TwinCube

Proposal for Tethered Supported Plasma Measurement 3-Unit CubeSat

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3rd Mission Idea Contest 2014

Outline of the presentation

1. Diagnostics of plasma
2. Technical description of TwinCube
3. Plasma and tether experiment
4. Implementation plan, challenges and feasibility

Introduction

Diagnostics of Plasma

<u>**Investigation of space plasma can lead to:**</u>

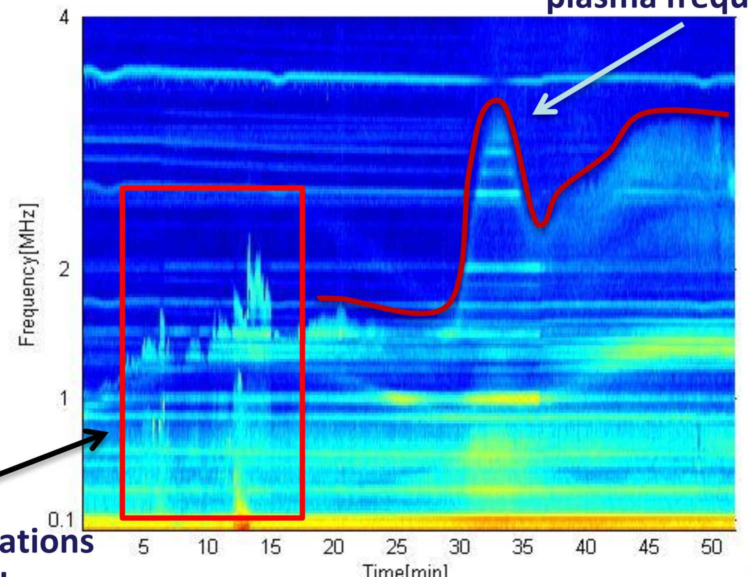
- **Receiving more reliable positioning and navigation services**
- **Improvement of communication satellite services**
- **Protection against effects of space radiation on electronic devices**

Passive measurements of electro-magnetic emissions in plasma are one of the ways to investigate the state of Earth’s environment.

<u>Example</u>:

RELEC mission with RFA instrument

- **Launched in June 2014**
- **Single point measurement of E-field in 3 axis**
- **Predecessor of miniaturized analyzer for CubeSats**



Introduction

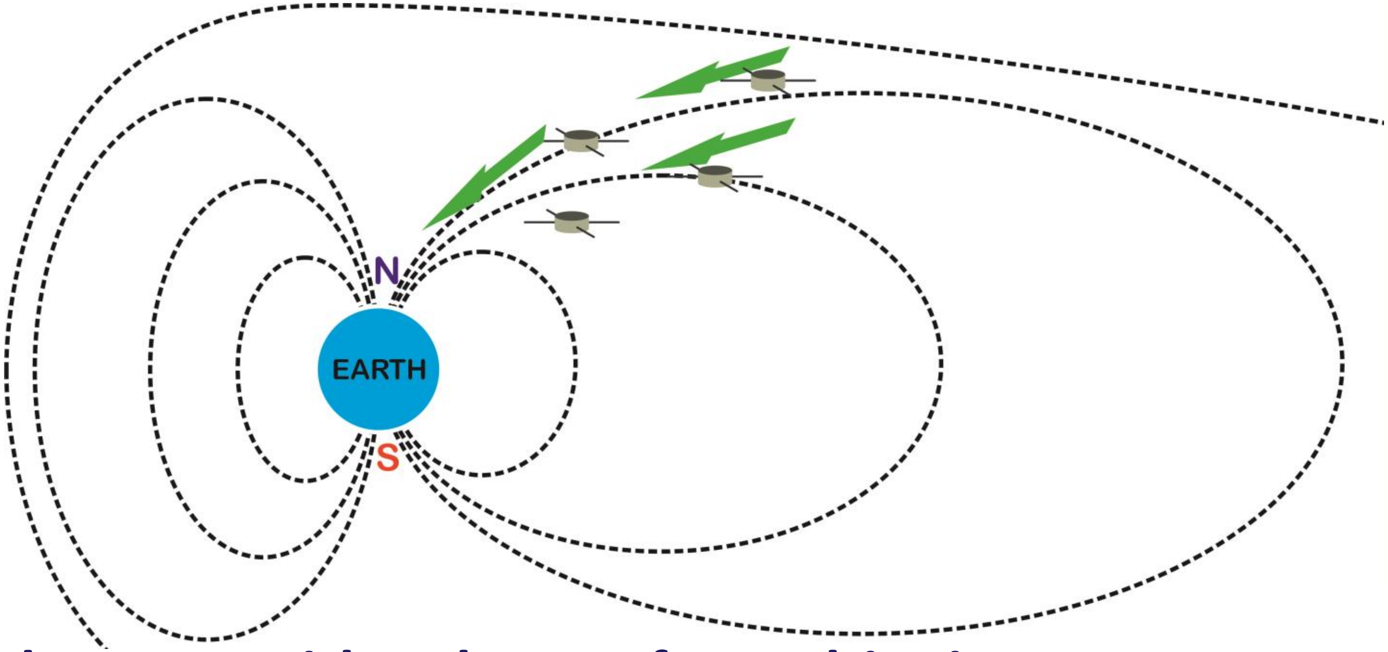
Multipoint Measurements - Tethered System

