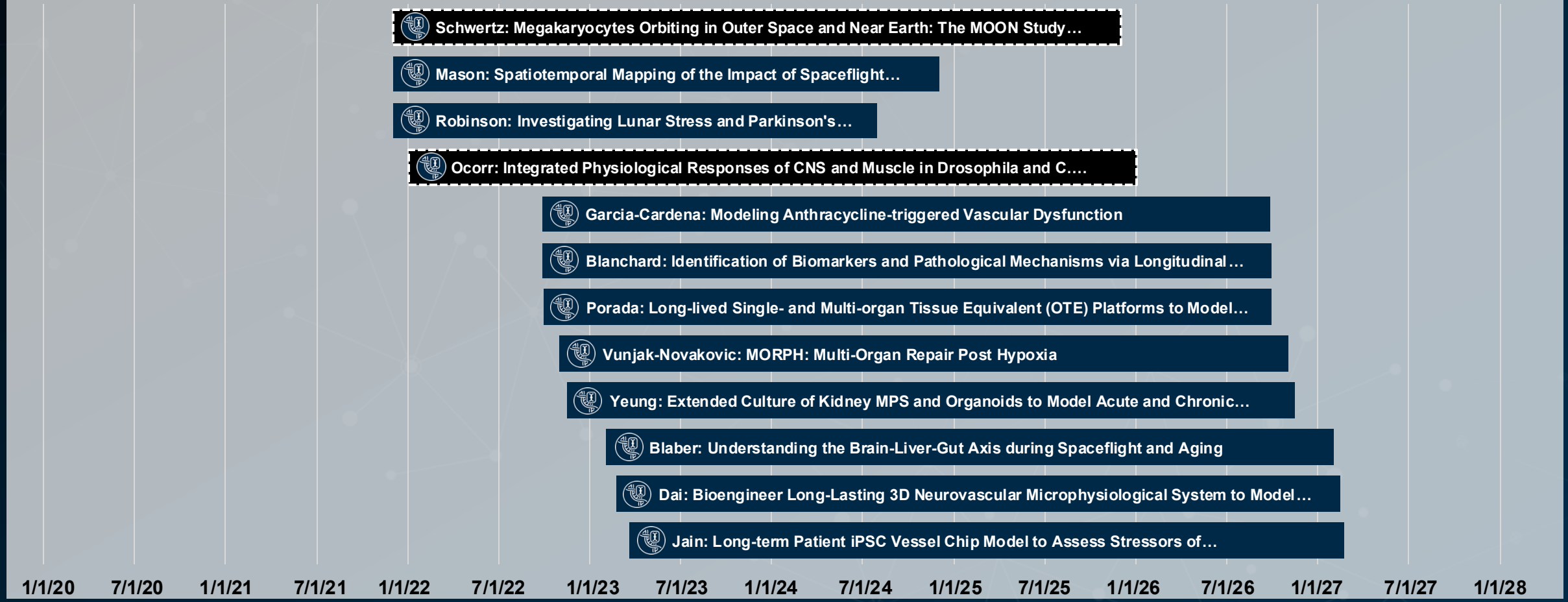
Funded Precision Health Research

Legend: Ground, Flight, Consortium

Aging & Disease



Funded Precision Health Research

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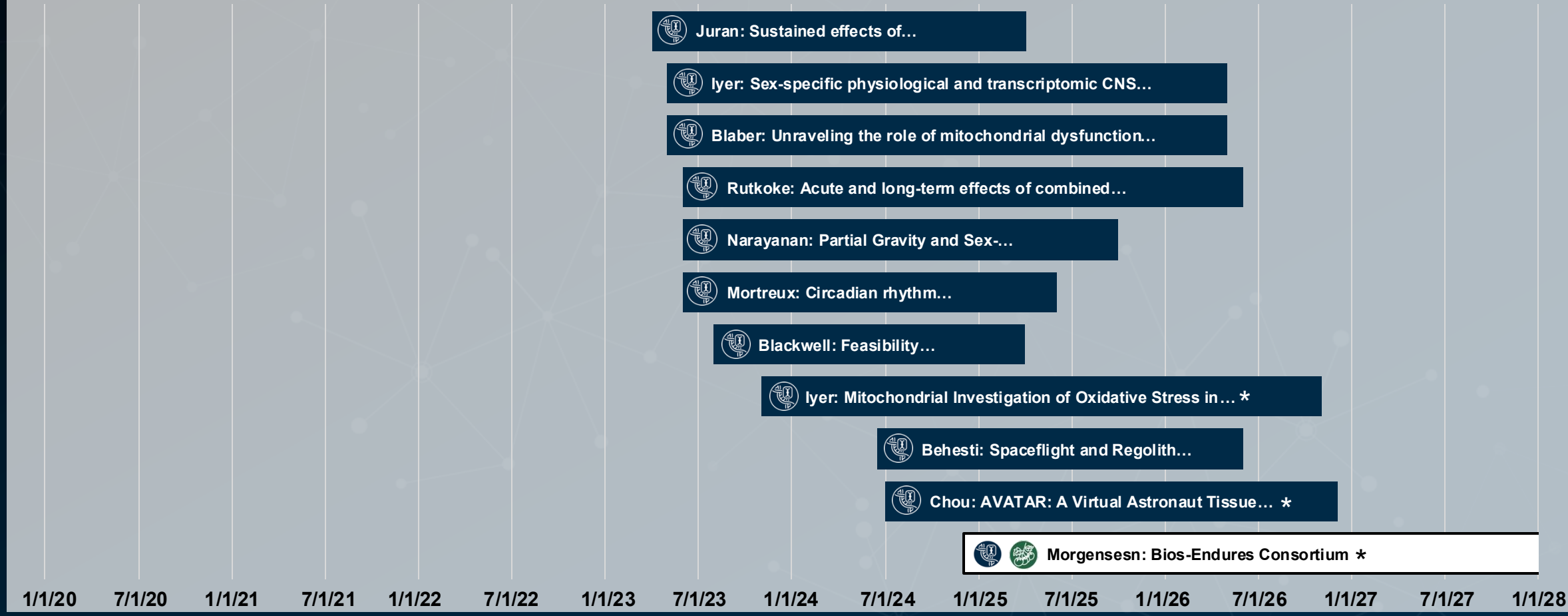
Aging & Disease



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Funded Precision Health Research

Legend
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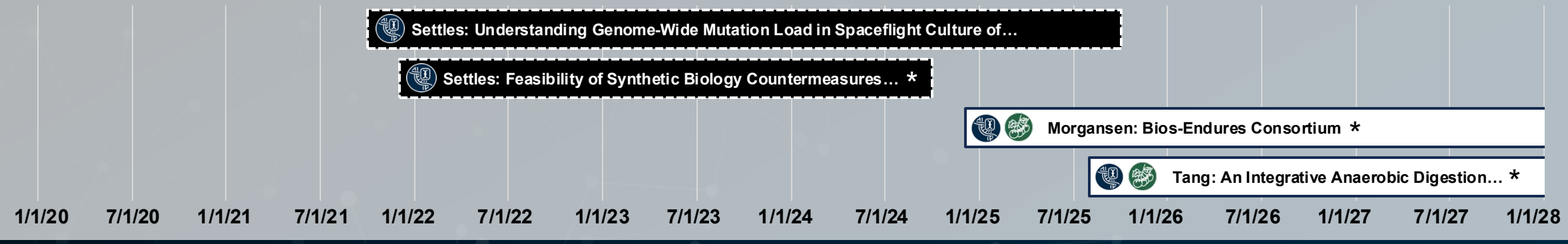
- Flight
- Consortium

Synthetic Biology



*Task Book link coming soon

Funded Precision Health Research

Legend: Ground, Flight, Consortium

Acclimation & Adaptation

- Mao: Space Flight Environment Induces Remodeling of Vascular Network and Glia-vascular Communication in Mouse Retina
- Everroad: Experimental Evolution of Bacillus subtilis Populations in Space; Mutation, Selection and Population Dynamics
- Christenson: Female Reproductive Health: Space Flight Induced Ovarian and Estrogen Signaling Dysfunction, Adaptation, and Recovery
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Funded Precision Health Research

Legend: Ground, Flight, Consortium

Acclimation & Adaptation

- Vitaterna: Effects of Partial Gravity on Multi-system Mammalian Physiology: Microbiome and Related Systems
- Carr: Enterococci Evolution in Space: Environmental Adaptations, Antibiotic Resistance, and Clinical…
- Lu: Develop a Novel Single-Cell Biodosimetry for Brain Genomic Instability and…
- Ramasubramanian: Thrombosis in Microgravity
- McGee-Lawrence: Osteocyte Plasma Membrane Disruptions in Skeletal Adaptation to Loading and Unloading
- Zubair: Role of Mesenchymal Stem Cells in Microgravity Induced Bone Loss, Part A (MABL-A and MABL-B)
- Rice: Assessing the Impact of Agr Quorum Sensing on Staphylococcus…
- Santa Maria: Acquisition of Beneficial Mutations Through Adaptive Evolution…
- Settles: Understanding Genome-Wide Mutation Load in Spaceflight Culture of…
- Schwertz: Megakaryocytes Orbiting in Outer Space and…
- Robinson: Investigating Lunar Stress and Parkinson's…
- Mason: Spatiotemporal Mapping of the Impact of Spaceflight on the Heart and Brain

