Title: Radio Telescope Nano-satellites

Primary POC: Hamed Kourouma
POC email: hamed.kourouma@gmail.com

Need

The Search for Extra Terrestrial Intelligence was initiated by the SETI Institute to conduct research that could provide evidence of other life forms in the universe through the acquisition, processing, and analysis of interstellar signals. This mission suggests another method for interstellar signal acquisition to assist in the search for extra terrestrial intelligence, only it is envisioned to operate at low earth orbit (LEO) with an objective to obtain more diversified data regarding the plausible evidence of other life forms in the universe.

Mission Objectives

1- To operate a constellation of 22 LEO radio telescope nano-satellites
2- Utilize ground station radio telescopes as references and as simultaneous data acquisition system for interstellar signal acquisition.
3- Each nano-satellite is to acquire data samples 24 times per orbit for a duration of 12 seconds for each sample.
4- Each nano-satellite will acquire and store raw data on board then beam it to the ground station at the completion of an orbit or about 16 times a day.
5- Acquire, store, process, and analyze interstellar data sent from nano-satellites to the ground station using digital signal processing techniques.

Concept of Operations

1- Ground Segment

There is a single location planned for the ground station. It is intended to receive data from each of the nano-satellites, and transmit monitoring and telemetry control data to the nano-satellites. A parabolic 2.4m dish antenna is used to receive nano-satellite data. The parabolic antenna is to be used in a dual mode feed for transmitting control data and for receiving radio telescope data, therefore the requirement for an orthomode transducer (OMT) allowing for the duplexing of uplink and downlink data. The antenna peripherals would include: On A Downlink Path: an antenna drive and antenna position control unit, a Feed horn, an OMT component to feedhorn, a Low Noise Amplifier (LNA) for uplink data, a Low Noise Block (LNB) for downlink data, a down converter to IF, a diplexer to separate command lines and data lines on a downlink path, a demodulator capable to support BPSK and QPSK modulation modes, and a PC Board Card for DSP processing of received data.

On an Uplink Path: a PC initiated control command for given nano-satellite, a physical interface to transmitter card, an S-Band ground transmitter with modulation, and an LNA routing for uplink transmission.

2- Radio Telescope Nano-satellite

Due to the limitations in available ground stations for the project, data acquired by the radio telescope nano-satellites is saved onboard for the duration of an orbit prior to be sent to the ground station. Each radio telescope is programmed to acquire data 24 times in an orbit. Each acquisition is stored onboard the nano-satellite. Once all 24 samples are stored the nano-satellite initiates a time-dependent routine allowing the device to be in view of the ground station prior to sending data. At the appropriate moment, the nano-satellite proceeds to the transfer of acquired data via the downlink transmitter to the ground station. This is expected to occur at the end of each orbital iteration. Therefore the constellation is able to provide up to 384 data samples per radio telescope nano-satellite on a daily basis.

