
CLARIS Cubesat Lander
Autonomous Rolling and
Inspection Satellite
L'impegno italiano nel settore dei CubeSat: tecnologie e missioni future
ASI

The concept

How can a cubesat move on a planetary surface and collect samples efficiently without occupying the internal volume of the probe?

CLARIS Operation Scenario

The **CLARIS** (**C**ubesat **L**ander **A**utonomous **R**olling and **I**nspection **S**atellite) family offers a versatile and innovative approach to planetary exploration, capable of being deployed from various platforms on the Moon, Mars, Martian moons, or asteroids. This scenario outlines its operational deployment and functionality.

Deployment from Rovers and Landers

CLARIS can be released from rovers or landers stationed on the lunar or Martian surface. Once deployed, its structural components transform into mobile "fingers" that enable the cubesat to roll across the terrain autonomously. These fingers, initially designed to support launch stresses, are repurposed for locomotion and sampling activities.

Martian Moon or asteroids

In scenarios involving Martian moons or asteroids, an orbiter may be deployed from a mothership and inserted into the sphere of influence of the target body. The orbiter would conduct a detailed survey and analysis, aiding in the selection of an optimal landing site. Following this, the orbiter would enter a close orbit and deploy the CLARIS lander for in-situ analyses, providing comprehensive data on the target surface.

Versatile Locomotion for Diverse Gravitational Environments

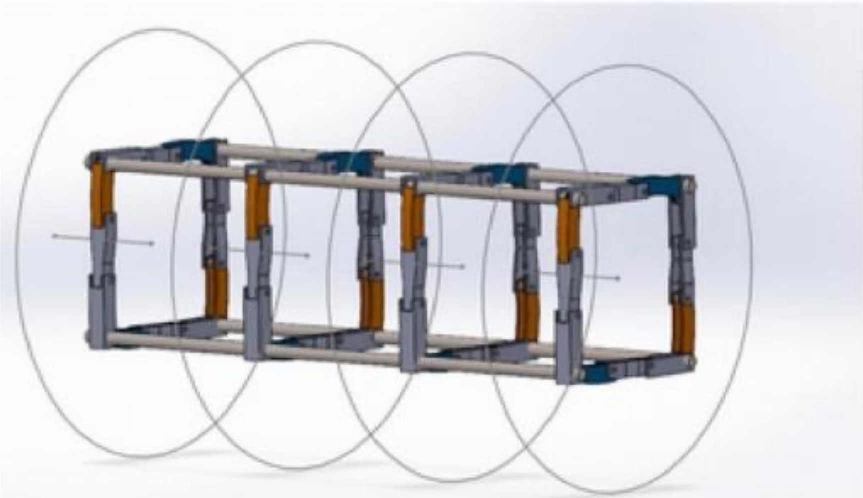
Depending on the gravity of the operating environment, CLARIS offers different locomotion options. For low-gravity environments, a specialized system will be employed to ensure effective movement and stability.

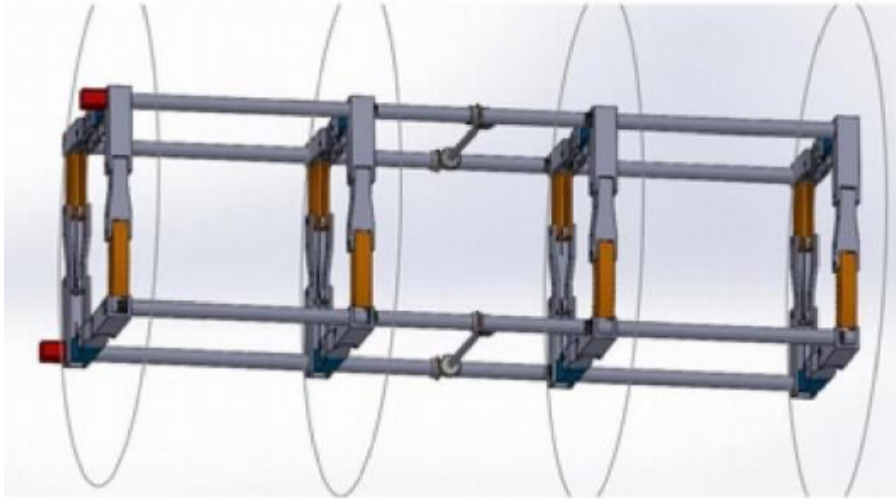
Low gravity solution

Innovative Design and Functionality

The innovative approach of CLARIS utilizes its structure beyond just load-bearing during launch. Once in operation, parts of the cubesat frame transform into mobile "fingers." These fingers allow CLARIS to roll across the surface and perform autonomous sampling activities. The central fingers are specifically designed to collect regolith samples and deposit them inside the satellite, where an analyzer instrument is located. This clever use of the cubesat's body ensures that the internal volume is preserved for scientific instruments and data processing units, maximizing the utility and efficiency of the space within the satellite.

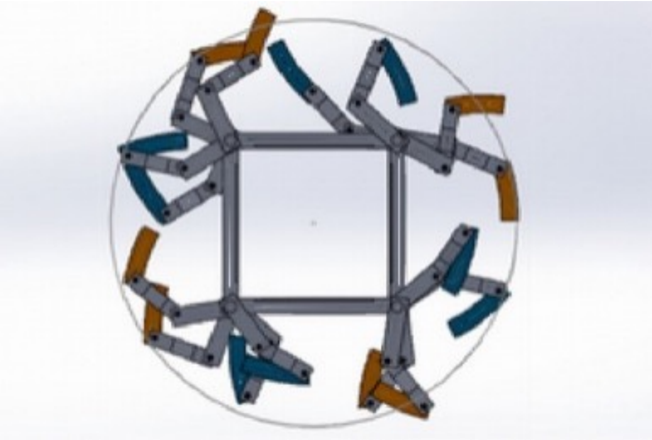
Original idea

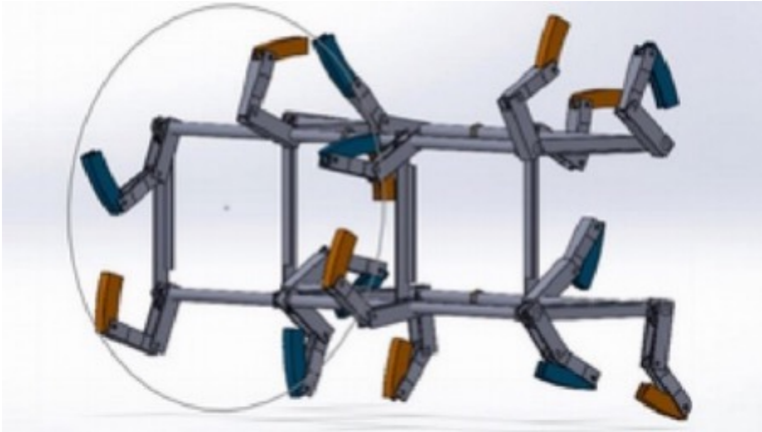




The sides of the square that form the structure of the cube-sat are segmented into parts. These segments, which act as fingers, are constrained in specific ways that allow the body to shift in space. The movement of these fingers enables the cube-sat to roll across the surface

