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ROMANIAN SATELLITE DEMONSTRATOR FOR MONITORING GROUND RF EMISSIONS

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ABSTRACT

The increasing reliance on radio communications for military, governmental, and civilian applications makes radio frequency (RF) monitoring a crucial aspect of national security. Unauthorized transmissions, spectrum interferences, and electronic warfare threats pose significant challenges that require advanced detection and localization capabilities. Space-based systems provide a strategic advantage by offering wide-area coverage, persistent surveillance, and rapid signal acquisition. The CORVUS satellite is designed as a dedicated platform for detecting and localizing radio signals over Romania. By utilizing advanced signal processing and geolocation techniques, CORVUS enhances situational awareness, supports defense and intelligence operations, and strengthens the country's ability to monitor the electromagnetic spectrum. This paper explores the satellite design, payload implementation, operational benefits, and security implications of the CORVUS satellite system.

KEYWORDS: communications, electronic warfare, RF monitoring, satellite, space defense

1. Introduction

Cyberspace is now recognized as one of the main pillars of defense and the RF spectrum, its physical resource, has increased its significance as a critical national resource to be safeguarded. CORVUS is a satellite developed as a demonstrator of an orbital radio frequency (RF) sensor that monitors emissions over a wide area. The scope is the detection and localization of radio sources operating in the VHF/UHF and GNSS bands in order to identify rogue stations capable of interfering with government sanctioned operations.

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The CORVUS satellite concept is part of a broader family of SIGINT (Signal Intelligence) platforms developed to detect and locate radio frequency emissions. Several systems worldwide demonstrate similar operational principles:

- **HawkEye 360:**

A commercial constellation comprised of small satellites dedicated to RF monitoring. HawkEye 360's design emphasizes near real-time detection and geolocation of radio signals over wide areas. Its scalable architecture and rapid revisit times enable dynamic mapping of electromagnetic emissions, making it a notable example of modern space-based signal intelligence detailed in HawkEye 360. (January 2020).

- **Vortex/Chalet and Mercury (United States):**

Historically, the U.S. National Reconnaissance Office (NRO) has operated multiple generations of SIGINT satellites. The Vortex series (formerly known as Chalet) used large dish antennas in geosynchronous orbits to intercept and analyze signals. These platforms were subsequently succeeded by the more advanced Mercury satellites, which refined signal collection and geolocation capabilities for defense and intelligence purposes, as described in Ball et al. (2015).

- **CERES (France):**

Launched in November 2021, the CERES constellation is a French SIGINT system designed to detect, locate, and characterize electromagnetic emissions—particularly from radar and communications sources. Operating in semi-synchronous orbit, CERES provides continuous, all-weather surveillance and represents a significant advancement in France's space-based electronic warfare capabilities, as per SatelliteObservation.net, 2016.

- **Luch Olymp (Russia):**

Luch Olymp is a Russian SIGINT satellite operating in geosynchronous orbit that maneuvers close to target communications satellites to intercept transmissions. Its dynamic orbital behavior underscores Russia's approach to space-based signal intelligence, focusing on proximity operations to enhance interception accuracy as included in Kratos Defense, 2023.

Each of these systems employs a unique mix of orbital configurations, antenna technologies, and signal processing methods. Like these established platforms, CORVUS leverages advanced geolocation techniques – specifically, Frequency Difference of Arrival (FDOA) – to pinpoint radio signal sources with high accuracy. However, CORVUS is optimized for the specific operational environment of Romania, addressing regional security challenges while drawing on proven SIGINT methodologies.

2. General Aspects of the CORVUS Satellite

The key characteristics of the demonstration mission are enumerated in this section.

1. **Orbital Configuration and Coverage:** CORVUS is designed to operate in a low Earth orbit (LEO) to ensure optimal coverage over Romania and neighboring regions. The satellite's altitude and inclination are carefully selected to balance resolution, revisit times, and signal acquisition efficiency. A constellation approach can be considered for enhanced coverage and redundancy once the mission and concepts of operations were validated in orbit.

2. **Signal Detection Capabilities:** The satellite is equipped with highly sensitive radio frequency receivers capable of detecting a wide range of signals, including military, commercial, and unauthorized transmissions. These receivers scan predefined frequency bands and capture signal characteristics such as frequency, bandwidth, and modulation type.

3. **Geolocation Techniques:** To determine the source of detected signals, CORVUS employs FDOA: By analyzing frequency shifts due to Doppler effects, CORVUS refines the location estimates for the RF sources, as described in Ali et al. (1998).

