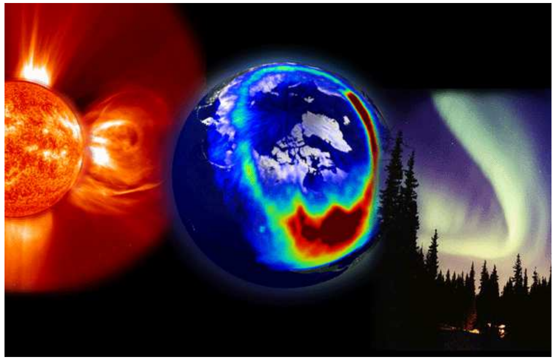


Heliospheric Data Center for Space Weather

ALTEC and OATo – INAF collaboration

The Italian Gateway to ISS

ALTEC – Aerospace Logistics Technology Engineerig Company

INAF – Italian National Astrophysics Institute

OATo – Turin Astro-physical Observatory

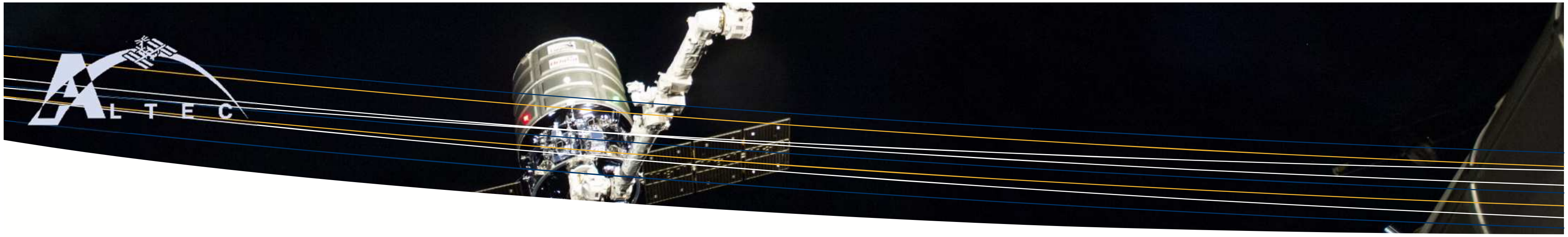
www.altecspace.it

Introduction

Gaia-DPCT @ ALTEC

Metis @ ALTEC Opsys

Following the excellent cooperation estabilished for Gaia Italian Data Processing Center, as well as Metis Coronagraph calibration and test campaign, ALTEC and OATo are joining efforts to create the Heliospheric Data Center as a key element of a Space Weather Data Center.



Space Weather Forecast

Heliospheric Data Center

Related OATo Competences

Related ALTEC Competences

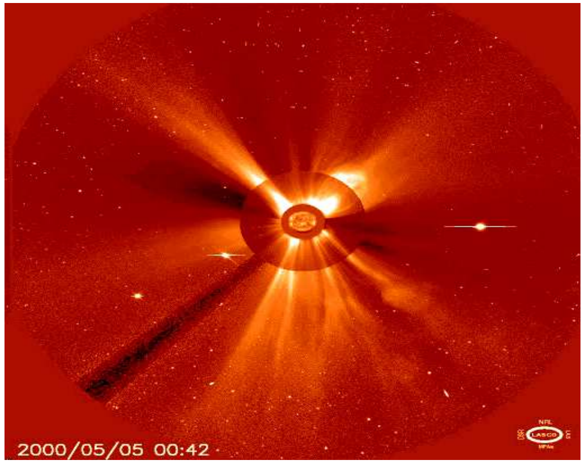
Current Activities

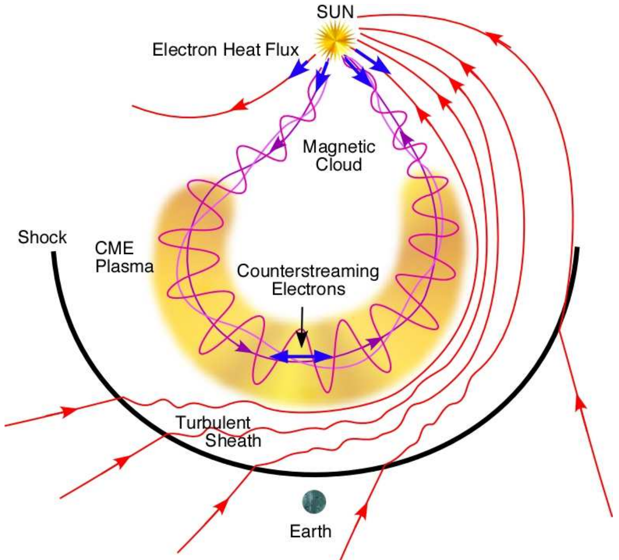
Future Prospects

Space Weather Forecast

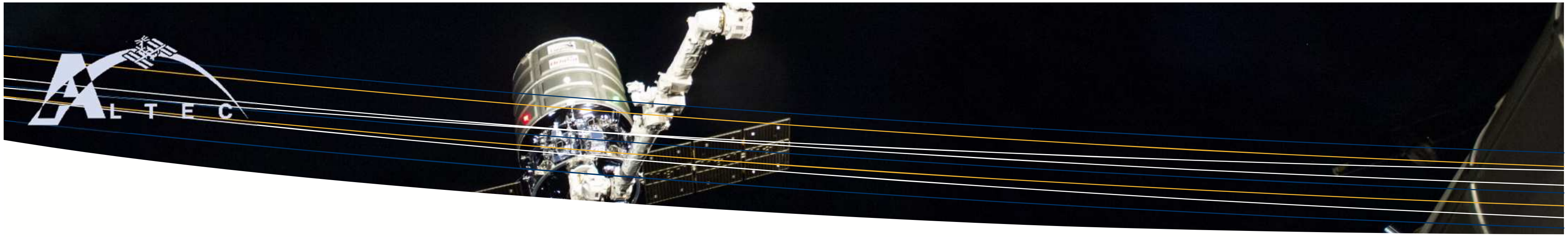
- Among other methods ALTEC/OATo focus on forecast by means of space observations of the outer solar corona and heliosphere

