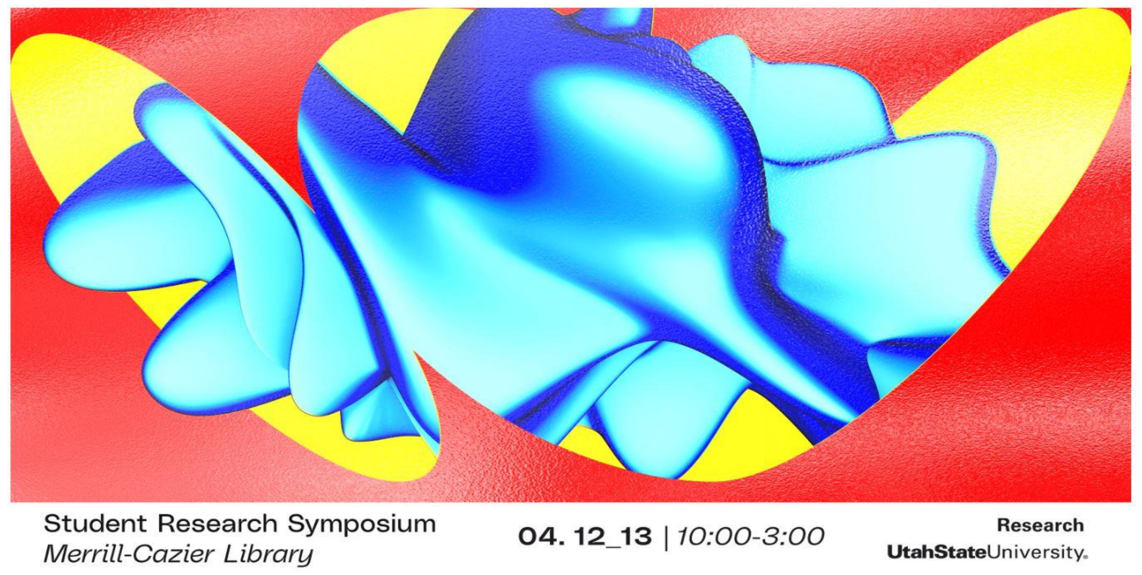
Simultaneous Simulation of Microgravity and Ionizing Radiation in a Laboratory Environment



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INTRODUCTION

- Astronauts suffer significant cellular damage during spaceflight.
- Main causes-
  - ➢ Simultaneous exposure to microgravity, and
  - ➢ Ionizing radiation
- **Goal**- Design a mini-rotary cell culture system (mRCCS) that can-
  - ➢ Simulate microgravity
  - ➢ Be used in combination with a radiation source, and
  - ➢ Is biologically compatible and autoclavable

