Seeking and Supporting Life Beyond Earth

Christopher E. Carr, Sc.D.
Assistant Professor, Georgia Institute of Technology
Daniel Guggenheim School of Aerospace Engineering
School of Earth and Atmospheric Sciences
cecarr@gatech.edu | @c_e_carr

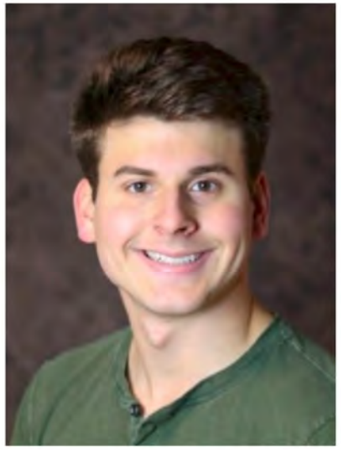
PXL

Georgia Tech

Planetary Exploration Lab

Jordan McKaig

Rachel A. Moore



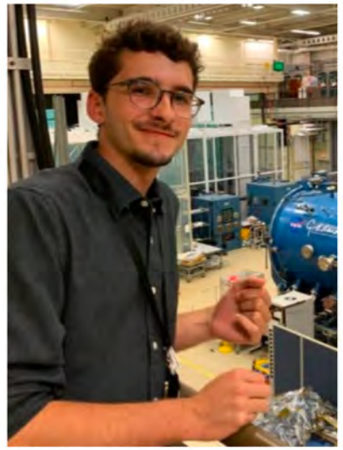
Alexander Chipps

Mirza Samnani

Staś M. Kowalski

Christopher E. Carr

Milad Mozayyani



José Luís Ramírez Colón

Cassius Tunis

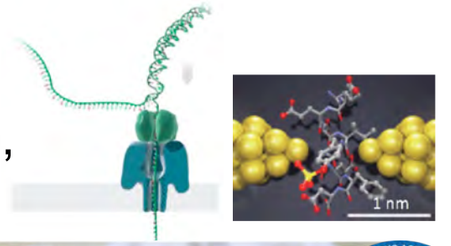
Uttoreo Saha

Emma Johnson

Georgia Tech

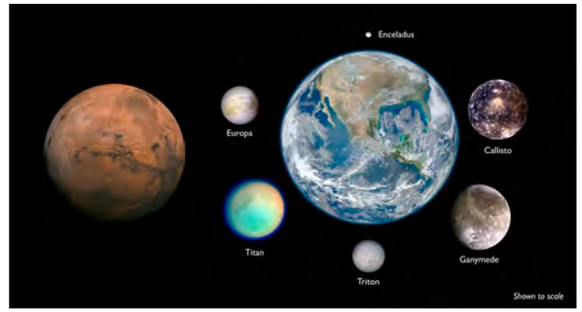
Overview

- **Space Instrument Development**
  SETG, ELIE, BOOST, **single molecule detection**, sample handling, technologies to instruments

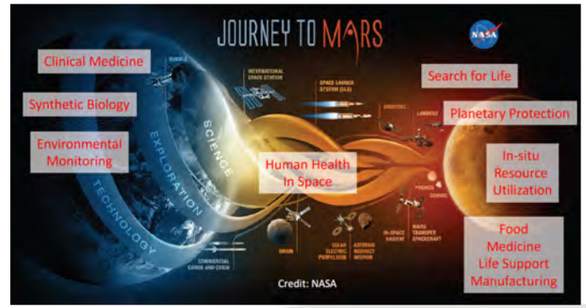


- **Life Beyond Earth**
  Habitability; biosignature preservation; instrument validation; ExoSalt, ExoArid, OAST

- **Space Missions**
  AI-enabled instruments & missions to seek life at Mars, Europa, Enceladus, Venus, elsewhere…



- **Planetary Protection**
  Facilitating **life detection** & **human Mars exploration missions**



