بسم الله الرحمن الرحيم

AS-COMSAT-1 – Technical Development Documentation

Requirements, SystemDesign, Mech/HW/SW Design&Realization, Off-the-shell/supplier parts, System Integration&Testing

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Anadolu-Sham COMSAT

Communication Platforms & Satellite Communication Systems

https://ascomsat.itechf1.com/

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Content

1 Requirements Database (RDD)

1.1 System Requirements

1.1.1 Orbit Specification, Number of required satellites[1]

For AIS application:

- 650 km altitude, elliptic semimajor axis a = 7027.748 km
- 10 minutes per satellite visibility - > 10 satellites
- - > 10 satellites
- - inclination: 100° - 127°

1.1.1.1 Analysis of required number of satellites, inclination und height

The ground station can receive AIS signals in a radius of 40-40 km when using an antenna 15 m above sea level. However, Terrestrial stations placed on a higher altitude may be able to extend the radius and get the signal from to 70-100 km subject to some other factors like weather, elevation, external antenna, and obstacles around it (1).

The altitude of the station antenna plays an important role to get better reception. Base stations in higher elevation extend the range and provide efficient reception and get signals from distant ships and vessels.

However, terrestrial network is not yet efficient for vessel tracking services because of its limitations considering seas and oceans. They are inevitable to be used in ports for clustering, traffic management, path prediction, identification and to get better understating of the current situation at ports and coastal areas.

But when going far into the open sea, it is hard to get the overall picture of what is going on there using terrestrial network-based receivers, but it does help in navigation for the vessels themselves and ensure the safety of the ships by providing collision avoidance solutions so the ships will be aware about each other and the location of each vessel. Thus, this can only work in coastal zones and ship-to-ship zone.

Satellite based AIS data can be more useful in the seas and oceans when no terrestrial base station can be found to receive and analyze AIS signals. It can provide a global and yet complete picture of the world's maritime network.

When satellites are used to handle these data, term S-AIS is used. While terrestrial network can be ideal solution for real-time vessel tracking and positions coverage at thousands of coastal areas and ports, satellites are promising solution to the next generation the AIS devices which need to be improved also to work better with the satellite-based networks. Because current AIS devices can not make better use of all the solutions, features and functions that satellites can provide.

CubeSat AIS receivers can be used to detect AIS signals in LEO orbit at the altitude of 650km (2). Satellites in higher altitudes may suffer from the propagation, AIS packets collision due to

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[1] [5]

Faraday effect which causes the signal's polarization plane to rotate subject to the elevation angle and magnetic flux intensity. Doppler effect also makes the signal to overlap. Hence, the detection probability has to be at its highest which can be obtained by satellites operating in LEO.

Orbital Period

The orbital period is defined by the time taken by an astronomical object to rotate in its orbit around another for one complete revolution.

A satellite's period is the amount of time it takes to make one full orbit around a planet, Earth. If the satellite is placed high above the surface of the planet, it will take a long time to complete its orbit. However, if the satellite gets closer to the surface of the planet, or to a lower altitude, it will take less time to complete its revolution - and its period will be shorter.

The time needed for a satellite for one period in the orbit is given by the formula:

$$T= \frac{2\pi}{\sqrt{\mu}}(R_e+z)^{3/2}$$

Where μ is the gravitational constant for the Earth equal to 398600 km3 /sec2.

- Re is Earth's equatorial radius 6378 km.

- z is the altitude.

Thus, a satellite launched into a sun-synchronous circular orbit with altitude 650 km will need a period of 97.72 minutes.

The period determines the semimajor axis a:

$$T= \frac{2\pi}{\sqrt{\mu}}(a)^{3/2}$$

Thus, the semimajor axis for the altitude 650 km and period 97.72 minutes is:

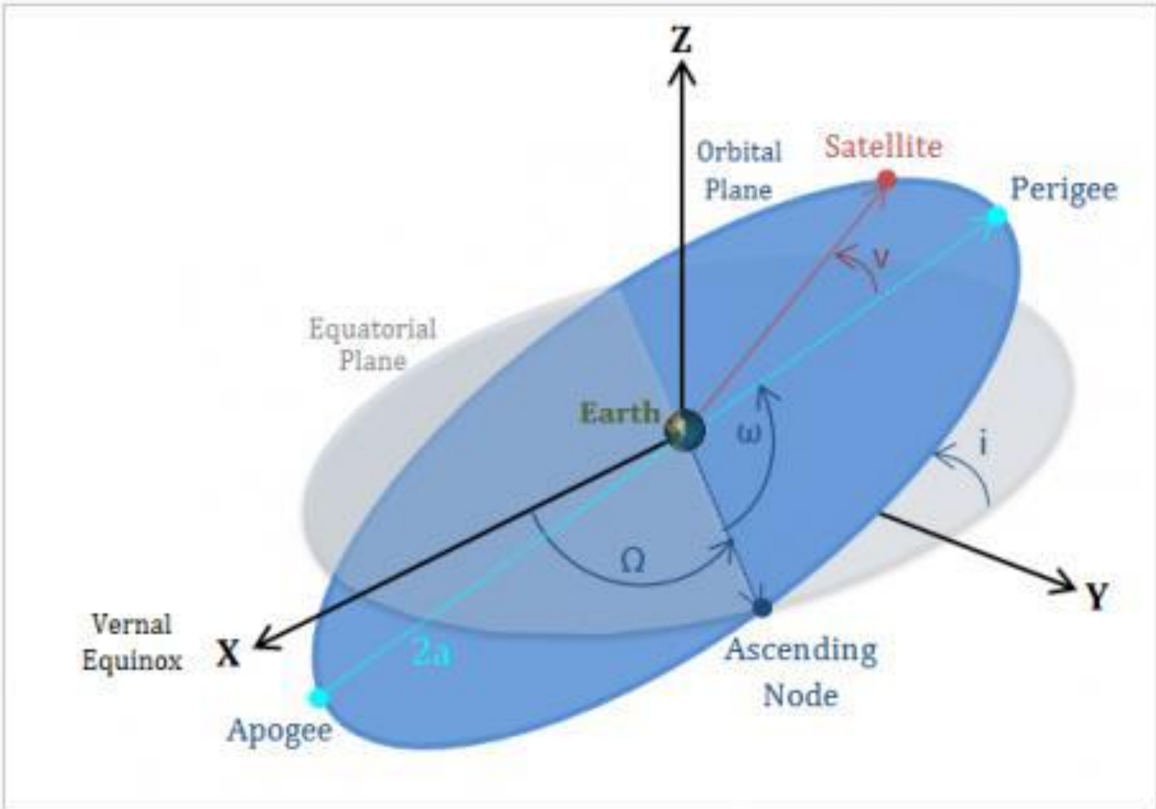
a= 7027.748766 km

Inclination Angle

The angle of inclination is the angle between the reference plane and the direction axis. It is an orbital element that determine the shape and direction of astronomical orbits.

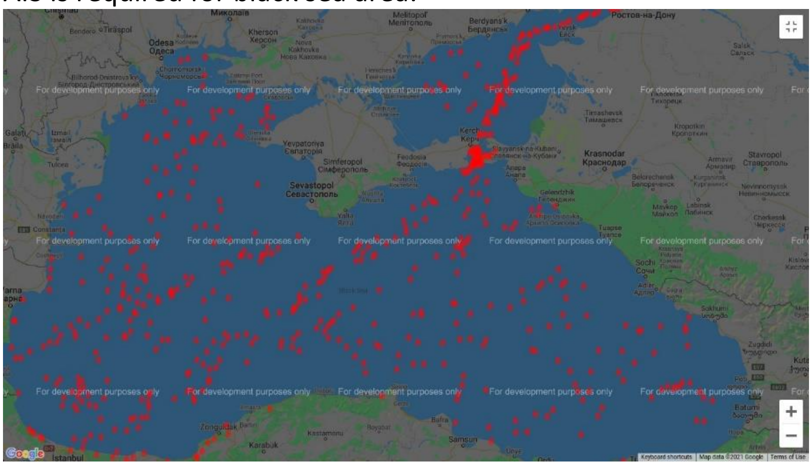
Description	The orbit plane of a satellite that rotate around the Earth straight above the equator line is the same as the equatorial plane of the Earth, and the orbital inclination in this case is 0°. **Inclination Angle**
The orbital object has a prograde orbit in the equatorial plane of the planet.	0°
Prograde orbit but not as same as the equatorial plane.	$0° < \propto < 90°$
Polar orbit, satellite passes over the poles of the planet.	90°

Critical inclination, zero apogee drift in elliptical orbits.	63.4°
Retrograde orbit, in which the satellite's position on the equatorial plane is projected in the opposite direction of the Earth's rotation.	90°<∝<180°
Retrograde equatorial orbit.	180°



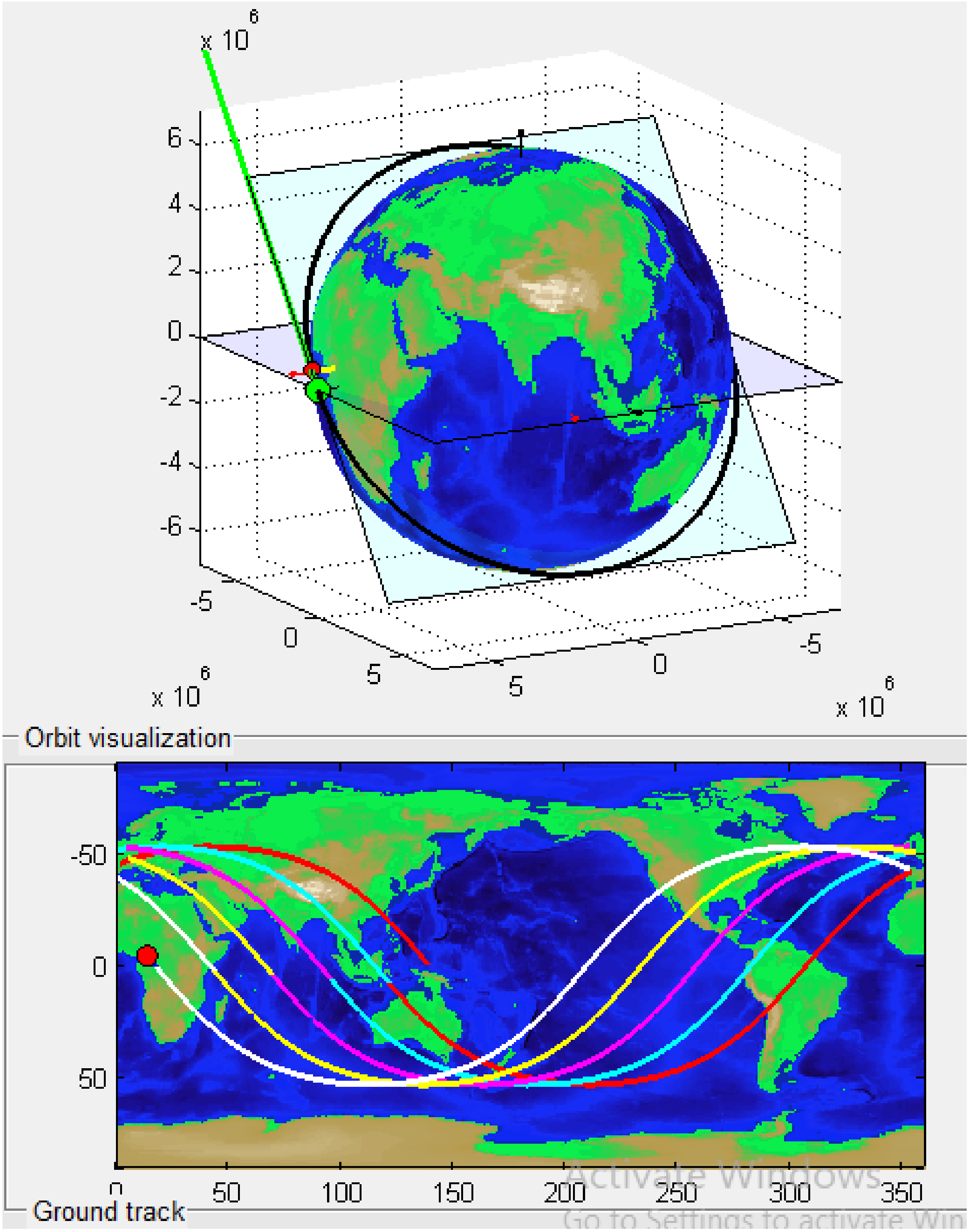
Orbital plane with its inclination (i) with respect to the equatorial plane, right ascension of the ascending node (Ω), argument of Perigee (ω) and true anomaly (v). The vernal equinox, the ascending node, the perigee and the equatorial plane are represented.

AIS is required for black sea area:



Considering Black Sea area, polar sun-synchronous orbits with 127° inclination at altitude 650 km and semimajor axis of 7027.748766 km with a revolution period of approximately 97.72 min is by far accepted to handle AIS data from this area.

Below, is a graph with five periods of the calculated orbital elements



1: The automatic identification system (AIS) : a data source for studying maritime traffic : The case of the Adriatic Sea. Arnaud Serry, 2017

2: Design of Automatic Identification System (AIS) Receiver for Low Earth Orbit (LEO) Satellite

Analysis with MATLAB AddOn “sat-lab”:

SAT-LAB: A MATLAB Graphical User Interface for simulating and visualizing Keplerian satellite orbits

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INTRODUCTION

SAT-LAB is a MATLAB-based Graphical User Interface (GUI), developed for simulating and visualizing satellite orbits. The primary purpose of SAT-LAB is to provide a software with a user-friendly interface that can be used for both academic and scientific purposes. The calculation of the satellite state vector (position and velocity) is done using a Keplerian propagator. After selecting the six Keplerian elements, the computation and visualization of the satellite orbit is performed simultaneously and in real time. Both the satellite orbit and the state vector at each epoch are given in two reference frames, i.e., the Inertial Reference Frame (IRF) and the Earth-Fixed Reference Frame (EFRF). For the EFRF, both the 3D Cartesian coordinates and the ground tracks of the orbit are provided. Other visualization options include selecting the appearance of the coastline, topography/bathymetry, satellite orbit, position, velocity and radial distance, and IRF and EFRF axes. SAT-LAB is also capable of visualizing orbits of operational satellites and real-time tracking of their position.

CURRENT LIMITATIONS

SAT-LAB users should use the current version only for educational purposes or for low-accuracy simulations of satellite orbits. Scientific usage is not yet advised. Satellite positions are calculated with an accuracy of several kilometers due to the following limitations:

- A Keplerian propagator is used, which cannot accurately describe the motion of a satellite orbiting a planet, especially in a low orbit. In low orbital altitudes, planet flattening and non-gravitational forces highly affect the satellite orbit.
- Two-line element (TLE) ephemerides are used for the computation and real-time tracking of operational satellites. Although TLE ephemerides provide the six Keplerian elements, they are suitable for use only with simplified perturbation models (e.g., SGP, SGP4, SDP4, etc.) and not with a Keplerian propagator. Even using simplified perturbation models, the accuracy of the satellite position using TLE ephemerides can reach several kilometers per day.
- Only the Earth's rotation is taken into account for the transformation of satellite position and velocity from IRF to EFRF. Formally, precession, nutation and polar motion effects should be taken into account as well.

SOFTWARE DESCRIPTION

The SAT-LAB GUI is presented in Figure 1. The main form consists of the 9 elements provided below, following the same numbering as in Figure 1:

1) Menu bar, which contains the “Satellite Data” menu and two submenus that allow the user to download orbital data from operational satellites and access their orbital elements, as well as other information.
2) “Inertial Reference Frame” panel, which shows the satellite orbit in the IRF.
3) “Earth Fixed Reference Frame” panel, which shows the satellite orbit in the EFRF.
4) “Earth Fixed Reference Frame (Ground Tracks)” panel, which shows the satellite orbit in the EFRF after converting the 3D Cartesian coordinates of the satellite to geodetic coordinates.
5) “Select Keplerian elements” panel. When the user selects or changes the Keplerian elements, SAT-LAB produces and simulates the orbit in real time.
6) “Select appearance” panel. The user can control which orbital and geometric components should be shown and can select their color. The changes are implemented in real time.
7) “Select resolution” panel. The user can define the spatial resolution of the topography/bathymetry (terrain), coastline and day/night map (for real-time positioning of operational satellites). For optimal performance, a medium resolution is recommended.
8) “Select satellite” panel. The user can select the orbit and real-time position of selected operational satellites.
9) “Animation” panel. Selecting at least one reference frame and clicking on the “Animate orbit” button, SAT-LAB produces an animation of the current satellite orbit.

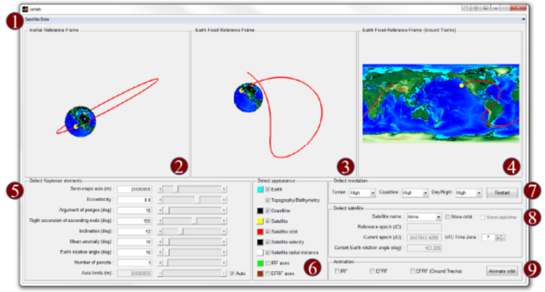

Figure 1 – SAT-LAB main form

ORBIT SIMULATION AND VISUALIZATION

Orbit simulation and visualization examples using SAT-LAB are given in Figures 2 to 5. The following types of orbits are presented:

- Geostationary orbit. A geostationary orbit is considered a special case of geosynchronous orbit. A satellite in geostationary orbit has a period of 1 sidereal day, an inclination of 0° (equatorial orbit) and an angular velocity equal to the Earth's angular rate.
- Tundra orbit. Tundra orbit is a geosynchronous, elliptical orbit with an inclination of 63.4°.
- Molniya orbit. Molniya orbit is an elliptical orbit with an inclination of 63.4°, an argument of perigee of 270° and a period of 0.5 sidereal days. A satellite in Molniya orbit spends the majority of its orbit in the northern hemisphere and, therefore, Molniya orbit is suitable for satellite observations over North America, Russia and northern Europe.
- Low Earth orbit. Low Earth orbit is any satellite orbit with an altitude of 200-2000 km. Earth observation satellites, such as altimetry and gravimetry satellites, are orbiting in low Earth orbits.

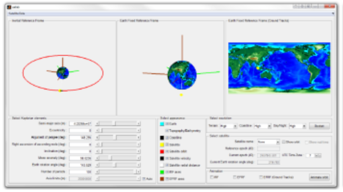
Figure 2 – Geostationary orbit

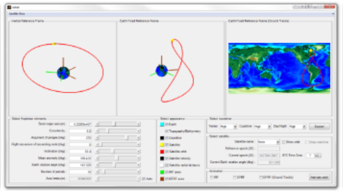
Figure 3 – Tundra orbit

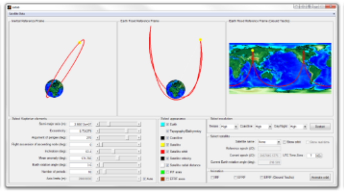
Figure 4 – Molniya orbit

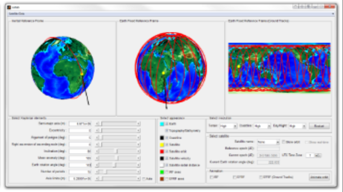
Figure 5 – Low Earth orbit

ORBIT VISUALIZATION OF OPERATIONAL SATELLITES

SAT-LAB provides the ability to download Keplerian elements and other information of operational satellites in the form of TLE ephemerides from https://celestrak.com/. The user can choose among the 41 satellite categories presented in Figure 6. Figure 9 provides the TLE information for GRACE-1 satellite. Here, the orbit of the following satellites is chosen to be visualized using SAT-LAB:

- LAGEOS 1 (Figure 7). LAGEOS is a satellite mission dedicated to providing geodetic and geodynamic data using the method of satellite laser ranging. The LAGEOS 1 satellite is a sphere of 60 cm diameter with 426 reflectors on its surface. LAGEOS 1 was lunched in 1976 and has an orbital altitude of 5860 km and an inclination of 109.84°.
- BEIDOU IGSO 2 (Figure 8). BEIDOU is the navigation satellite system of China, currently consisting of 21 operational satellites. The BEIDOU IGSO 2 satellite was launched in 2010 and operates at an altitude of 35700 km with an inclination of 55°.
- GPS BIIF-1 (Figure 10). GPS is a navigation satellite system operated by the U.S Department of Defense and currently consists of 31 operational satellites. The GPS BIIF-1 (PRN 25) satellite was launched in 2010 and has an altitude of 20000 km, an inclination of 55° and a period of approximately 12 hours.
- GRACE-1 (Figure 11). The GRACE satellite mission is designed to observe the temporal variations of the Earth's gravity field. GRACE-1 was launched in 2002 in a low Earth, circular and near-polar orbit.

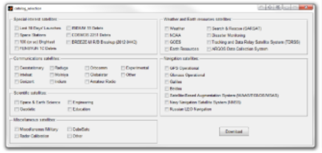
Figure 6 – Satellite catalogs

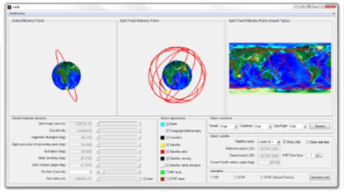
Figure 7 – Visualization of LAGEOS 1 satellite orbit

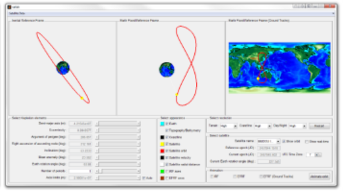
Figure 8 – Visualization of BEIDOU IGSO 2 satellite orbit

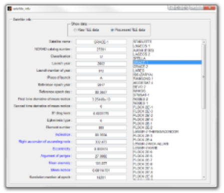
Figure 9 – Satellite information

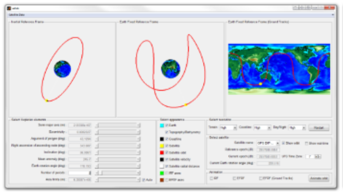
Figure 10 – Visualization of GPS BIIF-1 satellite orbit

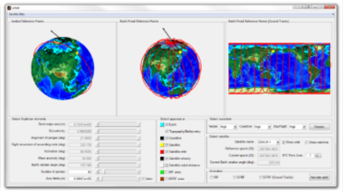
Figure 11 – Visualization of GRACE-1 satellite orbit

REAL-TIME SATELLITE TRACKING

The capability of real-time tracking of operational satellites is also implemented in SAT-LAB. Accurate real-time satellite tracking is possible only when the correct date/time settings and UTC time zone are selected by the user, depending on their location. A day and night map is also calculated and superimposed only for real-time satellite tracking. Examples of real-time tracking of GRACE-1 and International Space Station (ISS) satellites are given in Figures 12 and 13, respectively. The satellite position can be visually compared with results obtained from http://www.heavens-above.com/ , for both cases.

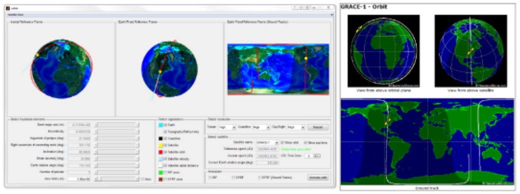

Figure 12 – Real-time tracking of GRACE-1 by SAT-LAB (left) and heavens-above.com (right)

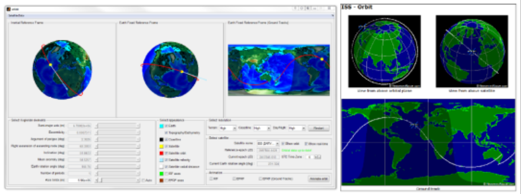

Figure 13 – Real-time tracking of ISS by SAT-LAB (left) and heavens-above.com (right)

SUMMARY

- The SAT-LAB software provides a friendly and easy-to-use GUI for orbit simulation, orbit visualization and real-time tracking of operational satellites.
- SAT-LAB is developed using MATLAB R2012 and tested in later releases (i.e., R2013a) in both 32- and 64-bit operating systems. Overall, SAT-LAB consists of 20 .m files (17 functions and 3 script files).
- The current version of SAT-LAB is suitable for educational purposes and low-accuracy orbit simulations only.
- More rigorous approaches to satellite orbit simulation and, possibly, more visualization options will be implemented in future releases of SAT-LAB.
- SAT-LAB is freely available for download at http://www.dimitriospiretzidis.com/satlab_home.html .

REFERENCES

Heavens-Above. http://heavens-above.com/. Accessed 3 Apr 2017a
CelesTrak. https://celestrak.com/. Accessed 3 Apr 2017b

EGU General Assembly 2017, Vienna, Austria, 23 – 28 April 2017

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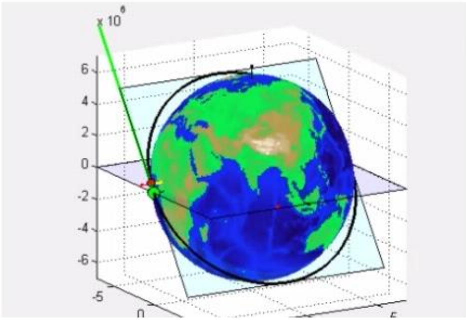
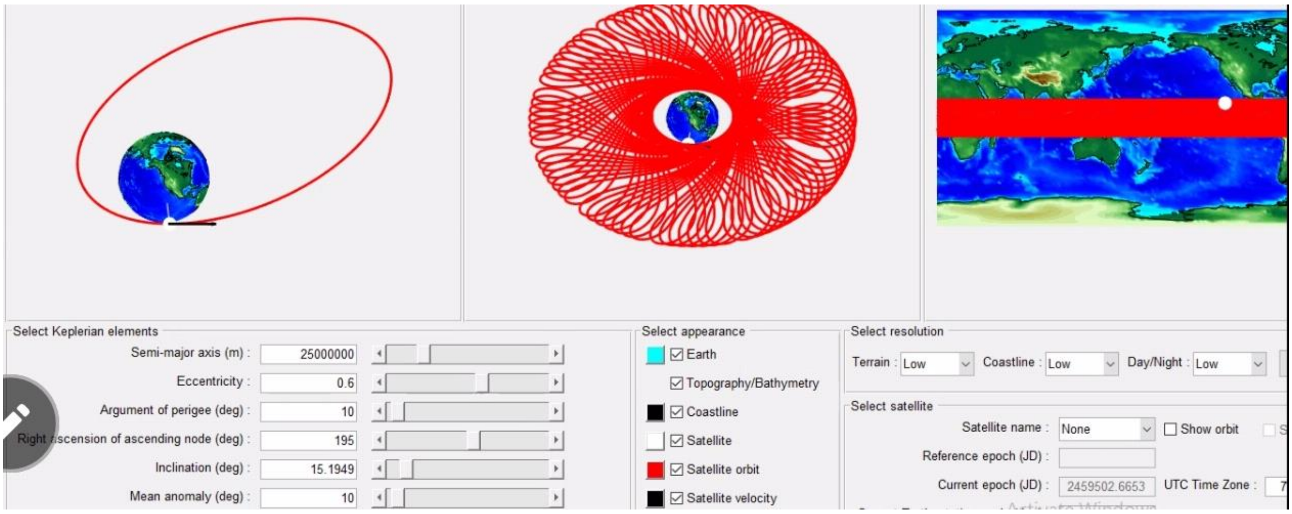
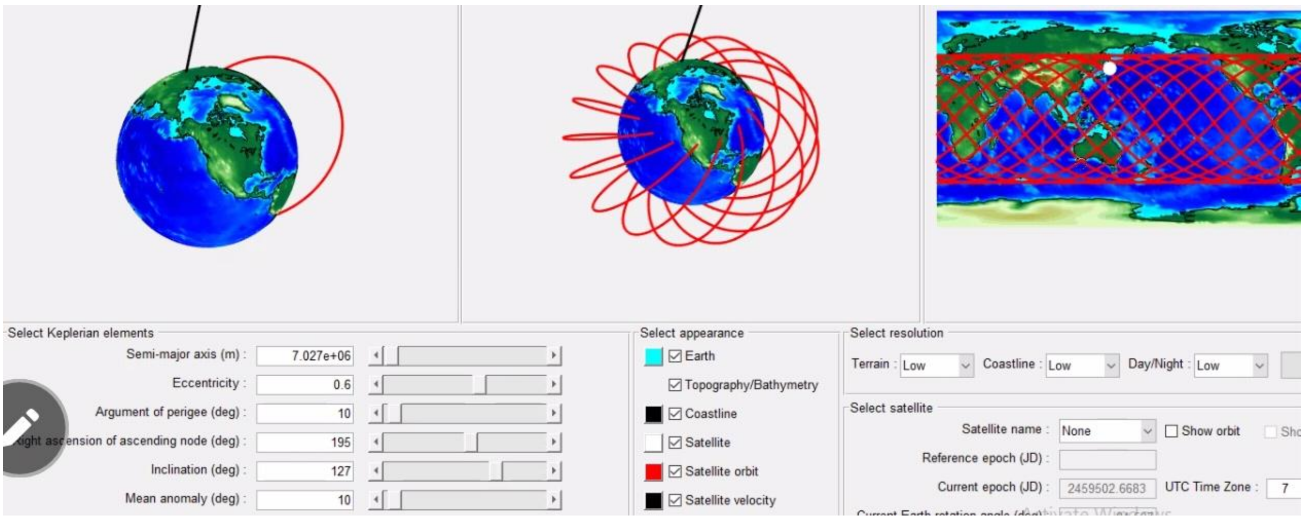






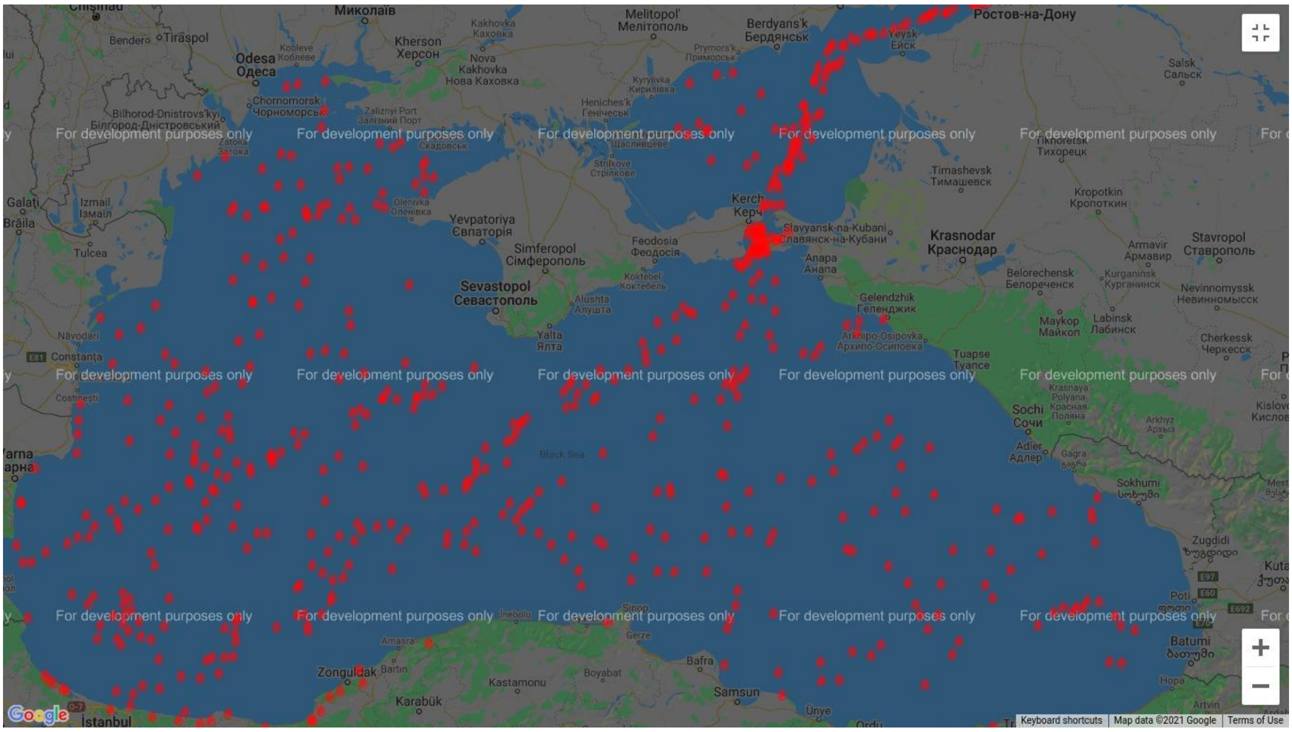
1.1.2 Mission purpose and Payload

1.1.2.1 X-Ray sensor

[SRQ 20] There shall be an astronomical x-ray sensor on board.

1.1.2.2 Satellite based AIS system

[SRQ 30] There shall be a AIS transponder system on board for coordinating AIS signals from ships in the black sea.



Tasks:

- Satellite Footprint investigation to know how many visible satellites we need for AIS for black sea

Result: Requirements for satellite system:

- Orbit height: 500-600 km (over 600 km we get problems with AIS signals)
- Sun-synchronous orbit (restriction from launcher)
- Inclination: ?

For AIS application:

- 650 km altitude, elliptic semimajor axis a = 7027.748 km
- 10 minutes per satellite visibility - > 10 satellites
- - > 10 satellites
- - inclination: 100° - 127°
-

1.1.3 ACS

[SRQ60] Shall be low cost. For this reason only magnetorquer and sun-sensor is shall be used.

1.1.4 TT&C System

[SRQ10] TT&C shall be realized with the same hardware card as payload COM

OBC -> TT&C/COM transceiver (SDR) -> flat antenna

		
On-Board Computer (RaspberryPi)	HackRF SDR Card	Antenna

2 System Design Document (SDD)

2.1 On-Board Telemetry, Tracking & Control (TT&C)

2.1.1 Overview - Bottum-Up Approach

[SRQ10] TT&C shall be realized with LimeSDR Mini.

2.1.2 Transceiver Card

[SRQ50] The Transceiver Card has to be maximum 10 cm x 10 cm x 1 cm.

2.2 Telemetry, Tracking & Control (TT&C) Ground Station

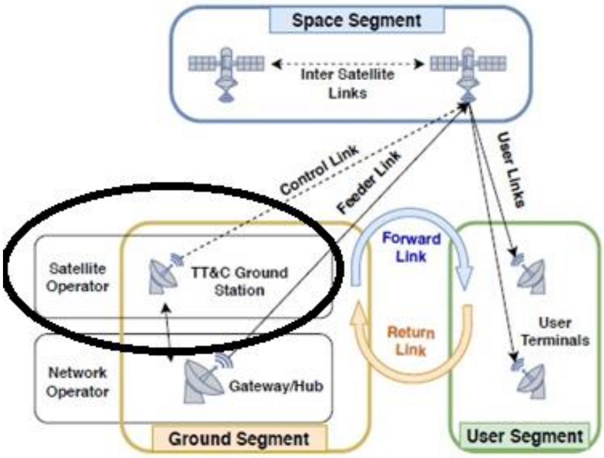
2.2.1 Bottum-Up Approach

At ground station the off-the-shell HackRF is suitable.

OBC -> TT&C/COM transceiver (SDR) -> flat antenna

		
On-Board Computer (RaspberryPi)	HackRF SDR Card	Antenna

2.2.2 Requirements (A DESCRIPTION OF A STANDARD SMALL SATELLITE GROUNDSTATION FOR USE BY WMO MEMBERS [4])



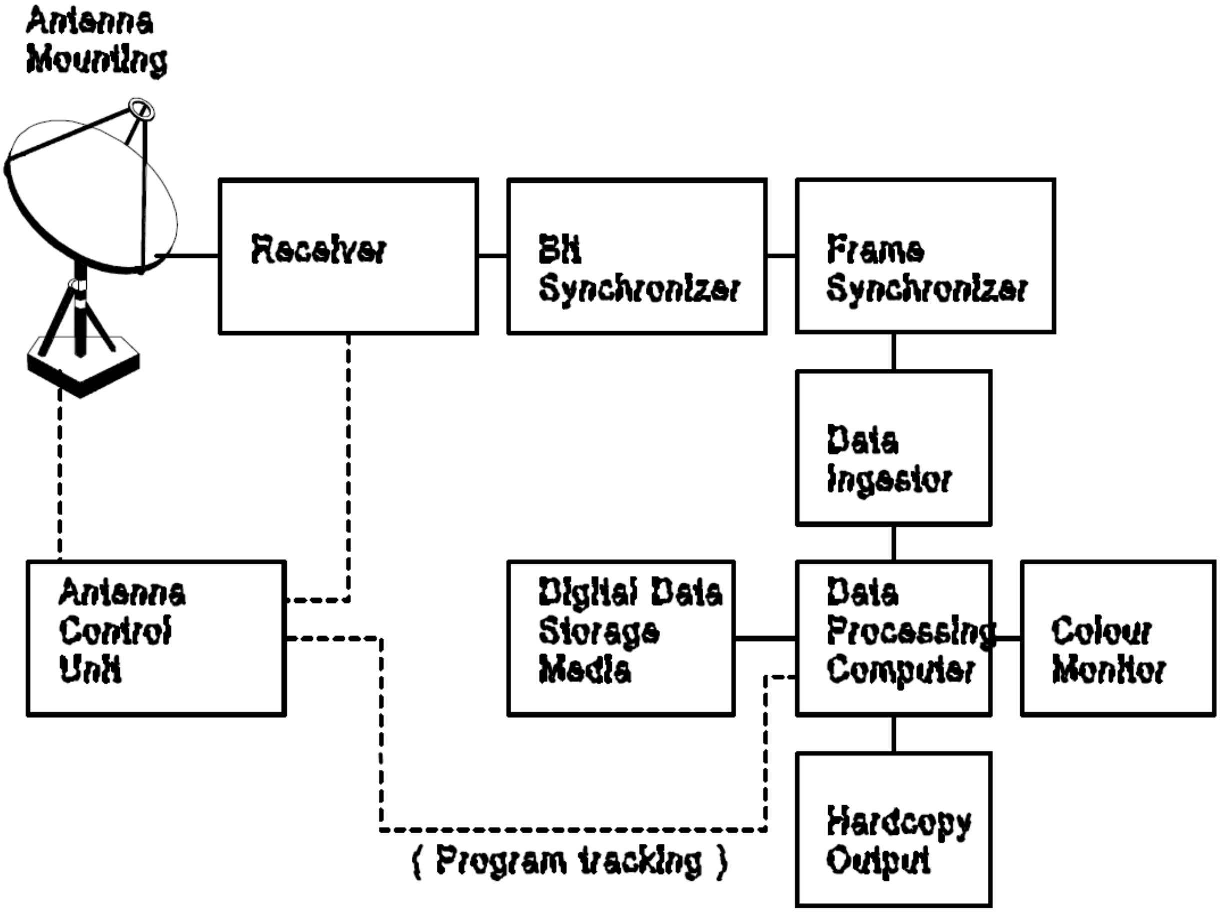


Fig.1 Block Diagram of a small satellite ground station

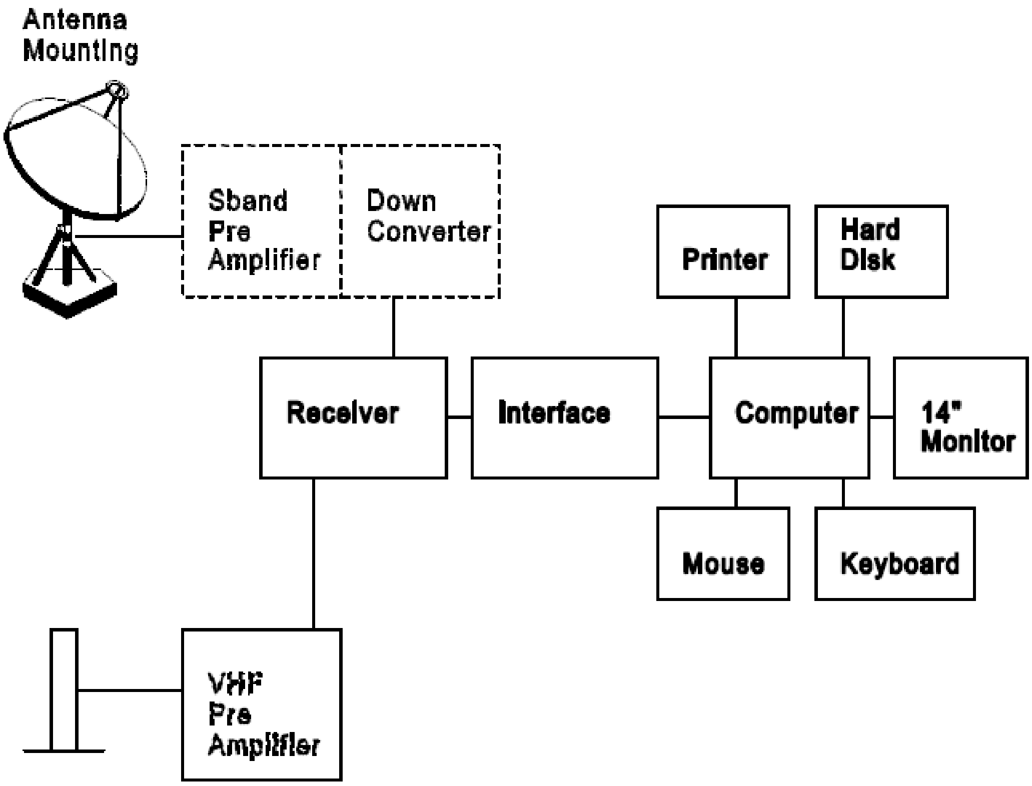


Fig.2 APT/WEFAX Receiving and Processing Station

5.1.1 S-band parabolic antenna

5.1.1.1	Diameter of antenna:	: 1.5 m
5.1.1.2	Gain	: 26.0 db
5.1.1.3	Beamwidth	: 8.1°
5.1.1.4	Frequency	: 1691.0 MHz
5.1.1.5	Polarization	: linear
5.1.1.6	Mount	:fixed, variable adjust, elevation 90°, azimuth (20° - 70°)
5.1.1.7	VSWR	: 1.5
5.1.1.8	Impedance	: 50 Ω

5.1.2 S-band preamplifier and down converter

5.1.2.1	RF input	: 1691.0 MHz
5.1.2.2	IF output	: 137.5 MHz or other
5.1.2.3	Band width	: 6 MHz
5.1.2.4	IF/RF gain	: 30 db
5.1.2.5	Noise figure	: 1.5 db
5.1.2.6	Stability	: 5×10^{-6}
5.1.2.7	Impedance	: 50 Ω
5.1.2.8	Cable length	: 60 m

5.1.3 VHF antenna

To reduce the price and for ease of maintenance, an OMNI directional non-tracking antenna is recommended. An OMNI directional non-tracking antenna must be able to receive data above an elevation of 5°. This requirement will reduce interference while maximizing the possibility for coverage of synoptic scale meteorological phenomena.

<u>OMNI directional antenna</u>

5.1.3.1	Frequency	: 137.5 MHz
5.1.3.2	Polarization	: right hand circular
5.1.3.3	Impedance	: 50 Ω
5.1.3.4	VSWR	: 2.1 max
5.1.3.5	Gain	: 3 dbi
5.1.3.6	Beamwidth	: 180°

Depending on the user's situation and requirements, an omni-directional antenna may not be sufficient for proper APT reception. Under these circumstances, the use of a directional antenna, such as a crossed Yagi, would provide higher performance and greater coverage. Note that use of program tracking and other antenna pointing methods would be required. The following information describes an alternative to the OMNI directional antenna described in sections 5.1.3.1 through 5.1.3.6.

<u>Directional antenna (Yagi)</u>

5.1.3.7	Centre frequency	: 137.5 MHz
5.1.3.8	Polarization	: right hand circular
5.1.3.9	VSWR	: 2.0 max
5.1.3.10	Gain	: 20 dBi or greater
5.1.3.11	Beamwidth	: 20 degrees at 20 dBi
5.1.3.12	Mount	: Elevation over azimuth
5.1.3.13	Program track	: Program track

5.1.4 VHF Preamplifier

5.1.4.1	Centre frequency	: 137.5 MHz
5.1.4.2	Gain	: 30 db
5.1.4.3	Noise figure	: 2 db
5.1.4.4	Installation	: in antenna base

5.1.5 Receiver

5.1.5.1	Type	: FM phase lock loop
5.1.5.2	Input frequency	:Switch selectable crystals for reception of APT and WEFAX
5.1.5.3	IF bandwidth	:50 KHz and 30 KHz --switch selectable
5.1.5.4	Noise figure	: 5 db

5.1.6 Computer

5.1.6.1	486 computer with TVGA card (1024 x 768 resolution)	
5.1.6.2	Colour monitor	:14"
5.1.6.3	Hard disk	: 120 MB
5.1.6.4	Memory	: 4 MB
5.1.6.5	Clock : 33 MHz	
5.1.6.6	Keyboard	
5.1.6.7	Mouse	
5.1.6.8*	Printer (optional)	

5.1.7 Outdoor environment

5.1.7.1	Temperature	: -40° C - +50° C
5.1.7.2	Humidity	: 98%
5.1.7.3	Wind	: operational 20 m/s, survival 35 m/s

5.1.8 Power

5.1.8.1	110v/220v +- 10%
5.1.8.2	50Hz/60Hz

5.2 Specification requirement, for high resolution ground station

The stations should be reliable and easy to operate. The block diagram of the high resolution ground station is shown in Fig.3. If the station receives geostationary satellite data, it should be equipped with a fixed antenna. If the station receives polar orbiting satellite data then it must be equipped with a tracking antenna and antenna control unit.

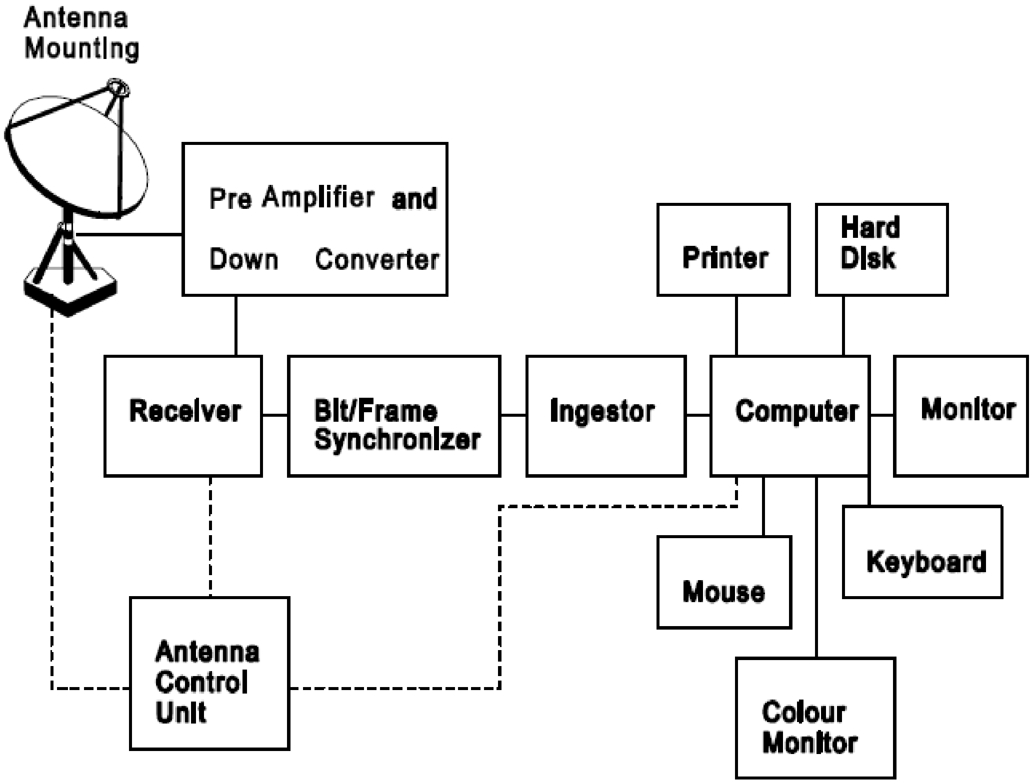


Fig.3 High Resolution Data Receiving and Processing Station

5.2.1 S-band tracking antenna and antenna control unit for receiving HRPT data

5.2.1.1	G/T merit of antenna system	:>6 db/K bit error rate is better than $1x10^{-6}$ at 5 degree elevation
5.2.1.2	Frequency	:1670~1710 MHz
5.2.1.3	Polarization	: RH, LH
5.2.1.4	Impedance	: 50/75 Ω
5.2.1.5	VSWR	: 1.5
5.2.1.6	Antenna mounting	: azimuth-elevation
5.2.1.7	Tracking coverage	: full geometric coverage including overhead passes (Z-pass), good performance of Z-pass tracking

5.2.2 S-band fixed antenna for receiving geostationary satellite

5.2.2.1	G/T merit of antenna system	:G/T depending on which satellite to be received, G/T must guarantee that bit error rate is less then 10^{-6} in the worst case
5.2.2.2	Frequency	: 1670~1710 MHz
5.2.2.3	Polarization	: linear
5.2.2.4	Mounting	: fixed, variable adjust elevation 90, azimuth 20° ~70°
5.2.2.5	VSWR	: 1.5
5.2.2.6	Impedance	: 50/75 Ω

2.2.3 As reference a ground station design from 2007 ([3]):

Abstract of [3] :

The CubeSat satellite ground station at the University of Wuerzburg is built with "commercial of the shelf" low cost amateur radio hardware. It opens up opportunities for students to receive and operate CubeSats, including Wuerzburgs UWE-1. As any other satellite ground station, it is built up on essential hardware, as there are Antenna, Antenna Rotator, Radio, Modem and Computers. Furthermore software is used to afford basic control over the ground station and provide tracking abilities to follow a satellite passing over the ground station.

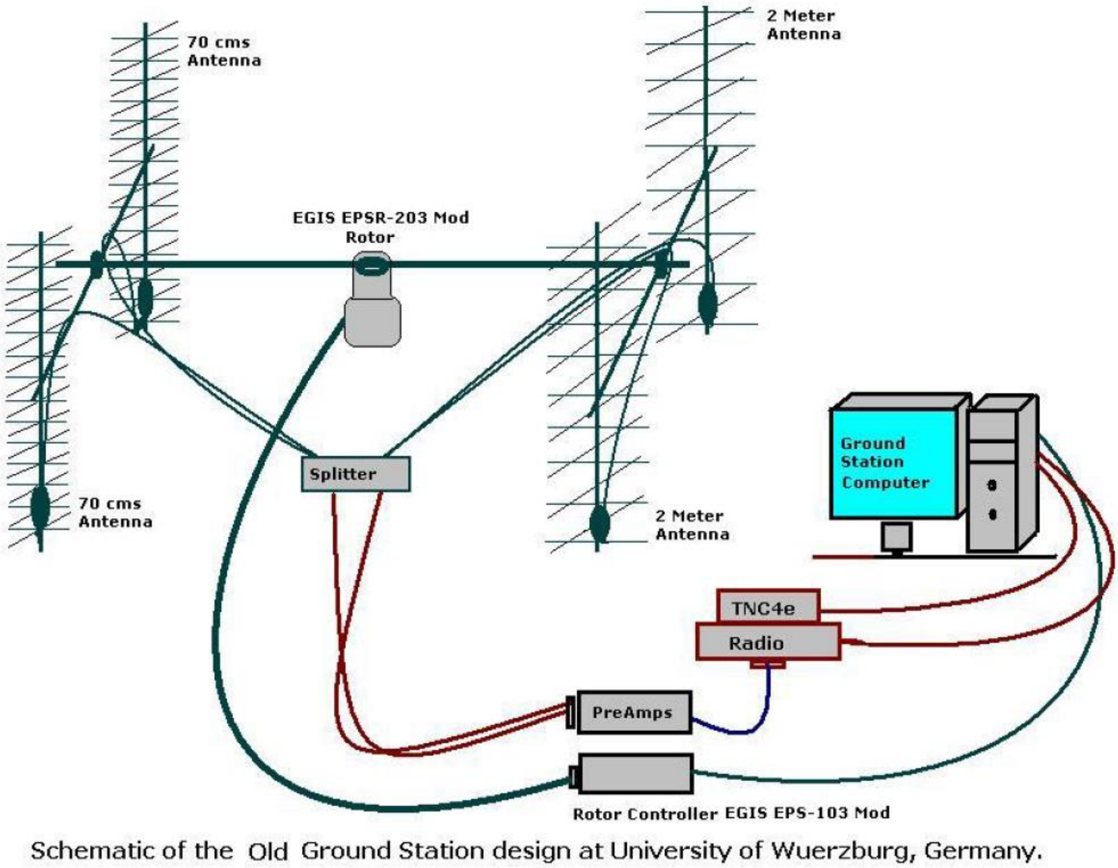
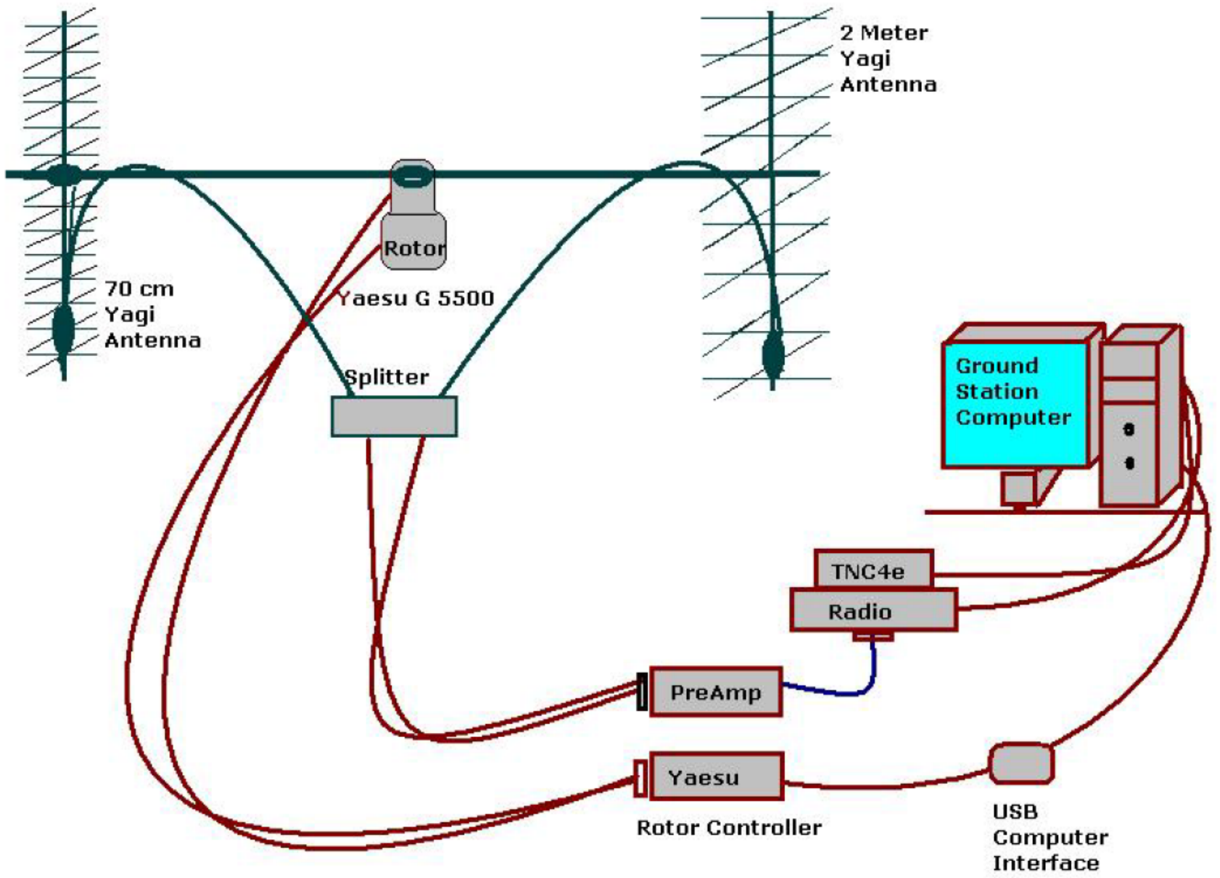


Figure 1.1: Old design of the Ground Station.

Ground Station structural study

Related CubeSat.	**University.**	**Antenna Rotor.**	**Rotor Computer Controller & Tracking Software.**
Delfi-C3	Delft University of Technology	Yaesu G-5500	NOVA for Windows
AAU Cubesat	Aalborg University of Technology	Yaesu G-5500	Predict
CubeSat	University of Arizona	Yaesu G-5500	NOVA for Windows with Uni_Trac
PolySat	California Polytechnic State University, U.S.	Yaesu G-5500	SatPC32
Cubesat	University of Tokyo, Japan	Elevation Rotator ERC5A (Creative Design) Azimuth Rotator RC5A-3 (Creative Design)	Orbital calculation software (Virtual Ground Station 3)
Cubesat	TU-Berlin	Yaesu G-5500	SatPC32 and ARSWIN
---	Kagawa University, Japan	ERC-5A (El) And RC5B-3P (Az)	Satellite Tracker is RAC825
---	Kyusyu University Ground Station.	EMOTATOR EV-800D	No avail info
---	Kyushu Institute of Technology.	Yaesu G-5500	GS-232A
---	Nara National College of Tech, Japan	Yaesu G-5500	GS-232A and Nova for Windows.
---	Soka University Ground Station Unit.	Yaesu G-550 (El) And Yaesu G-2300DXA (Az)	GS-232B

Figure 1.2: Ground Station Structural Study.



