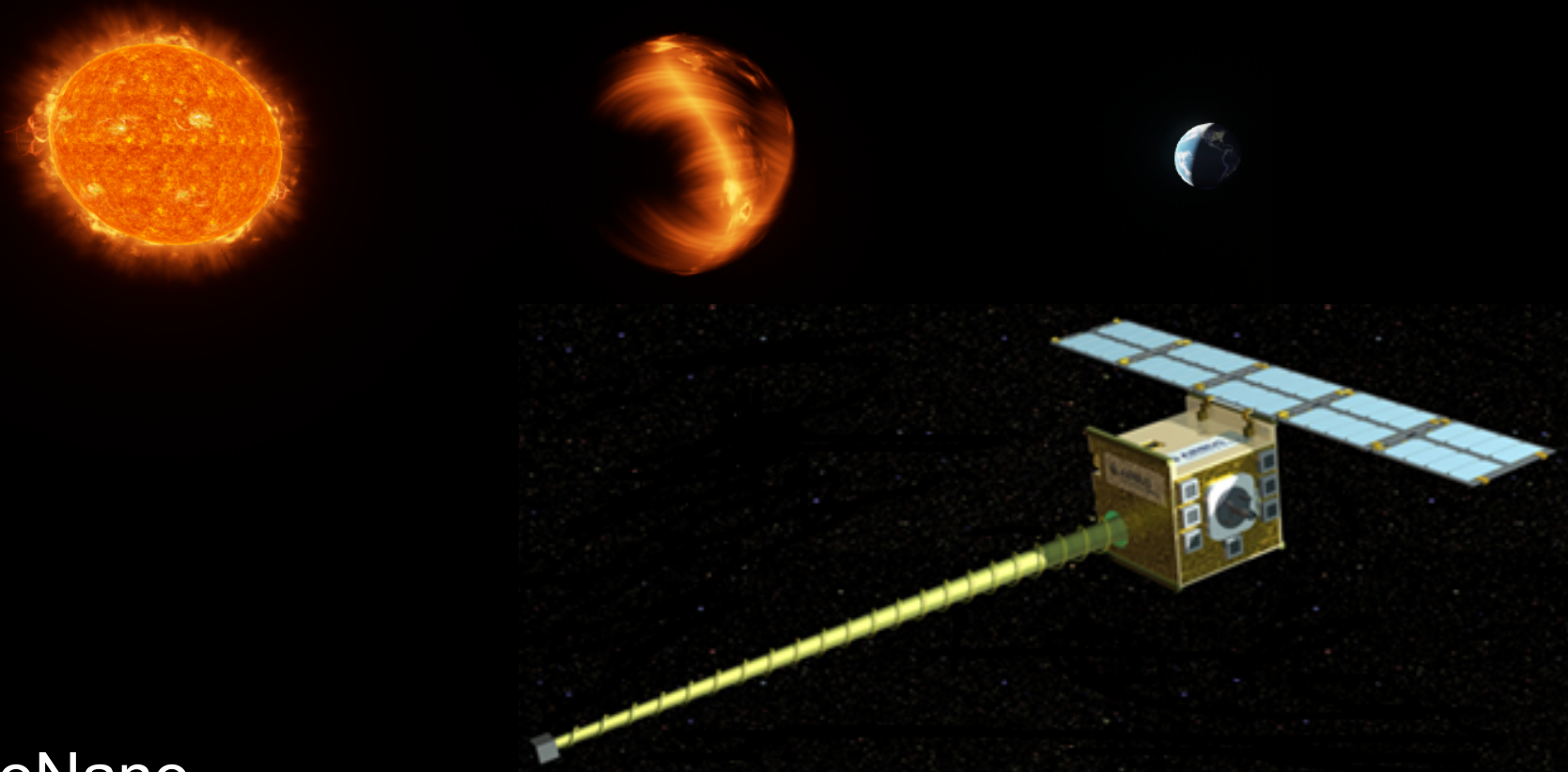


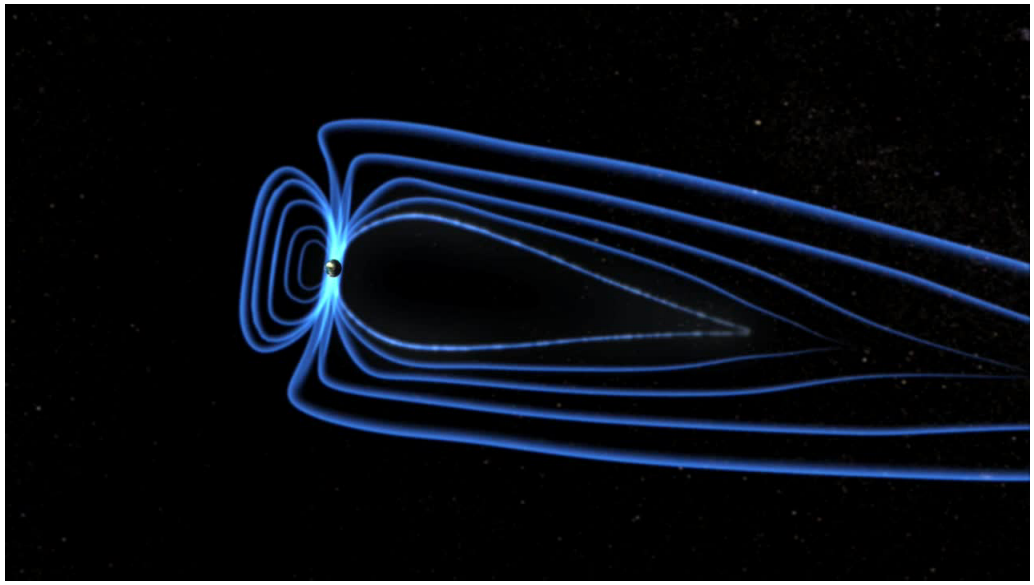
HeL1oNano

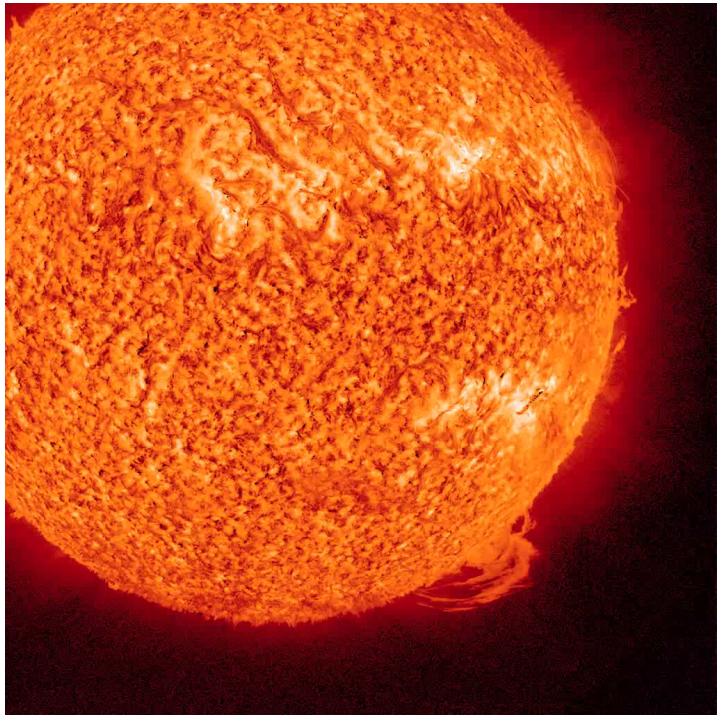
Heliophysics Science IOD at L1

Markos Trichas, Cyrille Tourneur, Matthew Stuttard
Airbus Defence & Space Future Programmes, UK
26 May 2015

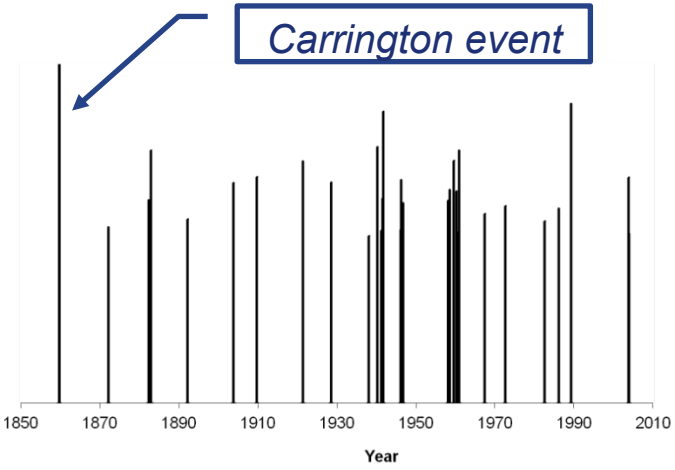
AIRBUS DEFENCE & SPACE

Coronal Mass Ejections (CME)





