National Aeronautics and Space Administration

SWARMS

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Project Objective

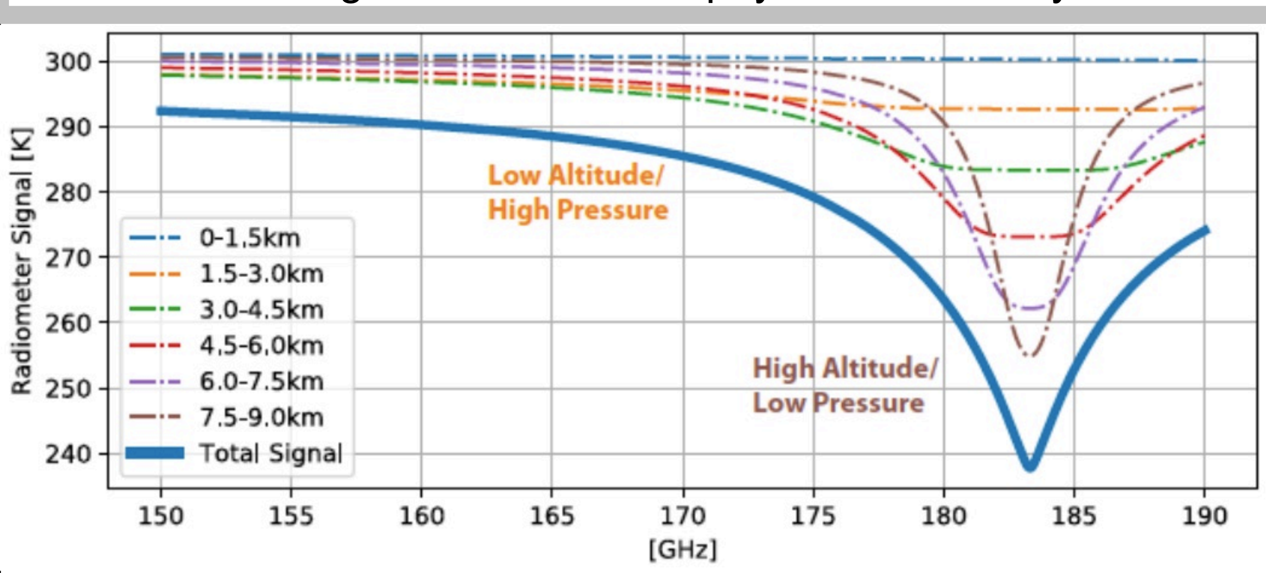
Our objective is to combine technologies and capabilities for laying the foundation of adaptive reconfigurable monolithic and distributed space platforms. A motivating example is the goal of assembling a reflector in orbit from smaller free-flying satellite elements. The team is investigating techniques and architectures that allow physical aggregation / disaggregation, resolve wavelength scale metrologies with realizable structural connections, and develop ubiquitous "rendezvous" methodologies that enable any type of swarm space elements to function safely. The combination of these technologies and capabilities will provide a set of baseline designs for CubeSat configurations that will enable a range of science-driven applications. It will also strategically place JPL to effectively respond and win proposals for CubeSat opportunities as they get rolled out by NASA SMD.

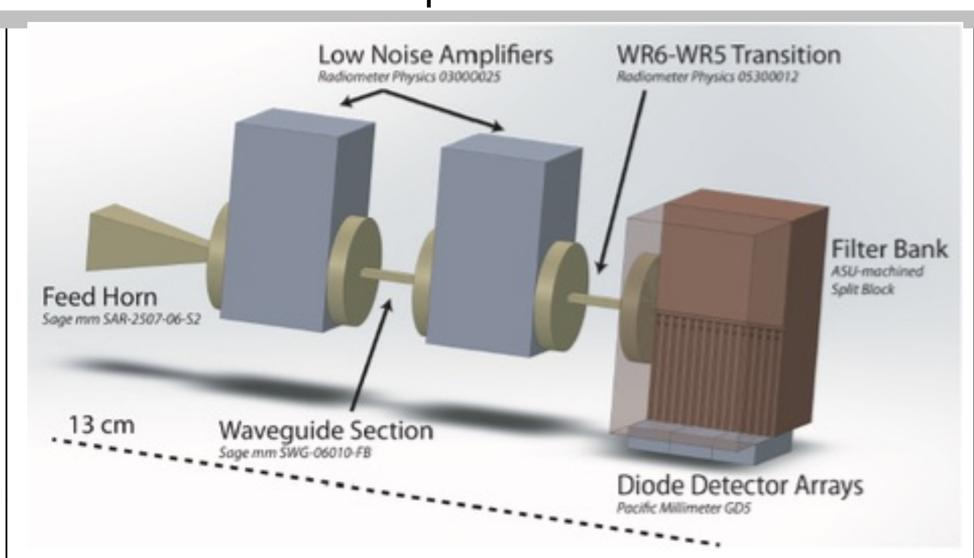
Science Instrument Approach:

