Smaller Satellites, Bigger Return

Mechanical Design and Testing of Deployable Wideband Antenna for Nano- and Micro-Satellites

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[1] Mission Overview

HawkEye 360 is an American geospatial analytics company that focuses on Radio Frequency (RF) signals. Satellite constellations comprised of microsatellite clusters use a unique formations to collect RF signals for geolocation. Spectrum-based frequency and geoanalytics are of great use in communication, wildlife preservation, and military defense.

The Space Flight Laboratory (SFL)'s work and DEFIANT bus has been vital to the success of the 21 microsatellites within HawkEye360's satellite constellation. The DEFIANT bus is one of SFL's satellite platforms that has a mass of 20 – 50 kg, a volume of 36 x 36 x 45 cm, and follows the microspace design approach. SFL has not only equipped HawkEye360 with the DEFIANT bus, but has developed technologies vital to the success of each cluster. More specifically, SFL has developed high performance attitude control systems, navigation technology, and SFL formation determination and control algorithms. There is a demand for improved communications antennas to ensure that the microsatellite industry is evolving to face new challenges. SFL's discone antenna will fly on the Cluster 9 satellites, enabling HawkEye360 to enhance their RF capabilities.

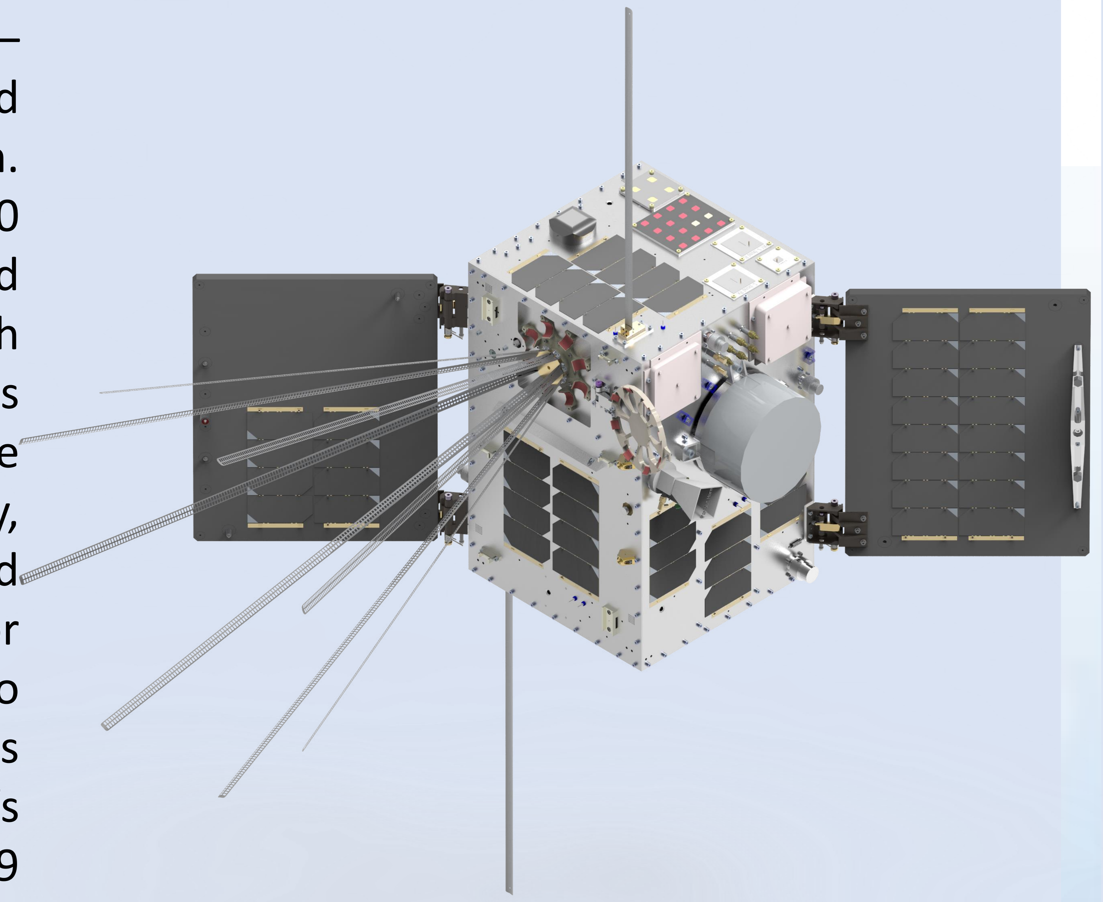

Figure 1: Cluster 9 Microsatellite

[2] Discone Antenna Overview

A deployable discone antenna was selected to address this gap due to its wideband properties giving it large frequency coverage capabilities. This deployable antenna has the ability to do the job of multiple antennas, optimizing spacecraft structure and mass. The mechanical challenges facing this type of solution include optimizing the mechanical structure as well as the deployment functionality.

The prototype is intended to be on-orbit and commissioned before the end of 2023. This antenna and its deployment design will enhance public safety through improved frequency coverage, accuracy, and efficiency of geolocation products.

Table 1: Discone Key Requirements

Key Requirements
[R1] The discone antenna shall not diminish the performance of the existing antennas past their required levels.
[R2] The deployment of the antenna elements shall not damage any external components on the spacecraft.
[R3] The antenna shall be able to be stowed and armed on the fully assembled flight spacecraft without any de-integration.
[R4] The discone antenna should be able to be tested while mounted to the flight spacecraft in a lab (1g, 1atm) environment.

[3] Mechanical Design

The fundamental parameters of a discone antenna to define the RF characteristics of the antenna are: the element length (A), base diameter (B), isolation distance (C), and element cone angle (D). These specifications were determined by the communications iterated on and given by the RF team.

