OBSERVATORIES OF SOLAR CORONA AND ACTIVE REGIONS (OSCAR)

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Abstract

Coronal Mass Ejections (CMEs) and Corotating Interaction Regions (CIRs) are major sources of magnetic storms at Earth and therefore they are of great importance for space weather. The Observatories of Solar Corona and Active Regions (OSCAR) is a mission proposed to identify 3D structure of coronal loops, study the trigger mechanism of CME in the Active Regions (ARs) and their evolution and propagation processes in the inner heliosphere. It will also provide monitoring and forecasting of the geo-effective CMEs and the CIRs at 1 AU. Thus, OSCAR shall contribute in the advancement in the field of solar physics, improve the current CME prediction models and provide data for space weather forecasting. This will be achieved by utilising two spacecraft, with identical remote-sensing as well as in-situ instrumentation, located at the Earth orbit. The spacecraft will be separated with an angle of $\sim 68^\circ$ to provide optimum stereoscopic view of the solar corona. The spacecraft are planned for launch in 2022-2025 for a nominal mission duration of 5 years.

1. SCIENTIFIC BACKGROUND

Space weather describes the changes in the near-Earth ambient plasma which result from solar and cosmic activity. The study of space weather is a field of major importance in society today because the changes in the environmental conditions, in the vicinity of Earth affect space and ground based systems.

More than the 80 % of geomagnetic storms are driven by CMEs, which represent an important threat for modern technology [15]. CMEs originate from complex magnetic structures within the solar AR and coronal loops arise from beneath the photosphere in the ARs. Magnetic shears and stresses within the photosphere lead to an increase of the energy stored in the coronal loops, eventually triggering magnetic reconnection inside the loops and leading to the release of CMEs. Multiple models have been developed to explain the triggering mechanisms of CMEs, but their unification is still a major challenge in solar astrophysics.

Once they are triggered, CMEs propagate outwards in the corona and can reach a distance of 1 AU in a time that ranges from 14 hours up to 5 days. The fast moving CMEs are generally considered to be the most dangerous events in terms of space weather and are also the most difficult to anticipate due to their high velocity. In addition, CMEs can either accelerate or decelerate during their propagation from Sun to Earth [7]. Hence, forecasts have to use either well-cadenced observations or solar wind models, that take into account the acceleration/deceleration processes.

CIRs are produced from compression effects within the solar wind, when the fast wind catches up the slow wind. Depending on their magnetic field orientation with respect to the Earth's magnetic field, the magnetosphere, they can lead to an increase in energy transfer to the magnetosphere and trigger geomagnetic storms measured by the Dst index [6].

When these CIRs interact with the magnetosphere of the Earth, weak to moderate magnetic storms are generated. However, some of these storms can cause significant damage, not only to space technology but also to communication, transportation, and electrical power systems.

OSCAR aims to provide new data to improve our understanding of space weather and to forecast geo-effective events such as CMEs and CIRs that affect the Earth and our lives.

There are currently missions like the Solar Terrestrial Relations Observatory (STEREO) and Solar Dynamic Observatory (SDO) which also aim to study CMEs and CIRs. However, OSCAR is different. In comparison to STEREO, OSCAR will measure the photospheric magnetic field and it will also provide real-time accurate CME and CIR forecasting. The latter is not provided by the SDO mission as well. The measurements from OSCAR will therefore complement the data from such space missions.

2. MISSION OBJECTIVES

The mission will address the difficult challenge of space weather forecasting, from the initiation of CMEs to their coupling with Earth's magnetosphere. In this context, we are interested in the most energetic CMEs and CIRs which can affect terrestrial environment and human life [9].

Primary objective:

- Identify the 3D structure of coronal loops inside active regions and physical trigger mechanism(s) of CMEs to improve the existing prediction models.

Secondary objectives:

- Provide data for forecasting geo-affecting CMEs.
- Provide data for forecasting geo-effective CIRs.
- Enhance our understanding of spatial structure of CMEs and CIRs at 1 AU.

Targets of opportunity:

- Investigate the propagation of CIRs with multi-point in-situ observations.

