

Open Science for Life in Space: Bioimaging, Data Sharing, and Tools for Knowledge Discovery

National Aeronautics and
Space Administration



Ryan T. Scott, ALSDA Project Scientist
From Images to Knowledge, May 6, 2022 #I2K2022
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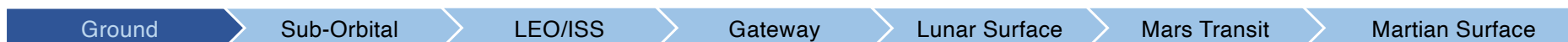
Thriving in Deep Space

- Ground studies
- Space studies
- Ground & space studies

DEEP SPACE STRESSORS



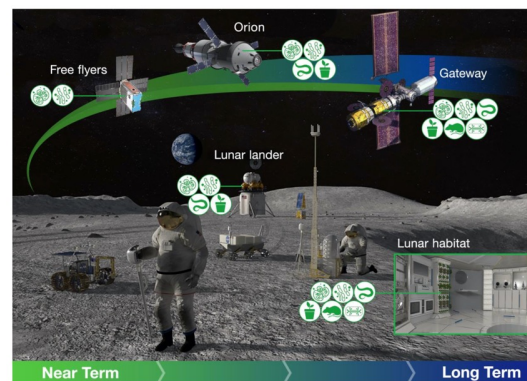
PLATFORM PROGRESSION



Understand
Fundamental
Mechanisms

Build a Foundation
through Lunar Science
and Experience for
Sustained Life on Mars

Build the
Blocks to
Support
Human Life



SCAN ME

MODEL ORGANISM PROGRESSION



(Credit: NASA Biological and Physical Science Division; Beyond LEO Instrumentation & Science Series Science Working Group, 2021 Report, <https://ntrs.nasa.gov/api/citations/20210023324/downloads/BLISS%20SWG%202021%20Report%20Final.pdf>)

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NASA Committed with 'Open-Source Science Initiative'

Unlocking the full potential of a more equitable, impactful, efficient, scientific future



Policy development, education, compliance tools
Updating NASA policies on scientific information to better enable the activation of open science



ROSES Elements
Supporting open-source software, tools, frameworks, libraries, platforms, and training with over \$5 million dollars in grants

