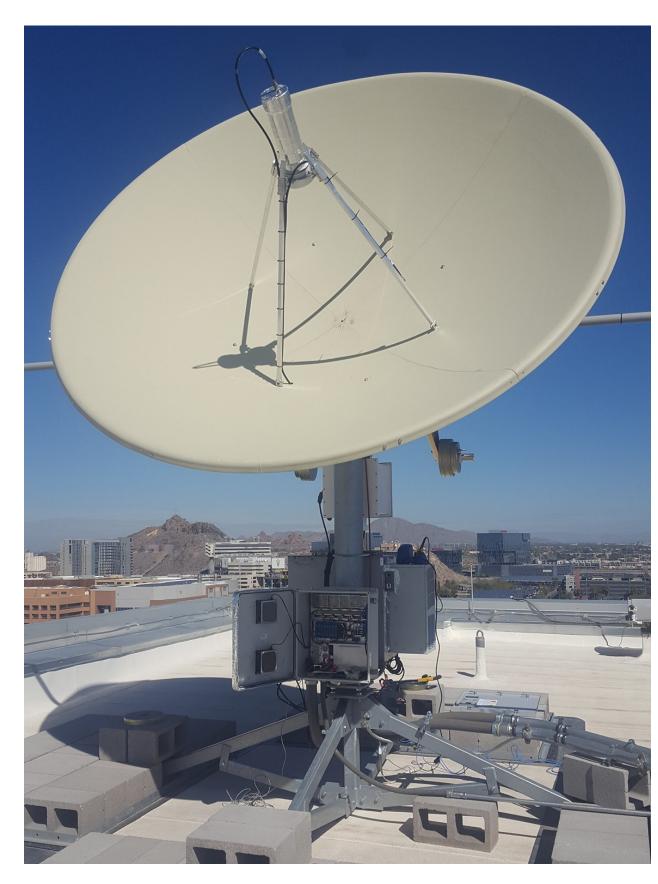


Operational Testing and Improvements of the ASU SmallSat Ground Station

Andrew Klesh (312), Jack Lightholder (398), John Mcdougal (Arizona State University), James Aberle (Arizona State University), Alessandra Babuscia (337), James Bell (Arizona State University), Christopher Groppi (Arizona State University), Daniel Jacobs (Arizona State University), Hamdi Mani (Arizona State University) Strategic University Research Partnership

<u>Objectives</u>

- Development of a ground station which supports LEO and interplanetary CubeSat operations. Focused support for upcoming ASU and JPL missions, reducing DSN load.
- Designing of re-configurable communication systems via a software defined radio (SDR)
- Gain knowledge of CCSDS standards and other protocols for DSN communications. Develop a Universal X-Band and S-Band communication system that also allows for real-time data transfer and analysis.



Ground Station Improvements

- Integration into the ASU mission operations center framework. This integration includes front-end software for future missions to interact with the dish in a user-friendly way. See figure 3.
- Performed general background noise measurements by capturing all of the signal levels seen between or perspective UHF (415-475MHz) and S-Band (2066-2660MHz) frequency ranges while performing 360 azimuth sweeps.

- Platform for student training in CubeSat operations, ground station development and radio hardware development.
- Support UHF, S-Band and X-band communications.

