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Microbes in Space:

Instrumentations and Capabilities for "Omics in Space" that are Required for Human Missions

***Kasthuri Venkateswaran* & OIS team**

Biotechnology and Planetary Protection Group

Jet Propulsion Laboratory; California Institute of Technology

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The ISS Team

Post-docs

Students

Co-investigators

$$$: NASA; Space Biology Program; JPL, USC, LBNL, and CASIS support funding

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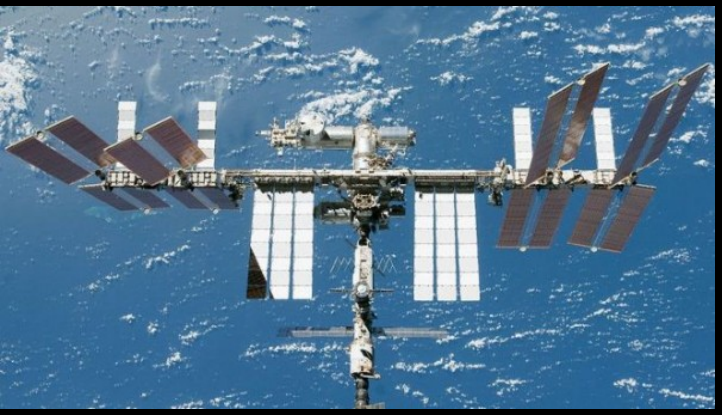
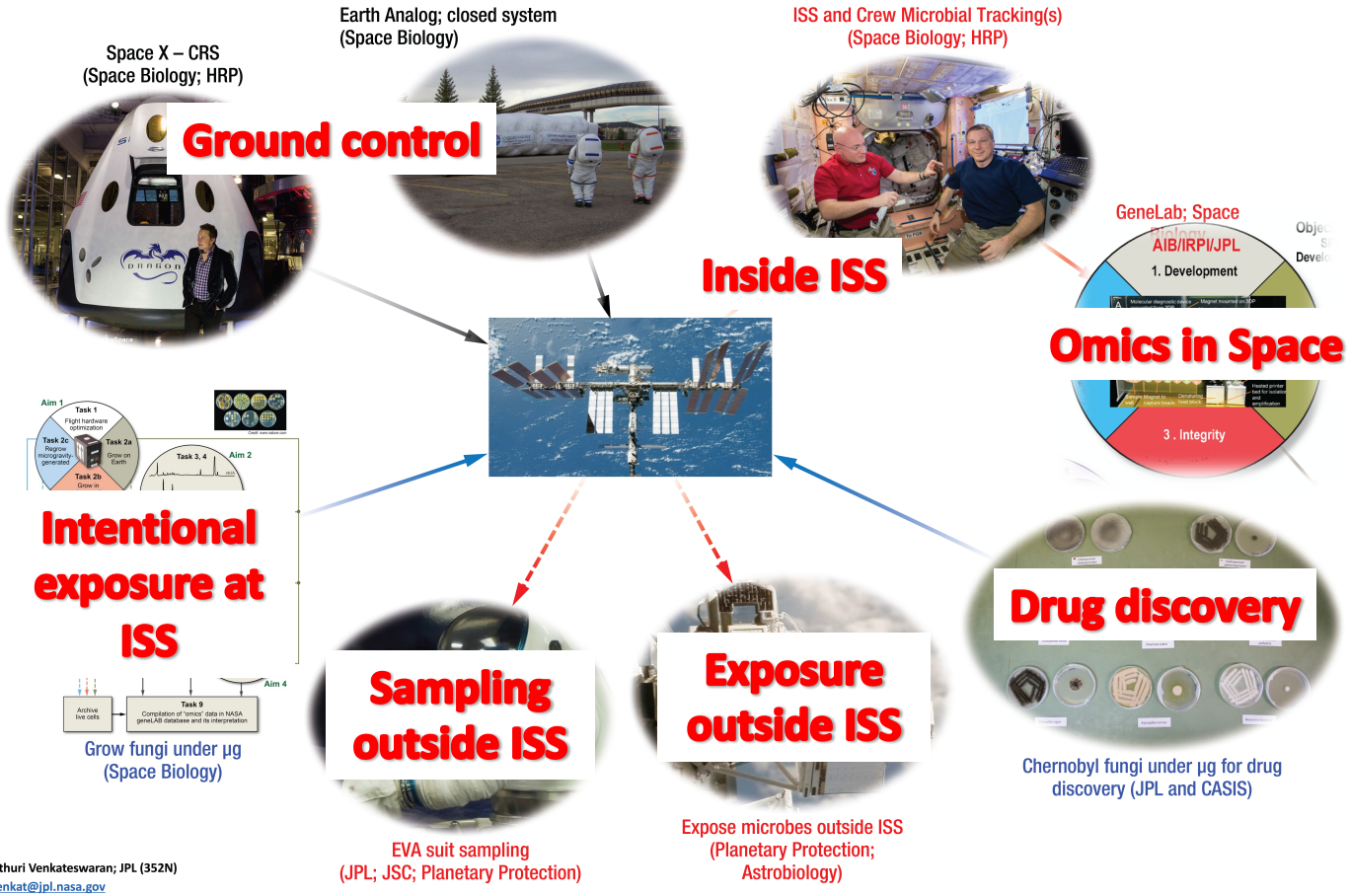
Outline of the talk

- Introduction on NASA Space Biology ”Omics” related projects.
- Microbiological requirements for safe working environment in space
  - present to future microbial monitoring efforts
- How research projects are being practiced now?
  - ISS microbial observatory projects
- What are the present Omics capabilities?
  - Q-PCR to Sequencing
- What is needed?
- Introducing Omics in Space (OIS), a biological detection in space



JPL Projects on Space Biology

and Its Relationship with Planetary Protection, Astrobiology, and HRP



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JPL Projects on Space Biology

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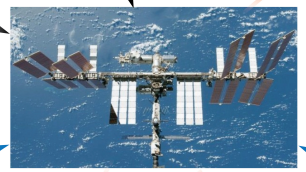
Space X – CRS
(Space Biology; HRP)

Earth Analog; closed system
(Space Biology)

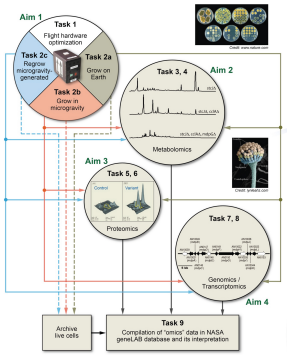
ISS and Crew Microbial Tracking(s)
(Space Biology; HRP)