- Identification of ejections of magnetic clouds, reaching the Earth magnetosphere
  - **Long-term forecast (days)** with coronal observations,
  - **Short-term forecast (hours)** with in situ heliospheric obs at L1

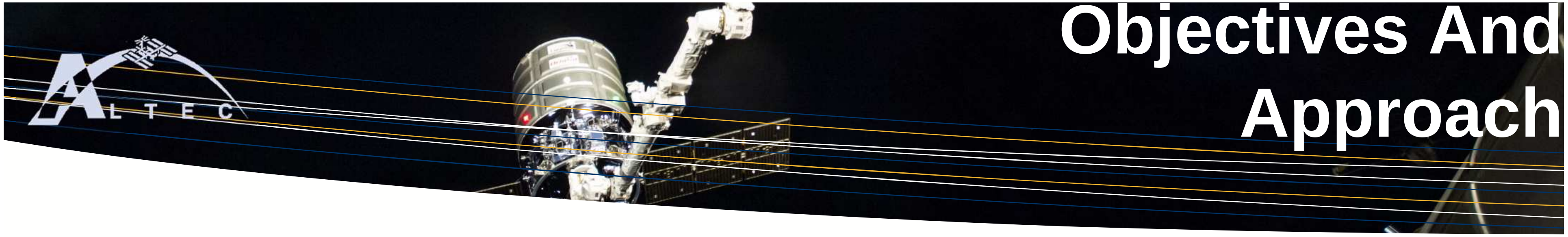

2000/05/05 00:42
LASCO


SUN
Electron Heat Flux
Magnetic Cloud
Shock
CME Plasma
Counterstreaming Electrons
Turbulent Sheath
Earth

Solar wind structure also allows predictions, days in advance, of minor geo-magnetic storm.



- Space Weather Forecast
- Heliospheric Data Center
- Related OATo Competences
- Related ALTEC Competences
- Current Activities
- Future Prospects