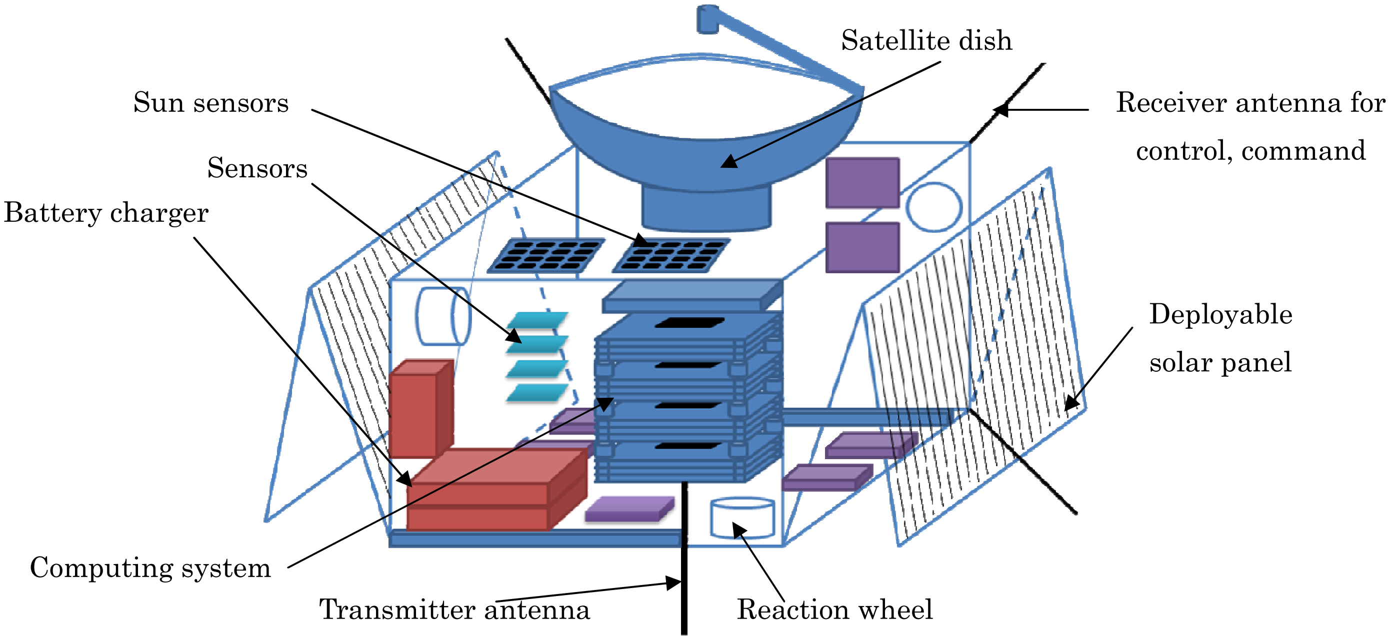


Figure 1- Illustration the Radio Telescope Nano-satellite

Here is a description of the subsystems to be included in the radio telescope nano-satellites:

Power System

Power is provided by high efficiency solar cells. The cells cover an estimated surface of 0.96 sq meters including the deployable panels. The deployable panels allow to double the amount of power available for the nano-satellite once fully deployed using stepper motors and linear actuators. A high power battery (150 Watt hour) is also included in the power subsystem and connected to the solar panels for charging. Below a certain threshold of sunlight, the battery can restitute power to the nano-satellite system efficiently and give the system about 120 minutes of autonomous activity without the panels.

Communications System

It includes an interstellar receiver having: a custom 30cm satellite dish, a Feedhorn and LNB, a down-converter and demodulator board, an analog-to-digital conversion card (ADC), and a small board computer (embedded computer) interface.

All modules for frequency processing from the radio telescope antenna should be done on a single board or dual board of PC104 format size. The Uplink receiver is containing: S-Band antennas on the side of the nano-satellite, an S-Band telemetry & command receiver. The S-Band telemetry and command receiver is connected to the embedded controller unit, and offers position management and control of the reaction wheels onboard. A Downlink

Transmitter containing: an antenna at the bottom of the nano-satellite, an embedded digital-to-analog card (DAC), an S-Band transmitter, an S-Band Amplifier. The amplifier receives packetized data converted into analog from the embedded DAC card which connects to the S-Band amplifier for transmission.

Control Subsystem

This is the small embedded computer board and the main control unit of the system. The board is responsible for handling monitoring and controlling data from the satellite position, it keeps track of the flow of data received from the satellite dish for temporary storage and transmission to the ground station. The embedded computer is designed to facilitate multi functional computing capacity in a small format as required by the nano-satellite, yet provides the various data handling, computing, and storage capacity needed for ground controlled operation and stand-alone operation of the nano-satellites.

Guidance, Positioning, and Attitude Control Subsystem

This subsystem contains the reaction wheels for attitude control and for ground station controlled positioning of the radio telescope satellite dishes. The set of wheels provide a 3D axis control from the embedded computer in orbit. The unit major elements include: three reaction wheels, a GPS receiver, an inertial measurement unit (IMU), and an interface to the embedded computer.

The Sensor Subsystem

The sensor unit is especially important in the design of the radio telescope nano-satellite. The sensor unit communicates acquired sensing data to the embedded board which allows the command and control of actuators as needed. Here are some of the sensors to include in this subsystem: magnetometer, sun sensor, IMU units, and thermal sensors. These essentially provide critical onboard information to monitor and control the behavior of each nano-satellite. Based on the data received from sensors, the onboard computer is able to send instructions to actuators for attitude modifications or corrections as needed.

Thermal & Structural Subsystem

This unit provides protection for the onboard electronics from the surrounding environment and monitoring from the thermal sensors. Because of the 30cm diameter satellite dish, the system requires a custom launcher to allow for the safe deployment of the integrated unit. The base of the satellite dish is designed circular to insure the integrity of the structure as if it were a single structure.

