بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

www.aecenar.com/institutes/iap

IAP-SAT

4th Project Report (2016)

- Integration of a meteorological data collecting Satellite Prototype
- Fiber Optic Gyro sensor
- ~~بث الصور الى الارض~~

Initial document: Ras Nhache, 19 January 2016

Last update: 08.01.2017

Authors:

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Mohammad Hasbini

Content

Project Status at Beginning of actual project phase

- Presentation film

- HIL test rig

- Concept for propulsion unit, concept for battery

1 Goal 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

1 Satellite Bus

- 1.1 Satellite Prototype
  HIL Testrig
- 1.2 Ground Station
  with direction finder
  SDR tracking

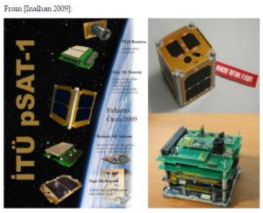
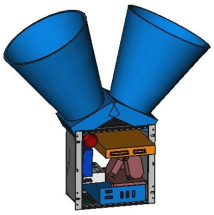
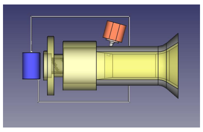
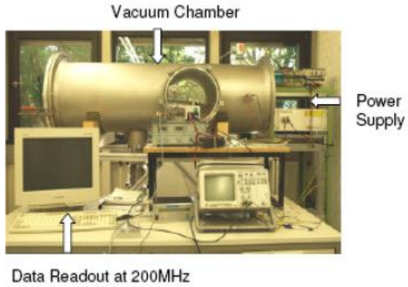
2 Payload: Earth surveillance camera

3 Mission Planning

- 3.1 Access to space (Planning: IAP, Operation: a contractor)
- 3.2 Operation of the satellite

2.2 Working Packages and Time Plan

2.2.1 Overview Planning & Budget IAP 2016

IAP	Completing IAP-SAT Prototype    Budget: 5000$	Building Experimental Rig for Electrical Satellite Propulsion Unit  **Figure 3. One of the I-MPD Test Facilities** Budget: 1500$

2.2.2 To do with internal ressources

WP No.	**Working package content**	**Time span, costs**	**Development environment (HW, SW)**	**Responsible**	**Status**
1	Implementation of control algorithm at On-Board-Computer and Closed-Loop-Integration of HIL				open
2	Visualization of satellite movement in orbit based on scilab simulation data				open
3	Specification, Design of star camera and algorithm			Practical Student Houssam Barbara	Partly finished

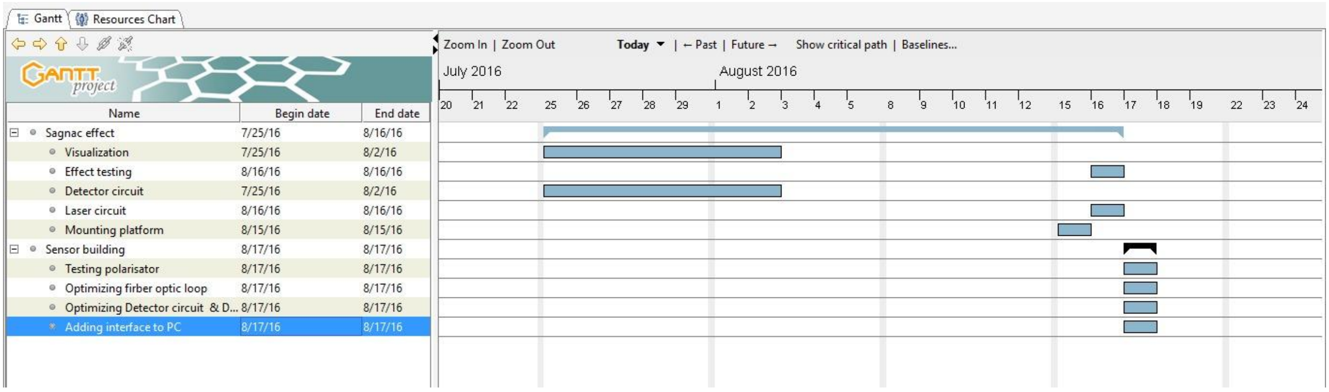
2.2.3 Master Thesis Tasks to complete the IAP-SAT prototype

From http://aecenar.com/job-opportunities

Title	**Keywords**	**Preferred Faculty/ Student Profile**	**AECENAR Project**
Development of a star tracking camera for a meteorological satellite		Electronics	IAP-SAT
Integration of GPS and star tracking		Electronics	IAP-SAT

to multisensor attitude control system for a meteorological satellite			
Development of a PPT propulsion unit for attitude control for a meteorological satellite		Electronics / Mechanical Engineering	IAP-SAT
Study (including vibration) and Planning of bringing a meteorological satellite into orbit		Mechanical Engineering	IAP-SAT
Development of a electrical propulsion unit (Pulsed Plasma Thruster (PPT)) for attitude control of a small meteorological satellite		Electronics / Mechanical Engineering	IAP-SAT

2.2.4 Time Plan FOG Development



2.2.5 PhD Tasks concerning the propulsion unit

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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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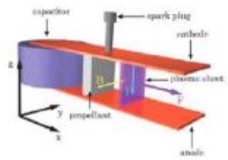

Figure 3.4: Working Principle of SIMP-LEX[60, 48]

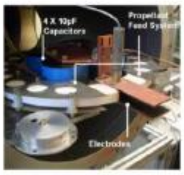

Figure 3.5: Test of SIMP-LEX propellant feed system[60, 48]

From [Nawaz et. al. 2005]:

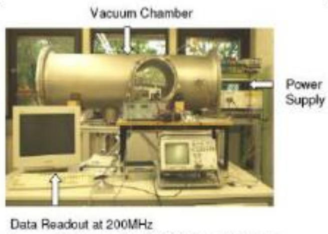

Figure 3. One of the I-MPD Test Facilities

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

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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 Gyroscope

3.1.1 Fiber Optic Gyro

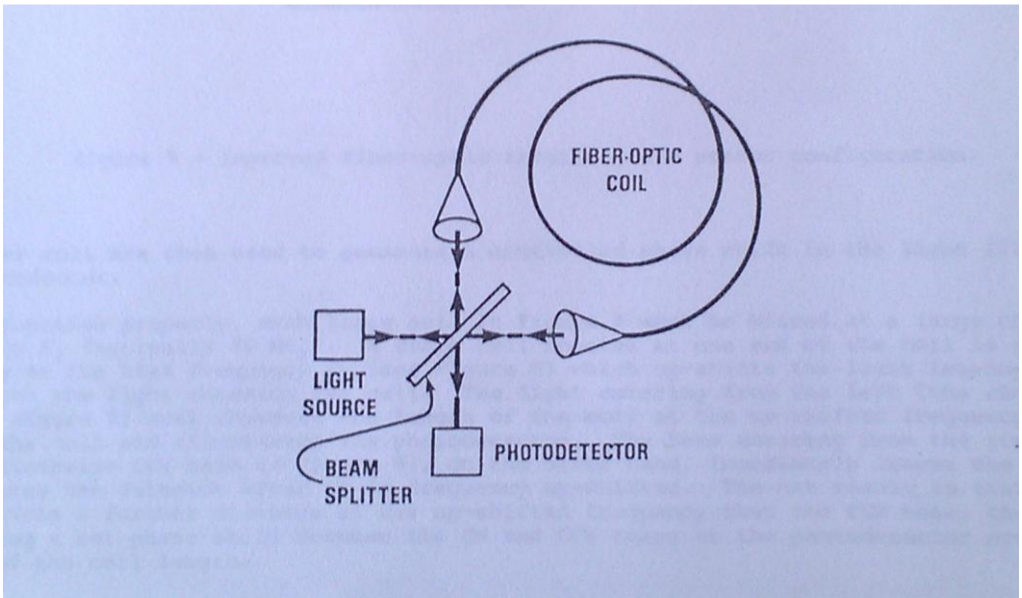


Figure 8 - Basic fiber-optic rotation rate sensor concept

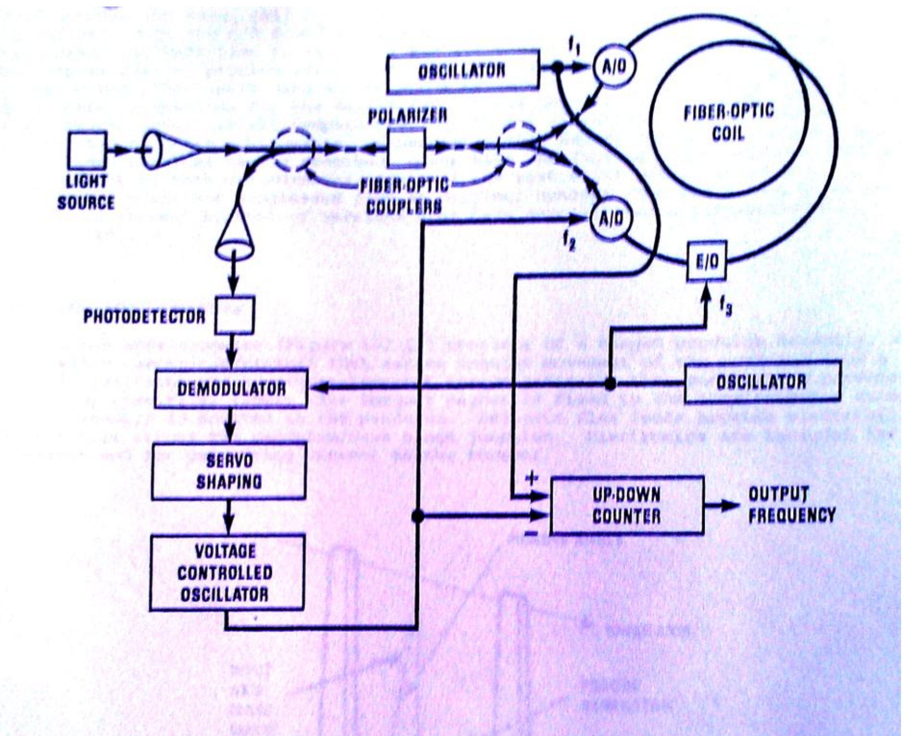


Figure 9 - Improved fiber-optic rotation rate sensor configuration.

From

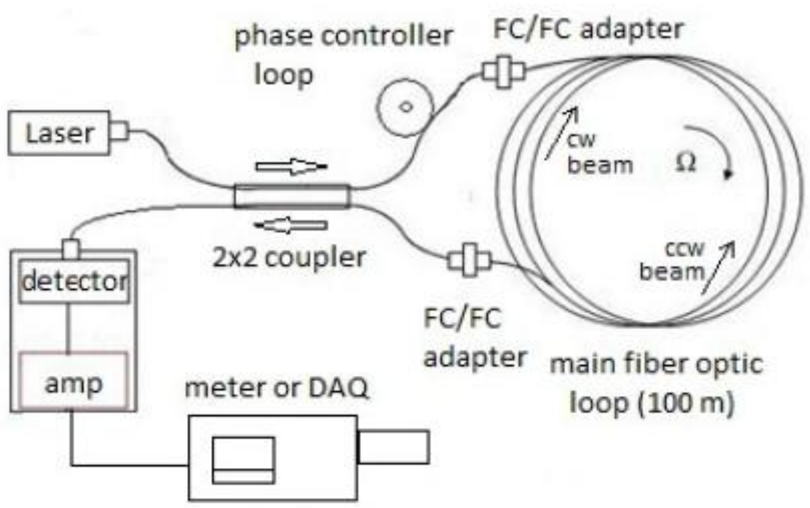
Single Mode Fiber Optic Sagnac Interferometer with Wireless Data Collection

Doug Marett

Skyhunt, Toronto, ON Canada

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

Figure 1: Fiber optic Sagnac interferometer block diagram (all components co-rotate on a platform)



II. MATERIALS

The essential parts for this project were as follows:

FP-MQW 1.3 um laser with FC/PC connector

2 x 2 coupler (single mode) with FC/PC connectors

Phase controller loop and mount

100 m or 1000 m single mode fiber optic loop

PIN diode IR detector with amplifier

Output voltmeter or wireless DAQ

Figure 2: Parts for the Sagnac interferometer

Figure 3: Phase Controller Detail

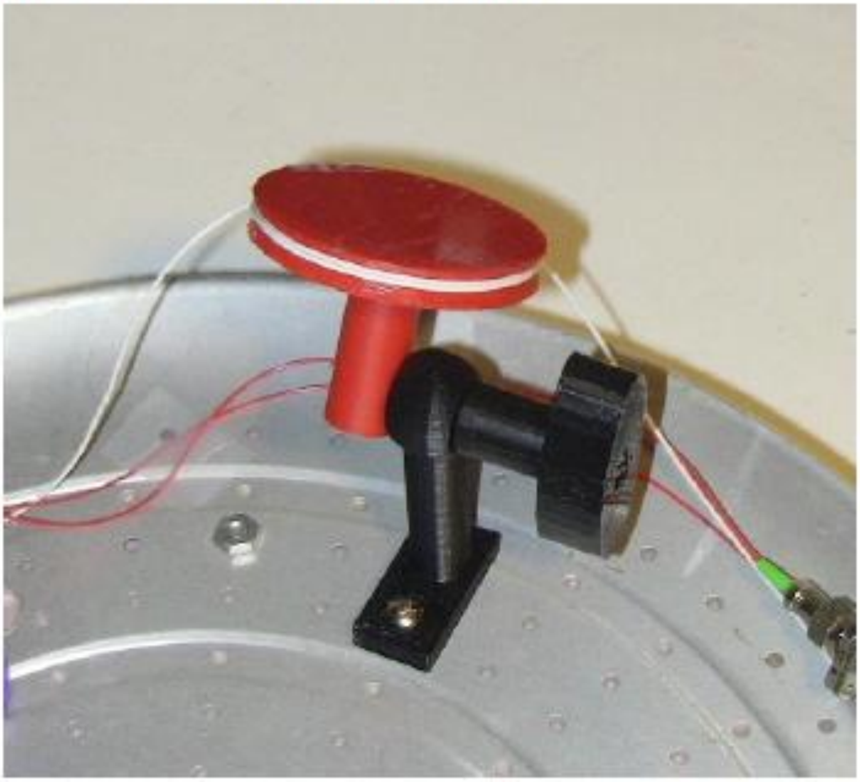


Figure 4: Assembled Sagnac interferometer

Figure 5: Interferometer output volts verses RPM collected using a wireless DAQ (100 m loop)

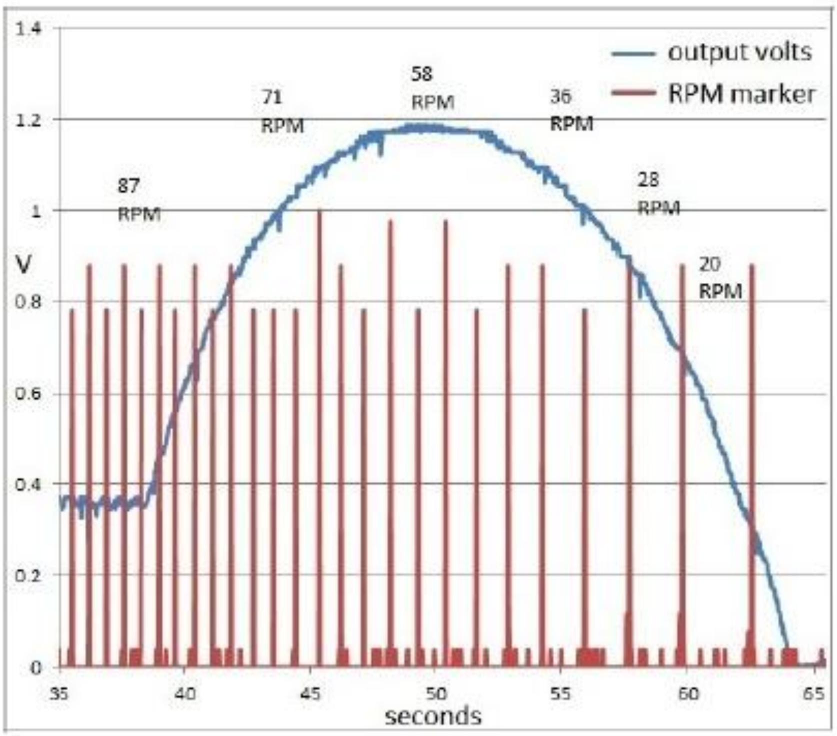
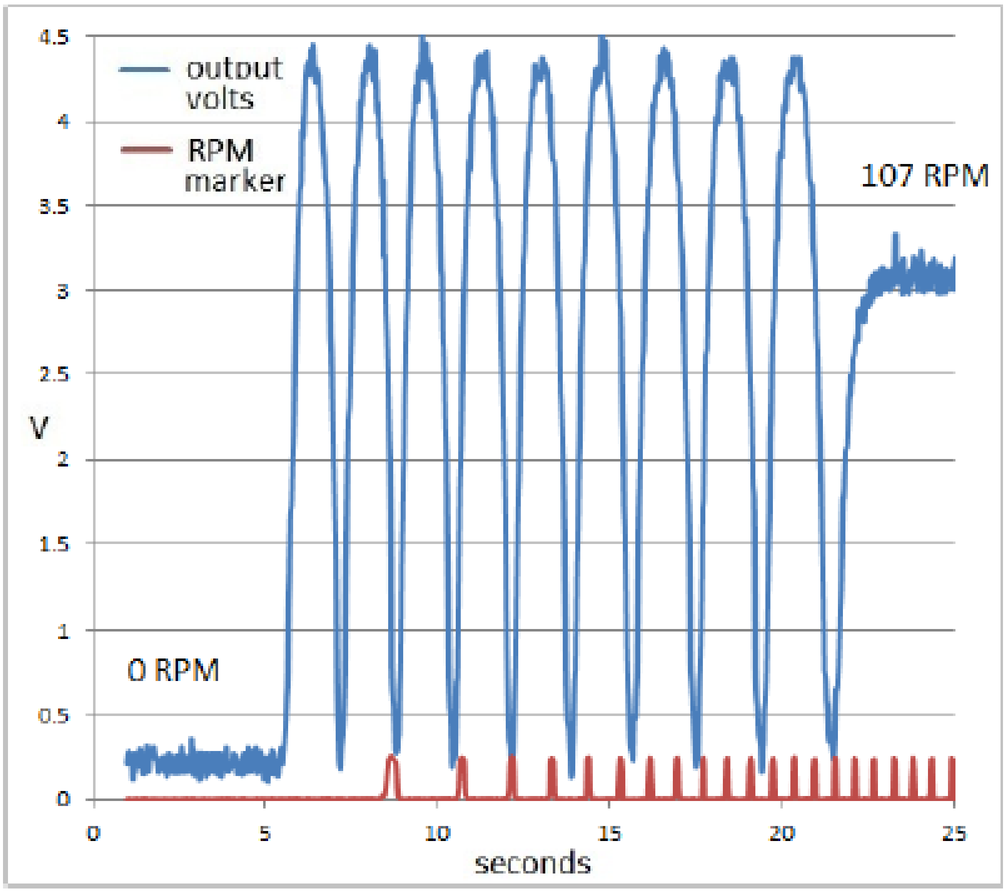


Figure 6: Interferometer output volts verses RPM collected using a wireless DAQ (1000 m loop)



Satellite Propulsion دفع القمر الاصطناعي 3.2

Unified Propulsion System

CHEMICAL ORBITAL PROPULSION MODULE

Chemical Orbital Propulsion Module for transfer orbit, attitude maneuver during transfer orbit, station keeping and deorbiting.