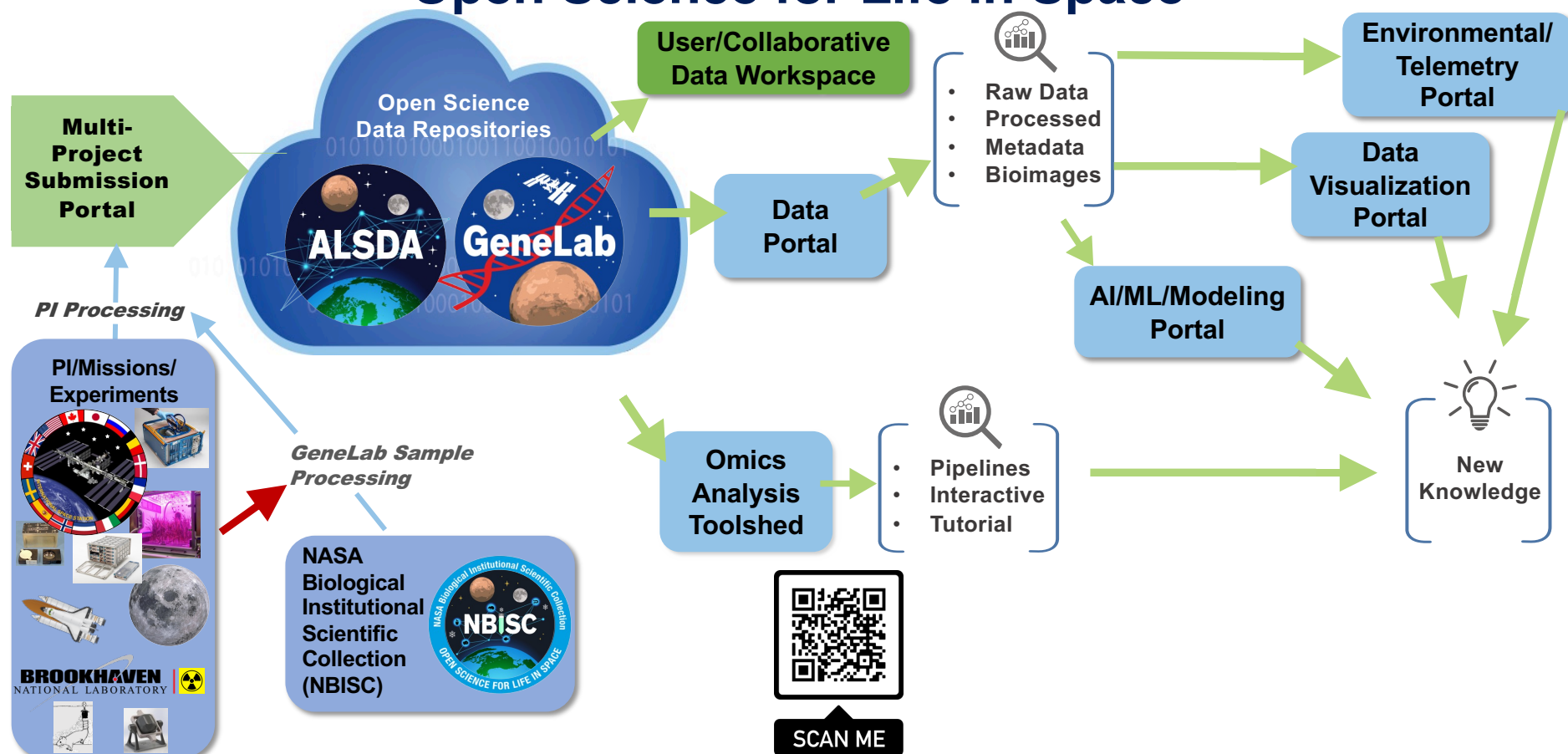


Core Services for Science Discovery
Developing core data and computing services to enable open science



Community Building & Partnerships - Transform to Open Science (TOPS)
Accelerating adoption of open science

Open Science for Life in Space

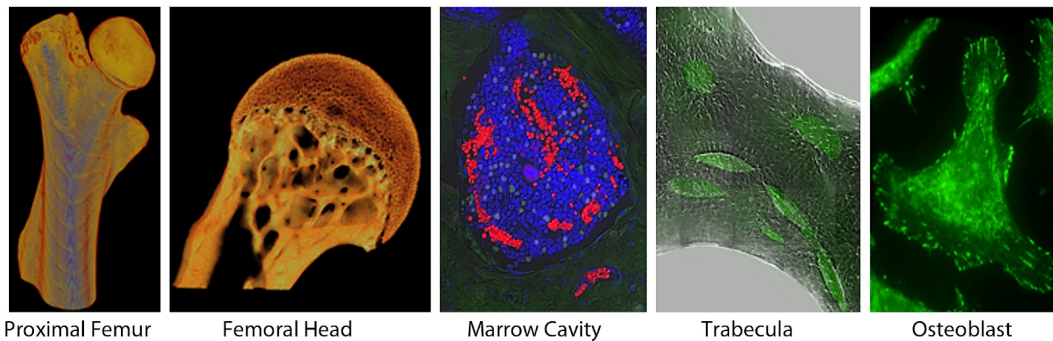


(Credit: Rodent Research Animal Enclosure Unit, Advanced Plant Habitat, Bioculture System, Biological Research in Canisters, NASA Space Radiation Laboratory, Ground Analog Hindlimb Unloading, Random Positioning Systems)

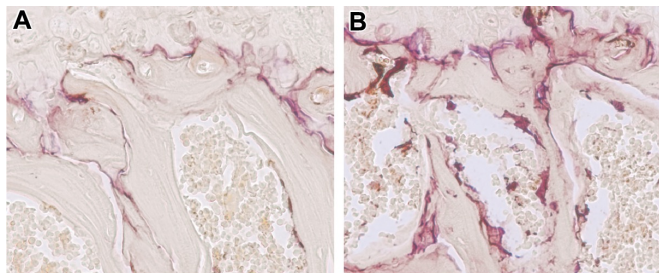
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Review of Space-relevant ALSDA Bioimaging #1