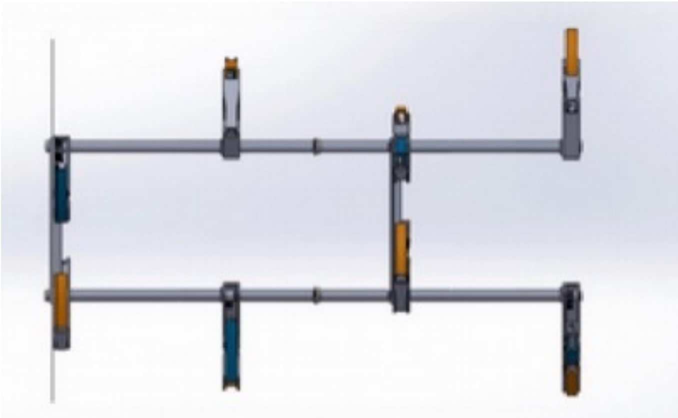
Locomotion Phase

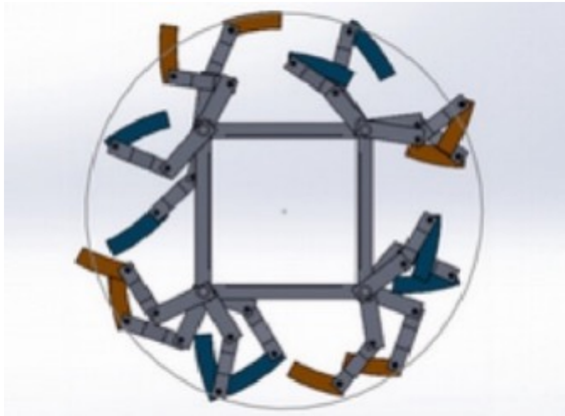




Each side of the square is conceptualized as a human finger, allowing us to design the segments in a configuration that enables the entire structure to move across a surface. The tips of the fingers are curved to enhance ground contact, and each segment is angled relative to the others to ensure continuous and effective contact with the ground.