2.1. Primary objective: Trigger mechanism of CMEs

The primary objective is to study the 3D structure of coronal loops and the physical trigger mechanism(s) of CMEs. The highly energetic CMEs that we are interested in are strongly associated with M- and X-class flares (only 10% of the X-class flares are not associated with CMEs [14]).

We will observe the magnetic field of sunspots, the flaring process and the 3D structure of coronal loops at the onset of CMEs. We know that flares and their associated CMEs (when these are present) occur on a time scale from minutes to hours [10]. The high time resolution of these three observations will allow us to sample in more detail the whole eruption process. This will in turn allow us to provide strong constraints on and will help to improve the various physical models of solar eruptions.

We will observe hundreds of ARs during the mission lifetime and create a catalog of ARs topology, associated with their ability to trigger CMEs. Combined with refined models obtained from our observations, this catalog will provide a robust basis for future forecasting of CME triggers.

2.2. Secondary objectives

Provide data for interplanetary CME and CIR forecasting

Real-time estimates of arrival time for geo-effective CMEs remain rather inaccurate today [5] and strongly depend on solar wind models. The aim of the mission is to provide data for accurate prediction of arrival time of those CMEs.

CIRs are producing 13% of gemomagnetic storms. Because they can last a long time and repeat themselves after a 27-day solar rotation, they represent a threat for space based infrastructure [3]. In particular, 11% of geomagnetic storms are mainly caused by CIRs ([15]). Thus, we will provide data for reliable forecast of CIRs.

Statistical characterization of CIRs and CMEs at 1 AU

Our knowledge of the geo-effective CIRs and CMEs composition, geometry and magnetic field is mainly based on local measurements in the vicinity of Earth. Our mission will provide data to characterize the composition of CMEs and CIRs at 1 AU. Because our mission will take place away from Earth's vicinity, it will provide complementary data for the structure and time evolution of those events.

3. SCIENCE REQUIREMENTS

In order to fulfill our objectives, we list the scientific requirements for each of them.

3.1. To determine the trigger mechanisms of CMEs

1. We shall provide stereo view of coronal loops at different heights in the lower corona. This will allow a 3D reconstruction of the coronal loops in the ARs [1].
   (a) The separation angle between the view points shall be between 22 and 125 degrees (see figure 1).
2. We shall capture the time scale of flares and hence observe the evolution of the triggering sequence of strong CMEs.
   (a) The time resolution of coronal loops images shall be 5 seconds.
3. We shall resolve distinct coronal loops with a resolution inferior to 500 km at the solar surface.
4. The stereo observation shall be synchronised to ensure a proper 3D reconstruction during the eruption process.
   (a) The two satellites shall be synchornised with a precision of 0.1 s.
5. We shall observe the vector magnetic field on the photosphere.
6. The duration of time for the mission shall be no less than 5 years to ensure high statistics for the CME triggering.

3.2. To provide data for CME forecasts

1. We shall track geo-directed CMEs from the lower corona to 1 AU.
2. We shall determine the shape, direction, and velocity of the leading edge of the CME.
3. We shall provide data enabling forecast of the arrival time of all geo-directed CMEs.
   (a) The data shall enable a 2 day forecast updated every 6 hours.

3.3. To provide data for CIRs forecast

1. We shall provide data for forecasting of geo-effective CIRs.

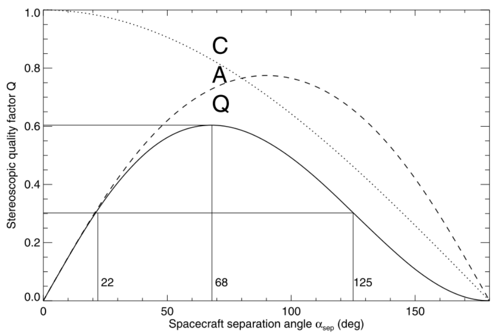

Figure 1: Quality factor Q of stereoscopic triangulation as a function of the spacecraft separation angle α_{sep}, which is a function of the accuracy A of triangulated stereoscopic positions and the stereoscopic correspondence quality factor C. The best quality (within a factor of 2) occurs in the range of $\alpha_{sep} = 22° - 125°$ with an optimal separation angle of 68°. Adapted from [2].