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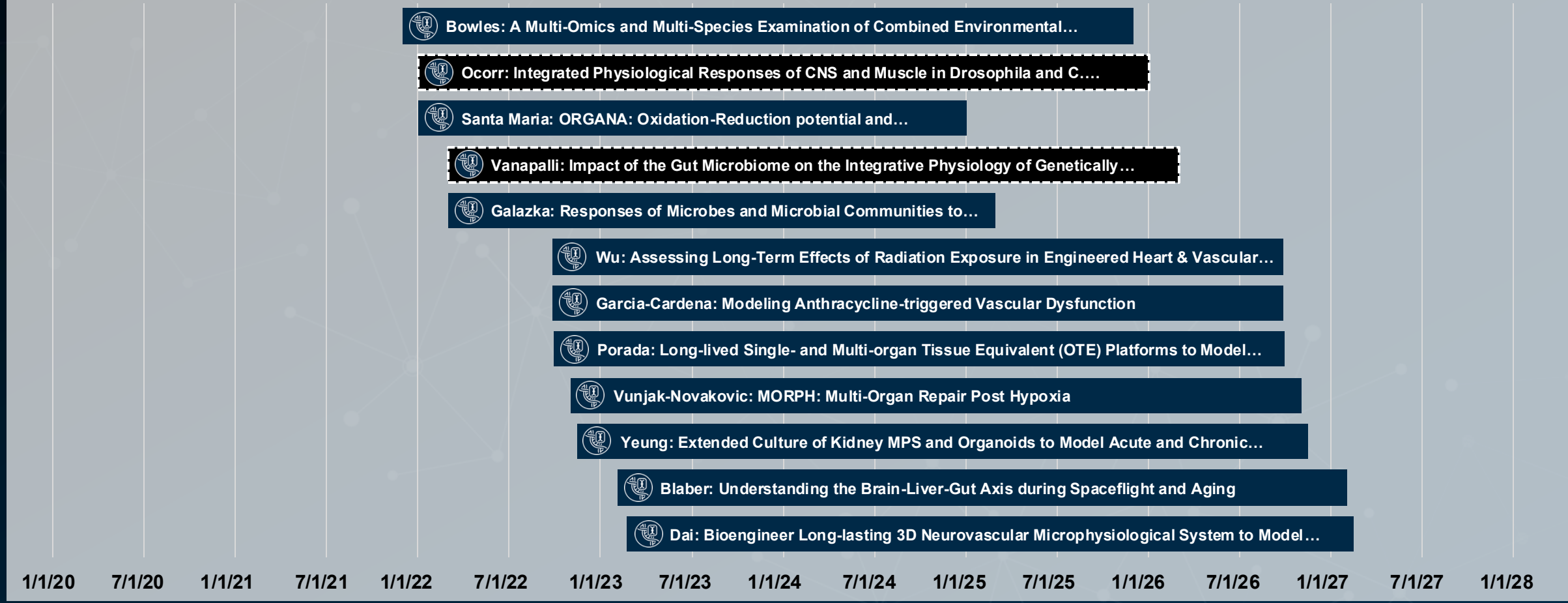
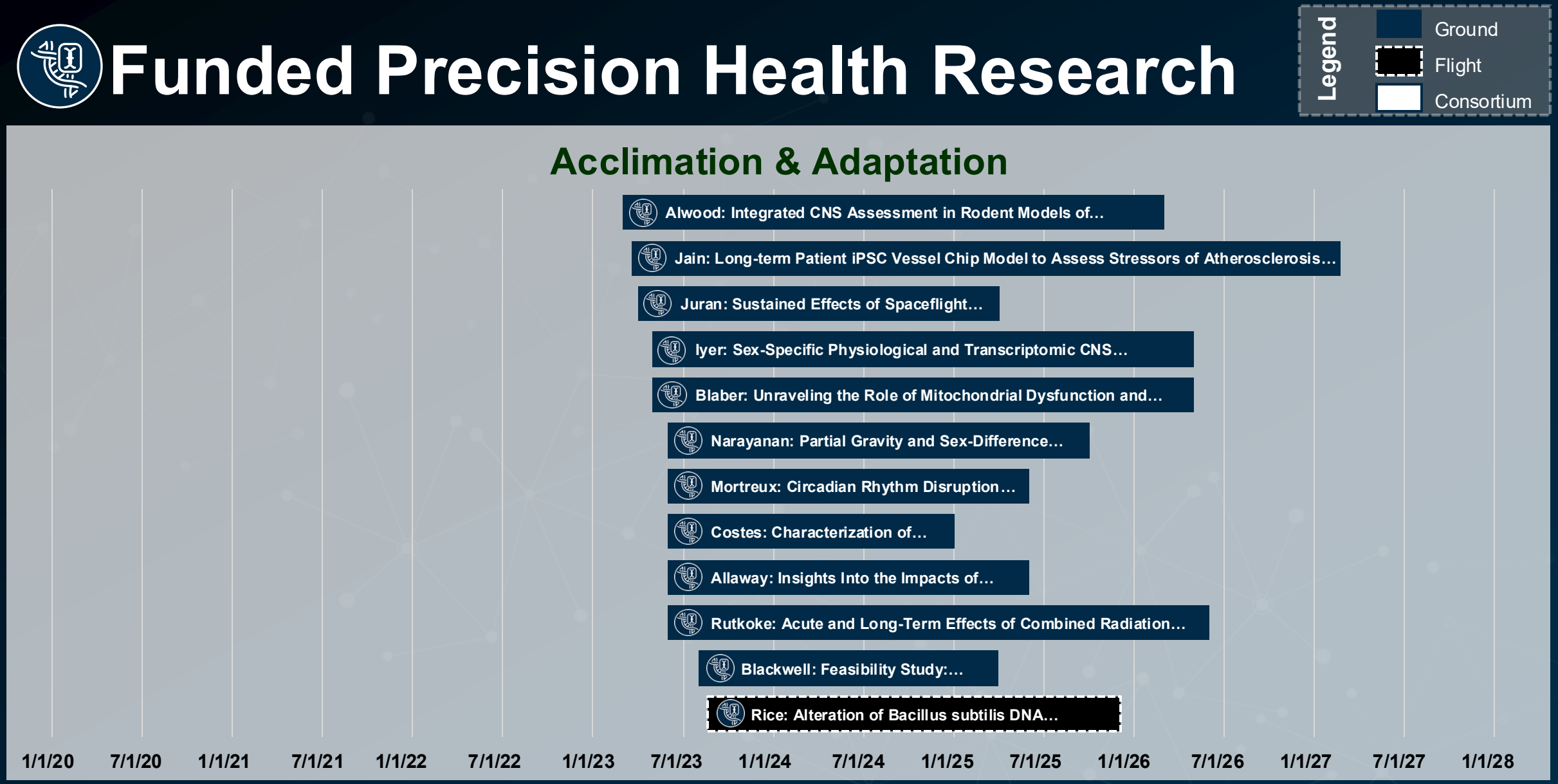
Funded Precision Health Research

Legend: Ground, Flight, Consortium

Acclimation & Adaptation



Funded Precision Health Research



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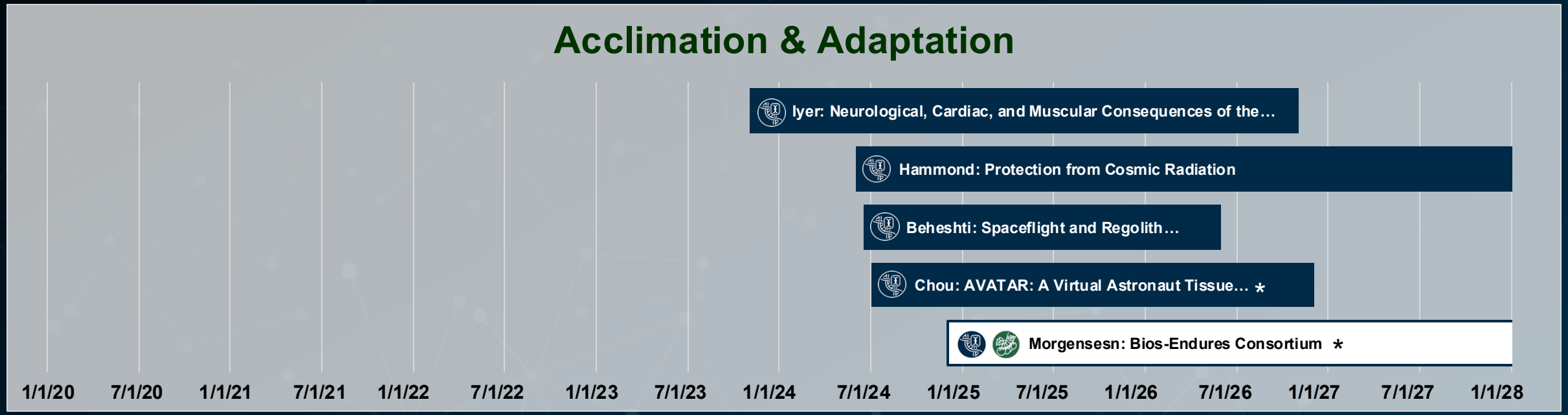


*Task Book link coming soon

SPACE CROPS

Boldly growing where no one has grown before

To go farther and stay longer in space, crew will need sustainable sources of food. Crops can provide fresh food, benefit astronaut mental well-being, and improve space habitats. Studying how plants adapt to harsh conditions in space can lead to agricultural innovations that support deep-space exploration and improve farming in austere environments on our home planet.

BPS Space Crops Theme Definitions

GOAL:

Space Crops

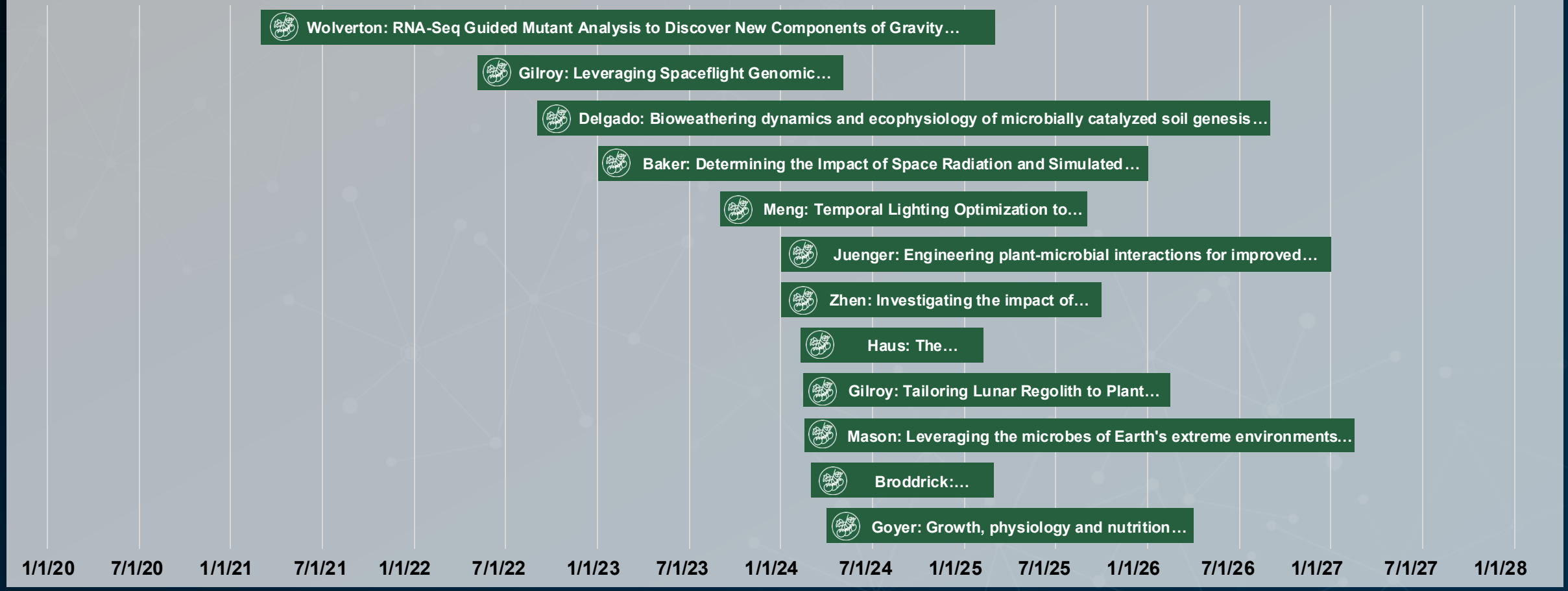
Plants will play a crucial role in human exploration beyond Earth, assisting in the production of oxygen, food, fiber, and fuel. Each space environment presents unique challenges to growing plants, including differing gravities, atmospheres, and access to resources. The four themes of Space Crops will inform the science and technology that harness the power of plants to enhance the quality of life for humans in space.

THEME:	Growth Medium	Crop Cultivars	Space Farming	Bioregenerative Life-Support Systems
THEME DEFINITION:	Since space lacks fertile soil, scientists must develop and utilize innovative methods for growing crops in austere environments. NASA research will lead to advancements in technologies for new plant growth media, including soilless cultivation methods such as hydroponics and aeroponics. NASA will also explore ways to make regolith found on other planets more amenable as a growth medium or source of fertilizer.	Astronauts will require nutrient-dense sources of food that can withstand the harsh conditions of space environments. NASA science will focus on selecting and cultivating crop varieties best suited for deep-space journeys. This research could lead to sustainable, nourishing provisions for crew as they go farther and stay longer in space.	Establishing sustainable space crop production systems to support exploration can be challenging because of the lack of mature enabling technologies to monitor plant health and manage water, fertilizer, and light inputs. NASA research will focus on developing space horticultural methods and technologies to support plant growth, while controlling crop disease outbreaks and ensuring that produce is safe for human consumption.	Sustainable bioregenerative life-support systems that produce fresh food and water, revitalize air, and recycle waste are essential for deep-space exploration. NASA research focuses on understanding how the biological components of crop production systems could best be integrated into the physical architecture of ecosystems in space. Insights could contribute to innovations in reusing and recycling resources in self-sustaining life support systems.