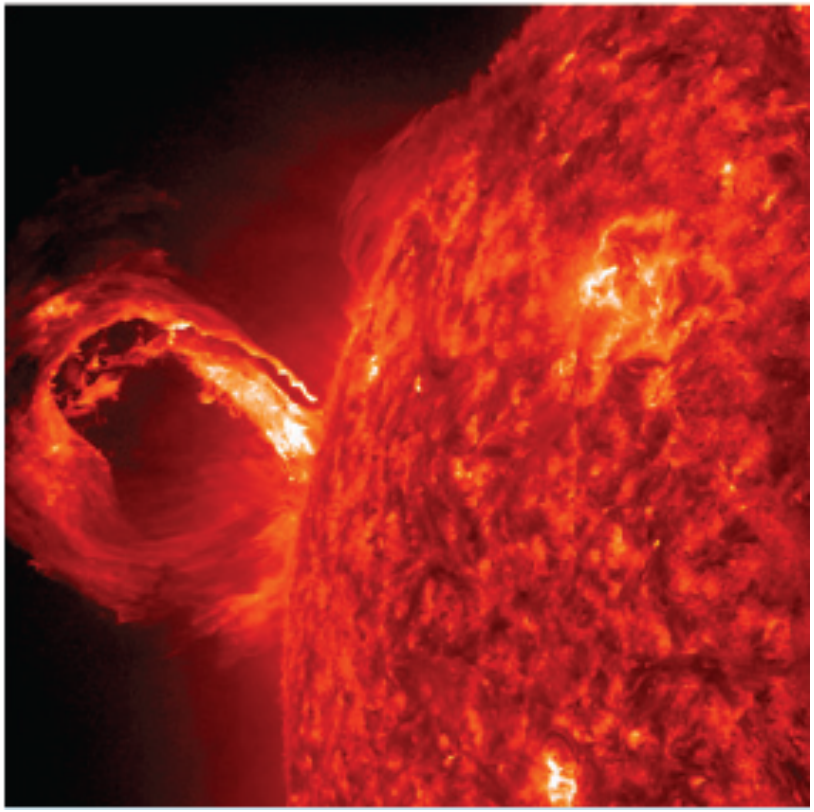
- Massive bursts of plasma
- Can cause of geomagnetic storms
- Propagate with speeds up to 2500 km/s
- Rare events but 10s of “near misses”
- Need to understand the science behind CME eruptions
- CubeSats can provide an affordable Heliophysics science mission
- Mission will contribute to fill gaps in knowledge of CMEs & heliophysics
- Proof of concept is needed



