# Sun cubE onE (SEE): a CubeSat Mission for High-Energy Solar Observations

Berrilli F., Giovannelli L., Marcelli L., Casolino M., Curti F., De Guzman M. A., Di Tana V., Pattanaro L., Marmonti M., Terracina A., Rossi A., Bruno A., Berretti M., Casara L., Del Moro D., Calchetti D., Cantoresi M., Chierichini S., Giri Nair A., Konow F., Lucaferri L., Nigro G., Penza V., Pucacco G., Reda R., Scardigli S., Tombesi F., Francisco G., V., Mazzotta P., Mugatwala R., Reali E., Albertini M., Benigno N., Iovanna F., Marcanio A., Turi A., Sarnari F., Cavazzuti E., Natalucci S., Urban D., Illiano S., Plainaki C., Carpentiero R.

Once the RTI is formed and we begin Phases C/D/E1, we'll be looking for contributions to SEE science from the Italian solar community (observations and models)
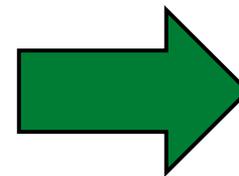
Scientific objectives

❑ Monitor solar flare emission from **soft-X** to **Gamma ray** energy range at very high cadence (up to 10 kHz)
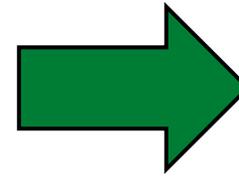
❑ **X/γ-ray payload**

❑ Monitor solar activity using **full disk** images in the **Mg II** at 280 nm, 4 images / day to better understand **solar-terrestrial relations**

❑ **UV imager payload**

Science requirements for the UV imager and X/γ-ray payloads

TOP LEVEL SCIENCE REQUIREMENTS	
Wavelength coverage	**From 279 to 281 nm (Mg II line)**
Spatial resolution	> 4 arcsec/pixel to resolve magnetic features
Spatial coverage (FOV)	Full disk + 50%, at least 50' x 50'
Pointing accuracy	9' or better
Pointing stability	20 arcsec Hz or better
Temporal resolution	**One image every 6 hours (context imager and segmentation of solar features)**
Temporal coverage	Uninterrupted unless eclipses or contingency
SNR	At least 10 considering out of band photons and straylight

TOP LEVEL SCIENCE REQUIREMENTS	
Energy coverage	**1,5 keV to 3 MeV**
Channels	4
Spatial resolution	Integrated measure (Sun-as-a-star)
Spatial coverage	Full disk, at least 32' x 32'
Temporal resolution	**Up to 10 kHz**
Temporal coverage	**Uninterrupted unless eclipses or contingency**
Energy resolution	Spectroscopic capabilities
SNR	At least 10 based on lower energy threshold

Observations of Fast-Time Variations in X/γ-ray Fluxes during Solar Flares

Subsecond Spikes

Observations have revealed the presence of **rapid, subsecond spikes in hard X-ray emissions** during solar flares, with some **spikes as narrow as 45 ms**. These findings impose significant constraints on the timescales associated with nonthermal particle acceleration models.

Spectral Evolution

High-energy γ-ray observations have revealed **rapid spectral evolution of accelerated ions** on timescales of approximately 30 seconds, mirroring the spectral changes observed in the lower-energy bremsstrahlung continuum.