Inside ISS



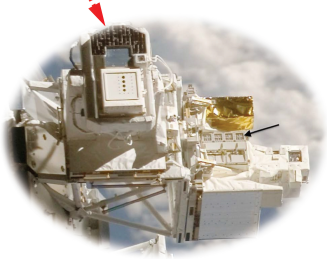
GeneLab; Space Biology

Omics in Space



Grow fungi under µg
(Space Biology)

EVA suit sampling
(JPL; JSC; Planetary Protection)



Expose microbes outside ISS
(Planetary Protection;
Astrobiology)

Chernobyl fungi under µg for drug
discovery (JPL and CASIS)

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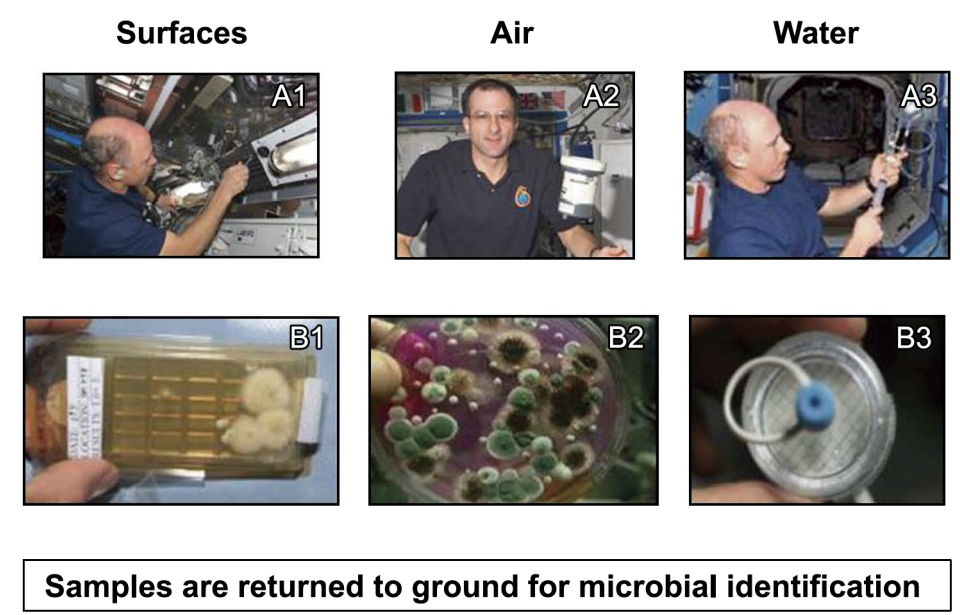
Microbial Monitoring of ISS

Preflight prevention
- examination of crew members
- Surface, air, cargo, food and water monitoring

In-flight
- Environmental monitoring:
  - Surfaces
  - Air (HEPA filters system
  - Water (recycled and testing)

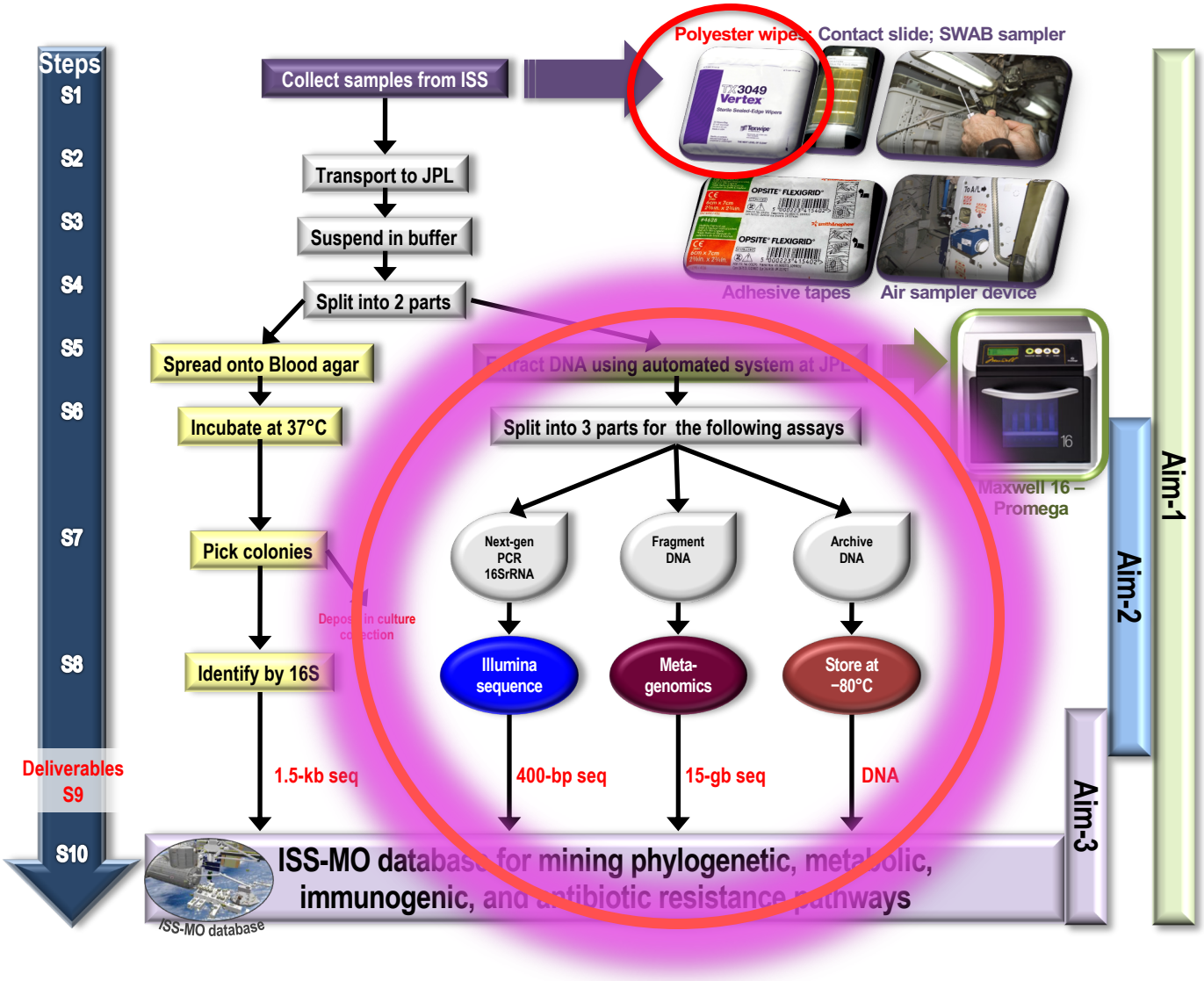


Acceptability limit for surfaces:
- Bacteria: 10^6 CFU per m^2
- Fungi: 10^4 CFU per m^2