Funded Space Crops Research

Legend
- Ground
- Flight
- Consortium

Growth Medium



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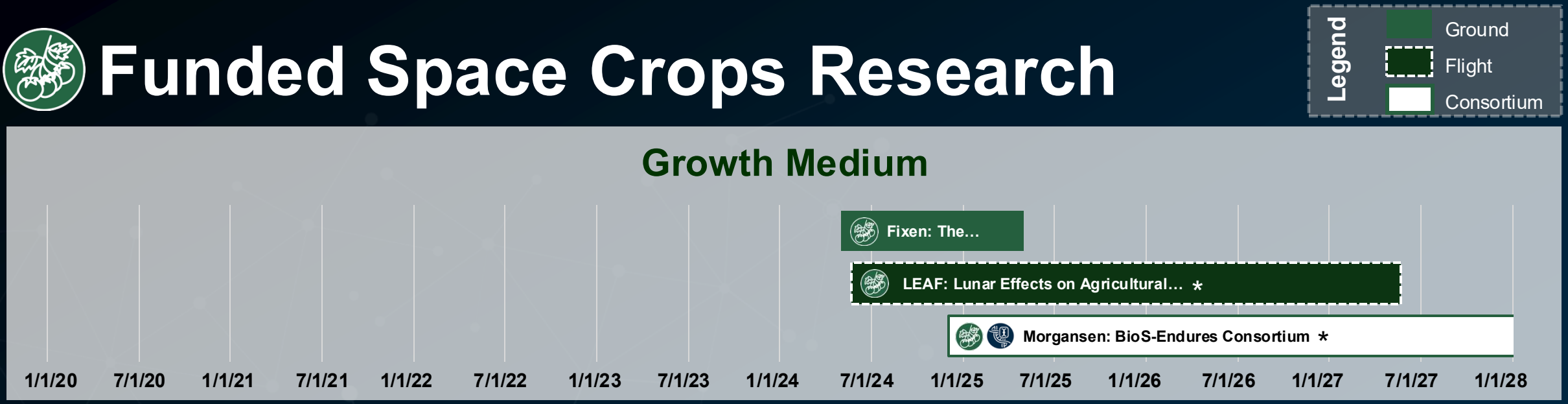
Funded Space Crops Research



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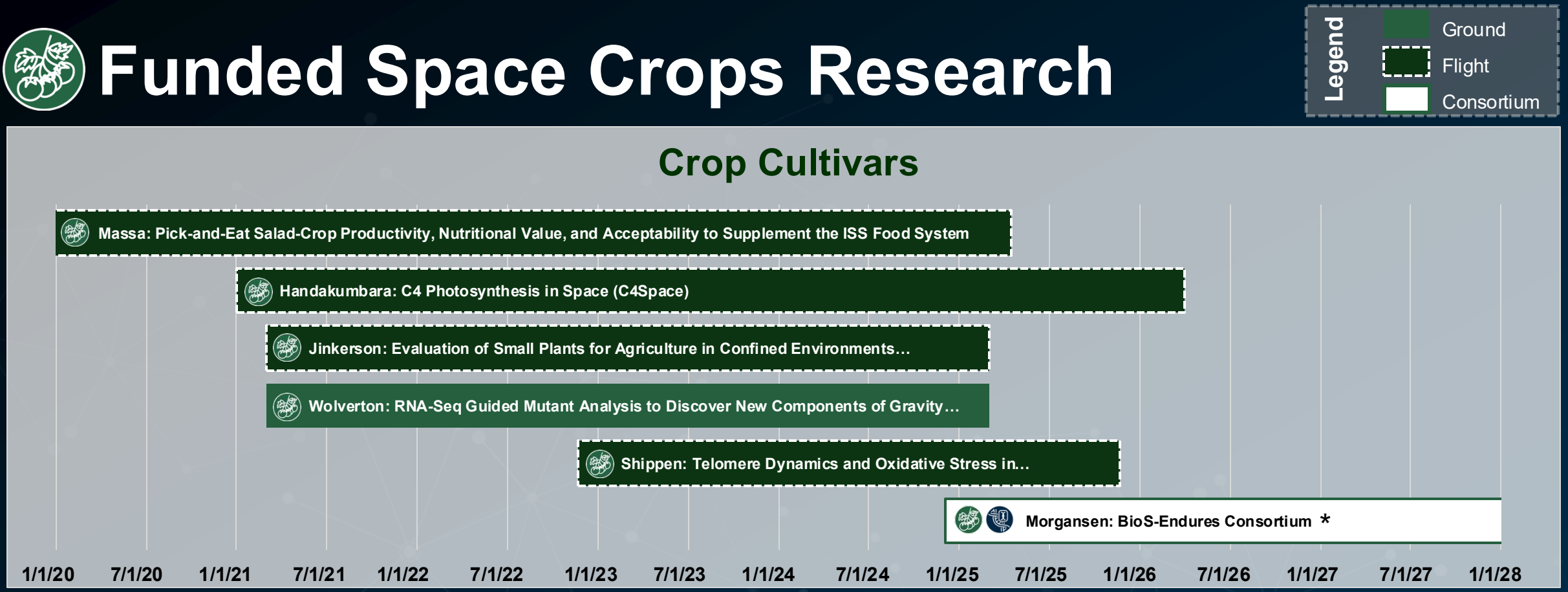
Funded Space Crops Research



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Funded Space Crops Research

Legend
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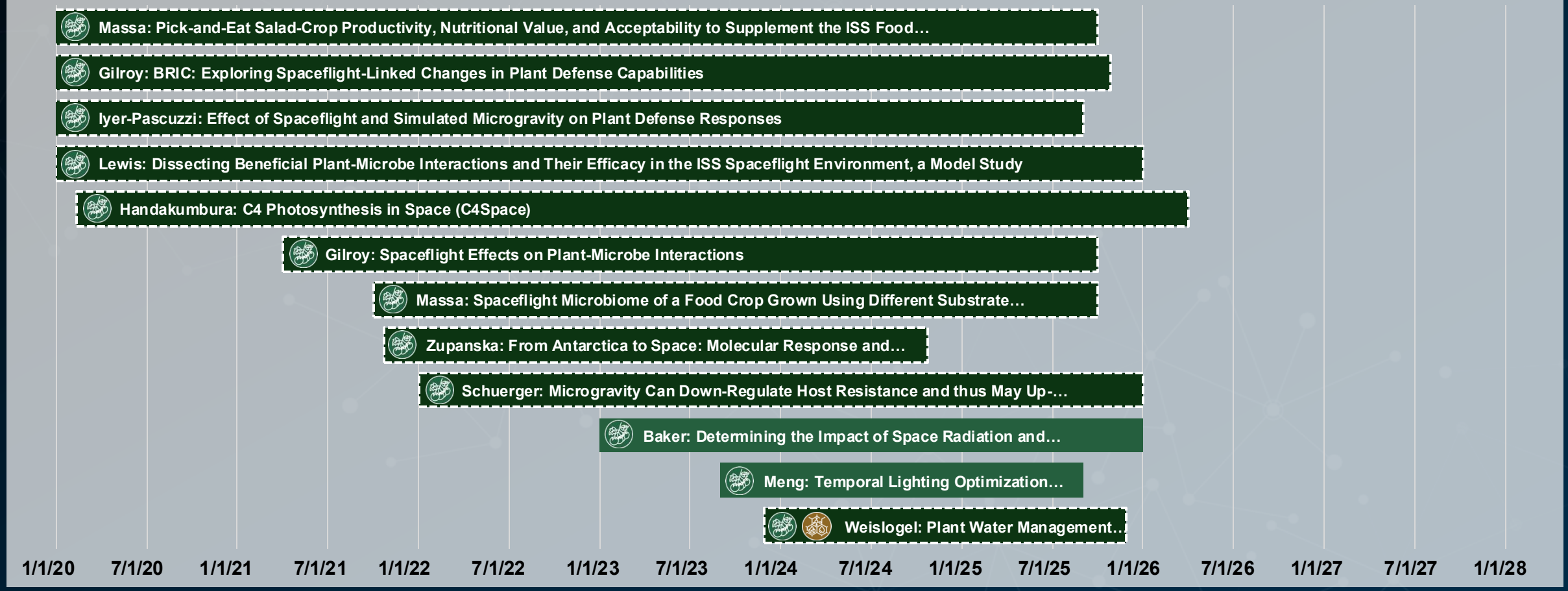
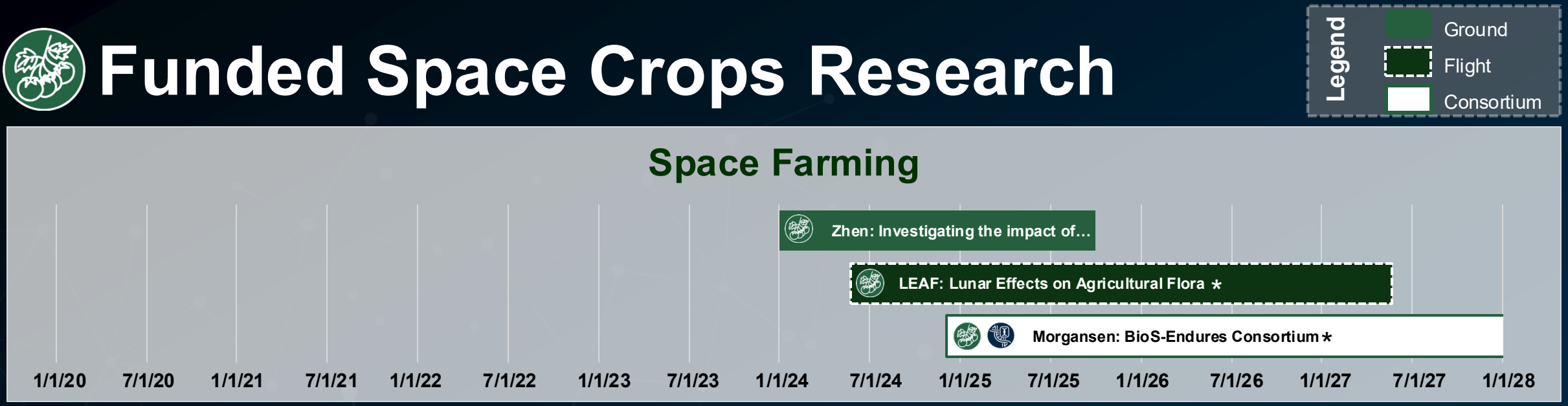
- Flight
- Consortium

