ISSRDC

Biomanufacturing of Autologous Cardiac Tissue in Low Earth Orbit

Aaron J. Rogers, PhD
Redwire Senior Scientist

AIRBUS
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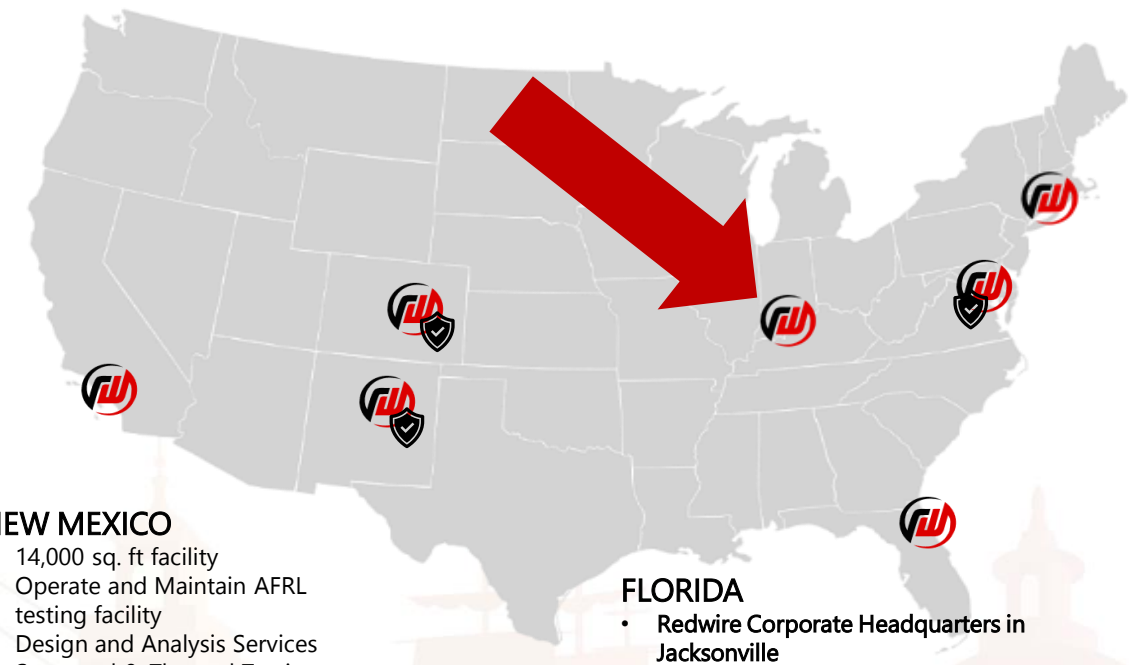
About Redwire

Over 750 Employees in the U.S. and Europe

COLORADO (Littleton and Longmont)
- 102,000 sq. ft total in CO
- Clean Rooms
- RF & Antenna Systems
- Deployable and Retractable Space Structures
- Solar Arrays, Batteries, Thermal Products
- Space Systems Engineering Services
- Camera Systems
- Flight Avionics
- Data Recovery Systems
- In-House Testing Capabilities
- Digital Engineering
- Modeling & Simulation



CALIFORNIA
- Collaborating with JPL
- 80,000 sq. ft. office & manufacturing area
- 3-Story High Bay
- Deployables IA&T
- ISS & PPE Large ROSA IA&T
- High Power Solar Array R&D

Cleared Personnel

NEW MEXICO
- 14,000 sq. ft facility
- Operate and Maintain AFRL testing facility
- Design and Analysis Services
- Structural & Thermal Testing
- Launch Accommodation Hardware
- Thermal Control Hardware
- Deployable Technologies

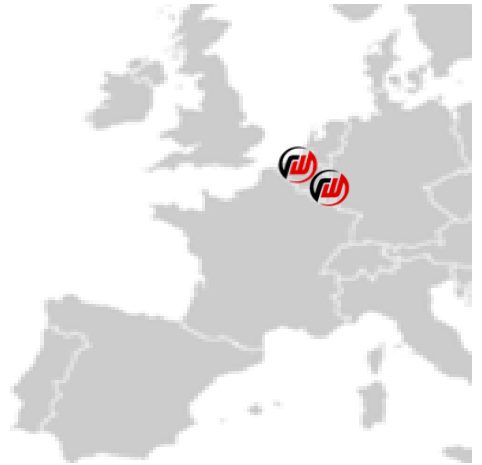
FLORIDA
- **Redwire Corporate Headquarters in Jacksonville**
- 37,247 sq. ft facility
- Clean rooms
- Advanced In-Space Manufacturing Technology
- Large In-Space Manufacturing Project – OSAM-2/Archinaut One
- ISS Payload Development

INDIANA
- 22,000 sq. ft facility
- In-space Research
- ISS Payload Development
- Advanced Space Manufacturing Technology
- Biotechnology, **bioprinting**, on-orbit manufacturing
- ISS/CASIS

MASSACHUSETTS
- 18,000 sq. ft. facility
- Clean Rooms
- Sun Sensors & Star Trackers
- Integrated Camera Systems
- ADACS Systems
- Satellite Systems

DC/VA/MD
- Engaging NASA GSFC in MD
- 8,000 sq. ft. facility under construction (2/3 SCIF)
- SCIF, Classified Systems Access
- Digital Engineering Lab

Merritt Island, FL (near KSC)
- 2,377 sq. ft. facility
- Strong partnership with NASA KSC
- Prelaunch processing laboratory and support
- Commercial partnership with Tupperware Brands
- In-space plant biology research
- ISS and lunar Payload Development

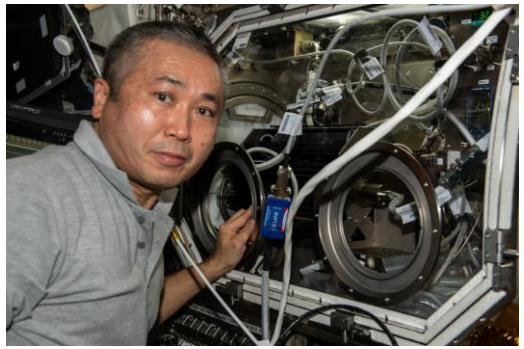


LUXEMBOURG
- Redwire Engineering & Sales Center in Europe
- 2,500 sq. ft facility
- Robotic Systems
- Avionics

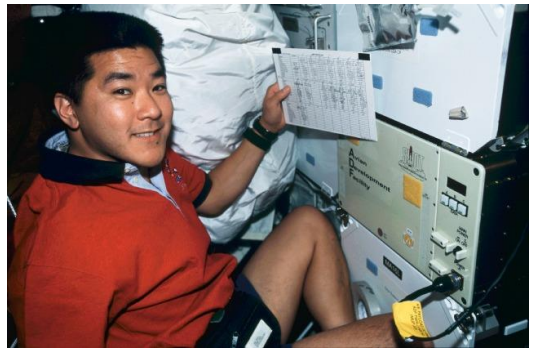
BELGIUM
- QinetiQ Space NV
- 19,000 sq. ft. facility
- Hi-Ref SmallSats, Berthing & Docking Mechanisms, Avionics

Redwire Heritage

Legendary Astronaut John Glenn with Redwire microgravity hardware aboard a space shuttle in 1998



JAXA Astronaut Koichi Wakata operating the Redwire managed PFMI furnace aboard the ISS in 2023



NASA Astronaut Dan Tani aboard space shuttle Endeavour with the Redwire Avian Development Facility in 2001

Canadian Astronaut David Saint-Jacques aboard the ISS with Redwire microgravity hardware in 2022