AIRBUS
DEFENCE & SPACE

NASA CubeSat Launch Initiative

- CubeSat piggy back launch (NASA – ELaNa)
- Bidder covers the cost of the CubeSat development
- US universities/non-profit, NASA centers
- Must fit within NASA strategic plan

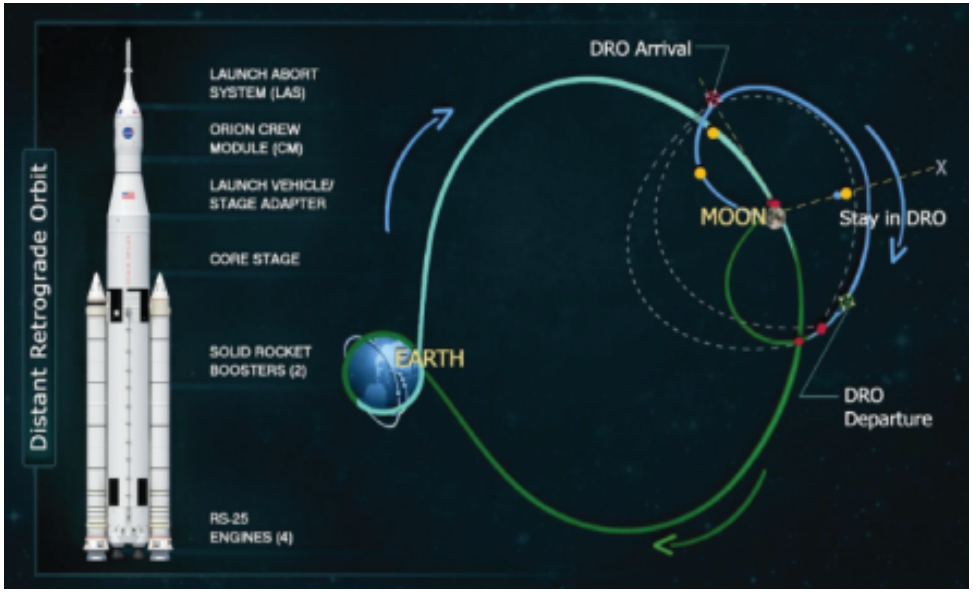


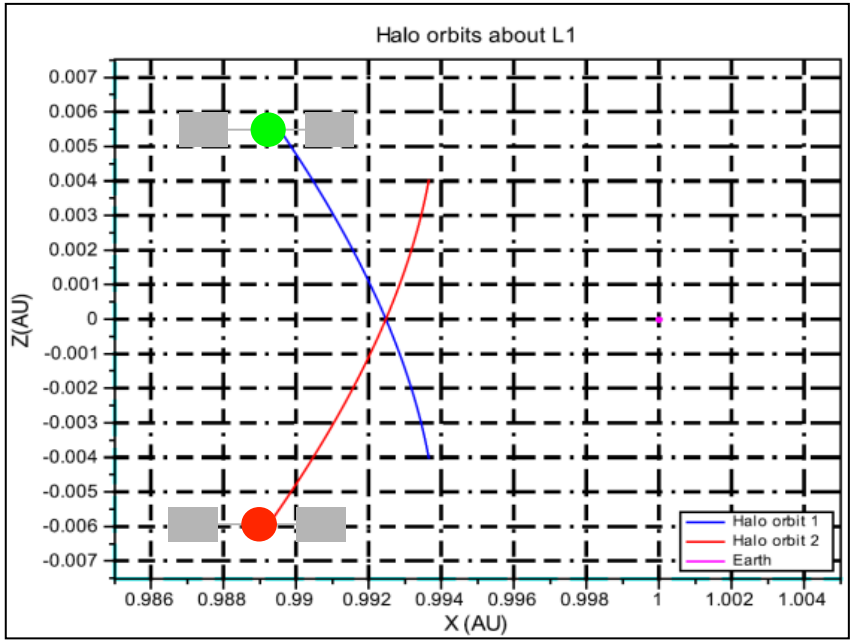
Objective 1.4: Understand the Sun and its interactions with Earth and the solar system, including space weather.