• Develop a millimeter-wave waveguide spectrometer technology .
• The signal from the scene is first amplified by a chain of commercial millimeter-wave low noise amplifiers.
• The signal is then sent to a millimeter-wave filter bank spectrometer.
• This passive device does not use any electrical power since it has resonant cavities to couple each frequency to a different output waveguide port.
• A millimeter-wave diode power detector is at each output port to detect the signal, which is then amplified by audio amplifiers before digitization. The radiometer system is coupled through a cross-track scanning mirror with a 5 cm aperture.
• The continuously rotating scan is one beam per second, i.e. 2 degrees per second.
• After rotating through -45^0 to +45^0 to scan across the atmosphere (and 1000 km cross track of ground), the mirror views a blackbody calibration load, then turns to view the cold sky, followed by a calibration load on the other side, before returning to the start of the atmosphere scan.
• This provides two different reference temperatures (blackbody and cold sky) for calibration.

Relevance to strategic focus area

- Study the water vapor distribution in the atmosphere of the earth, using a millimeter-wave 183 GHz atmospheric sounding instrument coupled to a 1.5 meters antenna.
- 1 km nominal ground resolution with 1.5 km vertical resolution v/s the current state-of-the-art ATMS instrument's 15.8+ km ground resolution and slightly less vertical resolution.
- Re-visit mid-latitude sites up to several times per day, as compared with existing satellites that observe any given target only once per day.
- Access distance and time scales in the atmosphere associated with cloud formation and other key weather processes.
- Improved horizontal and vertical resolution with reduced size, weight and power due to the new sensor used in the instrument.
- New approach but with high-heritage components.
- Novel docking mechanism called CLING (Complaint Low-profile Independent Non-protruding Genderless) to assemble the antenna elements of our instrument.
- The docking device allows for physical modularity between different satellites in a potential cluster.