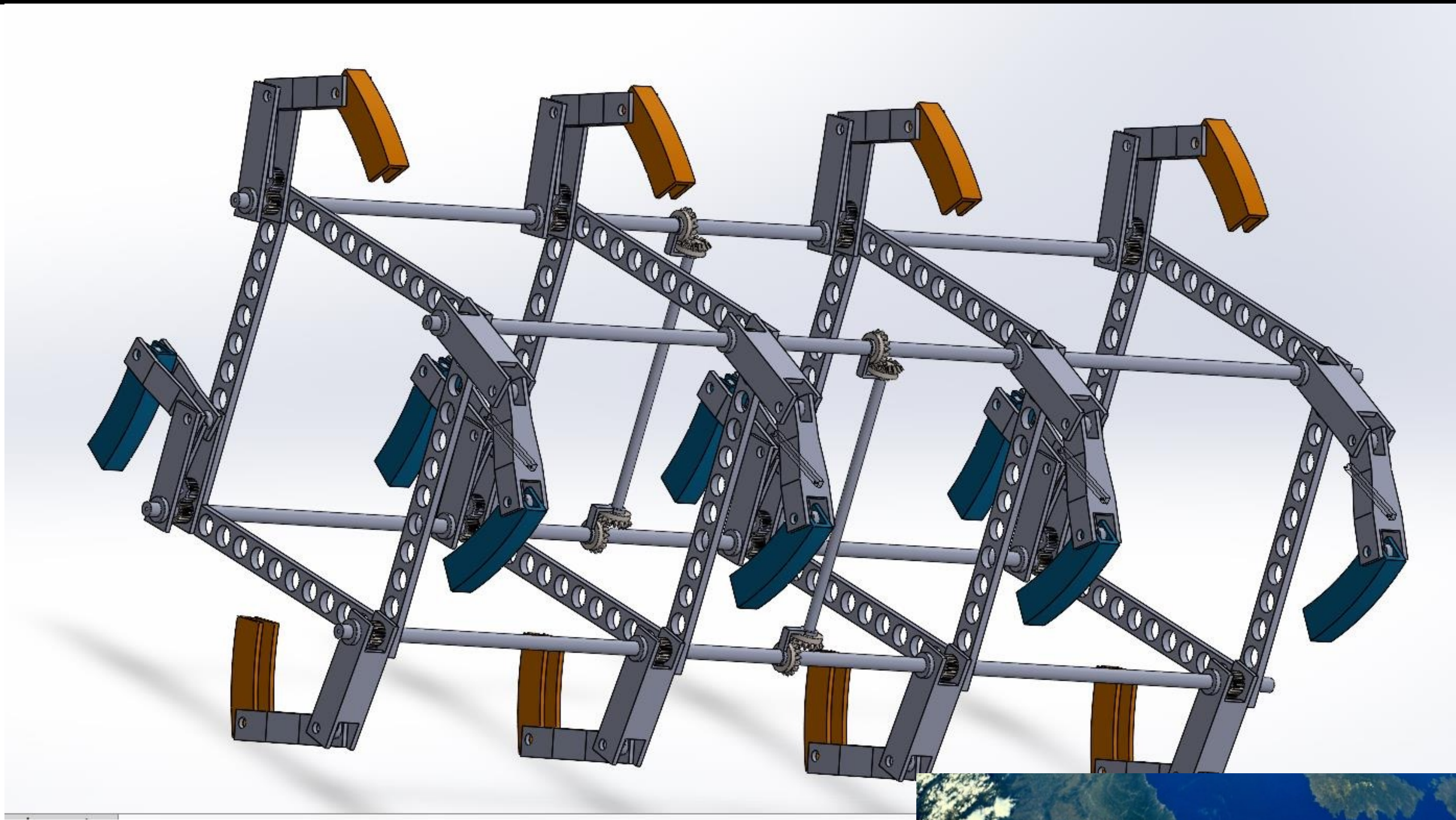
Locomotion Phase



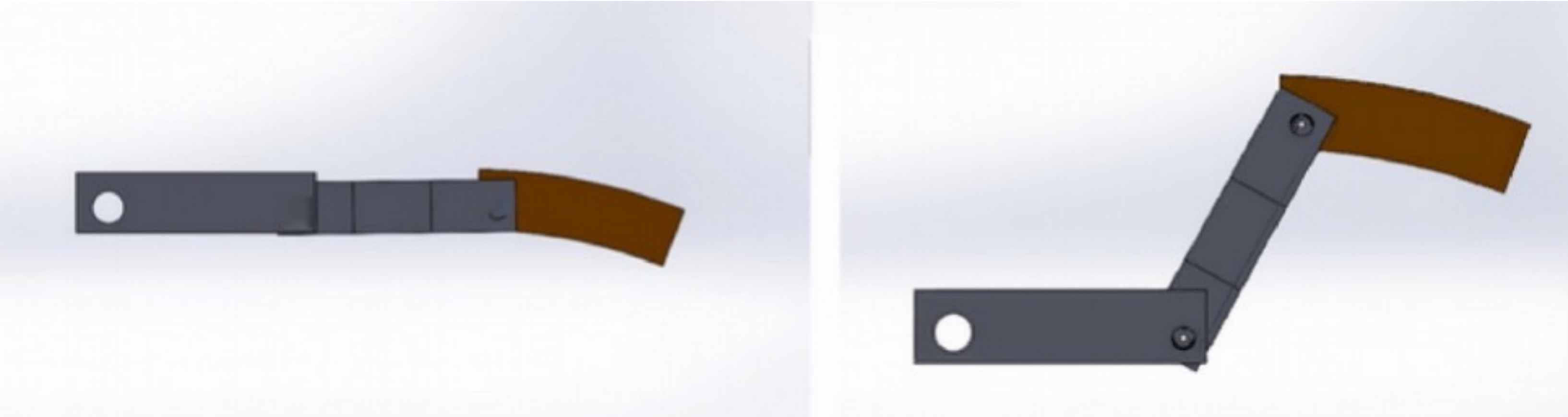


Each finger, once deployed around the body, covers a specific area. The arrangement of these elements extends the functionality of the cube-sat, enabling it to manoeuvre in space. This configuration is held in place by springs, which, when in the square configuration, are loaded with tension. Upon release, the springs forcefully extend the fingers into positions that facilitate movement

Final Configuration



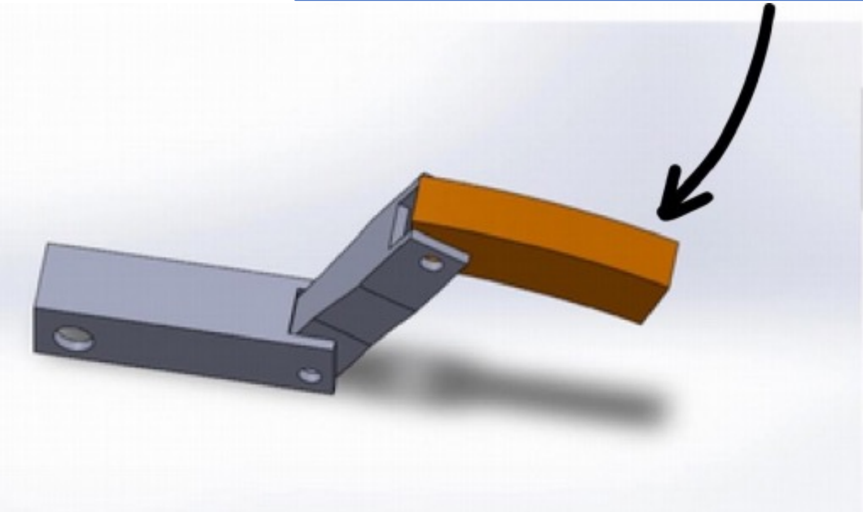
Fingers

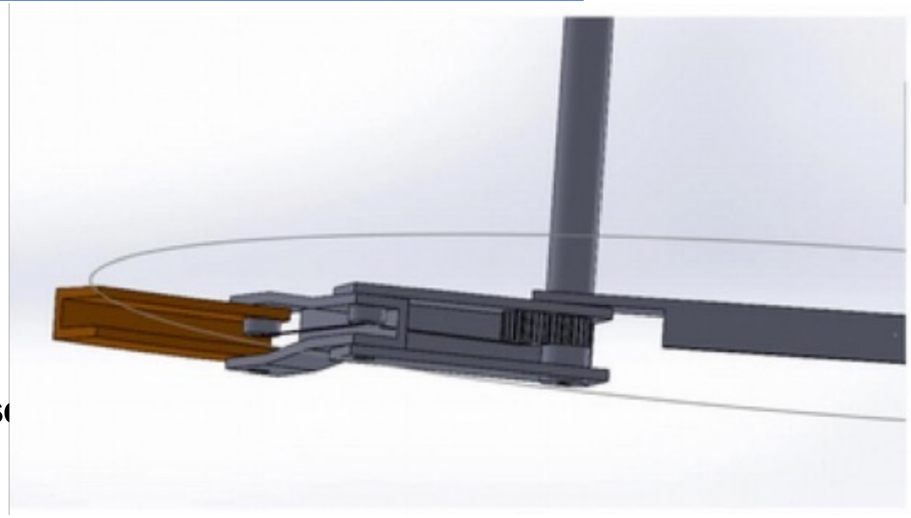


The design of each finger involves segmenting a 10 cm long bar. Using various springs, this segmented bar can achieve the position shown on the left once its constraints are released. A link-bar mechanism transmits torque from the base of the finger to the tip, focusing force on a restricted area and ensuring the stability of the other segments.

Fingers

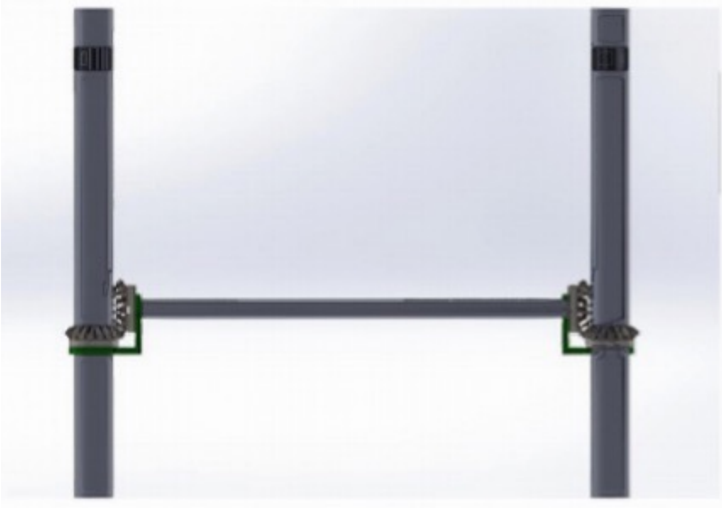
Phalange that can be used to collect regolith also

