2013
Interplanetary Small Satellite Conference
beyond LEO

Interplanetary CubeSats mission for space weather evaluations and technology demonstration

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Outline

- Introduction
- Mission
- CubeSats configuration
- Technological challenges
- Conclusions

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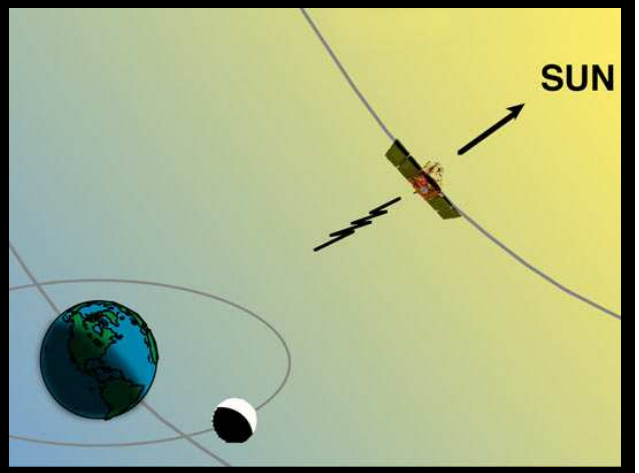
Introduction

- Since big missions are usually very costly, relying on CubeSats could be an interesting alternative to accomplish both scientific and technological tasks in deep space.
- Many scientific ojectives can be envisaged, e.g. space weather, asteroids characterization, etc.
- Interplanetary CubeSats can be also exploited as support for future human exploration of the solar systems as well as test-bed for advanced technologies (e.g. solar sails).

- The proposed CubeSats mission is aimed at supporting measurements of space weather and technology demonstration (telecommunications, solar sails).
- The mission envisages the deployment of a 6U CubeSats system in one of the Earth-Sun Lagrangian Points.



Mission Statement

"To perform solar observation and in-situ space weather measurements from an Earth-Sun Lagrangian point region, pursuing a low-cost approach relying on interplanetary CubeSats and providing a platform for advanced technologies test."

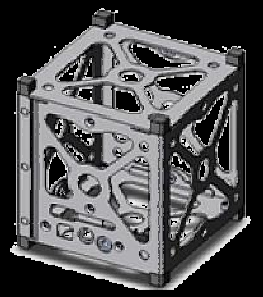
Mission Objectives

1. Scientific objectives:
   - *to observe the Sun*
   - *to perform plasma measurements*
   - *to perform radiation measurements*
2. Technological objectives:
   - *to develop a low-cost CubeSats platform*
   - *to implement solar sail propulsion*
   - *to communicate to Earth from very distant region (Earth-Sun L1)*
   - *to collect, store, manage and send to Earth large quantity of scientific data.*

Mission Requirements

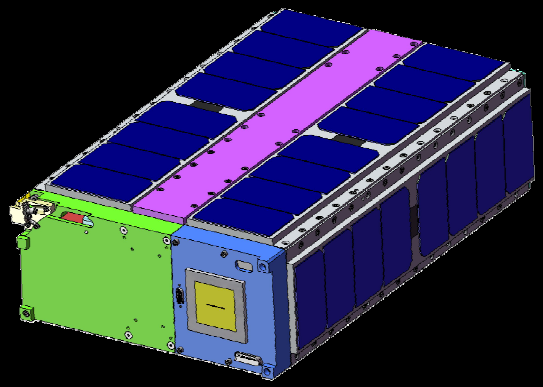
Functional requirements

- The system shall perform an interplanetary mission to the first Earth Sun Lagrangian point.
- The system shall be provided with interfaces with the launcher.
- The system shall withstand the launch loads.
- The system shall withstand the deep space environment.
- The system shall perform plasma measurement.
- The system shall take pictures of the Sun.
- The system shall perform radiations measurements (total ionizing dose).
- The system shall allow communications with Earth.
  - command data (uplink)
  - telemetry data (downlink)
  - scientific data (downlink)