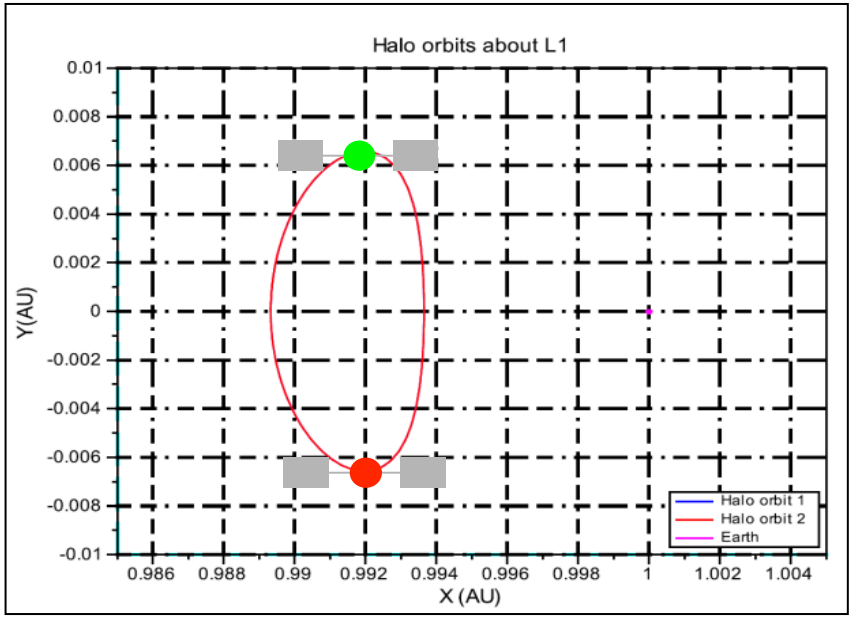
AIRBUS DEFENCE & SPACE

Mission concept

- 6U CubeSat (<14kg) on Halo orbit at L1
- Magnetometer and/or plasma meter
- SLS EM1 mid 2018 (scheduled in the landscape of CSLI launches)
- 30 mins daily contact
- DSN & ground facilities
- 1 year L1-lifetime + 6 months transfer



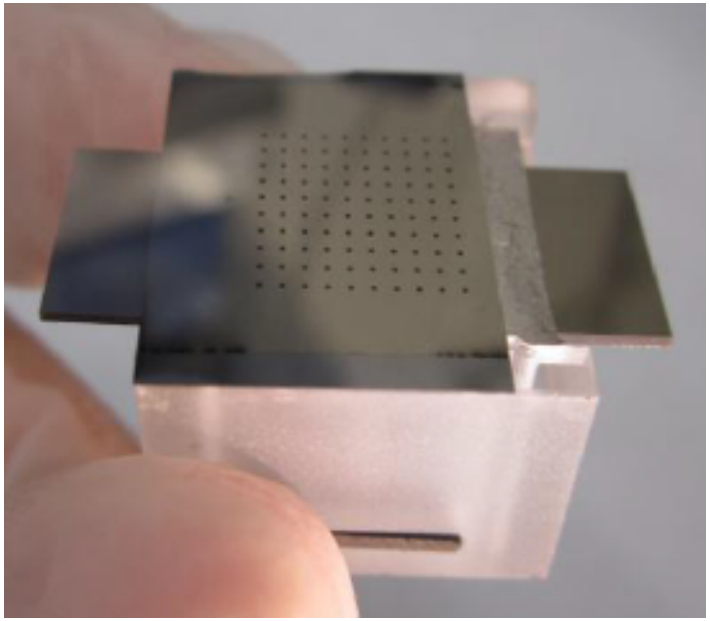


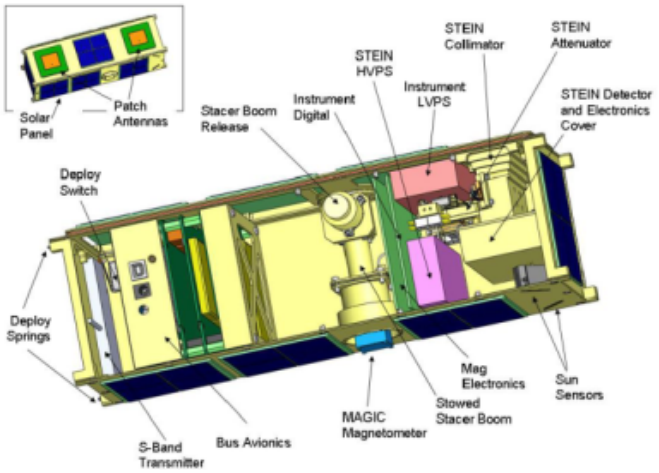


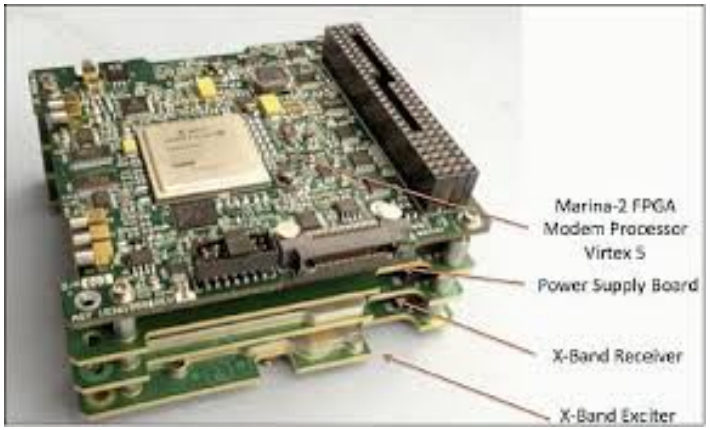
AIRBUS DEFENCE & SPACE

A challenging mission for a 6U cubesat

- Transfer to L1
  - *Launch opportunities (SLS EM1, JWST)*
  - *DV required (e.g. JPL MEP)*
- Communicate from L1
  - DSN for transfer & critical operations
  - Other antennae for routine operations
  - CubeSat transponder (e.g. JPL IRIS)
- Operate @ L1
  - Power (e.g. JPL Inspire program)
- Science @ L1
  - Nanoscale payloads (e.g. CINEMA, Sunjammer)