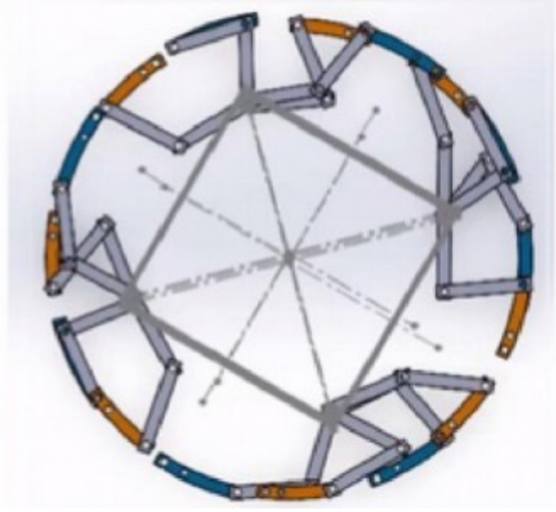




Finger Design: The fingers are crafted in a C-shaped model to minimize mass and enhance compactness. This design allows the movement mechanism to be integrated within the fingers themselves. When a sample is collected, the finger can transfer it directly to an analyzer inside the cubesat, facilitating immediate scientific analysis.

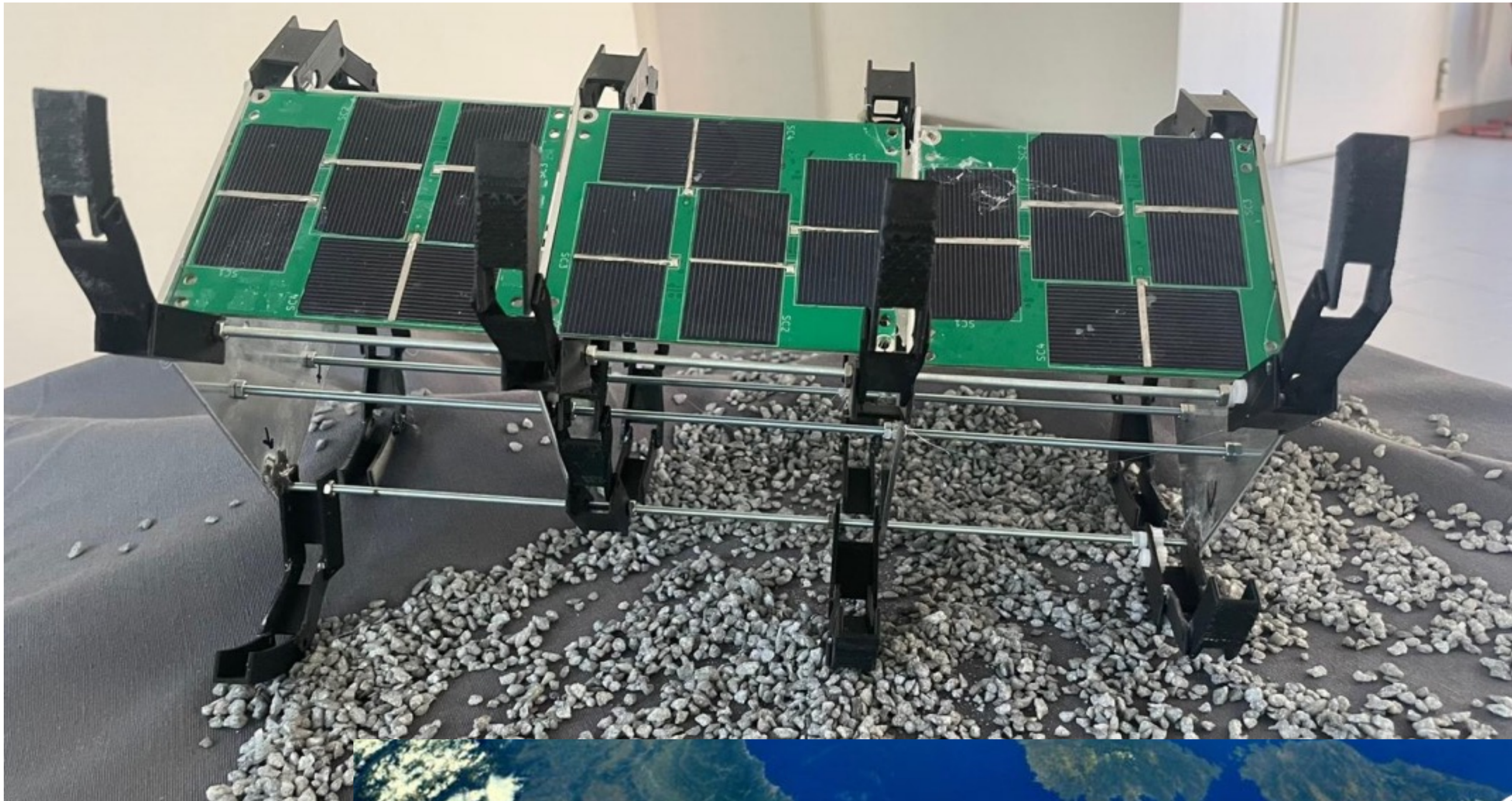
Motion transmission





Motion Transmission: The system requires only two small piezoelectric actuators to transmit torque from one shaft to another, effectively reducing the number of motors needed. In total, there are two piezo actuators, each 20 mm in diameter, developed in collaboration with Phi Drive. This efficient design ensures robust performance while maintaining a compact and lightweight structure