Space Farming



Funded Space Crops Research

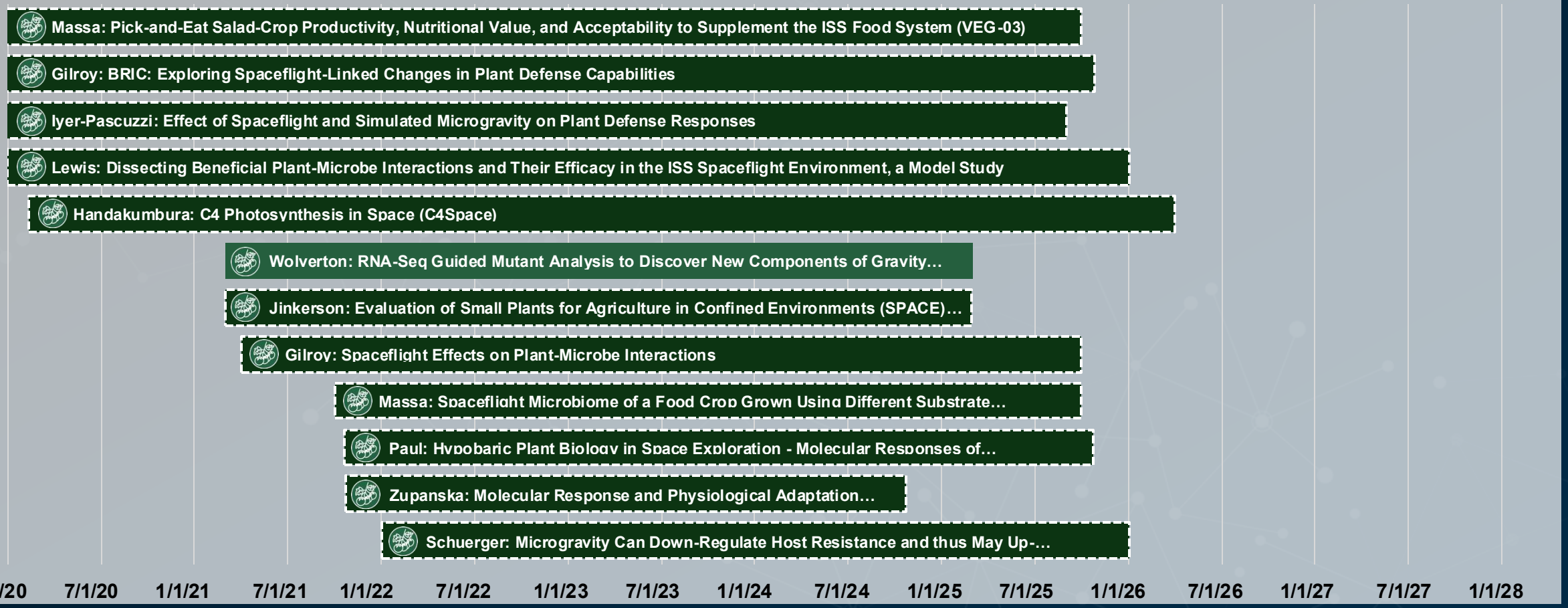


*Task Book link coming soon

Funded Space Crops Research

Legend: Ground, Flight, Consortium

Bioregenerative Life Support Systems



Funded Space Crops Research

Legend
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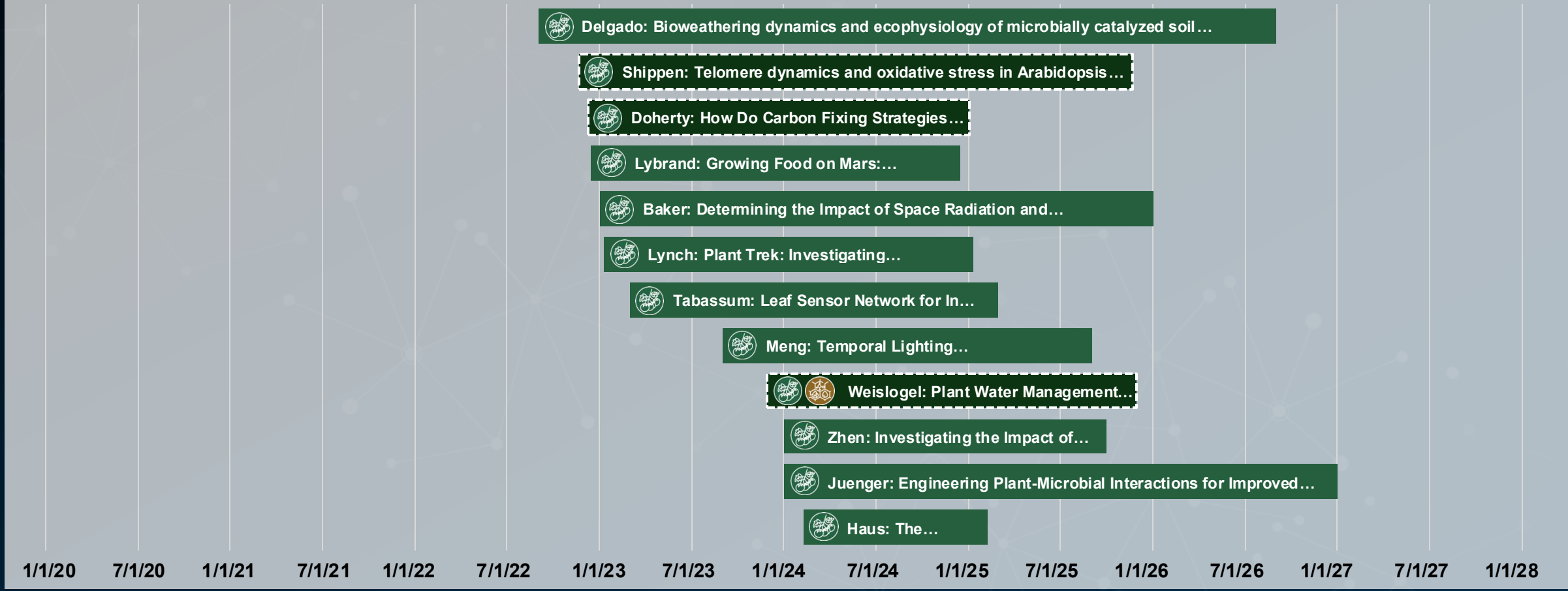
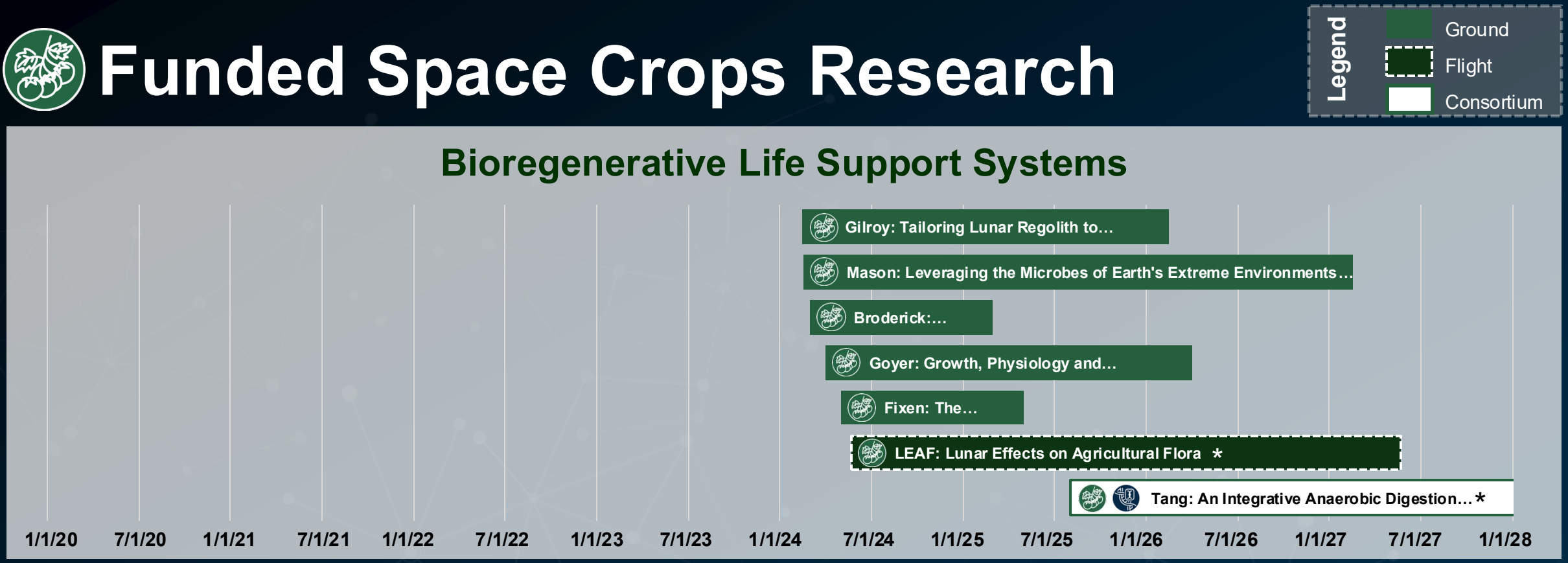
Bioregenerative Life Support Systems



Funded Space Crops Research



*Task Book link coming soon

QUANTUM LEAPS

Unraveling mysteries of the universe

While modern physics has led to numerous scientific breakthroughs, many aspects of quantum phenomena remain unexplained. NASA's research conducted in space offers unique opportunities to advance quantum science in ways that Earth-based studies cannot. Technologies like smartphones, computers, GPS, and medical imaging all stem from quantum research. Continued exploration in this field could unlock innovations beyond our most imaginative theories.

BPS Quantum Leaps Theme Definitions

GOAL:

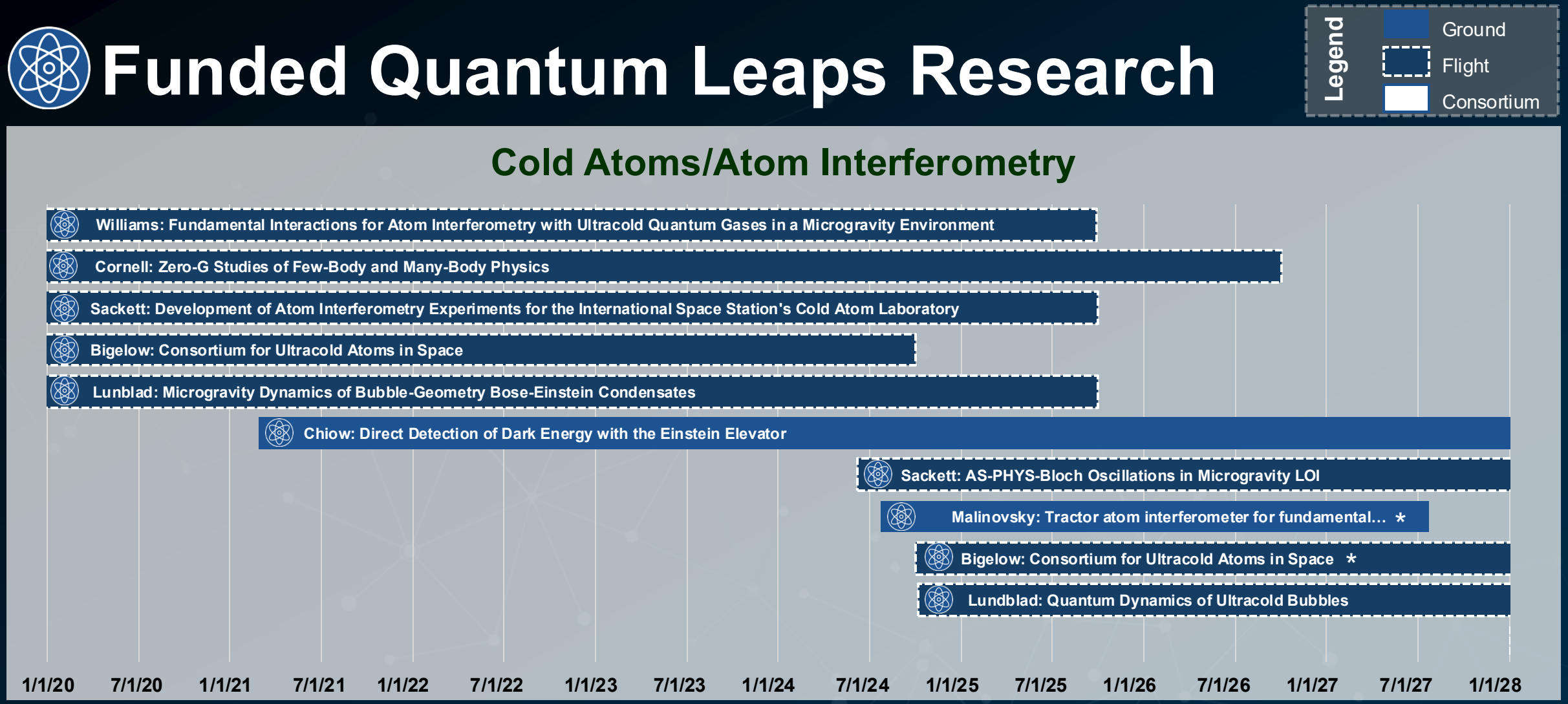
Quantum Leaps

Quantum science discoveries could fuel technology advancements, such as enabling human exploration of the solar system and the discovery of new laws of physics. Earth's gravity can obstruct the progress of highly advanced quantum sensors, so NASA is using space to develop new technologies. Quantum Leaps research will conduct experiments in space to challenge our understanding of modern physics, explain the cosmos, and catalyze new capabilities for the benefit of all.