   (a) The data shall enable a 2 day forecast updated every 6 hours

2. We shall provide in-situ measurements in between geoeffective CIRs and Earth
3. We shall measure the in-situ magnetic field.
   (a) The accuracy shall be 0.1 nT.
4. We shall measure the solar wind proton velocity.
   (a) Velocity shall be measured between 300 and 3000 km/s with an accuracy of 5 % [12].

3.4. To study CMEs and CIRs

1. We shall measure the magnetic field, temperature and density of the CMEs and CIRs passing adjacent to the satellite.
   (a) Accuracy and ranges are the same than the forecast requirements.
2. We shall measure th 3D electron distribution function.
3. We shall measure the ion composition.

4. INSTRUMENTATION

Each spacecraft will carry an identical range of instruments for the purposes of investigating the corona, loops, and the heliosphere. A suite of telescopes will image almost continuously the space between the Sun's surface and 1 AU on the Sun-Earth line, and another will measure the in-situ particle environment. An overview of the planned instruments is given in Table 5.

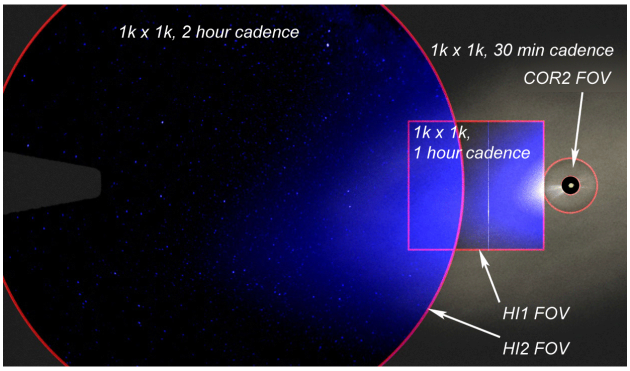

Figure 2: The combined field of view of the OSCAR coronal and heliospheric imagers

4.1. Remote sensing instrumentation

A package of imaging instruments will be provided consisting of 6 telescopes, the longest of which is 1.4 m, and with a total mass of 95.9 kg. Three will be focussed on the solar disk, and three on the corona and interplanetary plasma.

EUV Active Region Imager The EUV imagers will provide simultaneous measurements of the full solar disk in two different wavelengths. Since an instrument with these properties and suitable mass does not exist, development will be needed to produce an instrument to the specifications. This new instrument is planned as two telescopes on each spacecraft. One of these will be filtered to 171 $\AA$, and the other will be able to switch between 94 and 211 $\AA$ using a filter wheel. To provide more flexibility, to simplify the design and provide some redundancy, both telescopes will be equipped with filter wheels covering each wavelength.

Significant heritage is available for such an instrument: the Solar Dynamics Observatory, STEREO and Solar Orbiter have all flown, or will fly, instruments with some of the characteristics matching our requirements. The EUV Imager on Solar Orbiter will have two telescopes with a mass of 23.5 kg, but the filters and fields of view must be changed to suit an orbit at 1 AU. However, the development and testing of this instrument will be the greatest design challenge of the mission.

Coronagraph The coronagraph is a direct copy of COR2 on the STEREO spacecraft, which is capable of imaging the electron density of the solar corona through Thompson scattering between 2 and 15 $R_{\odot}$. An innner coronagraph was not included in this mission, since its use in space weather forecasting is limited.

Heliospheric imagers The heliospheric imager is taken directly from the equivalent instrument on STEREO. Since the field of view extends between 12 and 332 $R_{\odot}$, the volume in which CMEs can be viewed stereoscopically reaches from almost the Sun surface to the Earth, as seen in Figure 2.

Magnetograph The vector magnetic field and line-of-sight flow velocity will be imaged in high resolution by an instrument closely related to the PHI istrument currently being developed for Solar Orbiter. The instrument design might be simplified through the removal parts related to high resolution imaging only.

4.2. In-situ instrumentation

To detect and fully characterize the CIRs and CMEs for forecasting and modelling aspects we have to measure in-situ the magnetic field vector, solar wind proton velocity, density, temperature and the elemental and charge state composition of the solar wind heavy ions.