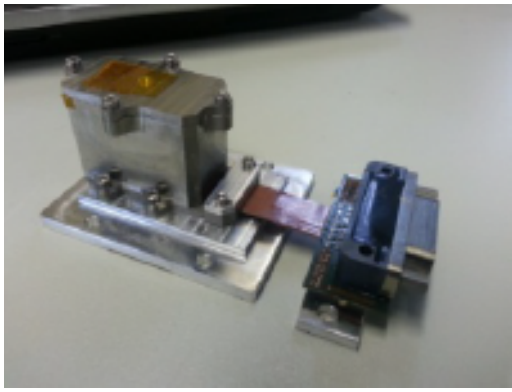


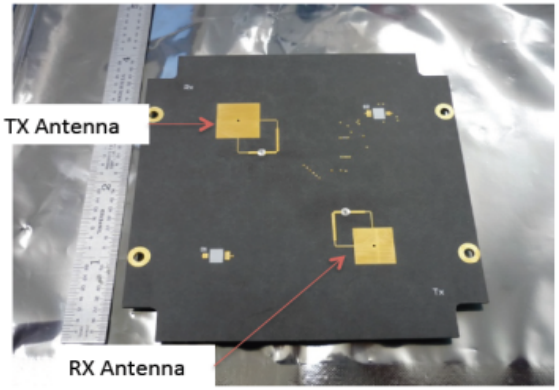


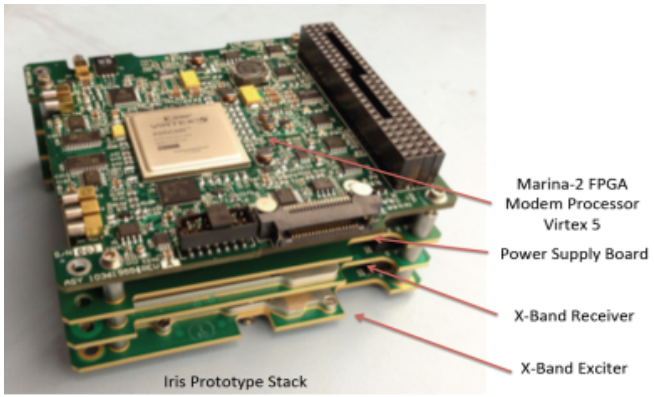
AIRBUS DEFENCE & SPACE

Preliminary concept

- 6U cubesat (3 x 2 x 1 U)
- 14 kg (NASA max) launch mass
- DV is the driver (~ 60 to 80 m/s needed)
- Magnetometer with 90cm boom (MAGIC)
- Plasma meter (HMRM)
- Chemical propulsion (0.1 N – 200s Isp – 80 to 150 m/s)
- IRIS V2 transponder & LGA from JPL (7.5 kbps from L1)
- 2x6 U deployable solar panel + 1x6 U body mounted cells side
- Up to 56 W power generation
- 3 axis control – Sun pointed (on station)
- 1 deg knowledge accuracy per axis
- Radiation shielding (~ 1 mm AL plate on Sun facing side)







AIRBUS DEFENCE & SPACE

Mass Budget – Summary

Subsystem	CEB Total Mass	CEB+DMM Total Mass	Unit	Notes
Structure	3273	3748	g	
Power	1270	1397	g	
Comms	500	600	g	
AOCS	1271	1525	g	
Propulsion	777	816	g	
Harness	398	450	g	Assumed 5% of the dry mass
Total Dry Mass (excluding Payload)	7445	8490	g	
Total Dry Mass (including Payload)	8445	9555	g	
System Margin		20	%	
Total Dry Mass (including system margin)	10134	11466	g	
Propellant Mass	957	1005	g	Assumed 5% margin
Total Wet Mass	11091	12470	g	

Payload Mass	CEB Total Mass	CEB+DMM Total Mass	Unit
HMRM	100	120	g
MAGIC + Boom	900	945	g
Total Payload Mass	1000	1065	g

20% margin assumed for the HMRM and 5% for MAGIC + Boom.

Please note that it has been assumed the whole propellant mass that is already stored into the VACCO system. The final mass slightly increases to <12.5kg.

AIRBUS DEFENCE & SPACE

Power Budget

Operational Modes

LEOP & Cruise Phase
- Dormant
- TM/TC

L1 Arrival
- Sun Monitoring
- Earth-Comms
- Offloading RWs
- Navigation

Safe
- Earth-Comms
- Survival

Space Weather Spacecraft	LEOP & Cruise Phase			L1 Arrival				Safe		
Subsystem	**Dormant**	**TM/TC**	**Navigation**	**Sun Monitoring**	**Earth-Comms**	**Offloading RWs**	**Navigation**	**Earth-Comms**	**Survival**	**Unit**
Comms	0	6.4	6.4	6.4	12.8	6.4	6.4	12.8	6.4	W
Propulsion	0.1	0.1	15	0.1	0.1	0.1	0.1	0.1	0.1	W
AOCS	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	W
Payload	0	0	0	3	3	3	3	0	0	W
10% PCDU losses	**0.6**	**1.2**	**2.7**	**1.5**	**2.2**	**1.5**	**1.3**	**1.9**	**1.3**	**W**
8% harness losses	**0.5**	**1**	**2.2**	**1.2**	**1.7**	**1.2**	**1**	**1.5**	**1**	**W**
Without margin	**6.7**	**14.3**	**31.9**	**18.1**	**25.6**	**18.1**	**15.1**	**22.6**	**15.1**	**W**
Including 25% system margin	**8.4**	**17.9**	**39.9**	**22.6**	**32.0**	**22.6**	**18.8**	**28.3**	**18.8**	**W**

