AstroChip: Real-Time Measurements of Electrical Activity of Cells in Space

Alana Aristimuno Millan[1], Anaya Bawiskar[1], Catherine Campbell[1], Anthony Dongchau[1], Camila Navas-Hahn[1], and Walter Cromer[2]

Department of Biomedical Engineering, Texas A&M University[1], Department of Medical Physiology, Texas A&M University[2]

Background

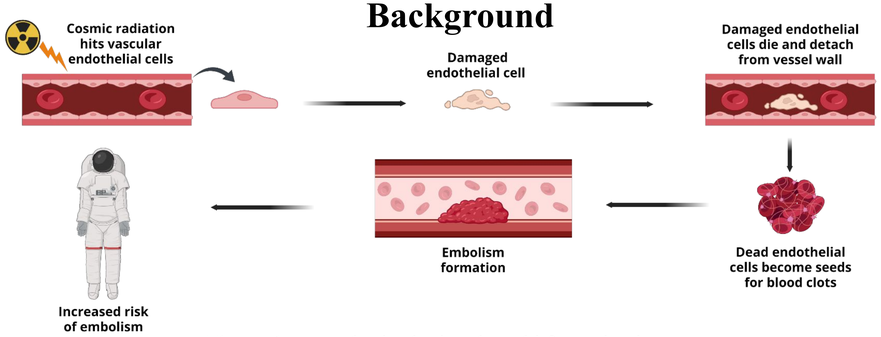


Figure 1. Hypothesized microthrombi formation in space.

- **Microthrombi** formation in microgravity can contribute to diffuse intravascular coagulation in astronauts [1].
- It is hypothesized that **high-energy space radiation** contribute to **thrombosis** through cell-death.
- **Impedance** and **cellular activity** measurements give insight on cell health and microthrombi formation.
- There are no solutions for **real-time microscale impedance** measurements in space.

Objective

Develop a microfluidic-integrated microelectrode array to measure **real-time** endothelial cell **impedance** and **electrical activity** with single-cell spatial resolution.

AstroChip Fabrication Process

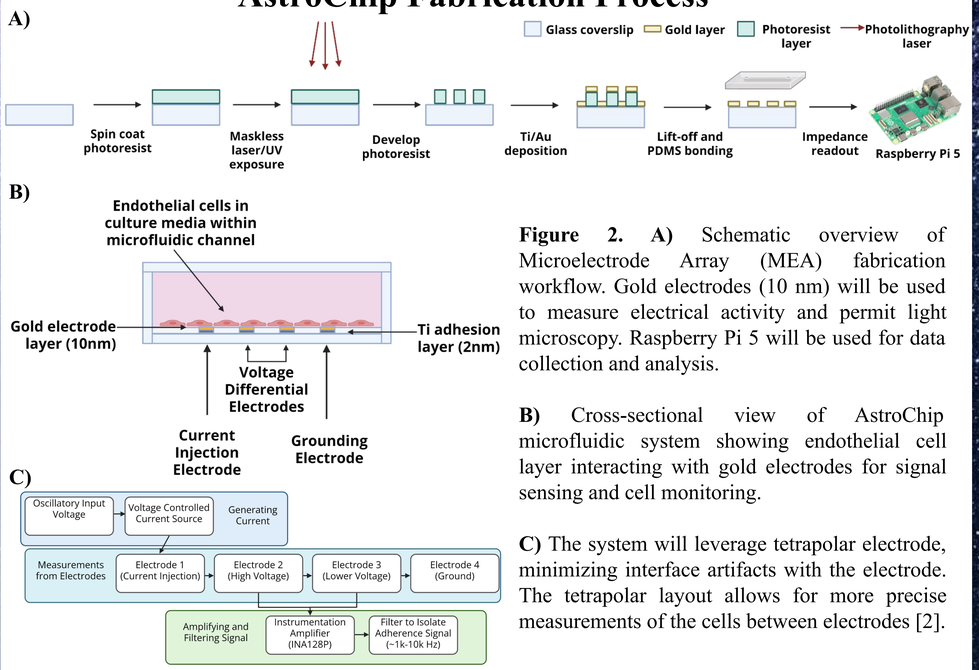


Figure 2. A) Schematic overview of Microelectrode Array (MEA) fabrication workflow. Gold electrodes (10 nm) will be used to measure electrical activity and permit light microscopy. Raspberry Pi 5 will be used for data collection and analysis.

B) Cross-sectional view of AstroChip microfluidic system showing endothelial cell layer interacting with gold electrodes for signal sensing and cell monitoring.

C) The system will leverage tetrapolar electrode, minimizing interface artifacts with the electrode. The tetrapolar layout allows for more precise measurements of the cells between electrodes [2].