Schematic of the new Ground Station design at University of Wuerzburg, Germany.

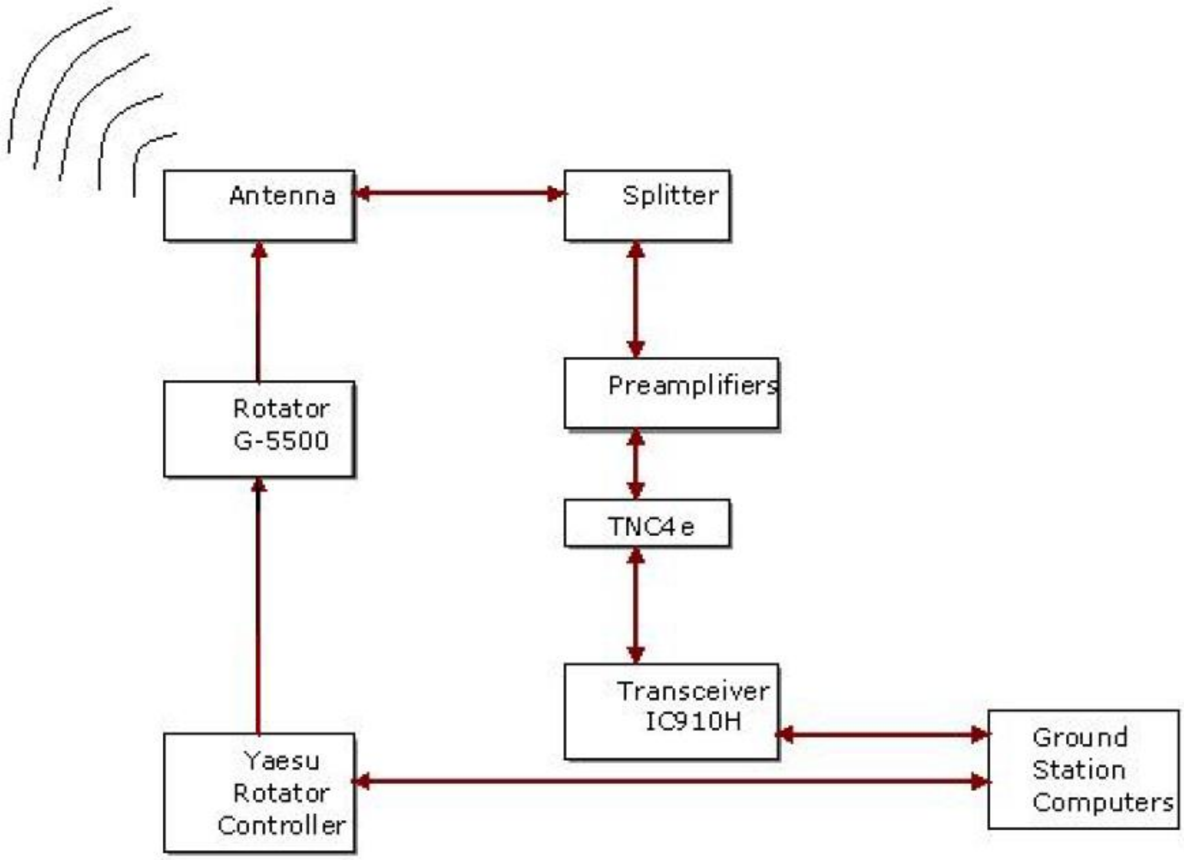
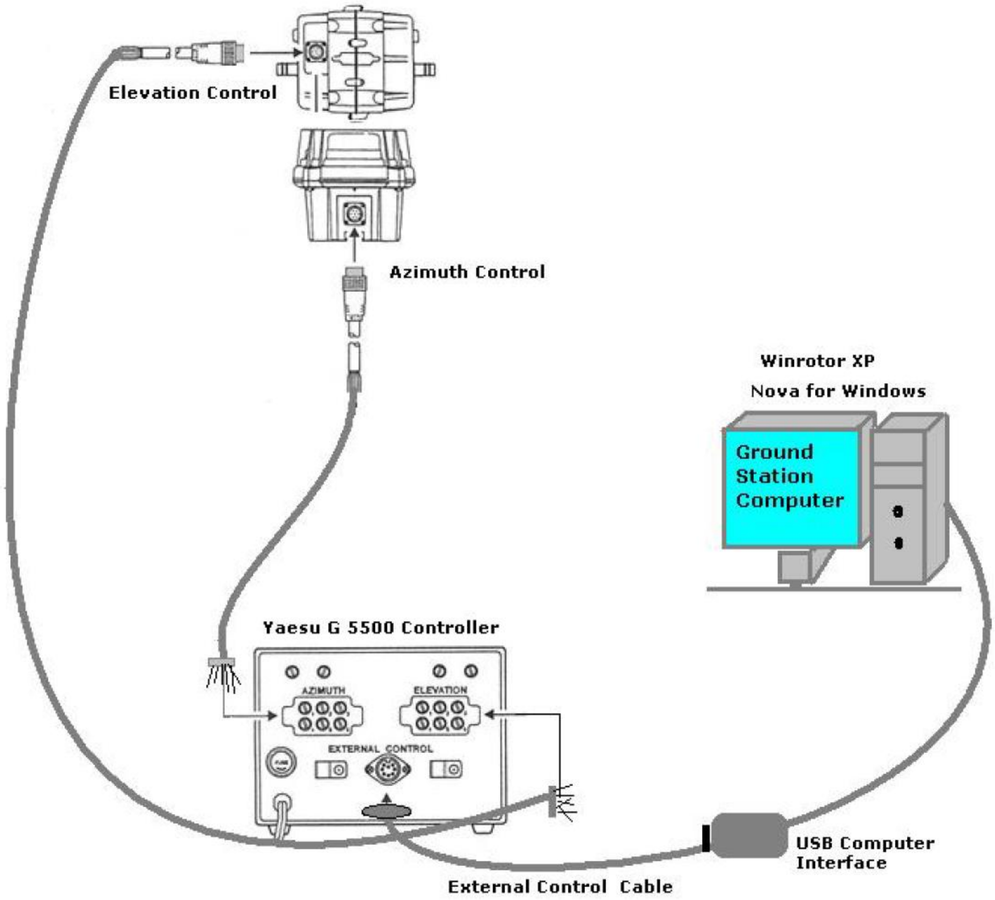


Figure 1.4: Block Diagram of the Ground Station.

Altitude	310 meters
Tower	Hummel Teletower Jumbo III
Operating frequencies	2m and 70 cms amateur bands
One 2 meter antenna	M2 2MCP22
One 70 cms antenna	M2 436CP42U/G
Antenna rotator and Controller	Yaesu G-5500
Rotator-Computer Interface	WinRotor
Rotator-Computer Interface driver	WinRotor XP
Radio	TNC4e
Polarisation switch	WiMO
Preamplifiers	LNA-145, SLN Series
Tranceiver	ICOM IC-910H
Power Supply	Microset 13.5 Volts
Two PCs	Fujitsu Siemens

Table 2.1: Hardware Specifications Table.



Rotor-Controller-Computer Interfacing.

2.2.4 Graphical User Interface

Installing Nova for Windows

(a) Insert the Nova for Windows CD into the CD-ROM drive of your computer.

(b) If the setup program doesnt start automatically, click on the Start button (lower left corner of the desktop).

(c) Click on Run.

(d) In the file name box, type **Setup.EXE**.

(e) Follow the directions in the Nova for Windows Setup.

Important:

Be sure to enter the serial number carefully. Serial number must include the NLD- prefix.

First step is to set the type of Map. In the screenshots shown below "Large Rectangular Map" is selected for convenience.

To choose the new map setting the path is-
"Views" then "Configure current view" and then Choose "Map display" and "Map Size".
Refer figure 2.11.

Second step is to set the position of the Ground Station in "Nova for Windows". The path is- "Setup" and then "Observers".

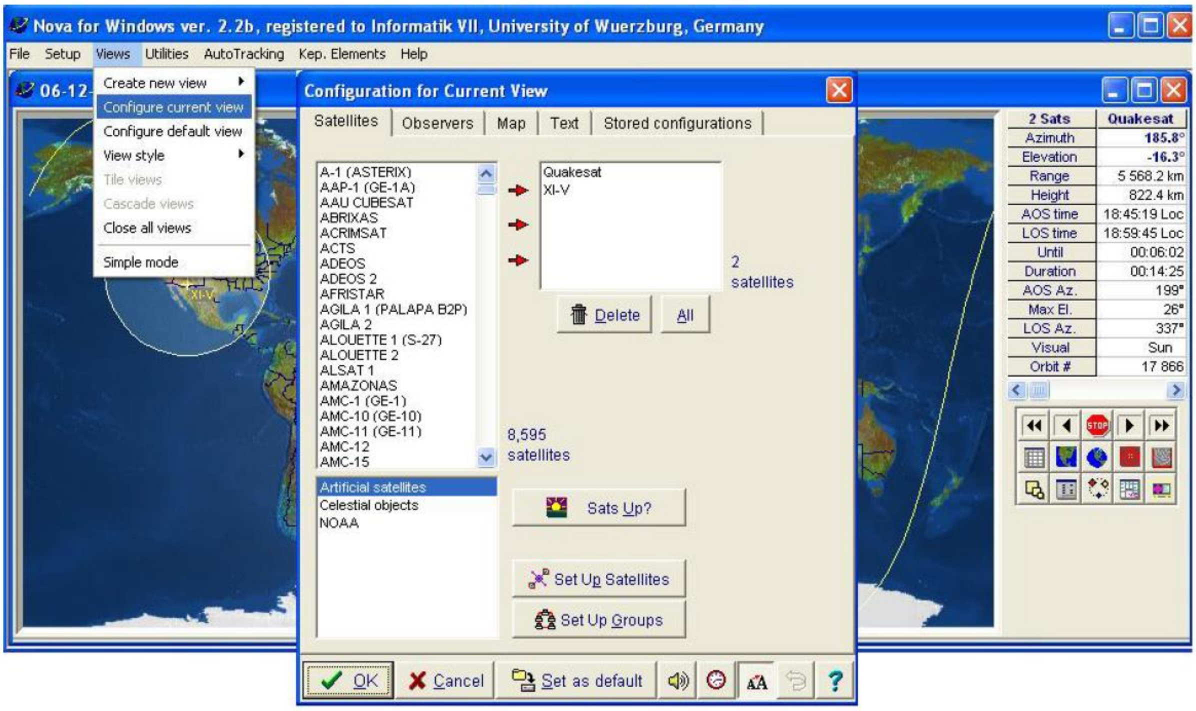


Figure B.1: Nova for Windwos - Configuring View.

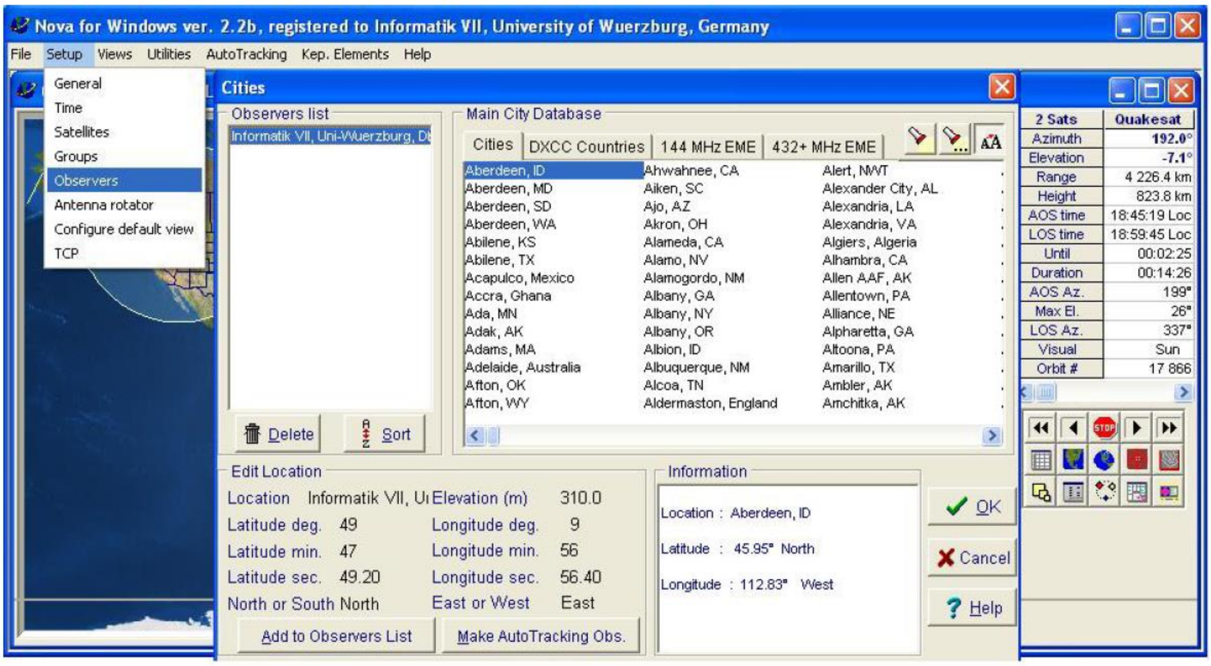


Figure B.2: Nova for Windows - Configuring Observer.

In our case it is:
Location: *"Informatics VII, Uni-Wuerzburg, Germany."*
Elevation is of *310 meters.*
Latitude is *49 degrees 47 minutes 49.20 seconds North.*

Longitude is *9 degrees 56 minutes 56.40 seconds East.*
Refer figure 2.12.

Third step is to check the availability of the specific satellite from the Satellite Editor in the database of “Nova for Windows”.
In this editor, new satellite names and its Keplerian elements can also be added. Also “Update Keplerian Elements” button provides the online update.
The path is “Setup” and then “Satellites”.
Refer figure 2.13.

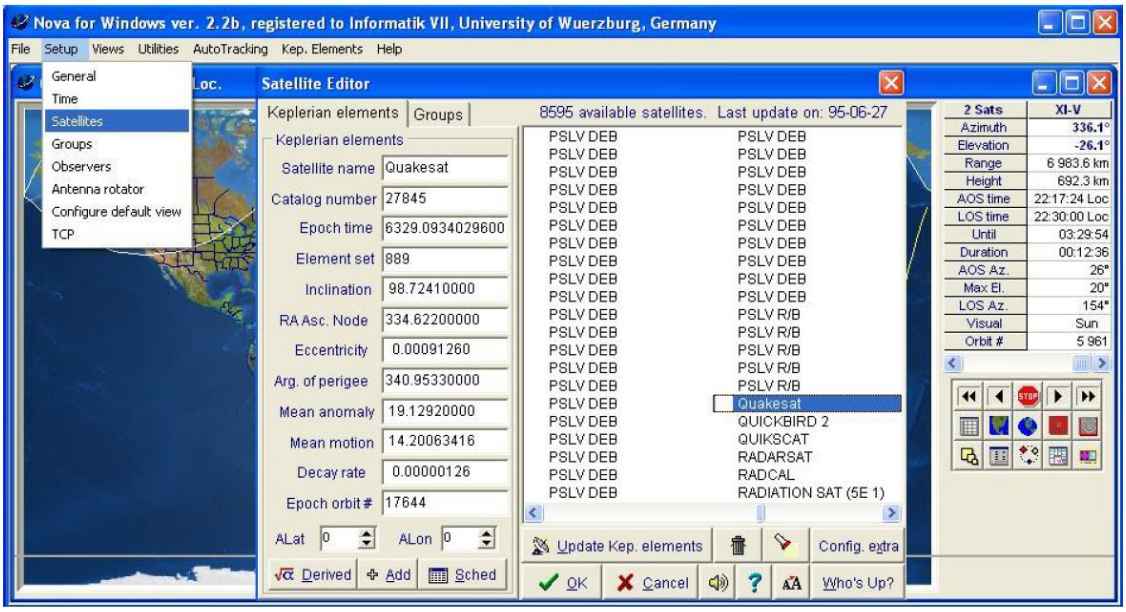


Figure B.3: Nova for Windows - Configuring Satellites.

To update Keplerian elements or to get related help click on “Kep Elements”. Refer figure 2.14.

Fourth step is to choose the “Current View” in order to see Satellite and Observer (Ground Station position) all together.
This provides a feature of selecting multiple Satellites and Observation points on the map at the same time.
The path is “Views” and then “Configure current view” and then “Satellites” or “Observes” or “Map” or “Text”. Refer figures 2.15 and 2.16.

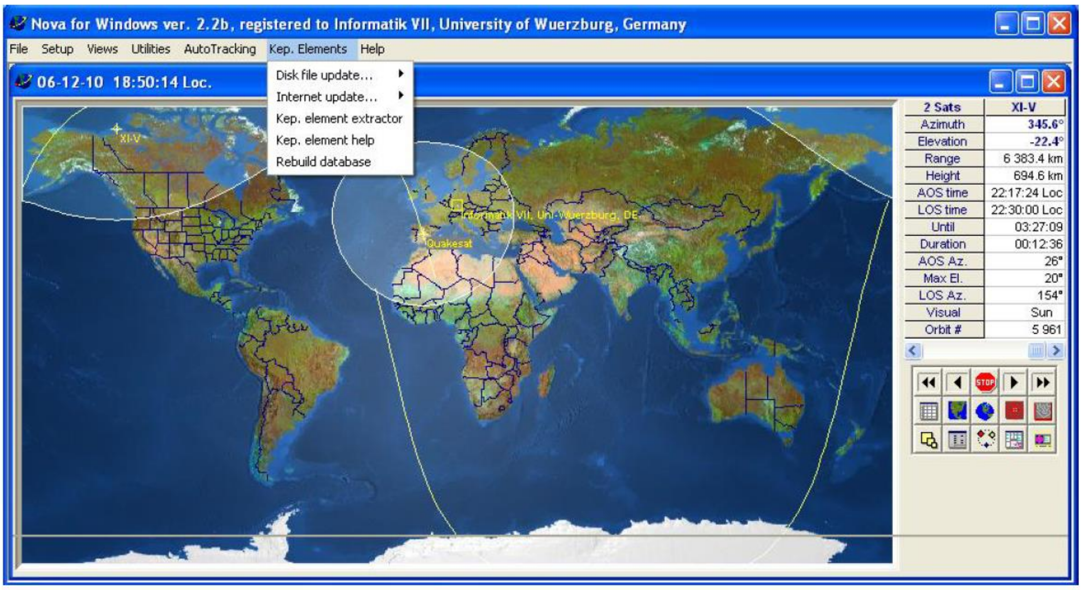


Figure B.4: Nova for Windows - TLE Updation

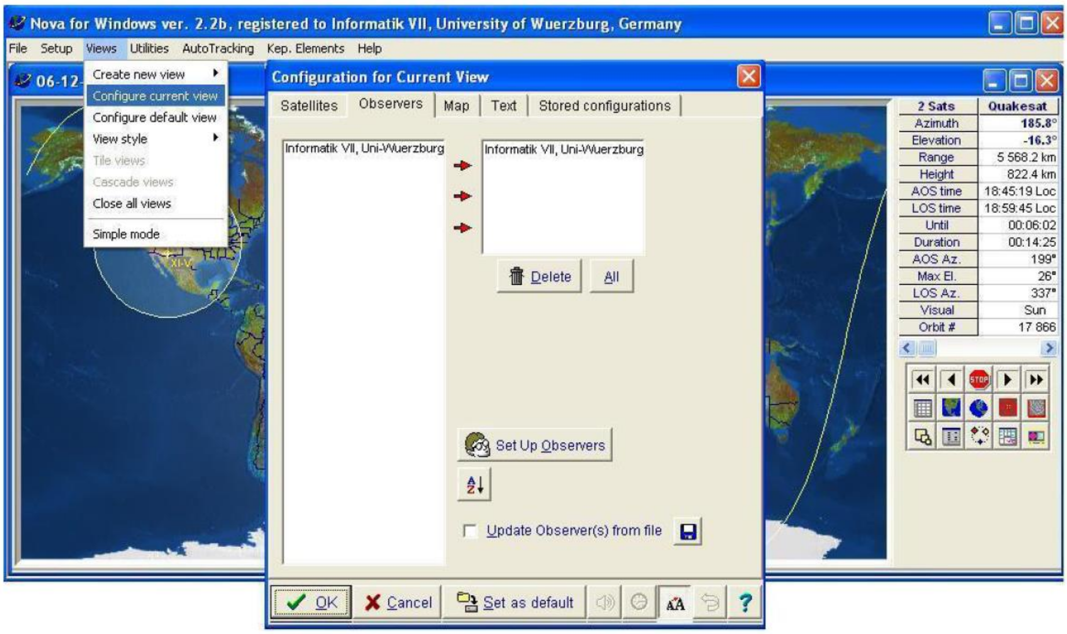


Figure B.5: Nova for Windows - Current View Observer.

On the Map, Footprint of the satellite/s and the Ground Station's position/s can be easily found. Refer figure 2.17.
On the Right hand side of the screen, Real-time text data of the con-

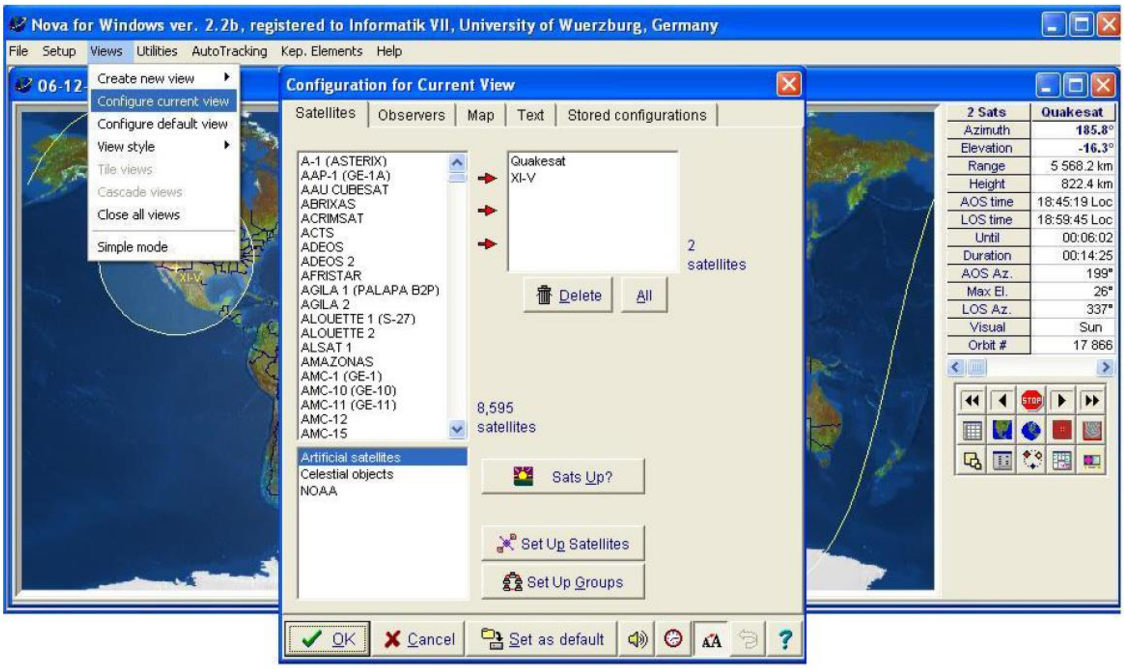


Figure B.6: Nova for Windows - Current View Satellite.

cerning satellite is available. The number of columns in the real-time text window depends on the number of satellites in the view.

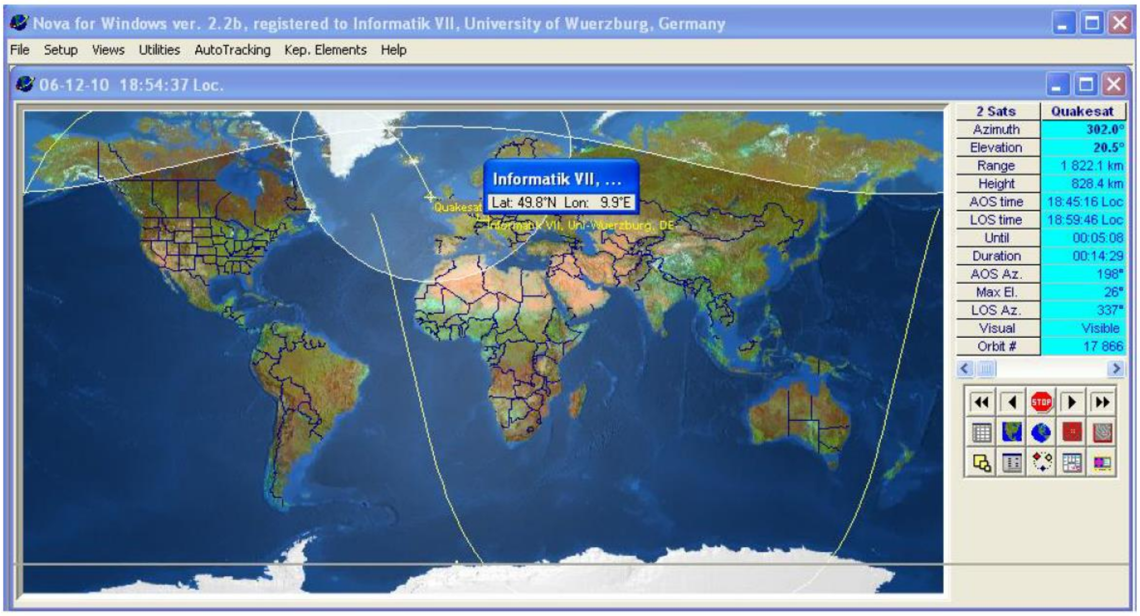


Figure B.7: Nova for Windows - Satellite Footprints.

Satellite Script.

"Satellite Script" features the prediction of the flyby time of the satellite or satellites over a particular Observer (Ground Station) up to 48 hours in advance.
This also enables "automatic script tracking". Refer figure 2.19.

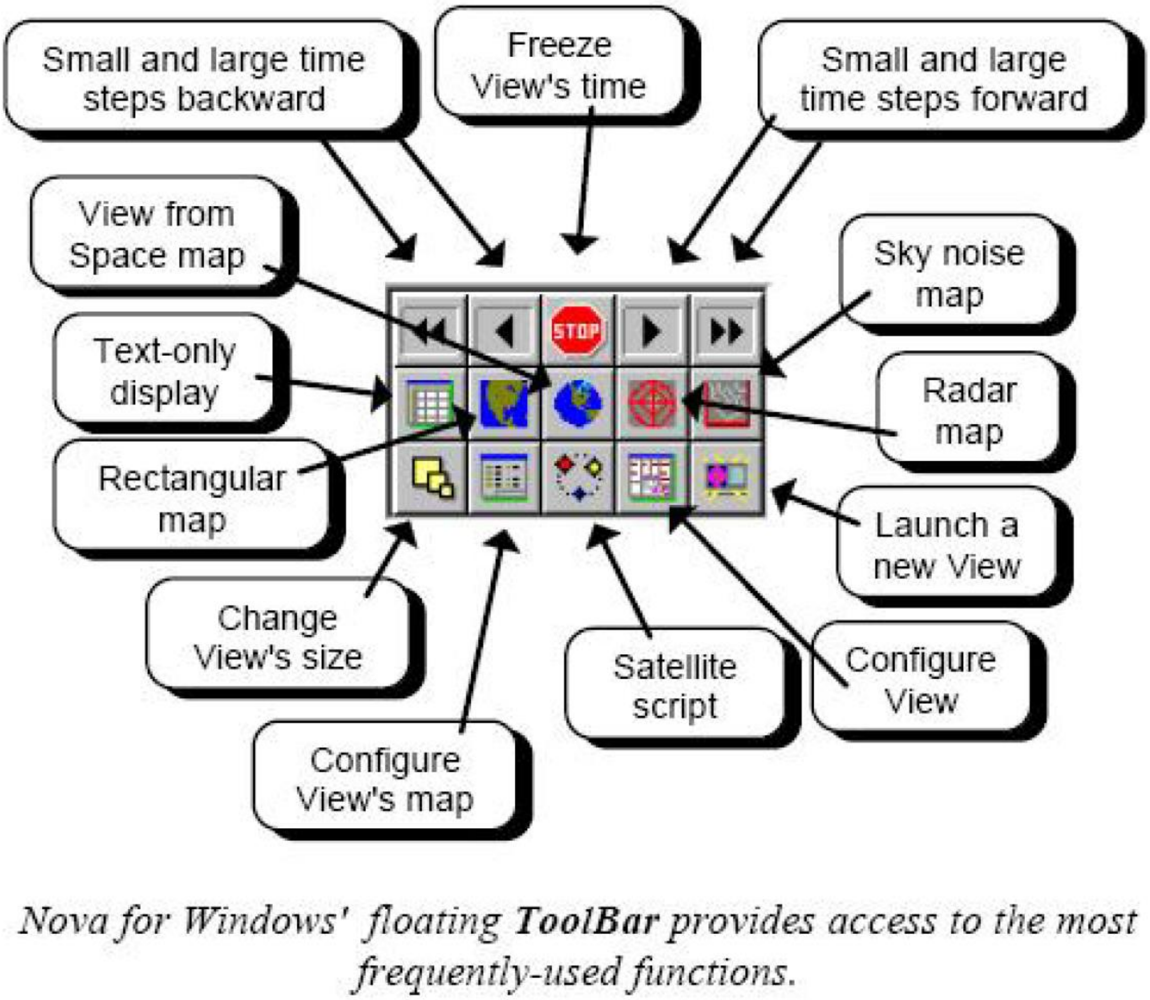
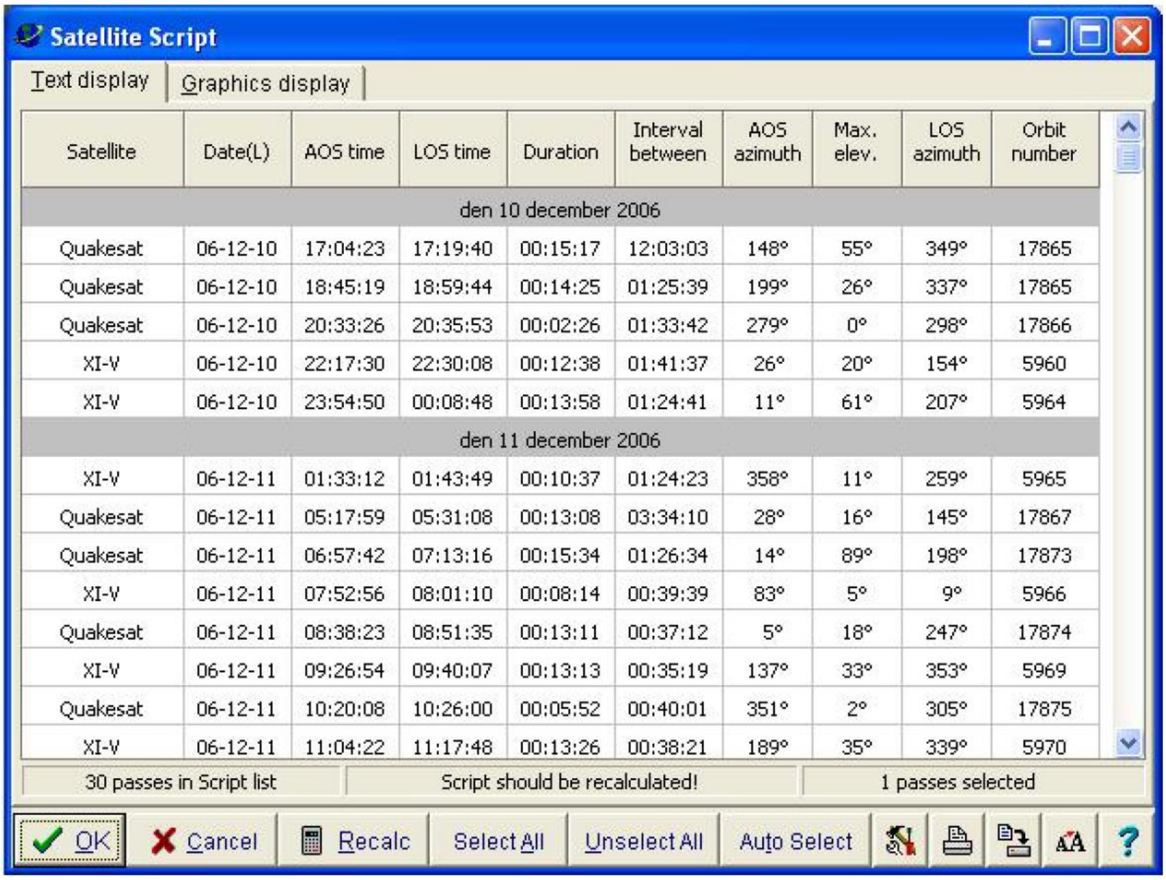


Figure B.8: Nova for Windows - Floating Toolbar.



Satellite	Date(L)	AOS time	LOS time	Duration	Interval between	AOS azimuth	Max. elev.	LOS azimuth	Orbit number
den 10 december 2006									
Quakesat	06-12-10	17:04:23	17:19:40	00:15:17	12:03:03	148°	55°	349°	17865
Quakesat	06-12-10	18:45:19	18:59:44	00:14:25	01:25:39	199°	26°	337°	17865
Quakesat	06-12-10	20:33:26	20:35:53	00:02:26	01:33:42	279°	0°	298°	17866
XI-V	06-12-10	22:17:30	22:30:08	00:12:38	01:41:37	26°	20°	154°	5960
XI-V	06-12-10	23:54:50	00:08:48	00:13:58	01:24:41	11°	61°	207°	5964
den 11 december 2006									
XI-V	06-12-11	01:33:12	01:43:49	00:10:37	01:24:23	358°	11°	259°	5965
Quakesat	06-12-11	05:17:59	05:31:08	00:13:08	03:34:10	28°	16°	145°	17867
Quakesat	06-12-11	06:57:42	07:13:16	00:15:34	01:26:34	14°	89°	198°	17873
XI-V	06-12-11	07:52:56	08:01:10	00:08:14	00:39:39	83°	5°	9°	5966
Quakesat	06-12-11	08:38:23	08:51:35	00:13:11	00:37:12	5°	18°	247°	17874
XI-V	06-12-11	09:26:54	09:40:07	00:13:13	00:35:19	137°	33°	353°	5969
Quakesat	06-12-11	10:20:08	10:26:00	00:05:52	00:40:01	351°	2°	305°	17875
XI-V	06-12-11	11:04:22	11:17:48	00:13:26	00:38:21	189°	35°	339°	5970

Figure B.9: Nova for Windows - Satellite Script.

Frequency display.
It also displays the Uplink and Downlink Frequencies, with the Doppler value for the particular selected satellite.
To check this, the path is "Utilities" and then "Frequency display".
Refer figure 2.20.

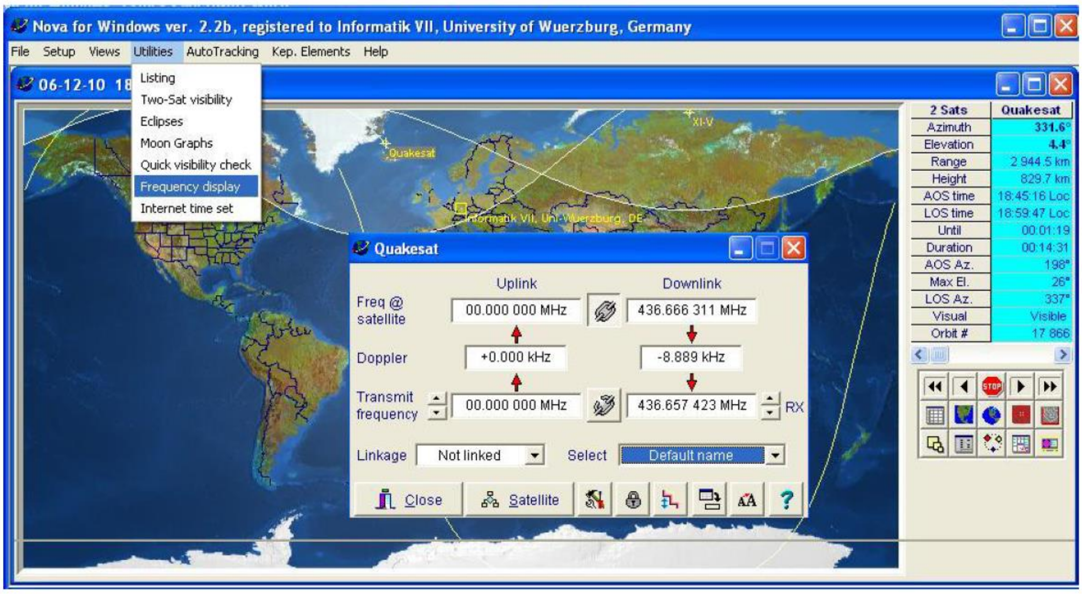


Figure B.10: Nova for Windows - Frequency Display.

To enable **Auto-Tracking** with "Nova for Windows", the first step is to select the type of Antenna Rotator from the Rotator Interface list. The path is "AutoTracking" and then "Antenna Rotator Setup" and then "Interface".
Select the Rotator Interface from the available list.
For the Ground Station at Informatics VII, University of Wuerzburg, "WinRotor" is the Rotator Interface.

For **Yaesu G-5500** azimuth rotator range is 0 to 360 degrees and elevation rotator range is 0 to 180 degrees. Refer figure 2.21.

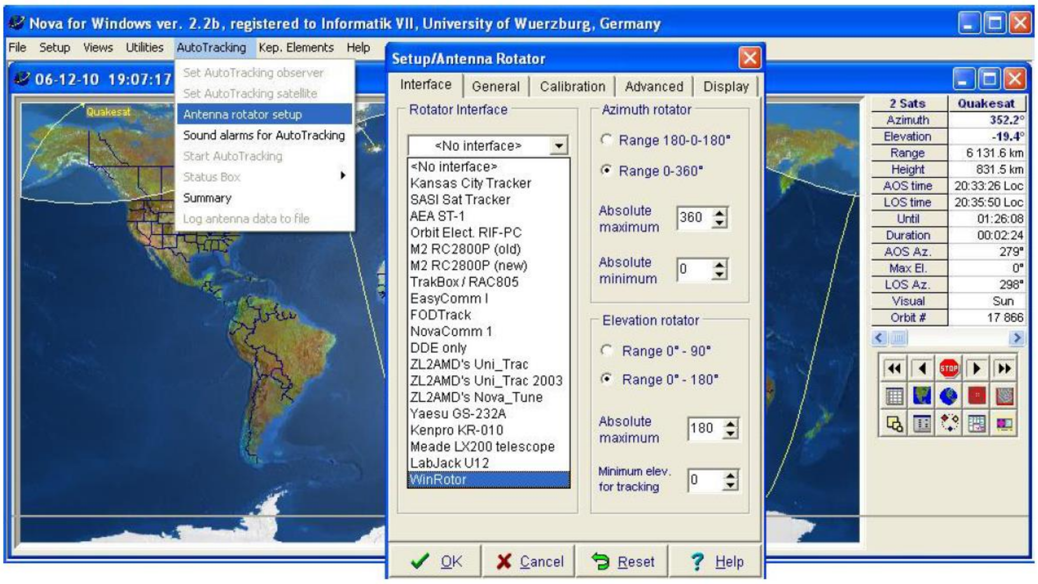


Figure B.11: Nova for Windows - Antenna-Rotator Setup.

More ***help*** regarding "Nova for Windows" can be available from "help" of the display window or please refer its detailed brochure. Refer figure 2.22.

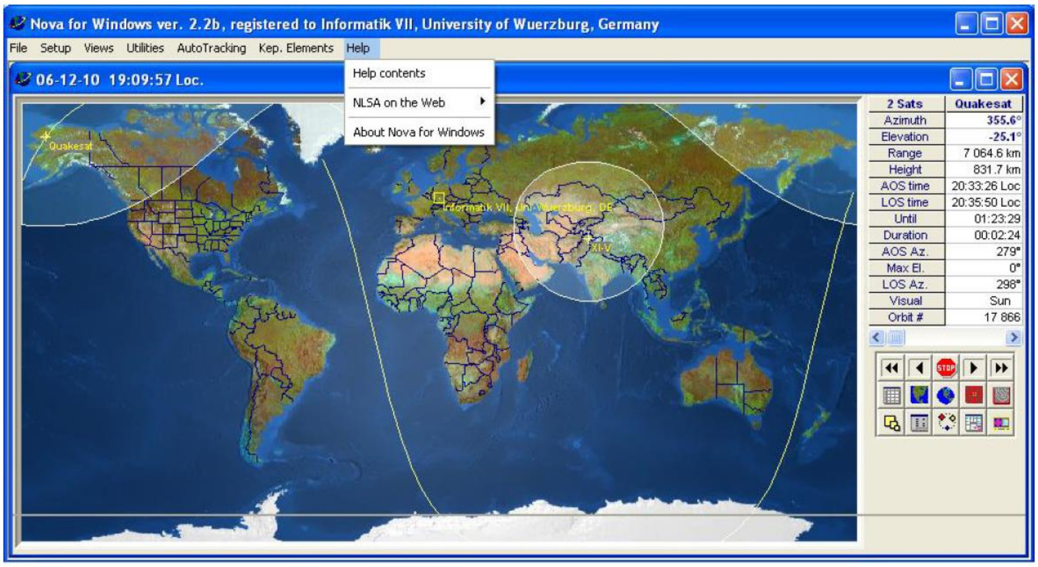


Figure B.12: Nova for Windows - Further Help.

Test Results

Eleven tests are documented in a duration of 10 days from 08 Dec 2006 to 18 Dec 2006. Testing summary is as follows:

08 December 2006	
AOS Time	16:04:08 Local Time
LOS Time	16:17:42 Local Time
Duration	00:13:33 hrs
AOS Azimuth	118 degrees
Maximum Elevation	21 degress
LOS Azimuth	355 degress

Table C.1: Testing - Satellite Script 08Dec2006.

Number of Beacons received : 3.

tnc4e2: fm KD7OVB to QST ctl UI pid=BB len 255 16:10:18
tnc4e2: fm KD7OVB to QST ctl UI pid=BB len 255 16:10:28
tnc4e2: fm KD7OVB to QST ctl UI pid=BB len 255 16:10:57

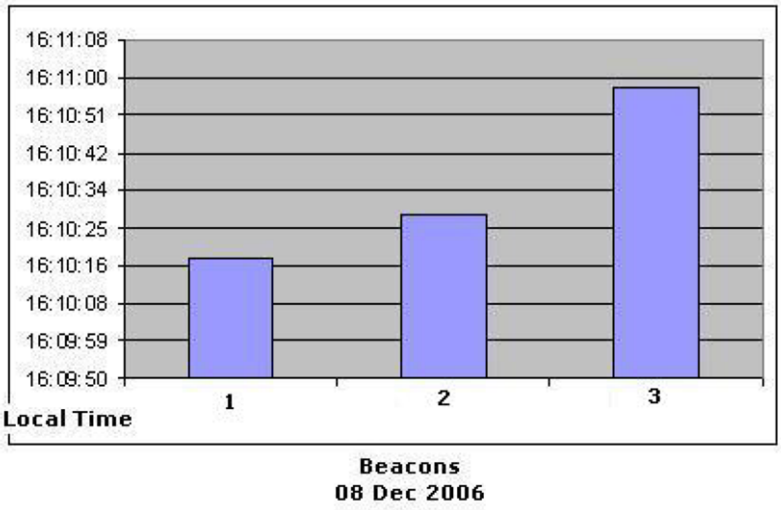


Figure C.1: Test Beacons on 08Dec2006.

11 December 2006	
AOS Time	15:08:46 Local Time
LOS Time	15:19:13 Local Time
Duration	00:10:26 hrs
AOS Azimuth	87 degrees
Maximum Elevation	8 degress
LOS Azimuth	1 degress

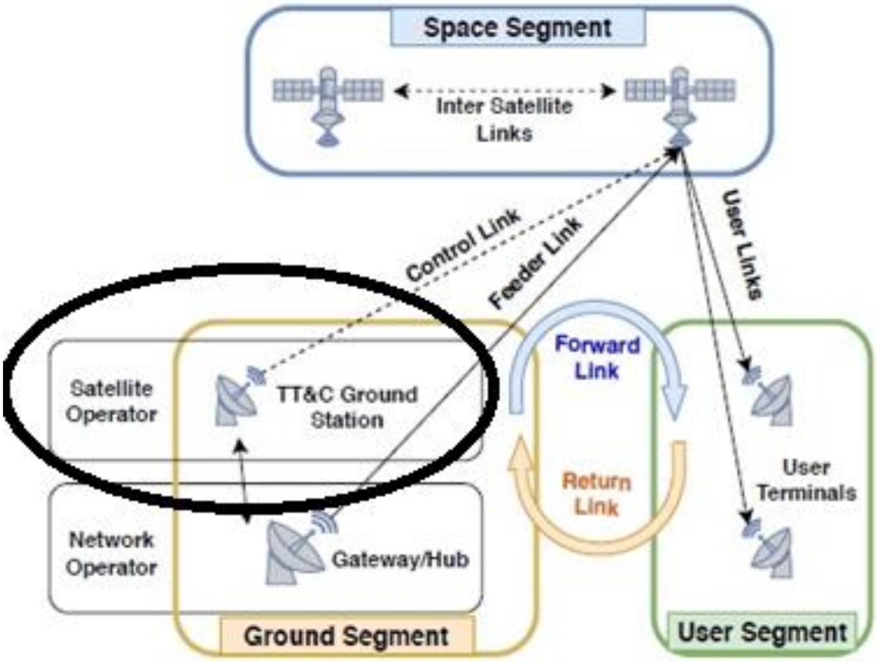
Table C.2: Testing - Satellite Script 11Dec2006.

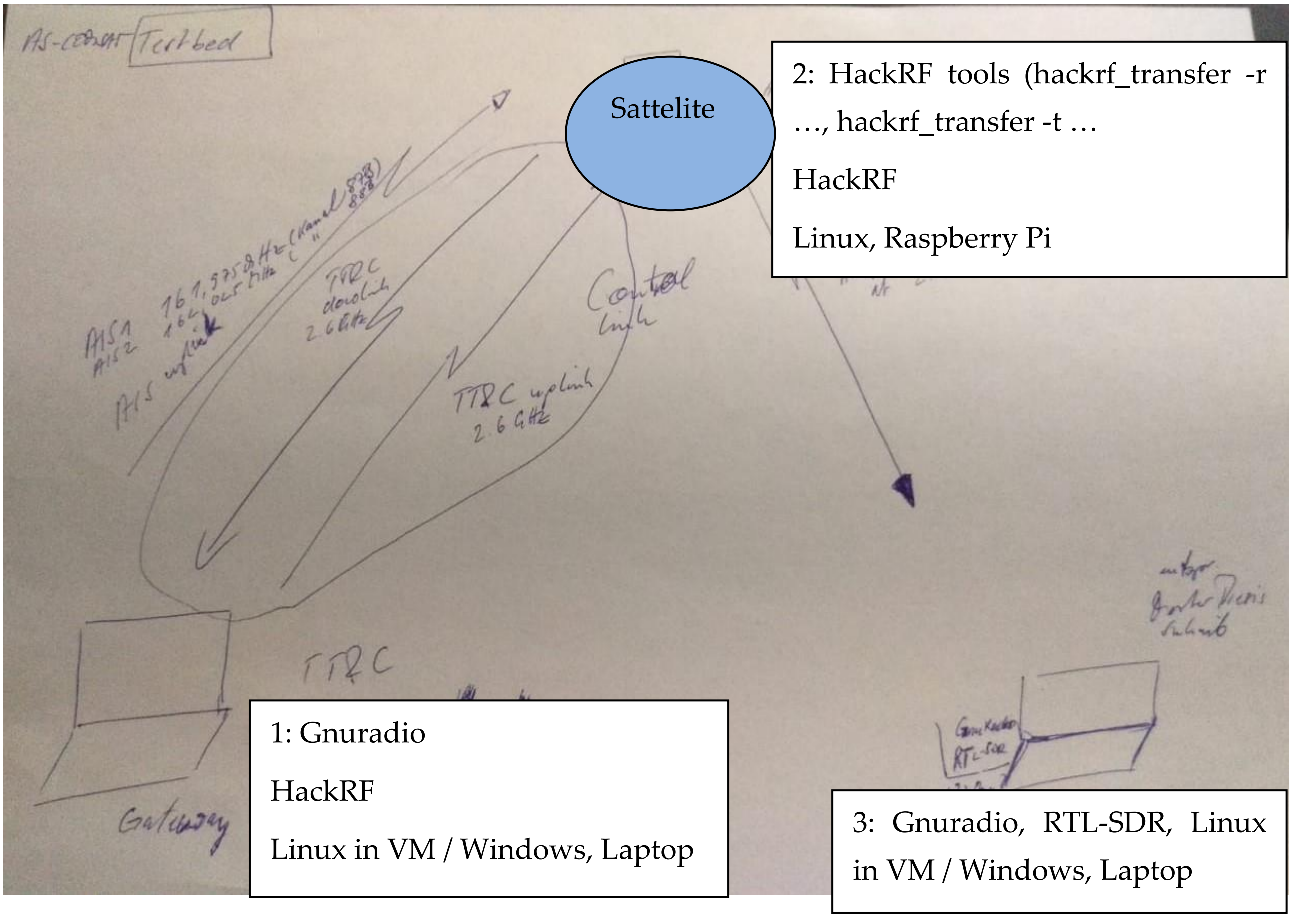
11 December 2006	
AOS Time	16:45:23 Local Time
LOS Time	17:00:18 Local Time
Duration	00:14:55 hrs
AOS Azimuth	139 degrees
Maximum Elevation	40 degress
LOS Azimuth	351 degress

Table C.3: Testing - Satellite Script 11Dec2006.

3 Hardware in the loop (HIL) Test System

3.1 System Design of HIL





Payload: Sending from 1 to 2 an AIS file on 161.975 MHz – Sending from 2 to 3 this file on 2.6 GHz

Telemetry, Tracking & Control (TT&C): Sending from 1 to 2 a control command file on 2.6 GHz, sending from 2 to 1 a file with sensor information on 2.6 GHz

3.2 HackRF - RTL-SDR - GNU RADIO Setup[2]

3.2.1 Orange Pi - Raspberry Pi

HackRF One is an SDR (Software Defined radio) working in transmission and reception in a wide frequency range. 1MHz to 6GHz. RTL-SDR is the cheapest and most well-known SDR working in reception only. Here we will discuss the connection of these 2 SDRs to an Orange Pi or a Raspberry PI and their operation with the GNU Radio software.

Connection of the HackRF One SDR to an Orange Pi Pc2 or Orange PI One Plus running on ARMBIAN or a Raspberry PI.

3.2.2 HackRF Library

In console mode, update your system:

sudo apt-get update

[2] HackRF – RTL-SDR – GNU RADIO Setup – F1ATB (https://f1atb.fr/index.php/2020/08/06/hackrf-orange-pi-gnuradio-setup/)

sudo apt-get upgrade

Install the library for hackrf:

sudo apt-get install hackrf

Connect the hackrf to an USB port and check it:

hackrf_info

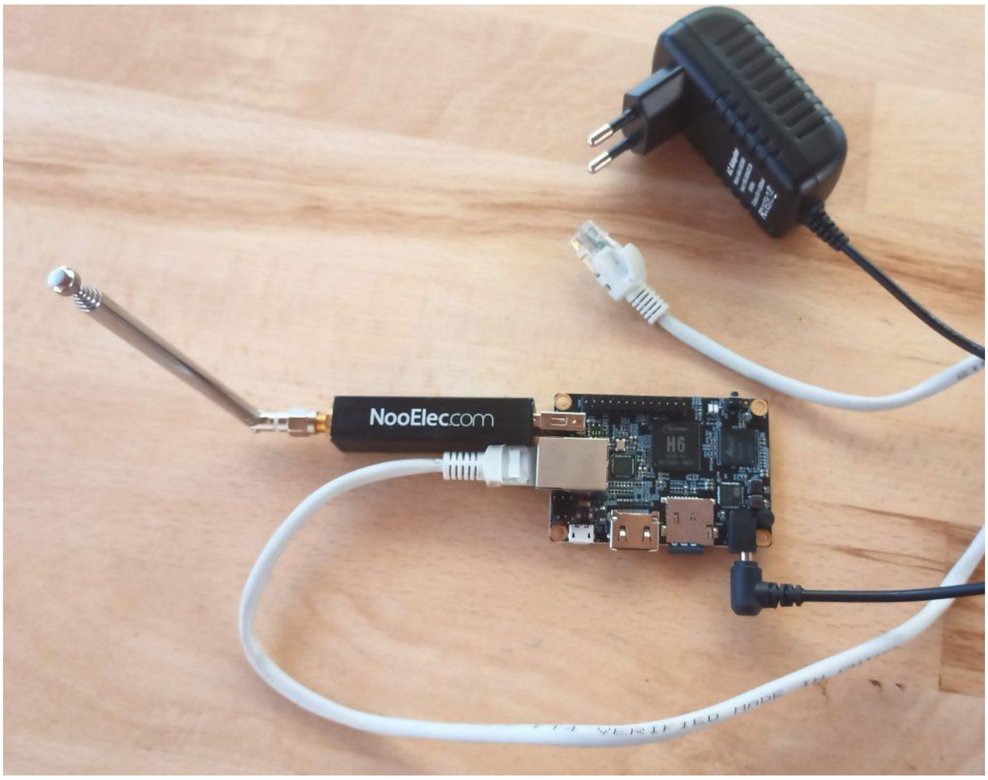
If the installation is good, you will get a response “Found HackRF” etc … Sometimes with some USB cables that connect the HackRF, there is no response. Change the cable in this case.

3.2.3 Installation GNU Radio Companion

GNU Radio is a very powerful tool for modelling signal processing chains. GNU Radio Companion is a complementary tool allowing to build radio processing chains graphically without writing a line of code. So far for Debian Buster there is only version 3.7.13 which is considered stable.

sudo apt-get install gnuradio

3.2.4 Installation Osmocom SDR and RTL-SDR Drivers



RTL-SDR and Orange PI One Plus

sudo apt-get update

Installation of the USB library:

sudo apt-get install cmake build-essential libusb-1.0-0-dev

We clone Osmocom in the user’s Downloads folder for example:

cd ~/Downloads

sudo git clone https://github.com/osmocom/rtl-sdr.git

Go to the folder rtl-sdr:

cd rtl-sdr

sudo mkdir build

cd build

sudo cmake ../ -DINSTALL_UDEV_RULES=ON -DDETACH_KERNEL_DRIVER=ON

At this point I sometimes got an error because the pkg-config package was not found. Make:

sudo apt-get install pkg-config

and relaunch the cmake from above.

sudo make

sudo make install

sudo ldconfig

3.2.5 Osmocom source module installation

sudo apt-get install gr-osmosdr

3.2.6 GNU Radio launch

You have to be in graphics mode to be able to use this superb signal processing design tool. Personally, I use my orange-pi or raspberry in remote mode. I connect to them by enabling VNC in setup and using the VNC extension in chrome on my PC. On a terminal in graphics mode type:

gnuradio-companion

A message "RANDR" missing … is not important.