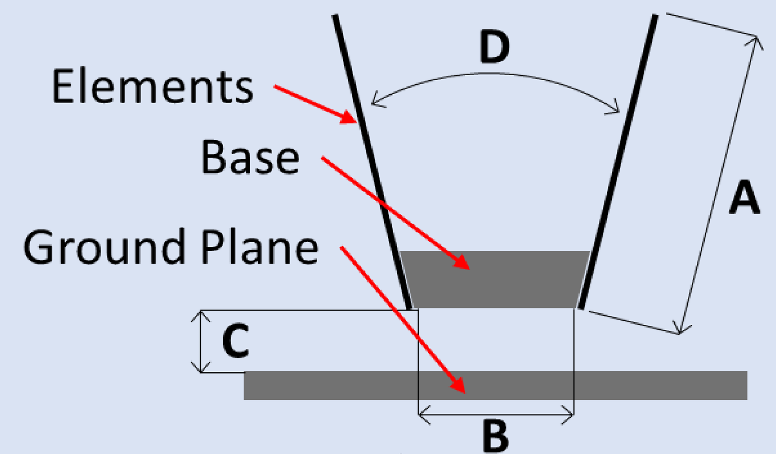

Figure 3: Typical Discone Diagram

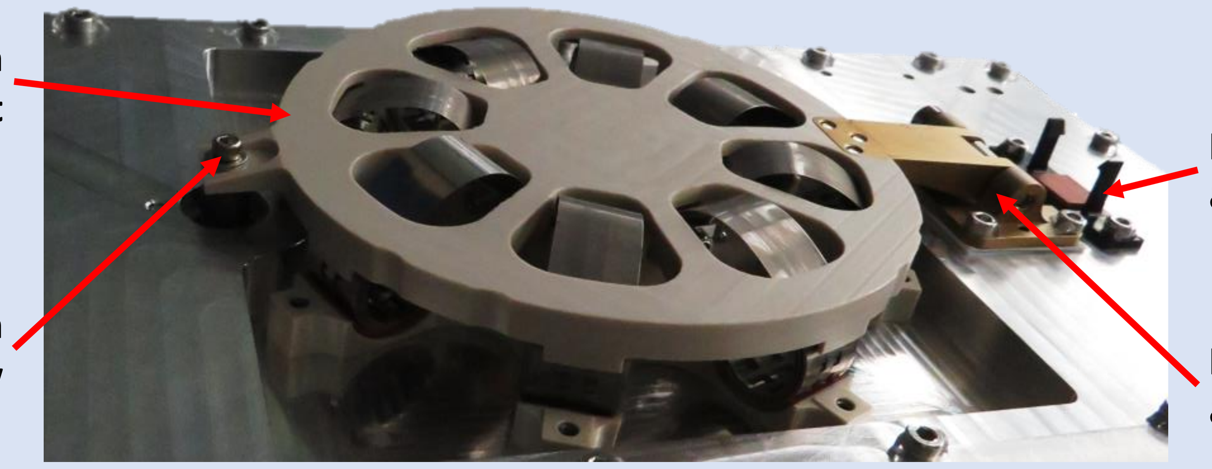

Figure 3: Fully Assembled Stowed Discone Antenna

The discone design has two main components: **the antenna** and **the hinge:**

- The antenna has 8 tape spring elements attached to its base. The base is mounted to the panel via a plastic and includes a SMA bulkhead to interface with the payload.
- The hinge holds the elements stowed during launch and releases them via a hold down release mechanism (HDRM) to deploy the antenna. The hold down bracket swings away from the antenna when the HDRM is actuated and is caught by a latch to secure it.

Design Challenges

The discone antenna is a new SFL design being integrated on a well established spacecraft platform which led to the following design and integration challenges which had to be solved:

[1] *Structural Interference:* The stowed antenna was required to fit within a 16 mm gap under the deployable solar array panel requiring the antenna to be designed extremely compactly.
