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SPIRIT OF INQUIRY

MISSION

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Observation of Telomere Length Changes in the Deep Space Radiation Environment

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UACA

AD SAPIENTIAM ET HONOREM

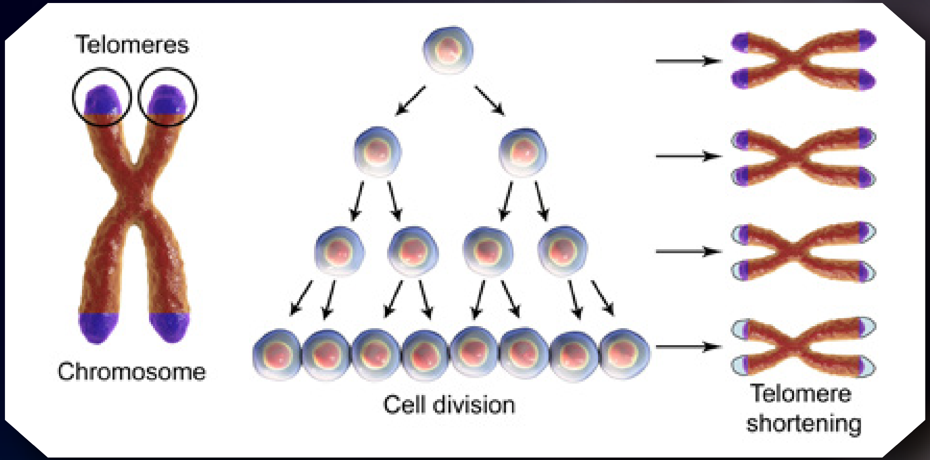
NEED

Between 2000 and 2015:

- Life expectancy at birth increased 5.5 years.
- Healthy life expectancy increased 4.6 years

What are Telomeres?

Telomeres are located at the tips of chromosomes. In humans, the telomeric repeat sequence is 5´ TTAGGG 3´ and this important structure is responsible for protecting chromoso-mesduring DNA replication by providing additional length during the replication process. Telomerase is an enzyme formed by a ribonu cleic acid protein complex, present in germ cells, differentiated stem cells and fetal tissues. Telome-res are shortened with each replication and telomerase resto-res telomeres, maintaining DNA homeostasis (i.e., the stable and ideal condition of the organi sm) When telomeres are kept long, the chromosome is properly protected, ensuring correct replications, and reducing the effects of aging such as mutations and excessive apoptosis (cell death)



Telomere shortening related diseases

Table 1 is a list of some of the diseases related to telomere shortening.

Neurological diseases	Genetic diseases	Other diseases.
Telomere shortening is related to the pathogenesis of neurological diseases and intellectual disabilities	Related to DNA mutation, because the telomeres are too short and do not produce enough telomerase to protect the genetic code.	
○ Autism Spectrum Disorders (ASD), Epilepsy and other intellectual disabilities: the telomeres, because of their short length causing the inability to protect the DNA well, lead to the mutation of the ACTL6B gene ○ Schizophrenia: related to the gene SETD1 A, a lysine methyltransferase. Deletions (shortening of DNA and therefore loss of genetic material) of chromosome 22, also called 22q11 . ○ Alzheimer's disease (AD): due to the death of cells due to their accelerated aging, caused by very short telomeres. ○ Parkinson's disease (PD). ○ Depression.	○ Cancer: cancer, also known as malignant neoplasm, is a disease caused by an uncontrolled multiplication of abnormal cells, which invade nearby tissues. DNA mutates due to telomere shortening, caused because of a deficit in telomerase production. A healthy cell wou ld undergo the process of senescence (cellular aging) and lead to apoptosis (programmed cell death). Cancer cells evade this process by producing telomerase. ○ Dyskeratosis congenita: related to telomere shortening, which is unable to protect the DNA correctly, generating a mutation in the DKC1 gene. ○ Aplastic anemia: the short telomere length in hematopoietic cells proceed to mutation.	○ Bone marrow failure: It is a hematopoietic dysfunction caused by defective and short telomere structure, causing DNA not to repair properly. ○ Pulmonary fibrosis: This disease is generated due to poor telomerase segregation, leading to telomere shortening to avoid mutations. It has also been observed that cryogenic liver cirrhosis is related to the mutations accompanying this disease.