Multipoint measurements allow to investigate spatial and temporal variability of plasma. Diagnostics at multiscales (time/space) is crucial to understand evolution of whole system.

Examples:

Cluster satellites
(ESA, 2000)

CROSS SCALES
(ESA, Proposal)



Using tethered system with CubeSats for multipoint measurements has advantage of:

- **Lower cost of the mission** (i.e. no formation maintaining)
- **Possibility to investigate new areas** (i.e. lower parts of ionosphere)

Introduction

Mission Objectives

TwinCube mission objectives:

1. Perform two-point measurements of electromagnetic small scale plasma turbulences.
2. Simulate and verify dynamics of two-satellite system and learn how to control its spin and oscillations.
3. Develop miniaturized lock&release mechanism and reliable tether winding/unwiding mechanism.

Additional objectives:

- Introduce students to philosophy of space projects
- Develop and increase TRL of certain sub-systems

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Satellite's Subsystem

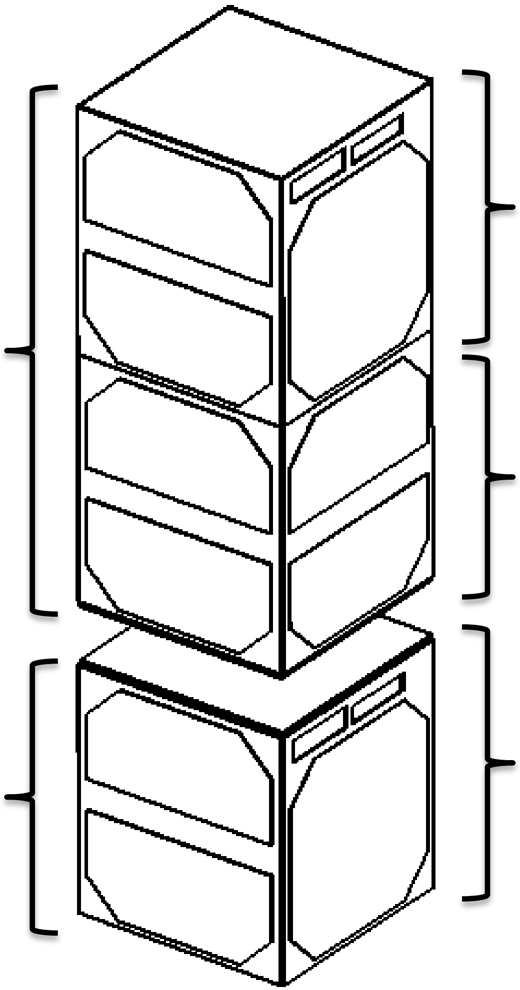
Sub-Satellite A

- UHF/VHF Communication System
- On-Board Computer
- Attitude Determination and Control System
- Electrical Power System
- S-Band Communication System
- Plasma Experiment Board

