Introduction to NASA, Space Biology, OSDR, and GeneLab

National Aeronautics and Space Administration

GL4U: Introduction 2024

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NASA GeneLab Science Lead

Contractor: KBR

Biological & **P**hysical **S**ciences

Acknowledgements

Open Science for Life in Space Teams

Open Science Analysis Working Group Members

Support

NASA Space Biology Program
NASA Science Mission Directorate
NASA Human Research Program
NASA Biological and Physical Sciences

Introduction to the National Aeronautics and Space Administration (NASA)

A Brief History of NACA

1903 Wright Brothers first flight

1915 NACA established

1917 Langley established

1940 Lewis (Glenn) established

1942 Ames established

1946 First supersonic flight

1947 Dryden (Armstrong) established

1950s NACA begins to look into the possibility of manned spaceflight

1957-8 Plan established to orbit a scientific satellite

https://www.nasa.gov/ames/the-national-advisory-committee-for-aeronautics

A Brief History of NASA

1957 — Soviet Union launches Sputnik 1

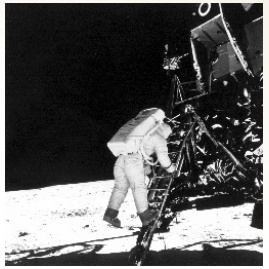
1958 — *'An Act to provide for research into the problems of flight within and outside the Earth's atmosphere, and for other purposes.'*

1958 — NASA established and absorbs itself into NACA

1961-3 — US launches it's first Earth satellite

1965-6 — **Mercury**'s single astronaut program: Can humans survive in space?

1968-72 — **Project Gemini**: Two astronauts practice space operations



1981 — **Project Apollo**: Explore the Moon

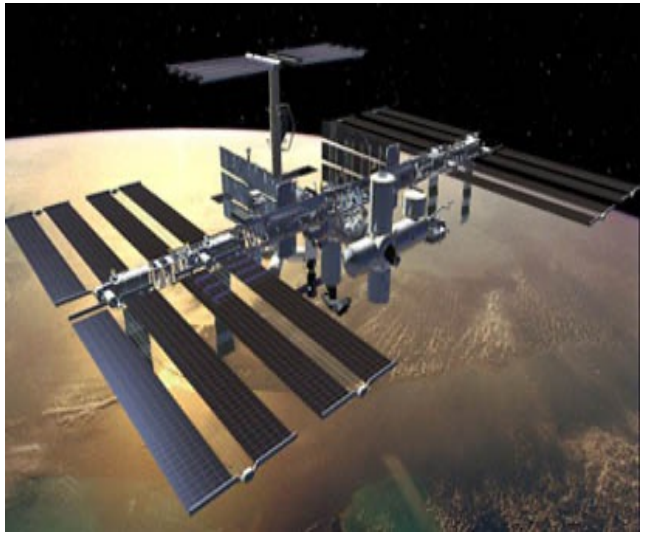
1984 — Congress authorized NASA to build the Space Station

2011 — Space Shuttle's first mission: STS-1

Last Space Shuttle Mission: STS-135

NASA's Vision

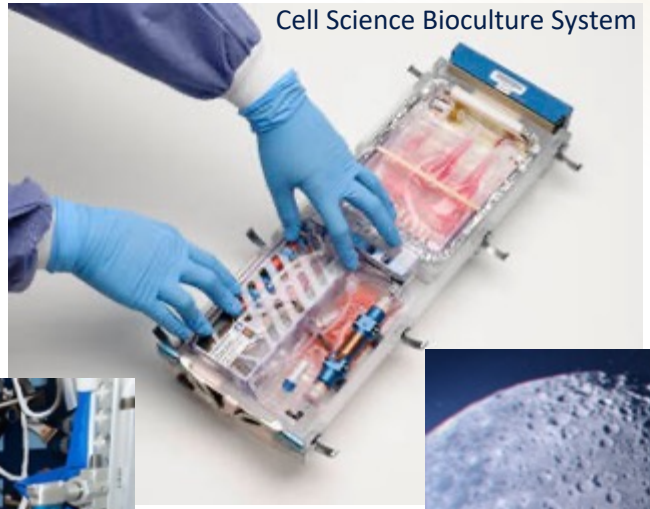
To reach for new heights and reveal the unknown for the benefit of humankind



NASA's Mission

To drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality and stewardship of Earth

https://www.nasa.gov/content/the-crawlers



Cell Science Bioculture System

NASA astronaut Christina Koch

https://www.nasa.gov/gateway/

How does NASA achieve its Mission?

- **NASA HQ** – Provides overall guidance and direction to the Agency
- **NASA Centers and Facilities** – Where the day-to-day NASA work is performed in laboratories, airfields, wind tunnels, etc.
- NASA conducts its work though six main organizations called **Mission Directorates**:

Space Operations (SOMD)

Exploration Systems Development Mission Directorate (ESDMD)

Space Technology (STMD)

Science (SMD)

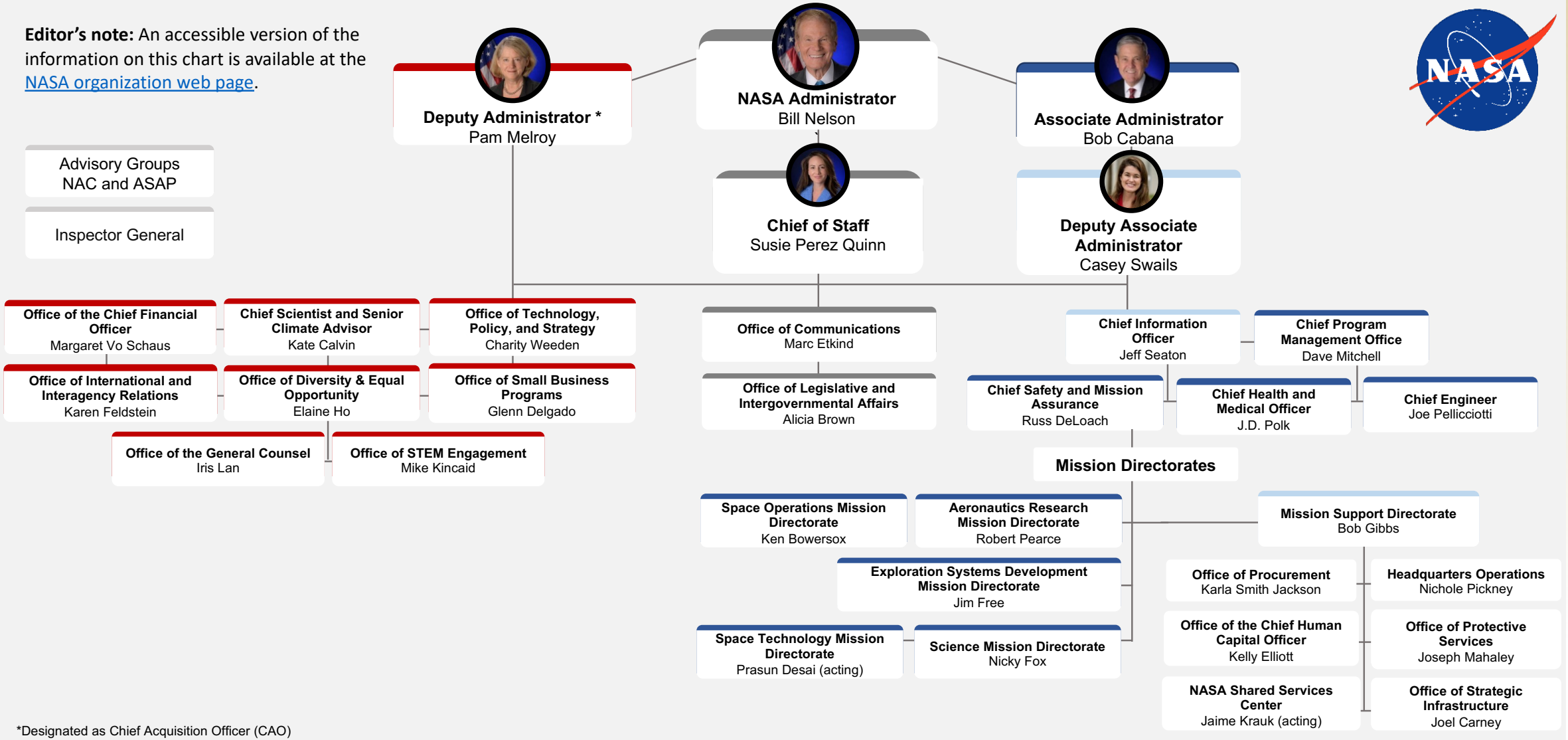
Mission Support (MSD)

Aeronautics Research (ARMD)

https://www.nasa.gov/directorates/

NASA Organization

Editor's note: An accessible version of the information on this chart is available at the NASA organization web page.



*Designated as Chief Acquisition Officer (CAO)

JPL is a Federally Funded Research and Development Center (FFRDC

Current as of Oct. 18, 2023

https://www.nasa.gov/organization/

NASA Leadership

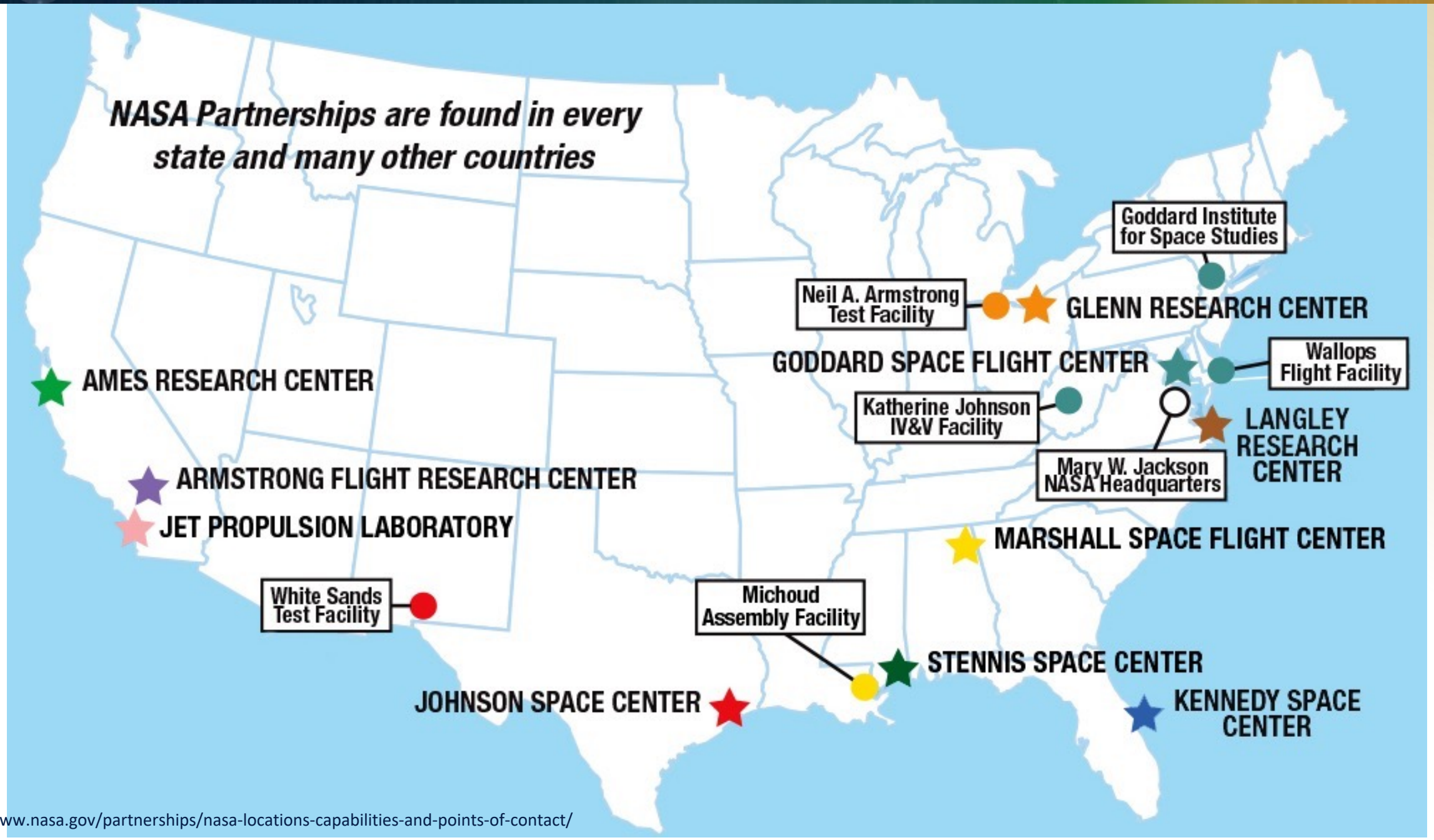
Administrator: Bill Nelson

Sen. Bill Nelson was sworn in as the 14th NASA administrator on May 3, 2021, tasked with carrying out the Biden-Harris administration's vision for the agency. Nelson served in the U.S. Senate for 18 years from Florida and as a payload specialist on space shuttle mission 61-C in 1986. Bill Nelson's full bio: https://www.nasa.gov/people/nasa-administrator-bill-nelson/

Deputy Administrator: Pamela Melroy

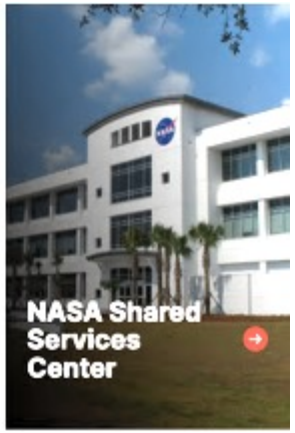
One of only two women to command a space shuttle, Melroy logged more than 38 days in space. All three of her missions were assembly missions to build the International Space Station. After serving more than two decades in the Air Force and as a NASA astronaut, Melroy took on a number of leadership roles, including at Lockheed Martin, the Federal Aviation Administration, the Defense Advanced Research Projects Agency, Nova Systems Pty, Australia, and as an advisor to the Australian Space Agency. She currently is an independent consultant and a member of the National Space Council's Users Advisory Group. Pam Melroy's full bio: https://www.nasa.gov/people/nasa-deputy-administrator-pam-melroy/

NASA Centers and Facilities



https://www.nasa.gov/partnerships/nasa-locations-capabilities-and-points-of-contact/

NASA Centers and Facilities



https://www.nasa.gov/centers-and-facilities/

What has NASA done for life on Earth?

Spinoffs from Mars!

NASA has been exploring Mars since the 1960s, pushing the frontier of innovation to get to the red planet and discover its secrets. This new technology has often found other uses here on Earth as well. A few highlights:

Generating Wind Power

Solar power is great until a Martian dust storm blacks it out. But there's another option for those blustery days: wind power. NASA helped design a low-maintenance wind turbine that can function in extreme conditions – on Mars or on Earth.

Guiding Cars with Tech for Mars

Autonomous navigation on Mars requires "brains" made up of advanced neural networks and deep learning algorithms. But if the rovers can manage on another planet, putting the same tech in cars, drones, and toys here on Earth is a no-brainer.

To learn more, visit: spinoff.nasa.gov/mars

Suturing with Mars-Grade Materials

Bringing home a Martian sample requires a perfectly sealed container to prevent contamination. A soft, flexible, strong material keeps Martian dust from interfering with the seal and is great for heart surgery sutures and stents.

Detecting Methane Leaks

To search for life on Mars, we look for clues – like methane, which is usually created by microbes. But tools to sniff out tiny traces of methane on Mars now help detect leaks in natural gas pipelines on Earth.

Carbonating Beer

Technology created to fuel a journey home from Mars (now helping recycle methane from oil drilling) also found another use on Earth: capturing carbon dioxide emitted by fermenting hops and using it to put the bubbles in beer.

https://www.jpl.nasa.gov/news/nasas-perseverance-pays-off-back-home/

What has NASA done for life on Earth?

More NASA Tech Helping to Solve Climate Challenges

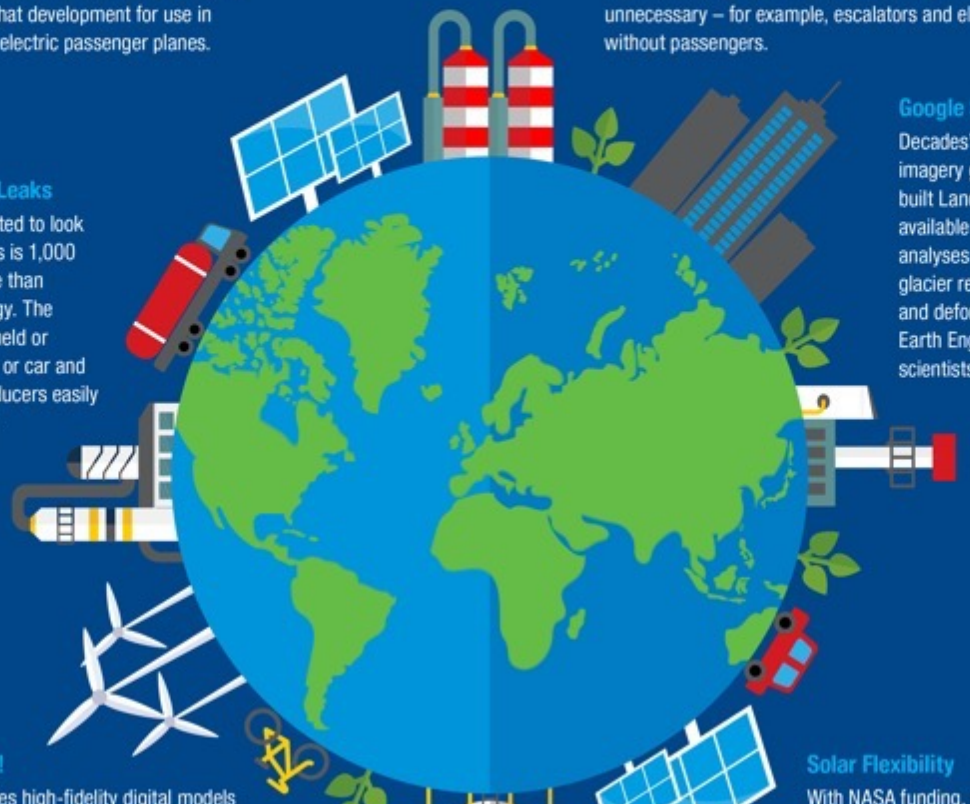
NASA research and innovations have led to more environment-saving spinoffs than we can count. Besides the ones described in this feature, here are a handful of additional technologies helping curb greenhouse gas emissions, advance renewable energy technologies, and better understand the processes leading to warming.
For more, visit spinoff.nasa.gov/climate-change

All-Electric Flight

With NASA's help, a company designed a high-power battery pack that could meet safety requirements for the agency's all-electric experimental airplane. Now the company is selling batteries based on that development for use in some of the first all-electric passenger planes.

Running on Empty

The voltage controller, invented by a NASA engineer in the 1970s, is one of NASA's most-used innovations. It enables machinery to automatically decrease energy consumption when full power is unnecessary – for example, escalators and elevators without passengers.



Google Searches Earth

Decades' worth of Earth imagery gathered by the NASA-built Landsat satellites is now available for free, enabling global analyses of surface trends like glacier retreat, desertification, and deforestation. Google Earth Engine is partnering with scientists to mine all that data.

Sniffing Out Gas Leaks

A spectrometer created to look for methane on Mars is 1,000 times more sensitive than competing technology. The device can be handheld or mounted on a drone or car and lets natural gas producers easily spot and stop leaks.

Send In the Clone!

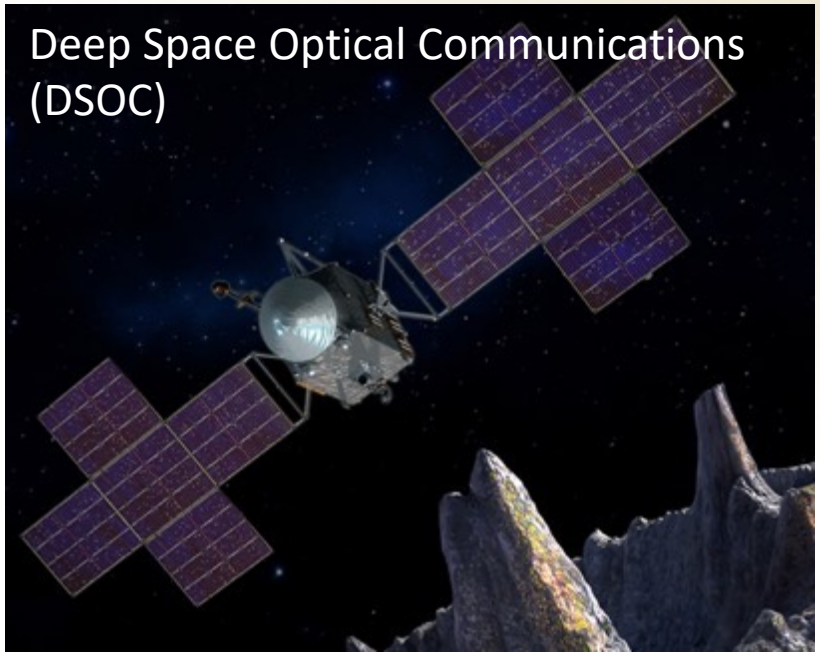
A program that creates high-fidelity digital models – or "clones" – of mechanical components or systems was validated against years' worth of NASA helicopter gear data. Now it allows some of the country's largest wind turbine operators predict and extend their turbines' lifespans

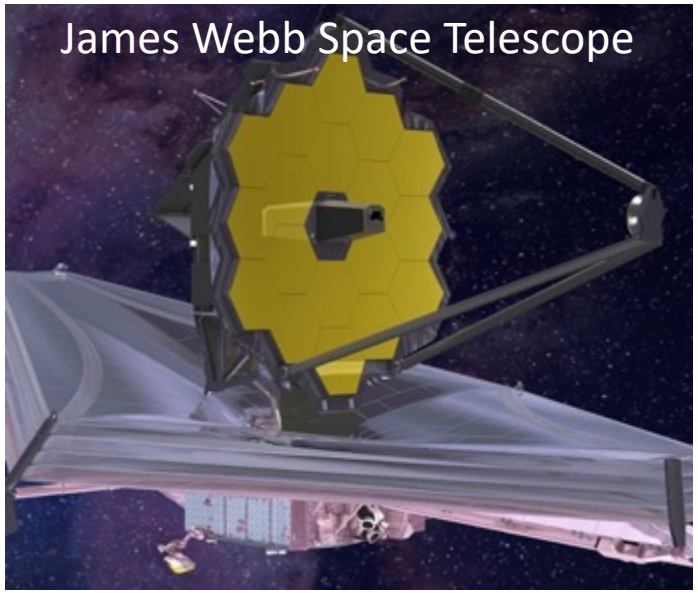
Solar Flexibility

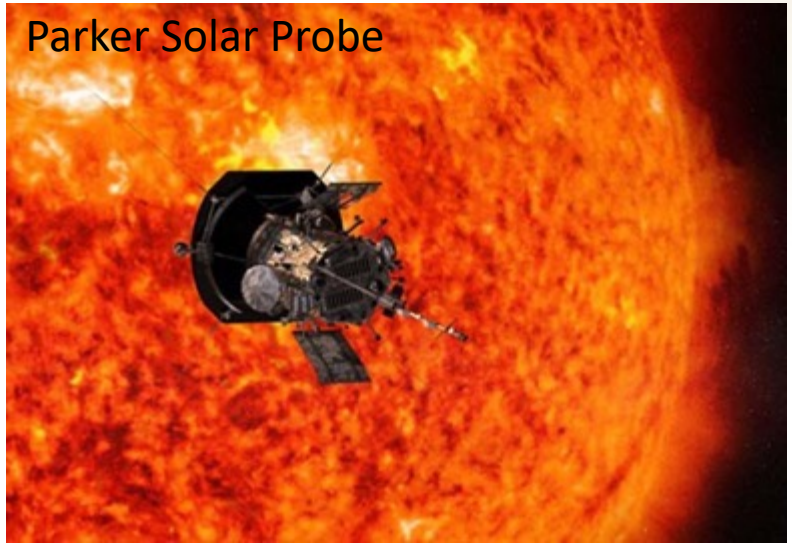
With NASA funding, one company developed a cheaper way to produce high-efficiency solar cells and used it to make affordable, portable, flexible solar panels. Its solar cells now power troops' devices in the field, as well aircraft and satellites.

https://science.nasa.gov/earth/climate-change/nasa-technologies-spin-off-to-fight-climate-change/

What's in store for NASA?



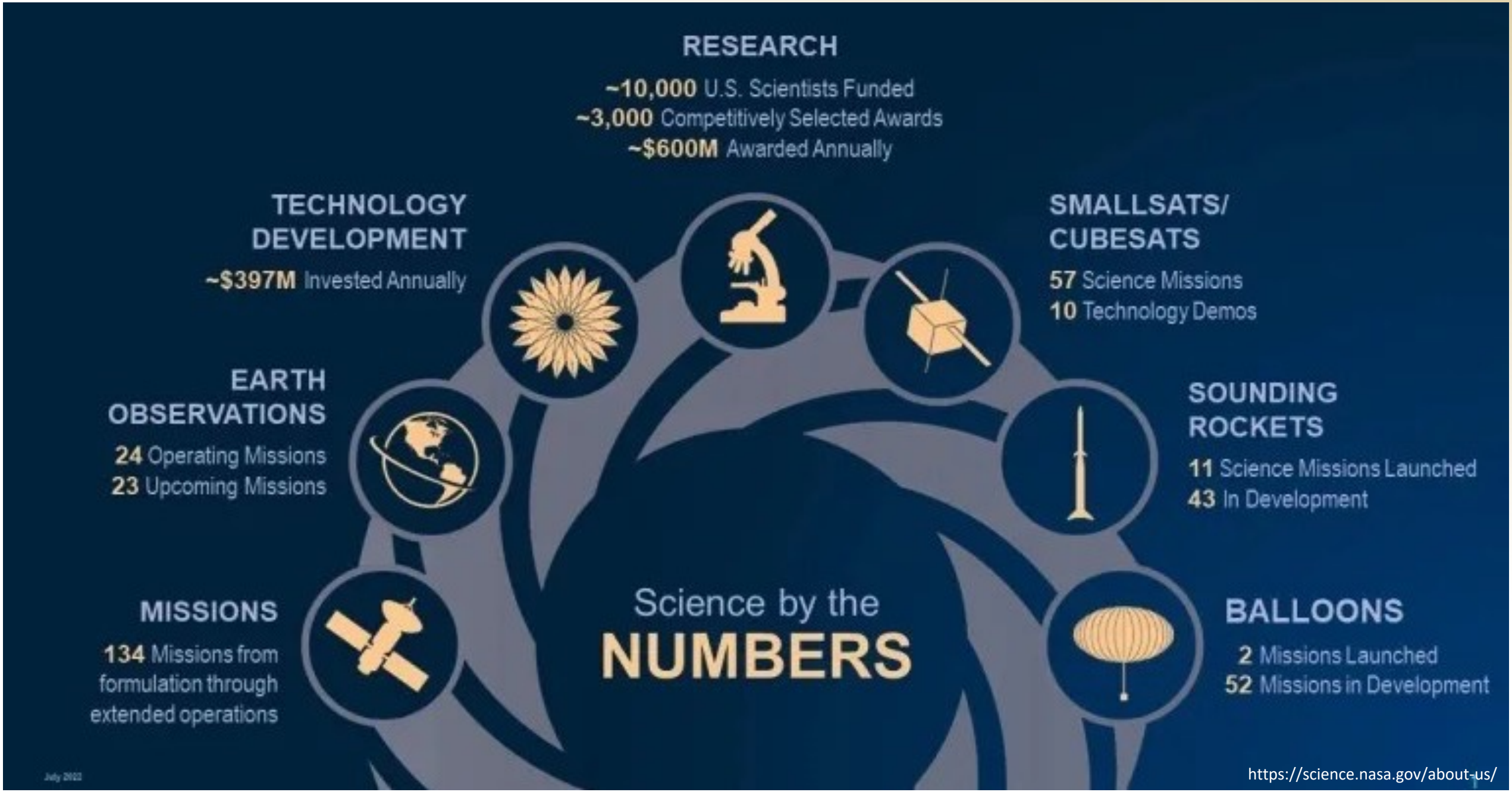




https://www.nasa.gov/specials/60counting/future.html

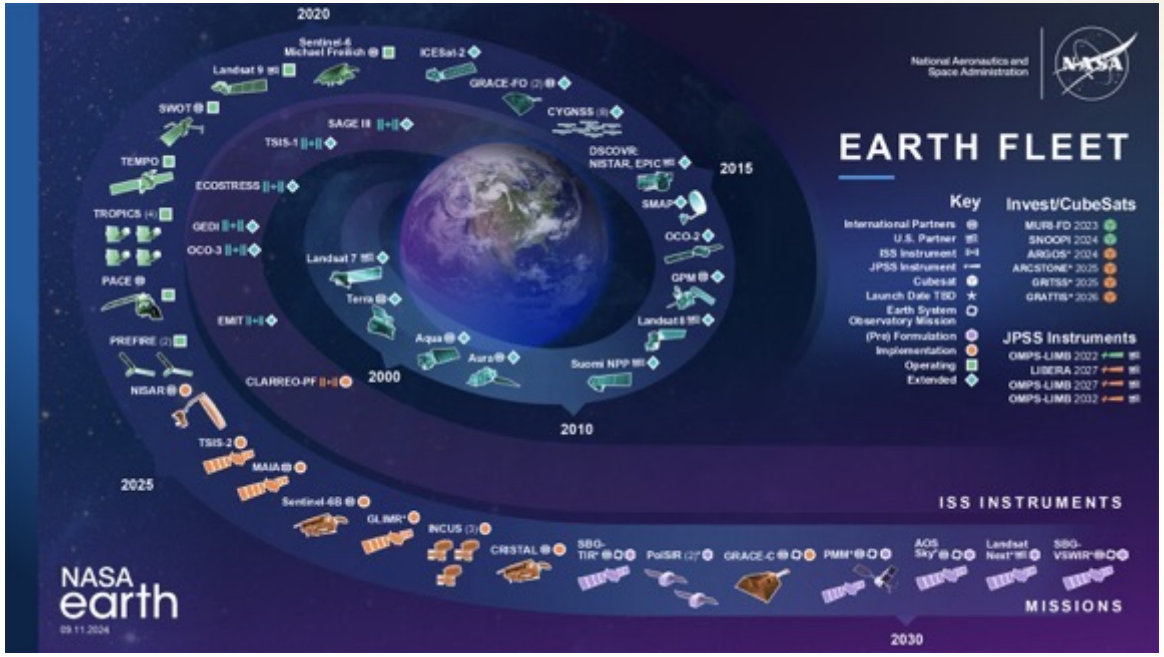
Introduction to NASA SMD, BPS, and Space Biology

