Team Red

OSCAR

Observatories of the **S**olar **C**orona and **A**ctive **R**egions

Outline

1. MISSION STATEMENT:
- Scientific objectives
- Top level requirements

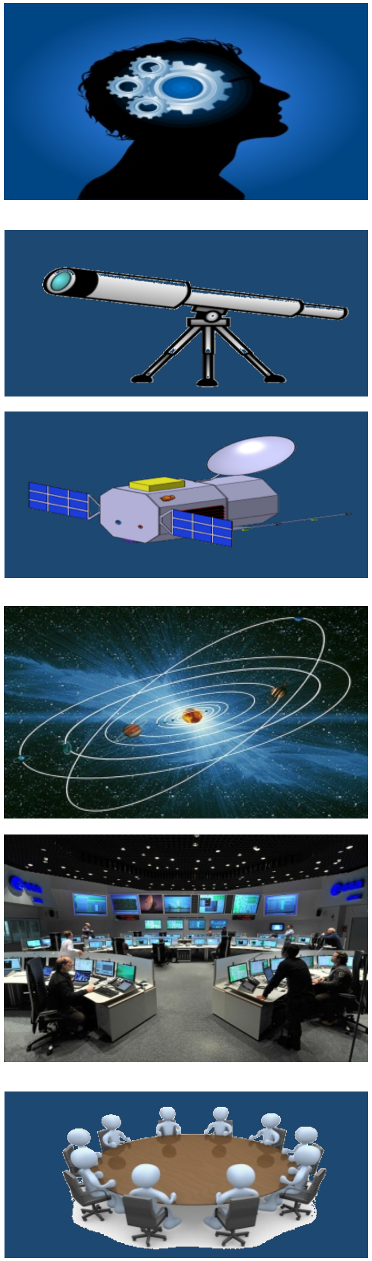
2. INSTRUMENTATION:
- Imaging instruments
- In-situ instruments

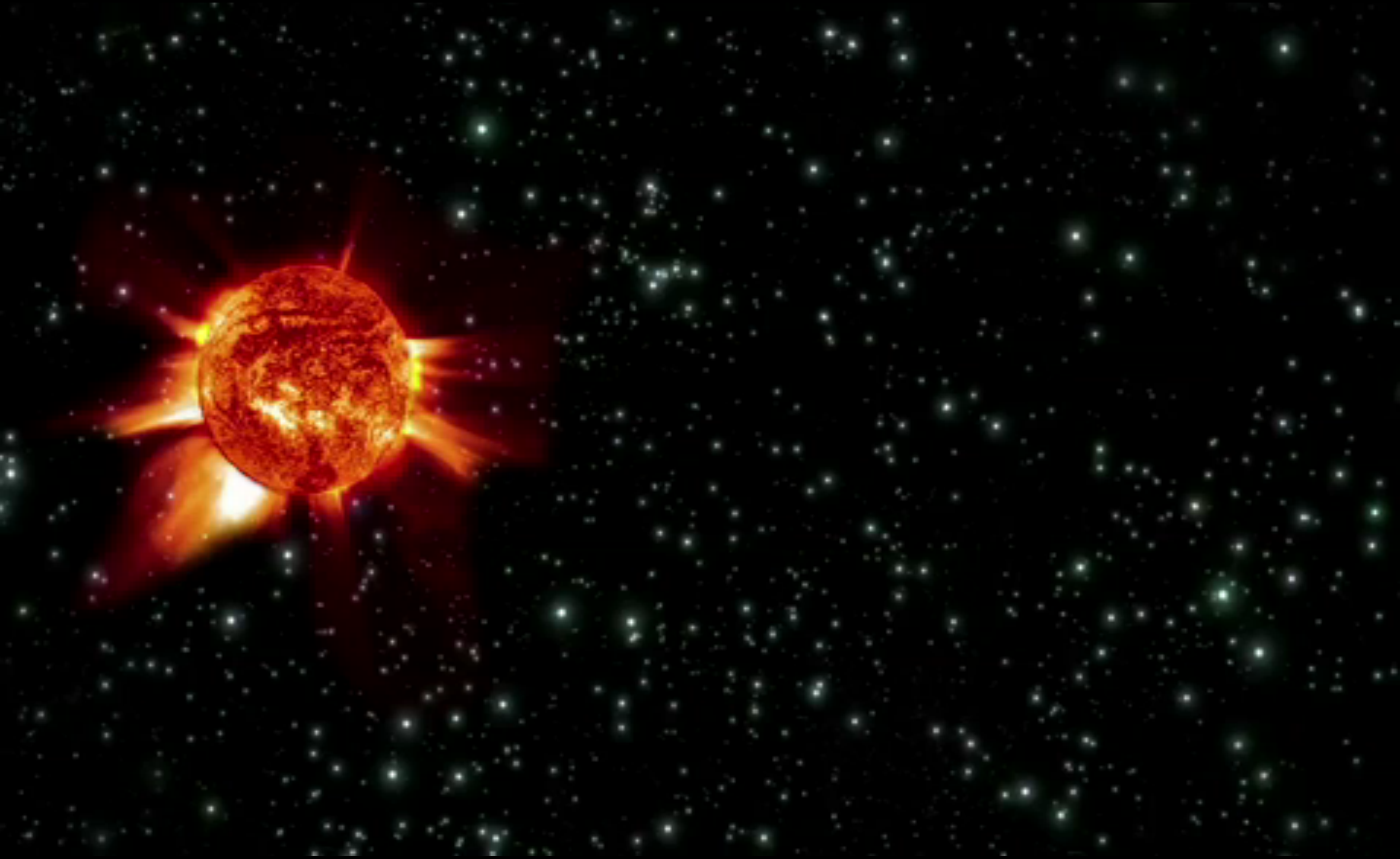
3. SPACECRAFT:
- Subsystems

4. MISSION PHASES:
- Launch and orbit transfers
- Orbit Constellation

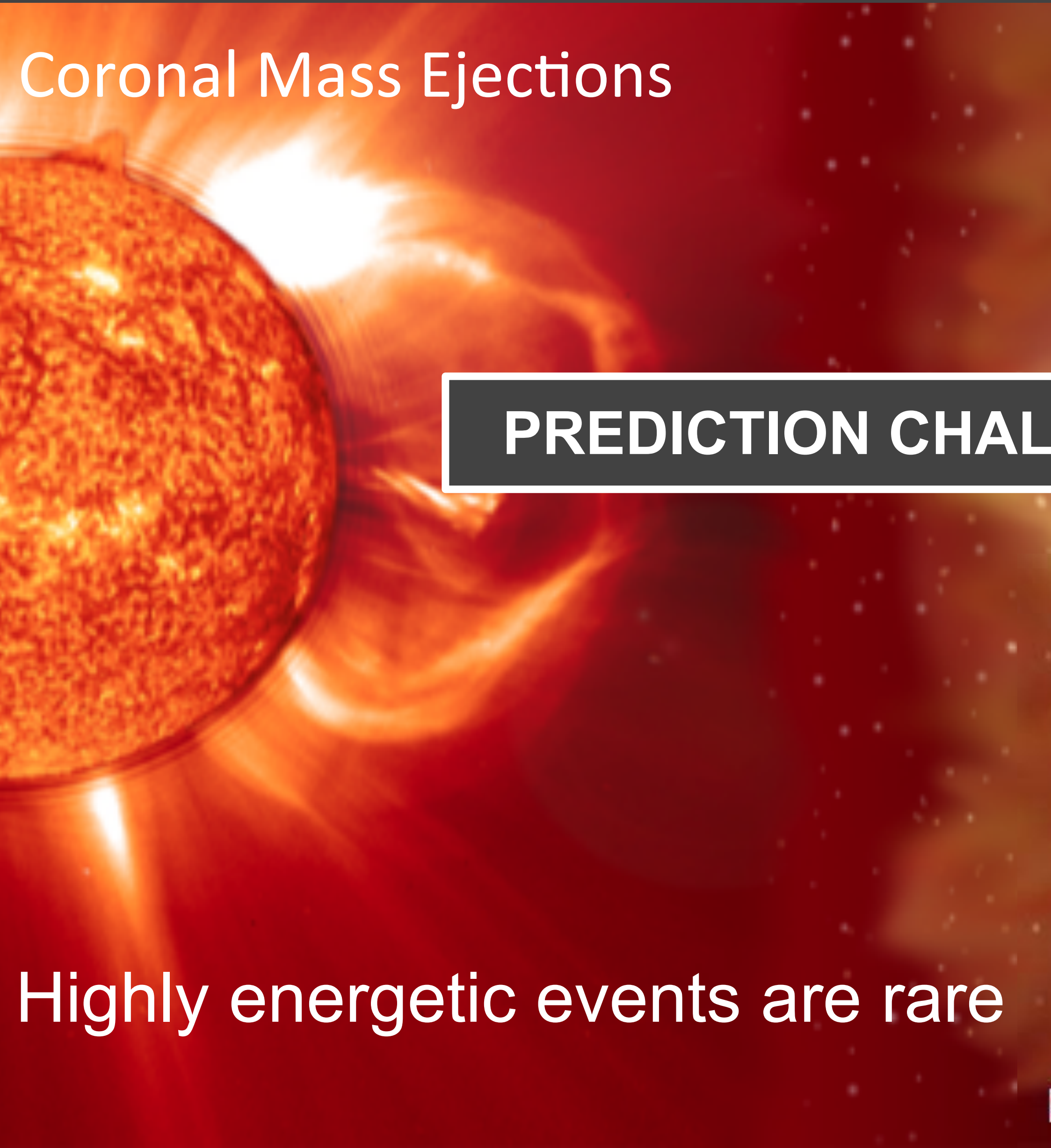
5. MISSION OPERATION:
- Data handling
- Groundstation(s)

6. MANAGEMENT:
- Risks and Costs
- Descoping Management





Space Weather context

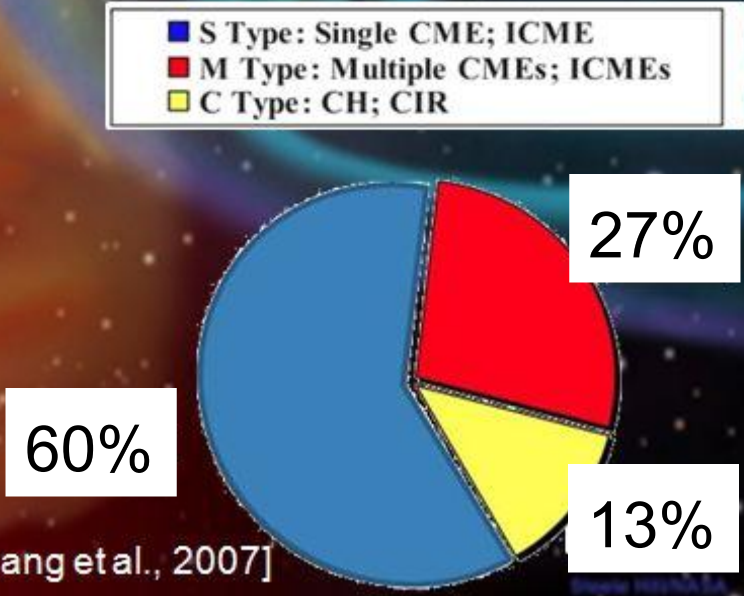


Coronal Mass Ejections

Corotating
Interacting regions

PREDICTION CHALLENGE!

Highly energetic events are rare



[Zhang et al., 2007]

Mission Objectives

Primary objective

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

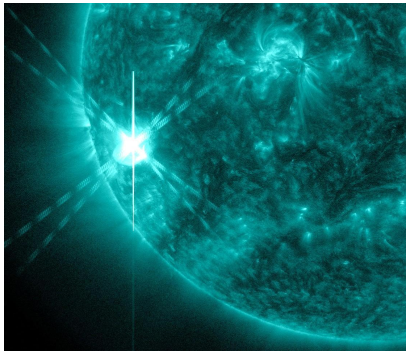
Secondary objectives

- Monitor and provide data for the forecast of the propagation of geo-affecting CMEs, and categorize them.
- Provide data for the forecast geo-effective CIRs.
- Statistically characterize CIRs and CMEs at 1AU.

Primary Objectives: CME Trigger Mechanism

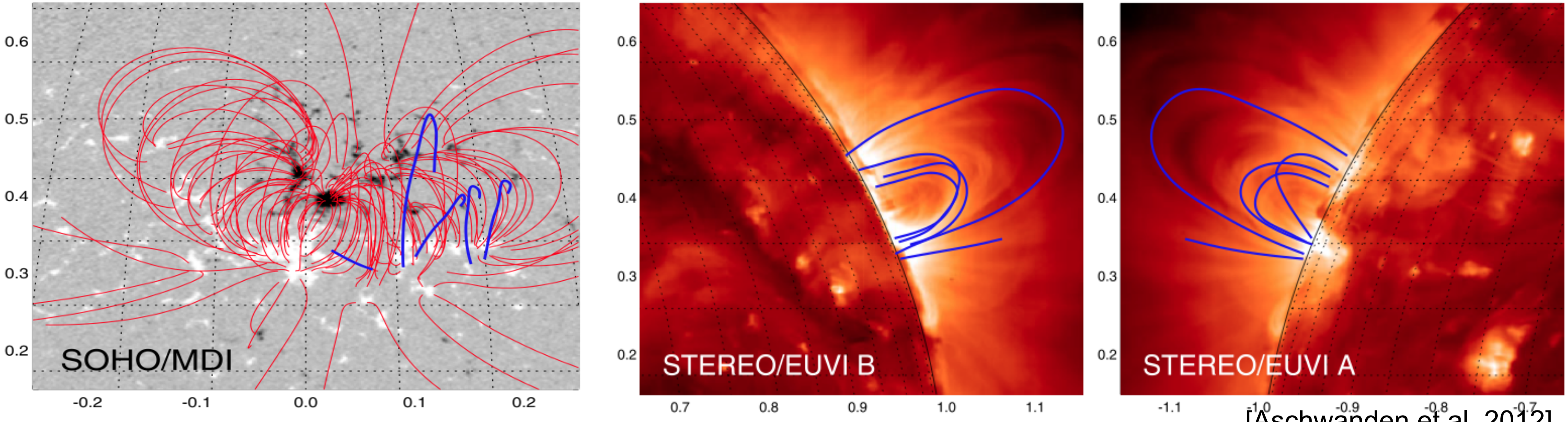
Objective: Provide measurements in order to

- **Distinguish** between existing models for CME trigger
- Create a **catalog of AR** and associated ability to produce a CME



Models for CME trigger mainly depend on

- **Reconnection** events and flares in active regions
- The magnetohydrodynamic stresses in the photosphere
- The **3D structure** of coronal loops

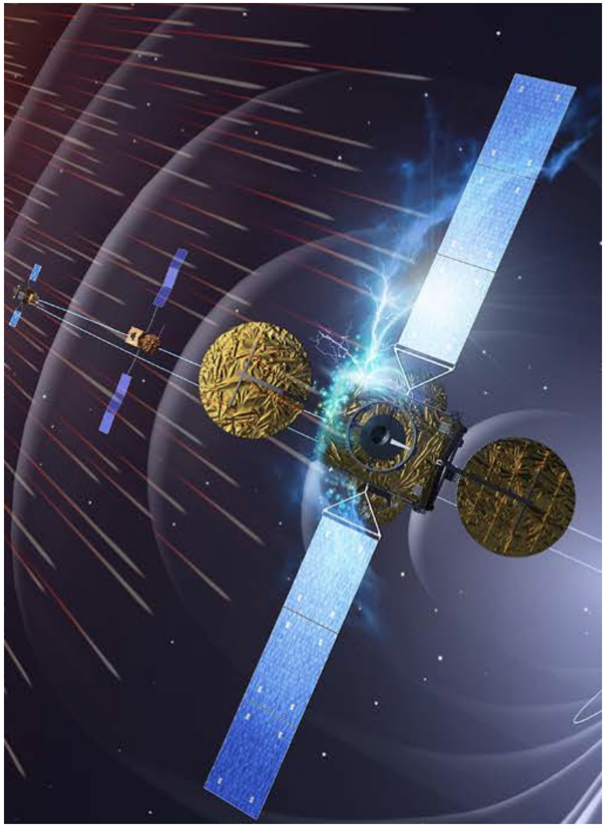


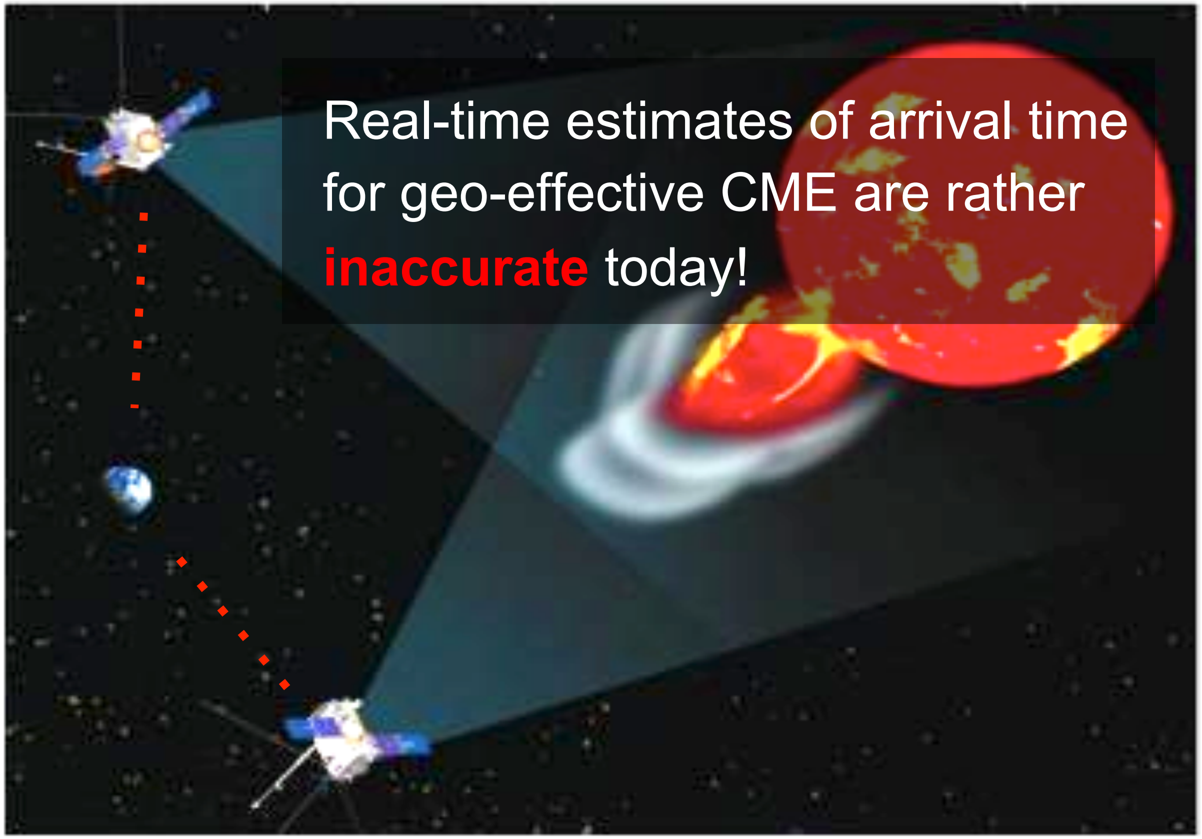
[Aschwanden et al. 2012]

Secondary Objectives: CME & CIR Forecast

Objectives:

- **Monitor** and provide data for **forecasting** the propagation of geo-affecting CMEs, and categorize them.
- Provide data for the **forecasting** of geo-effective CIRs



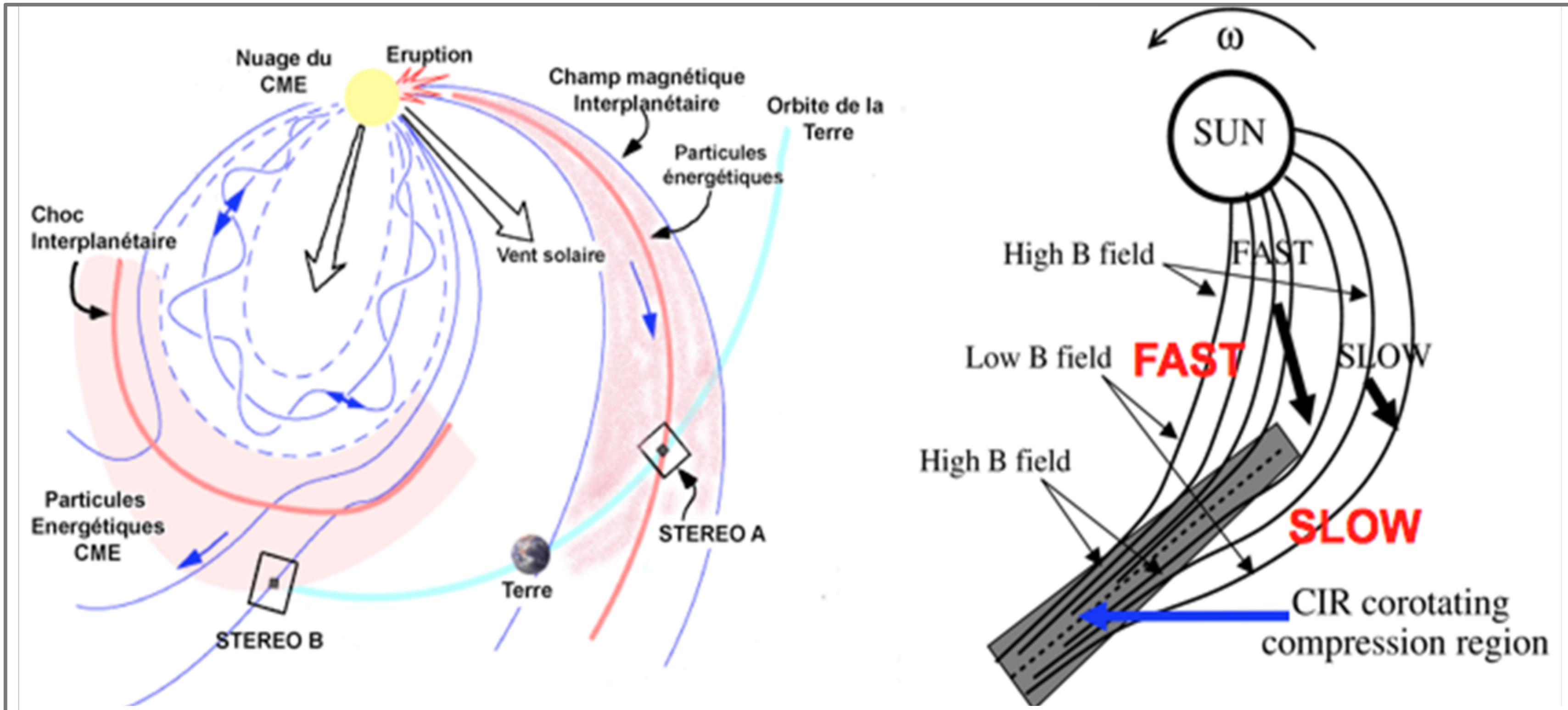


Real-time estimates of arrival time for geo-effective CME are rather **inaccurate** today!

Secondary Objectives: CME & CIR Statistics

Objective: Provide in-situ measurements at 1 AU

- **Improve** our knowledge on the 3D structure of CMEs and CIRs.
- **Study** the evolution of CIRs between two measurement points.



Coronal Mass Ejections

Corotating Interaction Regions

Top Level Requirements: Primary Objectives

1. We shall provide **stereo view** of coronal loops at different heights in the lower corona.
2. We shall capture the **time scale of flares** (order of minutes) and resolve distinct coronal loops.
3. The stereo observation shall be **synchronized** (0.1 s) to ensure a proper 3D reconstruction.
4. We shall observe the **vector magnetic field on the photosphere**.

Top Level Requirements: Secondary Objectives

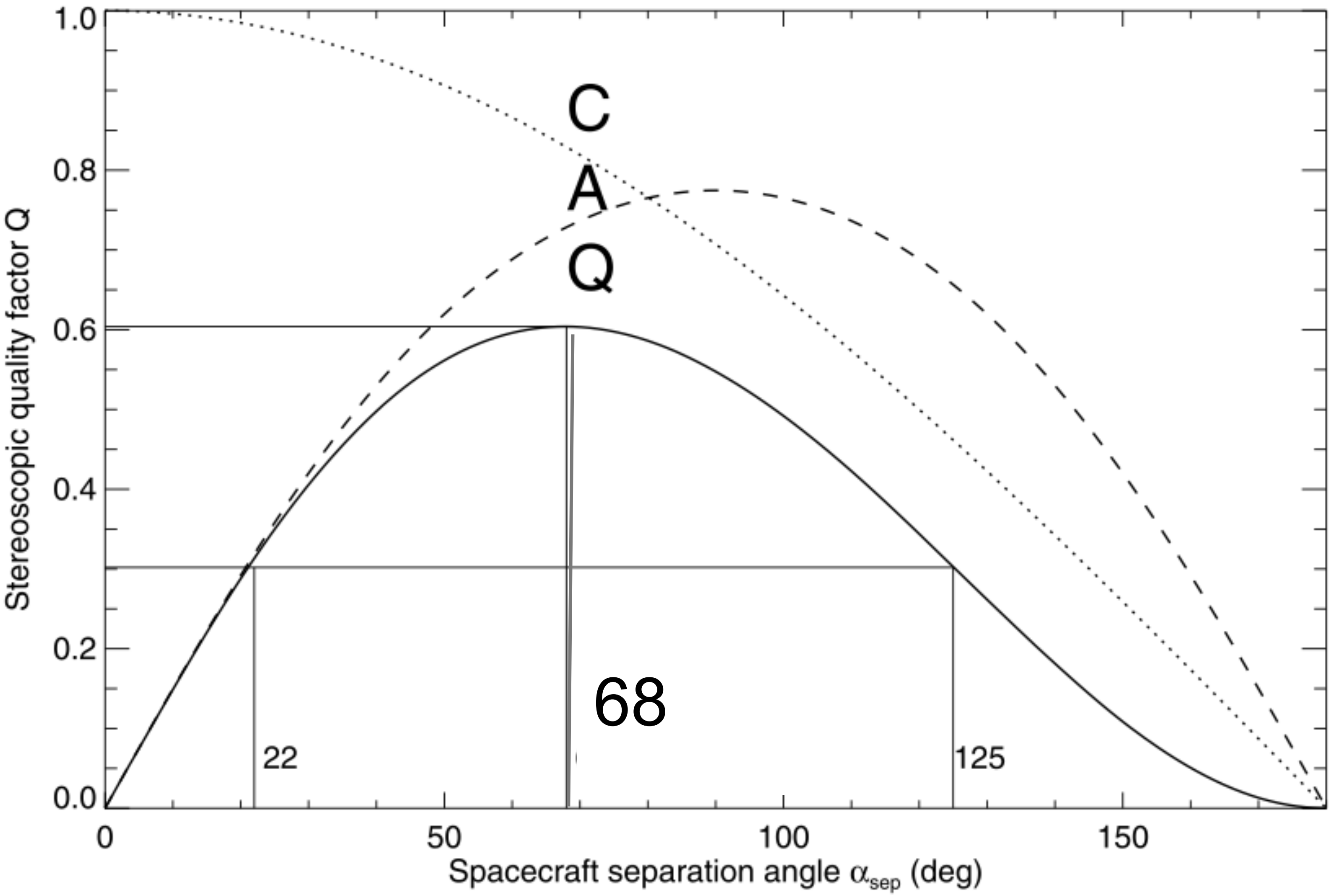
1. Provide data for **forecasting** of the **arrival time** of **geo-directed** CMEs and CIRs.
2. Track geo-directed CMEs **from the lower corona to 1 AU.**
3. Determine the **shape, direction and velocity** of the leading edge of the CME.
4. We shall provide **in-situ measurements** of geoeffective CIRs.
5. We shall measure **magnetic field** and the **velocity, density and temperature of charged particles** of CMEs and CIRs.