- Tether Experiment (1 km long non-conductive tether)
- Lock and Release Mechanism

Sub-Satellite B

- UHF/VHF Communication System
- On-Board Computer
- Attitude Determination and Control System
- Electrical Power System
- Plasma Experiment Board



Size: 100 x 100 x 340.5 mm

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Budgets

Mass budget falls under 4kg defined in CubeSat Design Specification.
www.CubeSat.org

Sub-satellite A (2U)	Mass [g]
OBD&OBDH	70
EPS	245
COMM UHF/VHF/S-Band	180
COMM Antennas	146
PLASMA Experiment	100
PLASMA Experiment Antenna	70
ADCS Components	259
Camera	166
Tether Spool	346
Tether Electronics/Mechanics	250
Separation Mechanism	50
Harness	50
Screws & Assembly	50
2U Structure	150
Walls (7 Walls)	196
Total Sub-Satellite A	**2328**

Sub-satellite B (1U)	Mass [g]
OBD&OBDH	70
EPS	175
COMM UHF/VHF	94
COMM UHF/VHF Antennas	87
PLASMA EXP	100
PLASMA EXP Antenna	70
ADCS Components	25
Dissipation Mechanism	50
Harness	50
Screws & Assembly	50
1U Structure	75
Walls (4 Walls)	112
Total Sub-Satellite B	**958**

Power budget is positive considering time-sharing.

Sub-Sat. A: avg. energy income: 3.38W

Sub-Sat. B: avg. energy income: 1.45W

	Subsystem	Minimum [W]	Plasma Measurement [W]	S-Band Transfer [W]	Tether Operations [W]
Sub-Sat. A	OBC	0.3	0.3	0.3	0.3
	ADCS	0.25	0.7	0.7	0.7
	COMM UHF/VHF	0.9	0.9	0.9	0.9
	COMM S-Band	0	0	6	0
	PLASMA Experiment	0	2	0	0
	TETHER OPERATIONS	0	0	0	1
	Total	**1.45**	**3.9**	**7.9**	**2.9**
Sub-Sat. B	OBC	0.3	0.3	-	-
	ADCS	0.25	0.25	-	-
	COMM UHF/VHF	0.9	0.9	-	-
	PLASMA Experiment	0	2	-	-
	Total	**1.45**	**3.45**	-	-

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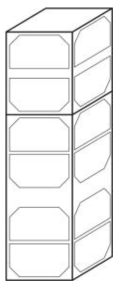
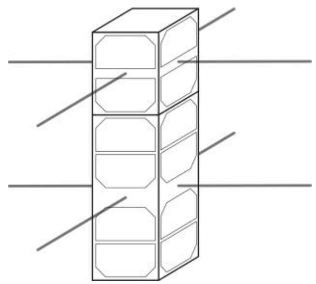
Nominal Operational Scenarios