NASA Astronaut Ricky Arnold calibrates the Redwire Bone Densitometer aboard the ISS in 2018

NASA Astronaut Josh Cassada installing the Redwire 3D BioFabrication Facility aboard the ISS in 2023

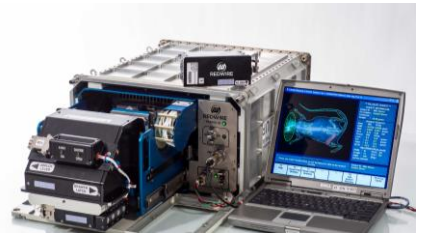
- Redwire has **10 payloads on the ISS**, more than any other company, with more hardware in development
- NASA has funded dozens of Redwire hardware initiatives
- Decades of direct experience with biotechnology and material science in space

Crew photos courtesy of NASA

Redwire ISS Payloads

3DP
First 3D Printer in Space (2014)

Bone Densitometer
DXA Scanner (2014)

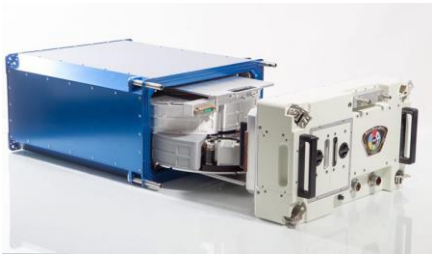


AMF
Additive Manufacturing Facility (2016)

ADSEP
Advanced Space Experiment Processor (2017)

Fiber
Commercial Fiber Optics Manufacturing (2017)

MVP
Multi-use Variable-gravity Platform (2018)



BFF
3D Biofabrication Facility (2019)

Recycler
Recycling of Plastic Materials (2019)

TSCM/TCMM
Turbines (2020)

ICF
Industrial Crystal Facility (2021)

ADSEP2
Advanced Space Experiment Processor2 (2021)

Cell Factory
Industrial Cell Production Laboratory

MSTIC
Semiconductor manufacturing

Redwire currently has 10 payloads aboard the ISS and has flown more than 600 experiments

Expertise - Biological Research

3D Bioprinting

Tissue culturing/engineering

Regenerative medicine

Stem cells

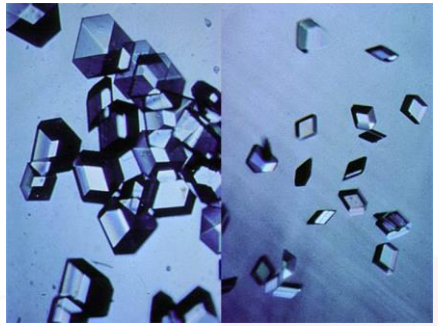
Pharmaceuticals

Bacteria

Genetics

Crop science

AND MORE!

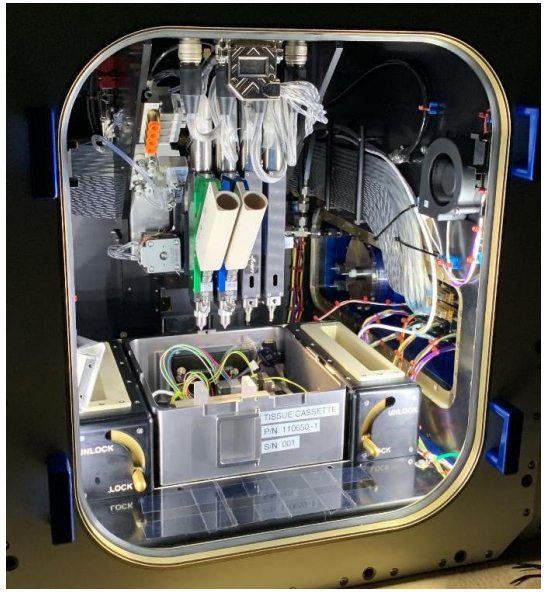


<u>Leveraging microgravity to improve human health on Earth</u>

Crew photos courtesy of NASA

Why Biotech in Microgravity?

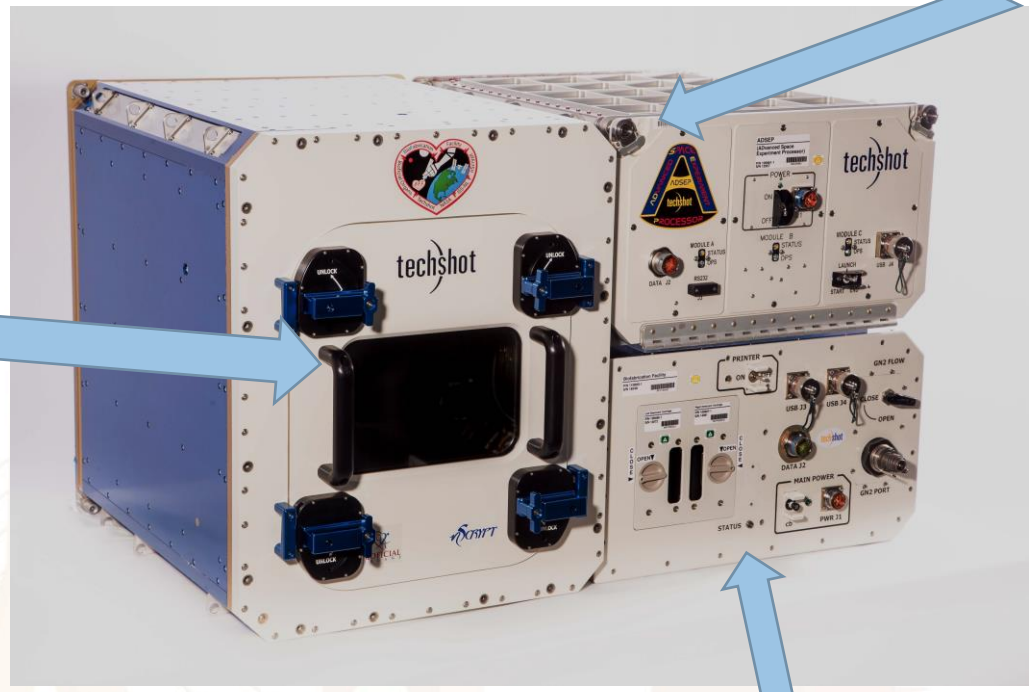
- No sedimentation or convection
- Diffusion and surface tensions driven environments
- Cell-cell interactions more like those in the human body
- Cells form 3D structures easier
- Allows 3D bioprinting of larger structures without structures collapsing under their own weight
- Bacteria can become more virulent
- Stem cells tend to behave more naïve



Crew photos courtesy of NASA

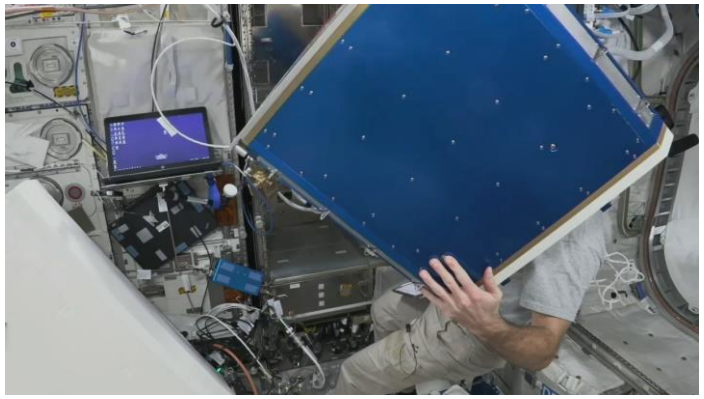
The BioFabrication Facility (BFF) Hardware