RADIATION EXPOSURE

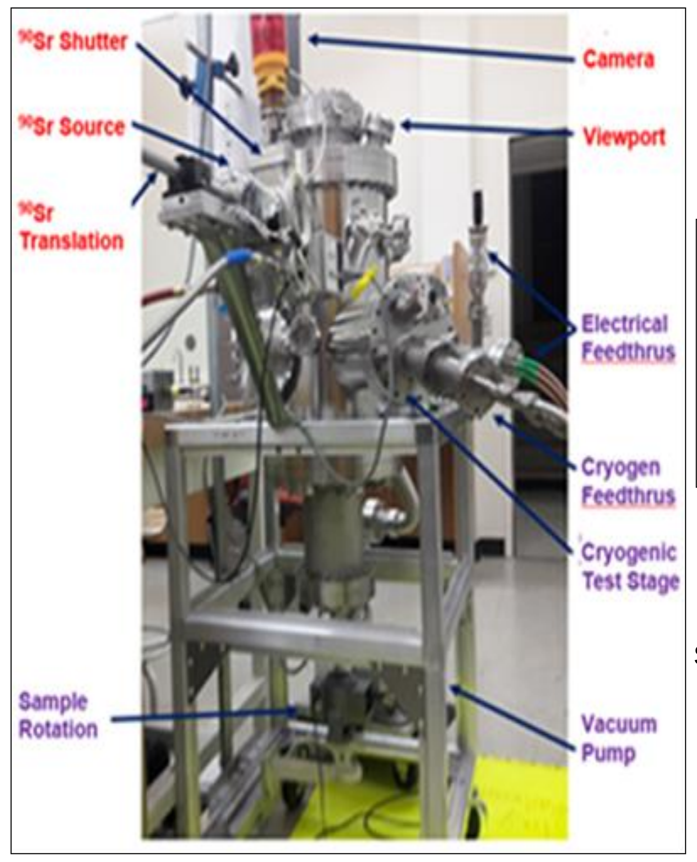


Fig.1 Space Survivability Test Chamber

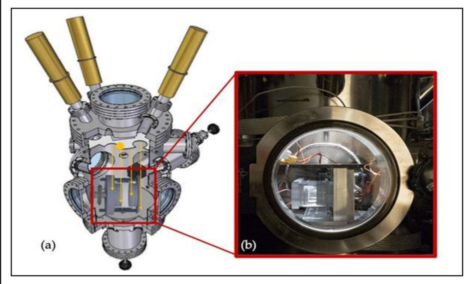


Fig. 2 (a) Cut away view of SST chamber experimental setup. (b) Image of the SST chamber with the mini-RCCS seated within the beam path of the ^{90}Sr source

METHODS

- Reduced gravity conditions for 200 µm microcarrier beads suspended in a media were achieved when-
  - ➢ Beads reached terminal settling velocity v_s, as the centripetal force (F_C) is balanced when they fall with near zero net forces from gravity (F_g), buoyancy (F_B), viscous drag (F_v).
  - ➢ $v_s = 2g(\rho_b - \rho)(R_{bead})^2/9\mu$ where ρ_b = density of the beads, ρ = density of the media, R_{bead} = radius of the beads, µ = dynamic viscosity of the media.
- For rotation calibration, different density liquids were chosen and vessels were rotated from 1 rpm to 55 rpm.
- Another measure of an effective mRCCS ⟶ low radial acceleration.

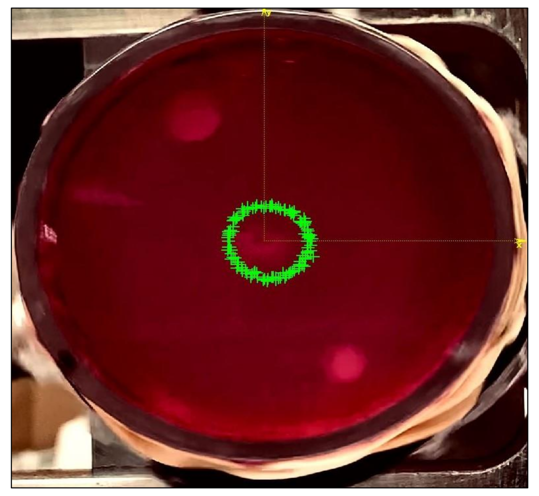


Fig.3 Microbeads cluster tracking inside the media.

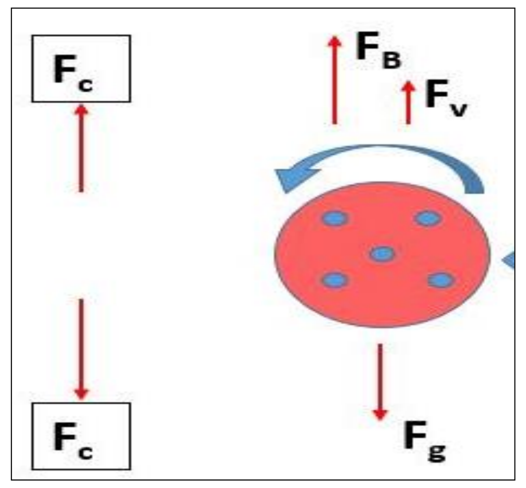


Fig.4 Balance of external forces from Stoke's law

RESULTS

- The range of rotational speeds for microbeads undergoing microgravity was confirmed for the media.
  - ➢ Lower limit = 6 rpm
  - ➢ Upper limit = 42 rpm
- Reduced gravity environments were reached from ~1*10^{-5} g to ~2*10^{-2} g
- The combined mini RCCS and SST chamber system can provide average effective dose rates for the cells controlled over a broad range 900 X).