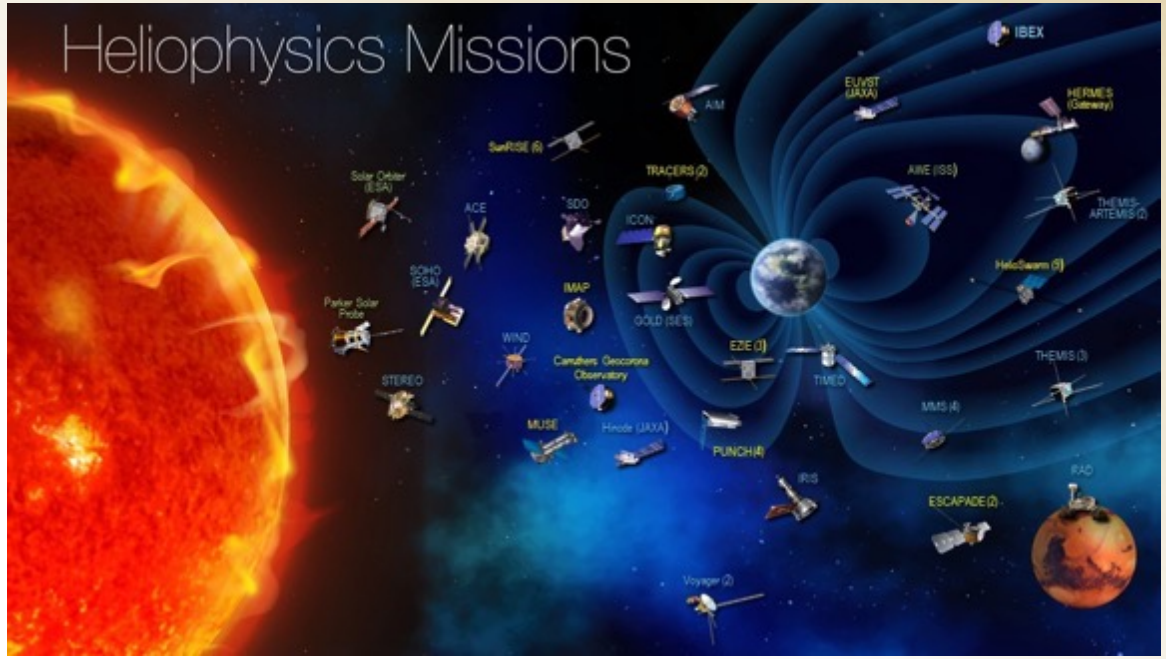
NASA SMD Science by the Numbers

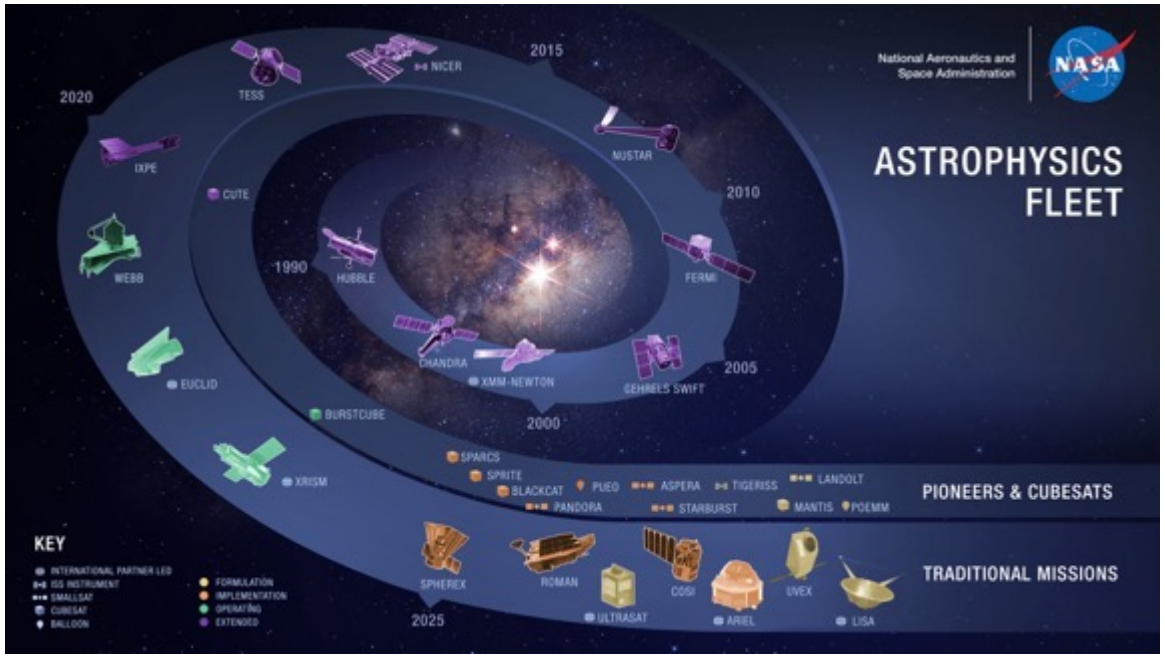


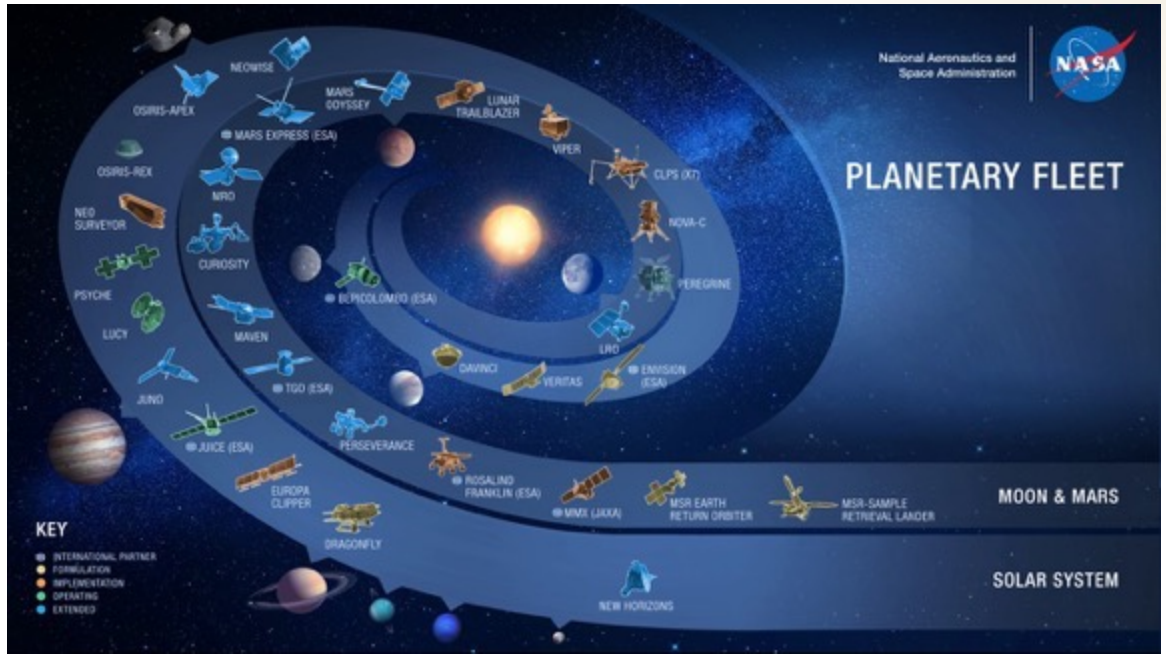
https://science.nasa.gov/about-us/

NASA Science Mission Directorate (SMD)

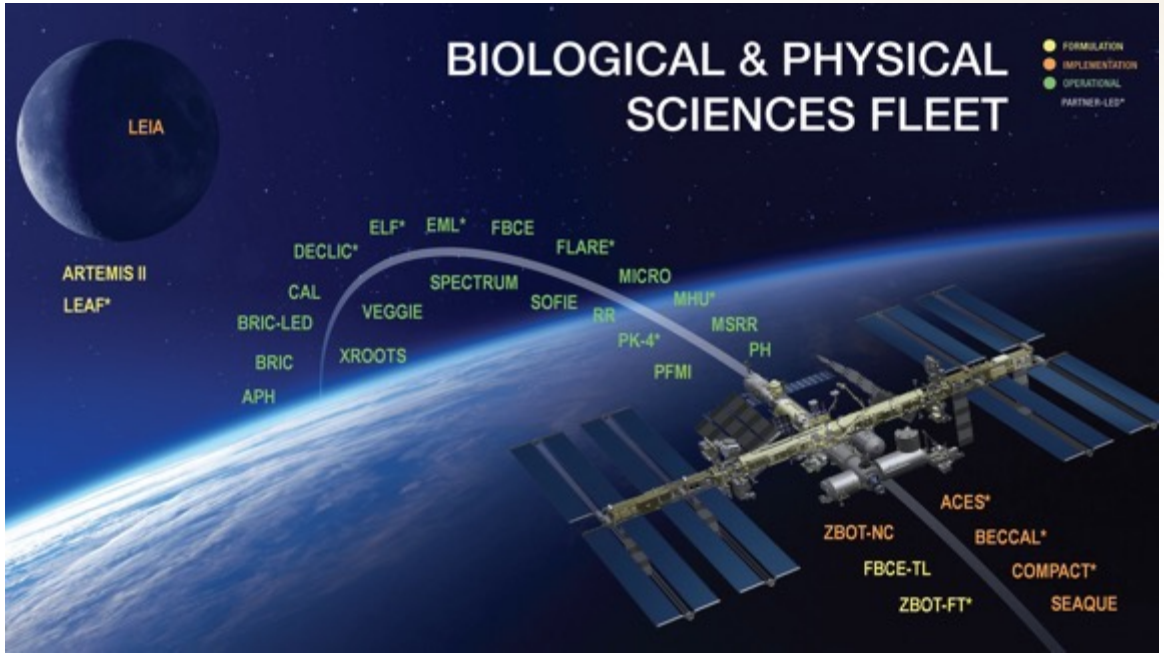


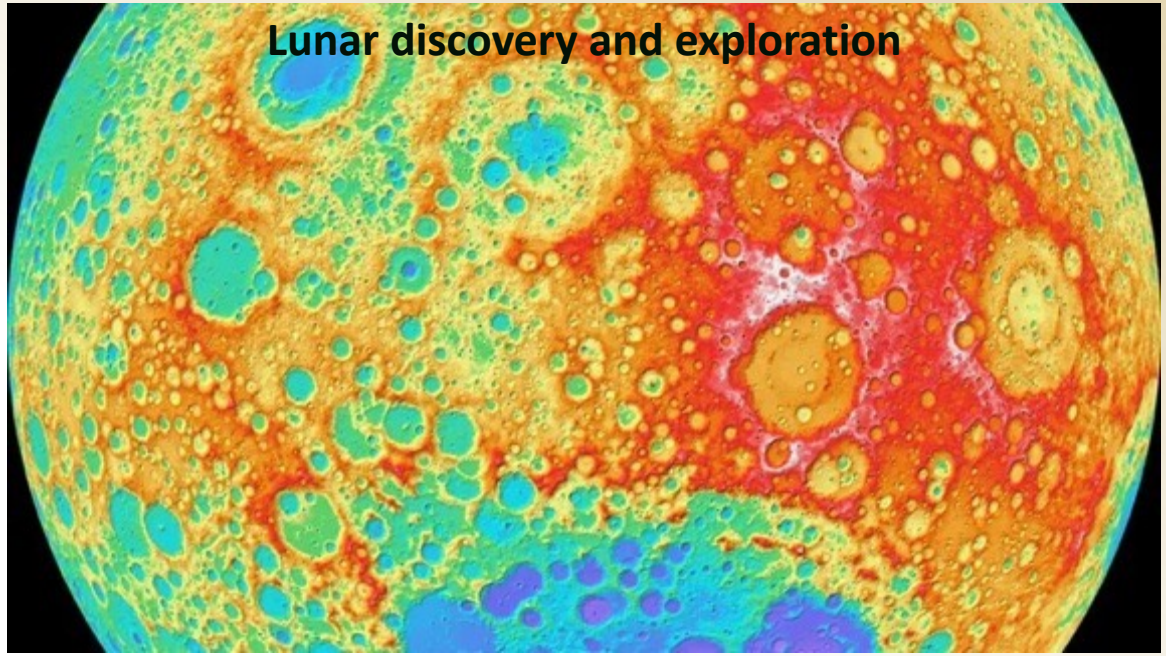


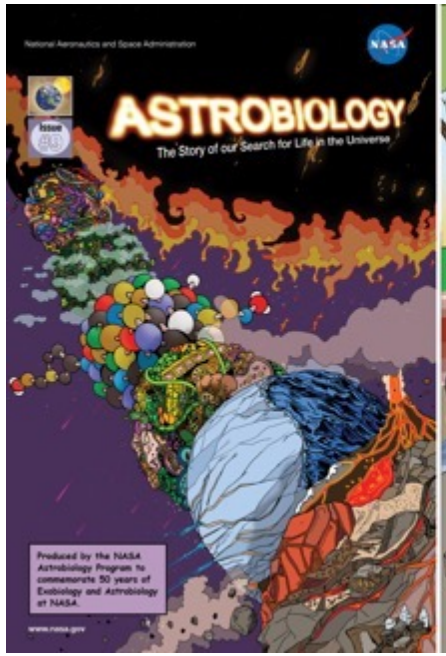


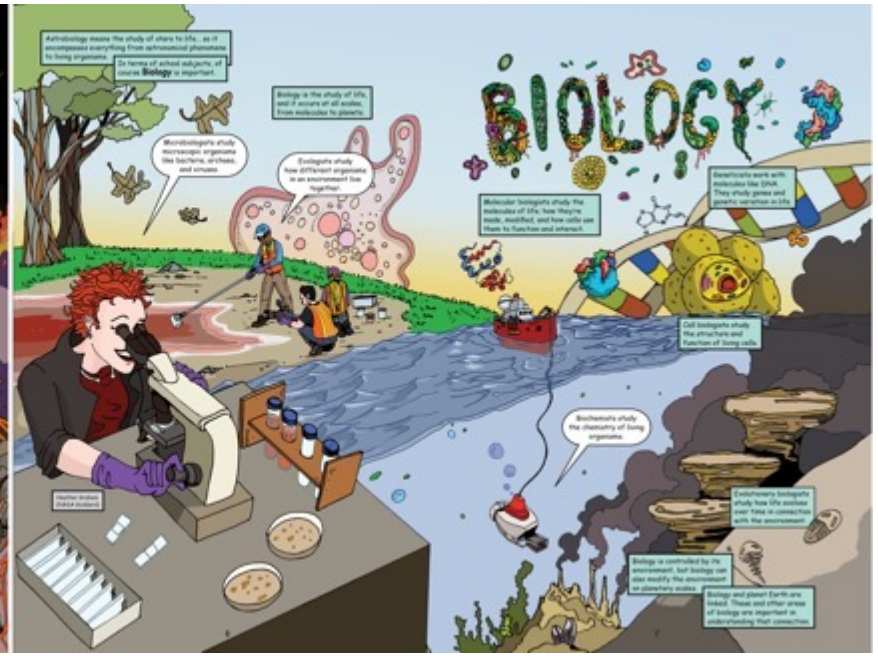


NASA Science Mission Directorate (SMD)

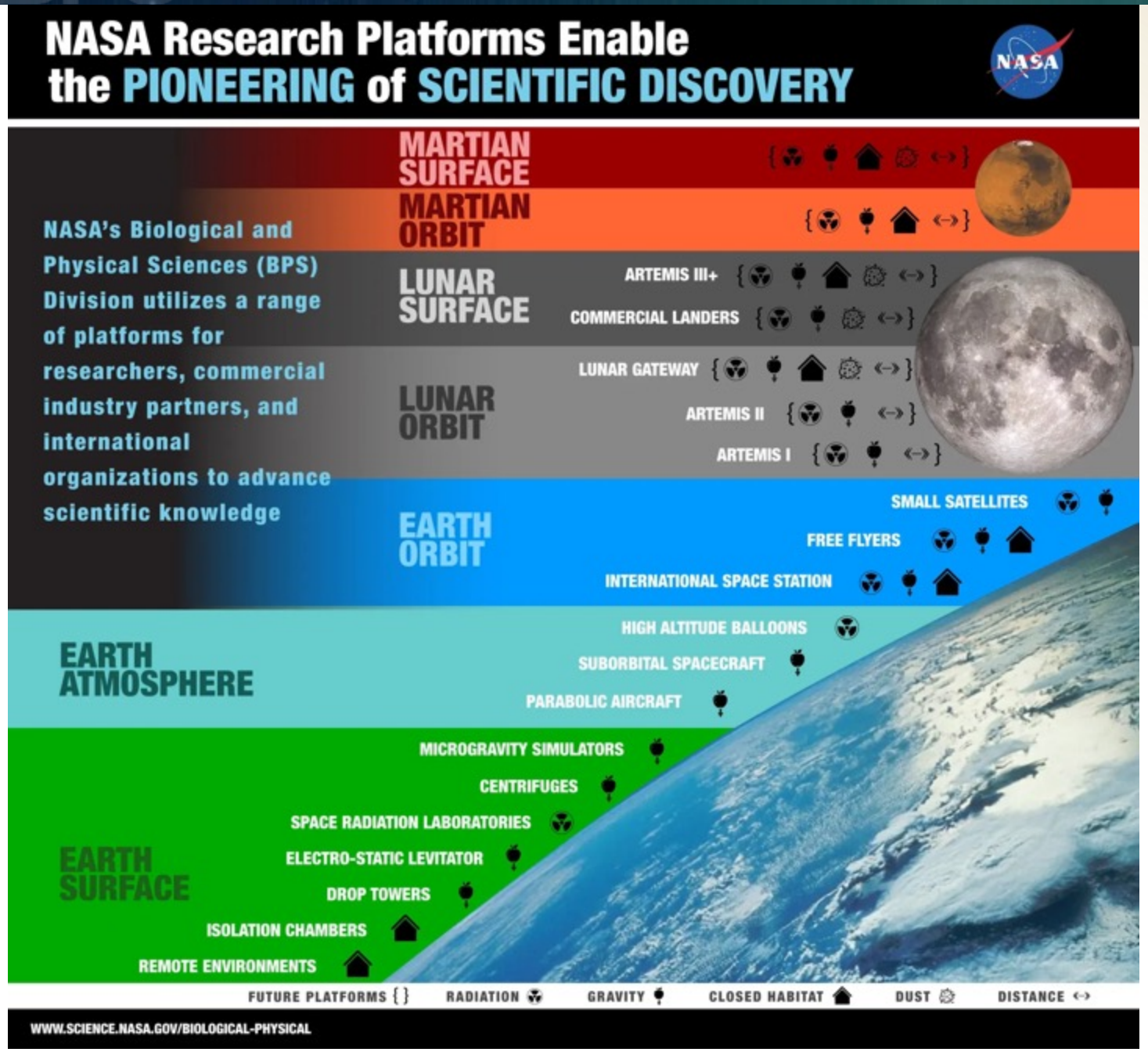








NASA SMD: Biological and Physical Sciences (BPS)

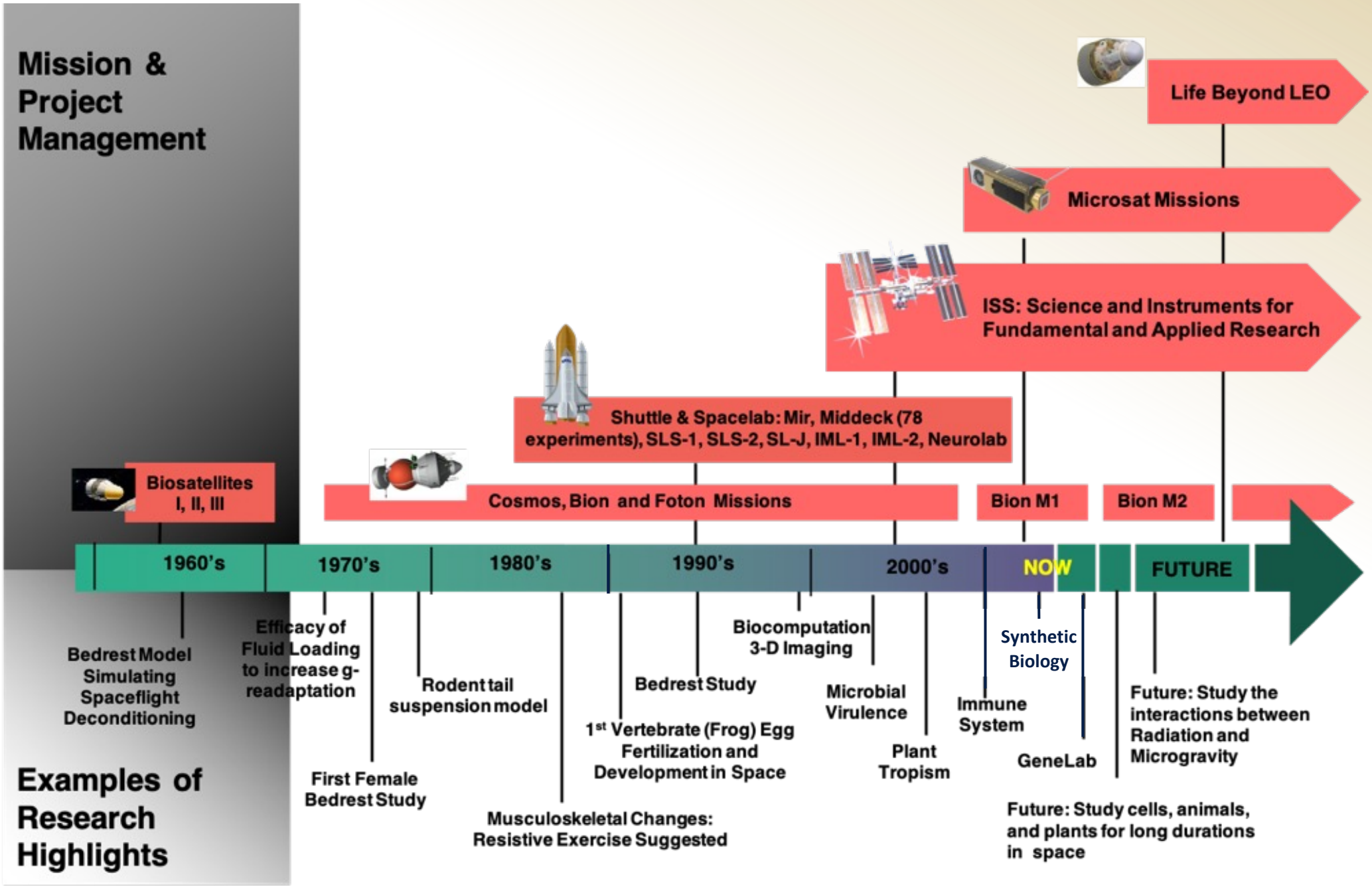


BPS Mission:

- Pioneer scientific discovery in and beyond low Earth orbit to drive advances in science, technology, and space exploration to enhance knowledge, education, innovation, and economic vitality
- Enable human spaceflight exploration to expand the frontiers of knowledge, capability, and opportunity in space

https://science.nasa.gov/biological-physical/

5+ Decades of NASA Life Sciences Research



Exposure to Spaceflight Changes our Physiological Systems

The Musculoskeletal System

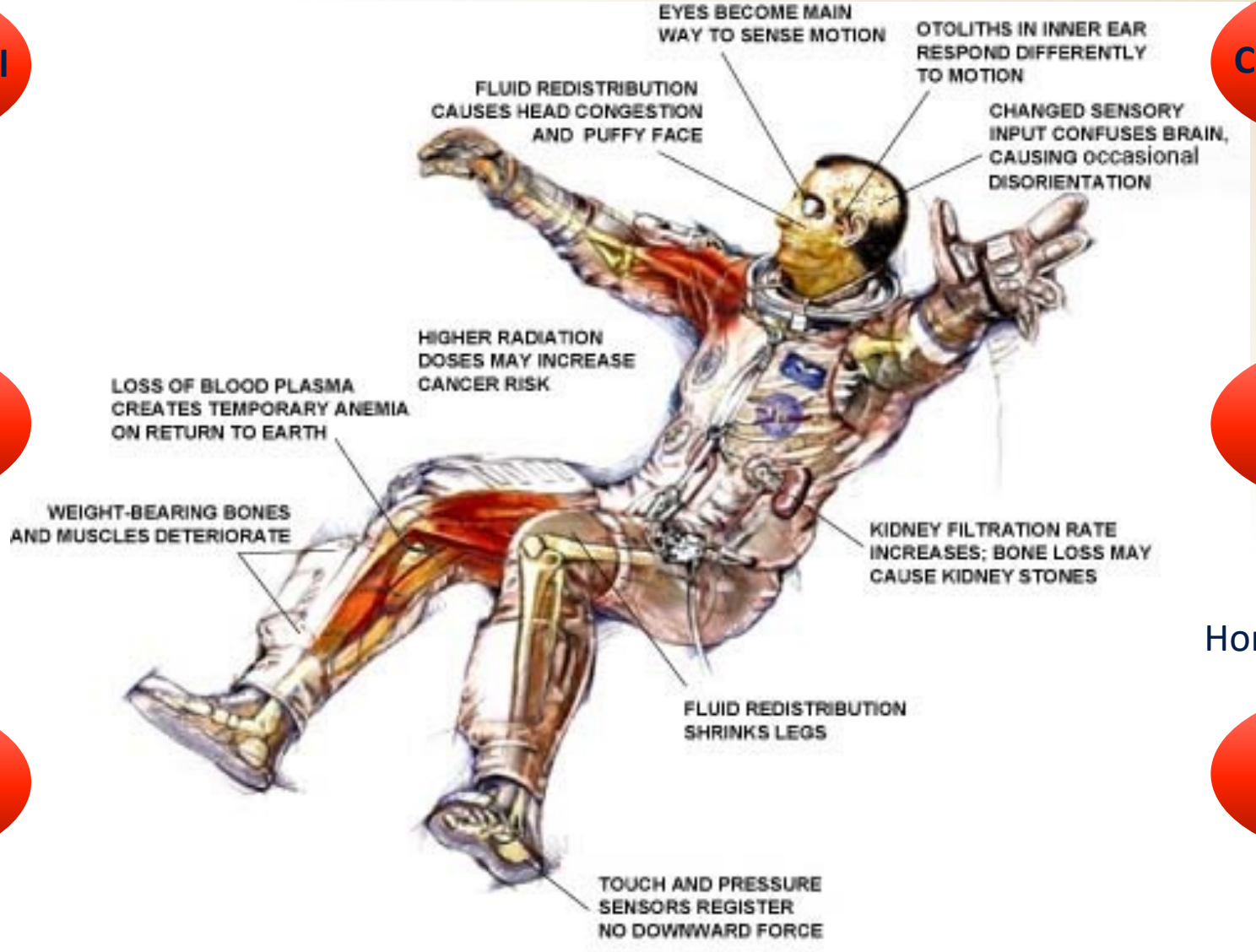
Osteoporosis
Osteoarthritis
Muscle atrophy

The Cardiovascular System

CVD
Atherosclerosis
Anemia

The Lymphatics

Lymphatic pump disorders



The Central Nervous System

Memory loss
Retinal edema

The Reproductive System

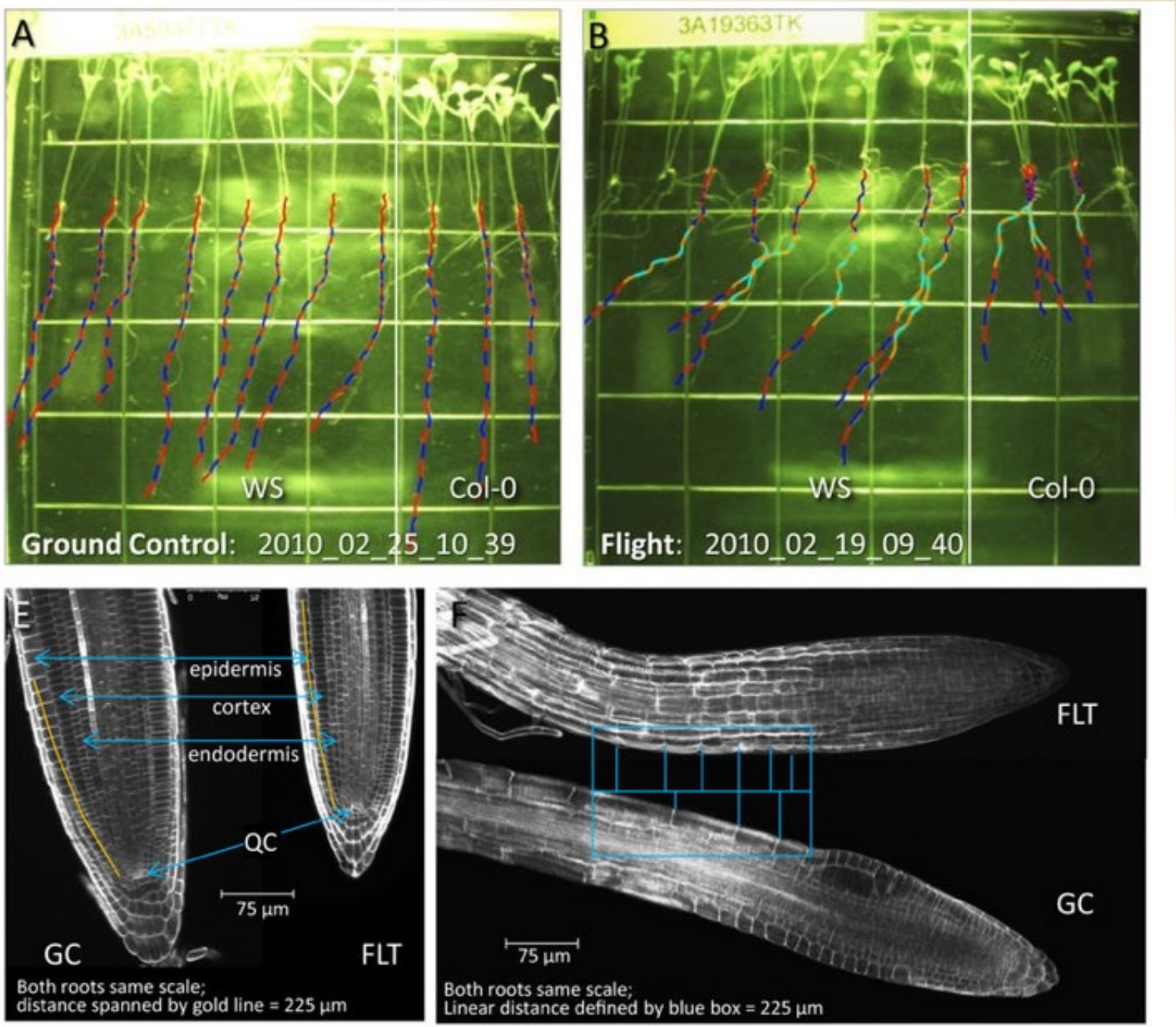
Sperm motility
Infertility
Hormonal imbalances

The Digestive System

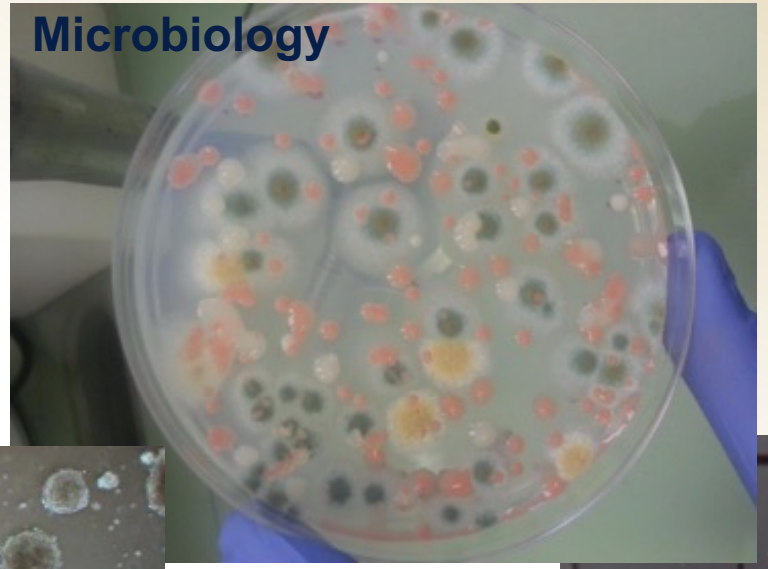
Liver fibrosis
NAFLD
IBS
Microbiome

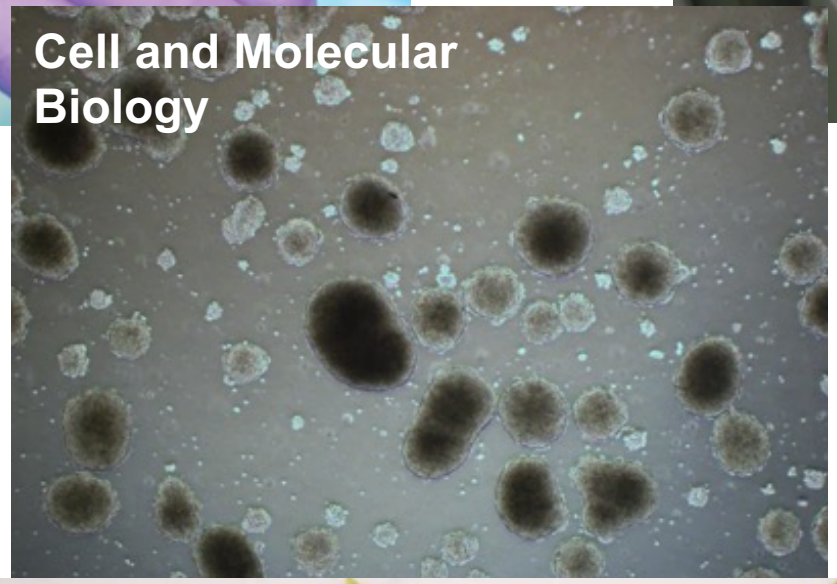
Astronaut image retrieved from http://marinscienceseminar.com/space-travel-how-does-outer-space-affect-your-body/

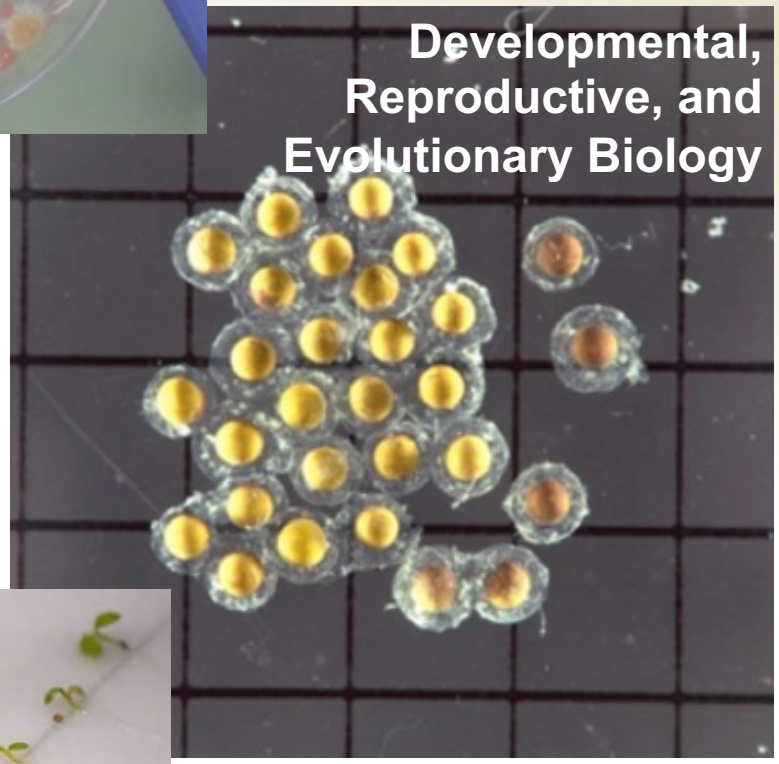
Exposure to Spaceflight Changes Plant Physiology Too