THEME:	Cold Atoms/Atom Interferometry	Quantum Entanglement	Deep Space Laser Ranging*	Precision Clocks
THEME DEFINITION:	Ultracold atoms can serve as tools for studying and harnessing the quantum nature of matter, including enabling the detection of dark matter and dark energy. NASA will test theories of modern physics by experimenting with quantum gases and developing atom interferometers in space and microgravity facilities. This research will contribute to a better understanding of physics and cosmology and improve human exploration capabilities through satellite navigation and positioning technologies.	Quantum entanglement lays the foundation for future space-based quantum networks. NASA's research into quantum aspects of light, including entanglement, could enable unprecedented advancements in secure encryption keys, space-based quantum internet, and networked quantum sensors. These new technologies will enhance capabilities in satellite communications, space-based quantum metrology, and navigation and allow humans to probe the fundamental nature of gravity.	Deep space laser ranging is a precision measurement capability that will transform our understanding of the solar system and its governing forces. With high-power lasers, ultra-stable clocks, and next-generation retroreflectors and transceivers, NASA will accurately measure distances between Earth-Moon–Mars and other bodies to a millimeter or better. These experiments will improve tests of Einstein's theories, probe new physics, and establish reference frames throughout the solar system to support human exploration.	Clock accuracy is essential, as it underpins many technologies used both on Earth and for space exploration, including navigation and fundamental science. NASA will conduct experiments in space to advance the precision sensing and timing capabilities of space-based clocks needed for future missions. This research may enable leaps forward in important technologies, serve as space-based references for timing throughout the solar system, and advance precision clocks for fundamental physics experiments in space.

*Themes marked with an asterisk will link to funded projects in future

Funded Quantum Leaps Research



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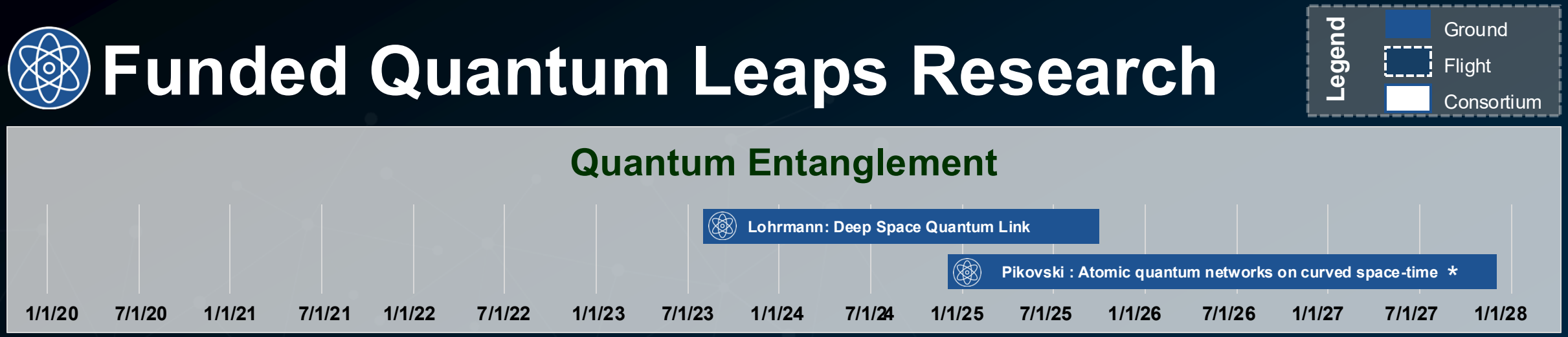
Funded Quantum Leaps Research



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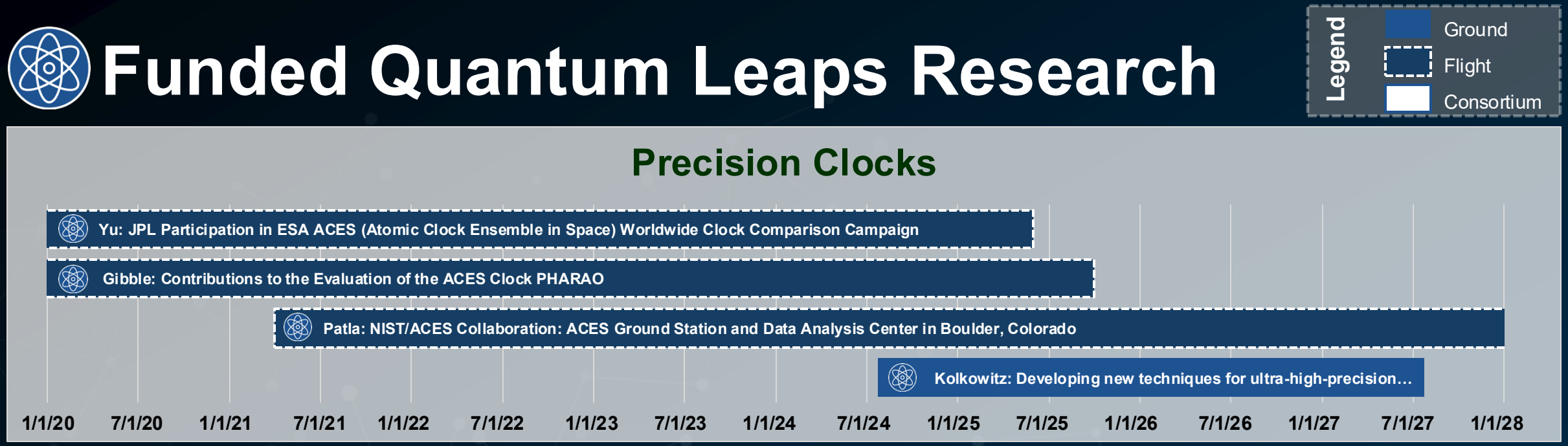
Funded Quantum Leaps Research



FOUNDATIONS

Revealing the novel behaviors of fluids, fire, and materials in space

Physical phenomena behave differently in space: how flames burn, fluids flow, and materials react to extreme conditions. Research in these areas can lead to scientific breakthroughs and new technologies that enable safe, sustained missions to the Moon, Mars, and beyond. It can also contribute to everyday life, including improvements in fire safety, manufacturing, commercial products, and more.

BPS Foundations Theme Definitions

GOAL:

Foundations

To go farther and stay longer in space, we must understand how physical systems respond to unique conditions beyond Earth. Fluids, flames, and materials are susceptible to variations in gravity, radiation, pressure, and other space stressors. NASA research delivers key insights that can inform many aspects of future deep space missions, including fire safety, fuel depots, habitats, astronaut health, and more. These studies are essential to helping us understand mission risks and requirements, use resources at exploration destinations, and advance technology for living off-world.

THEME:	Fluids & Thermal Management	Fire Safety	Recycling & Sustainability*	Building Blocks for ISRU
THEME DEFINITION:	From crew life-support systems to crop water management to fuel 'depots,' sustaining a human presence in space requires a fundamental understanding of how fluids and thermal energy behave in different space environments. Data from NASA research will help advance technologies used in spacecraft and habitats, including heating, refrigeration, fuel transfer, and more. These innovations will enable crew to go farther and stay longer in space.	Conditions on the Moon and Mars may prove more volatile, threatening human, vehicle, and habitat safety in space. It is essential to understand how fire, materials, and combustion respond to these environments. NASA research will develop tools to predict fire ignition, behavior, and spread, including the impacts of heat and smoke. This data could inform advancements in fire protection systems, future spacecrafts, habitats, and materials for spacesuits.	Establishing a sustainable presence on other worlds will require crew to reuse, recycle, and upcycle available materials in innovative ways. NASA research will investigate the properties and processing of materials used in exploration and how they behave in the harsh conditions of space. Insights could inform the selection of future materials, as well the design and development of applications and processes for sustaining a human presence in deep space.	Astronauts will need to make, not just take, supplies on long-duration missions. *In-situ* resource utilization (ISRU) involves using local resources on the Moon or Mars for life support, fuel, construction, and other needs. NASA research will study the materials found on other planetary surfaces, such as regolith, to understand their unique behaviors and characteristics. This knowledge could inform innovations for leveraging these materials, reducing the reliance on supplies transported from Earth.