Key Mission Requirements

1. The stereo imaging angle shall be between **22 and 125 degrees.**
2. The time resolution of coronal loops images shall be **5 seconds**.
3. Time resolution for heliospheric images shall be **2 hours**.
4. The duration time for the mission shall be no less than **5 years** (high statistics for the CMEs, > 750 CMEs triggered).
5. We shall provide data for **2 days** forecast updated every **6 hours.**
6. The proton velocity shall be measured from **300 to 3000 km/s** with a relative accuracy of 5%.
7. Measure O^{7+}/O^{6+} ratio and the abundance of the highly ionized iron charge states

Optimal Angle for Stereoscopic View

[Aschwanden et al. 2012]



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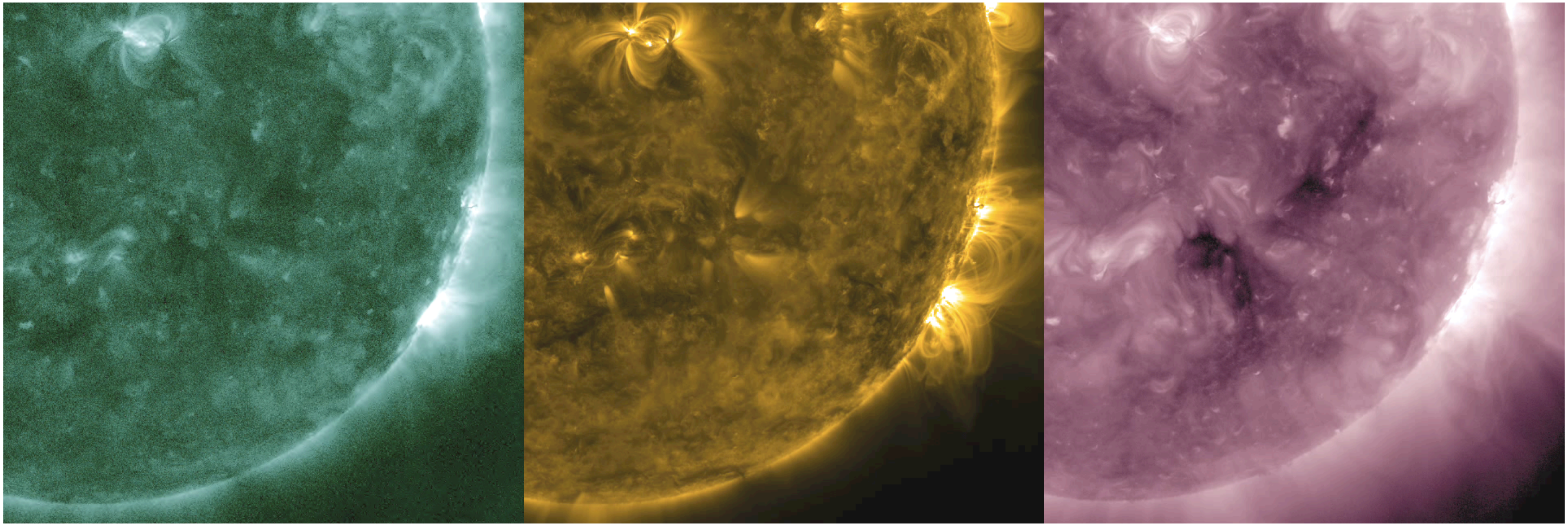
Flare on June 6th 2013 (SDO/AIA)



9.4 nm

17.1 nm

21.1 nm

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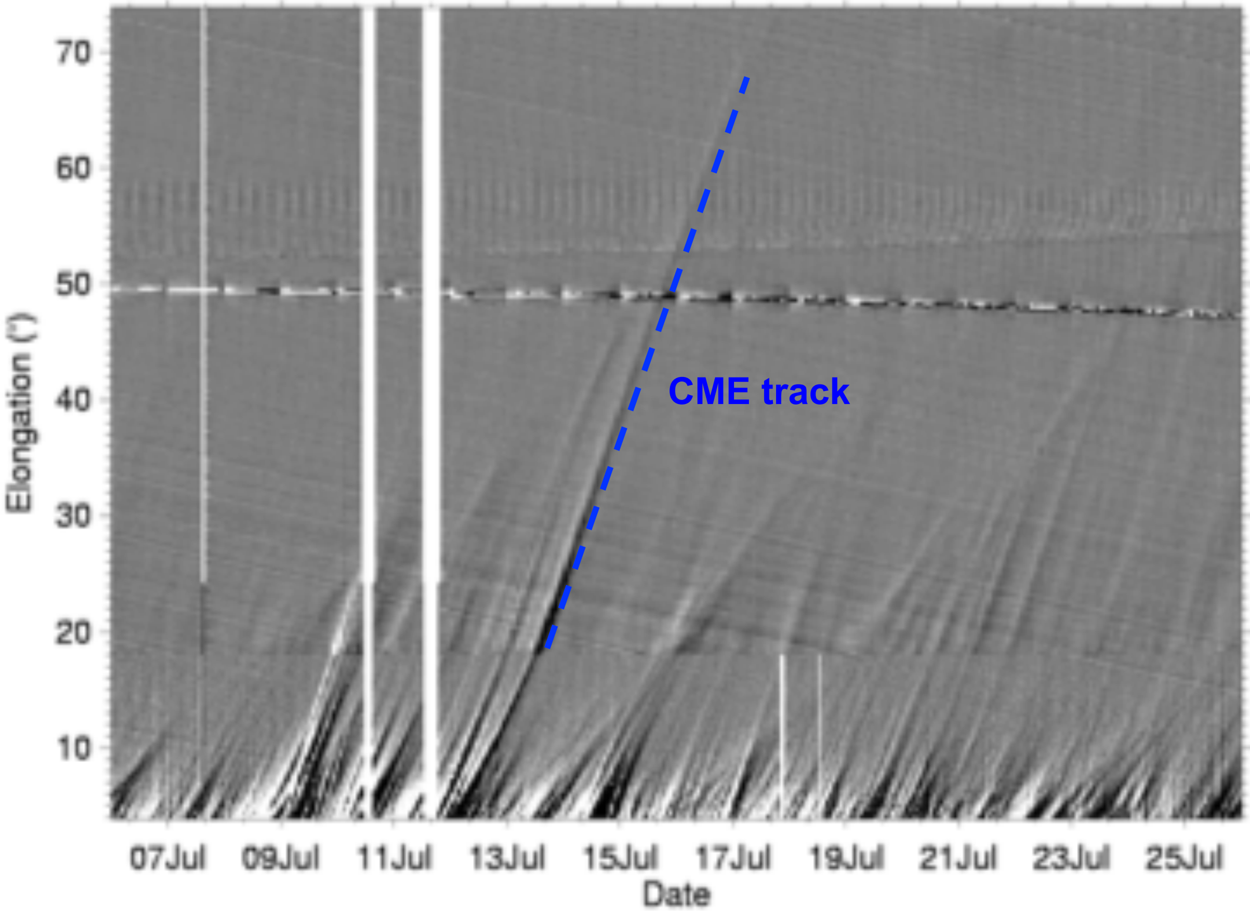
CME Travel Time from Heliospheric Images

Stereo J-map



[Davies et al 2012]

Fastest CMEs reach Earth in 14 hours. A 6 hour update of our data shall be sufficient to track and forecast all Earth-oriented CMEs

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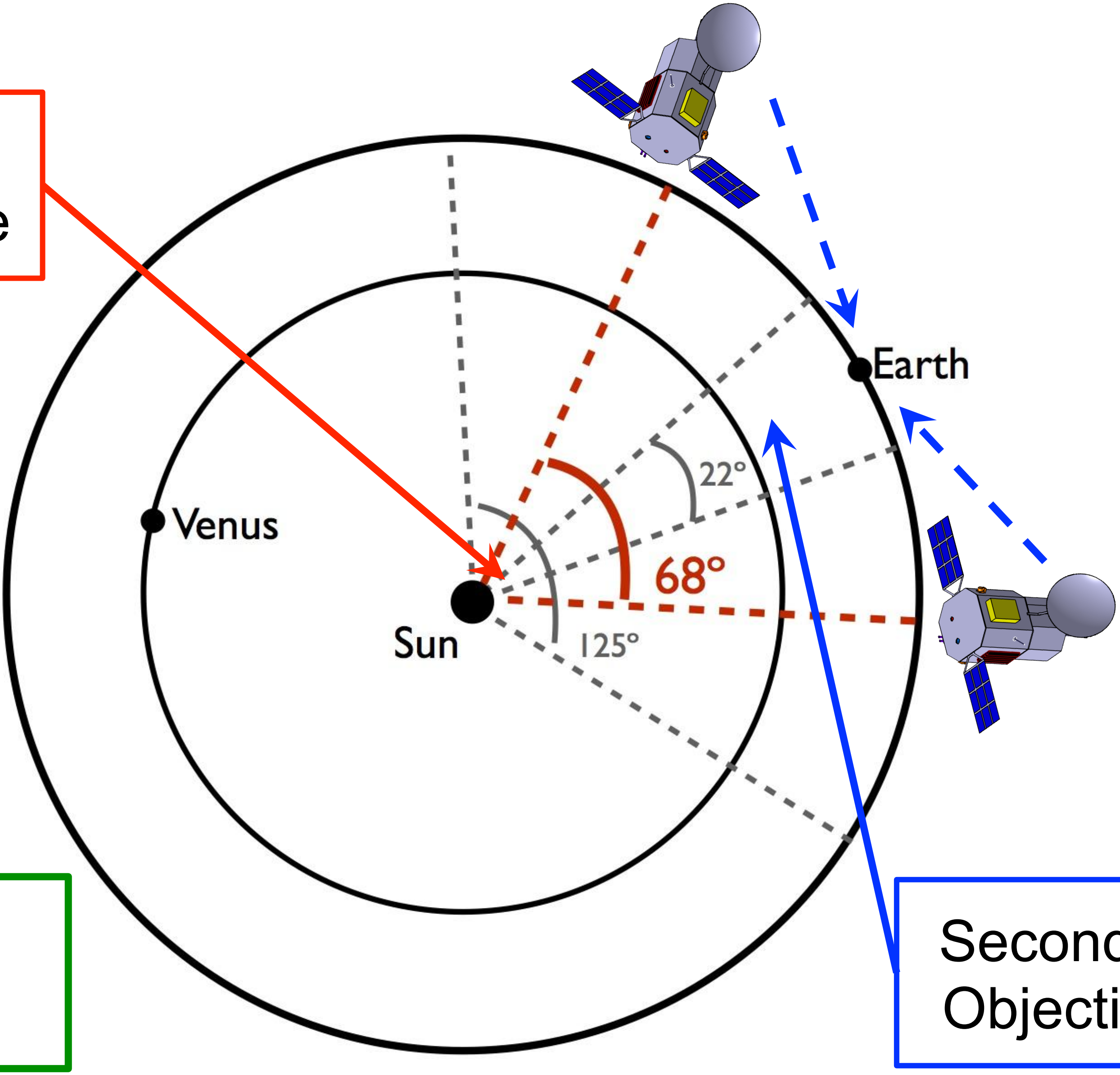
Basic Design



Primary Objective

Secondary Objectives

Fixed angle between spacecraft!

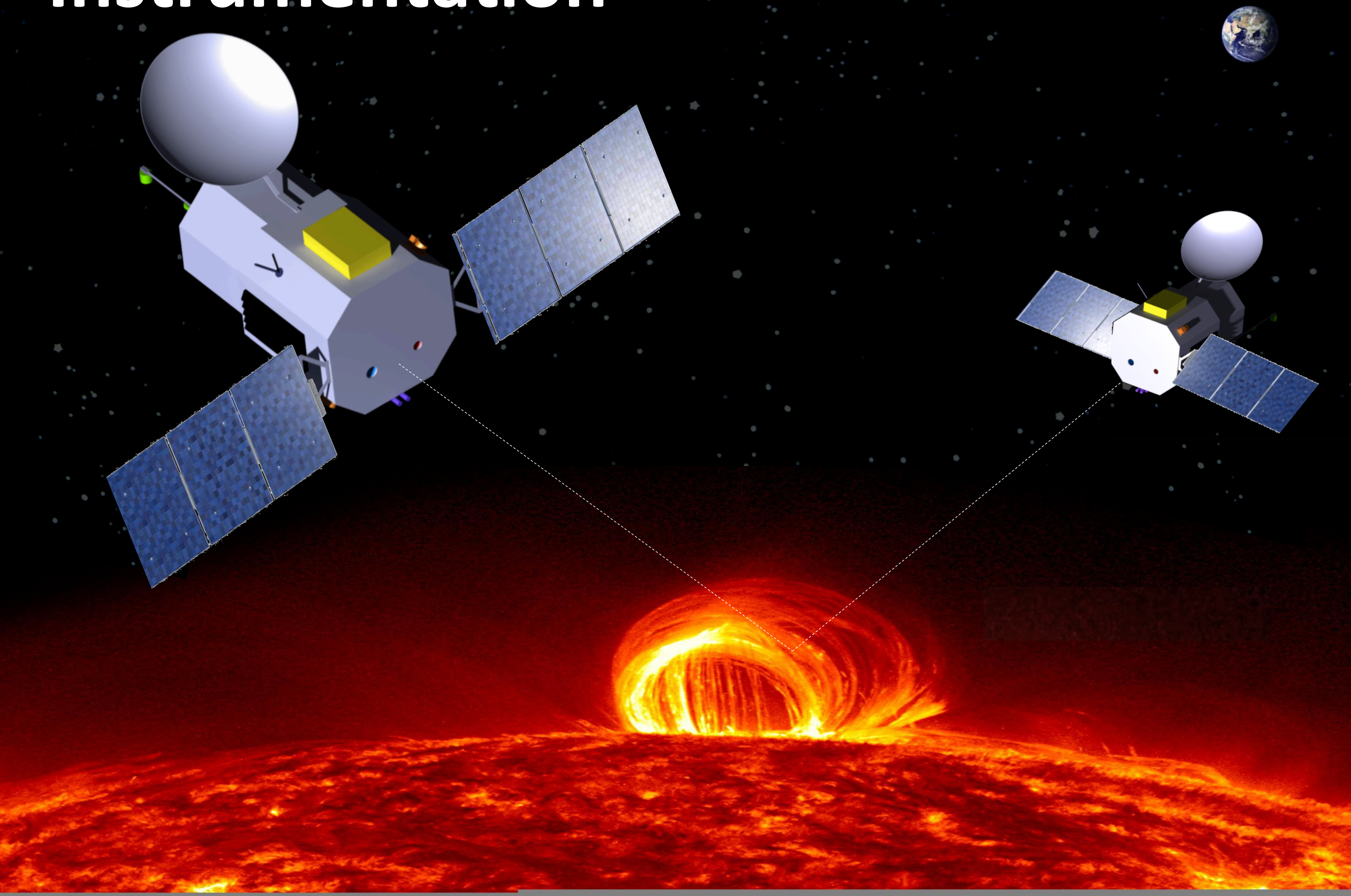
Not convinced?

STEREO !?
SDO !?
SOLAR-C !?
... !?

Our mission is **different**

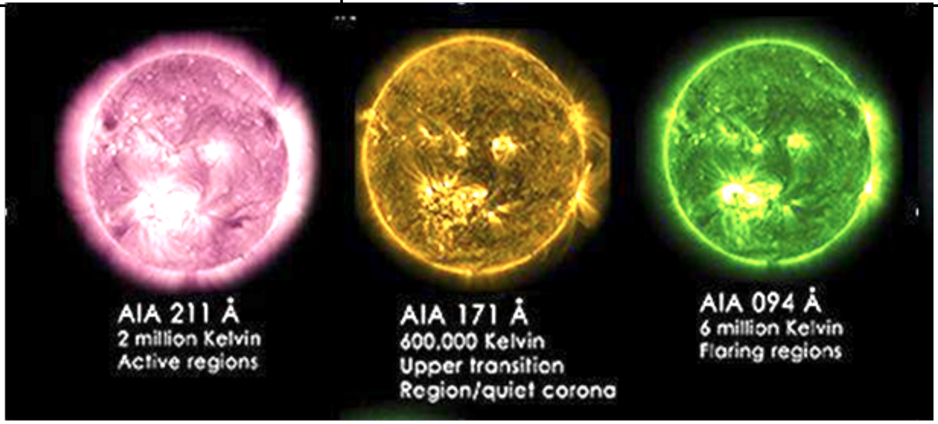
	SDO	*STEREO*	*SOLAR-C*	**OSCAR**
Stereographic view	✖	✔	✖	✔
Photospheric magnetic field measurement	✔	✖	✖	✔
High resolution coronal images at different altitudes	✔	✖	✔	✔
Statistical categorization of active regions	✔	✖	✔	✔
Near real-time accurate CME forecasting	✖	✖	✖	✔
Near real-time accurate CIR forecasting	✖	✖	✖	✔
CME and CIR observations at 1 AU	✖	✔	✖	✔

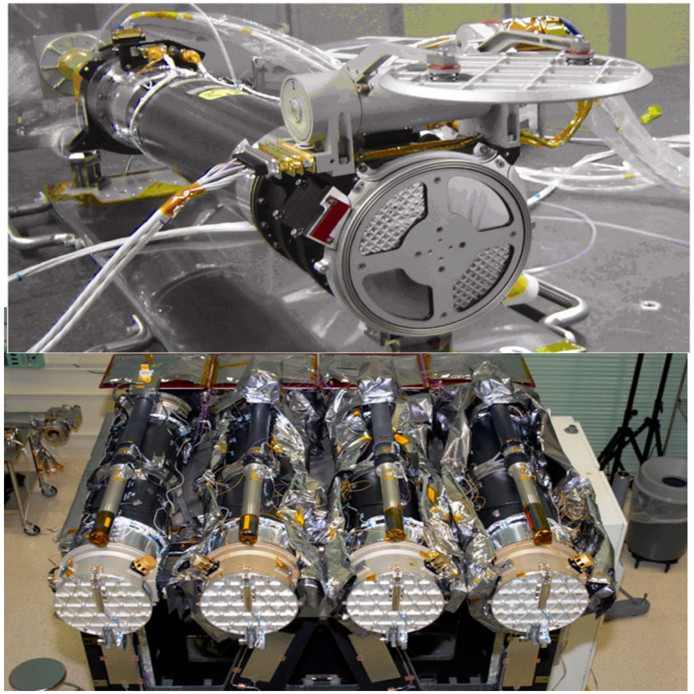
Instrumentation



Instrumentation: EUV Imager

	Observational Requirements
FOV	Full Sun disk
Surface resolution	500-1000km
Spatial resolution	0.6-1 arcsec/px
Exposure time	Max. 3s
Cadence	Max. 5s
Pointing Stability	0.2 – 0.35 arcsec
Number of telescopes	2 (simultanous measurements, redundancy)
Wavelengths	21.1 nm, 17.1nm, 94nm





Implementation: EUV Imager

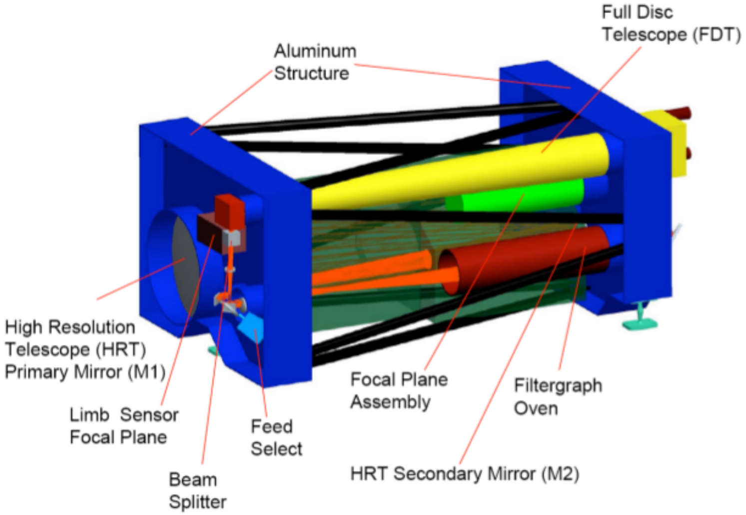
- Improved performance required
- Based on heritage telescopes
- Strongly inspired by AIA (SDO) design
- TRL 4

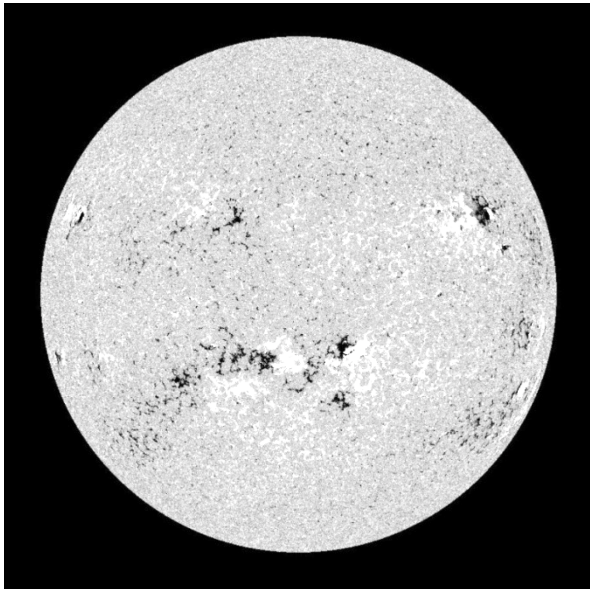
Instrumentation: Heritage Instruments

Specifications	**AIA (SDO)**	**EUVI (STEREO)**	**EUI (SO)**
FOV	Full Sun disk	Full Sun disk +- 1.7 Rs	Full Sun disk/High resolution
Surface resolution	750km	2500km	N/A
CCD resolution	4096x4096 px CCD203 0.6 arcsec/px	2048x2048 px CCD42-40 1.6 arcsec/px	2048x2048 APS 1 to 9 arcsec/px
Cadence	12 s All wavelengths	>2.5 min	10 s- 10 min
Wavelengths	170 nm, 30.4 nm, 160 nm, 17.1 nm, 19.3 nm, 21.1 nm, 33.5 nm, 9.4 nm, 13.1 nm, visible light	17.1 nm 19.5 nm 28.4 nm 30.4 nm	17.4 nm 30.4 nm 33.5 nm
# Telescopes	4	1	2.5
Weight	112kg + 26kg (electronics) + 17kg (harness)	14 ± 2kg	23.50kg

Instrumentation: Magnetograph

	Requirements
FOV	Full Sun disk
Surface resolution	500-1000km
Spatial resolution	41 x 41 arcsec
Exposure time	TBD
Pointing Stability	0.2 – 0.35 arcsec
Cadence	10 – 60s





Implementation

Vector Magnetograph inspired by the Polarimetric and Helioseismic Imager of Solar Orbiter

Minor redesign needed (sensor, layout)

TRL 5

Specifications

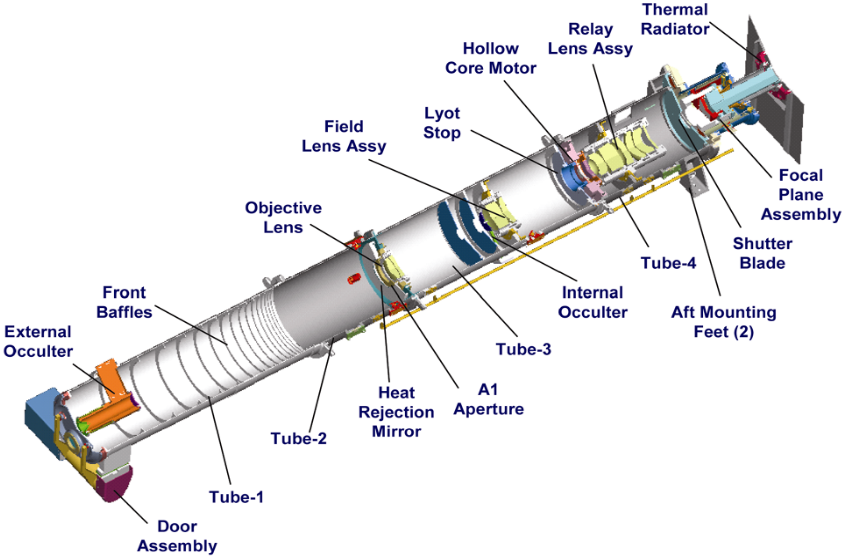
FOV: Full Sun disk

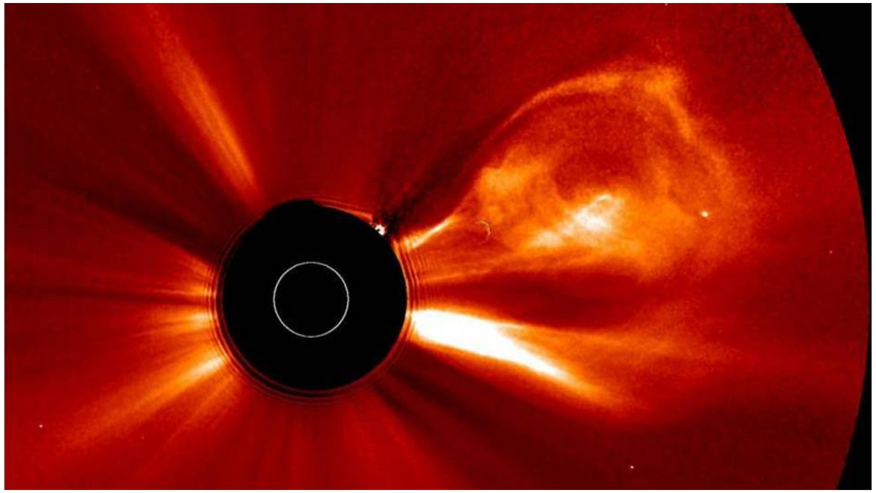
Surface Res. 750 km

Cadence 60s

Instrumentation: Coronagraph

	Requirements
FOV	Max. 8°
Inner/Outer limit	2-12 Rs
Spatial resolution	Min. 16 arcsec/px
Exposure time	< 8s
Cadence	30 min
Pointing Stability	2 arcsec
Wavelength	visible light





Implementation

Coronagraph 2 (STEREO) like

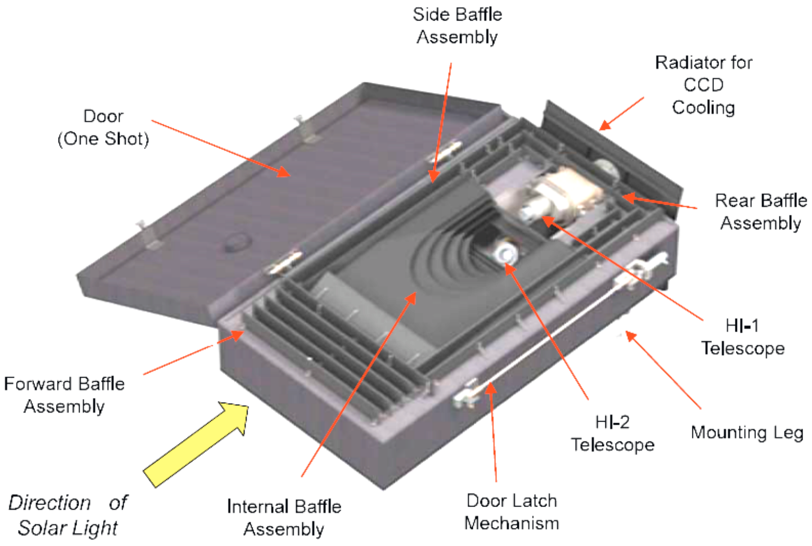
TRL 7

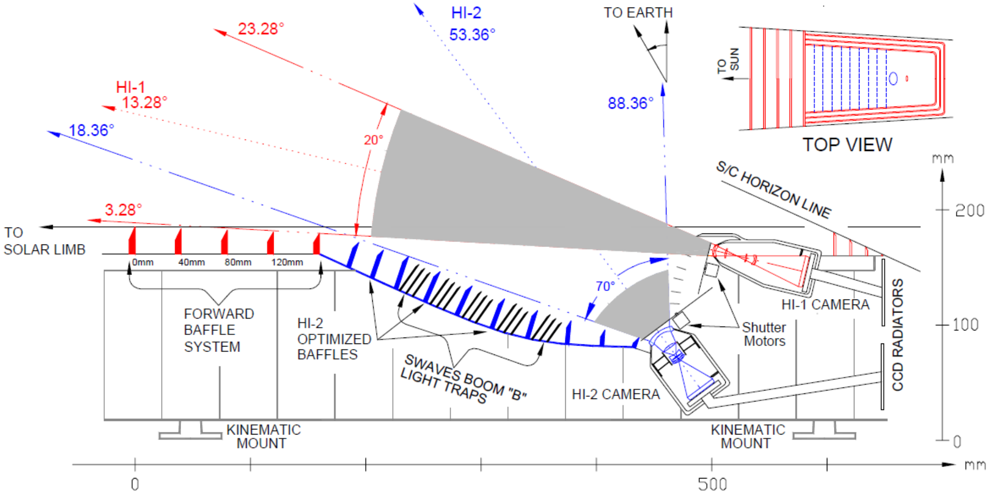
Specifications

FOV	4° half angle, 2-15Rs
CCD	2048 x 2048px, 15”/px
Cadence 15 min	
Exp. time	4s
Polarization	-60°, 0°, 60° visible light

Instrumentation: Helisopheric Imager

	Requirements
FOV	>= 73° (HI1 20° | HI2 70°)
Inner/Outer limit	15 - 215 Rs
Spatial resolution	HI1 < 140 arcsec | HI2 < 481 arcsec
Exposure time	HI1 10 – 30s | HI2 40 – 70s
Cadence	HI1 60 min | HI2 120 min
Pointing Stability	4.5 arcsec
Wavelength	White light