Particle monitor The Particle Monitor is a suite of three instruments which measures electrons, protons/alphas, and heavy ions [12] [8]. The heritage instrument is the Solar Wind Analyser (SWA) instrument aboard the SO spacecraft. However, the proton velocity range covered by the OSCAR Particle Monitor will be extended to 3000 km/s. With this optimisation, the instrument will be able to cover the entire solar wind proton speed range of CIRs and CMEs. The electron monitor will measure the 3D electron distribution function for additional information.

The proton/alpha instrument and the heavy ions instrument are both mounted on the spacecraft body. The electron instrument is mounted on the tip of the 3 metre long boom, to be away from any electric potential of the spacecraft. The specifications of each of the detectors in the Particle Monitor is given in Table 5.

Magnetometers We also use two identical magnetometers from Solar Orbiter. Both of the magnetometers are mounted on the boom: one 1.0 m and the other 2.25 m away from the spacecraft body. This makes a seperation of 1.25 m. By having one sensor closer to the spacecraft than the other, enables us to monitor how the two magnetometers are affected by the spacecraft magnetic field.

5. SPACECRAFT DESIGN

Figure 3 illustrates the system architecture. The solar panels are utilised to harvest energy which is processed in the Electrical Power System (EPS) and stored in the batteries. The Attitude Determination and Control System (ADCS) computes the attitude and if necessary utilises reaction wheels and lateral thrusters to alter the orientation. The communication subsystem consists of two redundant X-band transceivers connected to a high gain antenna and two low gain antennas.

5.1. Mass budget

Table 1 summarises the mass budget for each spacecraft of the OSCAR mission. The estimated mass for each satellite is 559 kg including a 20% margin, which provides us with an unused mass of 50 kg per spacecraft.

Table 1: Mass budget

Subsystem	**Nominal mass (kg)**	**Margin (%)**	**Mass with margin (kg)**
Structure	149.0	10.0	163.9
Payload	115.7	12.1	129.7
TT&C	23.1	5.6	24.4
ADCS	32.1	5.0	33.7
OBC&DH	5.0	5.0	5.3
EPS	18.1	5.0	19.0
Thermal	15.2	10.0	16.7
Propulsion	53.0	5.0	55.7
Harness	17.5	0.0	17.5
Total (dry mass)	428.7	8.7	465.9
Margin	-	20.0	93.2
Total+margin	-	-	**559.0**
Maximum	-	-	608.8
Unused	-	-	**49.8**

5.2. Power

The power system consists of three main modules: the primary module, the secondary module and the power control and distribution network.

The primary module covers the main power harvesting in order to operate the satellite. The utilised triple junction solar cells with a GaInP2/GaAs/Ge composition are produced by Spectrolab and are designed for space mission. The satellite has a solar panel area of 2.25 m^2 and a conversion efficiency of 29.5 %. The maximum available power is 814 W assuming a perpendicular angle to the Sun as well as temperature of 28 °C. The radiation degradation of the solar cells after 7 years of operation time, is expected to be approximately 10 %.

The secondary module consists of the backup power stored in rechargeable lithium ion batteries with a total energy capacity of 880 Wh.

The control and distribution of the power is handled by two low power Power Conditioning and Distribution Units (PCDUs) from ThalesAlenia Space. The PCDU manages the batteries and the MPPT of the solar panels. In addition to the regulated bus voltage of 28 V the PCDU moreover provides a non-regulated power bus of 22 to 37 V. Each PCDU is able to deliver up to 330 W.

5.3. Attitude control

The OSCAR spacecraft is actively pointing the main imaging instruments towards the Sun, and the heliospheric imager instruments towards the space between the Sun and Earth using a 3-axis control system. The attitude control system uses 5 reaction wheels of type RSI 4-75/60 (4Nms/75mNm) and an Astrium 3m2 inertial momentum unit for attitude control. Furthermore, 3 star trackers of type Sodern Hydra and 4 sun sensors manufactured by EADS Astrium provide attitude determination. This setup enables OSCAR to stay within its pointing requirements