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Funded Foundations Research

Legend
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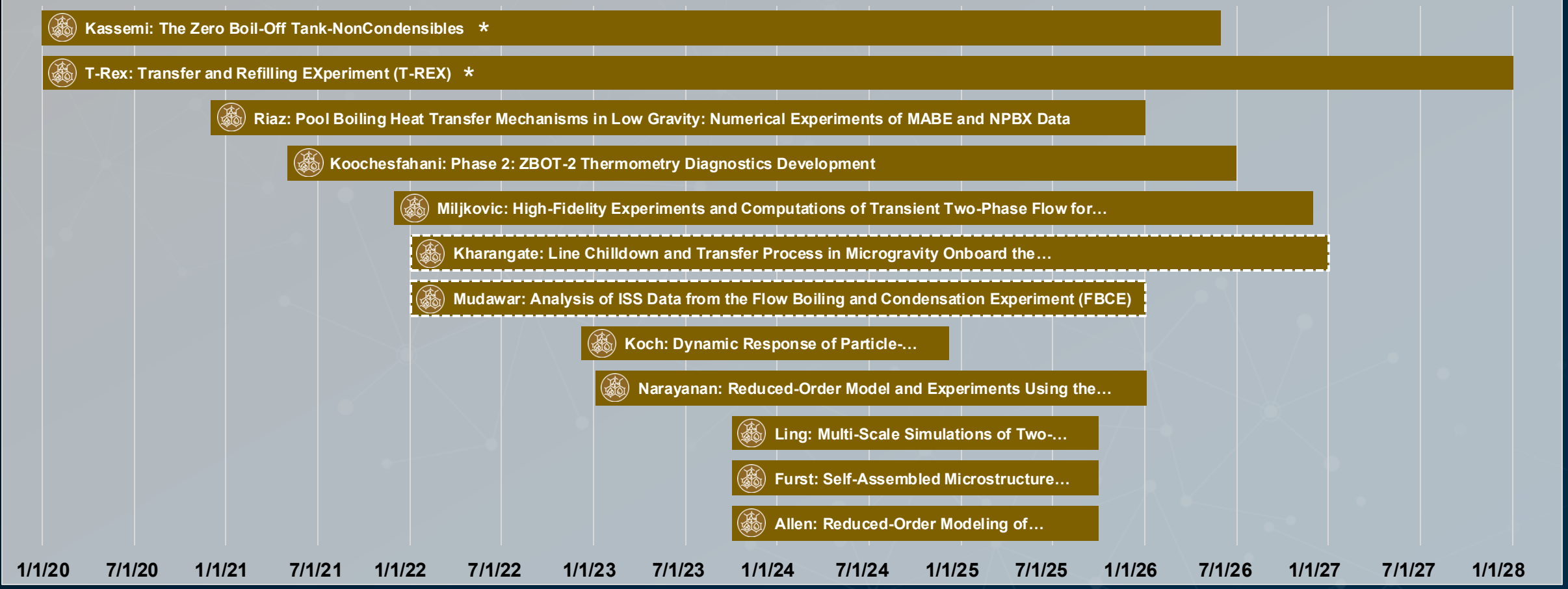
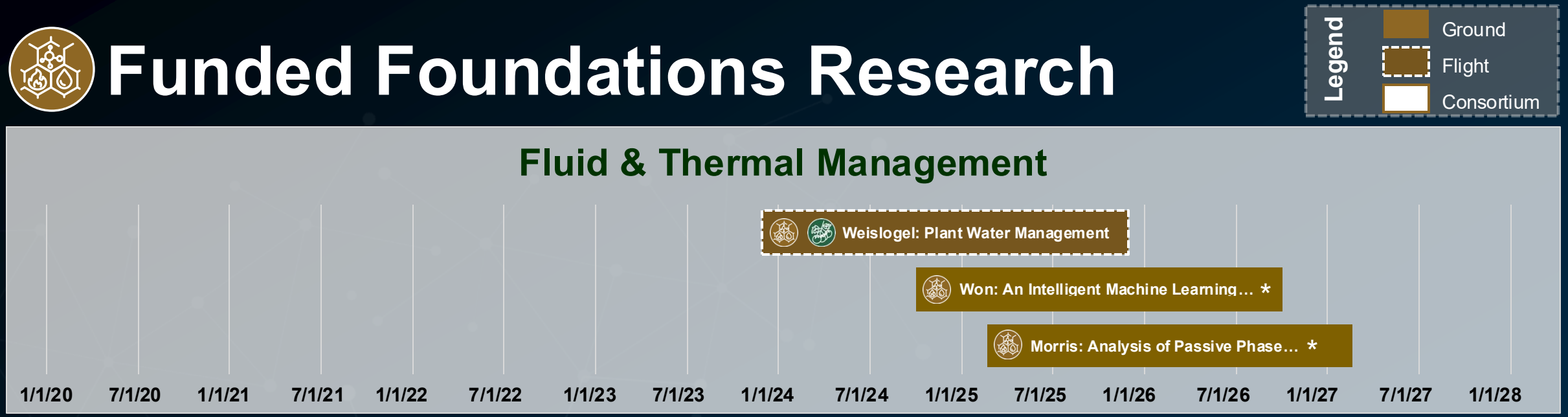
Fluid & Thermal Management



*Task Book link coming soon

Funded Foundations Research

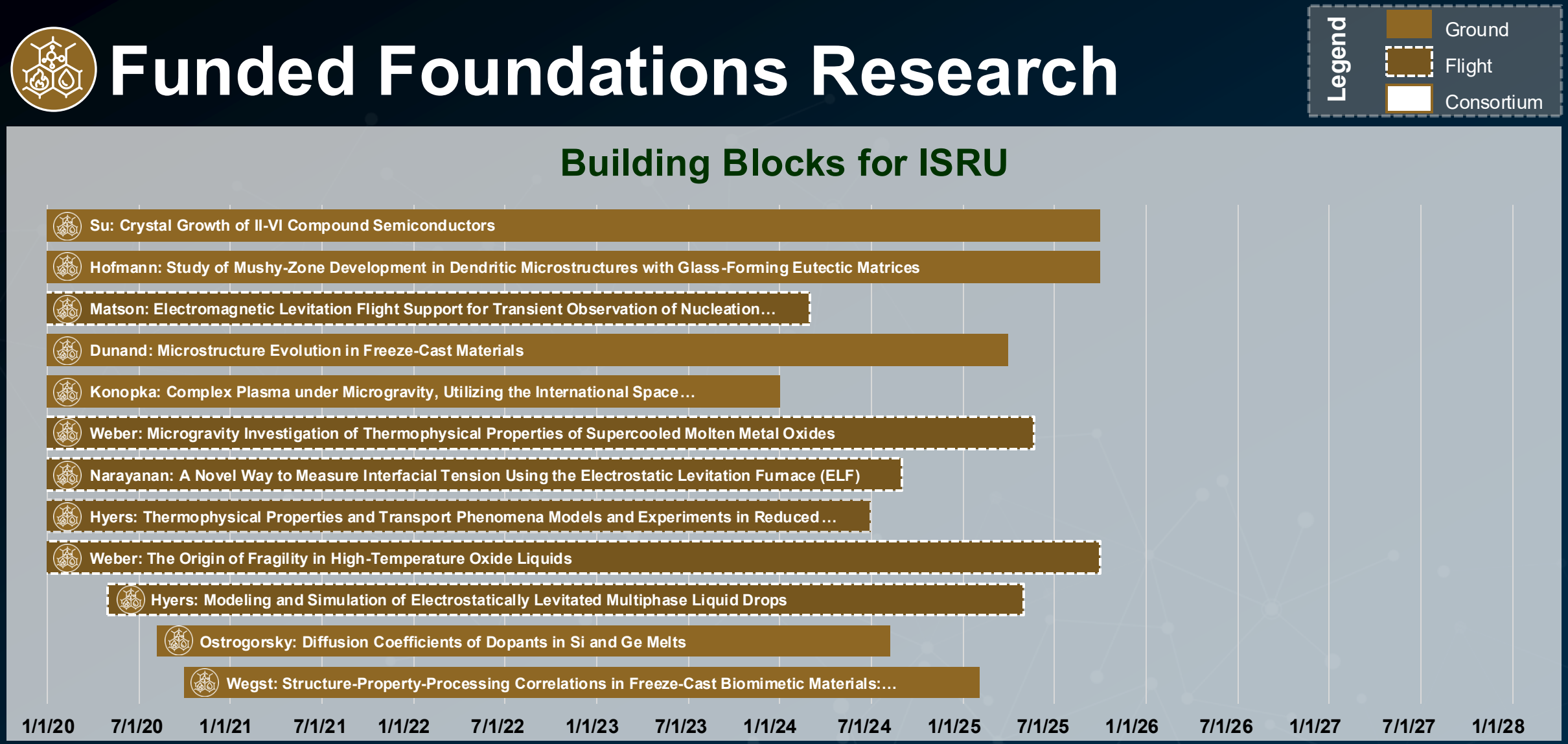


*Task Book link coming soon

Funded Foundations Research

*Task Book link coming soon

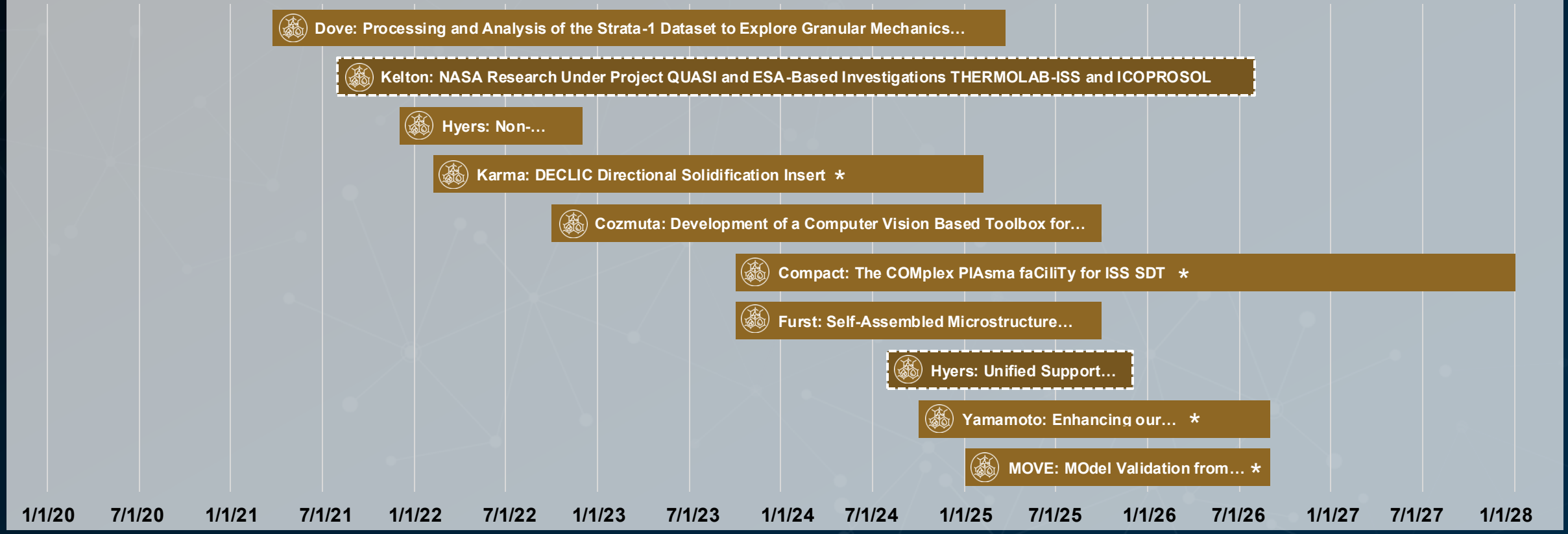
Funded Foundations Research



Funded Foundations Research

Legend
- Ground
- Flight
- Consortium

Building Blocks for ISRU



*Task Book link coming soon

SPACE LABS

Advancing research in space, on any platform, anywhere

Conducting experiments in space reveals phenomena impossible to observe on Earth. NASA's Space Labs enable the research capabilities across a spectrum of spaceflight environments—from suborbital and low Earth orbit to deep space and other worlds—to push the boundaries of scientific knowledge.