- Multi-Hierarchical; Multi-Modal; Heterogenous
- mCT, qPCT, MRI, DXA, OCT, Fundoscopy, Light-, Fluorescence-, Confocal-, Atomic Force-, Electron Microscopy (Scan & Trans)
- Ultrasonography, Images of Behavior Assays, Plant-Crop Growth, Microbes

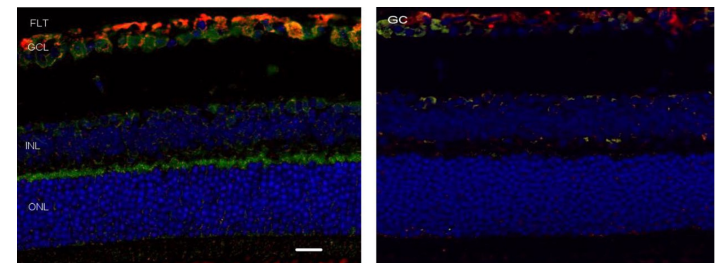


(RR10, NASA, Almeida 2020; <https://www.nasa.gov/ames/research/space-biosciences/rodent-research-10-spacex-21>)



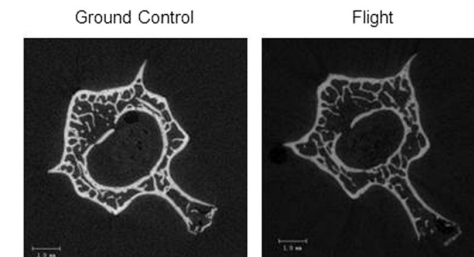
Light Microscopy (e.g. Cancellous Bone)

(Blaber et al., 2019 <https://doi.org/10.1371/journal.pone.0061372>)



Fluorescence Microscopy (e.g. Retinas)

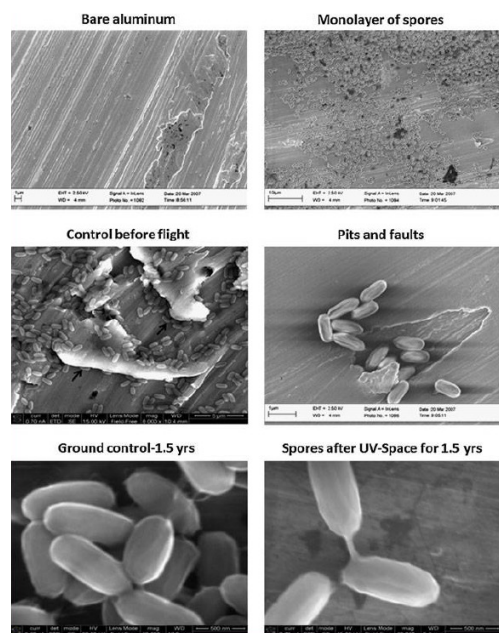
(Mao et al., 2019 <https://doi.org/10.1038/s41598-019-44696-0>)



Microcomputed Tomography (e.g. Vertebrae)

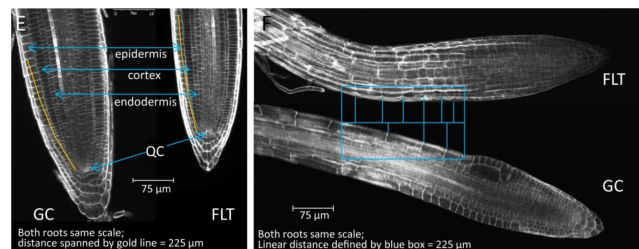
(Keune et al. 2015, <https://doi.org/10.1038/srep18671>)

Review of Space-relevant ALSDA Bioimaging #2



Microbes (e.g. *Bacillus Pumilus*)

(Vaishampayan et al., 2012; <https://doi.org/10.1089/ast.2011.0738>)