3.2.7 Error Xterm executable is missing

If you have when launching a model in gnuradio companion a message of the type Xterm executable is missing and if you are on Armbian or Raspbian (raspberry) go to the configuration folder.

cd ~/.gnuradio

edit grc.conf

sudo nano grc.conf

and add at the end of the file:

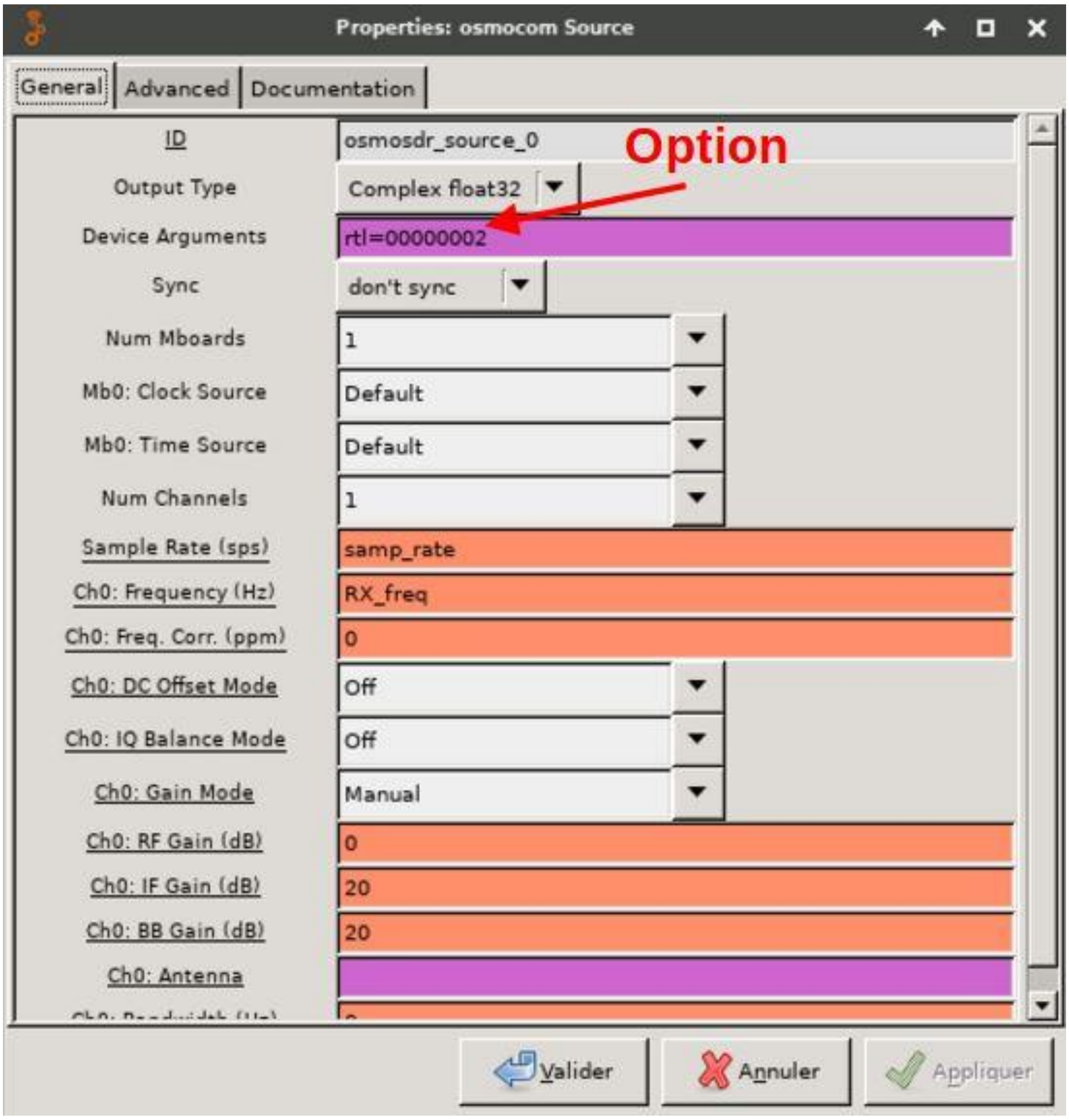
```
[grc]

xterm_executable = /usr/bin/lxterminal
```

First of all, check that the terminal is installed on your machine. Otherwise installed it with:

sudo apt install lxterminal

3.2.8 Osmocom module

To enter data from HackRF One or RTL-SDR, use the Osmocom source module in GNU-Radio.



It is not necessary to identify the SDR if only one is connected to the processing board. For the gains, it is necessary to make tests to find the good values according to the model of SDR.

3.2.8.1 Note On Hack RF Gains

HackRF One provides:

- RX : three different analog **gain** controls
    - RF (“amp”, 0 or 14 dB),
    - IF (“lna”, 0 to 40 dB in 8 dB steps),
    - baseband (“vga”, 0 to 62 dB in 2 dB steps)
- TX : two gain controls
    - RF (0 or 14 dB) ,
    - IF (0 to 47 dB in 1 dB steps)

The RX and TX, RF amplifiers have two settings: on or off. In the off state, the amps are completely bypassed. They nominally provide 14 dB of **gain** when on, but the actual amount of gain varies by frequency. In general, expect less gain at higher frequencies.

3.2.8.2 Note on RTL-SDR Gains

Only the RF gain parameter acts on the RTL-SDR. You can get the available gain values provided that the RTL-SDR was not started by an application. In a terminal window type:

rtl_test

```
root@opi-onep-70:~# rtl_test

Found 1 device(s):

  0:  Realtek, RTL2838UHIDIR, SN: 00000001



Using device 0: Generic RTL2832U OEM

Detached kernel driver

Found Rafael Micro R820T tuner

Supported gain values (29): 0.0 0.9 1.4 2.7 3.7 7.7 8.7 12.5 14.4 15.7 16.6 19.7 20.7 22.9 25.4 28.0 29.7 32.8 33.8 36.4 37.2 38.6 40.2 42.1 43.4 43.9 44.5 48.0 49.6

[R82XX] PLL not locked!

Sampling at 2048000 S/s.



Info: This tool will continuously read from the device, and report if

samples get lost. If you observe no further output, everything is fine.
```

3.2.9 Multi-SDR

In the case of several SDRs connected to the processing card, they must be identified. For a hackrf type in a terminal hackrf_info and retrieve the serial number and put it in the 'Device Arguments' box. Ex:

```
hackrf=000000000000000075b068dc3122a607
```

For an RTL-SDR, type rtl_eeprom and put the serial number. Ex:

```
rtl=00000002
```

The difficulty with RTL-SDRs is that they all carry the serial number 1 when they are manufactured. You can reprogram this number by typing:

```
rtl_eeprom -s 'numéro de série'
```

With the rtl_eeprom -h command, we have the corresponding help.

3.2.10 Purchases

The HackRF being developed in Open Source can be bought in China at Aliexpress for a hundred Euros. To use it, the Orange Pi solution is very interesting. We forget the Orange Pi Zero which, following the treatment defined in GNU-RADIO, quickly risks running out of power. We are going to move towards 64-bit 4-core processors like the H5 or the H6. I have successfully tested Orange Pi PC2 H5 and Orange PI One Plus H6 for SSB reception and SSB transmission.

Orange PI PC2

The Orange PI PC2 has the following advantages:

- several USB2 if you want to connect different SDRs
- An audio output on headphone jack, useful for an HF receiver

Orange PI One Plus

The Orange PI One Plus has the following advantages:

- The minimum required to control a Hack RF or a RTL-SDR from the network (USB, Ethernet 1Gb / s)
- A very low price: less than 30 € with food and transport (Ebay or Aliexpress)

3.2.11 Posts on Remote-SDR

- Remote SDR v3
- Gpredict — Remote SDR
- Remote SDR – Raspberry Pi 4B or Orange Pi Zero 2 image installation
- Remote SDR v3 – Manual Installation
- SA818 – RTL-SDR
- Remote SDR – Examples of realization
- Transmit over QO-100 satellite with a Smartphone
- Remote SDR V2 – Software Architecture
- Remote SDR v3 – Tips
- Remote SDR V1- Purchase
- Remote SDR V1 – Man Machine Interface
- Remote SDR V1 – Signal Processing
- Web Client to GNU Radio
- GNU Radio to Web client

- Remote SSB Transmitter
- Remote SSB Receiver
- GPIO on Orange PI One Plus H6
- TCXO installation on HackRF
- Q0-100 Transceiver with 2 SDR – Remote SDR V1

3.3 Other Gnuradio/HackRF instructions

3.3.1 Installing HackRF on Raspberry:

HackRF One installation

- Prerequisites

  If you did not install these for SDRplay:

```
sudo apt install libusb-1.0-0-dev libfftw3-3 libfftw3-dev
```

- Install

```
• cd ~/

• git clone https://github.com/mossmann/hackrf

• cd hackrf/host

• mkdir build

• cd build

• cmake ..

• make -j 4

• sudo make install
```

```
sudo ldconfig
```

- reboot

- You may need to update the firmware to match the version of the driver. As of this writing, the latest firmware/driver version was 2021.03.1

  Most HackRF devices have firmware version 2018.01.1 or earlier. Use hackrf_info to see if the firmware version matches the driver that you installed.

```
hackrf_info

# If you see "Firmware Version: 2021.03.1 (API:1.04)", then it is up to date.

# Transfer rate test:
hackrf_transfer -r /dev/null -s 21500000

#Test sending data:
hackrf_transfer -t /dev/zero
```

- Firmware updating instructions are based on this: https://hackrf.readthedocs.io/en/latest/updating_firmware.html#updating-the-spi-flash-firmware

  Note that the zip and tar.xz archives have the firmware files. The git clone procedure does not.

  Download hackrf-2021.03.1.zip

  Extract only the firmware-bin directory into the ~/hackrf directory

```
cd ~/hackrf/firmware-bin

```

- # To update the firmware on a working HackRF One, use the hackrf_spiflash program:
- hackrf_spiflash -w hackrf_one_usb.bin
-
- # Press the reset button on the HackRF.
- hackrf_info
-

```
# The new firmware version should now displayed.
```

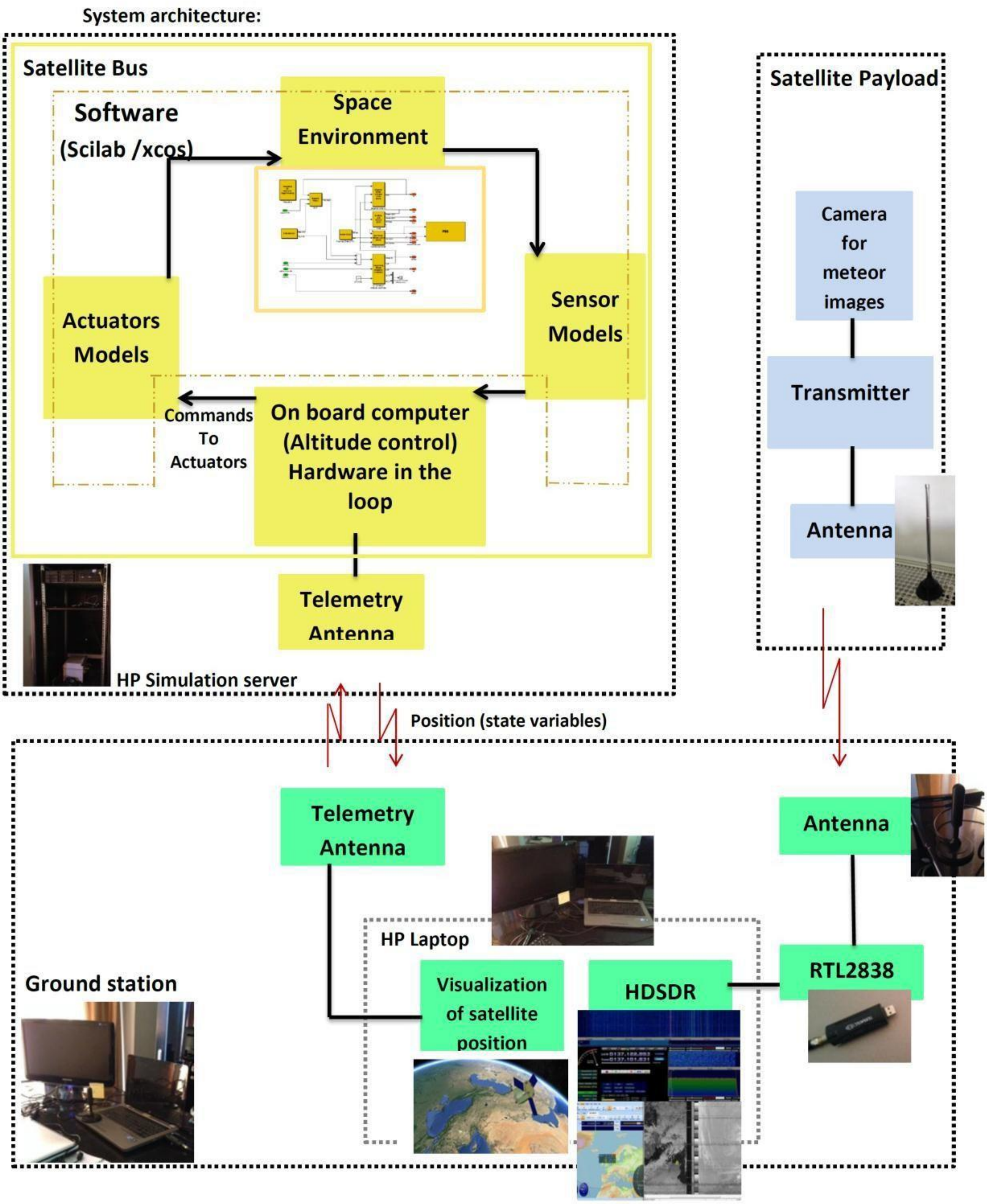
3.3.2 Installing gnuradio on raspberry:

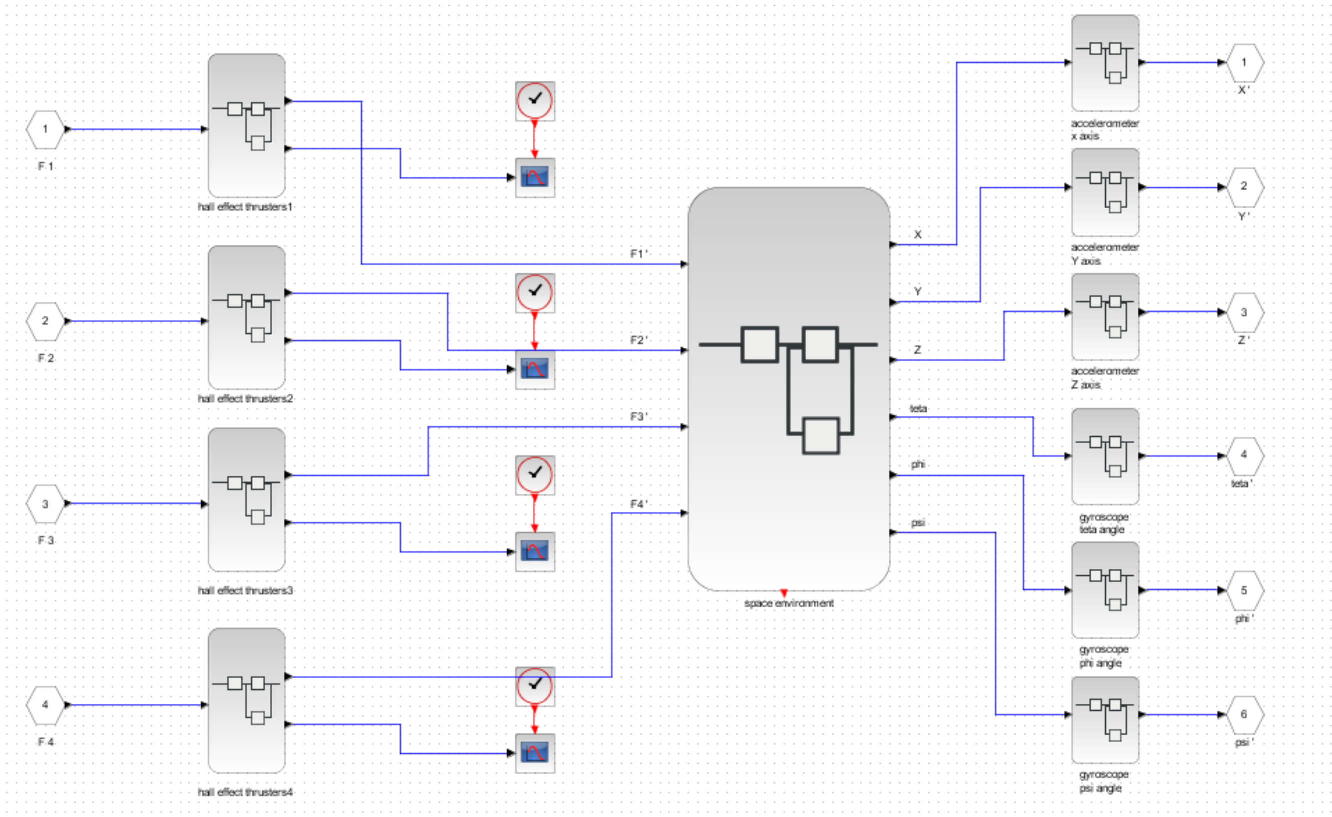
apt-get install -y gnuradio

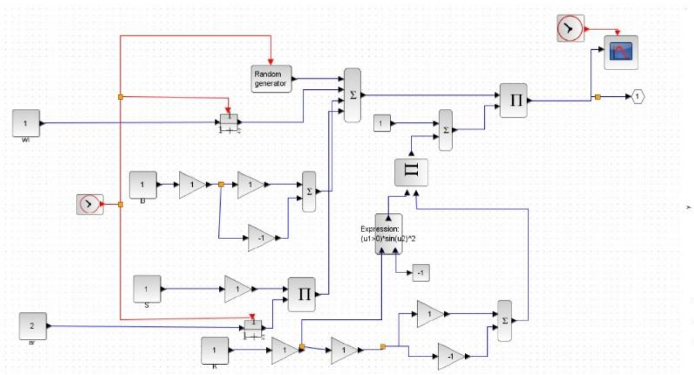
3.3.3 running gnuradio:

gnuradio-companion

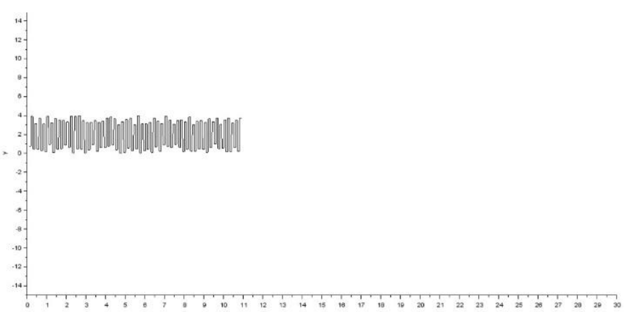
3.4 Hardware-in-the-Loop test rig for IAP-SAT (Overview) (2015)







After simulation:



In this figure, input 1 is the angular speed wi, and imput 2 is the acceleration. These inputs is passed by the scale factor, the noise, transfer function and the misalignement of the axis to measure the final angular speed as output of gyroscope.

Overview is including Simulation model of actuators, space model and sensors of IAP-SAT (for 1. xcos model, 2. Graphs of simulation results please refer to documentation)

- Interface between Simulation Server and Board Computer of IAP-SAT (for 1. xcos model, 2. Graphs of simulation results): please refer to documentation)

- Meteorological Images supply by HDSDR

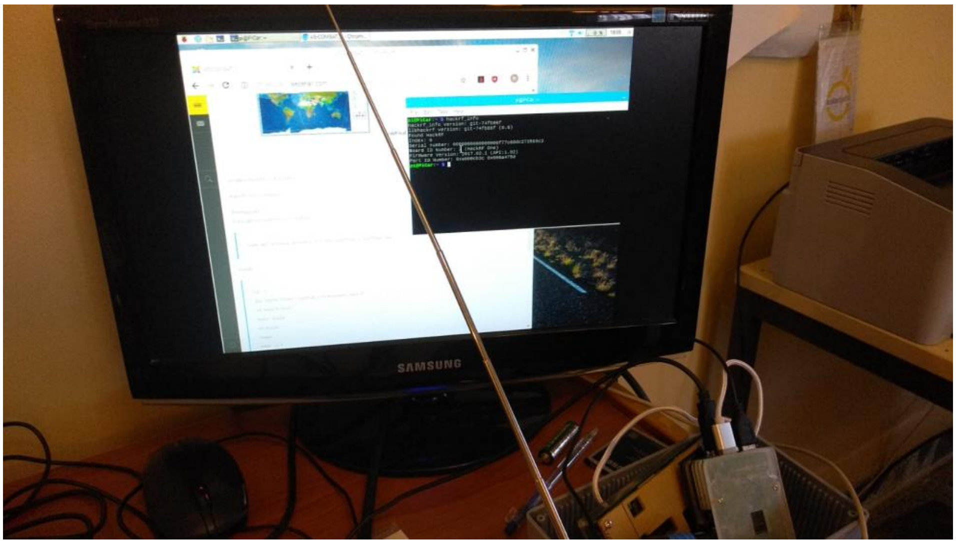
3.1 HIL 2021

3.1.1 Space Segment:

- Raspberry (Linux, Gnuradio, NASA coreFlightSystem)
- ACS (magnetorquer, IMU from IAP-SAT))

- HackRF
- Antenna
- Structure

Gnuradio program and HackRF drivers successfully installed on raspberry pi



3.1.1.1 Ground Segment:

- Laptop (Windows or Linux, GnuRadio/PothosSDR)
- Antenna
- HackRF

Also possible with

Programm CubicSDR, PothosFlow (instead of gnuradio)

3.1.1.2 Task Sending and Receiving file

1. On 2.6 GHz band: sending a file from space segment
2. Receiving this file on ground segment and visualize it
   Especially:
1. Recording file from remote control of car opening (probably 433,92 MHz) by raspberry
2. Sending this file to ground station

4 Hardware Design Document (HDD) & Hardware Realization Document (HRD)

4.1 TT&C Tranceiver

4.1.1 Crowd Supply LimeSDR Mini Boards

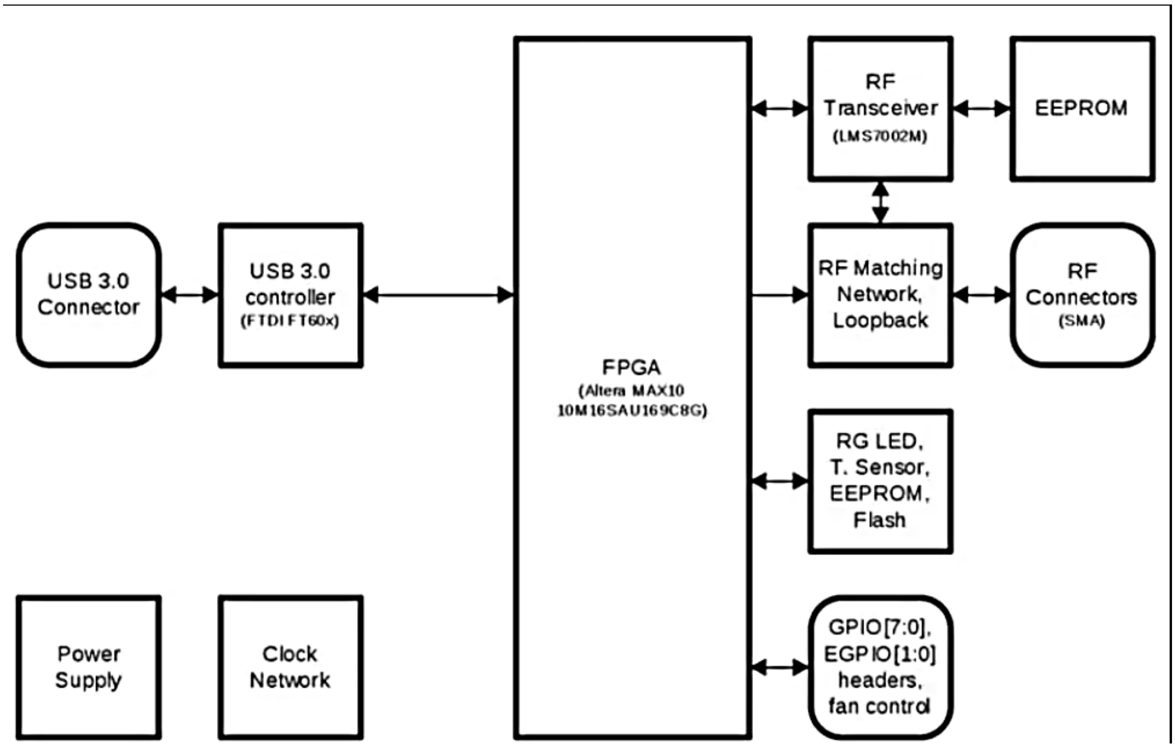
Crowd Supply Lime Software Defined Radio (SDR) Mini Boards are hardware platform for developing and prototyping high-performance and logic-intensive digital and RF designs. These boards use Altera's MAX 10 FPGA and Lime Microsystems' LMS7002M RF transceiver. The LimeSDR Mini boards are smaller, and less expensive when compared to the LimeSDR. These mini boards feature two 128KB for RF transceiver MCU firmware, and a 4MB flash memory for data.

The LimeSDR Boards feature 2 SMA (SubMiniature A) connectors for connecting external transmit and receive antennas, such as the Taoglas TG.09.0113. A U.FL connector is provided for an external clock source, such as GPSDO or atomic clock, via the Taoglas CAB.721 antenna.

4.1.1.1 Features

- **Lime Microsystems LMS7002M** MIMO FPRF transceiver
- **Altera MAX 10** (10M16SAU169C8G) FPGA:
  - 169-pin FBGA package
  - 549KB M9K memory
  - 2368KB user flash memory
  - 4 x fractional Phase Locked Loops (PLLs)
  - 130 x general purpose input/output (GPIO)
  - Single supply voltage
  - Flash feature
  - FPGA configuration via JTAG
- 2 x 128KB for RF transceiver MCU firmware and data
- 1 x 4MB flash memory for data
- General user inputs/outputs:
  - 2 x dual color (red and green) LED
  - 8 x FPGA GPIO pin header (3.3V)
- Connectivity:
  - USB 3.0 Type-A (FTDI FT601 controller)
  - 2 x coaxial RF SMA connectors
  - U.FL connector for external clock source
  - FPGA GPIO headers
  - FPGA JTAG connector
- Clock system:
  - 30.72MHz onboard VCTCXO
  - Possibility to tune VCTCXO with onboard DAC
  - External clock input via U.FL connector
- 69mm x 31.4mm dimensions
- Weighs about 20g

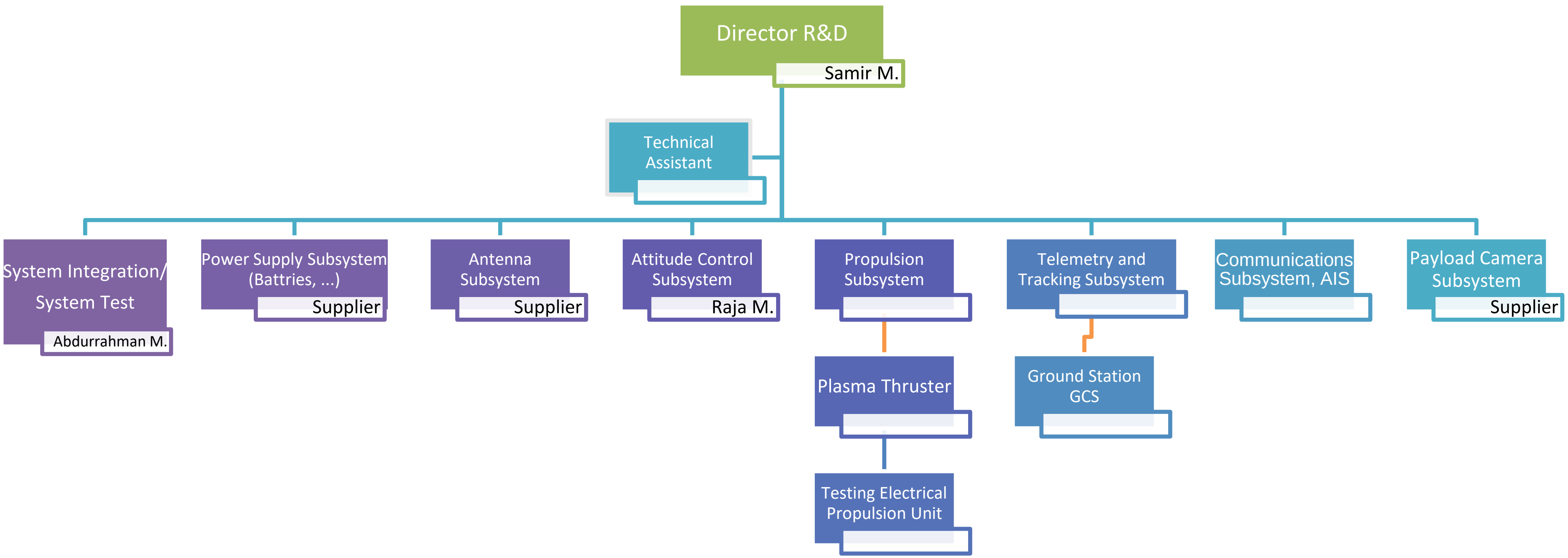
4.1.2 Lime SDR mini



4.1 TT&C Antenna

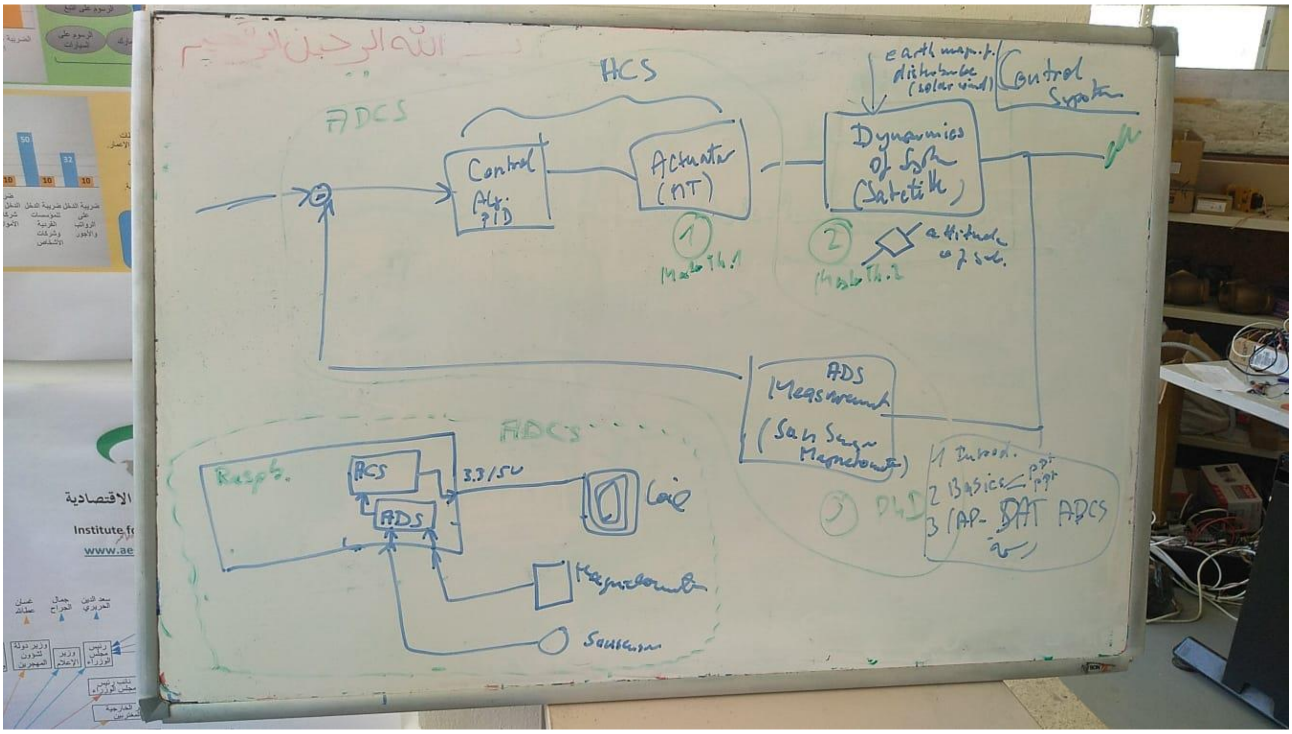
5 Software Design Document (SWDD) & Software Implementation Document (SWID)

5.1 Organizational chart (current and future)



6 AS-COMSAT-1 System (Hardware&SW)

6.1 System Concept for Attitude Determination and Control System (ADS, ACS)



6.2 On-Board Computer (Raspberry Pi)

On this computer the NASA core flight system shall be implemented. System design: Jana Othman (Internship AECENAR July-Aug 2021).

6.2.1 Physical System Overview

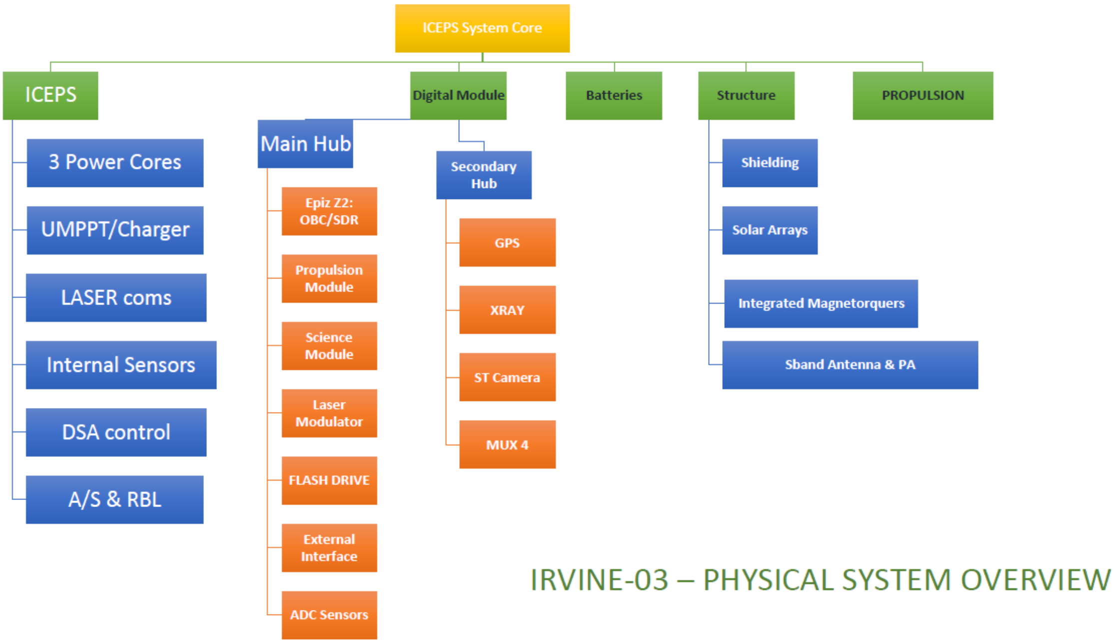


Figure 1: physical overview

6.2.2 How communication is done

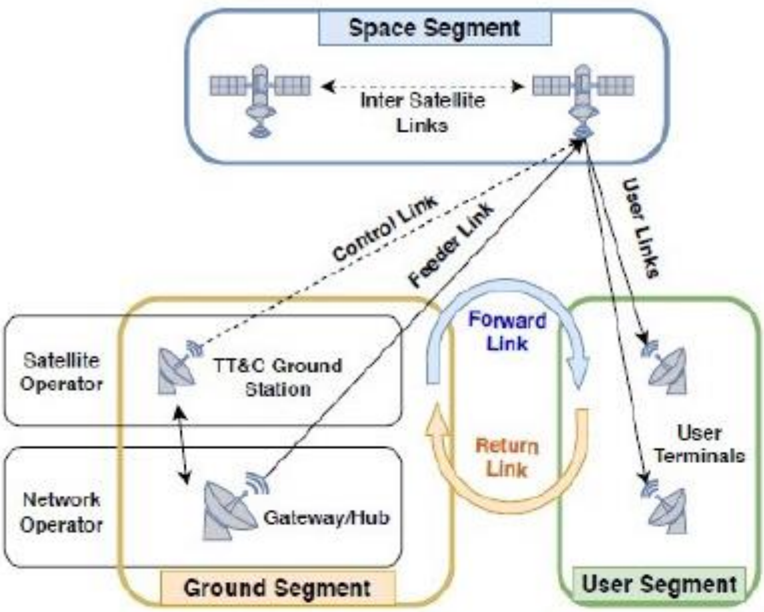


Figure 2: Communication and TT&C

6.2.3 OBC System

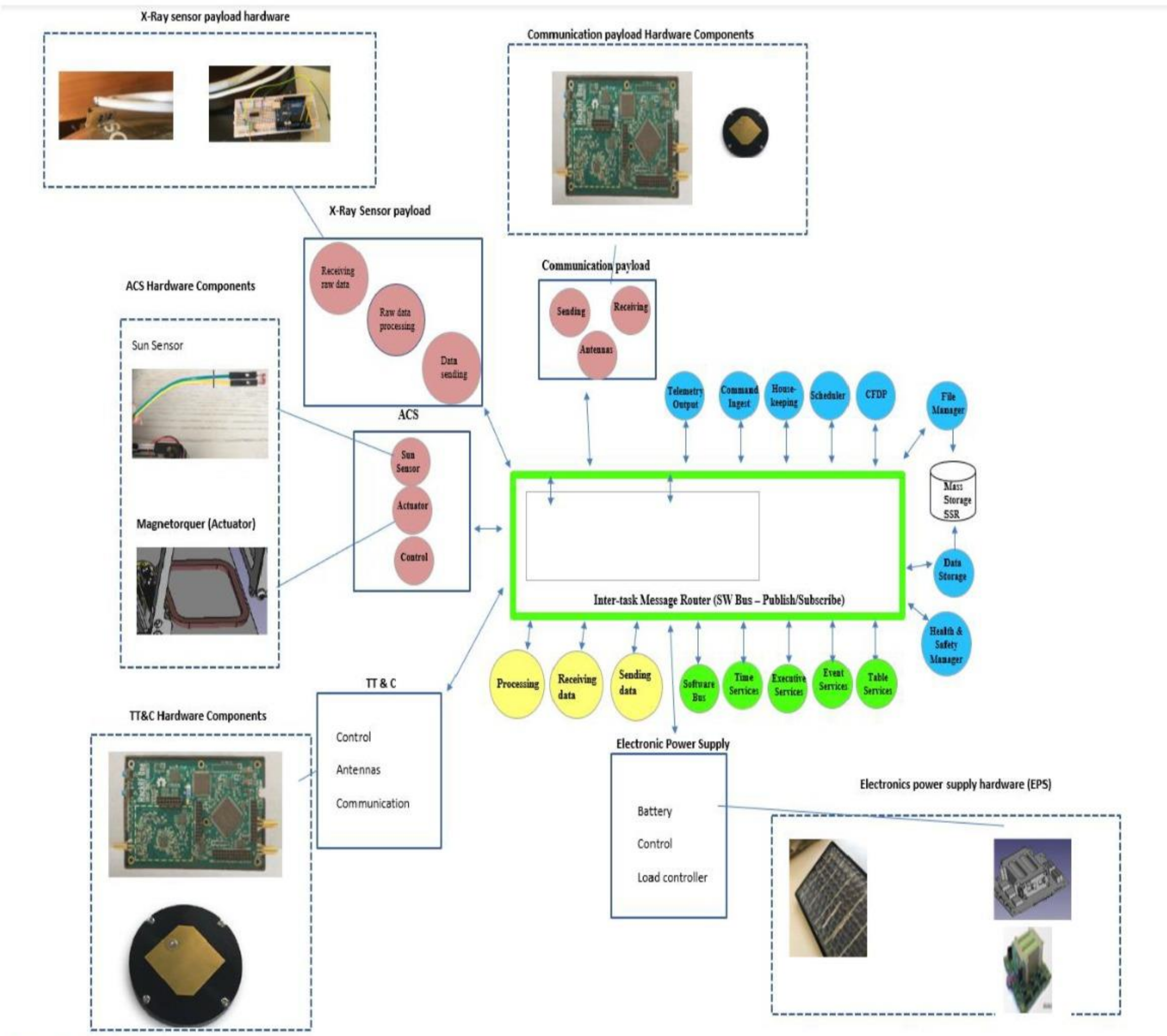


Figure 9: System Design

Legend:

: Components of a block

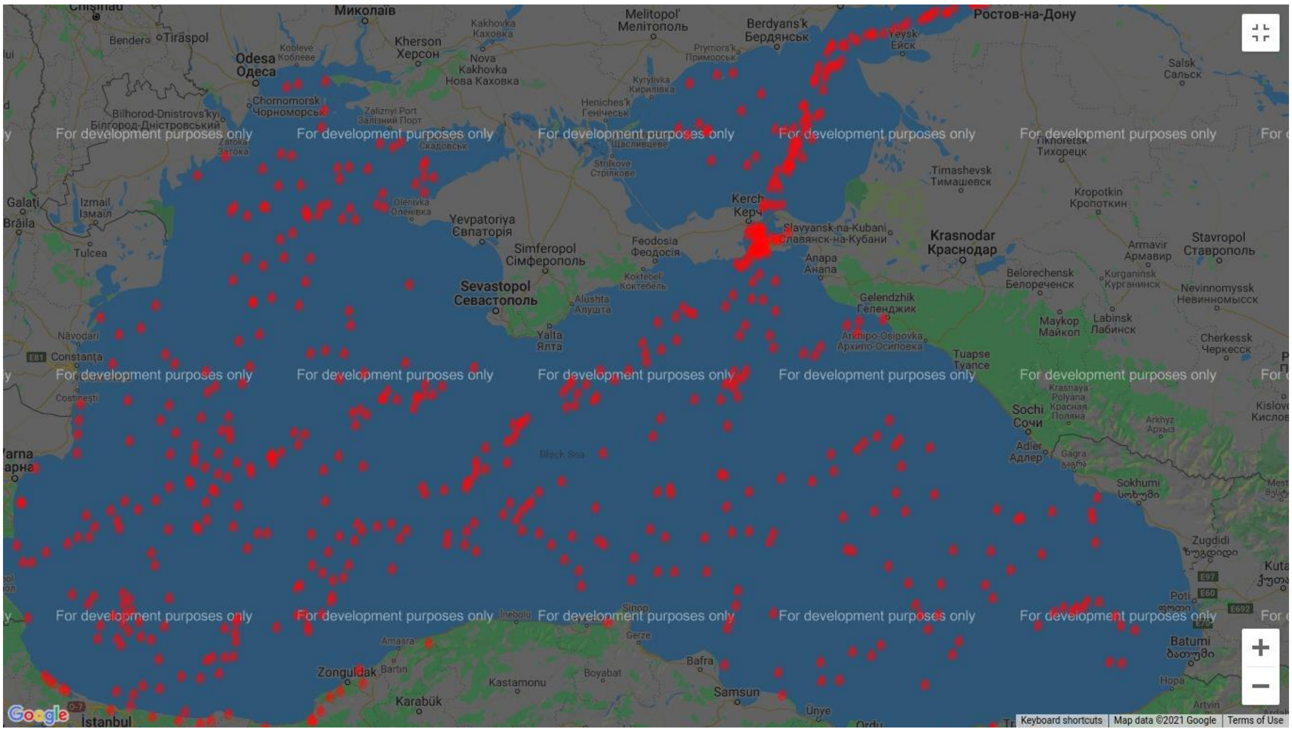
: CFS Configurable Applications

: cFE Core Services

: X-Ray Specific Apps

As payload also the AIS system shall be implemented (Rozan Mustafa as master thesis at Marmara Univ.)

6.2.4 AIS system on the OBC



6.3 HackRF Card (Responsible: Abdurrahman)

Establishing digital communication between HackRF and On-Board Computer

6.4 Attitude Control System (ACS) (Responsible: Raja)

Sensors: Sun sensor, IMU (see FCS of TEMOLeb-Mintad 2018 in TEMOLeb-Mintad Final Report[3])

Actuators: Magnetorquer

6.5 X-Ray Sensor (Responsible: Yahya, Raja)

This project will present the design and implementation of an X-ray detector system that is based on low-cost PIN diodes (BPW34). General procedure of designing the preamplifier and shaping amplifier will be presented as well as the practical approach to implement this system.

Typically, the PIN diodes (detectors) have low-voltage input signal and have to be amplified via an extremely low-noise preamplifier. The preamplifier acts as a first stage in a chain of amplifiers that has very sensitive characteristics. Then, a shaping amplifier is used to make a reasonable signal shape that has the shape of a tail which can be processed and interpreted by a microcontroller. An ADC will then be used to transform these analog quantities to digital. Figure 3 below shows the overall process of converting input charges from a detector into digital readable signal proportional to input charges.

---

[3] See [2]

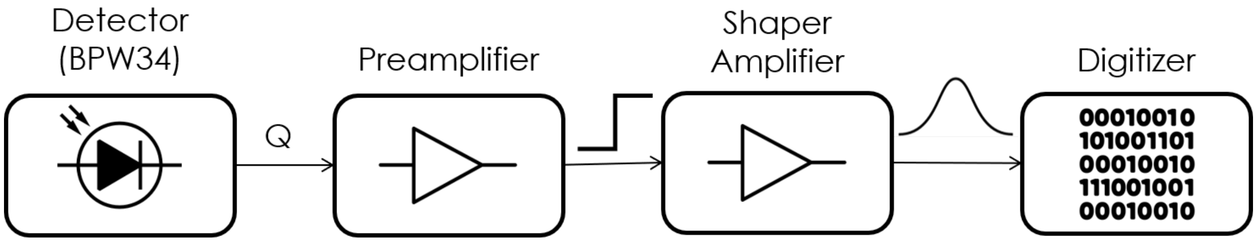


Figure 3. Silicon Detector Amplification Stages

There are mainly 3 types of preamplifiers and are listed below. However, we are just interested in charge-sensitive preamplifiers which are the type used for charge detector applications.

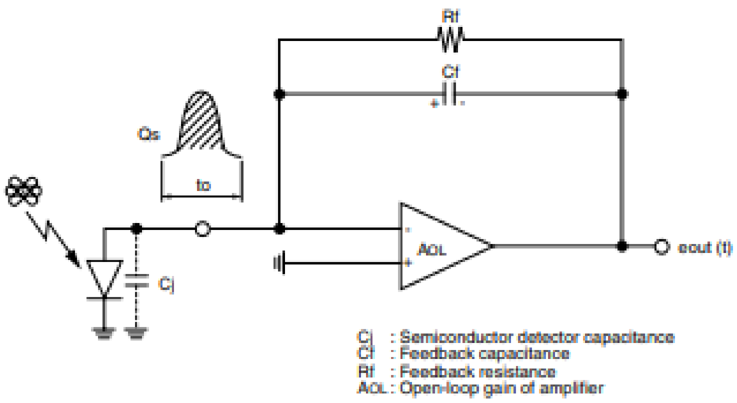
- Voltage-sensitive preamplifier.
- Current-sensitive preamplifier.
- Charge-sensitive preamplifier.

6.5.1 Charge Amplifier

As mentioned before, the PIN diode, when used to detect X-rays, outputs a very weak charge pulse having a pulse width of several tens of nano seconds. Since the detector is can be modeled as a capacitive device, its impedance is high and the preamplifier should be designed according to this criterion. For these applications, an integrator amplifier (using capacitor feedback) is used since it has high impedance, integrates weak charge pulses and converts them to voltage pulses ready for further amplification.

The first stage of charge amplifier (preamplifier) is usually a low-noise FET and its open loop gain must be set high in a way that the second amplification stage is not influenced by the detector capacitance.

When X rays strike into the detector, signal charges Q_s are generated with an amplitude proportional to the particle energy. These signal charges are all integrated in the feedback capacitance C_f (since it can be approximated that the current entering the op amp is equal 0) and then a pulse output $e_{out}(t)$ is generated.



In general, the following characteristics are required for the design of a good X ray charge amplifier:

- High gain
- Low noise (Excellent signal-to-noise ratio)
- Excellent integration linearity
- High speed rise time
- High temperature stability

6.5.2 Gain

The gain of charge amplifier is given in 2 ways; amplifier gain alone or the gain for detector/amplifier together. Amplifier gain (G_c) which is also referred to charge gain is given as:

$$G_c = \frac{V_{out}}{Q_s} = \frac{1}{C_f}\left[\frac{V}{Columb}\right] or \left[\frac{V}{picoColumb}\right] \quad (1)$$

The charge fall time of the amplifier can be determined by the feedback resistance and capacitor. $\tau_f = R_f C_f$

Amplifier with detector gain can be referred to as sensitivity (R_s). Sensitivity is expressed as output voltage mV per one MeV of energy particle irradiated onto the detector. The amplitude of the signal charge obtained with a semiconductor detector is determined by the input particle energy such as X-rays and also by the material of the semiconductor.

$$Q_s = \frac{E.e^-}{\varepsilon} \quad (2)$$

Where, E is the particle energy (MeV), e^- is the elementary charge ($1.6e^{-19}$ C), and ε is the energy required to create one electron/hole pair. For silicon, ε varies between 3.62 eV and 3.71 eV. From equations (1) and (2), amplifier's sensitivity can be written as:

$$R_s = \frac{V_{out}}{E} = \frac{e^-}{C_f}.\frac{1}{\varepsilon}\left[\frac{mV}{MeV}\right] \quad (3)$$

Noises:

Noises in charge amplifiers come generally from 3 sources: Thermal noise of first-stage FET, shot noise caused by the gate current of the first stage FET and dark current of the detector, and thermal noise caused by the feedback resistance. The noise of the first-stage FET is given as:

$$en_1 = \sqrt{\frac{8}{3}.\frac{KT}{g_m}} \quad (4)$$

Where, K is Boltzmann constant, T is the absolute temperature in Kalvin, and g_m is the mutual conductance of first-stage FET. The second noise source, shot noises, can be expressed as:

$$in = \sqrt{2q(I_G + I_D)}\ (A/\sqrt{Hz}) \tag{5}$$

Where, q is the elementary charge, I_G is the gate leakage current of first-stage FET, and I_D is the dark current of the detector. The third and final source of noises can be presented as:

$$en_2 = \sqrt{4kTR_f}\ (V/\sqrt{Hz}) \tag{6}$$

Where, R_f is the feedback resistance. From equations (4), (5), and (6), the total noise of a charge amplifier can be written as:

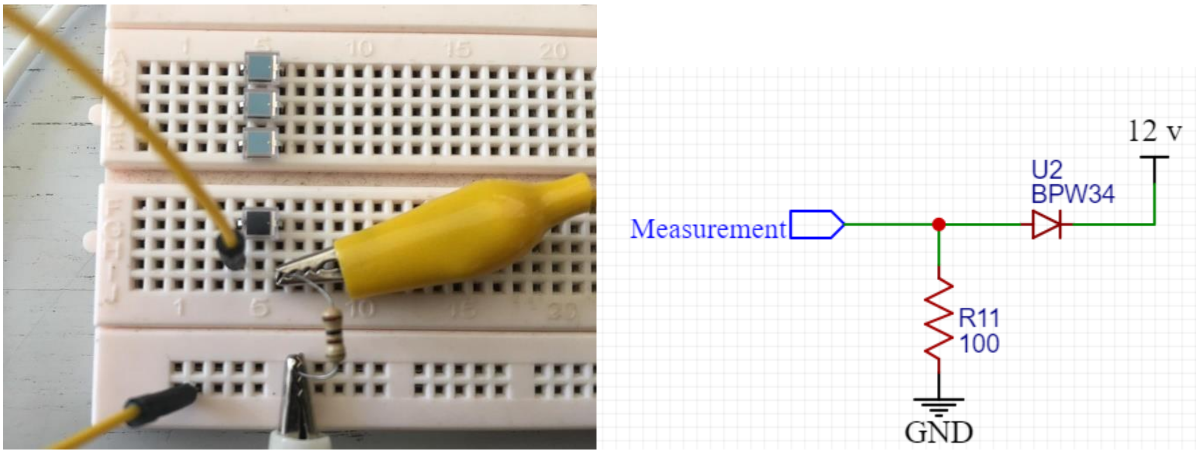
$$en_t(jw) = en_1^2 . \left(1 + \frac{C_{in}}{C_f}\right)^2 + \left[in^2 + \left(\frac{en_2}{R_f}\right)^2\right] . \frac{1}{(jwC_f)^2} \tag{7}$$

The first term is constant over the entire frequency range and amplified by the noise gain $(1 + \frac{C_{in}}{C_f})$ determined by the input capacitance. The second term component is constant regardless the input capacitance but it decreases with the frequency.

6.5.3 Experiments

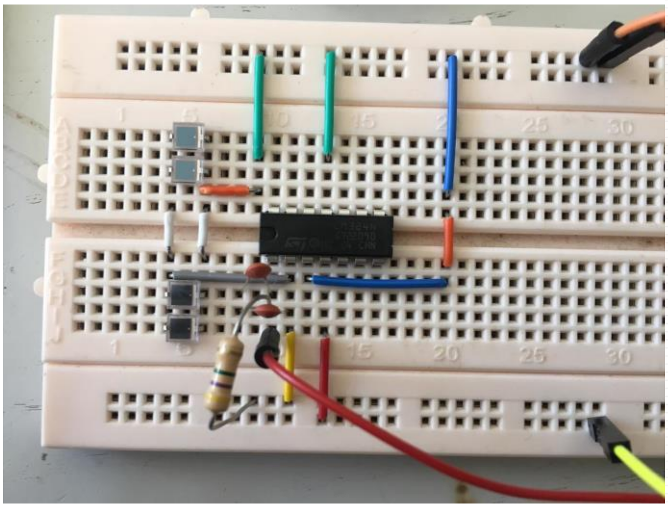
6.5.3.1 Experiment 1: I-V characteristics of BPW34 diode: (28-6-2021)

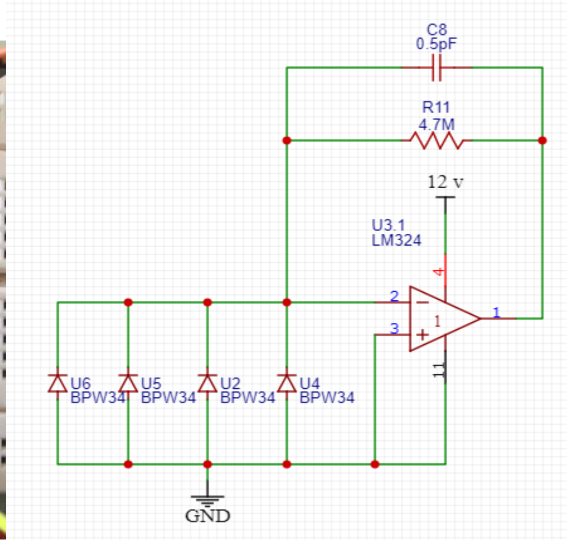
The I-V characteristics of a photodiode are studied with the same manner of an ordinary diode. The diode is studied under reverse voltage of 12 V to ensure its ionization and with a 100 ohms resistor to measure the current across it using an oscilloscope. A flash light from the phone is used as luminance input.

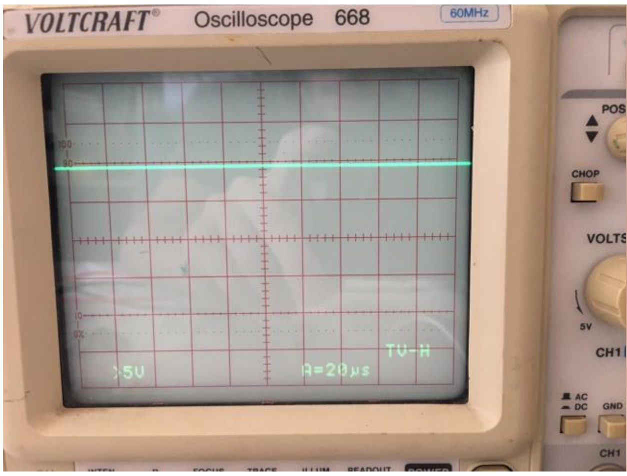


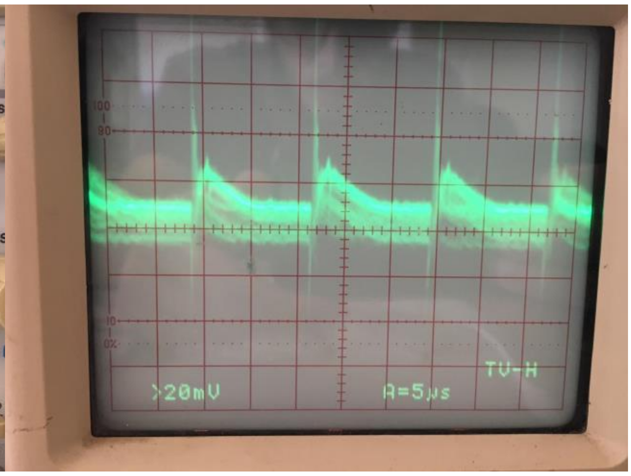
6.5.3.2 Experiment 2: Preamplifier Design: (28-6-2021)

This experiment uses an ordinary feedback integrator circuit with pulling down the non-inverting pin of the op amp. The charge op amp fall time is approximated to be 23.5 micro-seconds (5 pF * 4.7 M).