BPS Space Labs Theme Definitions

GOAL:

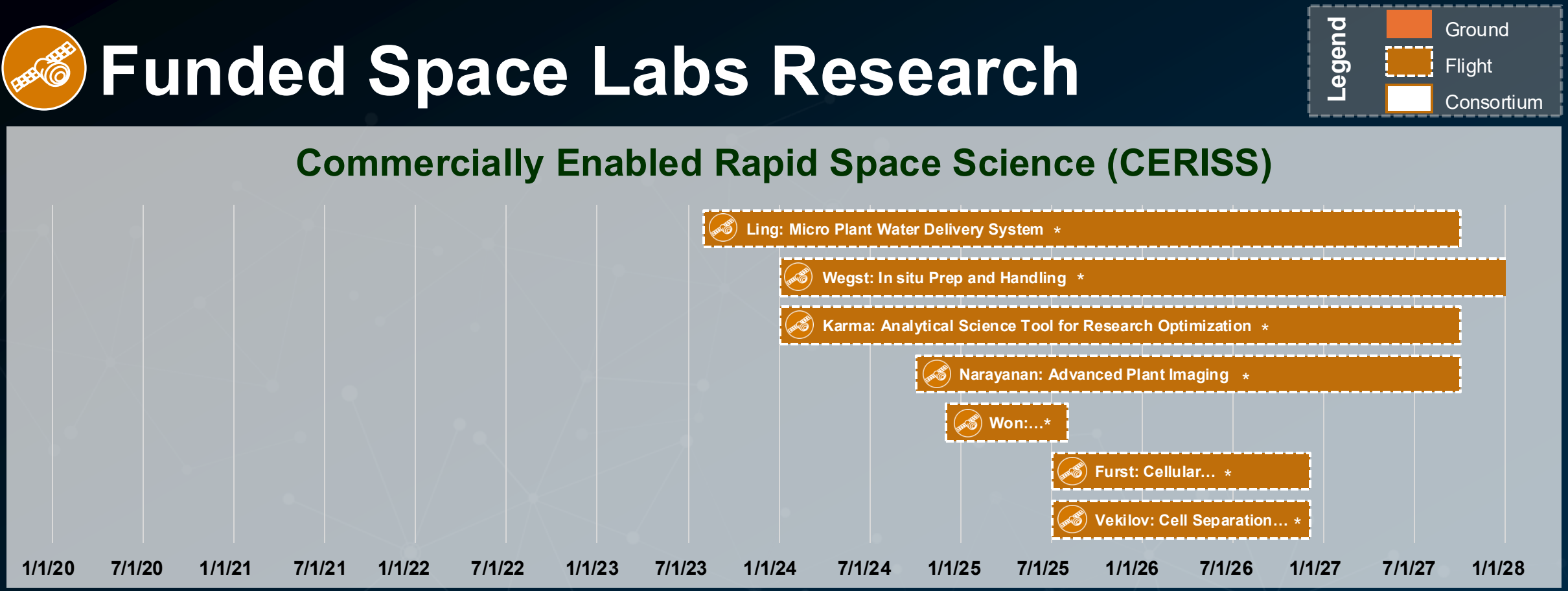
Space Labs

Space-based experiments offer different opportunities for research because of factors like space radiation and microgravity environments. The five themes of Space Labs will support the exploration of the Moon, Mars, and beyond by using spaceflight research facilities to enable cutting-edge science. The Space Labs goal will unlock discoveries not possible on Earth that are essential to human exploration, as well as contribute to breakthroughs that improve life on our home planet.

THEME:	CERISS	Low Earth Orbit (LEO)	Moon	Mars*	Interplanetary Space*
THEME DEFINITION:	Legacy approaches to space-based research have been costly, with lengthy delays in delivering samples or data to researchers on the ground. NASA's Commercially Enabled Rapid Space Science (CERISS) program will significantly accelerate the pace and productivity of research in space through commercial partnerships to develop and/or utilize innovative, cost-effective capabilities. This will expedite access to scientific insights that inform future missions and support the burgeoning space economy.	LEO is an essential environment for studying the effects of spaceflight stressors on life and physical phenomena — and serves as a steppingstone for future deep space missions. NASA will conduct exploration-focused research using facilities aboard the International Space Station and future Commercial LEO Destinations (CLDs), as well as employ other novel capabilities. This will enable NASA to advance the science and technology needed to achieve Moon-to-Mars objectives.	To sustain a human presence on the Moon — and eventually Mars — we must understand how harsh conditions affect our ability to thrive on these surfaces. NASA will develop and employ capabilities for studying how life, including humans and plants, and phenomena, such as flames and materials, respond to extreme stressors. This research will deliver key data which can inform new technologies and mitigate risks to human health, habitats, and spacecraft as we go farther and stay longer in space.	To send the first humans — Americans — to Mars, we must "know before we go" to reduce the risk to human health prior to crew embarking on their journeys. NASA will develop and utilize myriad platforms to conduct research at the Red Planet, including landers and free-flyers, among others. Focusing on autonomous capabilities and *in-situ* analysis enables NASA to gain access to important data which could inform the development of counter- and preventative measures prior to missions.	Conditions in space can vary widely, from planet to planet, Sun to distant stars, and the space between them. NASA plans to gather vast amounts of data on deep space stressors throughout the solar system and beyond by deploying research capabilities aboard a range of missions, whether as a primary or secondary payload. This will enable NASA to scale and expand knowledge needed to ensure safe and successful journeys to deep space destinations.

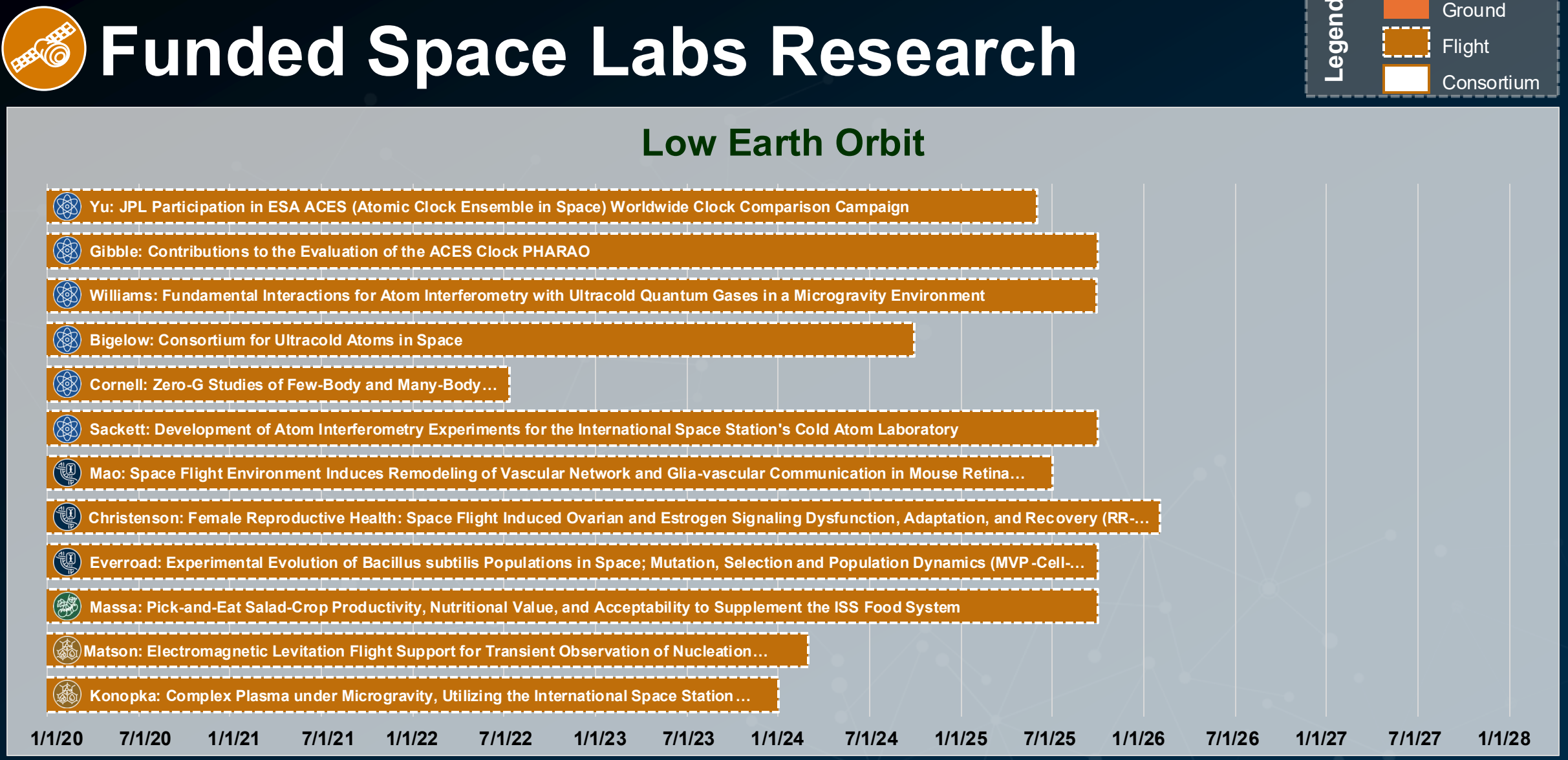
*Themes marked with an asterisk will link to funded projects in future