Breadboard Model

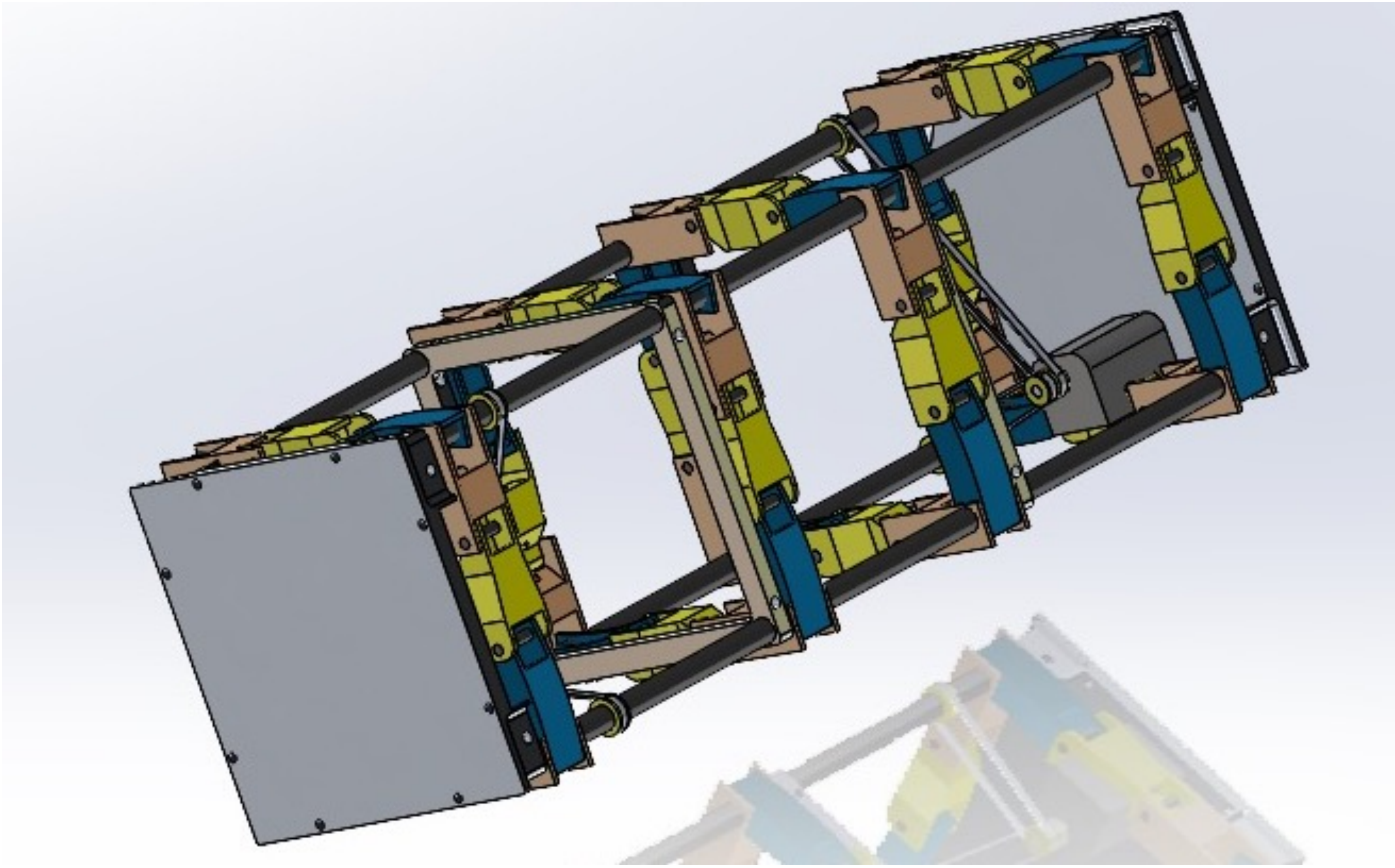


Improvements, Next Steps

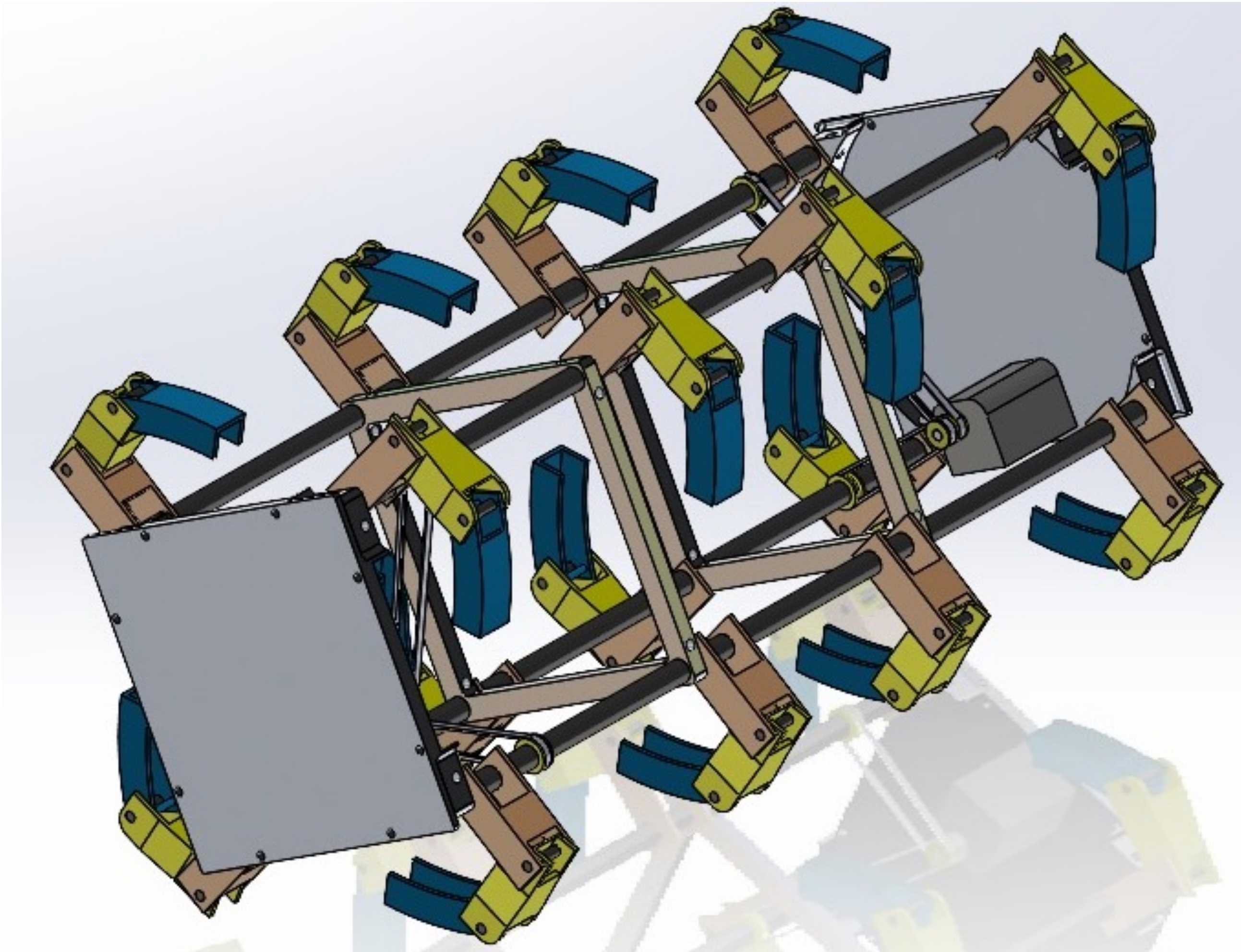
We are currently reviewing the mechanisms of the CLARIS cubesat, as described previously, to enhance performance and prevent potential failures caused by regolith particles (dust) that could jam the gear wheels. We are considering the use of compliant mechanisms for the fingers or a solution that actuates the fingers with Kevlar cables. Now, the latter solution seems the most promising.