Print Chamber



Tissue Culturing (ADSEP)

Electronics Compartment



NASA Astronaut Josh Cassada installing the Redwire BFF aboard the ISS

NASA Astronaut Megan McArthur with a Redwire ADSEP aboard the ISS

Crew photos courtesy of NASA

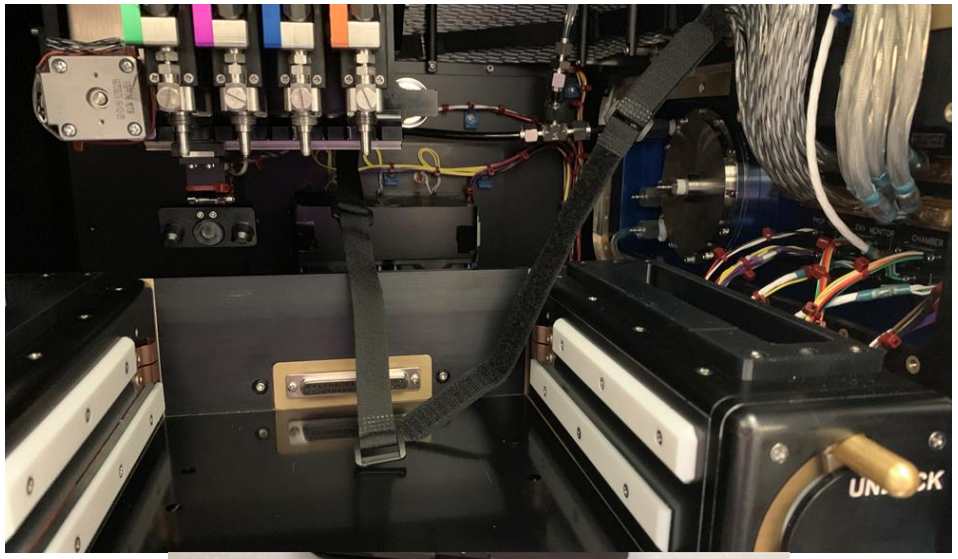
BFF Capabilities

Volume
- Workspace Without Culturing capability: 10cm x 10cm x 10cm
- Typical Bioreactor Print Volume (customizable): 3.1cm x 2.3cm x 2.3cm

Environment
- Chamber: 22 ± 5 °C (ambient), 50% - 80% RH (desiccant available)
- SmartPumps (dispensers): 4 – 40 °C

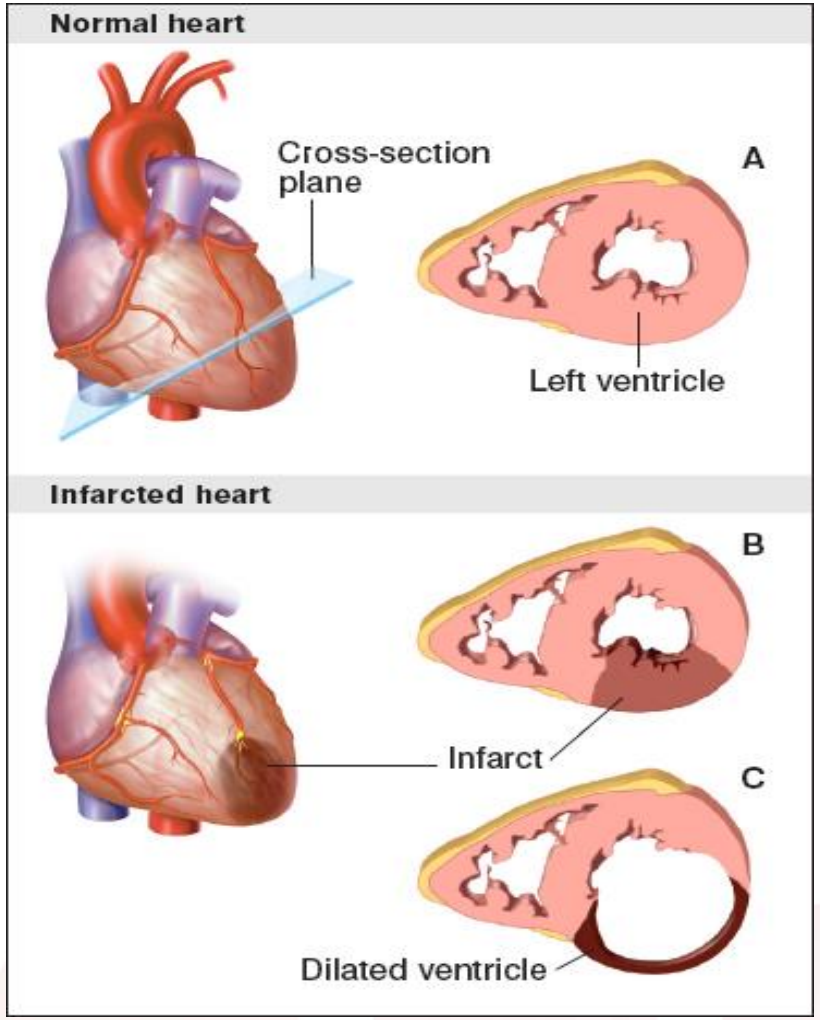
Motion and Dispensing
- Head speed >200mm/sec X, Y, and Z with acceleration limited to 0.5g
- 4 independently controlled SmartPump dispensers (1 – 1,000,000 cP)
- Bioink delivery from 10ml dispensing syringe
- Dispense through blunt needle or ceramic cone

Bioreactor
- Print Size 31mm(X) x 23mm(Y) x 23mm(Z)
- Media infusion through needle array embedded into construct
- Mechanical displacement up to 20%
- DC Electrical Stimulation
- Fully customizable configurations possible



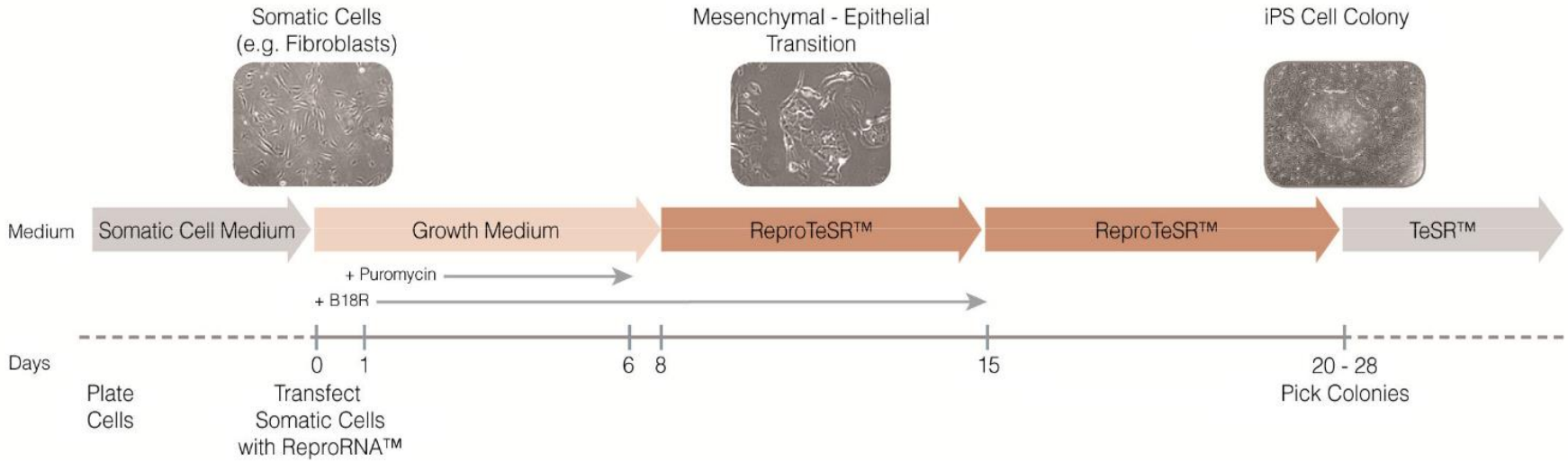
Cardiovascular Disease

- Myocardial Infarctions effect 600,000 Americans every year
  - #1 Killer in USA
  - Forms scar tissue
  - No reliable intrinsic regeneration
- Limited sources of mature human cardiomyocytes and cardiac tissue
  - Drug toxicity
  - Drug efficacy
  - Regenerative treatments