Objectives And Approach

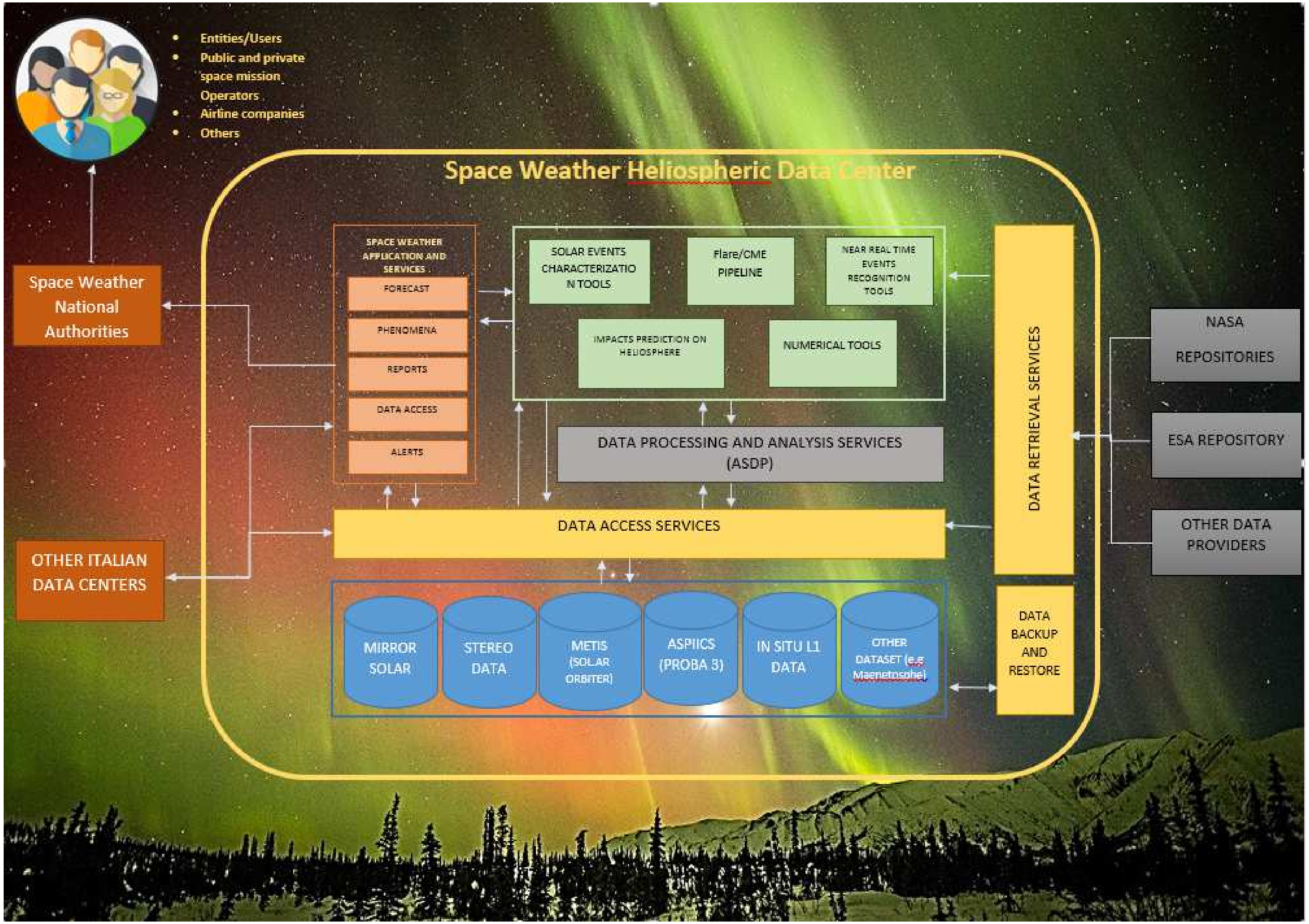
Objectives

- Consolidate and evolve the **Heliospheric Data Center**, initially set up with the SOHO data coming from the ESA approved **SOLAR (SOho Long-term ARchive) archive**, in order to manage additional solar archives storing solar coronal and heliospheric data coming from ESA and NASA space programs.
- Develop a **Heliospheric Space Weather Center** for early forecast of impacts of solar disturbances on the heliosphere and the Earth magnetosphere (**forecast** instead of ‘now’cast).

Approach

- The Heliospheric Data Center is a joint effort between ALTEC and OATo.
- The first version of the data center has been developed by building on already existing OATo and ALTEC software tools, infrastructures and competences.

Heliospheric Data Center



- Entities/Users
- Public and private space mission Operators
- Airline companies
- Others

Space Weather Heliospheric Data Center

Space Weather National Authorities

OTHER ITALIAN DATA CENTERS

SPACE WEATHER APPLICATION AND SERVICES

FORECAST

PHENOMENA

REPORTS

DATA ACCESS

ALERTS

SOLAR EVENTS CHARACTERIZATION TOOLS

Flare/CME PIPELINE

NEAR REAL TIME EVENTS RECOGNITION TOOLS

IMPACTS PREDICTION ON HELIOSPHERE

NUMERICAL TOOLS

DATA PROCESSING AND ANALYSIS SERVICES (ASDP)

DATA ACCESS SERVICES

MIRROR SOLAR

STEREO DATA

METIS (SOLAR ORBITER)

ASPIICS (PROBA 3)

IN SITU L1 DATA

OTHER DATASET (e.g Magnetosphe)

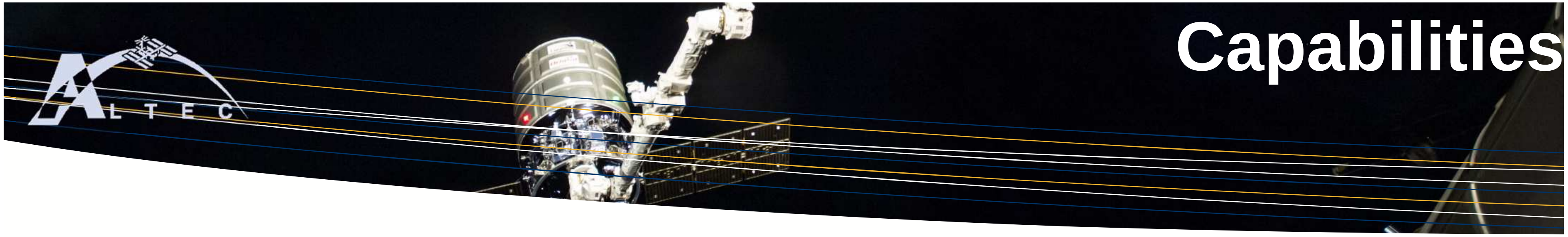
DATA RETRIEVAL SERVICES

DATA BACKUP AND RESTORE

NASA REPOSITORIES

ESA REPOSITORY

OTHER DATA PROVIDERS



Capabilities

Scientific capabilities

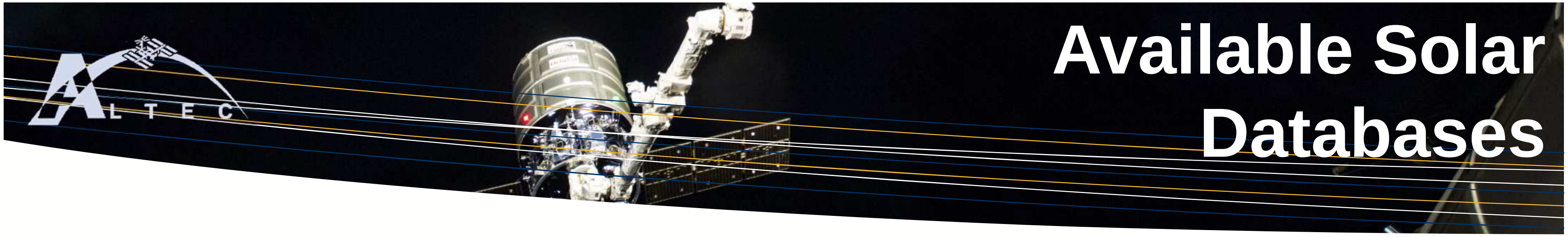
- Solar coronal events identification and characterization
- Solar coronal events heliospheric propagation characterization
- Prediction and validation with in situ data