Performance requirements

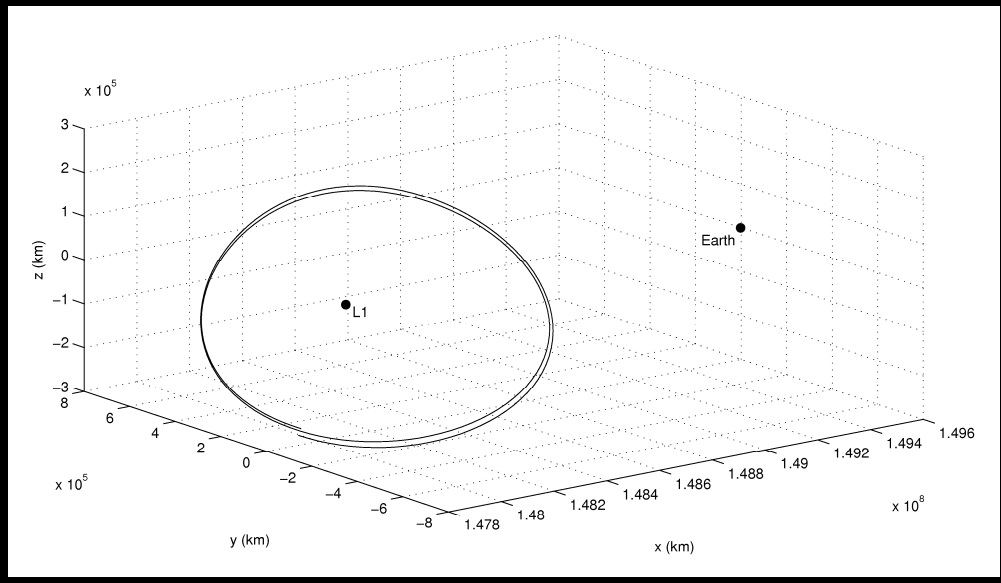
- The system shall be compliant with **6U CubeSats standards**
  - maximum envelope: 20mm x 30mm x 10mm
  - maximum total mass: 6kg
- The total required power shall not exceed 50W.
- The max required data rate shall not exceed 500kbps .



Mission Analysis

- Motion around the L1 unstable point is considered envisaging the third body, i.e. the 6U CubeSats system, equipped with a solar sail
- Cartesian reference frame Oxyz
  - origin fixed in the system barycentre, xy-plane coinciding with the plane of primaries motion, x-axis oriented along the Sun-Earth direction
- sail is supposed to be ideal (it reflects all the incoming radiation and no deformations are taken into consideration)

- For the L1 point, Halo orbits have a period T of approximately 177 days (roughly half a year); to simulate a one-year CubeSat trajectory, tests for 2T have been conducted.
- sample trajectory obtained from a Halo with z-axis amplitude Az = 250000 km



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Functional Analysis

Functions \ Devices	Structure S/S							Electrical Power S/S					Thermal Control S/S							Data Management S/S				Harness	Communications S/S																		Attitude & Orbit Det. & Control S/S				Mission Observation S/S			
	Radiation shielding	MDPS panels	Transport container	Integration stand	Hoisting fixture	Primary structure	Secondary structure	Solar arrays	Batteries	PDU	Regulators	Converters	Radiators	Heat pipes	TCS control	Heaters	Coolers	MLI	Surface finishes	Command acquisition unit/Receiv.	Command decoder	On-board computer	Memories	Harness	Comms/Antenna	Hardware timer	Watchdog timer	PLL	Antenna/optical photoreceptor	Antenna/LASER	Coherent demodulator	Detector	Data Bus	Carrier generator	Modulator	Coder	Receiver	Transmitter	Auto-tracking equipment	Selector	Orbit sensors	Thrusters/Solar sails	Attitude sensors	Attitude Actuators	Camera	Spectrometer	Magnetometer	Dosimeter
Radiation protection	X																																															
Micro meteoroids and debris protection		X																																														
Ground handling loads withstanding			X	X	X	X																																										
Flight accelerations withstanding						X																																										
Operational loads withstanding						X	X																																									
Power generation								X																																								
Energy storage									X																																							
Power distribution										X														X																								
Power regulation and control											X	X																																				
Heat rejection													X																																			
Heat collection and transportation														X	X																																	
Local heat sink																X	X																															
Thermal insulation																		X	X																													
Reception, validation, decoding & distribution commands to other S/C systems																				X	X	X	X	X																								
Gathering, processing and formatting S/C housekeeping and mission data																				X		X	X	X	X																							
Data reception, elaboration and command transmission to onboard systems for closed-loop control (attitude and orbit)																				X		X		X																								
Spacecraft time keeping performance																									X																							
Computer health monitoring provision																						X				X																						
Security interfaces provision																						X		X																								
Carrier tracking																												X																				
Command reception and detection																								X				X	X		X	X	X														
Telemetry modulation and transmission																														X			X	X	X	X	X										
Ranging																														X							X	X									
Subsystem operations																						X			X														X			X	X			X			
Orbit determination (navigation)																						X																			X							
Orbit control (guidance)																						X																				X						
Attitude determination																						X																					X					
Attitude control																						X																						X				
Sun/Deep space observations																																														X			
Plasma measurements																																														X	X		
Radiation measurements																																																X	