[2] *Electrical Connection:* The discone requires an isolation region between the base and ground plane making it difficult to mount a connector to the antenna.
[3] *Ground Testing:* While tape spring antennas are great at stowing and hold their shape on orbit, they lack the stiffness to hold their shape under gravity making ground testing difficult.
[4] Stowing Procedure: To ensure consistent and repeatable deployments of the antenna a detailed multi-step stowing procedure for the elements and entire discone is used with various different ground support equipment to facility this process.

[4] Testing and Validation

[1] *Deployment Testing:* Deployment testing was performed at varying orientations to observe element behaviour and deployment consistency. Deployment testing was performed in vacuum.

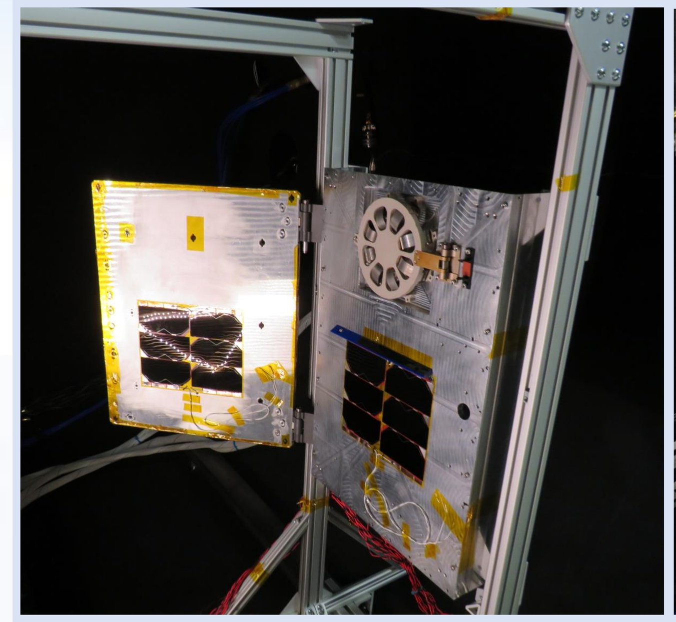

Figure 9: Horizontal Orientation (Stowed)