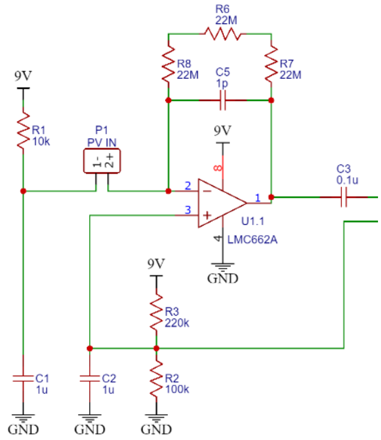


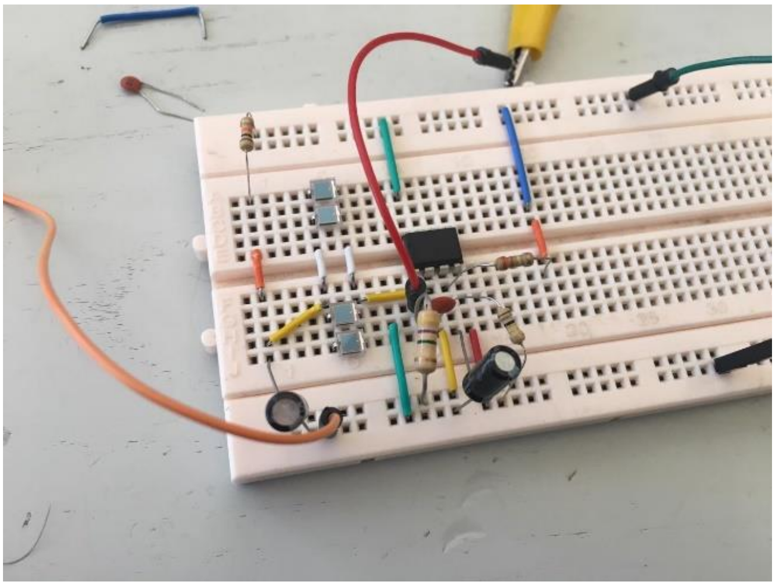


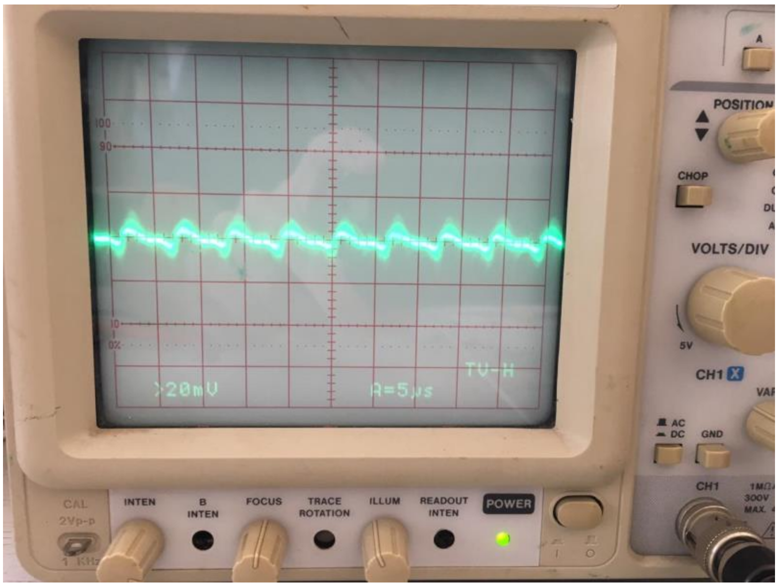
However, the output is constant (left figure) no matter how much light is presented at the photodiodes. After some modifications, a 10-pF capacitor is mounted between the photodiodes and the operational amplifier and it can be seen from the right figure above a nearly charging and discharging signal shape. **(FAILED)**

6.5.3.3 Experiment 3: Preamplifier Design: (29-6-2021)

Another experiment was done by presenting a bias voltage for the photo diodes by connecting a voltage divider network into the non-inverting operational amplifier pin. The output can still be seen as very noisy. **(FAILED)**



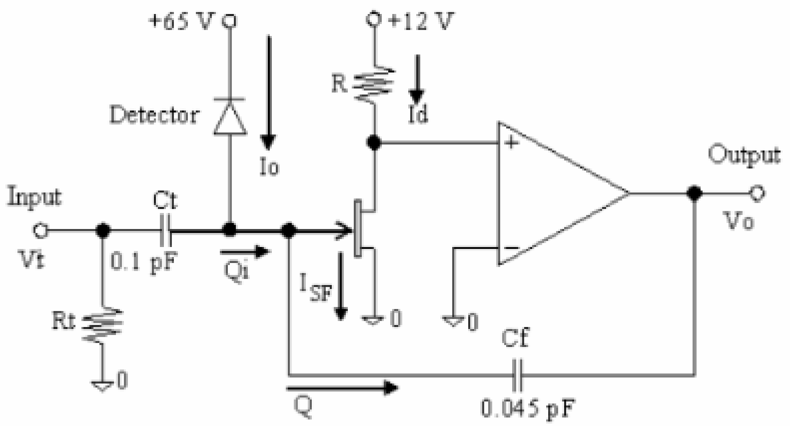




6.5.3.4 Conclusion: Preamplifier Design: (2-7-2021)

The previous experiments gave unsatisfactory results due to several reasons, such as:

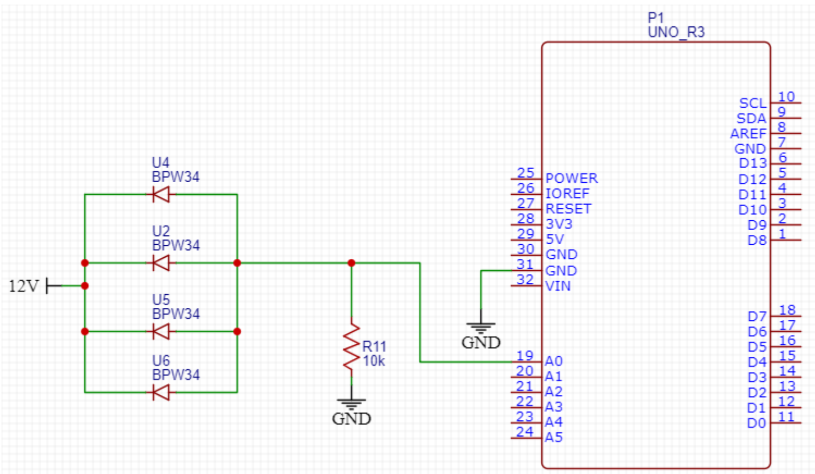
- A JFET transistor should be used at the output of the detector with low capacitance junction to collect the charges from the detector. JFET transistor suggestions can be: 2N4416, 2SK152, 2N6550.



- Another operational amplifier with JFET input should be used such as TLE2072 or OPA324.

6.5.4 Monitoring (6-7-2021)

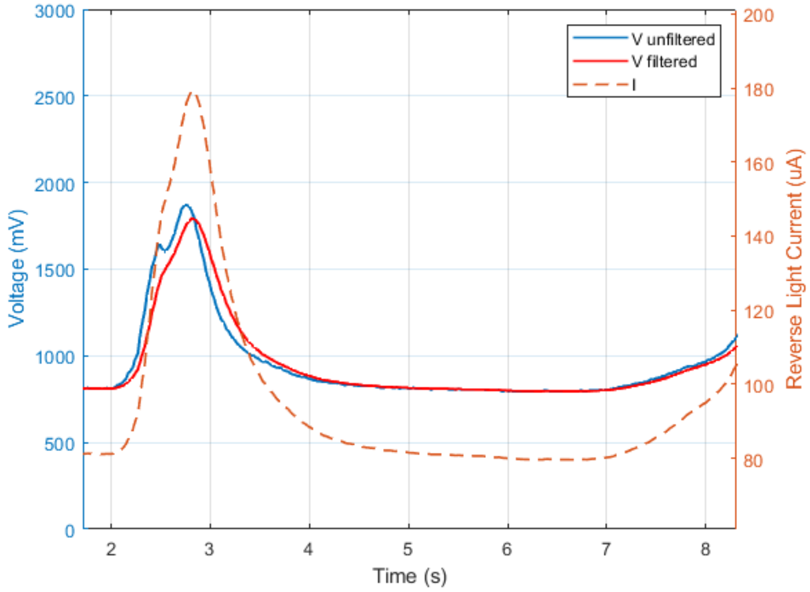
Another approach was taken in order to monitor the energy received by the photodiodes. The photodiodes in this experiment were dealt with as current sources. A resistor is connected to the reverse diodes in order to get a voltage image of the current. An Arduino Uno is used to read the voltage coming from the photo diodes through its analog pin A0 which will be then converted into current.



The nominal voltage, when the diodes are exposed to normal room lights, was approximately 750 mV. When an external light source (phone flashlight) is exposed to the diode array at a distance of approximately 8 cm, the voltage rises to 1780 mV. A complimentary filter is used to filter out measurement noises which has the following form:

$$V_{filt} = \alpha . V_{filt} + (1 - \alpha) . V_{measured} \tag{8}$$

Where, α is a wheighing constant between 0 and 1 which prefers one variable over the other, where it was chosen as 0.8. The current is calculated by dividing the output voltage by the load resistance of 10 k ohms.



The light intensity, at this stage, can be calculated from the current graphs given by the datasheet of the BPW34 photodiodes. It is noteworthy that there are 4 diodes connected in parallel so the current is added.

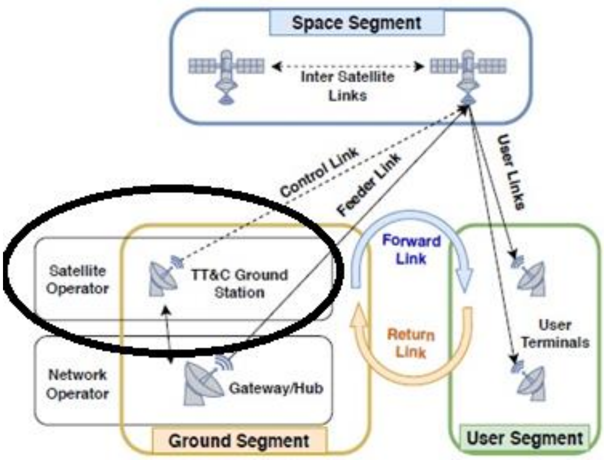
6.5.5 Testing X-Ray Sensor with e-beam on cupper

You can find the full vidoe on the following link:

https://drive.google.com/file/d/1ftpkXedKj8o95gi0vmIOGuOIiWHcSMjj/view?usp=drivesdk

6.6 Telemetry, Tracking & Control (TT&C) Ground Station

6.6.1 Requirements (A DESCRIPTION OF A STANDARD SMALL SATELLITE GROUNDSTATION FOR USE BY WMO MEMBERS [4])



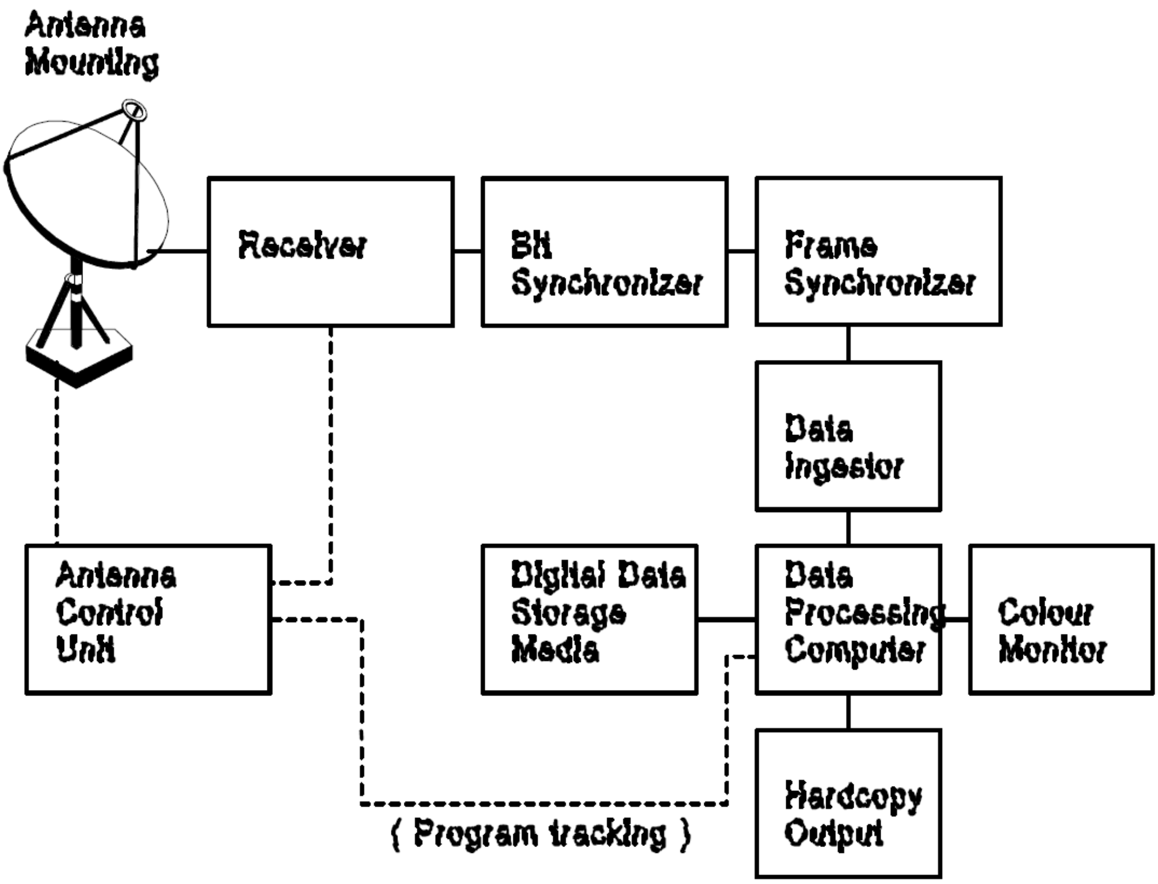


Fig.1 Block Diagram of a small satellite ground station

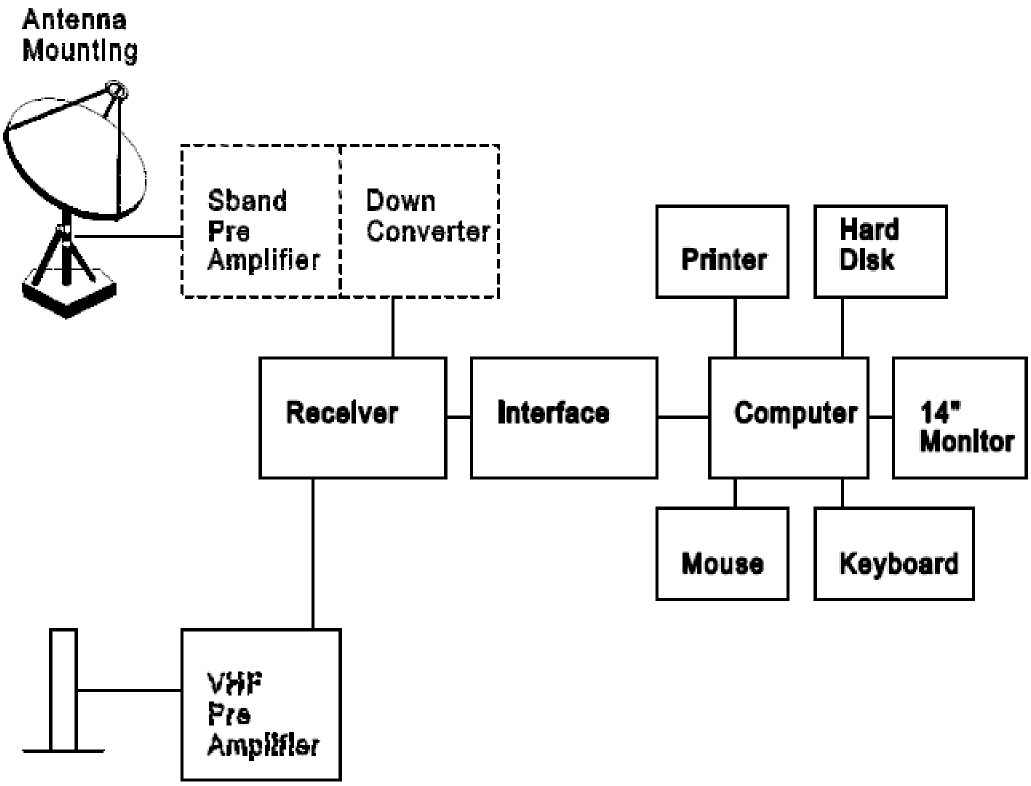


Fig.2 APT/WEFAX Receiving and Processing Station

5.1.1 S-band parabolic antenna

5.1.1.1	Diameter of antenna:	: 1.5 m
5.1.1.2	Gain	: 26.0 db
5.1.1.3	Beamwidth	: 8.1°
5.1.1.4	Frequency	: 1691.0 MHz
5.1.1.5	Polarization	: linear
5.1.1.6	Mount	:fixed, variable adjust, elevation 90°, azimuth (20° - 70°)
5.1.1.7	VSWR	: 1.5
5.1.1.8	Impedance	: 50 Ω

5.1.2 S-band preamplifier and down converter

5.1.2.1	RF input	: 1691.0 MHz
5.1.2.2	IF output	: 137.5 MHz or other
5.1.2.3	Band width	: 6 MHz
5.1.2.4	IF/RF gain	: 30 db
5.1.2.5	Noise figure	: 1.5 db
5.1.2.6	Stability	: 5×10^{-6}
5.1.2.7	Impedance	: 50 Ω
5.1.2.8	Cable length	: 60 m

5.1.3 VHF antenna

To reduce the price and for ease of maintenance, an OMNI directional non-tracking antenna is recommended. An OMNI directional non-tracking antenna must be able to receive data above an elevation of 5°. This requirement will reduce interference while maximizing the possibility for coverage of synoptic scale meteorological phenomena.

<u>OMNI directional antenna</u>

5.1.3.1	Frequency	: 137.5 MHz
5.1.3.2	Polarization	: right hand circular
5.1.3.3	Impedance	: 50 Ω
5.1.3.4	VSWR	: 2.1 max
5.1.3.5	Gain	: 3 dbi
5.1.3.6	Beamwidth	: 180°

Depending on the user's situation and requirements, an omni-directional antenna may not be sufficient for proper APT reception. Under these circumstances, the use of a directional antenna, such as a crossed Yagi, would provide higher performance and greater coverage. Note that use of program tracking and other antenna pointing methods would be required. The following information describes an alternative to the OMNI directional antenna described in sections 5.1.3.1 through 5.1.3.6.

<u>Directional antenna (Yagi)</u>

5.1.3.7	Centre frequency	: 137.5 MHz
5.1.3.8	Polarization	: right hand circular
5.1.3.9	VSWR	: 2.0 max
5.1.3.10	Gain	: 20 dBi or greater
5.1.3.11	Beamwidth	: 20 degrees at 20 dBi
5.1.3.12	Mount	: Elevation over azimuth
5.1.3.13	Program track	: Program track

5.1.4 VHF Preamplifier

5.1.4.1	Centre frequency	: 137.5 MHz
5.1.4.2	Gain	: 30 db
5.1.4.3	Noise figure	: 2 db
5.1.4.4	Installation	: in antenna base

5.1.5 Receiver

5.1.5.1	Type	: FM phase lock loop
5.1.5.2	Input frequency	:Switch selectable crystals for reception of APT and WEFAX
5.1.5.3	IF bandwidth	:50 KHz and 30 KHz --switch selectable
5.1.5.4	Noise figure	: 5 db

5.1.6 Computer

5.1.6.1	486 computer with TVGA card (1024 x 768 resolution)	
5.1.6.2	Colour monitor	:14"
5.1.6.3	Hard disk	: 120 MB
5.1.6.4	Memory	: 4 MB
5.1.6.5	Clock : 33 MHz	
5.1.6.6	Keyboard	
5.1.6.7	Mouse	
5.1.6.8*	Printer (optional)	

5.1.7 Outdoor environment

5.1.7.1	Temperature	: -40° C - +50° C
5.1.7.2	Humidity	: 98%
5.1.7.3	Wind	: operational 20 m/s, survival 35 m/s

5.1.8 Power

5.1.8.1	110v/220v +- 10%
5.1.8.2	50Hz/60Hz

5.2 Specification requirement, for high resolution ground station

The stations should be reliable and easy to operate. The block diagram of the high resolution ground station is shown in Fig.3. If the station receives geostationary satellite data, it should be equipped with a fixed antenna. If the station receives polar orbiting satellite data then it must be equipped with a tracking antenna and antenna control unit.

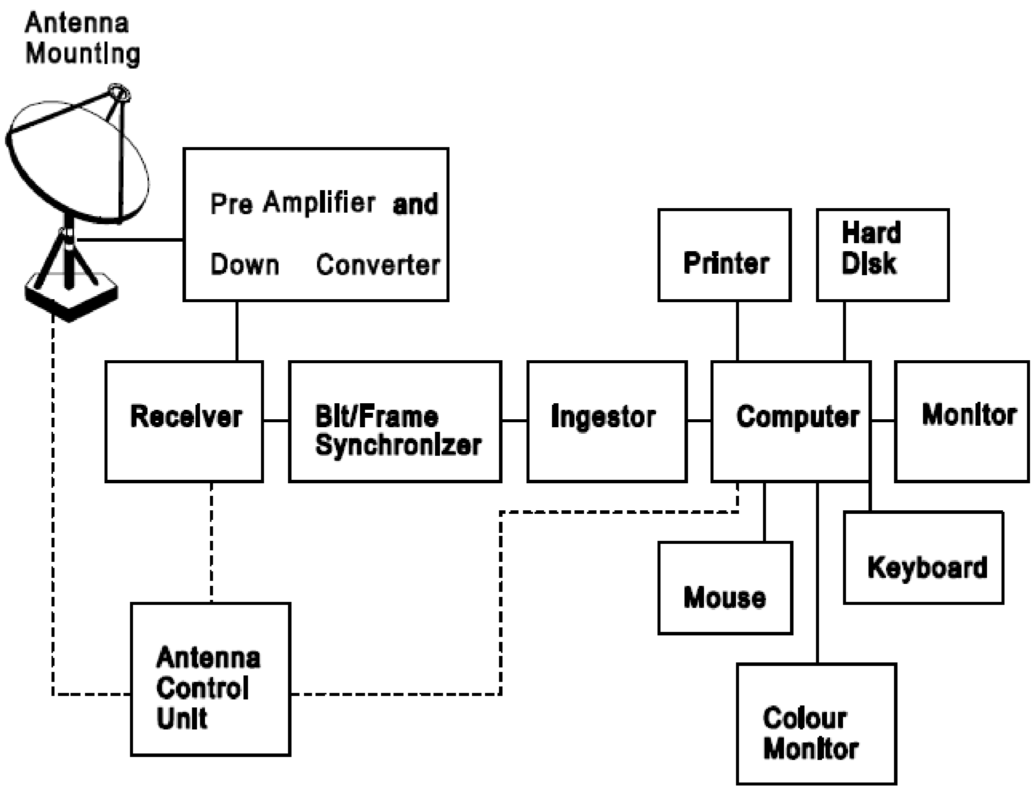


Fig.3 High Resolution Data Receiving and Processing Station

5.2.1	**S-band tracking antenna and antenna control unit for receiving HRPT data**	
5.2.1.1	G/T merit of antenna system	:>6 db/K bit error rate is better than $1x10^{-6}$ at 5 degree elevation
5.2.1.2	Frequency	:1670~1710 MHz
5.2.1.3	Polarization	: RH, LH
5.2.1.4	Impedance	: 50/75 Ω
5.2.1.5	VSWR	: 1.5
5.2.1.6	Antenna mounting	: azimuth-elevation
5.2.1.7	Tracking coverage	: full geometric coverage including overhead passes (Z-pass), good performance of Z-pass tracking
5.2.2	**S-band fixed antenna for receiving geostationary satellite**	
5.2.2.1	G/T merit of antenna system	:G/T depending on which satellite to be received, G/T must guarantee that bit error rate is less then 10^{-6} in the worst case
5.2.2.2	Frequency	: 1670~1710 MHz
5.2.2.3	Polarization	: linear
5.2.2.4	Mounting	: fixed, variable adjust elevation 90, azimuth 20° ~70°
5.2.2.5	VSWR	: 1.5
5.2.2.6	Impedance	: 50/75 Ω

6.6.2 As reference a ground station design from 2007 ([3]):

Abstract of [3] :

The CubeSat satellite ground station at the University of Wuerzburg is built with "commercial of the shelf" low cost amateur radio hardware. It opens up opportunities for students to receive and operate CubeSats, including Wuerzburgs UWE-1. As any other satellite ground station, it is built up on essential hardware, as there are Antenna, Antenna Rotator, Radio, Modem and Computers. Furthermore software is used to afford basic control over the ground station and provide tracking abilities to follow a satellite passing over the ground station.

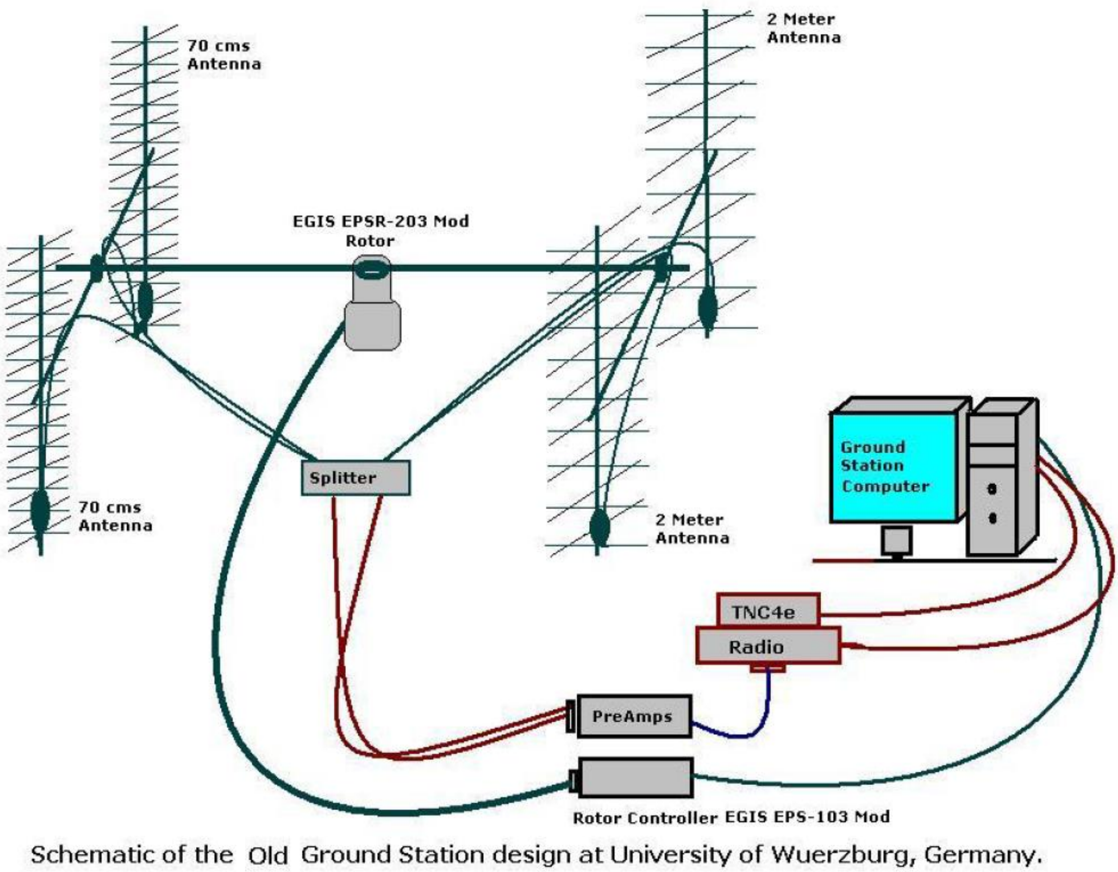
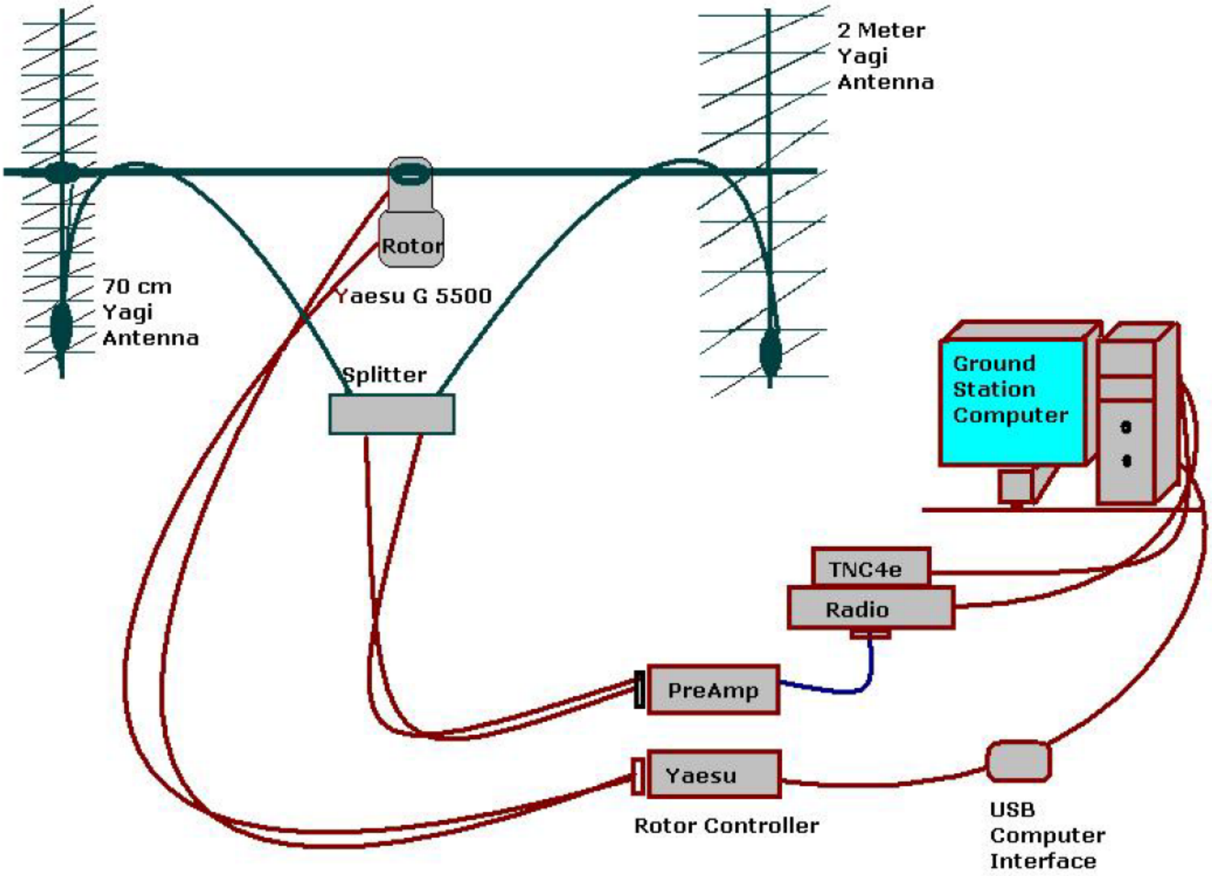


Figure 1.1: Old design of the Ground Station.

Ground Station structural study

Related CubeSat.	***University.***	***Antenna Rotor.***	***Rotor Computer Controller & Tracking Software.***
Delfi-C3	Delft University of Technology	Yaesu G-5500	NOVA for Windows
AAU Cubesat	Aalborg University of Technology	Yaesu G-5500	Predict
CubeSat	University of Arizona	Yaesu G-5500	NOVA for Windows with Uni_Trac
PolySat	California Polytechnic State University, U.S.	Yaesu G-5500	SatPC32
Cubesat	University of Tokyo, Japan	Elevation Rotator ERC5A (Creative Design) Azimuth Rotator RC5A-3 (Creative Design)	Orbital calculation software (Virtual Ground Station 3)
Cubesat	TU-Berlin	Yaesu G-5500	SatPC32 and ARSWIN
---	Kagawa University, Japan	ERC-5A (El) And RC5B-3P (Az)	Satellite Tracker is RAC825
--- ---	Kyusyu University Ground Station. Kyushu Institute of Technology.	EMOTATOR EV-800D Yaesu G-5500	No avail info GS-232A
---	Nara National College of Tech, Japan	Yaesu G-5500	GS-232A and Nova for Windows.
---	Soka University Ground Station Unit.	Yaesu G-550 (El) And Yaesu G-2300DXA (Az)	GS-232B

Figure 1.2: Ground Station Structural Study.



Schematic of the new Ground Station design at University of Wuerzburg, Germany.

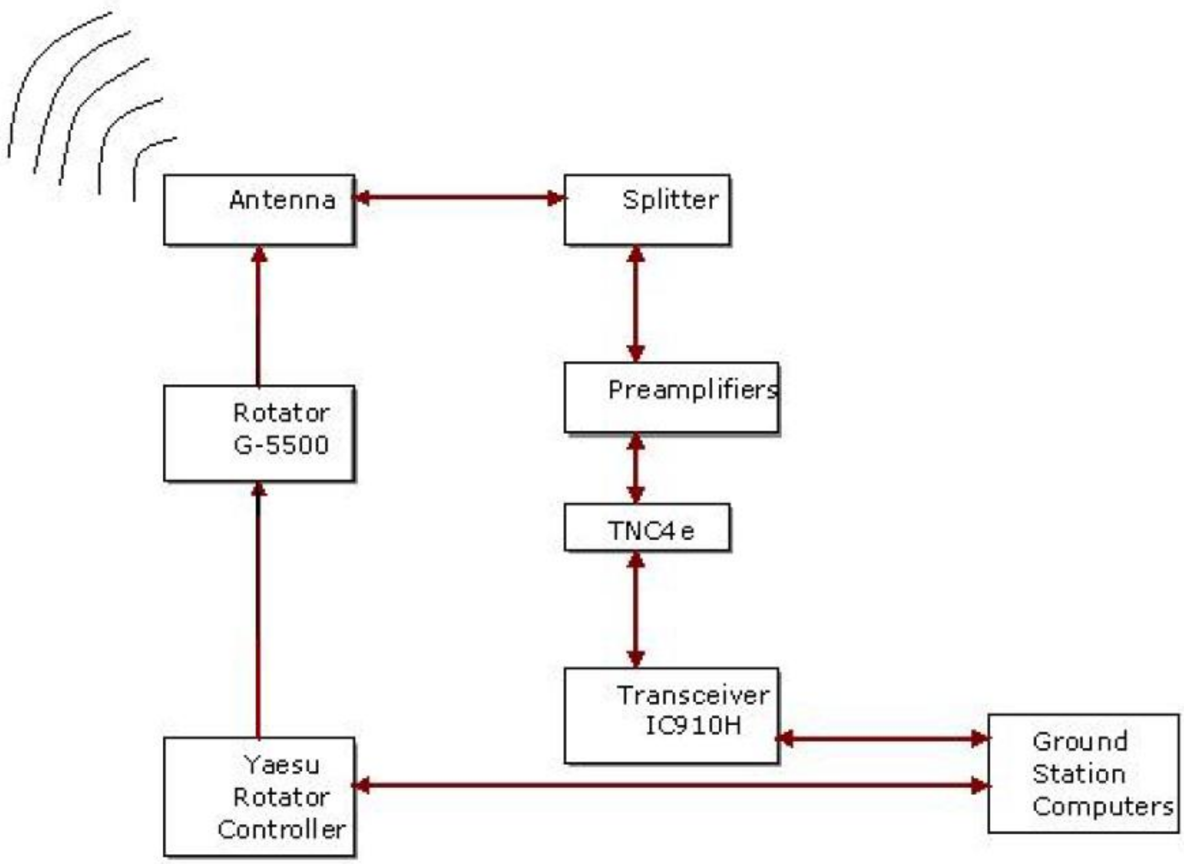
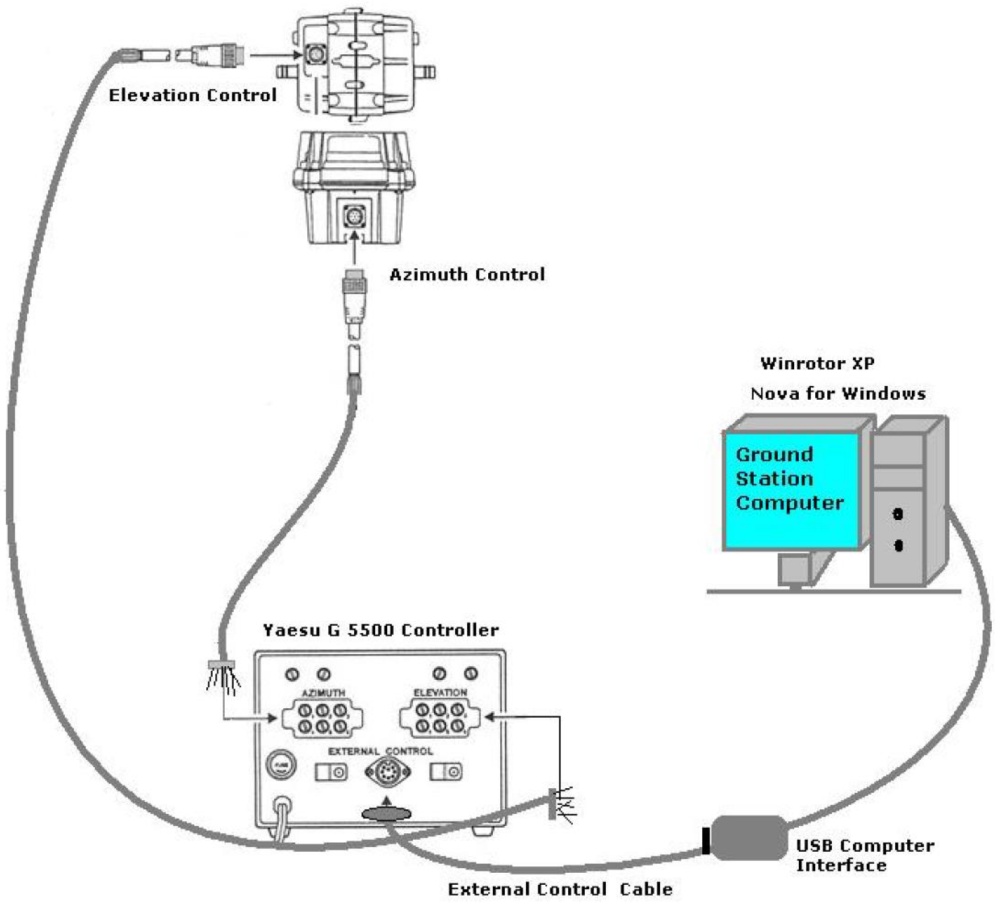


Figure 1.4: Block Diagram of the Ground Station.

Altitude	310 meters
Tower	Hummel Teletower Jumbo III
Operating frequencies	2m and 70 cms amateur bands
One 2 meter antenna	M2 2MCP22
One 70 cms antenna	M2 436CP42U/G
Antenna rotator and Controller	Yaesu G-5500
Rotator-Computer Interface	WinRotor
Rotator-Computer Interface driver	WinRotor XP
Radio	TNC4e
Polarisation switch	WiMO
Preamplifiers	LNA-145, SLN Series
Tranceiver	ICOM IC-910H
Power Supply	Microset 13.5 Volts
Two PCs	Fujitsu Siemens

Table 2.1: Hardware Specifications Table.



Rotor-Controller-Computer Interfacing.

6.6.3 Graphical User Interface

Installing Nova for Windows

(a) Insert the Nova for Windows CD into the CD-ROM drive of your computer.

(b) If the setup program doesnt start automatically, click on the Start button (lower left corner of the desktop).

(c) Click on Run.

(d) In the file name box, type **Setup.EXE**.

(e) Follow the directions in the Nova for Windows Setup.

Important:

Be sure to enter the serial number carefully. Serial number must include the NLD- prefix.

First step is to set the type of Map. In the screenshots shown below "Large Rectangular Map" is selected for convenience.

To choose the new map setting the path is-
"Views" then "Configure current view" and then Choose "Map display" and "Map Size".
Refer figure 2.11.

Second step is to set the position of the Ground Station in "Nova for Windows". The path is- "Setup" and then "Observers".

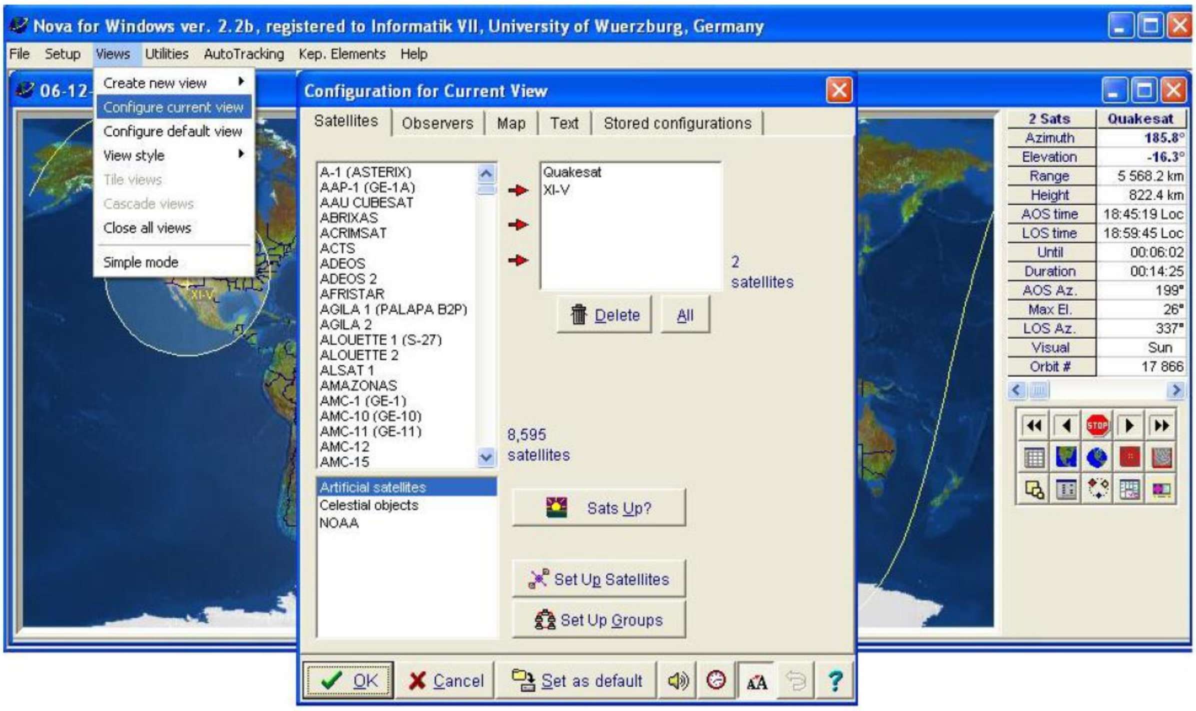


Figure B.1: Nova for Windwos - Configuring View.

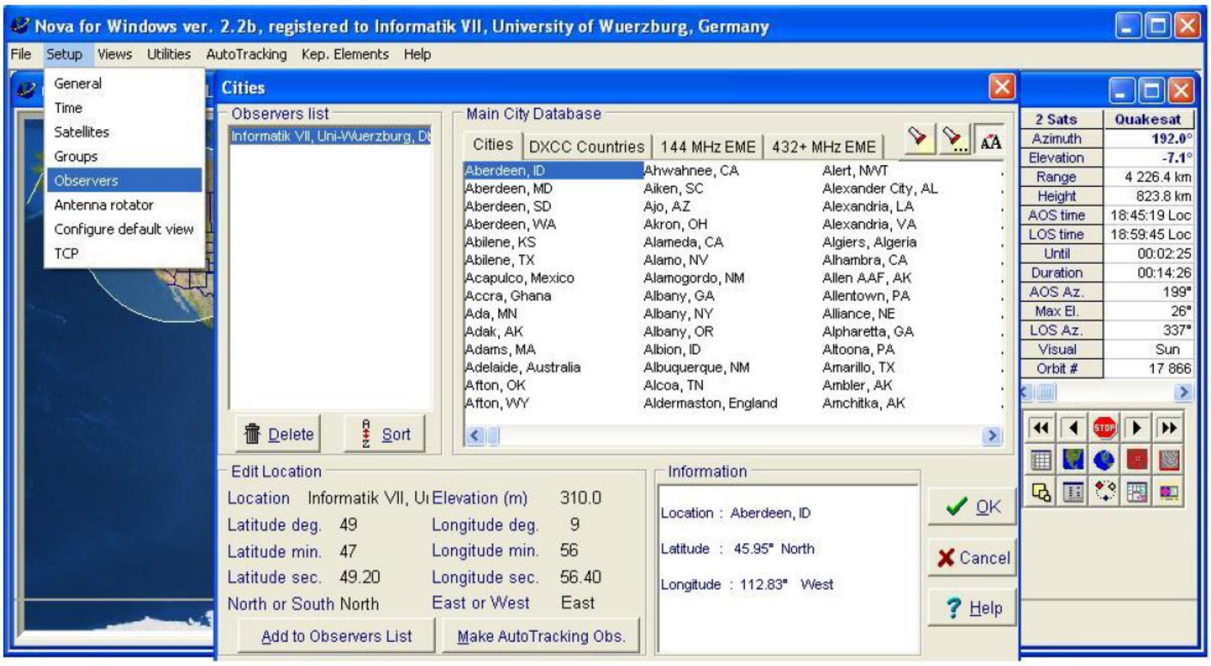


Figure B.2: Nova for Windows - Configuring Observer.

In our case it is:
Location: "*Informatics VII, Uni-Wuerzburg, Germany.*"
Elevation is of *310 meters.*
Latitude is *49 degrees 47 minutes 49.20 seconds North.*

Longitude is *9 degrees 56 minutes 56.40 seconds East.*
Refer figure 2.12.

Third step is to check the availability of the specific satellite from the Satellite Editor in the database of “Nova for Windows”.
In this editor, new satellite names and its Keplerian elements can also be added. Also “Update Keplerian Elements” button provides the on-line update.
The path is “Setup” and then “Satellites”.
Refer figure 2.13.

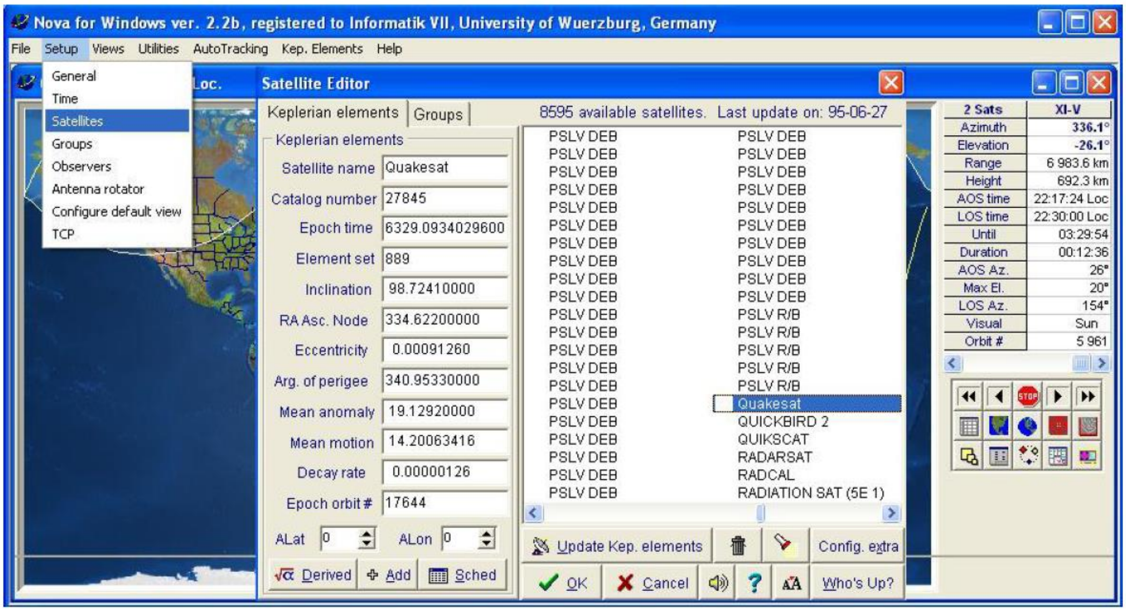


Figure B.3: Nova for Windows - Configuring Satellites.

To update Keplerian elements or to get related help click on “Kep Elements”. Refer figure 2.14.

Fourth step is to choose the “Current View” in order to see Satellite and Observer (Ground Station position) all together.
This provides a feature of selecting multiple Satellites and Observation points on the map at the same time.
The path is “Views” and then “Configure current view” and then “Satellites” or “Observes” or “Map” or “Text”. Refer figures 2.15 and 2.16.

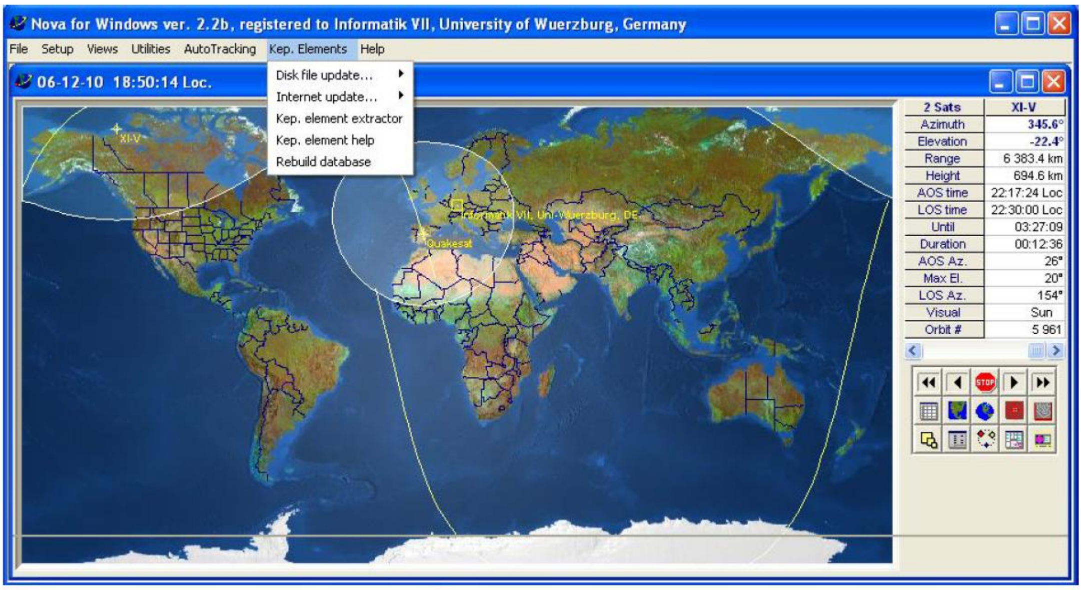


Figure B.4: Nova for Windows - TLE Updation

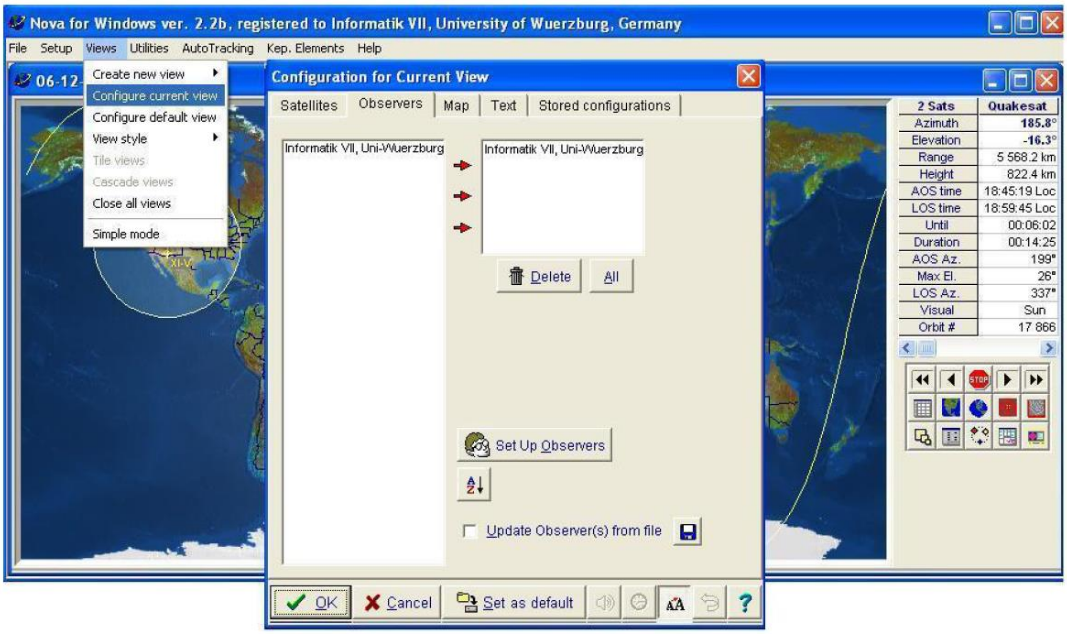


Figure B.5: Nova for Windows - Current View Observer.

On the Map, Footprint of the satellite/s and the Ground Station's position/s can be easily found. Refer figure 2.17.
On the Right hand side of the screen, Real-time text data of the con-

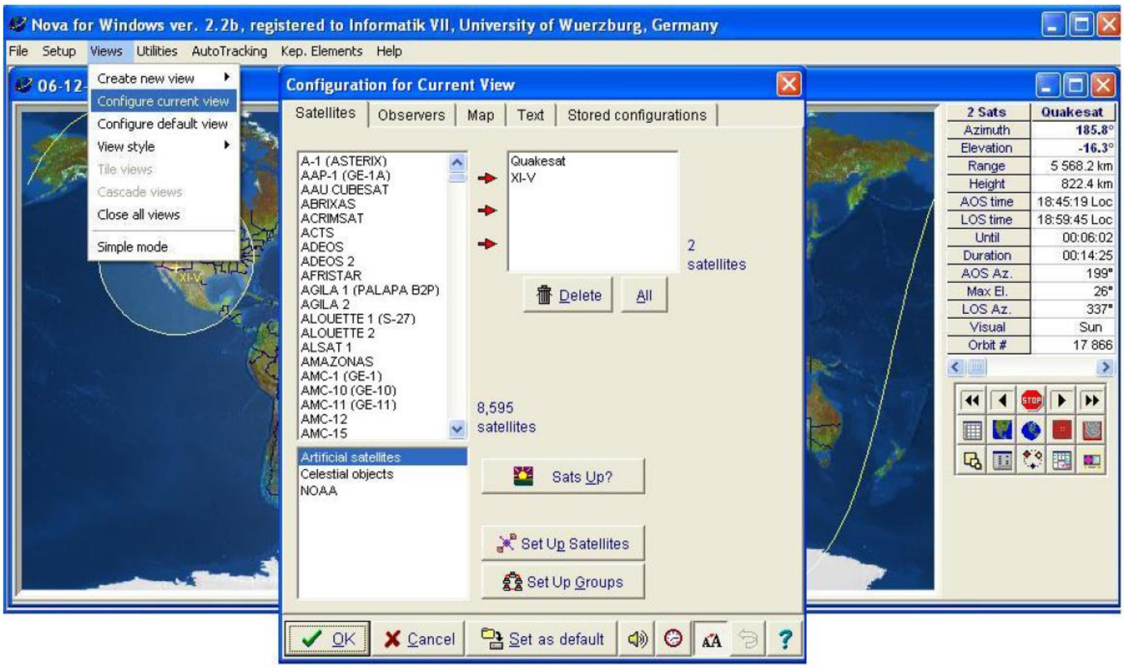


Figure B.6: Nova for Windows - Current View Satellite.

cerning satellite is available. The number of columns in the real-time text window depends on the number of satellites in the view.