Commercial telecommunication satellites and institutional missions that rely on bigger platforms fly with Airbus Defence and Space bipropellant subsystems and components. Our customers worldwide rely on an impressive heritage and success rate. Airbus Defence and Space orbital propulsion modules are used for transfer orbit, attitude maneuver during transfer orbit, station keeping and deorbiting.

Main Subsystems and Components:

Propulsion System

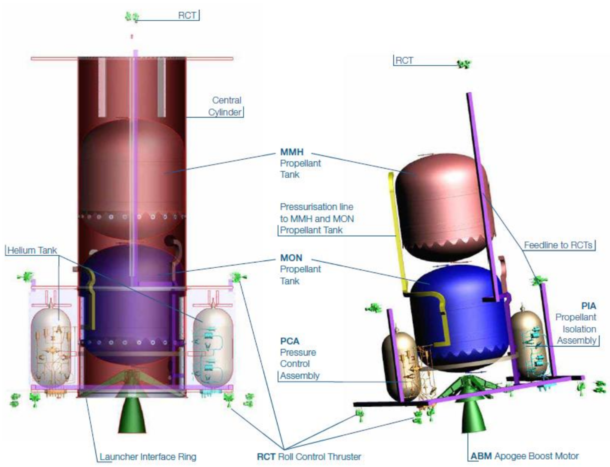
- Fuel Tank (700L – 1450L)
- Oxidizer Tank (700L – 1450L)
- 10N Thrusters – RCT
- 400N Apogee Boost Motor
- Pressure Control Assembly – PCA
- Propellant Isolation Assembly – PIA
- Helium Tank (51L – 90L)
- Pyrovalves
- Fill and Drain Valves
- Pressure Regulator
- Pressure Transducer

Central Cylinder with Launcher Interface Ring

Propulsion Thermal Control

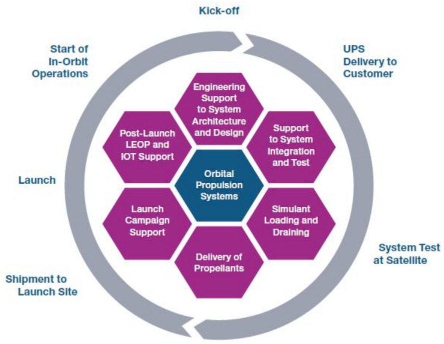
Key Features

- Reduced interface management
- Modular design
- Advantageous symmetry
- Fully integrated subassembly
- Multiple space proven equipment
- Provision of complete services around propulsion

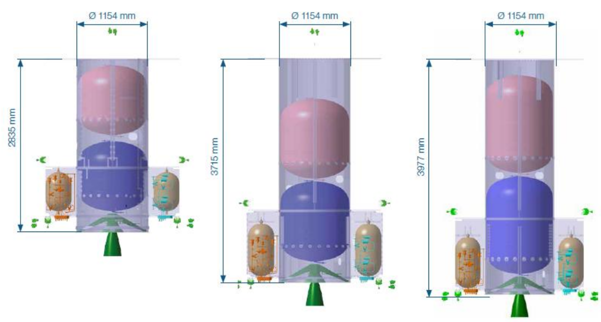


Unified Propulsion System

Airbus Defence and Space provides the complete range of services around the Unified Propulsion System (UPS), from engineering support for system architecture and design up to propellant loading and Launch Early Operations Phase (LEOP)



Bi-propellant UPS B2	Bi-propellant UPS B3	Bi-propellant UPS C3
Propellant Loading Mass: 1895 kg	Propellant Loading Mass: 2441 kg	Propellant Loading Mass: 3194 kg

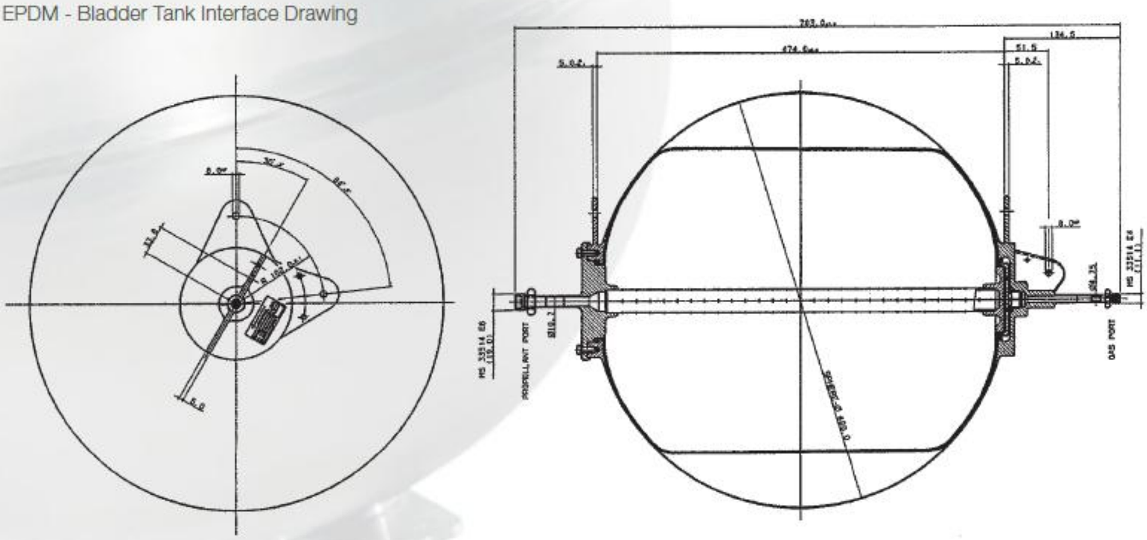


3.2.1 Space Propulsion Tanks

EPDM - BLADDER TANK BT 01/0

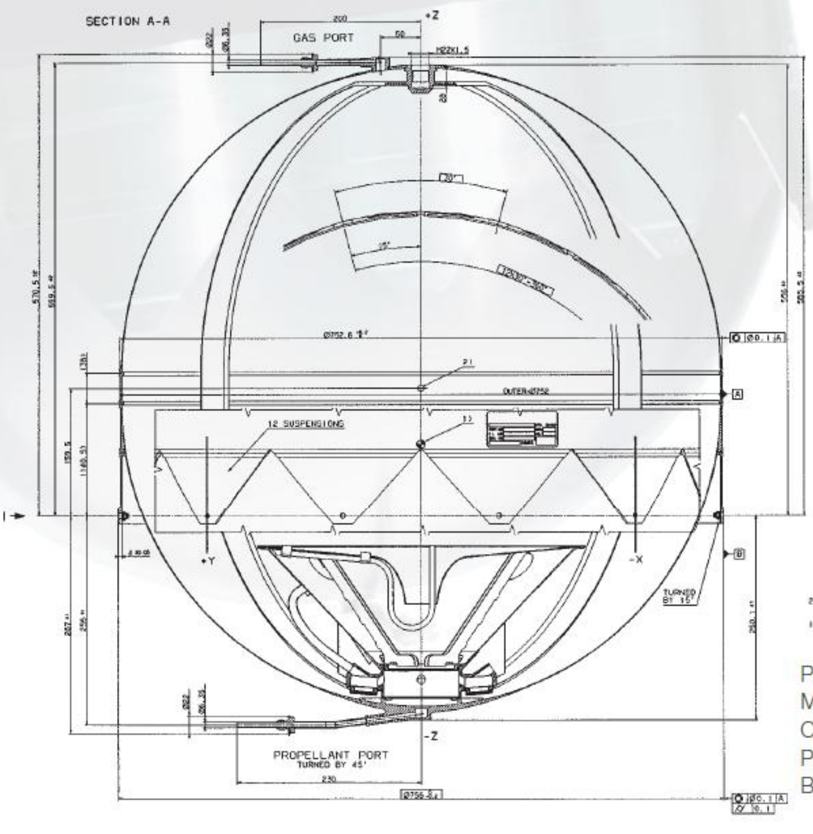
EPDM - Bladder Tank BT 01/0	
Tank Net Volume	58 Litres
Max. Propellant Volume	39 Litres
Propellant	Hydrazine (N_2H_4)
Pressurant Gas	Helium (He) or Nitrogen (N_2)
Maximum Expected Operating Pressure (MEOP)	26 bar
Proof Pressure (1.5 x MEOP)	39 bar
Burst Pressure (2.0 x MEOP)	52 bar
Interface Fixation	5 Fixation Holes ø 8H7
Materials	
- Pressure Vessel	Ti6Al4V Hemispheres 3.7164.1 (SPF)
- Gas & Propellant Ports	Ti6Al4V (3.7164.1)
- Bladder	Ethylene-Propylene-Diene Monomer (EPDM)
Tank Mass	< 8.5 kg (exclusive Support Structure)
Project Application	Ariane 5 SCA, ARD

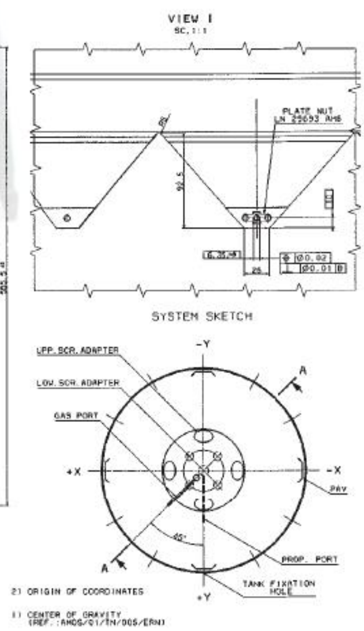
EPDM - Bladder Tank Interface Drawing



SURFACE TENSION PROPELLANT TANK OST 21/0

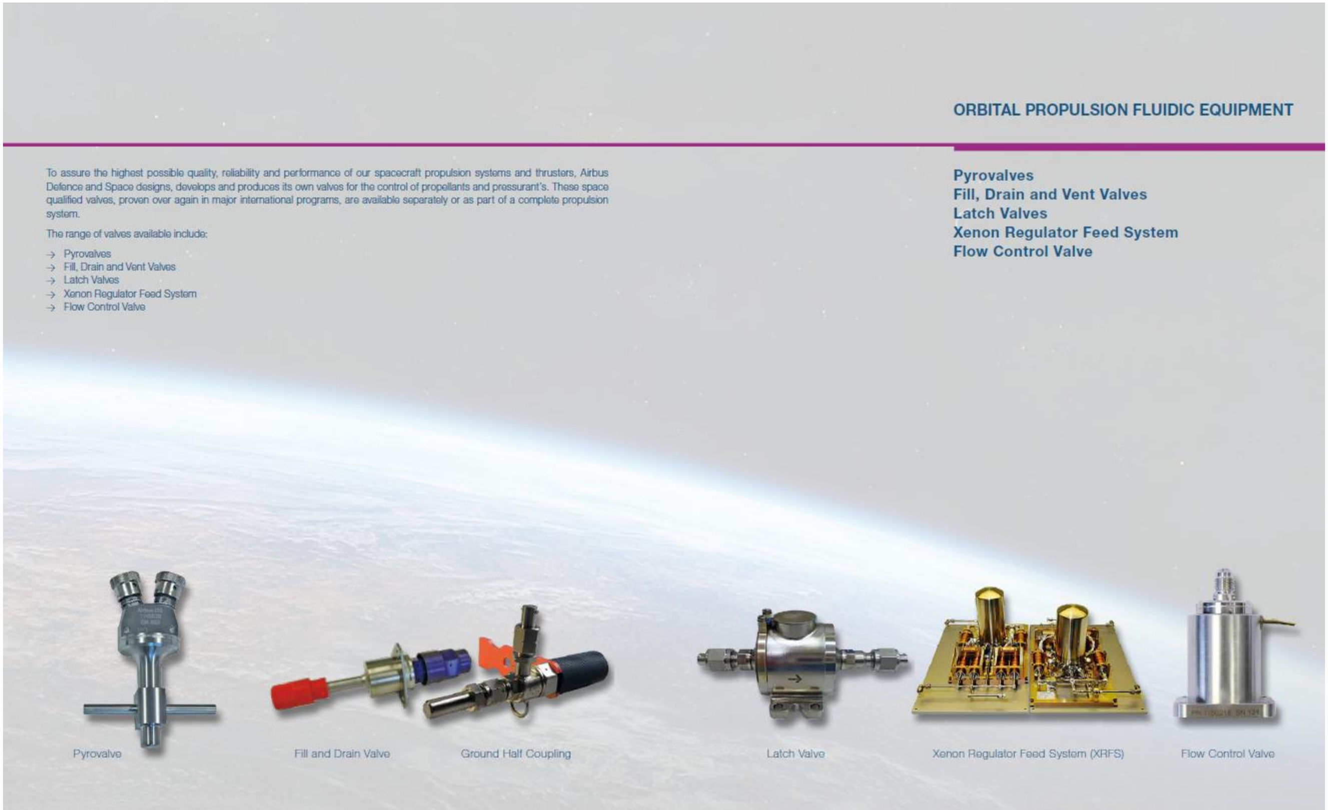
Surface Tension Propellant Tank OST 21/0	
Tank Net Volume	235 Litres
Propellants	MON respectively MMH
Geometrical Shape	Spherical with a cylindrical intersection
Interface Fixation	12 Suspension Tabs with floating nuts M6 x 1 (e.g.)
Materials	
- Pressure Vessel	Ti6Al4V STA (3.7164.7)
- Suspension/Ports	Ti6Al4V (3.7164.1)
- PMD	Ti99.4 (3.7034.1) and Ti6Al4V (3.7164.1)
- Screens	304L (1.4306); qualified also for Ti99.4 (3.7025.1)
Tank Mass	16 kg
Project Involvement	Amos





Pressurant Gas: Helium (He) or Nitrogene (N_2)
Maximum Expected
Operating Pressure (MEOP): 22.0 bar
Proof Pressure (1.5 x MEOP): 33.0 bar
Burst Pressure (2.0 x MEOP): 44.0 bar

3.2.2 Space Propulsion Valves



PYROTECHNICAL VALVES

Pyrovalves are widely used on spacecrafts and launchers where reliable one shot devices are needed for permanent opening or closing of a fluid circuit. Due to its excellent leak tightness capability prior to and after firing in combination with its low mass and low complexity, the pyrovalve presents state of the art propulsion system equipment suitable to fulfil the various mission needs.

Airbus Defence and Space offers a family of Normally Closed (NC) and Normally Open (NO) Pyrotechnical Valves with various different interfaces in order to fulfil the specific customer needs. The available product portfolio covers screwed as well as weldable interfaces (1/4" and 3/8"). All valve types are provided with redundant ESA standard initiators (squibs) which provides the energy needed for actuation.

The main function of the Pyrotechnical Valve is to definitely shut down or open a fluid circuit. Furthermore, as part of the propulsion subsystem they must ensure a minimal pressure drop as well as perfect external and internal leaktigthness prior to and after actuation. The latter is achieved by an all welded design in combination with a flexible titanium membrane, which pysically separates the combustion chamber from the hydraulic flow section. This membrane ensures a perfect pressure tightness between the pyrotechnic chambers and the fluid circuits before, during and after the actuation.

The Pyrotechnical Valve provides a highly reliable, fast acting, zero liquid leakage compact design at low equipment mass. Only a small pulse of electrical power is required for valve actuation.

Pyrovalve Key Technical Characteristics	
Initiators	Redundant ESA Standard Initiators
Design	All-welded Titanium design
Fluid Compability	Helium, Argon, Xenon, Nitrogen, MON, MMH, Hydrazine, Deionized Water, IPA
Response Time (Mechanical)	< 7ms
Mass	< 0.160 kg (depending on type)
Qualified Operating Temperature	-90°C ≤ T ≤ 100°C
Qualified Operating Pressure (MEOP)	310 bar
Proof Pressure	1.5 x MEOP (465 bar)
Burst Pressure (NO and NC)	
Pre firing	> 4x MEOP (rupture pressure: > 1240 bar)
Post firing	> 2.5x MEOP (rupture pressure: > 775 bar)
Leakage	
Normally Open	Internal leak after firing: < 1x10^{-6} scc/s (GHe) External leak before/after firing: < 1x10^{-6} scc/s (GHe)
Normally Closed	Internal leak before firing: < 1x10^{-6} scc/s (GHe) External leak before/after firing: < 1x10^{-6} scc/s (GHe)

Pyrovalve Heritage and Future Missions

The heritage of Airbus Defence and Space regarding Pyrotechnical Valves goes back to 1984, when the 1st generation has been developed by Aerospatial Les Mureaux with support from ESA. Following successful qualification in 1987, the first generation of Pyrovalves was produced until the year 2000. In 1999 a harmonisation and improvement of the first Pyrovalve generation was introduced and successfully qualified in 2001. Following 2 years of production all Pyrovalve activities were transferred from Airbus DS Les Mureaux to Airbus DS Lampoldshausen in 2004. The transfer was finished in 2006 with a successfully performed First Article validation program.