Acceptability limit for air:
- Bacteria: 10^3 CFU per m^3
- Fungi: 10^2 CFU per m^3

Acceptability limit for water:
- Bacteria: $5x10^4$ CFU per liter
- Coliforms: Below detection limit

Yamaguchi, N., Roberts, M., Castro, S., Oubre, C., Makimura, K., Leys, N., … Nasu, M. (2014). Microbial Monitoring of Crewed Habitats in Space—Current Status and Future Perspectives. *Microbes and Environments*, *29*(3), 250–260. doi:10.1264/jsme2.ME14031



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Microbial Observatory Experiment MT1B sampling crew; iss043e198419

NASA astronaut Scott Kelly

NASA astronaut Terry Virts, Commander collected the Microbial Observatory Experiment samples for MT1A and MT1B

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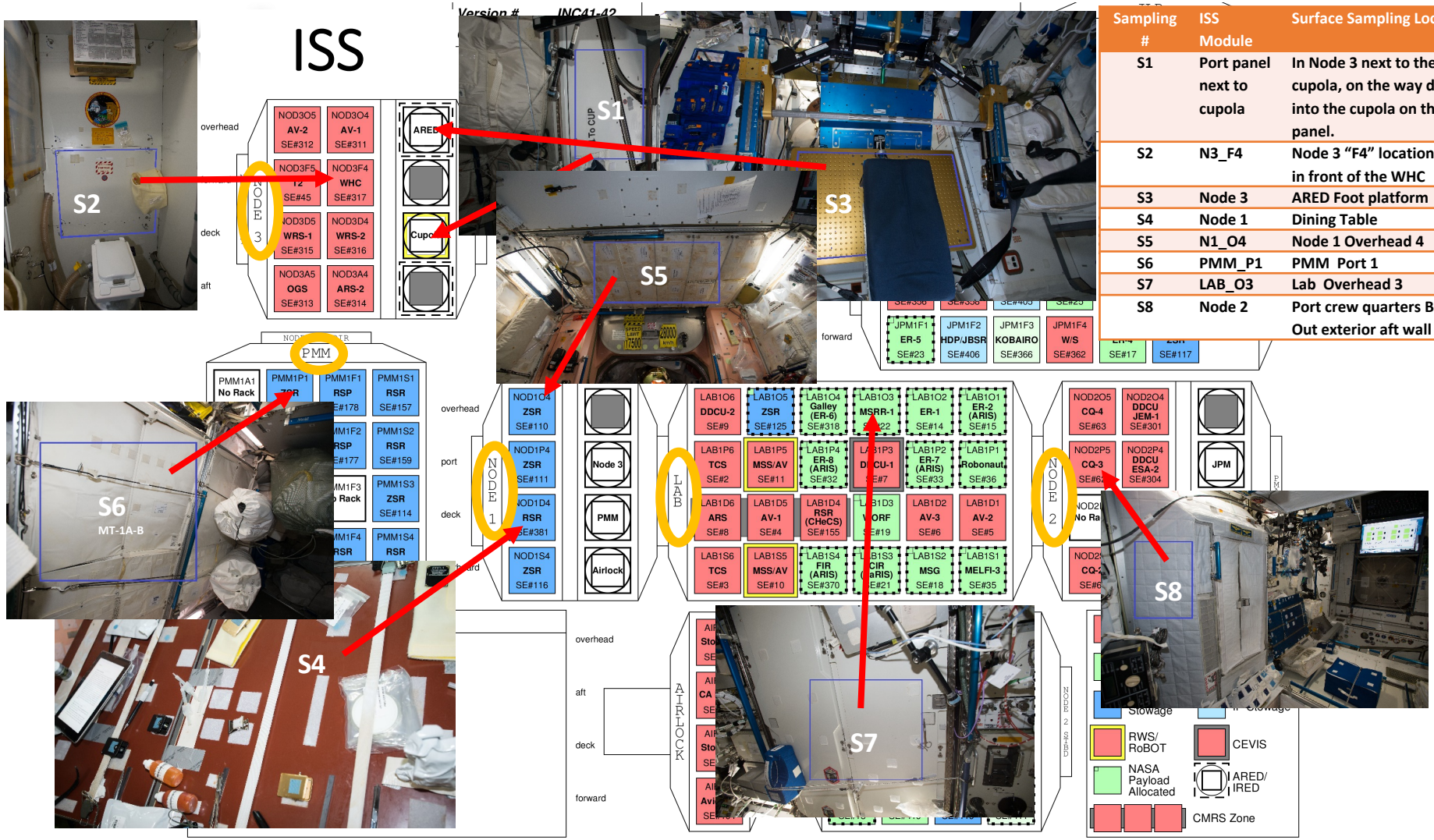
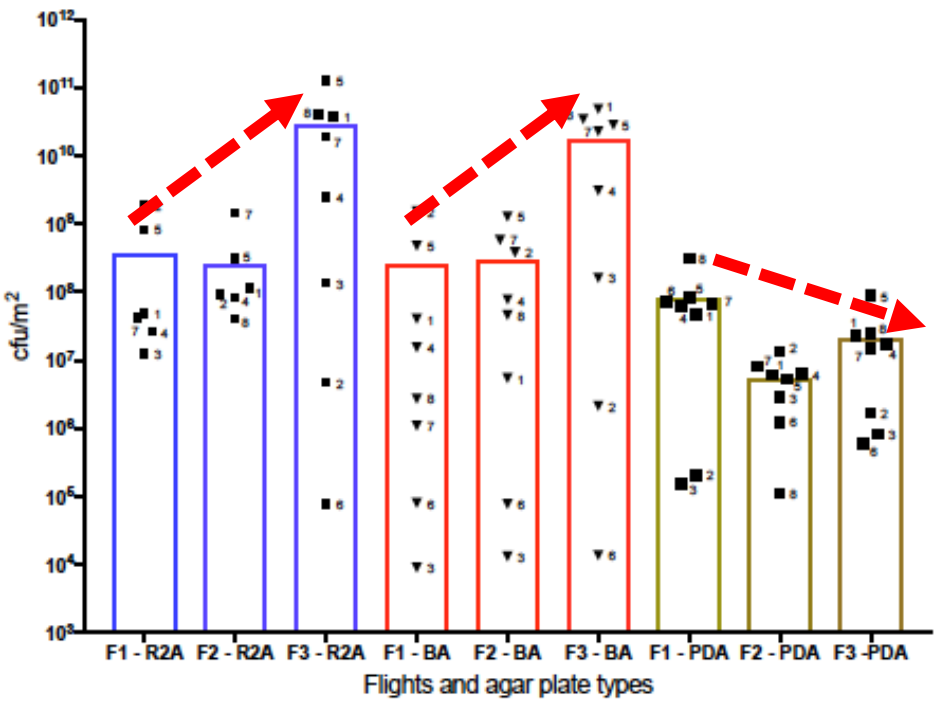