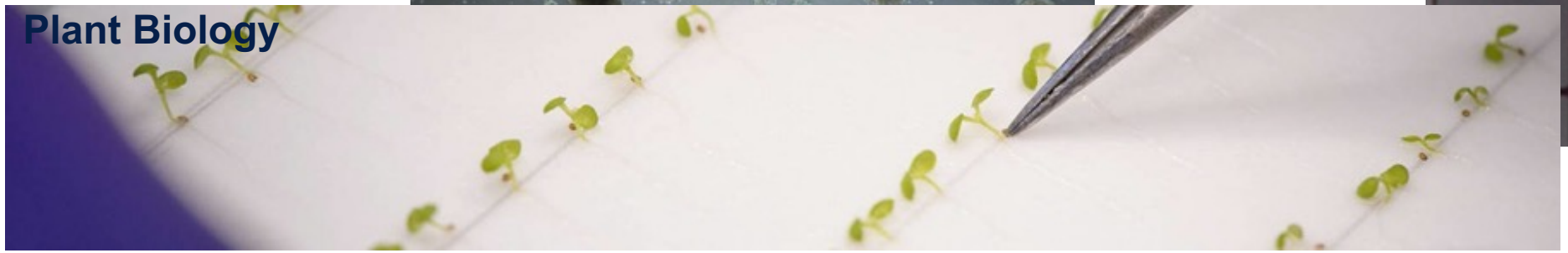


Space Biology Program







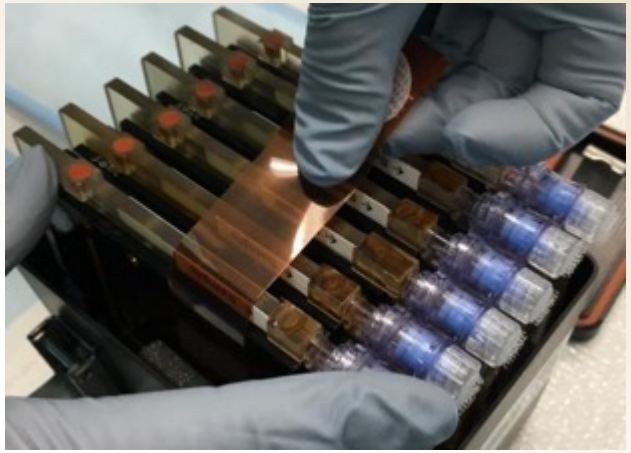


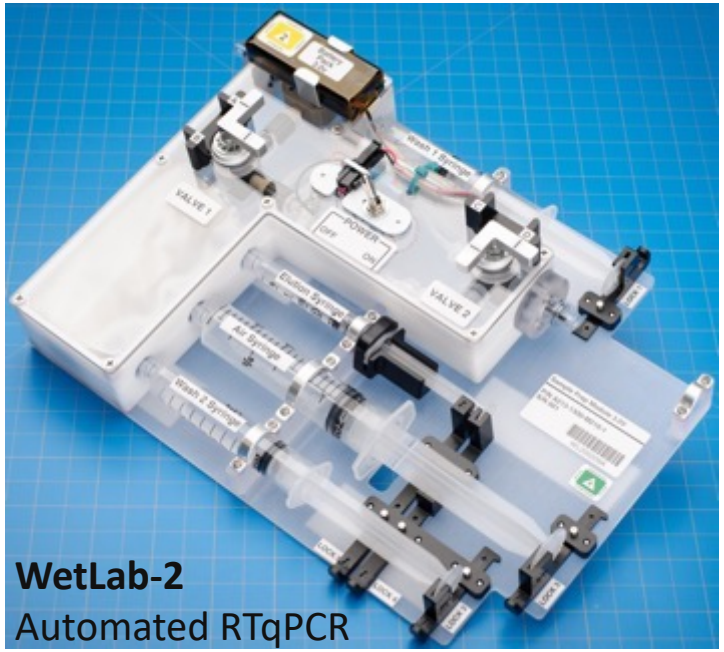
https://science.nasa.gov/biological-physical/programs/space-biology

Spaceflight Hardware: Cell Culture Systems

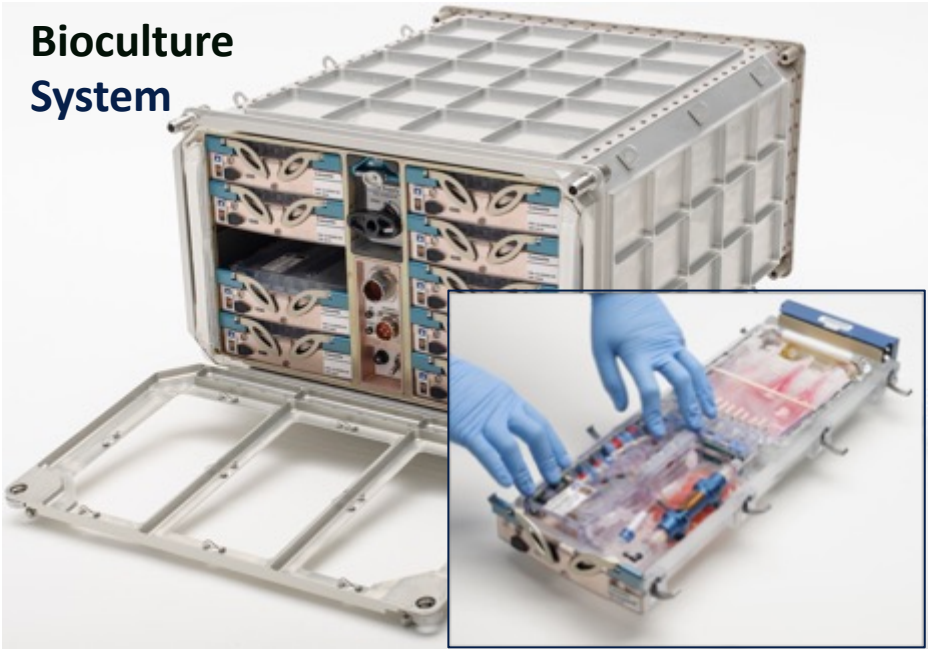
BioCell Research Applications

- Mammalian cells/tissues
- Small organisms (e.g., *C. elegans*)
- Yeast, bacteria, fungi, algae
- Biofilm formation studies





WetLab-2
Automated RTqPCR



Bioculture System

FPA Research Applications

- Microorganisms
- Mammalian cells and tissues
- Viruses and bacteria
- Protein crystal growth
- Biomaterials
- Small plants/seed germination

https://science.nasa.gov/biological-physical/focus-areas/cell-molecular/hardware/

Spaceflight Hardware: Microbiology and Small Organisms

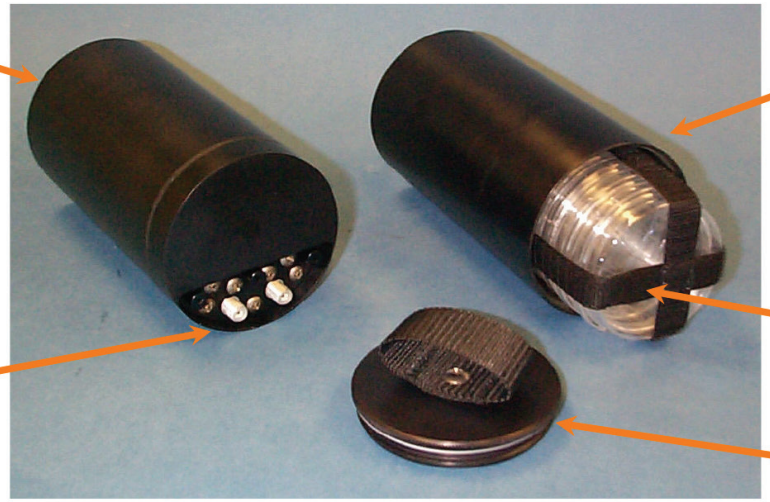


Fig. 1 BRIC-60 and BRIC-60M with petri dish configuration.

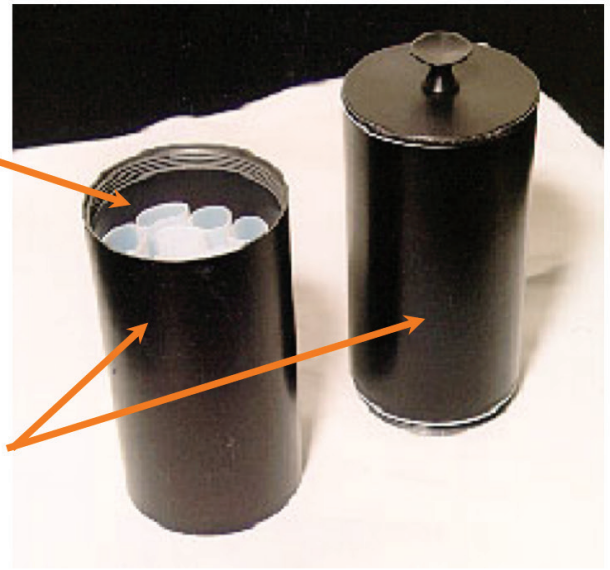
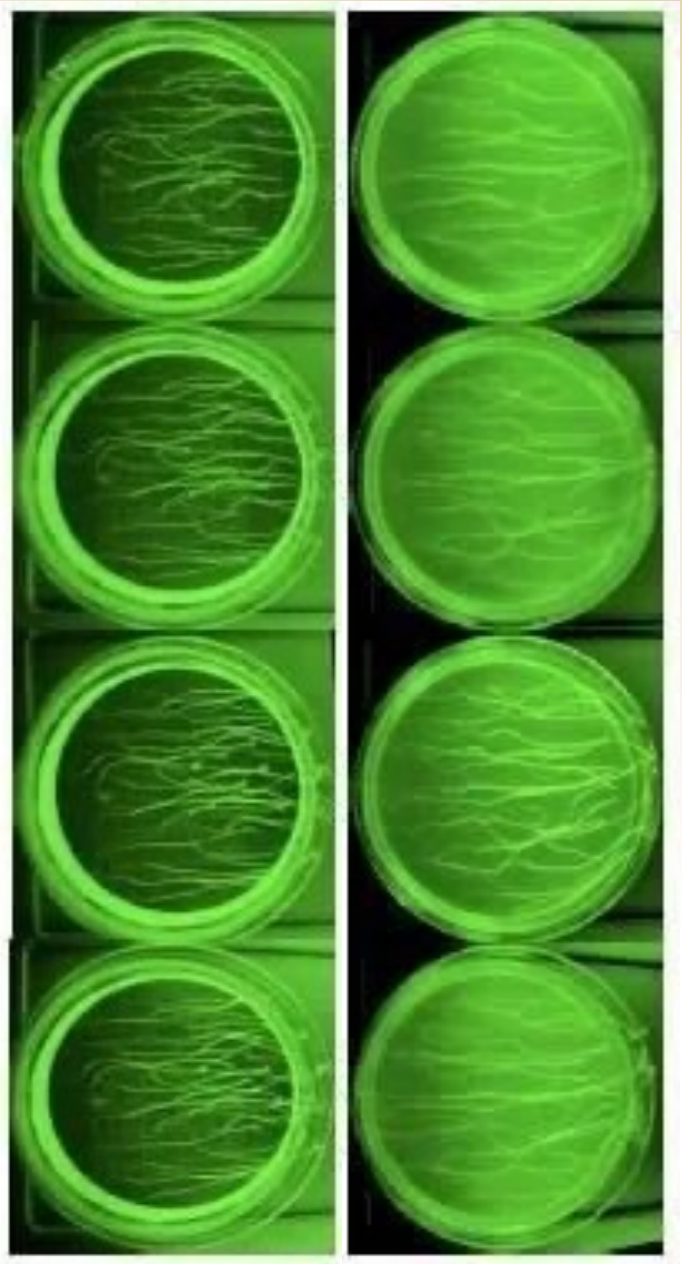


Fig. 2 BRIC-60 containing Teflon sample tubes.

Fig. 3 BRIC-60 Canisters as flown in an ISS stowage locker.

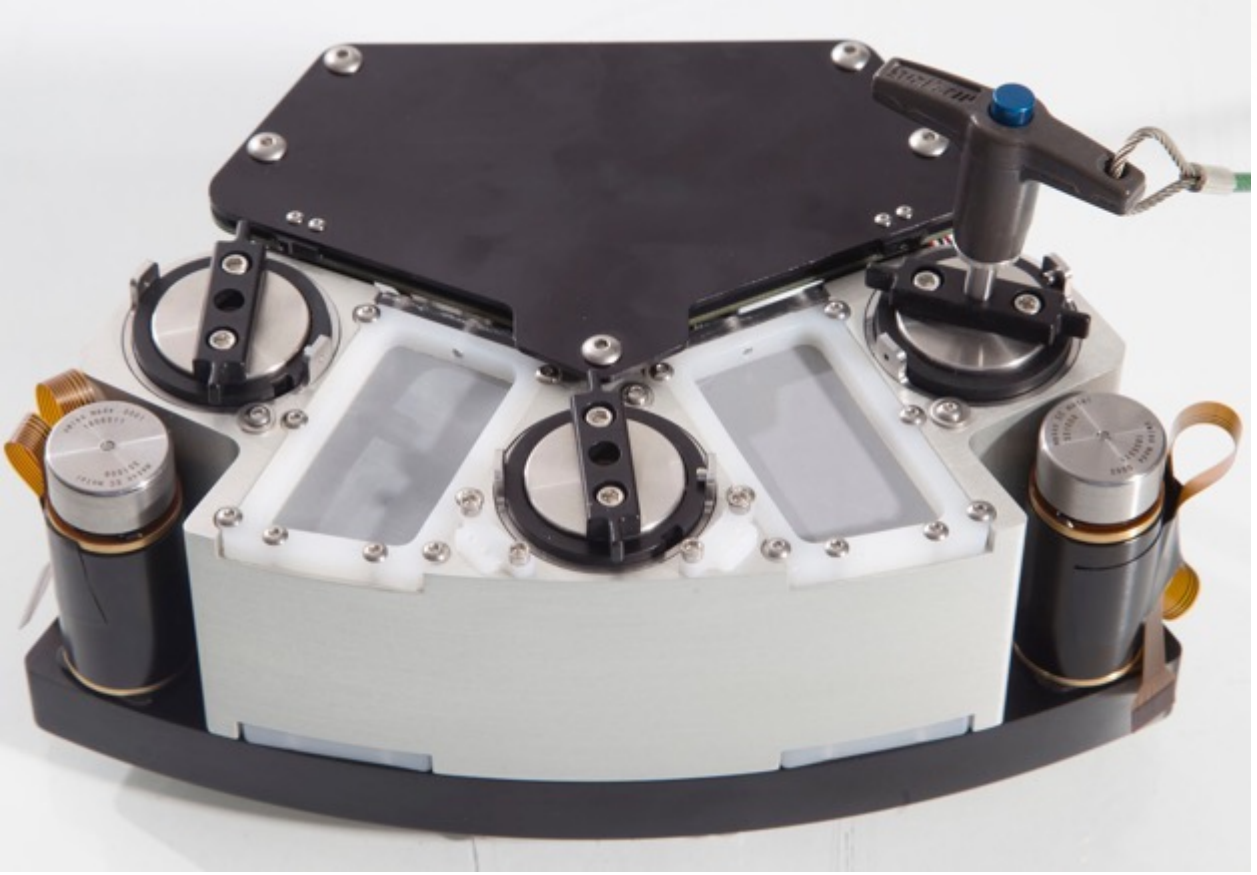


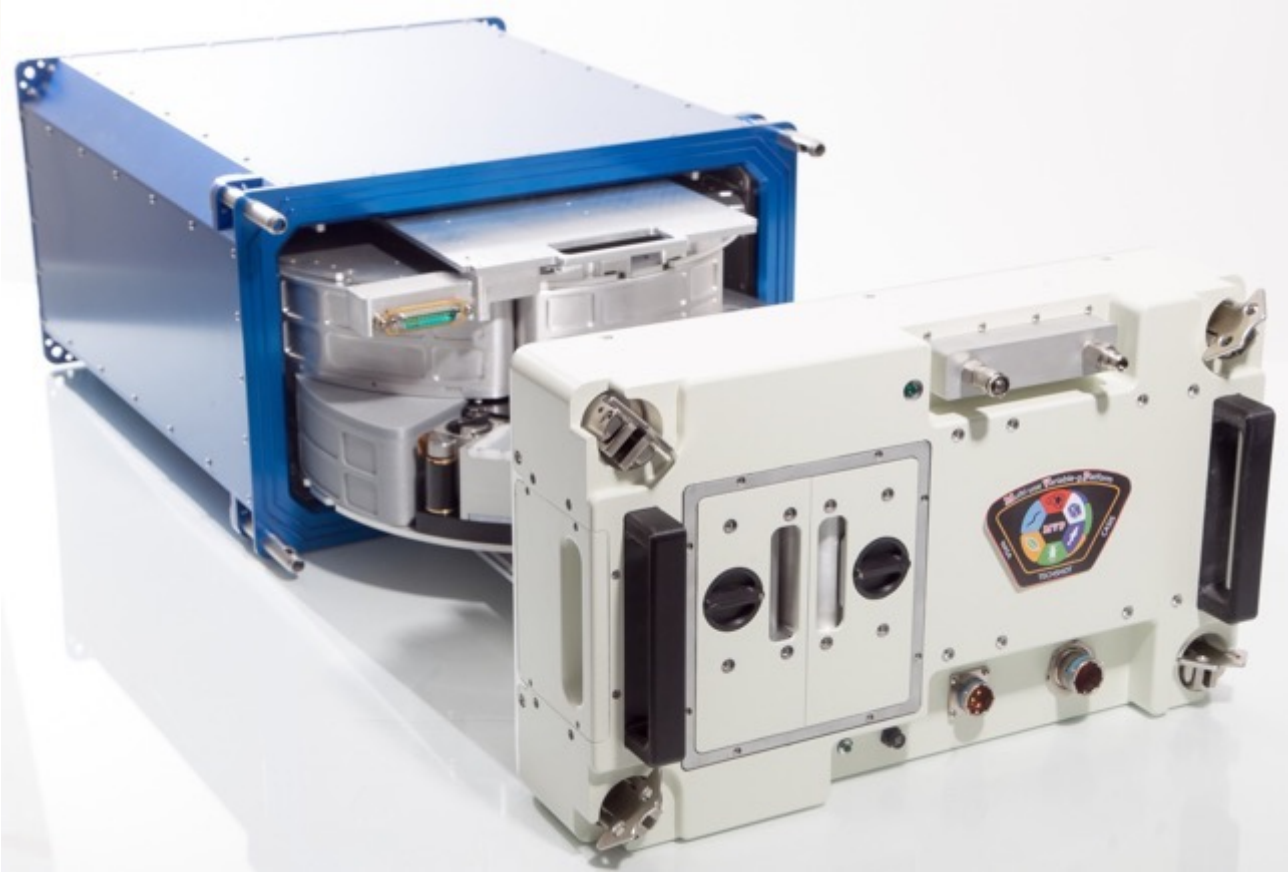
Biological Research in Canisters (BRIC)

https://science.nasa.gov/biological-physical/focus-areas/plant-biology/hardware/

Spaceflight Hardware: Small Animals

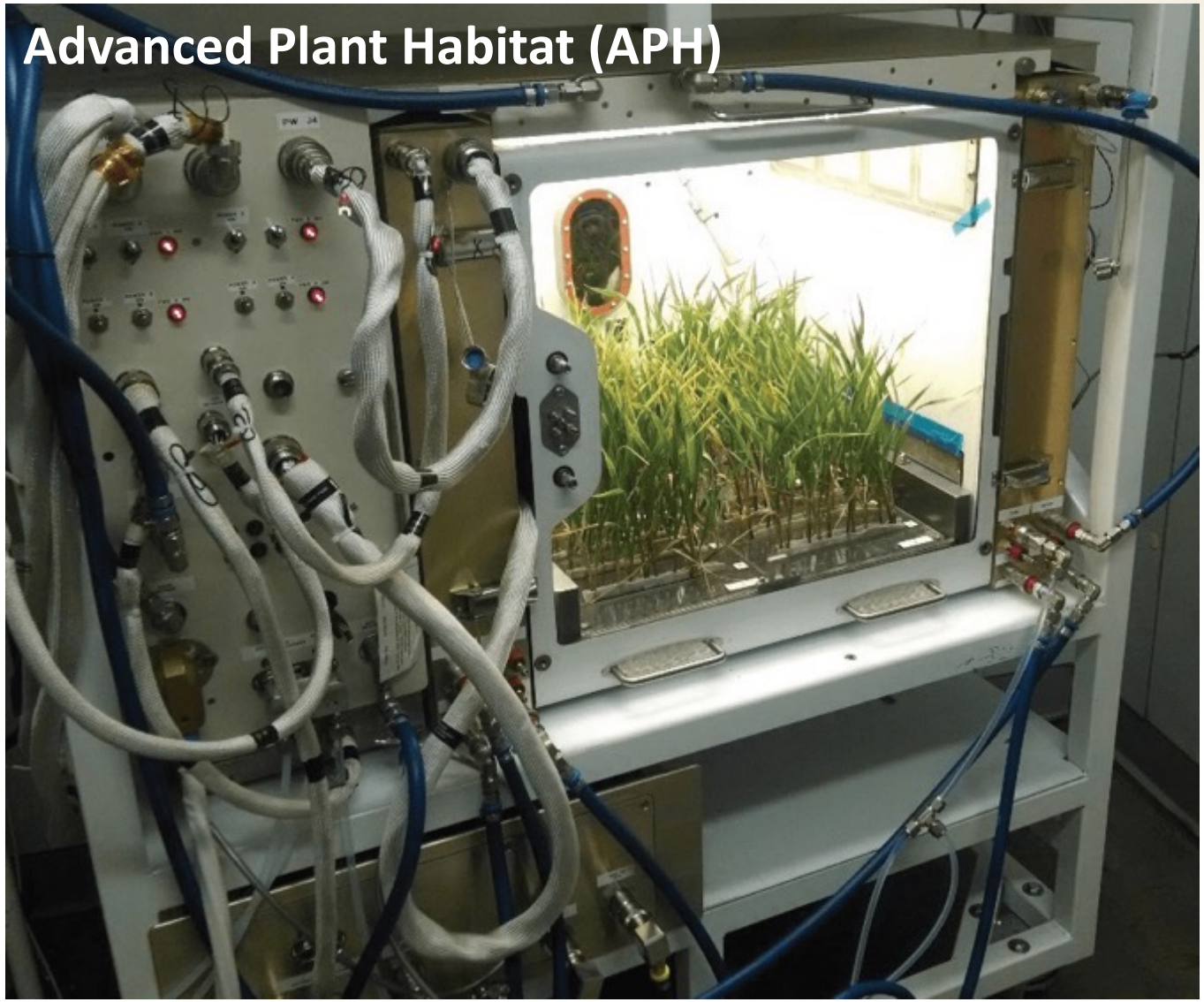
Multi-use Variable gravity Platform (MVP)





https://www.nasa.gov/ames/space-biosciences/multi-use-variable-gravity-platform-validation/

Spaceflight Hardware: Plants



Dwarf Wheat Growing in APH

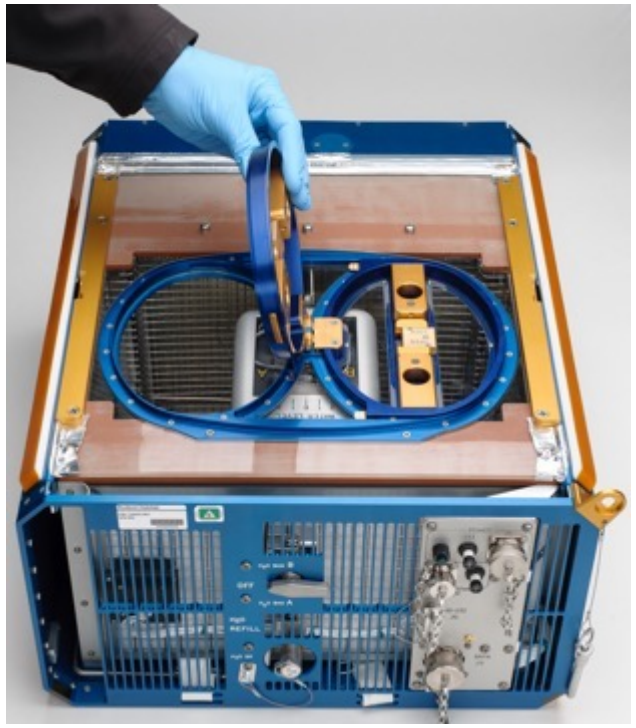
Astronaut Serena Auñón-Chancellor harvests red Russian kale and dragoon lettuce from Veggie on Nov. 28, 2018.

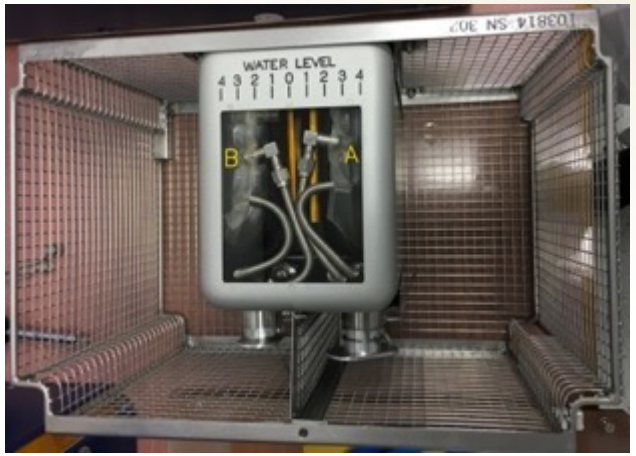
NASA astronaut Mike Hopkins has tended to multiple plant experiments on the International Space Station (ISS)

https://science.nasa.gov/biological-physical/focus-areas/plant-biology/hardware/

Spaceflight Hardware: Rodent Research

RR Habitat





Animal Access Unit (AAU)

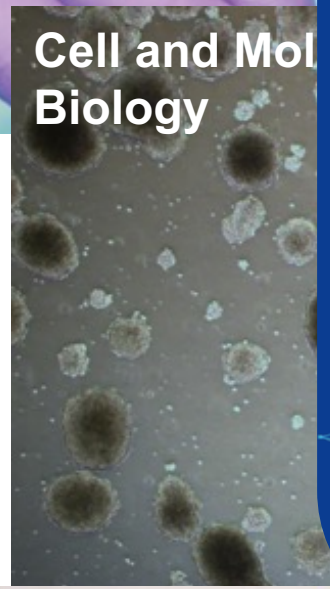
Ronca, A.E., Moyer, E.L., Talyansky, Y. *et al.* Behavior of mice aboard the International Space Station. *Sci Rep* **9,** 4717 (2019). https://doi.org/10.1038/s41598-019-40789-y

https://science.nasa.gov/biological-physical/focus-areas/animal-biology/hardware/

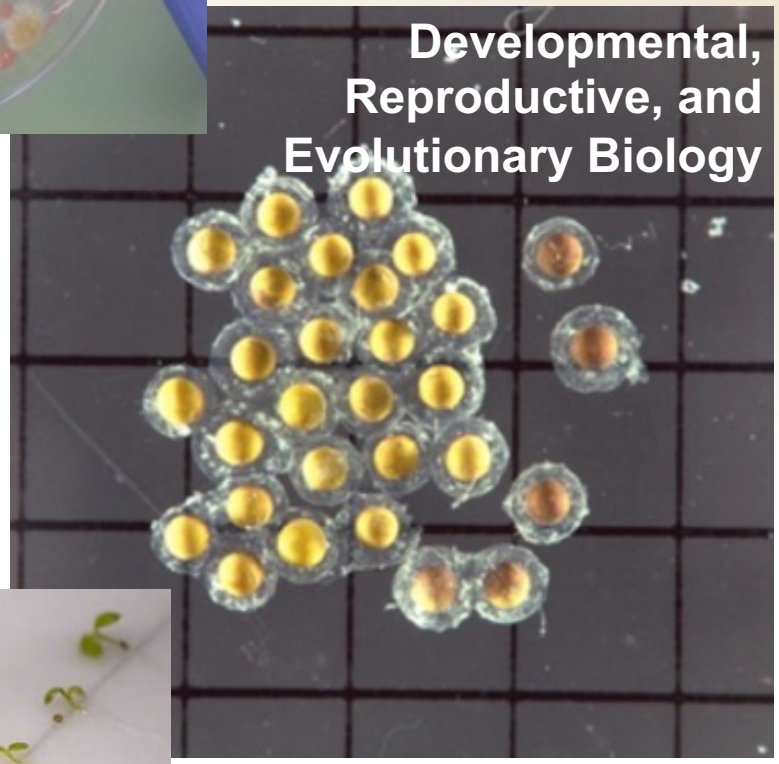
Spaceflight Hardware

https://www.nasa.gov/image-article/nasa-astronaut-jessica-meir-conducts-cardiac-research-2/

Space Biology Program



Open Science



https://science.nasa.gov/biological-physical/programs/space-biology

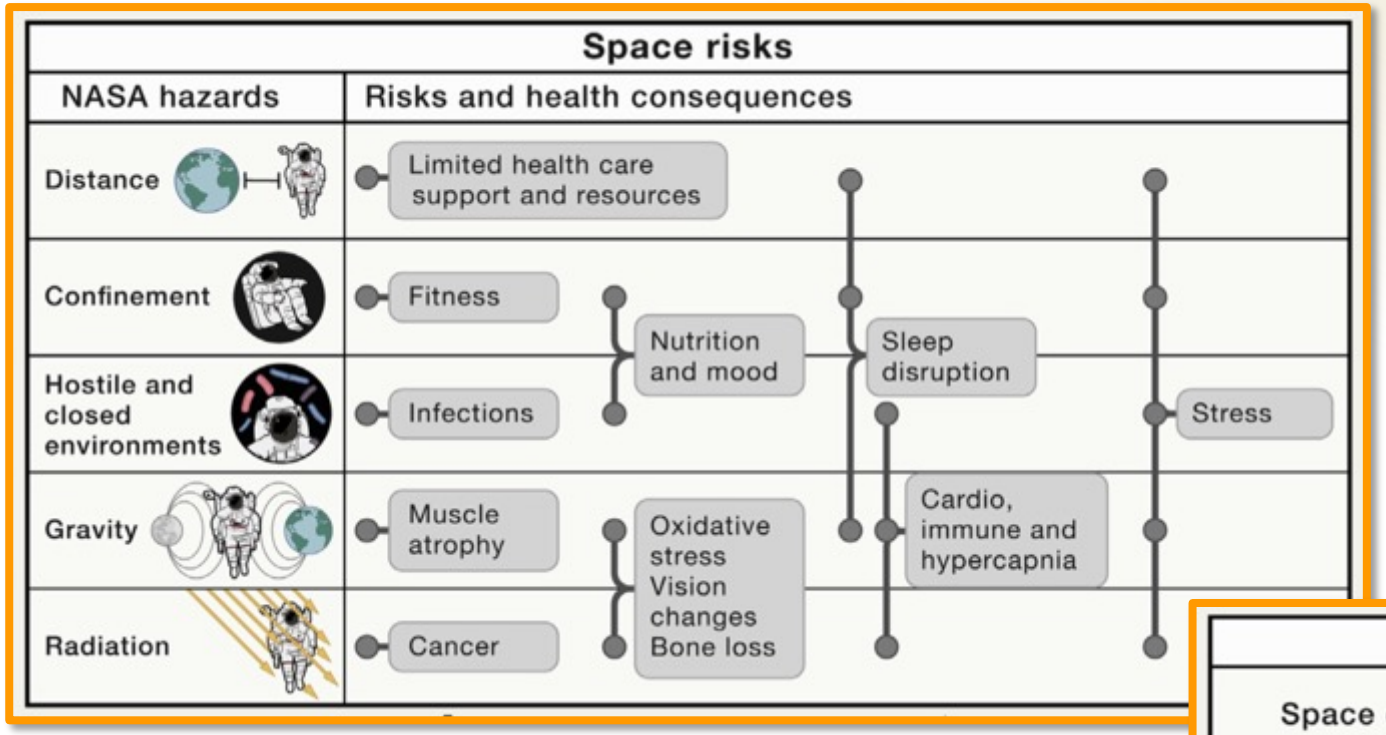
NASA Open Science Overview

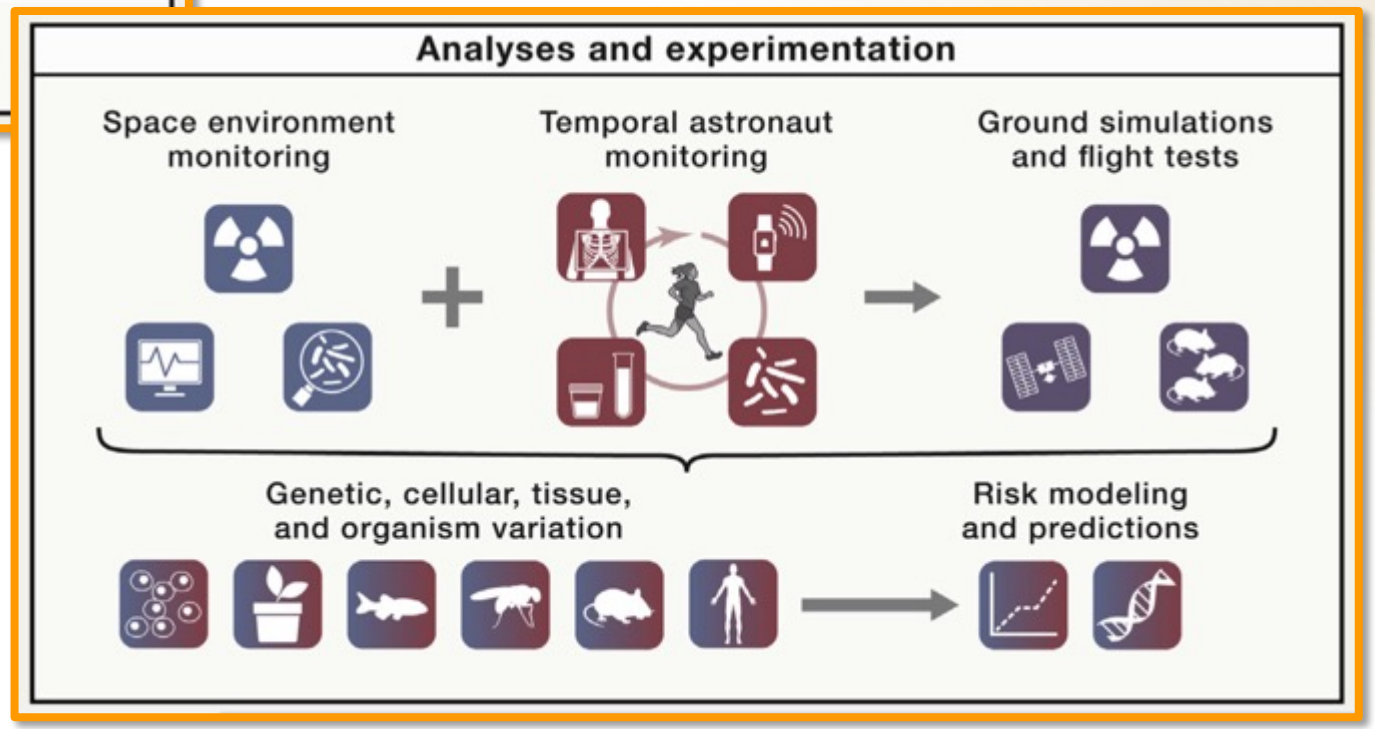
Open Science

"We define open science as a collaborative culture enabled by technology that empowers the **open sharing of data, information, and knowledge** within the scientific community and the wider public to accelerate scientific research and understanding."

