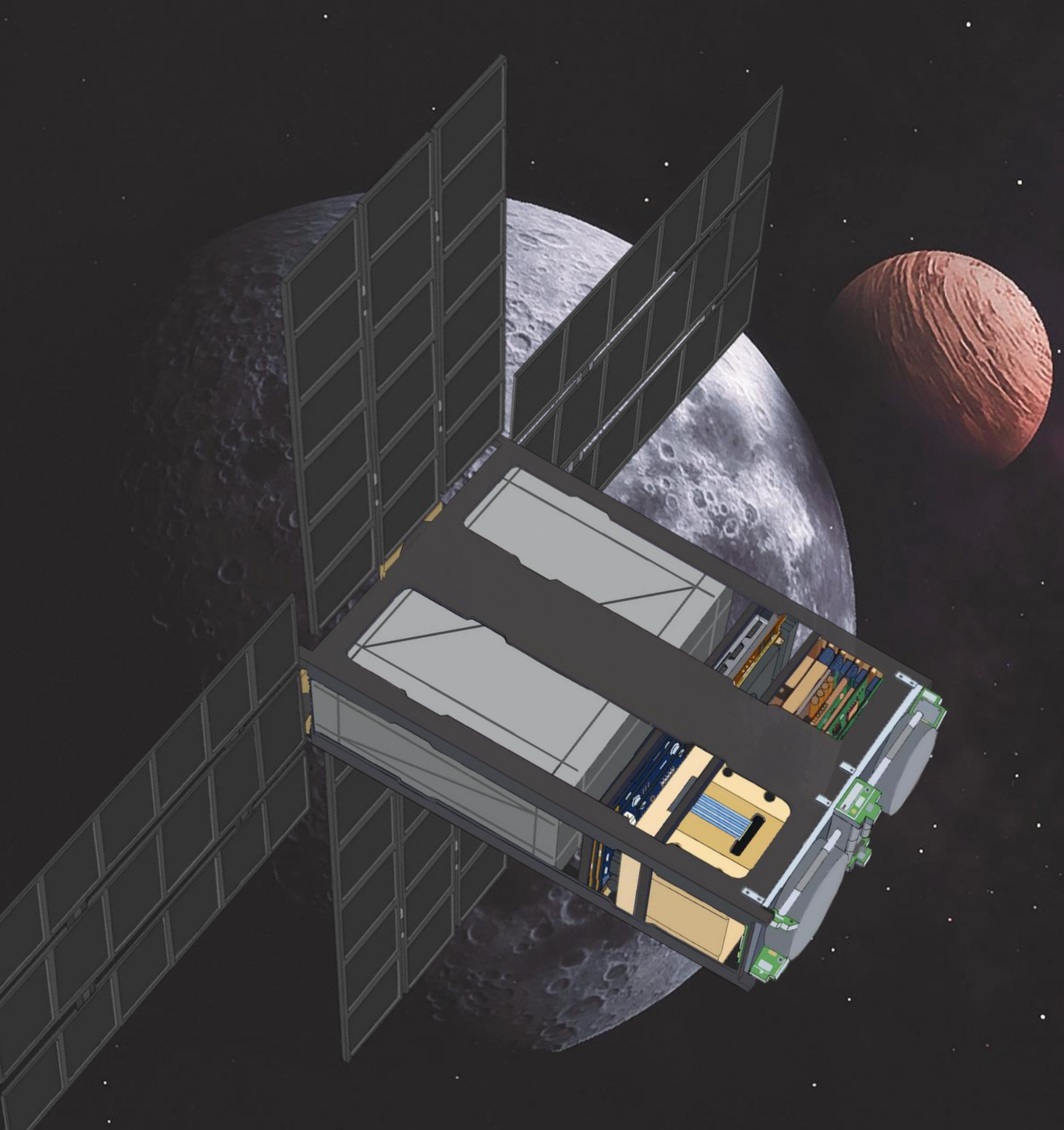


INTERNATIONAL SOCIETY OF SPACE ENGINEERING
IN LIFE SCIENCE & MEDICINE

MINERVA

A CubeSat for demonstrating DNA damage mitigation against space radiation in C. *elegans* by using genetic modification

Tanchanok Tangwattanasirikun

Sub-project Manager of Minerva

Sean Gallup

Science Co-lead of Minerva

Sumeth Klomchitcharoen

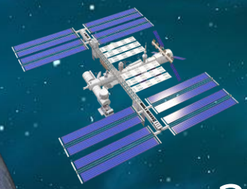
Project Manager of Minerva

Mahidol University

Space Ionizing Radiation

Severe health risk of Space exploration

2 mSv per year
on Earth

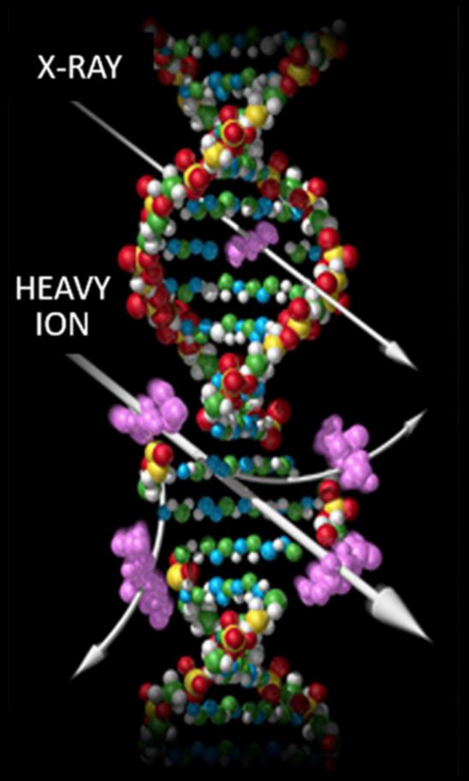


~300 mSv per year
on ISS

1200 mSv per round trip
during mission to Mars

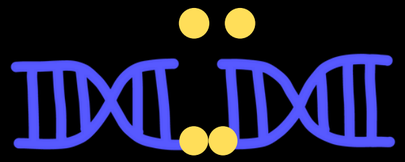
EFFECTS FROM SPACE IONIZING RADIATION

DNA damage



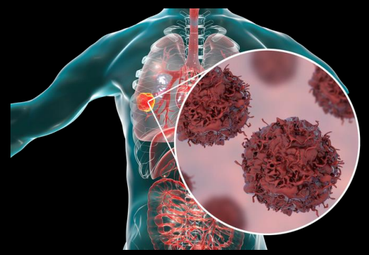
DNA lesion

Double strand break (DSBs)