Technical capabilities

- Near real time and off line solar data retrieval from ESA, NASA and others repositories
- Data management of heterogeneous solar databases
- Implementation and operation of complex automatic pipelines
- Space weather prediction tools to compose pipelines and provide services

▼

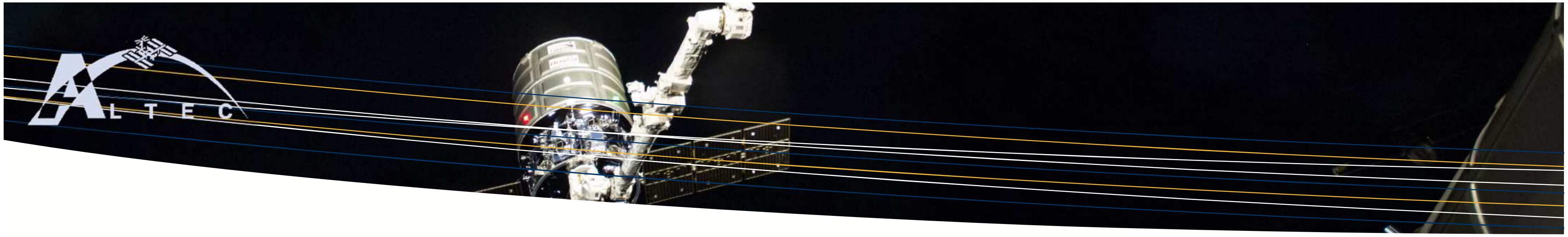
- **Front end to Space Weather National Authority to provide forecast, data access, reporting and alerting services**
- **Integration with other space weather data centers to compose additional services**



Available Solar Databases

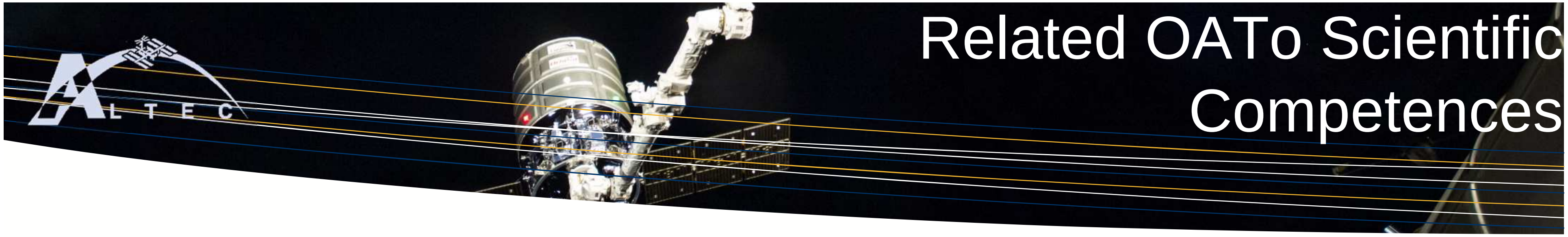
- The Heliospheric Data Center has access to several solar databases of both remote sensing and in situ data.
  - SOLAR MIRROR ARCHIVE (SOHO)
  - STEREO ARCHIVE
  - IN SITU L1 DATA (NASA Missions: SOHO, ACE, WIND, DISCOVER)
  - OTHER DATASET (e.g. geomagnetic, ionospheric data)

- The most relevant data for the current activities are coronagraphic data. At present there are only a very few space-based coronagraphs providing «real-time» images of the solar corona:
  - SOHO/LASCO-C2 and LASCO-C3 (1 spacecraft in L1)
  - STEREO/SECCHI/COR1 and COR2 (2 spacecraft orbiting around the Sun)

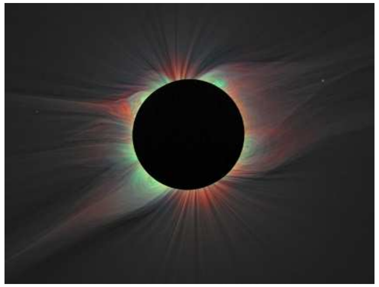


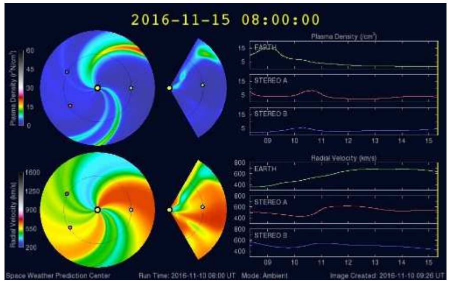
- Space Weather Forecast
- Heliospheric Data Center
- Related OATo Competences
- Related ALTEC Competences
- Current Activities
- Future Prospects