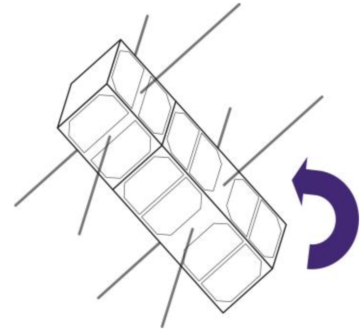
Detumbling after ejection from P-POD



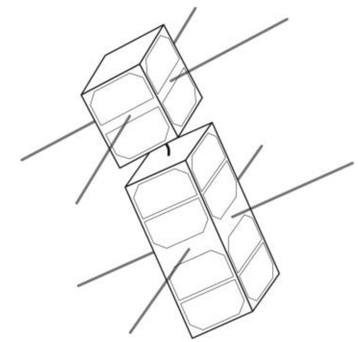
Antenna deployment



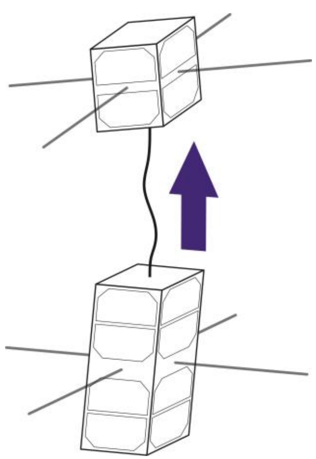
Initial spin of the CubeSat



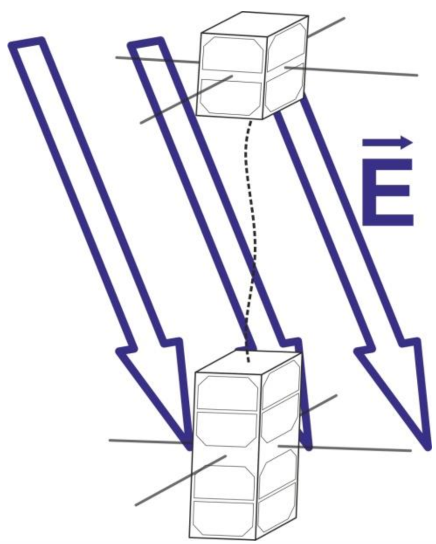
Unlock of the Sub-Satellites



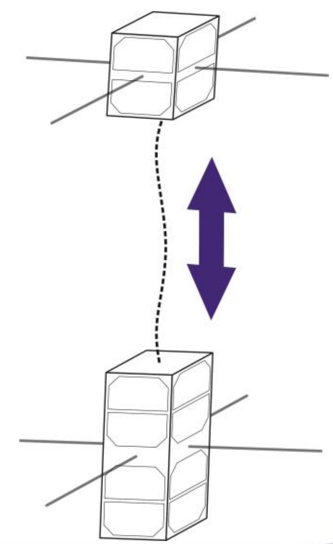
Unwinding of the tether



Commencement of plasma experiment



Commencement of tether experiment



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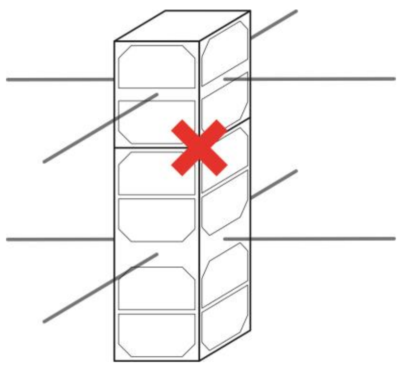
Risk Assessment

