بسم الله الرحمن الرحيم

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IAP-SAT

5th Project Report (2017)

- PPT Propulsion Unit
- Integration of IAP-SAT Prototype

Initial document: Ras Nhache, 04 August 2017

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Mariam Ruzz

Rami Nassouh (CNC Lab)

Content

Project Status at Beginning of actual project phase

- Presentation film
- HIL test rig
- Concept for propulsion unit, concept for battery
- CAD integrated satellite (FCS)
- FOG sensor investigations

1 Initial Goals of actual phase

- On-Board-Computer Integration with Control Algorithm
- Visualization of satellite movement in orbit based on scilab simulation data
- Integration
- Fiber Optic Gyro development test rig
- Mission Simulation of Orbitting IAP-SAT

2 Project Management

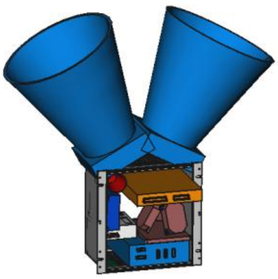
2.1 Organisation

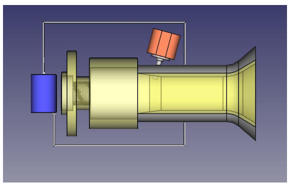
Satellite Bus	Satellite Bus Prototype - Conception - HIL Testrig - Intergration of Prototype	IAP-SAT Reports 1-5 (2012-2017)
Payload	Radioastronomy Sensor	[Kassar 2014]
Shuttle	Modeling of shuttle (motor, body) Mission Planning	IAP-TRANSPORTER (planned 2018)
Operation of satellite	Ground Station with direction finder SDR tracking	planned 2019

2.2 Working Packages and Time Plan

2.2.1 Overview Planning & Budget IAP-SAT 2017

Completing IAP-SAT Prototype, Budget: 1500$





Building Experimental Rig for Electrical Satellite Propulsion Unit, Budget: 500$

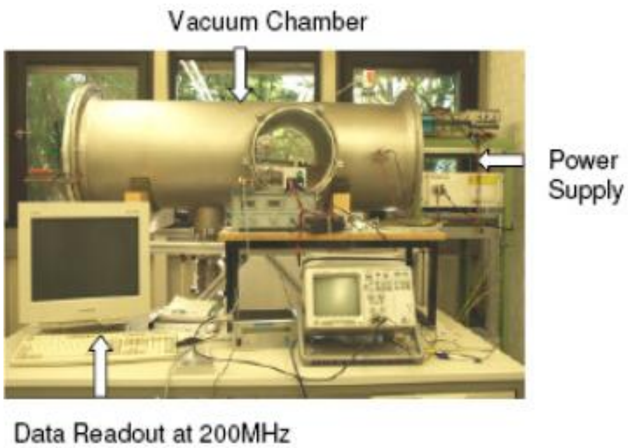


Figure 3. One of the I-MPD Test Facilities

2.2.2 To do for CNCLab

10.8.17: paid 600$

WP No.	**Working package content**	**Time span, costs**	**Development environment (HW, SW)**	**Due Date**	**Status**
1	IMU (Gyro+Acc.) 6DOF	1d, 50$			
2	OnBoardComputer	1d, 100$			
3	Star Camera	3d, 50$			

4	Electrical Propulsion Unit	3d			
5	Telemetry	1d			
6	Integration to IAP-SAT	2d			
7	Earth Station	2d			
8	Visualization of satellite movement in orbit based on scilab simulation data				

Working start: 18.8. **Due Date for total system: 1.9.17**

2.2.3 To do with internal ressources

WP No.	**Working package content**	**Time span, costs**	**Development environment (HW, SW)**	**Responsible**	**Status**
3	Development of a PPT propulsion unit for attitude control of IAP-SAT			Mariam Mourad	

2.2.4 PhD Tasks concerning the propulsion unit

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Association for Economical and Technological Cooperation in the Euro-Asian and North-African Region
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IAP
INSTITUTE FOR ASTROPHYSICS
Ras Nhache/Batroun
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Bismillah

IAP Laboratory at Ras Nhache/Batroun, Lebanon

IAP-SAT is the first Lebanese meteorological satellite. It will be used to take meteorological data to estimate the state of weather in Lebanon.

In 2015 there was established a hardware-in-loop test rig for IAP-SAT where the space environment was simulated. One of the next steps shall be the development of an electrical propulsion unit based on pulsed plasma thruster (PPT) technology. In two PhD theses there shall be investigated the PPT thruster and its interaction with Van Allen Belt magnetic field.

PhD Thesis:

CFD Simulation of interaction of IAP-SAT PPT with Van Allen magnetic field

Detailed description an working plan:

- Development of appropriate optimized CFD algorithm package able to undergo a fast simulation of PPT similar magnetic field environments
- Taking Simulation Data for interaction of IAP-SAT PPT with Van Allen Belt magnetic field.

Keywords: Electrical Space Propulsion Units, pulsed plasma thruster (PPT) technology, computational fluid dynamics.