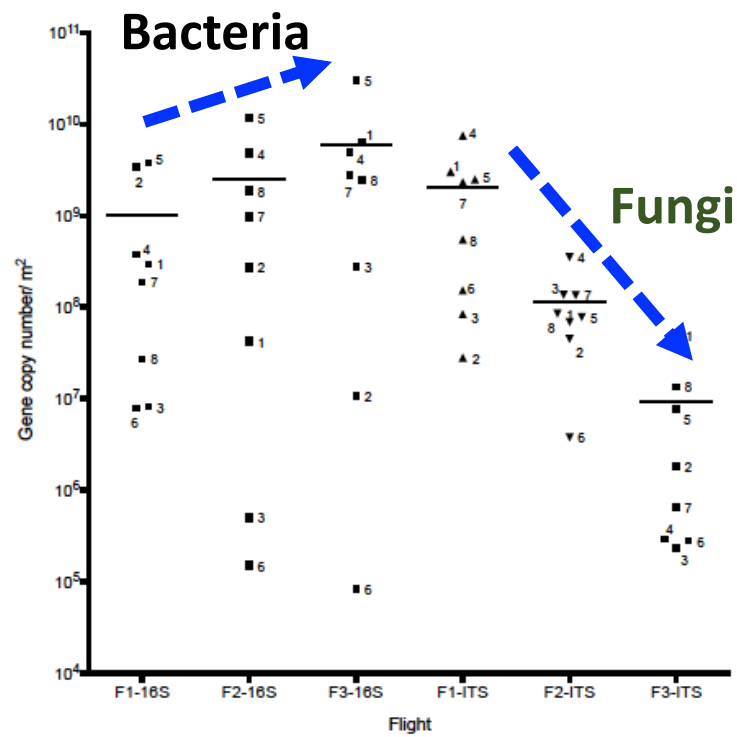
Sampling #	ISS Module	Surface Sampling Location
S1	Port panel next to cupola	In Node 3 next to the cupola, on the way down into the cupola on the port panel.
S2	N3_F4	Node 3 "F4" location right in front of the WHC
S3	Node 3	ARED Foot platform
S4	Node 1	Dining Table
S5	N1_O4	Node 1 Overhead 4
S6	PMM_P1	PMM Port 1
S7	LAB_O3	Lab Overhead 3
S8	Node 2	Port crew quarters Bump-Out exterior aft wall

Plate counts (CFU)



R2A/BA: Bacteria **Fungi**

PMA – qPCR



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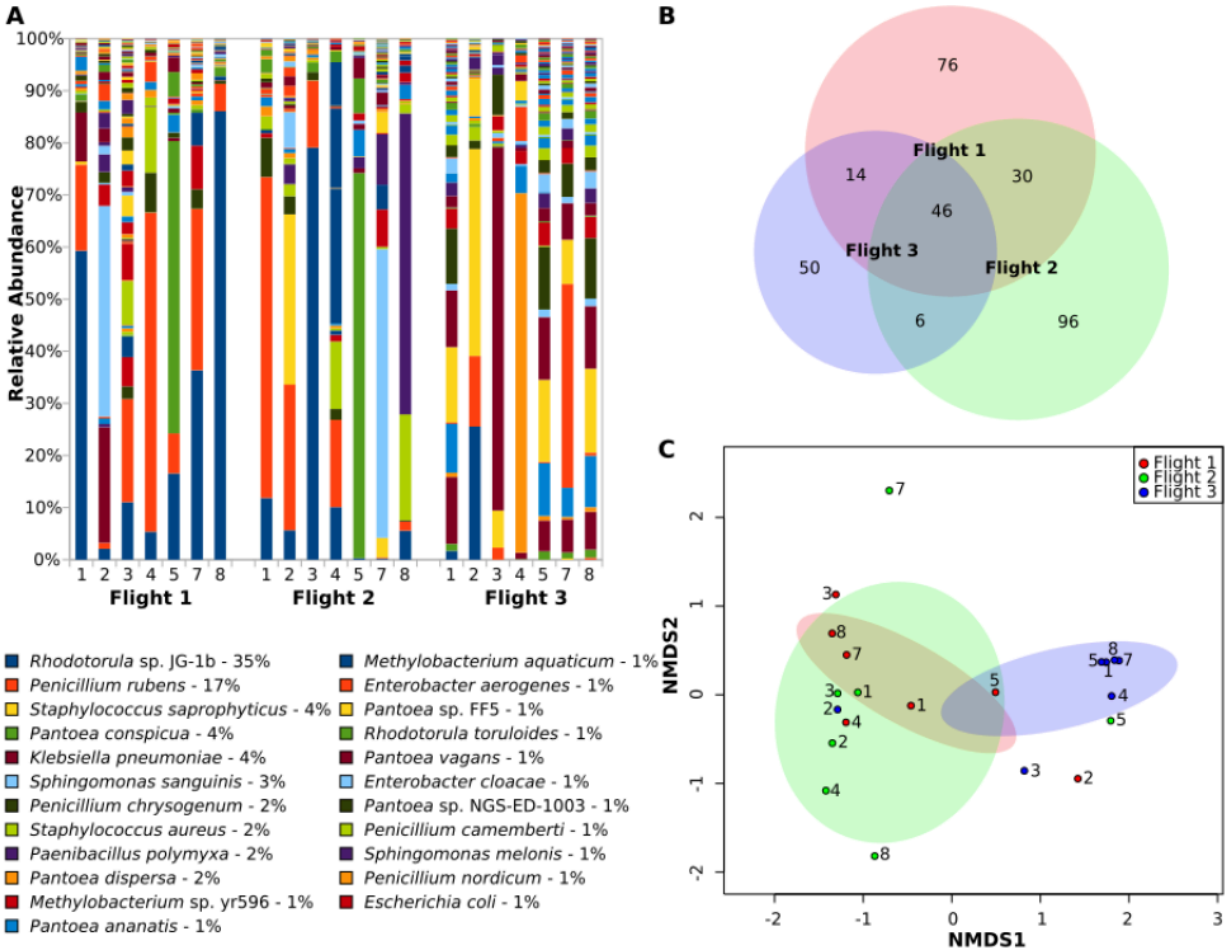
Shotgun metagenome resolved microbial diversity of ISS environmental surfaces