Late-Phase Emission

An extended late-phase γ-ray emission phenomenon has been identified, **occurring subsequent to the impulsive phase** and lasting for tens of minutes to tens of hours. This late-phase emission is **associated** with the occurrence of **fast coronal mass ejections**.
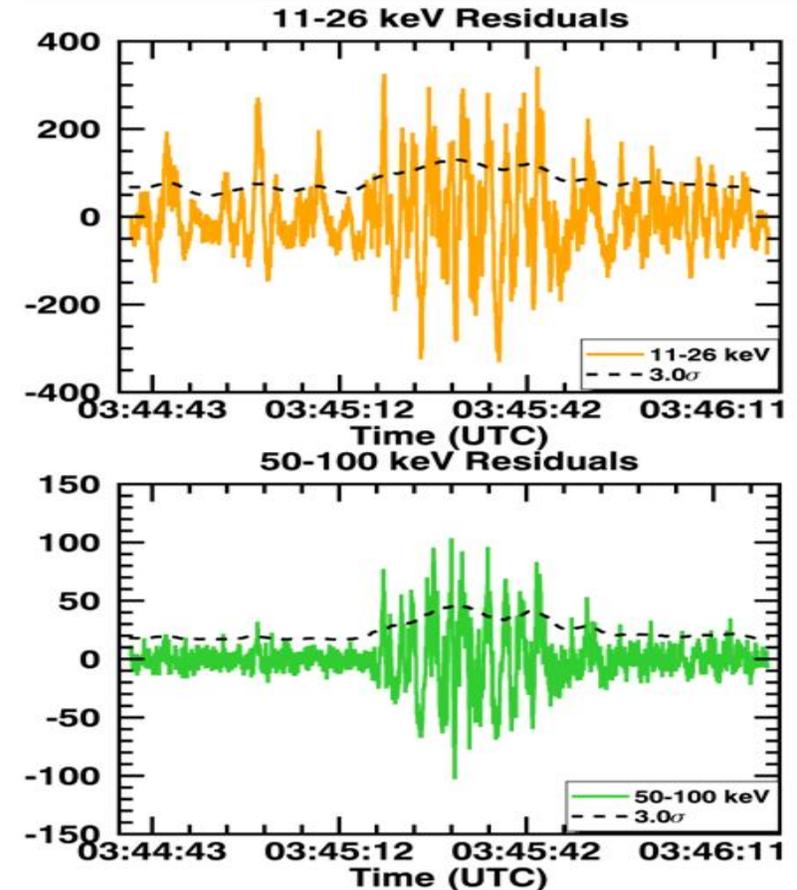
Credits fast fluctuations in Fermi Gamma-ray Burst Monitor (Fermi GBM) data from two M9.3 class solar flares that occurred on SOL2011-07-30 and SOL2011-08-04. Knuth & Glesener, 2020

UV Mg II 280 nm Imager

Solar UV irradiance drives atmospheric photochemistry and influences Earth's climate. The variability of this irradiance is closely tracked by the Mg II index, a measure derived from the h and k spectral line cores of magnesium. Consequently, the **Mg II index serves as a standard proxy for solar UV variability**.

The **goal of the SEE mission is to acquire full-disk solar images, enabling the identification and segmentation of magnetic features that drive changes in the Mg II index**. This data is critical for advancing both solar physics research and studies of solar-terrestrial connections in geophysics.

The baseline optical layout selected for the telescope, is catadioptric. The choice to use a catadioptric scheme compared to a dioptric scheme allows to have a compact longitudinal size with a good image quality all over the field of view.
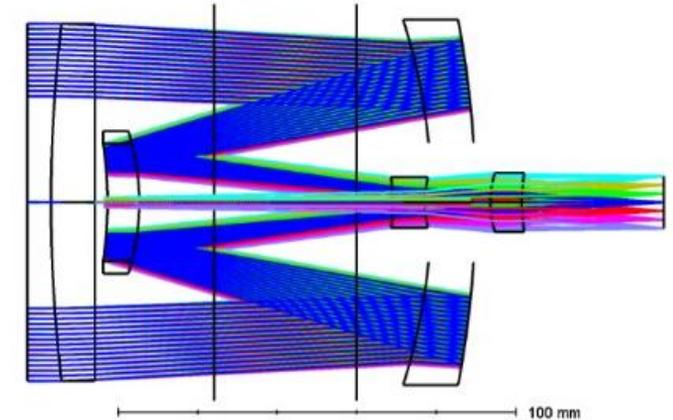
This catadioptric telescope presents two Mangin mirrors, that are lenses with the reflective surface on the rear side of the glass. The design is composed of only spherical elements, no conical or aspherical elements were used.

The compact design allows to fit the UV imager payload in less than 2U volume.