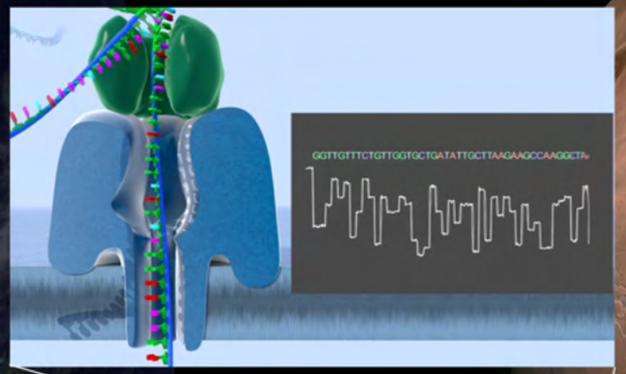
- **In Situ Resource Utilization**
  Enabling **sustainable human presence** beyond Low Earth Orbit – and on Earth.

- **Bioastronautics & Human Health**
  Understanding and augmenting **human** performance and **health** on and **off planet**

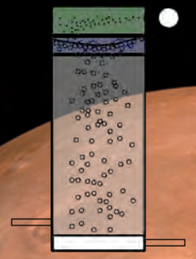
Georgia Tech

Sensitive, specific, and agnostic methods for life detection

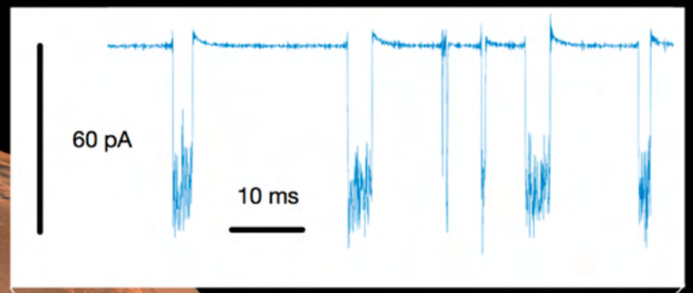
Search for Extra-Terrestrial Genomes (SETG)

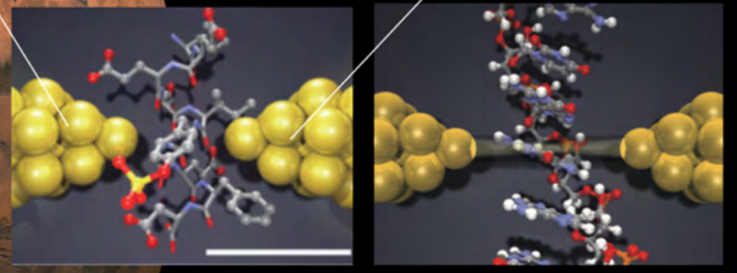


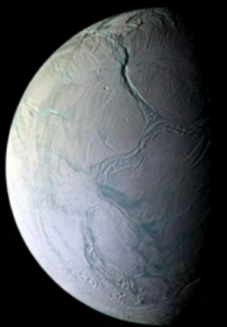
Biological nanopores



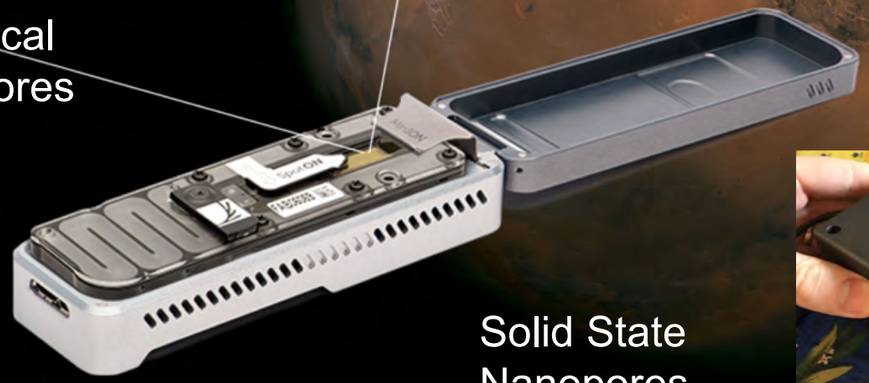
Preconcentration: Bubble-based Ocean-worlds Organics Sample Trap (BOOST)