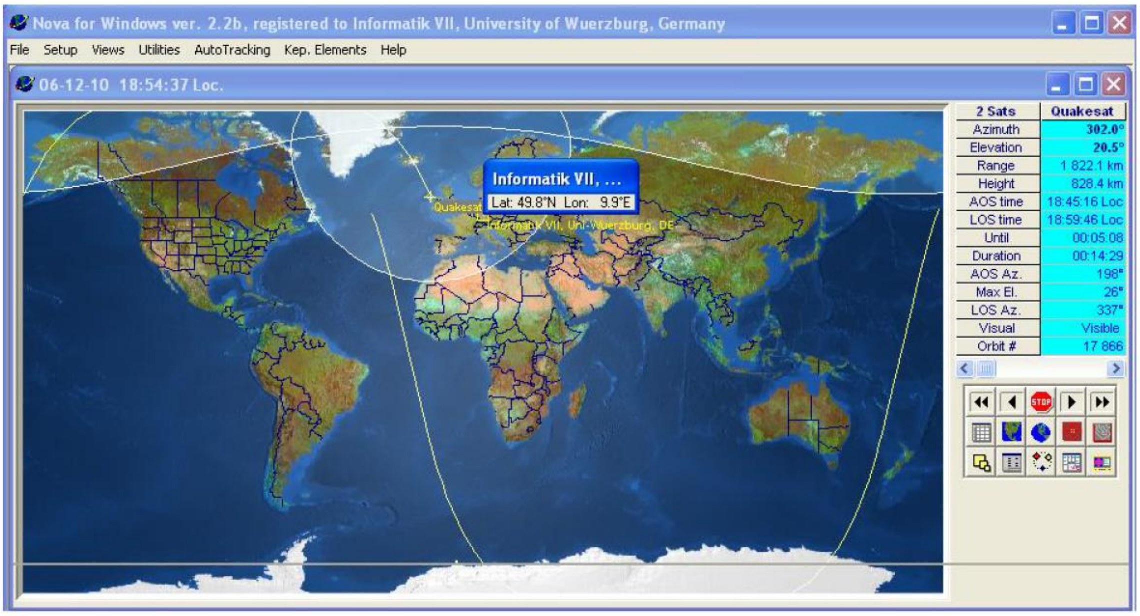
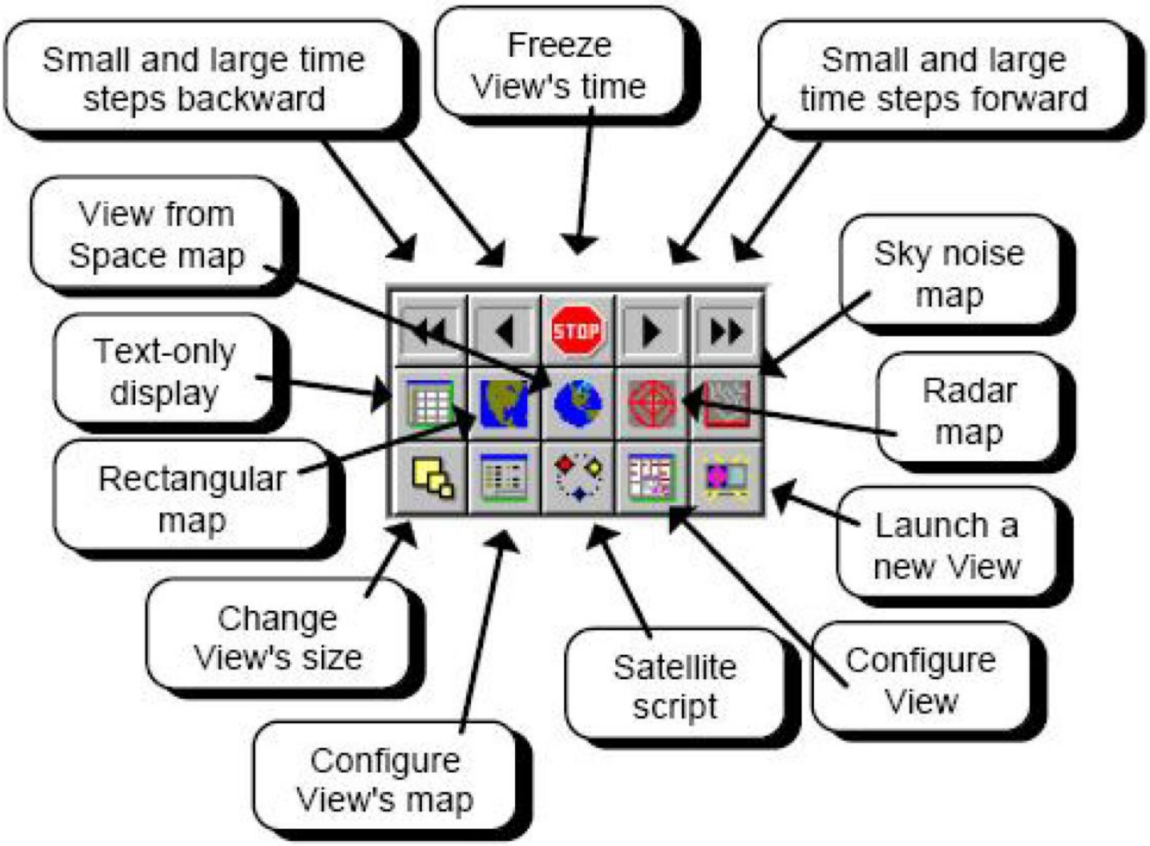


Figure B.7: Nova for Windows - Satellite Footprints.

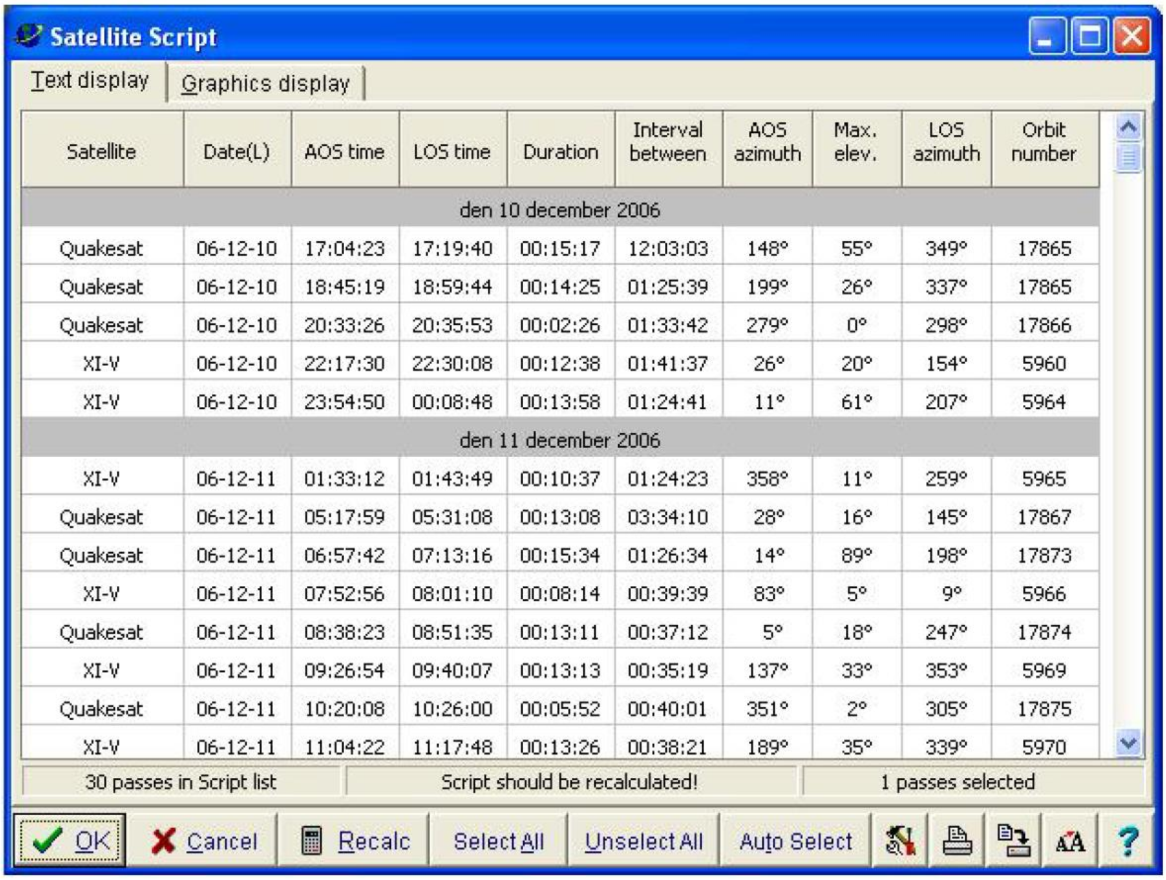
Satellite Script.

"Satellite Script" features the prediction of the flyby time of the satellite or satellites over a particular Observer (Ground Station) up to 48 hours in advance.
This also enables "automatic script tracking". Refer figure 2.19.



*Nova for Windows' floating **ToolBar** provides access to the most frequently-used functions.*

Figure B.8: Nova for Windows - Floating Toolbar.



Satellite	Date(L)	AOS time	LOS time	Duration	Interval between	AOS azimuth	Max. elev.	LOS azimuth	Orbit number
den 10 december 2006									
Quakesat	06-12-10	17:04:23	17:19:40	00:15:17	12:03:03	148°	55°	349°	17865
Quakesat	06-12-10	18:45:19	18:59:44	00:14:25	01:25:39	199°	26°	337°	17865
Quakesat	06-12-10	20:33:26	20:35:53	00:02:26	01:33:42	279°	0°	298°	17866
XI-V	06-12-10	22:17:30	22:30:08	00:12:38	01:41:37	26°	20°	154°	5960
XI-V	06-12-10	23:54:50	00:08:48	00:13:58	01:24:41	11°	61°	207°	5964
den 11 december 2006									
XI-V	06-12-11	01:33:12	01:43:49	00:10:37	01:24:23	358°	11°	259°	5965
Quakesat	06-12-11	05:17:59	05:31:08	00:13:08	03:34:10	28°	16°	145°	17867
Quakesat	06-12-11	06:57:42	07:13:16	00:15:34	01:26:34	14°	89°	198°	17873
XI-V	06-12-11	07:52:56	08:01:10	00:08:14	00:39:39	83°	5°	9°	5966
Quakesat	06-12-11	08:38:23	08:51:35	00:13:11	00:37:12	5°	18°	247°	17874
XI-V	06-12-11	09:26:54	09:40:07	00:13:13	00:35:19	137°	33°	353°	5969
Quakesat	06-12-11	10:20:08	10:26:00	00:05:52	00:40:01	351°	2°	305°	17875
XI-V	06-12-11	11:04:22	11:17:48	00:13:26	00:38:21	189°	35°	339°	5970

Figure B.9: Nova for Windows - Satellite Script.

Frequency display.

It also displays the Uplink and Downlink Frequencies, with the Doppler value for the particular selected satellite.

To check this, the path is "Utilities" and then "Frequency display". Refer figure 2.20.

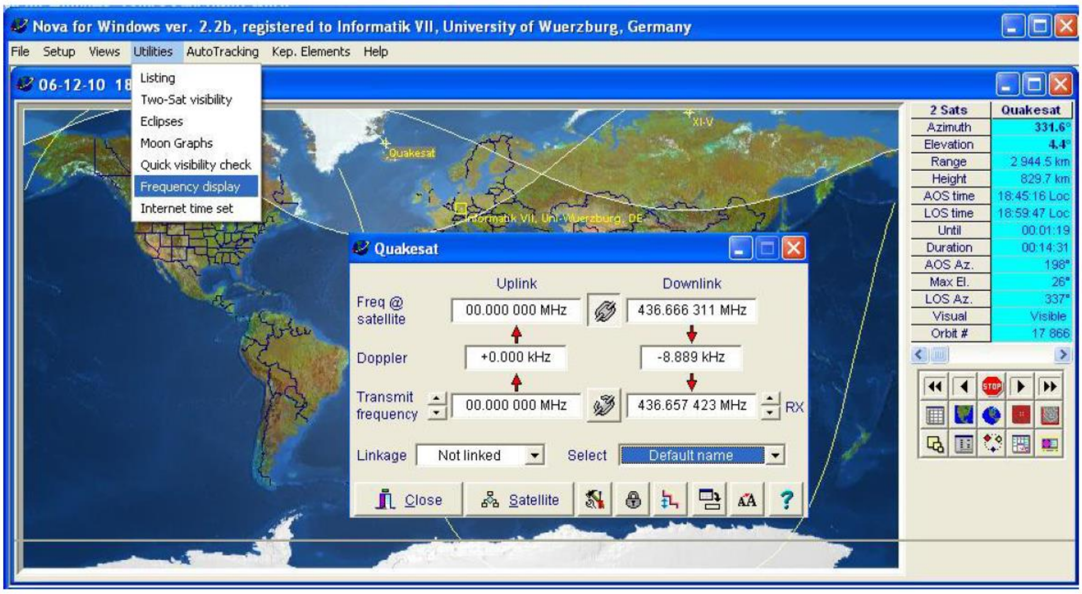


Figure B.10: Nova for Windows - Frequency Display.

To enable **Auto-Tracking** with "Nova for Windows", the first step is to select the type of Antenna Rotator from the Rotator Interface list. The path is "AutoTracking" and then "Antenna Rotator Setup" and then "Interface".
Select the Rotator Interface from the available list.
For the Ground Station at Informatics VII, University of Wuerzburg, "WinRotor" is the Rotator Interface.

For **Yaesu G-5500** azimuth rotator range is 0 to 360 degrees and elevation rotator range is 0 to 180 degrees. Refer figure 2.21.

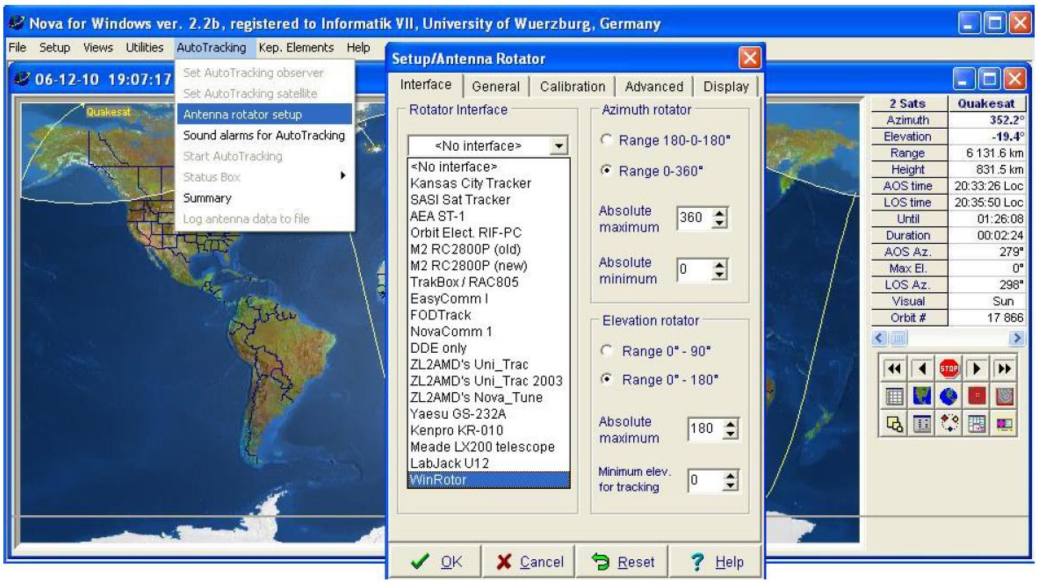


Figure B.11: Nova for Windows - Antenna-Rotator Setup.

More ***help*** regarding "Nova for Windows" can be available from "help" of the display window or please refer its detailed brochure. Refer figure 2.22.

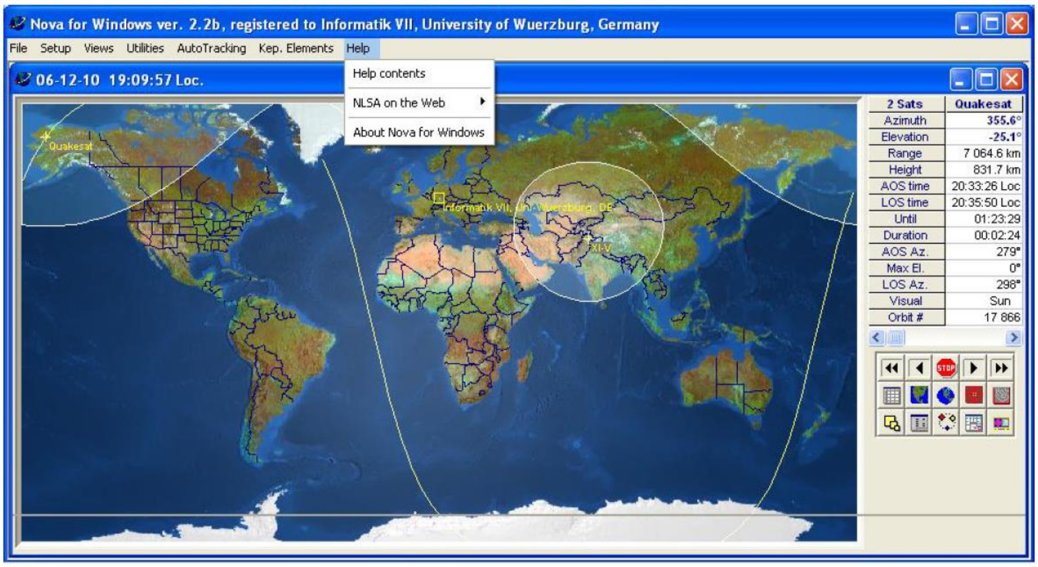


Figure B.12: Nova for Windows - Further Help.

Test Results

Eleven tests are documented in a duration of 10 days from 08 Dec 2006 to 18 Dec 2006. Testing summary is as follows:

08 December 2006	
AOS Time	16:04:08 Local Time
LOS Time	16:17:42 Local Time
Duration	00:13:33 hrs
AOS Azimuth	118 degrees
Maximum Elevation	21 degress
LOS Azimuth	355 degress

Table C.1: Testing - Satellite Script 08Dec2006.

Number of Beacons received : 3.

tnc4e2: fm KD7OVB to QST ctl UI pid=BB len 255 16:10:18
tnc4e2: fm KD7OVB to QST ctl UI pid=BB len 255 16:10:28
tnc4e2: fm KD7OVB to QST ctl UI pid=BB len 255 16:10:57

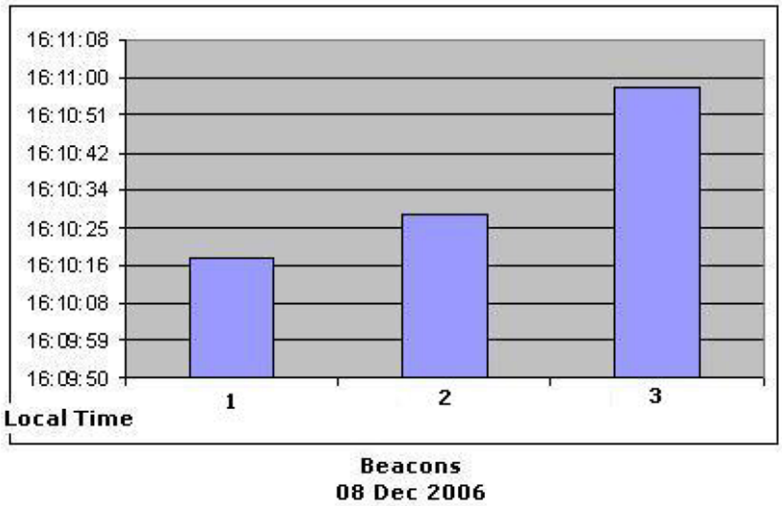


Figure C.1: Test Beacons on 08Dec2006.

11 December 2006	
AOS Time	15:08:46 Local Time
LOS Time	15:19:13 Local Time
Duration	00:10:26 hrs
AOS Azimuth	87 degrees
Maximum Elevation	8 degress
LOS Azimuth	1 degress

Table C.2: Testing - Satellite Script 11Dec2006.

11 December 2006	
AOS Time	16:45:23 Local Time
LOS Time	17:00:18 Local Time
Duration	00:14:55 hrs
AOS Azimuth	139 degrees
Maximum Elevation	40 degress
LOS Azimuth	351 degress

Table C.3: Testing - Satellite Script 11Dec2006.

6.1 Research plan to improve SDR communication system

- Research plan to improve SDR communication system

(Salih hocam lütfen:
Please put here your actual presentation slides)

TT&C Subystem – On-Board Part

Master Thesis Task at Marmara Univ./
Prof. Dr. Salih Bayar

Tarih: 14/01/2021

T.C.
MARMARA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ

YÜKSEK LİSANS TEZ ÖNERİSİ FORMU

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Öğrenci Numarası / *Student Number:*	525018020
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Programı / *Program:*	Program giriş için tıklayın veya dokunun.
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Tez Danışmanı / *Supervisor:*	Dr.Öğr.Üyesi SALİH BAYAR
İkinci Tez Danışmanı / *Co-Supervisor:*	-

TT&C Subystem – On-Board Part

Master Thesis Task at Marmara Univ./Prof.Dr. Salih Bayar

İngilizce Tez Başlığı / *Title of Thesis in English*
Software-defined Radio (SDR) based Data-Link Design for Small Mobile Platforms
İngilizce Tez Önerisi Özeti
Small mobile robot platforms designed to operate in air, land and water are today used in defense, aviation and space; It is used in medical, logistics and agricultural activities. Such mobile platforms, which are acted autonomously, semi-autonomously or manually, should generally be controlled or controlled from one or more centers. Between mobile platforms and the center, by the mission of the mobile platform or platforms; Real-time data such as motion, telemetry, video and audio must be transported safely with the help of wired or wireless communication tools insufficient channels, bandwidths and distances.
Service times are expected to be long due to the costs of the mentioned mobile robots. The software of the robots can be changed in the field to increase service times. In this way, new features can be added to these products and software errors can be corrected, even software solutions can be brought to hardware errors. In a mobile robot platform, communication equipment is also one of the important hardware that may need to be changed and developed during its lifetime. In traditional radio topologies, the fact that components such as mixer, filter, amplifier, modulator and demodulator are implemented with software is defined as Software-defined Radio (SDR). Thanks to the software-defined radio concept, wireless communication devices can be reconfigured throughout their lifetime and even during operation, so parameters such as broadcast frequency, modulation type, and bandwidth can be changed without interfering with the hardware. Besides, in today's world where data encryption methods are developing day by day, the ability to reconfigure crypto algorithms in-depth to ensure data security meets a critical need, especially in areas such as defense and aviation.
The aim of this thesis is to design a software-based data link with optimized physical dimensions that can communicate in **a high-frequency band and high data rate for use on small mobile robot platforms**. The design will consist **of two main units, a radio frequency front unit and a digital processing unit**. The radiofrequency front unit will consist of low noise amplifier (LNA), power amplifier (PA), mixer and filter groups. The digital processing unit will consist of analog to digital converter (ADC), digital to analog converter (DAC), Field Programmable Gate Array (FPGA) and memory units.
İngilizce Anahtar Kelimeler / *Keywords in English*
Software defined radio, digital radio, cognitive radio, digital signal processing

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Master Thesis Task at Marmara Univ./Prof.Dr. Salih Bayar

1. AMAÇ ve HEDEFLER / AIM AND OBJECTIVES

The aim of this thesis is to design a software-based data link with optimized physical dimensions that can communicate in a high-frequency band and high data rate for use on small mobile robot platforms. The design will consist of two main units, a radio frequency front unit and a digital processing unit. The radiofrequency front end unit will consist of low noise amplifier (LNA) power amplifier (PA), mixer and filter groups. The digital processing unit will consist of analog to digital converter, digital analog converter and FPGA and memory units. The software-defined radio device hardware will be designed as a stand-alone device to use both mobile platform side and base station side.
Our design goals listed below;

- less than 500gr
- less than 100cm3
- At least 2 hours operation without fan cooler (passive cooling).
- 1MHz to 6GHz operating frequency. (Both ISM and non-ISM bands)
- At least 0.05W Output Power @ 900MHz
- 20MHz channel bandwidth

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3. ÖZGÜN DEĞER / ORIGINALITY OF STUDY

There are studies on software-defined radio using ready-to-use devices like the HackRF. However, there are not any domestic software-defined radio hardware development works. In this context, it is clear that a software radio hardware design is needed domestically. Also, our work will be an open-source project for both hardware and firmware wise.

4. YÖNTEM / METHODOLOGY

We can roughly divide this work into two different parts; the digital signal processor unit and the radio frequency transceiver unit. We plan to use Zynq 7000 System-on-Chip (SoC) from Xilinx as a digital signal processor in our design. Also, we intend to use AD9361 or similar wideband RF transceiver integrated circuit will for RF microwave part which can operate at 6GHz. Having these two parts, we plan to place them on different stacked printed circuit boards. So, we will have flexibility in our design and decrease device volume.

Research plan to improve SDR communication system

Customized Software Defined Radio (SDR) Hardware Design

Asst. PROF. DR. Salİh Bayar

Agenda

- Personal information
- Business idea
- Facts that support the business idea
- Existing System Problems and Proposed Solution
- Innovative aspects of the project
- Business packages
- Budget
- Target customers & Competitors

Asst. Prof. Dr. Salih Bayar

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- ❖ MS: Karlsruhe Institute of Technology (KIT), 2007
- ❖ PhD: Boğaziçi Uni. - Computer Eng, 2015
- ❖ Worked places: Beko, Türk Telekom, KIT, TEMO Soft-, Hardware & Consulting e.K., Molex and Daimler Chrysler AG, Boğaziçi University, Beyken University, İstanbul Kültür University, Maltepe University, Idea Technology Solutions, Marmara University
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  - ❖ http://www.salihbayar.com/

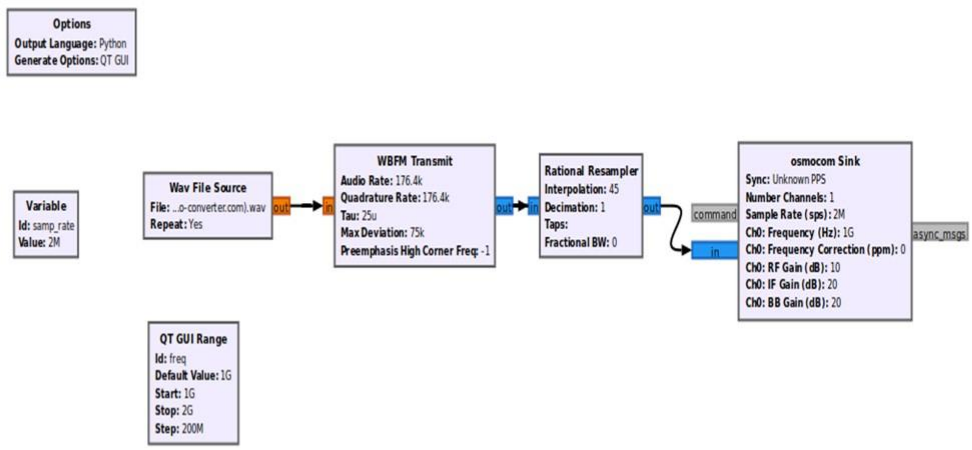
Business Idea

- A single software-based radio transmitter receiver that can replace separate hardware that can implement different frequency and modulation types for radio communication purposes.

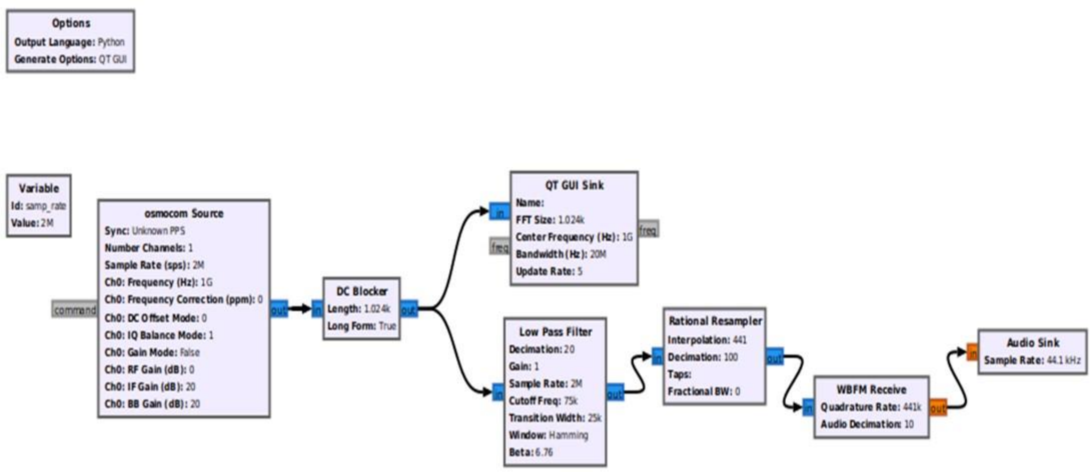
Facts that support the business idea

- Satellite communication and secure radio link production for our defense and industry needs. In this context, the development of a powerful communication card, which can be used in both satellite and defense industry at high frequency ranges (at least up to 20 GHz).

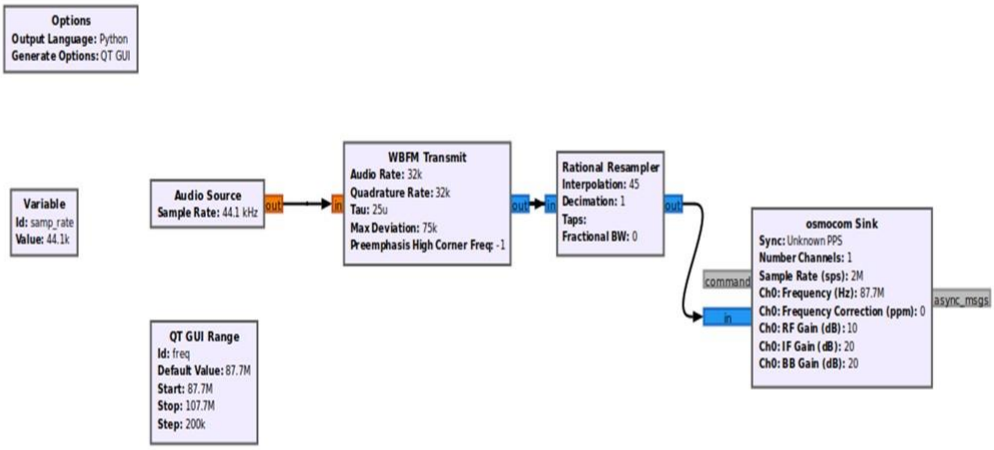
Work done so far: GnuRadio Reciever



Work done so far: GnuRadio Transmitter



Work done so far: GnuRadio Live Broadcast



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Work done so far – Analog broadcasting

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HackRF Problems

- Until now, communication tests have been carried out on HackRF style low-performance products that are already available related to the business idea. Such a requirement has arisen due to the fact that the frequencies of such devices are not very high (up to 6GHz) and the FPGA cards used on them are very weak and insufficient.

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The specific aspects of the project - Novelty

❖ It will have its own specific Linux-based operating system

❖ Thanks to the Linux-based operating system, many different features can be added

❖ High performance working capacity

❖ High frequency working capacity

❖ Having high data processing and transmission capacity

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Work Packages

Work Package 1 — **3 Months**

Reporting System
Literature Review
Design Document
Test Scenarios
Procurement Study

Work Package 2 — **2 Months**

……….

Work Package 3 — **3 Months**

……………..

Work Package 4 — **3 Months**

Embedded System Design and Implementation

Work Package 5 — **3 Months**

Prototype Production and Tests

Budger

General Operating Expenses	Amount	Amount Requested
Company / Company establishment expenses	1	4.000,00 TL
Electricity	12	2.400,00 TL
Dues	12	2.400,00 TL
Accounting	12	6.000,00 TL
Telephone and internet	12	1.800,00 TL
Travel expenses	2	4.500,00 TL
Fixture Expenses	1	4.000,00 TL

Budget cont.

Service Procurement and Consultancy	Amount Requested
Card design consultancy	15.000,00 TL
Embedded System and Software Consultancy	15.000,00 TL

Machine-Hardware-Software-Publication	Amount Requested
Laptop	16.000,00 TL

Personnel Expenses	Amount Requested
Business Owner – Salih Bayar	60.000,00 TL
Personnel	18.900,00 TL

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Budget cont.

Consumables	Amount	Amount Requested
FPGA	2	8.000,00 TL
Peripherals	12	12.000,00 TL
HackRF	2	5.000,00 TL
Antennes	4	3.600,00 TL

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Target Customers

- Government Agencies(TUSAŞ, TÜBİTAK, TÜRKSAT vb)
- Private Institutions
- Municipalities
- Personal Customers

Rivals

- HackRF
  - …………….
  - …………

References

1. HackRF, https://greatscottgadgets.com/hackrf/

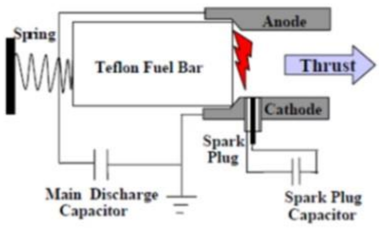
6.2 Electrical Propulsion Unit

Electrical Propulsion Unit for Orbit Control

Electrical Propulsion Unit for Orbit Control

Pulsed Plasma Thruster (PPT)

A pulsed plasma thruster (PPT) is a type of electromagnetic propulsion system , with a high specific impulse and low power and fuel requirements, that has been used on a number of satellites for station-keeping maneuvers.
A PPT works by ablating and ionizing material from a fuel bar (typically consisting of a chlorofluorocarbon such as Teflon) with the current from a discharging capacitor. The positive ions released are then accelerated between two flat-plate electrodes – one positive, the other negative – arranged in the form of two long parallel rails which are connected across the capacitor. Escaping from the spacecraft, the accelerated ions produce a thrust of some several hundred newtons. The capacitor is then charged up again from a power supply and the pulse cycle repeated.



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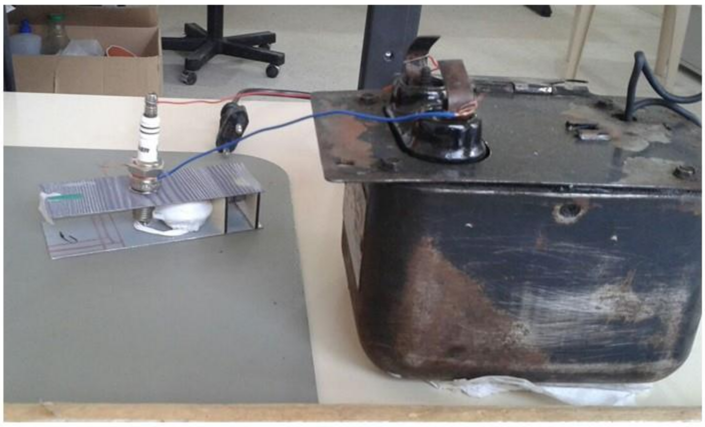
Electrical Propulsion Unit for Orbit Control

- Test Rig for Pulsed Plasma Thruster (PPT)



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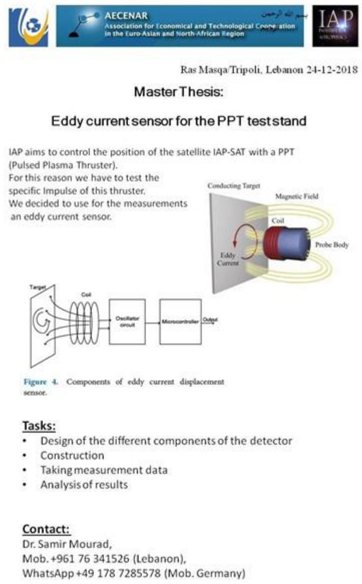
Electrical Propulsion Unit for Orbit Control

- Eddy Current Sensor for the Pulsed Plasma Thruster Test Rig


AECENAR
Association for Economical and Technological Cooperation in the Euro-Asian and North-African Region
IAP

Ras Masqa/Tripoli, Lebanon 24-12-2018

Master Thesis:

Eddy current sensor for the PPT teststand

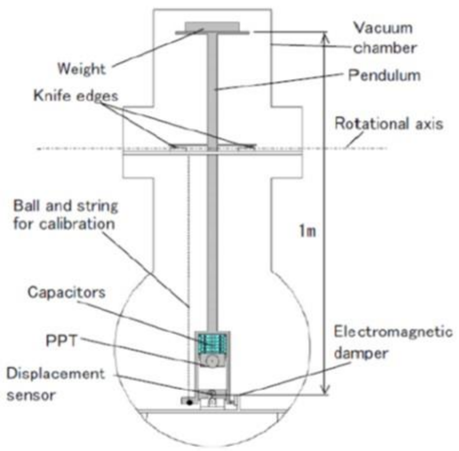
IAP aims to control the position of the satellite IAP-SAT with a PPT (Pulsed Plasma Thruster).
For this reason we have to test the specific Impulse of this thruster.
We decided to use for the measurements an eddy current sensor.

Figure 4. Components of eddy current displacement sensor.

Tasks:
- Design of the different components of the detector
- Construction
- Taking measurement data
- Analysis of results

Contact:
Dr. Samir Mourad,
Mob. +961 76 341526 (Lebanon),
WhatsApp +49 178 7285578 (Mob. Germany)

Electrical Propulsion Unit for Orbit Control

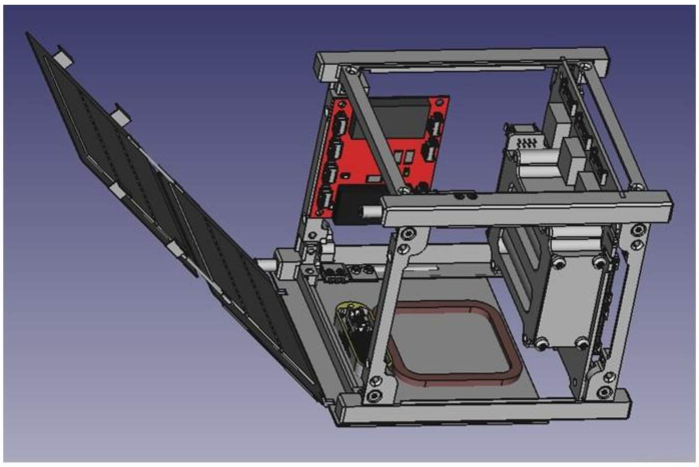


C:\Users\Aecenar1\Documents\IAP-SAT_2018\Mariam\IAP.Abgabe30.1.18.00..41\Pulsed Plasma Thruster (PPT) /engine

- Vacuum Chamber for the Pulsed Plasma Thruster Test Rig

6.1 CAD Model

AS-COMSAT 3D Model



Maximum 1.3 kg

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6.1 Simulation platform

Simulation platform

- https://www.rtl-sdr.com/building-a-fossasat-1-lora-iot-ground-station/

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6.2 Thermal Control

Source:

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Boushon, Katelyn Elizabeth, "Thermal analysis and control of small satellites in low Earth orbit" (2018). Masters Theses. 7755. https://scholarsmine.mst.edu/masters_theses/7755

6.2.1 INTRODUCTION

Spacecraft thermal control is integral to mission success. The process of thermal control for a spacecraft involves managing the energy entering and leaving the spacecraft to ensure that the components of the spacecraft remain within an acceptable temperature range.

6.2.1.1 THERMAL CONTROL HARDWARE

The thermal control system on a satellite generally uses two basic approaches fortemperaturemanagement: passive and active thermal control. ...4.1.1. Passive Thermal Control. Passive thermal control techniques includematerialproperty selection, controlling the path of heat transfer, and using insulation systems to ensure that temperatures remain within acceptable limits [22]. Techniques including the use of multilayer insulation (MLI) and thermal coatings have a long heritage on traditional satellites, but may require modifications for use in small satellites.

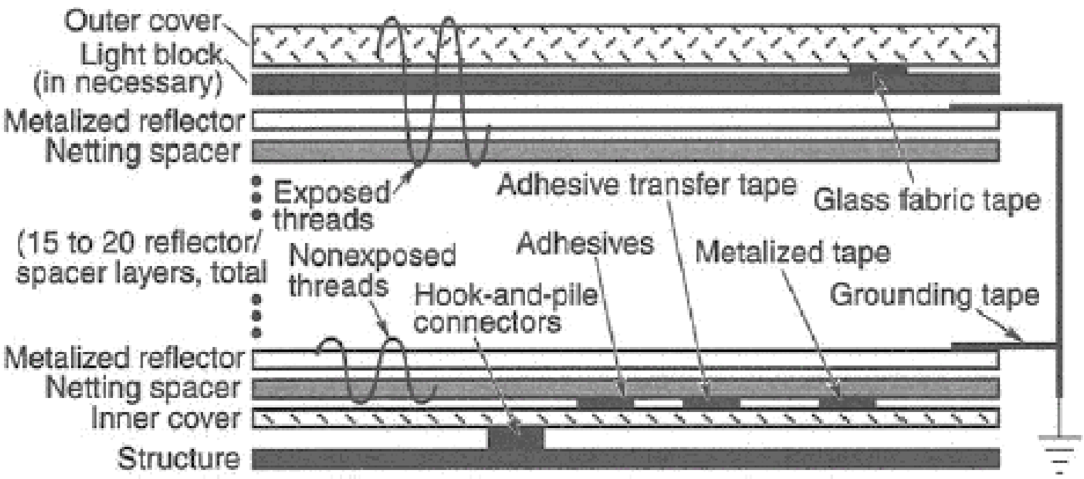


Figure 4.1. Typical MLI Blanket Composition [14]

Materials used for fabrication of an MLI blanket should always be treated as flight-critical hardware from the moment they are received. The materials should never be handled with bare hands and should never be exposed to uncontrolled and corrosive environments in order to avoid contamination and material degradation. Actions such as pulling or unnecessarily wrinkling the material should be avoided as this can cause stress in the layers and defects that may not appear until launch. Fabrication should occur in a temperature and humidity monitored Class 100,000 clean room to preserve the cleanliness and optical properties of the material. The fabrication area requires tables large enough to support the largest blanket being manufactured. All tools, equipment, templates, holding fixtures, and tables should be cleaned with a solvent that has a nonvolatile residue that does not exceed 0.02 g/L. The solvent must be compatible with the materials to avoid damaging the materials during normal cleaning operations. Clean white gloves or powder-free latex gloves suitable for clean room use must be used when handling the material, and clean room lab smocks must be worn [14].

6.2.1.2 Sunshields.

Sunshields offer shading for a satellite from direct solar

•impingement and the radiation environment of space [6]. Traditional sunshields have been made from a thin aluminum, titanium, or stainless-steel substrate, with a low absorptivity and high emissivity coating of silvered Teflon or white paint on the outer surface [1]. Sunshields for small satellites must unfold from a smaller form factor than their traditional counterparts. The implementation of sunshields for small satellites applications is fairly new, though Sierra Lobo has flown deployable sunshields on a few small satellite missions [10].

6.2.1.3 Radiators.

Waste satellite heat is rejected to space through the use of

•radiators. Regardless of the radiator configuration, be it a satellite structural panel or a flat plate radiator mounted to the satellite exterior, radiators reject heat from their surfaces by IR radiation. The optical properties determine the power of the radiator. Radiators must reject waste heat from the satellite while also rejecting heat impinging on the satellite. Most radiators have a high emissivity to maximize heat rejection and low absorptivity to limit heat loads from the space environment. Typical finishes include quartz mirrors, white paint, and silvered or aluminized Teflon [14].

•The simplest and most common radiators are the existing panels of the satellite exterior. For example, an exterior aluminum honeycomb panel can serve as a structural panel as well as a radiator. The face sheets of the panel distribute away from electronics boxes that are mounted to it, with the outside panel face acting as the radiating surface. The face sheets can also be made thicker to increase the heat distribution. Separate plates called “doublers,” typically made of aluminum, can also be added under high heat dissipating electronics boxes to help distribute the heat. These measures may result in mass increases that will not fit within the satellite mass budget. Heat pipes can be considered in this situation to distribute spread the heat.

4.1.2. Active Thermal Control

- **4.1.2.1 Heaters.** Heaters are often the simplest device to use for active
- thermal control [19]. Their main function is to maintain satellite components in the required temperature range, but they can also be used to warm up components that are dormant before their activation, to control temperature differences to greater stability, and to dissipate excess satellite power [1]. Heaters are the only active thermal control hardware that have been successfully miniaturized for use on small satellites [6].
- **4.1.2.1.1 Heater types.** The most commonly used type of heater is the patch
- heater. Patch heaters consist of an electrically resistant element bonded between two sheets of flexible electrically insulating material [14]. The electrically resistant element is typically an etched foil, such as Nichrome, and the insulating material is typically a Kapton film [1].

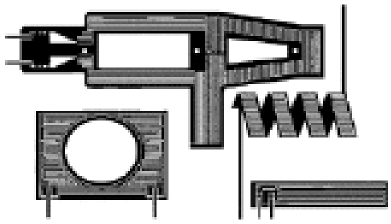


Figure 4.7. Custom Shaped Patch Heaters [14]

6.2.2 THERMAL DESIGN PROCESS

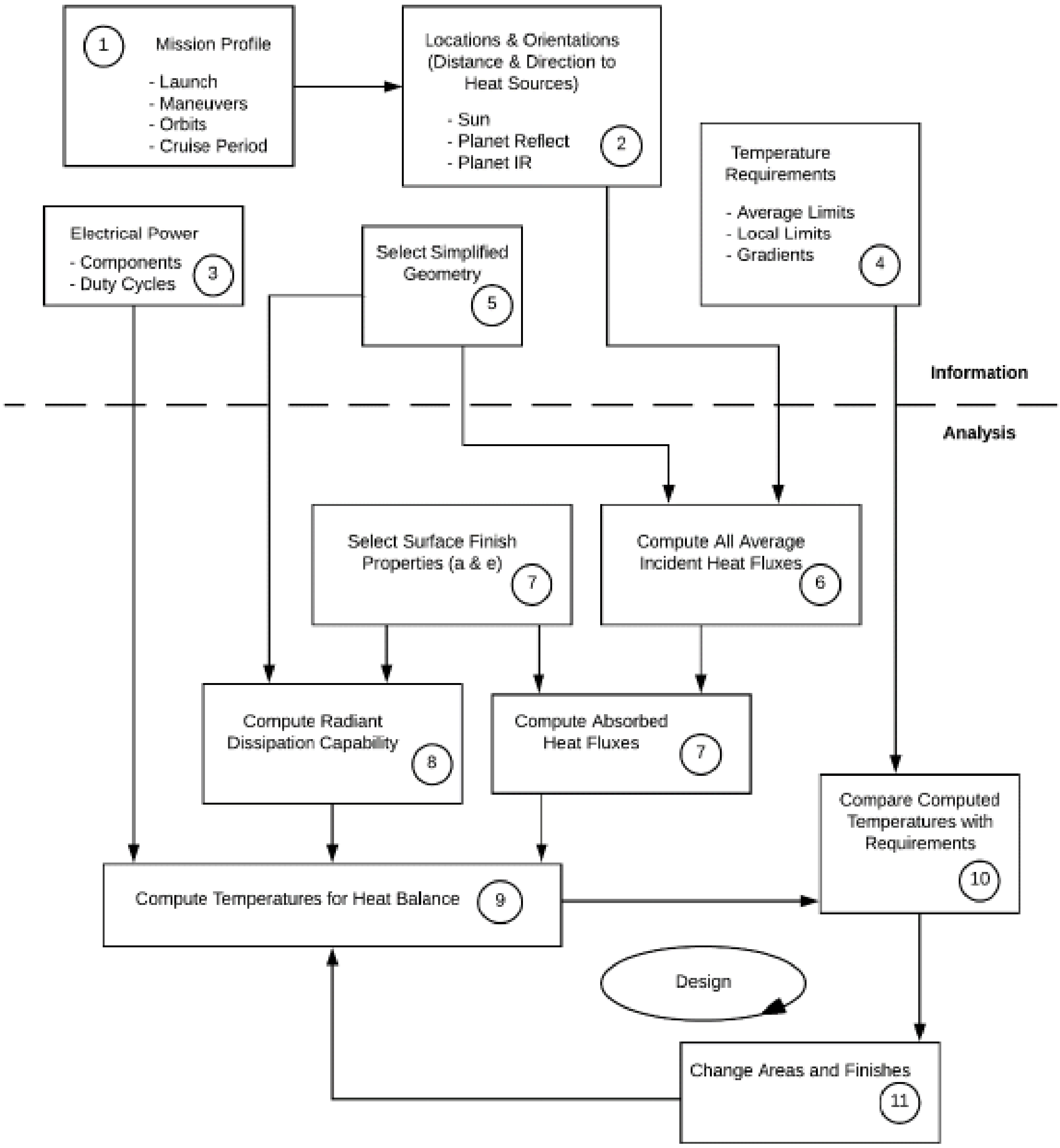


Figure 5.1. Thermal Analysis and Design Process [18]

Case Study

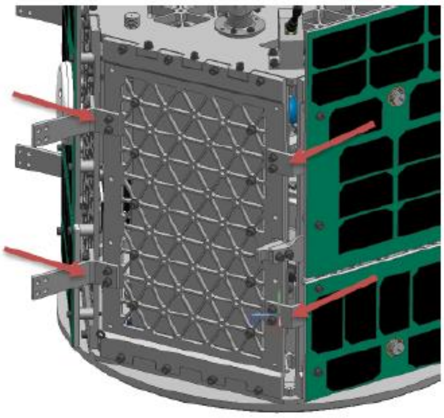


Figure 6.15. MR SAT Side Panel Brackets

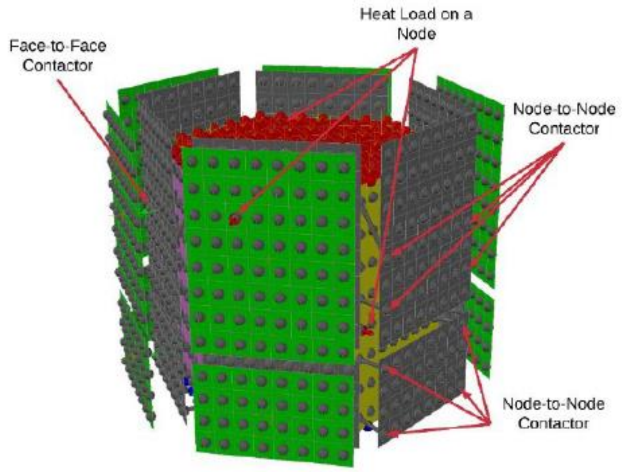


Figure 6.16. MR SAT Model Revision C – Conduction and Heat Load Locations

AS-COMSAT, Jan-Feb 2021

Case Study

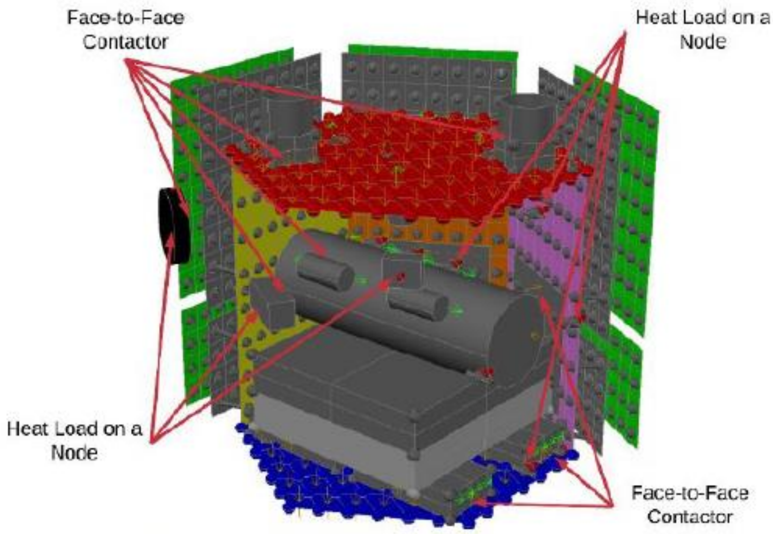


Figure 6.24. MR SAT Model Revision D – Conduction and Heat Load Locations

Case Study

Table 6.11. Model Revision E – Transient Results for Components

Component	Max Temp [°C] - Hot Case	Min Temp [°C] - Cold Case	Max Operating Temp [°C]	Min Operating Temp [°C]	Max Survival Temp [°C]	Min Survival Temp [°C]
TiNi 1	42.3084	2.4930	70	-65	-150	150
TiNi 2	38.6156	2.7749	70	-65	-150	150
TiNi 3	39.9796	2.7160	70	-65	-150	150
MCU Digital	46.7935	10.9856	85	-40	-65	150
Isovalve 1	47.0767	10.9767	49	-18	-	-
Isovalve 2	47.0771	10.9768	49	-18	-	-
Isovalve 3	47.0768	10.9767	49	-18	-	-
Thruster 1	47.5563	1.8898	49	-18	-	-
Thruster 2	46.8478	1.4100	49	-18	-	-
Thruster 3	48.0069	1.5618	49	-18	-	-
Thruster 4	48.9021	1.5535	49	-18	-	-
Thruster 5	34.8042	1.9214	49	-18	-	-
Thruster 6	35.5939	2.1649	49	-18	-	-
Thruster 7	37.3262	2.4853	49	-18	-	-
Thruster 8	36.0827	2.3751	49	-18	-	-
Thruster 9	41.0231	3.5942	49	-18	-	-
Thruster 10	42.4893	3.4262	49	-18	-	-
Thruster 11	38.4595	2.6354	49	-18	-	-
Thruster 12	42.1236	2.2227	49	-18	-	-
Pressure Transducer 1	46.6006	10.9703	82	-29	-	-
Pressure Transducer 2	46.5972	10.9711	82	-29	-	-
Comm Radio	46.6040	11.3703	70	-30	-30	85
GPS Receiver	46.8809	11.3115	85	-40	-55	95
GPS Antenna	39.1379	-1.9531	85	-55	-55	85
Flight Raspberry Pi	49.2888	13.7380	80	-25	-	-
IMU	46.7473	11.1784	85	-40	-	-
Sun Sensor Camera 1	23.1908	-2.2587	70	-10	95	-40
Sun Sensor Camera 2	58.0436	-3.2861	70	-10	95	-40

6.2.2.1 Lessons Learned.

Many lessons were learned throughout the process of thermal model construction, analysis, and application of thermal control. It is very important to keep up-to-date documentation during the process. Documentation should include information regarding all model input parameters including orbit profile, satellite dimensions, and material properties. It should be very clear in the documentation which parameters are used for which model revision. Each new model revision should be saved as a separate file and should be accompanied by its own documentation.

6.2.3 CONCLUSION

THESIS SUMMARY

Proper thermal analysis and control for spacecraft is essential for successful mission performance. Thermal control methods for traditional satellites are well documented, but many methods for small satellite applications are still in the development stages. This thesis study presents proven methods of thermal analysis and control specifically relating to small satellites in low Earth orbit in order to act as a resource for future reference.

Satellite thermal analysis typically involves using analytical processes assisted by computer software to determine temperatures at nodes in the model by applying a numerical approximation method, typically the finite difference method. The solar vector, albedo factors, satellite component dissipation, orbit beta angle, and orbit altitude all affect the outcome of the thermal analysis. Thermal extrema cases define the upper and lower bounds on temperature predictions. The results of thermal models are then verified through testing, and the thermal model adjusted to more closely reflect the test results.

Satellite thermal control methods are used to regulate temperatures to ensure that components function properly throughout the mission. Thermal control systems on a satellite can use both passive and active thermal control. Small satellites most commonly employ passive methods as they tend to be lighter, more reliable, and do not require power. Passive thermal control methods include the use of multilayer insulation, thermal surface coatings and finishes, tapes, sunshields, radiators, heat pipes, phase change materials, and heat switches.

6.2.4 CONTRIBUTIONS TO THE SMALL SATELLITE COMMUNITY

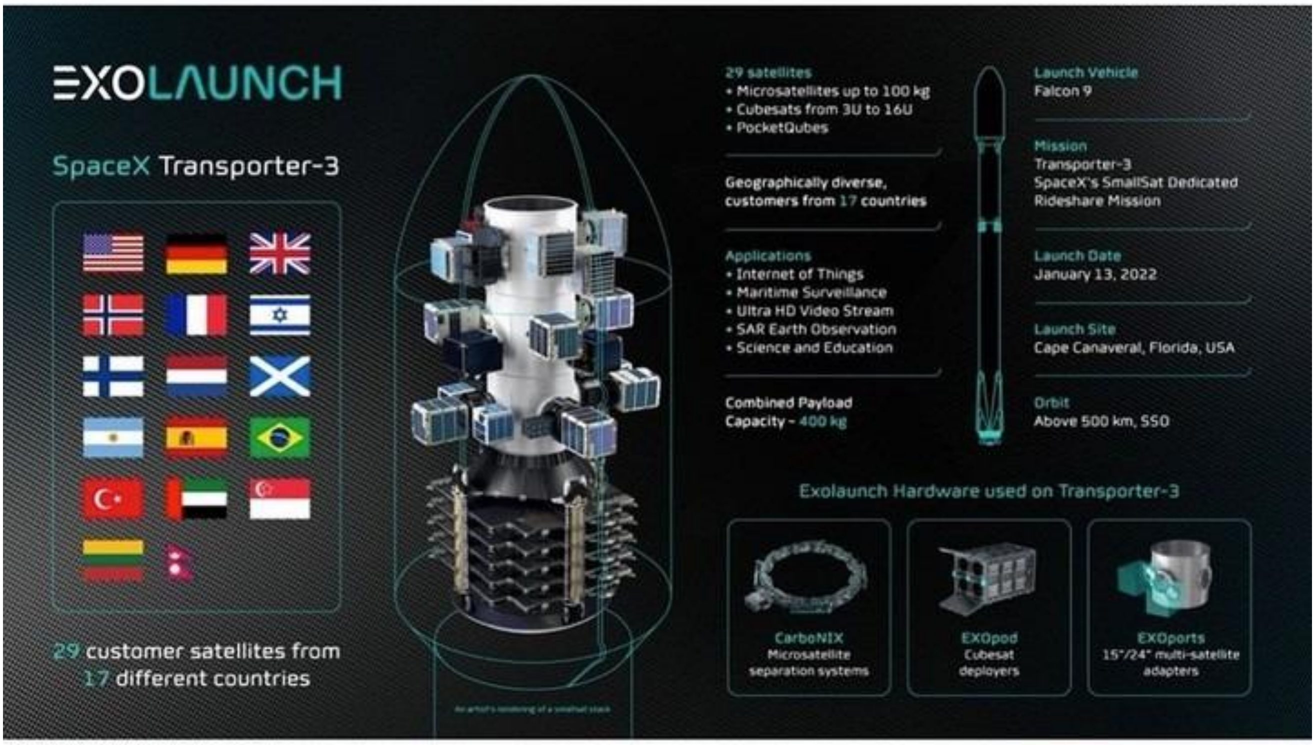
The goal of this thesis study has been to provide a resource to guide the small satellite thermal control system design and analysis process. Inexperienced engineers and academic teams will be able to use this thesis study as the starting point for their work in the thermal analysis and control of their small satellite designs. Basic heat transfer concepts and satellite heating environments are discussed for the benefit of student engineers still learning about the topics. Thermal analysis processes from various sources are summarized and presented, as well as a case study to demonstrate the use of these practices and an outline of the practical application of model construction, analysis, and design in Appendix A.