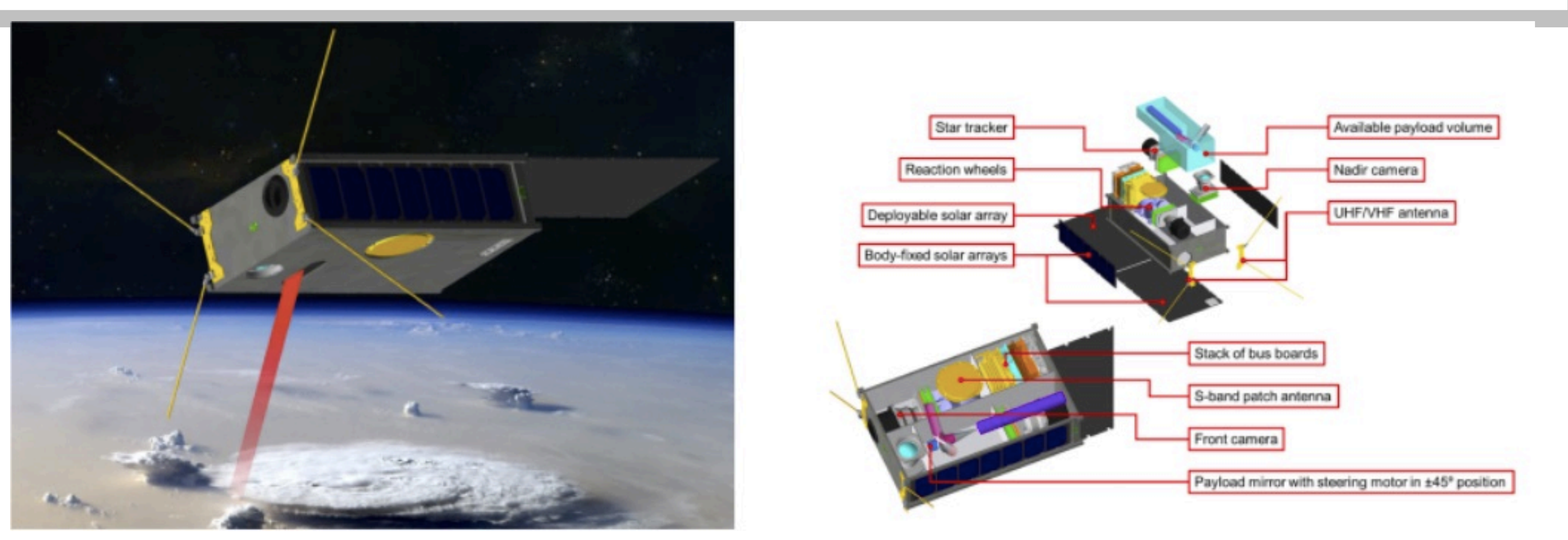
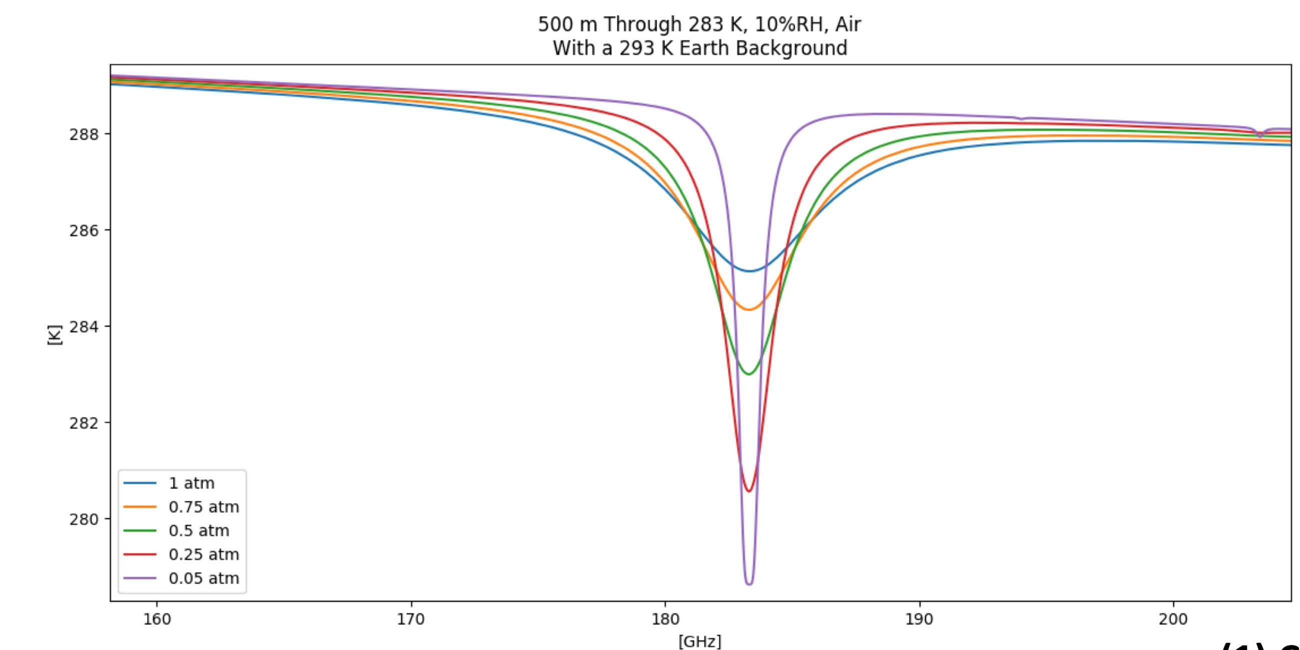


Figure 1: *(Top and Bottom) Total radiometer spectrum due to humidity in the atmosphere, with over plotted contributions from each Cube Sounder's vertical resolution element*

Figure 2: *Spectrometer system with the commercial parts. This whole instrument fits in a 3U of the 6U spacecraft. Everything shown weighs under 0.5 kg.*

Figure 3: *Left: Rendering of the Cube Sounder concept observing a desert storm over the western Sahara Desert. (Photo Credit NASA.) Right: Exploded view of the SWARMS CubeSat bus, electronics, pointing, camera, and water vapor radiometer systems*