As of today, Airbus DS has delivered more than 600 NC and more than 600 NO Pyrotechnical valves to leading satellite manufactures. More 500 FM units were already sucessfully actuated on various spacecrafts without any failure. The production stability is continuously monitored and verified throughout specific Destructive Lot Acceptance Test (DLAT) campaigns. Meanwhile more than 200 units were successfully actuated during extensive DLAT testing including vibration and shock testing, low and high temperature firings as well as under- and overcharge testing. This demonstrates the excellent reliability of the Pyrotechnical Valves manufactured by Airbus DS.

Spacecraft	Launch Year	Spacecraft	Launch Year	Spacecraft	Launch Year
Ariane-5	since 1996	Arabsat 5A	2010	Eutelsat W5A	2012
Arabsat 4B	2006	Arabsat 5B	2010	Eutelsat W6A	2012
Anik F3	2007	COM-5	2010	METOP-B	2012
Skynet 5B	2007	Alsat 2B	2010	Skynet 5D	2012
Arabsat 4 AR	2008	Eutelsat W3B	2010	VEGA	2012
Astra 1M	2008	KA-SAT	2010	Yamal 402	2012
ATV FM1	2008	ATV FM 2	2011	ATV FM 4	2013
HotBird 9	2008	Ekspress AM4	2011	Alphasat	2013
Nimiq-4	2008	Arabsat 5C	2011	AMOS 4	2013
Skynet 5C	2008	SSOT (Myriade)	2011	Astra 2E	2013
Amazonas-2	2009	YAHSAT 1A	2011	GAIA	2013
Eutelsat W7	2009	YAHSAT 1B	2011	SES-6	2013
HotBird 10	2009	Astra 1N	2011	ARSAT 1	2014
MILSAT-A	2009	Elisa FM1	2011	Astra 2G	2014
Palapa D	2009	Elisa FM2	2011	Astra 5B	2014
Spirale 1	2009	Elisa FM3	2011	ATV FM5	2014
Spirale 2	2009	Elisa FM4	2011	Arabsat 6B	2015
Thor-6	2009	Atlantic Bird	2011	LISA-Pathfinder	2015
Alsat 2A	2010	Eutelsat W3C	2011	BepiColombo	2016
Nilesat 201	2010	Apstar 7A	2012	ExoMars	2016
RASCOM-2	2010	Astra 2F	2012	METOP-C	2017
MILSAT-B	2010	ATV FM 3	2012		

FILL AND DRAIN VALVE

Airbus DS offers a wide range of Fill and Drain / Vent valves for spacecraft applications incorporating either two or three inhibits against leakage pending on customer demand. Propellant loading / venting valves are designed to provide three independent inhibts, while gas type or test port FCVs provide 2 independent ones.

With regard to the selected materials, the propellant type and test port FDVs provide an excellant compatibility with state of the art storable propellants such as MMH / Hydrazine / MON-1 as well as MON-3. Special high pressure gas type FDV are available for operation with Helium (He) and Xenon (Xe). In general all types are compatible with standard test agents (IPA / HFE 7100 / deionized water) and gases (He, N2).

In general six different valves types are available, each providing a different interface to prevent misconnection on spacecraft level. These types differ mainly in thread size and orientation.

The following design attributes and features are common to all six FDV types:

→ All piece parts of the valve are machined from titanium alloy (Ti6Al4V) leading to a light weight unit with 0.25 inch/ 6.4mm outlet diameter tube stub which forms a weldable connection to the titanium tubing of the subsystem

→ The interface to the subsystem structure is provided by a triangular flange with triple-screw attachment (thread size M4)

→ An all welded housing containing a spring supported guided valve poppet equipped with the primary seal. This ensures that the valve is kept closed in non actuated contions

→ In flight configuration the valve poppet sealing will be additionally protected and sealed by mounting a cap, thus providing a metal-to-metal seal (secondary seal)

→ Low pressure drop even at high mass flows ensured by design. The flow area is at least as large as the connected tubing

For servicing a dedicated Ground Half Coupling (GHC) has to be mounted. For each FDV type there is a respective GHC permitting only mating of the correct type. By this means a safe and easy to handle, leak-tight connection between the propulsion system and the ground support equipment is guaranteed.

Each GHC provides a robust specific opening / closing mechanism to safely operate the FDV. No specific tooling is required.

Fill and Drain Valve Heritage and Future Missions

Since their original qualification in 1983, thousands of fill, drain and vent valves have been produced and delivered for a variety of spacecraft programmes including Eutelsat W3A, Amazonas, Inmarsat 4 F1, Anik F3, Skynet 5A, Skynet 5B, Amos 2, Astar, Star 1, Galaxy 17, Hispasat, MSG-4, Microsats, Herschel Planck, Pleiades, Spacebus, Eurostar communication satellites, Mars Express, Venus Express and ESA's Automated Transfer Vehicle. The outstanding flight heritage underlines the excellent reliability of the Airbus DS Fill and Drain / Vent valves.

Ground Half Coupling

Fill and Drain Valve Propellant Loading

Fill & Drain Valves - 2 Failure Tolerant (3 inhibits against external leakage)	
Operating Media	Various fluids (Propellants and Pressurants)
Mass	< 0.09 kg
Total Length	109 ± 1 mm
Standard Tube Dimensions	
- outer diameter	6.4 ± 0.02mm
- inner diameter	4.9 + 0.01mm
- inner diameter (at weld i/f)	5.58 ± 0.02mm
Tube Length	43 mm
Adapter Thread	Fuel Loading 9/16" - 18 UNJF - 3A - RH. Fuel Venting 7/16" - 20 UNJF - 3A - RH. Ox Loading 9/16" - 18 UNJF - 3A - LH. Ox Venting 7/16" - 20 UNJF - 3A - LH. Note: All of the above threads require corresponding ground half couplings
MEOP - Fuel / Ox Loading / Venting	Up to 33 bar
Burst pressure	1240 bar
Sinusoidal Vibration	Up to 20 g
Random Vibration	Up to 5 g^2/Hz (56.3g RMS)
Pyrotechnic Shock	Up to 3250 g
All European	Yes

FDV Fuel Venting

Low Pressure Helium Valve

	Fuel Fill Valve	Fuel Vent Valve	High Pressure Helium Valve
Operating Media	Monomethyl Hydrazine (MMH)	Monomethyl Hydrazine (MMH)	Helium (High Pressure)
Mass	≤ 0.09 kg	≤ 0.09 kg	≤ 0.06 kg
Total Length	108.8 ± 1 mm	107.2 ± 1 mm	94.5 ± 1 mm
Standard Tube Dimensions			
- outer diameter	6.4 ± 0.02mm	6.4 ± 0.02 mm	6.4 ± 0.02 mm
- inner diameter	5.58 + 0.11 mm	5.58 + 0.02 mm	4.98 + 0.02 mm
Tube Length	43 mm	43 mm	43 mm
Adapter Thread	9/16" - 18 UNJF - 3A - RH. Requires corresponding ground half coupling	7/16" - 20 UNJF - 3A - RH. Requires corresponding ground half coupling	M 12 x 1.5 - RH. Requires corresponding ground half coupling
Life			
- Operational Life	About 16 years	About 16 years	About 16 years
- Storage Life	Up to 5 years in a protected environment	Up to 5 years in a protected environment	Up to 5 years in a protected environment
Open/Close Cycles	40 Cycles	40 Cycles	40 Cycles
Standard Operating Temp.	-30°C to 80°C	-30°C to 80°C	-30°C to 80°C
Leakage			
- external Leakage	< $1x10^{-6}$ scc/sec GHe	< $1x10^{-6}$ scc/sec GHe	< $1x10^{-6}$ scc/sec GHe
- internal Leakage	< $2.8x10^{-4}$ scc/sec GHe	< $2.8x10^{-4}$ scc/sec GHe	< $2.8x10^{-4}$ scc/sec GHe

	Low Pressure Helium Valve	Oxidiser Fill Valve	Oxidiser Vent Valve	High Pressure Xenon Valve
Operating Media	Helium (Low Pressure)	Nitrogen Tetroxide (MON)	Nitrogen Tetroxide (MON)	Xenon (High Pressure)
Mass	≤ 0.06 kg	< 0.09 kg	< 0.09 kg	≤ 0.06 kg
Total Length	94.5 ± 1 mm	108.8 ± 1 mm	107.2 ± 1 mm	115 ± 1 mm
Standard Tube Dimensions				
- outer diameter	6.4 ± 0.02 mm	6.4 ± 0.02 mm	6.4 ± 0.02 mm	6.4 ± 0.02 mm
- inner diameter	5.58 + 0.02 mm	5.58 + 0.02 mm	5.58 + 0.02 mm	4.9 + 0.1 mm
Tube Length	43 mm	43 mm	43 mm	61 mm
Adapter Thread	7/16" - 20 UNJF - 3A - RH. Requires corresponding ground half coupling	9/16" - 18 UNJF - 3A - LH. Requires corresponding ground half coupling	7/16" - 20 UNJF - 3A - LH. Requires corresponding ground half coupling	M 14 x 1.5 - RH. Requires corresponding ground half coupling
Life				
- Operational Life	About 16 years	About 16 years	About 16 years	About 16 years
- Storage Life	Up to 5 years in a protected environment	Up to 5 years in a protected environment	Up to 5 years in a protected environment	Up to 5 years in a protected environment
Open/Close Cycles	40 Cycles	40 Cycles	40 Cycles	40 Cycles
Standard Operating Temp.	-30°C to 80°C	-30°C to 80°C	-30°C to 80°C	-30°C to 80°C
Leakage				
- external Leakage	< $1x10^{-6}$ scc/sec GHe	< $1x10^{-6}$ scc/sec GHe	< $1x10^{-6}$ scc/sec GHe	< $1x10^{-6}$ scc/sec GHe
- internal Leakage	< $2.8x10^{-4}$ scc/sec GHe	< $2.8x10^{-4}$ scc/sec GHe	< $2.8x10^{-4}$ scc/sec GHe	< $2.8x10^{-4}$ scc/sec GHe

LATCH VALVES

The Airbus DS low pressure latching valve (named hereafter LPLV or LV) is a solenoid-operated, bi-stable valve constructed essentially of stainless steel and qualified to operate with a number of different working media, including hydrazine and its most common derivatives.

The LPLV provided by Airbus DS represents the switchable, fully reliable safety barrier in the propellant flow between tank and thrusters. It is equipped with a back-relief-function protecting the downstream lines and equipment against over-pressure (e.g. due to environmental effects).

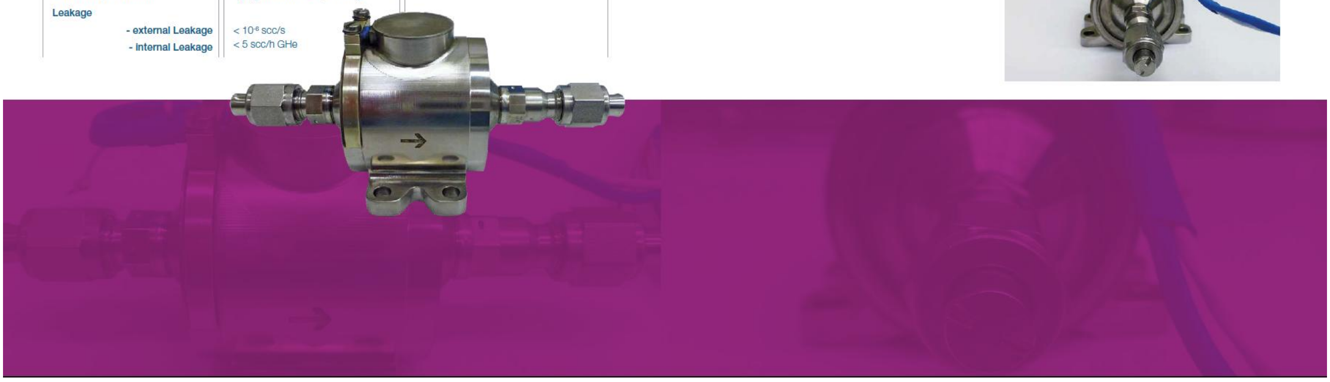
For switching 2 electromagnetic coils are to be activated to change the status of the valve to open or closed. Switching can be performed by using a non-regulated supply within a range of 22VDC < 28VDC ≤ 38 VDC. At room-temperature the LPLV can be closed or opened within a switch-time of 30ms while the cycle-time is defined to 50ms.

A microswitch is installed for position indication, activated by a pin, which is directly mounted on the LPLV-anchor.

The variant with welded interface is identical to the screwed-interface one except for the tubing connection.

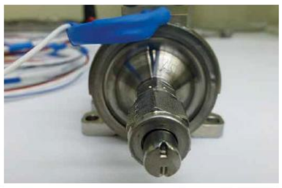
Latch Valve Technical Characteristics

Characteristics	Nominal Value	Remarks
Tubing Interface	1/4 inch	Screwed or welded versions available
Mass	545 g	
Operating voltage	22-32 VDC	Up to 50VDC for 50ms switching pulses
Response time	< 30 ms	Opening and Closing;
Coil resistance	37,5 Ω ± 1,5 Ω	At ambient temperature
Max.operating pressure	24,25 bar	Specified value; higher values possible
Back-Relief Pressure	8 to 14 bar	
Flow Rate and Pressure Drop	< 0.15 bar at 4.5 g/s	Flow rates up to > 20g/s usable
Fluid Compatibility	Water, hydrazine, MMH, NTO, IPA, He, N_2, Xe and others	
Opening/Closing cycles	> 500	
Operating Temperature	9° C to 50° C for use with hydrazine	
Electrical connection	Flying leads AWG26, 2m long	
Leakage		
- external Leakage	< 10^{-6} scc/s	
- internal Leakage	< 5 scc/h GHe	



Latch Valve Heritage and Future Missions

Spacecraft	Launch Year
Giotto	1984
Hipparcos	1986
Meteosat	1986-88
DFS	1987
Eureca	1990
HAPS	1990
ISO	1992
SOHO	1995
Galileo IOC	2010-14
Pléiades	2011-13
Spot 6	2012
Sentinel-1A	2014
Kazakhstan Gharysh Sapary	2014
Spot 7	2014
Sentinel-2A	2015
Seosat-Ingenio	2015
CSO	2016
Sentinel-1B	2016
Sentinel-2B	2016
Sentinel-5 Precursor	2016



XENON REGULATOR FEED SYSTEM (XRFS)

The XRFS is a bang-bang pressure regulator. It uses a system of valves, plenum volume, pressure transducers and flow restrictors to down regulate the high pressure of the xenon propellant under which it is stored in the Xenon Storage Tank to the supply pressure required by the Xenon Flow Controller (XFC).

The main components of the XRFS are:

- → The inlet filter protects the XRFS and the thruster modules downstream from any anomalous particulate contamination which could degrade the performance of the XRFS and the thruster modules
- → The base plate supports all the components and the brackets
- → The pipeworks feed the gas
- → The valve block at the base of the plenum is equipped with normally closed solenoid valves
- → The valves are arranged in 2 parallel redundant branches. Each branch a serial arrangement of 3 isolated and regulating solenoid valves is capable of fulfilling the mission requirements
- → The inserted flow restrictors limit the plenum filling rate
- → The plenum volume which is sized in order to ensure the beginning of life valve 'open' times limits the number of regulator valve cycles required by the system mission life
- → The two high pressure and four low-pressure transducers (ITAR) monitor the inlet and outlet pressure
- → Thermal hardware. Electronic circuits with thermistors measure the XRFS temperature. Heaters and thermostats ensure the maintaining of a minimum hardware temperature of +27 °C

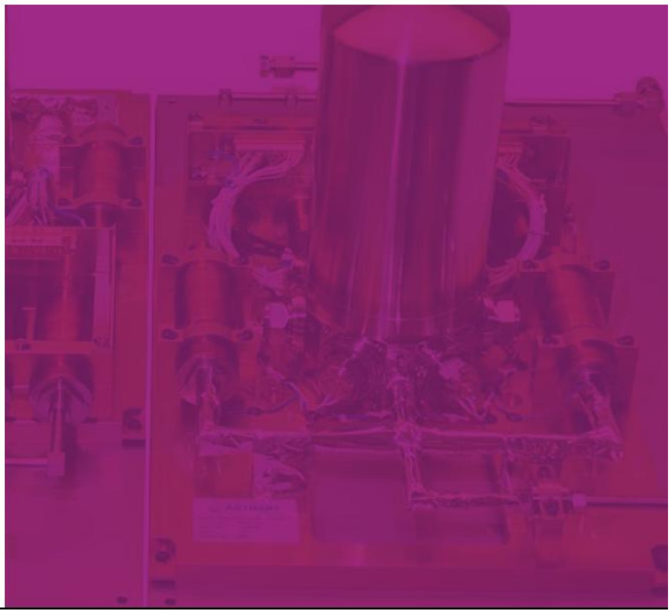
The XRFS provides a high degree of redundancy (series and parallel) and failure tolerance, to ensure the reliability and function during the whole mission.