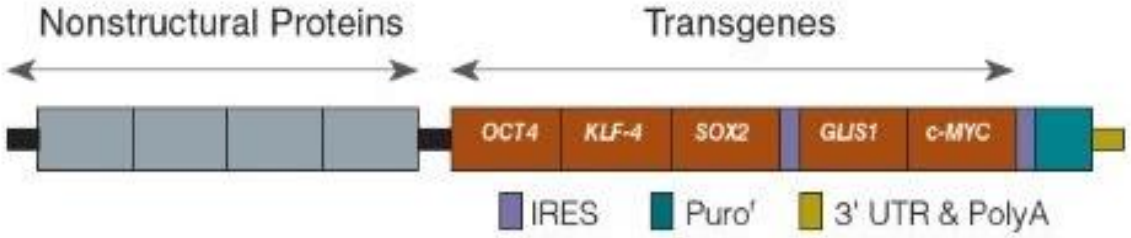


NIH, 2012

Reprogramming

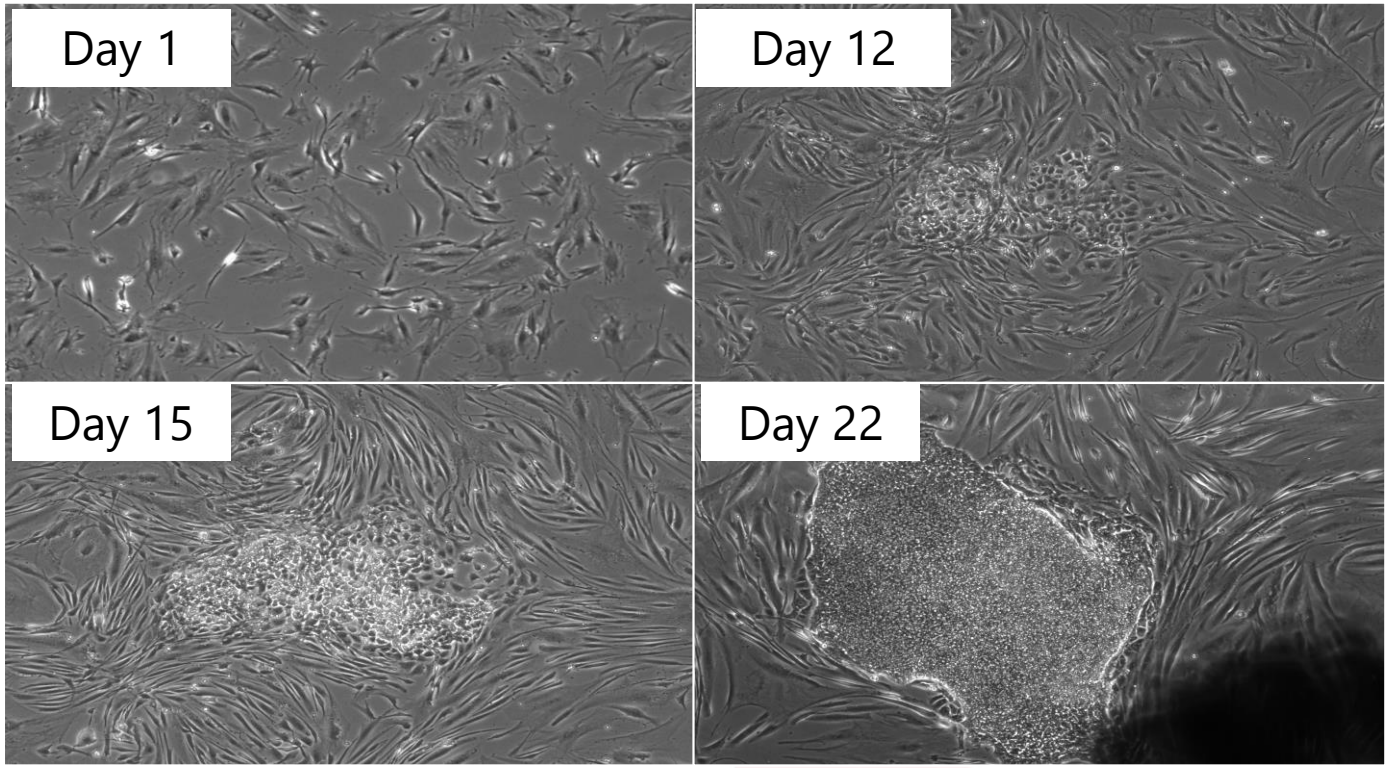


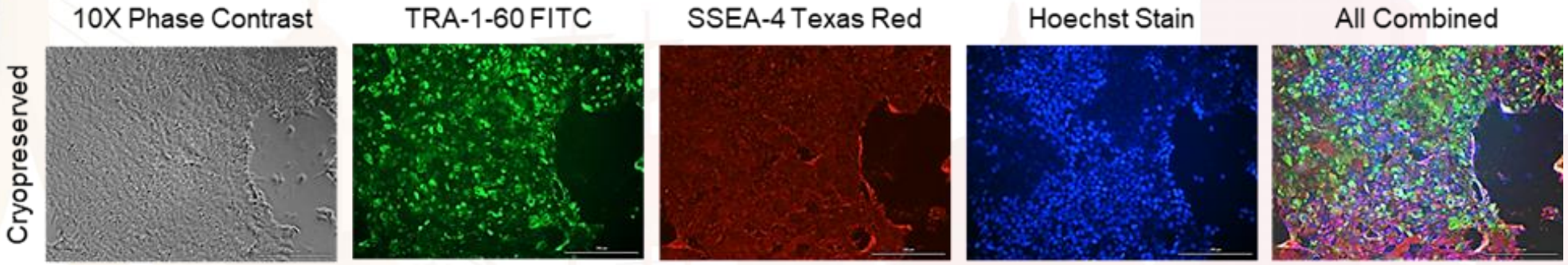
- ReproRNA™-OKSGM
  - OCT4, KLF-4, SOX2, GLIS1, and c-MYC
  - Self replicating RNA
  - B18R Protein to prevent degradation
  - Puromycin resistance selection
  - Lipofectamine transfection
- ReproTeSR
  - Stemcell Technologies media for feeder free reprogramming



