Name of the hosted payload: BeliefSat-0

A. Detailed description of Payload

a) Objective & Introduction

In the rapidly advancing field of space technology, ease of access has frequently posed a challenge, placing restrictions on educational and commercial ventures with limited funding. The proposed project, titled "BeliefSat-0," represents an inspired effort that aims to ignite student curiosity and engagement in the domains of radio-frequency communication and space technology. This project is set to serve as a driving force for STEM education, paving the way for fresh perspectives and involvement.

BeliefSat-0 is developed by students of K.J. Somaiya Institute of Technology to widen the reach of Amateur Radio-operators around the globe. The payload is a part of tribute to 100 years of Amateur Radio in India and meant to be in service to the Amateur radio community worldwide. The payload will perform UHF to VHF FM Voice Repeating and APRS Digipeating. It will have the following amateur radio payloads onboard:

1. Amateur Band UHF to VHF FM voice repeater with 2.5 KHz max bandwidth and 12.5 KHz channel spacing. 67.0 Hz CTCSS tone for uplink.
2. VHF APRS Digipeater with 71.9 Hz CTCSS tone on the uplink.

The ongoing project is in an advanced stage of development by the dedicated student team of our Institute's Student Satellite Program “New Leap Initiative”, led by the expertise of Principal Investigator Dr. Umesh Shinde. At present, significant progress has been made, with the engineering model fully developed and the project now entering the rigorous testing phase. The consistent support from the Institute, serving as the primary funding entity, has played a pivotal role in ensuring the project's continuous advancement, with allocated R&D funds providing vital resources as needed.The team also has got support from the Nanoscience centre of the University of Mumbai for use of cleanrooms, vacuum chambers.

The Principal Investigator has prior experience of creating a Conceptual design of the mission to Jupiter's moon during **"Touch the Jovian Moon: Lander Mission Design Contest" organised by LPSC-ISRO** in which they have been winners. The team also has worked on the development of **Radiosondes** for an Indigenous **Upper-Air Sounding System** being developed by K.J.S.I.T. in collaboration with **DataByte Services and Systems** under Make in India initiative. The principal investigator (VU3CDI) is a licensed Amateur Radio Operator. Additionally, the CROWN committee at its core, champions Amateur Radio by sharing essential knowledge and skills. Educational classes equip enthusiasts, including active students, for success in this field. Fostering unity and collaboration among members, especially students, leads to a vibrant exchange of insights and support. This collective effort drives the growth and innovation of the Amateur Radio community. Team has, in the past been successful in developing antennas and software setup for tracking NOAA, METEOR and ISS- ARISS-SSTV downlinks.

b) Payload Objectives :

1. Broad Objective:

The proposed project aims to develop and demonstrate the technology utilizing nano-satellite technology to make space-tech more accessible to educational and low budget commercial missions, by utilizing inexpensive, off the shelf technologies and easily available materials.

2. Technical Objective:

i. To design the telemetry downlink in such a way that students of different institutes could use inexpensive software-defined radios to receive it with minimal setup, thus giving fuel to curiosity and liking towards STEM education.

ii. To give the ability to the global amateur radio community to use the on-board UHF to VHF FM Voice Repeating and APRS Digipeating for QSOs using inexpensive handy radio setups. (In this case, Baofeng UV-5R being one of the cheapest and most popular handy radios among beginner amateur community, was targeted). This objective has a social and educational objective of getting more students and the general public involved in amateur radio hobby, by giving them an inexpensive access to space-based communication.

iii. To design FSK repeater capabilities in such a way that those could be accessible by off-the-shelf FSK modules available for general IoT projects as well as SDRs like RTL-SDR.

c) Payload specifications

The specifications of the proposed project have been shown in Table below.

1. Specifications of the Payload:

Maximum Estimate Mass of the payload	500 g
Payload Dimensions (Including Antenna)	Approx. 150x118x512 mm ^{3}
Electrical Interface	On Payload: M24308/23-25F D-Sub Mil Spec Connectors R/A RCP ASSY 9 POS SER 109 From Platform: The expected connection is a male DB9 D-sub connector (9 Pin) with locking screws on the platform, like a VGA cable
Power requirement from PS4-OP	28V(raw) for entire duration
Antenna	Nagoya NL-770S VHF/UHF High Gain Mobile Antenna
Participation in integration	Principal Investigator with 2 students will participate.