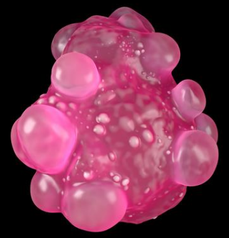
Decrease the repairability of DNA

Chronic health disease



Cancer

(Cell mutation)



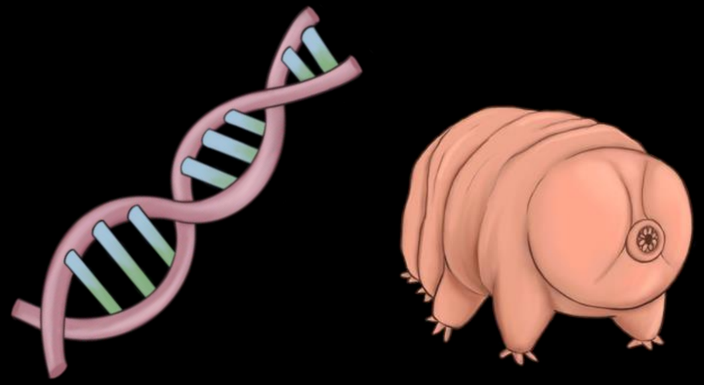
Apoptosis

(Cell death)

Our Paramount Objective

Inhibit DNA damage against deep-space radiation exposure by genetic modification

Gene Editing Process



Damage suppressor protein (Dsup)
in tardigrade

- Dsup proteins make tardigrade withstand radiation doses, up to 4000 Gy
- Prevent DNA damage occurring in tardigrade

Gene Editing Process

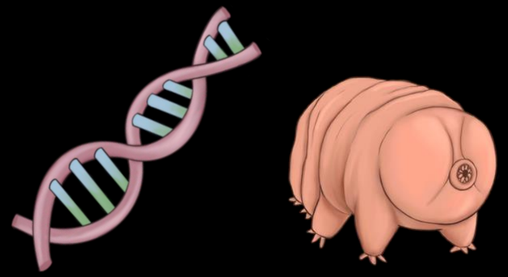
Model organism

Caenorhabditis elegans (C. elegans)

Credit photo: https://arstechnica.com/science/2017/05/worm-moms-pumps-eggs-full-of-toxin-demand-they-inherit-an-antidote/

- Animal (Animalia: Nematoda)
- Can hibernate up to 4 months
- 83 % of human homologous genes
- Has an ability to replicate human diseases

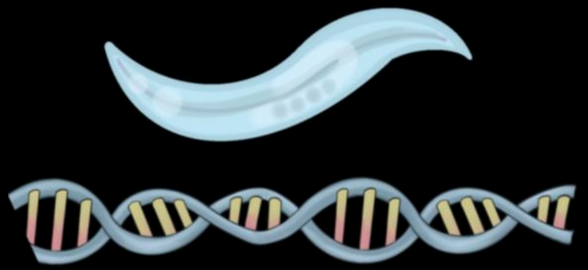
Gene Editing Process



Damage suppressor protein (Dsup)
in tardigrade

Synthesized Dsup-coding gene

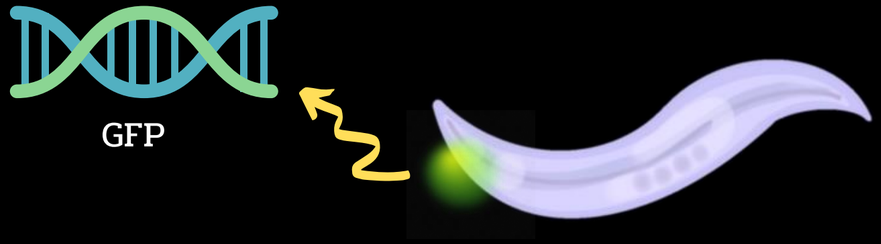
Microinjection



Wild-type
Caenorhabditis elegans
(C. elegans)

Gene insertion

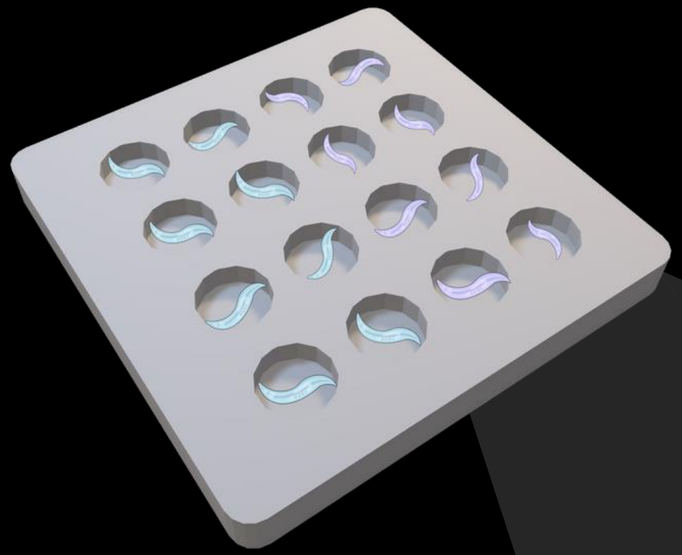
Transgenic C. elegans with Dsup protein
+ Green fluorescent protein (GFP)