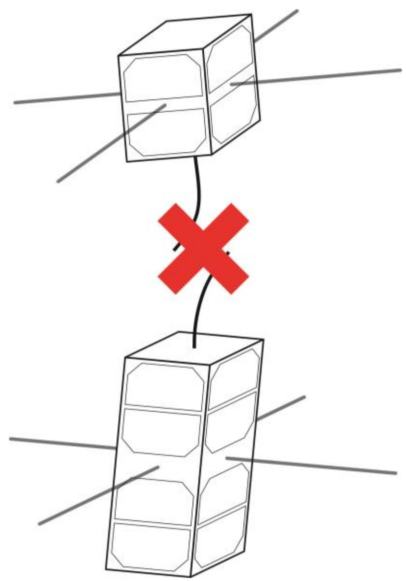
Lock&Release Failure

One point two axis plasma measurements



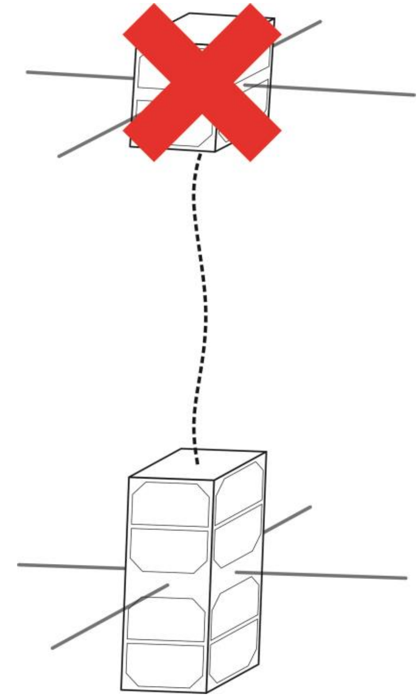
Tether Brakedown

Two independent plasma measurements



One Sub-Satellite Failure

One point plasma measurements, possibility of full tether experiment



Other potential risks:

- 1 km tether may cause collision – avoid SSO
- Chance of tangling the tether – stability of deployment is crucial

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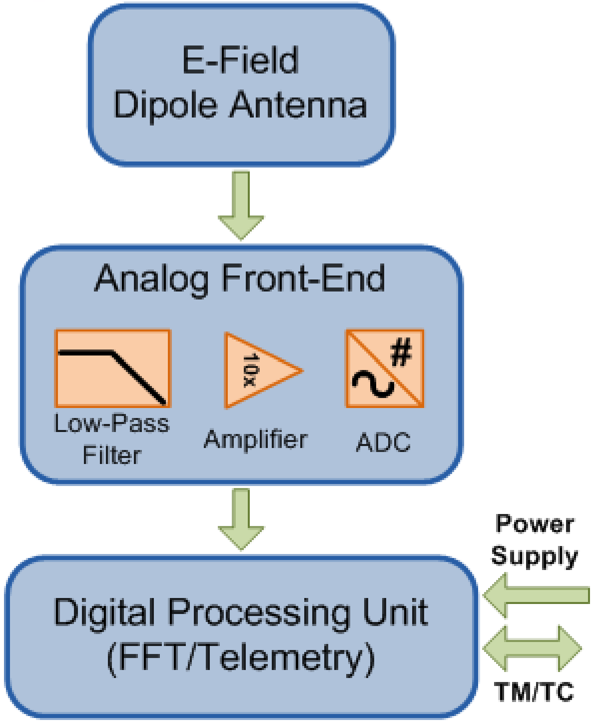
Plasma Experiment Instrument



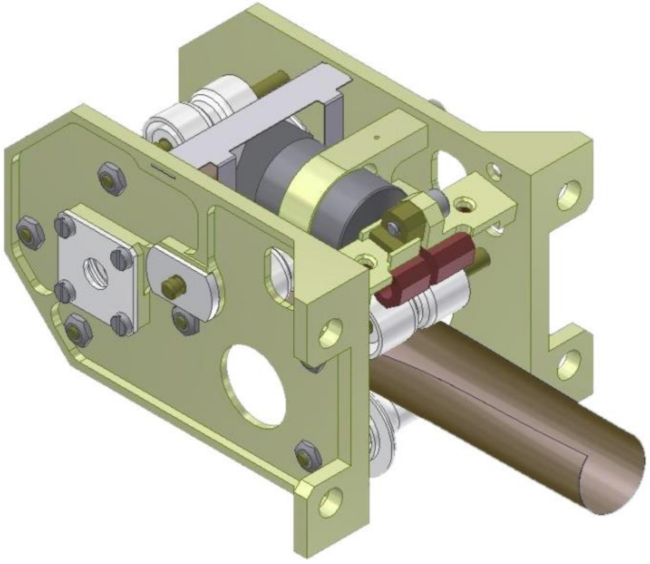
<u>Architecture based on design of many spaceborne analyzers</u>:

- **E-Field dipole antenna with preamplifier**
- **Analog Front-End with low-pass filters amplifiers and ADC converter**
- **Digital Processing Unit (FFT Processor)**

<u>Innovative plasma antenna</u>:

- **One meter boom antenna**
- **Steady slow deployment, no kick-off**
- **Ultra light and compact construction**

(45 grams, 25x45x25mm)



Marta Tokarz, BRITE-PL (SRC PAS)

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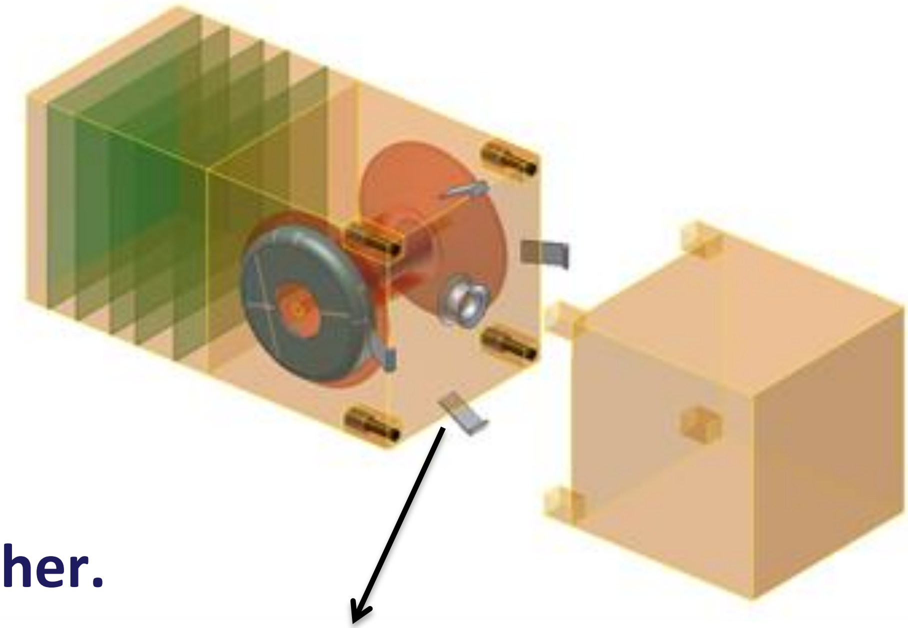
Tether Experiment

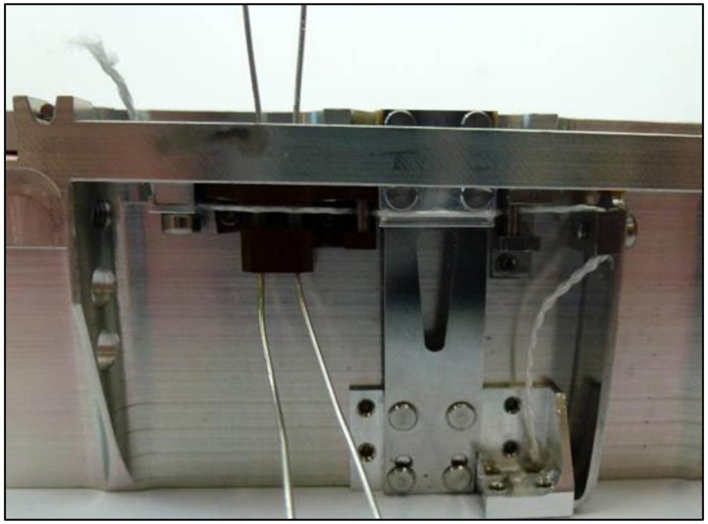
Tether Mechanism:
- Tether spool
- Motor
- Self-locking drive
- Tether eyelet
- Kick-off spring



The spool will contain 1 km of tether. Dyneema wire is considered.