XRFS Heritage and Future Missions

Project	Launch Year
INMARSAT 4 PFM	2005
INMARSAT 4 FM2	2005
INMARSTA 4 FM3	2008
KASAT	2010
YASAT 1A	2011
YASAT 1B	2012
DIRECT TV 15	2015
SES 10	2016
SkyBrazil-1	2016

XRFS Key Technical Characteristics

Regulator Type	"Bang-bang" type regulator (pulsing valves) with two parallel redundant regulation branches, each branch being twice redundant.
Flow Control	The maximum possible flow rate is limited by upstream pressure and smallest diameter in the system's flow path. The actual flow is controlled by regulation of the pressure within the plenum.
Inlet Pressure	3 to 120 bar
Outlet Pressure	2.65 bar ± 0.2 bar
Leakage	
- external Leakage	< $1x10^{-6}$ scc/s GHe
- internal Leakage	< $2x10^{-4}$ scc/s GHe
Flow Rate	> 6 mg/s gaseous xenon
Flow Restrictor	46800 Lohms
Total propellant throughput	300 kg max
Mass	< 5.9 kg
Dimensions	443.5 mm x 278 mm x 228 mm (plenum)
Temperature Range	27 C° to 45 C° (operating)
Design Life	15 years
Cycle Life	1.000.000 qualified
Reliability	> 0.998
Mechanical Interface	1/4" diameter titanium pipes (Ti3Al2.5V)
Electrical Interface	D-Sub Connectors

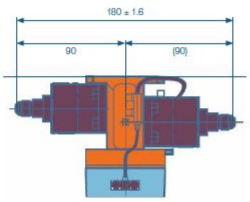


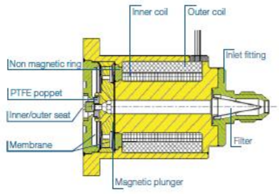
400N APOGEE ENGINE FLOW CONTROL VALVE

The 400N flow control valve is an electromagnetic controlled, normally closed valve with a non sliding fit suspended armature design and has redundant electric coils. The moving part, called magnetic plunger, is actuated with the magnetic force induced by the coil when supplied by direct current voltage.

With no voltage applied, the magnetic plunger returns to closed position thanks to the two preloaded membrane springs. The spring preload compresses the PTFE poppet on the metallic seats and enables to meet the required tightness level. After energizing of the coil, the valve opens and the flow passes through an annular gap. At the inlet of the valve a 40μ filter is located to protect the PTFE seat for any pollution.

More than 100 units were successfully build and more than 80 successfully used on Airbus DS 400N engine in orbit.



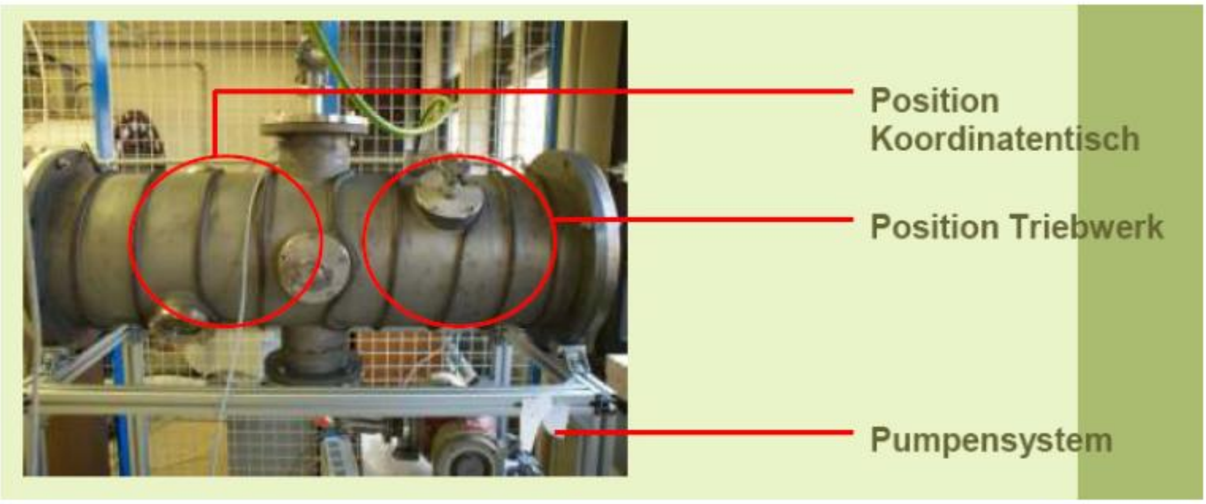


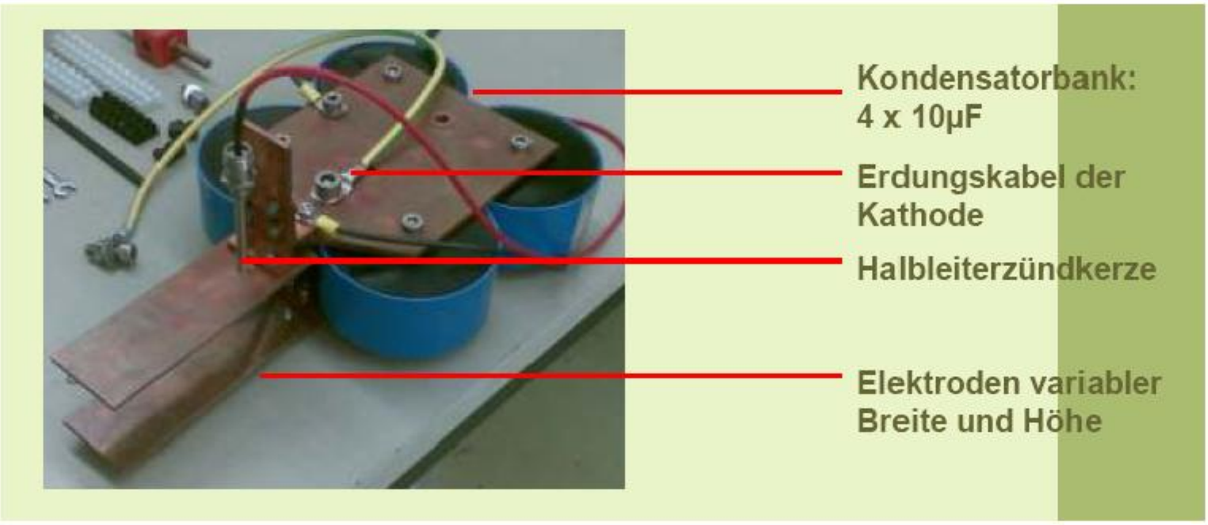
400N Apogee Engine Flow Control Valve (FCV) Key Technical Characteristics

Valve type		Dual-coil-solenoid monostable bipropellant engine valve (Normally-Closed), non sliding fit
Operating Voltage per Coil	VDC	21 to 27
Coil resistance	Ohms	20 ± 1 at 21°C
Power dissipation	Watt	38.4 at 27 VDC
Response time (20°C)	ms	< 30
Pull-in	VDC	≤ 18,3
Drop-out	VDC	> 1.5, < 5
Holding Voltage per Coil	VDC	≥ 7.5
Max inlet pressure (operational domain)	bar	34
Burst pressure	bar	88
Flow Rate / Pressure Drop		max 1.1 bar at 70 g/s H2O
Compatible Media		NTO, MMH, water
Seat material		PTFE
Other materials in contact with media		AISI 430, AISI 347, Elgiloy
Leakage		
- external Leakage	scc/s	< $1x10E^{-6}$
- internal Leakage	scc/s	< $5x10E^{-4}$
Electrical connection		AWG24 flying leads acc. ESA ECSS 3901.002 1.7m (4 single wires)
Media inlet connector		AN4 7/16 - 20 UNJF - 3A
Inlet filter		Mesh type, stainless steel, <40μm
Temperatures		
Operating	°C	0°C to 115°C
Acceptance	°C	-5°C to 120°C
Qualification	°C	-10°C to 125°C
Number of open/close cycles		5000
Life time	years	16

3.3 Test Environment for Electrical Propulsion

From [Böhrk et. al. 2007]:





3.4 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:

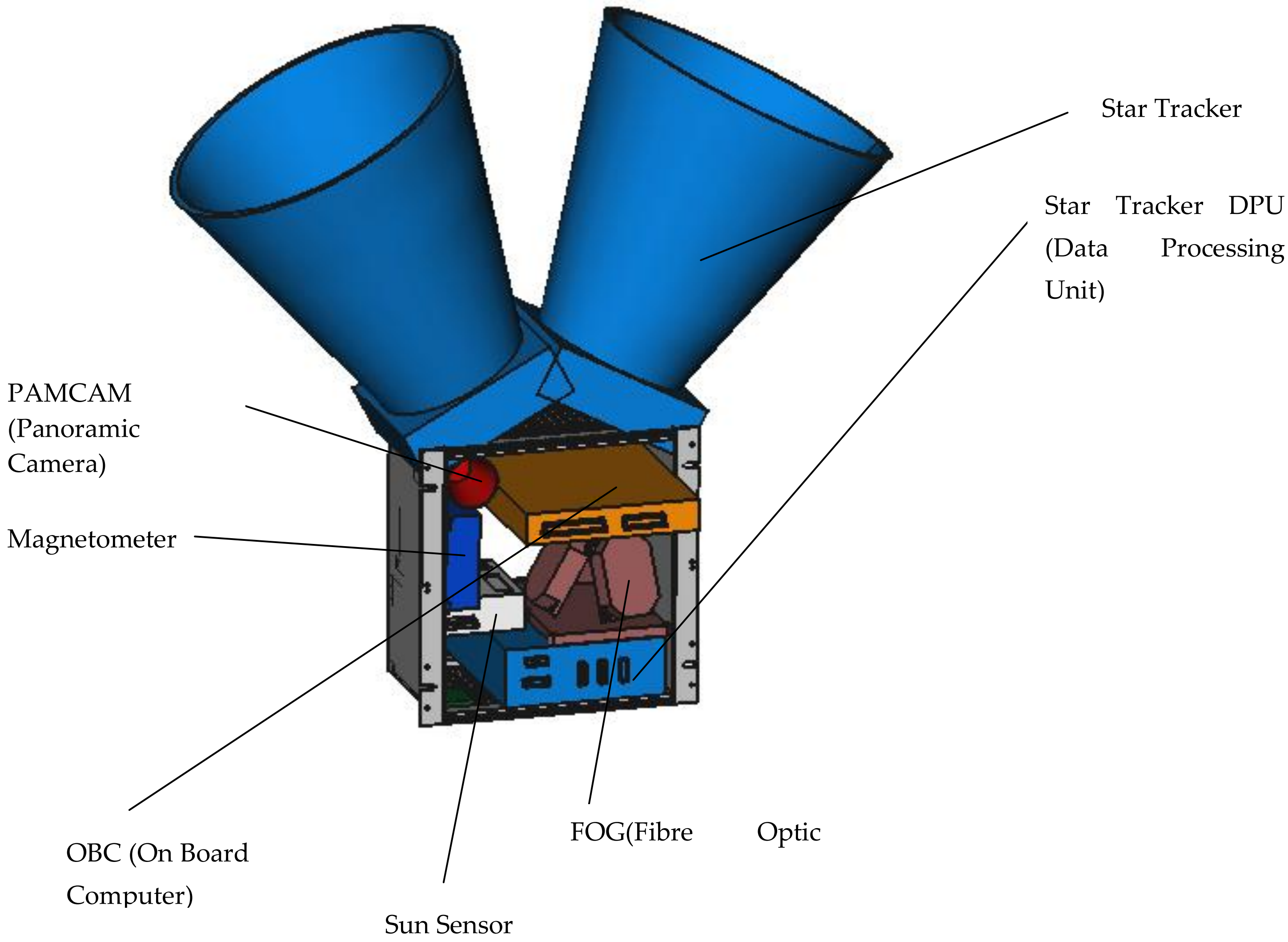
CADRE (41475U), CADRE is classified as Amateur radio

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

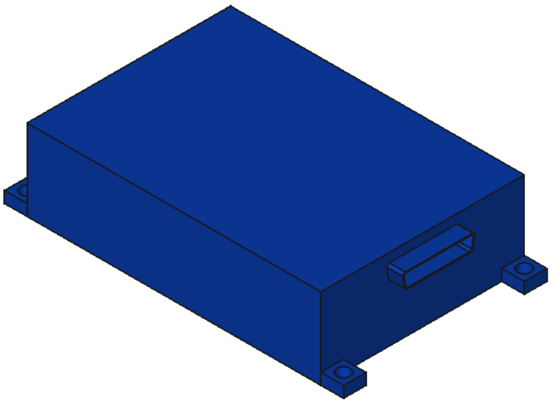
4 Attitude Control System (ACS) Components

Type	ACS Components
Sensors	3-axis Magnetometers
	sun sensors
	GPS Receiver
	Star Tracker camera head units
	Rate Gyros
Actuators	



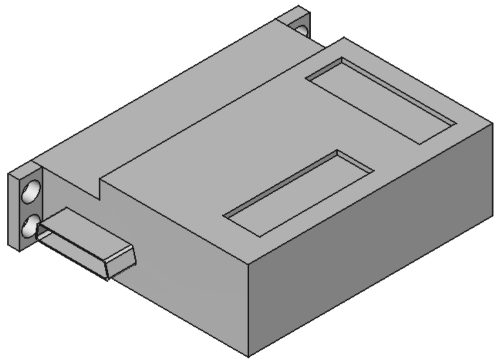
4.1 Magnetometer

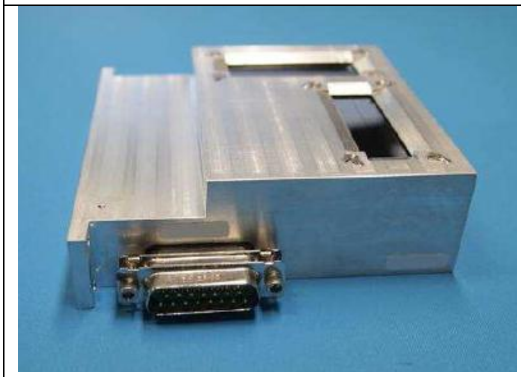
Sensitivity	± 10 nT
Range	± 60 μT
Bandwidth	10 Hz
Temperature Channel	1x 0 - 5V Analogue
Field Measurement	3x 0 - 5V Analogue
Mass	190 g
Dimensions (H x W x L)	36 x 90 x 130 mm
Power Supply	Supply ± 12 V Consumption <300mW
Temperature	-20 to +50°C operating -40 to +80°C non-operating
Random Vibration	15Grms in all axis
Radiation Tolerance	5kRad (Si)



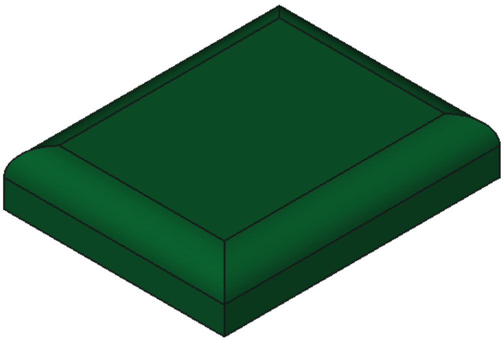
4.2 Sun sensor

Sensors	2 orthogonal axes
Sensor field of view	± 50°
Accuracy	1.0° (95%)
Analogue output	4x 0 - 5V per channel
Mass	~210g
Dimensions (H x W x L)	95x 107 x 35 mm
Power consumption	Sunlit: <100 mW; Dark: <10 mW
Power Supply	± 12V
Temperature	-30 to +60° C operating -40 to +80° C non-operating
Random Vibration	15Grms in all axis
Radiation Tolerance	5kRad (Si)





4.3 GPS

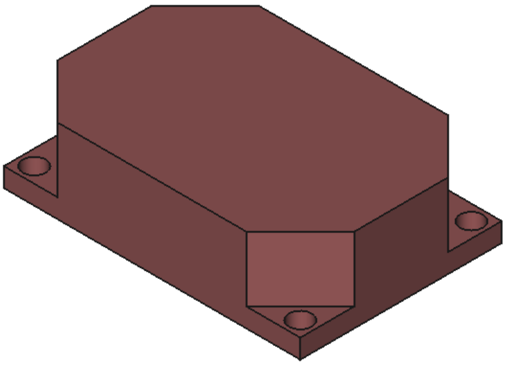


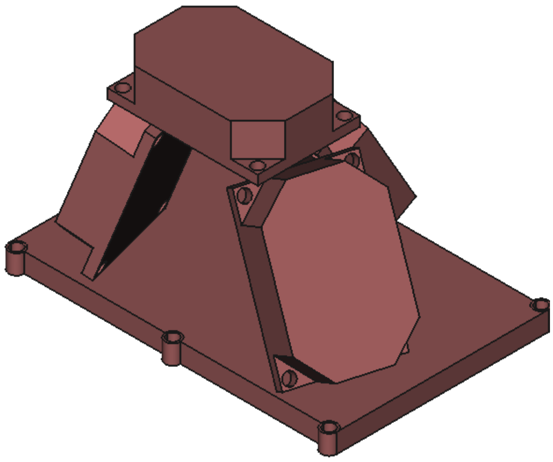
4.4 Fiber optic gyro unit

Fiber Optic Gyro unit is composed of four fiber optic gyros (FOG) used in a tetrahedron like configuration for the measurement of the body angular rates. The tetrahedron like configuration allows autonomous detection of a single failure.