Additionally, we are exploring the possibility of making the cubesat steerable by locking part of the fingers to allow rotation. This would enhance manoeuvrability and operational flexibility on the lunar surface.

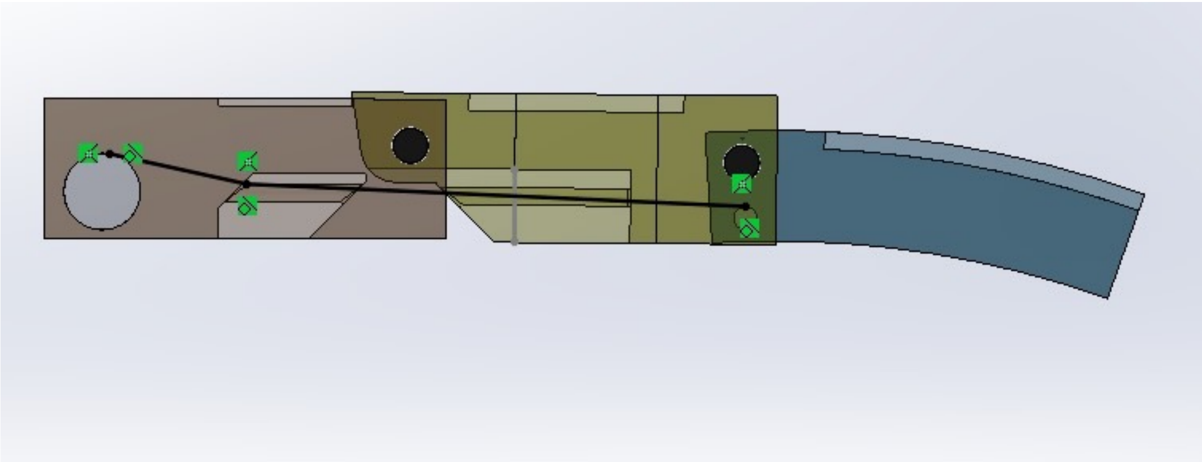
Configuration with Finger actuated with Kevlar



Configuration with Finger actuated with Kevlar



Finger actuated with Kevlar



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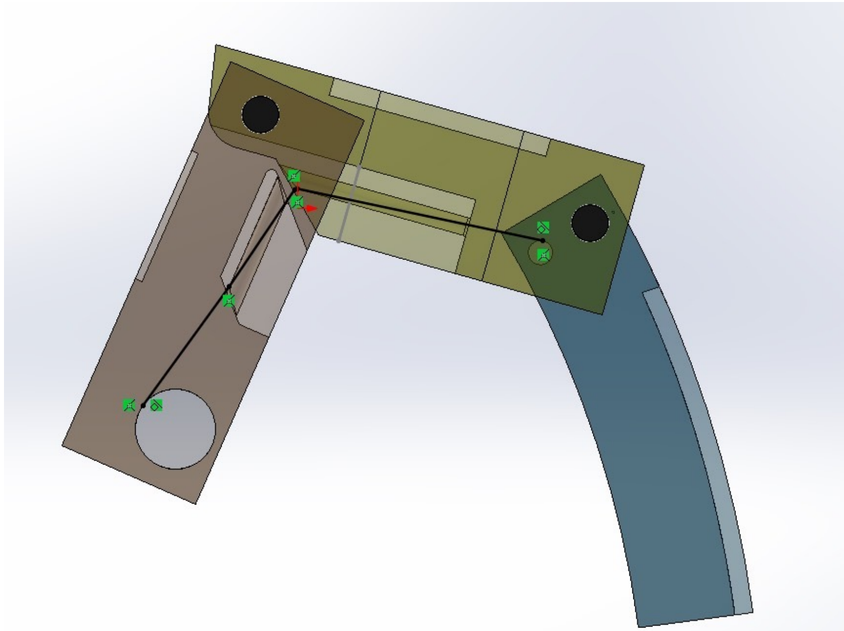