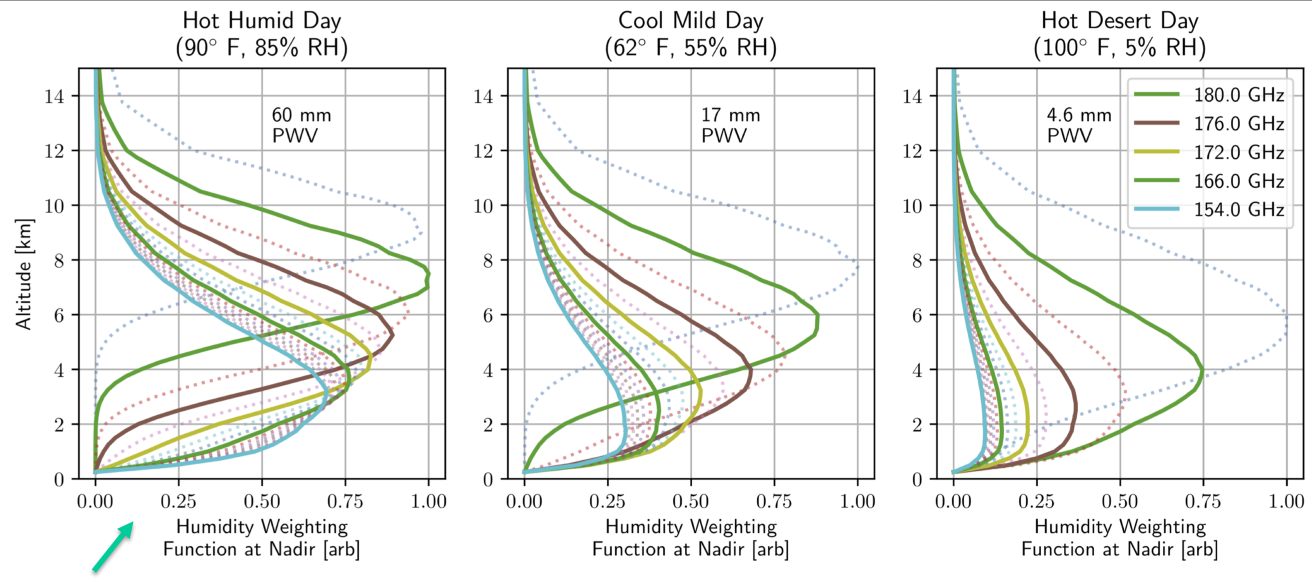


Figure 4: Altitude v/s Humidity Weighing

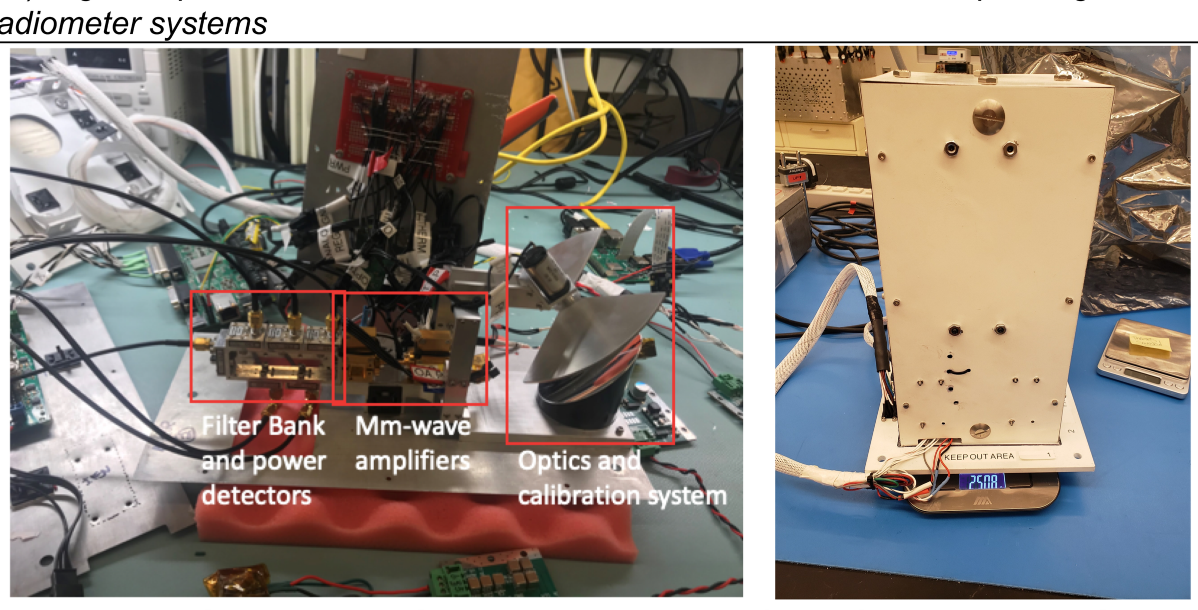


Figure 5: **ASU Prototype Science Payload:** *Built for NASA High Altitude Student Project (HASP) Stratospheric Balloon*

CLING Docking Mechanism

(1) C: Compliant – it can dock under relatively high positioning errors in all directions.
(2) L: Low profile – several CLING units can be installed on multiple faces of a spacecraft without any significant impact on size.
(3) I: Independent undocking ability – in case of failure, each module can disengage the docking on its own.
(4) N: Non-protruding – In passive mode, there are no protrusions and the motion is not limited.
(5) G: Genderless – there are no fixed male / female configurations, hence both of the modules in a pair are the same.