Peak Power → about 40WHr

AIRBUS DEFENCE & SPACE

Link Budget

Downlink

- Antenna Gain = 0dBi
- RFDA losses = 1.2dB
- S/C EIRP = -1.27dBW
- Atmospheric Attn = 0.63dB
- G/S G/T = 56.52dB/°K
- Downlink S/No = 47.43dBHz

Uplink

- G/S EIRP = 109.8dBW
- Atmospheric Attn = 0.51dB
- Antenna Gain = 0dBi
- RFDA losses = 1.2dB
- Power @ Rx Input = -96.4dBm
- Uplink S/No = 78.3dBHz

Case ID: Case 1 - W.C L1 Distance to Ground

Updated:	10/12/2014	**Orbit:**	Lissajous	**Mod. Index (TC):**	1.25	rad pk	
Ground Station:	DSS45 - 34m (X-Band)	**Altitude:**	1.70 Mkm	**RNG Mod. Index (TC):**		rad pk	
S/C Antenna:	Parametric Antenna	**Elevation:**	10 degrees	**Mod. Index (TM):**	1.25	rad pk	
Atmospheric Conditions:	Yearly Average	**Type:**	Up & Downlink	**RNG Mod. Index (TM):**		rad pk	
Polarisation:	C			**Downlink Carrier Rec. PLL BW:**	30.0	Hz	
Availability:	95.0 %			**Uplink Carrier Rec. PLL BW:**	300.0	Hz	
				Downlink RNG Rec. PLL BW:		Hz	
Amplifier RF Output:	1.00 W			**Uplink RNG Rec. PLL BW:**		MHz	
Information Rate (Fb):	7,500 bps			**DDOR Tone 1 Mod. Index:**		rad pk	
Downlink Data Rate (Fs):	17,152 s/s	**Uplink Data Rate:**	1,000 s/s	**DDOR Tone 2 Mod. Index:**		rad pk	

Coding Scheme: Rate 1/2, Constraint Length = 7 + 223/255 R/S Code
Modulation Scheme: PCM(NRZ-L)/PSK/PM **TLM Modulation Type:** Subcarrier Square Wave

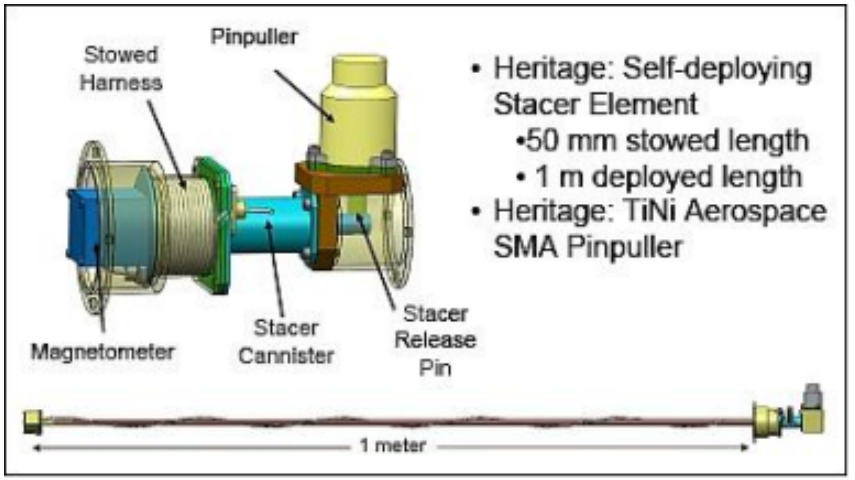
Downlink Margin Summary	Unit	Nominal	Adverse	Favour	Mean-3s	WC (RSS)
Carrier Recovery Margin	dB	5.63	-1.09	9.29	1.53	2.35
TM Recovery Margin	dB	4.69	0.29	6.16	1.68	2.08
Power Flux Density Margin	dB	49.4	48.9	52.4		
Occupied Bandwidth	MHz	0.02				

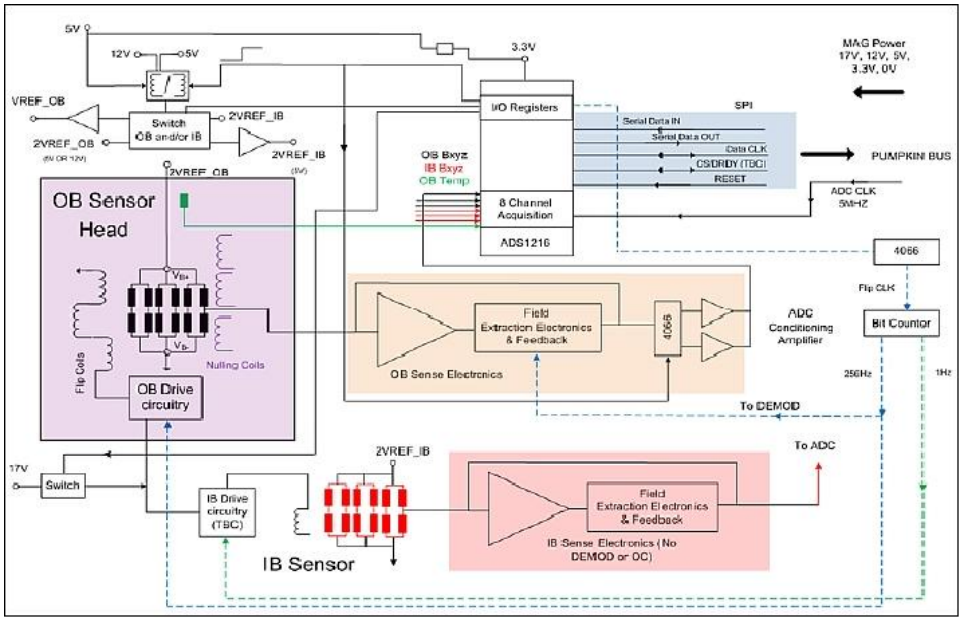
Uplink Margin Summary	Unit	Nominal	Adverse	Favour	Mean-3s	WC (RSS)
Carrier Recovery Margin	dB	38.77	33.82	39.96	35.28	35.96
TC Recovery Margin	dB	34.11	29.75	34.67	30.72	31.35
Margin at Receiver Input	dB	33.62	29.59	33.94		