Implementation

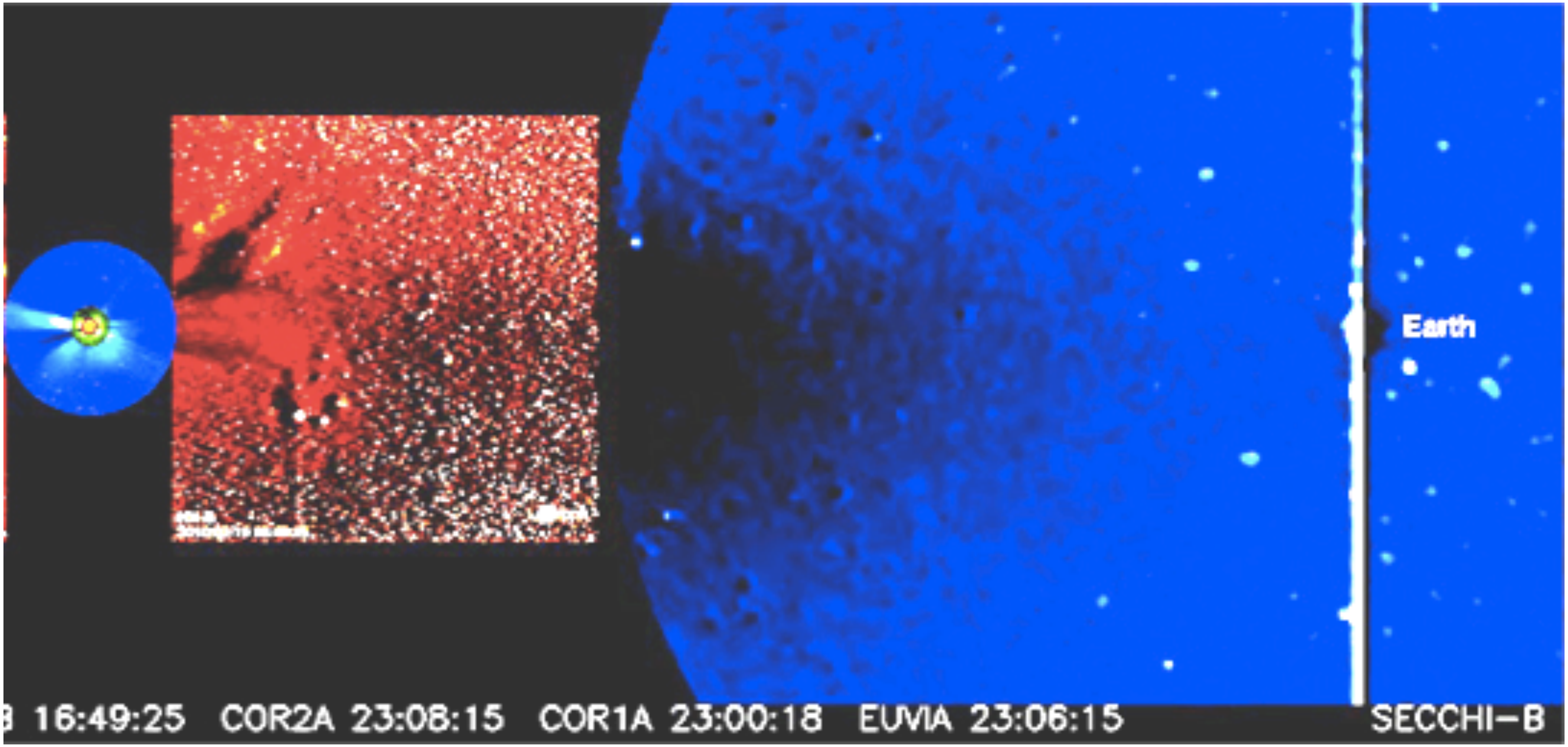
Heliospheric Imager (STEREO) like

TRL 7

Specifications

	HI 1	**HI2**
FOV	20°	70°
	12.3 - 87.3 Rs	72.8 – 332 Rs
CCD	70 arcsec	4 arcmin
	2048 x 2048px 13.5µm	
Cadence	60 min	120 min
Exp. Time	12 - 20s * 120	60 - 90s * 100

Instrumentation: Helisopheric Imager



Instrumentation: CIR In-Situ

Instrument requirements for CIR forecasting:

1. **B-field component** measurement:

- range: -100nT<Bi<100nT
- resolution: 0.1 nT
- time resolution: ~10s

[Tsurutani, 2007; Richardson, 2006]

2. **Solar wind velocity** measurement:

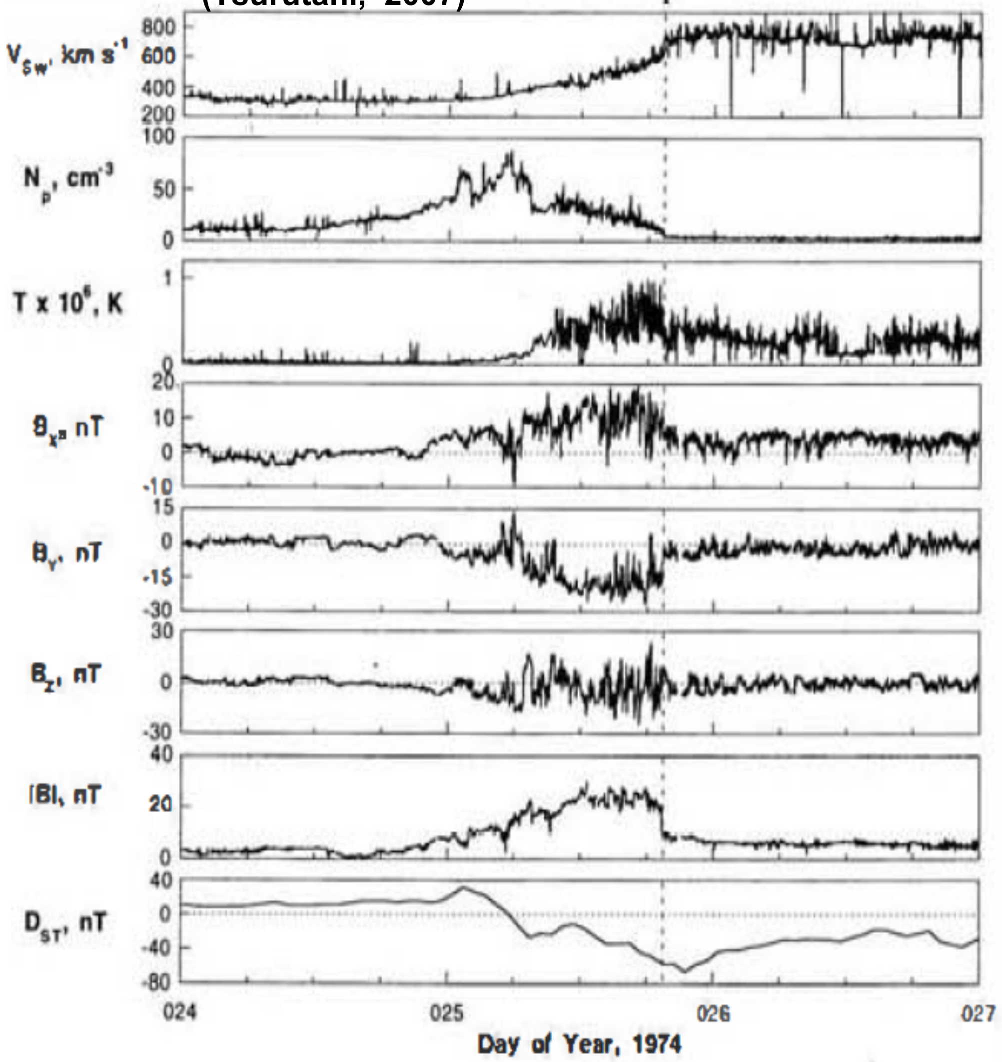
- ~300 km/s<vsw<~1000 km/s
- relative velocity resolution: 5%
- time resolution: ~10s

[Tsurutani, 2007; McComas, 2000]

3. **Solar wind heavy ion abundances**:

- ratio O^{7+}/O^{6+}

[Geiss,1995]



IMP-8

January 24-27, 1974 (Day 024-027)

(Tsurutani, 2007)

Instrumentation: CME In-Situ

Instrument requirements for CME measurement:

1. **B-field components**:

- range:-100nT<Bi<100nT
- resolution 0.1 nT
- time resolution: 10s

[Skoug et al. 2004]

2. **Solar wind velocity**:

- 300km/s to 3000 km/s
- relative velocity resolution: 5%
- time resolution: 10s

[Skoug et al. 2004]

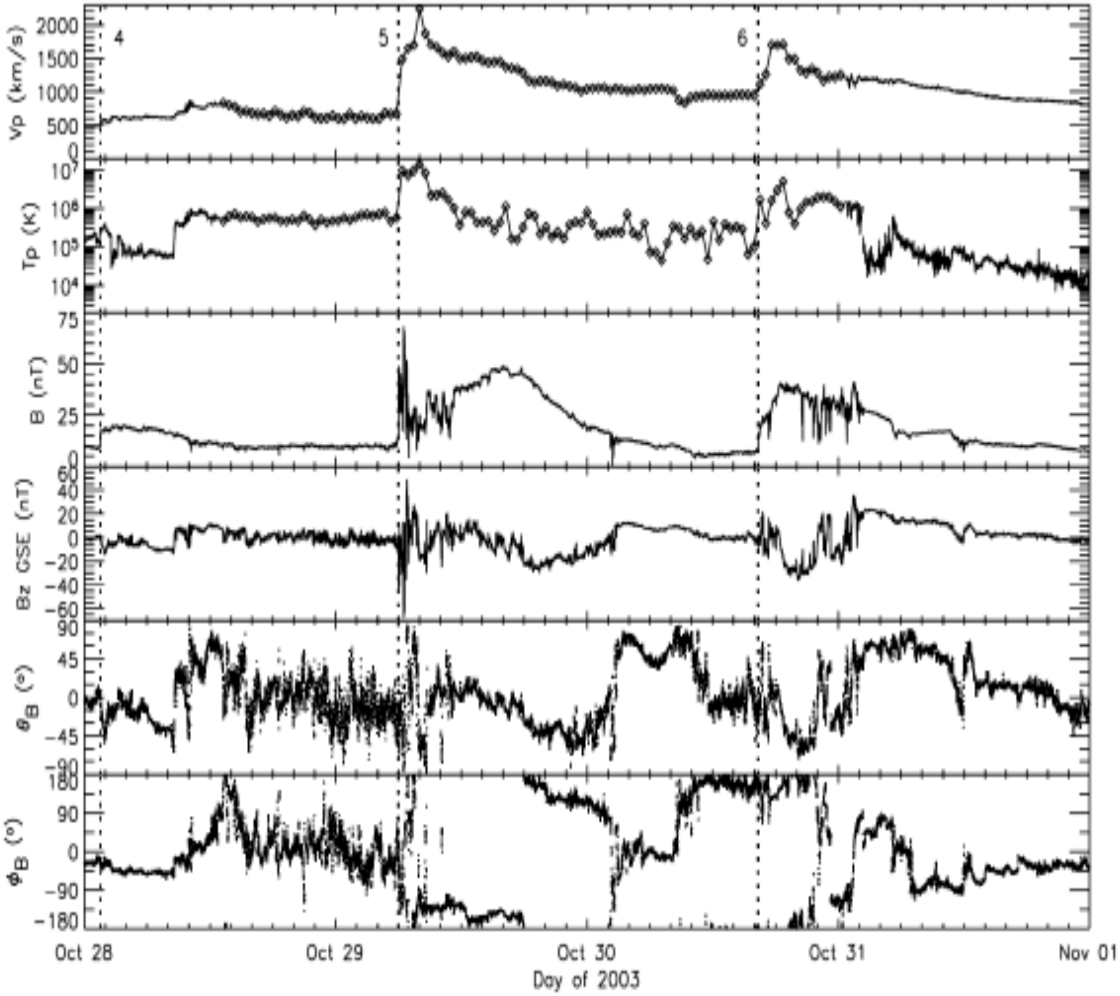
3. **Solar wind heavy ion abundances**

- abundances of Fe charge states up to Fe^{16+} (time resolution: ~ 10s)

[Lepri et al. 2001,]

Launch @Sun

Shock Arrival @1AU (L1)

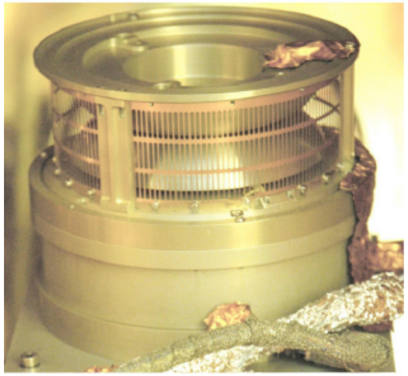


Measurements from ACE/SWEPAM (Skoug et al. 2004)

Instrumentation: CIR and CME In-Situ

Instrumentation requirements for CIR and CME measurements

Measurement	Ranges	Resolution	Sampling rate [s]
B-field	-100nT<B_i<100nT	0.1 nT	~10
Solar wind protons, heavy ions	300 <v_{sw}< ~3000 km/s	Rel. velocity res.: ~5 %	~10



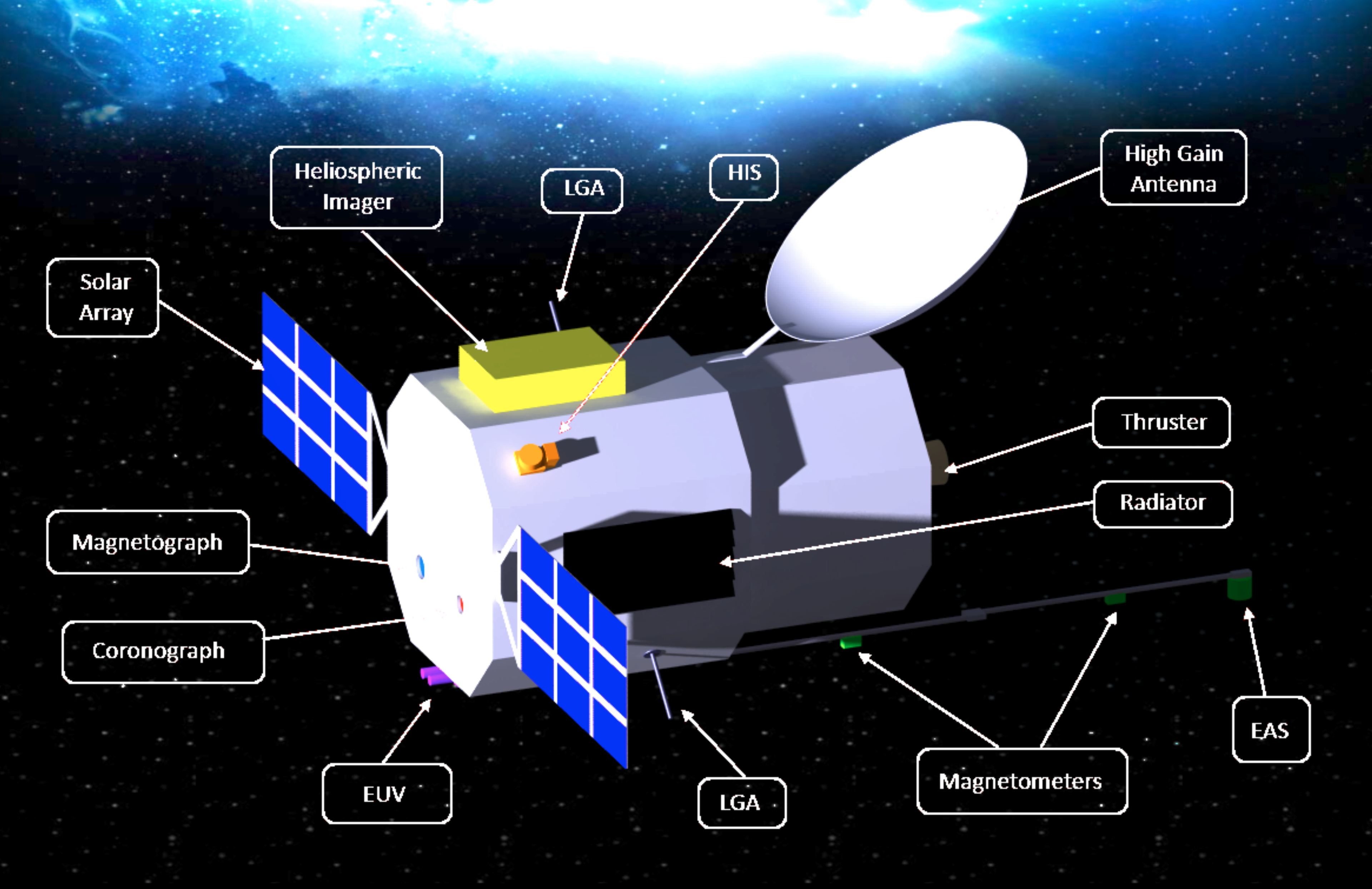
SOLO/SWA-EAS

Selected Instrumentation

Instrument	Ranges	Resolution	Sampling rate [s]	Weight [kg]	Power [W]	Purpose
2x SOLO MAG* (Fluxgate)	+/- 128 nT	0.004 nT	0.06	1.5	1.9	Measuring Bx, By, Bz
Improved SOLO SWA:** Electrons **protons, alphas** heavy ions (Z=3-26)	E or E/q: 1ev - 5keV 0.2 - **45 keV/q** 0.5 - 100 keV/q Proton Velocity: 200-**3000** km/s	Rel. energy res. : 12 % 7.5 % 5.6 % Rel. velocity res.: protons: - 3.75 %	 3 6 10	12	3.1	Measuring particle speed: V_e, V_p, V_{ions}

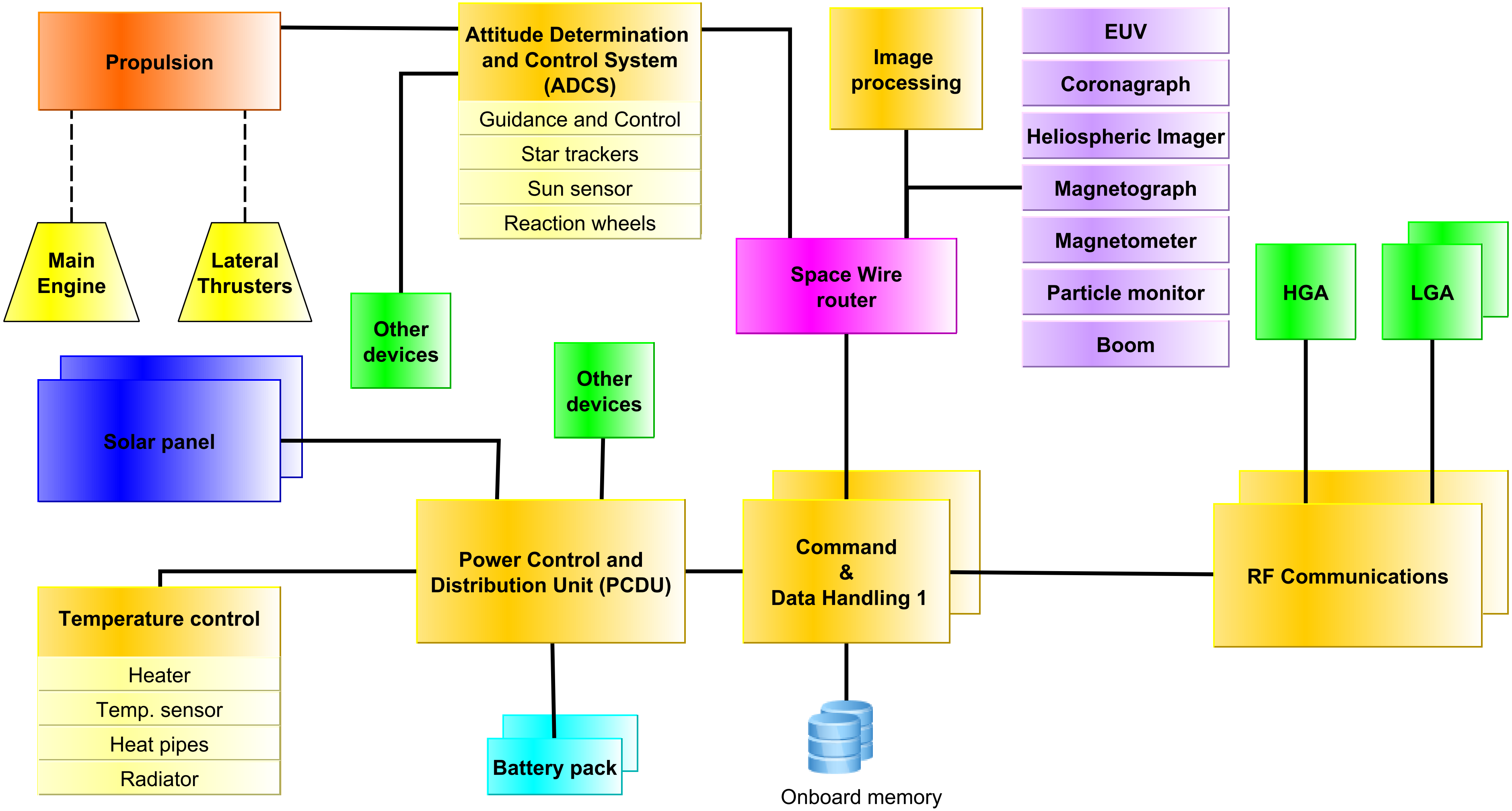
* fluxgate magnetometers on a 3m long boom placed at 0.75m and 2.25m from the spacecraft body

**Upper limit of the energy range of the *SWA Proton and Alpha Sensor* is extended from 20 keV/q to 45keV/q.



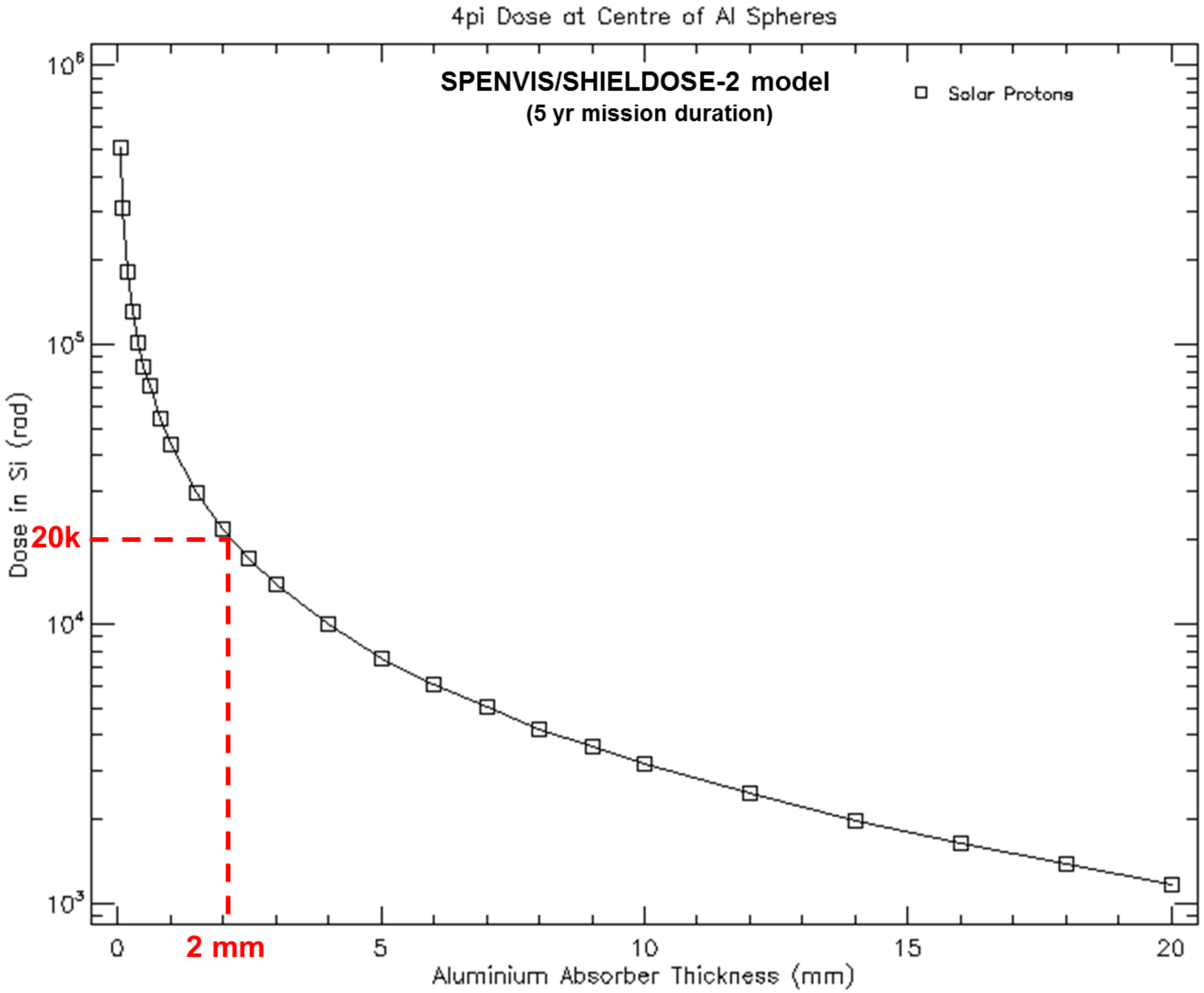
Spacecraft design

System Architecture



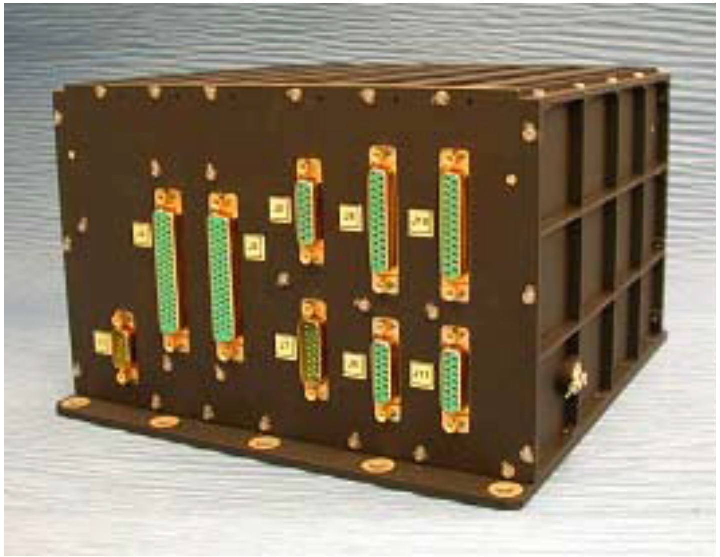
Radiation Hardness

- Total radiation dose for the entire mission



Electric power system

- Power Conditioning and Distribution Unit (2x)
  - Manufacturer: Thales Alenia Space
  - Conditioning of the solar array power by BOOST regulator (max. 330W)
  - Non-regulated power bus (BNR 22V – 37V)
  - Autonomous battery management
  - Distribution of the unregulated bus (BNR) and regulated voltages
  - Line protection



Onboard computer & data handling

- Compact computer based on LEON3 core
  - Manufacturer: Astrium
  - 26 MIPS @ 32 MHz or 40 MIPS @ 48 MHz
  - 128 Kbytes EEPROM for boot software
  - 256 Mbytes RAM memory
  - 512 Mbytes of exchange memory
  - High reliability thanks to full redundant architecture
  - Mass: 5 kg
  - Volume: 230 x 160 x 200 mm3
  - Power: 15 W max @ 26 MIPS

Power harvesting

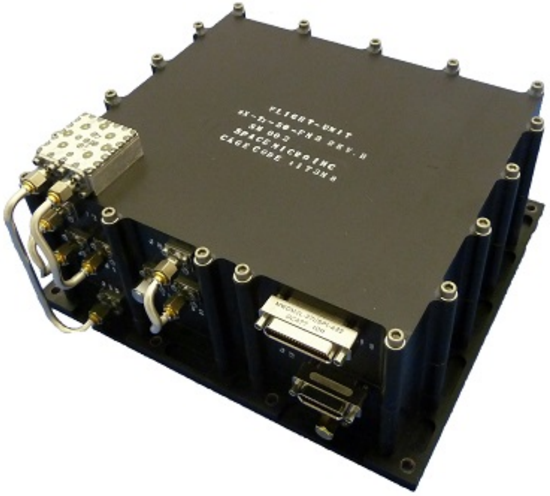
- High-efficiency triple-junction solar cells
  - Manufacturer: Spectrolab
  - Minimum Efficiency: 29.5%
  - Low long-term degradation

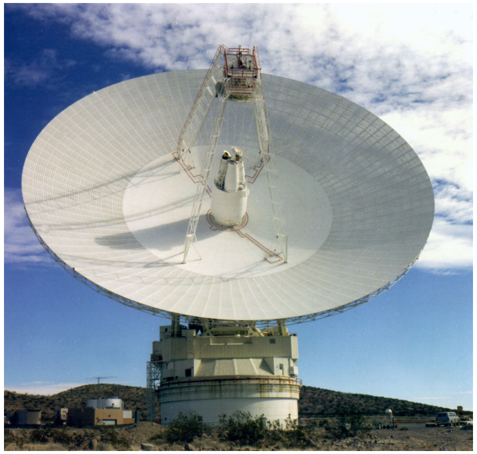
- Power harvesting budget estimation

Item	Value
Solar Panels Area [m2]	2.25
Solar Panels Efficiency [%]	32.0
Solar Panels Degradation [%/yr]	1.5
Incident Angle [°]	85.0
DC/DC Conversion Efficiency [%]	90.0
Mission Duration [yr]	5.0
Solar Constant at 1 AU [W/m2]	1,361
Output Power [W]	**814.6**

Telemetry, Tracking & Command

- HGA and LGA Transceivers
  - Manufacturer: Space Micro
  - Downlink frequency: 7.5 GHz
  - Data rate: 1.4 Mbps
  - Transmitter power: 200 W
  - Dish size: 1.7 m diameter
  - Utilization of ESA deep space network
  - For daily 4h slot duration:
    2.4 GB data per day
  - Two omni-directional LGA for safe mode communication





Propulsion System

- Comparison of propulsion systems
  - Specific impulse of at least 300 s is desired