Existing work on telomere lengthening in space.

The NASA twins experiment was the first project to question the effects of zero gravity and space travel on cellular aging. The results showed that the twin who remained on Earth had no major changes in their telomeres. However, what was impressive was tha t the telomeres of the twin in space lengthened significantly. This experiment demonstrates that antigravity may work as a possible solution to the treatment of diseases caused by short telomeres.

Why is our experiment important?

Spirit of Inquiry aims to study telomere biology by observing their behavior in deep space. This basic understanding of the molecular mechanisms could lead to a better understanding of the general aging process in humans and the resulting diseases. For this mission we have decided to study the effects of high energy radiation on telomeres, as this environment is difficult to replicate on Earth for prolonged periods. To our knowledge, there is not enough scientific evidence and knowledge about telomeres being exposed to ioni zing radiation and its consequences in the long term. According to the National Cancer Institute, high energy radiation is extremely dangerous
since it has sufficient energy to eject electrons from atoms or molecules, especially nucleic acids. Ionizing rad iation produces chemical changes in cells and damages DNA which could eventually lead to cancer development. Studies have shown that exposure of telomeres to ionizing radiation increases telomerase activity (key to telomere lengthening so that DNA remains healthy), especially in cancer cells

Sustainable Development-goals

Health and well-being

Studying how telomeres behave in the deep space environment will improve our understanding of the mechanisms that affect aging and disease, which could impr ove quality of life and increase life expectancy.

Innovation

This mission will serve as a demonstrator of using proven technologies to quickly develop and run new experiments while accelerating transfer of existing technologies to emerging space organiza tions. This is important for increasing democratization of deep space.

Reduced inequalities

The knowledge gained can help develop affordable treatments to attenuate the effects of cancer, cellular aging, and prevention of neurodegenerative and autoimmune diseases, reducing inequalities derived from elderly care.

MISSION OBJECTIVES

GENERAL

Investigate the effects of deep space high energy radiation and microgravity on telomeres using yeast as a model organism.

SPECIFIC

1 Contribute to future human missions to Mars by deepening the understanding of the risks presented by cosmic rays and high energy solar radiation during deep space flight.

2 Contribute to regenerative medicine by observing telomere length changes in deep space to better understand the aging process, cell rejuvenation, and identify mechanisms of cancer growth.

CONCEPT OF OPERATIONS

Including orbital design experimental concept and setup

FIRST PHASE | Pre launch operations

- The satellite is delivered to the launch provider 6 months in advance of the launch.
- The CubeSat is handed over to the integrator and the yeast remains dehydrated until launch.

SECOND PHASE | Launch and Coasting

- Launch as secondary payload.
- Coast for approximately 4 days after launch.

THIRD PHASE | Experiment operations

- Detumbling.
- Attitude correction and solar panel deployment.
- Rehydrated yeast