Concept of Operation

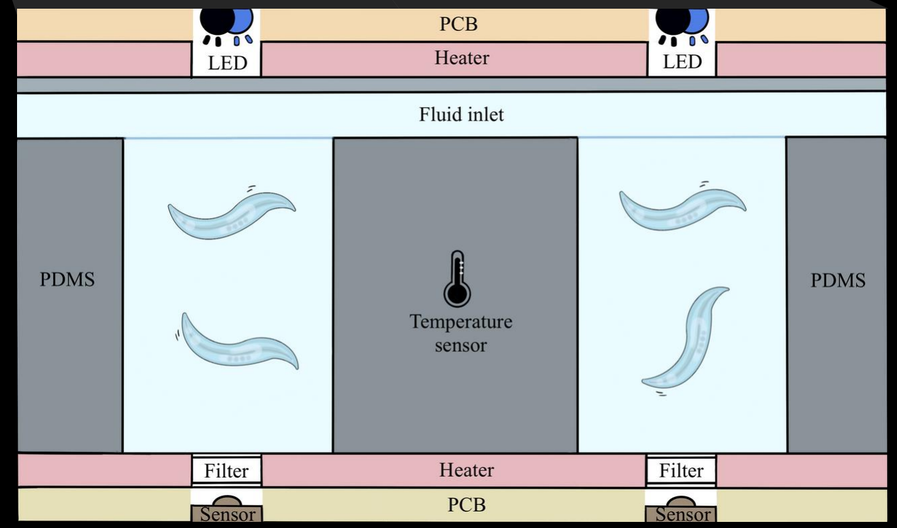
Transgenic C. elegans

Space-controlled group
wild-type C. elegans

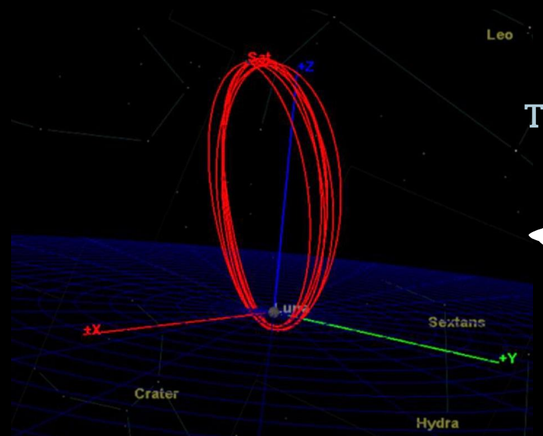


AIBO payload

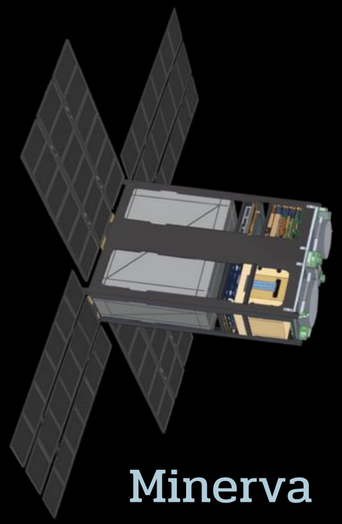
16 wells microfluidic chip



Trans-Lunar
Insertion



Near-rectilinear halo orbit
(Cis-lunar orbit)



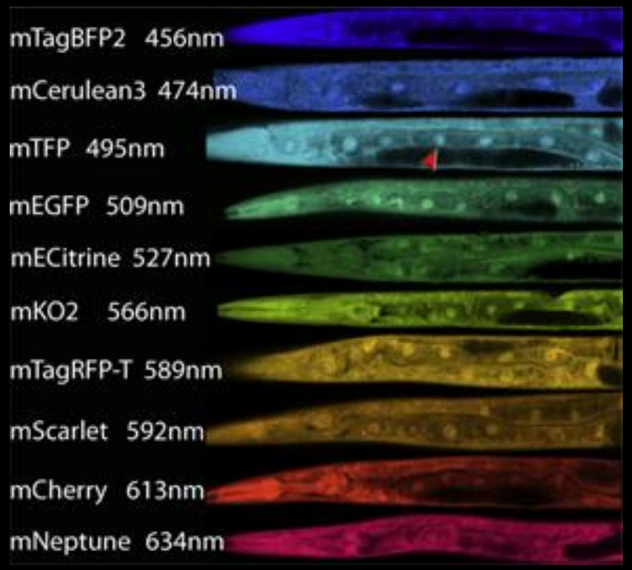
Minerva

Ground-controlled group C. elegans will remain on Earth as a reference

Experiment Analysis Method

How can we observe DNA damage?

Investigating amount of Green fluorescent protein (GFP) coexpression in neuron of C. elegans



Types of fluorescent protein

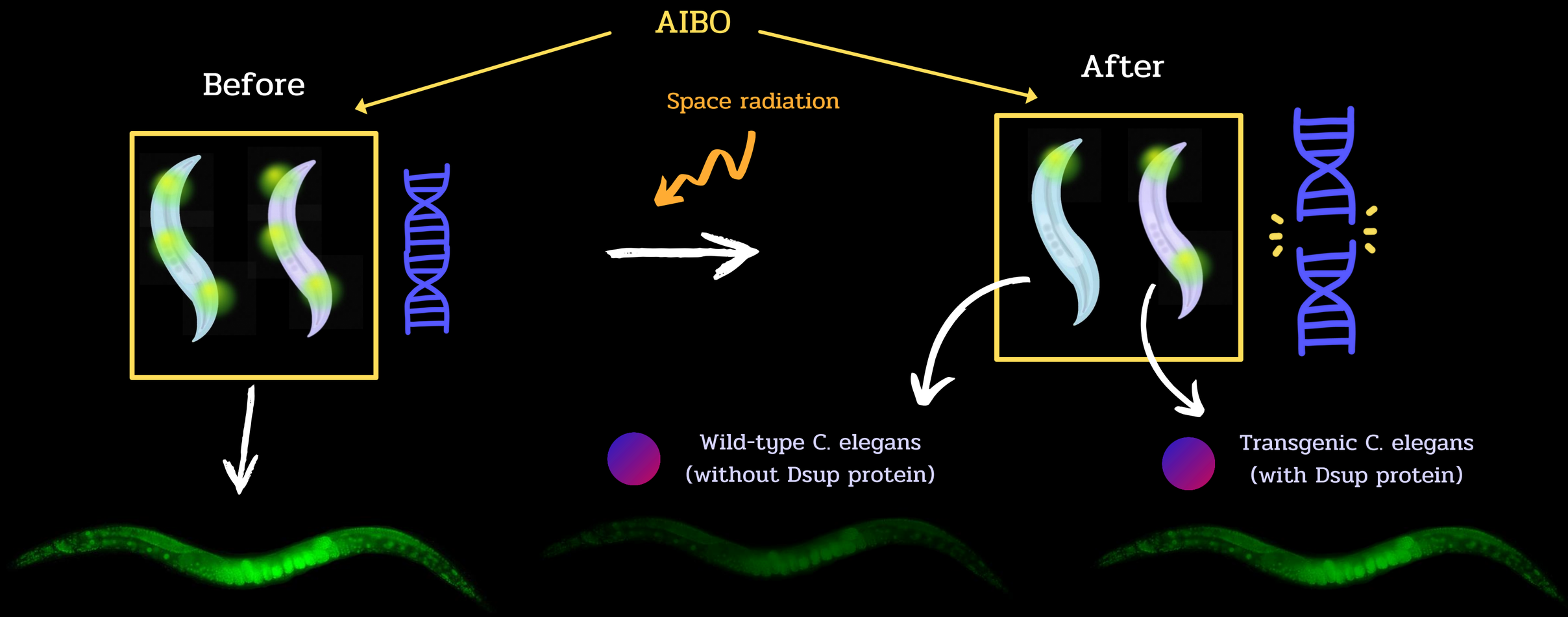
Credit photo: https://doi.org/10.1016/j.tma.2018.01.001