Propulsion System Technology		I_{sp} [s]	Δv [km/s]	Thrust [N]
Chemical	Solid	250 – 310	5.7 – 7.1	10^7
	Liquid	300 – 500	6.9 – 11.5	10^7
MHD		<200	4.6	10^5
Nuclear	Fission	500 – 800	11.5 – 20.7	10^6
	Fusion	10^4 – 10^5	230 – 2.3×10^3	10^5
	Antimatter	6×10^4	1.4×10^3	10^2
Electric	Electrothermal	150 – 1.2×10^3	3.5 – 27.6	10^1
	Electrostatic	1.2×10^3 – 10^4	27.6 – 230	3×10^{-1}
	Electromagnetic	700 – 5×10^3	16.1 – 115	10^2
Propellantless	Photon Rocket	3×10^7	unlimited	10^{-4}

Propulsion System

- Main Engine
  - Astrium 400 N Bi-Propellant Engine
  - Nominal thrust: 420 N
  - Specific impulse: 318 s
  - Total Δv requirement: 3.31 km/s
  - Total propellant mass: 258 kg

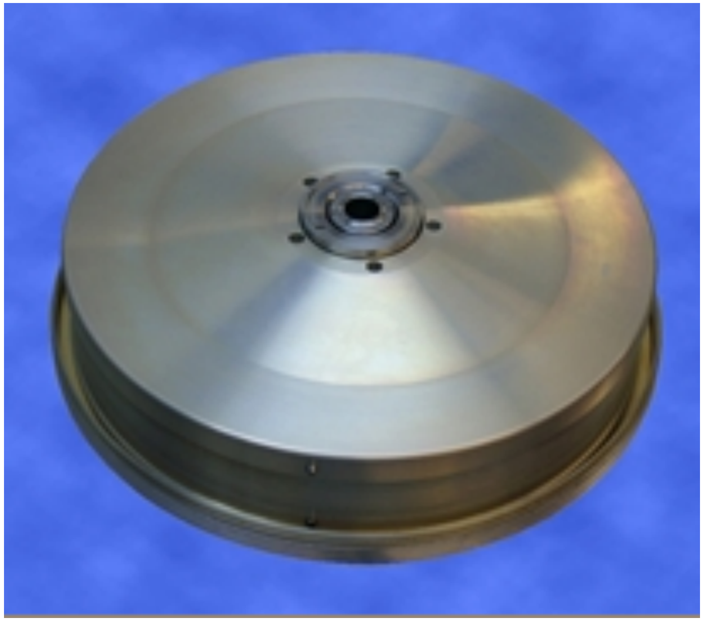
- Lateral Thrusters
  - Eight Astrium 10 N Bi-Propellant Thrusters
  - Nominal Thrust: 10 N
  - Specific impulse: 291 s
  - Purpose: attitude control and relaxation of reaction wheels
  - Shared propellant tank

Attitude determination & Control System

- 3-axis stabilized
- Permanently facing Sun
- Spacecraft pointing

	Roll	Pitch/Yaw
Knowledge	20 arcsec	± 0.1 arcsec
Control	0.1 deg	± 15 arcsec
Jitter	30 arcsec	0.2-0.35 arcsec

- Reaction Wheel
  - 5x RSI 4-75/60 4Nms
  - 2 redundant
- Star Tracker
  - 3x Sodern Hydra
  - 1 redundant
- Sun Sensor
  - Astrium Bass17R
  - 1 redundant



Thermal Control

Thermal analysis

First approximation of the satellite's temperature

T = -13.6640 °C

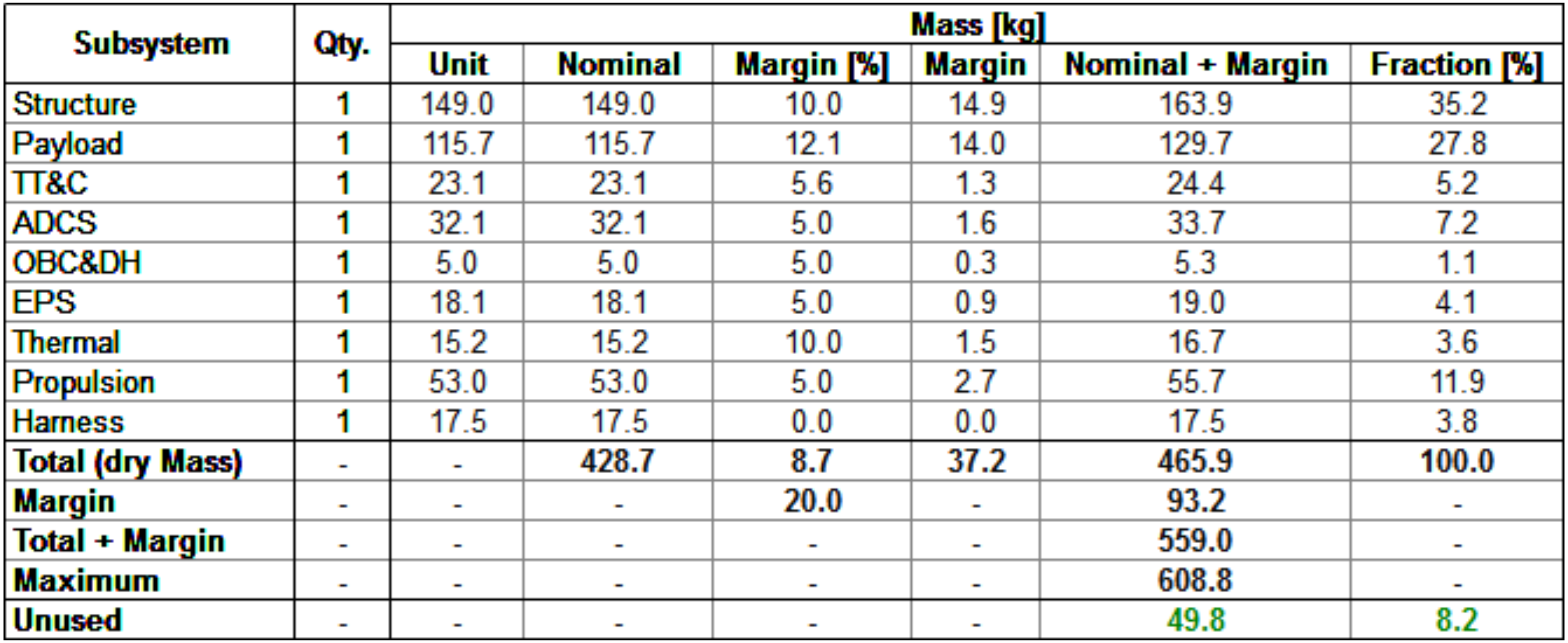
Maximum power dissipation on spacecraft	526 W
Minimum power dissipation on spacecraft	86 W
Upper temperature limit for the spacecraft	**30°C**
Lower temperature limit for the spacecraft	**-15 °C**
Radiator area to accommodate s/c power dissipation	**1.36 m^2**
Minimum temperature for given radiator area	-80.3 °C
Require heater power (during eclipse)	190.5 W
Additional surface area (*)	**0.1 m^2**

(*) The new emissivity of spacecraft surface is 0.8119.

Material for spacecraft's face turned towards the sun	*silver coated Teflon blanket with a coating of indium-tin oxide*
Material for spacecraft's face turned towards the space	*black-Kapton blanket*

System Budget

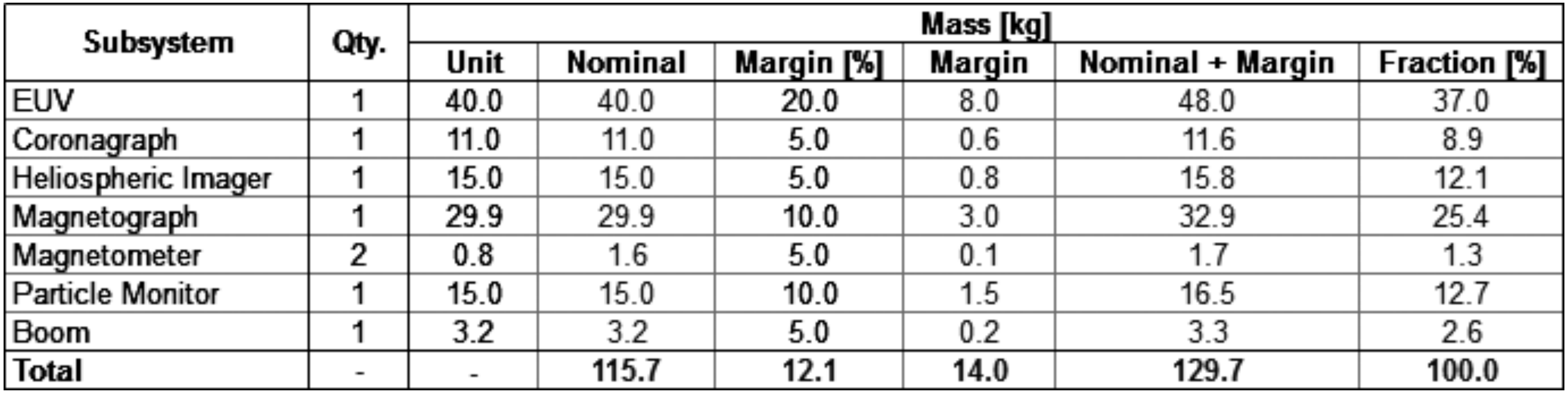
- Spacecraft Mass Budget for each Spacecraft



Subsystem	Qty.	Mass [kg]					
		Unit	Nominal	Margin [%]	Margin	Nominal + Margin	Fraction [%]
Structure	1	149.0	149.0	10.0	14.9	163.9	35.2
Payload	1	115.7	115.7	12.1	14.0	129.7	27.8
TT&C	1	23.1	23.1	5.6	1.3	24.4	5.2
ADCS	1	32.1	32.1	5.0	1.6	33.7	7.2
OBC&DH	1	5.0	5.0	5.0	0.3	5.3	1.1
EPS	1	18.1	18.1	5.0	0.9	19.0	4.1
Thermal	1	15.2	15.2	10.0	1.5	16.7	3.6
Propulsion	1	53.0	53.0	5.0	2.7	55.7	11.9
Harness	1	17.5	17.5	0.0	0.0	17.5	3.8
Total (dry Mass)	-	-	**428.7**	**8.7**	**37.2**	**465.9**	**100.0**
Margin	-	-	-	**20.0**	-	**93.2**	-
Total + Margin	-	-	-	-	-	**559.0**	-
Maximum	-	-	-	-	-	**608.8**	-
Unused	-	-	-	-	-	**49.8**	**8.2**

System Budget

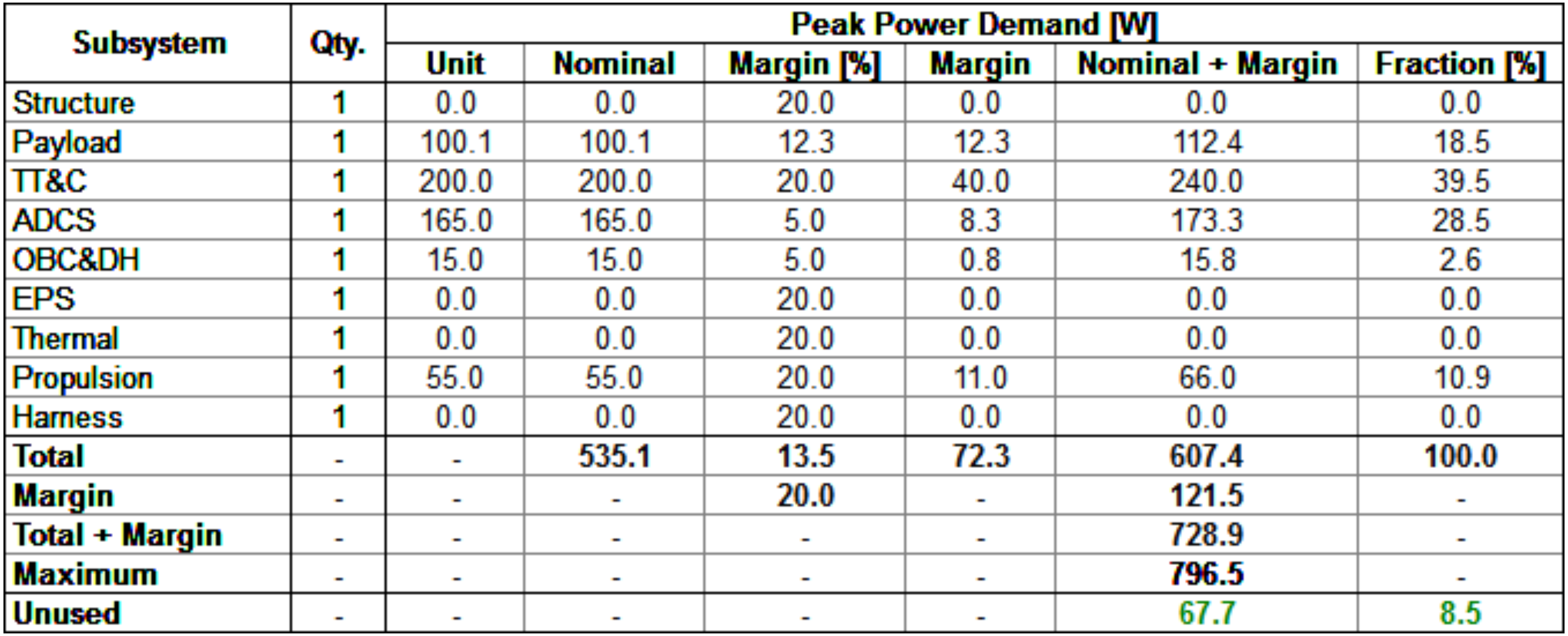
- Payload Mass Budget



Subsystem	Qty.	Mass [kg]					
		Unit	Nominal	Margin [%]	Margin	Nominal + Margin	Fraction [%]
EUV	1	40.0	40.0	20.0	8.0	48.0	37.0
Coronagraph	1	11.0	11.0	5.0	0.6	11.6	8.9
Heliospheric Imager	1	15.0	15.0	5.0	0.8	15.8	12.1
Magnetograph	1	29.9	29.9	10.0	3.0	32.9	25.4
Magnetometer	2	0.8	1.6	5.0	0.1	1.7	1.3
Particle Monitor	1	15.0	15.0	10.0	1.5	16.5	12.7
Boom	1	3.2	3.2	5.0	0.2	3.3	2.6
Total	-	-	**115.7**	**12.1**	**14.0**	**129.7**	**100.0**

Spacecraft Operation

- Spacecraft Power Budget



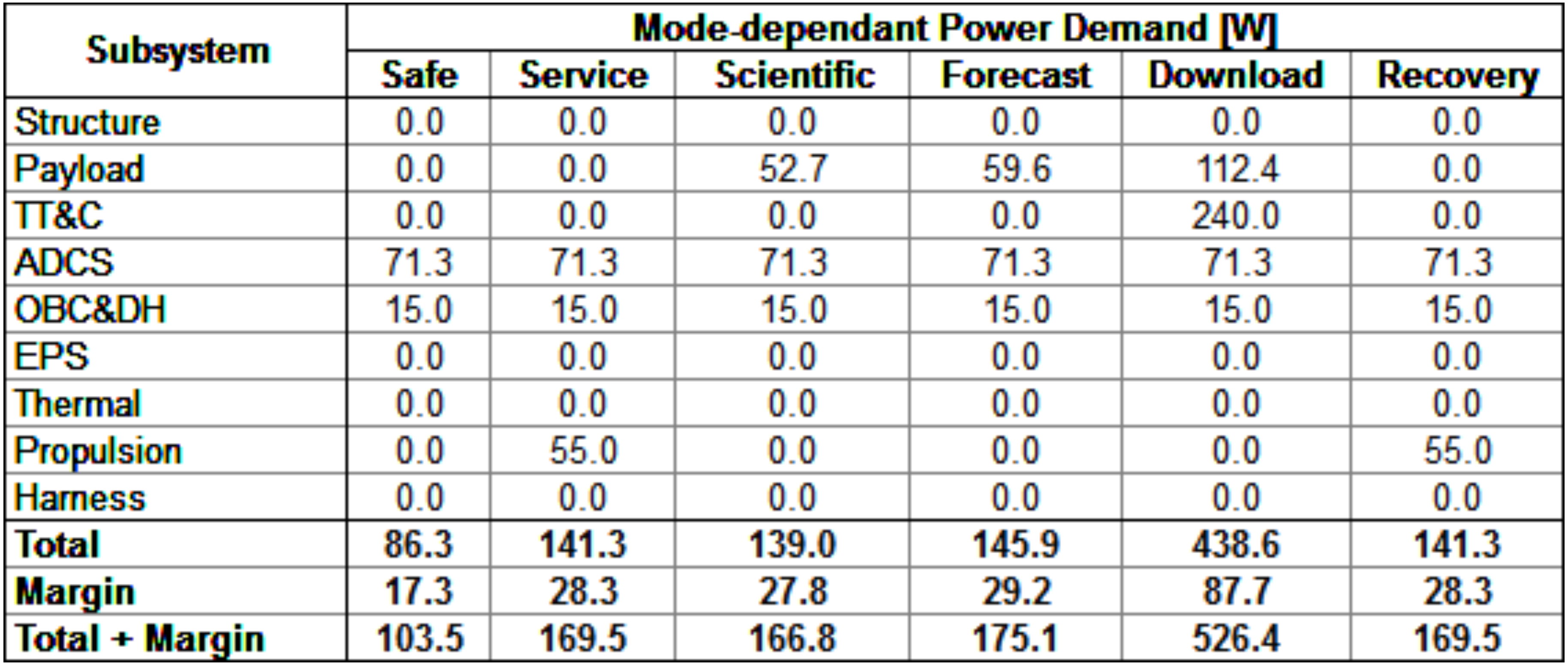
Subsystem	Qty.	Peak Power Demand [W]					
		Unit	Nominal	Margin [%]	Margin	Nominal + Margin	Fraction [%]
Structure	1	0.0	0.0	20.0	0.0	0.0	0.0
Payload	1	100.1	100.1	12.3	12.3	112.4	18.5
TT&C	1	200.0	200.0	20.0	40.0	240.0	39.5
ADCS	1	165.0	165.0	5.0	8.3	173.3	28.5
OBC&DH	1	15.0	15.0	5.0	0.8	15.8	2.6
EPS	1	0.0	0.0	20.0	0.0	0.0	0.0
Thermal	1	0.0	0.0	20.0	0.0	0.0	0.0
Propulsion	1	55.0	55.0	20.0	11.0	66.0	10.9
Harness	1	0.0	0.0	20.0	0.0	0.0	0.0
Total	-	-	**535.1**	**13.5**	**72.3**	**607.4**	**100.0**
Margin	-	-	-	**20.0**	-	**121.5**	-
Total + Margin	-	-	-	-	-	**728.9**	-
Maximum	-	-	-	-	-	**796.5**	-
Unused	-	-	-	-	-	**67.7**	**8.5**

Operation modes and Instrument Utilization

Safe	In case of failure, spacecraft might tumble
Service	Calibration of instruments; Relaxation of reaction wheel
Science	‘CME trigger’ data *EUV Imager, Magnetograph*
Forecast	Propagation of geo-effective CMEs *Coronagraph, Heliospheric Imagers, Magnetometers, SWA*
Download	Transmission of acquired data to ground stations *EUV Imager, Magnetograph, Coronagraph, Heliospheric Imagers, Magnetometers, SWA*
Recovery	After deployment; link establishment, ADCS starts to operate

Spacecraft Operation

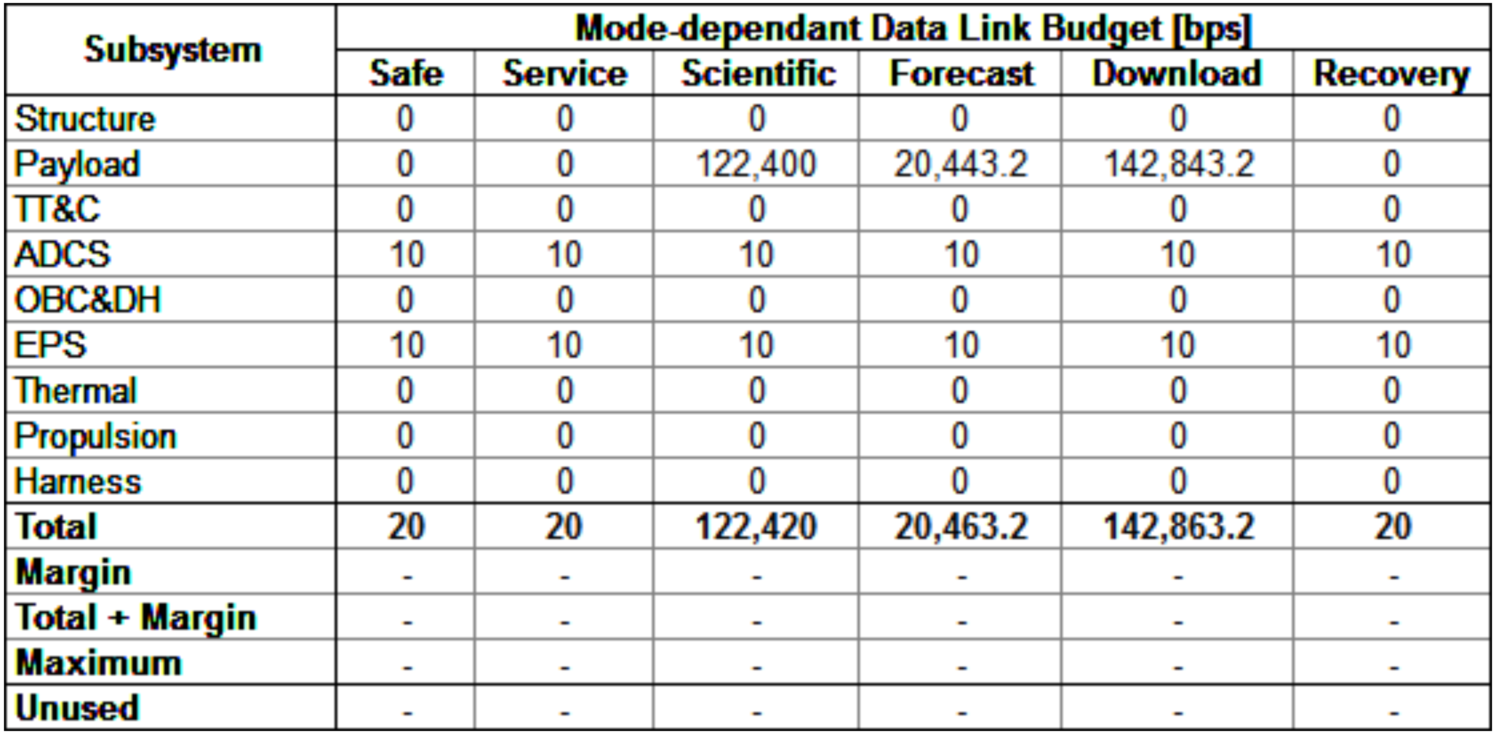
- Mode-dependant Power Demand



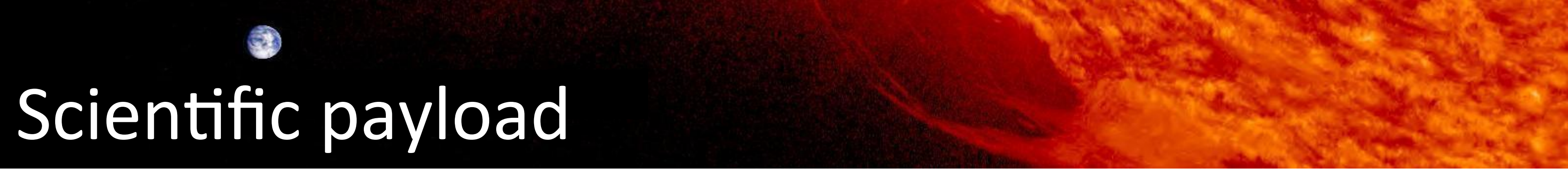
Subsystem	Mode-dependant Power Demand [W]					
	Safe	Service	Scientific	Forecast	Download	Recovery
Structure	0.0	0.0	0.0	0.0	0.0	0.0
Payload	0.0	0.0	52.7	59.6	112.4	0.0
TT&C	0.0	0.0	0.0	0.0	240.0	0.0
ADCS	71.3	71.3	71.3	71.3	71.3	71.3
OBC&DH	15.0	15.0	15.0	15.0	15.0	15.0
EPS	0.0	0.0	0.0	0.0	0.0	0.0
Thermal	0.0	0.0	0.0	0.0	0.0	0.0
Propulsion	0.0	55.0	0.0	0.0	0.0	55.0
Harness	0.0	0.0	0.0	0.0	0.0	0.0
Total	**86.3**	**141.3**	**139.0**	**145.9**	**438.6**	**141.3**
Margin	**17.3**	**28.3**	**27.8**	**29.2**	**87.7**	**28.3**
Total + Margin	**103.5**	**169.5**	**166.8**	**175.1**	**526.4**	**169.5**

System Budget

- Data Link Budget



Subsystem	Mode-dependant Data Link Budget [bps]					
	Safe	**Service**	**Scientific**	**Forecast**	**Download**	**Recovery**
Structure	0	0	0	0	0	0
Payload	0	0	122,400	20,443.2	142,843.2	0
TT&C	0	0	0	0	0	0
ADCS	10	10	10	10	10	10
OBC&DH	0	0	0	0	0	0
EPS	10	10	10	10	10	10
Thermal	0	0	0	0	0	0
Propulsion	0	0	0	0	0	0
Harness	0	0	0	0	0	0
Total	**20**	**20**	**122,420**	**20,463.2**	**142,863.2**	**20**
Margin	-	-	-	-	-	-
Total + Margin	-	-	-	-	-	-
Maximum	-	-	-	-	-	-
Unused	-	-	-	-	-	-



Scientific payload

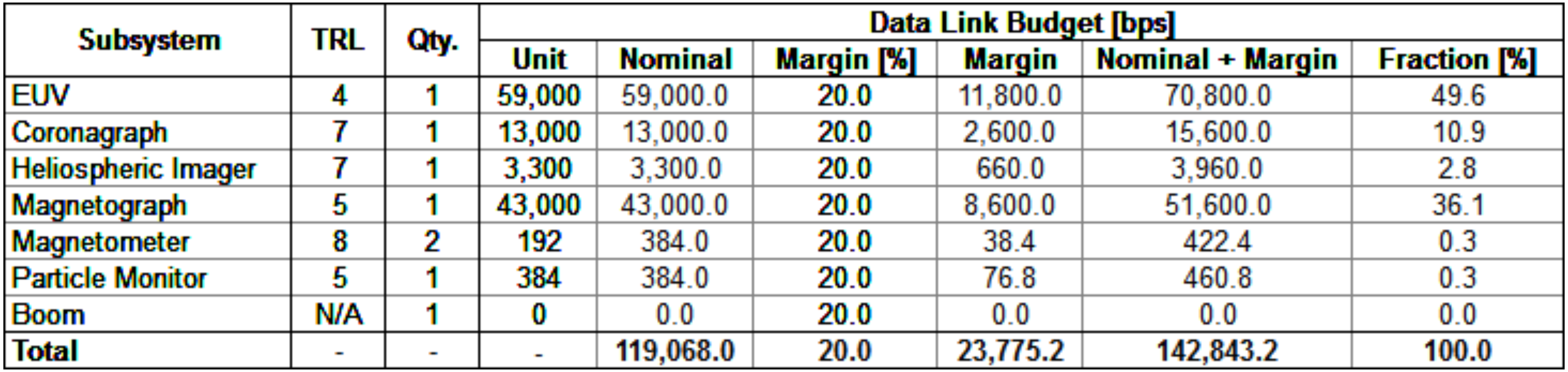
- Scientific Payload Mass and Power Budget

Subsystem	TRL	Qty.	Mass [kg]					
			Unit	Nominal	Margin [%]	Margin	Nominal + Margin	Fraction [%]
EUV	4	1	40.0	40.0	20.0	8.0	48.0	37.0
Coronagraph	7	1	11.0	11.0	5.0	0.6	11.6	8.9
Heliospheric Imager	7	1	15.0	15.0	5.0	0.8	15.8	12.1
Magnetograph	5	1	29.9	29.9	10.0	3.0	32.9	25.4
Magnetometer	8	2	0.8	1.6	5.0	0.1	1.7	1.3
Particle Monitor	5	1	15.0	15.0	10.0	1.5	16.5	12.7
Boom	N/A	1	3.2	3.2	5.0	0.2	3.3	2.6
Total		-	-	**115.7**	**12.1**	**14.0**	**129.7**	**100.0**

Subsystem	TRL	Qty.	Power [W]					
			Unit	Nominal	Margin [%]	Margin	Nominal + Margin	Fraction [%]
EUV	4	1	18.0	18.0	20.0	3.6	21.6	19.2
Coronagraph	7	1	15.0	15.0	20.0	3.0	18.0	16.0
Heliospheric Imager	7	1	15.0	15.0	5.0	0.8	15.8	14.0
Magnetograph	5	1	28.3	28.3	10.0	2.8	31.1	27.7
Magnetometer	8	2	1.9	3.8	5.0	0.1	3.9	3.5
Particle Monitor	5	1	20.0	20.0	10.0	2.0	22.0	19.6
Boom	N/A	1	0.0	0.0	5.0	0.0	0.0	0.0
Total		-	-	**100.1**	**12.3**	**12.3**	**112.4**	**100.0**