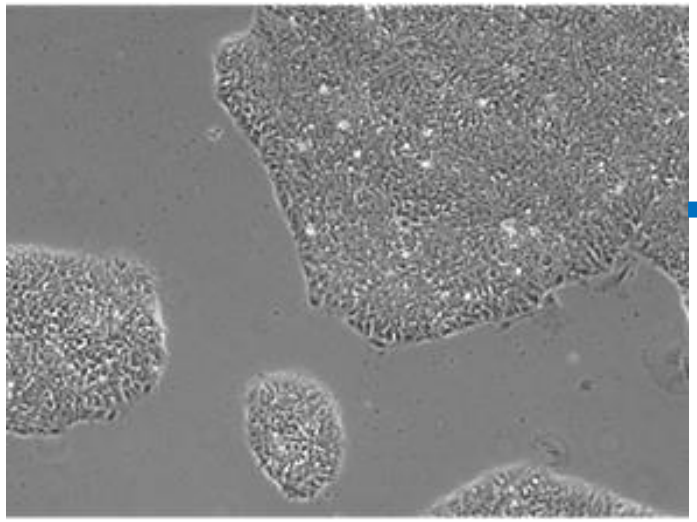
Verification

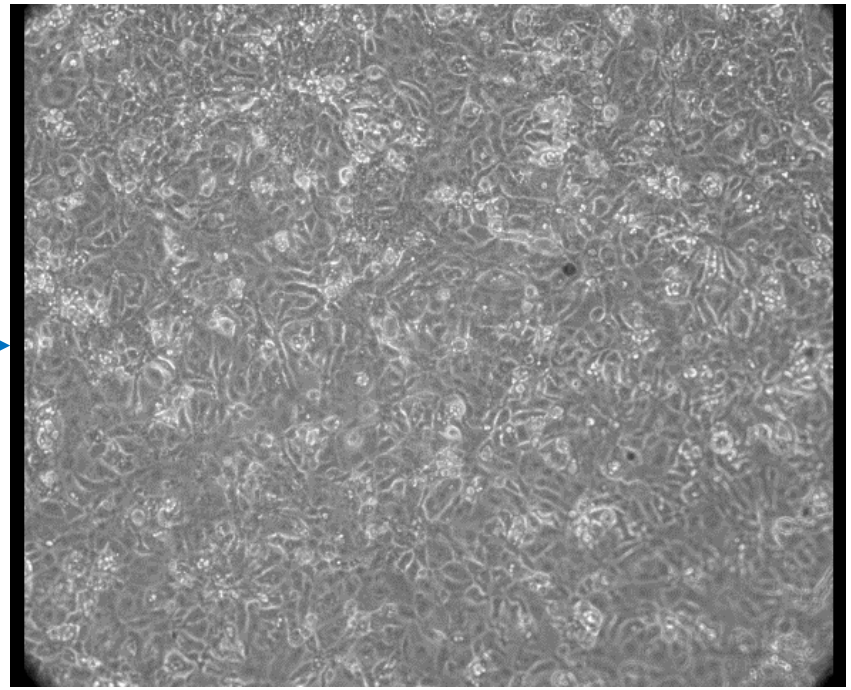
- Somatic Cell to iPSC Reprogramming
- Tested protocols for reprogramming of somatic cells
- COTS reprogramming kit
- 4 stable iPSC lines
  - 2 from an adult donor
  - 2 from a neonatal donor
  - All positive for pluripotency markers





Differentiation





Day -2
iPSCs seeded with Y-27632
On hESC Matrigel

48h

Day 0
CHIR 99021
10 µM

24h

Day 1
RPMI with B27 without insulin

48h

Day 3
IWP2
5 µM

48h

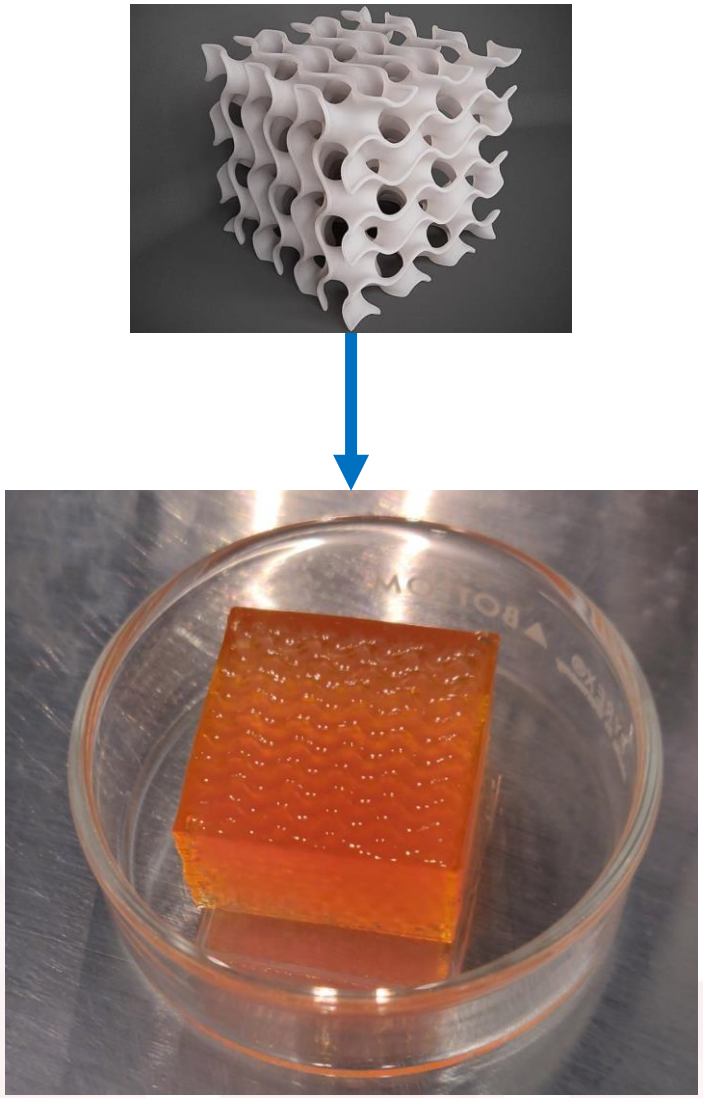
Day 5
RPMI with B27 without insulin

48h

Day 7
RPMI with B27 with insulin

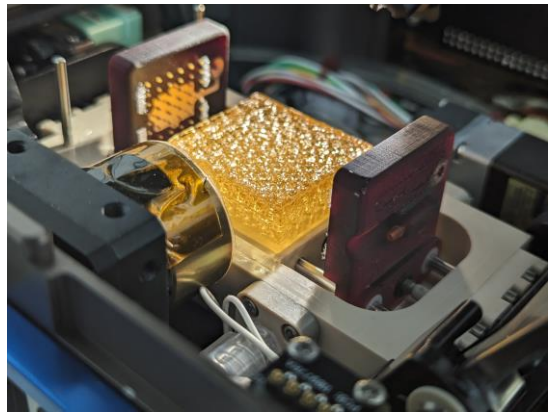
Bioink and Print Design

- Gyroid Structure
  - Infill design from CAD software
  - Creates large and obvious paths for nutrient and waste diffusion
  - Easily perfused
  - Single contiguous piece, good for structural stability
- Surface Level Crosslinking
  - Thrombin in Sacrificial Bioink (pluronic F127)
  - Fibrinogen in the Bioink containing cells
- Culture for 2-weeks