Without GFP tag

With GFP tag

Credit photo: http://wormcas9hr.weebly.com/

Experiment Analysis Method

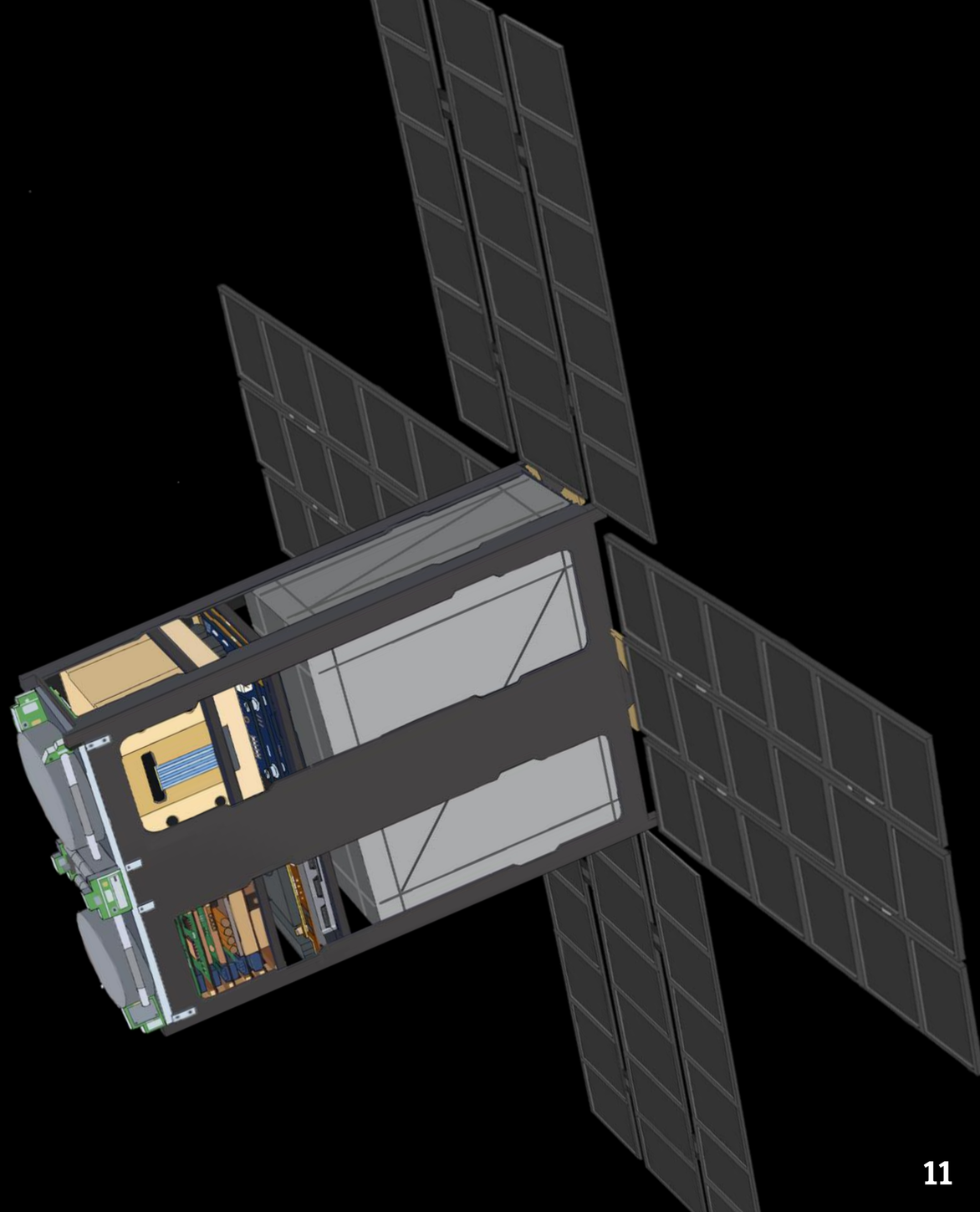


GFP expression in neuron of both C. elegans before radiation exposure

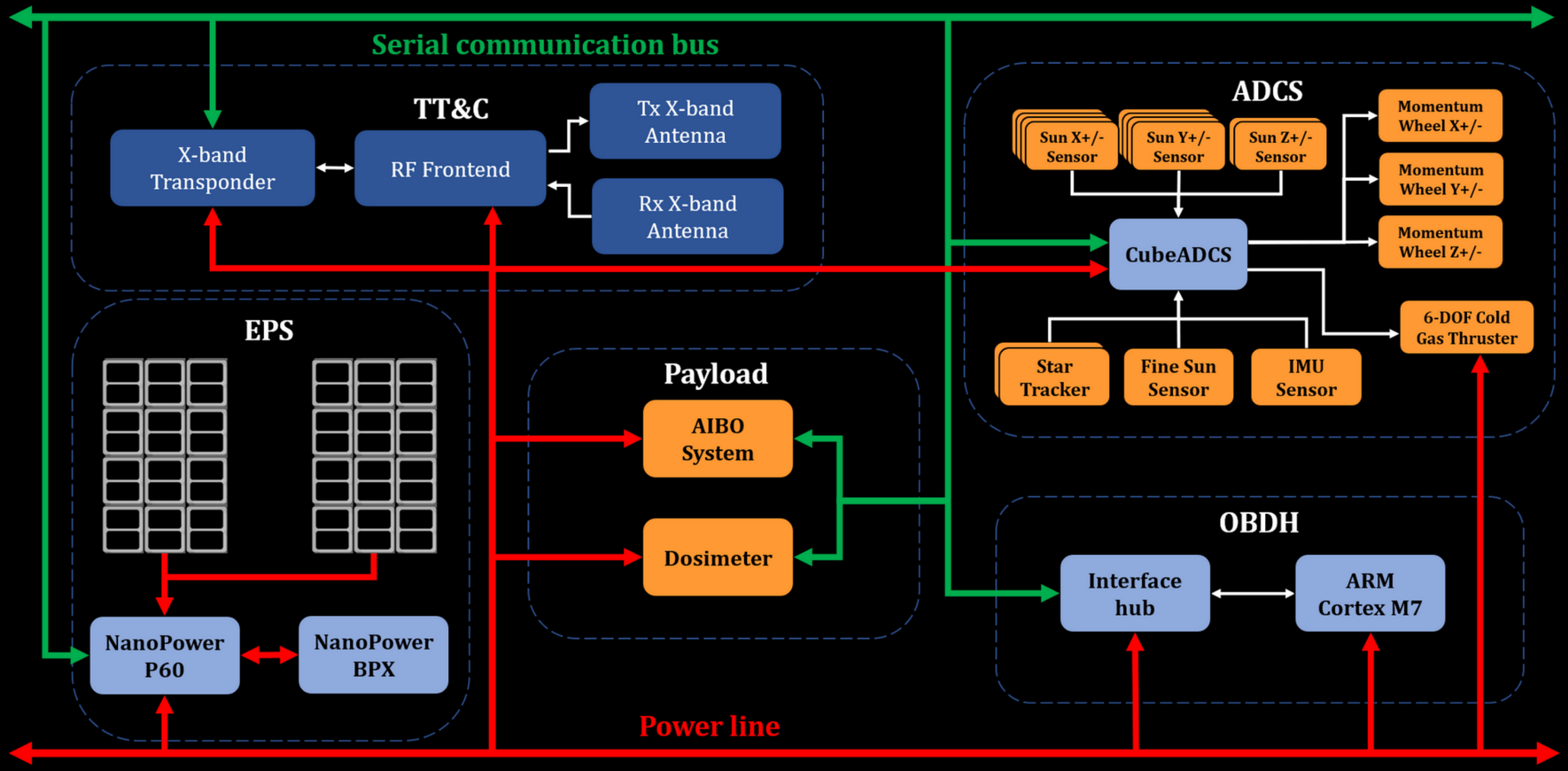
GFP expression decrease after exposure to radiation due to DNA damage

Minerva Specification

- 6U CubeSat
- Unique space mission in CubeSat with living animal
- Lifetime >4 months
- Total mass <12 kg
- Estimated cost ~ $ 1.2 Millions



Minerva System Diagram

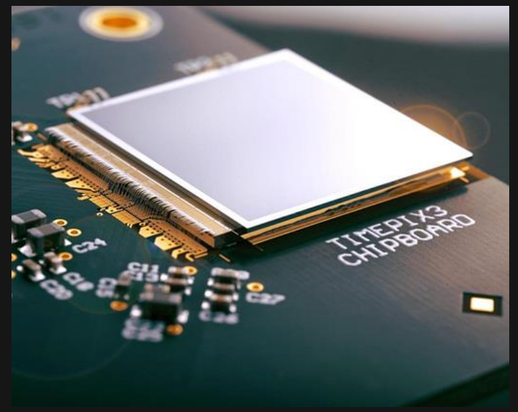


Acronym: **Autonomous Intelligence Biological Operating System (AIBO)**; Attitude determination and control subsystem (ADCS); Telemetry Tracking & Command Subsystem (TT&C); On-Board Data Handling Subsystem (OBDH); Electrical Power Subsystem (EPS)

Payload

Autonomous intelligence biological operating system

- 8 microfluidic chips (16 wells each)
- Thermal control system at 20 °C
- Two optical detecting system (Blue LED for monitoring GFP and near-infared LED for structure imaging)
- Syringe pumps for control C. elegans nutrients (control hibernation)

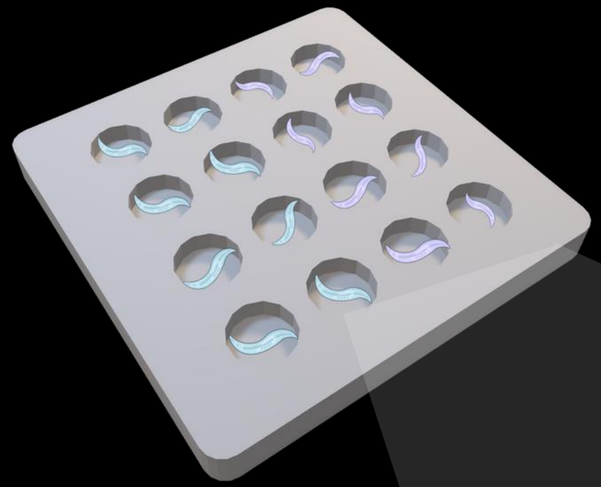


Radiation dosimeter

- Timepix-based linear energy transfer radiation spectrometer (LETS)
- Provide radiation dose measurement throughout the mission
- Compute and store total ionizing dose (TID)