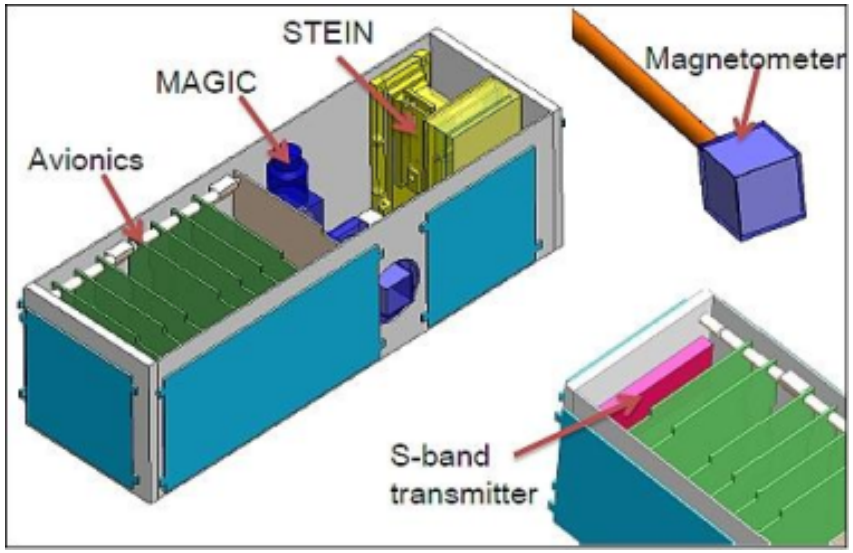
AIRBUS DEFENCE & SPACE

MAGIC magnetometer

- 3-axis on a 0.9m deployable boom
- Electronic + boom + sensor + harness ~1.1 kg
- < 0.5W (0.4W typ) in science mode
- 1U (stowed)
- Preferably on the shadowed side
- Instrument output in science mode: 8 x104 bits/s
- Already flown on CINEMA 3U cubesat
- Baselined for SunJammer
- 1 year max procurement time
- Requires magnetic cleanliness







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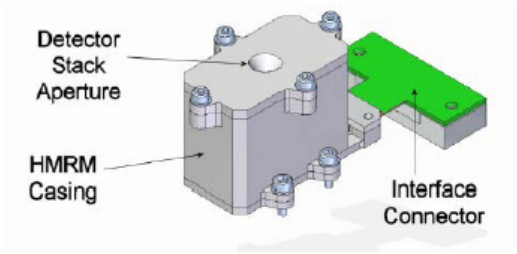
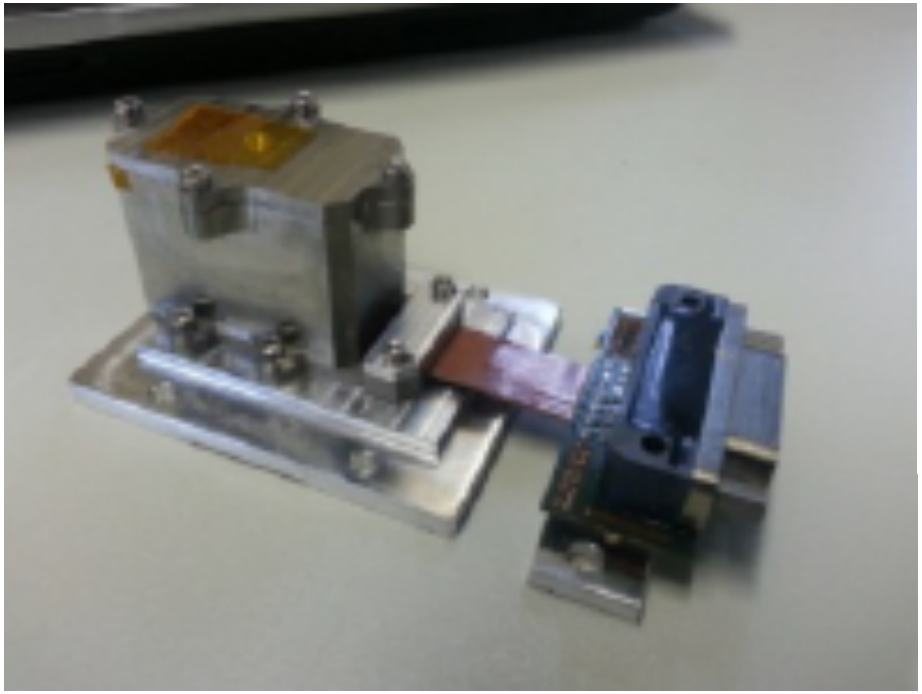
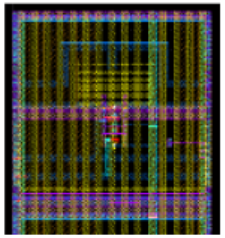
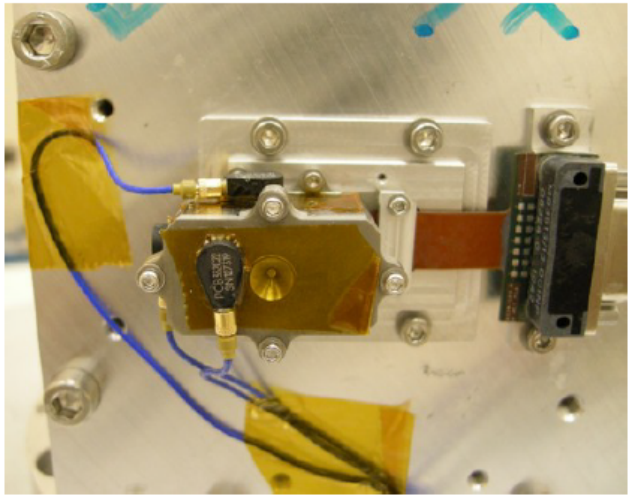
HMRM high energy particles detector