Scientific payload

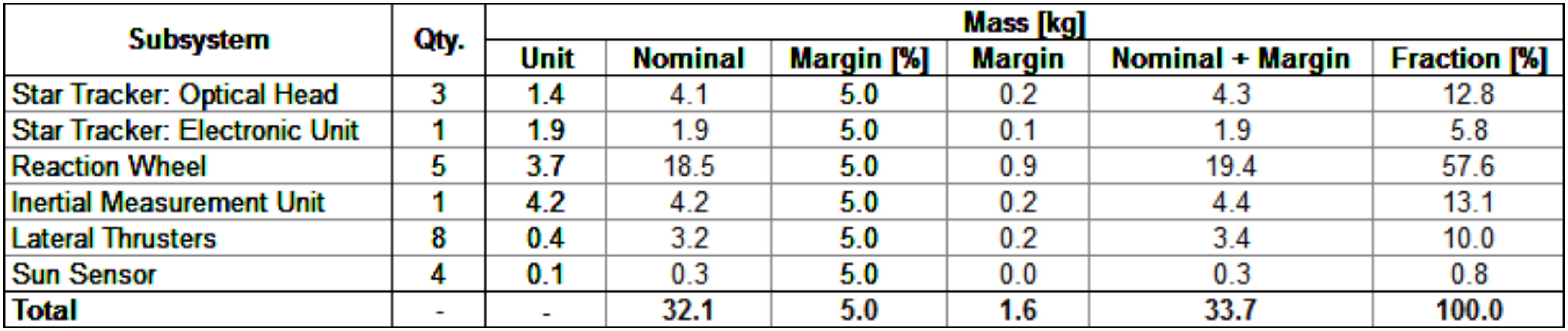
- Scientific Payload Downlink Data Budget



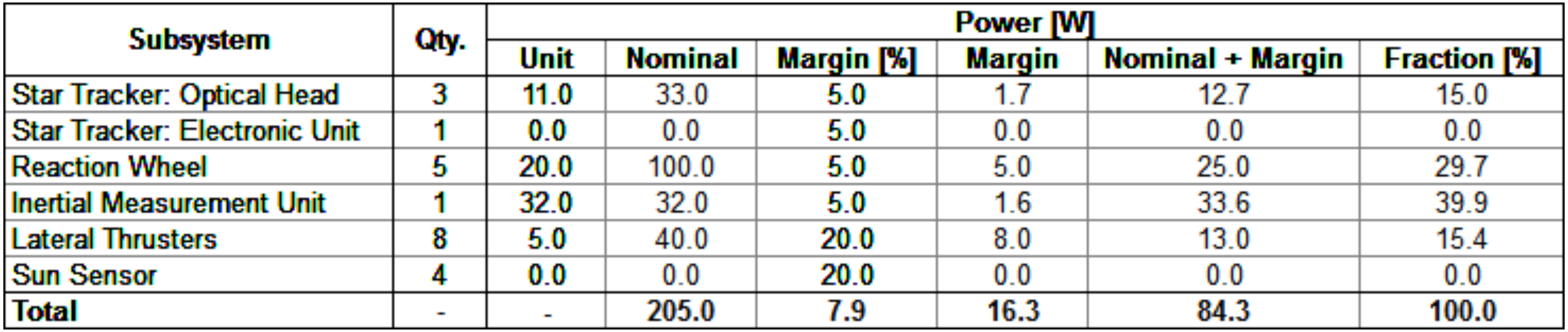
Subsystem	TRL	Qty.	Data Link Budget [bps]					
			Unit	Nominal	Margin [%]	Margin	Nominal + Margin	Fraction [%]
EUV	4	1	59,000	59,000.0	20.0	11,800.0	70,800.0	49.6
Coronagraph	7	1	13,000	13,000.0	20.0	2,600.0	15,600.0	10.9
Heliospheric Imager	7	1	3,300	3,300.0	20.0	660.0	3,960.0	2.8
Magnetograph	5	1	43,000	43,000.0	20.0	8,600.0	51,600.0	36.1
Magnetometer	8	2	192	384.0	20.0	38.4	422.4	0.3
Particle Monitor	5	1	384	384.0	20.0	76.8	460.8	0.3
Boom	N/A	1	0	0.0	20.0	0.0	0.0	0.0
Total	-	-	-	**119,068.0**	20.0	**23,775.2**	**142,843.2**	**100.0**

Attitude Control and Determination System

- ADCS Mass and Power Budget



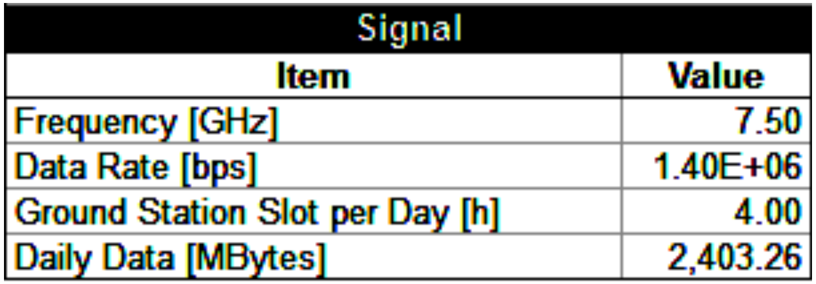
Subsystem	Qty.	Mass [kg]					
		Unit	Nominal	Margin [%]	Margin	Nominal + Margin	Fraction [%]
Star Tracker: Optical Head	3	1.4	4.1	5.0	0.2	4.3	12.8
Star Tracker: Electronic Unit	1	1.9	1.9	5.0	0.1	1.9	5.8
Reaction Wheel	5	3.7	18.5	5.0	0.9	19.4	57.6
Inertial Measurement Unit	1	4.2	4.2	5.0	0.2	4.4	13.1
Lateral Thrusters	8	0.4	3.2	5.0	0.2	3.4	10.0
Sun Sensor	4	0.1	0.3	5.0	0.0	0.3	0.8
Total	-	-	**32.1**	**5.0**	**1.6**	**33.7**	**100.0**



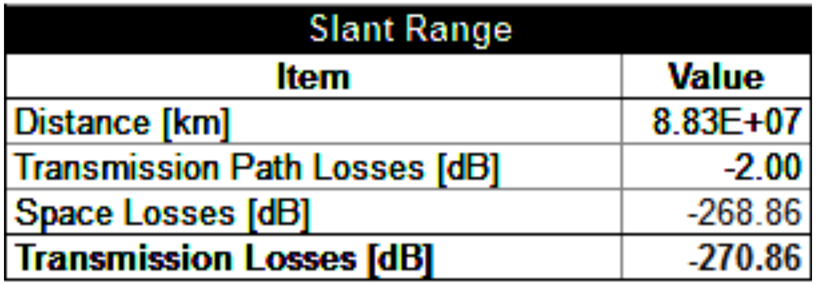
Subsystem	Qty.	Power [W]					
		Unit	Nominal	Margin [%]	Margin	Nominal + Margin	Fraction [%]
Star Tracker: Optical Head	3	11.0	33.0	5.0	1.7	12.7	15.0
Star Tracker: Electronic Unit	1	0.0	0.0	5.0	0.0	0.0	0.0
Reaction Wheel	5	20.0	100.0	5.0	5.0	25.0	29.7
Inertial Measurement Unit	1	32.0	32.0	5.0	1.6	33.6	39.9
Lateral Thrusters	8	5.0	40.0	20.0	8.0	13.0	15.4
Sun Sensor	4	0.0	0.0	20.0	0.0	0.0	0.0
Total	-	-	**205.0**	**7.9**	**16.3**	**84.3**	**100.0**

System Budget

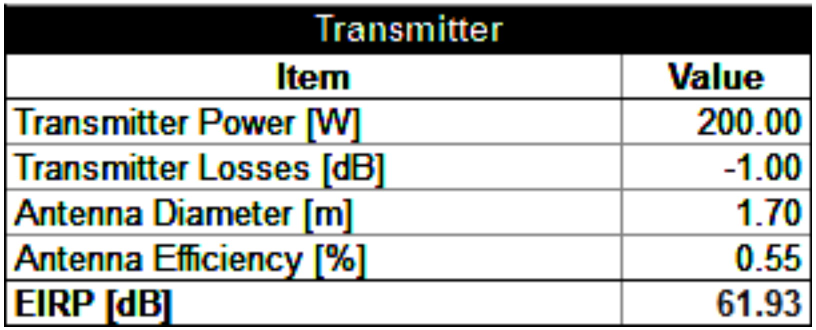
- X-Band Data Downlink (Deep Space Network)



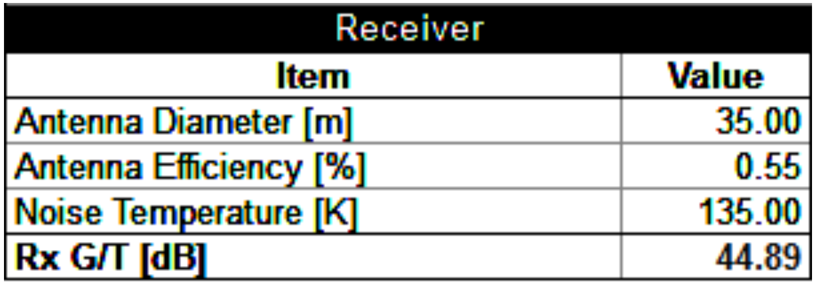
Signal	
Item	**Value**
Frequency [GHz]	7.50
Data Rate [bps]	1.40E+06
Ground Station Slot per Day [h]	4.00
Daily Data [MBytes]	2,403.26



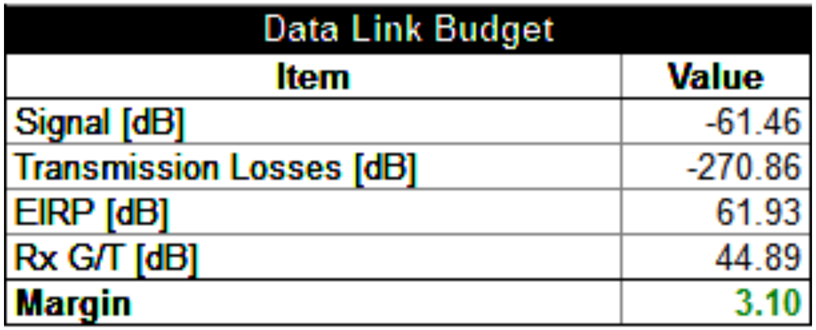
Slant Range	
Item	**Value**
Distance [km]	8.83E+07
Transmission Path Losses [dB]	-2.00
Space Losses [dB]	-268.86
Transmission Losses [dB]	-270.86



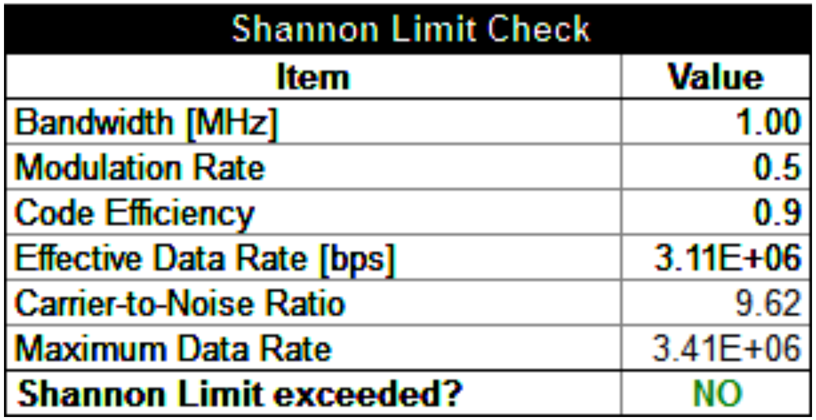
Transmitter	
Item	**Value**
Transmitter Power [W]	200.00
Transmitter Losses [dB]	-1.00
Antenna Diameter [m]	1.70
Antenna Efficiency [%]	0.55
EIRP [dB]	61.93



Receiver	
Item	**Value**
Antenna Diameter [m]	35.00
Antenna Efficiency [%]	0.55
Noise Temperature [K]	135.00
Rx G/T [dB]	44.89



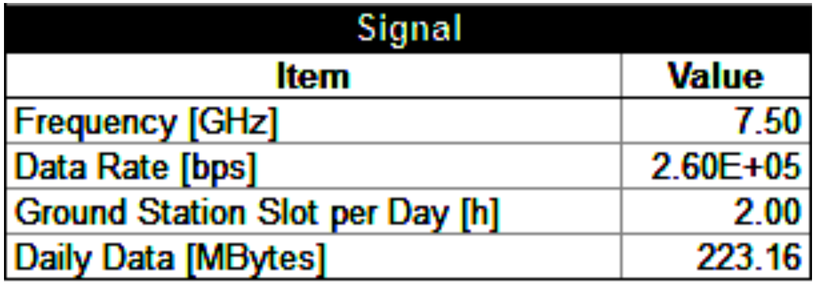
Data Link Budget	
Item	**Value**
Signal [dB]	-61.46
Transmission Losses [dB]	-270.86
EIRP [dB]	61.93
Rx G/T [dB]	44.89
Margin	3.10



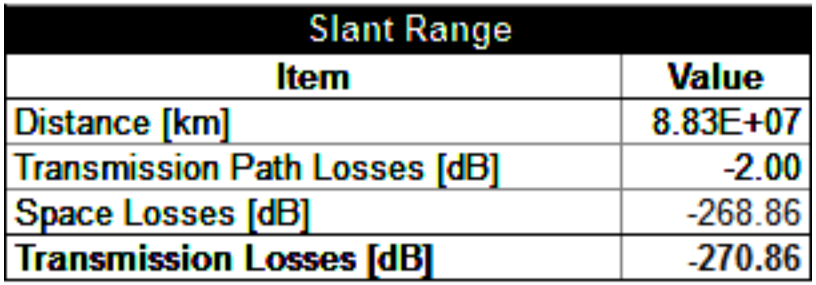
Shannon Limit Check	
Item	**Value**
Bandwidth [MHz]	1.00
Modulation Rate	0.5
Code Efficiency	0.9
Effective Data Rate [bps]	3.11E+06
Carrier-to-Noise Ratio	9.62
Maximum Data Rate	3.41E+06
Shannon Limit exceeded?	NO

System Budget

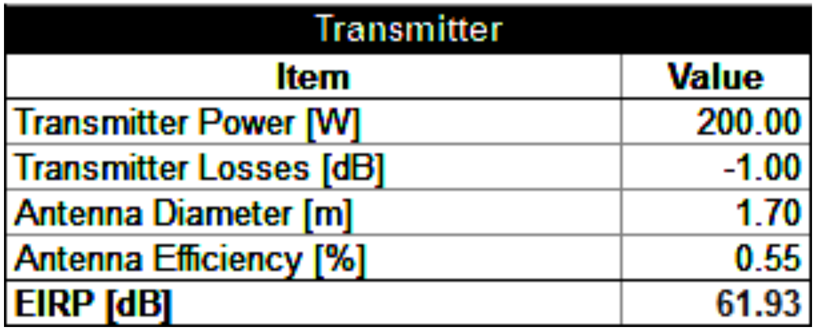
- X-Band Data Downlink



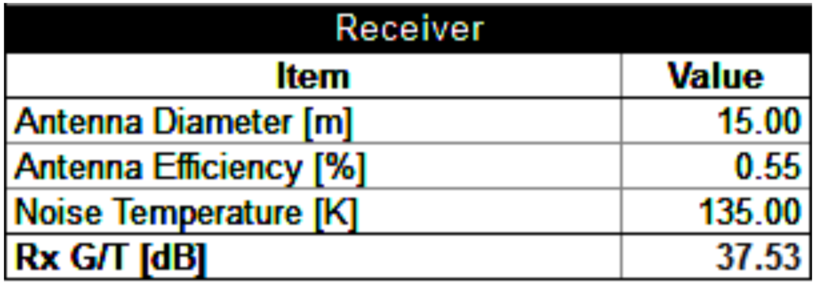
Signal	
Item	**Value**
Frequency [GHz]	7.50
Data Rate [bps]	2.60E+05
Ground Station Slot per Day [h]	2.00
Daily Data [MBytes]	223.16



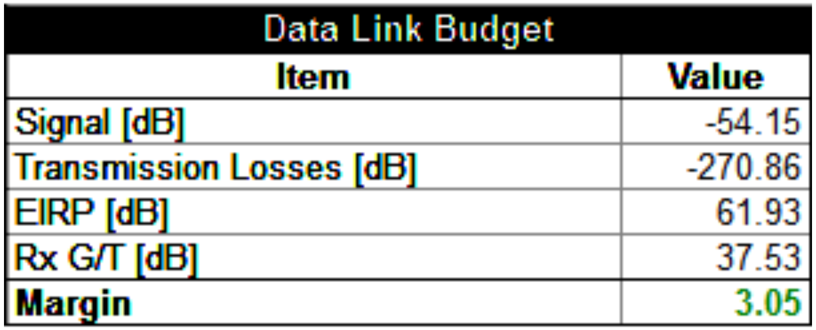
Slant Range	
Item	**Value**
Distance [km]	8.83E+07
Transmission Path Losses [dB]	-2.00
Space Losses [dB]	-268.86
Transmission Losses [dB]	-270.86



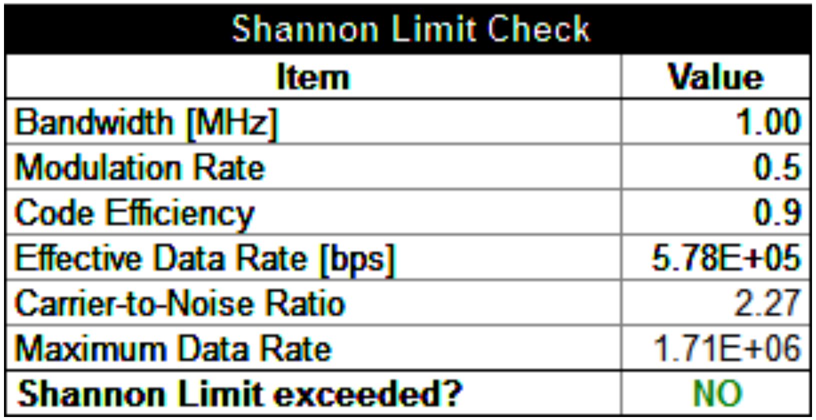
Transmitter	
Item	**Value**
Transmitter Power [W]	200.00
Transmitter Losses [dB]	-1.00
Antenna Diameter [m]	1.70
Antenna Efficiency [%]	0.55
EIRP [dB]	61.93



Receiver	
Item	**Value**
Antenna Diameter [m]	15.00
Antenna Efficiency [%]	0.55
Noise Temperature [K]	135.00
Rx G/T [dB]	37.53

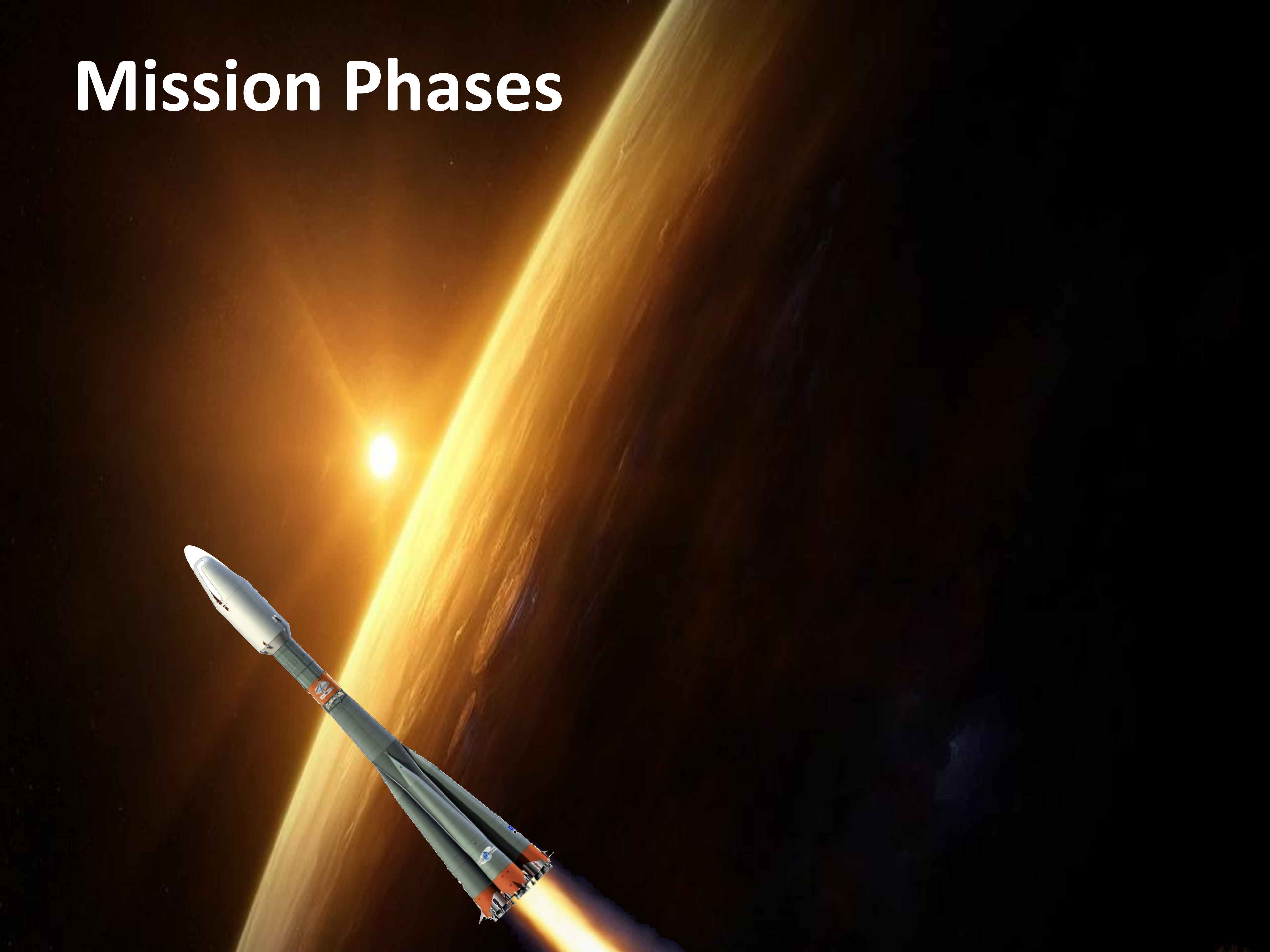


Data Link Budget	
Item	**Value**
Signal [dB]	-54.15
Transmission Losses [dB]	-270.86
EIRP [dB]	61.93
Rx G/T [dB]	37.53
Margin	3.05



Shannon Limit Check	
Item	**Value**
Bandwidth [MHz]	1.00
Modulation Rate	0.5
Code Efficiency	0.9
Effective Data Rate [bps]	5.78E+05
Carrier-to-Noise Ratio	2.27
Maximum Data Rate	1.71E+06
Shannon Limit exceeded?	NO

Mission Phases



Mission phases

- Mission phases

Phase 0

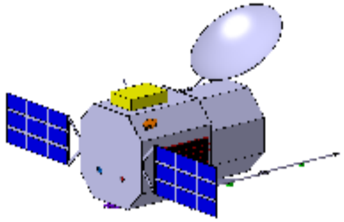
2013

Phase A/B1

2014 - 2015

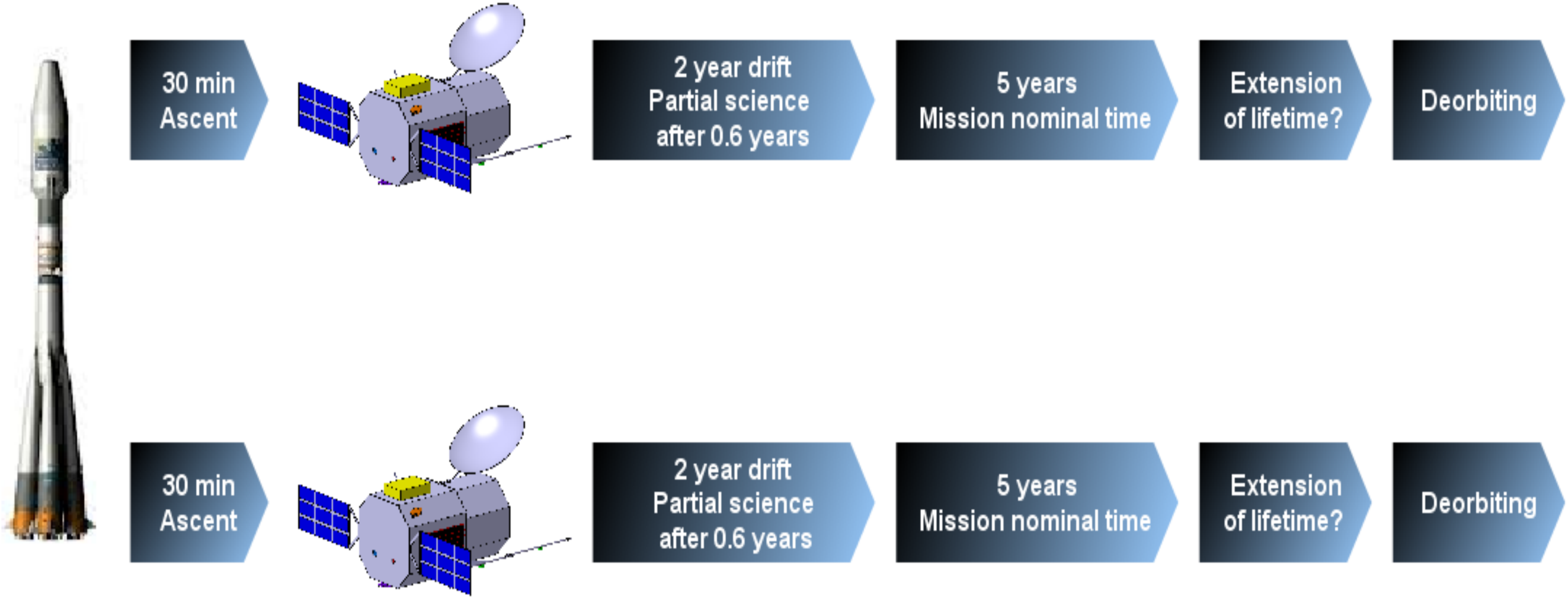
Phase B2/C/D

2016 - 2022



Mission phases

- Operation phases



30 min Ascent

2 year drift Partial science after 0.6 years

5 years Mission nominal time

Extension of lifetime?

Deorbiting

30 min Ascent

2 year drift Partial science after 0.6 years

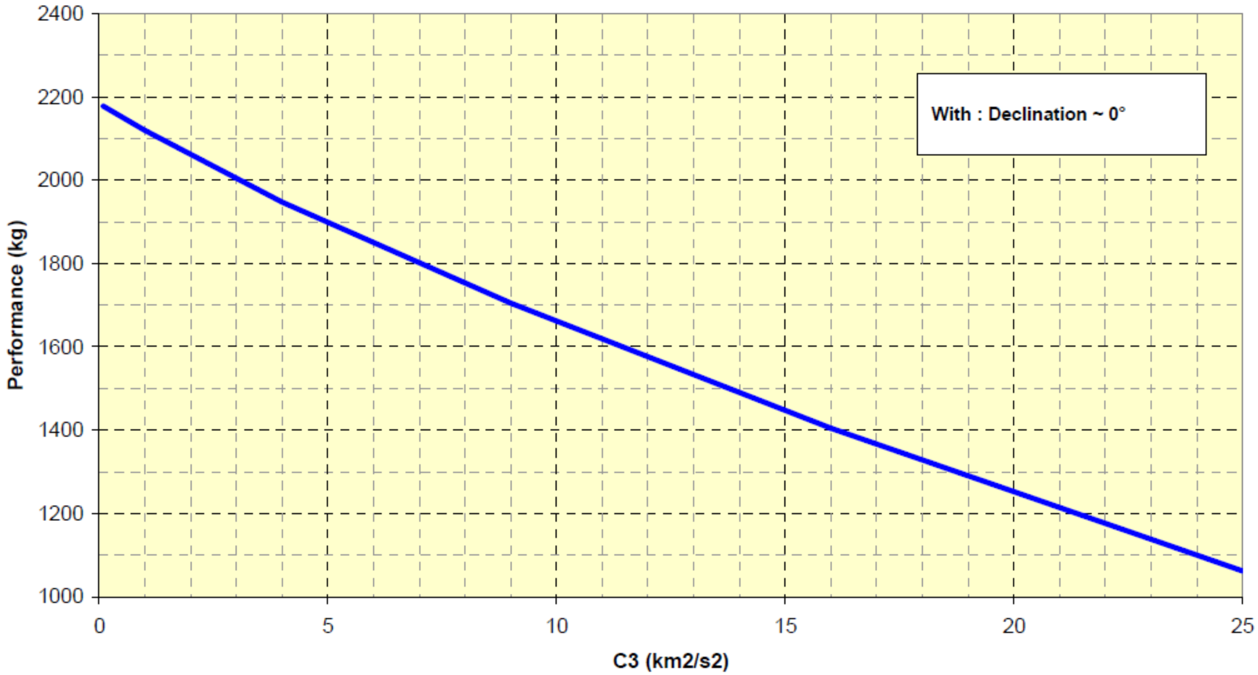
5 years Mission nominal time

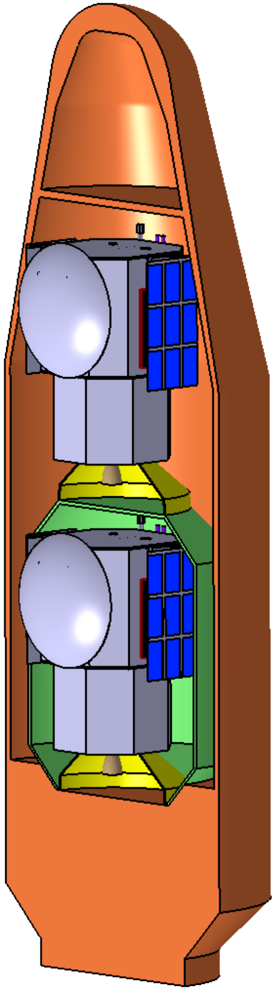
Extension of lifetime?