Lock&Release Mechanism

(PW-Sat payload developed in SRC PAS):
- Heat resistors (primary & backup)
- Dyneema wire
- Strip spring



Bartosz Kędziora (SRC PAS/PW-WUT)

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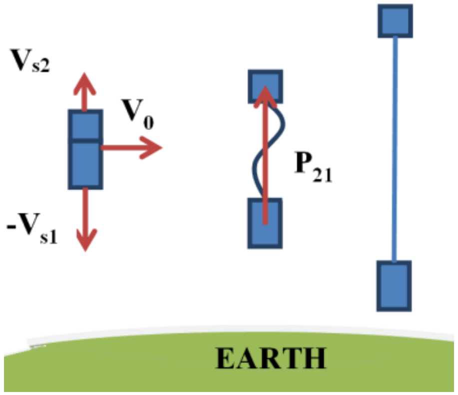
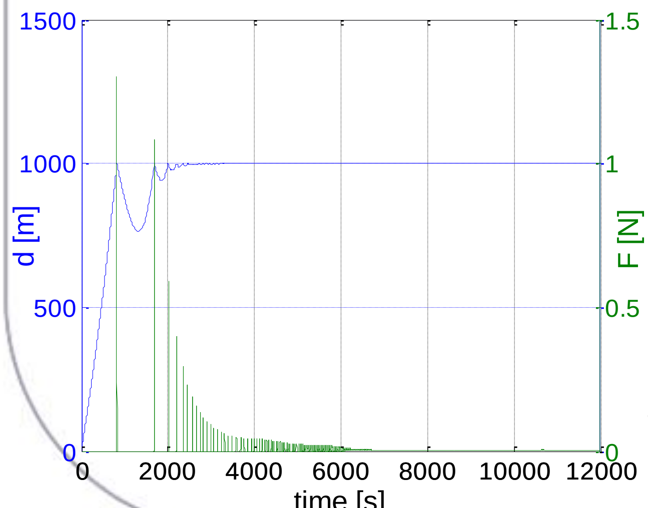
Tethered System Dynamics Simulations



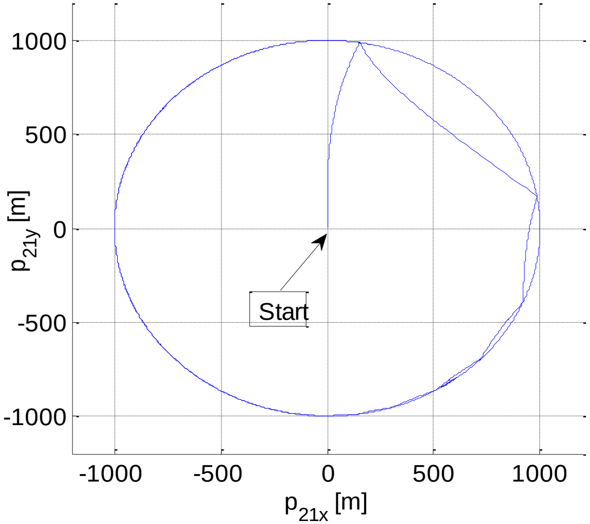
Tethered system stability simulation set-up:

- Chosen orbit: 1400 x 300 km (PW-Sat orbit)
- 1 km tether
- Sub-Satellite alignment parallel to orbit plane
- Kick-off velocity induced by springs (0.5 m/s)