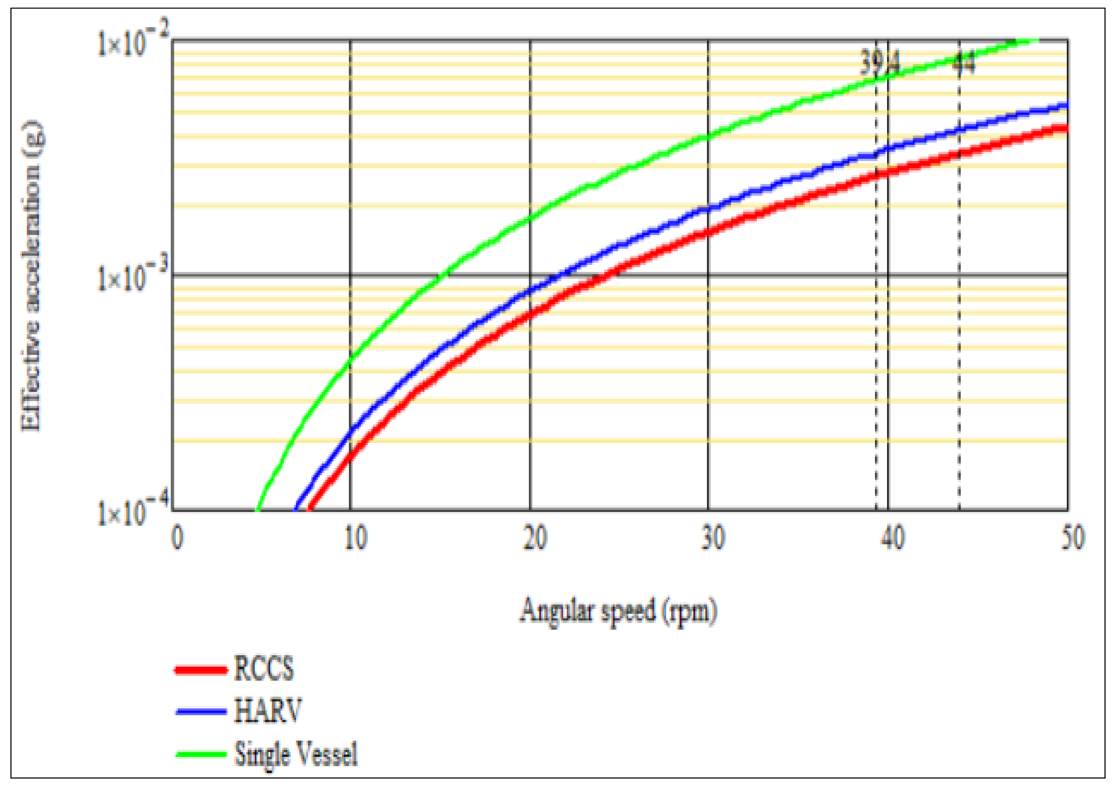