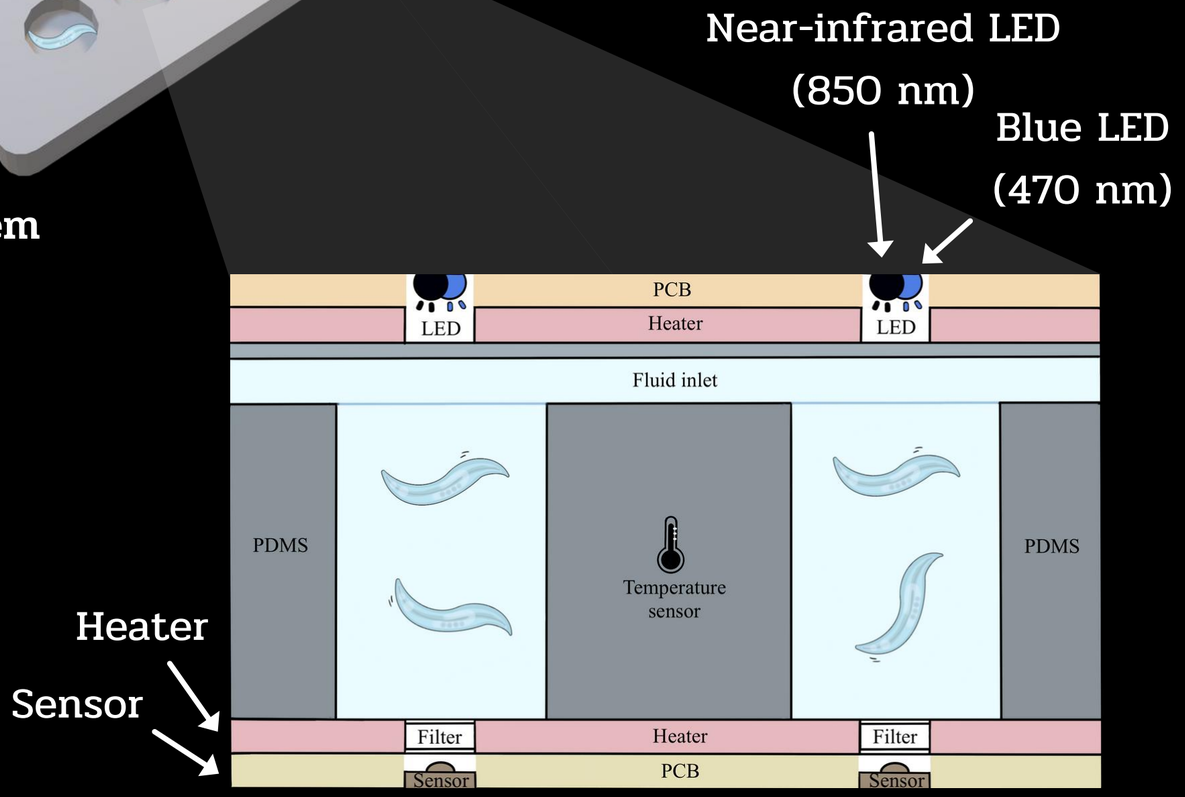
Credit photo: https://kt.cern/technologies/timepix3

Payload



AIBO payload

16 wells microfluidic chip



Autonomous intelligence biological operating system

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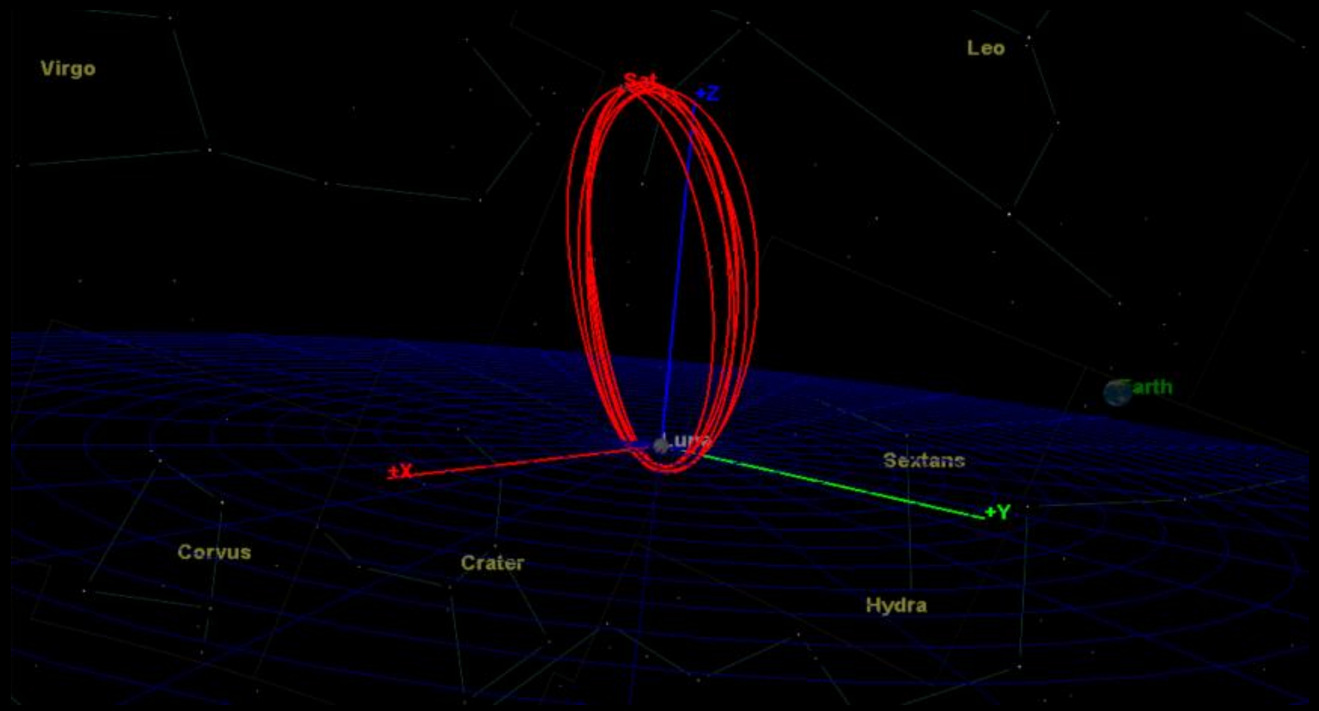
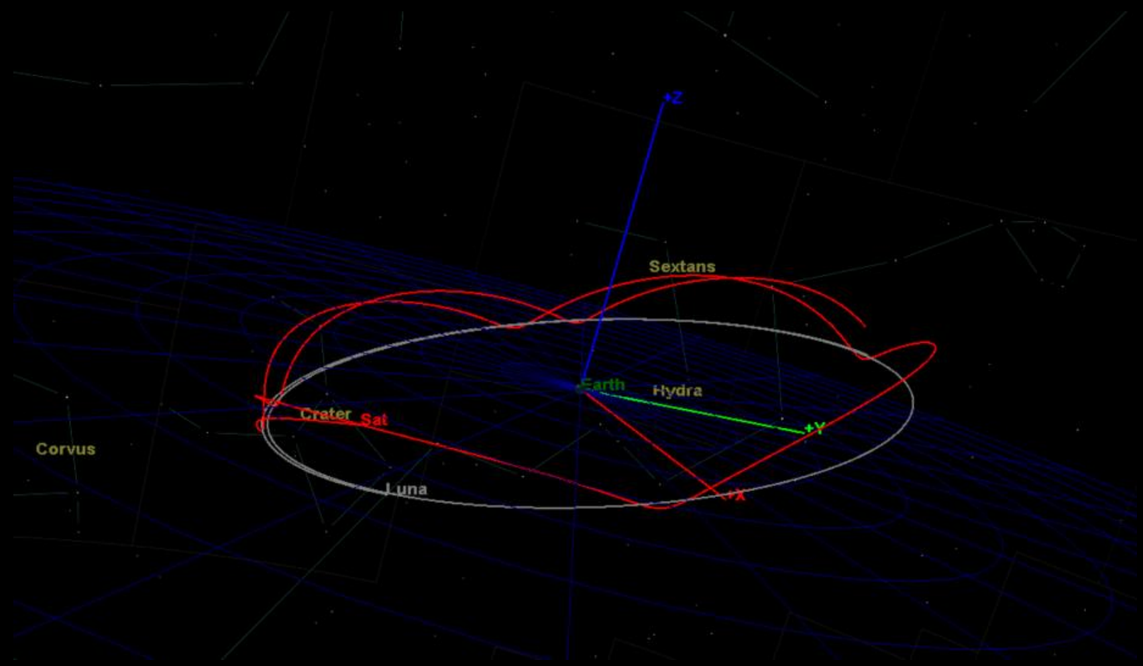
Credit photo: https://kt.cern/technologies/timepix3