Post Launch requirements	Tracking and TLE of BeliefSat-0
Command and control station location	KJSIT
Call-sign of the station operator	VU3CDI

Table 1: Specifications of Proposed Payload

2. Payload Description:

BeliefSat-0 is developed by students of K.J. Somaiya Institute of Technology to widen the reach of Amateur Radio-operators around the globe. The payload is a part of tribute to 100 years of Amateur Radio in India and meant to be in service to the Amateur radio community worldwide. The payload will perform UHF to VHF FM Voice Repeating and APRS Digipeating.

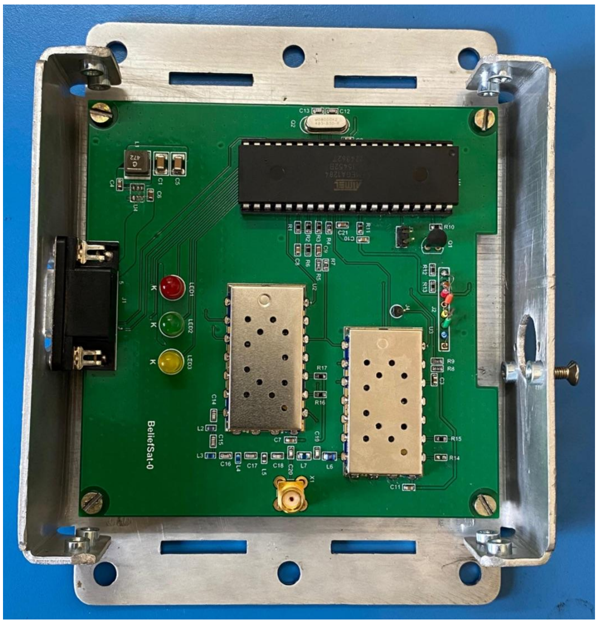


Fig 2: The engineering model of BeliefSat-0

i. <u>Antenna:</u>

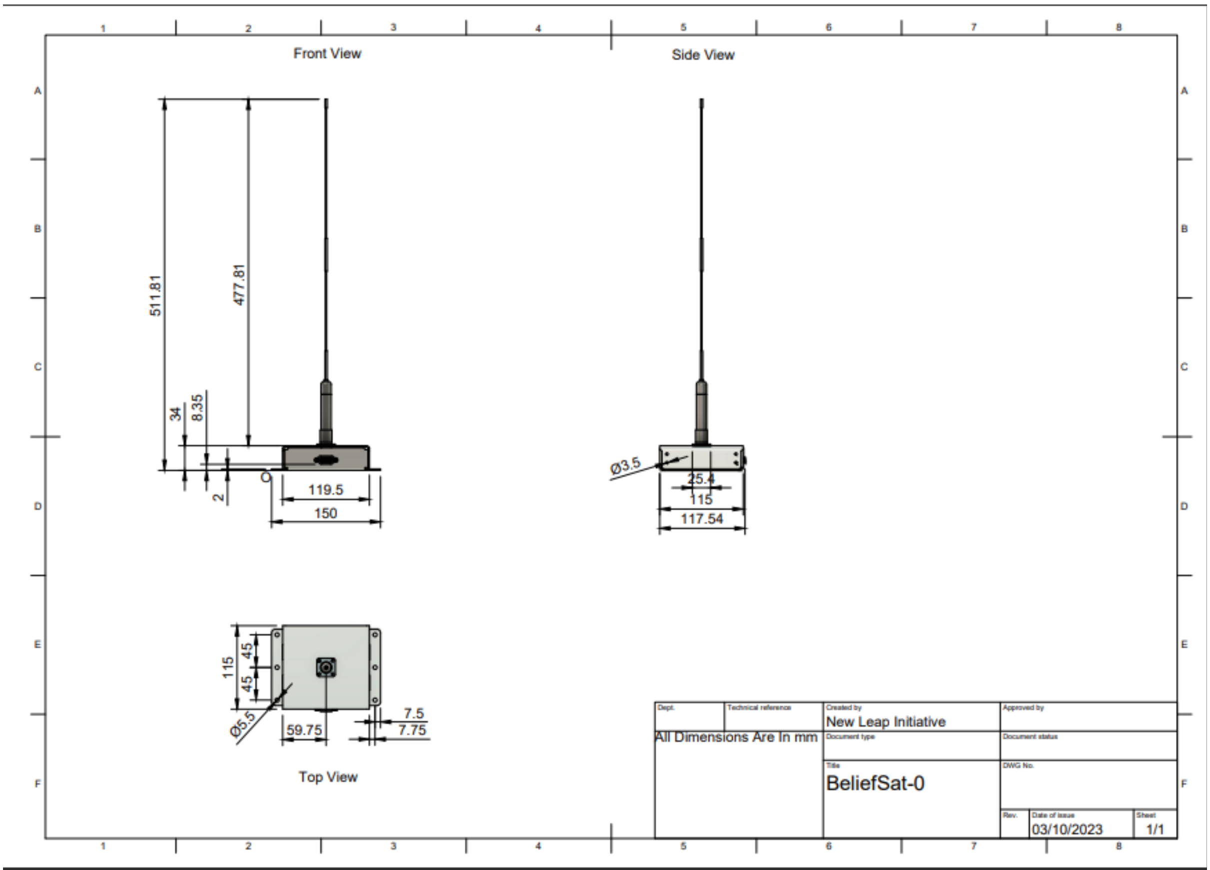
Nagoya NL-770S VHF/UHF High Gain Mobile Antenna:

This antenna boasts a unique feature where the satellite's outer cover serves as the grounding mechanism. The carefully engineered radiation pattern, along with impressive gain parameters, ensures strong signal reception and transmission.

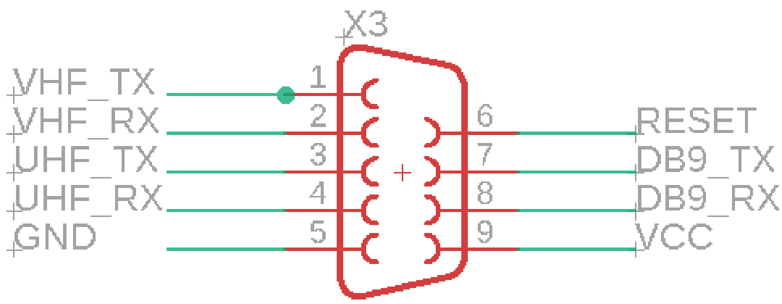
What sets the NL-770S apart is its robust construction, making it a reliable choice for various conditions. Its dual-band capabilities cover both VHF and UHF frequencies, enhancing its versatility. The antenna's strategic placement on the satellite, connected via a UHF connector at the top, optimizes signal performance.

ii) <u>Structure:</u>

Given below is the structural design of our payload with dimensions:



iii) Electrical Interface:



CONNECTOR TYPE	D-sub 9 Pin Connector
On BeliefSat-0	RECEPTACLE-TYPE (female)
On Launch Vehicle	PIN-TYPE (male)

iv) Microcontroller:

ATmega328P is the microcontroller used. The ATmega series is developed by Microchip Technology (formerly Atmel Corporation) is part of the AVR microcontroller family and offers a range of features suitable for various applications, including embedded systems, robotics, and electronics projects. With its advanced capabilities and generous memory, the ATmega328P is well-suited for complex tasks that require efficient processing and control. The selected microcontroller has peripherals like SPI, I2C, Serial, which makes it compatible with most modules in the market. Additionally, it can be easily programmed using Arduino IDE.

v) UHF/VHF Voice Repeater:

An innovative crossband repeater strategy involves pairing VHF and UHF DRA818 transceivers. This dynamic setup enables the seamless rebroadcasting of FM-modulated voice or APRS signals from an input UHF frequency to an output VHF frequency. Emitting at 0.5W output power, the signal remains accessible even to basic walkie talkies. The exceptional input sensitivity of -122dBm ensures quick activation, triggered by the standard 4W output power of prevalent terrestrial amateur radio walkie talkies like the Baofeng UV-5R.

vi) FSK Digipeater:

The primary transceiver also boasts an additional capability to adeptly store-and-forward repeater for concise messages of up to 140 characters. This advanced feature relies on FSK modules, enabling the transceiver to adeptly process and relay brief messages sent its way.

vii) Link Budget:

- UHF Uplink Budget:

i. Calculation of FSPL() = 20x log(D) + 20x log(F) + 20x log (4x pi/c) - G_{TX} - G_{RX}

= 149.9724 dBm

ii. Calculation of Power Received (P_{RX}) =P_{TX}+G_{TX}-L_{TX}-L_{FSPL} -L_{RX} +G_{RX} - L_M
=46.99 + 0 - 0 - 149.9724 - 0 + 0 - 0
= -102.9824 dBm

iii. Link Margin = P_{RX} - RS (Receive Sensitivity)
= (-102.9824) - (-122)
= 19.0176 dBm