Considering only the optical parts, the dimension of the telescope is about 100 (diameter) x 160 mm.

The mass of the telescope (optical elements only) is about 600 gr.

Usually for this layout, an external baffle is not used, but two internal baffles will be integrated to avoid straylight.

System optical specifications are resumed in the following table:

| Description	Value
Focal Length	690 mm
Image format	17,52 mm diagonal (14 x 10,53 mm)
Field of View (FOV)	± 0,73°
Sun Field of View	± 0,55°
Max aperture (F/N)	F/N = 7,6
Wavelength range	UV range 280 ± 2 nm
T/Number[1]	$T/N = \dfrac{F/N}{\sqrt{transmittance}} = 11,68$
Resolution	Diffraction Limit MTF = 24% @ 140lp/mm
Distortion	< 1%
Vignetting	Negligible. Considering obstruction <35
Obscuration	36 mm (physical obscuration)
Dimensions without mechanics	Diameter about 100 mm x 160 mm axial length
Interfaces	TBD

Table 4-1: Technical characteristics

Mission profile

SEE is a 12U CubeSat (up to 24 kg) based on the ARGOTEC HAWK platform (used in LICIACube and ArgoMoon).

The HAWK platform provides: Attitude Determination and Control, Data Handling, Telemetry, Tracking & Command and Thermal Control. Most of the components already have TRL-9.
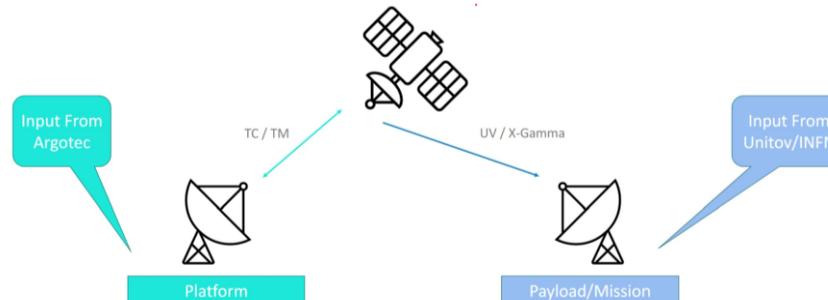
GS Definition & Operations
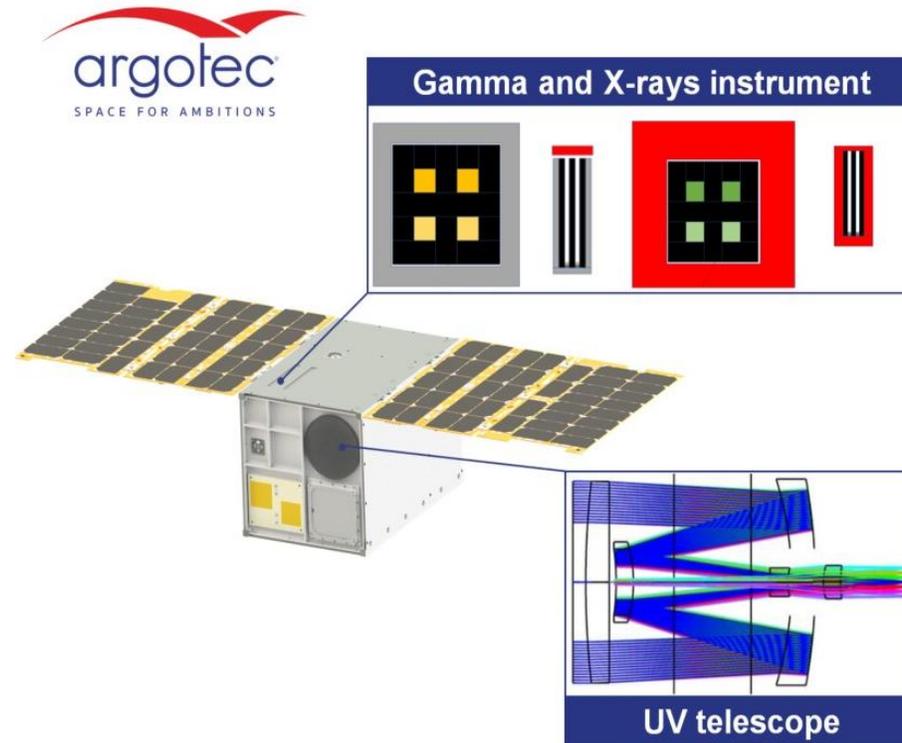