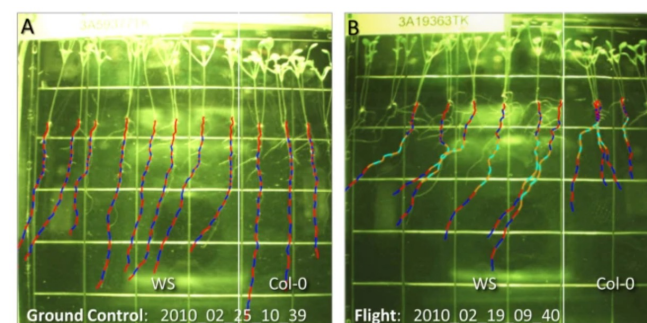
Plant Root Tips (e.g. *Arabidopsis*)

(Paul et al., 2012; <https://doi.org/10.1186/1471-2229-12-232>)



Crop Growth Impacts (e.g. *Azola*)

(Barker and Gilroy Lab; 2021)



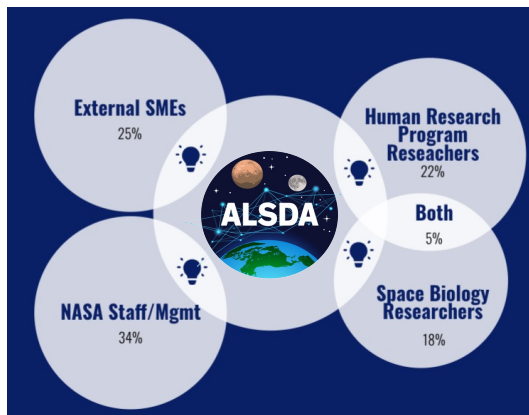
Plant Growth Patterns (e.g. *Arabidopsis*)

(Paul et al., 2012; <https://doi.org/10.1186/1471-2229-12-232>)

ALSDA Science Community-Driven Curation Standards

ALSDA Analysis Working Group:

- 7 Meetings
- July, Sept, Oct, Dec, Feb, Mar, Apr
- ~100 members
- ~45/meeting



Would love more Bioimage and Programming SMEs to join!
arc-dl-alsda@mail.nasa.gov

Assay Metadata Configurations	Drafted	AWG Covered	Deployed	Dataset Used
Bone Microstructure (MicroCT)	✓	09/08/21	✓	✓
Behavior (Novel Object Recognition)	✓	09/08/21	✓	✓
Molecular/Cellular Imaging (Lt/Fluor Microscopy)	✓	09/08/21	✓	✓
Flow Cytometry (Flow Cytometry)	✓	09/08/21	✓	✓
Behavior (Elevated Plus Maze)	✓	12/08/21	✓	✓
Behavior (Open Field)	✓	12/08/21	✓	✓
Behavior (Gait)	✓	12/08/21	✓	✓
Protein Analysis (Western Blot/Immunoblot)	✓	12/08/21	✓	✓
Calcium Uptake (Spectrofluorometry)	✓	12/08/21	✓	✓
Behavior (Barnes Maze)	✓	12/08/21	✓	✓
Osteocellular (Histomorphometry)	✓	02/16/22	✓	✓
Mechanical Test (3pt-Bend)	✓	02/16/22	✓	✓
Intra-Ocular Pressure (Rebound Tonometry)	✓			
Blood Analysis (Serum Metabolites)	✓			
Echocardiogram (Ultrasonography)	✓	03/09/22	✓	✓
ELISA (ELISA)	✓	03/09/22	✓	✓
Behavior (Radial Arm; Water Maze)	✓	03/09/22	✓	✓
Behavior (3-Chamber Social Interaction)	✓	03/09/22	✓	✓
Behavior (Attentional Set-Shifting)	✓		✓	✓
Behavior (Unconstrained Cognitive Flexibility)	✓		✓	✓
Behavior (Morris; Water Maze)	✓		✓	✓
Muscle Physiology (Muscle Fiber Typing)	✓			
In Vivo Bone (pQCT)	✓			
Mineral Density and Composition (DXA)	✓			
Behavior (Object in Place)				
Behavior (Novel Location)				
Electron Microscopy (Scanning)				
Electron Microscopy (Transmission)				
Neurophysiology (Electrophysiological Recordings)				
Physiology (Blood Pressure)				
Physiology (Pulse Oximetry)				
Metabolites (HPLC with ECD)				
Cardiovascular Imaging (MRI)				
Neuroimaging (MRI)				
Eye Microstructure (microCT)				
Grip Force (Force Transducer)				
Behavior (Spatial Novelty Y Maze)				
Behavior (Tail Suspension Test)				
Behavior (Startle Test)				
Behavior (Prepulse Inhibition)				