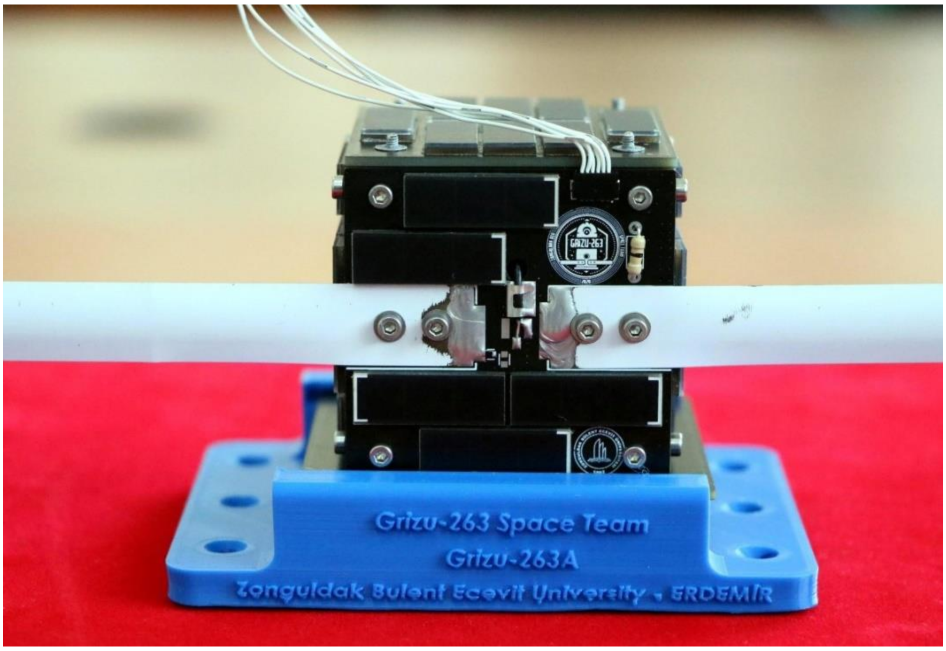
Optical Properties of Common Surface Coatings and Finishes [14]

Material	Absorptivity	Emissivity
Optical Solar Reflectors		
Teflon, Aluminized, 0.5 mm	0.14	0.4
Teflon, Aluminized, 1 mm	0.14	0.6
Teflon, silvered, 2 mm	0.08	0.68
Teflon, silvered, 10 mm	0.09	0.88
Black Coating		
Chemglaze Z306 Black Paint	0.96	0.91
Black Z306 polyurethane paint, 3 mm	0.95	0.87
Ebanol C Black	0.97	0.73
Rough black matte, black paint	0.9	0.9
Films and Tapes		
Kapton, aluminized, 0.25 mm	0.31	0.45
Kapton, black (carbon loaded), 1 mm	0.92	0.88
Tape, 235-3M, black	0.95	0.9
Tape, aluminum	0.1	0.04
White Coatings		
Chemglaze A276 white paint	0.24	0.9
Hughson A-276 white paint	0.26	0.88
Magnesium oxide white paint	0.09	0.9
Polyurethane white paint	0.27	0.84
Other Paints		
Aluminum Paint	0.3	0.31
Chromacoat aluminum paint	0.28	0.05
Silicone aluminum paint	0.29	0.3
Metals		
Aluminum, buffed	0.16	0.03
Aluminum, polished	0.15	0.05
Beryllium copper	0.31	0.03
Copper, buffed	0.3	0.03
Copper foil tape, tarnished	0.55	0.04
Gold, electroplated	0.23	0.03
Silver, polished, unoxidized	0.04	0.02
Stainless steel	0.47	0.14
Titanium	0.4	0.55
Anodized Aluminum		
Black anodize	0.65	0.82
Chromic anodize	0.44	0.56
Clear anodize	0.27	0.76
Plain anodize	0.26	0.04

7 Launch issues

7.1 Exolaunch





I think they used a tape meter for the antennas. They can be folded and they can open like a switchblade by the tension of the material which is a nice idea. I have seen yagi type antennas from cut tape measures made by RF amateurs before .

5x5x5 cm pocket sat Grizu 263A is on air https://www.aa.com.tr/tr/bilim-teknoloji/turkiyenin-ilk-cep-uydusu-grizu-263a-uzay-yolculuguna-hazirlaniyor/1861764

7.2 Offer from Russian Company (Launch with Soyuz) from May 2021

www.gklaunch.ru, info@gklaunch.ru

GK LAUNCH SERVICES

CONFIDENTIAL
#00548 06.05.2021

2 U, 3 kg: 110,000$

Dear Samir! Thank you for your launch quote request. We have prepared a ROM price proposal based on your satellite's characteristics and selected a suitable mission.

Mission:

> Cluster launch
> Launch period: 2 quarter of 2022
> Orbit: SSO, LTAN 11:00
> Baikonur Cosmodrome
> Primary payload: contracted
> Secondary payload: available

Launch price:

for 3kg satellite is 110000$

The price includes:

1. Program management and program documents;
2. Support of Customer personnel visits;
3. Administrative support to the Customer personnel at GK facilities in accordance with the terms and conditions to be defined in the contract;
4. Program reviews and meetings as may be necessary;
5. Interface Control Document with the results of analyses and reports as may be necessary;
6. Hardware (adapter and separation system, umbilical connector, harness for testing), personnel and equipment for fit-check to be performed at the NPOL facility (SC dummy for testing to be provided by Customer);
7. Hardware (adapter and separation system, umbilical connector, harness), personnel and equipment for integration of the flight SC with the launcher;
8. Hardware, ground support equipment (Space Head Module (SHM), Fregat upper stage, launch vehicle) and personnel for processing of the SHM with SC and execution of launch;
9. Customs clearance of SC/GSE on entry into Russia, customs clearance of GSE on exit from Russia;
10. Transportation of satellite and GSE from the entry/exit port to payload preparation

facility and back of GSE, including their customs clearance;
11. Performance of launch campaign and provision of:
Work place in AITB;
Administrative and storage premises;
Power supply;
Provision of logistics to Customer's personnel whilst at the launch site (payment for the services to be made by Customer);
Communications services (international telephone calls to be paid for in accordance with the terms and conditions to be defined in the contra�).
Launch of deployer with CubeSat(s) into the required orbit;
12. Provision to Customer of LV telemetry data confirming the SC separation and initial orbit parameters;
13. Post-launch services;
14. Photographic and video documentation;
15. Linguistic support;
16. Procurement of third party liability insurance for the damage due to the launch activities and support in obtaining the satellite insurance;
17. Launch observation.
You can add insurance of the satellite ground and space related risks and insurance of
the launch service. To do so, call us or write a response letter.
This is a ROM launch price proposal to be finalized after we receive all the documents. Some mission parameters may change.

Standard Milestone payment plan:

	Milestone	Payment, USD (%)	Preliminary Date of milestone completion and submission of invoice
1	Manifesting of Payload on a Launch Mission	15%	Manifesting of Payload
2	IRD review	15%	Completion of IRD review
3	ICD approval	25%	Approval of ICD
4	Ground Tests	20%	Completion of ground tests
5	Start of Launch Campaign	15%	Upon Payload arrival at Launch Site
6	Successful launch	10%	L+2 weeks

7.3 Companies launch satellite

From


AECENAR
Association for Economical and Technological Cooperation in the Euro-Asian and North-African Region
IAP
INSTITUTE FOR ASTROPHYSICS

Steps for Launching Satellite

Author:
Siham Aisha

Last Update: 27.12.2021

7.3.1 GK laucnh (Russian)[4]

GK Launch Services is a company established by Glavkosmos (a subsidiary of ROSCOSMOS State Space Corporation) and International Space Company Kosmotras. GK Launch Services is an operator of Soyuz-2 commercial launches from the Russian spaceports.

The key targets this joint venture aims at include advancing of commercial launch services, promotion of Russian launch vehicles on the world market, and strengthening the positions of Russia as the most competitive launch service provider.

A solid competence of the two partners facilitates achieving these ambitious goals. Glavkosmos has been participating in global international space projects over 30 years and has already had experience in provision of launch services with Soyuz-2 rocket. Kosmotras has lofted over 100 payloads within 22 commercial launches.

7.3.2 Swarm company (U.S)[5]

Swarm Technologies, Inc. is a private company building a low Earth orbit satellite constellation for communications with Internet Of Things (IOT) devices using a Store and forward design. An early investor was Craft Ventures. On July 16, 2021, Swarm entered into an agreement to become a direct wholly-owned subsidiary of SpaceX.[2]

They have an Federal Communications Commission (FCC) licence for low bandwidth communications satellites in low Earth orbit.[3]

In 2018 Swarm became the first ever company found to have deployed satellites without regulatory approval after an FCC investigation into the startup's launch on an Indian PSLV rocket of its first four picosatellites in January that year.[4]

By December 2020, Swarm had launched 9 test satellites and 36 of a planned 150 low Earth orbit satellites to provide communication with IOT devices.[5]

---

[4] http://gklaunch.ru/en/

[5] https://en.wikipedia.org/wiki/Swarm_Technologies

In February 2021 Swarm announced that its commercial services were now live using 72 commercial satellites providing its global low cost data to customers.[6]

The Swarm Tile is its dedicated satellite two-way data modem designed to be low energy and embedded on the PCB of third party products. Other products include a data plan and development kit.[7]

7.3.3 Exolaunch company (Germany)[6]

The protocol of launching is:

1) ***LAUNCH PLANNING***

Every mission is unique. We listen to you and offer solutions that will enable the successful launch of your satellite. With precision, knowledge and expertise, we make the complex work of your specific campaign a simple and affordable experience. No stress.

2) ***MISSION MANAGEMENT***

Next, we produce your event. We provide technical management of the satellite adaptation to a launch vehicle, interface control document development, mission analysis delivery, and launch schedule coordination.

3) ***SEPARATION SYSTEMS***

EXOpod deployers for cubesats and CarboNIX, the shock-free separation systems for microsatellites, are designed and produced by Exolaunch to support your mission needs. Later, we adapt the deployment systems to the launch vehicle to safely deliver your satellite into its target orbit.

4) ***DEPLOYMENT SEQUENCER***

EXObox is essential for smallsat cluster launches. It is a unique, highly reliable and modular deployment sequencer to manage the deployment of up to 50 satellites with just one EXObox unit. It will precisely and safely separate small satellites into their target orbits.

5) ***LICENSING***

In this phase, we handle the complex legal and regulatory support documents that are required for launch. Your desk is now clean!

6) ***ENVIRONMENTAL TESTING***

Our fully-fledged environmental testing services are tailored to the requirements of any launch vehicle, ensuring your satellite has made the grade. All of the tests are performed in Berlin, and yEnvironmental tests profiles and types:

a. **Vibration and shock testing**

[6] https://exolaunch.com/

We provide a full range of mechanical testing to cover the qualification, proto-flight or acceptance requirements of all launch vehicles.

b. Thermal and vacuum testing

Thermal cycling and thermal vacuum testing is available to meet your mission requirements. Whether testing survivability limits or simply performing a vacuum bake-out, we can perform the tests that fit your needs.

c. Qualifation and acceptance test

Qualification of your design based on the composed mechanical loads in order to meet the requirements of most common launch vehicles. Tailored acceptance testing profiles of your flight models to the launch vehicle of your choice, ensuring the function of your spacecraft while increasing confidence in its reliability.

d. Test profiles design

We offer support to develop individual specifications for mission tailored test profiles with optimized loads and durations. Inclusive our acceptance guarantee of the test profiles by the launch authority.

e. Adapters & additional hardware

We offer TestPods and other test fixtures with the test interfaces identical to the launch vehicle interfaces, ensuring the validity of all test results. ou are offered our cleanroom for satellite checkouts.

7) SHIPMENT

Our expertise in global logistics and experience with customs clearance allows us to process worldwide shipping of payloads and equipment in a safe, convenient and timely fashion. We will ensure your satellite reaches the launch site safely and without hassle.

8) INTEGRATION SERVICES

When your satellite meets the launch vehicle. We will seamlessly integrate your satellite with the support hardware onto its launch vehicle.

9) LAUNCH

The launch vehicle has left Earth. Shortly afterwards, we receive a positive signal that your satellite is in orbit and is ready to start changing the world.

7.3.4 Gunter's space page[7]

The four **SpaceBEE**, formerly known as **BEE**s (**Basic Electronic Elements**), picosatellites, built to the 0.25U CubeSat form factor are to demonstrate two-way satellite communications and data relay for Swarm Technologies Inc.

[7] https://space.skyrocket.de/doc_sdat/spacebee.htm

The mission is to test the world's smallest two-way communications satellites to serve as a cost-effective low-data rate Internet of Things (IoT) network connectivity solution for remote and mobile sensors. The initial experimental space deployment is comprised of four satellites, each with a 1/4U form factor employing radar signature enhancement technology, which enables them to be passively tracked, and using VHF band frequencies for communications. There will also be an experimental deployment of ground stations for communications with the space units.

The mission is to demonstrate the capabilities of these picosatellites for serving low data rate communication relays for remote sensors and data collectors. Experimental operations is scheduled to begin upon launch for a period of at least 6 months and up to 2 years

The tiny satellites have very small radar cross section, which might complicate the tracking. Therefore they featured a GPS device in each satellite that would broadcast its position on request. Also the four smallest faces of the satellites are covered with an experimental passive radar reflector developed by the U.S. Navy's Space and Naval Warfare Systems Command, which according to the FCC application would increase the satellites radar profile by a factor of 10.

The FCC dismissed Swarm's application. Nevertheless, the satellites have been launched, apparently without a valid licence, in January 2018 on an Indian PSLV-XL rocket under the name **SpaceBEE**. The ownership of the SpaceBEEs remained obscure, until in an IEEE Spectrum article the identity of the SpaceBEEs with Swarm's BEE satellites was revealed.

A follow-on mission, SpaceBEE 5 to 8, with larger 1U CubeSats was also not granted a licence after this. Later the licesnce was granted. SpaceBEE 1 to 4 were also granted an operation licence.

The operational 2nd generation SpaceBEE satellites reverted back to the 0.25U form factor.

7.3.5 Antrix corporation[8]

I contact this company and the emails is below:

7.3.6 RE: FW: question for procedure to launch a satellite

November 25, 2021 7:44 am 28 KB
From:

Ganesh Mohan <ganesh_mohan@antrix.co.in>
To:

siham.aisha@temo-group.com

Hi Siham,

Could you please elaborate on what is it that you're looking for in administrative and legal procedures?

[8] https://www.antrix.co.in/

I presume all the permits, authorisations and notices of non-opposition including frequency filing / other regulatory mandates would be already done by you, during the course of the project.

We will support in any administrative matters during the import and re-export of the payload and the auxiliaries, including transportation, testing facilities, accommodation of personnel etc during the launch base. Once the satellite is separated in a low earth orbit, the control gets passed over to you. All the other aspects like Indemnity, Insurances etc would be covered in the launch contract and we can discuss over it during the course of execution of the contract.

Thanks

Ganesh

From: Siham [mailto:siham.aisha@temo-group.com]
Sent: 22 November 2021 15:53
To: Ganesh Mohan
Subject: Re: FW: question for procedure to launch a satellite

Hello,
Thank you for your response.

We need know what is the administrative and legal procedure in details, I mean if we want to keep some legal files we wish to inform us.

I prefer an email contact to be clearly.
our location is in Lebanon - Tripoli - Ras masqa, name of my organization is North Alternative Power departement TemoGroup

Regards

On November 22, 2021 at 11:57:24 am +02:00, Ganesh Mohan <ganesh_mohan@antrix.co.in> wrote:

Hi Siham,

Thanks for your interest in Antrix.

The procedure is that

1. there will be a launch services agreement that we will have to execute, wherein the said satellite will be accommodated as a ride share with one of the upcoming PSLV / SSLV missions.

2. There will be an Interface control document, where all the details of the testing, Dynamic studies, sequencing, power supply etc would be addressed and cleared.

3. The launch would happen from Sriharikotta, where the necessary testing / operations / safety procedures would be happening.

With respect to the pricing, it will vary. May I know where are you based at and the company that you're working for? We can probably discuss it over a call.

Thanks

Ganesh Mohan

Manager, Antrix Corporation

From: Siham [mailto:siham.aisha@temo-group.com]
Sent: 16 November 2021 15:39
To: sonali@antrix.co.in
Subject: question for procedure to launch a satellite

Hello,

I want to launch a satellite, Could I have a quote of price and what is the procedure to launch it?

1- the time frame it's about in the middle of 2022

2- launch to the same inclination, I mean in the same orbit and the inclination is 100 degre - 127 degre

3- our spacecraft don't have propulsion

4- size of our spacecraft is : 10X10X20 cm 2U for 2 satellites

5- mass is: 3Kg

6- the purpose: small pilot system for communication satellite.

7- altitude: 650 km

8- elliptic semimajor axis a = 7027.748 km

9- orbit heigh: 500- 600 km

Regards,

Siham

7.3.7 Procedure to launch a satellite in India[9][10]

Norms, Guidelines and Procedures for Satellite Communications Announced

The Government has approved a policy that envisages allocation of INSAT system capacity for non-governmental users, registration of Indian satellite systems by private Indian companies and limited use of foreign satellites in special circumstances. The Department of Space (DOS) will be the administrative ministry in all matters related to satellite systems in India.

As per the policy, the Indian National Satellite System (INSAT) capacity will be made available to non-government (private) Indian Service Providers on a commercial basis subject to availability after meeting the government needs. The DOS will allocate INSAT capacity for private users. DOS may also build capacity in INSAT system for private users on request on commercial basis.

Private Indian companies with a foreign equity less than 74 percent are now allowed to establish Indian Satellite Systems. These companies can submit their applications for registering their satellite systems to the Committee for Authorising the establishment and operation of Indian Satellite Systems (CAISS). The office of CAISS is set up at the SatCom Programs Office at ISRO Headquarters, Antariksh Bhavan, New BEL Road, Bangalore- 560 094. The authorisation to operate the Satellite System and the Orbit spectrum notification/registration will be done by CAISS. However, operating licenses for services to be provided by the Indian Satellite Systems will be issued only by the concerned administrative departments like Department of Telecommunication for telecom services and Ministry of Information and Broadcasting for TV/Radio broadcasting.

[9] https://www.isro.gov.in/update/08-may-2000/norms-guidelines-and-procedures-satellite-communications-announced

[10] https://www.isro.gov.in/contact-us-0

Foreign satellites will also have allowed to be used in special circumstances for satellite communication services in India. The service licensing departments may allow the use of foreign satellites only in consultation with the Department of Space. If suitable capacity/capability is available in INSAT or Indian Satellite Systems, operations with foreign satellites will not be permitted. For the use of foreign satellites for Internet Service Provider (ISP) gateways, the existing procedures established by Telecom Commission will apply.

7.3.7.1 India's Space Policy[11]

Remote sensing

Recognizing that Remote Sensing data provides much essential and critical information - which is an input for developmental activities at different levels, and is also of benefit to society.

Noting that a large number of users - both within and outside government, use Remote Sensing data from Indian and foreign remote sensing satellites for various developmental applications.

Taking into consideration the recent availability of very high-resolution images, from foreign and commercial remote sensing satellites, and noting the need for proper and better management of the data acquisition/ distribution from these satellites in India.

Recognizing that national interest is paramount, and that security consideration of the country needs to be given utmost importance.

The Government of India adopts the Remote Sensing Data Policy (RSDP) - 2011 containing modalities for managing and/ or permitting the acquisition / dissemination of remote sensing data in support of developmental activities. Department of Space (DOS) of the Government of India shall be the nodal agency for all actions under this policy, unless otherwise stated.

1. For operating a remote sensing satellite from India, license and/ or permission of the Government, through the nodal agency, shall be necessary.
    - As a national commitment and as a "public good", Government assures a continuous and improved observing/ imaging capability from its own Indian Remote Sensing Satellites (IRS) programme.
    - The Government, through the nodal agency, shall be the sole and exclusive owner of all data collected/ received from IRS. All users will be provided with only a license to use the said data, and add value to the satellite data.

[11] https://www.isro.gov.in/indias-space-policy-0

- Government reserves the right to impose control over imaging tasks and distribution of data from IRS or any other Indian remote sensing satellite, when it is of the opinion that national security and/ or international obligations and/ or foreign policies of the Government so require.
-

2. For acquisition/ distribution of remote sensing data within India, license/ permission from the Government of India, through the nodal agency, shall be necessary.
   - Government reserves the right to select and permit agencies to acquire/ distribute satellite remote sensing data in India. DOS shall be competent to decide on the procedure for granting license/ permission for dissemination of such data, and for the levy of necessary fees.
   - To cater to the developmental needs of the country, the National Remote Sensing Centre (NRSC) of the Indian Space Research Organisation (ISRO)/ DOS is vested with the authority to acquire and disseminate all satellite remote sensing data in India, both from Indian and foreign satellites.
     - NRSC shall enter into appropriate arrangements with DOS for acquiring/ distributing data from IRS within the visibility circle of NRSC's receiving station(s).
     - NRSC and/ or Antrix Corporation Ltd., shall be competent to enter into agreements with foreign satellite operator(s) for acquisition/distribution of foreign satellite data in India. However, NRSC will distribute the data as per terms agreed to with Antrix Corporation Ltd.
   - NRSC shall maintain a systematic National Remote Sensing Data Archive, and a log of all acquisitions/ sales of data for all satellites.
3. For acquisition and distribution of IRS data for use in countries other than India, the Government of India, through the nodal agency, shall grant license to such bodies/ agencies of those countries as are interested in the acquisition/ distribution of IRS data, as per specific procedures.
   - The Antrix Corporation Ltd. (of DOS) is vested with the authority for receiving the applications for grant of license for acquisition/ distribution of IRS data outside of India; to consider and decide on the granting of license within the policy considerations of the Government, and to enter into licensing agreements with the prospective users on behalf of the Government. Antrix Corporation Ltd. shall also be competent to levy such fees for granting licenses as may be considered appropriate by it. It shall also be responsible, where necessary, for rendering any further help/ guidance needed by the license.
   - The Government reserves right to impose restrictions over imaging tasks and distribution of IRS data in any country when it is of the opinion that national security and/ or international obligations and/ or foreign policies of the Government so require.
4. The Government prescribes the following guidelines to be adopted for dissemination of satellite remote sensing data in India:
   - All data of resolutions up to 1 m shall be distributed on a non-discriminatory basis and on "as requested basis"
   - With a view to protect national security interests, all data of better than 1 m resolution shall be screened and cleared by the appropriate agency prior to distribution; and the following procedure shall be followed:

- Government users namely, Ministries/ Departments/ Public Sector/ Autonomous Bodies/ Government R&D institutions/ Government Educational/ Academic Institutions, can obtain the data without any further clearance.
- Private sector agencies, recommended at least by one Government agency, for supporting development activities, can obtain the data without any further clearance.
- Private sector agencies, recommended at least by one Government agency, for supporting development activities, can obtain the data without any further clearance.
- Specific requests for data of sensitive areas, by any user, can be serviced only after obtaining clearance from the HRC.
- Specific sale/ non-disclosure agreements to be concluded between NRSC and other users for data of better than 1 m resolution.

5. This Policy (RSDP-2011) comes into effect immediately, and may be reviewed from time-to-time-by Government.

I contact spaceflight:

7.3.8 RE: [External] - Sales - Website Submission

November 17, 2021 6:31 am 52 KB
From:

Keiko Nasu <knasu@spaceflight.com>
To:

siham.aisha@temo-group.com

Hello,

Sorry, for some reason your e-mail has been in the spam box and it took me a while to find your response. I deeply apologize for that.

We are just to close the manifest for June 2022 SpaceX rideshare. We need to provide a good portion of deliverables to SpaceX by December 1, but if you will be able to do that, we might be able to launch your satellite with that mission.

The issue is how you would like to separate the 2 satellites. Our Sherpa-OTV could provide in-plane phasing but it’s not going to be very economical for 2U satellite (and I heard that our Sherpa capacity is already filled).
We might be able to separate a little bit by delay the second satellite deployment (30min or so at most), but it will not give you a lot of separation.

Please confirm SSO is the orbit you would like to go, and will check other possible launch options.

Let me know if you prefer to have a brief call.

Warm regards,

Keiko Nasu
Business Development, Spaceflight Inc.
KNasu@spaceflight.com
Mobile:+1-206-384-0678

From: Siham <siham.aisha@temo-group.com>
Sent: Monday, November 15, 2021 1:36 AM
To: Keiko Nasu <knasu@spaceflight.com>
Subject: RE: [External] - Sales - Website Submission

CAUTION: This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

hello,
I'm waiting for response.
another question: what is the procedure to launch a satellite ?

Regards,
Siham

On October 2, 2021 at 9:20:37 am +03:00, Siham <siham.aisha@temo-group.com> wrote:
Hello Keiko,

1- the time frame it's about in the middle of 2022
2- launch to the same inclination, I mean in the same orbit
3- our spacecraft don't have propulsion
4- size of our spacecraft is : 10X10X20 cm 2U for 2 satellites
5- mass is: 3Kg
6- the purpose: small pilot system for communication satellite.

Regards,
Siham

On September 29, 2021 at 1:34:32 am +03:00, Keiko Nasu <knasu@spaceflight.com> wrote:

Hello Siham,

Thank you so much for reaching out to us.

In order to figure out the launch options and pricing, could you provide below?

- What is the time frame you are looking to launch?
- What orbit do you want to launch your spacecraft to?

-> Do you mean to launch to Mid-inc? 45 degrees inclination, Or you would like to launch to the same inclination but do the plane phasing?

- Will your spacecraft have propulsion?
- What is the size of your spacecraft?

->2U x 2 satellites

- What is the mass of your spacecraft?
- What is the purpose of your spacecraft?

Thank you!

Keiko Nasu

Business Development, Spaceflight Inc.

KNasu@spaceflight.com

Mobile:+1-206-384-0678

8 Tasks and Responsibilities, Technical Documentation

Working Package	Responsible	Name of Technical Documentation	Department/ Stakeholder
	Samir	**System Design**	**IAP**
		ACDS Technical Report	**IAP**
	Rozan	AIS Clustering	**Marmara University, Istanbul, Faculty of Computer Science**
		Orbit and Altitude Specification	
	Abd	**COM/OBD**	
	Yahya	X-Ray Sensor	**IAP**
		Vibration damper	
		Thermal Isolation	

Packages:

1. CoreFlightSystem, on-board computer
2. Attitude control system
3. Telemetry and payload COM system, intersatellite communication
4. Ground station
5. Launching issues
6. AIS

Staff:

For 1: new Turkish bachelor student group

For 2: Raja

For 3: Abdurrahman

For 4: new Turkish bachelor students

For 5: Siham

For 6: Rozan

8.1.1 Summary of System Parts

MAGNETOMETERS - Magnetometers sense magnetic field strengths and direction. The measurements are compared to the Earth's magnetic field map (which is dependent on the spacecraft position) to determine the attitude. Moreover, it can only be used at low altitude orbits, where the magnetic field is strong enough.

8.1.2 Status of Hardware

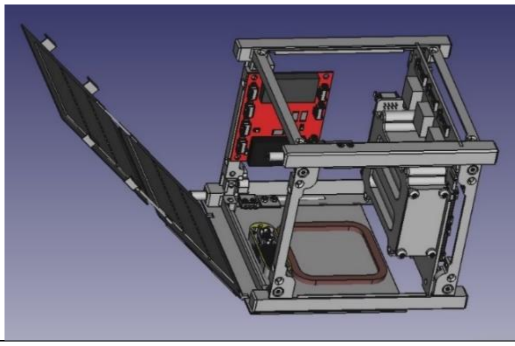
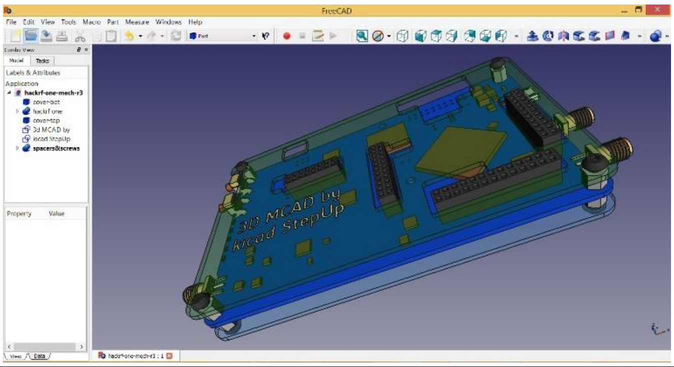
Hardware	Status
Onboard Computer	Received
Solar Cells	Received
Power System	Ordered – 10 Week Lead Time
Chassis	Ordered – Unknown Lead Time
ITC Designed Solar Panel PCBs	Designed – Out for Quote
Radio	Ordered – 6 Month Lead Time
Clean Room	Procured and Setup for Ribbon Cutting
Deployable Antenna	Ordered – Unknown Lead Time
Camera	Received

8.1 Project Documents & Databases for AS-COMSAT-1 (1 Satellite 10cmx10cmx10cm) (Last update: 8.4.21)

8.1.1 Development Documents

Development Phase	Name of Document	Purpose/Content
Analysis	Fire Detection System Description Presentation	about 130 pages Project Description, Supplier Parts
	Initial Cost Estimation	381,000 $ for satellite and ground station (including launch)
Systemdesign	System Design Document	
Mechanical Design		
Hardware Design	HackRF	
SW Specification	Software Specification Document (SDS)	on OBC and HackRF
SW Design	Software Design Document (SDD)	

8.1.2 Mechanical CAD Models

AS-COMSAT- 1 Integration	
Payload 1 (X-Raysensor)	9,5 cm x 2,5 cm x 7 cm
PV Cells and Controller	
Load Controller&Batteries	
Magnetorquer	
Sun Sensor (Photocell)	
On-Board-Computer (OBD)	Raspberry Pi 3
SDR (HackRF) (TT&C and Payload COM)	

9 Suppliers

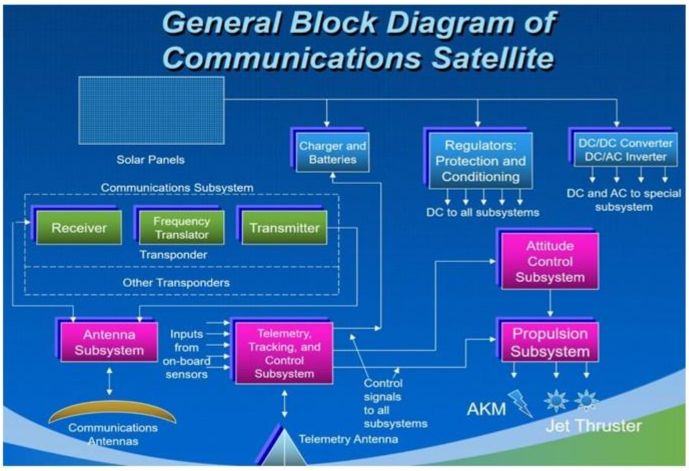
9.1 Satellite Parts

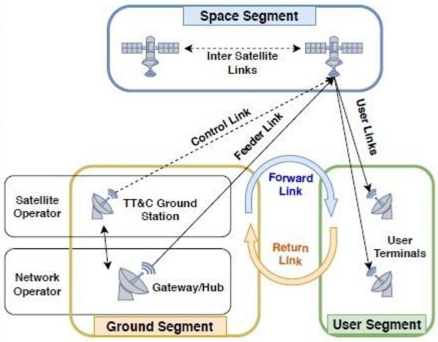
www.cubesatshop.com

10 Parts from Suppliers

10.1 2U Sommunication Satellite System

Communication Satellite System





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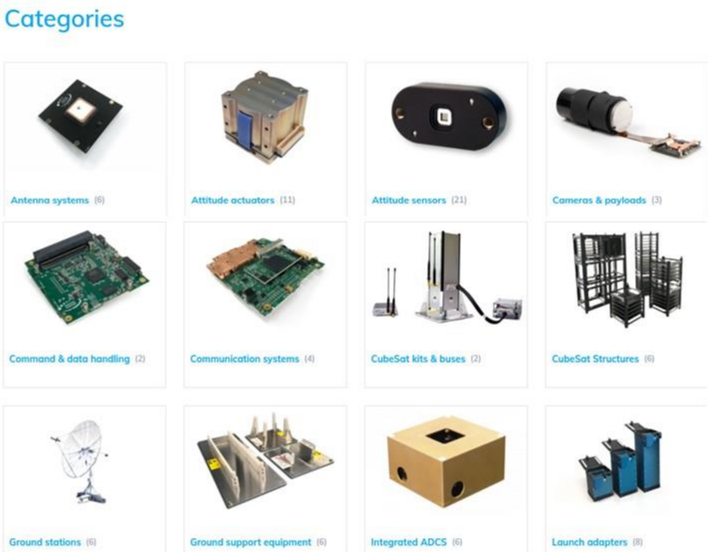
Cubesat off-the-shelf satellite elements

Suppliers:
https://www.cubesatshop.com



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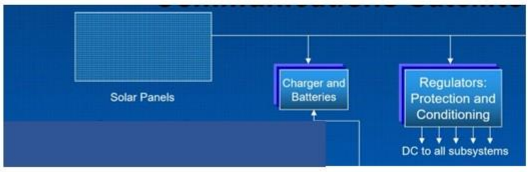
10.2 SAT - Power Supply System

Power Supply

- Solar Panels
- Charger and Batteries
- Regulators
- DC/AC Converter



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Solar Panel Suppliers

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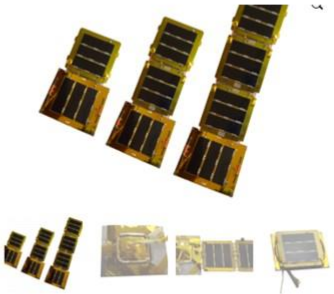
Solar Panel Suppliers



The EXA DSA/1A (Titanium Deployable Solar Array for 1U) is the entry-level product of a family of deployable solar arrays based on artificial muscles for CubeSats in the range of 1U to 6U. The arrays are composed by 5 panels, 3 on top 2 on bottom that attached to the CubeSat structure just as another solar panel and once in orbit deploys to full extension, includes deploy and release contact sensors and custom options are available on requests like sun and temperature sensors, 7-panel configuration and your choice of solar cells like our low-cost solar cells to AzurSpace 3G-30 for very high power missions.

Every array is tested and qualified in our own facilities and shipped with full reports, their very thin yet robust Titanium scaffold of only 0.25mm thickness allows a 1U CubeSat to pack as much power as a full 3U mission. The DSA/1UA yields the best results when coupled with high capacity batteries like our BA01/S and they are fully customizable to your mission needs.

Vendor: EXA

Configuration 1-Panel Array, deploys as 3 panels (2 on top side, 1

Extra Options None

Clear

€3,500

2 in top side, 1 on bottom side,
Low cost cells 2.75 W each

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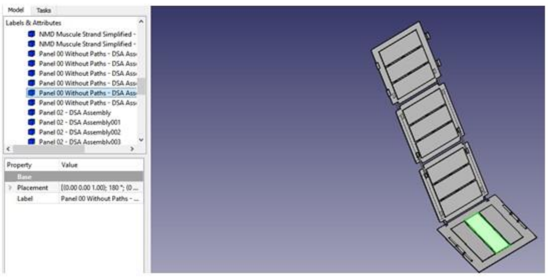
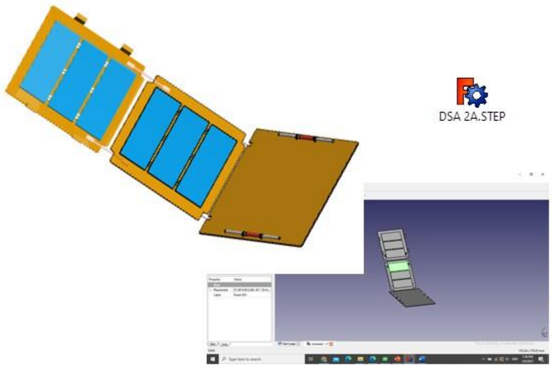
EXA Solar Panel

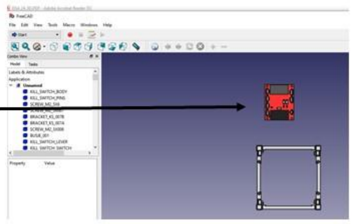
DSA 3A.STEP





DSA 2A.STEP

DSA Control.STEP



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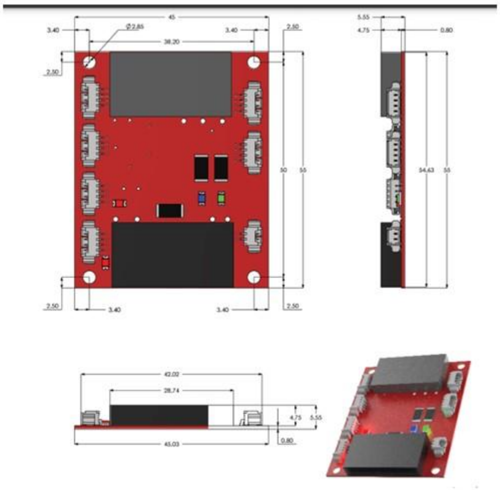
EXA Solar Panel

DSA Control



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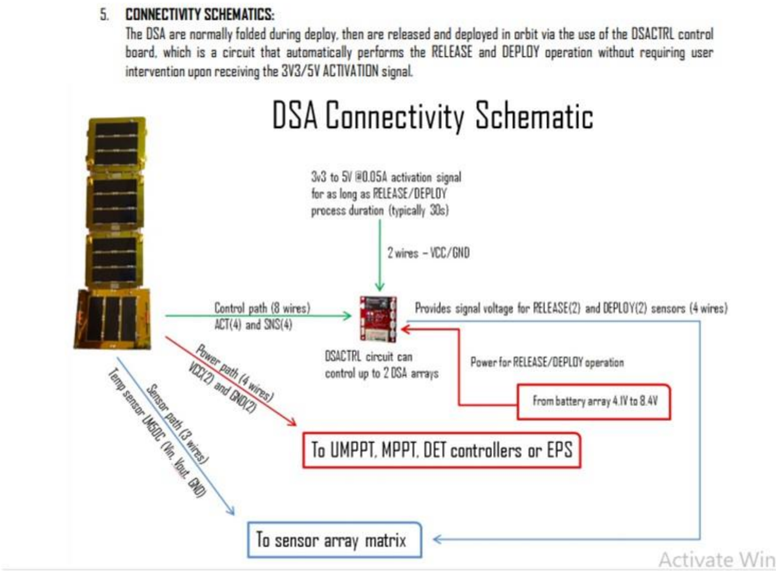
EXA Solar Panel

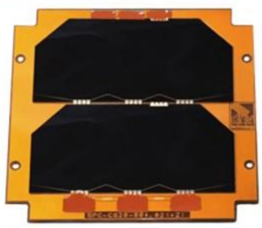


Solar Panel Suppliers

DHV 1U Solar Cell

Home / Solar panels / CubeSat Solar panel DHV-CS-10

Flight Heritage since 2015



€1,450

Solar panels have been tested in qualified laboratories for space applications, as well as solar cells are fully qualified. Different mechanical and electrical designs can be manufactured to meet with subsystems on board. The PCB substrates are made in conformance with ECSS-Q-ST-70-11C. Solar panels are manufactured following the standard ECSS-E-ST-20-08C.

DHV-CS-10 products are solar arrays for 1U CubeSats, there are available top, bottom and side versions. The solar cells are Azur Space 3G30C, qualified solar cells for space applications with 30% efficiency using triple-junction technology. Two solar cells are connected in series to get about 4.8 V. Magnetometer and temperature sensor are integrated on the PCB. Wires and connectors are included.

Availability: 4 – 5 weeks

Vendor: DHV Technology

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Solar Panel Suppliers

DHV 1U Solar Cell

Performance

Solar Cell String (Spectrum: AM0 WRC = 1367 W/m2; T = 28 °C; Series configuration)
- Type: TJ Solar Cell 3G30C – Advanced
- Base material: GaInP/GaAs/Ge on Ge substrate
- Open Circuit Voltage (Voc): 5.4 V
- Short Circuit Current (Isc): 0.52 A
- Voltage at max. Power (Vmp): 4.82 V
- Current at max. Power (Imp): 0.5 A
- Efficiency: 30 %

Temperature sensor:
- Manufacturer: MAXIM
- Model: LM75BIMM-3+
- Package: µMAX® (µSOP)
- Type: Temperature sensor /Over-temperature detector
- Supply Voltage: 3.3V
- Current: 4µA (Shutdown Mode), 250µA (typ), 1mA (max)
- Communication: I2C (configurable address)
- Conversion time: 100ms
- Accuracy: ±2°C
- Resolution: 9bits
- Temperature range: -55°C to +125°C

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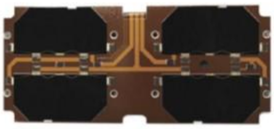
Solar Panel Suppliers

1-Unit-Solarpanel 2500 EUR

CONFIGURATIONS

- Top/Bottom 1U panels
- On top of the ISIS AntS Antenna System
- 1U/2U/3U/6U configuration
- Deployable Panels (optional hold down release mechanism)
- Dummy panels with sensors without cells
- Custom configurations available on request



2U solar panels for CubeSats

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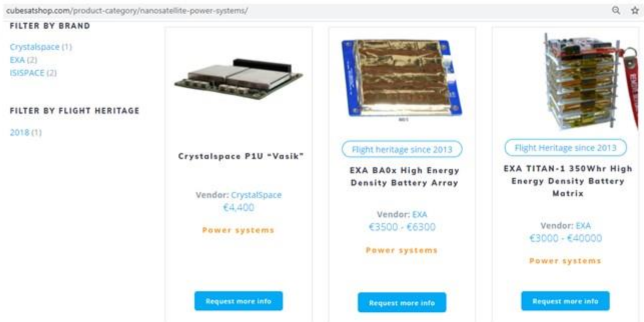
Charger and Batteries Suppliers

- EXA TITAN-1
- Price: 3000 EUR
- Supplier: EXA

- CrystalSpace:
- 1PU
- Price: 4400 EUR



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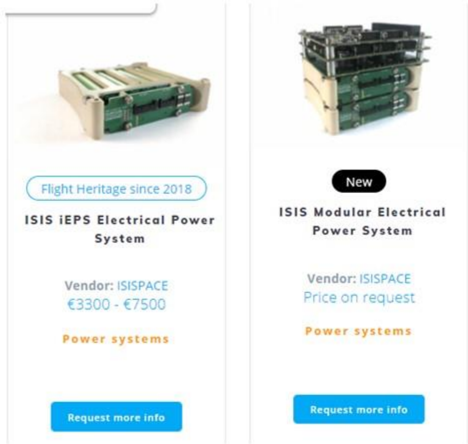

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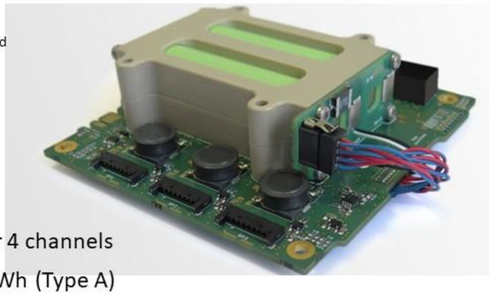
Electrical Power System (EPS)

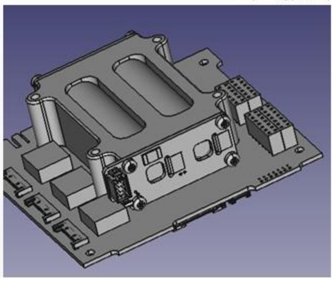
The ISIS Electrical Power System (iEPS) is the second-generation compact power system for nanosatellites, ideal for 1U up to 3U CubeSats. The system leverages wide bandgap semiconductor technologies, implementing GaN-FETs to improve solar power conversion efficiency and performance. It is equipped with an integrated heater, hardware-based Maximum Power Point Tracking (MPPT) and hardware voltage and over-current protection. The iEPS provides 3.3V and 5 V regulated buses, as well as an unregulated bus. An add-on daughter board allows additional configurations to suitably power the system and payload instruments.

Type A (2-cell battery pack): 4,600 EUR

icepsv2_type_a.stp

Compact single PC/104 form factor board solution
FRAM based MCUs for improved radiation tolerance
Hardware voltage, over-current protection and hardware-based maximum power point tracking
Designed for low (idle) power consumption
Solar Panel interface utilizes GaN-FETs
Allows customizations through mountable daughter-board





Power delivered	20W @ 5V over 4 channels
Energy storage	6300mAh/22.5Wh (Type A)

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Electrical Power System (EPS)

Flight Heritage since 2018

ISIS iEPS Electrical Power System

Vendor: ISISPACE
€3300 - €7500

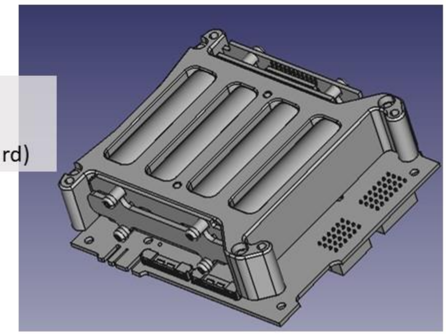
Power systems

The ISIS Electrical Power System (iEPS) is the second-generation compact power system for nanosatellites, ideal for 1U up to 3U CubeSats. The system leverages wide bandgap semiconductor technologies, implementing GaN-FETs to improve solar power conversion efficiency and performance. It is equipped with an integrated heater, hardware-based Maximum Power Point Tracking (MPPT) and hardware voltage and over-current protection. The iEPS provides 3.3V and 5 V regulated buses, as well as an unregulated bus. An add-on daughter board allows additional configurations to suitably power the system and payload instruments.

Type B (4-cell battery pack): 6,400 EUR

Mass	Type A 184 ± 5 grams (2 cell battery pack) Type B 310 ± 5 grams (4 cell battery pack) Type C 360 ± 5 grams (4 cell battery pack + daughterboard)

Power delivered	20W @ 5V over 4 channels
Energy storage	6300mAh/22.5Wh (Type A) 12800mAh/22.5Wh (Type B/C)



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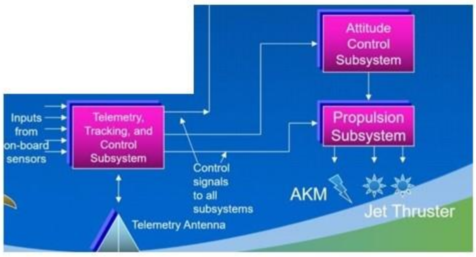
10.3 SAT -Attitude Control System

Satellite Bus and Attitude Control Sytem

- Antenna Subsystem
- Telemetry Tacking and Control Subsystem
- Attitude Control Subsystem
- Propulsion Subsystem



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Attitude Control Subsystem

aecenar.com

arcsec Sagitta Star Tracker

Vendor: arcsec
Price on request

Attitude sensors

arcsec Twinkle star tracker

Vendor: arcsec
Price on request

Attitude sensors

BiSon64-ET

Vendor: Lens R&D
€8,708

Attitude sensors

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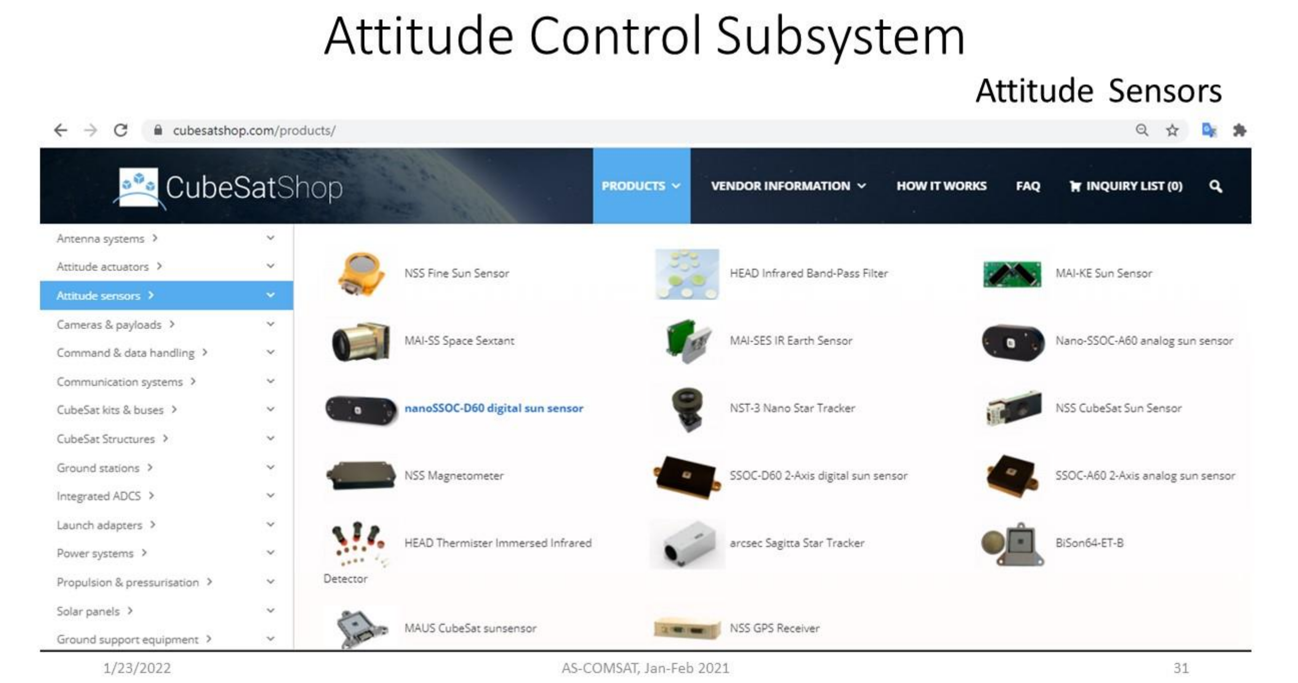
Attitude Control Subsystem
Attitude Sensors
cubesatshop.com/products/
CubeSatShop
PRODUCTS
VENDOR INFORMATION
HOW IT WORKS
FAQ
INQUIRY LIST (0)
Antenna systems
Attitude actuators
Attitude sensors
Cameras & payloads
Command & data handling
Communication systems
CubeSat kits & buses
CubeSat Structures
Ground stations
Integrated ADCS
Launch adapters
Power systems
Propulsion & pressurisation
Solar panels
Ground support equipment
NSS Fine Sun Sensor
HEAD Infrared Band-Pass Filter
MAI-KE Sun Sensor
MAI-SS Space Sextant
MAI-SES IR Earth Sensor
Nano-SSOC-A60 analog sun sensor
nanoSSOC-D60 digital sun sensor
NST-3 Nano Star Tracker
NSS CubeSat Sun Sensor
NSS Magnetometer
SSOC-D60 2-Axis digital sun sensor
SSOC-A60 2-Axis analog sun sensor
HEAD Thermister Immersed Infrared Detector
arcsec Sagitta Star Tracker
BiSon64-ET-B
MAUS CubeSat sunsensor
NSS GPS Receiver
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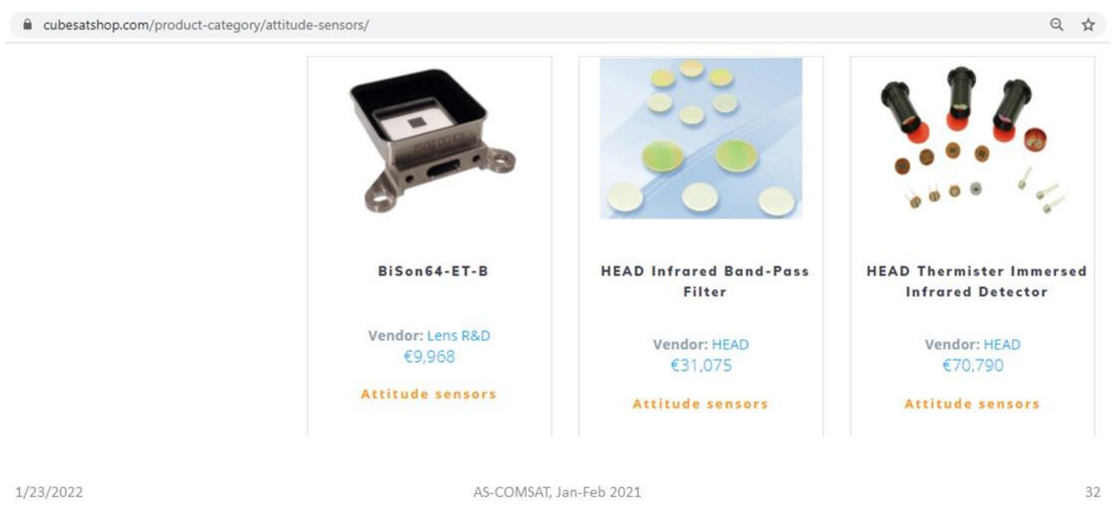
cubesatshop.com/product-category/attitude-sensors/
BiSon64-ET-B
Vendor: Lens R&D
€9,968
Attitude sensors
HEAD Infrared Band-Pass Filter
Vendor: HEAD
€31,075
Attitude sensors
HEAD Thermister Immersed Infrared Detector
Vendor: HEAD
€70,790
Attitude sensors
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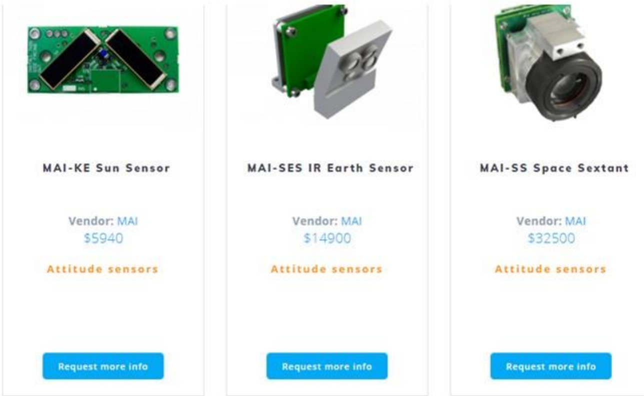

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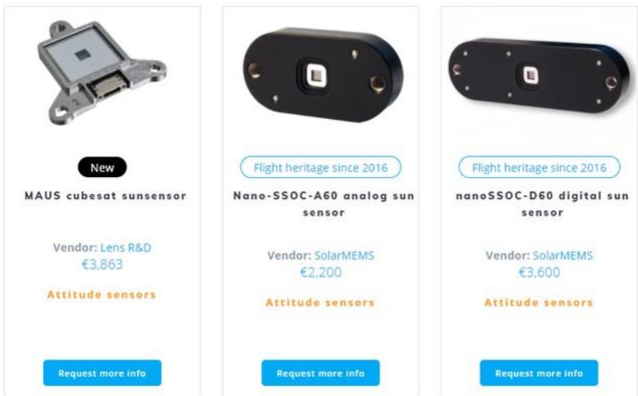

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NSS CubeSat Sun Sensor
Vendor: NewSpace
$3300
Attitude sensors
NSS Fine Sun Sensor
Vendor: NewSpace
$12000
Attitude sensors
NSS GPS Receiver
Vendor: NewSpace
Price on request
Attitude sensors
1/23/2022
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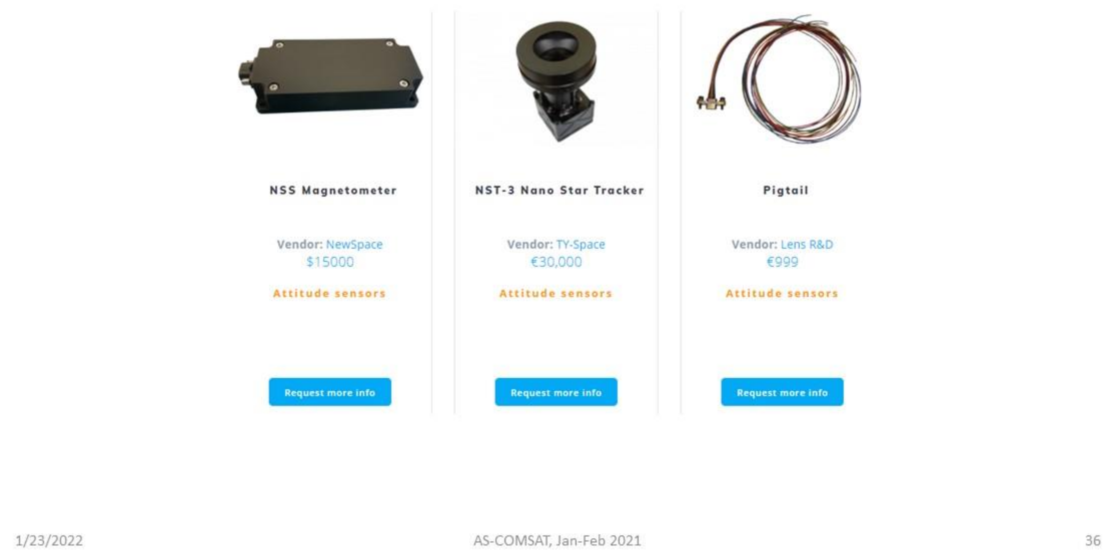
NSS Magnetometer
Vendor: NewSpace
$15000
Attitude sensors
Request more info
NST-3 Nano Star Tracker
Vendor: TY-Space
€30,000
Attitude sensors
Request more info
Pigtail
Vendor: Lens R&D
€999
Attitude sensors
Request more info
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Flight heritage since 2009
SSOC-A60 2-Axis analog sun sensor
Vendor: SolarMEMS
€7,200
Attitude sensors
Flight heritage since 2009
SSOC-D60 2-Axis digital sun sensor
Vendor: SolarMEMS
€12,200
Attitude sensors
Transport box
Vendor: Lens R&D
€159
Attitude sensors
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Attitude Control Subsystem
Attitude Sensors
SOLARMEMS
nanoSSOC-D60
Sun Sensor for Nano-Satellites
Digital Interface
ITAR FREE
Technical Chracteristics:
Type 2 orthogonal axes
Field of View ±60°
Accuracy < 0.5 ° (3sigma) < 0.1 ° (precision)
Electrical interface UART, I2C or SPI 10-pin micro-connector
Power supply 3.3V / 5V < 23mA consumption
Mechanical interface 43 x 14 x 5.9 mm 6.5 g
Housing Aluminum 6082 Black anodizing
Digital Space Qualified
Sun Sensor on a Chip (SSOC)
nanoSSOC-D60 digital sun sensor
€3,600
Sun Sensor on a Chip (SSOC) is a two-axes and low cost sun sensor for high accurate sun-tracking, pointing and attitude determination. The device measures the incident angle of sun ray in two orthogonal axes, providing a high sensitivity based on the geometrical dimensions of the design. nanoSSOC sun sensor is based on MEMS fabrication processes to achieve high integrated sensing structures.
nanoSSOC-A60 has tiny size, low weight and low power consumption to be the perfect ADCS solution for nanosatellite platforms like Cubesats.
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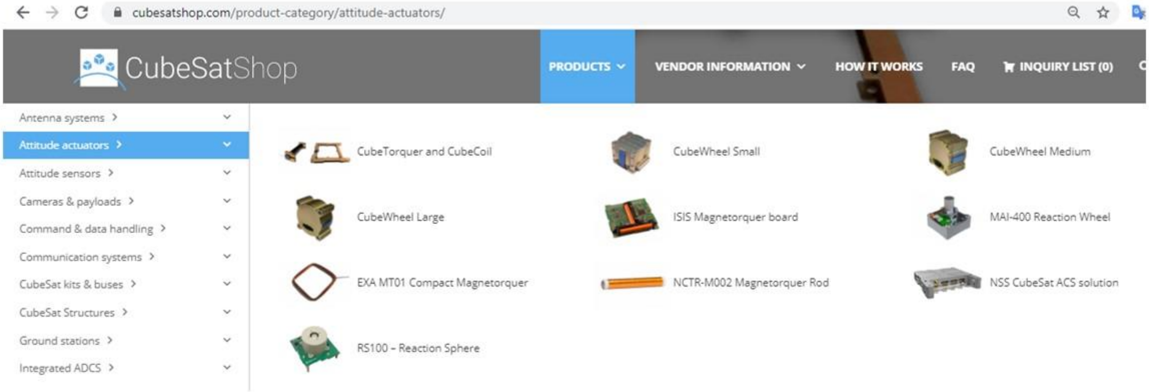
Attitude Actuators



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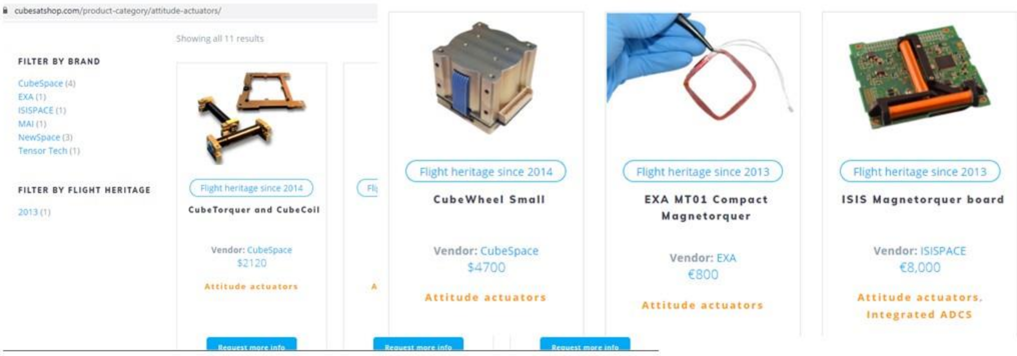
Attitude Actuators



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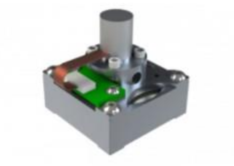
Attitude Actuators



MAI-400 Reaction Wheel

Vendor: MAI
$7100

Attitude actuators

NCTR-M002 Magnetorquer Rod

Vendor: NewSpace
$1200

Attitude actuators

NCTR-M012 Magnetorquer Rod

Vendor: NewSpace
$2000

Attitude actuators

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Attitude Actuators

Home / Attitude actuators / EXA MT01 Compact Magnetorquer

€800

With only 7.5 grams and 3.2 millimeters thickness, the MT01 Compact Magnetorquer is a vacuum core magnetic coil designed fo ADCS control in cubesat mission from 1U to 3U that boast an impressive performance compared to its small footprint over the mass, power and area budget of the spacecraft. Even with that small dimensions the MT01 is capable of greater magnetic moments, turn speeds and angular accelerations than comparable products on the market, yet the power usage is kept to a minimum: It can turn a 1U mass 90 degrees in 60 seconds using only 0.2 Watts at a LEO orbit of 500kms.