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Bismillah

IAP Laboratory at Ras Nhache/Batroun, Lebanon

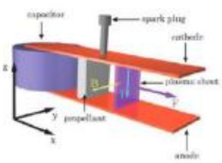


Figure 3.4: Working Principle of SIMP-LEX[60, 48]

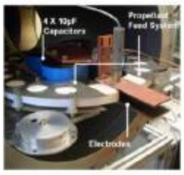


Figure 3.5: Test of SIMP-LEX propellant feed system[60, 48]

From [Nawaz et. al. 2005]:

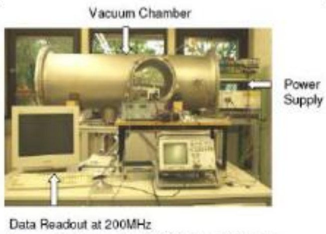


Figure 3. One of the I-MPD Test Facilities

similar project environment at IRS, Stuttgart (

IAP-SAT is the first Lebanese meteorological satellite. It shall be used to take meteorological data to estimate the state of weather in Lebanon. In 2015 there was established a hardware-in-loop test rig for IAP-SAT where the space environment was simulated. One of the next steps shall be the development of an electrical propulsion unit based on pulsed plasma thruster (PPT) technology. In two PhD theses there shall be investigated the PPT thruster and its interaction with Van Allen Belt magnetic field.

PhD Thesis: Measurement of interaction of IAP-SAT PPT with a laboratory Van Allen belt environment

Detailed description an working plan:

- Development of IAP-PPT unit
- Development of measurement environment
- Taking measurement data

Keywords: Electrical Space Propulsion Units, pulsed plasma thruster (PPT) technology, Van Allen Belt magnetic field

Contact: Samir Mourad, Email: samir.mourad@aecenar.com, Mobile: +961 76341526

2.3 Estimated Costs of IAP-SAT (satellite development and the launching)

Satellite Development Cost and Launch Cost

Working Package	Material Cost	Man Month	Qualification	Salary/MM	Personnel Cost per item	Total item cost
Camera	$40,000	6	Eng	$5,000	$30,000	$70,000
Chemical Propulsion System	$50,000	10	Eng	$5,000	$50,000	$100,000
Gyroscopes	$20,000	10	Eng	$5,000	$50,000	$70,000
Accelerometers	$20,000	10	Eng	$5,000	$50,000	$70,000
Tank for fuel	$10,000	5	Eng	$5,000	$25,000	$35,000
Tank for oxygen	$10,000	5	Eng	$5,000	$25,000	$35,000
Solar panels incuding battery system	$15,000	10	Eng	$5,000	$50,000	$65,000
Communication's board	$5,000	10	Eng	$5,000	$50,000	$55,000
Board Control Computer	$10,000	10	Eng	$5,000	$50,000	$60,000
Antenna system	$10,000	10	Eng	$5,000	$50,000	$60,000
Integration	$10,000	5	Eng	$5,000	$25,000	$35,000
Test	$10,000	15	Eng	$5,000	$75,000	$85,000
Launch	$1,600,000			$5,000	$0	$1,600,000
Ground Station	$100,000			$5,000	$0	$100,000
				Total Cost		**$2,440,000**

Operational Cost per year

Working Package	Material Cost	Man Month	Qualification	Salary/MM	Personnel Cost per item	Total item cost
Maintenance	$40,000	12	Eng	$5,000	$60,000	$100,000
Ground Station	$20,000	36		$3,000	$108,000	$128,000
				Total Cost		**$228,000**

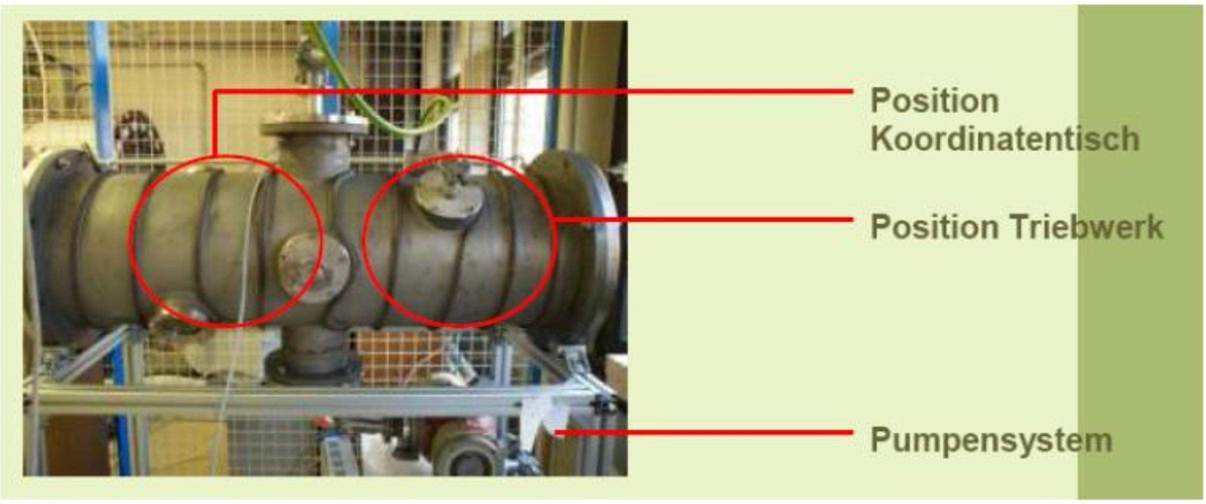
Table1: Costs of development and launching of IAP