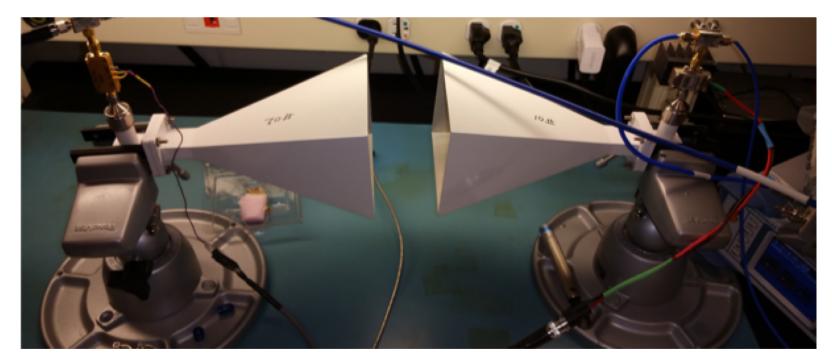
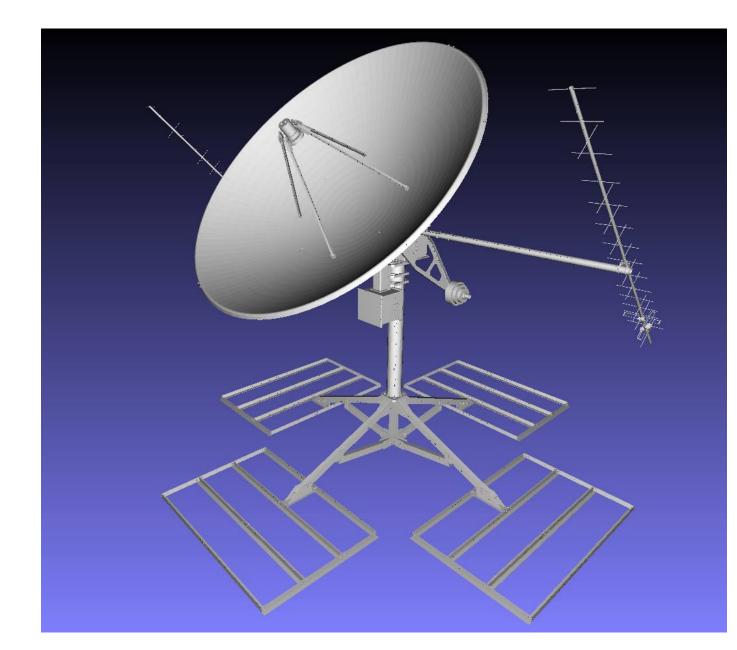


Figure 1: Testing the CCSDS 131.0-B-3 transponder by radiating the signal into free space via the horn and USRP. The signal is then received by the opposing horn and the TM signal is received and decoded.

Figure 2: Installation of revised ground station on the roof of an ASU building in February of 2018. Replaced parts include a steel-case rotor, 75% lighter dish. Upgrades include a new student-built power control box, and a weather station.

- Designed and fabricated amplifier protection circuit for the RF component power states and a 250W power distribution board.
- Implementation of a re-configurable communication system via an Ettus USRPN210 (SDR)
- Development of new, professional CCSDS code to be used in gnuradio.



Cryogenic Low Noise Amplification

- Overcoming small dish size through improved low noise amplification.
- Key Features:
 - Power Gain: 30dB
 - Gain Flatness: < 1 dB on 500-3000MHz band
 - Noise Temperature : 5-6 Kelvin
 (Noise figure 0.075 dB)

| ID: CCSDS trast 4 Hardware Generate Options: QT GUI | QT GUI Tab Widget Num Tabs: 3 Label 0: fft Label 1: const | QT GUI Label ID: variable_qtgui_label_0 Label: frames sent Default Value: 0 | QT GUI Label ID: variablei label 0 1 0 Label: frames decoded Default Value: 0 | Function Probe ID: subframes_decoded Value: 0 Block ID: ccsds decoder | Function Probe ID: frames_sent Value: 0 Block ID: ccsds encoder | Functi ID: frames_rec Value: 0 Block ID: ccsd | | QT GUI Range ID: tx_noise_ampl Default Value: 1m Start: 1m |
|---|---|---|--|--|---|--|---|--|
| Variable Variable | Label 2: stats | | | Function Name: numdecoded Poll Rate (Hz): 10 | Function Name: num_frame Poll Rate (Hz): 10 | s Function Nam Poll Rate (Hz) | ne: numeceived | Stop: 1 Step: 1m |
| ID: fit size ID: samp rate Value: 10:24k Value: 1M Variable Variable ID: samp rate ID: samp rate Variable Value: 1M Value: 8 Value: 1M | QT GUI Label ID: variable dtgui label Label: frames received Default Value: 0 QT GUI Entry ID: msg str Default Value: Helio Wor | Label: subframes deco Default Value: 0 | | Function Probe ID: frames_decoded Value: 0 Block ID: ccsds_decoder Function Name: numdecoded Poll Rate (Hz): 10 | Default Value: 520m Start: 30m Stop: 30 Star: 10m | QT GUI Range D: cf Default Value: 70M Itart: 60M Itap: 80M Itap: 1k | QT GUI Range ID: bw Default Value: 1k Start: 100 Stop: 10k Step: 100 | QT GUI Range ID: rx.g Default Value: 520n Start: 30m Stop: 30 Step: 10m |
| File Source File:a_transfer_test 1_TX Repeat: Yes | Head Num Items: 1.1150 | Stream to Tagg Packet Length: 1 Length Tag Key: | .115k | Throttle Sample Rate: 1M | QT GUI Frequency Si FFT Size: 1.024k Center Frequency (H2): Bandwidth (H2): 1k | | QT GUI Freque FFT Size: 1.024k Center Frequenc Bandwidth (H2): | y (Hz): 70M |
| | | | | | | | | |
| CCSDS Encode Length tag key: packe RS Encode: Yes Interleave: Yes Dual Basis: Yes Scramble: Yes Interleave Count: 5 | et lenn Constel Constel Differen Samples | ellation Modulator lation: <gru7800> > itial Encoding: Yes s/Symbol: 8 BW: 350m</gru7800> | Multiply Const Constant: 520m | Noise Source Noise Type: Gaussian Amplitude: Im Seed: 0 | Add Phase Inc | ator rement: 0 mp_rate/2 | UHD: USR Samp Rate (Sp: Ch0: Center Fre Ch0: Gain Value Ch0: Antenna: | P Sink s): 1M q (Hz) : 70M : 520m |