AstroChip is a Promising Model for Bioimpedance Measurements in Space

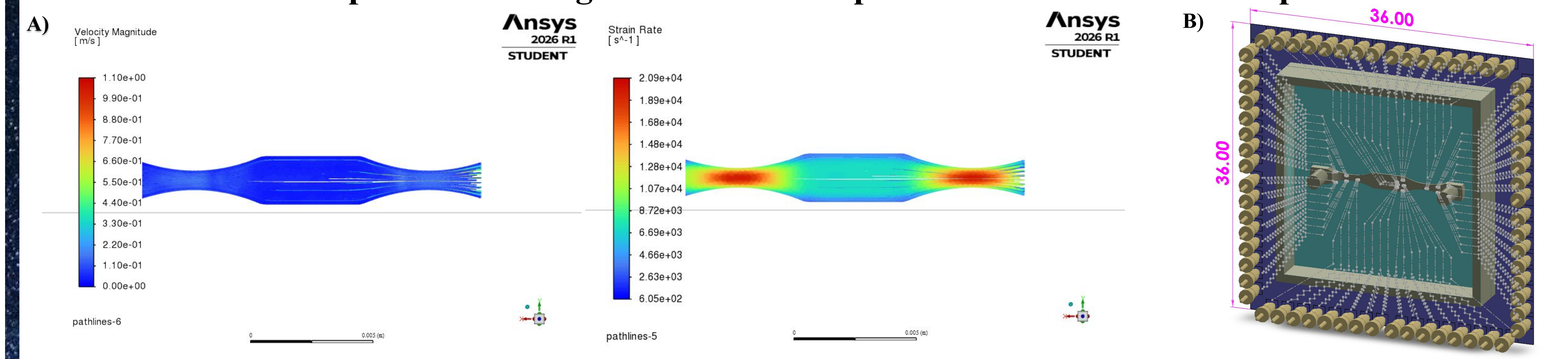


Figure 3. A) Fluid simulation informs optimal electrode placement for cellular response sampling. **B)** SolidWorks design of electrode assembly with pogo pins for reusable, solder-free connectors and rapid chip replacement. Scale bar = 36 mm.

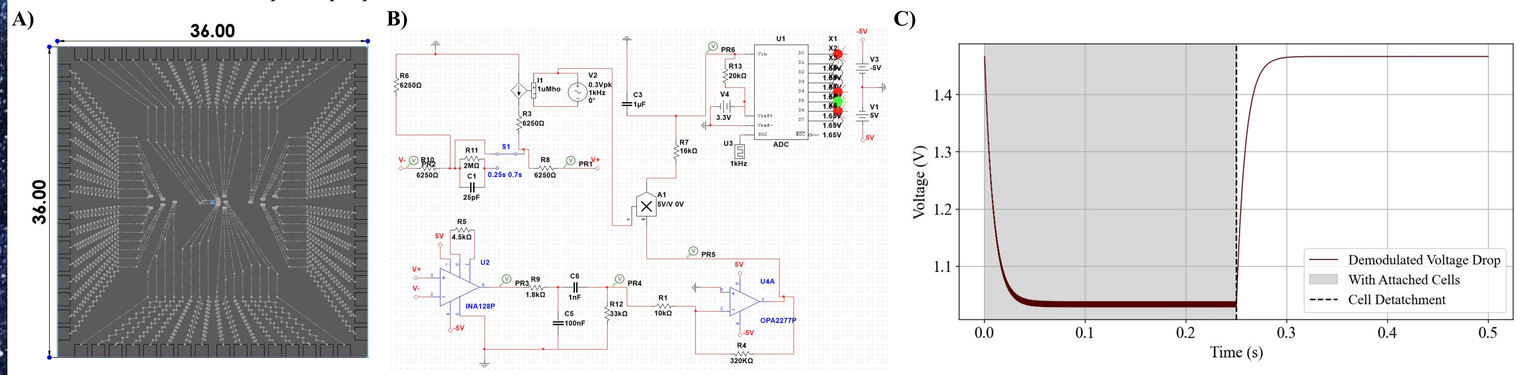


Figure 4. A) SolidWorks tetrapolar MEA electrode design. Scale bar = 36 mm. **B)** Multisim simulation of tetrapolar electrodes and cells. **C)** Simulated voltage response to detached and adherent cells shows measurable change in voltage and validity of circuit design.

Summary

- A custom, **tetrapolar MEA** captures real-time, localized changes in cell **impedance** in a microfluidic system.
- **Automated, low-power** cellular measurement systems compatible with Raspberry Pi 5 and standard microfluidics advance space lab-on-a-chip systems.
- This enables investigation of **microgravity** and **radiation** effects on endothelial cells.
- Understanding **microthrombi formation** in space will help protect astronaut cardiovascular health.

Future Directions

- Refine **fabrication workflow** to attain consistent electrode and trace fabrication.
- **Integrate** electrode system with microfluidics chip.
- Create a **prototype evaluation system** to test, characterize, and validate electrode designs.
  - Evaluation board and chip will be used to simplify front-end and testing.
  - Pumps, media, and cell cultures incorporated to simulate the working conditions with the prototype.

References & Acknowledgements

References

[1] K. Marshall-Goebel et al., "Assessment of Jugular Venous Blood Flow Stasis and Thrombosis During Spaceflight," *JAMA Network Open*, vol. 2, no. 11, pp. e1915011–e1915011, Nov. 2019, doi: 10.1001/jamanetworkopen.2019.15011.

[2] H. Ma, Y. Su, and A. Nathan, "Cell Constant Studies of Bipolar and Tetrapolar Electrode Systems for Impedance Measurement," *Sensors and Actuators B: Chemical*, vol. 221, pp. 1264–1270, Dec. 2015, doi: 10.1016/j.snb.2015.07.089.

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