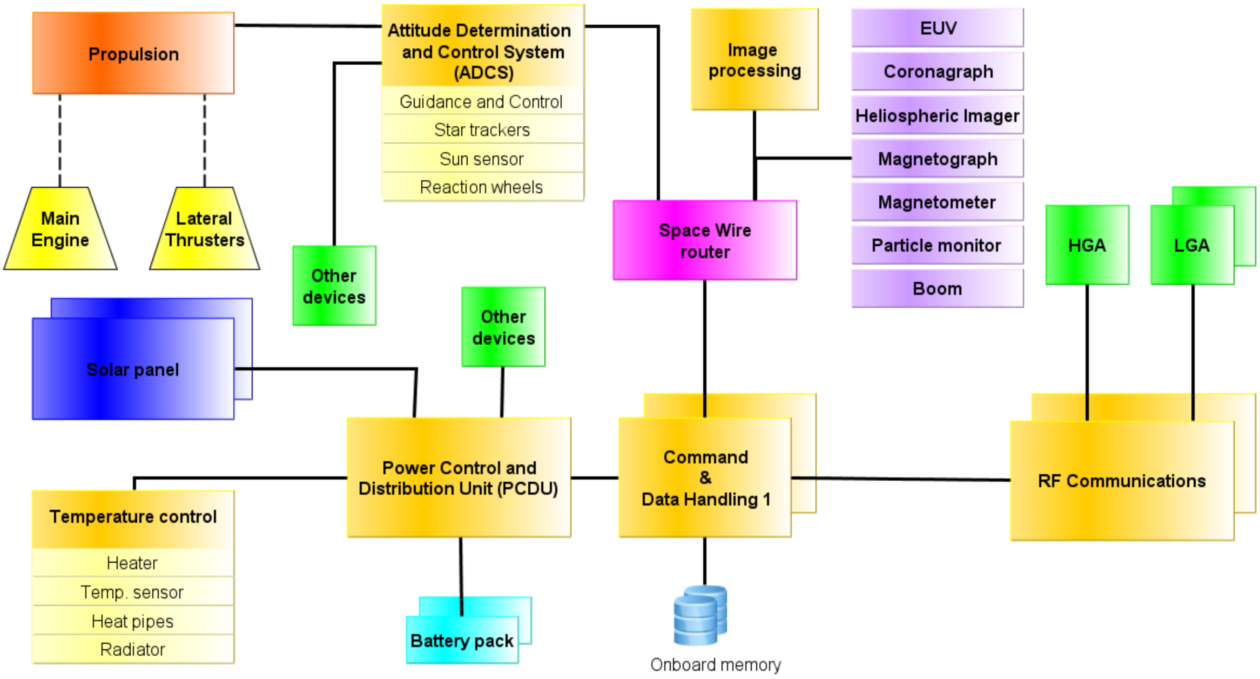

Figure 3: System architecture

Table 2: Power budget

Subsystem	Nominal power (W)	Margin %	Power w/ margin
Structure	0.0	20.0	0.0
Payload	100.1	12.3	112.4
TT&C	200.0	20.0	240.0
ADCS	205.0	7.9	221.3
OBC&DH	15.0	5.0	15.8
EPS	0.0	20.0	0.0
Thermal	0.0	20.0	0.0
Propulsion	55.0	20.0	66.0
Harness	0.0	20.0	0.0
Total	575.1	14.0	655.4
Margin	-	20.0	131.1
Total+margin	-	-	**786.5**
Maximum	-	-	814.6
Unused	-	-	**28.2**

(see Table 3).

Table 3: Pointing requirements

	Roll	Pitch/Yaw
Knowledge	±20	±0.1
Control	±0.1°	±15
Jitter	±30	±0.2

5.4. Onboard computer and data handling

The data onboard the satellite is handled by an On Board Computer (OBC) of the type OSCAR manufactured by EADS Astrium. The OBC utilises the LEON3 core and provides up to 40 MIPS at 48 MHz core frequency. With 256 MB of RAM and 512 MB of exchange memory the computer meets our requirements. Not only the telemetry data and command handling but also the execution of the ADCS algorithms and time synchronization are performed on the OBC. The processing and analysis of acquired images is dedicated to the separate image processing unit.

5.5. Telemetry, tracking & command

The data and in particular images acquired by scientific instruments in required to be downloaded to the ground station or ground station network periodically. In order to provide sufficient downlink budget X-band communication is utilised. Two redundant transceivers with the output power of 200 W each feeding the 1.7 m diameter parabola antenna ensure the downlink data rate of 1.4 Mbps if the ESA

ESTRACK network is used and 260 kbps if smaller 15 m ground station antennas are utilised. The total daily data budget is 2.35 GB and 218 MB respectively. In both cases the signal margin of 3 dB is maintained to guarantee proper operation.