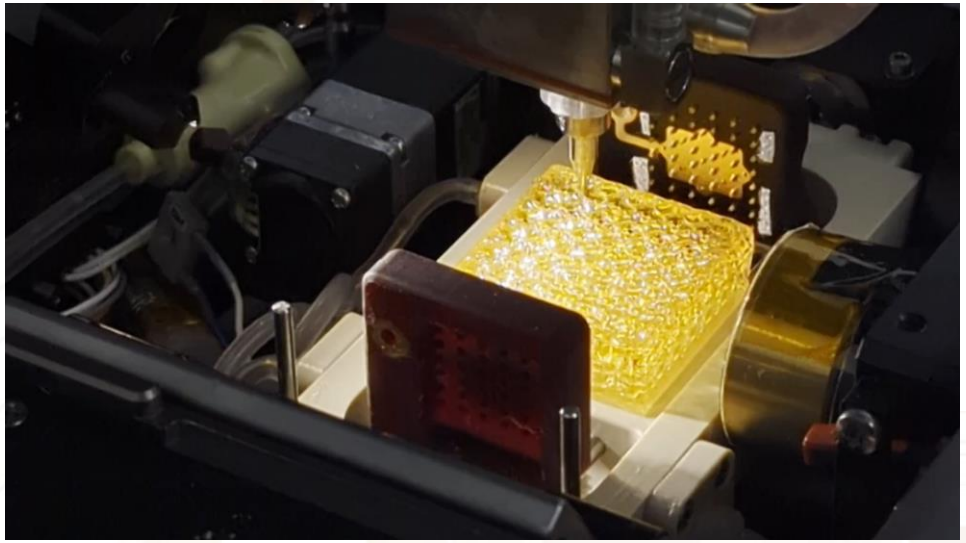


EVT (Flight Like Test)