ALSDA Assay Metadata, Image, Outcome Measure Configuration for microCT	Micro-Computed Tomography (microCT; µCT)
File Folders will contain: Study Metadata, File, Measurement, Bone Microstructure	
Assay Log File	ALSDA Assay Metadata Configuration for Western Blot/Immunoblot
Supporting Literature	Western Blot/Immunoblot
Assay Log File	ALSDA Assay Metadata, Setup, Outcome Measure Configuration for Barnes Maze
Supporting Literature	Barnes Maze
Assay Log File	ALSDA Assay Metadata, Setup, Outcome Measure Configuration for Gait
Supporting Literature	Gait
Assay Log File	ALSDA Assay Metadata, Setup, Outcome Measure Configuration for Open Field
Supporting Literature	Open Field
Assay Log File	ALSDA Assay Metadata, Image Configuration for Microscopy
Supporting Literature	Microscopy
Assay Log File	ALSDA Assay Metadata, Setup, Outcome Measure Configuration for Elevated Plus Maze (EPM)
Supporting Literature	Elevated Plus Maze (EPM)
Assay Log File	ALSDA Assay Metadata, Setup, Outcome Measure Configuration for Behavior
Supporting Literature	Behavior
Assay Log File	ALSDA Assay Metadata, Setup, Outcome Measure Configuration for Example Value
Supporting Literature	Example Value
Assay Log File	ALSDA Assay Metadata for EPM
Supporting Literature	COGNITIVE ASSAY ARRANGEMENT
Assay Log File	Tracking and Analysis system (name/company/version)
Supporting Literature	e.g. Ethovision XT 12.0
Assay Log File	Other behavioral assays conducted prior or concurrent to EPM (free text)
Supporting Literature	e.g. Open Field, Elevated Plus Maze, NOR
Assay Log File	Vector of the sequence of all behavioral tests performed in order, denoting position of EPM (free text)
Supporting Literature	e.g. 1. Open Field, 2. Elevated Plus Maze, 3. NOR, 4. R
Assay Log File	EPM Assay Repeated (unit: YES/NO)
Supporting Literature	e.g. No
Assay Log File	Number of times EPM Assay Repeated (unit: number)
Supporting Literature	e.g. 0
Assay Log File	PHYSICAL ENVIRONMENT
Supporting Literature	Subject Handling Frequency and Technique (free text)
Assay Log File	e.g. Twice a day, scroffline posterior neck

ALSDA AWG:
~17 'Ready' Assay Configs in new system

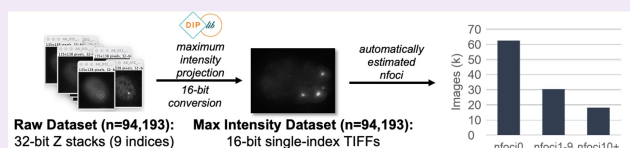
(Credit: Amazing ALSDA AWG Members)

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ALSDA Data Currently in Reuse: Pilot Projects

Benchmark Microscopy Dataset

- Huge amounts of microscopy data in space biology, time consuming, manual annotate
- Approach:**
- Radiation exposure microscopy DNA damage dataset, distinct foci (PI: Costes)