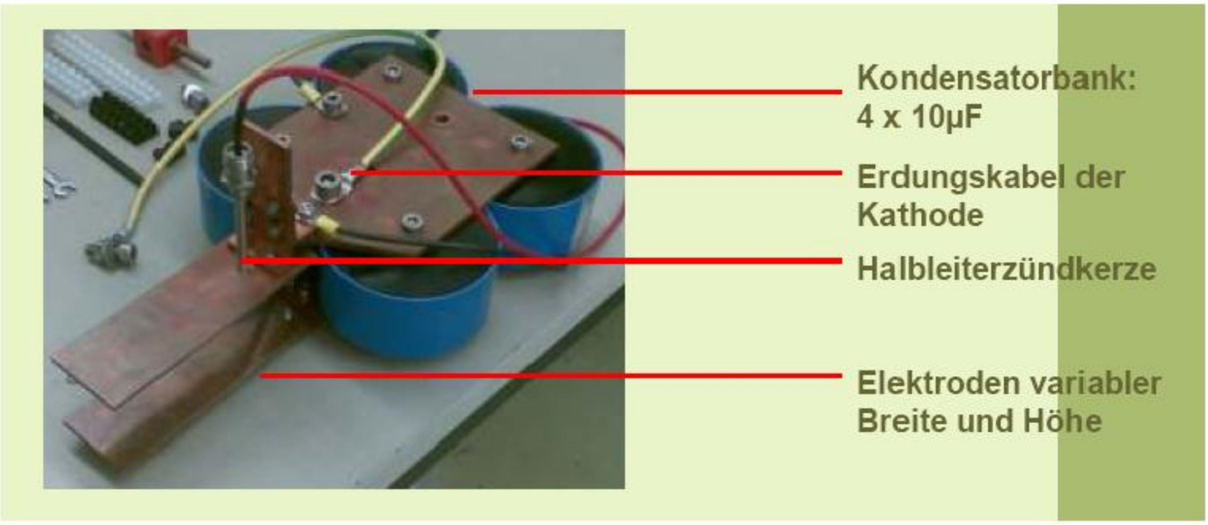
With the consideration of the maintenance and operational cost, the total cost of IAP-SAT is around 2,668,000$. The satellite's expected life time is at least 5 years.

3 Basics

3.1 Test Environment for Electrical Propulsion

From [Böhrk et. al. 2007]:





3.2 Low Orbit Satellites at very low altitude

https://www.quora.com/Which-satellite-occupies-the-lowest-earth-orbit-and-at-what-altitude?redirected_qid=1431376:

The lowest that I know of was KH7-16, with a perigee of 92 km and an apogee of 155 km, for a semi-major axis of 123 km.

https://www.n2yo.com/satellite/?s=41475:

CADRE (41475U), CADRE is classified as Amateur radio

NORAD ID: 41475
Int'l Code: 1998-067HV
Perigee: 270.7 km
Apogee: 279.2 km

Inclination: 51.6 °
Period: 89.9 minutes
Semi major axis: 6645 km
RCS: Unknown
Launch date: November 20, 1998
Source: United States (US)
Launch site: TYURATAM MISSILE AND SPACE COMPLEX (TTMTR)
Uplink (MHz):
Downlink (MHz): 437.485/3404.000
Beacon (MHz):
Mode: 9600bps GMSK 1Mbit OQPSK

3.3 Mission Simulation for satellite operation

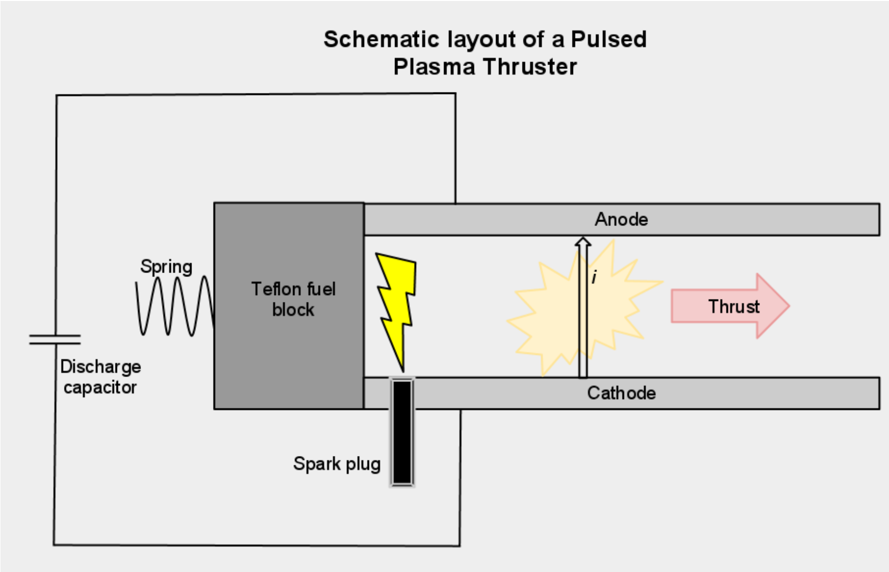
see scilab celestlab

4 Concept for the Propulsion Unit[1]

4.1.1 Primitively modeling the chosen Pulsed Plasma Thruster (PPT)

Amongst all the inspected Propulsion systems, PPT was chosen and it had to be designed on FreeCad.

PPT's working mechanism was carefully studied and its different components were identified. The primitive 2D sketch that our design depends on is below.