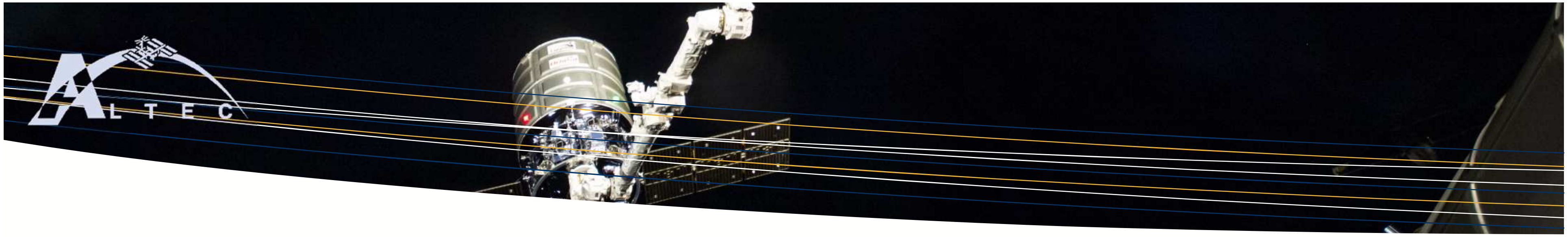
Related OATo Scientific Competences



- Main Research Fields: Physics of the solar corona and heliosphere, understanding the origin and evolution of the main drivers of geomagnetic storms :
  - Solar Wind
  - Coronal Mass Ejections (CMEs)
- Competence on combined UV & VL coronagraphy and related diagnostics (Doppler dimming techniques)
- Development of tools also applicable to Space Weather
  - Coronal mass ejection directionality identification (UVCS-SOHO)
  - Coronal Mass ejection flag (Metis - Solar Orbiter)
  - Identification of coronal wind structure (to infer the heliospheric one) (UVCS-SOHO, Metis – Solar Orbiter)
- The OATo Group has a leading role in the coronagraph instrument development and operation
  - development and operation of the UV Coronagraph Spectrometer (UCVS) on SOHO
  - coordination of the development of Metis, Solar Orbiter

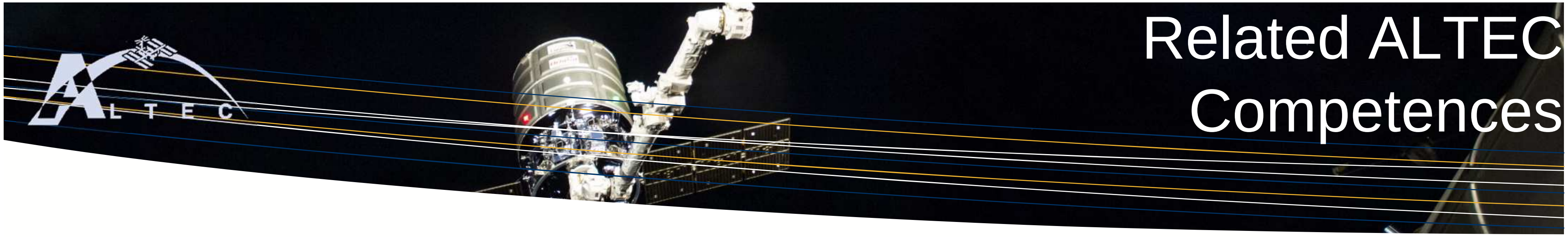




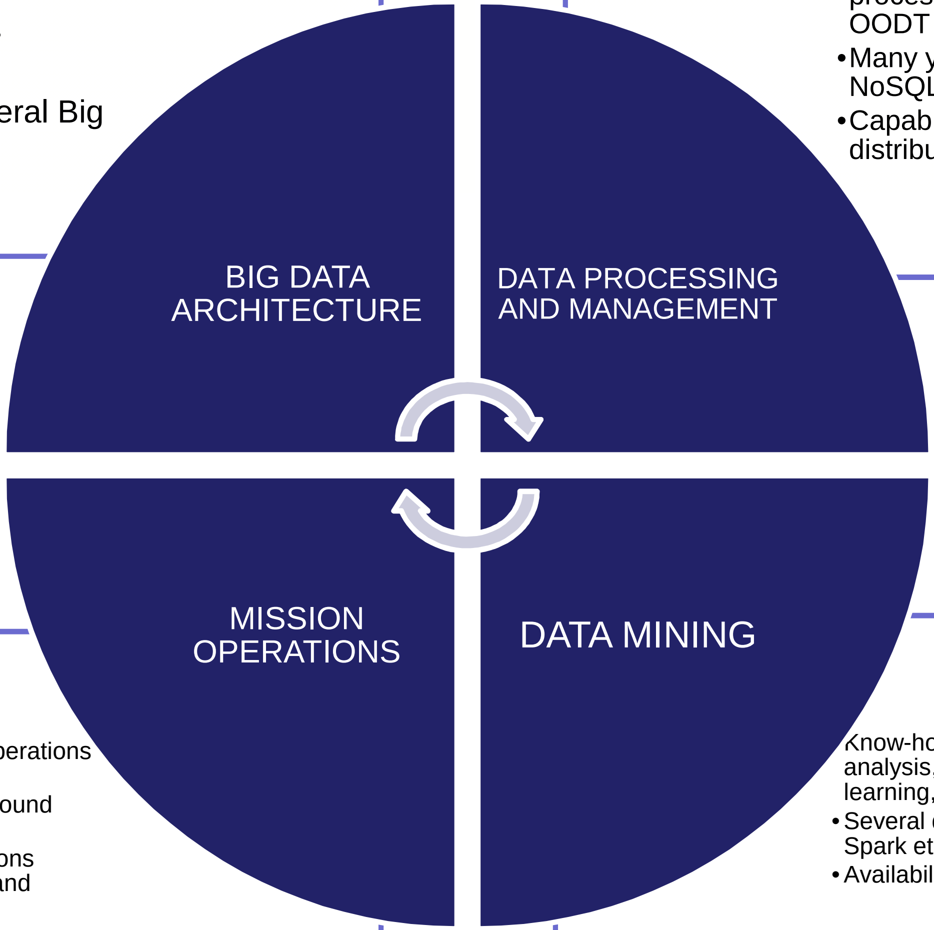


- Space Weather Forecast
- Heliospheric Data Center
- Related OATo Competences
- 🟥 Related ALTEC Competences
- Current Activities
- Future Prospects