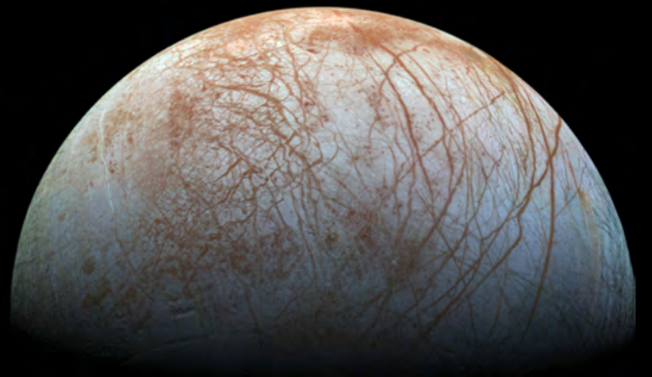




Electronic Life-detection Instrument for Enceladus / Europa (ELIE)

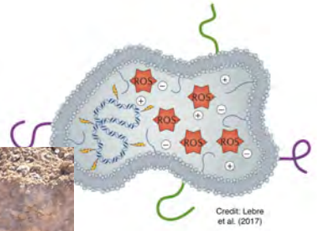


Solid State Nanopores

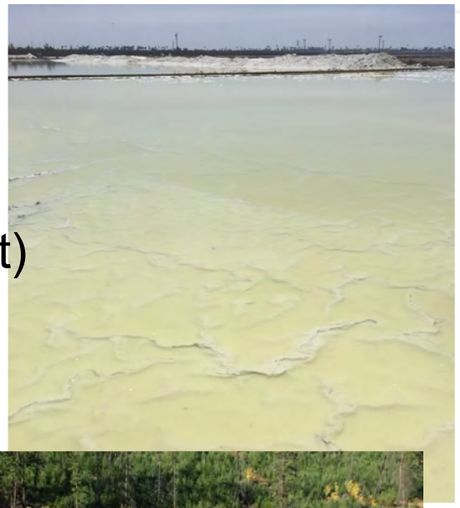


Ground and Field-Based Research

Microbial Adaptation to Aridity (ExoArid)
2019-2024 Atacama Desert + Lab Studies



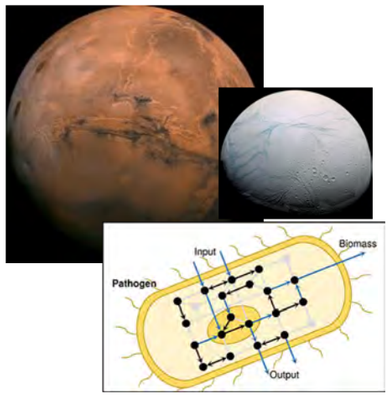
Oceans Across Space and Time
2019-2024
Georgia Tech (Schmidt)



In-Situ Production of CO and CH_4 in Arctic Ice
2022-2023 DRI
(Chellman)

Biosignature Preservation in Sulfate-dominated Systems
2019-2024
Georgetown (Pontefract)