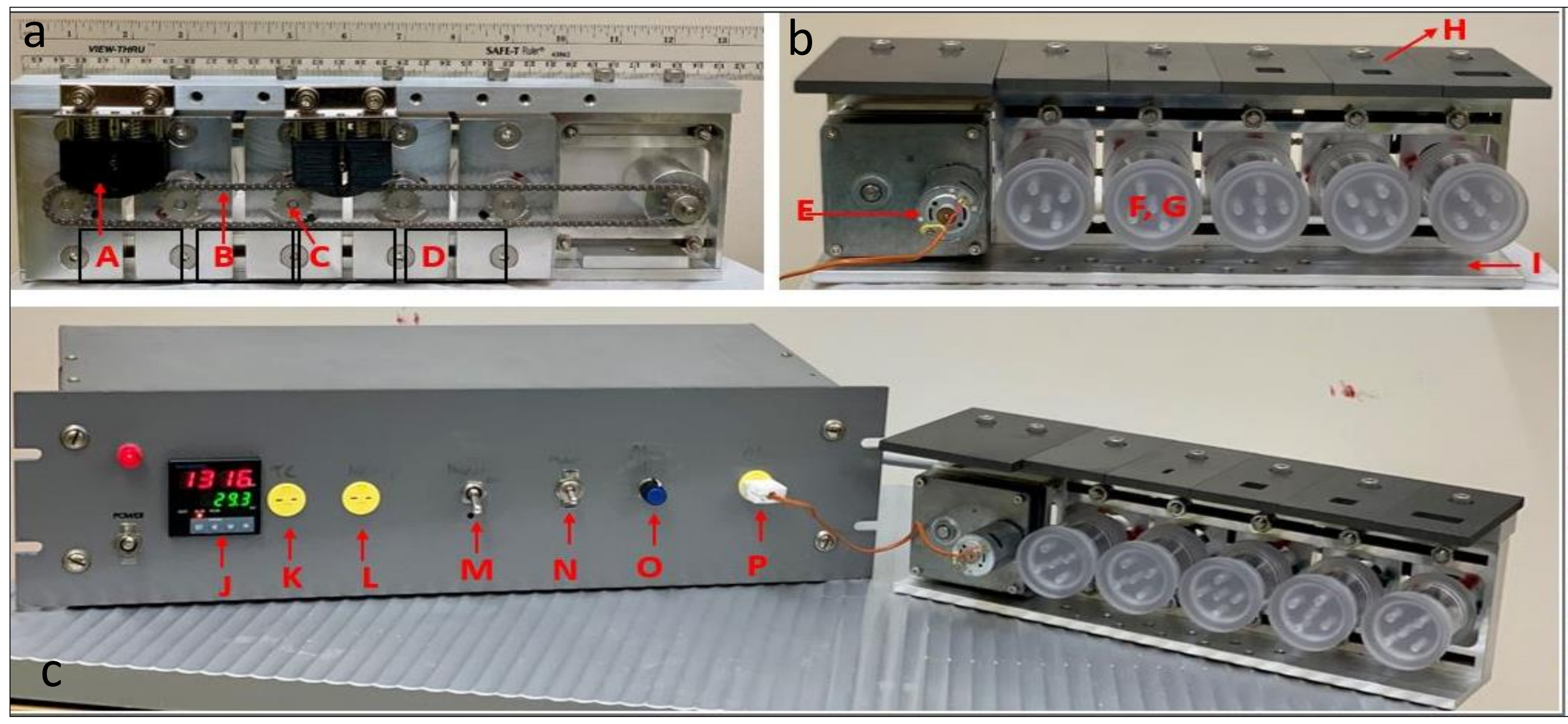