CLOSED

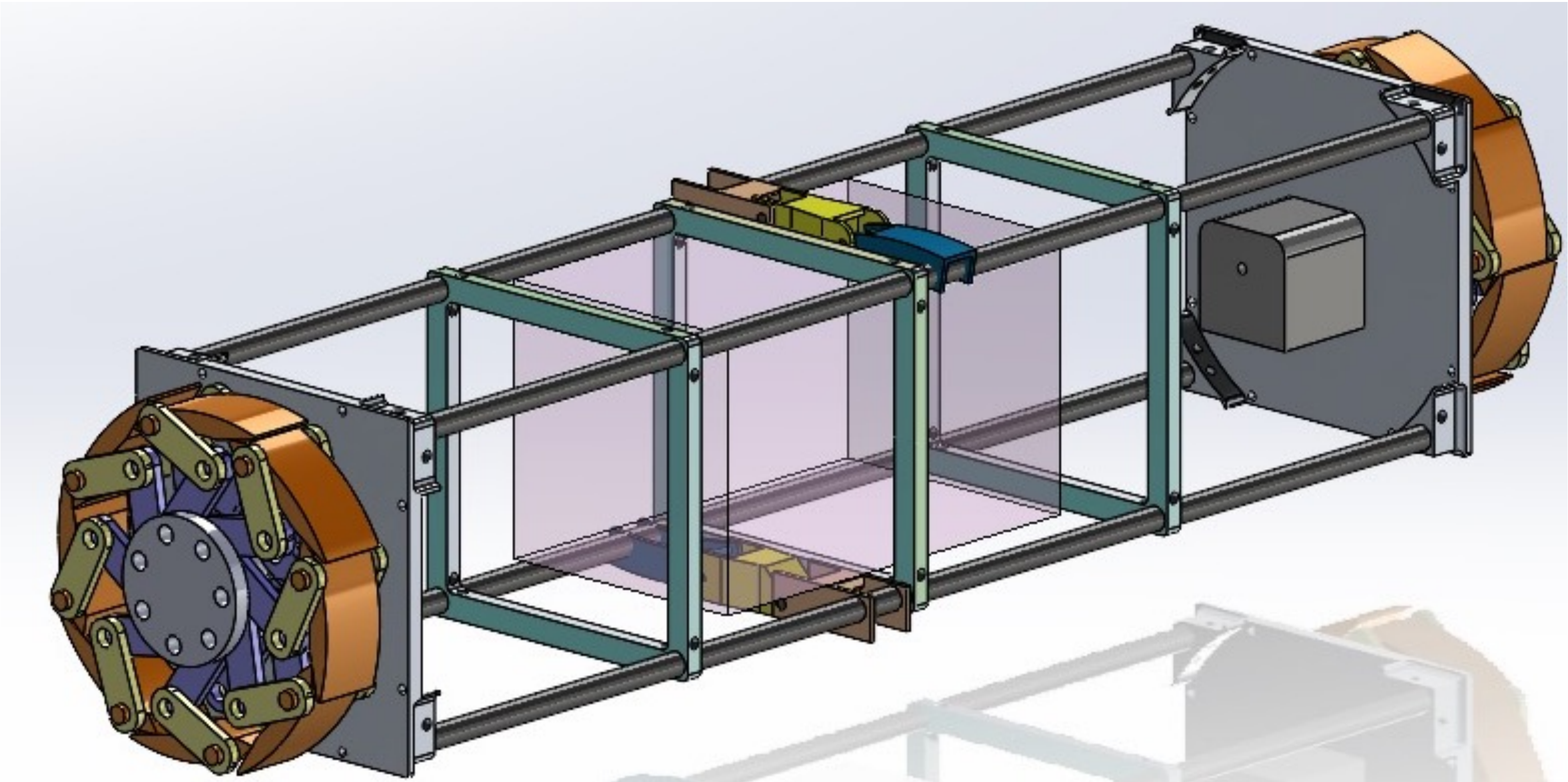
Concept evolution

Mixed Wheel and Passive Finger System
For missions where gravity becomes a significant factor, we propose a hybrid system featuring two wheels and passive fingers. This configuration is suitable for operations on the Moon or Mars.

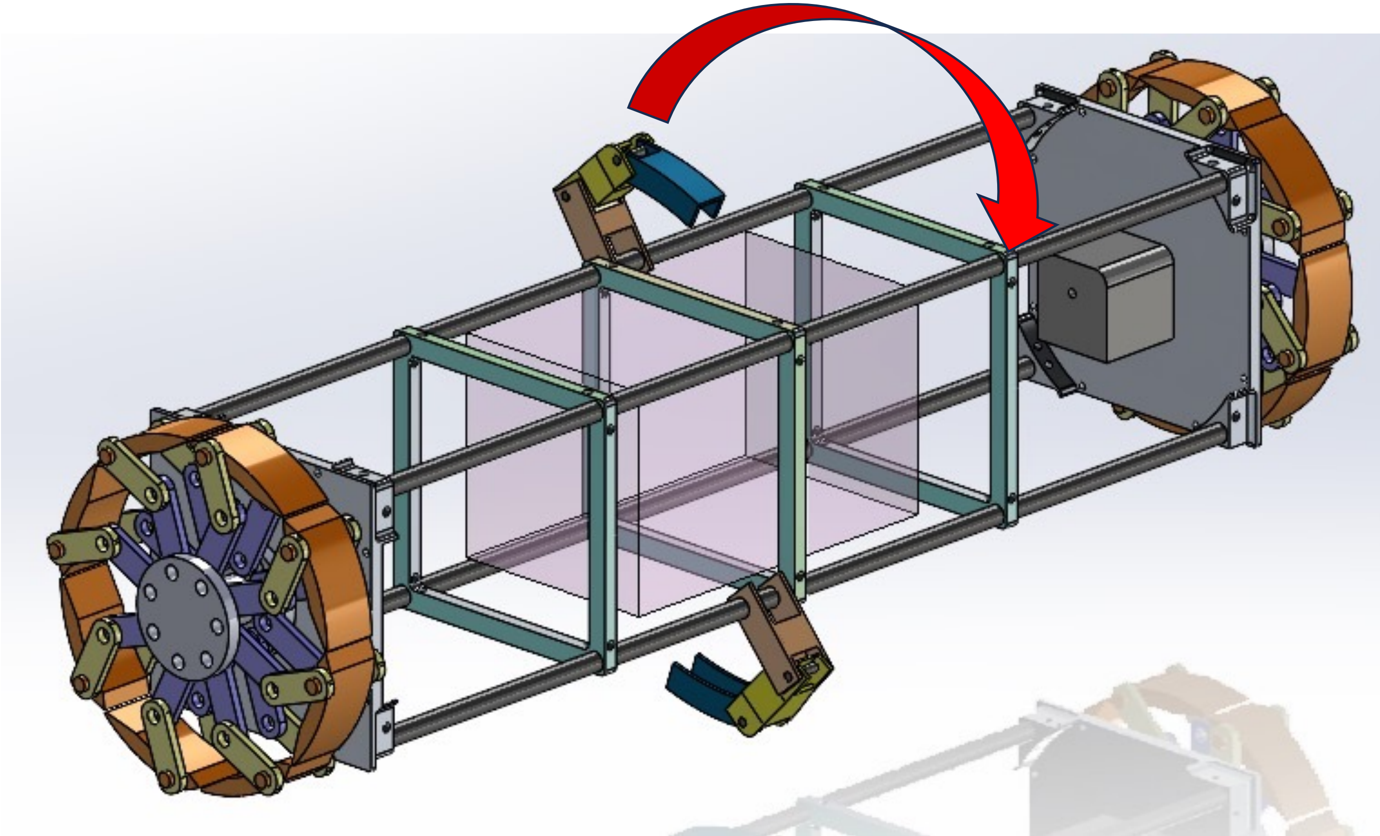
Deployment Mechanism
During launch, both the wheels and fingers are in a stowed position, secured by Kevlar cables. Upon reaching the lunar or Martian surface, these cables are released, allowing the components to deploy.

Wheel Configuration
Two Wheels: are positioned at both ends of the cubesat and are fixed to the structure, allowing it to roll efficiently across the surface.
Motors: Each wheel is driven by an individual motor, providing steerability and mobility.
Stowed Position: Wheels are secured during launch and deployed upon landing.
Passive Fingers
The passive fingers, initially stowed, are actuated by the cubesat’s movement across the surface. These fingers collect samples and transfer them into the instrument for analysis, enabling effective in-situ scientific investigations.