Platform Overview
Payload

- Distinguish the particle acceleration mechanism during solar flares

- Four bands:
  1,5 – 12 keV   30 – 300 keV
  3 -25 keV   0,3 – 3 MeV

- Study the structure responsible for the Mg II h and k emission lines

- Wavelength: 280 ± 1 nm

ASI nanosatellite initiative

The **Alcor program** was established as a dedicated **nanosatellite initiative** to position Italian space community as a leader in Europe and globally.

It functions as a technological incubator, enabling innovators to **develop first prototypes** with a customer-oriented approach, autonomously identifying potential users across sectors including civil protection. The program's twenty missions span all major space domains, **Earth observation**, telecommunications, in-orbit servicing, space sustainability, **astrophysics**, and exploration, as well as emerging trends such as **cooperative satellite constellations**.

THE ALCOR FLEET
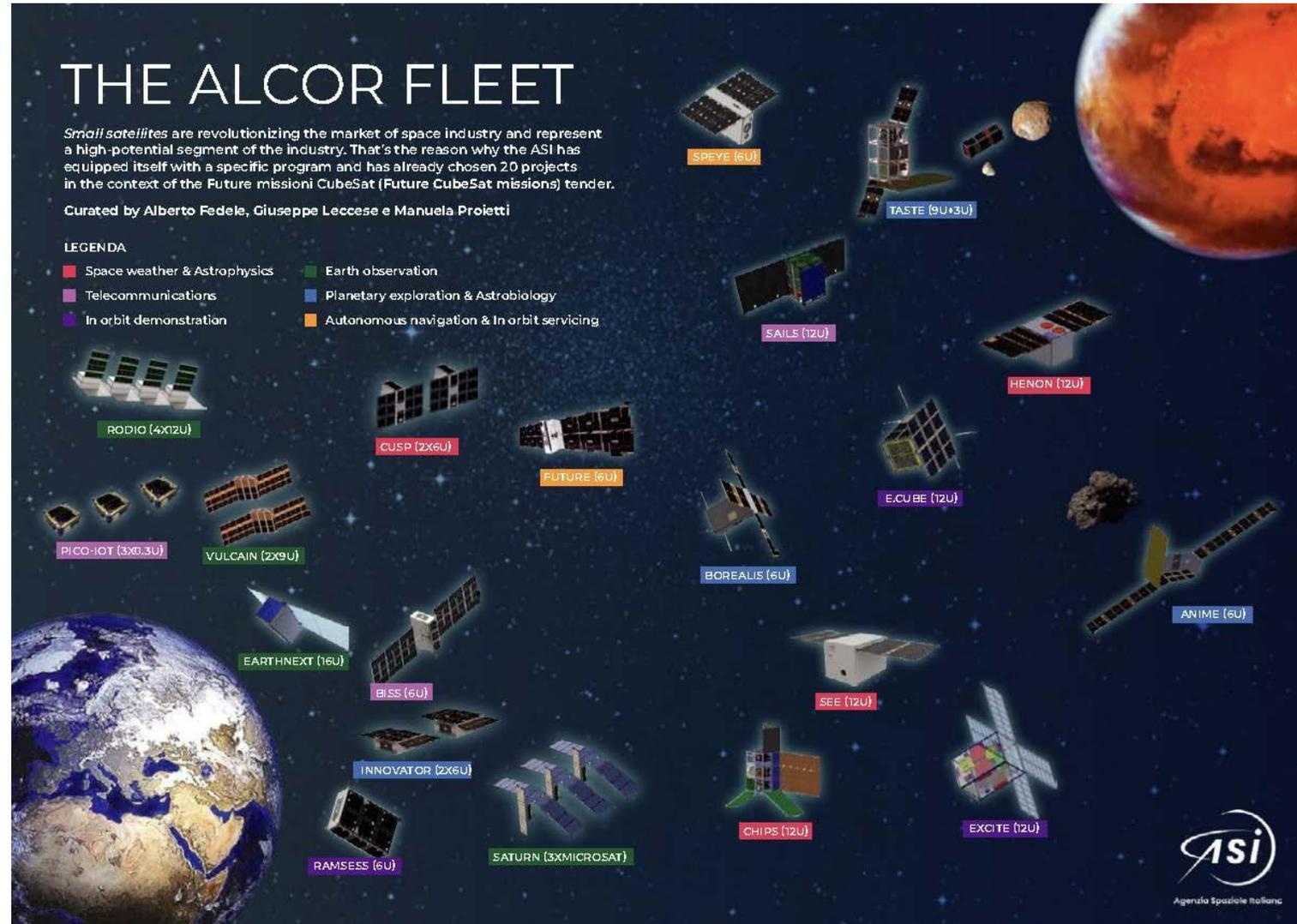
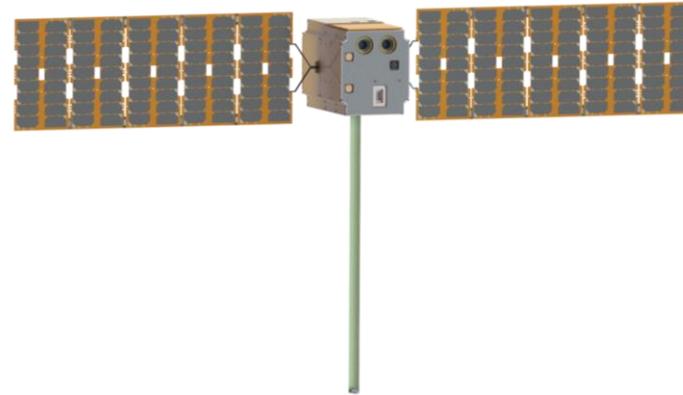# Heliospheric ALCOR missions