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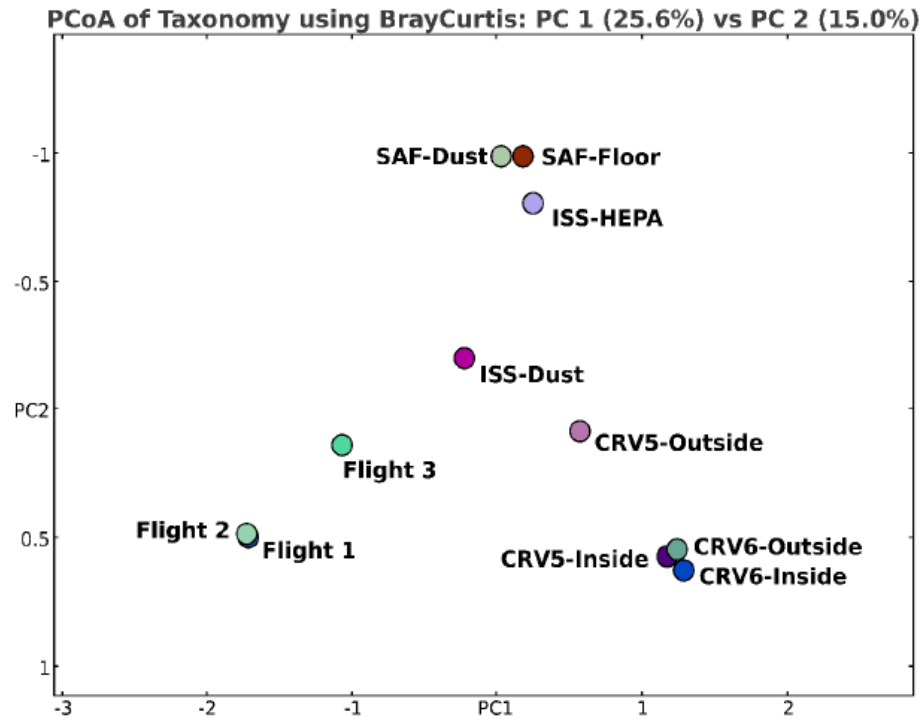
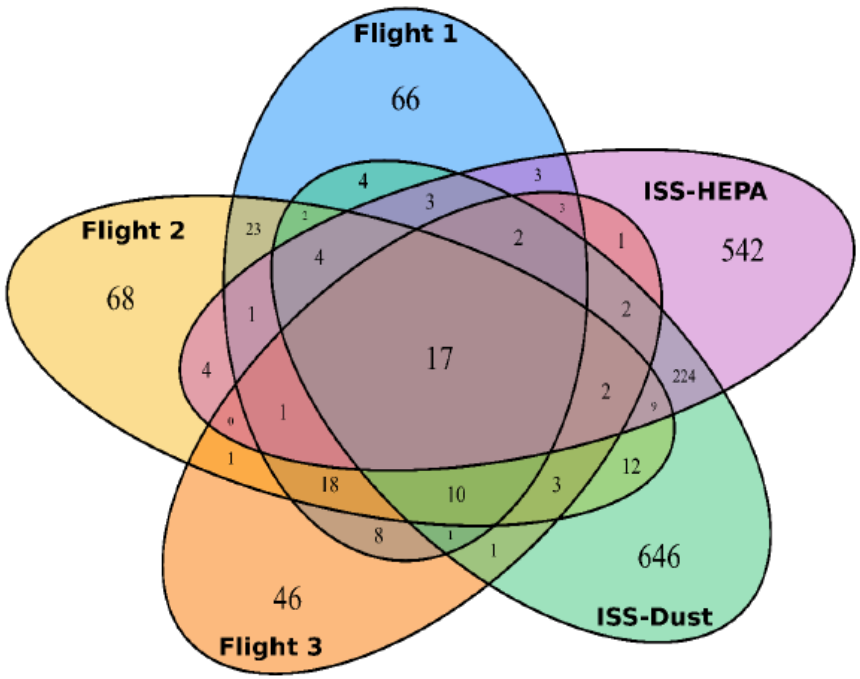
Source of ISS microbial population