Funded Space Labs Research



*Task Book link coming soon

Funded Space Labs Research



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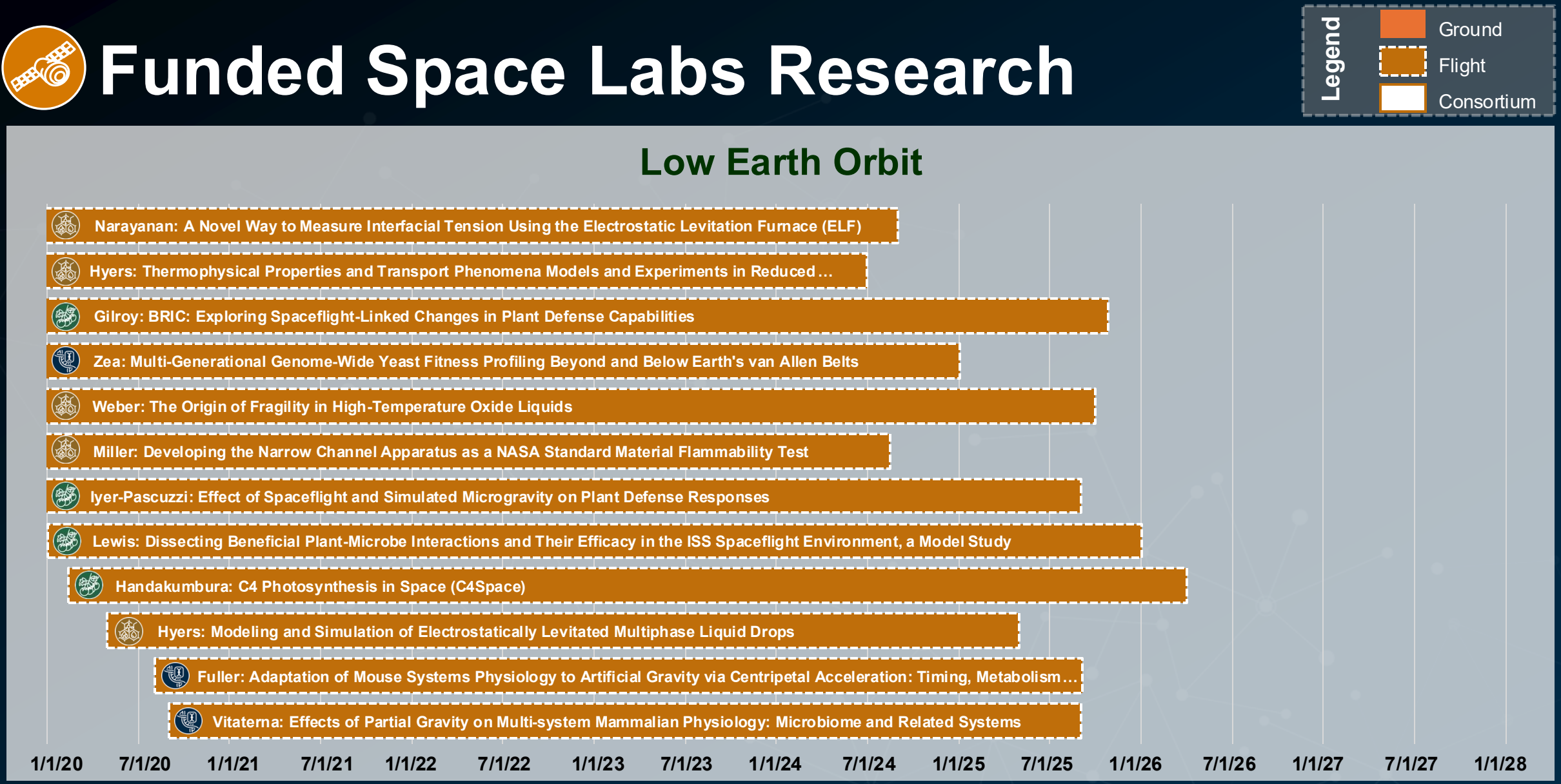
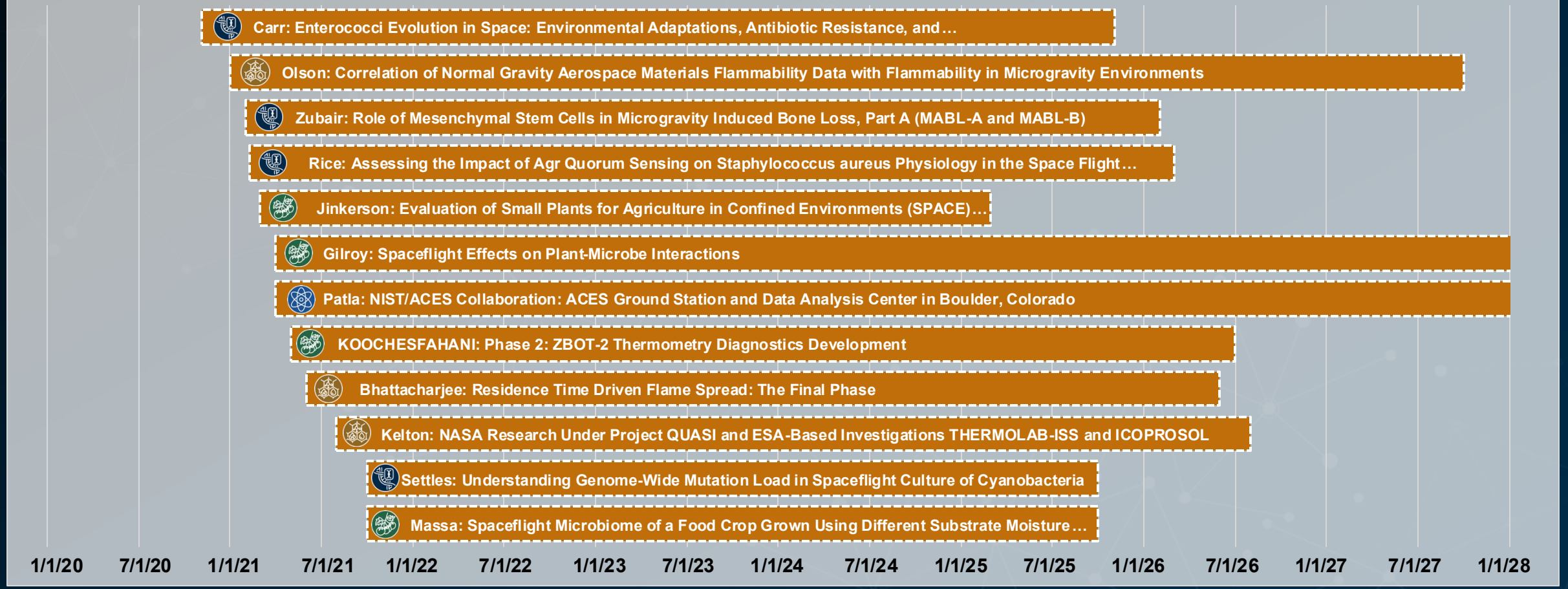


Funded Space Labs Research

Legend
- Ground
- Flight
- Consortium

Low Earth Orbit



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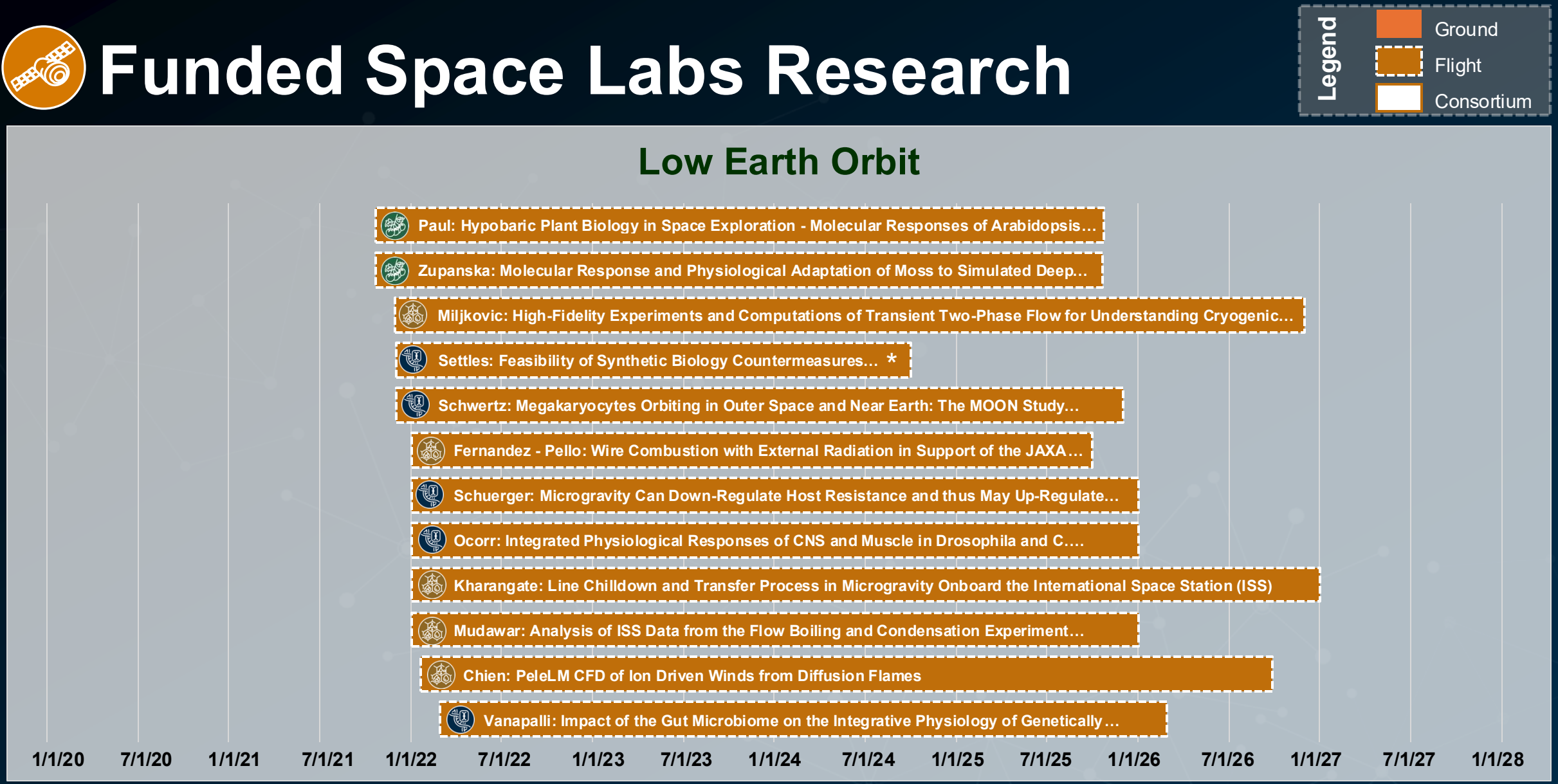

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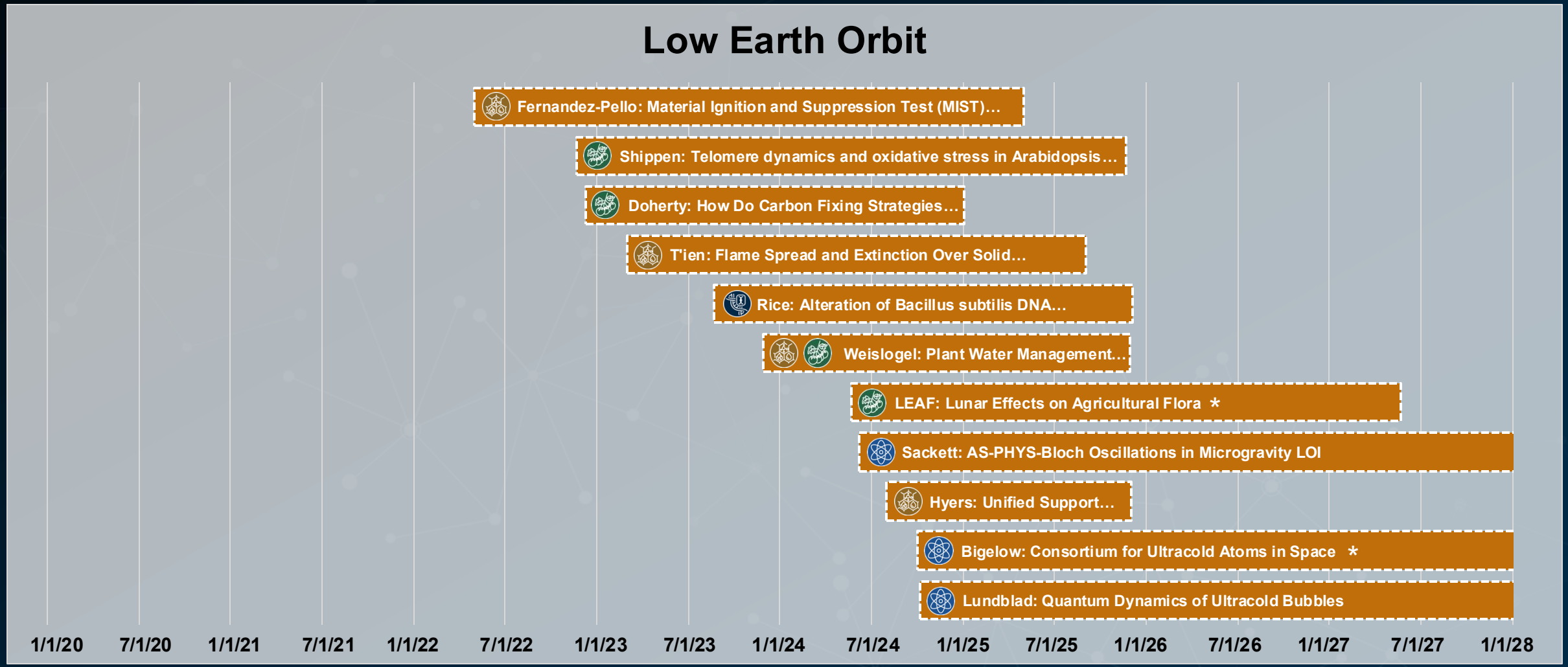

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*Task Book link coming soon

Appendix

Document Change Log

Date of Update	Old Version #	New Version #	Description of Changes	Update Completed by [NAME]
06/30/2025		1.0	▸ Original internal version for review	▸ Sarah Hemmings
07/10/25	1.0	1.1	▸ Updates to theme definitions; fixes to formatting and links throughout Gantt charts	▸ Sarah Hemmings
9/11/25	1.1	1.2	▸ Update of Flight/Ground research histogram; fixes to formatting and links throughout Gantt charts. Theme color and name revisions to Space Crops and Quantum Leaps content.	▸ Sarah Hemmings