Ramachandran, R., Bugbee, K., & Murphy, K. J. **Moving from Open Data to Open Science**. Earth and Space Science, Wiley Publication. https://doi.org/10.1029/2020EA001562

Space Travel Introduces Risks for Living Systems

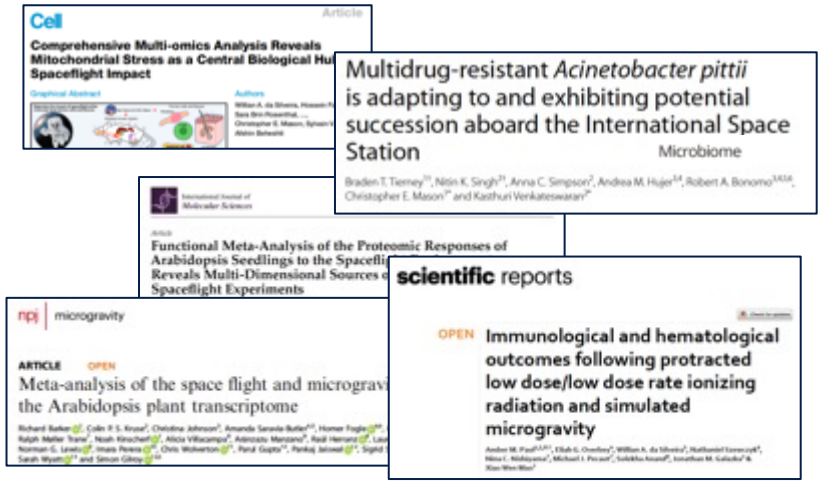




Afshinnekoo et al., *Cell*, 2020

Reusable Data is Essential for Life and Humans to Thrive in Deep Space

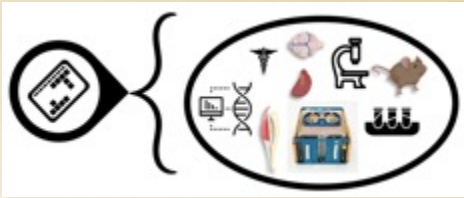
Knowledge Discovery



Advanced Computational Methods

Model development
Active and adaptive learning
Causal and network inference
Explainable AI
Federated learning
Few- or one-shot learning
Generative learning (synthetic datasets)
Knowledge graphs
Lifelong learning (living lab)
Out-of-distribution learning
Transfer learning

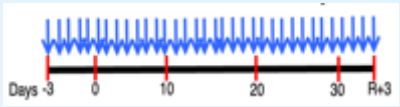
Telemetry for Biomedical Context



Analysis Across Missions

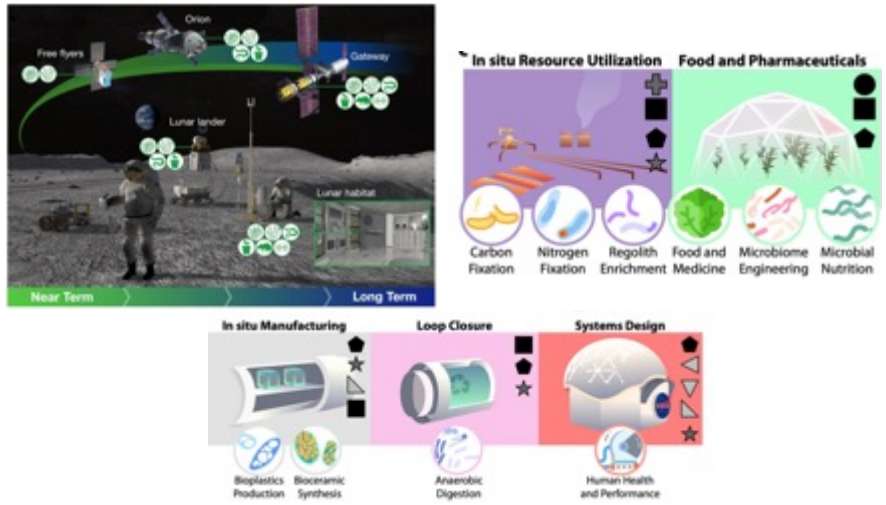
Across Hazards

Across Species, Multimodal Data Types

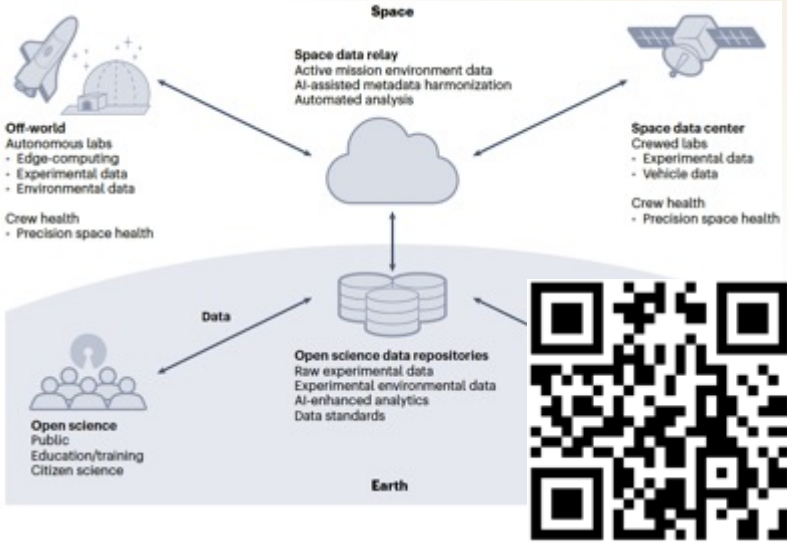


Longitudinal, Biomonitoring, & Experimental

Novel Ecosystem, Platform, Countermeasure Development, Health Risk Quantification



Involve the World in Spaceflight



(Scott et al., 2023 https://rdcu.be/c8jSO; Sanders et al., 2023 https://rdcu.be/c8jSS)

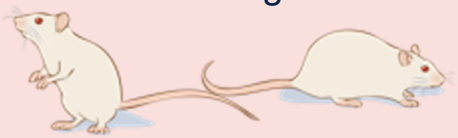
(Berliner et al., 2022 https://doi.org/10.1038/s44172-022-00012-9; Everroad et al., 2021 https://ntrs.nasa.gov/citations/20210023324)

NASA Biological Open Science Resources

Biospecimen Sharing Program (BSP)

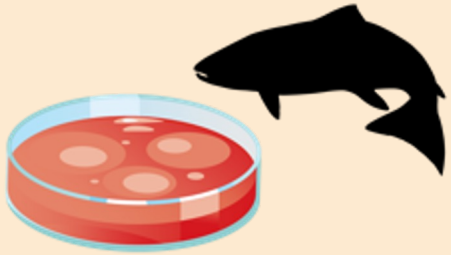
Dissection and preservation of rodent tissues from Flight and Ground investigations

Coordination of internal tissue sharing



NASA Biological Institutional Scientific Collection (NBISC)

Collection of non-human specimens and space microbial culture



NASA GeneLab (GL)

Collection and curation of omics data

Ames Life Sciences Data Archive (ALSDA)

Collection and curation of mission, project, and imaging data

NASA Internal Program

Open Source Science Programs — Available Globally

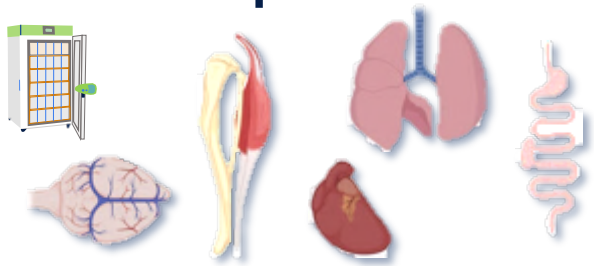
NASA Open Science Data Repository Overview

Physiological/Phenotypic/Imaging/ Environmental Telemetry Data

Tabular, text, imaging, video, code

Molecular/Omics Data

Biospecimens



ALSDA

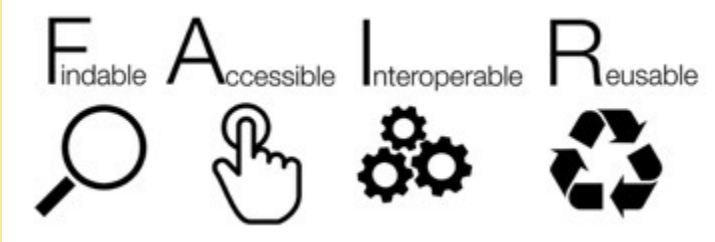
GeneLab

NBISC

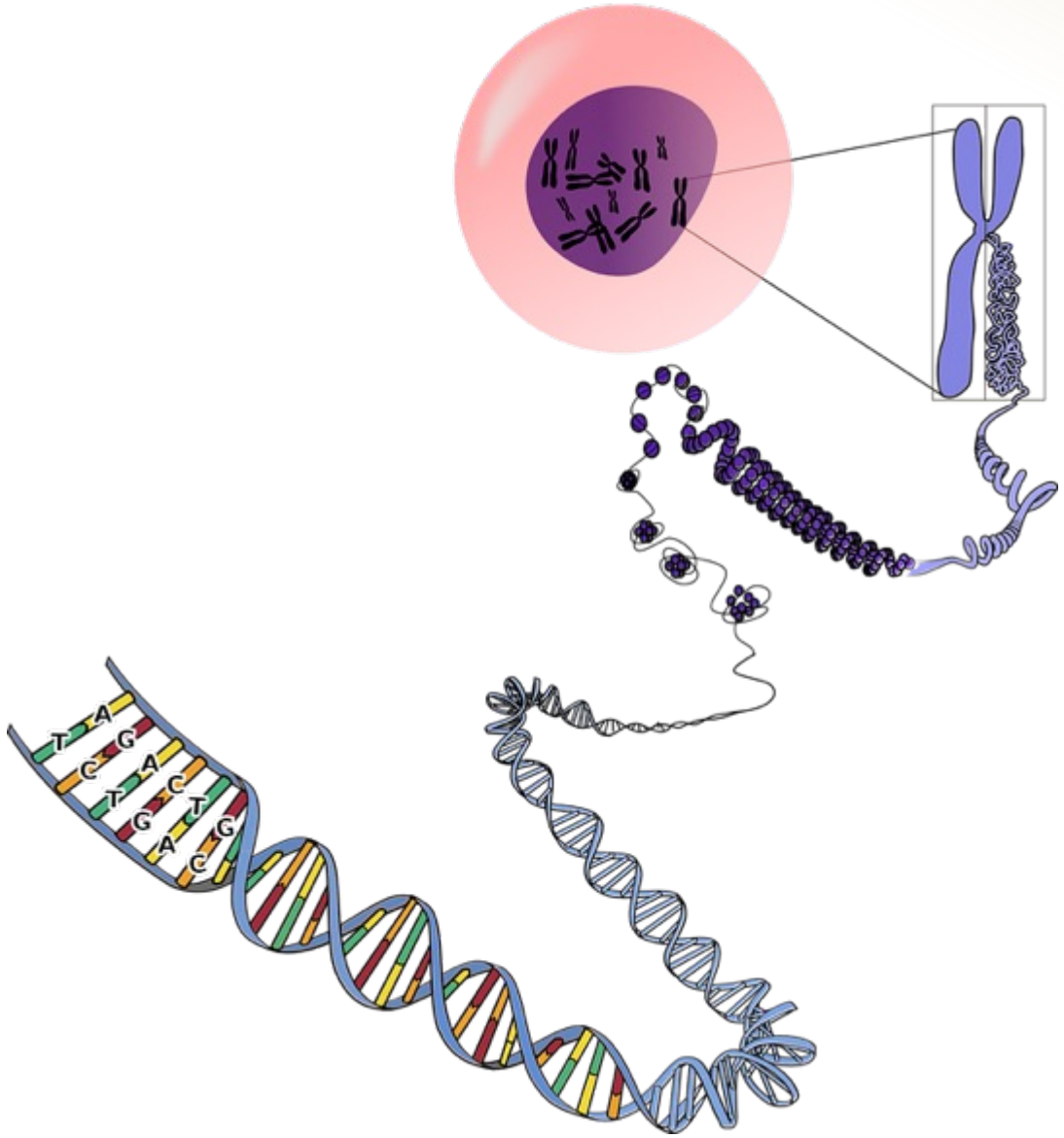
NASA Open Science Data Repository (OSDR)

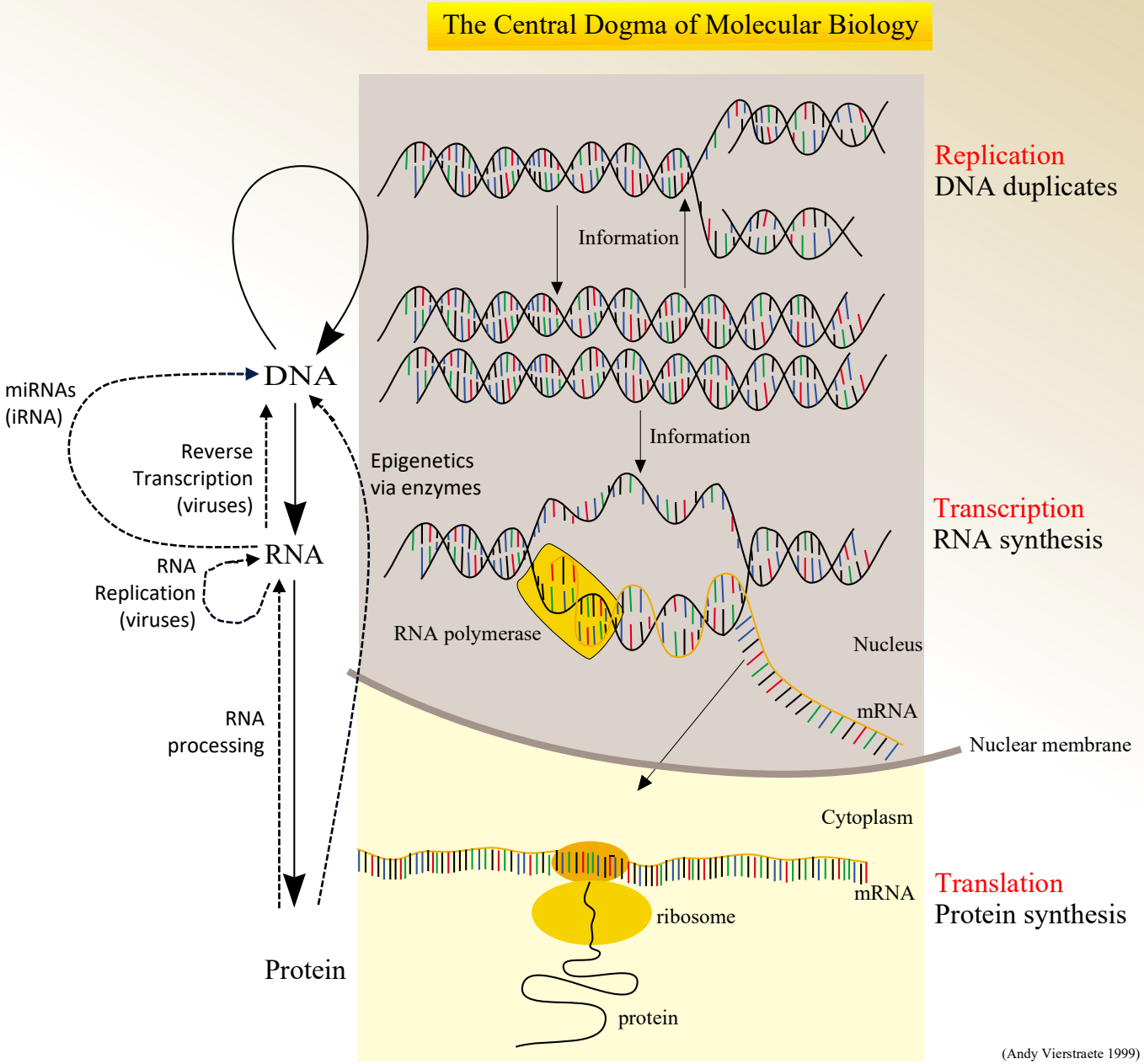
osdr.nasa.gov/bio

- Single Submission Portal (BDME)
- User Interface/Website Tool for RDSAs (Research Data Submission Agreements)
- Maximally Open Access with Necessary Controls for Sensitive Data
- Data Maximally FAIR



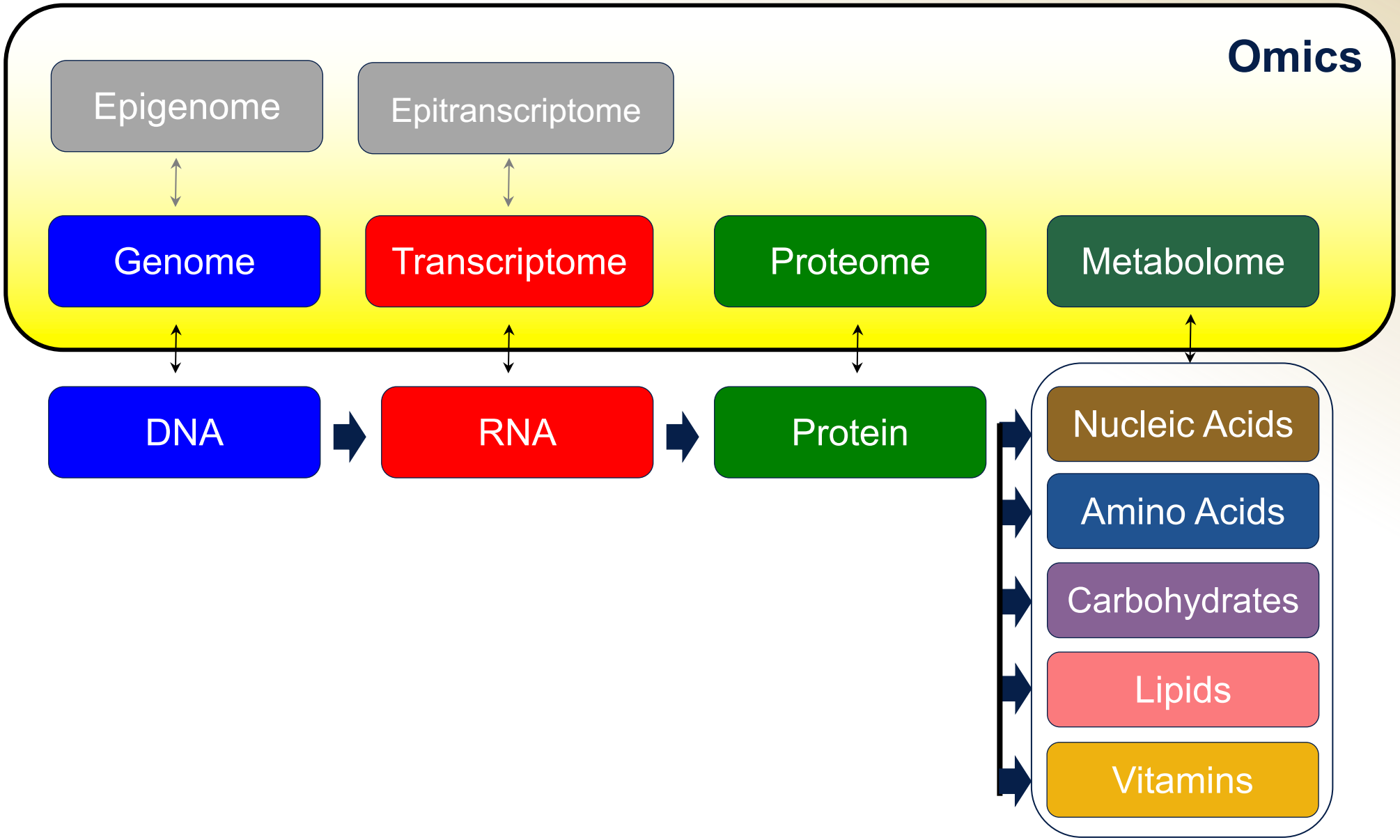
What are ‘omics?





(Andy Vierstraete 1999)

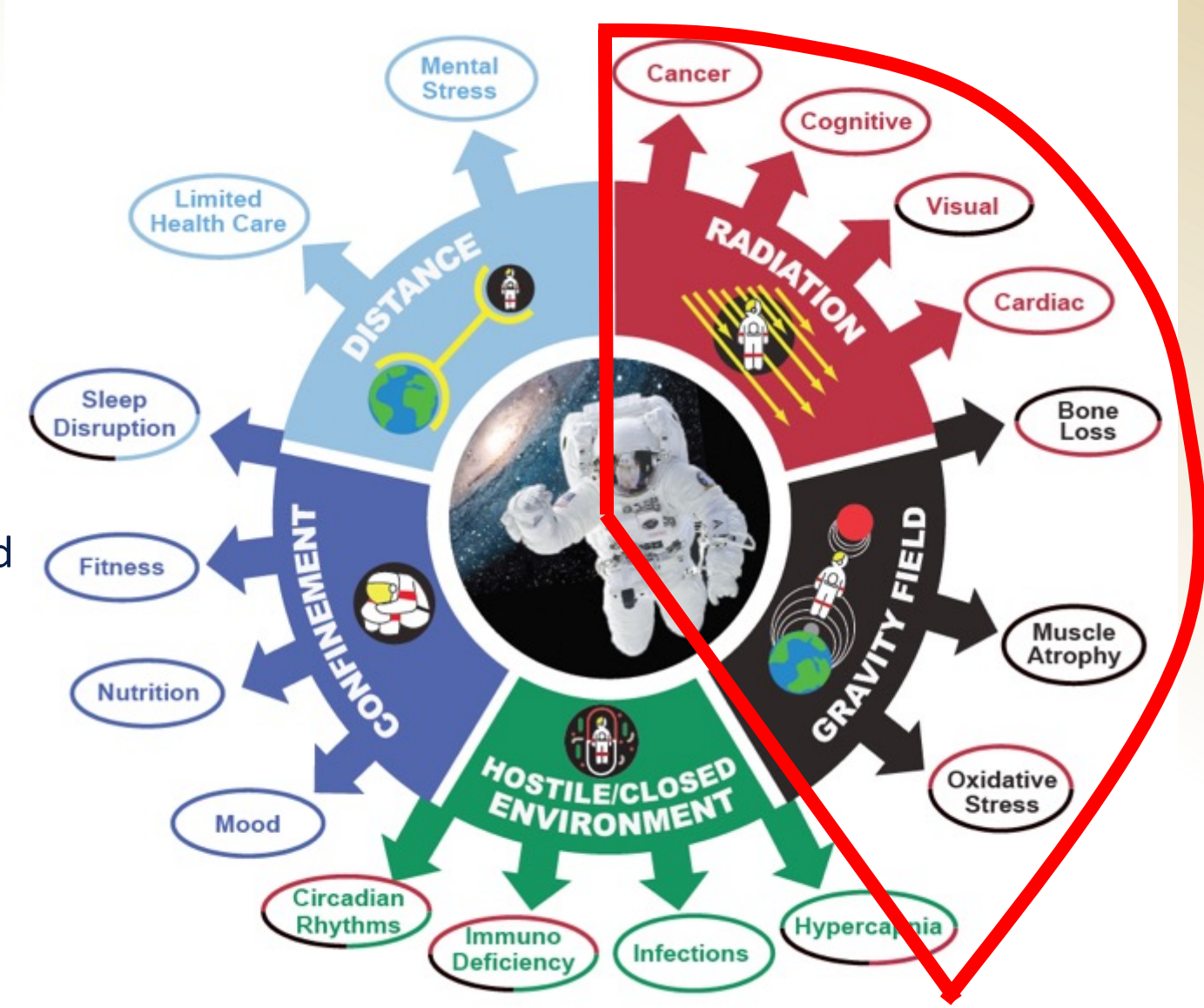
What are ‘omics?



Why is studying omics important for spaceflight?

- What, when, and where genes are expressed allow for cell type diversity and enable living organisms to respond and adapt to surroundings
- Gene expression is primarily regulated by environmental factors both micro (cell's micro-environment) and macro (organism's external stimuli or stressors)
- Spaceflight alters the transcriptional patterns and molecular signaling networks within our cells, which in turn causes physiological changes
- Understanding such changes will enable development of mitigation strategies to better withstand the rigors of long-duration spaceflight

Primary Stressors of Spaceflight



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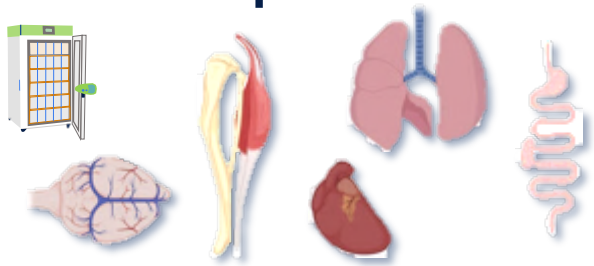
Tabular, text, imaging, video, code

Molecular/Omics Data

Biospecimens



ALSDA

GeneLab

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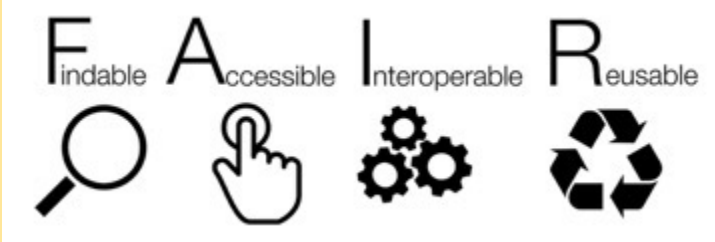