The type of the sensor is C-FORS

Parameters	FOG C-FORS Sensor
Sensor Performance	
Rate bias	$\leq 2°/\text{h}$ (1 σ)
Random walk	$\leq 0.15°/\sqrt{h}$
Scale Factor	$\leq$ 1000 ppm (1 σ)
Axis misalignment	$\leq$ 10 mrad (Absolute) $\leq$ 1 mrad (Stability)
Maximum measurement range	$\pm$ 1000°/s
Initialization time	$\leq$ 120 ms
Mechanical Properties	
weight	$\leq$ 130 g
Dimensions	78 mm x 53 mm x 22 mm
Case	Hermetically sealed
Electrical Properties	
Power Consumption	2.8 W
Communication Interface	IBIS
Supply voltage	+5.0 V -5.0 V +3.3 V

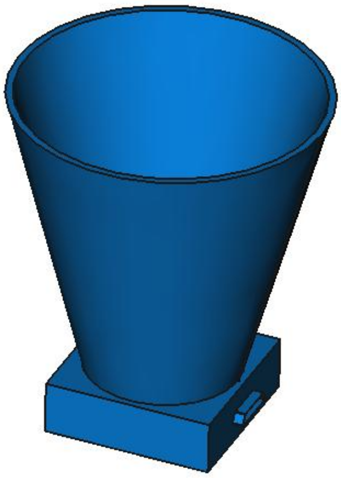


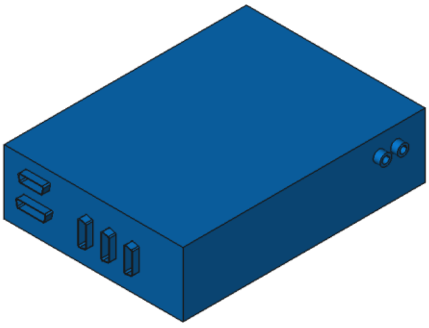


4.5 Star tracker system

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 |

Physical Characteristics	
Dimensions (mm)	DPU: 155 x 210 x 56 30º baffle CHU: Ø147 x 283 (H)
Power	16 – 50 V unregulated DPU: 6.5W, CHU: 0.5W
Mass (kg)	DPU: <1.2 , 30º baffle CHU: 1.4
Radiation	5 kRad (Si)
Random vibration	15 G_{rms} in all axis
Lifetime	7.5 years LEO Orbit (< 800Km)
Temperature	-30° C to +15 ° C performance -20° C to +50 ° C operating -30° C to +60 ° C non-operating
Performance Properties	
Relative Accuracy	X/Y < 3 arcsec (1σ) Z < 25 arcsec (1σ)
Bias	X/Y < 5 arcsec (1σ) Z < 3.5 arcsec (1σ)
Maximum rate/ acceleration	6 deg/sec / 2.5 deg/s^2
Attitude Acquisition Time	8 s from power ON
Update Rate	1 Hz to 16 Hz
Sun/Earth Exclusion Angle	30 Degrees
Moon Exclusion Angle	Robust to Moon in field of view (22.6 x 22.6 deg)
Time synchronisation	PPS input via LVDS. RS485 or optional RS422
TM/TC interface	CAN-SU or Optional (RS422 & SpaceWire)



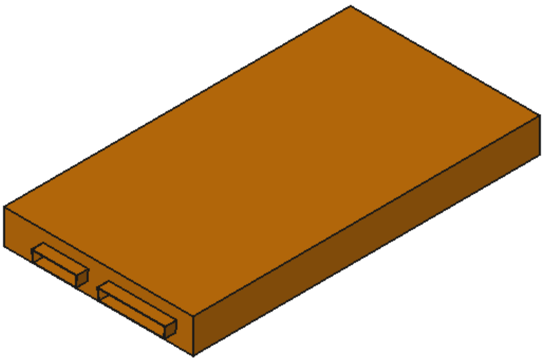


4.6 Other Components

4.6.1 OBC

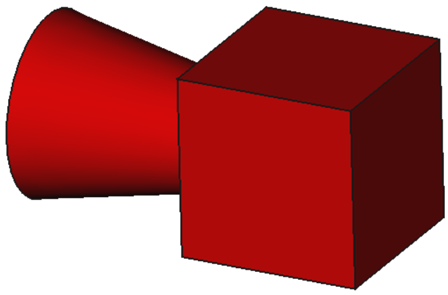
Specification form © Surrey Satellite Technology Ltd., Tycho House, 20 Stephenson Road, Surrey Research Park, Guildford, Surrey, GU27YE, United Kingdom, **Tel:** +44(0)1483803803 | **Fax:**+44(0)1483803804 | **Email:** info@sstl.co.uk |

Performance Properties	
Processor	IBM PPC750FL 500 Dhrystone 2 MIPS 296 Whetstone MWIPS
Operating System	VxWorks, Others may be available on request
Memory	512MiBytes (EDAC 16,8) 24MiBytes MRAM 4MiBytes Flash (EDAC 16,8)
Interfaces	MIL-STD-1553B 2 x Dual CAN bus 8x LVDS Inputs/ 8x LVDS Outputs 4x Opto Isolated Inputs 4x Opto Driver Outputs 12x RS485/ MLVDS Transceiver RS422 receiver/transmitter links
Protocols	MIL-STD-1553 (optional), Spacewire (optional), CAN-SU, UART (optional RS422/RS485), HDLC, Pulse-Per-Second Synchronisation Others available on request



Physical Characteristics	
Dimensions	306x167x 30mm (single board)
Power at 28V	<10W
Mass	1.5kg
Radiation	5kRad (Si)
Random Vibration	10 G_{rms} in all axis
Lifetime	up to 7.5years
Temperature	-20° C to +50 ° C operating -30° C to +60 ° C non-operating

4.6.2 PAMCAM



This so called Panoramic Camera (PAMCAM) should be able to take color images in order to increase the public outreach of the Small Satellite Program.

4.7 Concept for Power Supply and Battery[1]

Satellites need electric energy to pursue operation. This energy is acquired from solar power using solar cells which transform radiation energy into electricity. New developments in solar panel's technology have increased the efficiency of such systems to 30%. However the satellite will be deprived of such source of energy during eclipses, that is when the satellite is passing through the shadow of the earth. This phenomenon becomes more profound for LEO satellites which pass through an eclipse every 100 minutes and which the eclipse represents up to 40% of the total cycle time. In order to provide the continuity of electric energy supply, satellites are equipped with rechargeable batteries. These batteries simply charge during times when solar energy is available and discharge during shadow periods.

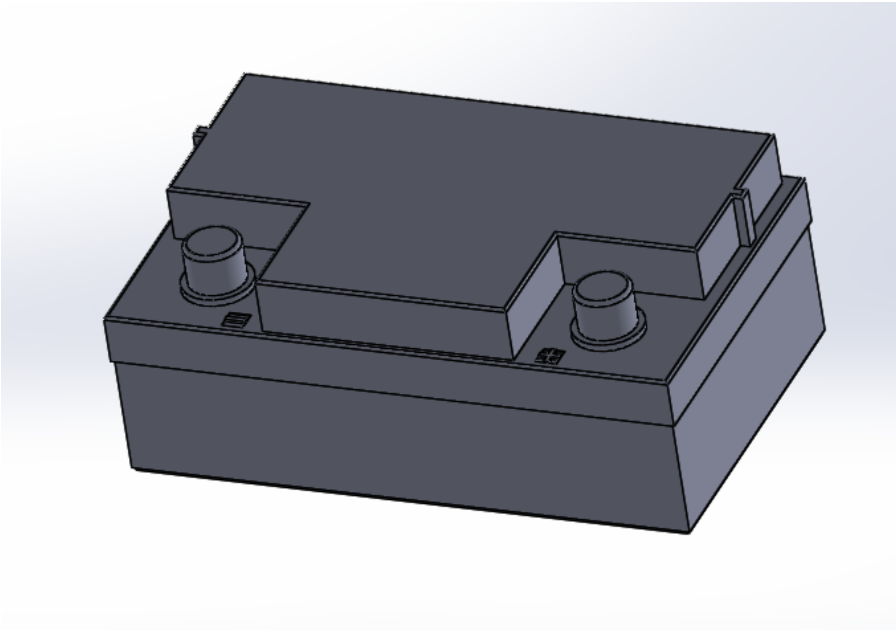
The first utilized battery in a spacecraft was the silver-zinc battery which provided high energy density. However because Ag-Zn batteries have low cycle life, they were replace by Ni-Cd batteries that dominated the space industry for 20 years. After that, various batteries were used however restrictions and robust standards imposed on batteries used in space industry rendered many of them obsolete.

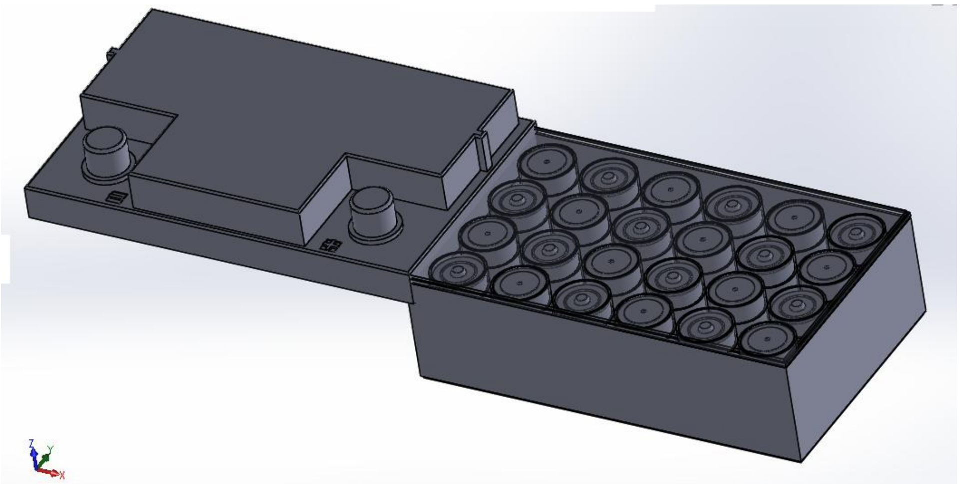
Aerospace industry now adopted the lithium-ion-based batteries in its satellite projects since lithium has:

- High energy density
- High specific energy
- Long cycle life
- Ability to be charged and discharged fast

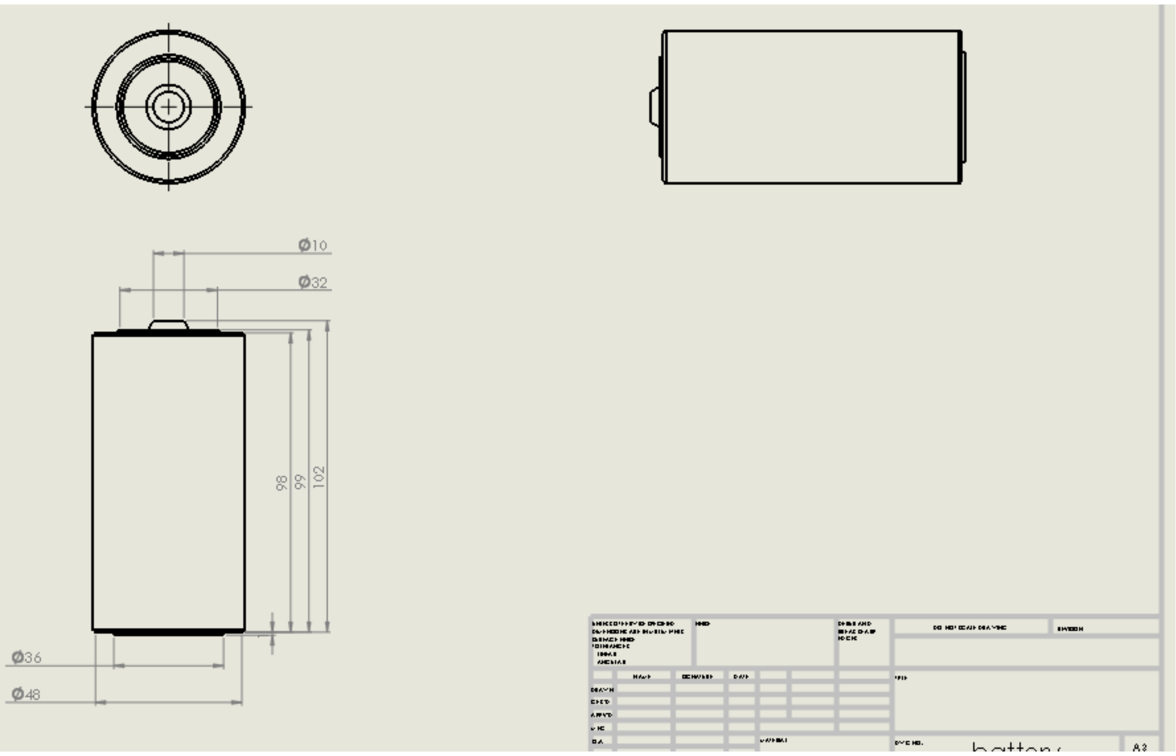
[1] From Ibrahim Ghanim, Practical Work at AECENAR Ras Nhache, July/August 2015

- Compact shape

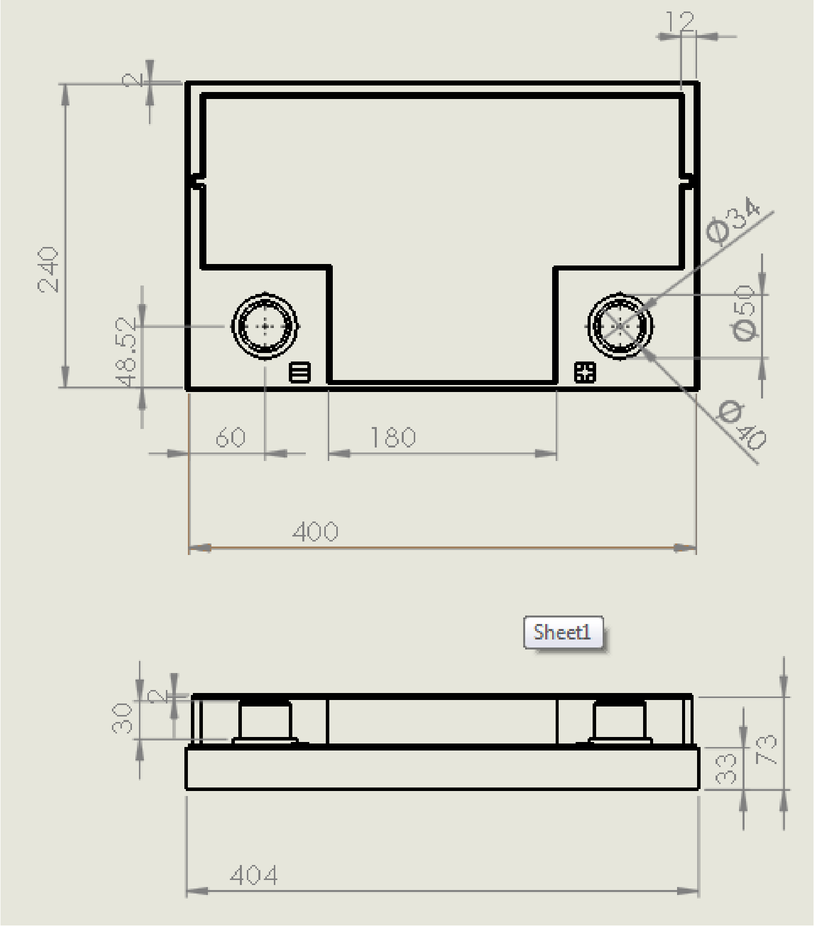




Battery:



Body:

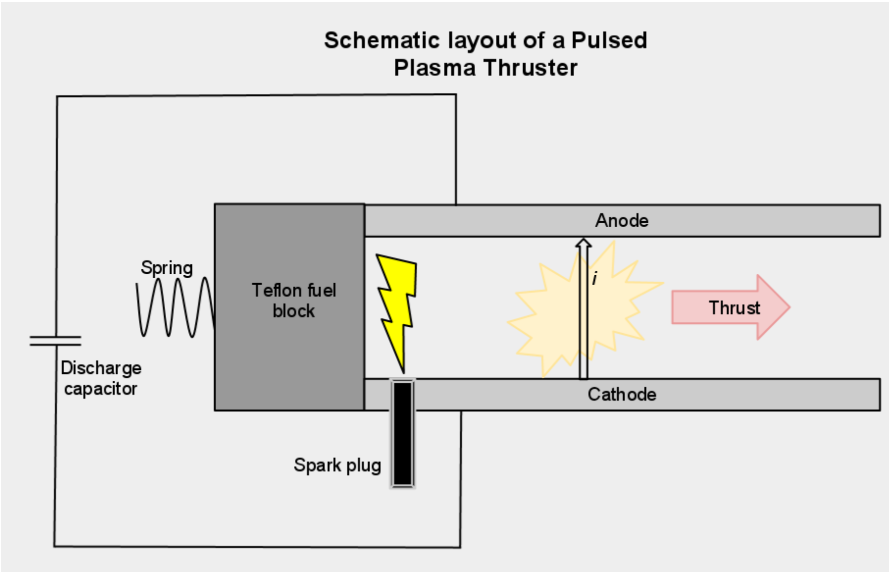


4.8 Concept for the Propulsion Unit[2]

4.8.1 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

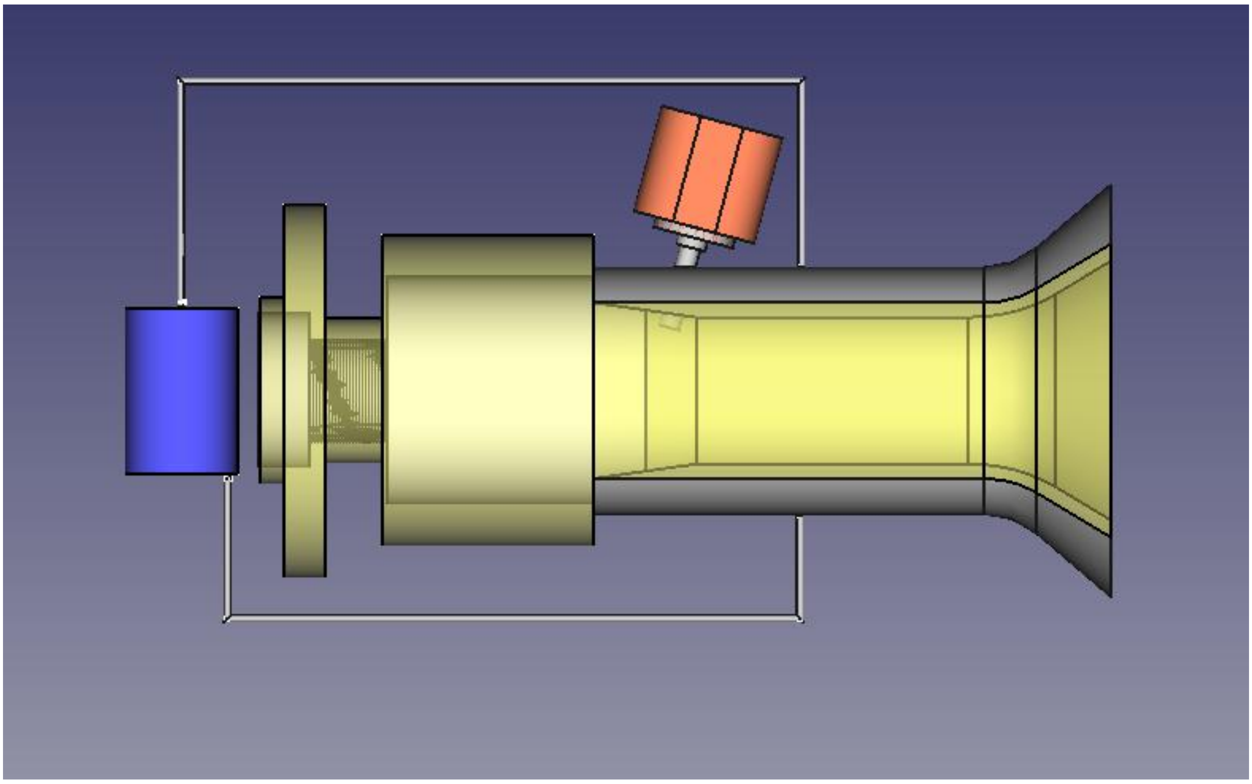
Mechanism: The first step of PPT mechanism is plasma formation. An igniter directed to the solid fuel bar produces a spark that ablates and sublimates the surface of the propellant forming plasma. Since the plasma is positively charged, it completes the circuit between the 2 plates. The interaction between 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.