JPL Benefits

- X-band capabilities allow for interoperability with assets requiring DSN time.
- Offloading interplanetary CubeSat communications to university ground stations reduces DSN load.
- Increased CubeSat partnerships with ASU expands collaboration potential for operation of future JPL CubeSats.

Figure 3: A centralized hardware framework gives the ground station a small footprint, supporting ease of installation and modification. This flexible design allows for easy hardware modifications, supporting the receiver research and design objectives.

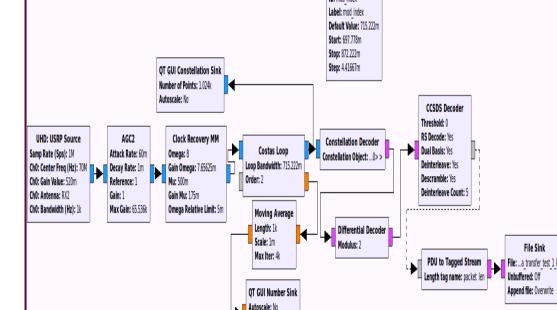
- Input and Output Impedance: 50 OHM
- Input Return Loss: < -10dB
- Output Return Loss: < -10dB
- Unconditionally stable with any input / output impedance .
- Input 1dB Compression @ 2GHz: -36dBm
- Power consumption: 10mW at 10K

Next Steps

- Attempt signal collection from known LEO CubeSats. To-date only carrier signal have been collected.
- Develop a waveguide that is capable of cryogenically cooling the internal electronics of the feed system.
- Develop an X-band LNA/filter/switch/coupler, including down-conversion to UHF, circuit for new waveguide.
- Document and peer-review the process obtaining the system noise level temperature, G/T and supporting measurements of the ground station system with the new feed circuit. Show performance comparisons between passive and cryogenically cooled implementations.
- Demonstration of signal reception/processing and data forwarding for S-Band and X-Band signals using collaboration spacecraft (MarCO and LunaH-Map).
- Develop an SDR capable of communicating with swarms of CubeSats simultaneously without data loss or corruption.
- Software based system that does not rely on Cassy or commercial AIT/AMPCS hardware for TC and AOS CCSDS signal processing.

National Aeronautics and Space Administration

Jet Propulsion Laboratory California Institute of Technology Pasadena, California



- **Figure 4:** Block diagram in Gnuradio Companion (GRC) of our current Software Defined Radio transponder. The system is functional and operates using the CCSDS 131.0-B-3 for gathering telemetry data.
- Provides a testbed location for the testing of future JPL radio receiver prototypes.
- Student training pathway provides JPL interns and ECH hires with real world experience and familiarity with JPL toolchains.
- Advancement of reconfigurable communication systems and SDR technology by expanding CCSDS code libraries for SDRs.



Figure 5: Dust storms pose great risk in the Phoenix metro area. Storm winds can reach 30 mph. The dish, positioned on the roof of an 8 story building, requires supplemental mechanical safeguards to ensure damage does not occur on the ground station gearing system. "birdbath mode" is used during storms to reduce the wind pressure on the dish.

PI/Task Manager Contact Information Andrew Klesh (626) 720-7251





Copyright 2019. All rights reserved.