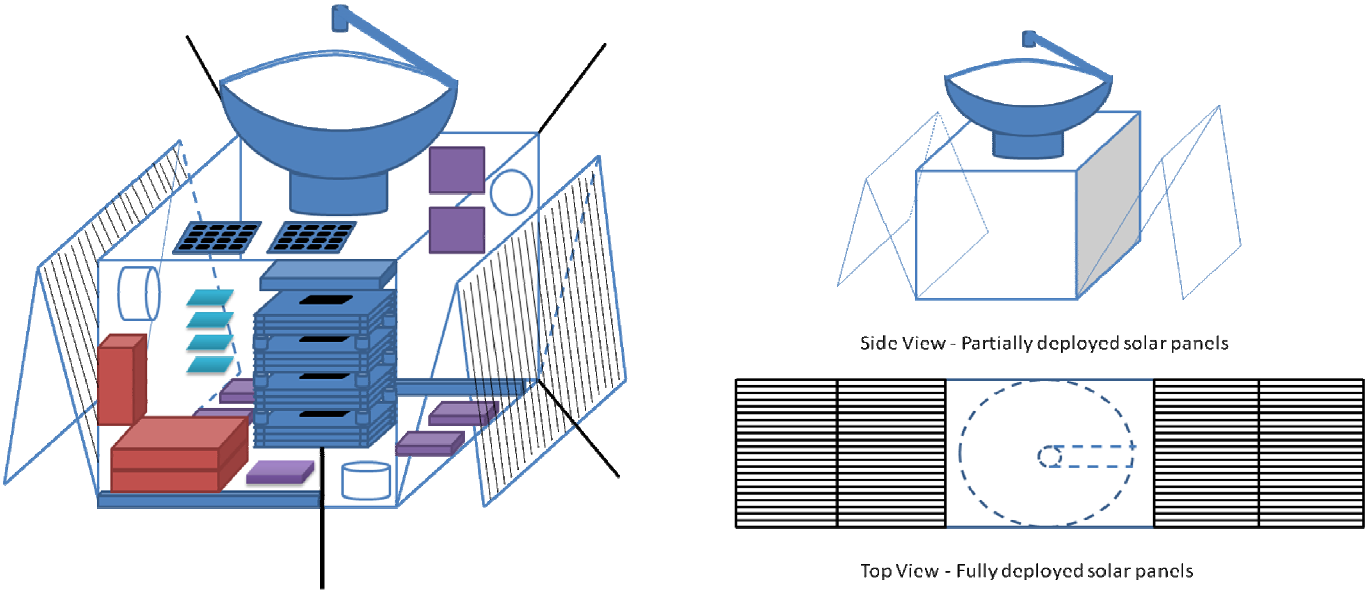
Launcher

Due to the unusual shape of the overall system, launch and deployment mechanisms are especially delicate procedures. Air-launchers to orbit are the primary consideration for this mission for launch cost considerations, and for having dedicated launching procedures. A majority of orbital air-launchers have payload capabilities for satellites up to 100kg. Pre-launch vibration tests will be applied to the structure of the nano-satellites to insure structural integrity can be conserved during launch processes. A custom made deployment mechanism is needed for the radio telescope nano-satellites. The built in parabolic antenna to the satellite's structure enforces such precaution.

Key Performance Parameters

1. Successful vibration tests for structural integrity
2. Proper formation of constellation – equidistant arc of 1.873 x 10 exp 6 m apart
3. Confirm location/positioning of each nano-satellite based on GPS data and IMU unit
4. Establish reference data by pointing telescopes at a same reference point in the cosmos
5. Confirm the ability to capture data from any visible point source in the sky