CME Trigger Study Since our primary objective is to study the trigger mechanism(s) of CMEs in high detail, and we can only transmit a limited amount of data to ground stations, we realise there is a need for onboard autonomy. Instead of sending data from all instruments at full cadence and full resolution, our satellites will perform onboard CME trigger event detection using one of the EUV telescopes. We will use a dedicated image processing unit as well as customizable CME trigger event detection software.

Both EUV telescopes and the magnetograph telescope shall continously buffer images at full resolution and their fastest cadence. The buffering shall be synchronised using ground stations on both satellites taking into account their distance to the sun. One EUV telescope will record images in 17.1 nm, while the other can switch between the 9.4 nm and the 21.1 nm channel. The trigger detection shall be based on the detection of strong flares in the 9.4 nm channel. Whenever a strong flare is detected the satellite will change the 9.4 nm filter to 21.1 nm for the next hour. This ensures that we always have 17.1 nm images available, and most of the time right after an event is detected also 21.1 nm images. After one hour the satellite will switch back to the 9.4 nm channel to continue the online flare detection.

The output of the event detection is an estimate of the class of the flare, as well as the location. This meta-data will be sent back to a ground station, where, based on the trigger detection meta-data from both satellites and possibly other sources, is decided which data from both the EUV and magnetograph instruments to request from both satellites. It is also possible to request any of the other buffered data, given external trigger detection using third-party data.

Other possibilities for online CME trigger event detection can be based on dimmings and EUV waves, instead of on strong flares. Both dimmings and EUV waves are strongly related to the onset of CMEs [16]. An advantage over the flare detector operating on 9.4 nm images would be that both EUV telescopes can continously record in the wavelengths that are best suited for coronal loop imaging (17.1 and 21.1 nm), also for the minutes leading up to CME trigger event. Both EUV waves and dimming detectors as well as flare detectors are currently being developed at the Royal Observatory of Belgium as part of the FP7 project AFFECTS. These can be adapted for near real-time operation on satellites.

Instead of requesting full-resolution data, cropped images will be downloaded for a time period spanning from 10 minutes before the event until 60 minutes after the event was detected. This ensures the total telemetry, given on average 200 M1 or stronger flares per year [11], does not exceed 1235 MB per day for each satellite (see table 4). To retrieve this data we make use of the ESA's Deep Space Network, using one timeslot of 8 hours each day per satellite.

Real-time forecasting For near real-time forecasting we depend on the availability of 15 metre telescopes that receive data from both satellites every 6 hours. The total telemetry for near real-time forecasting is estimated to be 47 MB every six hours per satellite. This includes telemetry for the coronograph (36 MB), the HI instruments (9 MB), and the in-situ measurements provided by the Particle monitor and Magnetometer (2 MB). This amount of data can be transfer in less than 1 hour.

5.6. Thermal Control System

For the first approximation, it is possible to assume an isothermal and spherical spacecraft with radius equal to the maximum dimension of the longest subsystem. With this approximation the temperature of the spacecraft is of 259.5 K. For last approximation it is possible to compare the temperature range of the operability for each component and also for all instruments. In particular, the temperature range of the EUV imager and PHI instruments are not critical for the thermal analysis because the objective is just to study the stability of the system. At the end of the analysis we have chosen the material for the spacecraft: a silver coated teflon blanket with a coating of indium-tin oxide, for the face of the spacecraft in front of the sun, and a black-kapton blanket for the back. This will also provide optimal thermal control.

6. MISSION DESIGN

After the determination of mission objectives (phase 0) the mission requirements were set up and the feasibility of the mission was confirmed in the PDR (phase A/B1). The more detailed analysis of the objectives was performed and precise orbital manoeuvres were simulated and confirmed in the FDR (B2/C/D).

6.1. Planned orbit

For optimum obervation of the Sun surface and the optimal acquisition of binocular high-resolution images the angle between both spacecraft and the Sun shall be $68 \pm 3°$. This constellation not only allows the proper investigation of CMEs and coronal loops at Sun surface, but is suitable for observation of the CME propagation along the way to the Earth moreover.