4. **Communication and Data Transmission:** The satellite transmits collected data to secure ground stations via encrypted communication links. For activation as part of an operational service it is recommended to augment the CORVUS detection with a network of ground receivers that processes and verifies signal intelligence for integration into a national security framework. To ensure minimal latency, CORVUS sends pre-processed data directly to the ground station. For in-depth analysis, the satellite is capable of recording and sending, in real-time, raw RF signals to be processed on ground.

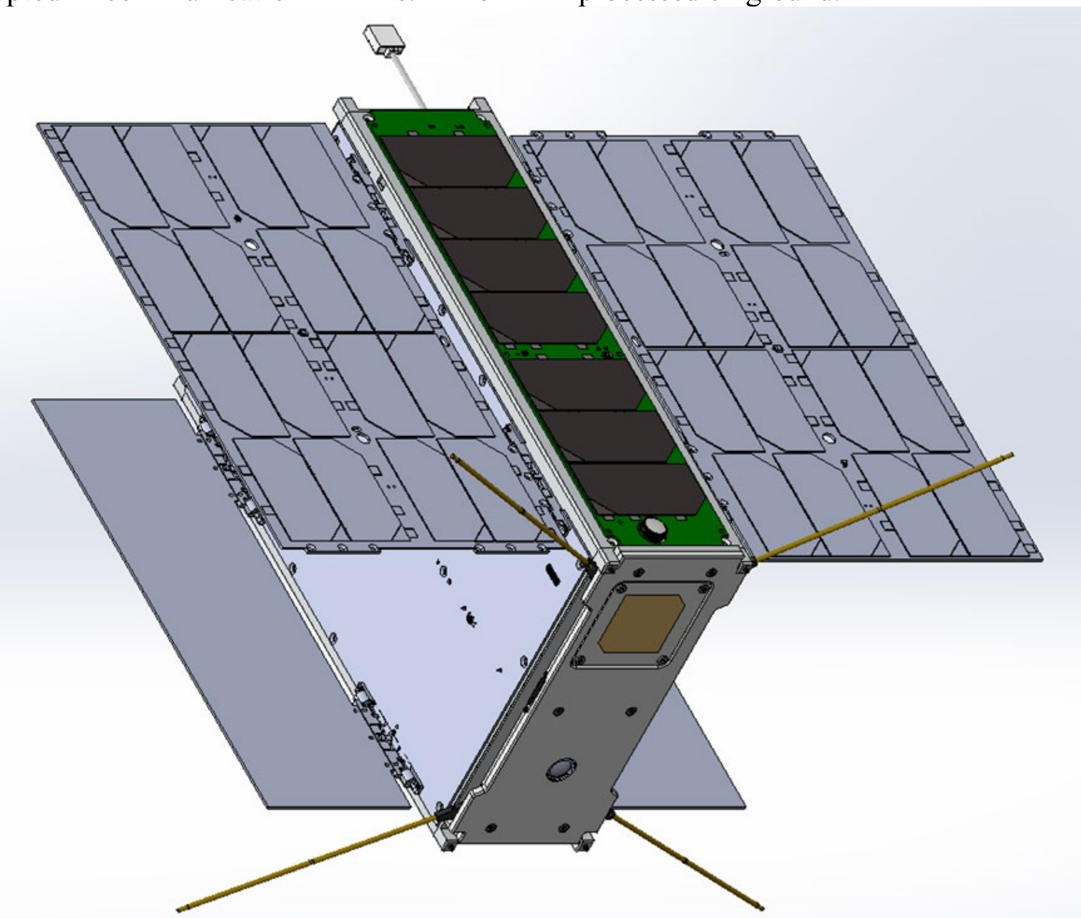

Figure no. 1: *Satellite deployed configuration (front view)*
(credit: CORVUS consortium)

5. **Security and Countermeasures:** Given the risk of electronic countermeasures such as jamming and spoofing, CORVUS incorporates robust security features:

- Anti-jamming technologies to maintain operational reliability in contested environments.
- Encrypted communication channels to protect transmitted data.

CORVUS is a small satellite from the CubeSat class, corresponding to the 6U form factor. In its stowed configuration, the satellite measures 100 x 226 x 366 mm^3, adhering to the CubeSat Design Specification, The CubeSat Program, 2020. It is hosted in a special dispenser during launch and deploys its solar panels and antennas after insertion in LEO (Low Earth Orbit).

Figure no. 1 presents the orbital configuration with the after all deployables have been triggered. The CAD representations are made in SolidWorks.