Space Segment Description



Side View - Partially deployed solar panels

Top View - Fully deployed solar panels

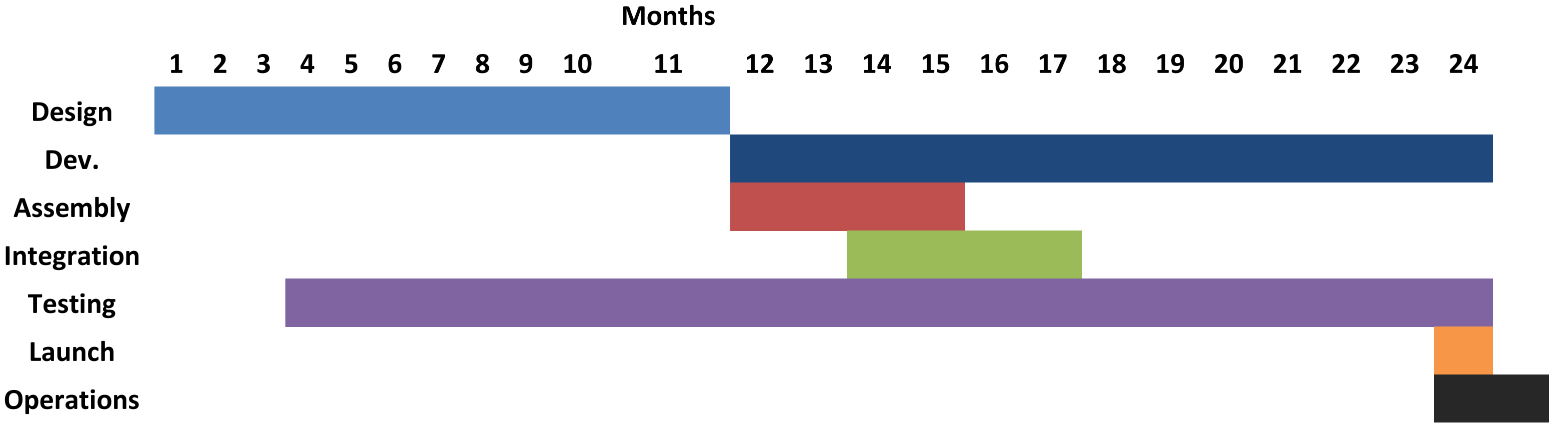
Figure 2- Illustration of deployable solar panels.

Satellite Detailed Specifications
Estimated Mass: 14kg
Volume: 48,000 cubic centimeter
Dimensions : 40cm x 40cm x 30cm
Power Consumption: 65W (Peak)
Average Orbit: 160km
Communications: S-Band (2-4Ghz)

Orbital Parameters	
Semi-major axis	6548km
Average altitude	160km
Inclination angle	137°
Estimated Eccentricity	0

Orbit/Constellation Description

The nano-satellites are designed to orbit the Earth at 159km. The chosen inclination allows the ground station to be located at the Allen Telescope Array or at a comparable geographical location (latitude of about 40°). The objective is to provide a useful and operating reference point for data acquisition and processing for interstellar acquisition at LEO. The orbital speed of the satellites is estimated at 7,794m/s with an orbital period of 89 min. The constellation will be made up of 22 nano-satellites in a singular orbital plane. All 22 telescopes will share the orbital plane in an equidistant manner. The constellation can otherwise be launched in a cluster formation giving the acquisition potential of an equivalent multi-meter radio telescope at LEO, similar to the Allen Telescope Array only at LEO. Imagine the type of results we could obtain from a 150m diameter cluster of nano-satellites. That would be provide the equivalent data acquisition potential of a 150m radio telescope in a position of the sky that allows for much better availability of signals from outer space. The challenge resides in launching the cluster of nano-satellites at LEO without post launch cluster formation which would demand additional weight, space, control, and propulsion on the nano-satellites. For the purpose of this mission, we will ignore the cluster formation option.



Implementation Plan

Project Risks

1- Maintain structural integrity through the launch
2- Noisy data in communications transfer
3- Small meteorite and space debris damage
4- Target point source alignment issues.

Estimated Budget

Item	Cost for single nano-satellite	Cost for constellation
Design	-	$ 480,000.00
Development	-	$ 480,000.00
Assembly	$ 60,000.0	$ 1,320,000.00
Integration	$ 25,000.0	$ 550,000.00
Testing	-	$ 500,000.00
Launch	-	-
Operations	-	$ 460,000.00
Disposal		
Total (excluding launch)	$ 85,000.0	$ 3,790,000.00

References

The Halca Mission, designed and managed by the Japan Aerospace Exploration Agency, http://www.isas.jaxa.jp/e/enterp/missions/halca/index.shtml#relatedLink, 1997-2005.

Allen Telescope Array, Search for Extra Terrestrial Intelligence Institute, http://www.seti.org/ata