The components necessary for the PPT are:

- Parallel anode/cathode plates
- Spark igniter
- Teflon circular block
- Spring system
- High voltage capacitor

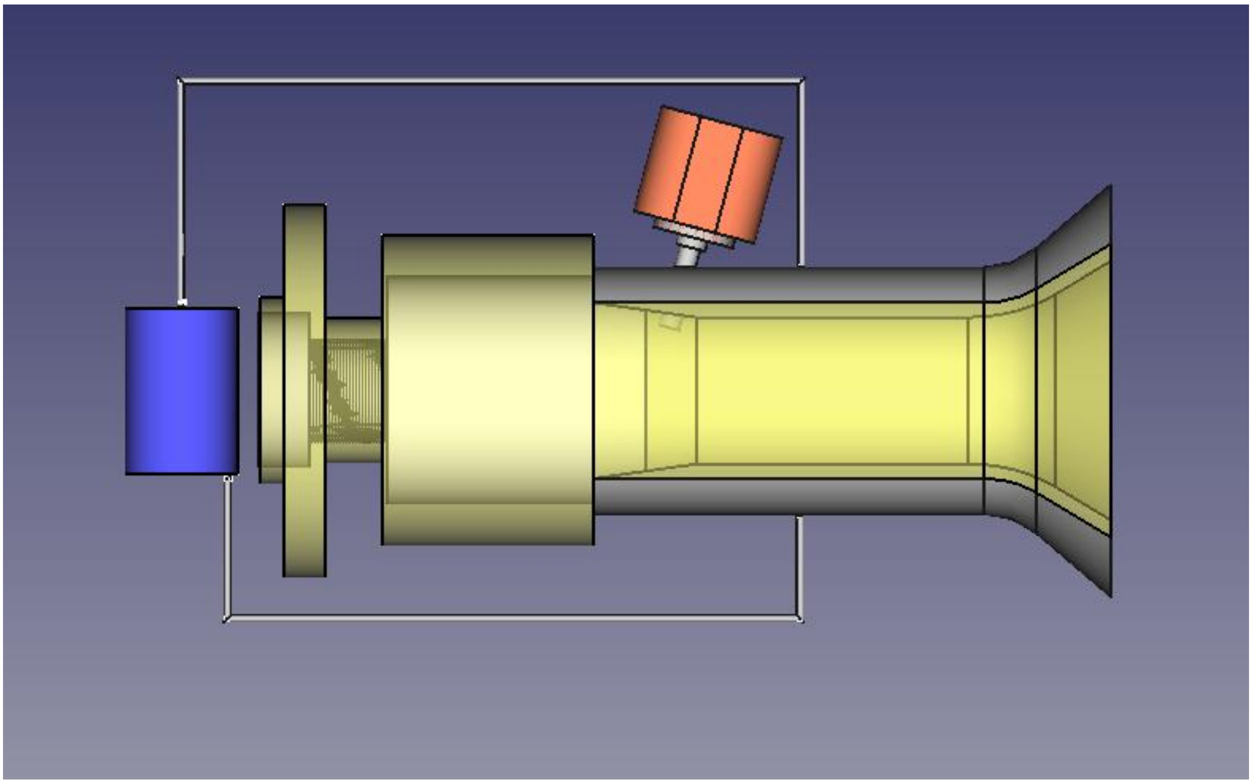
Mechanism: The first step of PPT mechanism is plasma formation. An igniter directed to the solid fuel bar produces a spark that ablates and sublimates the surface of the propellant forming plasma. Since the plasma is positively charged, it completes the circuit between the 2 plates. The interaction between the formed electric and magnetic field produces a Lorentz force that acts on the plasma and accelerates it out of the exhaust at high speeds.

4.1.2 Modeling our PPT design in FreeCad

After identifying the different components of our PPT system and taking into consideration its working mechanism, the propulsion system was modelled on FreeCad.

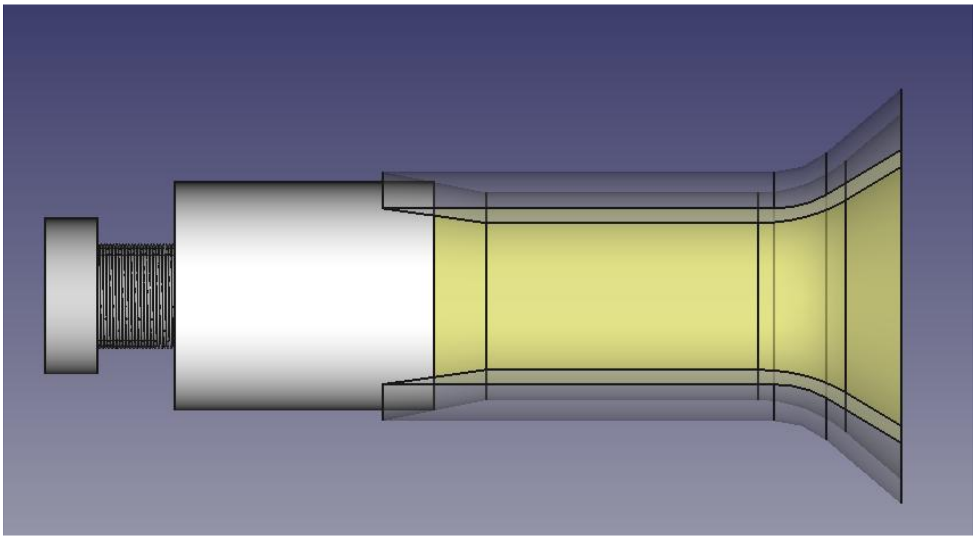
The following is the FreeCad model of the PPT:

[1] From Ibrahim Ghanim, Practical Work at AECENAR Ras Nhache, July/August 2015



4.1.2.1 Modelling “fuel continues supplying system”

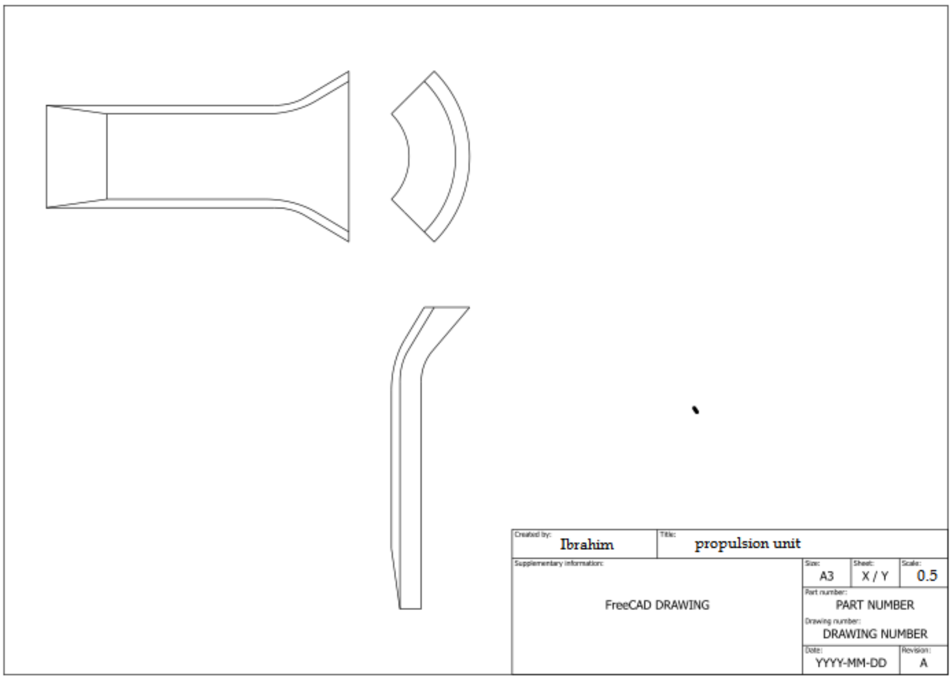
Most of propulsion systems use fluid fuel which its supply is easily provided by maintaining a pressure difference between the fuel reservoir and the ionization chamber. However pulsed plasma thrusters use solid fuel, that’s why its continuous fuel supply was insured by a spring system mounted on the fuel rod.



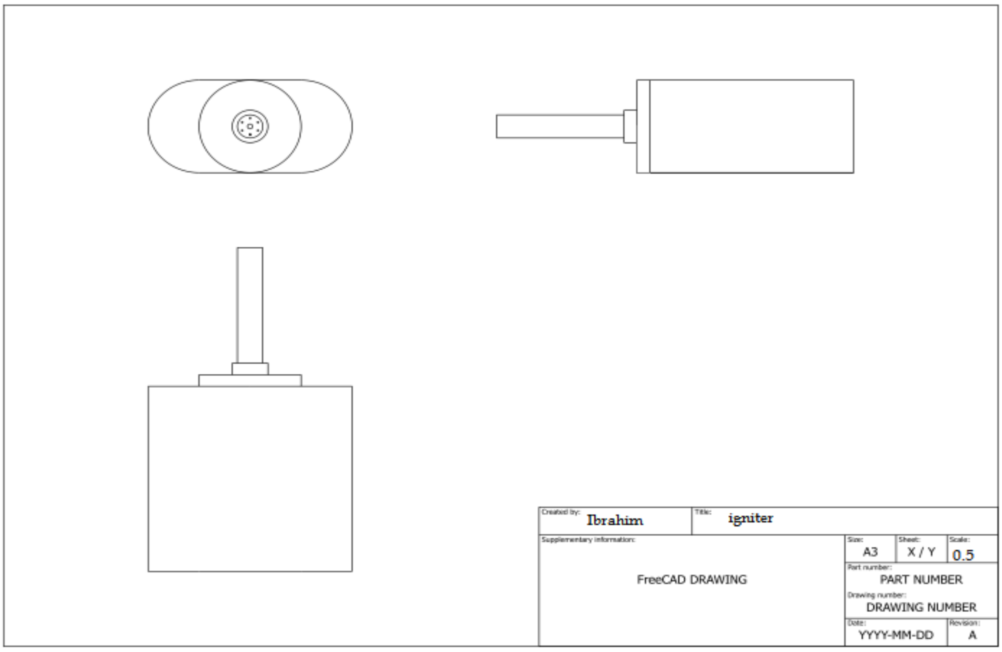
The propulsion unit is designed with a cone shaped ending such that its outer nozzle is slightly larger than the fuel rod and its inner nozzle is smaller than the fuel rode. A compressed spring is mounted to the end of the fuel rod such that the rod is always under pushing force. When the igniter produces a spark and the outer surface of the fuel rod gets ablated and sublimated, the spring system pushes the rod inward such that it returns to its previous position in the propulsion unit.