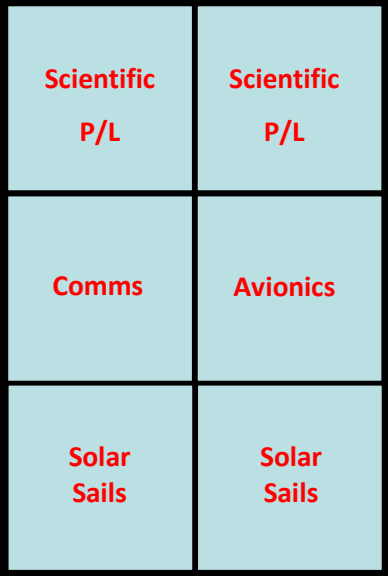
Subsystems

- **structure**
- **electrical power subsystem**
- **thermal control** (passive solution)
- **command and data handling** (possible solution to be implemented is represented by the Tyvak's Intrepid Embedded Linux System Board)
- **attitude and orbit determination and control** ("iACDS-100" solution, from Berlin Space Technologies can be used as reference; solar sails are exploited for orbit control)
- **communications** (optical communication)
- **harness**
- **mission observation** subsystem

Spacecraft Configuration

6U CubeSats system

- **2U** occupied by the scientific payloads
- **2U** for the solar sails
- **1U** devoted to telecommunications
- **1U** for the attitude control system and command and data handling



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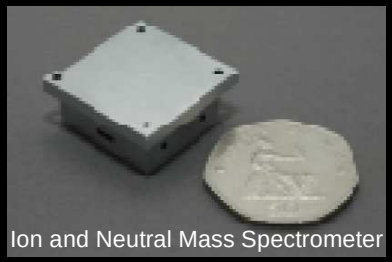
Scientific Payloads

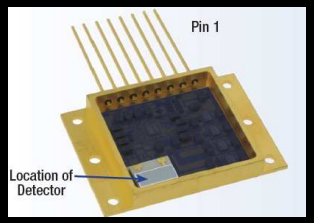
Plasma Instruments

- 1 Magnetometer
- 1Plasma Spectrometer


Ion and Neutral Mass Spectrometer

Radiation Dosimeters and Advanced Materials

- 3 radiation micro dosimeters



- advanced shielding materials
  - kevlar
  - high density polyethylene

Imagers/Cameras

- 1 NanoCam C1U

Instrument	Mass	Volume	Power	Data
Magnetometer	Sensor: 15g Electronics: 150g	Sensor: 10x10x5mm Electronics: 90x30x11mm	Power consumption: 400mW Power supply: +5V and +15V DC or 28V unregulated option	Measurement range: +50,000nT to -50,000nT Sensitivity: 10nT Update rate: up to 10Hz Data Rate: 140bps
INMS	Mass: 350g	Envelope: 100x100x50mm (½U)	Power consumption: 500mW	Data Rate: ~23bps
Dosimeter	Mass: 20g	Envelope: 35x25x10mm	Power consumption: 280mW Electronic I/F: 10mA at 13-40VDC	Measures up to 40 krads Data Rate: 1 Byte/s
NanoCam C1U	Mass: 170g	Envelope:96x90x58mm	Power consumption: •Idle: 360mW •Image acquisition: 634mW •Image processing: 660mW Supply voltage: 3.3V	CMOS camera Data Rate: 400kbps

Technology challenges

1. **Solar Sails**
   - *the main issue is related to the size limitations*
   - *this results in small available thrust acceleration*
2. **Communications:**
   - *trade-off radio frequency (RF) vs optical communications.*
   - *laser communications advantages over RF*
     - *higher data rates, relatively small antennas diameters, lower system masses.*
   - *laser communications difficulties*
     - *typically narrow optical beams, difficulties in acquiring and pointing accurately, more complex pointing mechanisms.*
   - *Due to the long distance and the small CubeSats standard sizes, optical communication is preferred to enable very compact, low power uplink/downlink over interplanetary distances and allow a good scientific data transfer capability to Earth.*

Conclusions

- A 6U CubeSats system interplanetary mission to one of the Earth-Sun Lagrangian point has been presented.
- A mission like this would represent a good opportunity to improve the national interest and capabilities in the exploration of the solar systems, pursuing both scientific and technological objectives, foreseeing sun observation and plasma measurements, as well as advanced technologies demonstration (e.g. optical communications, solar sails).
- It would give the chance to expand the academic presence in developing systems needed for future missions, including human expeditions.

Thank you!

If you have any question please contact
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