ORBITAL TRAJECTORY SIMULATION

L2 North family near-rectilinear halo orbit (NRHO)

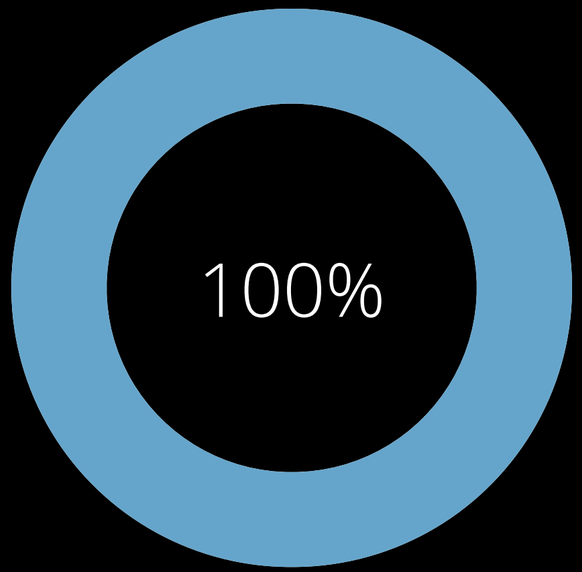


Moon-centered Earth-Moon rotating frame



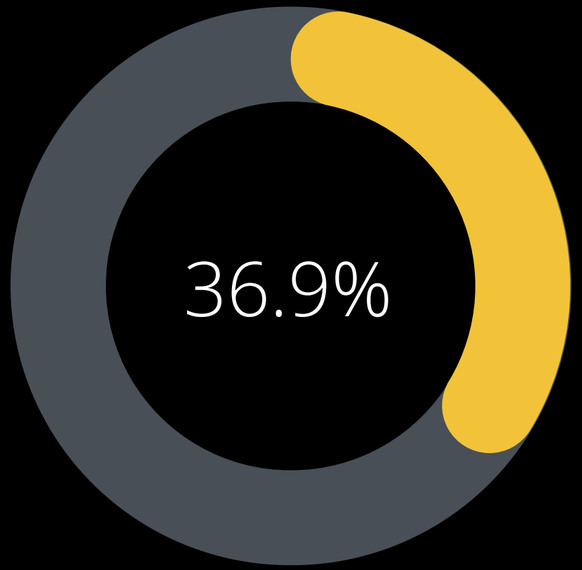
Earth-centered Sun-Earth rotating frame

POWER BUDGET ANALYSIS



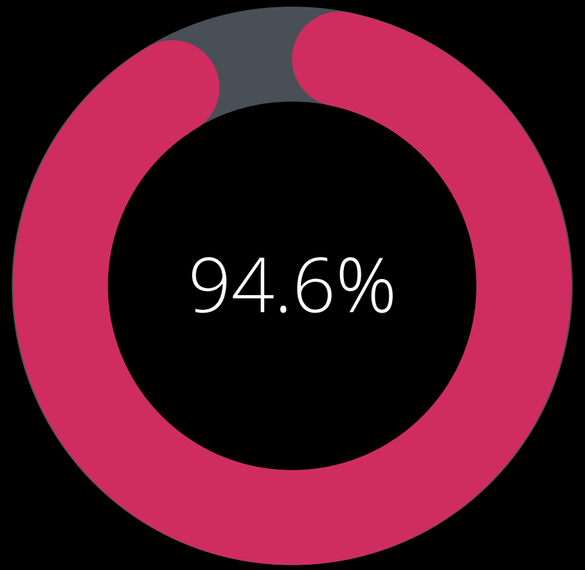
Maximum Generated

84 W at BOL



Average Consumption

30.998 W

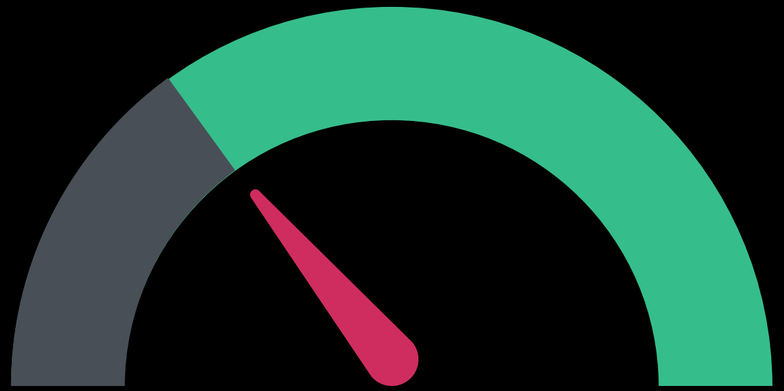


Peak Consumption

78.593 W

LINK BUDGET ANALYSIS

Downlink



Power Min. 10.5 dB

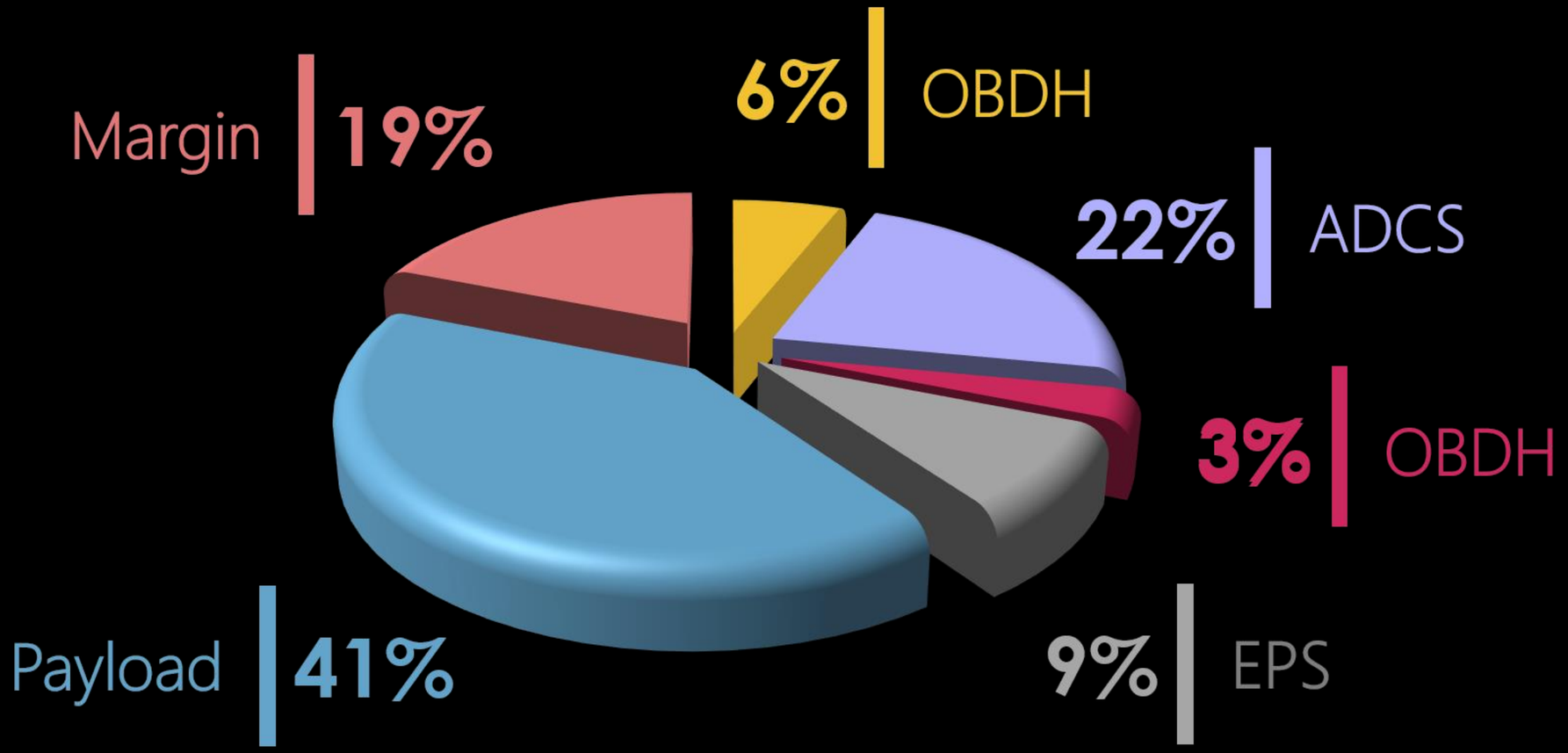
70% Link margin

Uplink

Power Min. 10.5 dB

87.5% Link margin

VOLUME BUDGET ANALYSIS



Mission Timeline

START

1 Literature review & Mission design
May 2021

2 Mission analysis
July 2021

3 Preliminary research on transgenic yeast (S. cerevisiae)
Mar 2022

4 Ethic submission
Jan 2021

5 Preliminary design review
Mar 2022

6 Study C. elegans hibernation & Radiation exposure
Apr 2021

7 Gene modification in C. elegans
July 2022

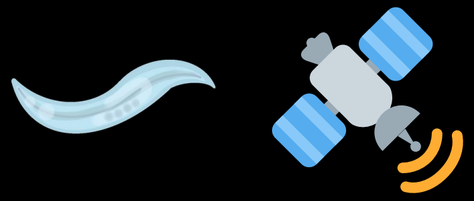
8 Engineering model development
Dec 2022

9 Subsystems assembly, integration and testing
Sep 2023

10 Build flight model
Jan 2024

LAUNCH
2025

Conclusion



CubeSat platform with autonomous technologies for culturing C. elegans and DNA damage detection

Prevent long term chronic health disease

Future space medicine development