Related ALTEC Competences



- Infrastructure designed to maintain PBs of Data (i.e DPCT)
- Integration to external super computer (e.g. CINECA)
- Cloud Environment and several Big Data cluster to develop new innovative project



BIG DATA ARCHITECTURE

DATA PROCESSING AND MANAGEMENT

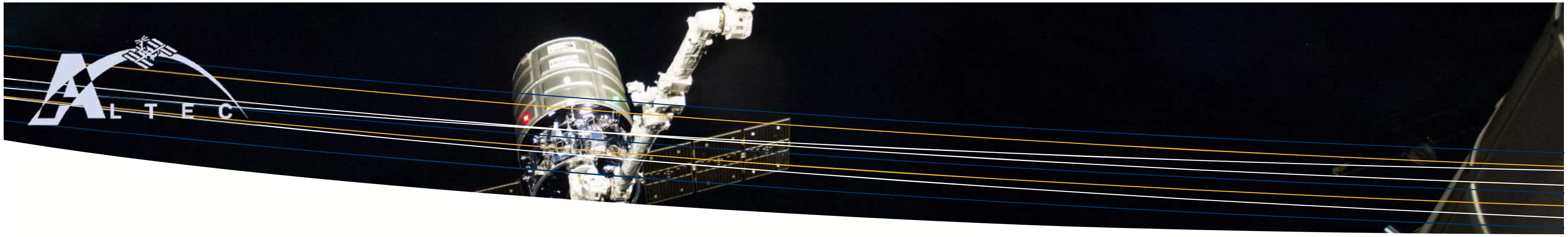
MISSION OPERATIONS

DATA MINING

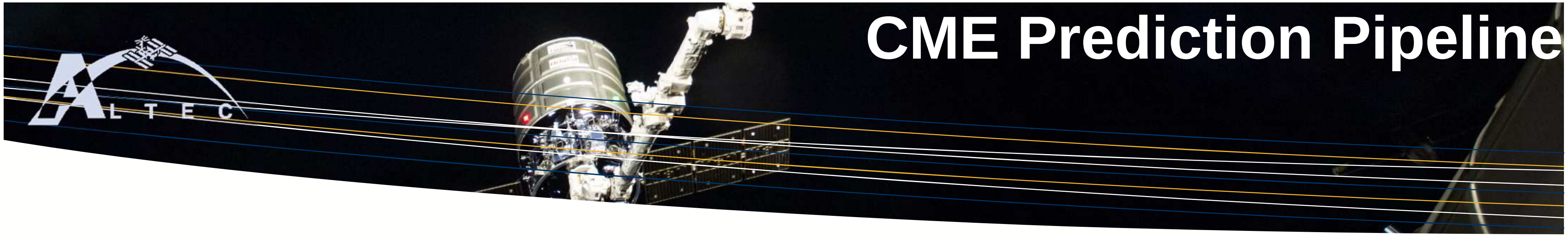
- Usage of the most largely deployed big data processing frameworks: Hadoop & Spark, OODT etc
- Many years of experience in Relational and NoSQL databases
- Capability to develop an in-house distributed processing framework (ASDP).

- ALTEC has being involved in space operations since its foundation.
- Operations execution of both space ground segment and science data center.
- Evaluate and manage mission operations impacts on data processing activities and services delivery.

- Know-how in several techniques: multidimensional analysis, full and partial cross-correlation, machine learning, classification, etc.
- Several data mining environment : R, IDL, Hadoop, Spark etc.
- Availability of huge datasets to extract information.

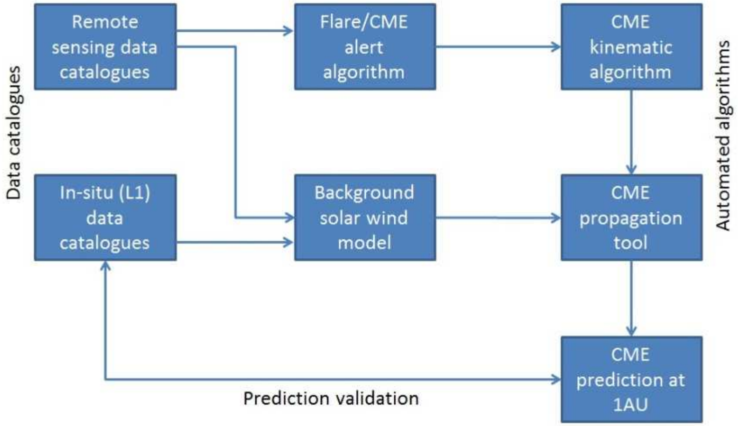


- Space Weather Forecast
- Heliospheric Data Center
- Related OATo Competences
- Related ALTEC Competences
- Current Activities
- Future Prospects



CME Prediction Pipeline

- **The automatic CME prediction pipeline is implemented by integrating known algorithms developed as modular building blocks:**
  - The **CME alert module** is based on the algorithm developed for the Metis CME flag (Bemporad et al. 2014)
  - The **flare alert module** is based on work done by Caballero & Aranda (2013) for SOHO/EIT images
  - The first **CME kinematic module** is based on the CME cone model by Xue et al. (2005) where CMEs are approximated as circular cone and a hemispherical front on top.
  - An **alternative CME kinematic module** will use the algorithm based on measurements of the polarized brightness will be available, it will be possible to apply the polarization ratio.