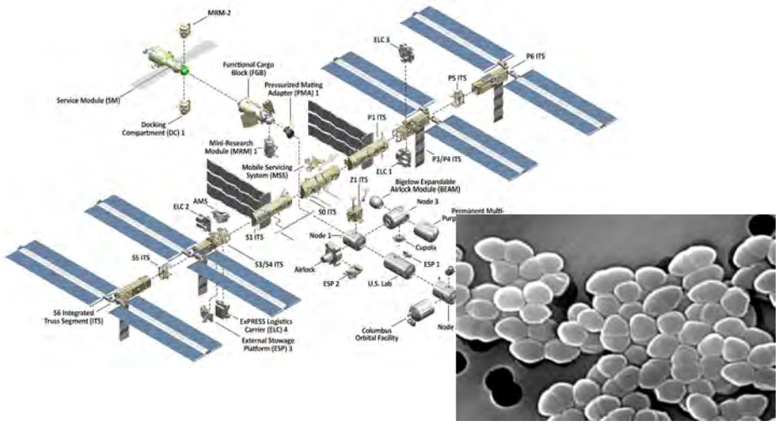
Genome Informed Habitability & Methane Production (ExoMethane)
2022-2025 Modeling + Experiment
(Science PI Moore)



Georgia Tech

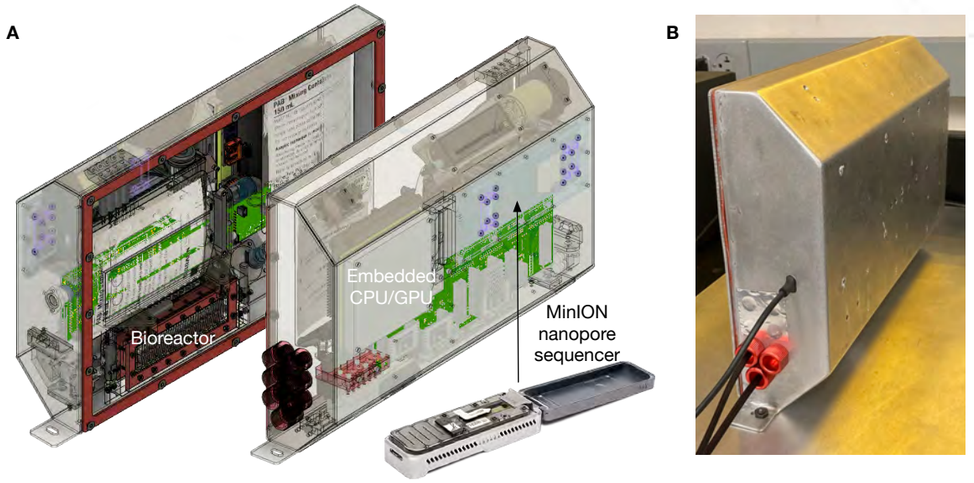
Flight Projects

Enterococcus Evolution in Space
2020-2023 Multi PI Team (Lead: Carr)

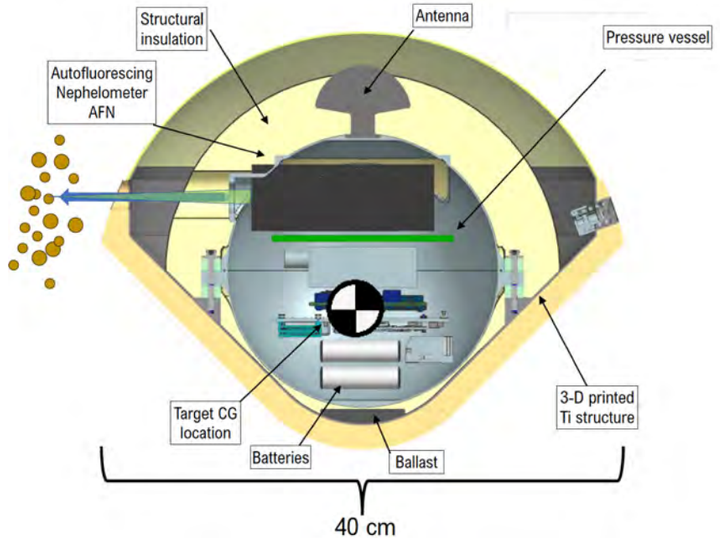


GEARS, EnteroGAIT, AERES

Biological Exploration Payload 2 (BioX2)
Nanoracks ISS payload, launch Nov 22



Rocket Labs interplanetary Photon



Target launch May ‘23
(backup Dec ‘24)