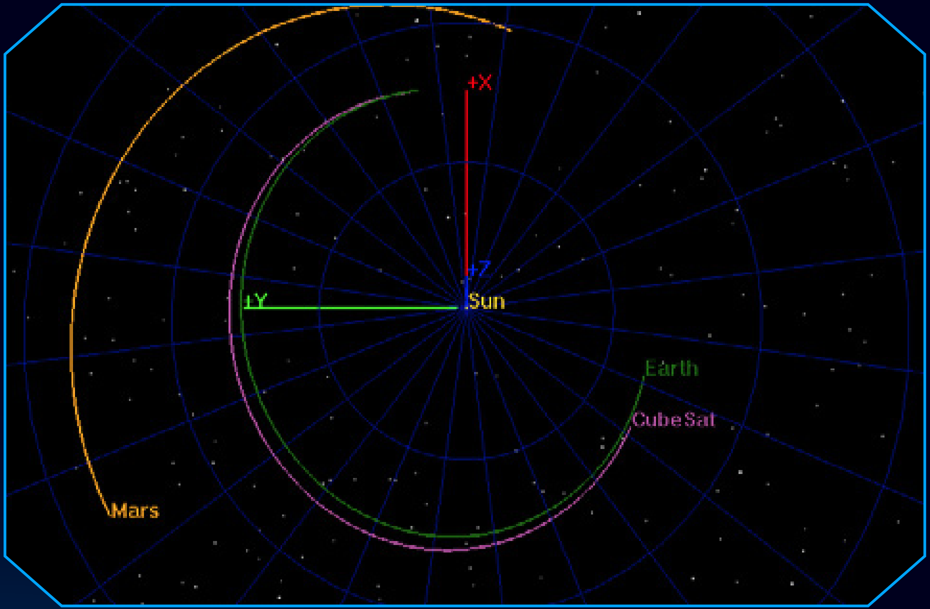
FOURTH PHASE | Mission disposal

- Remain in heliocentric orbit and transmit position.

ORBITAL DESIGN

- Heliocentric orbit.
- Upper stage disposal.
- Maximum distance during mission from earth 0.3 AU and Sun 1.04 AU.
- Perihelion 0.99 AU aphelion 1.05 AU.

Diagram of mission's orbit



KEY PERFORMACE PARAMETERS

Telomere observation will be performed once daily over a period of 8 months.

The downlink bit rate ranges from 8 bit/s to 32 kbit/s. Uplink has two modes: 16 bit/s for emergency and 1000 bit/s for normal operations. The TT&C and communications sys tem is effective up to 0.4 AU. The maneuverable antenna is accurate to 1°.

The yeast will be supplied with nutrients and rehydrated after Spirit of Inquiry exits Earth's magnetosphere.

Temperature within the research payload of 25C ±1

Each satellite will carry ten microfluidic cartridges. Each cartridge will contain eight unhealthy short telomere yeast samples, and eight health y normal telomere yeast samples.

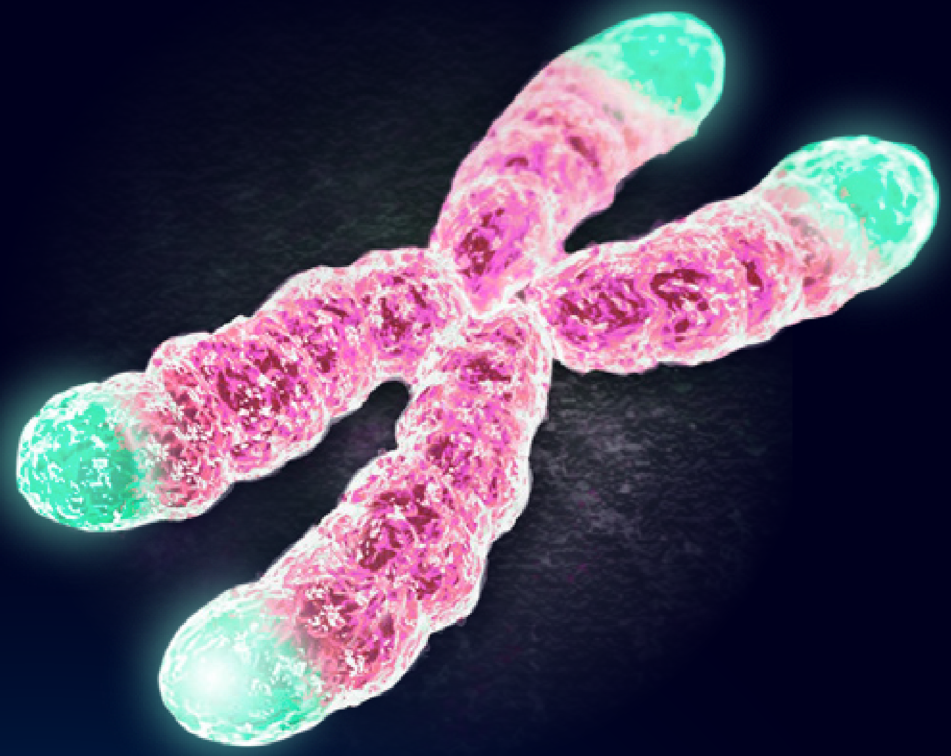
Technologies that must be further developed:

- **Inserting fluorescent proteins (GFPs) next to telomere sequences:**

  The Technology Readiness Level of inserting fluorescent proteins (GFPs) next to telomere sequences is nine because it has been tested successfully, for example to study interactions of human telomeric DNA binding proteins with telomeric DNA

- **Cold gas attitude thrusters:**

  The Technology Readiness Level of Cold gas attitude thrusters is nine because it has been tested in successful mission operations. The development of cold gas thrusters in CubeSats is not as advanced as in rockets, but there is resear ch in the development of 3D Printed Cold gas thrusters for the BioSentinel mission.

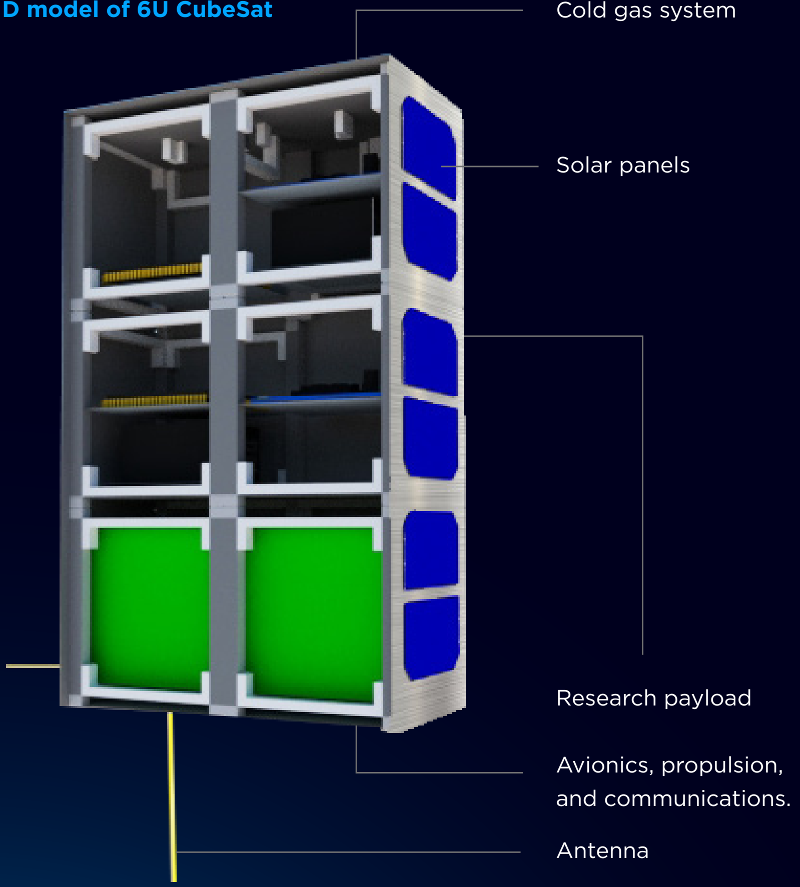


SPACE SEGMENT
DESCRIPTION

OVERVIEW

- 6U
- 19kg
- Solar powered
- Reaction wheels and thrusters
- 4U for experiment

3 D model of 6U CubeSat



EXPERIMENT
EQUIPMENT

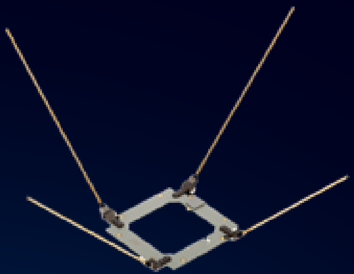
For the experiment, yeast will be used to study the behavior of DNA in deep space, specifically S. Castelli, because it is known for having regular telomere sequences (TCTGG-G(TG). This is crucial for simulating human telomeres. Inserting Green Fluorescent Proteins (GFPs) next to these sequences will allow the length of telomeres to be monitored. The proteins fluoresce when exposed to light of a specific wavelength, which is provide d by an LED. Photodiodes detect the fluorescent light and record the intensity, which corresponds to the length of the telomeres. These intensities will be compared to a control sample on Earth.