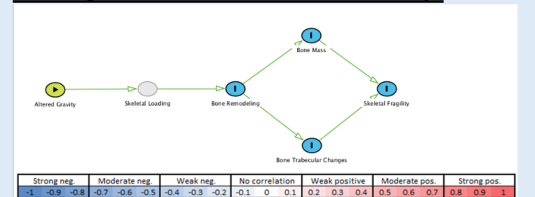


Genomic to Phenotypic: CRISP and Hepatic Dysfunction

- Transcriptomics, Histology; Four Spaceflown Rodent Liver Datasets
- Ensemble Learning; Causal Research and Inference Search Platform



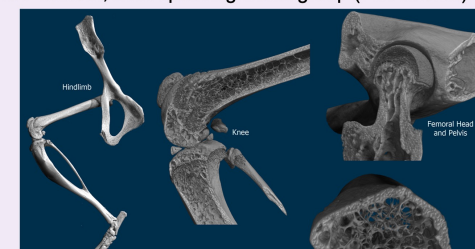
Quantify Bone Risk: DAG Proof of Concept



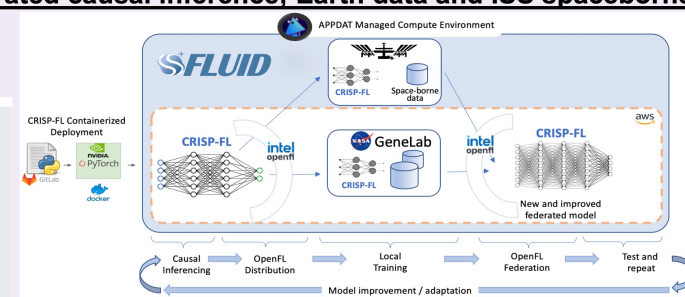
(Credit: BMs: Sylvain Costes & Eduardo Almeida; CRISP: Makenna Myrick, James Casaletto, Sanders et al., 2021; FLUID: Graham Mackintosh, 2022; DAG: Rob Reynolds, et al., 2021; ALSDA Vis, Fu et al., 2021, Svetlana Komarova)

Benchmark microCT Dataset

- CT is key to assess space biological bone impacts
- Approach:**
- Mouse mCT dataset, both spaceflight and group (PI: Almeida)



Federated causal inference: Earth data and ISS spaceborne data



ALSDA Visualization

 LSDS-110

Mission: STS-108

 LSDC 115

Mission: STS-118

Tissue: Femur (M)

 LDS-117

Tissue: Femur (M)

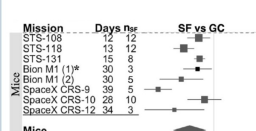
 LSDS-89

Mission: Bion M1 (1)
Tissue: Femur (M.D)

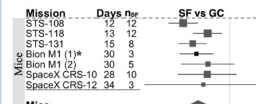
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TRABECULAR BV/TV – FOREST PLO