NASA OSDR – By The Numbers

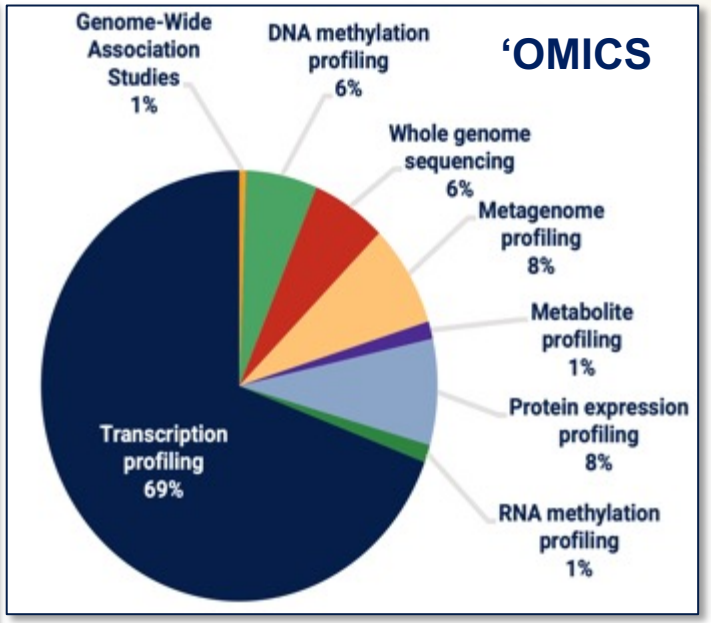
505 Studies

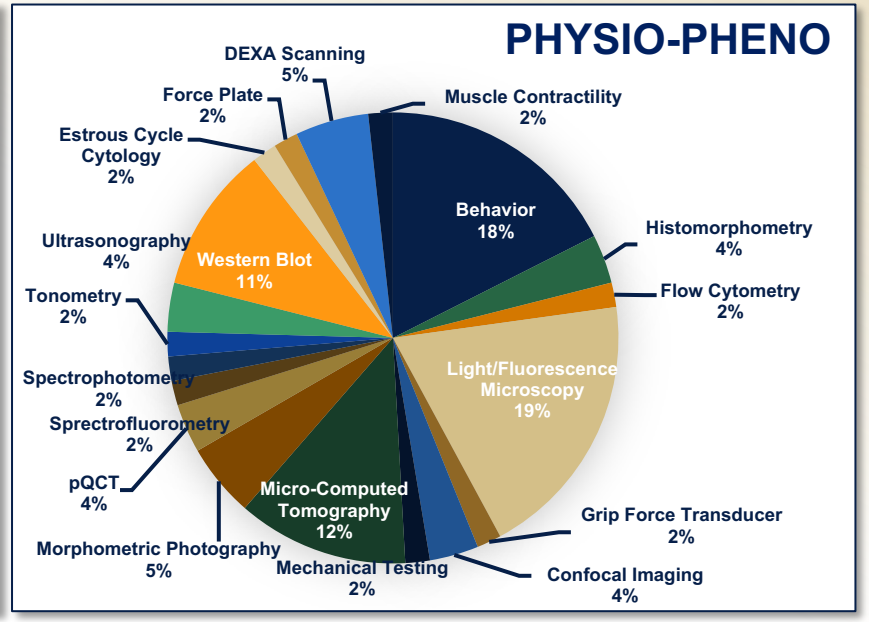
969 Datasets

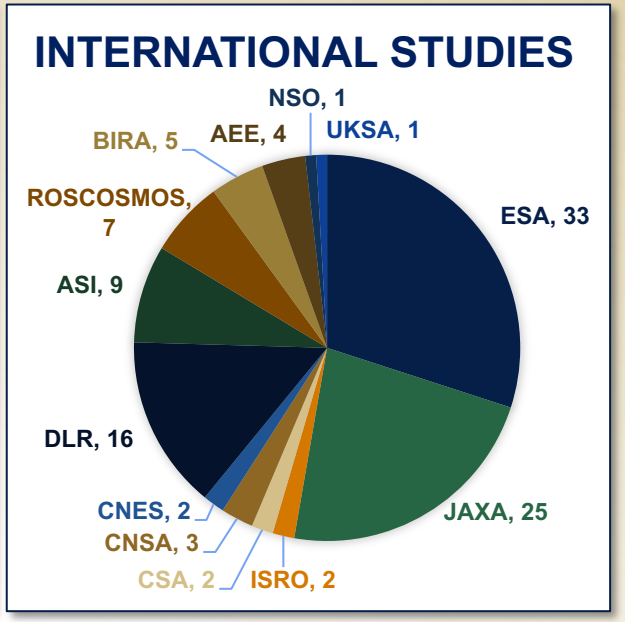
45 Species

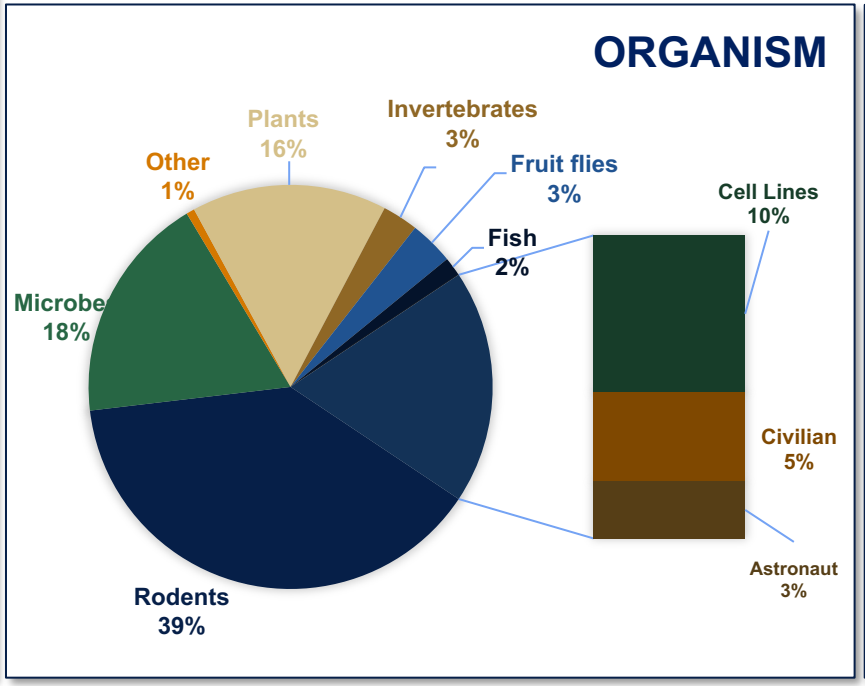
>80 Assays

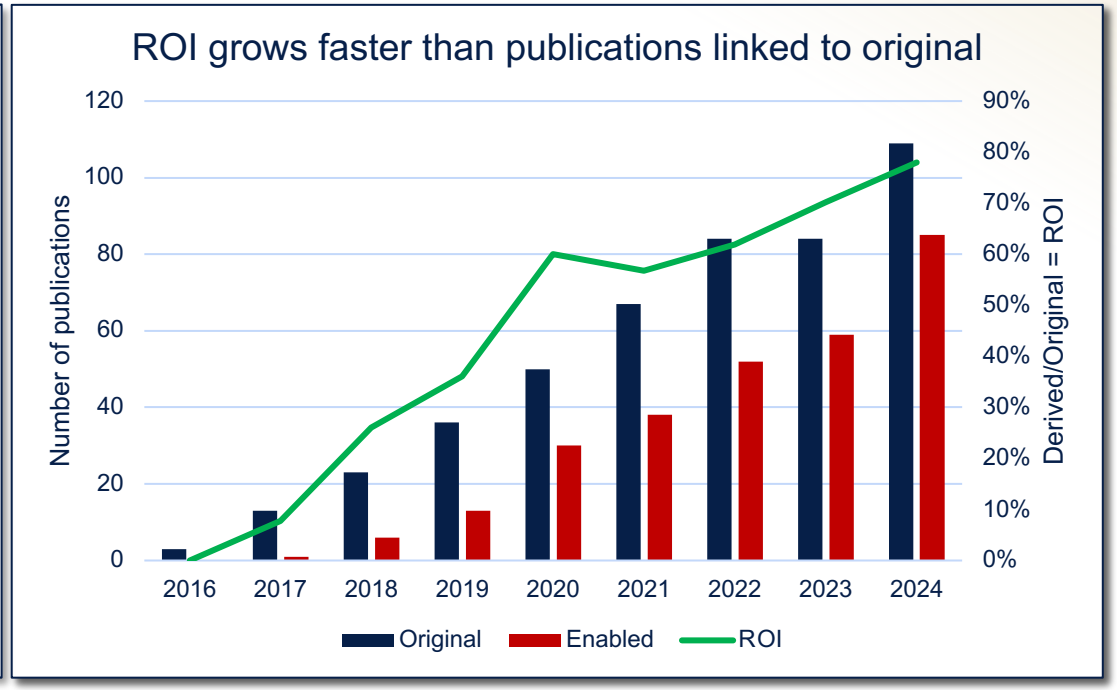
>160TB Data











85 Enabled Publications linked to OSDR

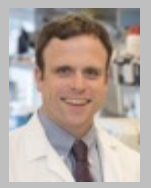
109 Original Publications linked to OSDR

150+ Datasets used in enabled publications

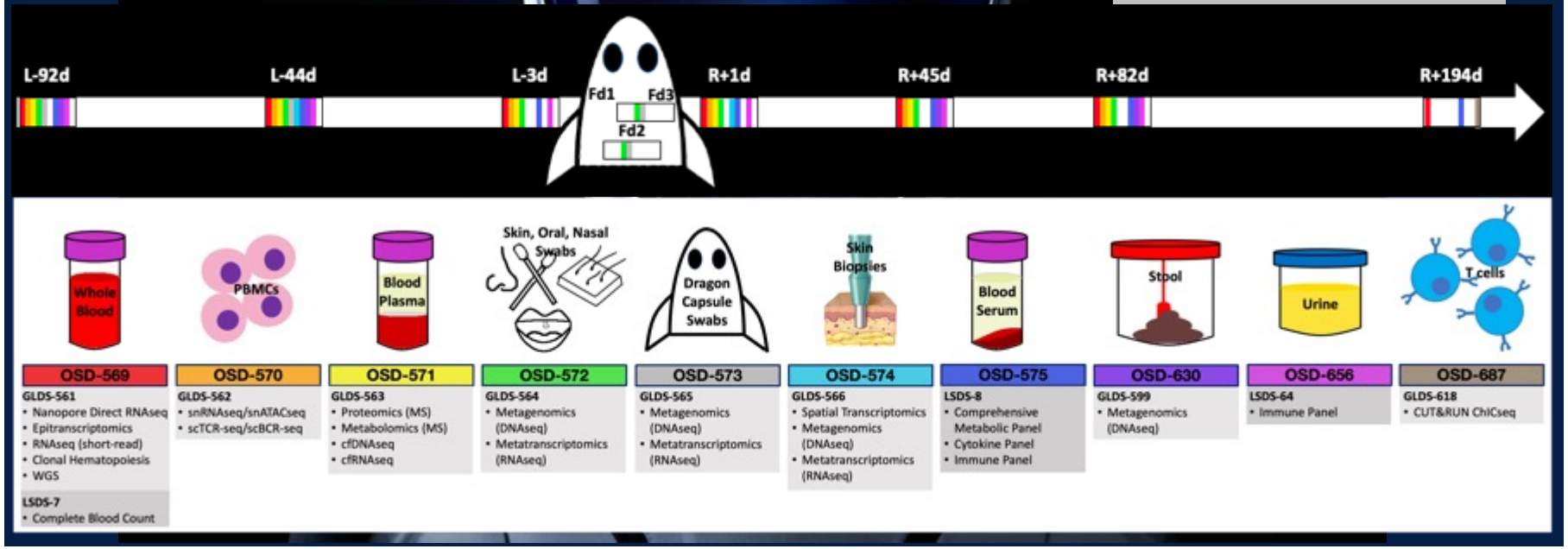
Civilian Human Spaceflight Data

INSPIRATION 4

- Nature Portfolio Collection (2024): Space Omics and Medical Atlas (SOMA) across orbits
- I4 Image Credit: Chris Mason's Lab



Chris Mason Eliah Overbey
Weil Cornell Medicine

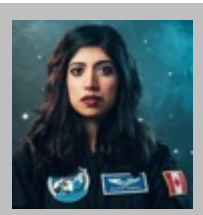


IAS International Institute for Astronautical Sciences

- **Commercial Sub-Orbital**
- **Galactic-05 – Flew Nov. 2**
  - **Astroskin: ECG, systolic BP, heart rate (HR), breathing rate (BR), skin temperature, activity levels (provided by 3-axis accelerometer), and oxygen saturation in blood (SpO2)**
  - **Blood Glucose Monitoring Device**

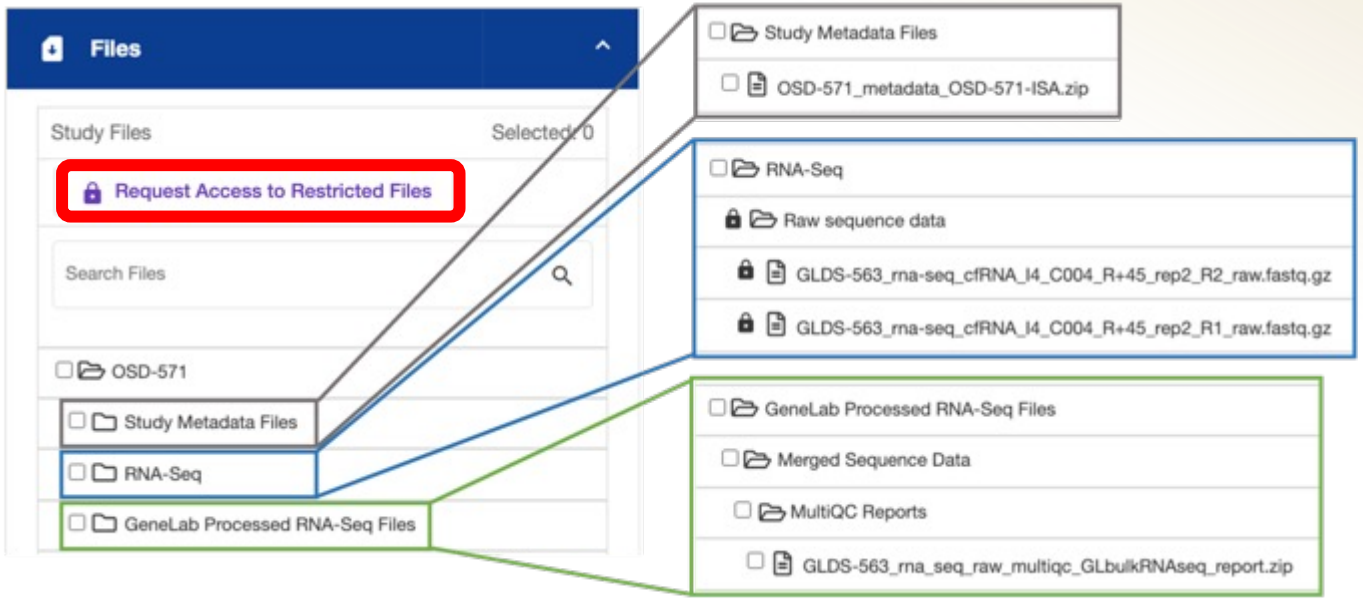
Soon!

- **Credit: Dr. Shawna Pandya**



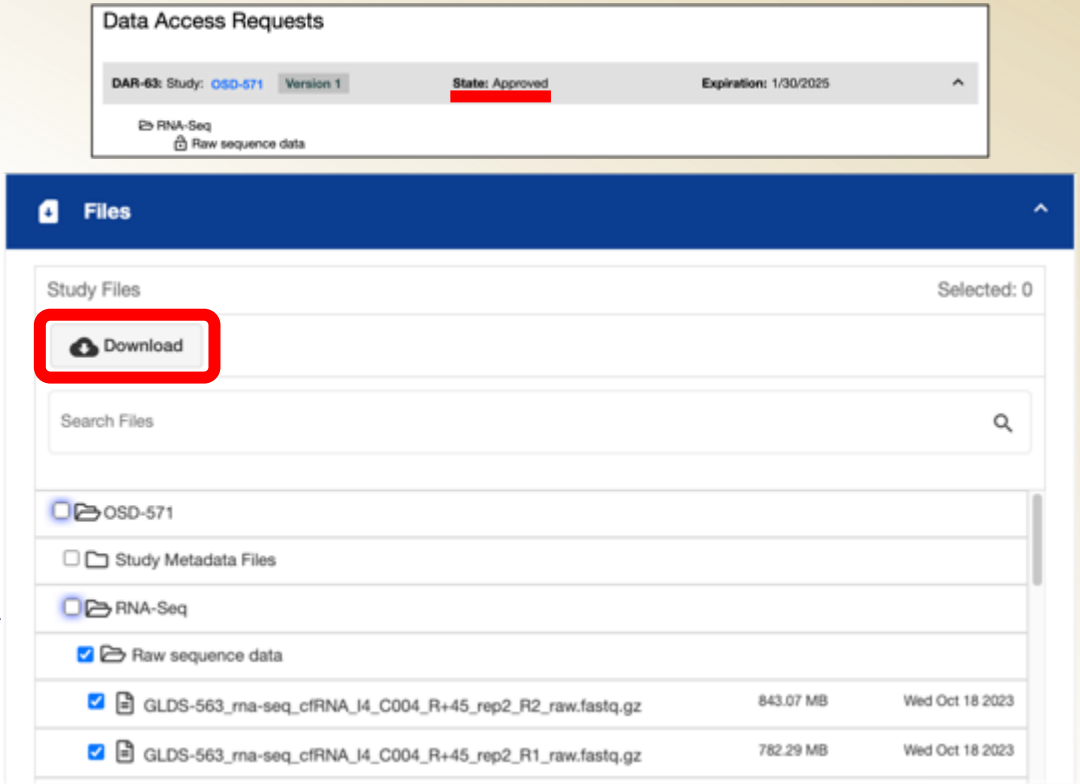
Shawna Pandya
IIAS Space Medicine

Access Request Process for Private Data



If Approved

Data Access Info Available On DAR Portal



Access Request Process for Private Data

1	2	3	4	5	6	7
Pre-Submission	Investigator Submits	Signing Official Reviews	Data Access Committee Reviews	Access Data	Renew Project (Optional)	Close Out Project
Request Button clicked in OSD dataset	OSDR Data Request Package sent w/ Data Use Agreement	OSDR Follow-Up with your institution	Review Board with Specific Stakeholders (OSDR, PIs, etc)	Approved / Denied Secure Access	Approved / Denied	Access removed at end of IRB, upon participant request, or if conditions of Data Use Agreement are violated

Process inspired by NIH's Database of Genotypes and Phenotypes (dbGaP)

Navigating OSDR

Open Science Data Repository (nasa.gov/osdr)

OSDR Home | About | Data & Tools | Research & Resources | Services | Working Groups | Engage with Us | Help

Open Science Data Repository

The NASA Open Science Data Repository (OSDR) enables access to space-related data from experiments and missions that investigate biological and health responses of terrestrial life to spaceflight. The goal of OSDR is to enable multi-modal and multi-hierarchical fundamental space life science data be reused toward basic science, applied science, and operational outcomes for space exploration and knowledge discovery. These data include 'omics, phenotypic, physiological, behavioral, hardware, environmental telemetry; raw, processed; tabular, text, code, bioimaging, and video.

Learn More About OSDR

Explore and Contribute

Open Science Data Repository

Search and upload spaceflight datasets

Explore the Data Repository

Submit Data to OSDR

Have space-relevant data to submit?

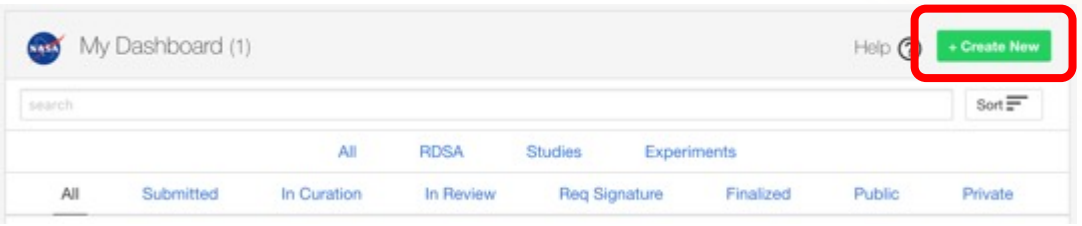
Contribute via the Submission Portal

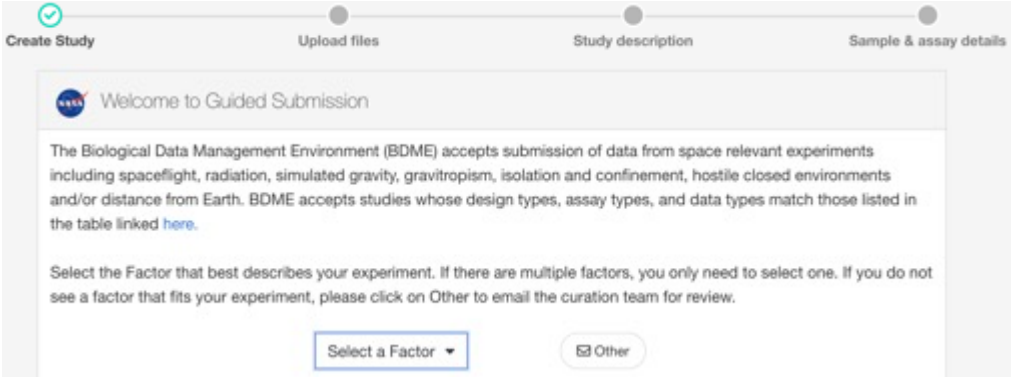
Join OSDR AWG's

We look forward to collaborating with you!

Interested in participating in an AWG?

Submission Portal – BDME (https://osdr.nasa.gov/bio/submission-sso-login.html)





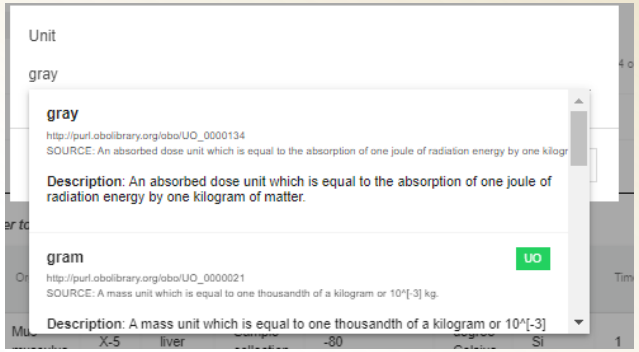
Sample level data

Sample Name	Organism	Strain	Material Type	Protocol REF	Parameter Value - Storage Temperature Setting	Unit	Ionizing Radiation	Time	Unit	Dose	Unit
Sample1	Mus musculus	X-5	liver	Sample collection	-80	degree Celsius	Silicon	1	hour	1	gray
Sample2	Mus musculus	X-5	liver	Sample collection	-80	degree Celsius	Sham-irradiated	0	hour	0	gray

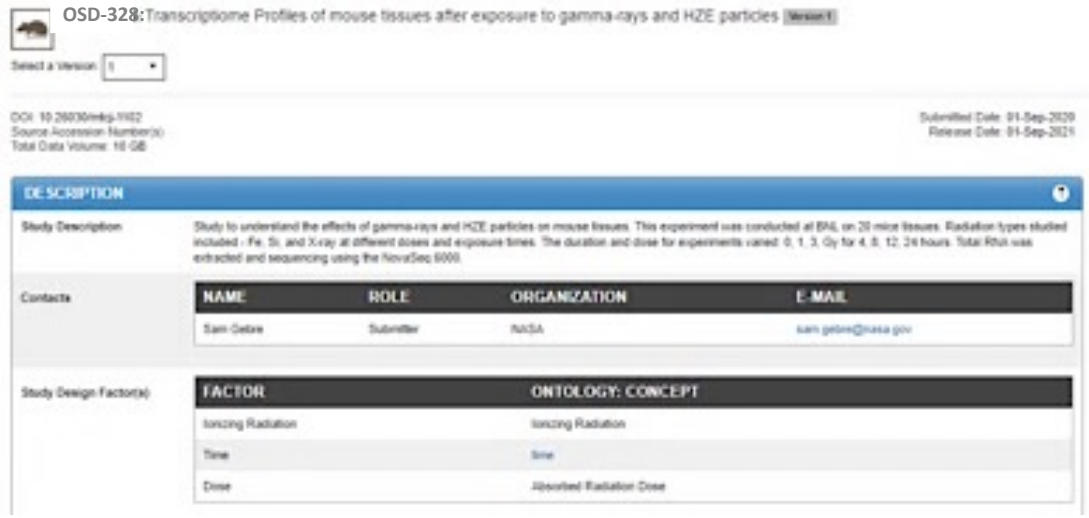
Assay level data with assay-specific fields

Sample Name	Protocol REF	Parameter Value - QA Instrument	Parameter Value - QA Assay	Parameter Value - QA Score	Unit	Extract Name	Protocol REF
Sample1	Nucleic Acid Extraction	BioAnalyzer	NanoChip	8	RIN	Extract 1	Library Construction
Sample2	Nucleic Acid Extraction	BioAnalyzer	NanoChip	9	RIN	Extract 2	Library Construction
Sample3	Nucleic Acid Extraction	BioAnalyzer	NanoChip	9.1	RIN	Extract 3	Library Construction

Terms are connected to a controlled ontology



- PIs can now submit data through BDME.
- Allows efficient input of sample and assay level metadata alongside data files.
- Tailored to specialized needs of spaceflight samples.
- Used for both omics (GeneLab) and non-omics (ALSDA) data submissions.



PIs are presented with a study preview and a private link for sharing with reviewers and collaborators.

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NASA Open Science for Life in Space

Home | About | Data & Tools | Working Groups | Help

General Search Filters

Data Source

- [x] GeneLab
- [x] ALSDA
- [ ] NIH GEO
- [ ] EBI PRIDE
- [ ] ANL MG-RAST

Data Type

- [x] Study
- [ ] Experiment
- [ ] Subject
- [ ] Biospecimen
- [ ] Payload

Show more

Study Search Filters

Project Type

- [ ] Ground
- [ ] Spaceflight
- [ ] High Altitude

Assay Type

- [ ] Amplicon Sequencing Assay
- [ ] Bisulfite Sequencing
- [ ] ChIP-Seq
- [ ] Behavior (Gait)
- [ ] Gel Electrophoresis

Show more

Organism

Open Science Data Repository Search

Search Datasets

Sort By: Release Date

Items per page: 25 | 1 – 25 of 435

Study OSD-385

Persistence of Escherichia coli in the microbiomes of red Romaine lettuce (Lactuca sativa cv. 'Outredgeous')- does seed sanitization matter?

Organisms	Factors	Assay Types	Release Date	Description
Microbiota	Treatment Seed Sanitization Tissue	Amplicon Sequencing	19-Apr-2024	Seed sanitization via chemical processes removes/reduces microbes from the external surfaces of the seed and thereby could have an impact on the plants,health or productivity. To determine the impact ...

Highlights: *cgene*

Study OSD-580

Transcriptional profiling of heart tissue from mice flown on the RRRM-2 mission

Organisms	Factors	Assay Types	Release Date	Description
Mus musculus	Spaceflight Age Euthanasia Location	transcription profiling	03-Jan-2024	In the Rodent Research Reference Mission (RRRM-2), forty female C57BL/6NTac mice were flown on the International Space Station. To assess differences in outcomes due to age, twenty 12 week-old and twe...

Highlights: *cgene*

Study OSD-576

Transcriptional profiling of tibialis anterior muscle from mice flown on the RR-23 mission

Organisms	Factors	Assay Types	Release Date	Description
Mus musculus	Spaceflight	transcription profiling	12-Dec-2023	The objective of the Rodent Research-23 mission (RR-23) was to better understand the effects of spaceflight on the eyes, specifically on the structure and function of the arteries, veins, and lymphati...

Highlights: *cgene*

Study OSD-524

Ionizing radiation induces transgenerational effects of DNA methylation in zebrafish

Organisms	Factors	Assay Types	Release Date	Description
Danio rerio	Ionizing Radiation Generation	DNA methylation profiling	31-Aug-2023	Ionizing radiation is known to cause DNA damage, yet the mechanisms underlying potential transgenerational effects of exposure have been scarcely studied. Previously, we observed effects in offspring ...

OSDR: Study Page

- Description
- Experiments
- Payloads
- Missions
- Protocols
- Samples
- Assays
- Publications
- Files
- Version History
- Visualization

2.50 TB

OSD-137 Version 8

Rodent Research-3-CASIS: Mouse liver transcriptomic, proteomic, epigenomic and histology data

Study

Submitted Date: 04-Aug-2017
Initial Release Date: 28-Aug-2017

GeneLab ID: GLDS-137
ALSDA ID: LSDS-28
DOI: 10.26030/9k6w-4c28
License: CC0-1.0

Cite this Study

Description

Description

The Rodent Research-3 (RR-3) mission was sponsored by the pharmaceutical company Eli Lilly and Co. and the Center for the Advancement of Science in Space to study the effectiveness of a potential countermeasure for the loss of muscle and bone mass that occurs during spaceflight. Twenty BALB/c, 12-weeks old female mice (ten controls and ten treated) were flown to the ISS and housed in the Rodent Habitat for 39-42 days. Twenty mice of similar age, sex and strain were used for ground controls housed in identical hardware and matching ISS environmental conditions. Basal controls were housed in standard vivarium cages. Spaceflight, ground controls and basal groups had blood collected, then were euthanized, had one hind limb removed, and finally whole carcasses were stored at -80 C until dissection. All mice in this data set received only the control/sham injection.

OSDR: Cite Study & Export Specific Metadata Table Columns

- Description
- Experiments
- Payloads
- Missions
- Protocols
- Samples
- Assays

OSD-137 Version 8

Rodent Research-3-CASIS: Mouse liver transcriptomic, proteomic, epigenomic and histology data

2.50 TB | Study

Submitted Date: 04-Aug-2017
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License: CC0-1.0

Cite this Study

Smith R, Cramer M, Globus R, Galazka J. "Rodent Research-3-CASIS: Mouse liver transcriptomic, proteomic, epigenomic and histology data", NASA Open Science Data Repository, Version 8, http://doi.org/10.26030/9k6w-4c28

Download Citation (BibTex) | Download Citation (RIS)

- Description
- Experiments
- Payloads
- Missions
- Protocols
- Samples
- Assays
- Publications
- Files
- Version History
- Visualization

Samples

Select Export Columns

Select columns of the samples panel below to export | Export CSV

- Source Name
- Sample Name
- Characteristics: Organism
- Characteristics: Strain
- Characteristics: Animal Source
- Characteristics: sex
- Characteristics: Age at Launch
- Characteristics: Diet
- Comment: Feeding Schedule
- Characteristics: Material Type
- Factor Value: Spaceflight
- Protocol REF

close | select all | unselect all

Source Name	Sample Name	Characteristics: Organism	Characteristics: Strain	Characteristics: Animal Source	Characteristics: sex	Characteristics: Age at Launch	Characteristics: Diet	Comment: Feeding Schedule	Characteristics: Materi Type
CB1	Mmus_BAL-TAL_LVR_BSL_Rep1_B1	Mus musculus	BALB/c	Taconic Biosciences	female	12 week	Nutrient Upgraded Rodent Food Bar (NuRFB)	ad libitum	liver
CB2	Mmus_BAL-TAL_LVR_BSL_Rep2_B2	Mus musculus	BALB/c	Taconic Biosciences	female	12 week	Nutrient Upgraded Rodent Food Bar (NuRFB)	ad libitum	liver
CB3	Mmus_BAL-TAL_LVR_BSL_Rep3_B3	Mus musculus	BALB/c	Taconic Biosciences	female	12 week	Nutrient Upgraded Rodent Food Bar (NuRFB)	ad libitum	liver

OSDR: Download Study Files

Search Bar

- Description
- Experiments
- Payloads
- Missions
- Protocols
- Samples
- Assays
- Publications
- **Files**
- Version History
- Visualization

Files

Study Files

Selected: 3

Download

Search Files

OSDR API

OSDR AWS s3

- OSD-137
  - Study Metadata Files
  - Histology
  - RNA-Seq
  - Whole Genome Bisulfite Sequencing
  - GeneLab Processed RNA-Seq Files
    - Differential Expression Analysis Data
      - GLDS-137_rna_seq_contrasts.csv — 407.0 B — Fri Feb 17 2023
      - GLDS-137_rna_seq_differential_expression.csv — 25.5 MB — Fri Feb 17 2023
      - GLDS-137_rna_seq_SampleTable.csv — 855.0 B — Fri Feb 17 2023
    - Merged sequence data
    - Trimmed sequence data
    - Aligned sequence data

GeneLab Data Processing

Build consensus data processing pipelines with the scientific community

Raw Sequence Data

```
@A00654:12:HFY5YDSXX:1:1101:2121:1000_CTCGCGTTT 1:N:0:NGGAGAGT+TCCTACCT
AATATCAGTGATATTTAGAAACCACATAGTAAGCTAACAACTAATAATGGAATGGTTTTAATATCCTGTGACAAGTTAATGTGGATACTATGCGGTCTTCCTTAAAA
+
FFFFFFFFFFFFFFFFFFF:FFFFFFFFFFFFFF:FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF:FFFFFFFFFFFFFFFFFF:FF
@A00654:12:HFY5YDSXX:1:1101:5466:1000_CCTCCCTCG 1:N:0:NGGAGAGT+TCCTACCT
GGCGGGTCTGAGCAAGAACACTCTGCCATCGCCGGCTCGGGACGGGAGGCCCACCCGTGGCCGAGCACGCAGACCTGGATGAACCGAGGCCTCGATGGGCCTGGACG
+
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@A00654:12:HFY5YDSXX:1:1101:14109:1000_TGATCTACG 1:N:0:NGGAGAGT+TCCTACCT
TGTCACTACAACCAGCTGTGCCTGTGCTATTGCAGTTACACAGTGTCACTACAACCAACTGTGCCTGTGCTATTGCAGTTACACAGTGTCACTACAACCAGCAGATC
+
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF:FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF,:FFFFFFF:FF:F:FF
```
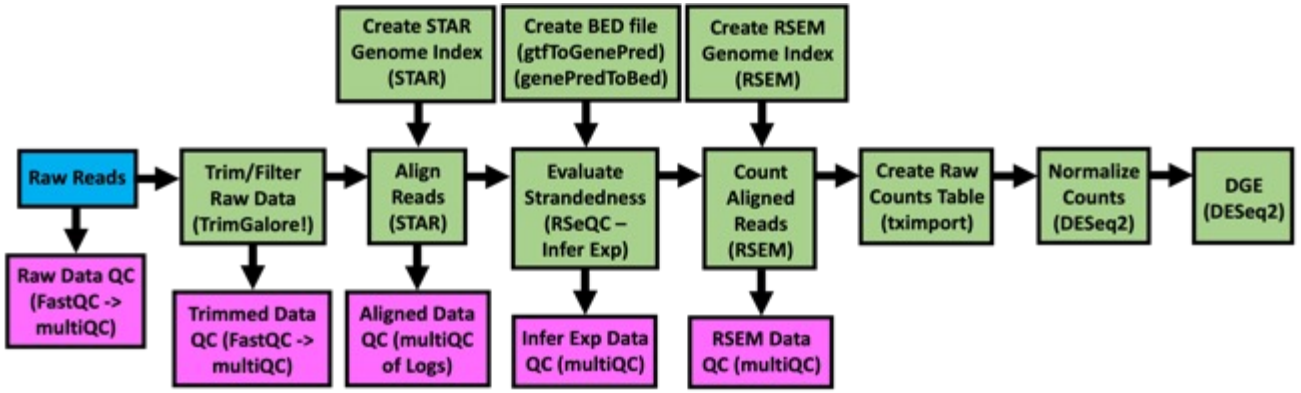
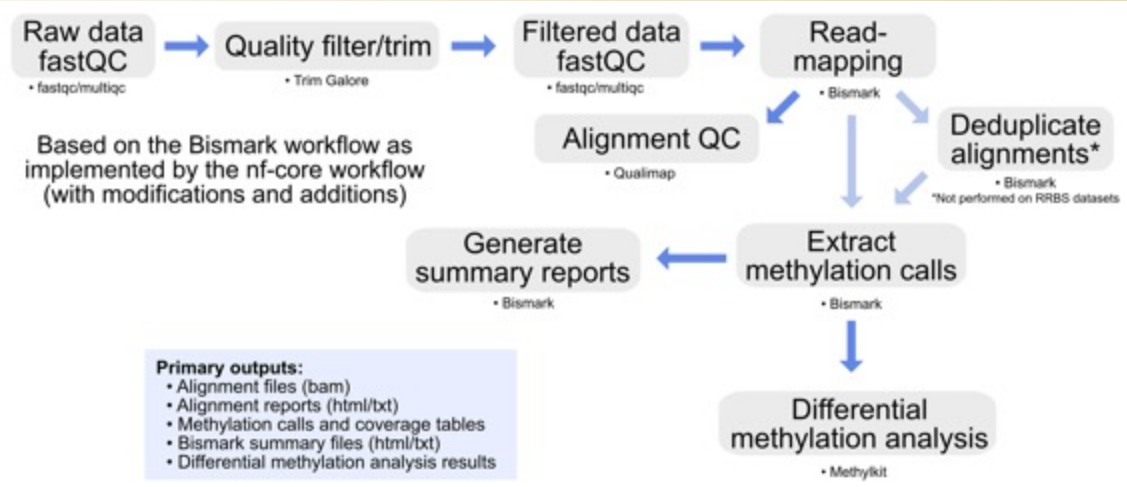

Processed RNA Sequence Data: Differential Gene Expression

SYMBOL	GENENAME	Group.Mean_(FLT)	Group.Mean_(GC)	Log2fc_(FLT)v(GC)	P.value_(FLT)v(GC)	Adj.p.value_(FLT)v(GC)
Timm17a	translocase of inner mitochondrial membrane 17a	3.91	15.11	-2.67	0.00	0.00
NA	NA	166.47	108.32	0.63	0.00	0.00
NA	NA	325.78	171.64	0.93	0.00	0.00
Dnajc7	DnaJ heat shock protein family (Hsp40) member C7	22.31	42.16	-0.95	0.00	0.00
Slc15a4	solute carrier family 15, member 4	2.75	9.38	-2.32	0.00	0.00
Ckap5	cytoskeleton associated protein 5	18.24	46.64	-1.39	0.00	0.00
NA	NA	104.49	67.33	0.64	0.00	0.00

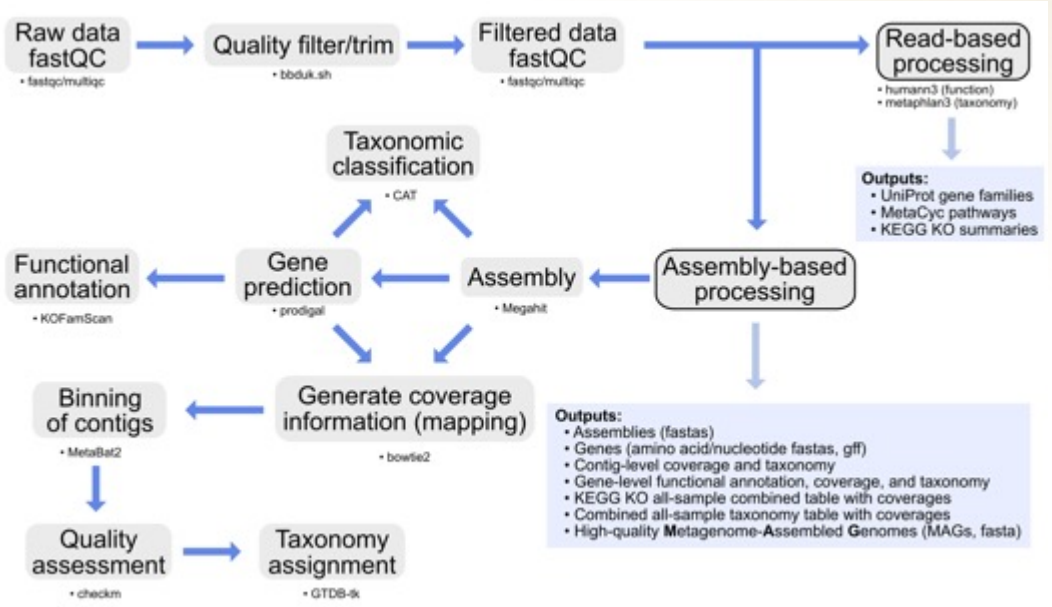
RNA Sequencing Data



Methylation Sequencing Data



Metagenomics Data



GeneLab Data Processing GitHub Repo

Search or jump to... / Pull requests Issues Marketplace Explore

nasa / GeneLab_Data_Processing Public

Edit Pins

README.md

Open Science for Life in Space

GeneLab_Data_Processing

About

The NASA GeneLab Data Processing team and Analysis Working Group members have created standard pipelines for processing omics data from spaceflight and space-relevant experiments. This repository contains the processing pipelines that have been standardized to date for the assay types indicated below. Each subdirectory in this repository holds current and previous pipeline versions for the respective assay type, including detailed descriptions and processing instructions as well as the exact processing commands used to generate processed data for datasets hosted in the GeneLab Data Repository.