Data catalogues

Remote sensing data catalogues

In-situ (L1) data catalogues

Flare/CME alert algorithm

Background solar wind model

CME kinematic algorithm

CME propagation tool

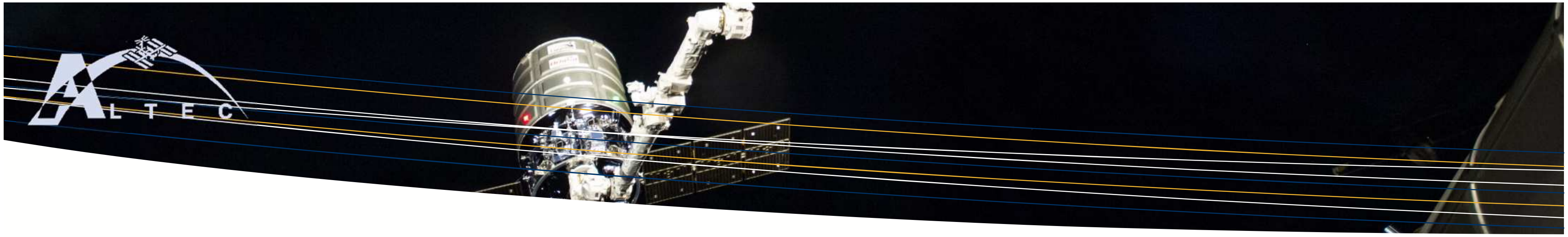
CME prediction at 1AU

Automated algorithms

Prediction validation

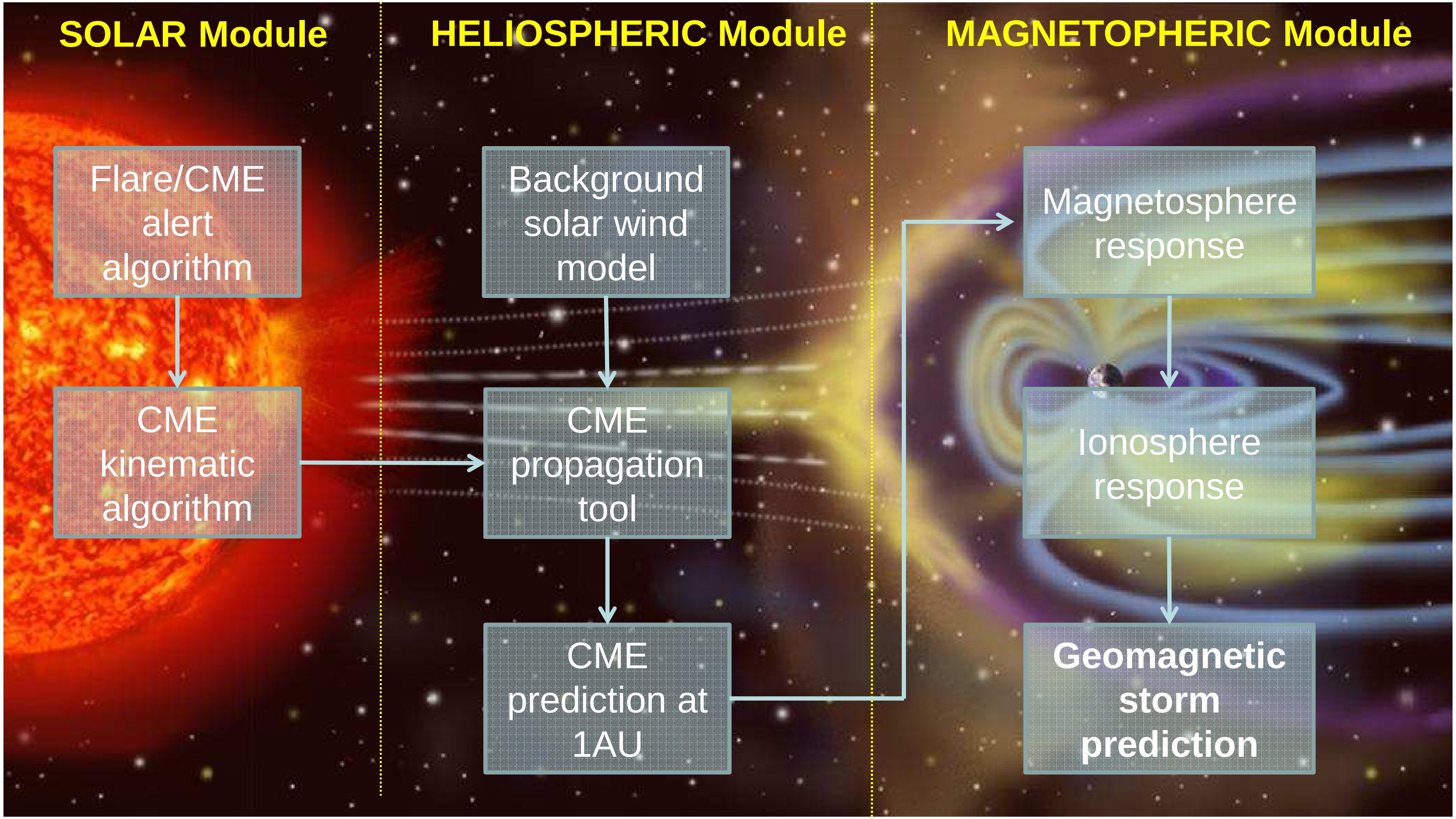
  - The **module dedicated to model the background solar** wind uses radial speed profile based on the empirical model by Sheeley et al. (1997).
  - The first implementation of the **CME propagation block** is based on the Drag Based Model + Empirical Solar wind Forecast (Vršnak, Temmer, Veronig, 2007; Rotter et al., 2015) that estimates of arrival time and impact factor with Earth.
  - As for previous blocks, **the prediction module**, necessary to predict not only the CME speed and arrival time but also information on the plasma dragged by the CME will be based on empirical relationships derived on a statistical basis (e.g. Owens & Cargill 2004).