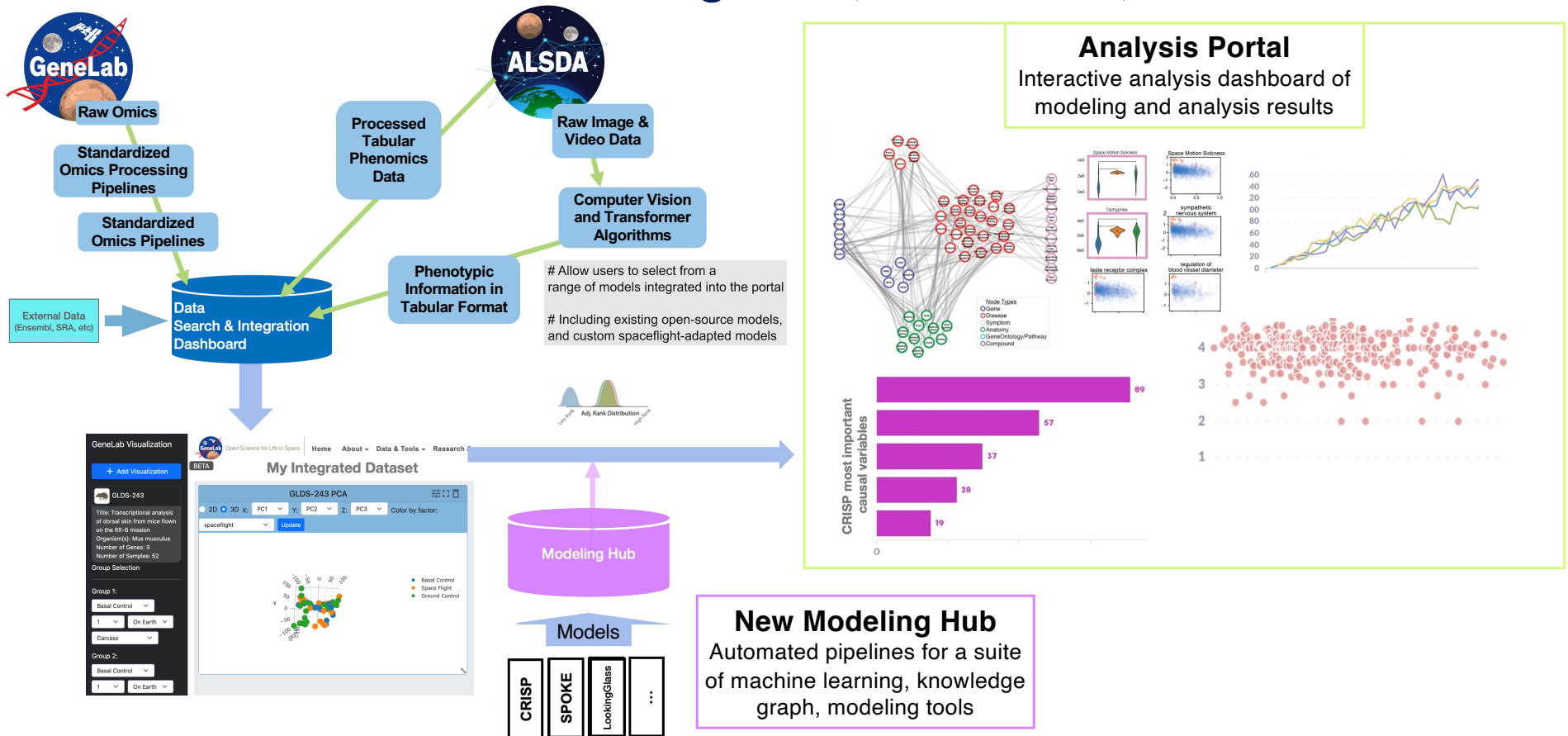


TRABECULAR THICKNESS – FOREST PLOT 773



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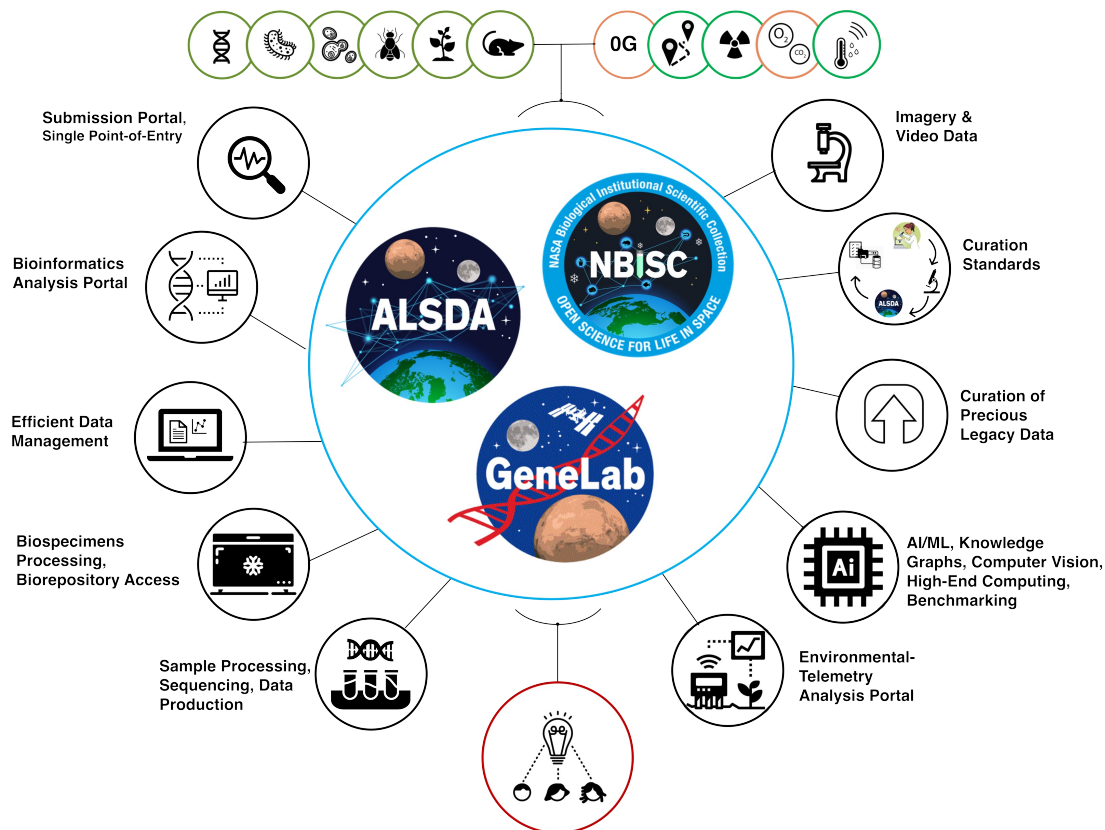
Future: Streamlined Data Integration, Multimodal, Multihierarchical