4.8.2 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.

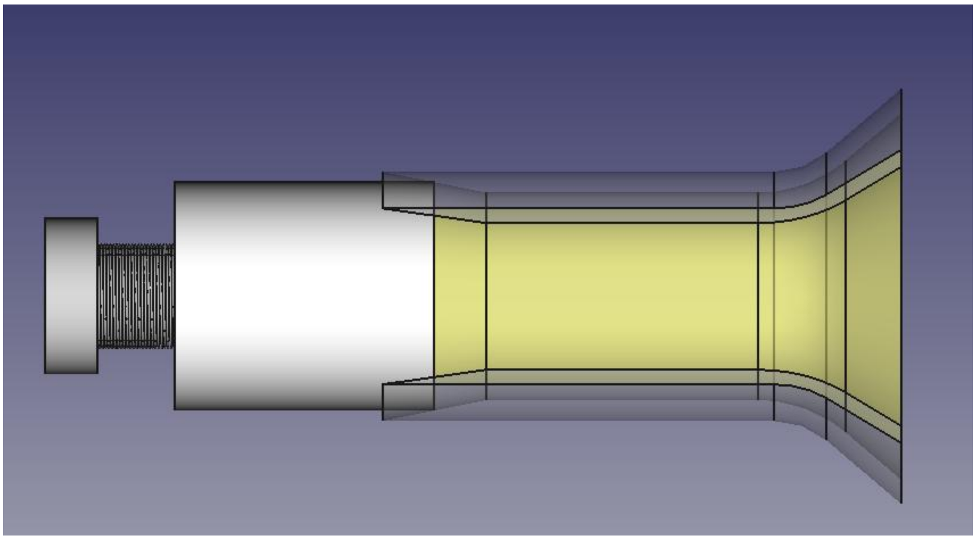
The following is the FreeCad model of the PPT:

2 From Ibrahim Ghanim, Practical Work at AECENAR Ras Nhache, July/August 2015



4.8.2.1 Modelling "fuel continues supplying system"

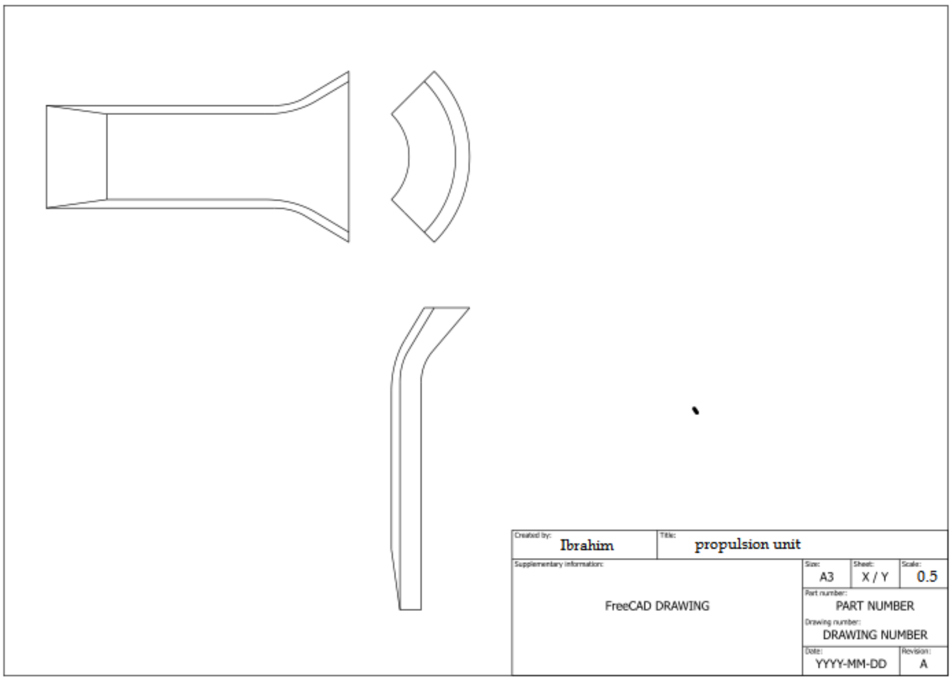
Most of propulsion systems use fluid fuel which its supply is easily provided by maintaining a pressure difference between the fuel reservoir and the ionization chamber. However pulsed plasma thrusters use solid fuel, that's why its continuous fuel supply was insured by a spring system mounted on the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



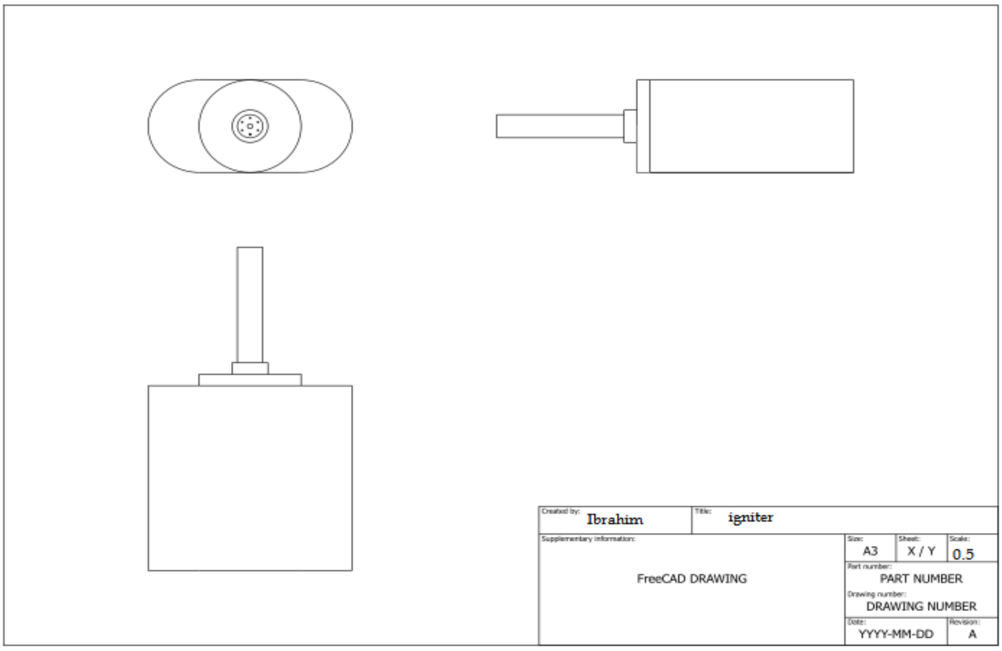
The propulsion unit is designed with a cone shaped ending such that its outer nozzle is slightly larger than the fuel rod and its inner nozzle is smaller than the fuel rode. A compressed spring is mounted to the end of the fuel rod such that the rod is always under pushing force. When the igniter produces 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.

4.8.2.2 2D projections of important parts of the propulsion system

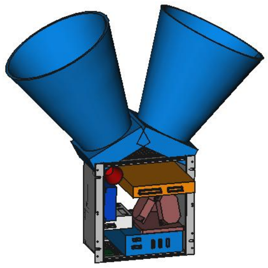
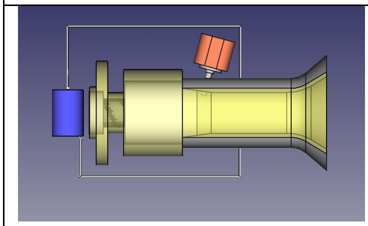
1) Propulsion unit



2) Igniter



4.9 FreeCAD files

	170116IAP-SAT_Integration.FCStd
	propulsion chamber.FCStd

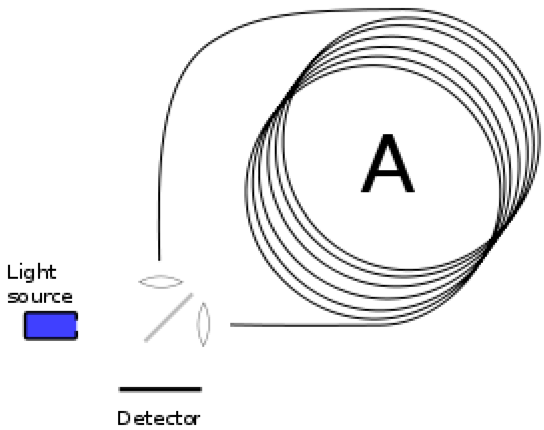
5 Fiber Optic Gyro development test rig and Fiber optic gyroscope sensor

5.1 Sagnac effect

5.1.1 Definition:

The Sagnac effect (also called Sagnac interference), named after French physicist Georges Sagnac, is a phenomenon encountered in interferometry that is elicited by rotation. The Sagnac effect manifests itself in a setup called a ring interferometer. A beam of light is split and the two beams are made to follow the same path but in opposite directions. To act as a ring the trajectory must enclose an area. On return to the point of entry the two light beams are allowed to exit the ring and undergo interference. The relative phases of the two exiting beams, and thus the position of the interference fringes, are shifted according to the angular velocity of the apparatus. This arrangement is also called a Sagnac interferometer.

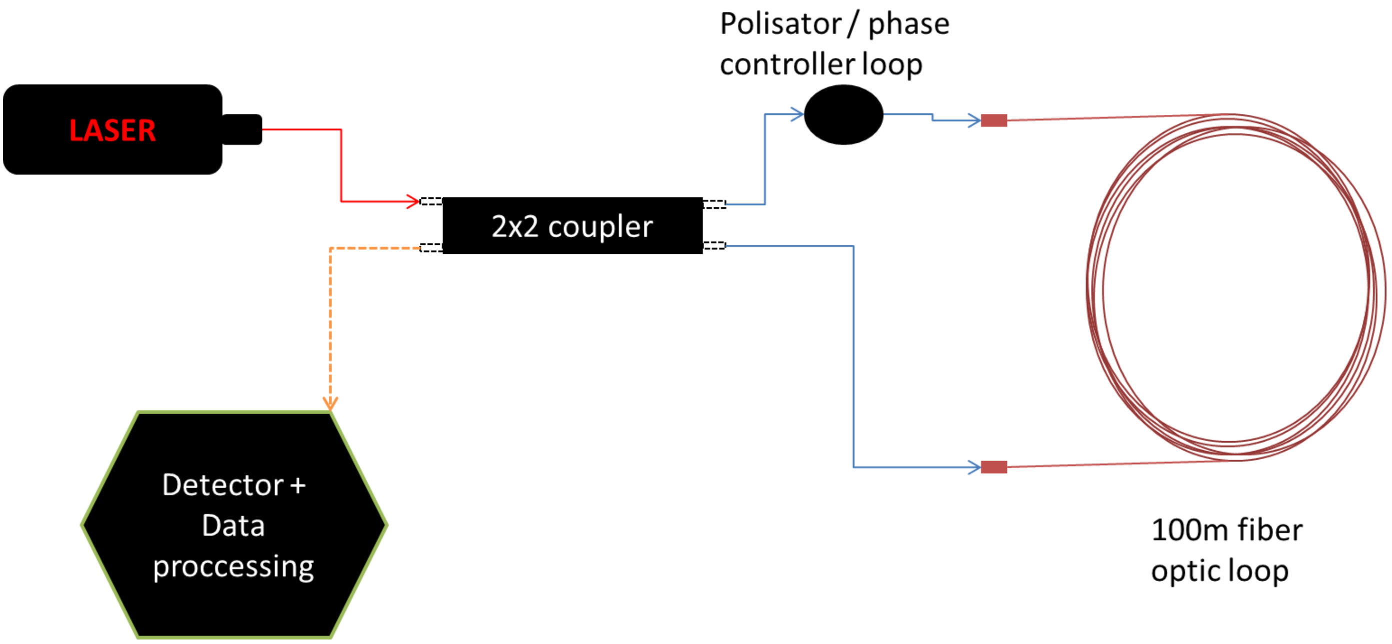
[1]



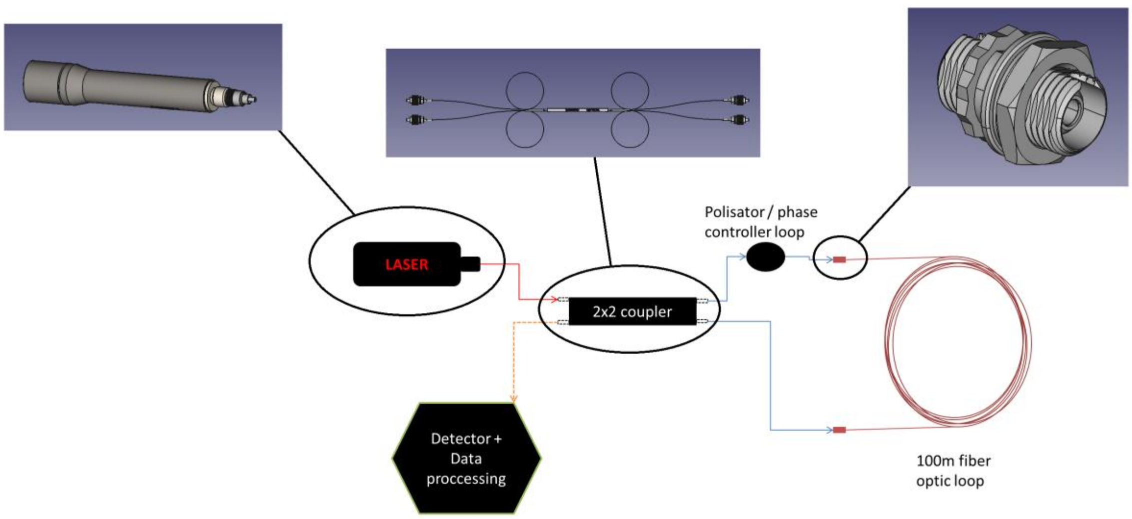
Title: *Figure 1. Schematic representation of a Sagnac interferometer.*

5.1.2 Experiment:

i. Schema:



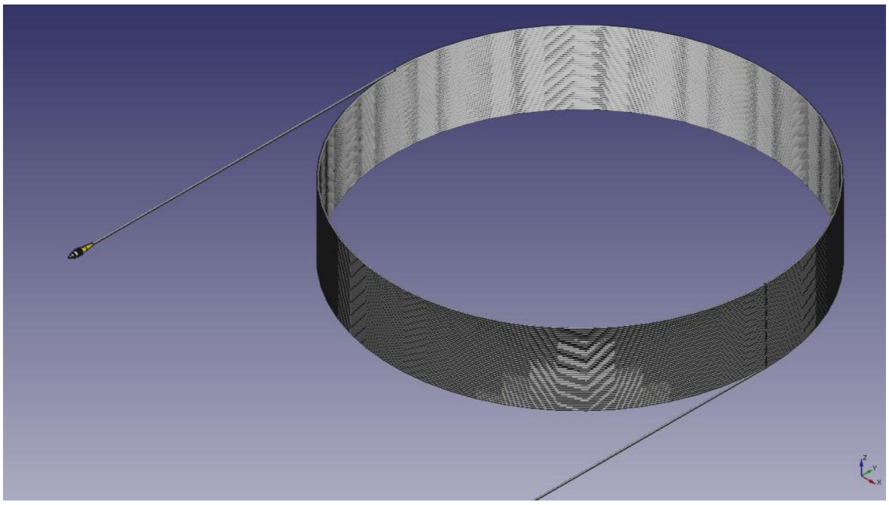
Title: *Figure 2. Sagnac effect schema.*