A



B



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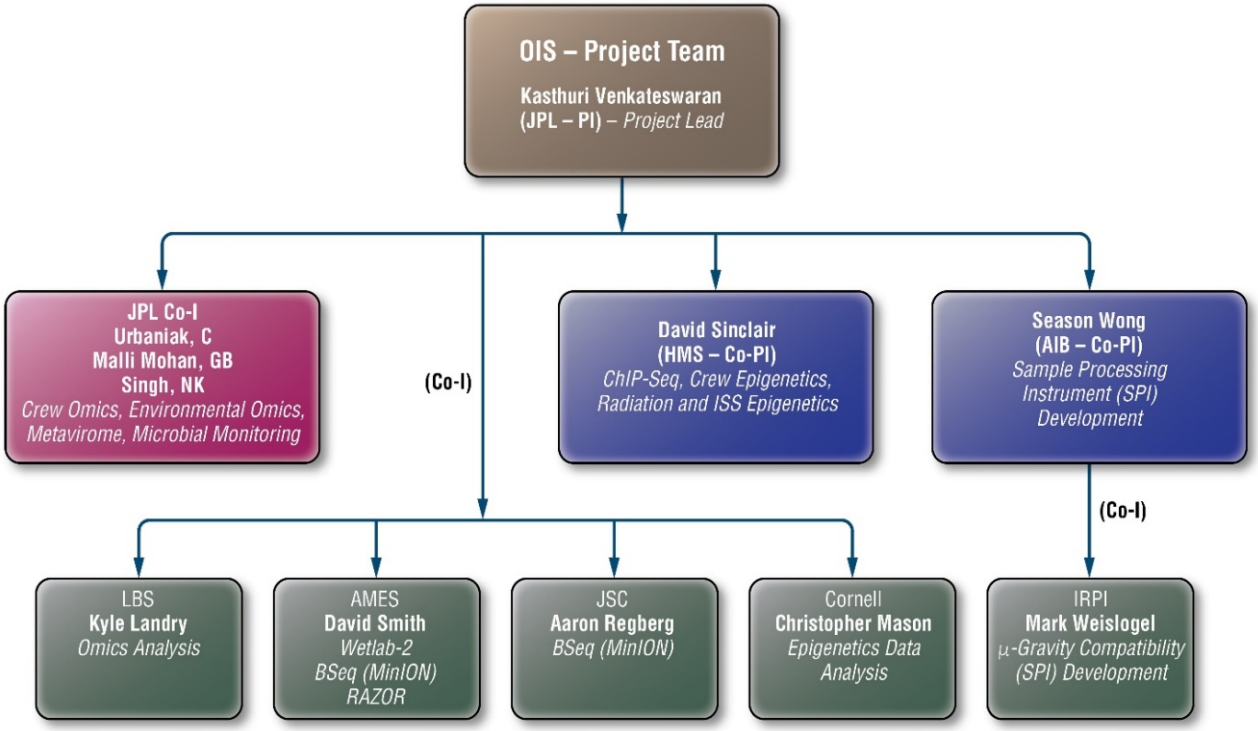
Translational Research Institute for Space Health
OIS – Project Team members



JPL: Jet Propulsion Laboratory; HMS: Harvard Medical School; AIB: AI BioSciences, Inc.
LBS: Liberty BioSecurity; Ames: NASA; JSC: Johnson Space Center; Cornell; IRPI: Microfluidics Co.

The institute is a consortium led by Baylor College of Medicine and includes California Institute of Technology and the Massachusetts Institute of Technology.

www.bcm.edu/centers/space-medicine/translational-research-institute

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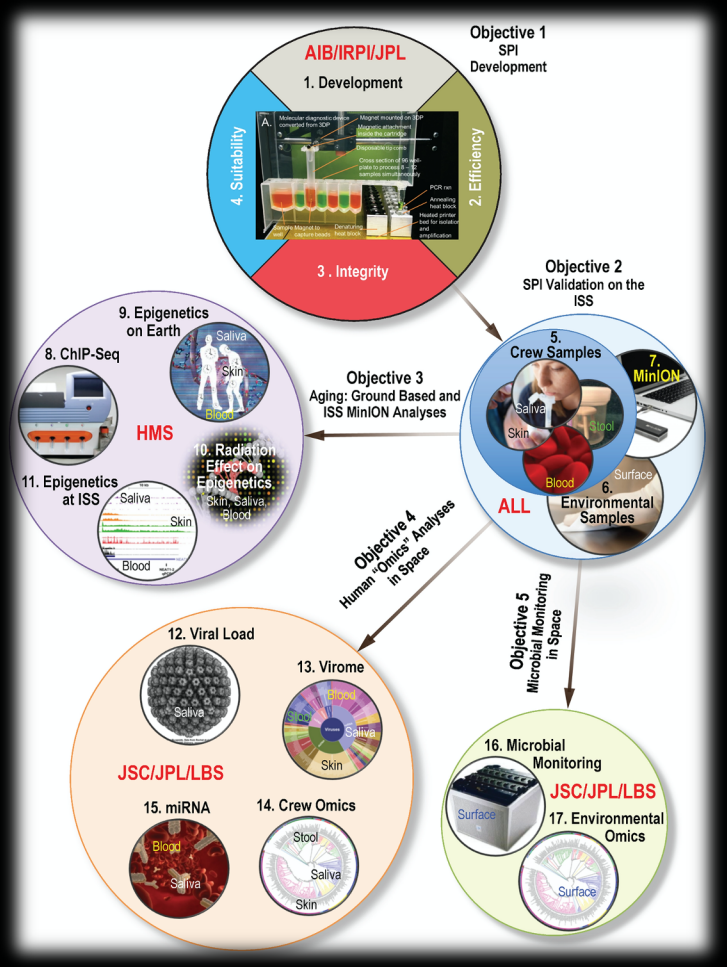
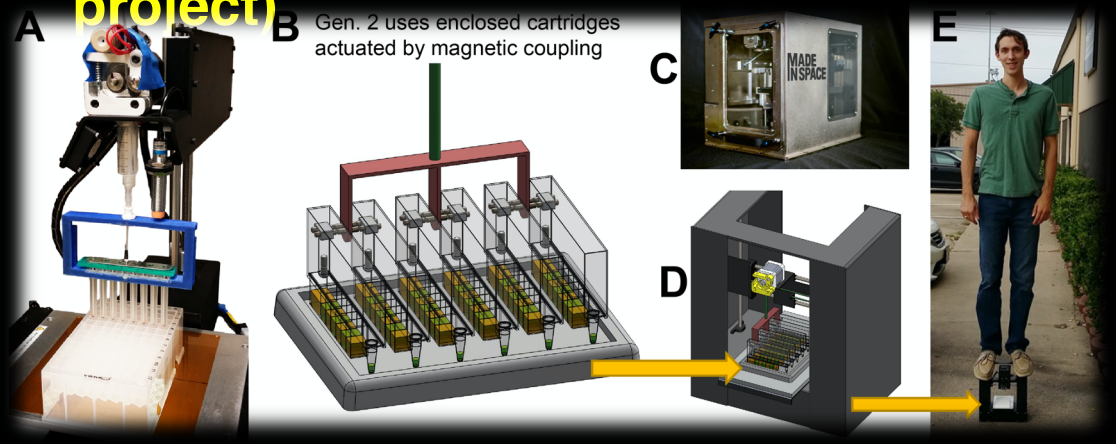
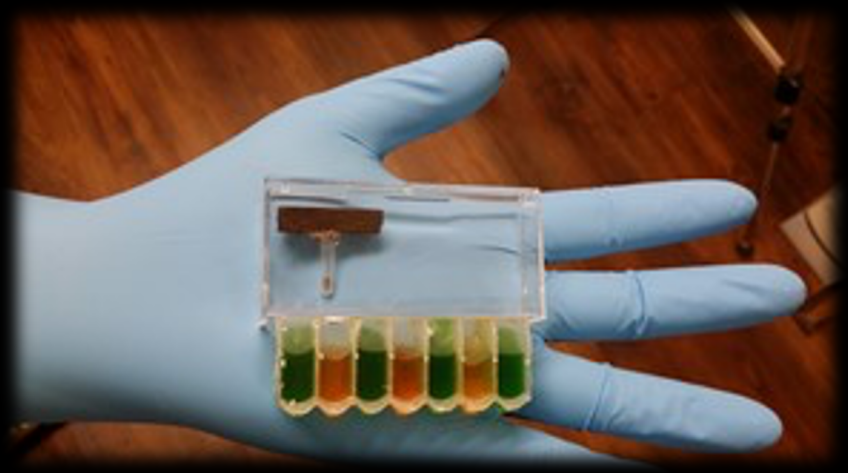
Challenges for DNA/RNA sequencing in space