Deorbiting

Mission phases

- Soyuz launch to parabolic orbit
  - Maximum launch lass: 2200 kg (-5% margin)
  - Launcher adapters: 110 kg + 160 kg (Sylda-Soyuz)
  - Maximum launch mass for both spacecraft: 2090 kg, single: 1045 kg





System Budget

- Propulsion and orbit transfer
  - Soyuz is launching both spacecraft to parabolic orbit
  - After deployment the separation phase is triggered
  - At final point spacecraft is decelerated to keep position

Single Soyuz Launch to parabolic Orbit	
Item	**Value**
Declination [°]	0
Launch Mass [kg]	2,200
Launch Mass Margin [%]	5.0
Launch Mass + Margin [kg]	**2,090.0**

Bipropellant Chemical Propulsion System	
Item	**Value**
Specific Impulse [s]	318
Nominal Thrust [N]	420

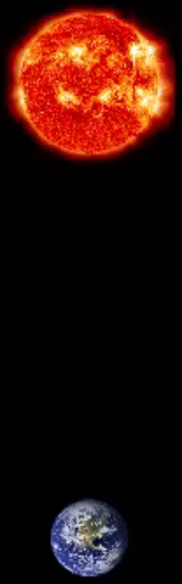
Transfer to final Destination (0.59 AU)	
Item	**Value**
Δv Budget [km/s]	0.94
Duration [h]	0.42
Consumed Propellant [kg]	202.5

Payload Mass Budget	
Item	**Value**
Adapter / Separator Weight [kg]	270.0
max. wet Spacecraft Weight [kg]	**910.0**
max. dry Spacecraft Weight [kg]	**608.8**

Propellant Budget	
Item	**Value**
Additional Δv Budget [km/s]	0.20
Total Δv Budget [km/s]	1.14
Required [kg]	229.7
Margin [%]	10.0
Total + Margin [kg]	**257.7**
Wet Spacecraft Weight [kg]	**778.4**
Remaining [kg]	**55.1**

Mission phases

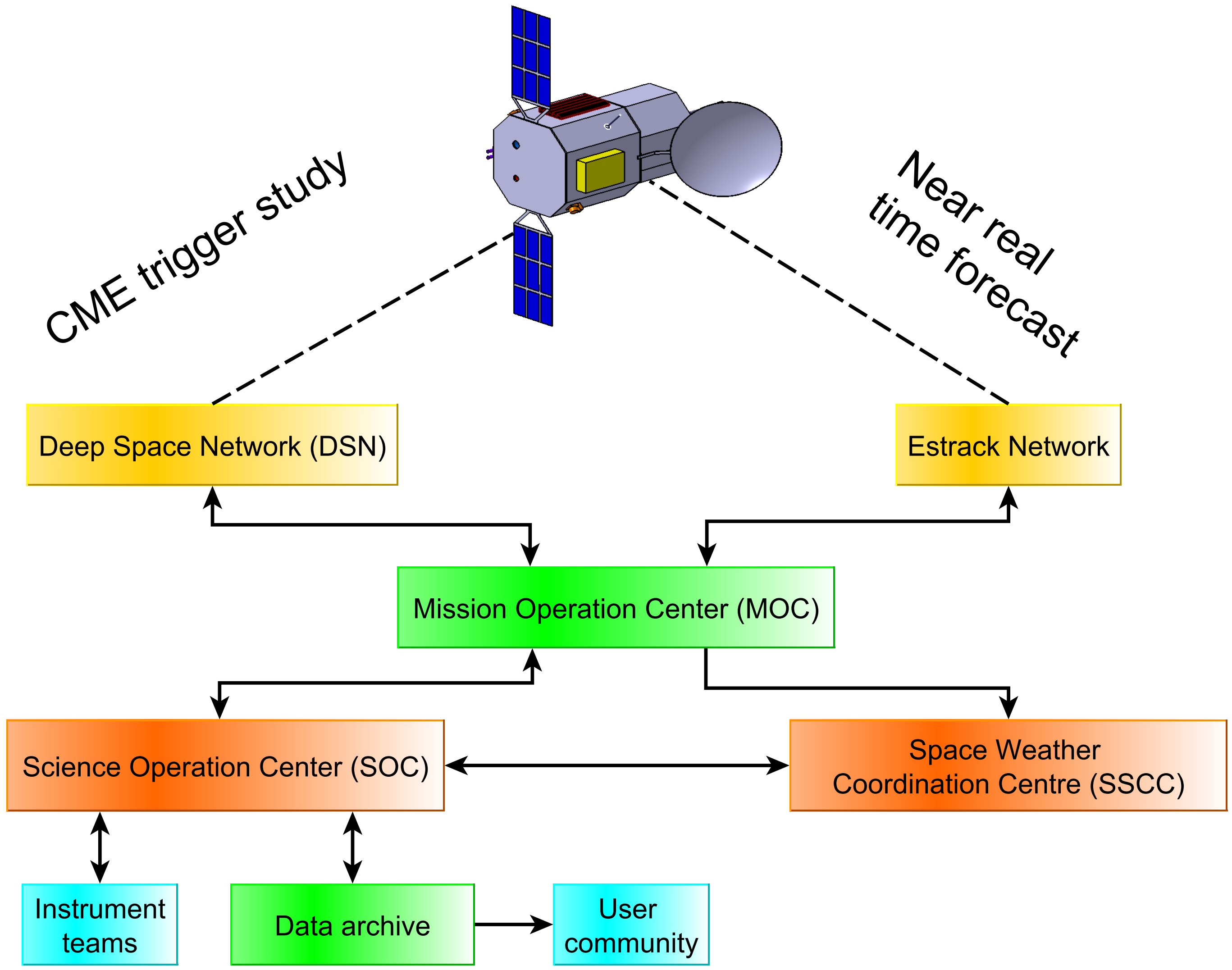
- First thrust impulse
  - Δv of 0.47 km/s applied
  - Propellant consumption: 109 kg
  - Firing time: 0.22 h
- Final position (0.59 AU) reached after two years
- Second thrust impulse
  - Δv of 0.47 km/s applied
  - Propellant consumption: 109 kg
  - Firing time: 0.22 h
- Scientific mission can start earlier
  - After 8 month minimum angle of 22° is achieved



Mission Operation

Did I show you my big banana?

Data Handling



Deep Space Network (DSN)

Estrack Network

Mission Operation Center (MOC)

Science Operation Center (SOC)

Space Weather Coordination Centre (SSCC)

Instrument teams

Data archive

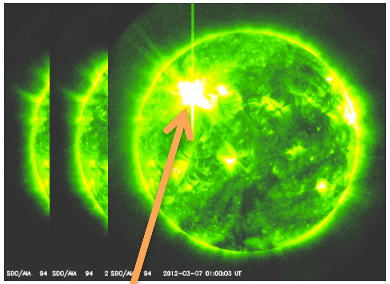
User community

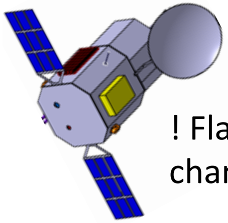
Telemetry: CME triggering data

Onboard CME Trigger Detection based on Flares in 9.4nm channel

9.4 nm

EUV 1

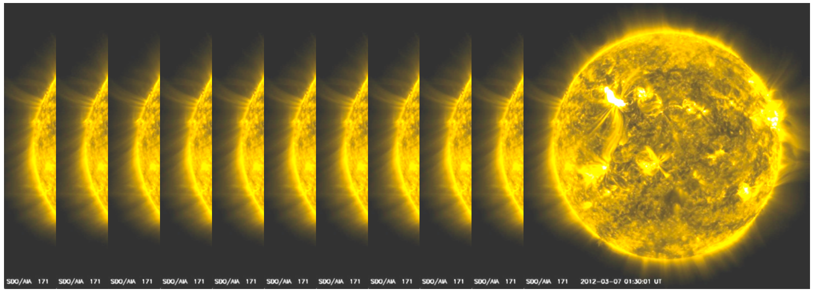




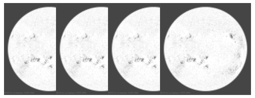
! Flare Found !
change filters to 21.1nm

17.1 nm

EUV 2

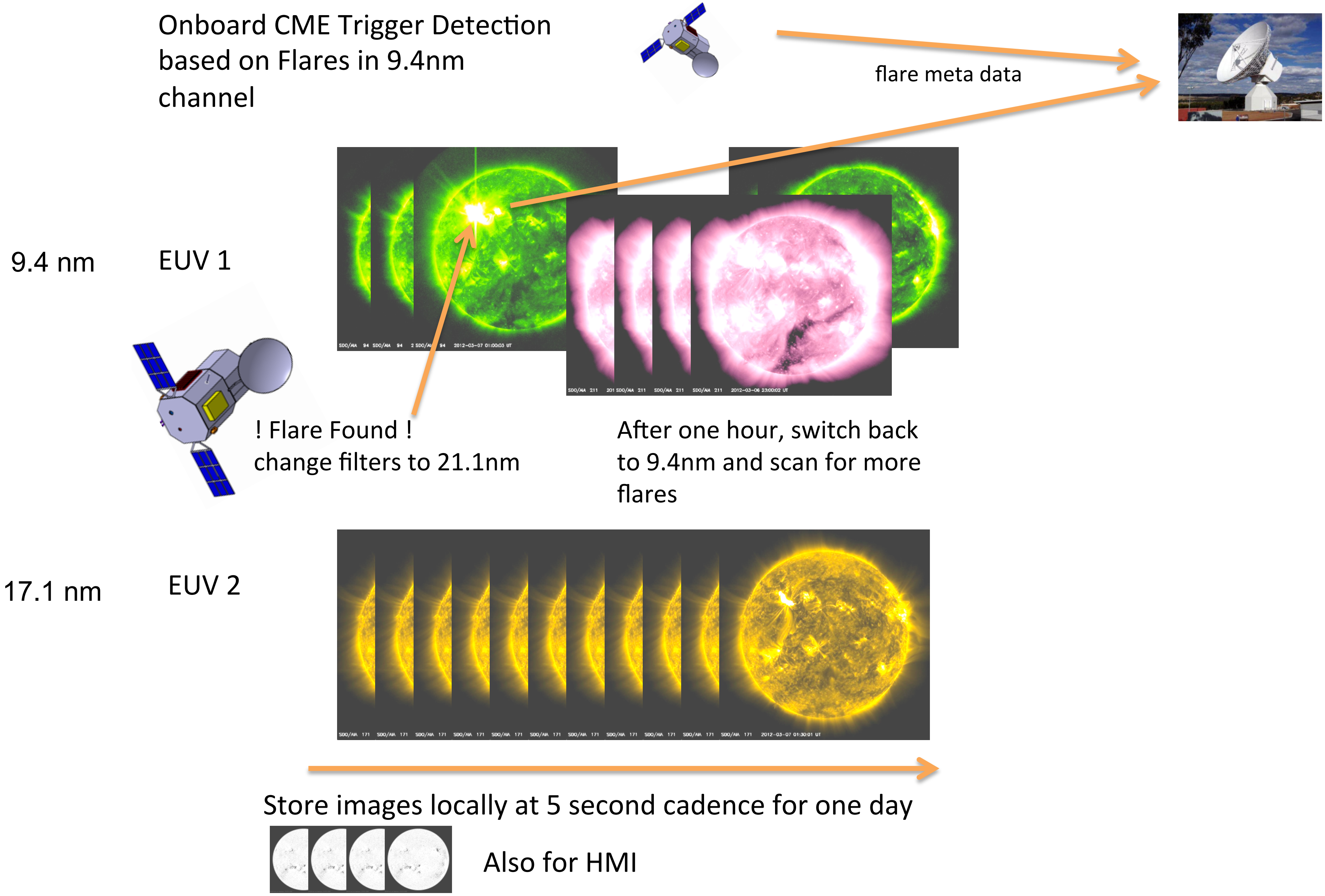


Store images locally at 5 second cadence for one day



Also for HMI

Telemetry: CME triggering data



Onboard CME Trigger Detection based on Flares in 9.4nm channel

flare meta data

9.4 nm

EUV 1

! Flare Found !
change filters to 21.1nm

After one hour, switch back to 9.4nm and scan for more flares

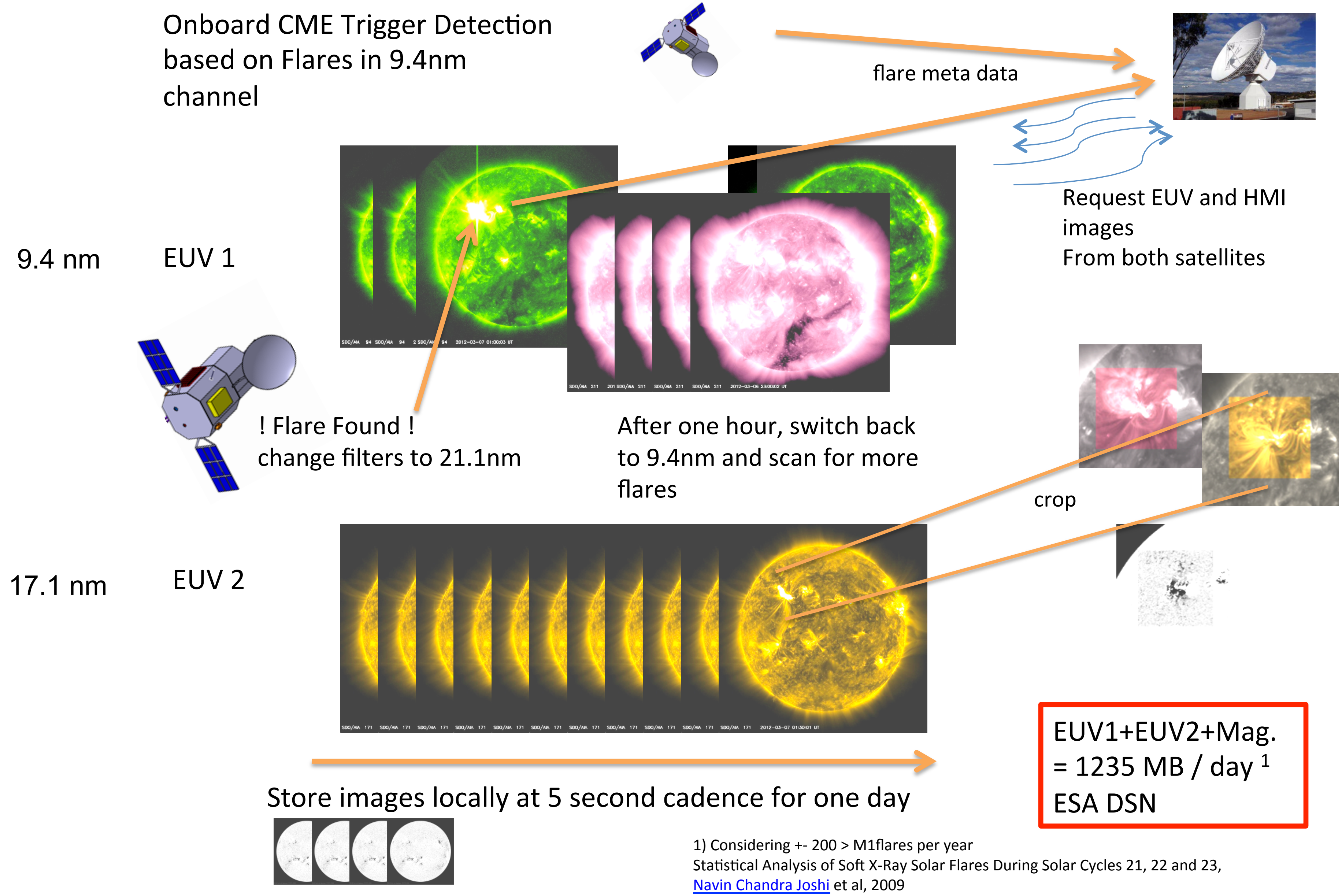
17.1 nm

EUV 2

Store images locally at 5 second cadence for one day

Also for HMI

Telemetry: CME triggering data



Onboard CME Trigger Detection based on Flares in 9.4nm channel

flare meta data

Request EUV and HMI images
From both satellites

9.4 nm

EUV 1

! Flare Found !
change filters to 21.1nm

After one hour, switch back to 9.4nm and scan for more flares

crop

17.1 nm

EUV 2

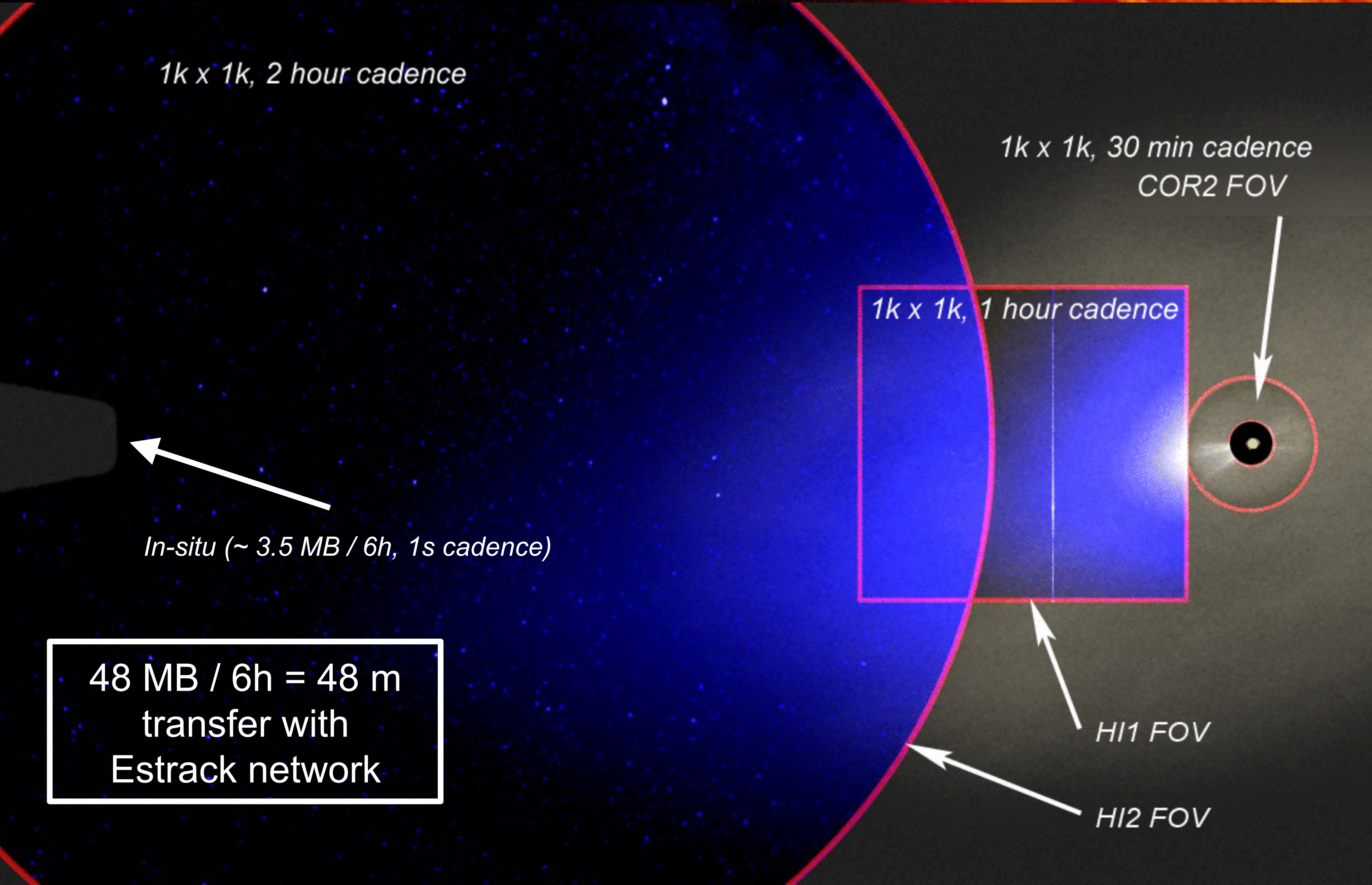
Store images locally at 5 second cadence for one day

EUV1+EUV2+Mag.
= 1235 MB / day [1]
ESA DSN

---

[1] Considering +- 200 > M1flares per year
Statistical Analysis of Soft X-Ray Solar Flares During Solar Cycles 21, 22 and 23, Navin Chandra Joshi et al, 2009

Telemetry: Forecast CMEs and CIRs



1k x 1k, 2 hour cadence

1k x 1k, 30 min cadence
COR2 FOV

1k x 1k, 1 hour cadence

In-situ (~ 3.5 MB / 6h, 1s cadence)

HI1 FOV

HI2 FOV

48 MB / 6h = 48 m
transfer with
Estrack network

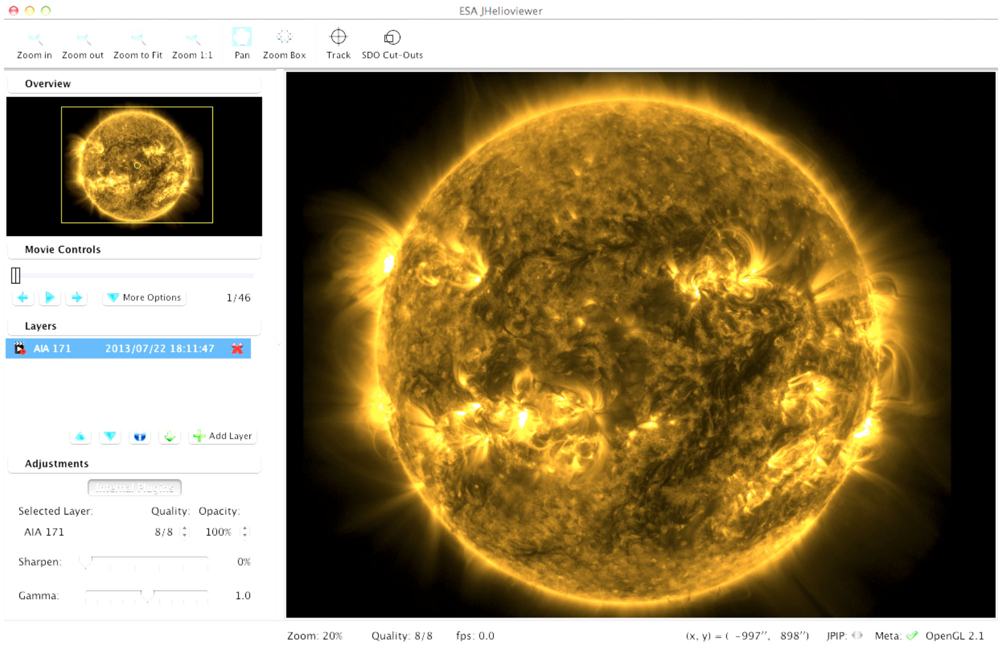
Data availability

"Science data": understanding the physical mechanism triggering of CMEs, in-situ measurements of CMEs and CIRs

- User Community
    - Particular collaboration with CME modellers
    - Annual conference organization on the mission results
    - Call for observational campaigns (300 Mbytes/day available)

- Nominal data (1 hour/3 min cadence)
    - Mission website
    - Helioviewer
    - Solarsoft Library (IDL)
    - ...

- High resolution "events" data
    - Modelling comparison with identified collaborators
    - Public release after a 6 months time
    - Helioviewer
    - Solarsoft Library (IDL)
    - ...



1/46

AIA 171 2013/07/22 18:11:47

Selected Layer: AIA 171

Quality: 8/8

Opacity: 100%

Sharpen: 0%

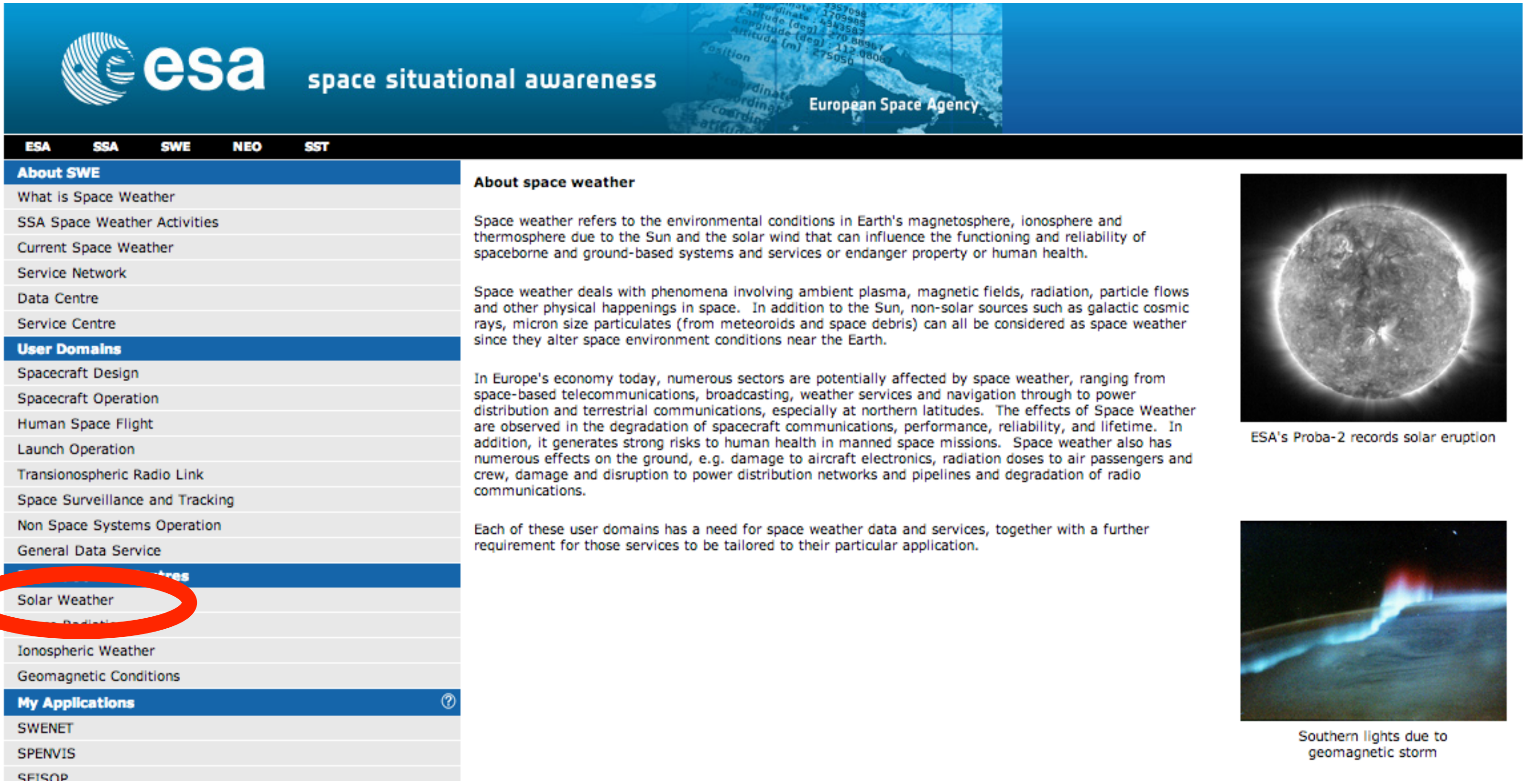
Gamma: 1.0

Zoom: 20%
Quality: 8/8
fps: 0.0
(x, y) = (-997'', 898'')
JPIP:
Meta: ✓
OpenGL 2.1

Data availability

Forecast data: forecasting CMEs and CIRs

- 6 hours cadence data
  - Post-processing for **pure forecast** (either in-house or at a space weather center)
  - **Space Weather forecasts and alerts** through **SSCC/SIDC-AIT**
  - Solarsoft Library (IDL)
  - ...



About space weather

Space weather refers to the environmental conditions in Earth's magnetosphere, ionosphere and thermosphere due to the Sun and the solar wind that can influence the functioning and reliability of spaceborne and ground-based systems and services or endanger property or human health.

Space weather deals with phenomena involving ambient plasma, magnetic fields, radiation, particle flows and other physical happenings in space. In addition to the Sun, non-solar sources such as galactic cosmic rays, micron size particulates (from meteoroids and space debris) can all be considered as space weather since they alter space environment conditions near the Earth.

In Europe's economy today, numerous sectors are potentially affected by space weather, ranging from space-based telecommunications, broadcasting, weather services and navigation through to power distribution and terrestrial communications, especially at northern latitudes. The effects of Space Weather are observed in the degradation of spacecraft communications, performance, reliability, and lifetime. In addition, it generates strong risks to human health in manned space missions. Space weather also has numerous effects on the ground, e.g. damage to aircraft electronics, radiation doses to air passengers and crew, damage and disruption to power distribution networks and pipelines and degradation of radio communications.