- **In order to prepare input data and manage the output of the CME pipeline several data management activities are executed:**
  - Near real time data retrieval from NASA and ESA repositories
  - Data organization in data store suitable for the processing
  - Output data distribution to authorized users and data archiving



- Space Weather Forecast
- Heliospheric Data Center
- Related OATo Competences
- Related ALTEC Competences
- Current Activities
- Future Prospects

Future prospects
Magnetospheric Tools



SOLAR Module

HELIOSPHERIC Module

MAGNETOPHERIC Module

Flare/CME alert algorithm

CME kinematic algorithm

Background solar wind model

CME propagation tool

CME prediction at 1AU

Magnetosphere response

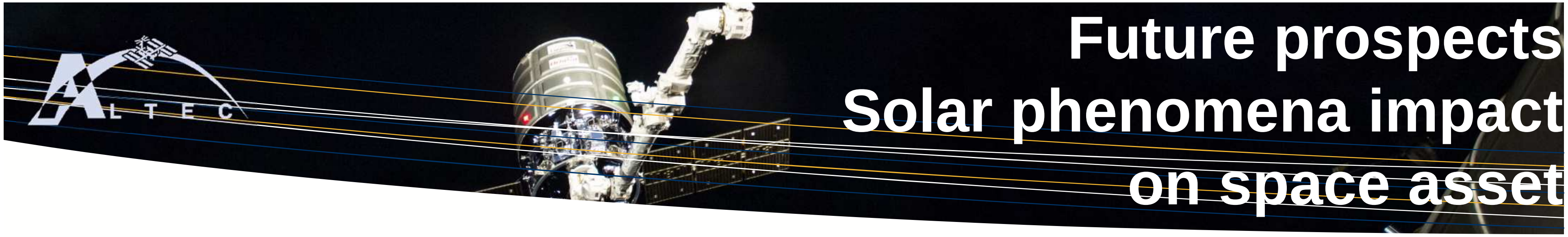
Ionosphere response

Geomagnetic storm prediction

Future prospects
More Solar Databases

- Start to manage additional data archives of existing missions in order to support new algorithms and improve validation of the existing ones.
  - STEREO
  - SDO

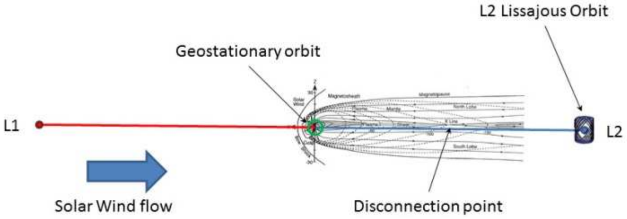
- Set up the data center to manage the new data archives that will be avaible in the next years when the missions acquiring them will be in the operation phase.
  - Metis – Solar Orbiter
  - ASPIICS - PROBA-3

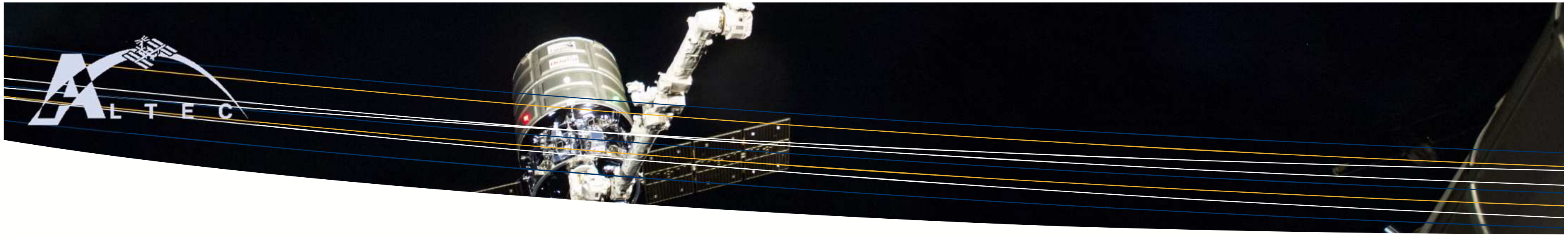


Future prospects Solar phenomena impact on space asset

- Investigation of correlation and cause-effect relations among events occurred in different space position to improve design, operations and maintenance of space asset.
  - The solar data available in the Heliospheric Data Center are used to continue in the development of data analysis techniques to exploit the content of existing very large DBs (“big data”) for the forecast of solar phenomena impact on space assets.

- TECSEL2 (TEmporal Characterization of the remote SEnsors response to radiation damage in L2) is the first ALTEC research project with the goal of providing analyses of generic time series and comparisons between them.
  - This is scientifically interesting because it could provide new information about the not-well-known magnetic environment near the Lagrangian point L2, where Gaia operates.
  - Results showed a correlation between particles fluxes detected at L1 and charge flux and background detected on Gaia CCDs at L2 and processed by AIM. This correlation reaches its maximum with barely 4 hours of delay.
  - The project is developed using only Big Data technologies (NoSQL database, in memory time series processing ecc.)





Thanks for your attention!