6.2. Operational phases

The entire operation consists of 5 sections: the launch, a 2 year low-thrust drift, 5 years of nominal mission time with possible extension and potential deorbiting.
The launch from ground to parabolic orbit takes approximately 30 minutes and is accomplished by a Soyuz rocket whose total payload capability is 2.2 tons. Once the satellites are in parabolic orbit, the propulsion system of both

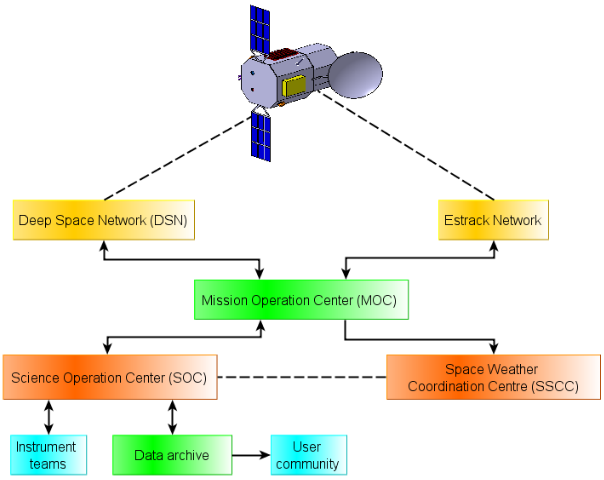

Figure 4: OSCAR ground segment design.

spacecraft is activated and they will start drifting in opposite direction along the orbital path of the Earth around the Sun and will reach their final destination after 2 years. After 8 months the angle between the Sun and both spacecraft will have reached the minimum requirement of 22°; part of the science mission can already be started and this allows us to evaluate and if necessary optimise the data handling and propagation of data from the ground station to data centres.
The scheduled science operation phase is 5 years and an extension of the mission duration is optional since the margin on the propellant and the power requirements are generous. After the end of mission both spacecraft will be transfered to a disposal orbit around the Sun with the major semi-axis length of 0.99 AU.

7. GROUND SEGMENT

The operational modes described in section 5.5 require a specific design for the mission ground segment. A schematic of our ground segment operation is given in figure 4.

Our design involves the communication with two networks of antennas: the ESA Deep Space Network for the CME trigger study, and the ESTRACK Network for the forecasting data. Our Mission Operation Center (MOC) will provide an interface between the two antenna networks and the science operation and space weather centers. It will also interact with the two satellites for the data downloading requests.

We will aggregate a scientific community around our CME trigger study. Specific partners research institutes will be involved in the analysis and use of the data to achieve our first mission objective. The nominal data (see Table 4) will be immediately released, and the event related data will be kept for the OSCAR collaboration during a period of six months. We will organise an annual conference on the mission results, and open calls for observational campaigns (within the limits of the available telemetry). When released, our data will be archived by our Science Operation Center (SOC) and made available through the Solarsoft Library, and the Helioviewer ESA software.

The forecast data will be directly interfaced with the ESA Space weather Coordination Centre (SSCC) through our MOC. A constant link between SSCC and the OSCAR SOC will enable a good use of our forecast data. The forecast itself will be either provided by the SOC or by SSCC, depending on the available manpower. Subsequently, SSCC will be in charge of releasing the forecast and alerts obtained from our data. Additionally our forecast data may be combined with other spacecrafts data to provide a better insight on the 3D structure and temporal evolution of CMEs and CIRs at 1 AU. Hence, our SOC will also combine this data with the Solarsoft Library.

8. RISK MITIGATION

Technically, a large proportion of the risk to the mission lies in the requirement to develop a new instrument - the EUV Active Region Imager telescope - based on three already-developed EUV imagers, which by the time of launch will each be flight-proven. Since the data produced by this instrument are critical for mission success, redundancy in certain crucial wavelength imaging will be built into the design in case of damage during launch or flight. Research and development into the new design is planned to begin immediately.