Georgia Tech

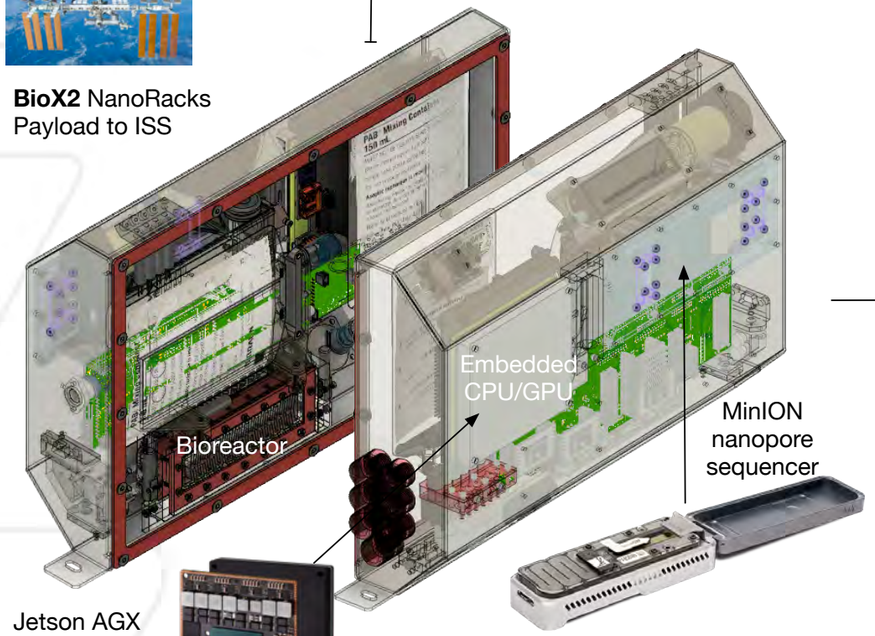
Biological Exploration Payload 2 (BioX2) – Status & Plans

2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | Future

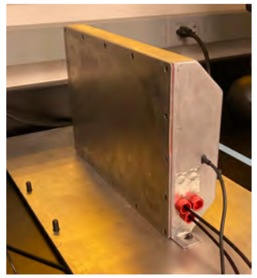
Launch

GEARS, EnteroGAIT on ISS

BioX2 NanoRacks Payload to ISS

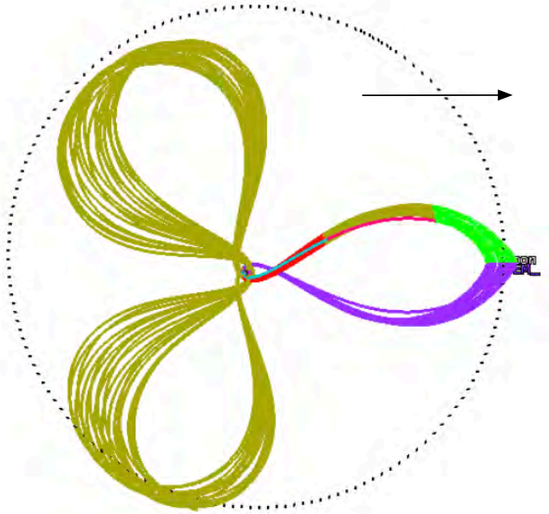


Jetson AGX
"AI inside"
32 TeraOPS
10-30W
8-core ARM
512-core GPU

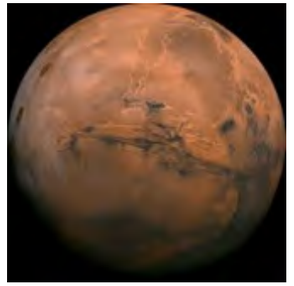


- Bioreactor
- Nucleic acid extraction
- Nucleic acid concentration
- Single molecule nanopore sequencing
- GPU-powered neural network basecalling
- On-orbit genome assembly