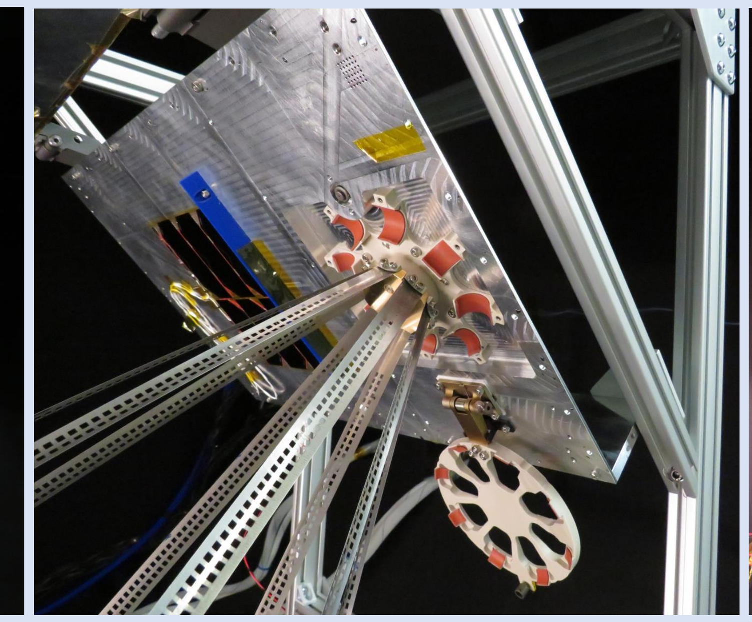

Figure 10: 45° Wing-Down Orientation (Deployed)

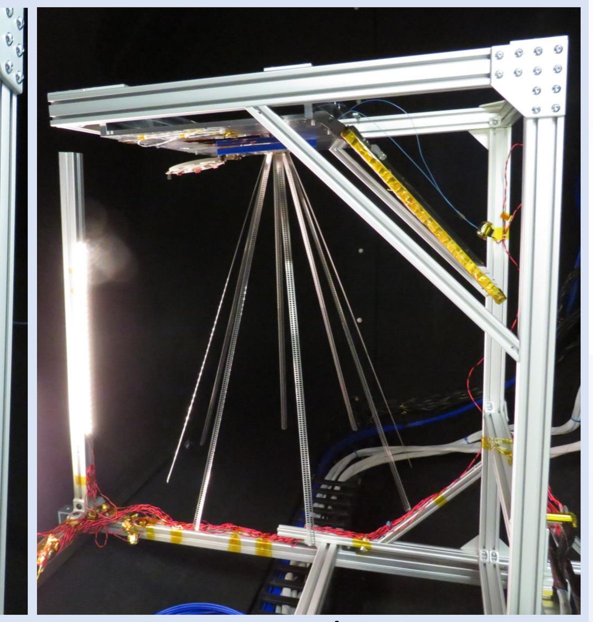

Figure 11: Vertical Orientation (Deployed)

[2] *Thermal Testing:* Thermal environments were accounted for during the testing of the discone antenna. Thermal gradients between main components located on the panel where the antenna is located and the spacecraft were analyzed extensively.
[3] *Long-Term Stowage Testing:* Stowing the structure at higher temperatures or for longer periods of time can increase the dynamic deployment time of the structure by decreasing the stored strained energy available for deployment.
[4] *Vibration Testing:* Vibration testing worked to verify the discone antenna's structural and mechanical compliance and established confidence that the discone antenna will function as needed after exposure to high loads that will be experienced during the mission.

[5] Conclusion

- A deployable wideband antenna was designed, tested, and validated to enhance HawkEye 360's RF capabilities and will fly in 2023 and 2024.
- The discone antenna will be utilized for the first time on HawkEye 360's Cluster 9 microsatellites as well as future clusters with launches scheduled for 2023 and 2024

[6] Future Work

- HawkEye 360 Cluster 9 Launch and Flight Validation (Fall 2023)
- Discone antenna usage on future clusters

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