(Credit: Adrienne Hoarfrost, James Casaleto, Lauren Sanders;
Images: Nelson et al., 2021, <https://doi.org/10.3390/life11010042>
Casaleto et al., 2022, CRISP & Liver, in preparation)

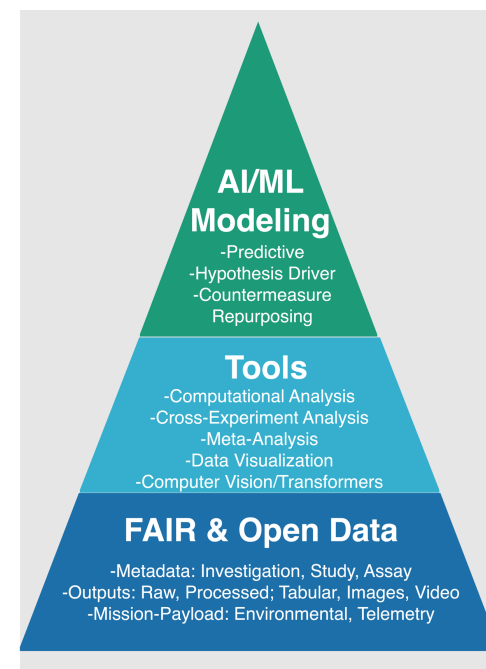
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Open Science Data Repositories



**New Knowledge; Faster Pace;
Inclusive & Diverse Access**

Big Picture



ACKNOWLEDGE



Open Science for Life in Space (Open Science Data Repositories)

ALSDA

- Danielle Lopez
- Evelyn Wong
- Alan Wood
- Kira Rienecker
- Sylvain Costes



GeneLab & Data System Support

- San-huei Lai Polo
- Sam Gebre
- Ana Uriarte Acuna
- Jamie Bales
- Brennan Cooper
- Matias Fernandez
- Nico Garcia
- Sylvain Costes



AI/ML Team

- James Casaletto
- Lauren Sanders
- Graham Mackintosh
- Adrienne Hoarfrost
- Sylvain Costes

NBISC



Biospecimen Sharing Program



Collaborators

ALSDA AWG

- ~100 Members

UCSF SPOKE Team

- C. Nelson, K. Sorman, S. Baranzini

2021 AI Workshop Participants

- ~100 Participants

Frontier Development Lab 2020 & 2021 Astronaut Health Teams



Stakeholders-Management

NASA Space Biology Program

NASA Biological and Physical Sciences

NASA Human Research Program



OPEN SCIENCE FOR LIFE IN SPACE