Print



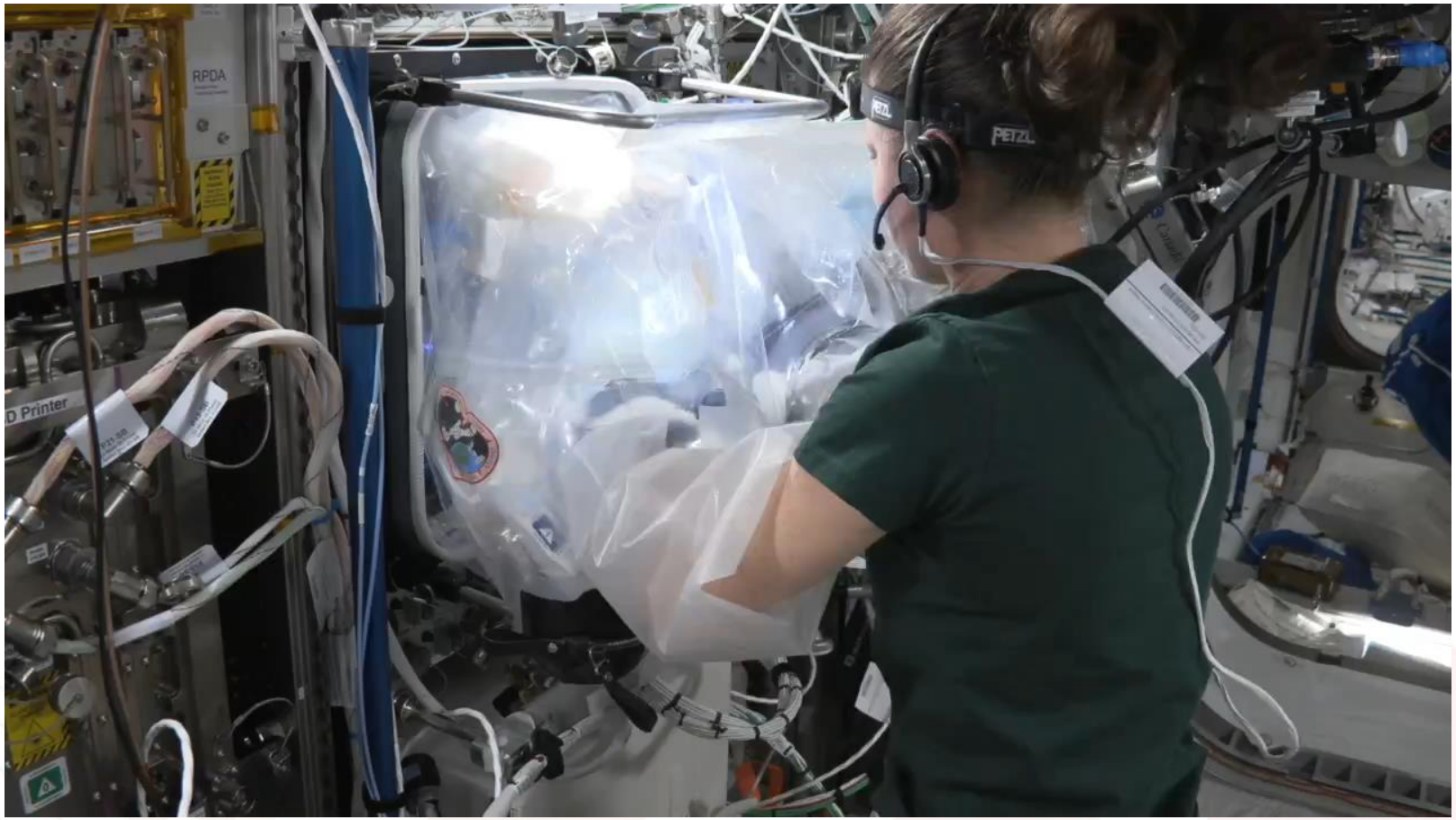
Fill



Culture

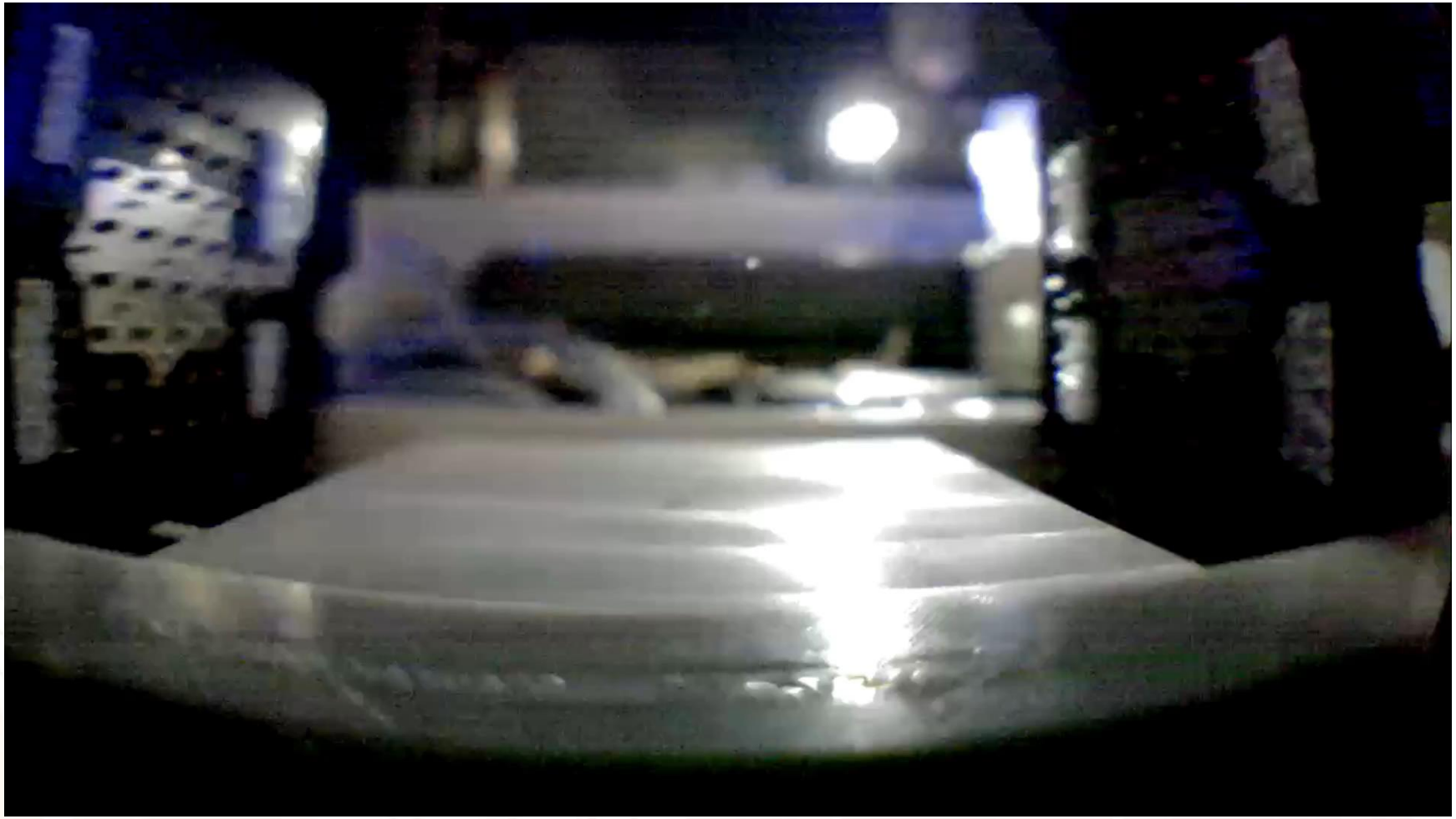
10/25/23

Flight – Setting Up

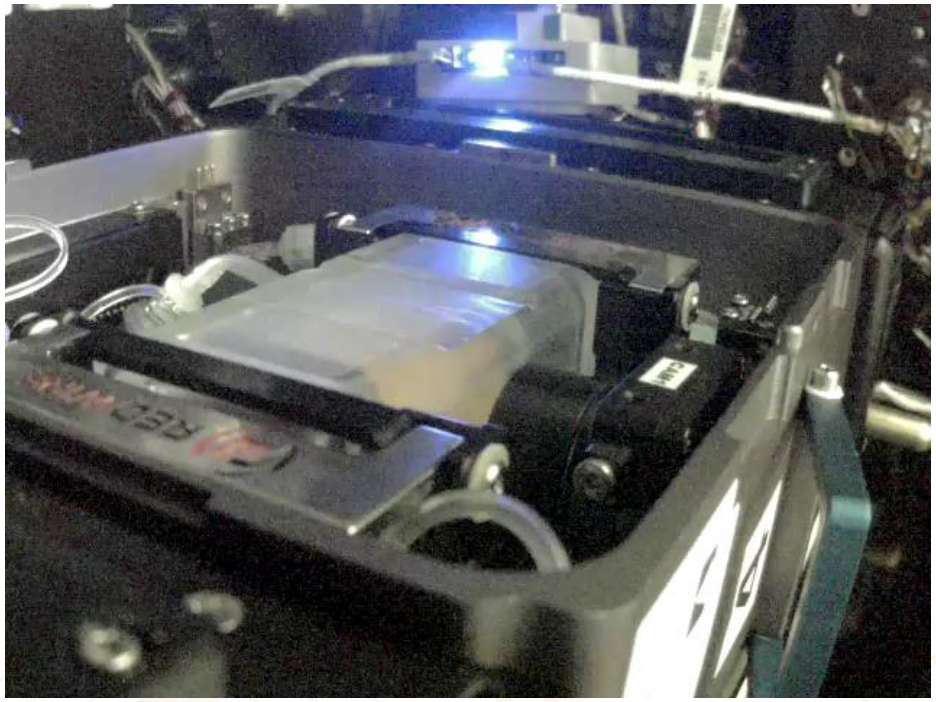


NASA Astronaut Tracy (TC) Caldwell Dyson

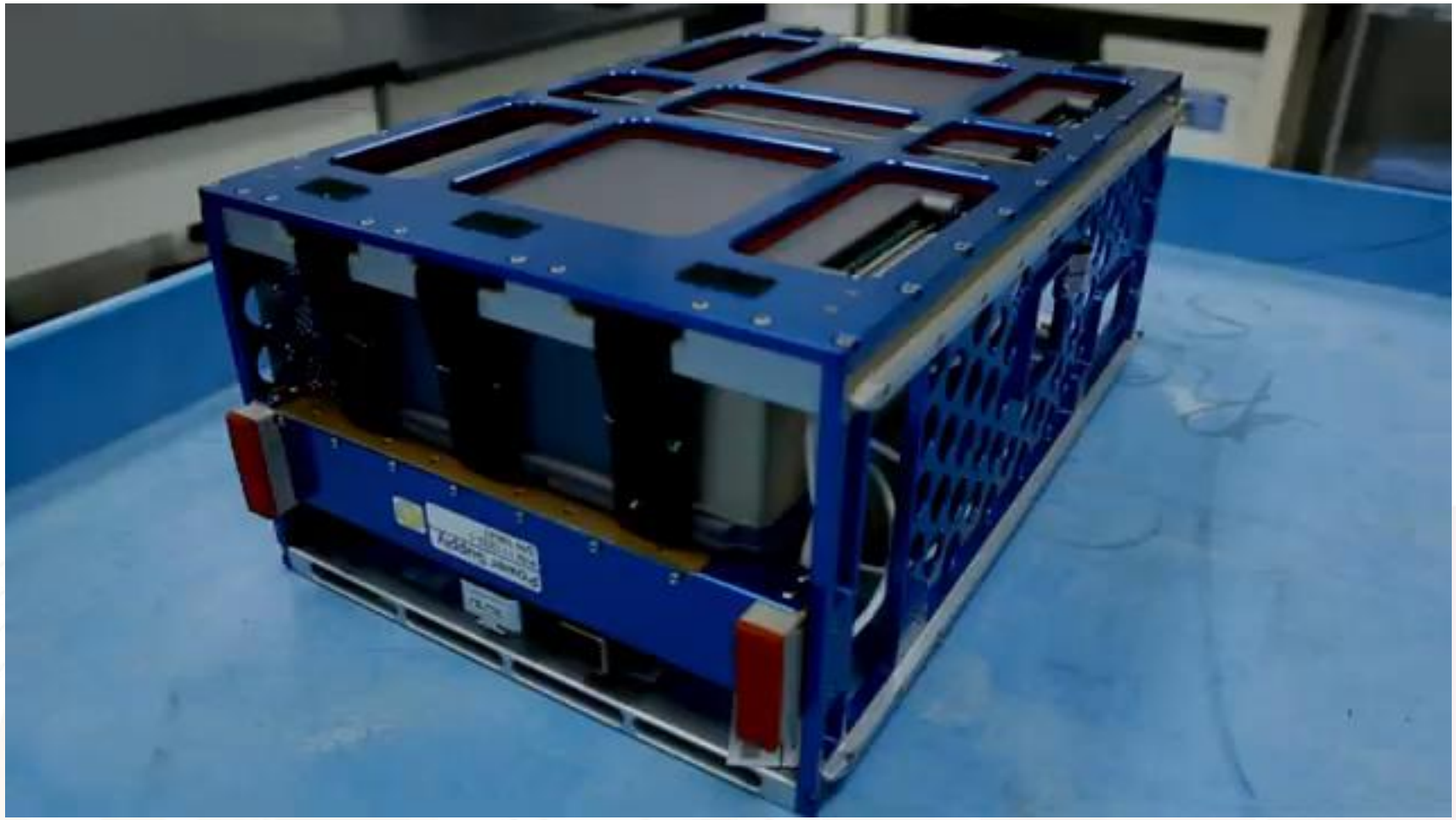
Flight – Printing the Gyroid



Flight – Two weeks of Culture in ADSEP

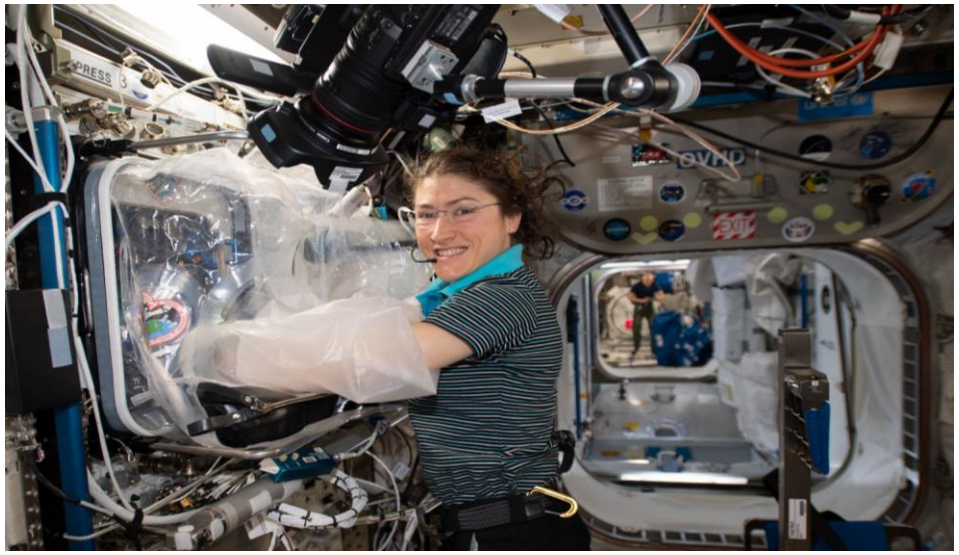


Flight – Return ALIVE



The Future of BFF

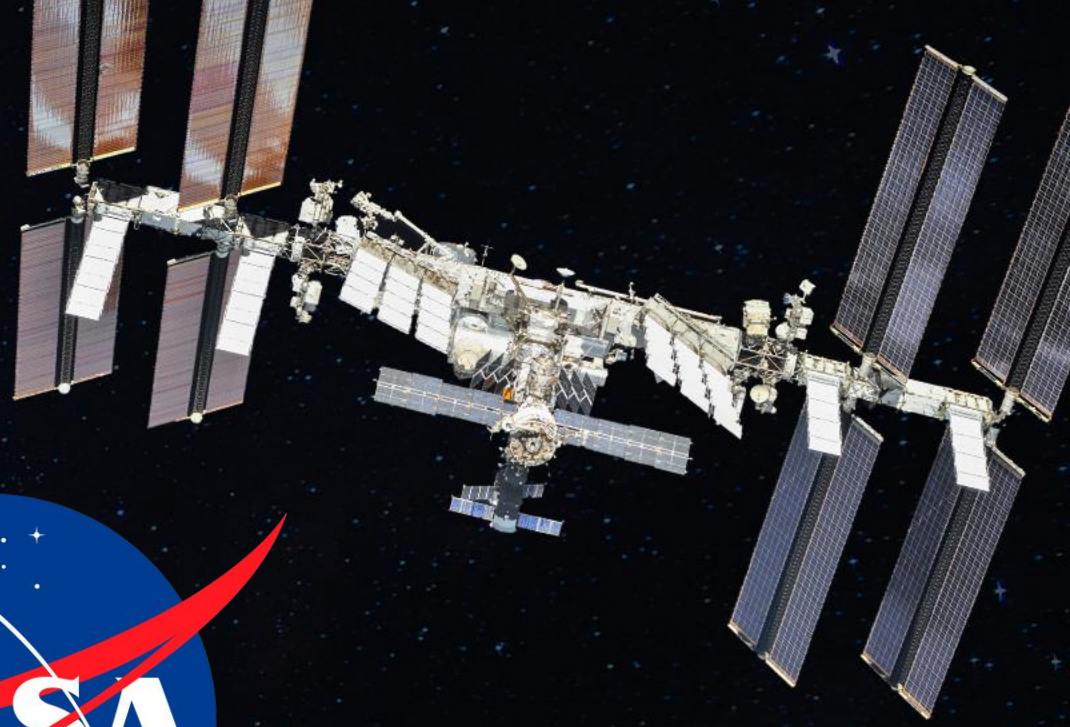
- Cell Expansion Facility
- Cell Differentiation Facility
- Bioink Production Facility
- BFF / ADSEP Combination