Fig. 5 Comparison of mRCCS effective gravitational acceleration of with commercial systems



Mini RCCS Components

- **A** Chain Tensioner
- **B** Drive Chain
- **C** Vessel Gear
- **D** Bearing Plates
- **E** Servomotor
- **F** Gas Permeable Membrane
- **G** Front Endcap
- **H** Graphite Shields
- **I** Aluminum Base
- **J** Temperature Controller
- **K** Type K Thermocouple
- **L** Heater
- **M** Heater Switch
- **N** Motor Switch
- **O** Potentiometer
- **P** Motor Output

Fig. 6(a) Rear- view of the mRCCS. **(b)** Front view of the mRCCS with variable slit widths of graphite plates. **(c)** mRCCS with controller.

CONCLUSIONS AND FUTURE WORK

- A novel, versatile, cost-effective system is developed that can-
  - ➢ Model cellular damage from microgravity and ionizing radiation
  - ➢ Provide stable, simultaneous space-like radiation and reduced gravity environments
  - ➢ Be used to model microgravity at the same level as the commercially available systems.
- Further analysis of rotation calibration will be done for salt water, IPA etc.

	Four vessel RCCS (Synthecon)	Single vessel RCCS (Synthecon)	Mini - RCCS	ISS	Moon	Mars
Vessel radius (mm)	21.5	44.1	17.1	-	-	-
Rotational speed (rpm)	39.4	27.8	44.4 *	5.3 *	311 *	470 *
Effective gravitational acceleration (g)	3.3x10^{-3}	3.4x10^{-3}	3.4x10^{-3}	4.84x10^{-5}	0.165	0.376

* Rotation to achieve effective gravitational acceleration.

Table 1 Comparison of effective gravitational force of mRCCS to gravitational force on the ISS, Moon, and Mars

Fluid	Density (g/cm^3)	Rotation Speeds (rad/s)	Average Radius (cm)	Radius Amplitude (cm)
Water	0.99	4.35	0.550	0.0343
Isopropyl Alcohol	0.79	4.79	0.317	0.0241
Salt Water	1.18	4.42	1.15	0.0013
Media	0.98	4.33	0.312	0.0351

Table 2 Rotation speeds of different density liquids.

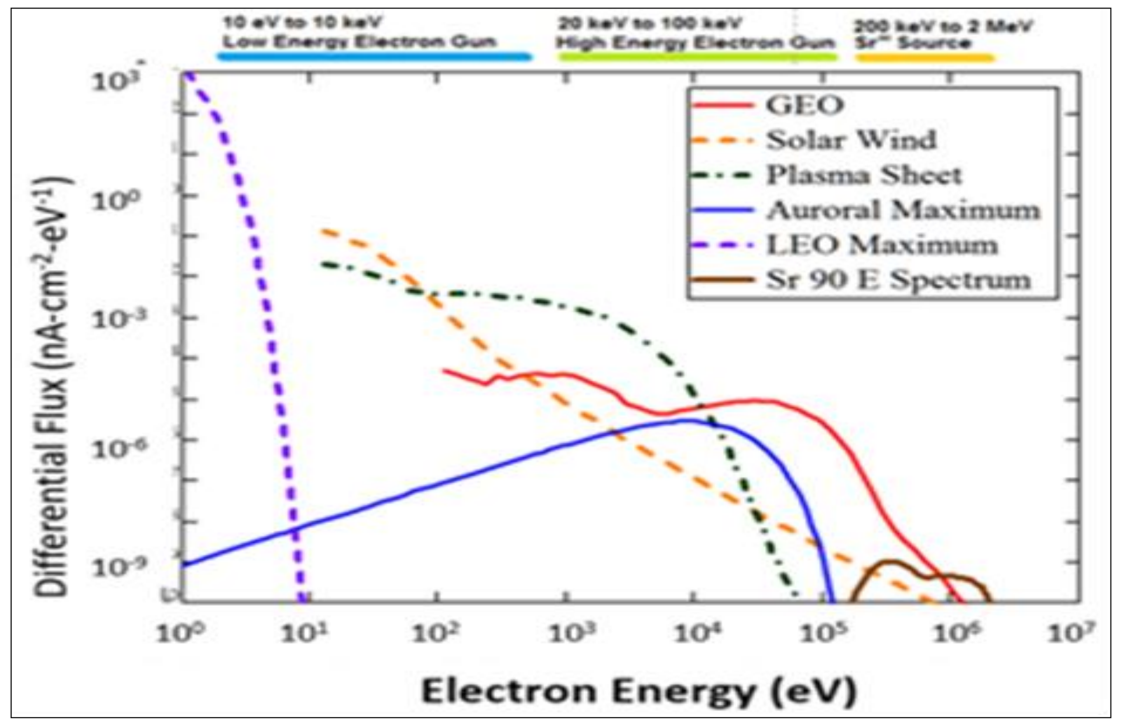


Fig. 7 Differential electron flux for five typical space environments. ^{90}Sr source electron emission spectrum is also shown..

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