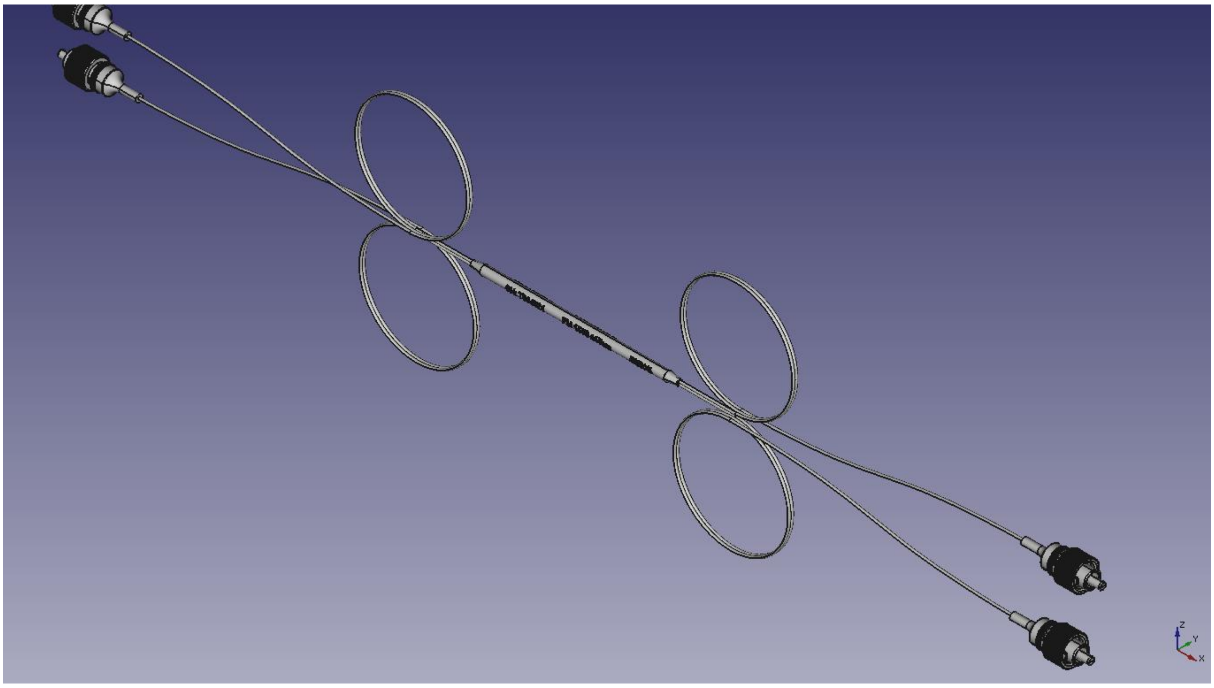
ii. Materials:

- Single or Multi mode fiber optic cable (10 - 40 m) with FC/UPC connectors.
- Fiber optic coupler 2x2 (50:50 split) with FC/UPC connectors.
- Detector ciruit.
- Laser.
- (Polarisator) We won't use a polarisator in the first stage of sagnac effect experiment

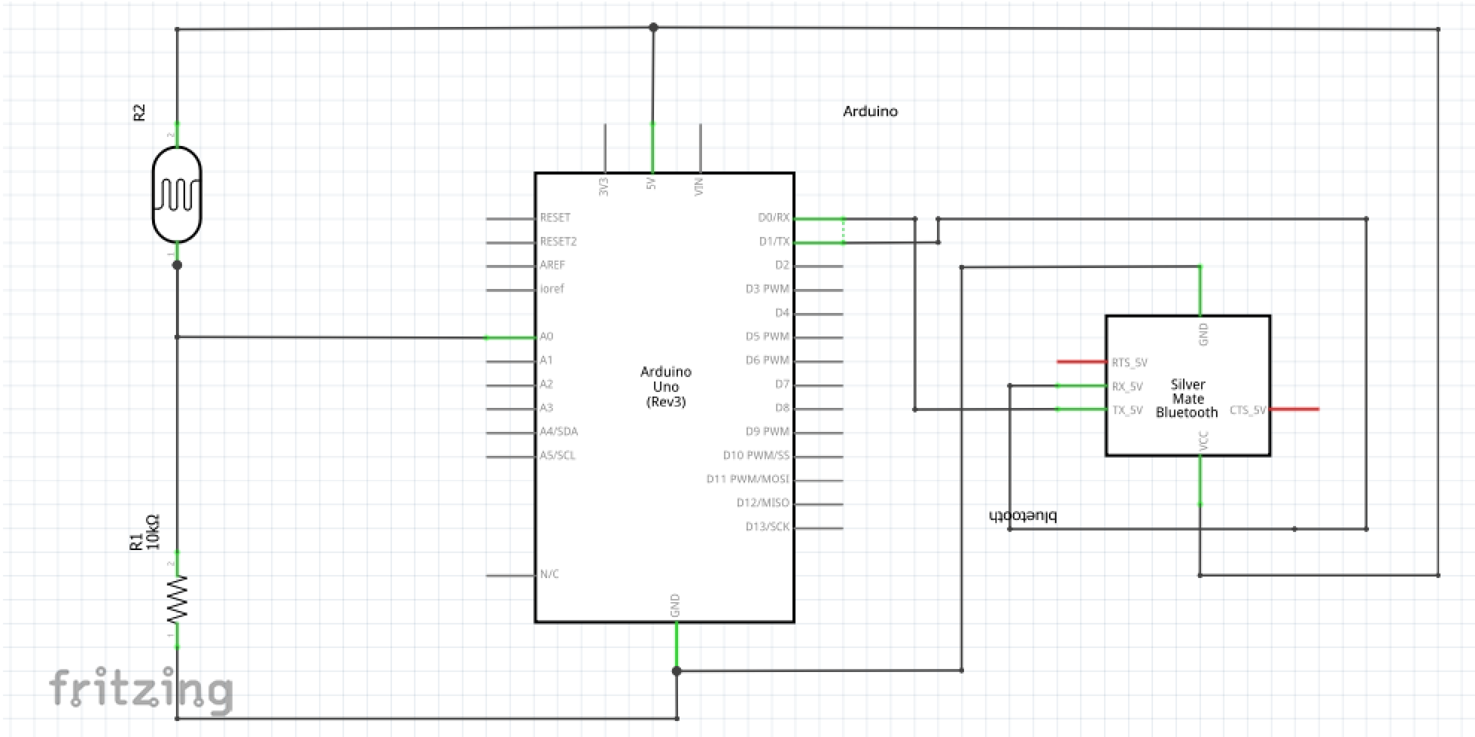
ii.1. Fiber optic cable [TBD]



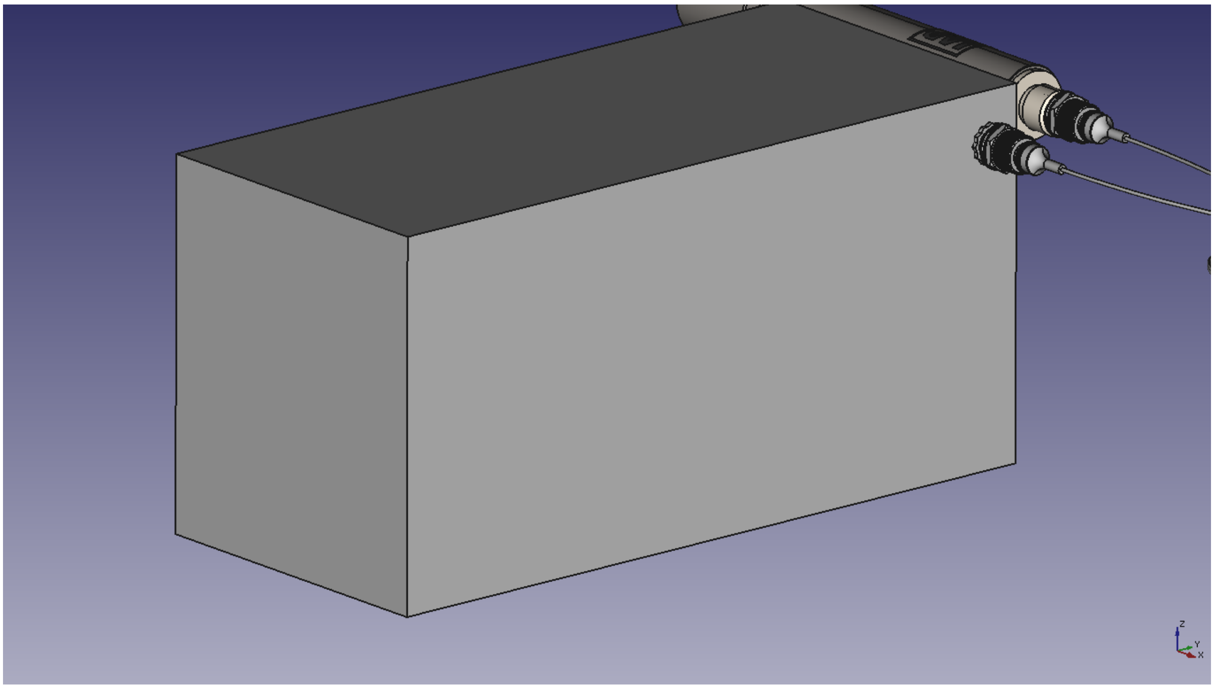
ii.2. Fiber optic coupler [TBD]



ii.3. Detector circuit



Title: *Figure 3. Detector schema.*



Component:

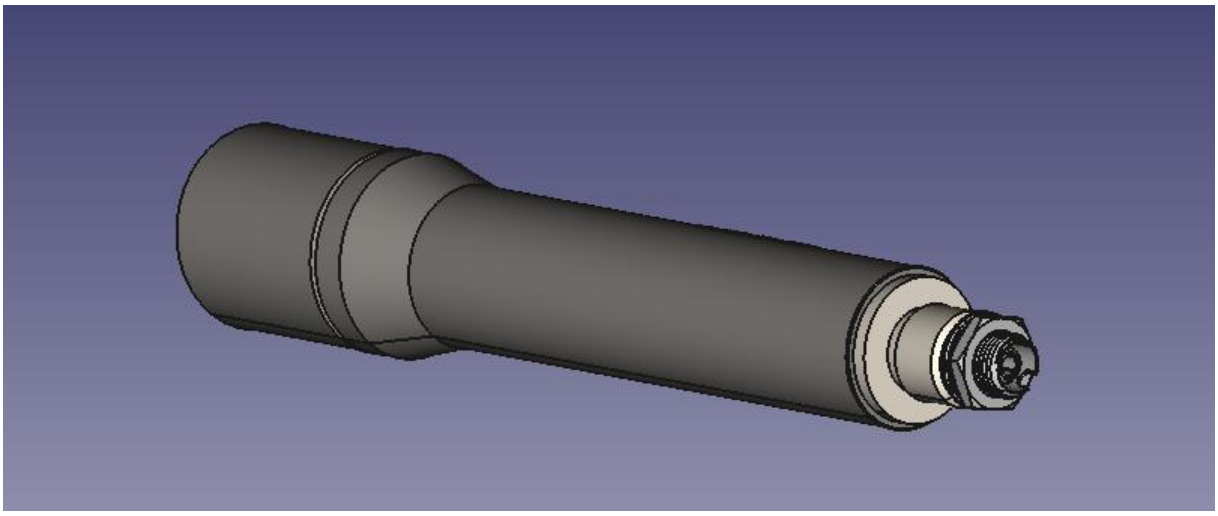
* Arduino UNO

* Bluetooth slave client

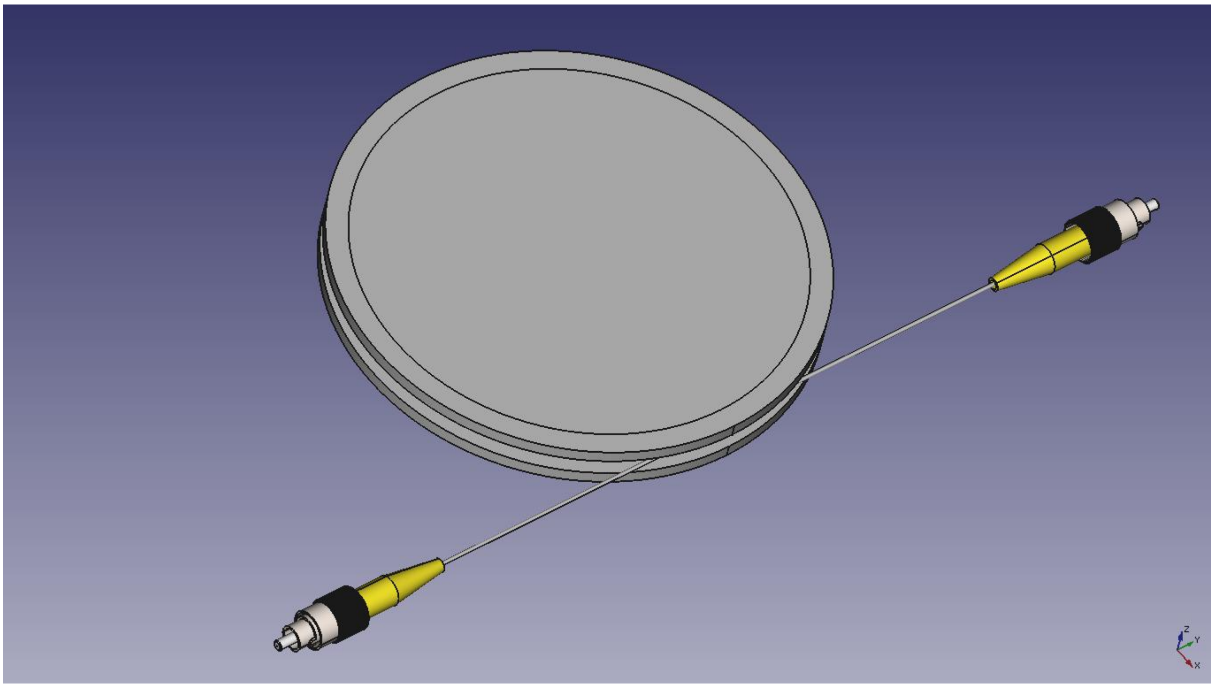
* Resistor 10k ohm

* Photodiode

ii.4. Laser [TBD]



ii.5. Polarisator [TBD]



5.2 FOG

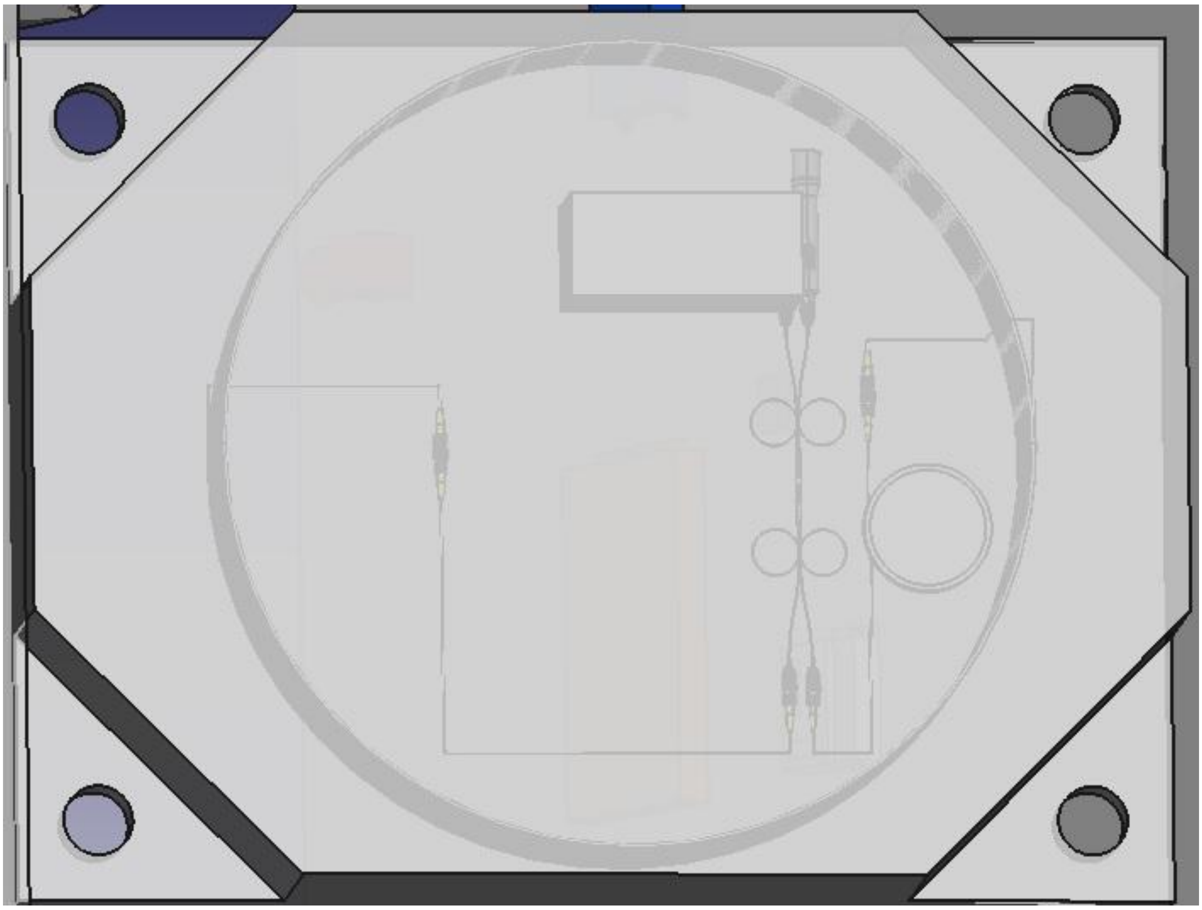


Fig.: FOG Sensor

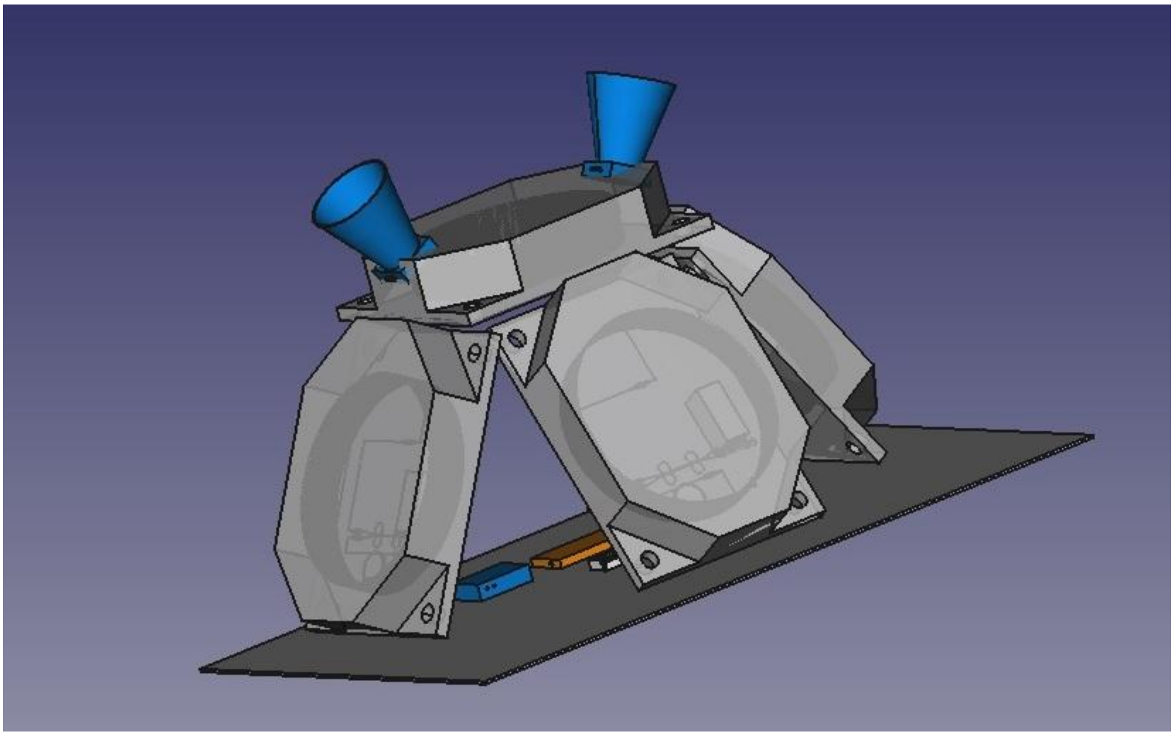
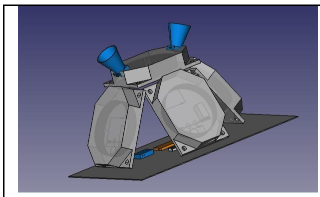