For Moon or Mars applications



For Moon or Mars applications with wheels solution



Claris Family

Configuration	Planetary Body	Locomotion Type	Size (U)	Instruments
CLARIS-Lunar	**Moon**	Rolling Fingers: 12 active fingers	4U	ABCS Integration, camera
		Rolling Fingers: 12 active fingers	3U	Sample container, Camera
CLARIS-Martian	**Mars**	Rolling Wheels & Fingers: 2 expandeble wheel and 2 passive finger	4U	ABCS Integration, camera
CLARIS-Asteroid	**Asteroid**	Rolling Fingers; 12 active fingers	4U	ABCS Integration, camera

Scientific Instrument

AstroBio CubeSat Instrument Overview

Claris, specifically designed to house the AstroBio CubeSat (ABCS) instrument, has been developed in collaboration with INAF (Istituto Nazionale di Astrofisica). This 3U CubeSat, launched on July 13th, 2022, with the Vega C maiden flight, hosts a mini laboratory based on Lab-on-Chip (LoC) technology, aimed at astrobiological research.

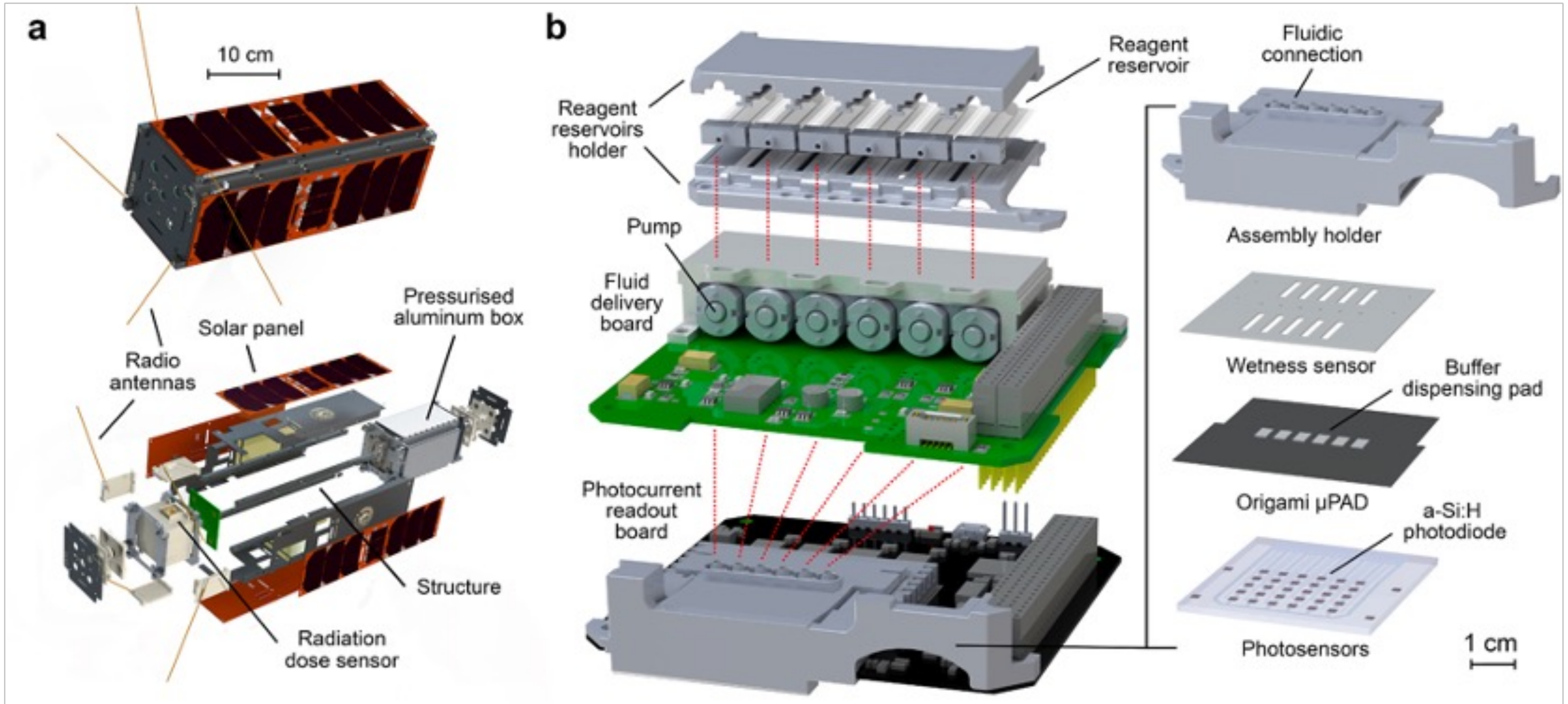
Instrument Details

- Lab-on-Chip Technology: The ABCS utilizes innovative LoC technology to conduct automated bioanalytical experiments in space.
- Chemiluminescence Detection: The instrument employs immunoassay techniques that use chemiluminescence detection to analyze samples.
- Harsh Environment Operation: Designed to function within the challenging environment of the Van Allen belt, it includes a pressurized and thermally controlled inner aluminium box to protect against radiation and maintain stable conditions for experiments.
- Autonomous Bioanalytical Experiments: Capable of executing bioanalytical experiments without human intervention, it assesses the stability of biomolecules in space and handles liquids in microgravity.
- Mission Objectives

The integration of the ABCS into Claris represents a significant advancement in the field of space-based astrobiology, enabling comprehensive scientific investigations with minimal human support.

ABCS – AstroBio CubeSat

Succesfully launched with the Vega-C maiden flight on July 13th 2022 in a circular orbit (altitude 5980 km, inclination 70°)



The AstroBio CubeSat instrument has a volume of 1.5U and will be integrated into the central position of CLARIS. It will be equipped with a regolith collector to gather and analyze samples.

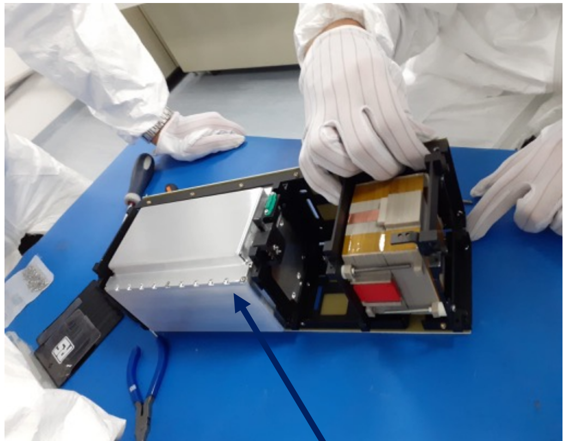
Objectives

ABCS hosts a miniaturized laboratory based on Lab-on-Chip technology providing a platform for an automatic bioanalytical experiments.

Quantitative chemiluminescence-based method is used with signals detected by photosensors.

The scientific applications are:

- **To search for signs of life in planetary exploration missions;**
- **To execute autonomous bioanalytical experiment in space;**
- **To monitor the human health in manned missions.**



Aluminum sealed box