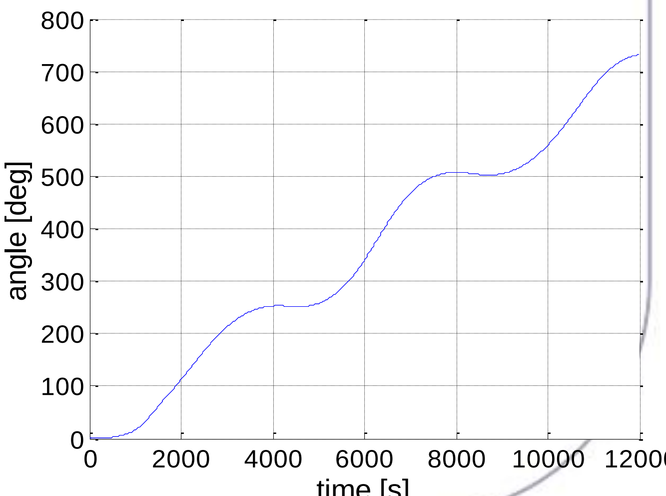
Distance between Sub-Satellites & tether tension force



Relative motion of the Sub-Sat. B with respect to Sub-Sat. A



Rotation angle of the constellation



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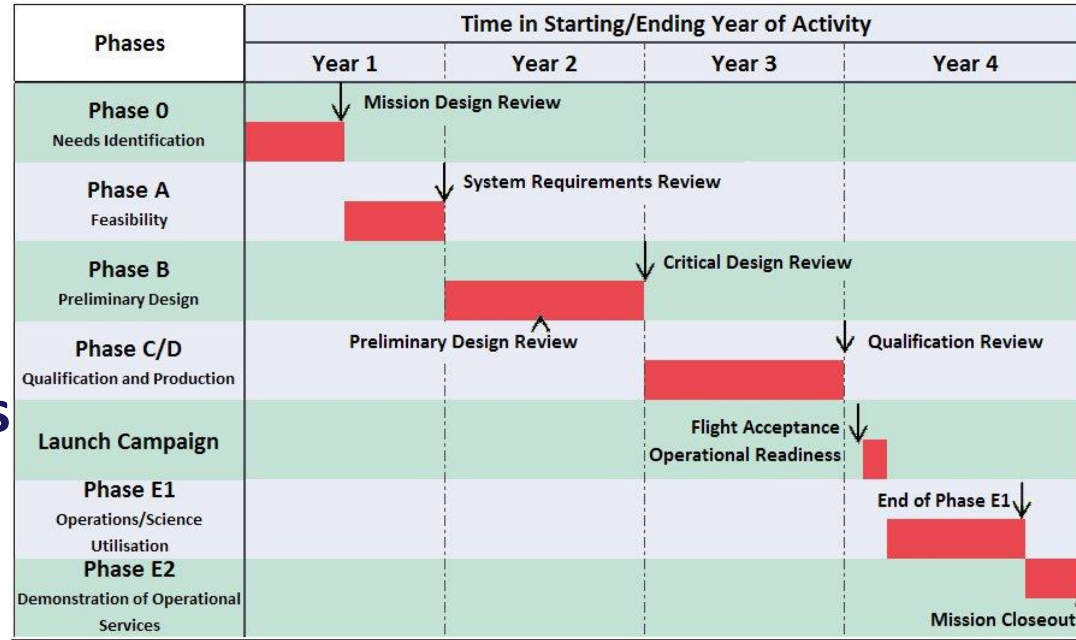
Implementation Plan

Mission phases arranged to fit into 4 year plan.

3-year development phase
1-year in-orbit phase

Availability of infrastructure used to develop instruments for various missions.

clean room/mechanical workshop/vacuum chambers/laminar flow cabinet



Ground station can be provided by our partners (UHF/VHF/S-Band).

Nicolaus Copernicus Astronomical Center

Nicolaus Copernicus University

Photo: S.Krawczyk

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Feasibility & Technical Challanges

<u>Technical feasibility:</u>

- Ultralight antenna has already high TRL
- Good experience with lock & release mechanisms
- Experience with system dynamics simulation & control
- ‘Full sized’ analyzers successfully flown and operational

<u>Awareness of technical challenges important for mission outcome:</u>

- Reliable tether mechanism implemented on CubeSat
- Simulation and control issues of tethered system
- Miniaturization of all sub-systems to fit into 3U CubeSat

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Thank you for your attention!

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