Increase feasibility for future space exploration

United Nation Sustainable Development Goals (UNSDGs)

- Provide CubeSat platform to study the biological effects of C. elegans
- Provide a rudimentary basis for developing space medicine that protects astronauts from radiation in the future

- Space community for educating next generation of space engineer
- Establish a learning foundation corresponding to space biology

Our Team

Assoc. Prof. Dr. Yodchanan Wongsawat
Project Investigator

Sumeth Klomchitcharoen
Project Manager

Tanchanok Tangwattansirikun
Sub-project Manager

Sean Gallup
Science Co-lead
Astrophysics

Norawit Nangsue
Guidance, Navigation & Control

Pichamon Phatthanaanukun
Spacecraft System

Jin Tangkijngamwong
Structure & Thermal control

Pisitchai Tachavises
Science Co-lead
Astrobiology

Benjamard Jirapanyalerd
AIBO & Dosimeter

Siripak Chattanupakorn
Radiobiology

Visarut Rungpongvanich
Caenorhabditis elegans

Noparin Smerwong
Gene editing

Peetimon Arunwiriyahkit
Gene editing

Question?

Contact us

Instagram: https://www.instagram.com/isslm_minerva

Facebook: https://www.facebook.com/ISSLsM

Sumeth Klomchitcharoen

Project Manager of Minerva

Email: sumeth.klo@student.mahidol.ac.th

Tanchanok Tangwattanasirikun

Sub-project Manager of Minerva

Email: tanchanok.tan@student.mahidol.ac.th