- 52 g – incl. connector
- 1W
- 20x25x30 mm
- Look along the ecliptic plane. Sun facing.
- Instrument science frame: 1024 bits
- Flown on board TechDemoSat nanosatellite
- 1.5 to 2 years max development time (TBC)









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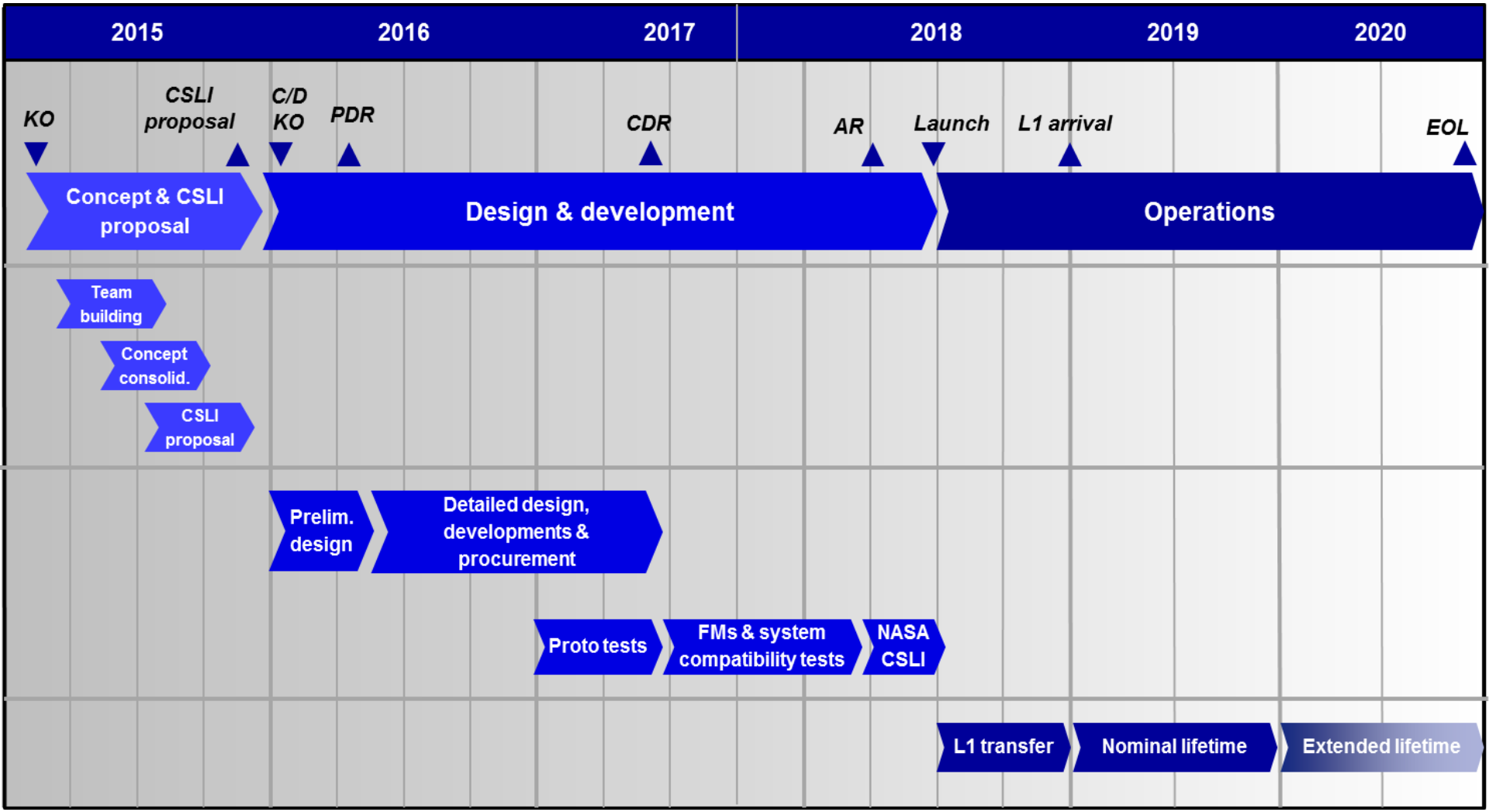
Teaming & Next Steps

AIRBUS GROUP
CAL POLY SAN LUIS OBISPO
JPL Jet Propulsion Laboratory California Institute of Technology
tyvak Nano-Satellite Systems Inc. A Terran Orbital Company



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