- Microgravity (containing liquid)
- Automation (avoiding multiple steps)
- Crew time
- Easy to use (10th grade level)
- Light weight
- Less space
- Less consumable (3D printing capability)

Omics in Space (NASA Translational Research Institute project)



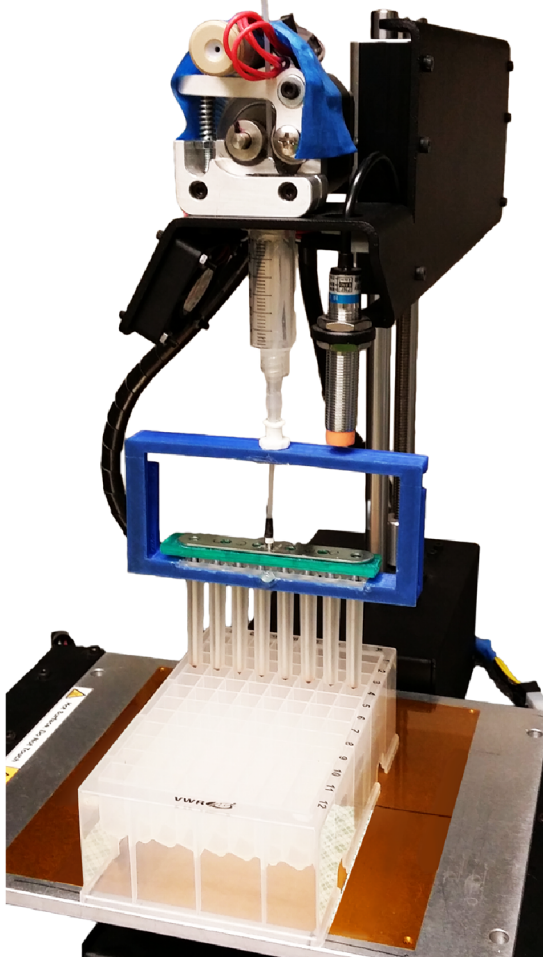




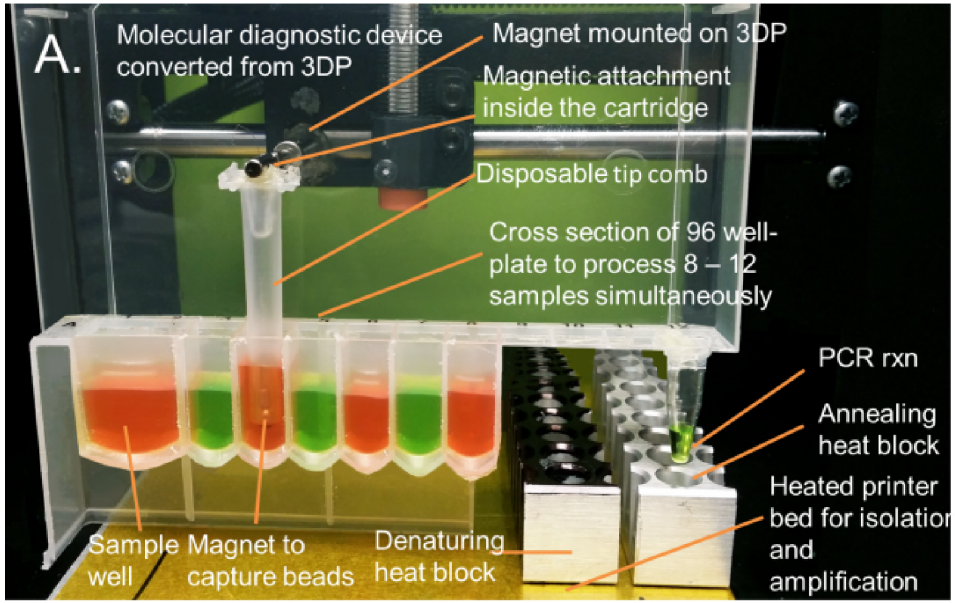
K. Venkateswaran

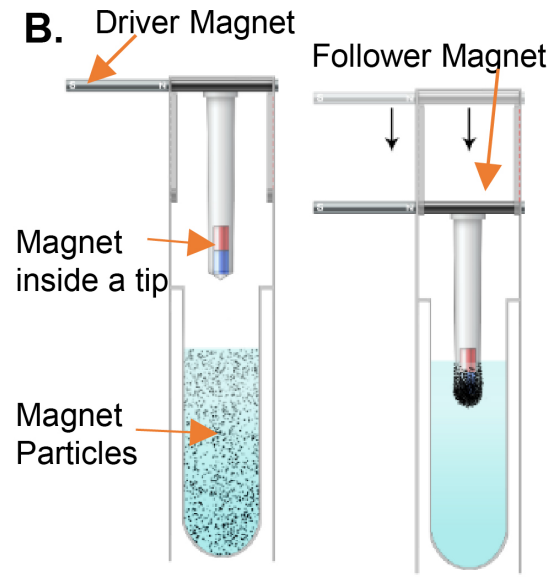
- The OIS team recognizes limitations in ISS that are:
  - Sample collection
  - Sample processing
  - Shotgun Library preparations
- The OIS team will develop an automated Sample Processing Instrumentation (SPI) for nucleic extraction (NA) that is:
  - streamlining sample collection to detection procedures
  - needing minimal crew time
  - reducing the amount of contamination between samples
  - producing consistent results