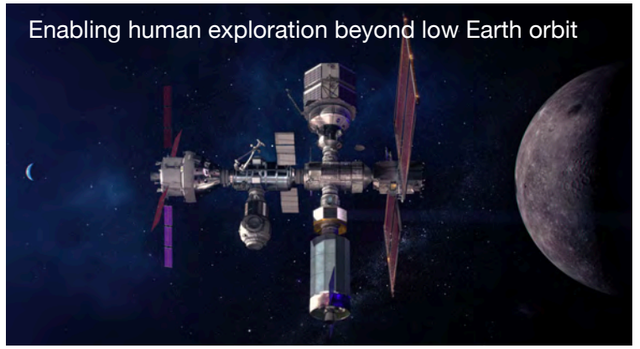
BioX3
Candidate Orbit: Petal Earth-Moon cycler orbit shown in Earth-Moon rotating coordinate frame (Genova and Aldrin, 2015)



- Technology validation for deep space
- Biological response to space radiation
- Autonomous payloads
- Routine inexpensive access to cis-lunar space and Earth return



Post Mars-2020 Life Detection Mission

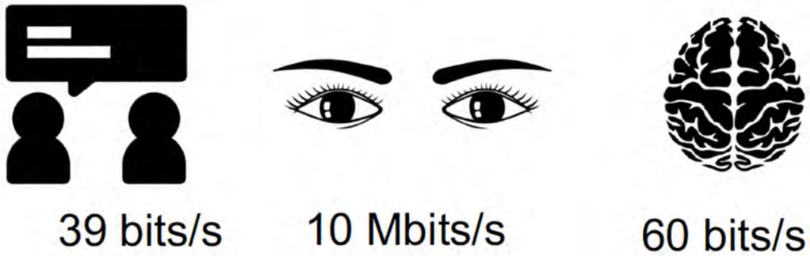


Cis-Lunar (NASA Gateway) and Lunar Human Exploration

Georgia Tech

Teaching

Technical Communication



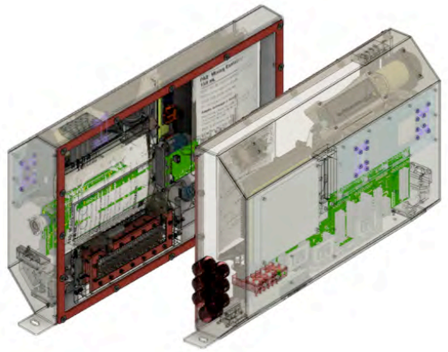
Technical writing
Effective Graphics
Report Organization & Composition
Memos, E-mails, Proposals, Posters
Ethics
Storytelling
Individual & Group Work

Transform your career & your life!

Future work: Integrate with Space Entrepreneurship certificate program (in review).

Space Instrumentation for Life Detection

BioX2 Command & Control
BioX2 DNA Extraction
BioX2 Nanopore Sequencer Loading
BioX2 Modeling
BioX2 Science: UV & Genomics
Icy Brine DNA Survivability
Smart Gas Detection of Metabolism
Submersible Water Activity Sensor
Venus Gas Analyzer Study



Highlighted guest lecture:

Stacy Weinstein-Weiss
Deputy Payload Manager,
Europa Clipper

Space Instruments from Proposal to Flight

Georgia Tech

Current open positions

- **Undergraduate openings:**
  - Nanopore sequencing & bioinformatics (python, docker, unix, cloud computing)
  - BioX2 payload testing and future design improvements
  - BioX3 automated payload and/or cubesat development
  - BOOST hardware design, integration, and testing
  - ELIE software for instrument operation including sub-nm gap control

- **GRA openings:**
  - Space biology (microbial culturing, space biology flight projects)
  - Machine learning, coding (ELIE)

Georgia Tech

Thank you

- SSDL
- PXL Lab Members
- Extended project teams.

We gratefully acknowledge NASA support from MATISSE, PICASSO, Astrobiology/Exobiology, and Space Biology programs, and NSF Arctic program support.