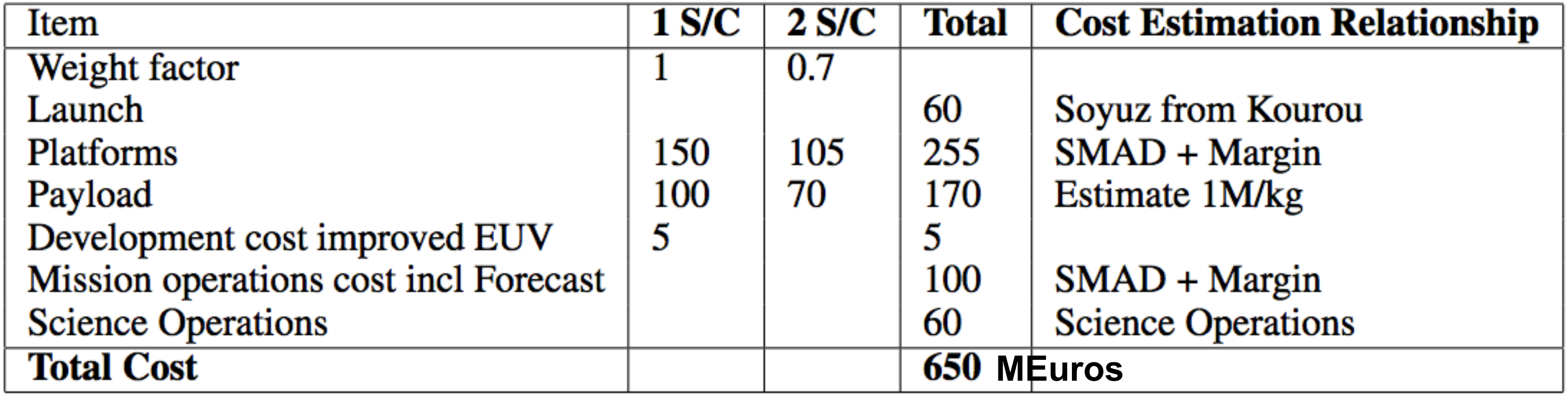
Each of these user domains has a need for space weather data and services, together with a further requirement for those services to be tailored to their particular application.

ESA's Proba-2 records solar eruption

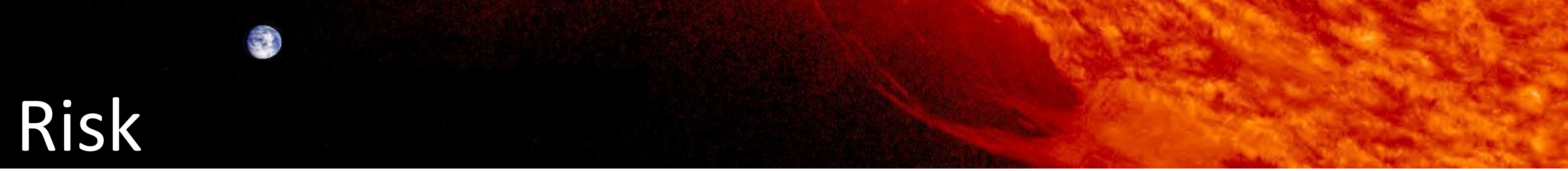
Southern lights due to geomagnetic storm

Management

Cost Budget

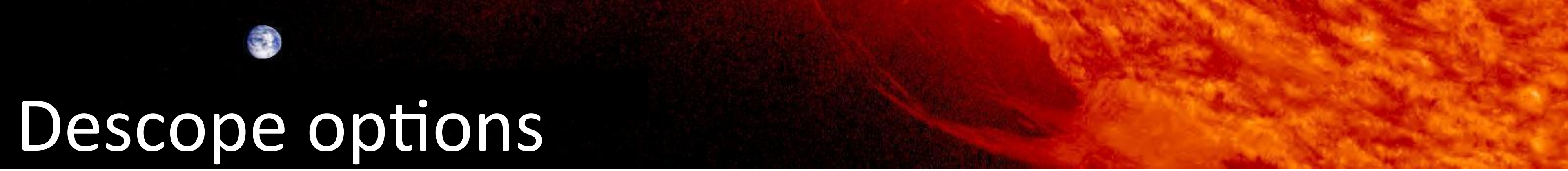


Item	1 S/C	2 S/C	Total	Cost Estimation Relationship
Weight factor	1	0.7		
Launch			60	Soyuz from Kourou
Platforms	150	105	255	SMAD + Margin
Payload	100	70	170	Estimate 1M/kg
Development cost improved EUV	5		5	
Mission operations cost incl Forecast			100	SMAD + Margin
Science Operations			60	Science Operations
Total Cost			**650** MEuros	



Risk

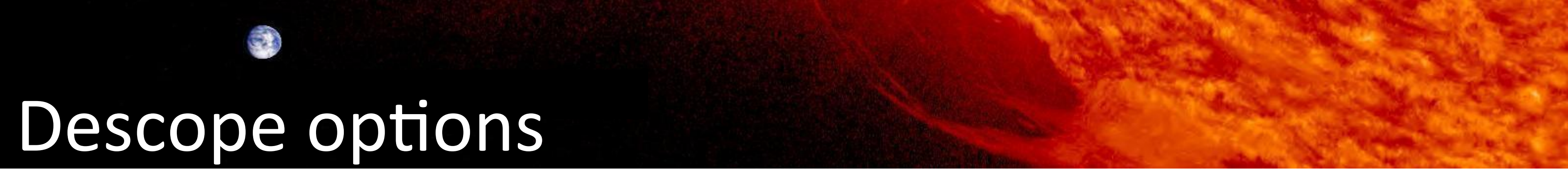
Risk (after mitigation)	Likelihood	Severity	index	Notes on the mitigation
Instrument requirements unable to be met because TRL of EUV imaging instrument low	2	4	8	Use of all available knowledge on the performance of imagers on SDO, SO, STEREO; begin research and development immediately
Progress in solar physics before launch reduces the value of the science data	2	2	4	Comparable data are not provided by any other mission
Damage to mission-critical telescope during launch or commissioning	1	4	4	Redundancy within the design of the EUV telescope
The Sun switches off in another Maunder minimum	1	3	3	Magnetic field and stereo information would improve models aiming to understand the changes
Delay in launch reduces the value of the science data	2	1	2	Sunspots are available most of the way through the solar cycle and in a mission of 5 years, a good sample of active regions can be investigated



Descope options

If only one satellite (behind) was used:

- L5 (instead of -34°) would provide an improved angle for stereo imaging
- Active region imaging studies would require complementary (almost certainly unsynchronised) data from another mission at L1/Earth to reach similar stereoscopic accuracy
- CME forecasting would reduce in accuracy for Earth-directed CMEs
- CIR forecasting would decrease in accuracy of in-situ parameters

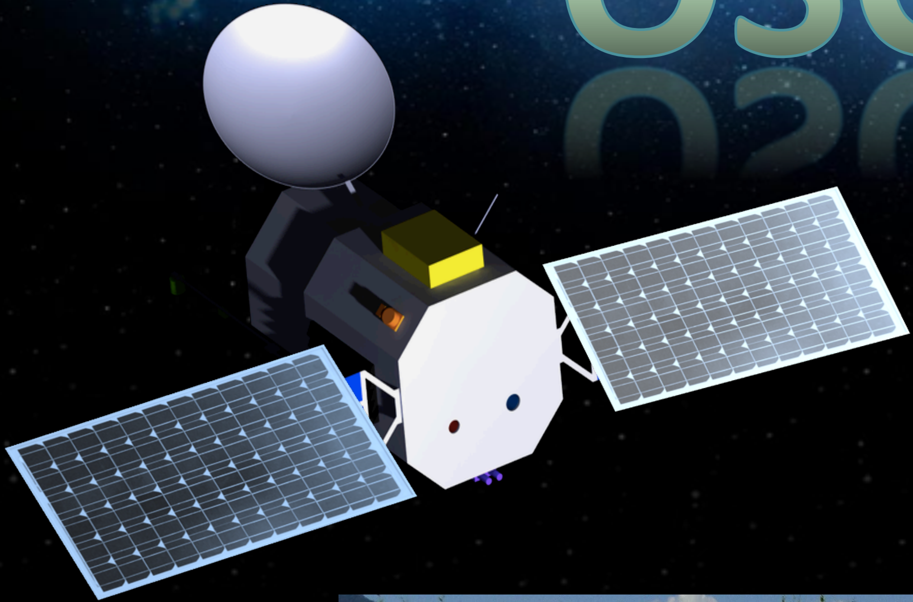


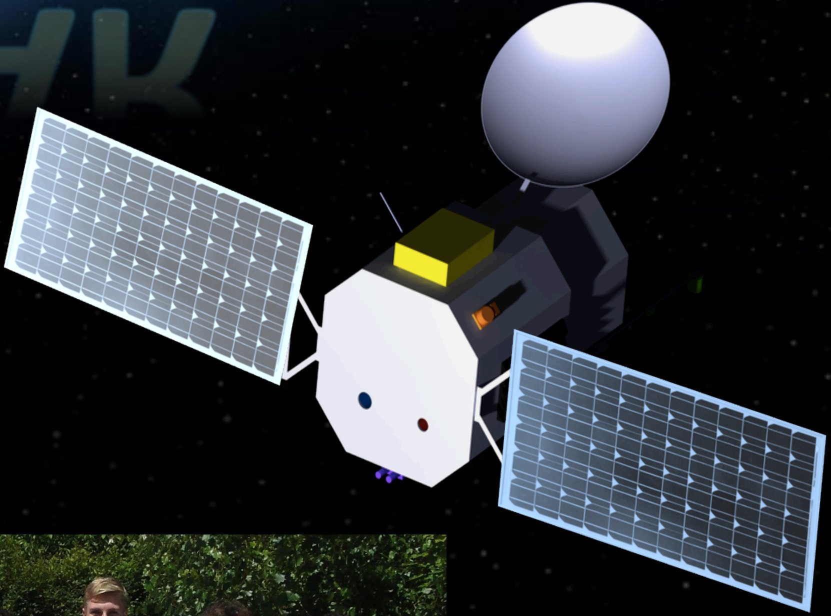
Descope options

If telemetry were less frequent:

- Requirement for a telemetry window every 6 hours no longer exists
- Space weather forecasts require frequent downlink; removing 6 hourly downlink windows eliminate most space weather predictions
- Primary objective would still be fulfilled

OSCAR





Backup Slides

Descope options

If telemetry volume were reduced:

- If total telemetry data volume more infrequent use of the ground stations would be necessary.
- Operation mode would change: low resolution/cadence data would be downloaded and event details requested from a large on-board data buffer
- This would reduce the amount of data and events available
- Focus of triggering would be on the strongest events

Telemetry: Identify 3D Structure

Onboard Autonomy

- EUV/HMI image buffer
  - 1 day, 5 second cadence
  - EUV: 4k x 4k (9.4/21.1 nm **and** 17.1 nm)
  - HMI: 2k x 2k
- Trigger detection software running in NRT
  - detect and estimate location and class of flare in 9.4 nm
- Event detected?
  - filter change 9.4 to 21.1 nm
  - after 1 hour filter change 21.1 to 9.4 nm, and continue flare detection

Data transfer per day

- < 0.1 MB of meta-data on flare detection
- on average 757 MB, 5s cadence, cropped to 800x800 event related images [1]
- 50 MB nominal images (full resolution, 1h cadence)
- 302 MB lossy compressed images (reduced to 1k x 1k, 3mn cadence)
- **total** 1100 MB / day
  - using 4 hours for each satellite on ESA DSN

---

1) Considering +- 200 > M1flares per year Statistical Analysis of Soft X-Ray Solar Flares During Solar Cycles 21, 22 and 23, Navin Chandra Joshi et al, 2009

Telemetry: Identify 3D Structure

Ground Automation

- Use trigger detection output
  - Location and estimate of flare class
- And possibly other sources
  - e.g. Actual goes flux value instead of flare class estimation
- Request for science data
  - retrieve synchronized images for both satellites from 10 minutes before event (in 9.4 and 17.1 nm) to 1 hour after (in 17.1 and 21.1 nm)

- Possibly lossy compressed images for offline automatic event detection or manual event detection/verification

Possible onboard trigger detection software

- Dimming detection module
- EUV Wave detection module
  - e.g. in 21.1 nm, which allows for 17.1 and 21.1 nm images from before trigger to after trigger in high cadence

Telemetry:_______Forecast CMEs and CIRs

Coronograph

- 1k x 1k resolution
- 30 minutes cadence
- 36 MB / 6 hours

Heliospheric Imager 1

- 1k x 1k resolution
- 1 hour cadence
- 6MB / 6 hours

Heliospheric Imager 2

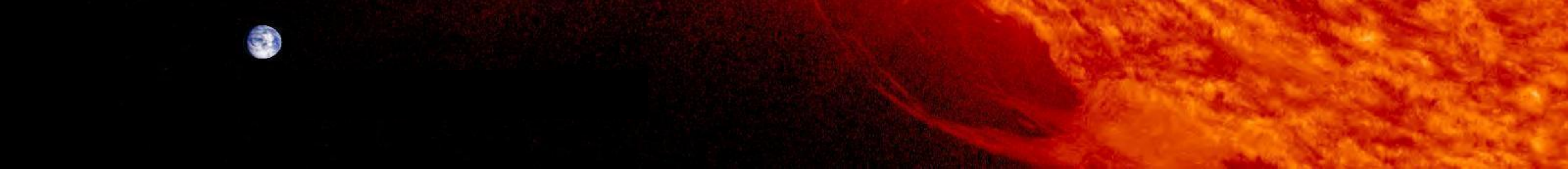
- 1k x 1k resolution
- 2 hour cadence
- 3MB / 6 hours

in-situ

- 3.5MB / 6 hours

total forecast data transfer

- 46MB
- 48 minutes transfer time using 15 meter dishes, every 6 hours



Mission Phases

Single Soyuz Launch to GTO

Item	Value	Notes
Altitude of Apogee [km]	35,950	Soyuz Launcher Manual 2012
Altitude of Perigee [km]	250	Soyuz Launcher Manual 2012
Inclination [°]	6	Soyuz Launcher Manual 2012
Argument of Perigee [°]	178	Soyuz Launcher Manual 2012
max. Payload [kg]	3,250.0	Soyuz Launcher Manual 2012

Transfer from GTO to GEO

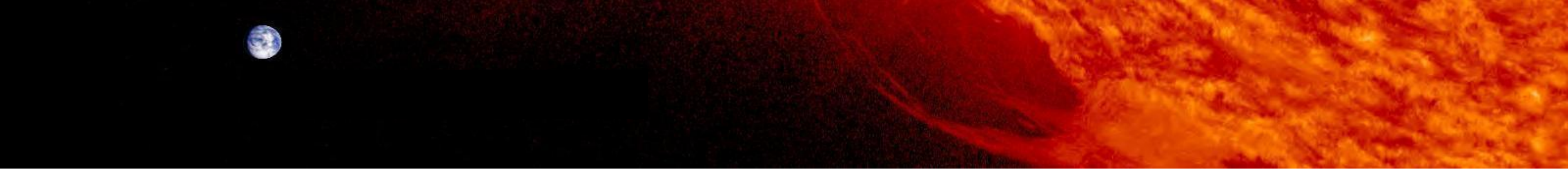
Item	Value	Notes
Δv Budget [km/s]	1.60	http://en.wikipedia.org/wiki/Delta-v_budget
GEO Altitude [km]	42,000	http://en.wikipedia.org/wiki/Specific_orbital_energy
GEO Velocity [km/s]	3.08	http://en.wikipedia.org/wiki/Specific_orbital_energy

Transfer from GEO to hyperbolic Orbit

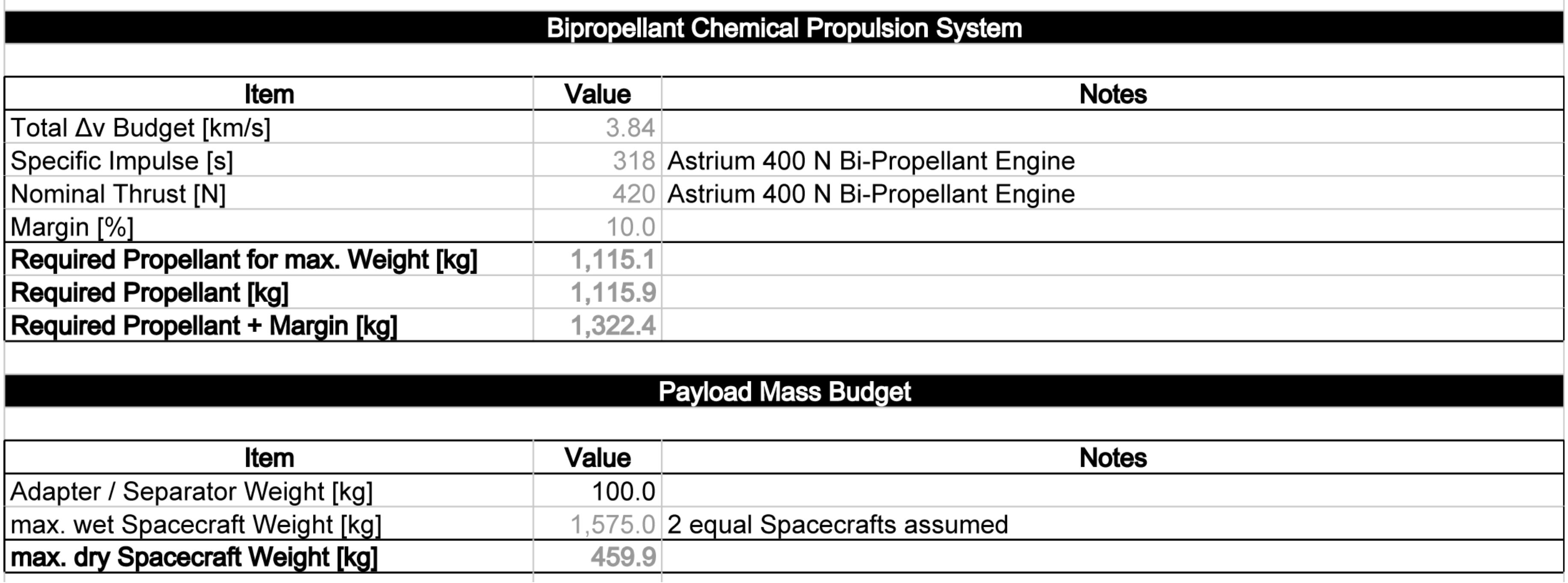
Item	Value	Notes
Δv Budget [km/s]	1.30	http://en.wikipedia.org/wiki/Delta-v_budget

Transfer to final Destination (68° Separation, 0.59 AU from Earth)

Item	Value	Notes
Δv Budget [km/s]	0.94	Drift and Compensation: 2x0.47 km/s for 2 years, 2x0.27 km/s for 3 years



Mission Phases

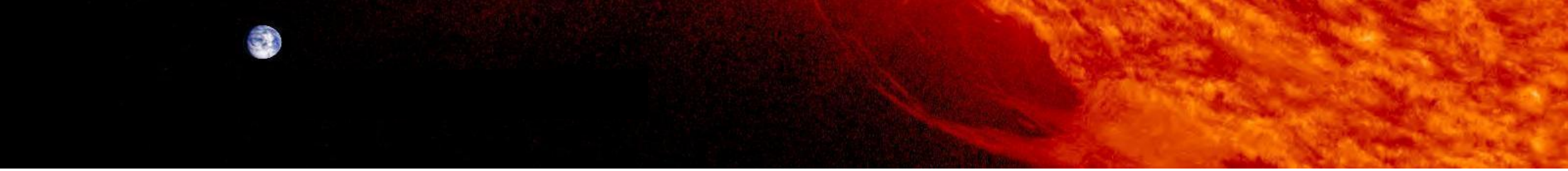


Bipropellant Chemical Propulsion System

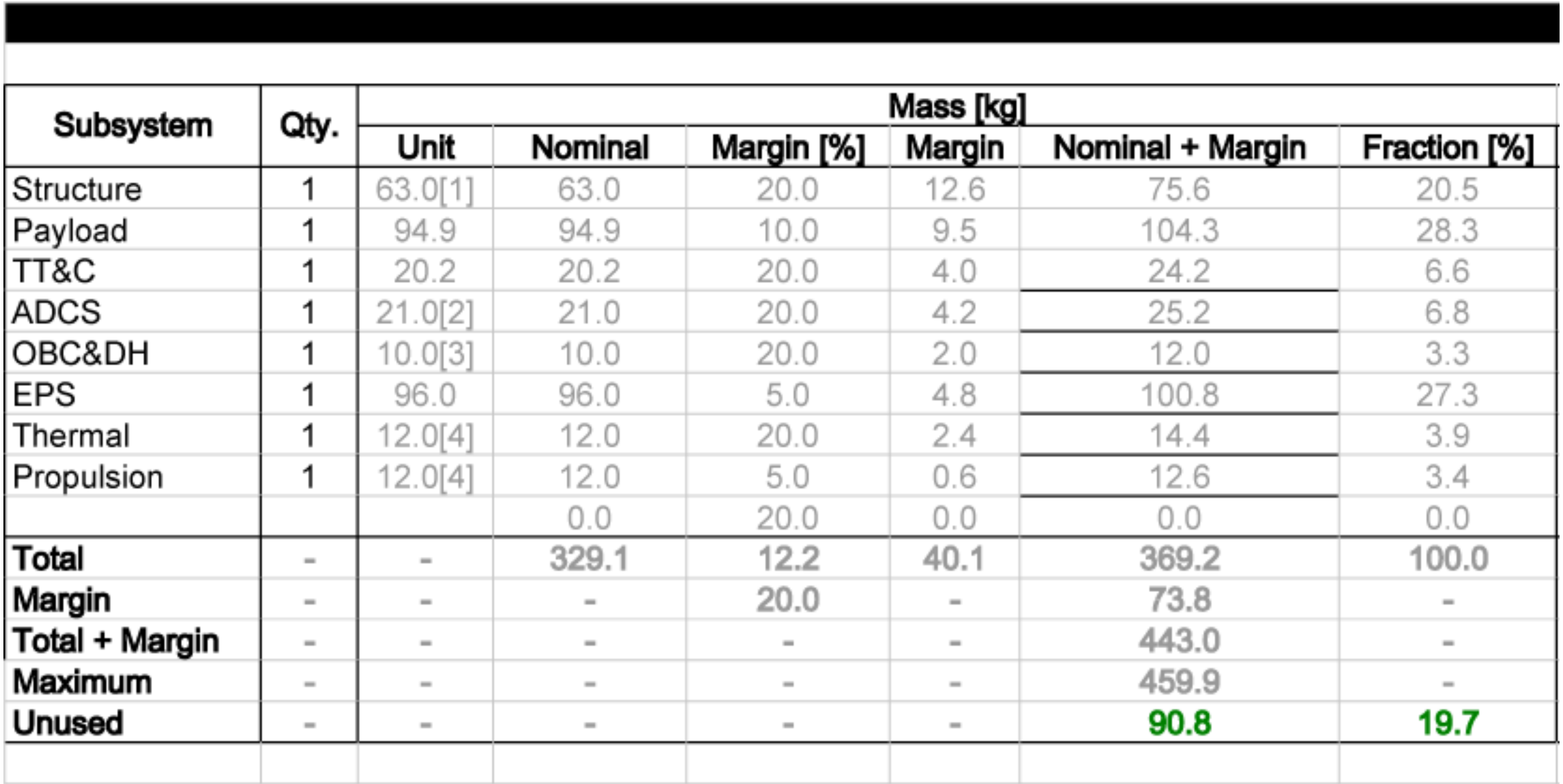
Item	Value	Notes
Total Δv Budget [km/s]	3.84	
Specific Impulse [s]	318	Astrium 400 N Bi-Propellant Engine
Nominal Thrust [N]	420	Astrium 400 N Bi-Propellant Engine
Margin [%]	10.0	
Required Propellant for max. Weight [kg]	**1,115.1**	
Required Propellant [kg]	**1,115.9**	
Required Propellant + Margin [kg]	**1,322.4**	

Payload Mass Budget

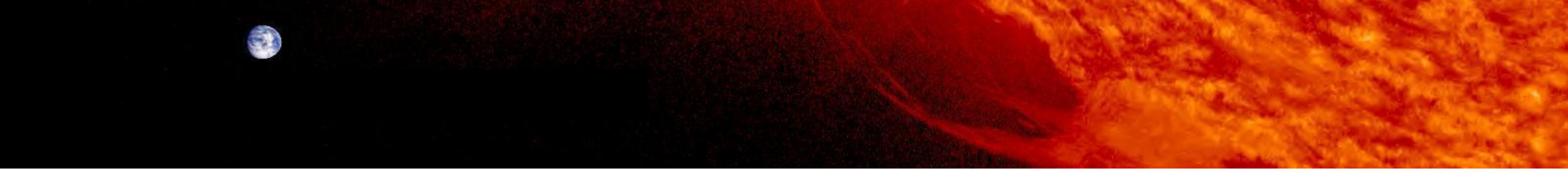
Item	Value	Notes
Adapter / Separator Weight [kg]	100.0	
max. wet Spacecraft Weight [kg]	1,575.0	2 equal Spacecrafts assumed
max. dry Spacecraft Weight [kg]	**459.9**	



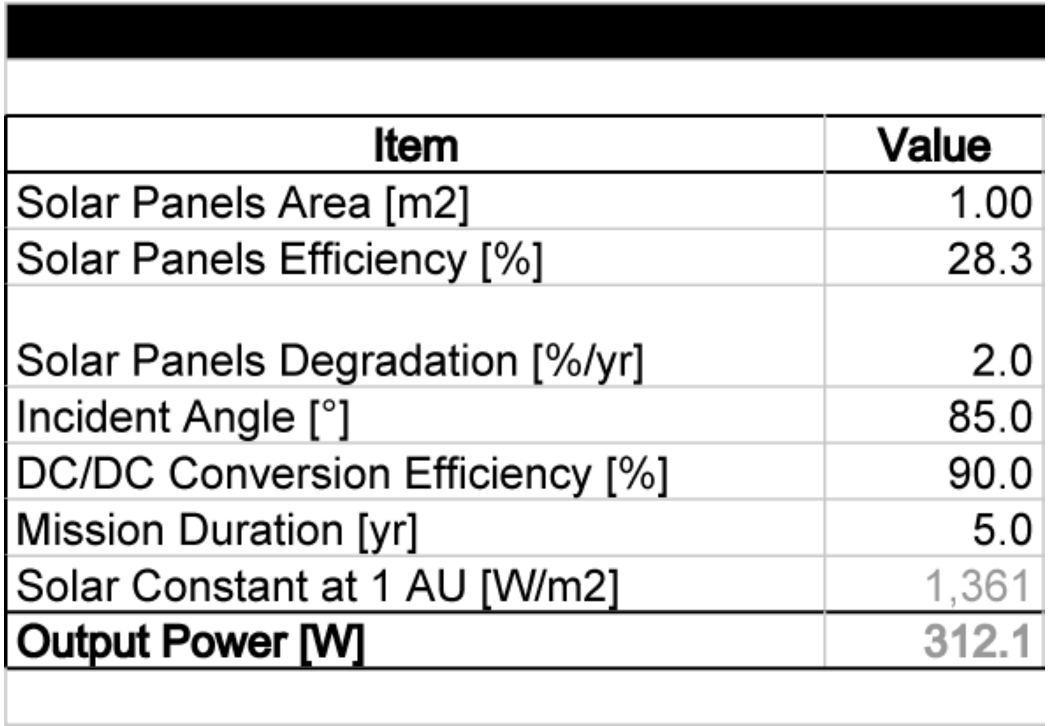
Mass Budget



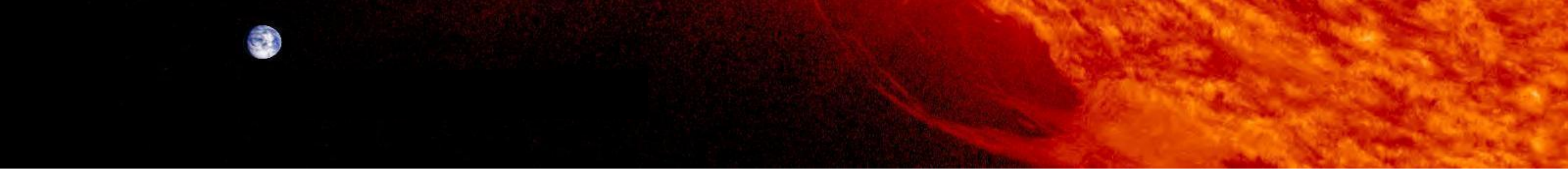
Subsystem	Qty.	Mass [kg]					
		Unit	Nominal	Margin [%]	Margin	Nominal + Margin	Fraction [%]
Structure	1	63.0[1]	63.0	20.0	12.6	75.6	20.5
Payload	1	94.9	94.9	10.0	9.5	104.3	28.3
TT&C	1	20.2	20.2	20.0	4.0	24.2	6.6
ADCS	1	21.0[2]	21.0	20.0	4.2	25.2	6.8
OBC&DH	1	10.0[3]	10.0	20.0	2.0	12.0	3.3
EPS	1	96.0	96.0	5.0	4.8	100.8	27.3
Thermal	1	12.0[4]	12.0	20.0	2.4	14.4	3.9
Propulsion	1	12.0[4]	12.0	5.0	0.6	12.6	3.4
			0.0	20.0	0.0	0.0	0.0
Total	-	-	329.1	12.2	40.1	369.2	100.0
Margin	-	-	-	20.0	-	73.8	-
Total + Margin	-	-	-	-	-	443.0	-
Maximum	-	-	-	-	-	459.9	-
Unused	-	-	-	-	-	90.8	19.7