Sun CubE OnE (SEE)

Payloads:
1. UV Full Disk Imager
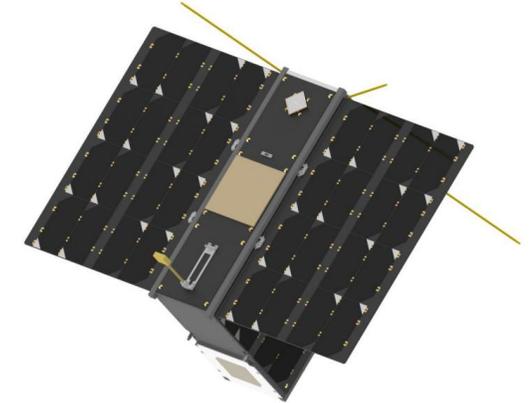2. X-ray Detector
3. γ-ray Detectors

HENON

Payloads:
1. Energetic particle flux telescope (proto/electron/heavy ion)
2. magnetometer on boom,
3. Faraday Cup Analyzer

**CUbesat Solar Polarimeter (CUSP)**

Payloads:
1. dual-phase Compton scattering polarimeter

Ecosystem architecture for data from space mission

The ecosystem architecture for data from space mission exploration is a multi-layered, cloud-native framework designed to ingest, process, store, and distribute vast amounts of satellite and planetary data. Key examples, such as the **Copernicus Data Space Ecosystem (CDSE)** and **NASA's Planetary Data Ecosystem (PDE)**, **transition from traditional, siloed data storage to integrated, open-access environments.**

This architecture generally comprises three primary layers:

1. **Infrastructure,**
2. **Data/Processing,**
3. **Application/Access/Solution**.
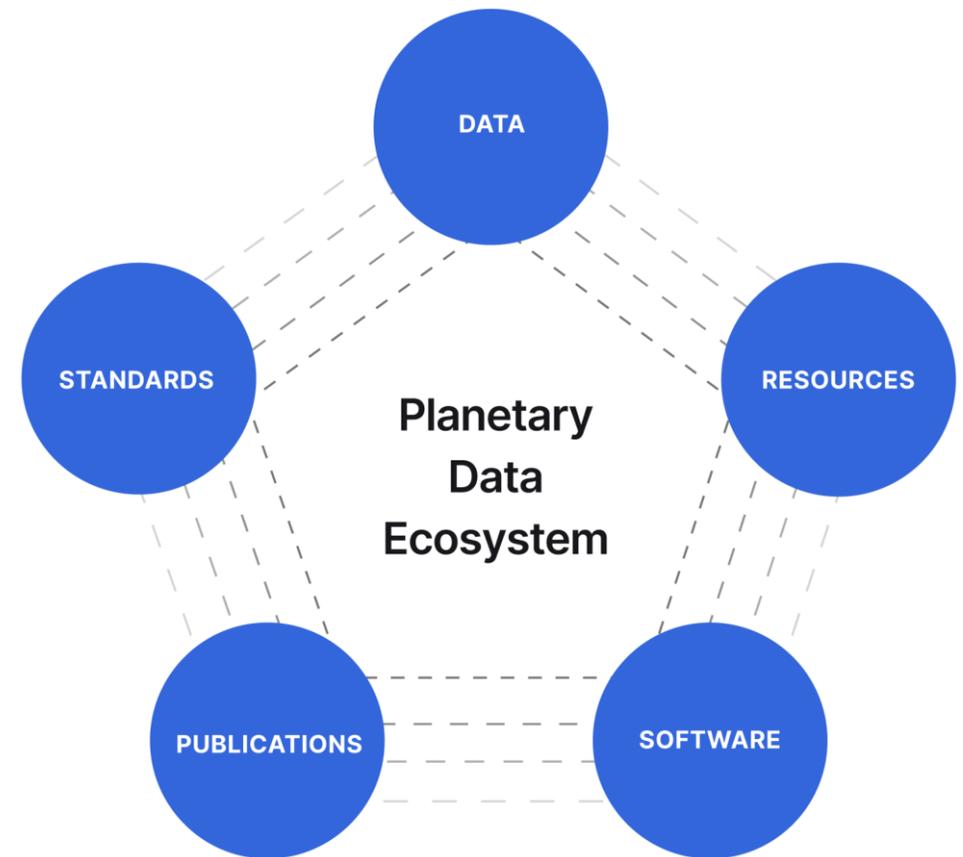
Credits: https://pds.nasa.gov/home/about/PlanetaryDataSystemRMS17-26_20jun17.pdf

Main Points and Key Takeaways

1. **Pioneering Italian Solar Observation**
   1. **The Milestone:** SEE marks Italy's first dedicated solar mission featuring a solar disk imager.
   2. **Strategic Growth:** The optimization of the SEE telescope and CMOS camera for UV wavelengths establishes a relevant national **technological know-how** in a critical spectral range.
2. **Scientific Synergy & Innovation**
   1. **Bridging Communities:** By focusing on the **Mg II line**, SEE acts as a scientific bridge, connecting the Heliophysics and Geophysics research communities.
   2. **A New Window into Flares:** High-cadence X/Gamma-ray sampling allows us to observe solar flare dynamics with unprecedented temporal resolution, unlocking new insights into particle acceleration.
3. **The Cubesat Revolution in Space Weather**
   1. **The Fleet Advantage:** The collaboration between **SEE, HENON, and CUSP** creates a distributed "Cubesat Fleet" for solar physics and heliospheric space plasma physics
   2. **Innovative Intelligence:** This network provides interconnected, multi-messanger data that is essential for modern Solar Physics and Space Weather forecasting.
4. **Building a Future Ecosystem**
   1. **Data Architecture:** We are laying the groundwork for a robust **Ecosystem Architecture**, ensuring that data from heliophysics missions is integrated, accessible, and scalable for future space exploration.