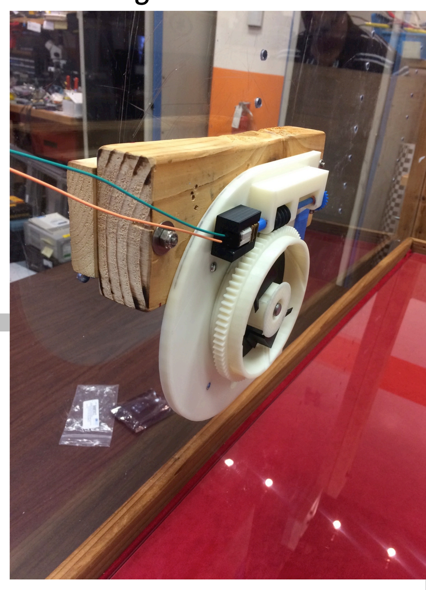


Figure 6: Right: *3D printed version of CLING using ABS*

CLING Features

- Fixed structure "product" that has all electronics, mechanisms and operating capability into a single 1U form factor.
- The sensor system in each CLING to communicates with any other CLING.
- CLING module transmits range and attitude information from another CLING to its host spacecraft or platform.
- Automatic sensing and actuation when two CLING devices get close to autonomously engage and allow for soft to hard docking transition.
- Electrical, data, and fluid transfer capability into the CLING housing via the connecting pins.

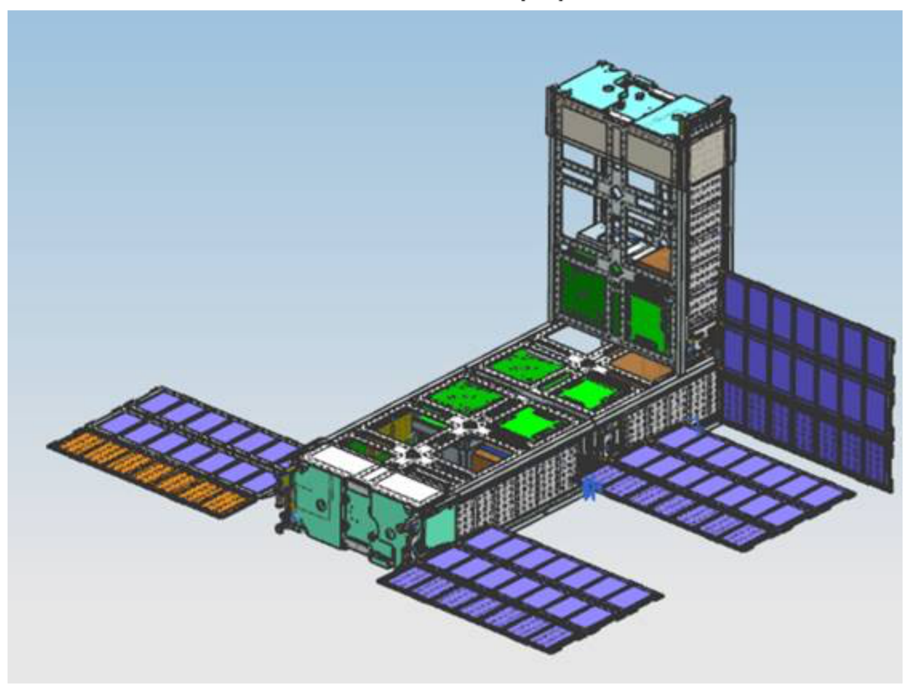


Figure 7: *Current SWARMS design configuration post orbital assembly*

- Stratospheric balloon payload.
- NASA High Altitude Student Project (HASP) hosted 12 student-built payloads, approximately CubeSat sized which, was a competitive process to get ride
- ASU team flew SWARMS prototype radiometer.
- Balloon flew at 125kft. Atmospheric pressure 0.3 mbar.
- Above 99.7% of atmosphere.

Figure 8: *NASA High Altitude Student Project (HASP)*

Publications:

Publications expected to follow

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• James Smith, Payload & Small Spacecraft Mechanical Engineering, JPL
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