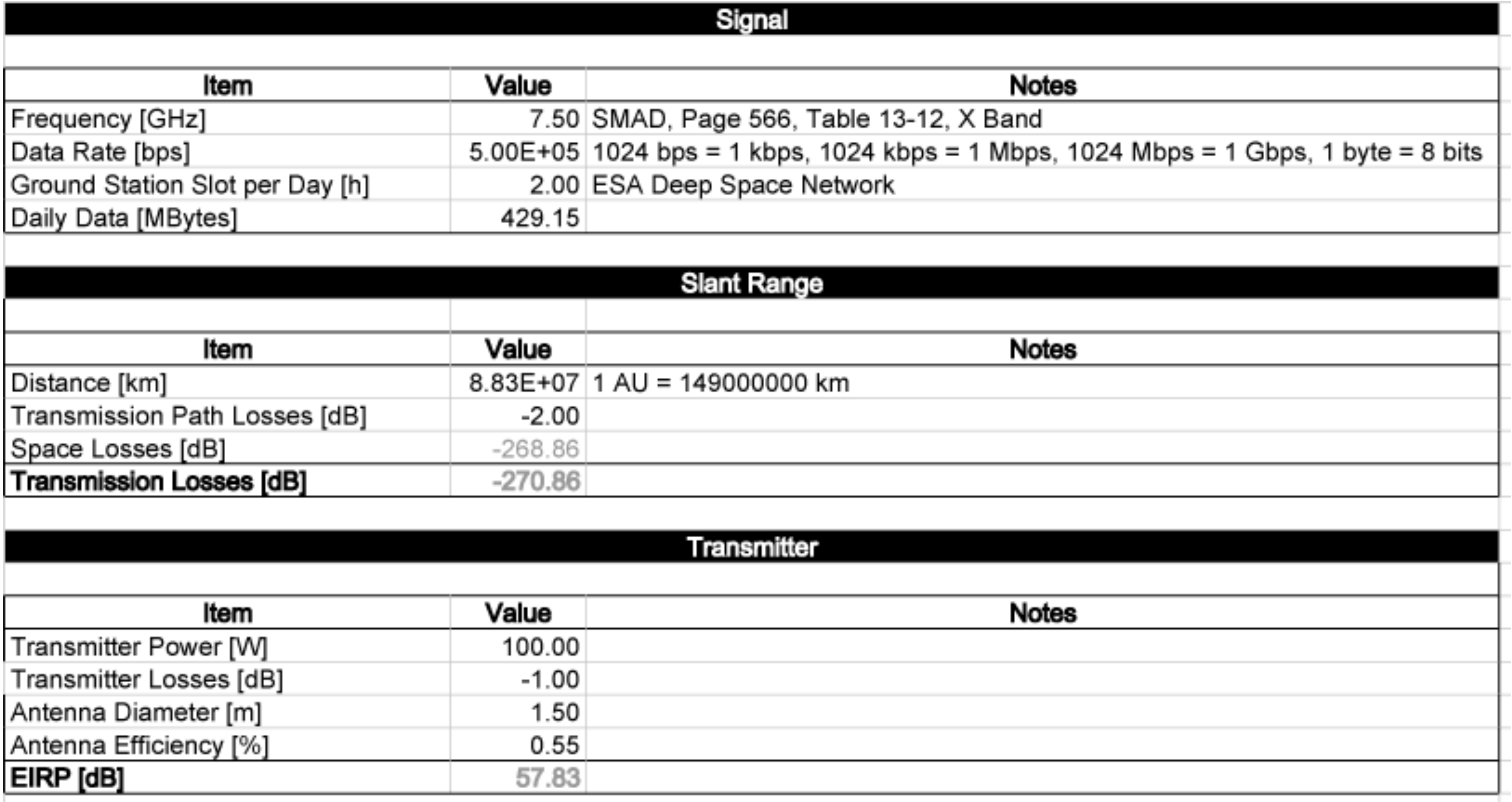
Power Harvesting



Item	Value
Solar Panels Area [m2]	1.00
Solar Panels Efficiency [%]	28.3
Solar Panels Degradation [%/yr]	2.0
Incident Angle [°]	85.0
DC/DC Conversion Efficiency [%]	90.0
Mission Duration [yr]	5.0
Solar Constant at 1 AU [W/m2]	1,361
Output Power [W]	**312.1**



TT&C



Signal

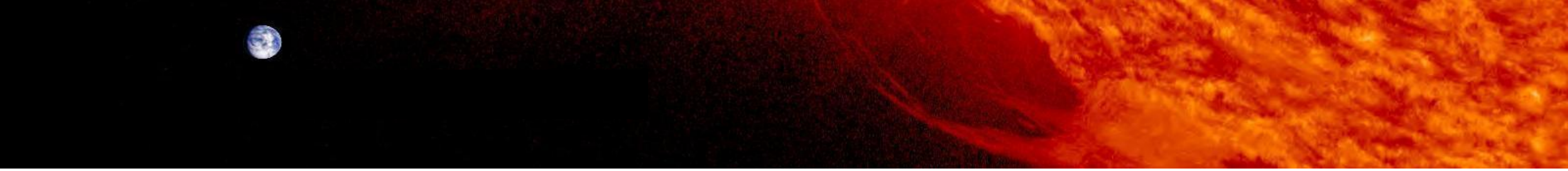
Item	Value	Notes
Frequency [GHz]	7.50	SMAD, Page 566, Table 13-12, X Band
Data Rate [bps]	5.00E+05	1024 bps = 1 kbps, 1024 kbps = 1 Mbps, 1024 Mbps = 1 Gbps, 1 byte = 8 bits
Ground Station Slot per Day [h]	2.00	ESA Deep Space Network
Daily Data [MBytes]	429.15	

Slant Range

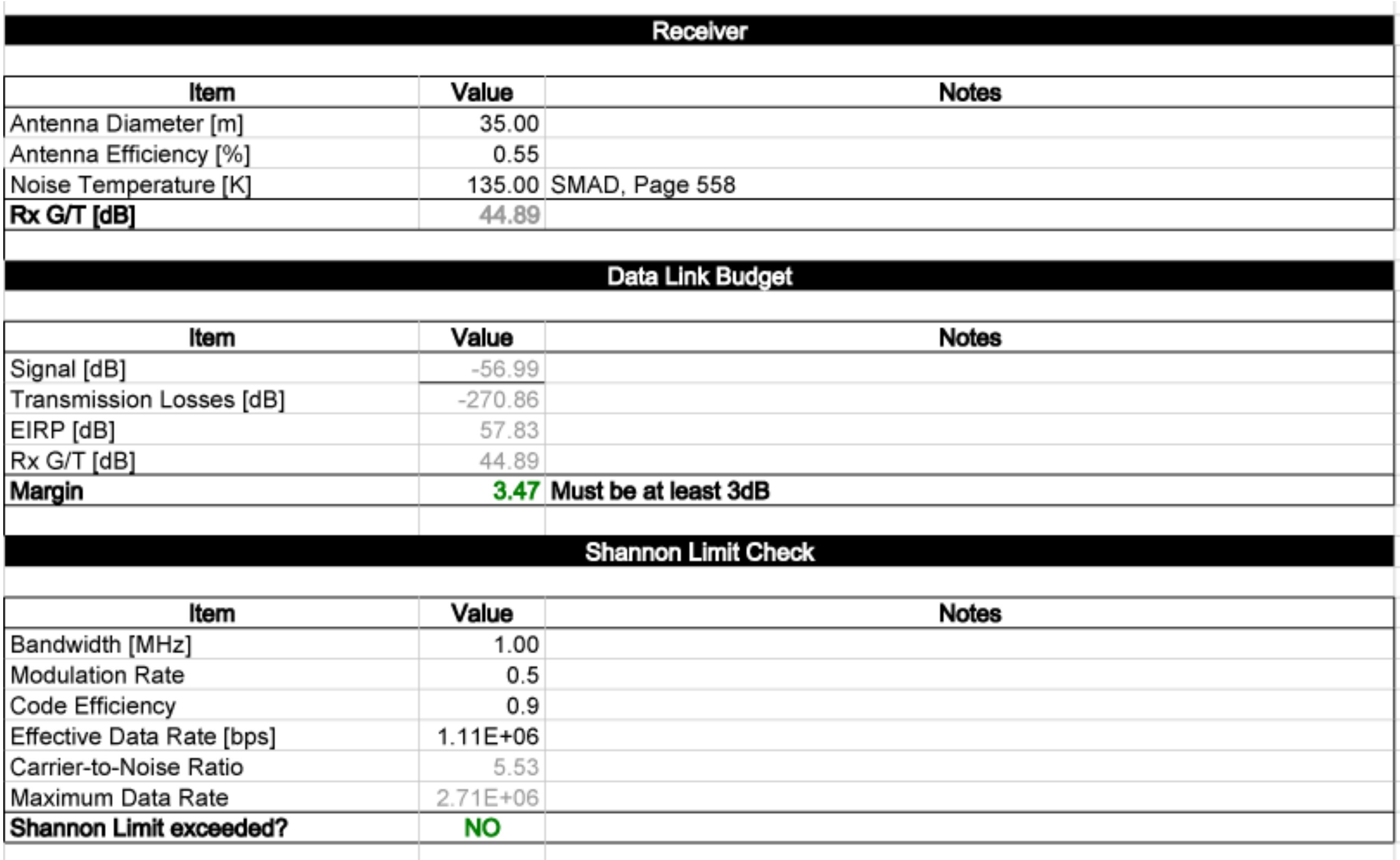
Item	Value	Notes
Distance [km]	8.83E+07	1 AU = 149000000 km
Transmission Path Losses [dB]	-2.00	
Space Losses [dB]	-268.86	
Transmission Losses [dB]	-270.86	

Transmitter

Item	Value	Notes
Transmitter Power [W]	100.00	
Transmitter Losses [dB]	-1.00	
Antenna Diameter [m]	1.50	
Antenna Efficiency [%]	0.55	
EIRP [dB]	57.83	



TT&C



Receiver

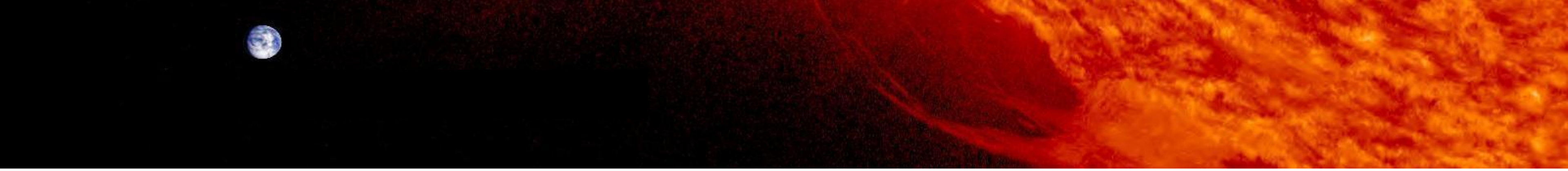
Item	Value	Notes
Antenna Diameter [m]	35.00	
Antenna Efficiency [%]	0.55	
Noise Temperature [K]	135.00	SMAD, Page 558
Rx G/T [dB]	44.89	

Data Link Budget

Item	Value	Notes
Signal [dB]	-56.99	
Transmission Losses [dB]	-270.86	
EIRP [dB]	57.83	
Rx G/T [dB]	44.89	
Margin	**3.47**	**Must be at least 3dB**

Shannon Limit Check

Item	Value	Notes
Bandwidth [MHz]	1.00	
Modulation Rate	0.5	
Code Efficiency	0.9	
Effective Data Rate [bps]	1.11E+06	
Carrier-to-Noise Ratio	5.53	
Maximum Data Rate	2.71E+06	
Shannon Limit exceeded?	**NO**	



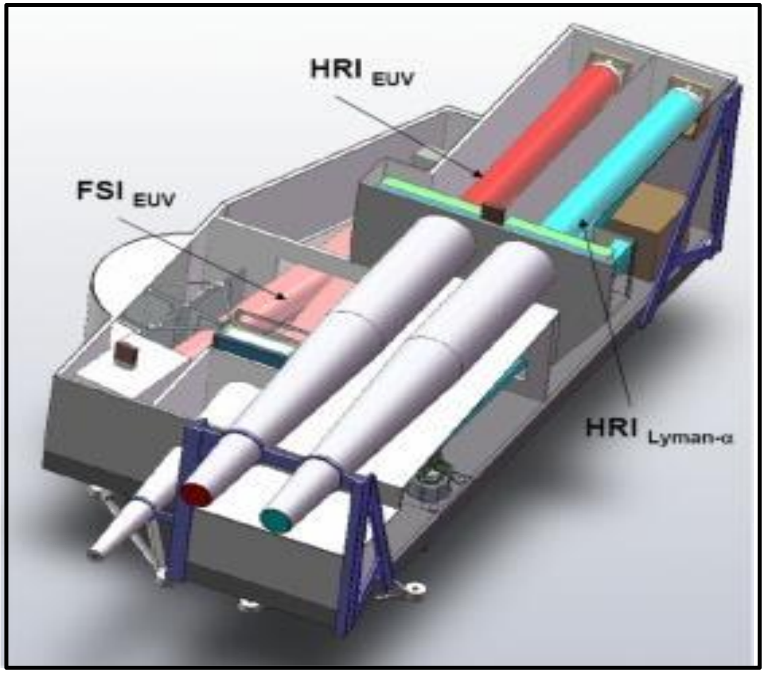
Scientific Payload

Subsystem	Qty.	Mass [kg]					
		Unit	Nominal	Margin [%]	Margin	Nominal + Margin	Fraction [%]
EUV	1	23.5	23.5	10.0	2.4	25.9	25.8
Coronograph	1	11.0	11.0	10.0	1.1	12.1	12.1
Heliospheric Imager	1	15.0	15.0	10.0	1.5	16.5	16.5
Magnetograph	1	29.9	29.9	10.0	3.0	32.9	32.9
Magnetometer	2	4.3	8.6	10.0	0.9	5.2	5.2
Proton monitor	1	3.7	3.7	10.0	0.4	4.1	4.1
Boom	1	3.2	3.2	10.0	0.3	3.5	3.5
Total	-	-	**94.9**	**10.0**	**9.5**	**100.0**	**100.0**

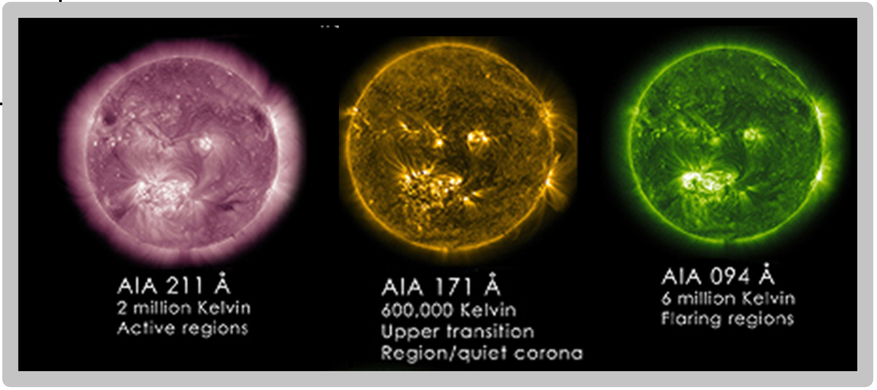
Subsystem	Qty.	Power [W]					
		Unit	Nominal	Margin [%]	Margin	Nominal + Margin	Fraction [%]
EUV	1	18.0	18.0	20.0	3.6	21.6	23.9
Coronograph	1		0.0	20.0	0.0	0.0	0.0
Heliospheric Imager	1	15.0	15.0	20.0	3.0	18.0	19.9
Magnetograph	1	28.3	28.3	20.0	5.7	34.0	37.5
Magnetometer	2	4.4	8.8	20.0	0.9	5.3	5.8
Proton monitor	1	3.1	3.1	20.0	0.6	3.7	4.1
Boom	1	6.6	6.6	20.0	1.3	7.9	8.8
Total	-	-	**79.8**	**18.9**	**15.1**	**90.5**	**100.0**

EUV Active Region Imager

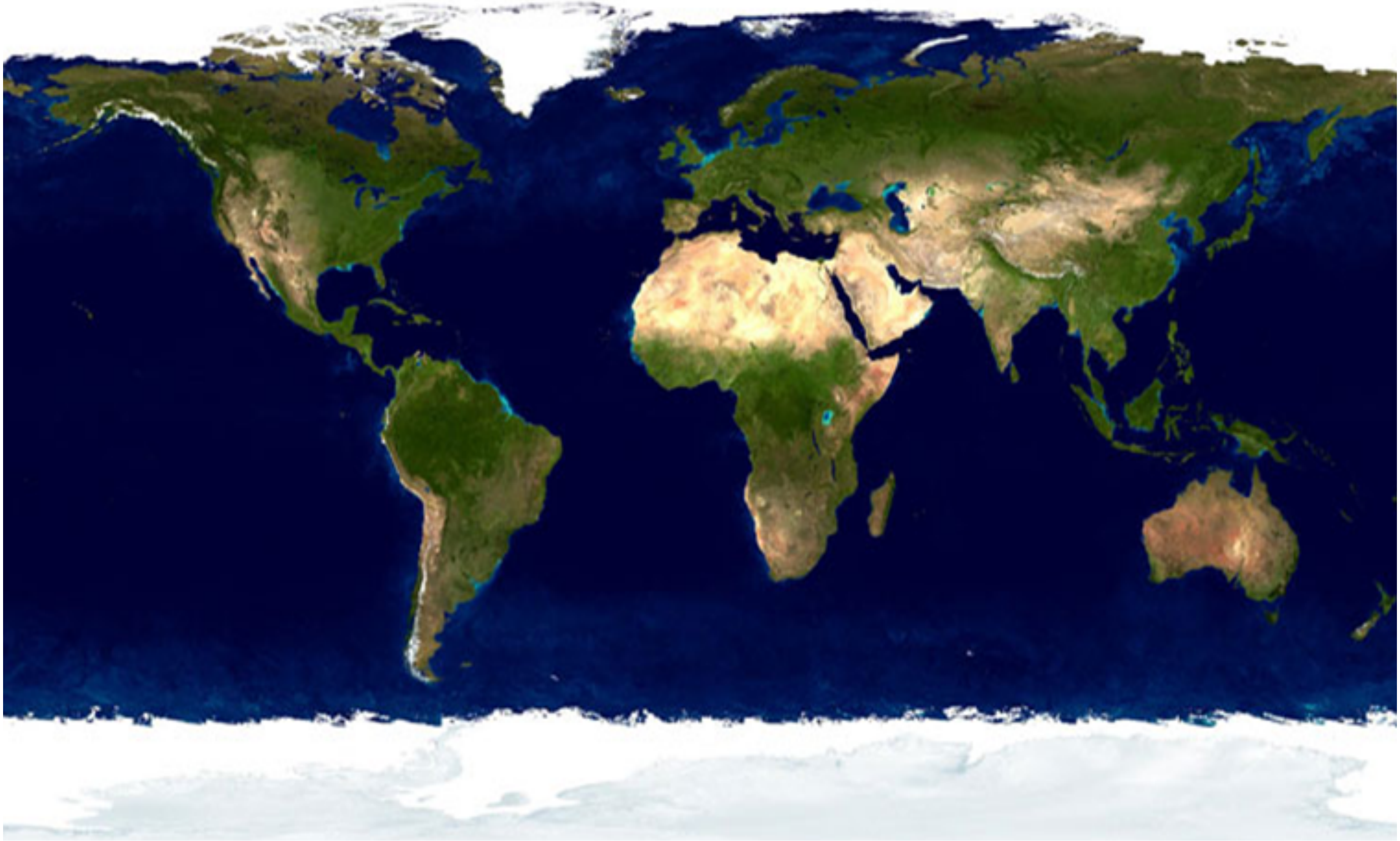
Full name	Extreme-Ultraviolet Imager
Purpose	- provide image sequences of the solar atmospheric layers above the photosphere - providing an indispensable link between the solar surface and outer corona
Description	Suite composed of two High Resolution Imagers (HRI), modify the instrument (Wavelength)
Scanning Technique	Sun pointing from a geosynchronous (inclined) orbit
Coverage	Full sun disk near continuous



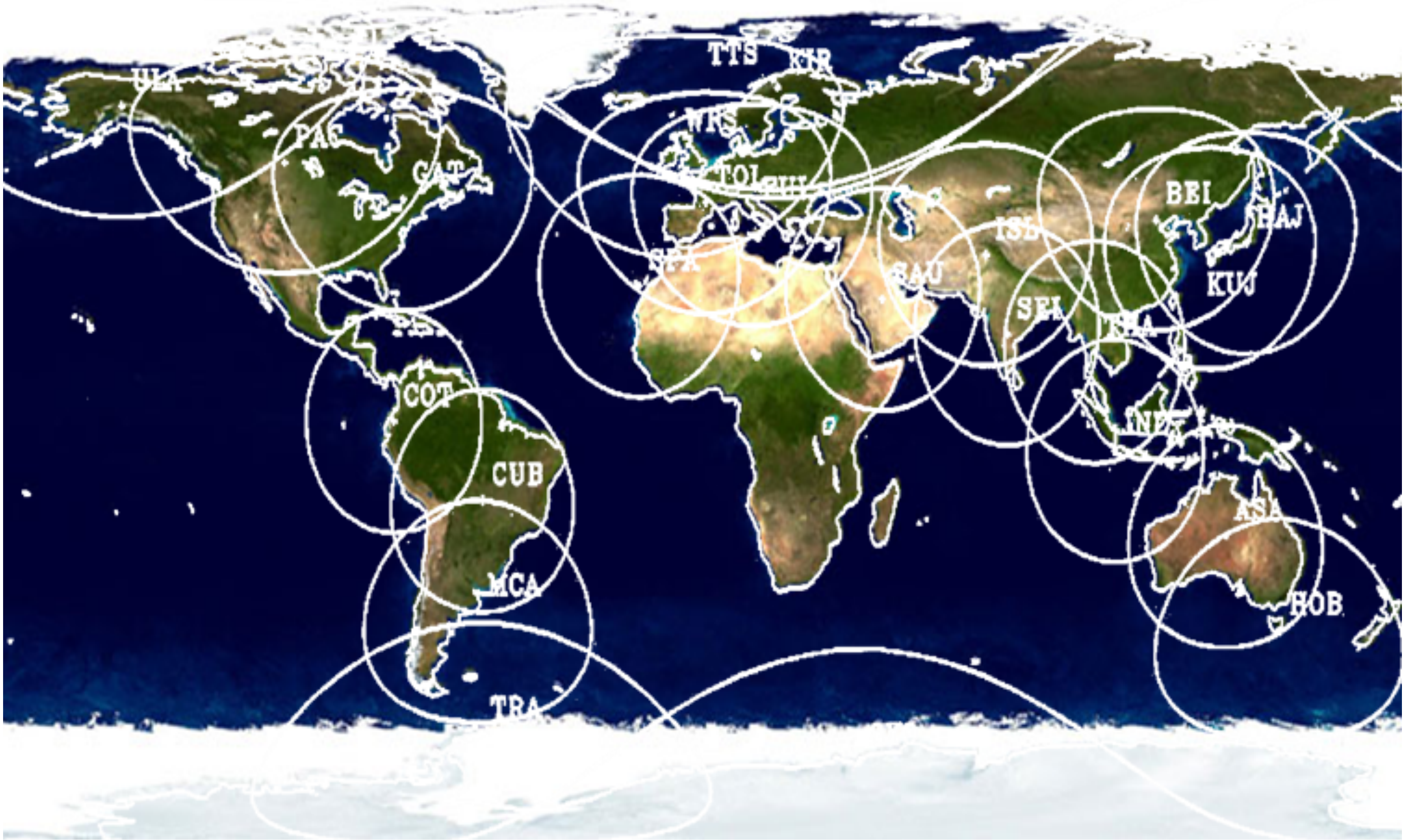
Wavelengths	
211nm	high corona
171nm	lower corona
94nm	flares at the base of the loops



Tech solution Ground stations



Tech solution Ground stations



Other missions and their measurements

- **SDO**
  - Helioseismic and magnetic imager (HMi).
  - Measure solar atmosphere in multiple wavelengths (AIA).
  - Measure extreme ultraviolet spectral irradiance (EVE).

- **Solar-C**
  - Measure magnetic field in the chromosphere and photosphere (UV-Visible-IR telescope).
  - High resolution spectroscopic observations of the chromosphere and corona (EUV/FUV spectroscopic telescope).
  - Spectroscopic imaging of high temperature plasma in corona and solar flares (X-ray telescope).

STEREOs measurments

- **SECCHI:**
  - Extreme Ultraviolet Imager (EUVI)
  - Inner and outer coronagraphs (COR1 and COR2)
  - Heliospheric Imager (HI)
- **IMPACT:**
  - Magnetic field, solar wind electron and energetic particles
- **PLASTIC:**
  - Solar wind proton and ion composition.
- **SWAVES:**
  - Measures electromagnetic waves with three antennas

Our mission is different

- from SDO and Solar-C
  - We have **stereoscopic images** to construct the 3D structure of coronal loops
- from STEREO
  - Our mission includes magnetograph to measure the **magnetic field vector** in the photosphere
  - 3D reconstruction from EUV telescope will be possible from **two different altitudes (various temporal stages)**
  - Better EUV telescope **spatial and temporal resolution**
  - Our images will be provided possible for at least 5 years (**good statistics**)
  - Our data will enable a **reliable** forecast of CMEs and CIRs

Thermal environment

Solar radiation (Js)	1371 W/m^2
a	0.33
Factor visibility (F)	0
Terrestrial radius (R_E)	6371 Km
Orbit radius (R_{orbit})	88264000
Planetary radiation (J_p)	1.2348
Radius of the satellite (r_{sat})	3 m
A_p	12.56 m^2
A_{solar}	12.56 m^2
A_{albedo}	12.56 m^2
σ	5.67 x 10^{-8} W/m^2 K^4
α	0.6
ε	0.8
α/ε	0.75

First aproximation of the satellite's temperature →

$$T = \left(\frac{A_p \, J_p}{A_{sup} \, \sigma} + \frac{A_{solar} \, J_s}{A_{sup} \, \sigma} \, \frac{\alpha}{\varepsilon} \right)^{1/4}$$

-13.6640 °C

Sheila Spina

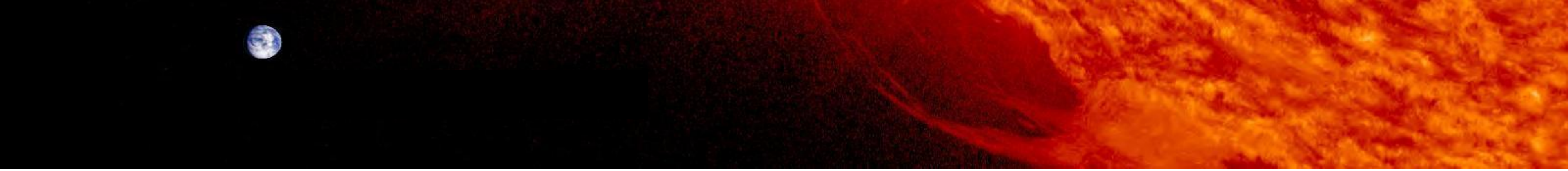
First approximation of the satellite's temperature

$T = -13.6640\ °C$

Maximum power dissipation on spacecraft	526 W
Minimum power dissipation on spacecraft	86 W
Upper temperature limit for the spacecraft	**30°C**
Lower temperature limit for the spacecraft	**-15 °C**
Radiator area to accommodate s/c power dissipation	**1.36 m^2**
Minimum temperature for given radiator area	-80.3 °C
Require heater power (during eclipse)	190.5 W
Additional surface area (*)	**0.1 m^2**

(*) The new emissivity of spacecraft surface is 0.8119.

Material for spacecraft's face turned towards the sun	*silver coated Teflon blanket with a coating of indium-tin oxide*
Material for spacecraft's face turned towards the space	*black-Kapton blanket*



Typical Operating Temperature Ranges for Selected Spacecraft Components

Component	Typical operational temperature ranges (°C)	Typical survival temperature ranges (°C)
Batteries	-15 to 60	-5 to 50
Reaction wheels	-5 to 50	-20 to 60
Sun sensor (Astrium Bass17R)	-80 to 95	-40 to 90
Star trackers (Hydra)	-30 to 60	-40 to 70
C&DH box baseplates	-20 to 60	-40 to 75
Antenna Gimbals	-40 to 80	-50 to 90
Antennas	-100 to 100	-120 to 120
Solar panels	-150 to 110	-200 to 130
EUV imager	In development	In development
Coronagrapher (COR 2)	0 to 40	-20 to 55
Heliospheric Imager (HI 1)	-20 to 30	-60 to 60
Heliospheric Imager (HI 2)	-20 to 30	-60 to 60
Magnetograph (PHI)	Not critical	Not critical
Magnetometer	-80 to 80	-80 to 80

Thermal Analysis

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spacecraft's face turned towards the sun

↓

silver coated Teflon blanket with a coating of indium-tin oxide

spacecraft's face turned towards the space

↓

black-Kapton blanket

Radiation Hardness

Estimated solar cell degradation