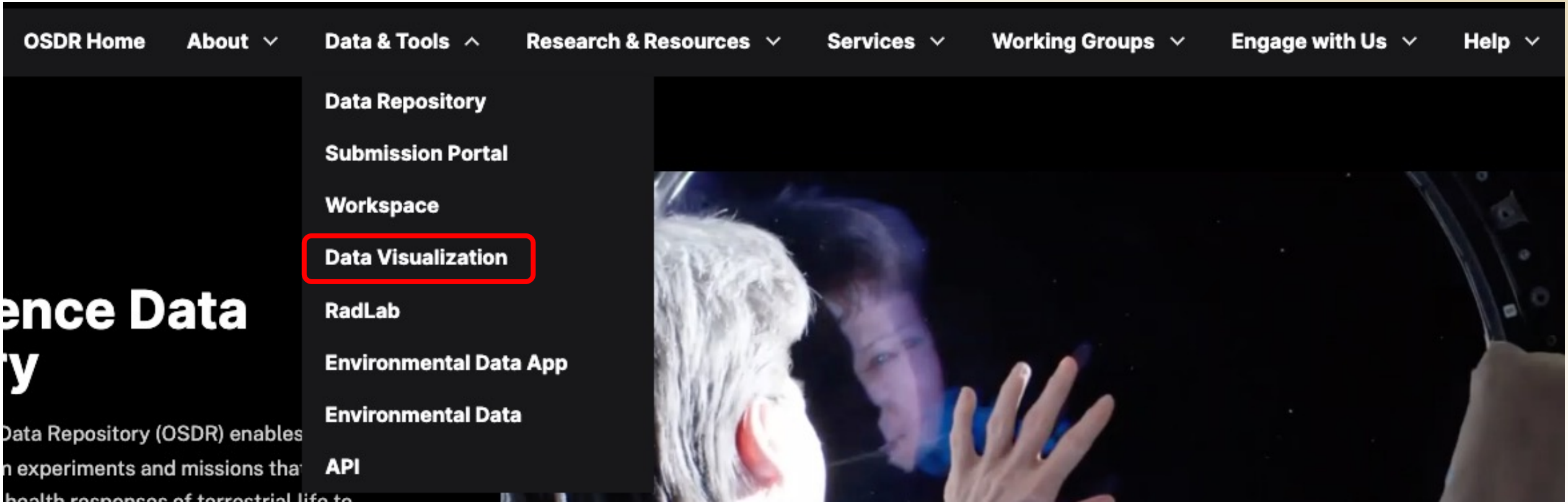
Assay Types

Click on an assay type below for data processing information.

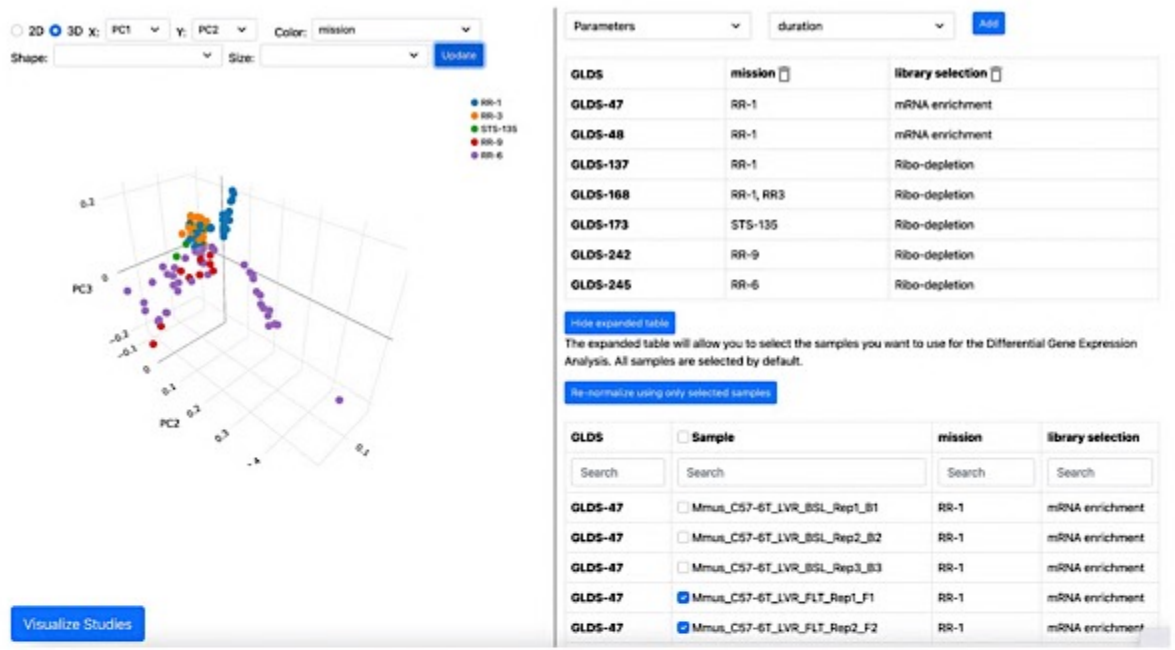
- Create GeneLab Reference Annotations
- Amplicon Sequencing
  - Illumina
  - 454 and Ion-Torrent
- Metagenomics
  - Removing human reads
  - Illumina
- (bulk) RNAseq
- single cell RNAseq

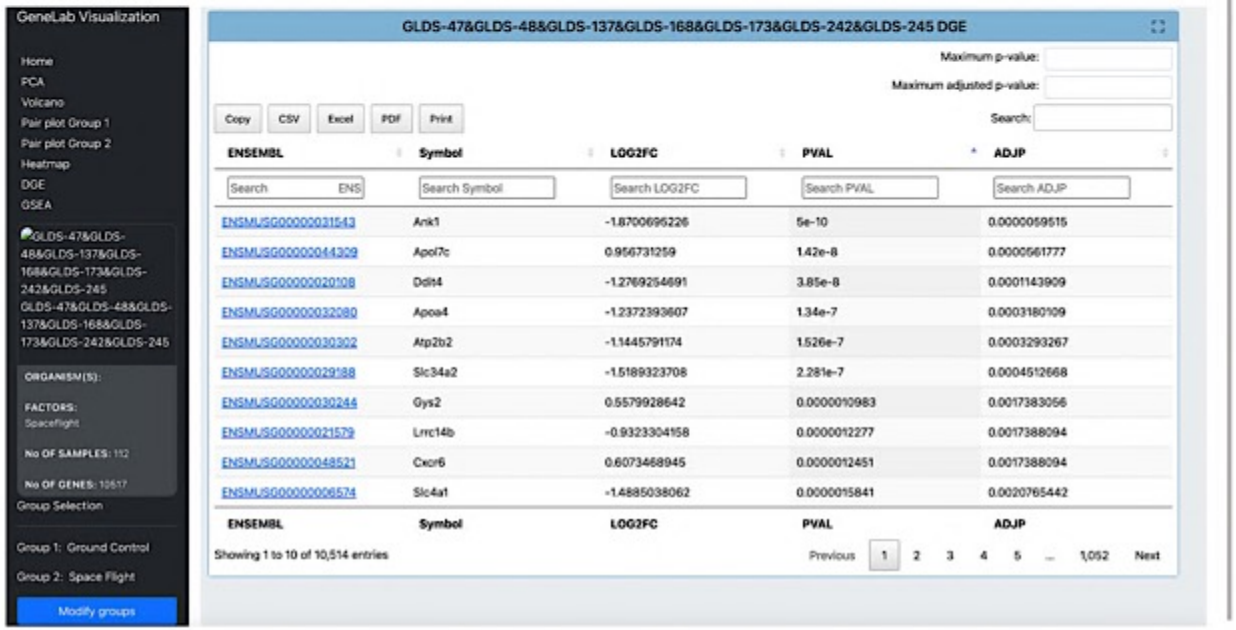
https://github.com/nasa/GeneLab_Data_Processing

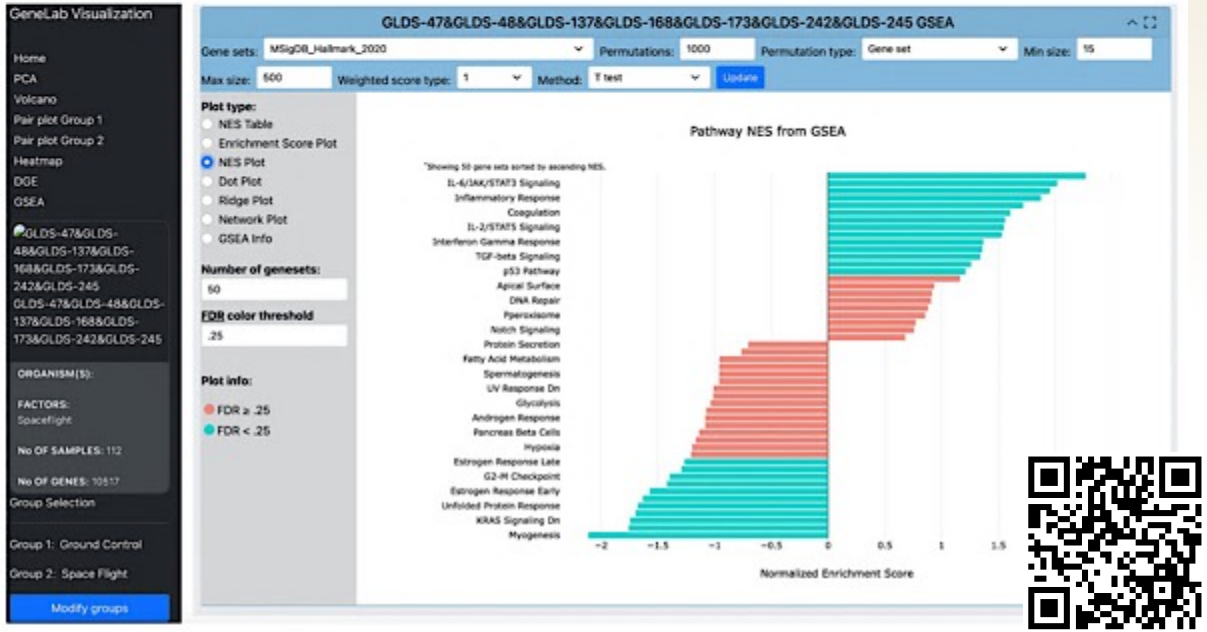
OSDR: Data Visualization



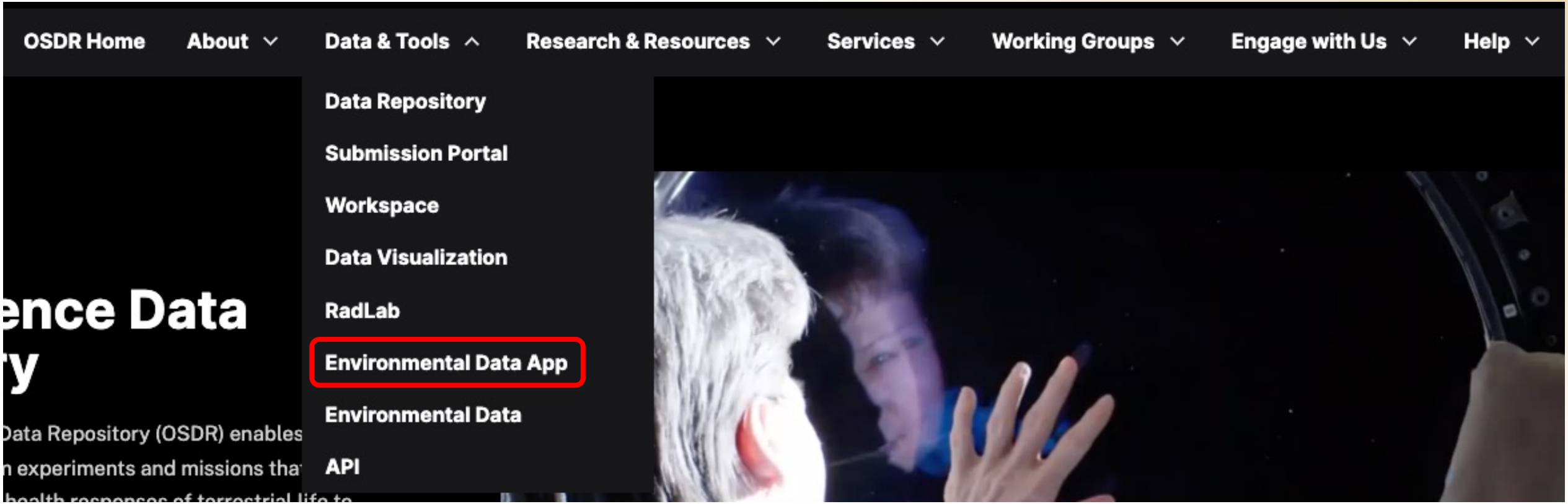
Data Visualization Portal (https://visualization.genelab.nasa.gov/data/)



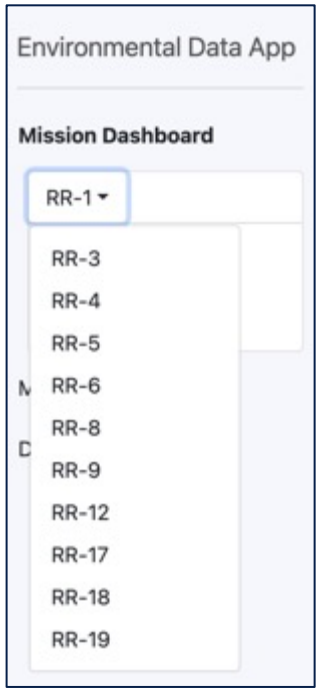


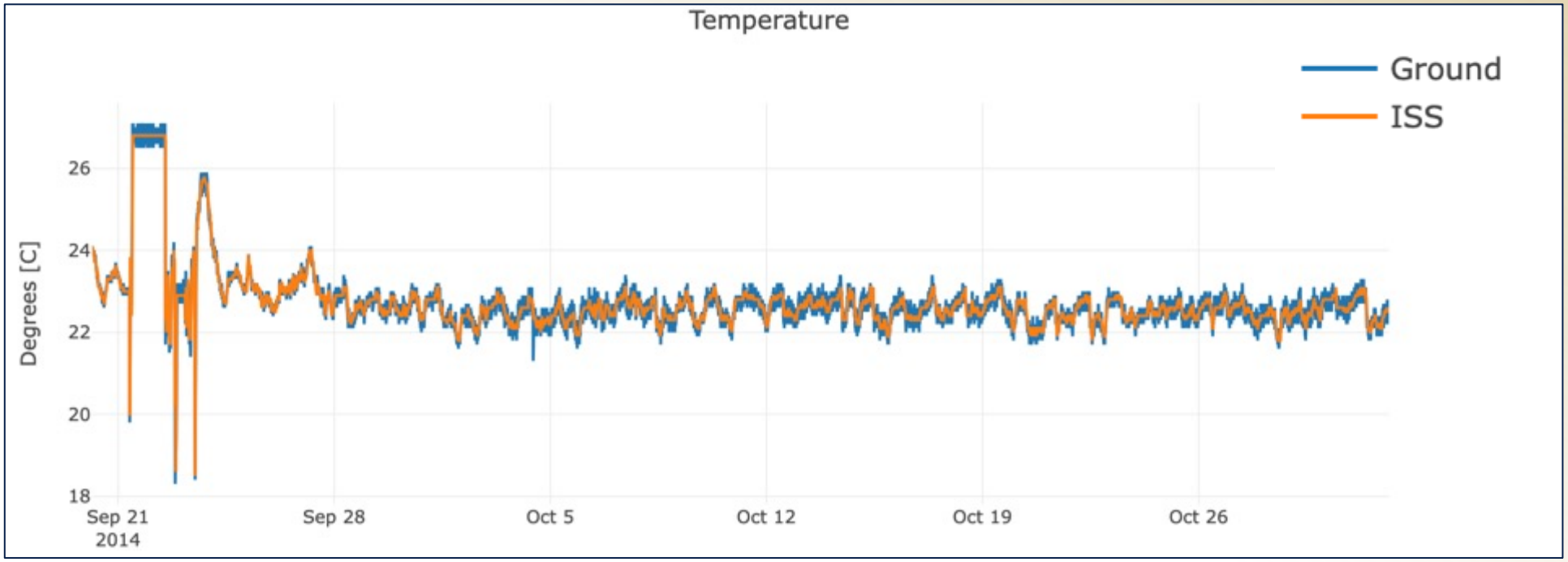


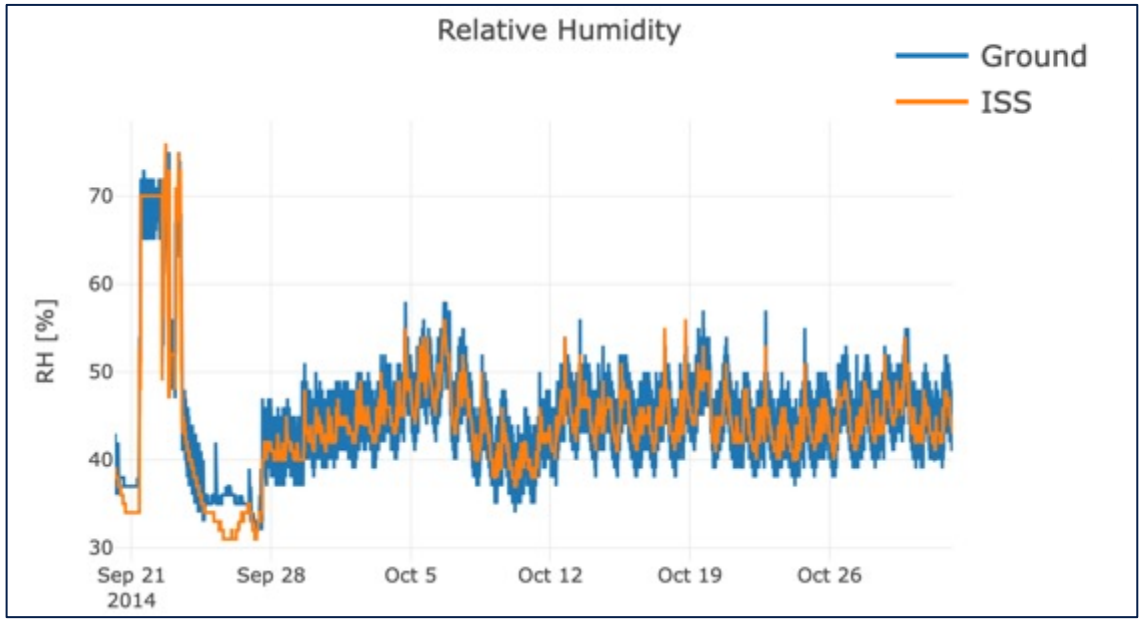
OSDR: Environmental Data Application (EDA)

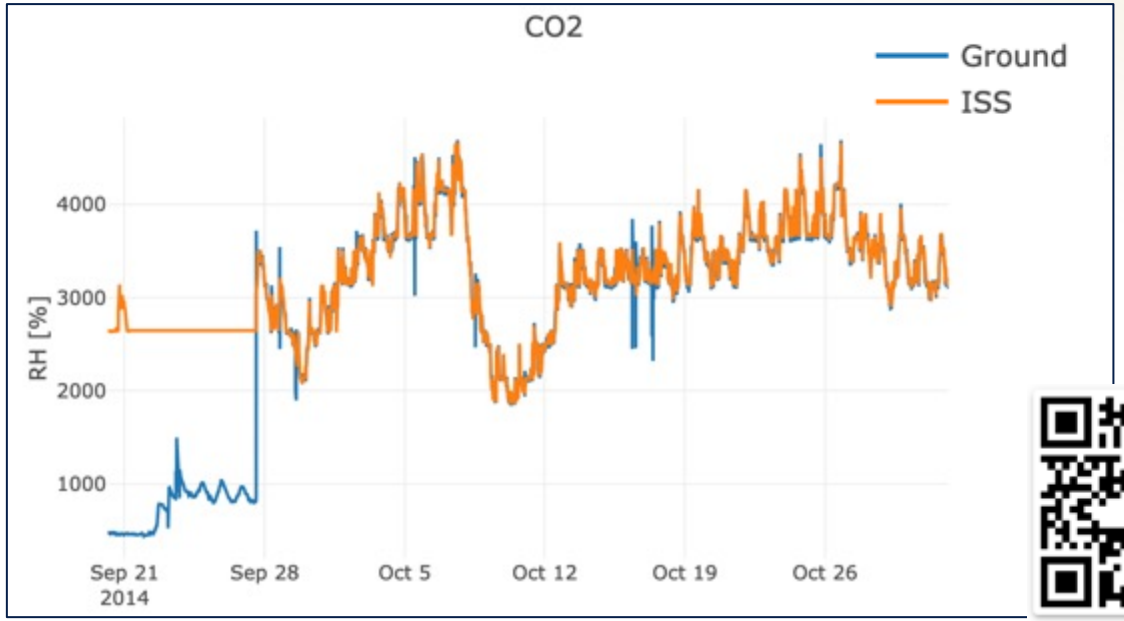


Environmental Data Application (EDA)









Environmental Data Application (EDA)

View Biologically Relevant Mission Milestones

Mission Milestone Dates

Display Mission milestones

Launch: 2014-09-21 09:49:00

Reached orbit: 2014-09-23 17:19:00

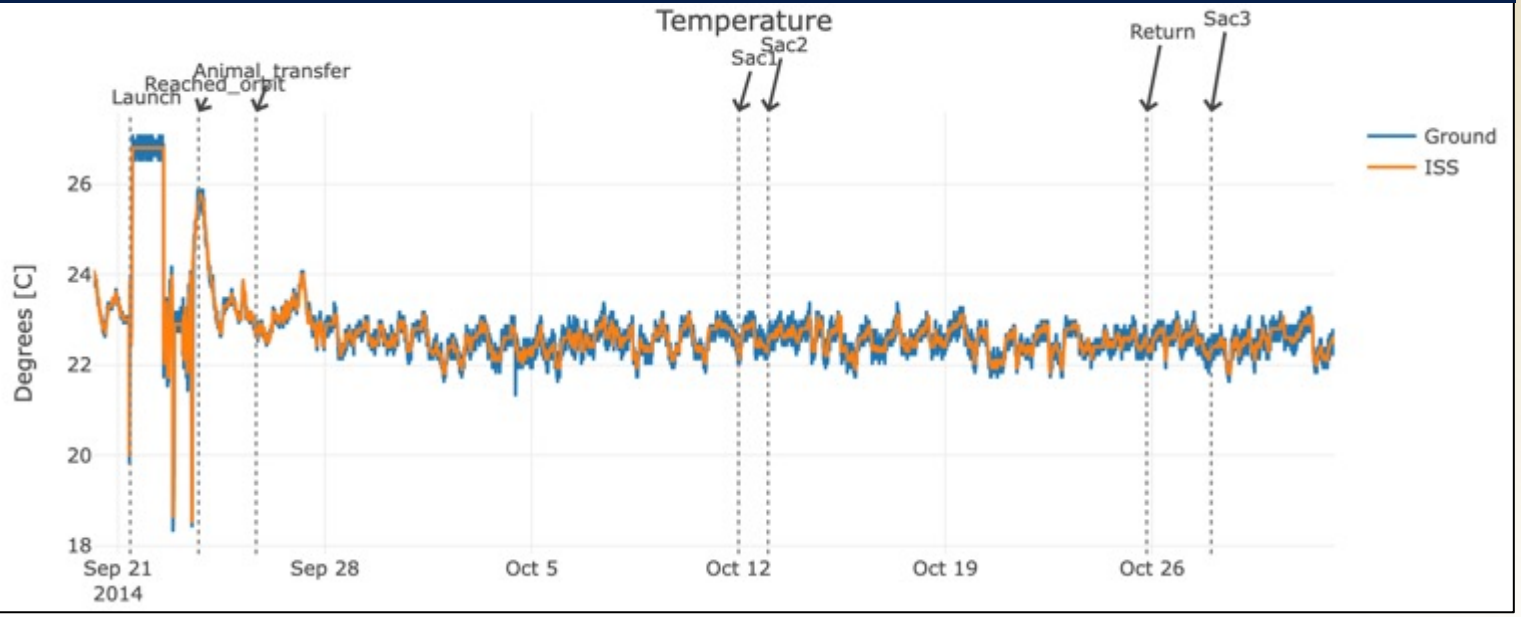
Animal transfer: 2014-09-25 16:05:00

Sac1: 2014-10-12

Sac2: 2014-10-13

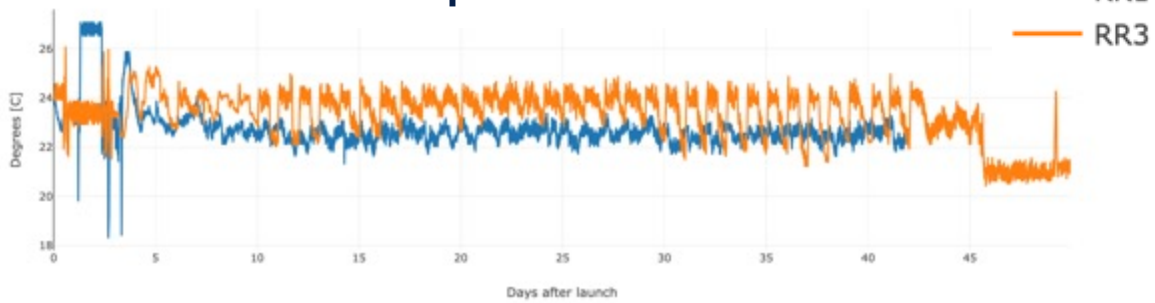
Return: 2014-10-25 19:36:00

Sac3: 2014-10-28 00:01:00



Compare Data From Multiple Missions

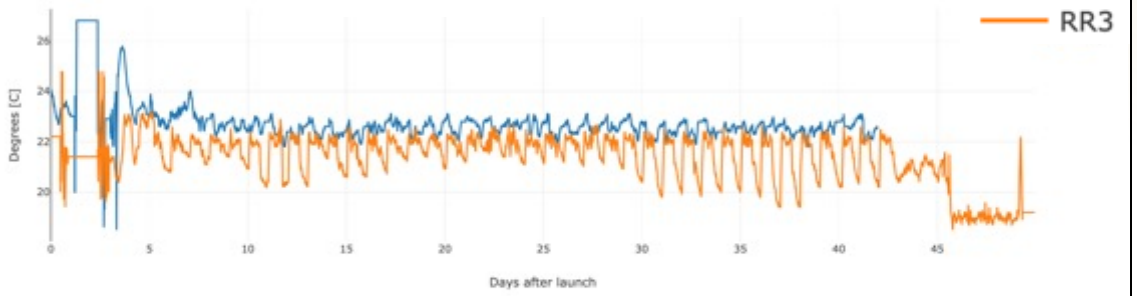
Temperature Ground



Copy Excel CSV PDF Print Search:

Mission	Min temperature Ground Degrees [C]	Max temperature Ground Degrees [C]	Mean temperature Ground Degrees [C]	Standard Deviation temperature Ground Degrees [C]	Median temperature Ground Degrees [C]
RR1	18.30	27.10	22.76	0.82	22.60
RR3	20.40	26.10	23.36	0.97	23.70
	Min	Max	Mean	Standard Deviation	Median

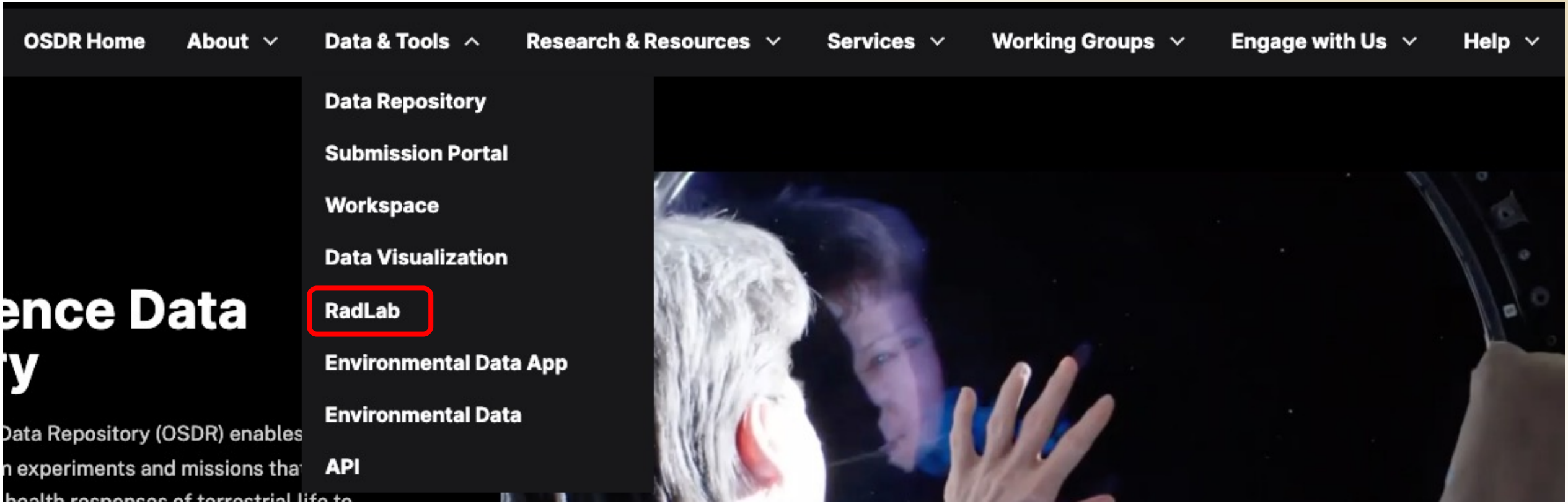
Temperature ISS



Copy Excel CSV PDF Print Search:

Mission	Min temperature ISS Degrees [C]	Max temperature ISS Degrees [C]	Mean temperature ISS Degrees [C]	Standard Deviation temperature ISS Degrees [C]	Median temperature ISS Degrees [C]
RR1	18.50	26.80	22.76	0.81	22.60
RR3	18.50	24.80	21.37	0.97	21.70
	Min	Max	Mean	Standard Deviation	Median

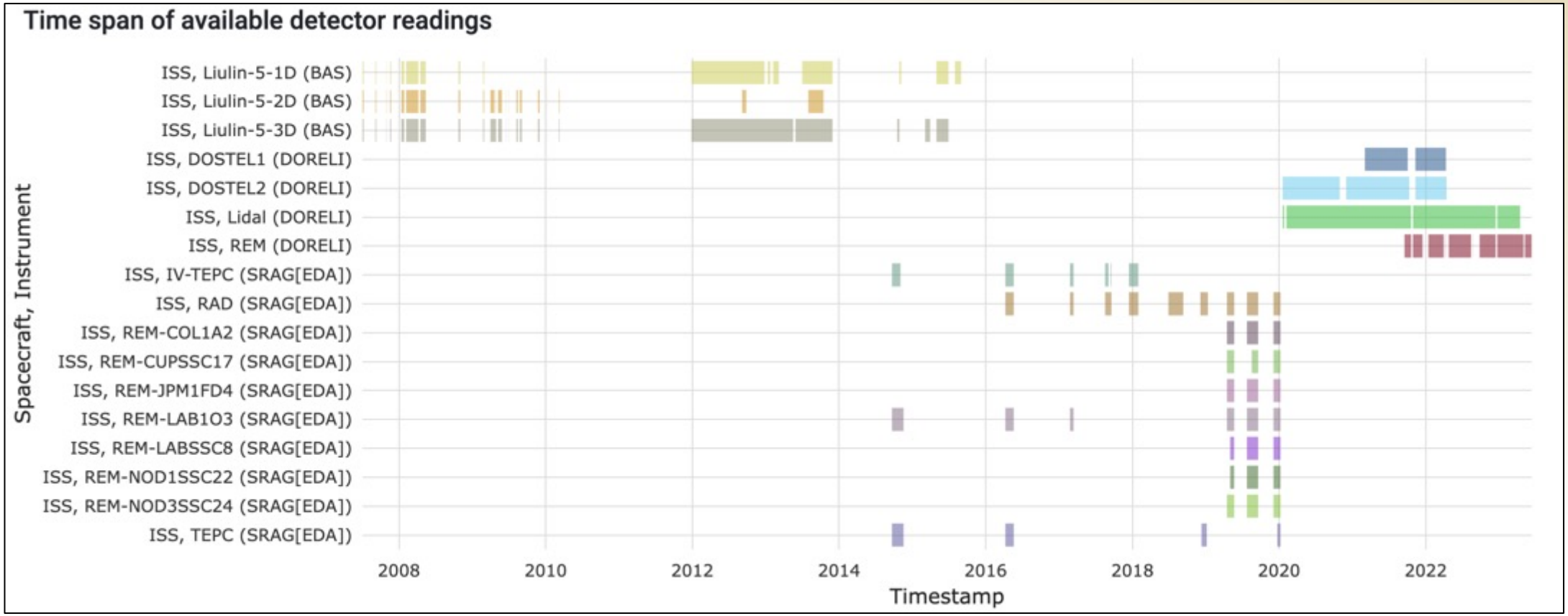
RadLab Platform



RadLab Portal and Data API

RadLab

- ▸ **Data overview**
- Time series plots
- Data comparison
- Geospatial plots
- Data access / API



RadLab Portal and Data API

Time Series Plots

Spacecraft, Instrument *(hover to reveal full list)*

- [x] ISS, DOSTEL1
- [x] ISS, DOSTEL2
- [x] ISS, Lidal
- [x] ISS, REM

Measurement
- (•) Total dose rate
- ( ) Total flux

Time period
Start: 04/01/2022, 12:00 AM
End: 04/02/2022, 12:00 AM

Scale
- ( ) Linear
- (•) Log

Update

Retrieved data
Formats:
CSV, TSV, JSON, HTML

Compare Two Detectors

Spacecraft, Instrument (X axis) *(hover to re*
- (•) ISS, Lidal

Spacecraft, Instrument (Y axis) *(hover to reveal full list)*
- (•) ISS, REM

Measurement
- (•) Total dose rate
- ( ) Total flux

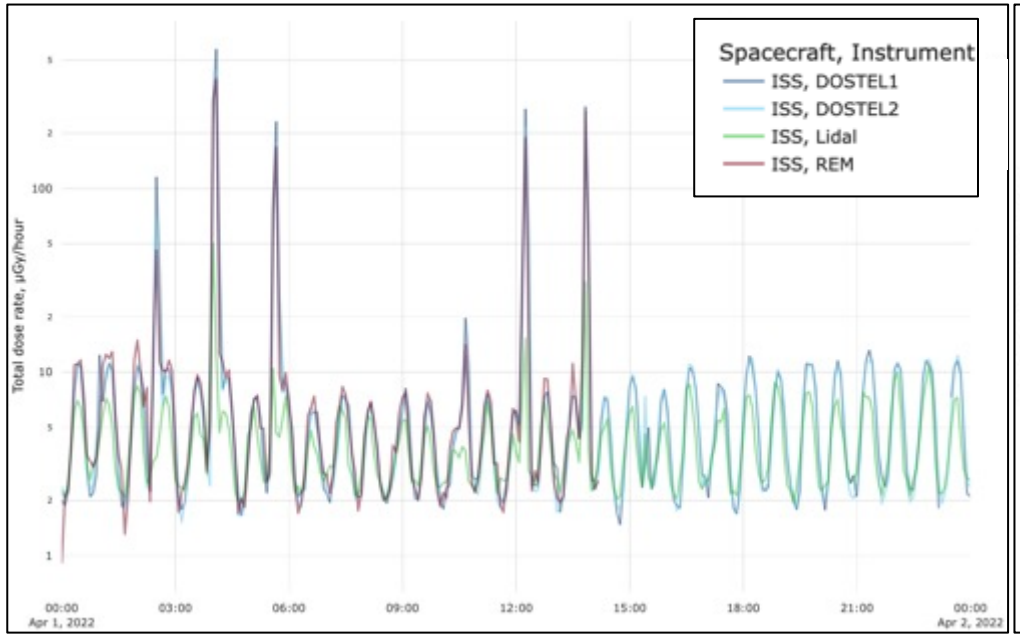
Time period
Start: 03/01/2022, 12:00 AM
End: 03/02/2022, 12:00 AM

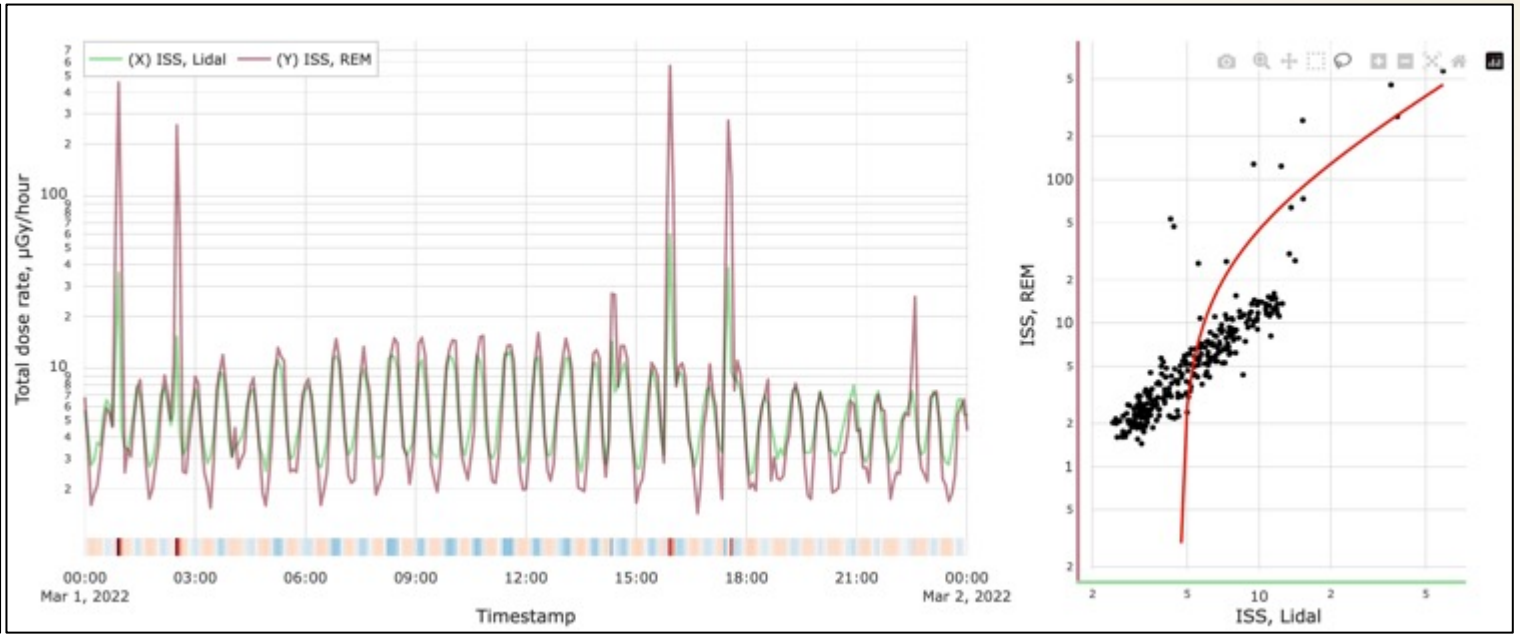
Time series scale
- ( ) Linear
- (•) Log

Pair plot scale
- ( ) Linear
- (•) Log

Update

Retrieved data
Formats:
CSV, TSV, JSON, HTML





RadLab Portal and Data API

Geospatial Plots

Spacecraft, Instrument *(hover to reveal full list)*

- (•) ISS, Lidal

Measurement

- (•) Total dose rate
- ( ) Total flux

Time period

Start: 01/01/2022, 12:00 AM

End: 01/01/2023, 12:00 AM

Scale

- ( ) Linear
- (•) Log

Projection

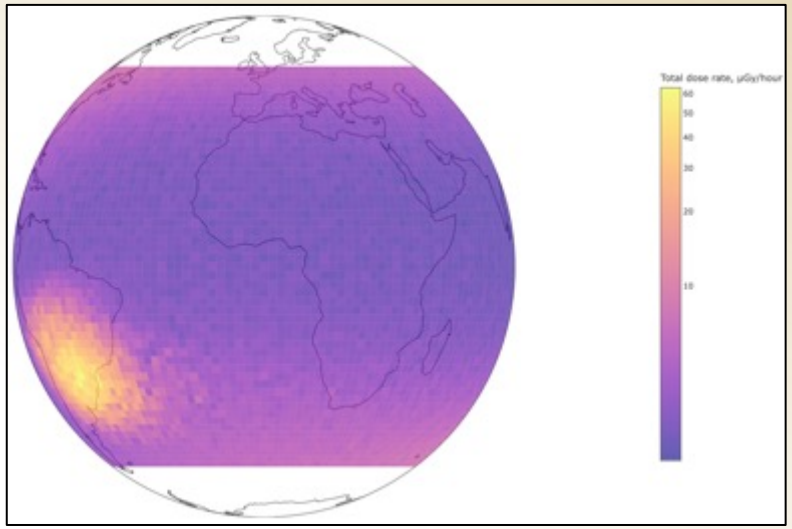
Orthographic

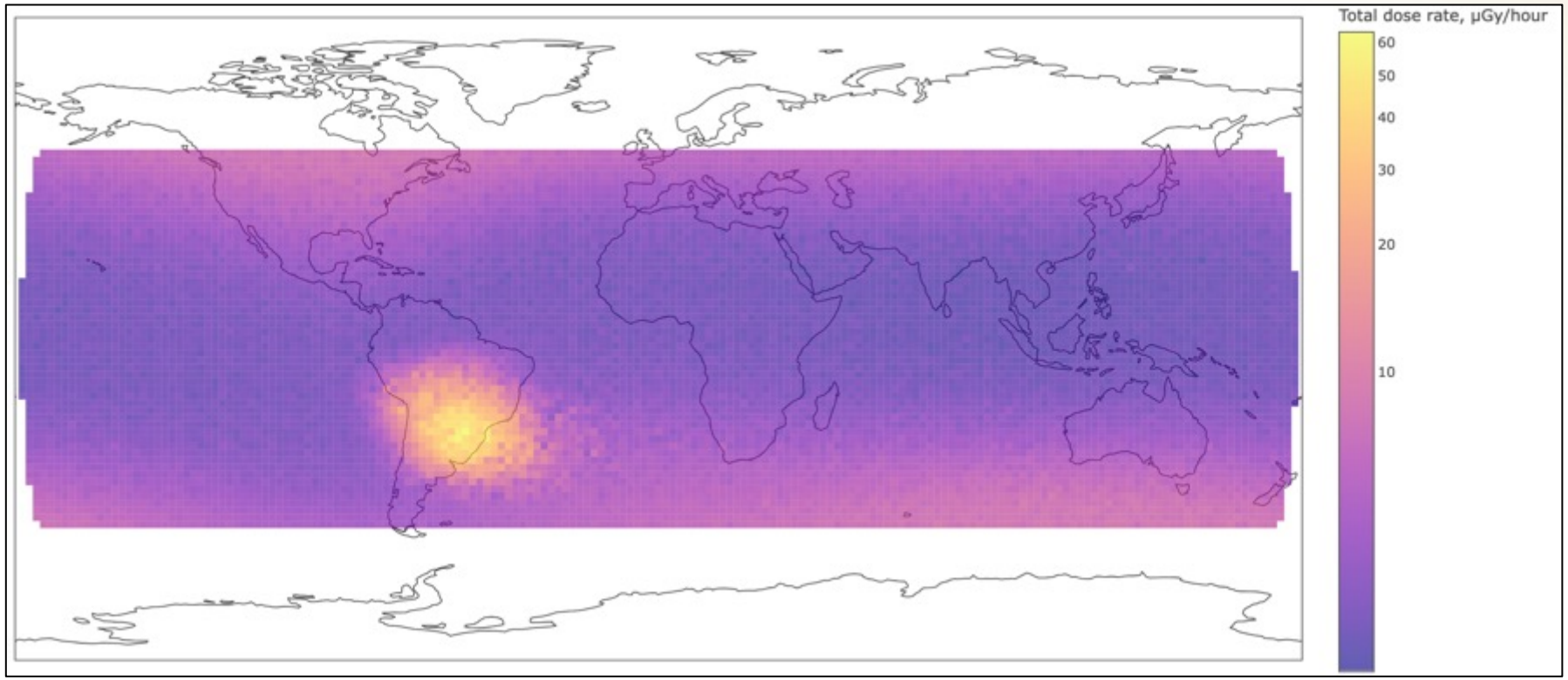
Update

Retrieved data

Formats:

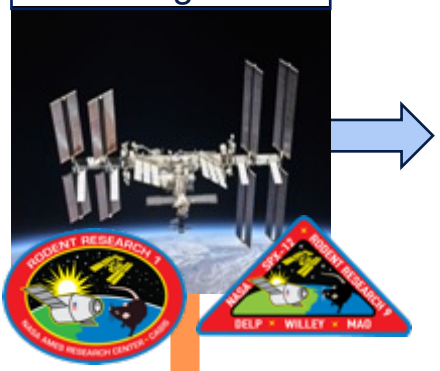
CSV, TSV, JSON, HTML





Maximizing Scientific Return Using Open Science Resources

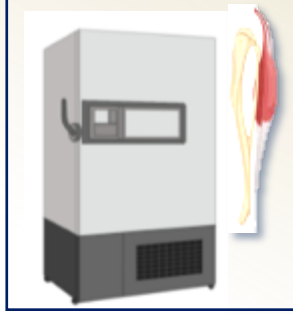
Principal Investigation



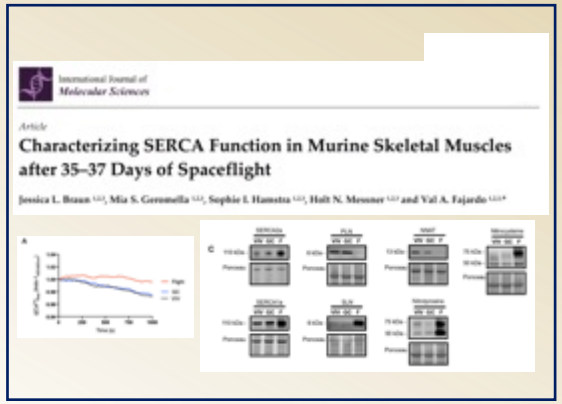
Dissections

Tissue Storage

Tissue Request

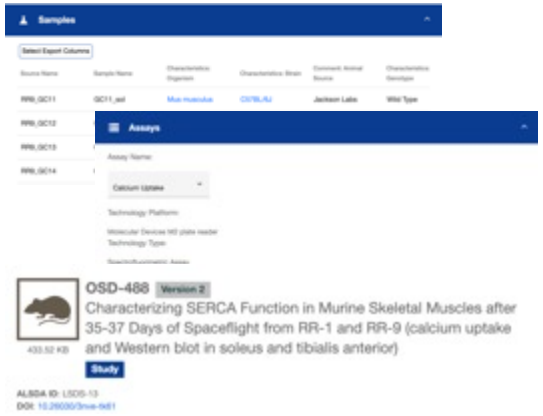


Analysis and Publication



PI Results

Submitted & Curated Datasets



Data Reused

Soleus (SOL) Muscle Data:

- Proteomics (quantitative mass spectrometry)
- Transcriptomics (bulk RNA-seq)
- Epigenomics (DNA methylation)
- Calcium Reuptake

Tibialis Anterior (TA) Muscle Data:

- Transcriptomics (bulk RNA-seq)
- Epigenomics (DNA methylation)
- Calcium Reuptake

- Omics & phenotypic data: RR-9, RR-1
- Qlattice xAI (explainable AI) in AWG collaboration
- Li et al., 2023 npj Microgravity 🎉

Training Programs Using OSDR Data

GeneLab for High Schools (GL4HS)

Overview:

- **GeneLab for High Schools (GL4HS)** is a four-week space biology virtual training program for rising high school juniors and seniors in the US.
- For the **GL4HS Teacher Program**, educators learn alongside students for weeks 1-2 then spend weeks 3-4 developing personalized curriculum material using teacher template documents.
- The program has three components:
  - **LEARN** general cell biology, bioinformatics and omics, and applications for space biology both on Earth and in spaceflight conditions.
  - **NETWORK** with professionals including NASA researchers, and other guests from academia, industry, and private and non-profit sectors.
  - **RESEARCH** and present an analysis of a transcriptomic dataset from the Open Science Data Repository.

Objectives:

- To inspire the next generation of scientists to become involved in space-based research
- To introduce and teach high school students about 'omics data and how it relates to biological research, with a specific focus on space-based research
- To introduce and teach high school students basic bioinformatics skills enabling them to excel in both their college curriculum and academic research laboratories
- To provide students with networking opportunities with their peers, NASA research scientists, NASA Space Biology management and University professors
- To present students with an opportunity to conduct hypothesis driven research of a publishable standard in collaboration with a NASA mentor at a NASA research facility
- To provide tools for teachers to include GeneLab and bioinformatics analysis in their classrooms

GeneLab for Colleges and Universities (GL4U)

Background:

- NASA's GeneLab project empowers researchers with open access to space-relevant multi-omics data through the Open Science Data Repository (OSDR)
- GeneLab for Colleges and Universities (GL4U) offers **bioinformatics training for space biology** to:
  - ➢ Increase accessibility and interpretability of multi-omics Space Biology data
  - ➢ Train a diverse next generation of Space Biology researchers
  - ➢ Enhance awareness and understanding of Space Biology data

Objectives:

- **Educate and train** the next generation of scientists to process, analyze, and interpret space-relevant ‘omics data using publicly available data and bioinformatics tools
- **Maximize** the number of scientists who understand and utilize NASA’s open-source ‘omics data and tools
- **Provide educators with** the **knowledge and resources** required to train and inspire their students using GeneLab bioinformatic analyses as an entree into Space Biology

GL4U Content Design

GL4U materials are organized into introduction and omics-specific modules

Introduction Module

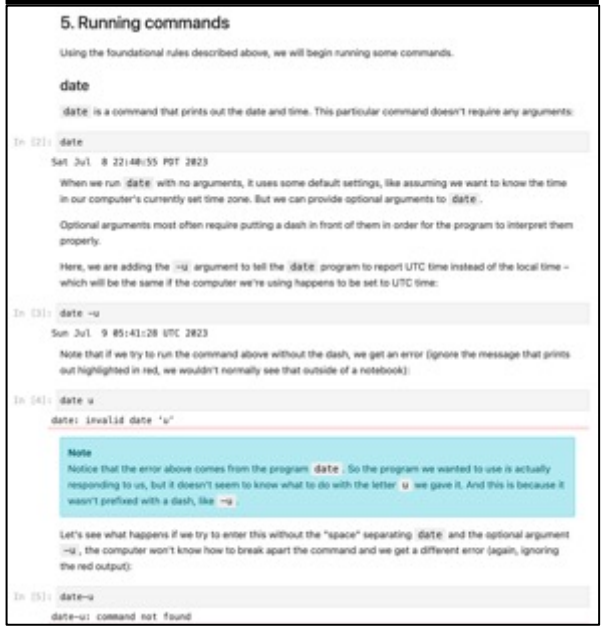
- Overview Lecture (NASA, SMD, BPS, OSDR, GeneLab)
- Jupyter Lab Tutorial
- Unix Jupyter Notebook (hands-on training)
- R Jupyter Notebook (hands-on training)

The Intro Module serves as a pre-requisite for any omics-specific module

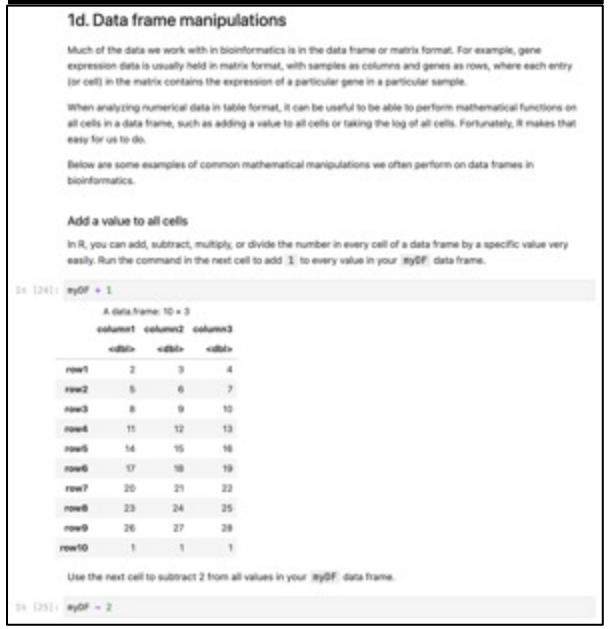
Omics-specific Modules (RNAseq, Amplicon Seq, etc.)

- Omics Data Lectures
  - Experimental design
  - Sample preparation and quality control
  - Data processing tools and visualizations
  - Results analysis and interpretation
- Hands-on data processing and analysis of an OSDR dataset via Jupyter Notebooks (JNs)

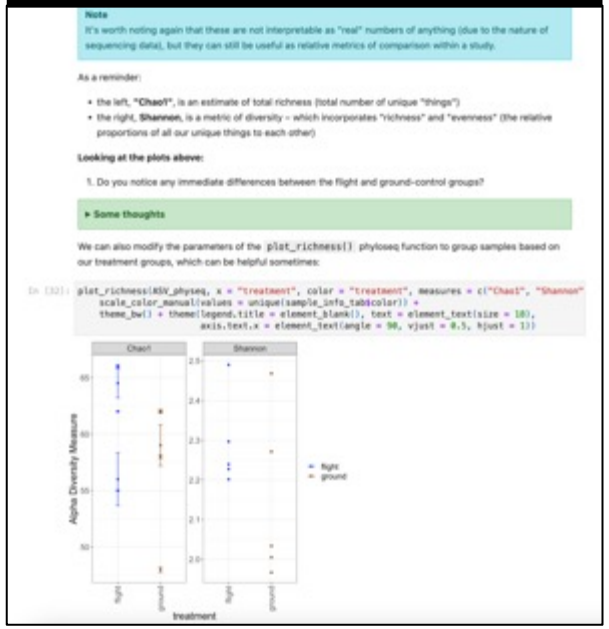
Unix Intro JN



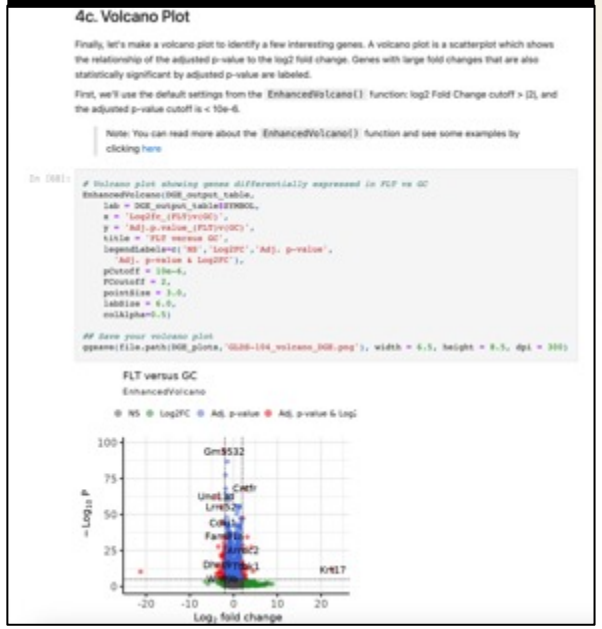
R Intro JN



AmpSeq JN



RNAseq JN



GL4U Approach

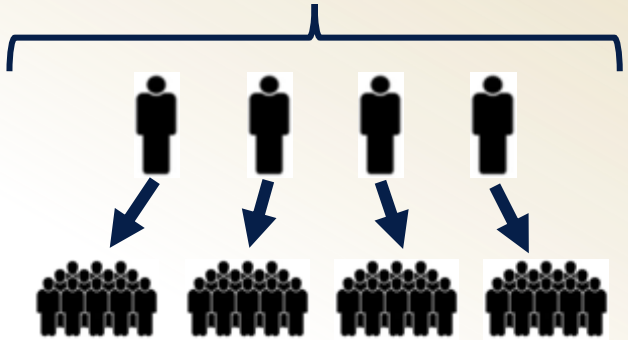
GL4U Direct Approach

MSI/HBCU Students

- Space biology-relevant training in bioinformatics
- Uses **direct** (training students) and **indirect** (training educators) approaches
- The GL4U Introduction module and one omics-specific module is taught to students or educators during a 1-2 week-long bootcamp
- Training focused on MSIs and HBCUs
- Compute resources are provided to all participants
  - ➢ For indirect bootcamps: educators receive materials and training to enable them to run the bootcamp at their home institutions
- All GL4U modules are made publicly available on GitHub (https://github.com/nasa/GeneLab-Training/tree/main/GL4U) and virtual bootcamps are recorded to enable independent learning

GL4U Indirect Approach

MSI/HBCU Educators



GL4U RNAseq Certification

GL4U Introduction Module
- ☑ Pre-Intro Module Survey
- ☑ Intro Lectures
- ☑ Intro JNs
- ☑ Post-Intro Module Survey

+

GL4U RNAseq Module
- ☑ Pre-RNAseq Module Survey
- ☑ RNAseq Lectures
- ☑ RNAseq JNs
- ☑ Post-RNAseq Module Survey

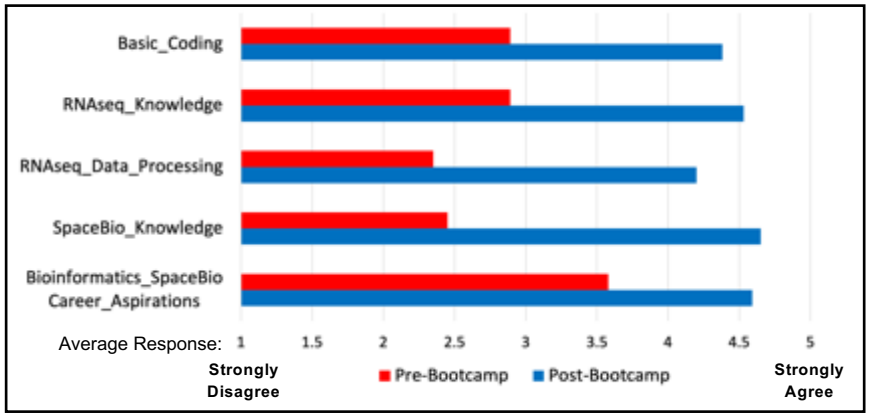
- Pre- and post- bootcamp surveys used to assess participant knowledge before and after training and to collect feedback
- GL4U certification offered for completing the GL4U Introduction module and one omics-specific module
  - ➢ *GL4U RNAseq certification shown as an example*

COMING FALL 2024: GL4U ON-DEMAND

GL4U Student & Educator Bootcamps To-Date

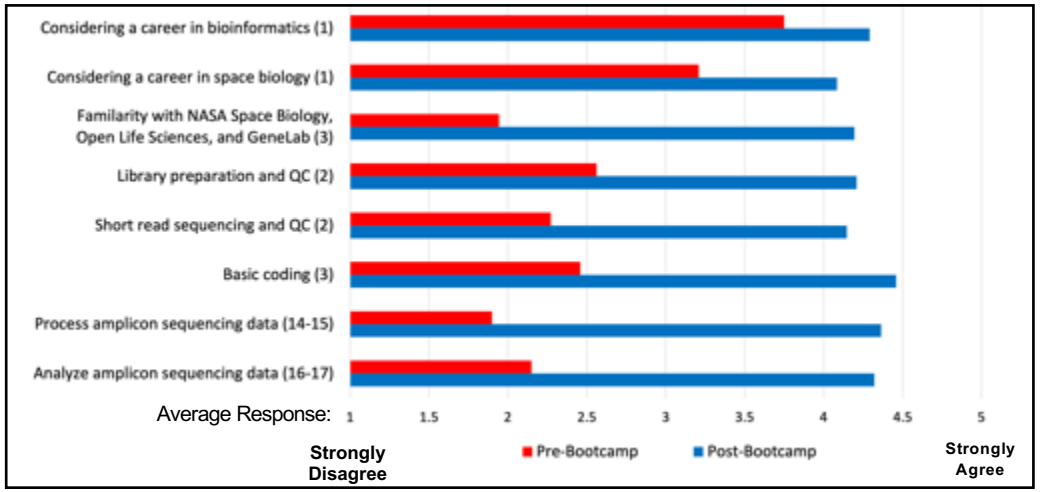
GL4U: RNAseq Student Bootcamp with SJSU, 06/2021

- Virtual 1-week long bootcamp with 17 **SJSU** students
- *Compute resources*: SJSU HPC
- Bootcamp covered GL4U Introduction and RNA Sequencing (RNAseq) modules



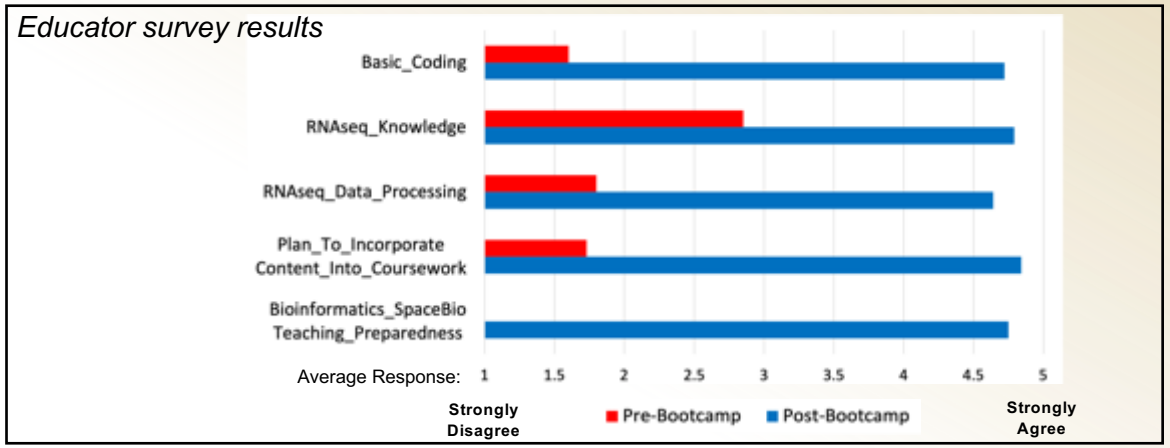
GL4U: AmpSeq Student Bootcamp at CSULA, 07/2023

- In-person 4-day bootcamp with 24 **CSULA** students
- *Compute resources*: NSF ACCESS
- Bootcamp covered GL4U Introduction and Amplicon Sequencing (AmpSeq) modules



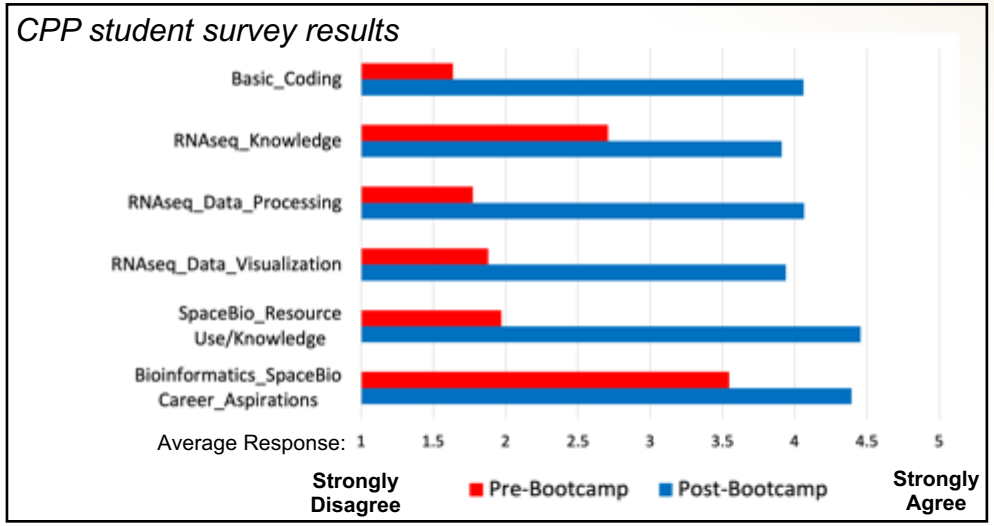
GL4U: RNAseq Educator Bootcamp with MSIs/HBCUs, 06/2022

- Virtual 9-day long bootcamp with 6 professors and 4 graduate students from **4 HBCUs/MSIs**:
  - CalState Northridge
  - New Mexico State University
  - Alabama A&M
  - CalPoly Pomona
- *Compute resources*: NASA NCCS SMCE
- Bootcamp covered GL4U Introduction and RNA Sequencing (RNAseq) modules



CPP-GL4U RNAseq Independent Study Course, Fall 2022

- Dr. Lin taught GL4U RNAseq content for 11 junior & senior CalPoly Pomona (CPP) undergraduate students
- *Compute resources*: NASA NCCS SMCE



Complete NASA's open science curriculum!