Fig: FOG integration in satellite (4 FOG sensors)

5.3 FreeCAD files

	081016IAP-SAT_Integration.FCStd

5.4 References:

[1]: https://en.wikipedia.org/wiki/Sagnac_effect

Useful links:

- https://www.youtube.com/watch?v=AwcQsbgy7AY
- http://laserpointerforums.com/f42/diy-homemade-laser-diode-driver-26339.html
- regulator: https://www.youtube.com/watch?v=IjJWWGPjc-w
- http://www.instructables.com/id/How-to-Build-a-Bench-Top-Power-Supply/
- http://www.instructables.com/id/How-to-build-a-laser-general-guide/

We can buy diode laser from: http://www.ekt2.com/EKT/Educational/Led_AND_Laser/Laser/

5.5 Ordered Materials (Oktober 2016)

- Single or Multi mode fiber optic cable (100 m) with FC/PC connectors.
- Fiber optic coupler 2x2 with FC/UPC connectors.
- Single Fibre Collimator with FC/PC Connector
- FC/PC to FC/PC Adapter and FC/APC to FC/PC Adapter

BYNET **Shenzhen Bynet Communication Technology Co., Ltd**

Add: 3/F, Building 7, Jiayiyuan Science and Techo. Park, Hua ning Road, Dalang, Longhua Town, Shenzhen, China, 518109
Tel: 86-755-33673743 Fax: 86-755-33673745
E-mail: sales13@szbynet.com Website: www.szbynet.com

Proforma Invoice

Invoice No.:
Buyer:
Add.:
Attn:
Tel:

Invoice Date: 14/Oct/2016
Shipping Date:
Shipped by:
Destination: Lebanon
P/O NO.

No.	Item Number	Goods and Description	QTY (PCS)	U/PRICE (USD)	T/PRICE (USD)
					PRICE TERM: FOB SHENZHEN
	1	Optical Fused Coupler FBT 2x2/ mini module Fiber Optical Splitter	4	4.28	17.10
	2	Fiber optical FC/PC to FC/PC Adapter and FC/APC to FC/PC Adapter	10	0.35	3.53
	3	patch cord cable single-mode simplex 3 mm 100m with FC/PC Connectors	5	6.42	32.10
	4	Single Fiber Collimator with FC/PC connector/ferrule	4	3.20	12.80
	5	shipping fee			95.78
TOTAL					161.31

TOTAL: SAY USD SEVENTY THREE DOLLAR AND SIXTY TWO CENT

Payment term: 30 days credit date of invoice

1. Payment to the seller's following account when order confirmation:
BENEFICIARY: OVEROCEAN PHOTONICS TECHNOLOGY LIMITED
ACCOUNT NO.: 2204593108001
ACCOUNT BANK: Wing Hang Bank (China) Limited Shenzhen Branch
BANK ADDRESS: 5F, Shun Hing Square,Di Wang Commercial Centre,No. 5002, Shennan Road East,Shenzhen China
SWIFT CODE: WIHBCNBXSZB

2. Bynet will only be held liable for local bank charges only.

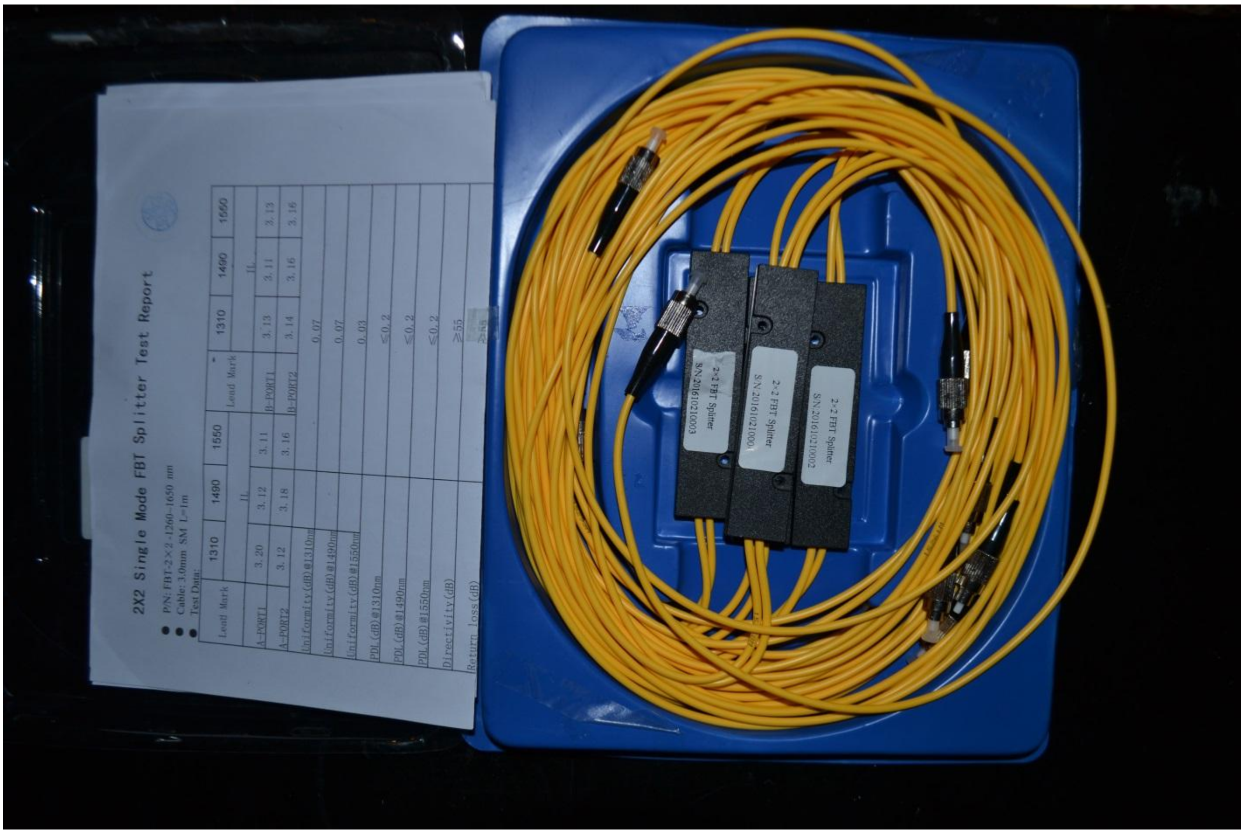
Buyer: **Seller: Shenzhen Bynet Communication Technology Co., Ltd**

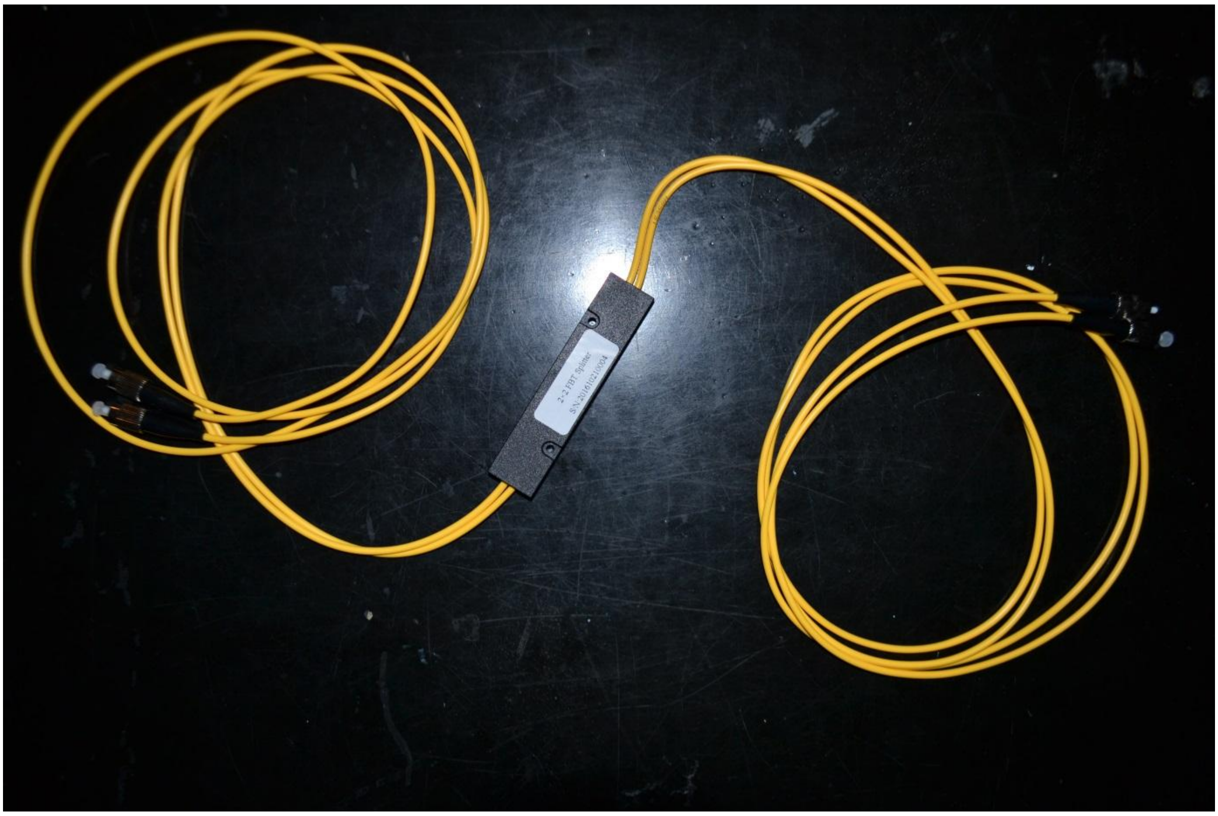
Authorized Signature Authorized Signature

Additionnally: Customs (in Lebanon: about 60$) (about 100% of original material cost without shipping)

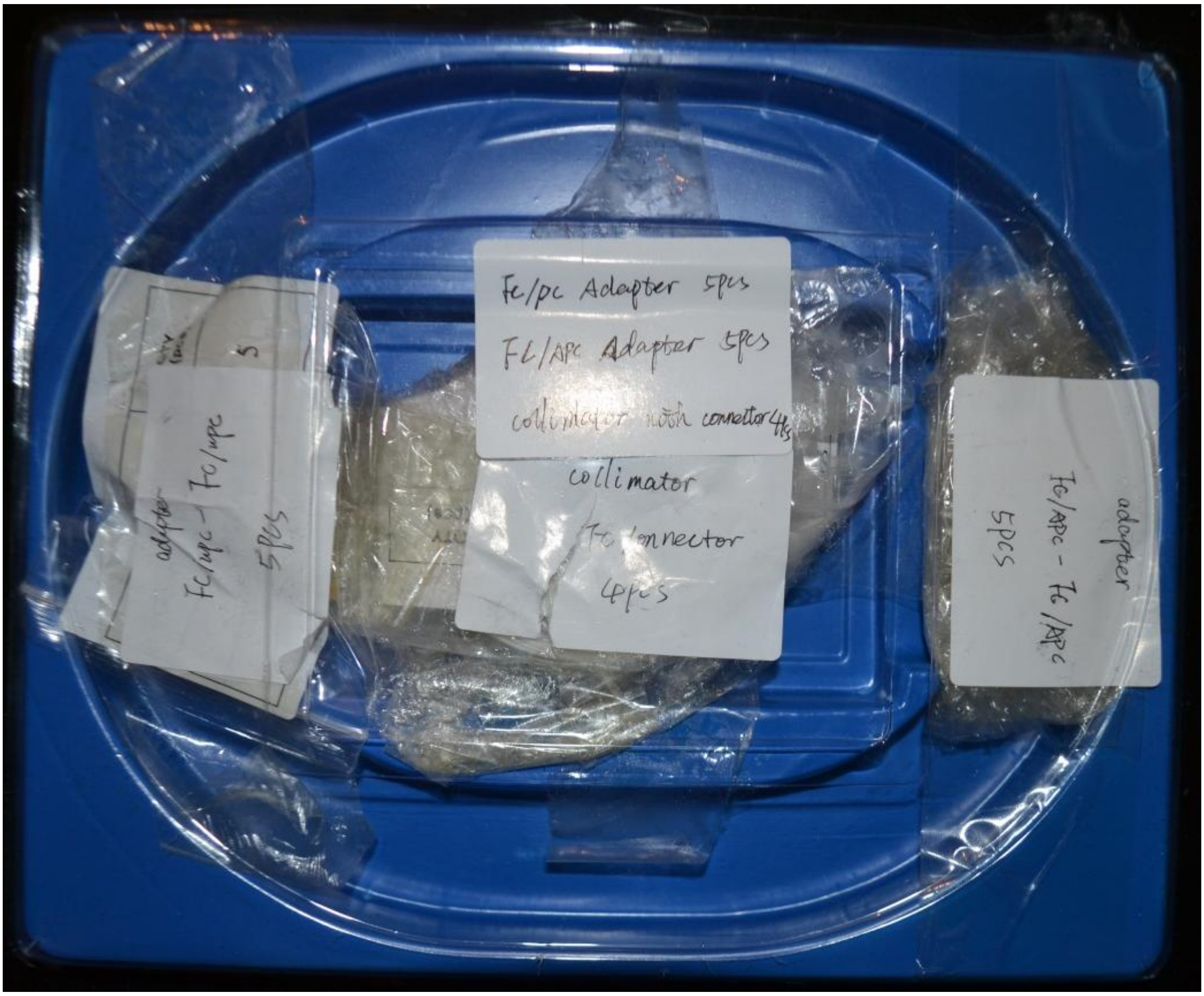
5.5.1.1 Fiber optic cable

5.5.1.2 Fiber optic coupler





5.5.1.3 Single Fibre Collimator and FC/PC to FC/PC Adapter


Fc/pc Adapter 5pcs
FL/APC Adapter 5pcs
collimator with connector 4pcs
collimator
Fc connector
4pcs

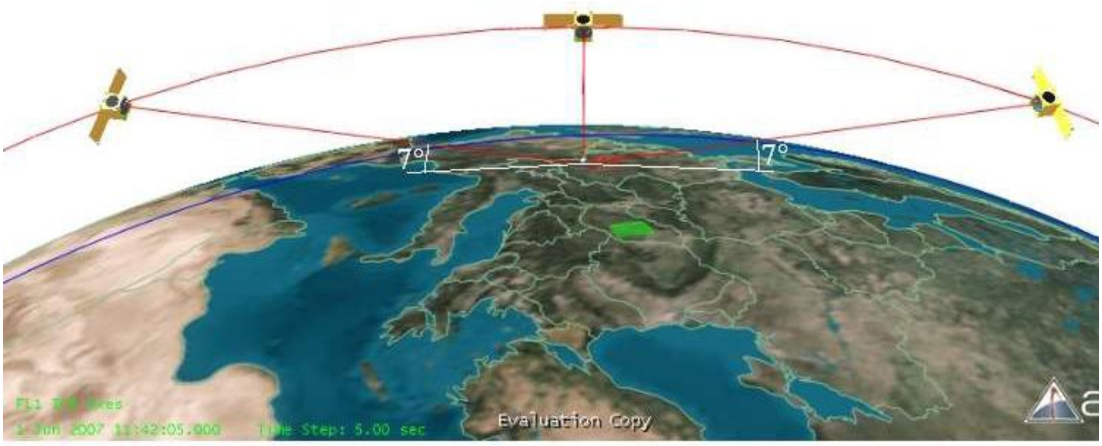

Goods and Description
QTY (pcs)
Fiber optical FC/APC to FC/PC Adapter
5
Goods and Description
QTY (pcs)
4
QTY (pcs)
5

5.5.1.4 Packed


PATCH CORD

6 Next working packages

- Star Camera
- Tracked Downlink (fixed direction to receiver station)



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

- Mission Simulation of Orbitting IAP-SAT with scilab

7 Suppliers Data

7.1 Electronics

- قطرنجي للإلكترونيات EKT Beirut
  - Number: 01 820020
  - Website: www.ekt2.com
- Bashir electronics - البشير للإلكترونيات

7.2 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.

7.3 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.

7.4 3D Printing (Plastics)

http://www.cnclablb.com/

7.5 تصنيع قطع (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