4.1.2.2 2D projections of important parts of the propulsion system

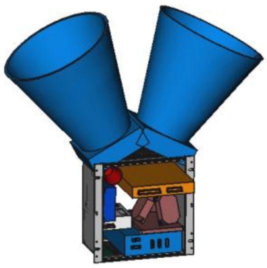
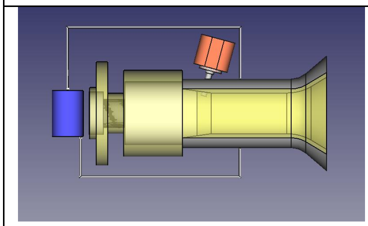
1) Propulsion unit



2) Igniter



4.2 FreeCAD files

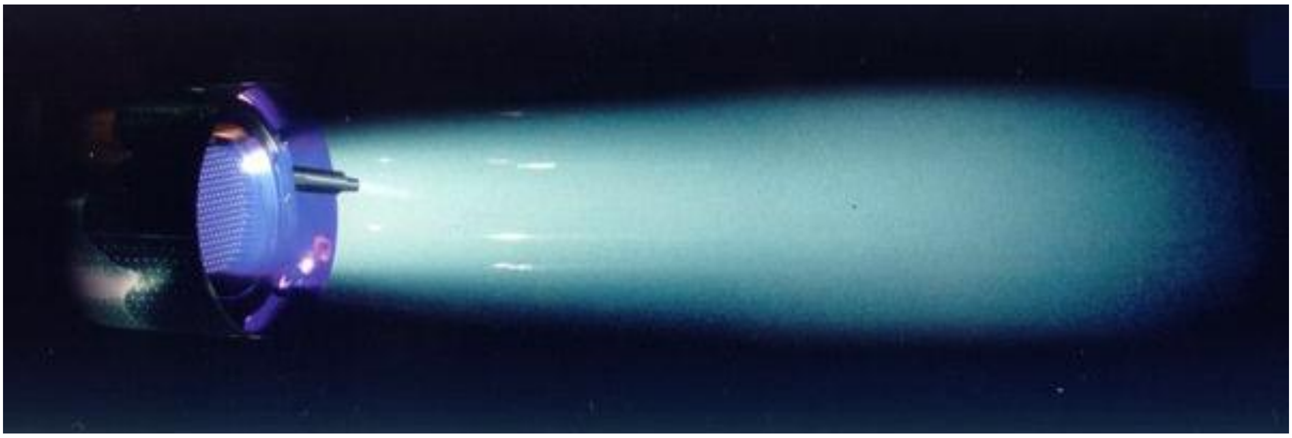
	170116IAP-SAT_Integration.FCStd
	propulsion chamber.FCStd

5 PPT Electrical Propulsion Unit

To be cpmpleted by Mariam Mourad

بسم الله الرحمن الرحيم

kapitel: Raumfahrtsysteme, Kap. 4, 6, 7



Änderung: Eigenfeldantrieb (PPT oder PTT) statt Ionenantrieb; da wir damit schon in einer früheren Studie begonnen haben.

5.1 Eigenfeldantrieb

Betriebszustand: stationär gepulst

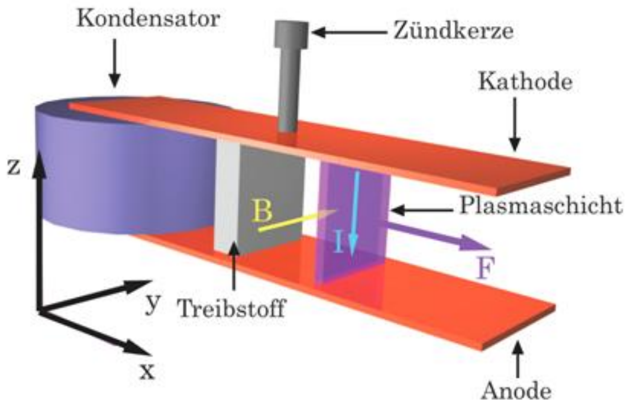
Treibstoffe: Gase,Teflon

Ionisationsgrad: 0.5-1

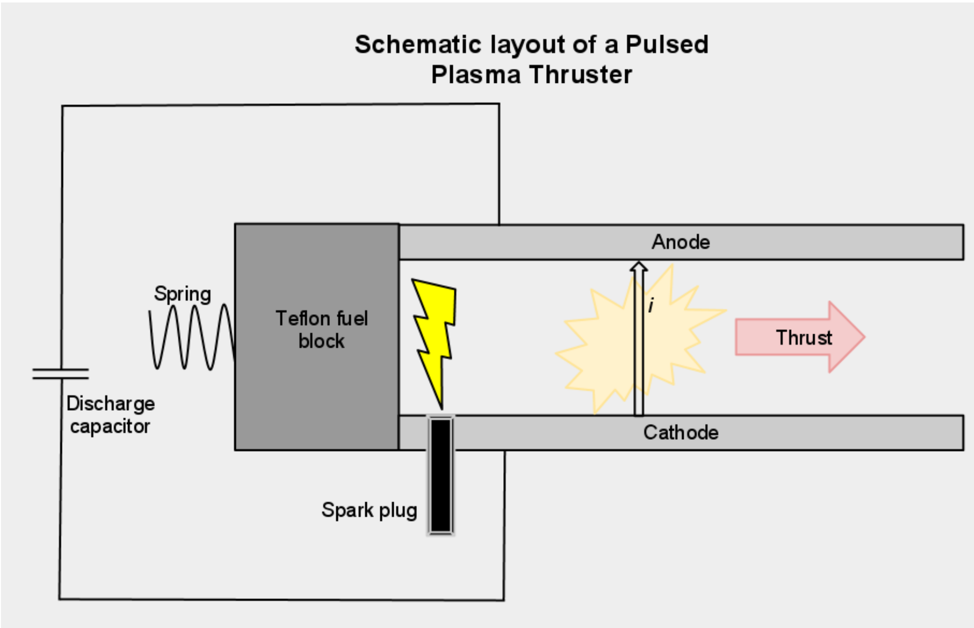
(T.6.1 aus Raumfahrtsysteme)