MT01 can be integrated in to our BA0x family of high capacity compact batteries and our DSA Deployable Solar Array family too, the biggest advantage of the MT01 is that it can be easily affixed anywhere on your spacecraft using a minimal area.

Every coil is tested and qualified in our own facilities and shipped with full reports and packed with additional match connectors interfaces.
Availability: 2 weeks

Vendor: EXA

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Attitude Actuators

EXA Magnetorquer

Performance

•Working Voltage: From 1.25V to 7.5V
•Working Current: From 100mAh to 2000 mAh
•Nominal Magnetic moment: >0.19 Am2
•Saturation Magnetic moment: >0.85 Am2
•Linearity: +/- 4% across operating design rang
•Residual moment: <0.0045 Am2
•Torque: 5.36 μNm @ 7.2-3 Tesla (1U mass)
•Angular acceleration: 3.2-3 Rad/sec-2 (1U mas
•B-center = 8.9 Gauss
•B-corners = 14.5 Gauss
•Supply Power: From 250mW to 1750mW
•Typical resistance: 4.1 to 4.7 ohms @ 25°C
•Random Vibration: 16g rms
•Lifetime: >10 years

Features | Performance | Product properties | Materials | Testing | Configurations | Documents

Configuration	Price
MT01 Compact Magnetorquer 50x50x3.2 mm	€ 800
Optional: Integrated to BA0x High Capacity Battery Array	- € 100
Optional: Integrated to DSA Deployable Solar Array	- € 100
Optional: Integrated thermal sensor	+ € 150

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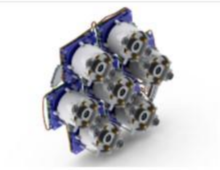
Propulsion Unit (Thruster)



Cluster of IFM Nano Thruster for Smallsats

Vendor: ENPULSION
€50000 - €210000

Propulsion & pressurisation

Flight Heritage since 2018

IFM Nano Thruster for CubeSats

Vendor: ENPULSION
€38,400

Propulsion & pressurisation

Nanosatellite Micropropulsion System

Vendor: MicroSpace
€81000 - €129000

Propulsion & pressurisation

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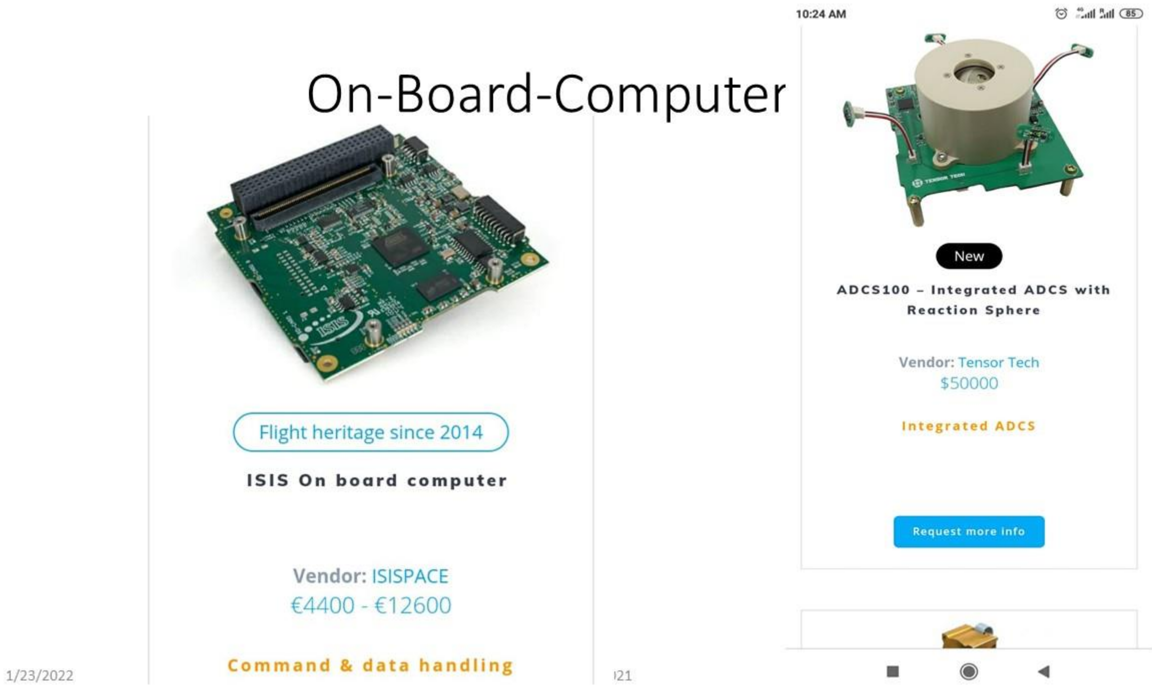
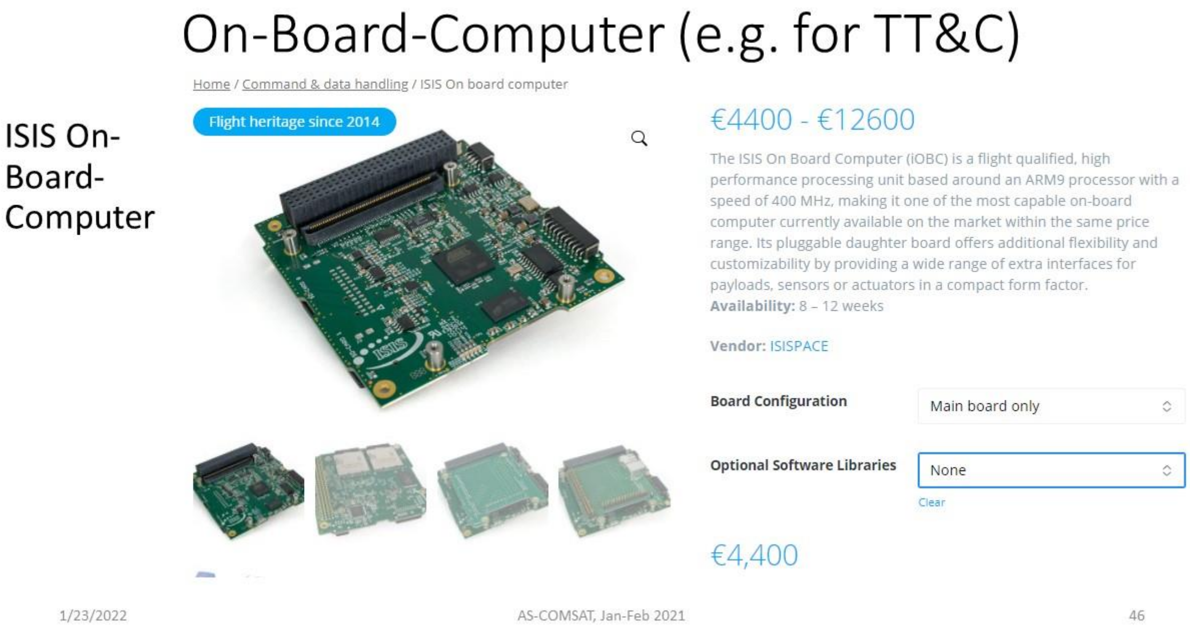
10.4 Command&Data Handling (On-Board Computer)





On-Board-Computer

Flight heritage since 2014

ISIS On board computer

Vendor: ISISPACE
€4400 - €12600

Command & data handling

The ISIS on-board computer (iOBC) is a flight proven, high performance processing unit based around an ARM9 processor with a clock speed of 400 MHz and offers a multitude of standardized interfaces. Combined with its daughterboard architecture, allowing for easy addition of mission specific electronics or interfaces, this makes the iOBC the ideal candidate for your main mission computer or payload processing unit.

FEATURES

- 400 MHz, power efficient ARM9 processor
- Multiple OS options available:
  → FreeRTOS operating system for simple and lightweight cooperative multitasking
  → KubOS Linux (coming in 2017)
- On-board telemetry: voltages, currents, and temperature
- External on-board watchdog, power-controller, and real time clock
- High reliability data storage and fail safe filesystem
- Flexible daughterboard architecture
- Robust design

INTERFACES

- I²C master or slave mode
- SPI master mode (up to 8 slaves)
- 2x UART (RS232 + RS232 / RS485 / RS422)
- General Purpose Input / Output pins (GPIO)
- ADC (10-bit, 8 channels)
- Pulse Width Modulation (PWM)
- JTAG for programming and debugging
- Dedicated debug LEDs and UART
- USB host and device
- Image Sensor Interface

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On-Board-Computer

Flight heritage since 2014

ISIS On board computer

Vendor: ISISPACE
€4400 - €12600

Command & data handling

PRODUCT PROPERTIES

- Operating Temperature:-25 °C to +65 °C
- Power Supply: 3.3V
- Dimensions: 96 x 90 x 12.4mm (incl. FM daughter board)
- Mass: 76g mainboard only, 100g with EM daughter board
- Power Consumption: 400mW average

DAUGHTERBOARD ARCHITECTURE

- The pluggable daughterboard offers flexibility and customizability by providing a wide range of interfaces for payloads, sensors, actuators in a compact form factor
- EM daughterboard: all interfaces for development and debugging
- FM daughterboard: all interfaces in compact form factor using high reliability connectors
- Custom daughterboard: design your own daughterboard with additional interfacing and electronics based on mission requirements

AVAILABLE SOFTWARE LIBRARIES

SD card slots

EM Daughter Board

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On-Board-Computer

AVAILABLE SOFTWARE LIBRARIES

iOBC Hardware Abstraction Layer library (included)
- Library that supports all iOBC hardware peripherals and includes FreeRTOS and the fail-safe FAT32 filesystem

Subsystems interface library (optional)
- Library for interfacing the iOBC with the most commonly used satellite subsystems over the I²C databus

Mission Support library (optional)
- Library providing high level mission software functionality, includes flight parameter storage and logging modules

Custom solutions on request

iOBC with FM Daughter Board

PRODUCT CONTENTS AND ACCESSORIES

- iOBC main board
- JTAG programmer / debugger + USB cable
- Adapter board (including debug UART to USB conversion) + USB cable
- 2 x 2 GB high reliability SD cards
- Power break-out board for easy connection to power supply
- USB drive containing manuals, iOBC SDK installer, and applicable software libraries

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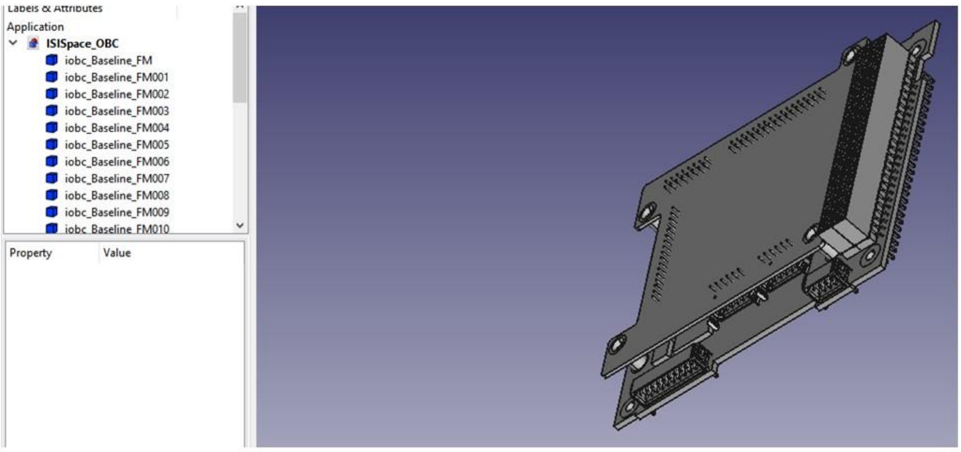
On-Board-Computer

CAD File:

iobc_Baseline_FM.zip



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On-Board-Computer (from ISIS)

ISIS On Board Computer
€4.400,00 – €6.850,00
•400 MHz, power efficient ARM9 processor
•Multiple OS options available:
- FreeRTOS operating system for simple and lightweight cooperative multitasking
- KubOS Linux

•On-board telemetry: voltages, power-controller, and real time clock
•High reliability data storage and fail safe filesystem
•Flexible daughterboard architecture
•Robust design
•Includes Hardware Abstraction Layer Library

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On-Board-Computer

Flight heritage since 2014

Cube ADCS

Vendor: CubeSpace
$24700 - $37400

Integrated ADCS

$24700 - $37400

CubeADCS bundles offer custom solutions for a variety of satellite requirements. The ADCS OBC can also serve as a main satellite OBC. Each bundle consists of an integrated stack of CubeSpace components with UART, I2C, and CAN interfaces to other satellite subsystems. High-level ADCS software libraries are also available on any CubeADCS bundle. The bundles are compact and have low power consumption.

Vendor: CubeSpace

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On-Board-Computer inclusive other components

New

EXA ICEPS Spacecraft System Core

Vendor: EXA

€16500 - €53000

All in one USB 2.0 bus OBC, SDR radio, Laser comms, EPS, Solar panel manager, Deployables manager Cubesat system core

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On-Board-Computer inclusive other components

All in one USB 2.0 bus OBC, SDR radio, Laser comms, EPS, Solar panel manager, Deployables manager Cubesat system core

Configuration Choose an option

Choose an option
- 1 - FULL EPS ONLY (I2C INTERFACE) + 25W BATTERY (1 single deck)
- 2 - FULL EPS (USB/I2C)+ OBC/SDR RADIO/32GB SSD
- 3 - FULL EPS (USB/I2C) + OBC/SDR RADIO/256GB SSD + LASER COMMS
- 4 - FULL EPS (USB/I2C) + OBC/SDR RADIO/256GB SSD + LASER COMMS + D/R CONTROL
- 5 - FULL EPS (USB/I2C) + OBC/SDR RADIO/512GB SSD + LASER COMMS + D/R CONTROL + 25W BATTERY
- 6 - FULL EPS (USB/I2C)+ OBC/SDR RADIO/512GB SSD + LASER COMMS + D/R CONTROL + 50W BATTERY (2 single deck or 1 double deck)
- 7 - FULL EPS (USB/I2C)+ OBC/SDR RADIO/512GB SSD + LASER COMMS + D/R CONTROL + 100W BATTERY (2 double deck)

Configuration 2 - FULL EPS (USB/I2C)+ OBC/SDR RADIO/32GB SSD

Clear

€29,000

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On-Board-Computer inclusive other components

New

EXA ICEPS Spacecraft System Core

Vendor: EXA

€16500 - €53000

ICEPS System Core Specifications:

Bus type:	USB 2.0, I2C
OBC:	Xilinx Zynq XC7Z010-2I System-on-Chip: Programmable Logic (PL) Specification: -28K Logic Cells -2.1 Mbits BlockRAM -80 DSP slices Processor System (PS) Specification: -Dual-core ARM Cortex A9 CPU running up to 733 MHz -Linux 4.11 • 512 MB of DDR3L RAM • 32 MB of QSPI flash storage for uboot bootloader, kernel, and root file system Temperature Sensor: TMP103AYFFR Accuracy: -40 deg C to +125 deg C (+/- 1 deg C typ), Resolution: 1 deg C
OBC/OS:	Linux computer running IIOS
Radio:	SDR from 70Mhz to 6GHz
EIRP	+28.5 dBm integrated LNB
Sensitivity:	-110 dBm
Antenna ports:	2 RX and 1 Transceiver (TX/RX)
System Storage	From 32 to 512 Gigabytes 60MB/s r/w (user chooses)
Number of ports:	USB2.0 60MB/s 14 total: 6 external, 8 internal; 1 I2C port
High Speed Laser communications	405nm or 450 nm solid state laser, temperature stabilized , 10 Mbps, variable beam aperture, variable focus. Integrated temperature sensor range -50C to +125C
Power rails:	5V@3A; 12V@3A(adjustable), 3v3@3.6A(2 redundant); 4.2 ~ 3.6 (unregulated) @ 12A ; 1 auxiliary APU port
Battery packs	One or two at 3.7@6A, 50W max nominal
Power delivery	50W Nominal (continuously) , 65W Maximum, 100W peak for 2.5 sec.
Solar mgmt:	4 UMPPT channels 16V@2A max each
Solar charger:	Based on TPS100 2A continuously, 1S, 2S,3S
Internal sensors:	20 internal sensors; integrated IMU
Actuators:	Integrated automatic management of Release/deploy mechanisms ; integrated automatic LNB/PA switching
Built in protection	RBL; 10A Activation switch w/ MTBF>1000, 2A and 7A resettable fuses
Inertial Measurement Unit:	6-axis MotionTracking Device: (3-axis gyroscope, 3-axis accelerometer) TDK / InvenSense ICM-20602 - Gyroscope sensitivity error: ±1% - Gyroscope noise: ±4 mdps/√Hz - Accelerometer noise: 100 µg/g/√Hz
Mass	100 grams
Operating temp.	-50C to +125C
Dimensions	96x96x25mm

- The system is modular, this is a full description, but the user can choose what components to be added or subtracted.

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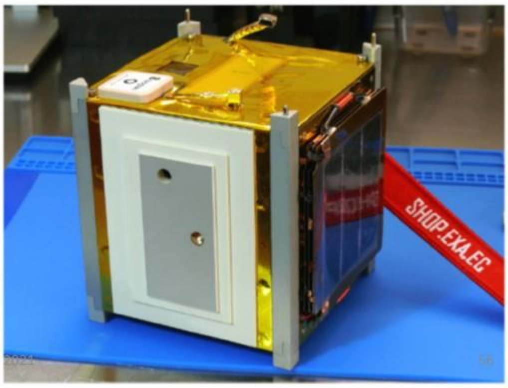
On-Board-Computer inclusive other components

New

EXA ICEPS Spacecraft System Core

Vendor: EXA

€16500 - €53000



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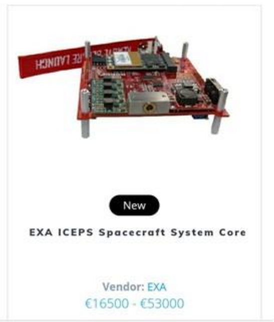
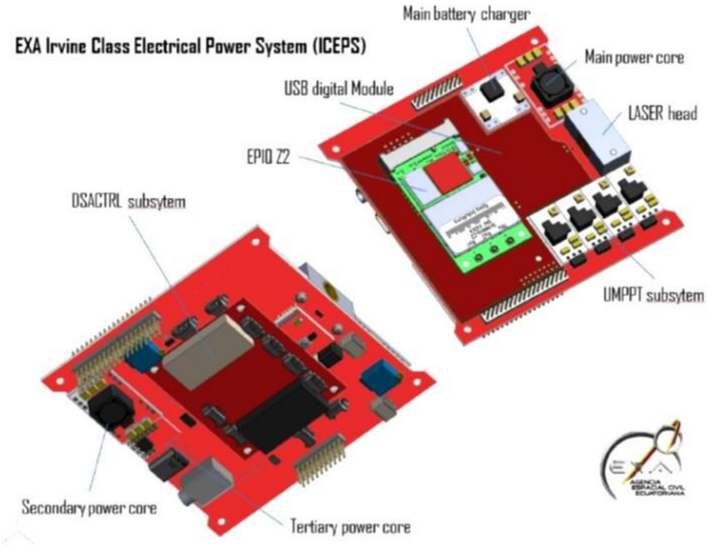
On-Board-Computer inclusive other components





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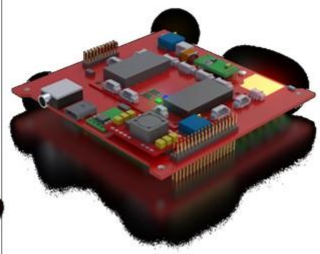
DESIGN:

A. USB architecture
B. Solar charge (UMPPT)
C. Laser Communications Module
D. Power Supply
E. High Capacity SSD Storage
F. Epiq Sidekick Z2 OBC
G. Software Defined Radio
H. DSA Deployment Control
I. Sensors and actuators



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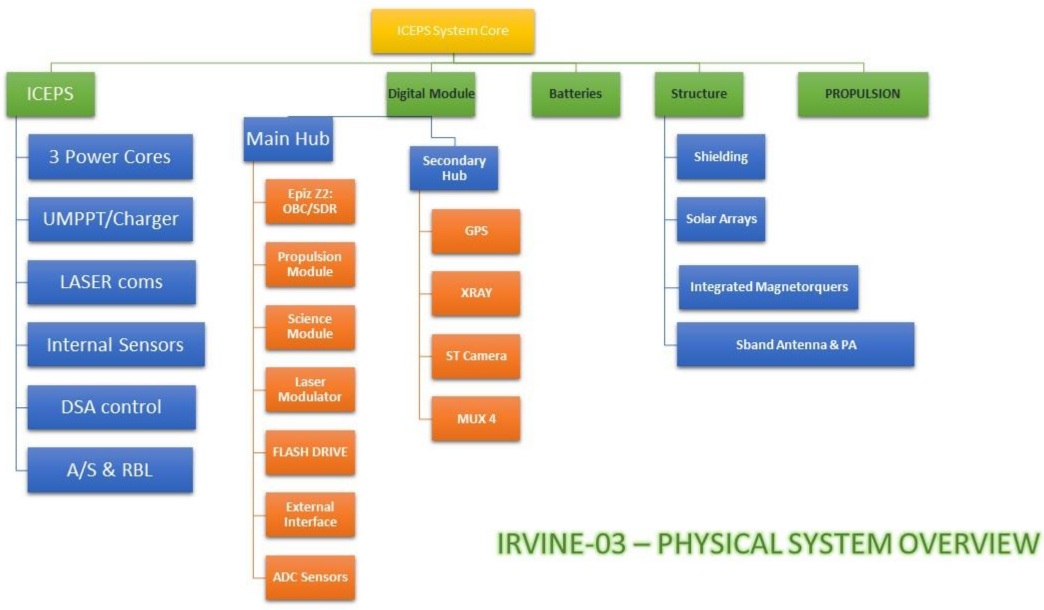
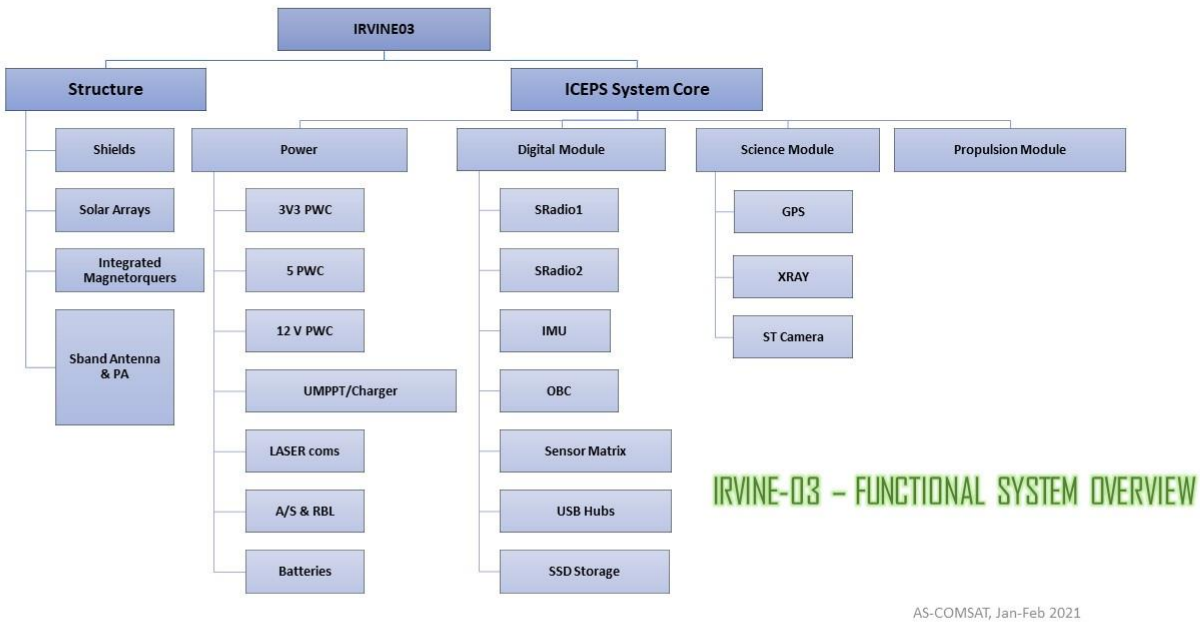
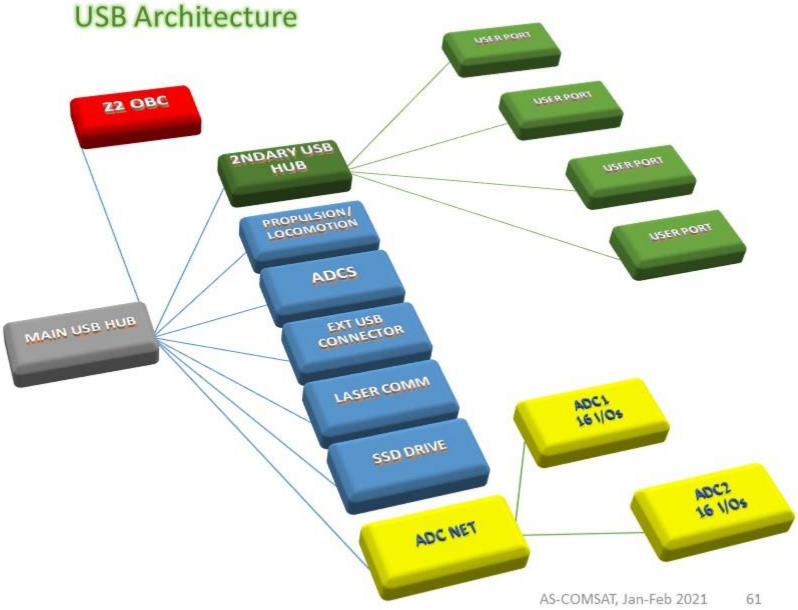

ICEPS System Core
ICEPS
Digital Module
Batteries
Structure
PROPULSION
3 Power Cores
UMPPT/Charger
LASER coms
Internal Sensors
DSA control
A/S & RBL
Main Hub
Epiz Z2: OBC/SDR
Propulsion Module
Science Module
Laser Modulator
FLASH DRIVE
External Interface
ADC Sensors
Secondary Hub
GPS
XRAY
ST Camera
MUX 4
Shielding
Solar Arrays
Integrated Magnetorquers
Sband Antenna & PA
IRVINE-03 – PHYSICAL SYSTEM OVERVIEW
AS-COMSAT, Jan-Feb 2021


IRVINE03
Structure
ICEPS System Core
Shields
Solar Arrays
Integrated Magnetorquers
Sband Antenna & PA
Power
3V3 PWC
5 PWC
12 V PWC
UMPPT/Charger
LASER coms
A/S & RBL
Batteries
Digital Module
SRadio1
SRadio2
IMU
OBC
Sensor Matrix
USB Hubs
SSD Storage
Science Module
GPS
XRAY
ST Camera
Propulsion Module
IRVINE-03 – FUNCTIONAL SYSTEM OVERVIEW
AS-COMSAT, Jan-Feb 2021

USB Architecture

- From I2C/SPI to USB 2.0
- The USB core has up to 14 ports, 8 of them used by ICEPS, 6 available for user.
- The OBC is on upstream port of main USB hub
- The ADC network has room for 32 GPIOs
- USB-C connector is backward compatible and normally uses USB 2.0 protocol.



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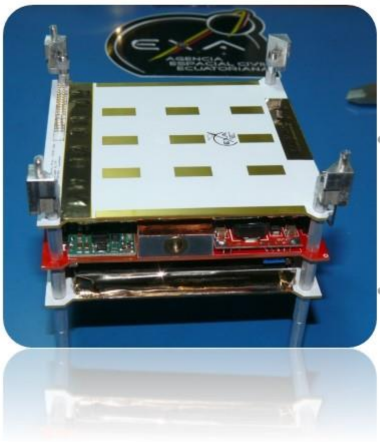
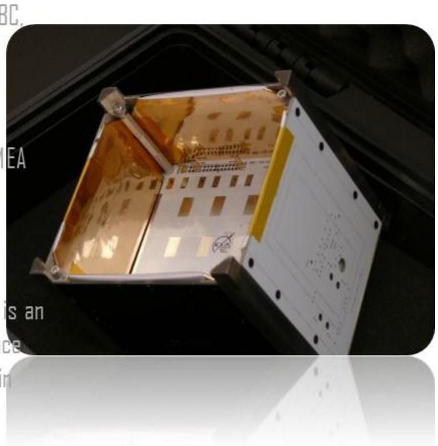
USB bus resilience against radiation



- To mitigate the impact of SLEs and SUEs in the OBC, the ICEPS board is encased between 2 BA01/S battery packs
- The second radiation protection is the SEAM/NEMEA shielding MLI that protects all the sides of the cubesat
- The Space Environment Attenuation MLI (NEMEA) is an MLI of 27 layers that has spaceflight heritage since 2013 and has been demonstrated very effective in regulating radiation, temperature and plasma environments.



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Solar charge using Unified Maximum Power Point Tracking

- The power generation architecture of IRVINE-03 includes 2 Deployable Solar Arrays (DSA), each one with two nanomorphodynamic actuator sets
- The DSAs have two sides and each one is equipped with solar cells, hence the need for four UMPPT channels, in order to harness as much power as possible without sacrificing the other partially illuminated side.
- The UMPPT bus to which the channels are connected feed the charging circuit to which the battery arrays are directly connected.

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Laser Communications Module PLM02

- This laser module has higher data transfer rates that can handle large payload data sizes and can potentially achieve downloads as big as 100MB in 1 to 5 minutes.
- The laser communications module can be set to transmit as low as 115Kbps and as high as 10Mbps.
- The wavelength of the communications laser is 450nm or 405nm.

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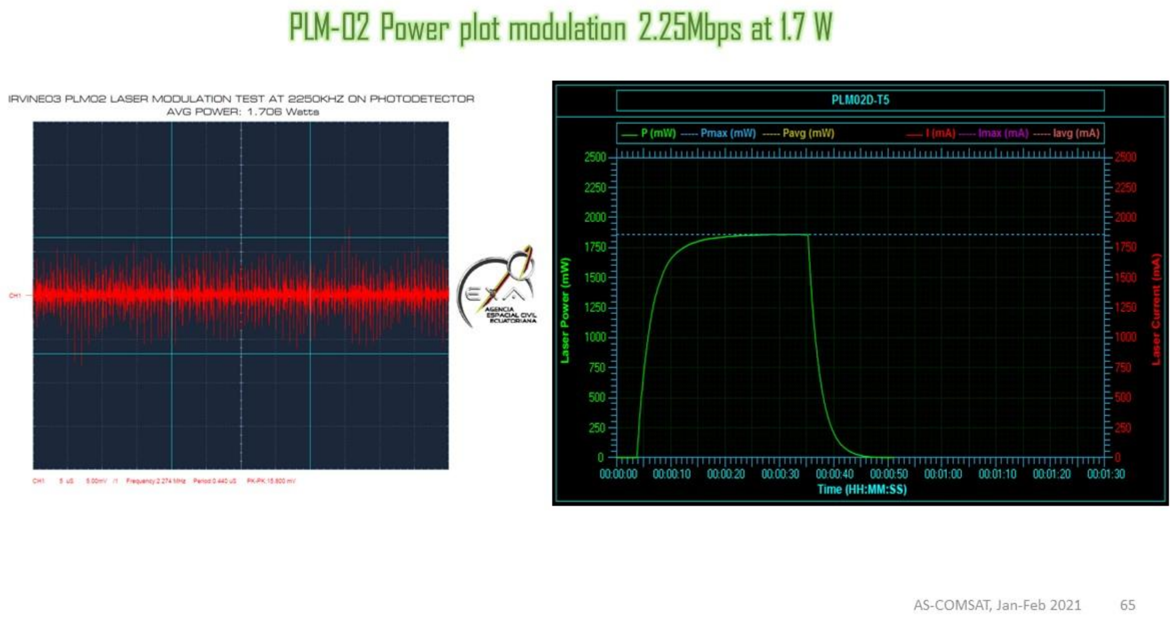
PLM-02 Power plot modulation 2.25Mbps at 1.7 W
IRVINE03 PLM02 LASER MODULATION TEST AT 2250KHZ ON PHOTODETECTOR
AVG POWER: 1.706 Watts
PLM02D-T5
P (mW) Pmax (mW) Pavg (mW) I (mA) Imax (mA) Iavg (mA)
Laser Power (mW)
Laser Current (mA)
Time (HH:MM:SS)
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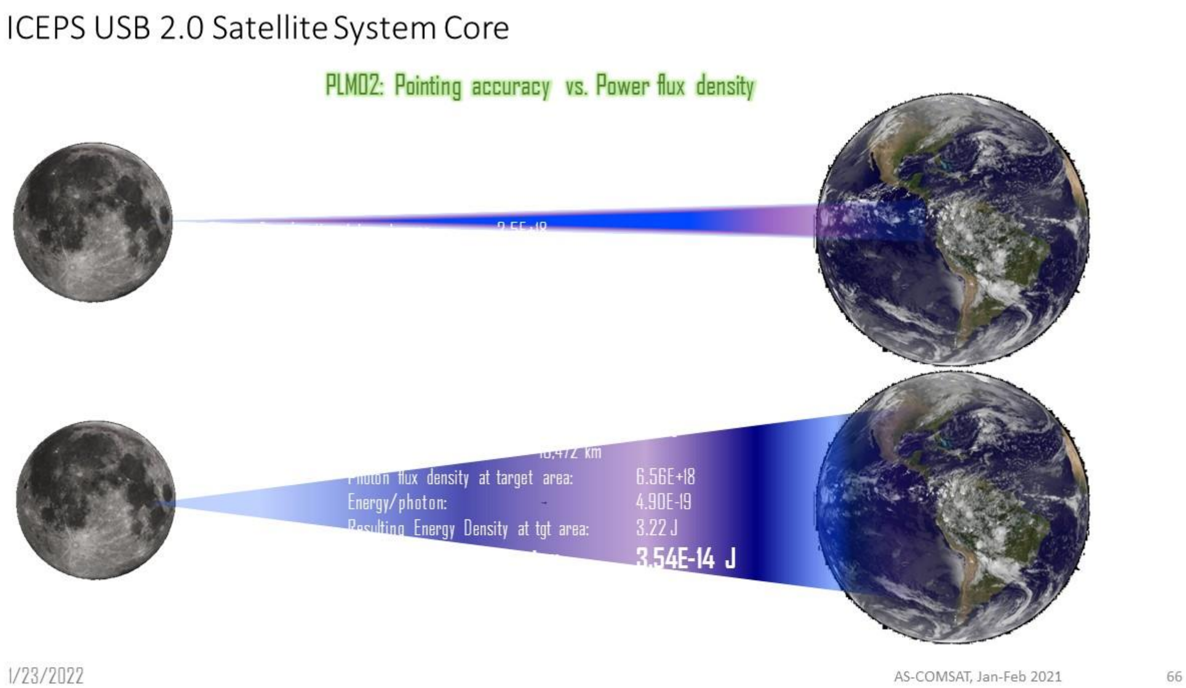
ICEPS USB 2.0 Satellite System Core
PLM02: Pointing accuracy vs. Power flux density
Energy/photon:
6.56E+18
4.90E-19
3.22 J
3.54E-14 J
1/23/2022
AS-COMSAT, Jan-Feb 2021
66

512GB of high speed, radiation tolerant SSD storage

- ICEPS can be fitted with a minimum of 32GB and a maximum of 512GB of high speed (60 MB/s read/write) USB 2.0 SSD storage, which is natively radiation tolerant made by Samsung.
- In addition to that native tolerance, the SSD is protected by its own radiation shielding, encased between 2 battery banks and protected by the NEMEA shielding.
- The SSD is connected to a high priority USB 2.0 channel, so it can drive at a top speed of 480Mbps if needed.

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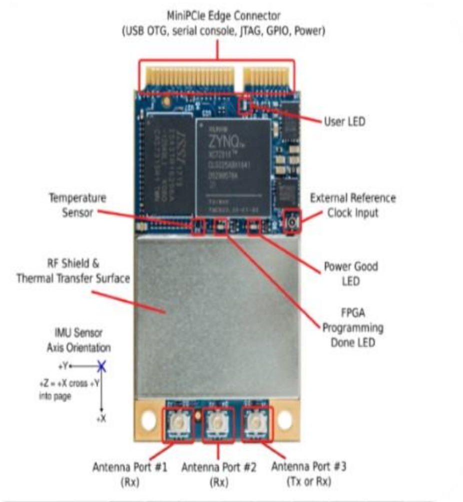
Epiq Sidekiq Z2 OBC

ICEPS computing core is an Epiq's Sidekiq Z2:

- Dual-core ARM Cortex A9 CPU running up to 733 MHz
- Linux computer running IIOS
- 512 MB of DDR3L RAM
- 32 MB of QSPI flash storage for uboot bootloader, Linux kernel, and root file system
- USB 2.0 main network port
- Internal independent watchdog and temp. sensor
- Internal IMU, 6 axis sensor, ADCS ready



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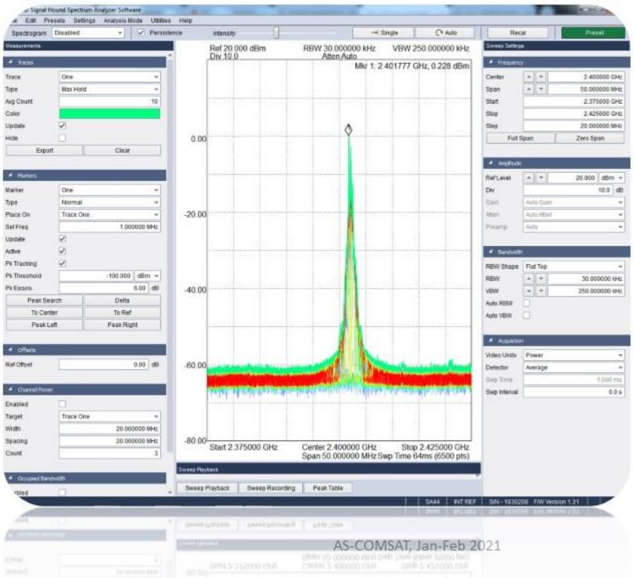
Z2 Software Defined Radio OBC

The ICEPS's Sidekiq Z2 is an SDR Engine:

- SDR range: 70Mhz to 6GHz
- EIRP: +28.5 dBm w/ext. LNB
- Sensitivity: -110 dBm
- Antenna ports: 2 RX
  1 Transceiver (TX/RX)
- Complete libraries in C++ and Linux programming environment.
- Automated RF Switch integrated into the S/C bus



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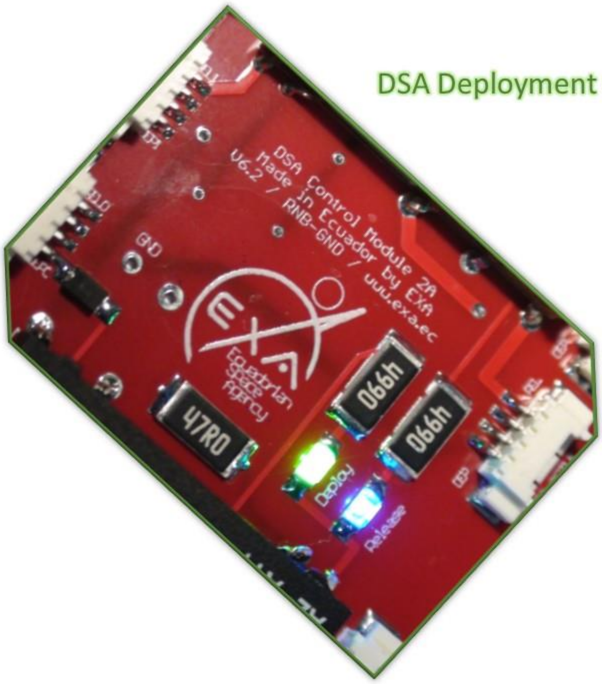

DSA Deployment Control

The Deployable Solar Array Deployment control allows the user to rely on ICEPS for deployment and release control.

- Just one simple command from the user.
- DSA/DC automates the release and deploy sequence.
- If using EXA DSA arrays, release/deploy is guaranteed.
- Natively manages artificial muscles and Nitinol-based R/D devices
- Can also manage thermal knife user devices using up to 15W.

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Sensors and Actuators Control

ICEPS has 24 internal sensors:

- Laser(1), OBC(1), External (2) and battery(2) temperature
- Solar panel voltage (4)
- Power rails (3) voltage
- Solar array deploy/release (4)
- UMMPT bus (1)
- 6 Axis gyroscope (6)

And 4 actuators:

- DSA R/D sequence, Power amplifier, power rail control (2)

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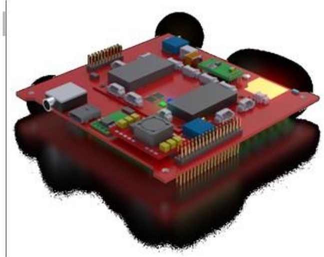
MODULARITY

ICEPS can be configured from an EPS configuration only to a full System Core configuration at user request:

- Power rails, 1 to 6, user configurable output
- Solar channels, 1 to 4
- Solar charging manager, single or dual
- Release/Deploy circuitry, 0 to 1
- Laser comm module, 0 to 1
- Onboard OBC, 0 to 1
- Battery arrays, 1 to 4
- USB 2.0 bus or just GPIO



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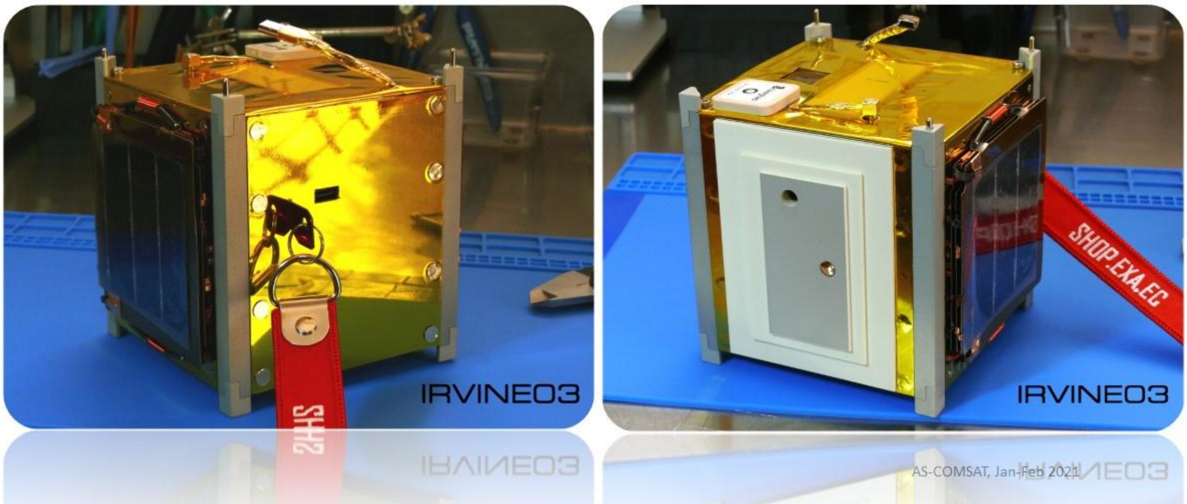
IN-ORBIT DEMONSTRATION

ICEPS ONBOARD IRVINE03 TO BE LAUNCHED ON NASA ELaNA SLOT IN Q2/2020



LUNAR DEMONSTRATION

ICEPS ONBOARD QBWALKER TO LAND ON THE MOON ON BOARD ASTROBOTIC'S PEREGRINE IN Q3/2021

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CONCLUSIONS

Pros:

- Can serve missions from 1U to 24U.
- Takes the cubesat community beyond the limitations of the I2C, SPI, CAN-bus etc.
- High computing power, throughput, high capacity storage and high speed laser communications are included. SDR naturally embedded into the system.
- Modularity allows great configuration and cost flexibility.
- USB bus enables cubesats to interface with the millions of devices on the ground that have long since standardized to it.

Cons:

- Needs heavier radiation shielding, but EXA's NEMEA solves this need
- The payload development needs to strictly follow USB 2.0 developing guidelines

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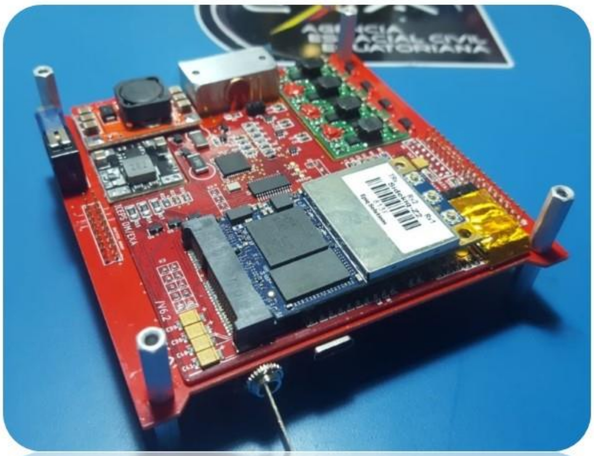
Thank you for your attention

info@exa.ec



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On-Board-Computer inclusive other components

New

EXA ICEPS Spacecraft System Core

Vendor: EXA
€16500 - €53000

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On-Board-Computer inclusive other components

New

EXA ICEPS Spacecraft System Core

Vendor: EXA
€16500 - €53000

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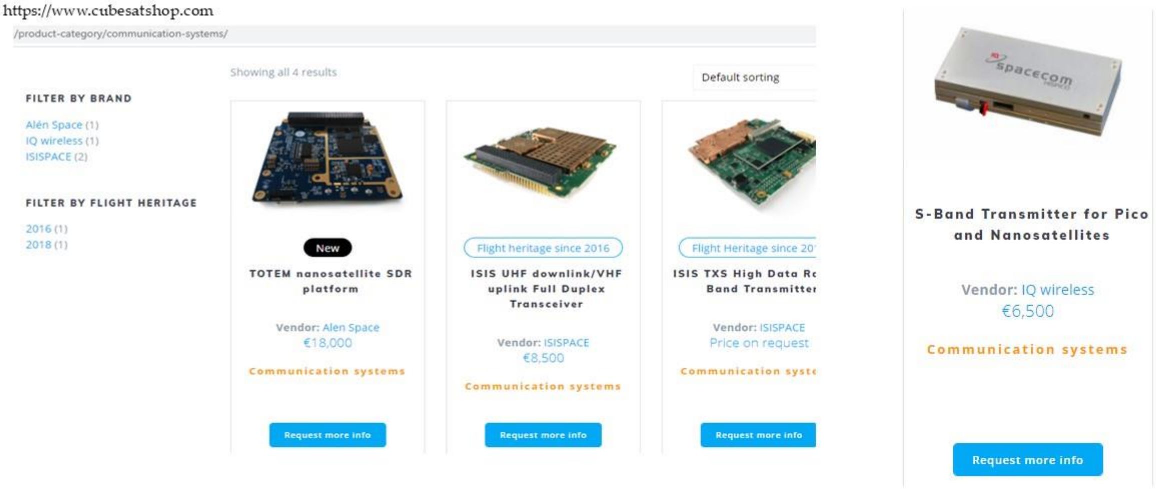
10.5 COM Elements: TT&C and payload COM

Communication Elements (TT&C, payload COM)



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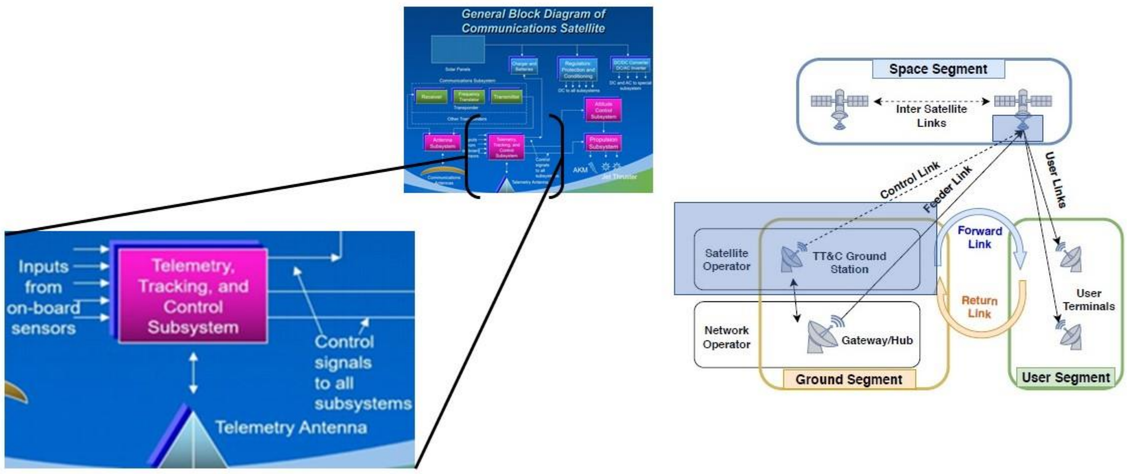
10.6 SAT - TT&C System

Telemetry, Tracking and Control (TT&C) Subystem



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10.6.1 TT&C GCS

TT&C Subystem – Ground Control System (GCS)

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TT&C Subystem – Ground Control System (GCS)

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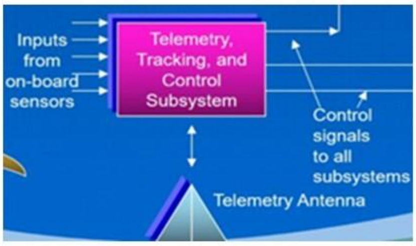
10.6.2 TT&C On-board part

TT&C Subystem – On-Board Part



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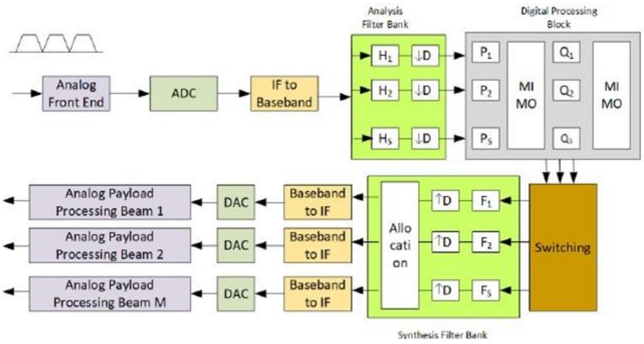
TT&C Subystem – On-Board Part



On-board processing architecture (from: A. I. Prez-Neira et. al., "Signal processing for high throughput satellites: Challenges in new interference-limited scenarios, IEEE Signal Processing Magazine, vol. 36, no. 4, pp. 112–131, 2019.)