To reduce development time and risk, the yeast will be stor ed and grown with the system developed for NASA's Bio-Sentinel mission. Microfluidic cartridges will contain the yeast, with one cartridge having 16 wells. Eight wells will be filled with unhealthy yeast that have short telomeres, and the other eight are fi lled with healthy yeast with normal telomeres. The cartridges will allow for nutrient control and a stable growth environment. Heating elements will also be used for temperature stability. The yeast will be deprived of sugar and water until the spacecraft is released from the upper stage and stabilized. On earth, 10 microfluidic cartridges will be grown in the same system and monitored as the control. The onboard computer will capture the length measurements along with measurements of the radiation and send them back. On earth, 10 microfluidic cartridges will be grown in the same system, and monitored as the control

COMMUNICATIONS EQUIPMENT

- TT&C and communications system used by PROCYON.
- Two low gain X band patch antennas for uplink with 7.1 GHz of frequency
- Two low gain X band patch antennas for downlink with 8.4 GHz of frequency.
- One medium gain X band patch antenna, and one maneuverable high gain X band antenna.
- Bit rate varies from 8bps to 32kbps.
- High efficiency (30%) Gallium Nitride power amplifiers.

The power consumption of the system is 44 W. 60 min per pass to retrieve mission science, health and status, and performance data and to uplink commands.



- Emergency telemetry and high rate telemetry: the time delay for communications could be around 20 minutes.
- For ground operations , we will use the Ground Station for Deep Space Exploration and Telecommunication located in Saku City in Japan.

NASA’s Deep Space Network

POSITION AND ATTITUDE CONTROL

- Star-tracker, IMU and sun sensors
- Reaction wheels for fine adjustments
- Cold gas thrusters for detumbling and desaturation
- 150g isobutane with Isp of 65 s

POWER GENERATION AND STORAGE:

- 73W generated from solar panels
- No day/ night equipment cycle
- Peak load 63 W
- Idle in experiment mode 21W
- 48.8 Wh of battery capacity

SPECIAL ASPECTS
OF THE MISSION

Estimated hardware costs

Research $33,824	Power: $98,400	Propulsion $88,936	Communications $24,797	Structural $6,400
1 S. Castelli yeast: $490	Solar Panels: $9900	Reaction wheels: $20,000	Low Gain Patch: $8795	6U CubeSat
1 Fluorescent Protein: $294	Batteries: $28.15	IMU: $236	Antennas: $1993	
1 Photodiode sensor:$60		Cold Gas Thrusters $ 20,000	PSK modulation: $4515	
1 Temperature sensor:$232		Monopropellant thruster:$13400	2 medium gain patch antenna:$5394	
1 Radiation sensor:$475		Star Tracker: $32 000	X band patch antenna: $4100	
1 Pressure sensor:$378		Sun sensors:$3300		
1 LEDs:$185				

Estimated total costs

Hardware Costs	Development costs	Launch costs	Operations costs	TOTAL
$252 357	$200,000	It is approximately $ 600 thousand dollars for 6 units, however CubeSats have not been sent commercially to deep space before.	$40 000	$492,000 - $1, 092,000

Project Implementation 2022 2024

Design	5 - 6 Months
Development (experiment & software)	8 Months
Construction	4 Months
Testing	2 Months
Launch Vehicle Integration	6 Months
Primary Mission	8 months

RISK MITIGATION

RISKS

Maximizing launch opportunities

Reducing likelihood of delays

Reduce likelihood of component failure

Increasing safety margins

R&D for Telomere Observation Method	Medium
Battery Degradation	Low
Radiation Damage to instruments	Medium
Yeast life support failure	Low
Insufficient funding	High
Unsuccessful initial communication with satellite	Medium - High

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