Gen 1 3DP converted Sample Prep Machine



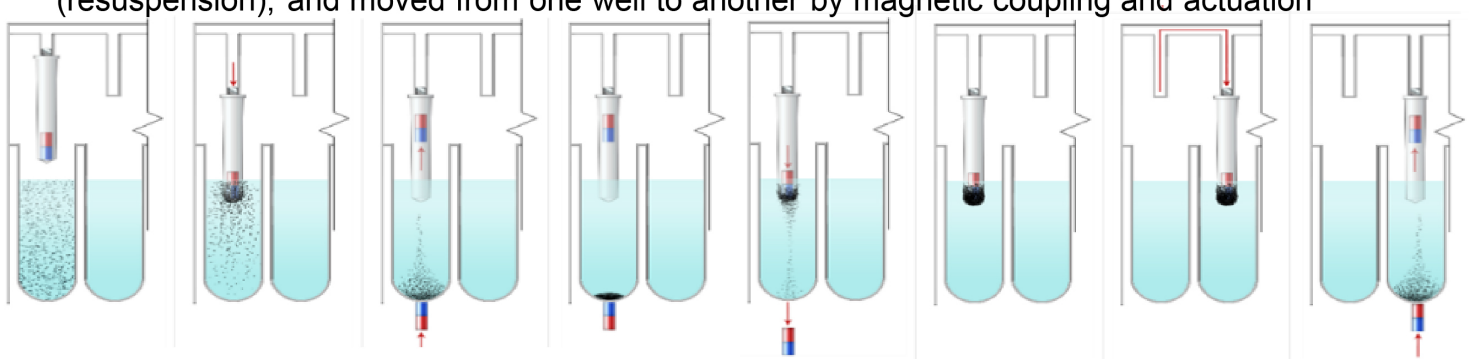
3DP with soda can for size reference

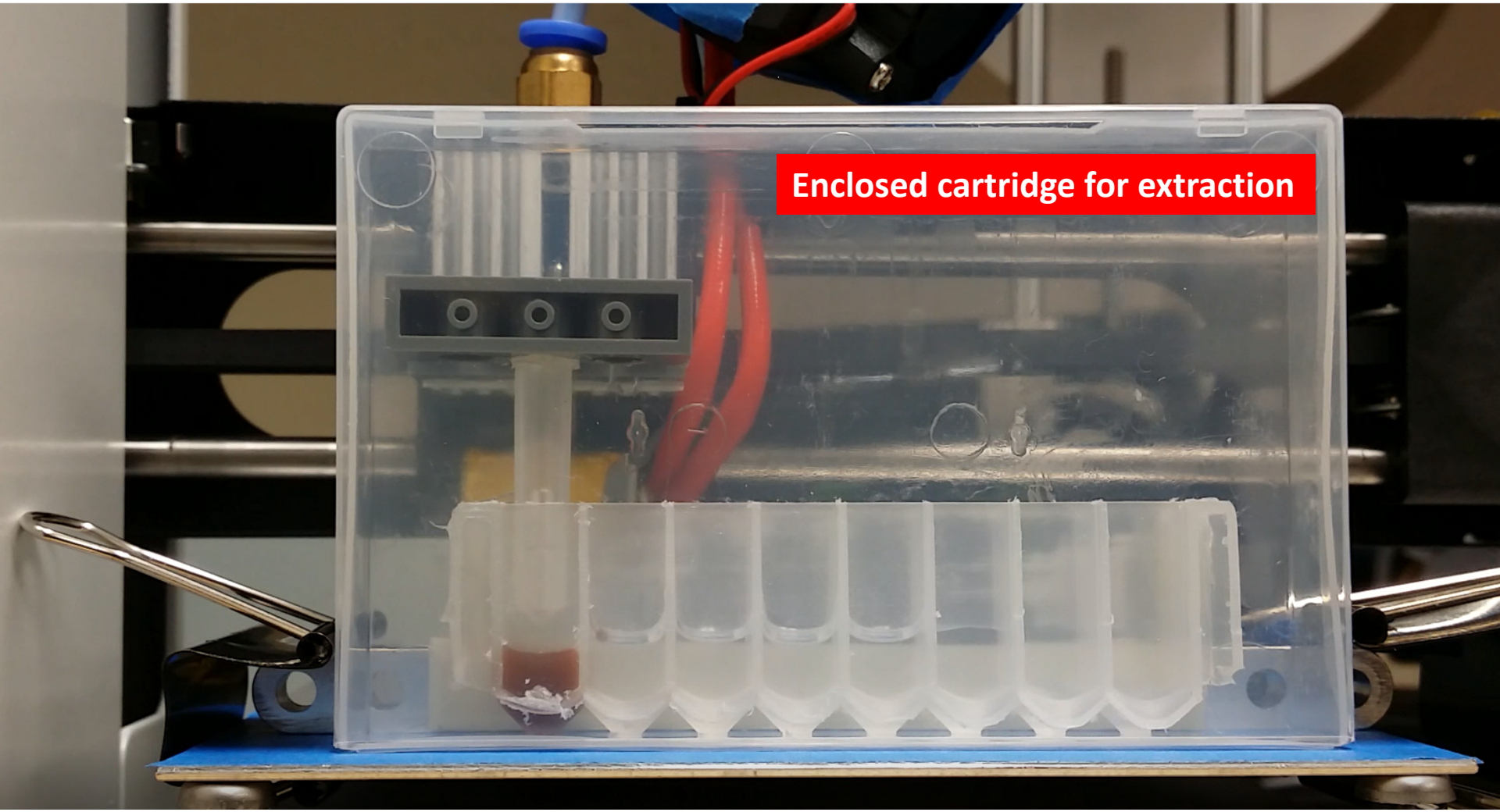




Front view of cartridge

C. **Side view of cartridge (only 2 wells are shown)** showing MP capture, washing (resuspension), and moved from one well to another by magnetic coupling and actuation




Enclosed cartridge for extraction

- Factors such as the quantity and physical characteristics of the NAs and the desired application(s) will be addressed in the context of preparing high-quality sequencing libraries.
- We will generate microbiome (targeted for bacteria, fungi, and viruses) to address microbial composition, metagenome (crew and environments) for functional characteristics, and miRNA for immunological function.
- We will examine epigenetic data to elucidate radiation-induced damage, cellular disruption, and aging of astronauts.