Open Science 101:

A community-developed introduction to **core open science skills**

- Know how to write a NASA open science and data management plan
- Learn about tools and best practices
- Increase the impact & visibility of your science
- Earn your digital NASA open science badge

All 5 modules available through a self-paced online course and through in-person and virtual instructor-led workshops.

Take OS101!

https://go.nasa.gov/40pPQMx

CC BY

TOPS-T *ScienceCore* AI/ML Training – Synchronous

- *ScienceCore*: discipline-specific training materials showcasing open science workflows
- *Training in Artificial Intelligence and Machine Learning for Space Biological Sciences Using NASA Cloud-Based Data*
  - AI/ML training with a focus on space biology
  - Real-world use cases with NASA cloud-based scientific datasets

Cloud based NASA biology data:
https://registry.opendata.aws/bps_rnaseq
https://registry.opendata.aws/bps_microscopy

canvas.instructure.com/courses/9450036

AI/ML 2024 › Syllabus

Training in Artificial Intelligence and Machine Learning for Space Biological Sciences Using NASA Cloud-Based Data

Account
Dashboard
Courses
Calendar
Inbox
History
Commons
Help

Home
Announcements
Assignments
Discussions
Grades
People
Pages
Files
Syllabus
Outcomes
Rubrics
Quizzes
Modules
BigBlueButton
Collaborations
Attendance
New Analytics
Settings

AI/ML AWG Summer 2024 Training Program

Jump to Today | Edit

Welcome to "Using AI/ML for space biology research"!

This class was designed the teach the basics of data analysis and machine learning in the context of space biology research. The course modules and presumptive schedule are as follows:

Module 1: Introduction to this course

- Introduction to space biology and Google Colab
- Introduction to machine learning for space biology
- Introduction to space biology data

Module 2: Working with data

- Working with tabular data
- Working with image data
- Visualizing data

Module 3: Building basic models

- Introduction to clustering
- Introduction to regression
- Introduction to classification

Module 4: Interpreting results

- Using bioinformatic tools
- Explainable AI
- Open science

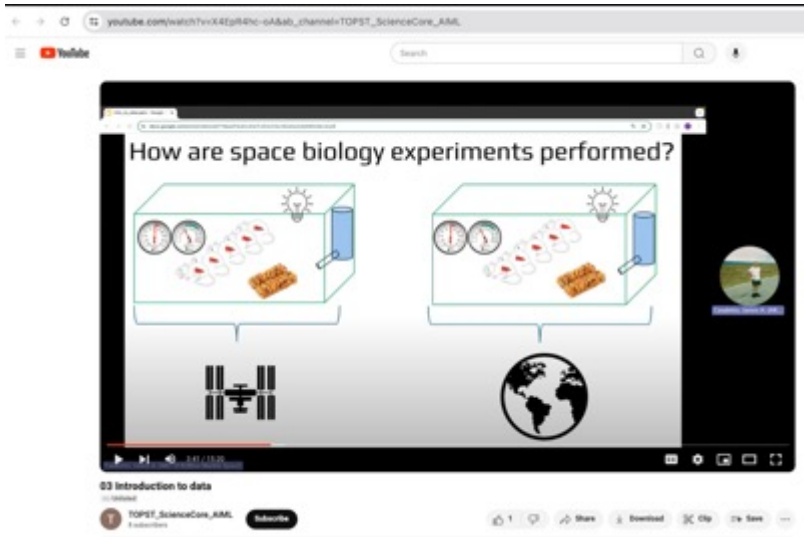
- *2024 Course:*
  - 6/25 – 7/25
  - Tues & Thurs 7-830am PT
- *Topics:*
  - Space biology
  - Building models
  - Working with data
  - Interpreting results
  - Advanced models
- *Content:*
  - 8 Lectures
  - 9 Jupyter Notebooks
  - 4 Quizzes
- *Participants:*
  - 141 High School Students
  - 7 TAs

Course Summary:

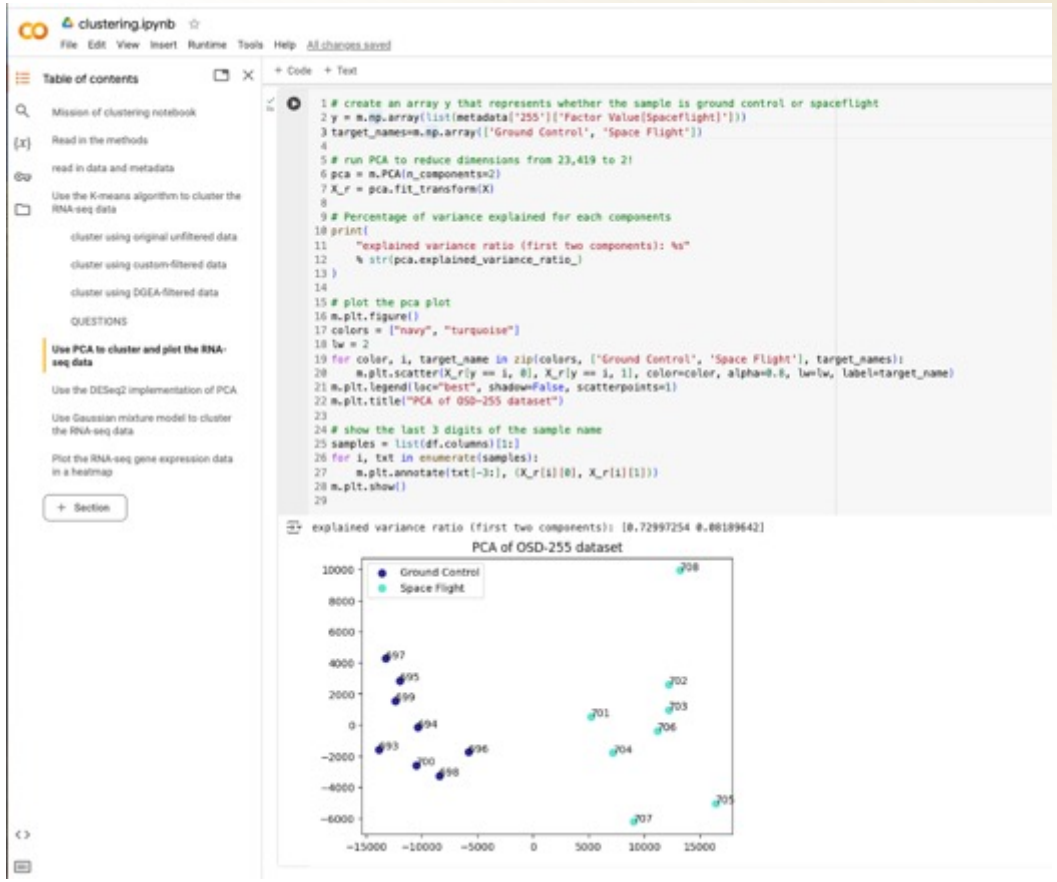
Date	Details	Due
Tue Jun 25, 2024	Module 1 lecture (interactive)	due by 7am
Thu Jun 27, 2024	Module 1 hands-on notebook lecture	due by 7am

TOPS-T *ScienceCore* AI/ML Training – Asynchronous

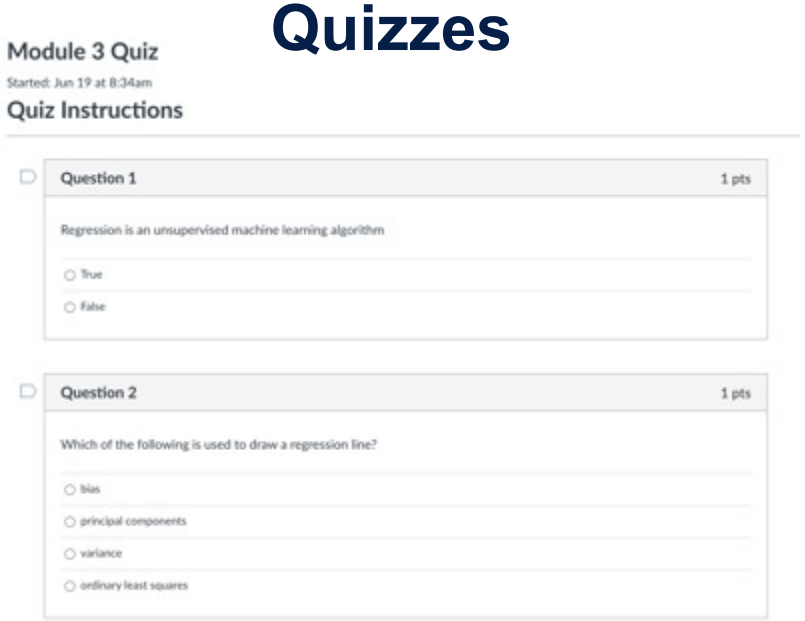
Pre-recorded lectures



Interactive Python notebooks



Quizzes



To enroll in this course, visit:

https://canvas.instructure.com/enroll/8JYKD7

Training in Artificial Intelligence and Machine Learning for Space Biological Sciences Using NASA Cloud-Based Data

- 2 week curriculum
- 2.5 hours / day
- *Topics:*
  - Space biology
  - Working with data
  - Building models
  - Interpreting results
  - Capstone projects

- Available Summer 2024 for independent learning

Get Involved!

Open Science Analysis Working Groups (AWGs)

Join an AWG!

ANIMAL

180 members

MULTI-OMICS

306 members

MICROBIAL

163 members

PLANTS

132 members

AI/ML

230 members

ALSDA

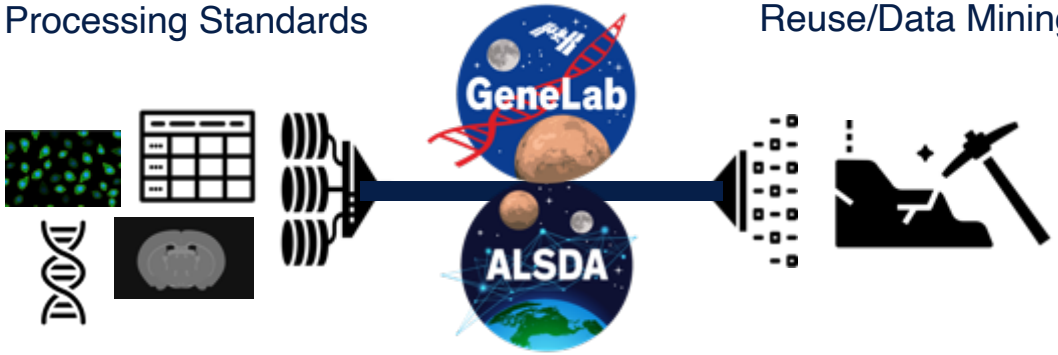
(Physiological/BioMedical)

189 members

Feedback on Ingress/Egress Standards

Ingestion, Curation, Processing Standards

Standards to Enable Reuse/Data Mining



Collaborate on Data Mining/Publications

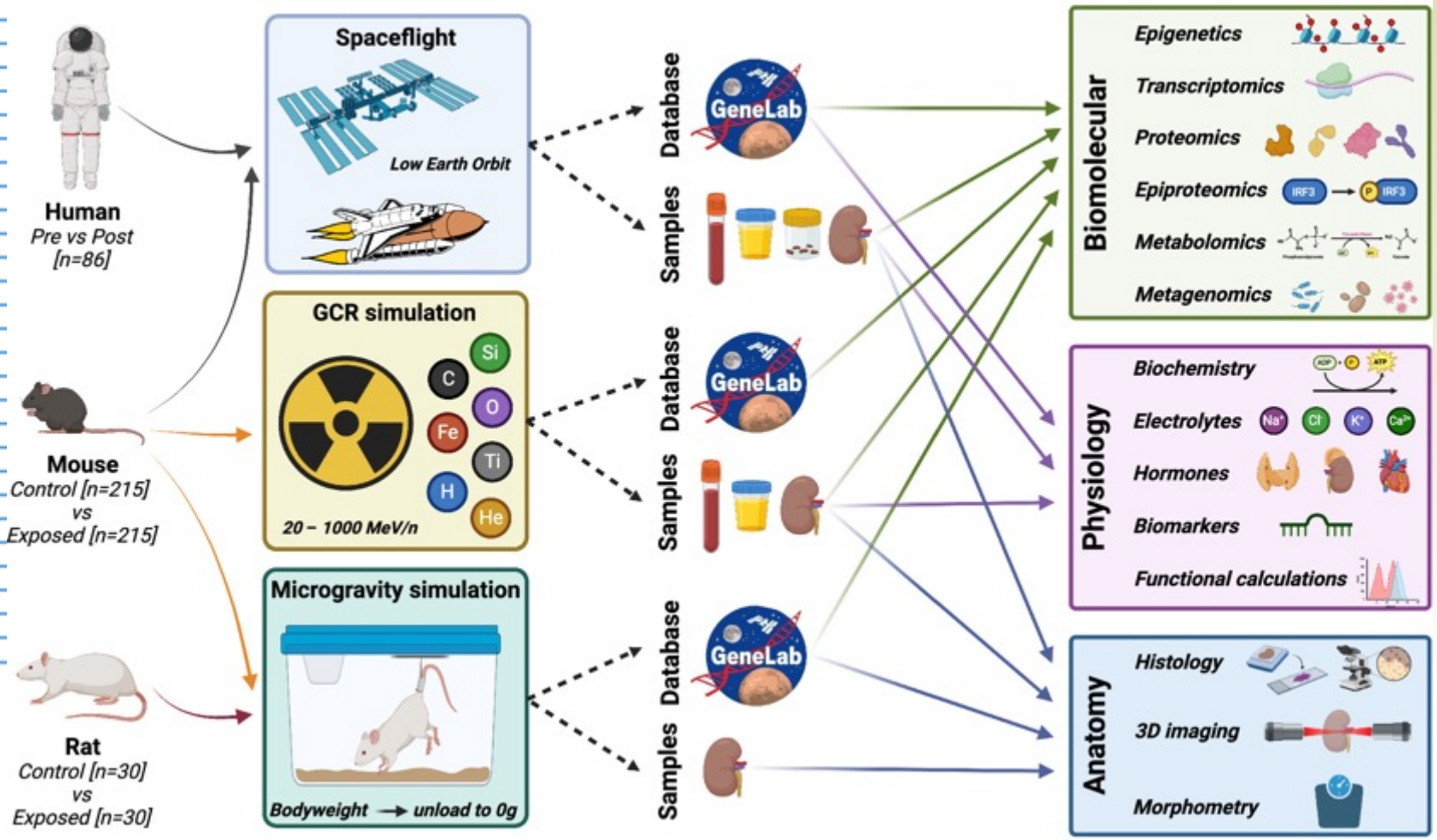
Cell Press Package 2020:
The Biology of Spaceflight
https://www.cell.com/c/the-biology-of-spaceflight

Nature Portfolio Collection 2024:
Space Omics and Medical Atlas across orbits (SOMA)
https://www.nature.com/collections/ebdbcahdgc

List of 74 publications enabled by OSDR
https://osdr.nasa.gov/bio/data/publications.html

Example of Open Science AWG Collaboration and Publication

Mission	Experimental Condition	Species	Sex	Background	GCR (mG)	Mission Duration (d)	Sample Collection	n	Control	Data Source	Tissue	DNA	RNA	Protein	PTMs	Metab	Microbes	Physiol	Anatomy
Inspiration4	Spaceflight	Human	Mix	USA	Unknown	3	R+0	4	Paired	Original	P, U			✓		✓		✓	
JAXA	Spaceflight	Human	♂	Japan	Unknown	120	L+120	6	Paired	Original	P		✓						
NASA	Spaceflight	Human	Mix	USA	Unknown	180	L+120	66	Paired	Database	P, U							✓	
Roscosmos	Spaceflight	Human	♂	Russia	Unknown	199	R+1	10											
BNL-1	simGCRsim	Mouse	♀	C57BL/6	500.0	~1.5yr sim	PE+1	10											
	MGsim				N/A	14	PE+1	10											
	simGCRsim + MGsim				500.0	~1.5yr sim	PE+1	10											
BNL-2	simGCRsim	Mouse	♀	C57BL/6	500.0	~1.5yr sim	PE+1	10											
	MGsim				N/A	14	PE+1	10											
	simGCRsim + MGsim				500.0	~1.5yr sim	PE+1	10											
BNL-3	simGCRsim	Mouse	♀	C57BL/6	500.0	~1.5yr sim	PE+1	10											
	MGsim				N/A	14	PE+1	10											
	simGCRsim + MGsim				500.0	~1.5yr sim	PE+1	10											
NSRL-22A	GCRsim	Mouse	♀	C57BL/6	750.0	~2.5yr sim	PE+180	12											
	GCRsim	Mouse	♂	C57BL/6	750.0	~2.5yr sim	PE+180	12											
STS-135	Spaceflight	Mouse	♀	C57BL/6CR	4.7	13	R+0	7											
RR-1	Spaceflight	Mouse	♀	C57BL/6J	5.0	38	L+38	6											
RR-3	Spaceflight	Mouse	♀	BALB/c	5.9	41	L+41	6											
RR-6	Spaceflight	Mouse	♀	C57BL/6NTac	8.2	29	R+4	9											
					16.1	57	L+75	9											
RR-7	Spaceflight	Mouse	♀	C3H/Hej	4.4	25	L+25	5											
					13.2	75	L+75	5											
				C57BL/6	4.4	25	L+25	5											
					13.2	75	L+75	5											
RR-9	Spaceflight	Mouse	♂	C57BL/6J	5.5	33	R+1	5											
RR-10	Spaceflight	Mouse	♀	B6129SF2/J	4.2	28	L+28	10											
RR-19	Spaceflight	Mouse	♀	C57BL/6N	5.2	35	R+0	8											
RR-23	Spaceflight	Mouse	♂	C57BL/6J	5.8	37	R+1	9											
MHU-1	Spaceflight	Mouse	♂	C57BL/6J	9.0	35	R+2	6											
MHU-3	Spaceflight	Mouse	♂	C57BL/6NCrl	9.0	31	R+0	6											
CNSA	MGsim	Rat	♂	Sprague-Dawley	N/A	28	R+0	30											



- **Renal/Kidney Research**
  - 20 spaceflight missions & ground simulations
  - 50+ datasets
  - 5 continents of collaborators

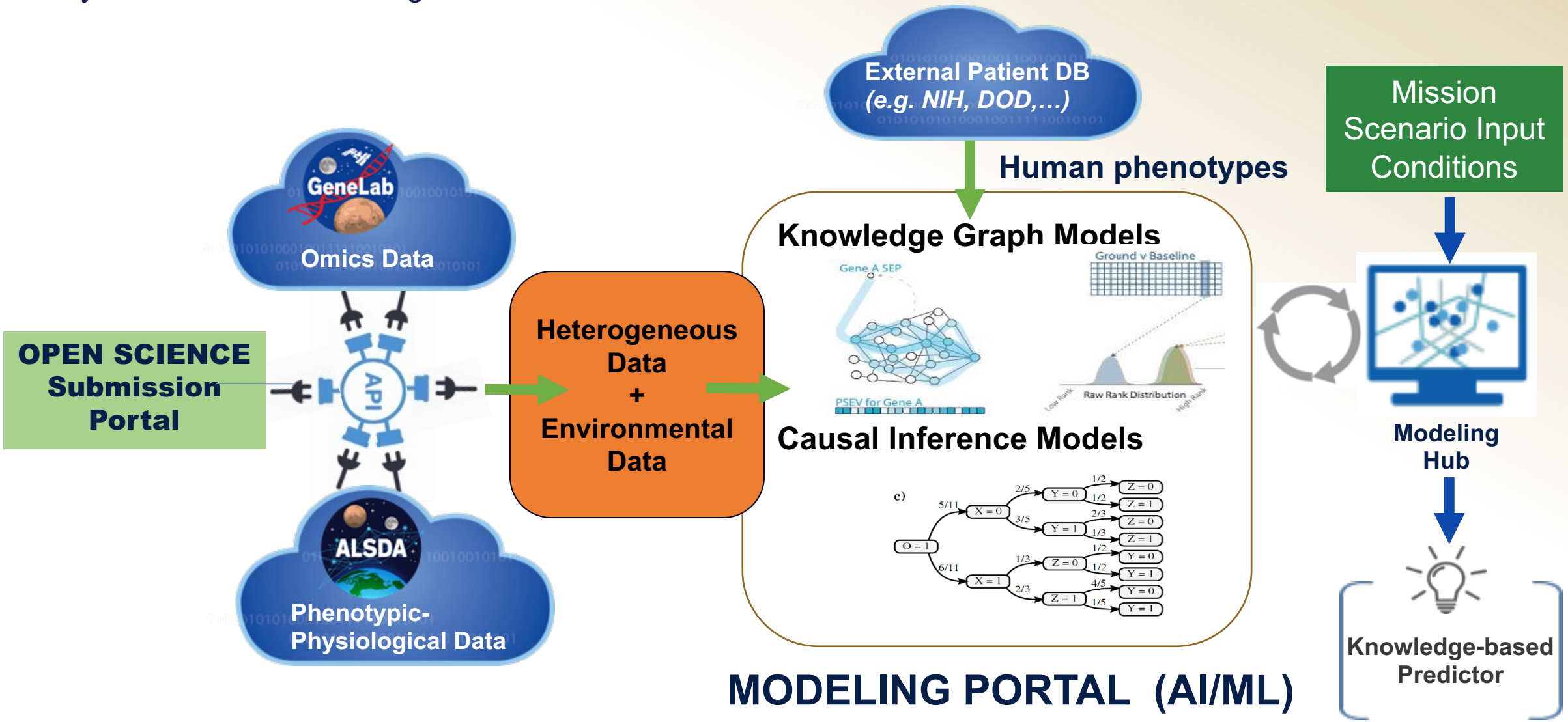
Cosmic Kidney Disease: The Effects of Spaceflight and Galactic Cosmic Radiation on Renal Structure and Function.

Siew, K., et al., Nat Communications 15, 4568 (June 2024). https://doi.org/10.1038/s41467-024-49212-1

What’s Next?

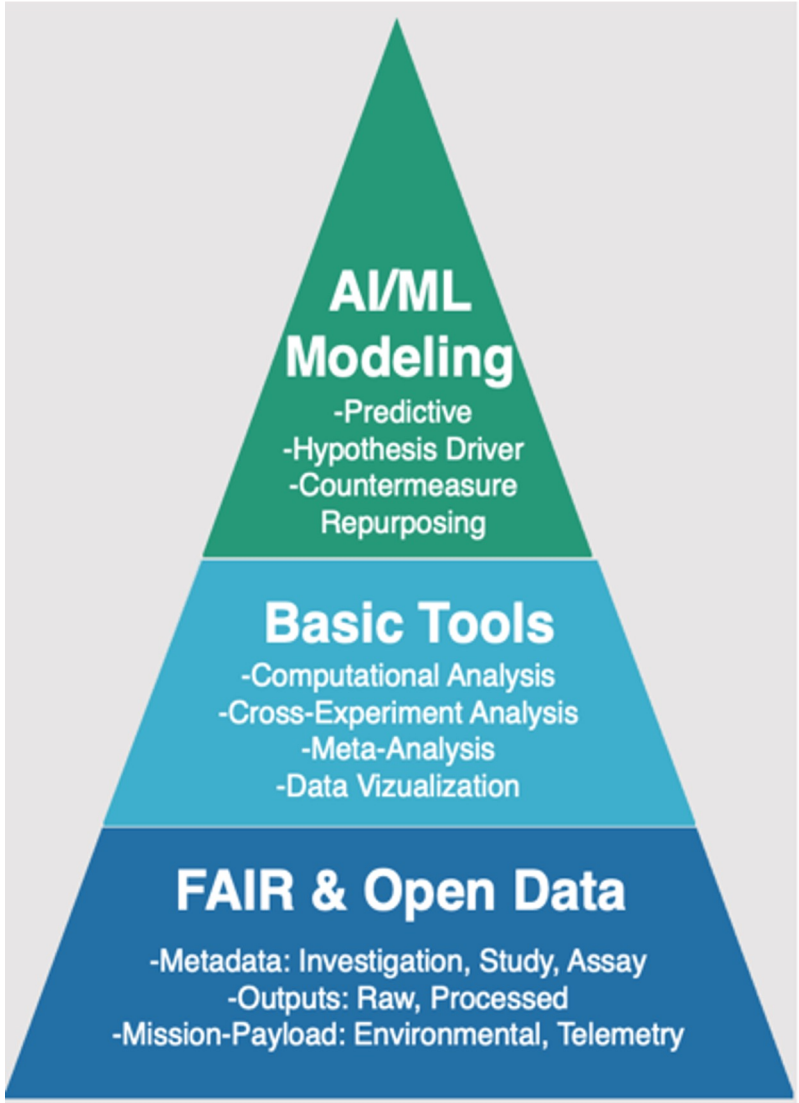
From Multiple Databases to a Knowledge-Based System

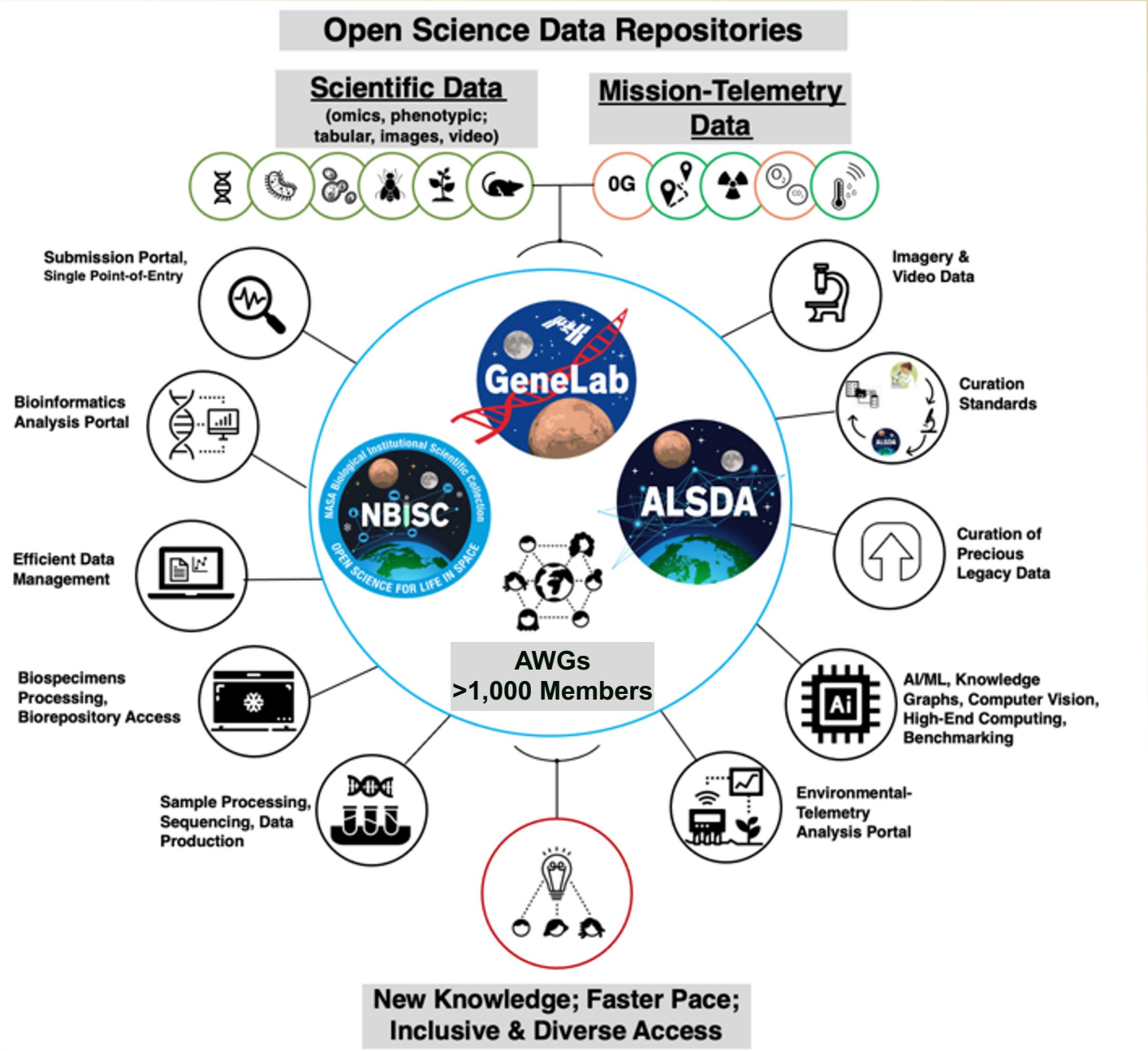
AI ready FAIR data for modeling and risk assessment



Credit: Nelson et al., 2021, https://doi.org/10.3390/life11010042; Genewein et al., 2020, arXiv:2010.12237v1 [cs.AI])

Big Picture for Open Science for Life in Space





Opportunities & Resources

Training and Other Opportunities at NASA

GeneLab for High Schools (GL4HS): A four-week intensive training summer program for rising high school juniors and seniors to learn bioinformatics and computational biology methods and techniques to analyze space omics data.

Learn more and apply at: https://www.nasa.gov/ames/genelab-for-high-schools

GeneLab for Colleges/Universities (GL4U): For educators and students to learn how analyze omics data using GeneLab standard pipelines and space-relevant data

Access to course materials: https://github.com/nasa/GeneLab-Training/tree/main/GL4U

Space Life Sciences Training Program (SLSTP): Provides undergraduate students entering their junior or senior years, and entering graduate students, with professional experience in space life science disciplines.

Learn more and apply at: https://www.nasa.gov/ames/research/space-life-sciences-training-program

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NASA Postdoctoral Program: If you're an early-career or senior scientist, apply to the NASA Postdoctoral Program to help pursue NASA's mission and experience the world's most diverse technology and expertise.

Learn more and apply at : https://npp.orau.org/

NASA Pathways Program: Provides current students and recent grads with a dynamic career development program at a NASA center. Participants are given an opportunity for permanent employment with NASA.

Learn more and apply at : https://www.nasa.gov/careers/pathways-program

Spaceflight Technology, Applications, and Research (STAR): The annual course targets principal investigators (PIs), senior research scientists, and postdoctoral scholars and aims to facilitate their entry to space biology and preparation for conducting spaceflight experiments using NASA and commercial platforms.

Learn more and apply at : https://science.nasa.gov/biological-physical/programs/star

Acknowledgements

Open Science for Life in Space Teams

Open Science Analysis Working Group Members

Support

NASA Space Biology Program
NASA Science Mission Directorate
NASA Human Research Program
NASA Biological and Physical Sciences

Questions & Discussion