- Bioprinted Tissue for Research and Therapeutics



Crew photos courtesy of NASA

Acknowledgements

- Redwire BFF Team
- NASA
- ISS National Laboratory
- ISSRDC



REDWIRE

NASA

BioFabrication Facility
Bioficial Organs
nScrypt
BFF
Techshot
NASA
ISS-NL

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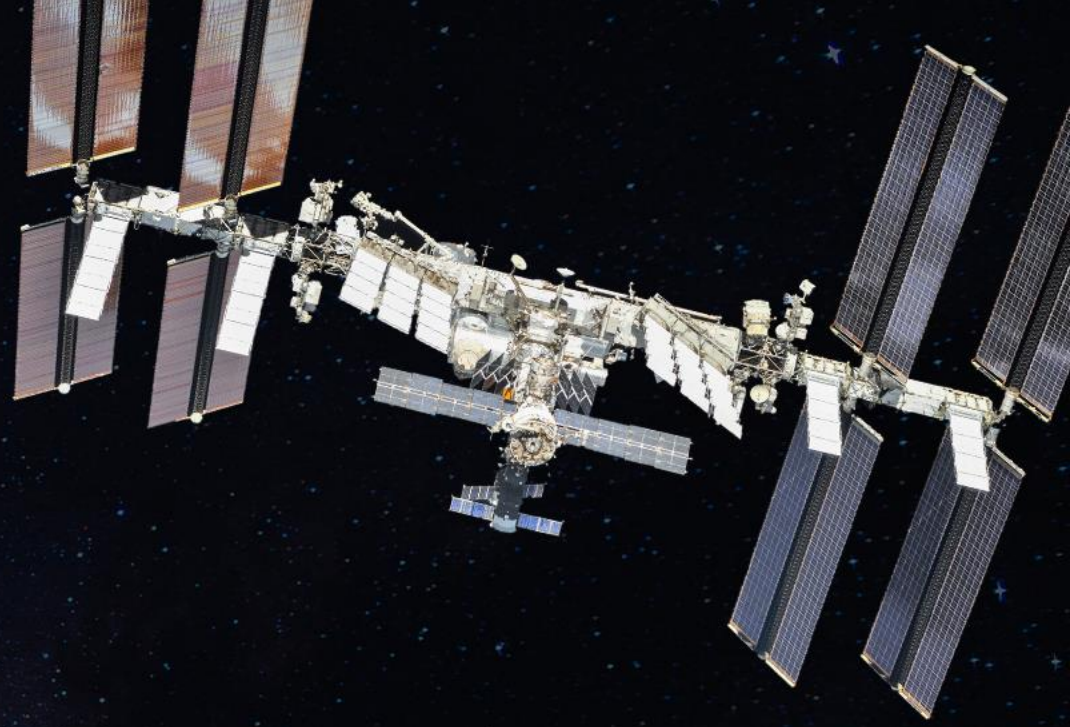

Want to know more? Contact me!

Aaron.Rogers@redwirespace.com

International Space Station Research and Design Conference 2024

Tuesday July 30, 2024

In-Space Production Applications

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