5.2 Gepulster Plasmatriebwerk

5.2.1 Prinzip:



Funktionsprinzip des gepulsten Plasmatriebwerks



$F = -(p_0 A_t c_{Fel} + \mu_0/(4\prod) I^2 (3/4 + \ln(r_a/r_k))) e_z$

F=IXB

A_t : Düsenhalsquerschnitt

μ_0 : magnetische Feldkonstante

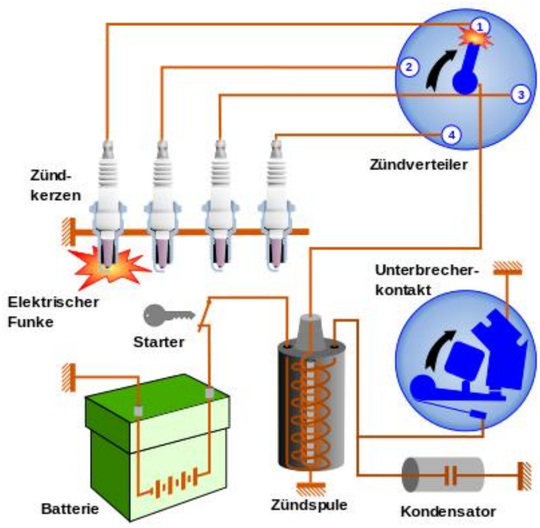
c_{Fel} : Schubkoeffizient

r_a : Anodenradius: groß

r_k : Kathodenradius:fest

Treibstoff: Teflon: fest.Spart Behälter und weitere Komplikationen wie z.B Temperaturerhaltung.

Zünder:



Die Solarplatten versorgen den Zünder-Schaltkreis mit Gleichstrom.

Der Unterbrecherkontakt sorgt für alternativen Strom. Der ist notwendig um mit der Zündspule, die die Rolle eines Transformators spielt, die Spannung zu erhöhen.

Der Zündkondensator hat meistens 0.22 µF.

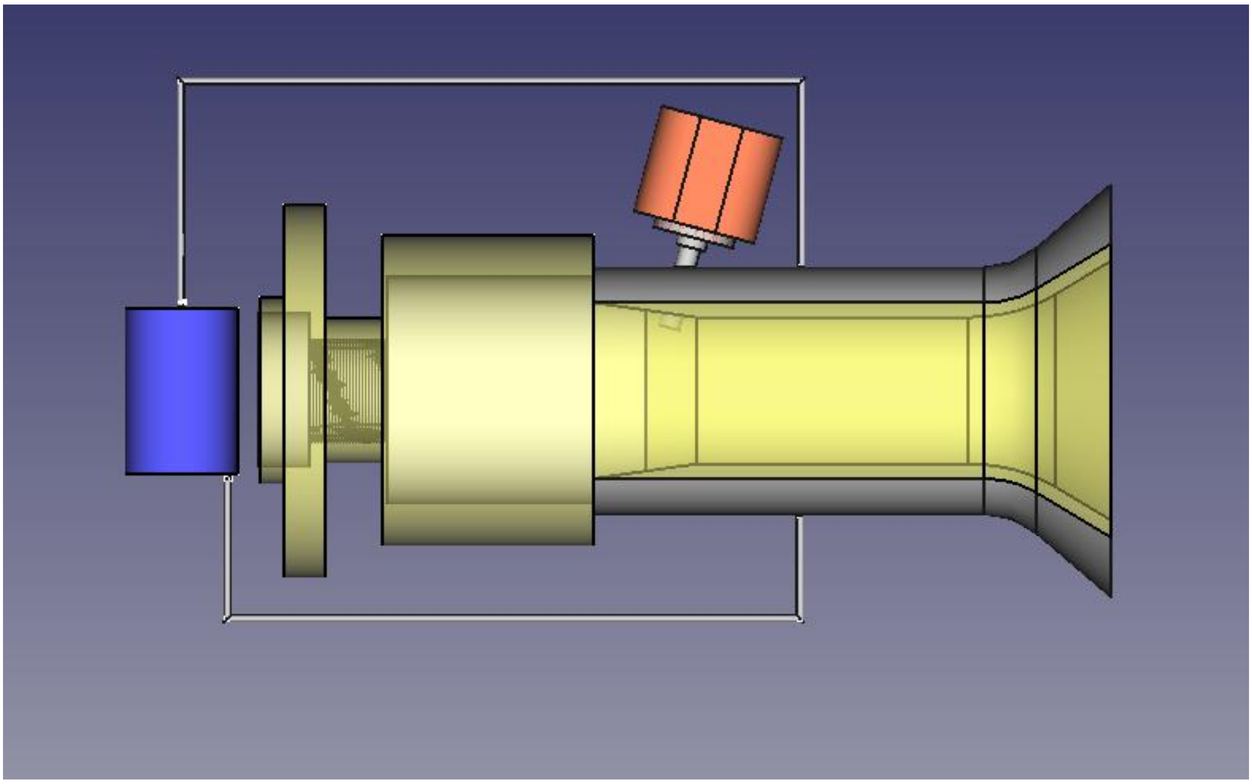
Kondensator:

bei Zündung auf 500 V aufladen

$V=Z_cI$

$Z_c=1/(jCW)$ => **$C=1/(jZ_cW)=1/(j(V/I)2\prod f)$**

$W=2\prod f$



circuit 1

4 thrusters

*En but de chercher la valeur du condensateur, on prends par hypothèse que:

Force F=860 µN

Vitesse v=13.7m/s

Puissance P= 70W

On a : $P=U.I^2$; $I= (P/U)^{1/2}=(70/500)^{1/2}= 0.374$ A

I=q.U ; q=I/U =0.374/500 =0.027 C

$F=q\,\mathbf{v\wedge B} = \mathbf{i\wedge B} = \mathbf{i.B}.\sin(i,B) = i.B$; $B=F/i=(860.10^{-6})/0.374 = 2.299.10^{-3}$ T

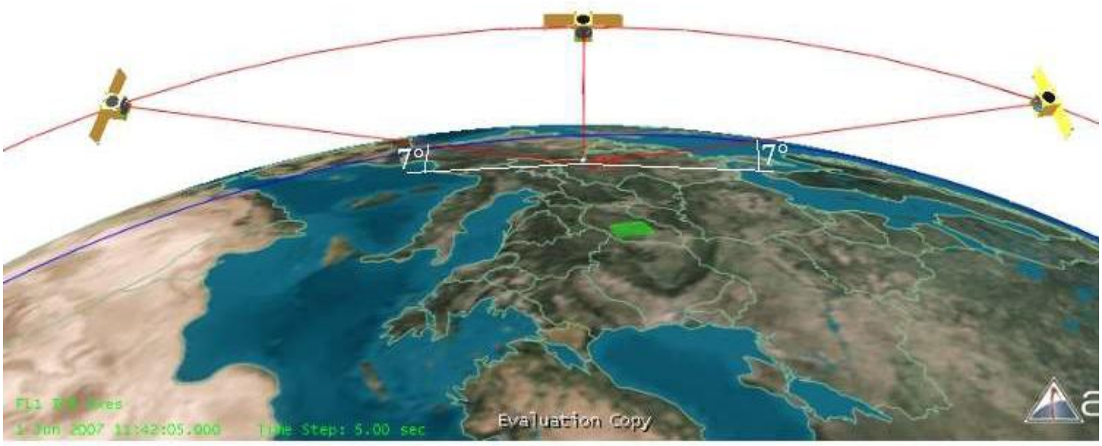
q=C.U ; C= q/U = 0.027/500 = 54 µF

6 Integration of IAP-SAT

To be done by CNCLab (Rami Nassouh)

7 Next working packages

- Tracked Downlink (fixed direction to receiver station)



Target pointing mode (from [Yasir 2010], p.22)

- Mission Simulation of Orbitting IAP-SAT with scilab

8 Suppliers Data

8.1 Electronics, Control

- CNCLab
- قطرنجي للإلكترونيات EKT Beirut
    - Number: 01 820020
    - Website: www.ekt2.com

    - Bashir electronics - البشير للإلكترونيات

8.2 Satellite Parts

Specification form © Surrey Satellite Technology Ltd., Tycho House, 20 Stephenson Road, Surrey Research Park, Guildford, Surrey, GU27YE, United Kingdom, Tel: +44(0)1483803803 | **Fax:**+44(0)1483803804 | **Email:** info@sstl.co.uk | **Web:**www.sstl.co.uk

Remark: No answer to email has come.

8.3 CNC Fine Mechanics (2D)

The company HI-TECH Facrication takes CAD Data (in .dxf format) -> Changing to CAM Data.

Satellite Parts are in Alluminium Alloy.

8.4 3D Printing (Plastics)

http://www.cnclablb.com/

8.5 CNC

Company	Phone number	Description	Address	E-mail web site
CNC LAB	06 412 895 03 476 916	Manufacture 3D design in plastic & open source hardware	Tripoli,Lebanon Bahsas,Behind Haykalieh Hospital, Harba Bld.	www.cnclab.com info@cnclablb.com
Hasan Al Baba	03 828 256	Manufacture and casting	Tripoli, Lebanon Mina, Industry and Commerce street	
HI-Tech fabrication Fawaz Abdel Hadi	06 442 787 70 751 522	Precision mechanical parts manufacturing brass & steel marking heads maker	Tripoli, Lebanon Mahjar suhi P.O. Box 1274	www.hitechfabrication.com info@hitechfabrication.com sirfawaz@yahoo.com
Hannuf mechanical 'Corporation for casting and art construction	06 387 723 03 717 107	Manufacture and casting	Tripoli, Lebanon Al Badawi	
GPS Steel	03 196 225	Uses electric discharge machining process to shape any metal material rapidly by using desired modeled electrodes	Beirut, Lebanon Burj Hammoud	Gps.steel.co@gmail.com
Riyako factory	79 118 779	3D CNC machine, manufacture cupboard for cars	Tripoli, Lebanon Badawi, behind Al Ridani bakery	

References

[1] Datasheets Surrey Satellite Technology Ltd., Tycho House, 20 Stephenson Road, Surrey Research Park, Guildford, Surrey, GU27YE, United Kingdom, Tel: +44(0)1483803803 | Fax:+44(0)1483803804 | Email: info@sstl.co.uk |

[2]

Single Mode Fiber Optic Sagnac Interferometer with Wireless Data Collection

Doug Marett

Skyhunt, Toronto, ON Canada

Fiber optic Gyroscope, IFOG, FOG, Sagnac Interferometer, wireless data acquisition

[Yassir 2010] Muhammad Yassir, *Development and Implementation of the attitude control algorithms for the e micro-satellite Flying Laptop*, PhD thesis, IRS, University of Stuttgart, 2010

[Kassar 2014] Suhaib Kassar, *Prototype for a base station for supernova remnant HI line radio wave detector and analyzer (SRWDA)*, Master Thesis, AECENAR, 2014