In addition, the risk to the value of the data gathered is considered. Further developments in solar theory and modelling in the years before the launch may reduce the need for the planned data collection, and delays to the launch would influence the number of active regions and CIRs measured. However, since the data to be gathered will be well beyond the currently-available and planned images, the study of active regions and space weather can still be expected to benefit significantly from this mission

9. COST ANALYSIS

The cost analysis for the mission is outlined in the next paragraph. We aimed to identify cost-effective solutions to meet the program requirements. To this end, the Soyuz launcher is chosen due to its low cost and reliability. The near-equatorial launch location also reduces total mission cost. Predictably weight, power, and performance are the main cost drivers. The largest cost in the mission is for the platform which represents 57 % of the cost, for which orbit and attitude control and data management represent a large proportion of the platform budget. The payload cost was also considerable, estimated at €170M [13]. The total cost for the two satellites is €650M which is comparable to the STEREO project which amounted to €550M (2003). The cost of the second satellite, was less due to savings on spacecraft research and design. The cost estimate is based on previous missions and estimates provided by Faulkner P. is listed below.

The weight factor for using two spacecrafts is 0.7 (two spacecrafts only cost 40 % more then the cost of one). The Soyuz launch from Kourou costs 60 M€, platform a total of 255 M€ (105 for each, without margins). The payload is 170 M€ (estimate of € 1M/kg). The development cost of the improved EUV is estimated to be 5 M€. Mission cost including forecast is 100 M€ with margins, and the science operations are estimated to cost 60 M€. This makes a total of 650 M€.

10. DESCOPE OPTIONS

Should it be necessary to reduce the scope of the mission, particularly to reduce the cost, the following option has been investigated:

Reduction to one satellite Since both spacecraft have identical instrumentation, a possibility would be launch only one of them. For this to retain the objective of loop reconstruction, this spacecraft would need an orbit located at L5 and would rely on additional image data in the equivalent wavelengths and cadences from L1 or Earth. If this could be provided by other partners the primary objective could be fulfilled, while investigating a different portion of the Sun's surface.

However, the matching of suitable data would be a significant challenge, and data would likely need to be processed and interpolated to match in time with the mission data. In addition, the data rate would be expected to drop by 64% compared to the nominal mission plan due to the additional spacecraft distance.

11. CONCLUSIONS

Our mission will provide a unique opportunity to study the 3D structure of coronal loops and the trigger mechanisms of CMEs. The mission data will improve CME initiation models and finally will lead to a significant improvement of CME predictions. With the in-situ instruments it will also be possible to investigate the stucture of CMEs and CIRs at 1 AU. Finally data will be provided for accurate near-real time forecasting of geo-effective CMEs and CIRs for the very first time.

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TABLES

Table 4: Telemetry: CME Trigger (for one satellite).

Instrument	**Lossless**	**Resolution**	**Cadence (s)**	**Storage** MB / day	**Telemetry** MB / day
EUV	y	4k x 4k	5	580,000	
	y	4k x 4k	3600	34	34
	y	800 x 800	5	504	504
	n	1k x 1k	180	101	101
Magnetograph	y	2k x 2k	5	290,000	
	y	2k x 2k	3600	17	17
	y	400 x 400	5	252	252
	n	1k x 1k	180	202	202
Total				**870,000**	**1,110**

Table 5: OSCAR instrumentation

Instrument	**Measurement**	**Ranges**	**Resolution**	**Sampling rate [s]**
2x SolO MAG (fluxgate)	B-field vector	±128 nT	0.004 nT	1/16
SolO SWA (improved)	Mass, charge, energy of ions	1-5 keV e$^-$ 0.2-45 keV/q H$^+$, α 0.5-100 keV/q ions	12% ($\Delta E/E$) 7.5% ($\Delta E/E$) 5.6% ($\Delta E/E$)	3s 3s 10s
Magnetograph	Vector magnetic field Line-of-sight flow velocity	Full solar disk	2048×2048 pix 750 km at surface	10s
EUVARI	EUV images 94, 171, 211 Å	Full solar disk	2048×2048 pix 750 km at surface	10s
Coronagraph	White light images	2-15 R$_\odot$	1024×1024 15 arcsec/pix	15 min
Heliospheric imagers (2×)	White light images	12.3 - 332 R$_\odot$	1024×1024 70-240 arcsec/pix	1-2 hour