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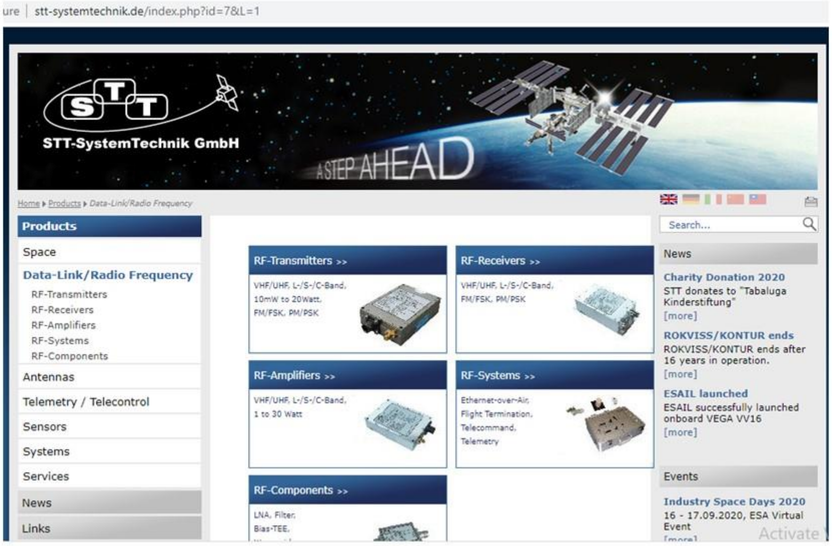

stt-systemtechnik.de

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TT&C Subystem – On-Board Part

TOTEM nanosatellite SDR platform

- SDR + UHF front end platform
  - 5 W @ 30 dBm in 437 MHz
- SDR tunnable from 70 MHz to 6 GHz
- UHF front end as a piggyback board
  - Unregulated voltage supply from EPS and 3V3
  - Multiple GPIOs and DACs available
- Embedded Linux
- Multiple interfaces: CAN, UART, Ethernet
- PC/104 standard
- Physical properties
  - Mass: 131 g (shieldings included)
  - Dimensions : 89.3 mm x 93.3 x 13.9 mm
  - Power consumption
  - ~ 5 W @ 30 dBm output power
  - < 2 W in RX mode
  - 1.36 W with front end OFF

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TT&C Subystem – On-Board Part

ISIS VHF uplink/UHF downlink transceiver

The ISIS VHF uplink/UHF downlink transceiver is a full duplex communication system for CubeSat **TT&C** applications. The radio can operate in commercial and amateur bands of the VHF/UHF frequency spectrum. It is low power, low mass, and highly configurable, offering the flexibility of changing data rates and frequencies in flight. This radio is tailored for CubeSat missions and cross-compatible with other subsystems such as onboard computers and antenna systems. Flight proven since 2016.
Availability: 8 – 12 weeks
Vendor: ISISPACE

TT&C Subystem – On-Board Part

ISIS VHF uplink/UHF downlink transceiver

FEATURES

- Full duplex communication
- Data rate re-configurable in-flight
- FM transponder mode available
- Safety watchdog
- Low power consumption
- Single PCB radio
- Single board Telemetry, Telecommand and Beacon capabilities

PRODUCT PROPERTIES

Dimensions:	90 x 96 x 15 mm
Mass:	75g
Supply voltage range:	6.5 – 20 V DC
Power consumption:	0.48W (receiver only) 4 W (transmitter on)
Operating temperature:	-20 to +60 deg C
RF interfaces:	MMCX (50 ohm)
Data interfaces:	I²C

TT&C Subystem – On-Board Part

ISIS VHF uplink/UHF downlink transceiver

PERFORMANCE

Transmitter	
Frequency range:	435 – 438 MHz (amateur-satellite UHF allocation). Other ranges are available on request
Transmit power: Modulation options:	27 dBm Binary Phase Shift Keying (BPSK) with G3RUH scrambling Gaussian Minimum Shift Keying (GMSK) with G3RUH scrambling
Data rate selectable:	1200, 2400, 4800 and 9600 bps
Data link layer protocol:	AX.25 or HDLC

Receiver	
Frequency range:	145.8 MHz – 146 MHz
Modulation:	Frequency Shift Keying (FSK) with G3RUH scrambling
Data rate:	1200, 9600 bps
Sensitivity:	-104 dBm Sensitivity for BER 1E-5
Data link layer protocol:	AX.25

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TT&C Subystem – On-Board Part

ISIS VHF uplink/UHF downlink transceiver

QUALIFICATION AND ACCEPTANCE TESTING

Test	QT	AT
Functional	✓	✓
Vibration	✓	-
Mechanical Shock	✓	-
Thermal Cycling	✓	✓
Thermal Vacuum	✓	-

*QT is performed on the design/qualification model
*AT is performed on the unit to be shipped

Configuration

- Receiver/Transmitter operating frequency
- Downlink data rate
- Custom beacon message (AX.25)
- CSKB connector type and location
- RF connector position and orientation
- I^2C watchdog implementation

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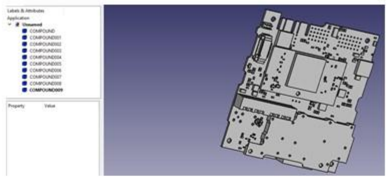
TT&C Subystem – On-Board Part

ISIS.TXS.DS.001, version 1.0   TXS S-band Transmitter Datasheet

ISIS_TXS_RevC.stp



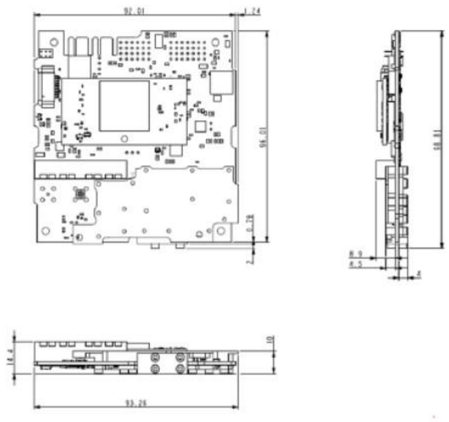


Figure 8 Mechanical outline[1]

Physical layout

Figure 6 Top view

Figure 7 Bottom view

TT&C Subystem – On-Board Part

TXS S-band Transmitter Datasheet

Absolute Maximum Ratings

Stresses at or above the absolute maximum ratings in Table 3 may cause permanent damage to the product. Operation at or beyond the maximum operating ratings may affect product reliability.

Table 3 Absolute Maximum Ratings

Parameter	Symbol	Min	Max	Unit
Supply voltage	V_{CC}	6	26	V
Operating temperature range	T_{amb}	-40	70	°C
Storage temperature range	$T_{storage}$	-40	85	°C
Voltage on I^2C pins	V_{I2C}	-0.5	7	V
I^2C pull up resistor value	R_{pu}	1.2		kOhm
LVDS input pin voltage	V_{IN_LVDS}	-0.3	3.6	V
LVDS output pin voltage	V_{OUT_LVDS}	-0.3	3.6	V
GPIO input voltage, any GPIO pin	V_{IN_GPIO}	-0.3	3.6	V

TT&C Subystem – On-Board Part

TXS S-band Transmitter Datasheet

Block diagram

TXS is based on a MicroSemi SmartFusion2 SoC. A separate supervisor MCU takes care of power switching, telemetry gathering and watchdog functionality. An LVDS interface is provided for high speed payload data, although (low speed) data to be transmitted can also be routed via the I_2C bus.

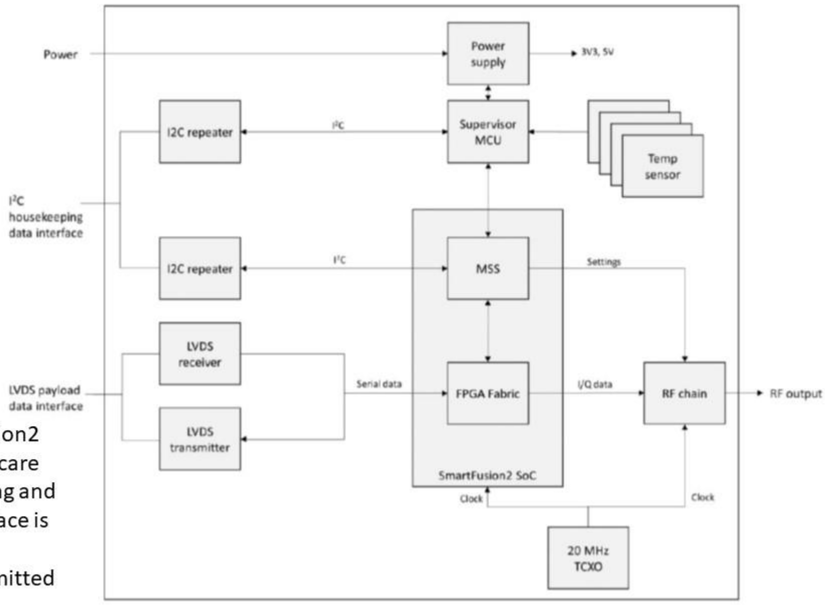


Figure 1 TXS high level block diagram

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TT&C Subystem – On-Board Part

TXS S-band Transmitter Datasheet

Typical link budget

Table 4 provides a typical link budget achieved with TXS to a small groundstation (1.9 m diameter), for a link with these parameters, 2.1 Mbit/s OQPSK can be supported from 5 degrees elevation. With higher groundstation G/T, larger usable datarates can be supported.

Table 4 Typical TXS link budget

Parameter	Value	Unit	Rationale
Frequency	2245.0	MHz	2200-2290 MHz SOS / EESS / SRS space-to-Earth allocation
Satellite transmitter power	3.0	dBW	2W / 33 dBm
Satellite TX losses	1.0	dB	Assumption
Satellite antenna gain	0.0	dBi	Typical patch antenna gain for 5 deg elevation and Nadir pointing satellite
Satellite EIRP	2.0	dBW	
Satellite pointing loss	0.5	dB	Assumption
Orbital altitude	600000.0	m	Typical LEO orbit
Elevation angle	5	deg	Minimum elevation for communication
Range	2329031.4	m	
Path loss	166.8	dB	
Atmospheric losses	0.5	dB	Source: RD3, 99% of the time, Madrid DSN
Ionospheric losses	0.1	dB	Approximate mean values for low earth station elevation angle
Polarization losses	0.0	dB	No polarization mismatch assumed
Earth station pointing loss	1.0	dB	Assumption
Earth station figure of merit	9.0	dB/K	Typical S-band station figure of merit (1.9 m diameter antenna)
Channel symbol rate	2500000.0	sym/s	2.5 Msym/sec
Code rate	0.430502	-	CCSDS RS (255, 223) + conv R = 1/2
Information bitrate	2152510	bit/s	5 Msym/sec OQPSK, RS (255, 223) + conv R = 1/2, interleaving depth = 1
Information bitrate	63.3	dBHz	in dBHz
Implementation loss	2.0	dB	Pessimistic assumption for a typical demodulator
Eb/N0	5.4	dB	
Required Eb/N0	2.4	dB	OQPSK, RS(255, 2223) + C(7, 1/2) for a BER 1E-5
Link margin	3.0	dB	

Note: in the above table, losses are denoted by a positive number.

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TT&C Subystem – On-Board Part

Antenna system

VHF/UHF Antenna

The ISIS deployable antenna system for 1U/3U CubeSats contains four tape spring antennas of up to 55 cm length. The deployment system relies on a thermal knife composed of one wire and two redundant heating elements per tape. RF phasing / BalUn circuitry ties the antennas together in a turnstile configuration.
Depending on the configuration, one or two radios in the CubeSat can connect to the antenna system by means of miniature RF connectors. The top face of the antenna system can accommodate a two solar cell solar panel and it can be customized for accommodating sensors or other systems to protrude to the exterior, e.g. camera apertures.
The antenna is compatible with any UHF and/or VHF radio system. It can be mounted on all ISIS CubeSat structures and Pumpkin rev C and rev D CubeSat structures. For custom made structures, which adhere to the CubeSat standard mechanical envelope, mounting should also be possible.
Availability: 8-12 weeks
Vendor: ISISPACE

TT&C Subystem – On-Board Part

Antenna system

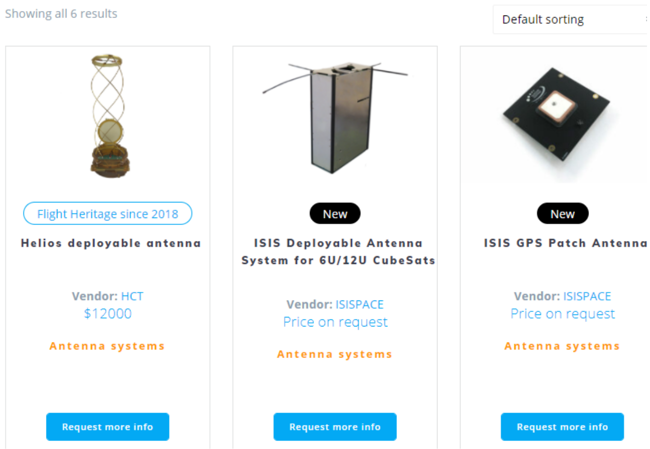
IEEE S band	
Frequency range	2 – 4 GHz
Wavelength range	15 – 7.5 cm
Related bands	•E / F bands (NATO) •UHF / SHF (ITU)

Frequency Allocations

Band	Uplink (GHz)	Downlink (GHz)	Bandwidth (MHz)
C	5.9 – 6.4	3.7 – 4.2	500
X	7.9 – 8.4	7.25 – 7.75	500
Ku	14 – 14.5	11.7 – 12.2	500
Ka	27 – 30	17 – 20	-----
	30 – 31	20 – 21	-----

10.6.2.1 Antenna system

Antenna System



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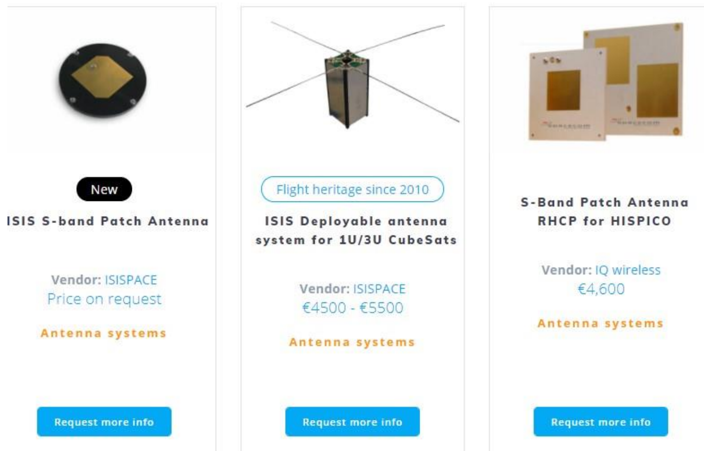

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€4500 - €5500

Antenna system ISIS Antenna

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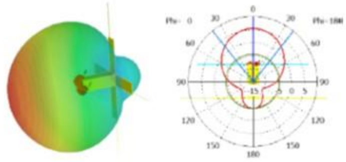
Antenna system ISIS Antenna

PERFORMANCE

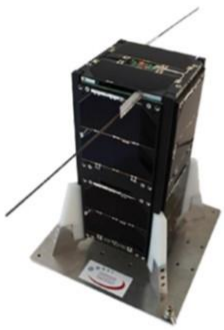
- Antenna main beam gain:
  - → UHF: 0 dBi
  - → VHF: 0 dBi
- Max RF Power: 2W
- Bandwidth:
  - → UHF: >50 Mhz (-10db bandwidth)
  - → VHF: >10 Mhz (-10db bandwidth)
- Antenna element deployment duration: <3s at 15°C



Radiation pattern simulation

PRODUCT PROPERTIES

- Mass: 77-85g (depends on configuration)
- Envelope stowed (l x w x h): 98x98x7mm³
- Antenna length
  - → UHF: 17cm average
  - → VHF: 55cm average
- 30mm diameter through-hole for pass-through of payload or other interfaces (not available for turnstile configuration)
- Power consumption
  - → Nominal: < 40 mW
  - → During deployment: < 2W
- Interfaces:
  - → Electrical: Miniature 9 pin OMNETICS connector
    - → Power: 3.3V or 5V
    - → Data: I2C
  - → RF input/output: MMCX and SSMCX, female 50 ohm
- Qualified operational temperature range: -20°C to +60°C



Antenna mounted on CubeSat

CONFIGURATIONS

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TT&C Subystem – On-Board Part

Antenna system
ISIS Antenna

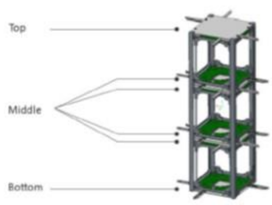
CONFIGURATIONS

- RF Antenna configurations
  - → Single/multiple monopoles (UHF and/or VHF)
  - → Single/dual dipoles (UHF and/or VHF)
  - → Combination of monopole and dipole
  - → UHF or VHF turnstile
- Supply voltage 3.3V or 5V
- RF Harness length and connector type and orientation (MMCX, MCX, SMA)
- Top lid accommodation (solar panel, through hole, mounting points, sensors etc.)
- Customization and simulation on request

DELIVERABLES

- Hardware: antenna, RF harness, refurbishment kit for flight preparation
- Documentation: user manual, test and build reports
- Services: fine tuning, functional and thermal testing

Antenna mounted on CubeSat

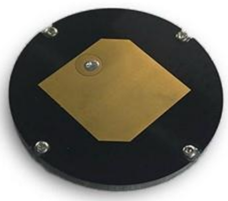


Antenna position configuration

TT&C Subystem – On-Board Part

Antenna system

ISIS S-band Patch Antenna



Description

The ISIS S-band patch antenna is a part of a new generation of antennas designed for S-band communications on nanosatellites and CubeSats. It is an off the shelf compact antenna designed to complement the ISIS S-band transmitter for telemetry and payload data transmissions. The antenna is mounted onto a Rogers PCB, ideal for high-frequency RF circuitry ensuring fewer losses than traditional FR-4 PCBS.

The ISIS S-band patch antenna is a compact, low mass solution suitable for the commercial S-band frequency range of 2200-2290 MHz. This passive antenna is suitable for any CubeSat platform.

ISIS S-band transmitter for telemetry and payload data transmissions

TT&C Subystem – On-Board Part

Antenna system

• Applications:
– CubeSat TT&C
– CubeSat RF Payloads
• Lefthand or Righthand Circular antenna polarization
• Dual Modular Redundant Release Mechanism
• Designed for combination with multiple Receiver/Transceivers
• Compatible with ISIS products and recent Pumpkin, ClydeSpace and GomSpace products
• Compliant to CubeSat standard

RF Impedance (deployed): 50 Ohms

• Max RF Power: 1 Watt
• Frequency Range: 400-3000 MHz
• Electrical Power: 8 VDC at 7 Amps for 1 minute to deploy
• Envelope Stowed (l x w x h): 100mm x 100mm x 35mm
• Antenna Axial Height (deployed): 330mm
• Supply Voltage: 8 VDC at 7 Amps for 1 minute to deploy
• Operational Temperature Range: -40°C to 85°C
• Antenna main beam gain: 3dBi+
• Deployment Duration: 60-90s
• Antenna Return Loss at resonance frequency: >10 dB
• Power Consumption:
– Nominal: 0

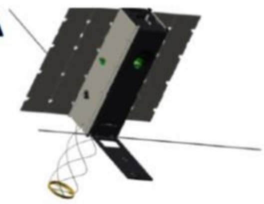
TT&C Subystem – On-Board Part

Antenna system

HCT· Helical Communication Technologies

HCT 400 or 437 MHz Heritage QHA

400 or 437MHz Heritage UHF QHA



634 Barnes Boulevard Suite #206, Rockledge, FL 32955
O: 321-208-8978
E: HelicalCommunicationTech@gmail.com

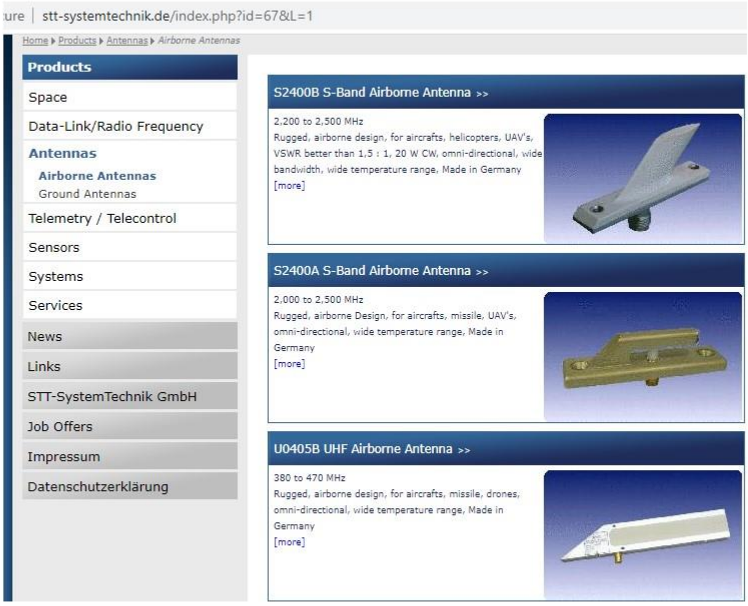
https://www.helicomtech.com/

About Us

Helical Communication Technologies was formed to serve the increasing need for specialized antennas for use with ground-based and space-based communication with satellites placed in low earth orbit and deep space.

TT&C Subsystem – On-Board Part

Antenna system



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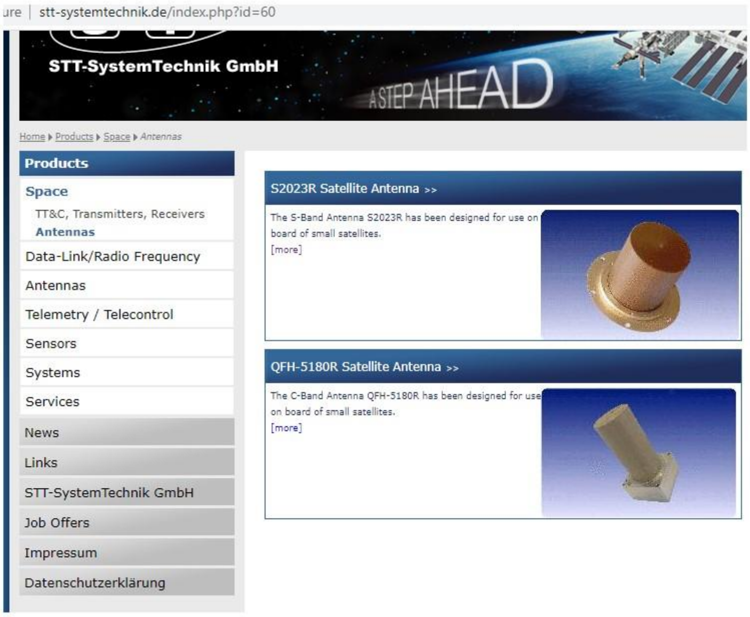
TT&C Subsystem – On-Board Part

Antenna system



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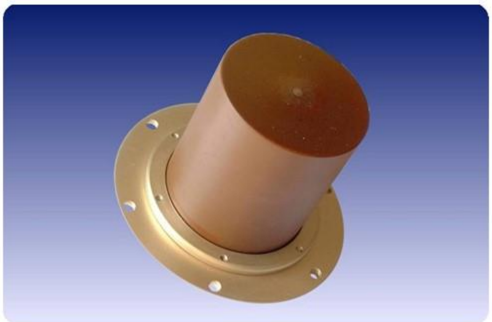
TT&C Subystem – On-Board Part

Antenna system



S2023R S-Band Satellite Antenna

The S-Band Antenna S2023R has been designed for use on board of small satellites. The pattern shape has been optimized particularly for low earth orbit (LEO) missions with NADIR orientation. The antenna is broadband and operates at both the standard S-Band frequencies for satellite missions, i.e. downlink at 2200 to 2290 MHz and uplink at 2025 to 2110 MHz.
The antenna design is compact, solid and very rugged.
To achieve spherical coverage the S2023R could be used in pairs with opposite placement at the satellite body.

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TT&C Subystem – On-Board Part

Antenna system

S2023R S-Band Satellite Antenna

frequencies for satellite missions, i.e. downlink at 2200 to 2290 MHz and uplink at 2025 to 2110 MHz.

The antenna design is compact, solid and very rugged.

To achieve spherical coverage the S2023R could be used in pairs with opposite placement at the satellite body.

Electrical Specifications

Frequency Range	2025 MHz...2110 MHz uplink 2200 MHz...2290 MHz downlink
Gain	3 dBic boresight, typ. > 0 dBic for $-45° < \Theta < +45°$, typ. > -6 dBic for $-90° < \Theta < +90°$, typ.
Coverage	Hemispherical
HP Bandwidth	140° typical
Polarization	Right circular (Left circular optional)
Power	40 dBm CW, max.
Impedance	50 ohms
VSWR	better than 1,5 : 1
Connector	SMA female

Environmental Specifications

Operating Temperature	-60°C...+120°C (extended range upon request)
Vibration	20...2,000 Hz; 25g rms random, 3-axis
Shock	100g (100 Hz), 3,500g (>1000 Hz)

Mechanical Specifications

Dimensions	Length approx. 70 mm w/o connector Reflector d = 100 mm Radome d = 60 mm
Mounting	6 holes each 4.2 mm
Weight	ca.140g
Radome	PEEK (beige) VESPEL (gold brown) optional
Reflector	AW6082 with finish Alodine1200 or SURtec650

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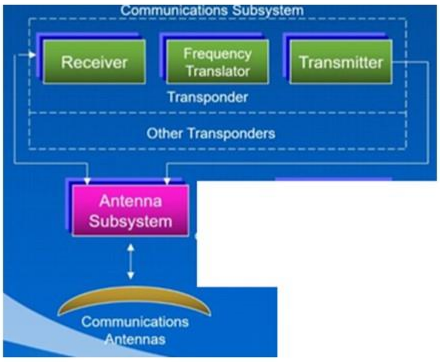
10.7 SAT - Payload Communications Subsystem

Payload Communications Subsystem

- Receiver
- Frequency Translator
- Transmitter



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COM Payload – On-Board Part (Downlink)

ISIS.TXS.DS.001, version 1.0 TXS S-band Transmitter Datasheet

Overview

The ISIS High Data-rate S-band Transmitter is a CubeSat compatible transmitter designed to meet the needs of high data-rate downlinks of up to 4.3 Mbps (usable information bit-rate at CCSDS TM Transfer Frame level). **The transmitter can be used for both TT&C or Payload Data downlinks**. The S-band transmitter is flexible, implementing CCSDS as data link layer protocol and allowing in-flight configuration of data-rate, modulation scheme, frequency, and RF output power.

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SDR (Software Defined Radio): HackRF Hardware Platform and GnuRadio Software Library - Introduction

Tutorials

First steps and analog modulation

This tutorial/guide is a good start into HackRF and Gnuradio, including installation instructions, theoretical basics, and simple examples for analog (de)modulation.

After installing and trying out the software HDSDR and SDRSharp, we made 3 tutorials out of this guide: Receiving, Transmitting, and Live Broadcasting FM Radio Signals.

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Figure 4: equipment: 2x HackRF One, smartphone as FM radio (receiver), laptop(not in picture), traditional radio(not in picture)

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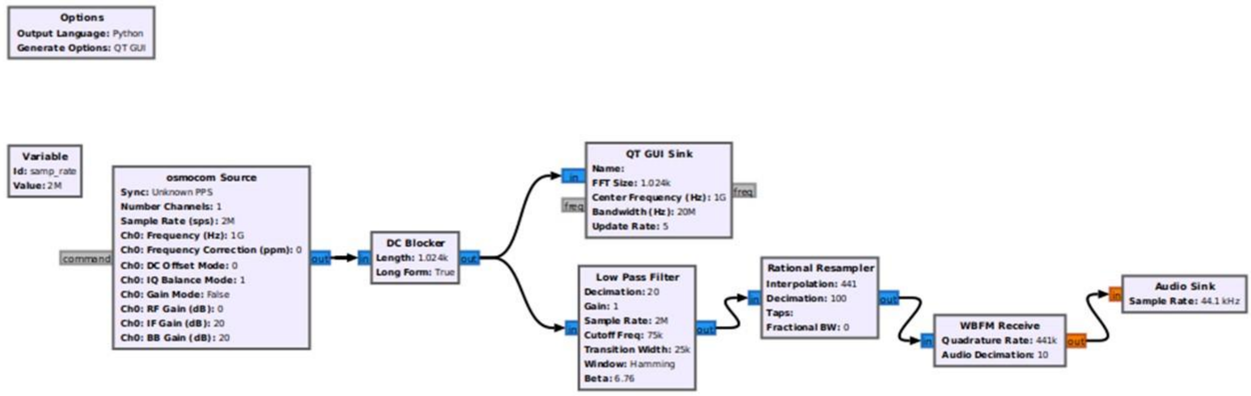

Figure 1: Gnuradio flowgraph – Analog Receiving

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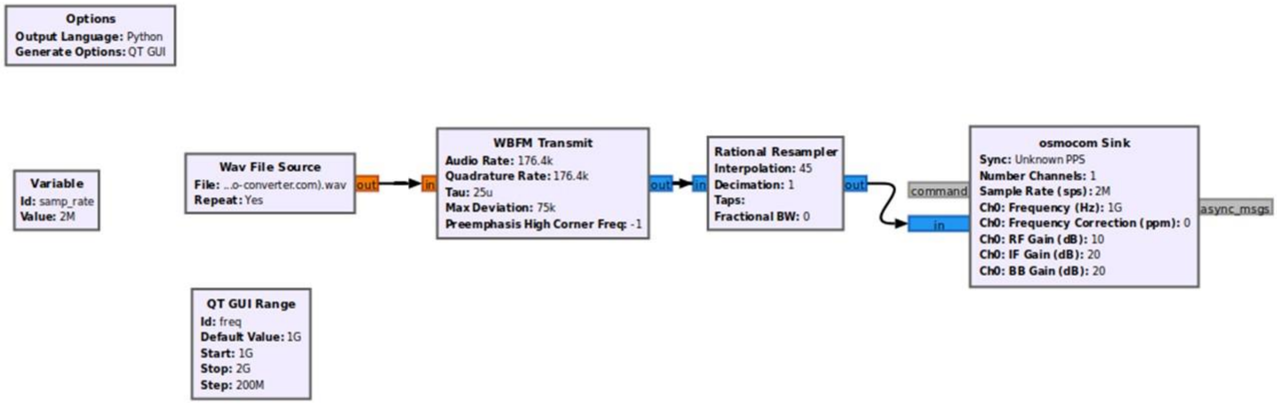

Figure 2: Gnuradio flowgraph – Analog Transmitting

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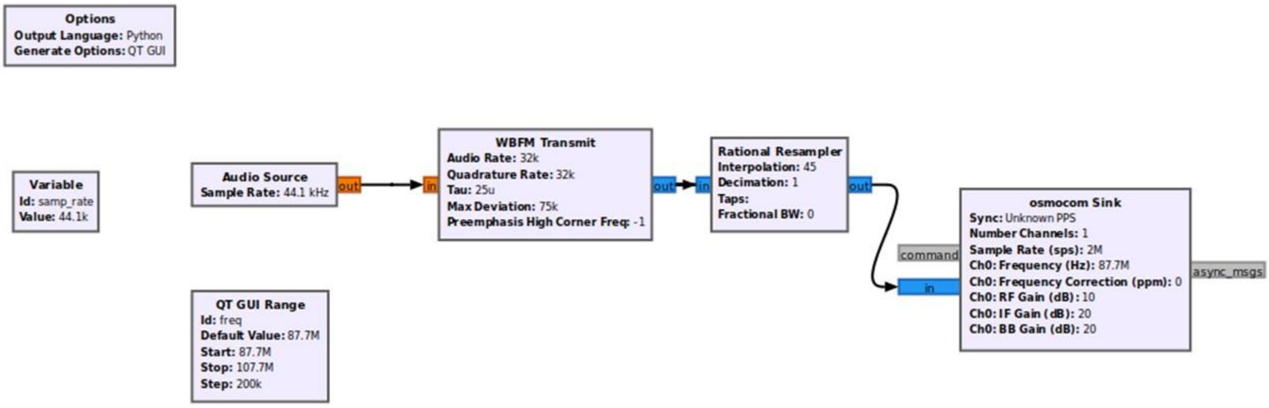

Figure 3: Gnuradio flowgraph - Live Broadcast

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Technical info

GNU Radio Companion: 3.8.1.0 (Python 3.8.5)

OS: Ubuntu 20.04.1 LTS as Virtual machine on Windows 10 Host (using VirtualBox)

HackRF One Firmware version: 2015.07.2 (API:1.00)

2. HackRF One Firmware Version: 2018.01.1 (API:1.02)

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Digital modulation

Here is our current stand. In addition to other well-known digital (de)modulations, there is the PSK (de)modulation, we are currently trying the following tutorial:

https://wiki.gnuradio.org/index.php/Guided_Tutorial_PSK_Demodulation

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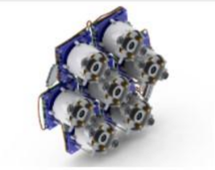
10.8 Electrical Propulsion Unit

Propulsion Unit



Cluster of IFM Nano Thruster for Smallsats

Vendor: ENPULSION
€50000 - €210000

Propulsion & pressurisation

Flight Heritage since 2018

IFM Nano Thruster for CubeSats

Vendor: ENPULSION
€38,400

Propulsion & pressurisation

Nanosatellite Micropropulsion System

Vendor: MicroSpace
€81000 - €129000

Propulsion & pressurisation

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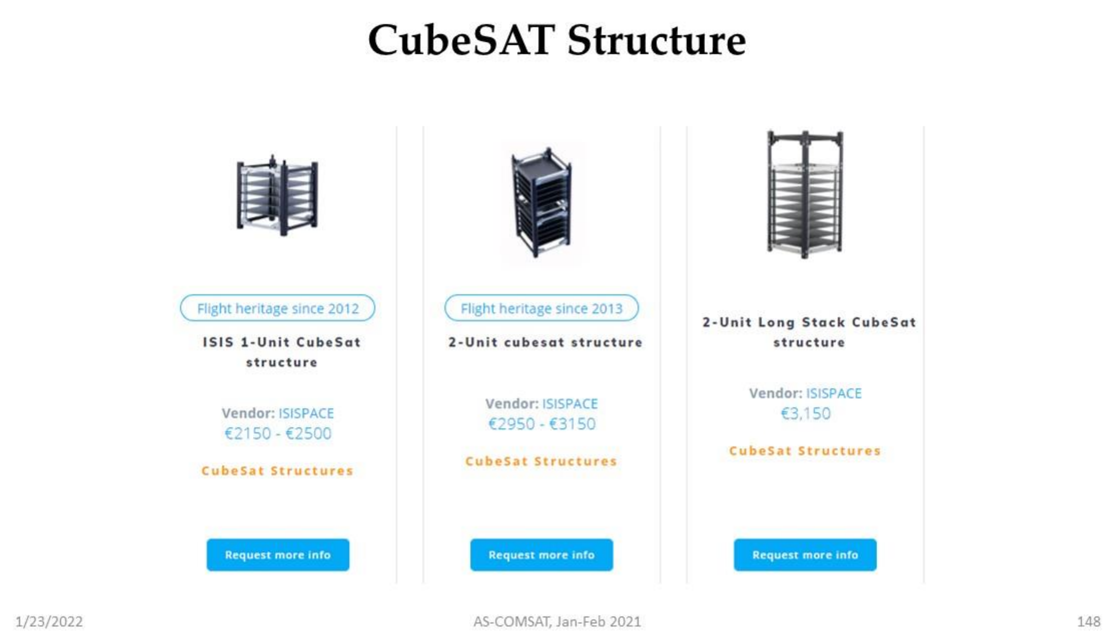
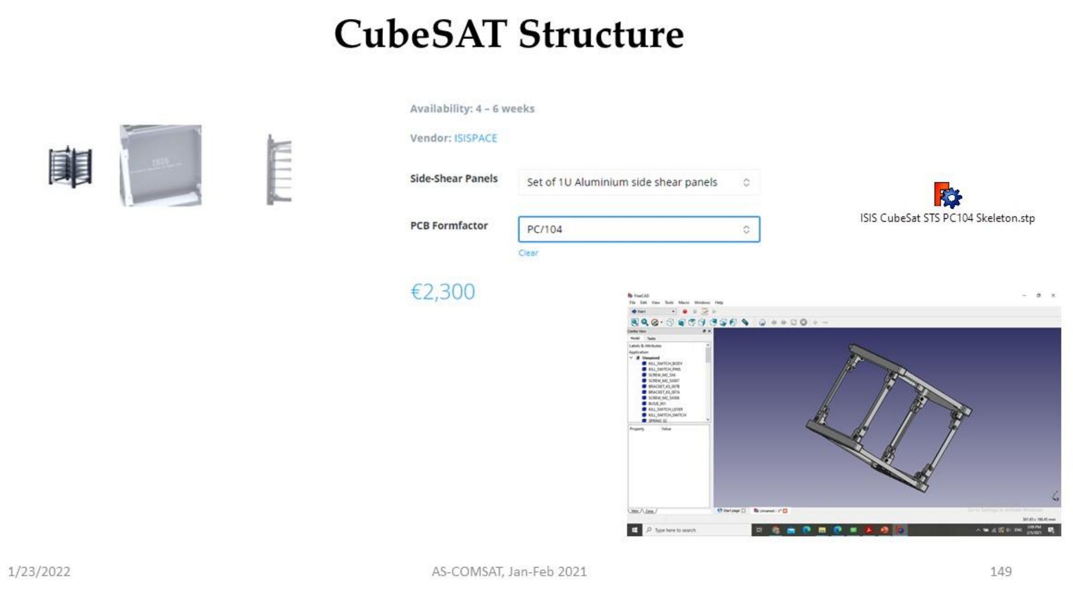
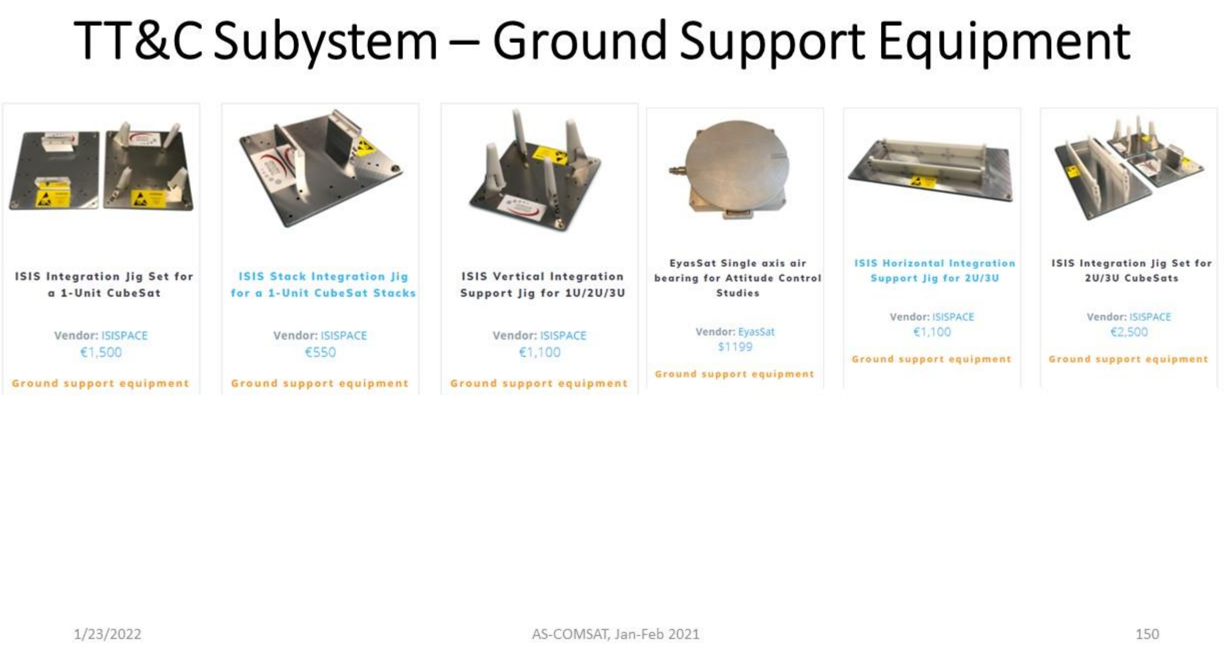
10.9 CubeSAT Structure






TT&C Subystem – Ground Support Equipment
ISIS Integration Jig Set for a 1-Unit CubeSat
Vendor: ISISPACE
€1,500
Ground support equipment
ISIS Stack Integration Jig for a 1-Unit CubeSat Stacks
Vendor: ISISPACE
€550
Ground support equipment
ISIS Vertical Integration Support Jig for 1U/2U/3U
Vendor: ISISPACE
€1,100
Ground support equipment
EyasSat Single axis air bearing for Attitude Control Studies
Vendor: EyasSat
$1199
Ground support equipment
ISIS Horizontal Integration Support Jig for 2U/3U
Vendor: ISISPACE
€1,100
Ground support equipment
ISIS Integration Jig Set for 2U/3U CubeSats
Vendor: ISISPACE
€2,500
Ground support equipment
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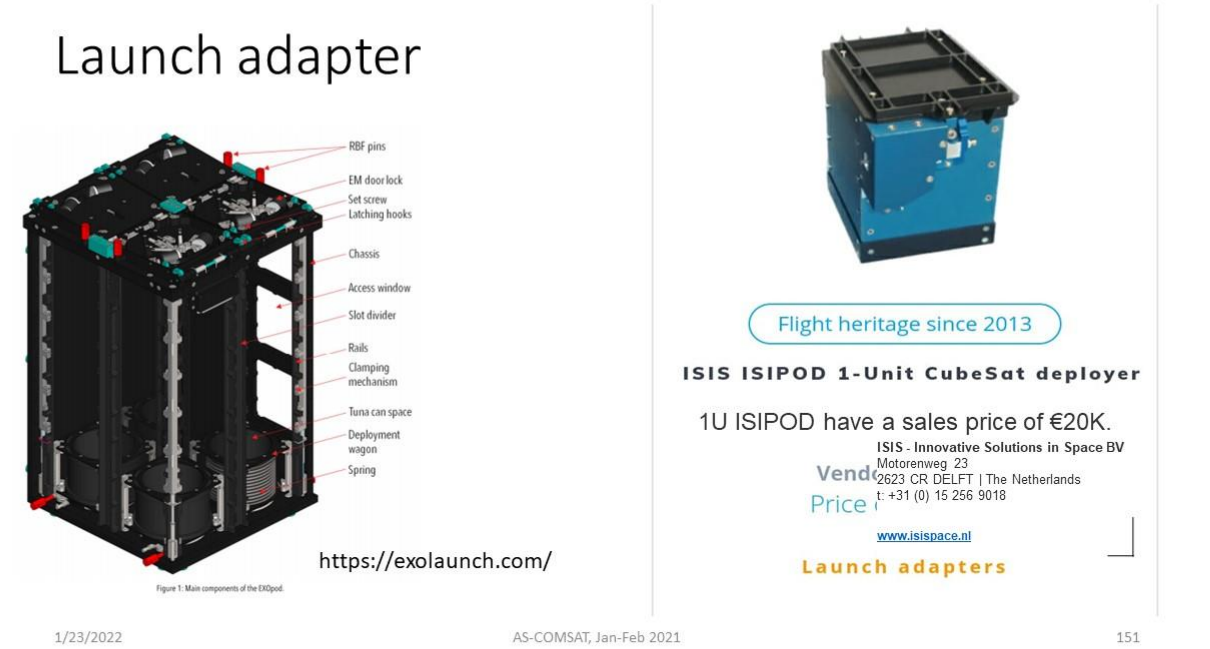
Launch adapter
RBF pins
EM door lock
Set screw
Latching hooks
Chassis
Access window
Slot divider
Rails
Clamping mechanism
Tuna can space
Deployment wagon
Spring
Figure 1: Main components of the EXOpod.
https://exolaunch.com/
Flight heritage since 2013
ISIS ISIPOD 1-Unit CubeSat deployer
1U ISIPOD have a sales price of €20K.
ISIS - Innovative Solutions in Space BV
Motorenweg 23
2623 CR DELFT | The Netherlands
t: +31 (0) 15 256 9018
www.isispace.nl
Launch adapters
1/23/2022
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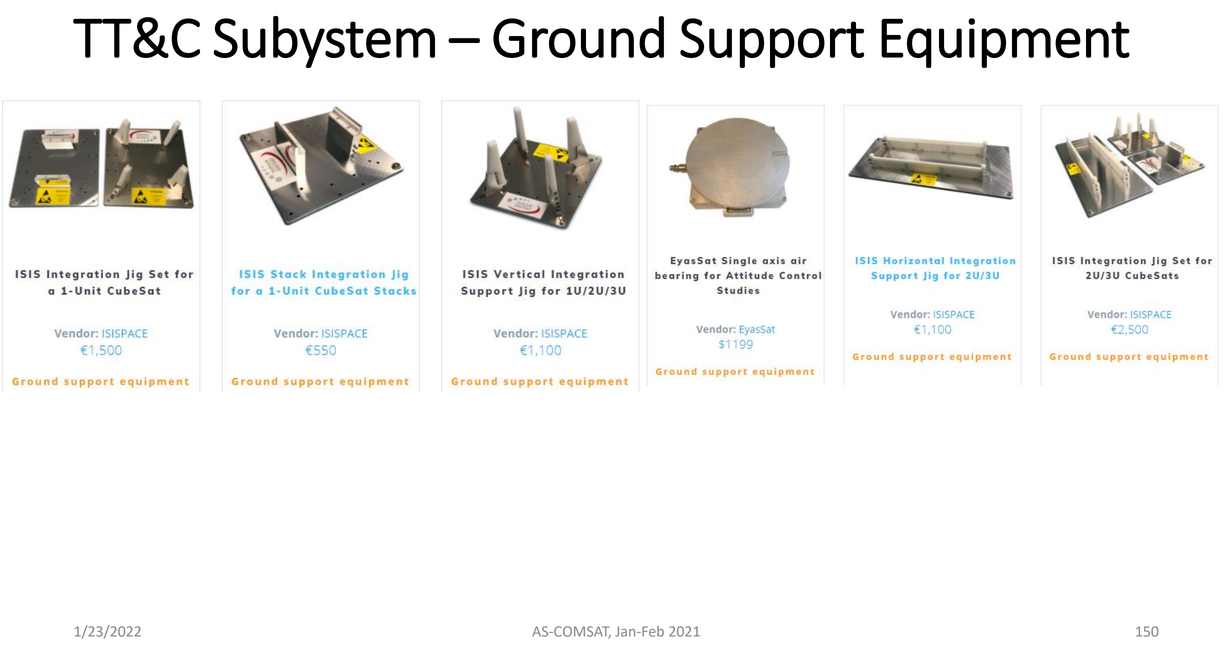
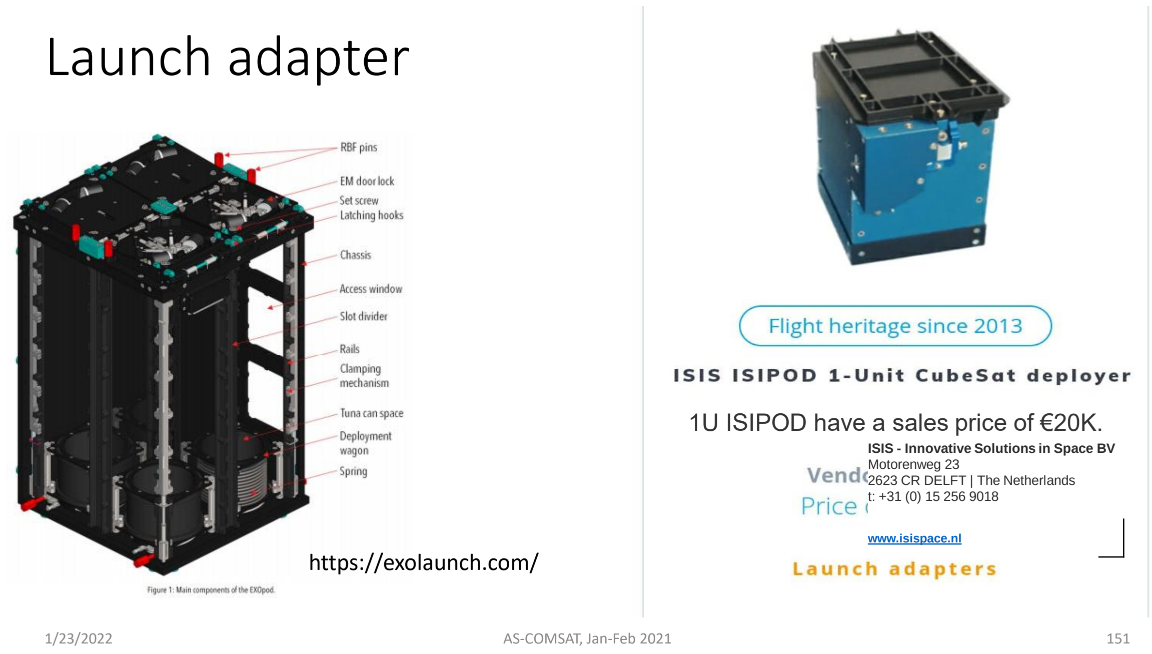
10.10 Ground Support Equipment

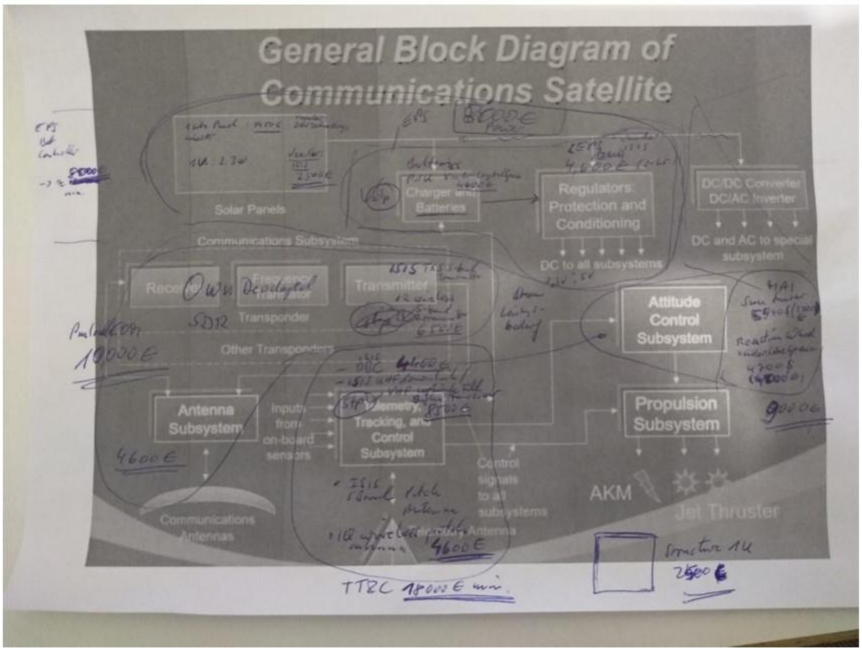


10.11 Launch adapter (SAT deployment)



10.12 Minimal System

Minimal System for Demonstration



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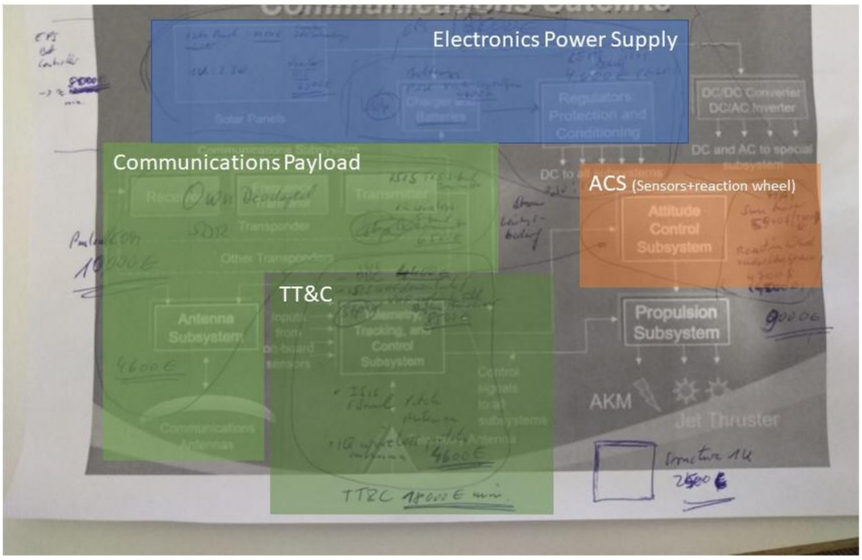
Minimal System for Demonstration



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Minimal System for Demonstration

The parts for a minimal communication 1U cubesat (without camera, only communication payload) will cost inscha Allah about 48,000 EUR (See above sheet). The launch also about 40,000 EUR.

That means we need about 90,000 EUR for a demonstration satellite system.

The communication payload costs about 10,000 EUR from cubesatshop.With the master thesis proposal from Salih hoca this will be reduced to the cost of an S-band patch antenna (about 4600 EUR)

When we have this demonstration system working, then we will find inscha Allah investors for larger systems.

Next step:

Verifying power requirements for electronic parts. (Is the 1U Power Solar Panels + Batteries System enough?)

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Minimal System for Demonstration
Next working packages

Scientific:

- ...

Technical:

- Verifying power requirements for electronic parts. (Is the 1U Power Solar Panels + Batteries System enough?)
- ...

Administrative:

- Business Plans (ROI for municipalities, ...)

TODO: Specifying working packages

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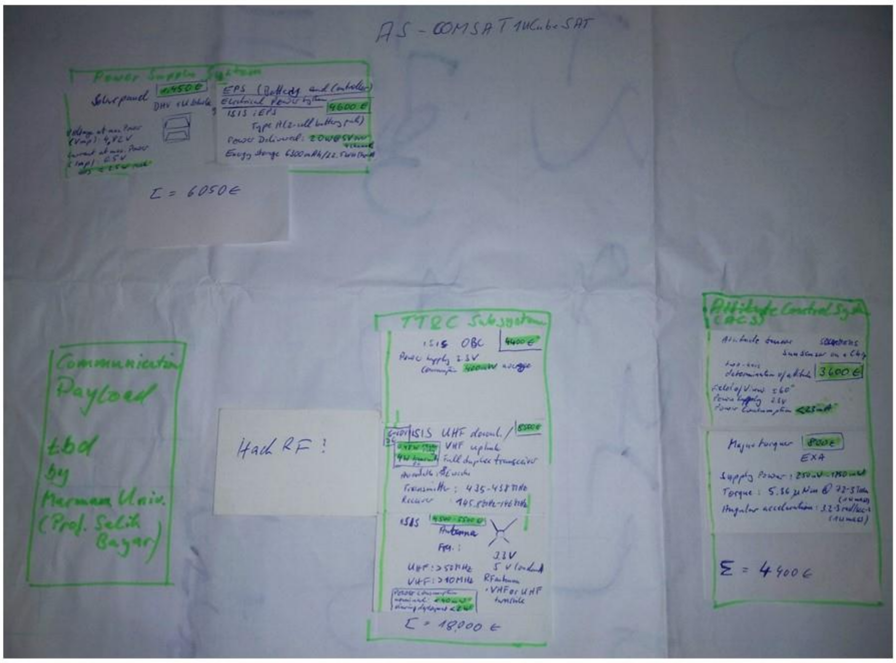
Minimal System for Demonstration



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11 References

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