- VHF Uplink Budget:

i. Calculation of FSPL = 20x log(D) + 20x log(F) + 20x log (4x pi/c) - G_{TX} - G_{RX}

= 140.4300 dBm

ii. Calculation of Power Received (P_{RX}) =P_{TX}+G_{TX}-L_{TX}-L_{FSPL} -L_{RX} +G_{RX} - L_M
=46.99 + 0 - 0 - 140.4300 - 0 + 0 - 0
= -93.44 dBm

iii. Link Margin = P_{RX} - RS (Receive Sensitivity)
= (-93.44) - (-122)
= 28.56 dBm

- VHF Downlink Budget:

i. Calculation of FSPL = 20x log(D) + 20x log(F) + 20x log (4x pi/c) - G_{TX} - G_{RX}

= 140.4300 dBm

ii. Calculation of Power Received (P_{RX}) = $P_{TX}+G_{TX}-L_{TX}-L_{FSPL}-L_{RX}+G_{RX}-L_{M}$
=30 + 0 - 0 - 140.4300 - 0 + 0 - 0
= -110.43 dBm

iii. Link Margin = P_{RX} - RS (Receive Sensitivity)
= (-110.43) - (-121.88)
= 11.45 dBm

c) Specific requirements from POEM (Stability, pointing, orbit type, power etc.) and constraints on payload operation (Electrical, mechanical, environmental)

1. We require 28V(raw) power for the entire duration via male DB9 Connector.
2. Stabilized platform not required

d) Plans for data processing, management and archival

The telemetry and the packets reflected by the digipeater will be received by indigenous ground-stations at K. J. Somaiya Institute of Technology (KJSIT) and will be stored in a local database.

e) Definition of success criteria of the payload

The successful operation of the payload is voice repeating, APRS digipeating functions and changing through different modes of operation using commands sent from the ground station.

B. Development strategy

T0	Present	1. Prototype fabrication completed
T0 + 5 weeks	In-house functional testing with firmware	1. Functional testing of prototype 2. Application for ITU and IARU frequency coordination 3. Designing firmware
T0 + 6 weeks	RF output sensitivity and testing using spectrum analyser	1. RF output sensitivity and testing using spectrum analyser 2. In-house RF output and Power generation functional testing.
T0 + 7 weeks	Functional testing at Nano-science centre	1. Preliminary thermal-vacuum bakeout after integration with the satellite at Nanoscience centre University of Mumbai.
T0 + 9 weeks	Flight model fabrication & testing	1. Fabrication of the flight model (if necessary) 2. Assembly of flight model in clean-room
T0 + 10 weeks	Testing payload using in-house ground station	1. Testing payload using in-house ground station
T0 + 12 weeks	Qualification Testing	1. Performing all the required tests like environmental testing, themovac testing, vibration testing and other necessary standard tests.
T0 + 13 weeks	Submission of payload and all the relevant documentation to ISRO	1. Documentation of code, designs and final test procedures and finalization of required permissions and documents.

C. In case POEM communication capabilities are not required

The team plans to set up its own indigenous ground station at KJ Somaiya Institute of Technology (KJSIT), Sion Mumbai. KJSIT hosts its own Amateur Radio Club – **CROWN (Club of Radio Operations and Wireless Networks, VU2CWN)** which is a registered club under Wireless Planning and Communication (WPC) wing of Department Of Telecommunication (DOT).

The location of the institute is:

KJ Somaiya Institute of Technology, Sion Mumbai
Somaiya Ayurvihar Complex, Eastern Express Highway, Near Everard Nagar, Sion East, Mumbai, Maharashtra 400022.
CROWN (Club of Radio Operations and Wireless Networks, VU2CWN)
Managed by Dr. Umesh Shinde.

Parameter	Value
Max Bandwidth	2.5 KHz
Modulation	Frequency Shift Keying (FSK)
Uplink Frequency	437.525 MHz
Downlink Frequency	145.525 MHz
Channel Spacing	12.5 KHz

Data Rates in bps	
Telemetry Downlink	1200
Digipeater Downlink	1200
Command Uplink	1200
Digipeater Uplink	1200

CTCSS tone for uplink	
Voice Repeater	67.0 Hz
APRS Digipeater	71.9 Hz

D. Description of required post-launch ground operation support.

a. Coordinates of payload.

b. Initial TLEs for the deployed satellite to be provided by the launch service provider.

E. Expected cost for payload realization and source of funding (Intended end use of the experimental payload)

Fully funded by KJ Somaiya Institute of Technology, Sion Mumbai.