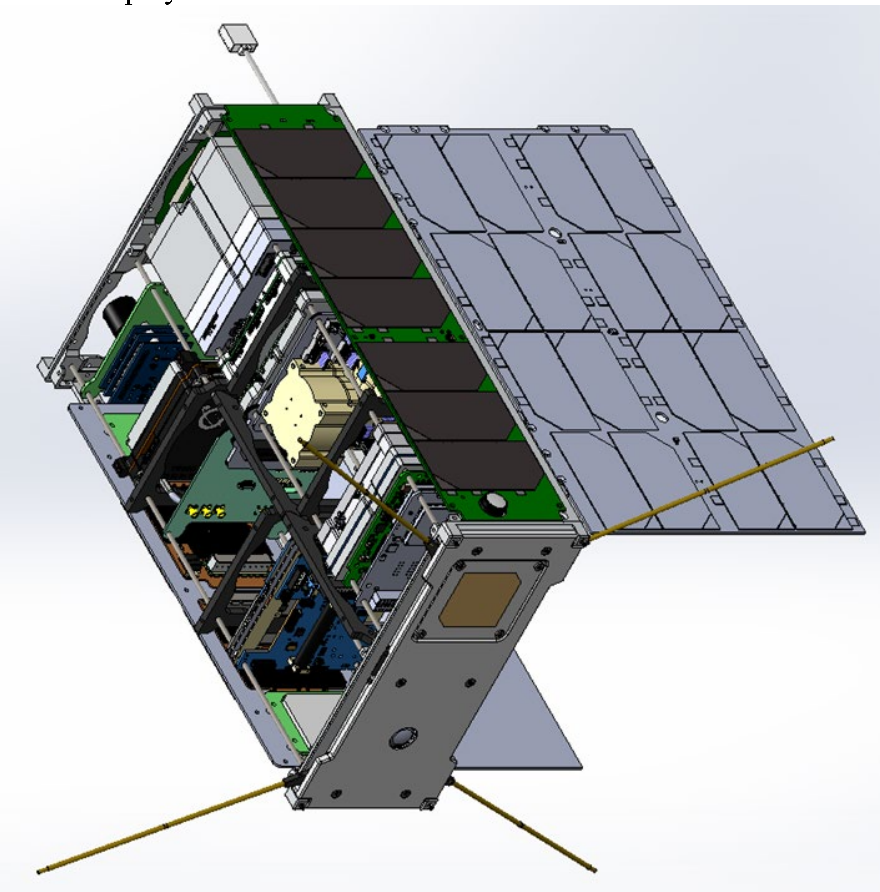

Figure no. 2: *Satellite configuration (internal view)*
(credit: CORVUS consortium)

To allow for a short development of such an ambition demonstrator project, the team has opted on the use of available COTS (commercial off the shelf) components. Nevertheless, most of the subsystems or platforms used already have flight heritage, which reduces the risk of premature failures. Subsystems are stacked in two parallels stacks and connect through a bus connector similar with the PC/104 standard. The stacks are mechanically fixed by screwed rods connecting the ends of the satellite. The internal subsystems stacked internally are presented in Figure no. 2.

To stay within the necessary constraints of the CubeSat standard, several components need to be deployed after orbit insertion. These are: the two solar panels, the two wide-band antennas of the payload system (operating in VHF/UHF), the UHF antenna and the magnetometer, which is part of the ADCS (Attitude Determination and Control System). Once in orbit the satellite shall firstly confirm positive power budget and enter a commissioning phase that includes solar panel deployment.

The orientation of the satellite is critical for the ability to conduct its mission to the required performance indicators. The VHF/ UHF antennas and the GNSS antennas used as part of the payload need to be oriented mainly towards nadir (the region of interest for the RF spectrum monitoring). The solar panels shall be oriented towards the Sun for maximum solar panel production. Similar to Figure no. 1, which shows the view from the Sun, Figure no. 3 shows the view from the ground, with the antennas visible.

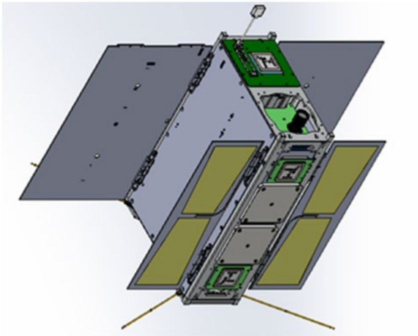

Figure no. 3: *Satellite deployed configuration (Earth direction)*
(credit: CORVUS consortium)

The payload is comprised of several functional units. The SDR (software defined radio) transceiver can monitor all RF spectrum intervals relevant for the mission: the VHF/UHF band and the GNSS frequencies (including their immediate vicinity). Besides the GNSS antennas of the satellite BUS, two GNSS antennas are dedicated to monitoring any sources from the ground. Similarly, for the VHF/UHF band there are two antennas monitoring emissions in these frequencies. Besides the SDR, the GNSS monitoring is using OrbFIX, the GNSS receiver developed by RISE, that also functions as a spectrum analyzer for all GNSS frequencies (and satellite constellations).

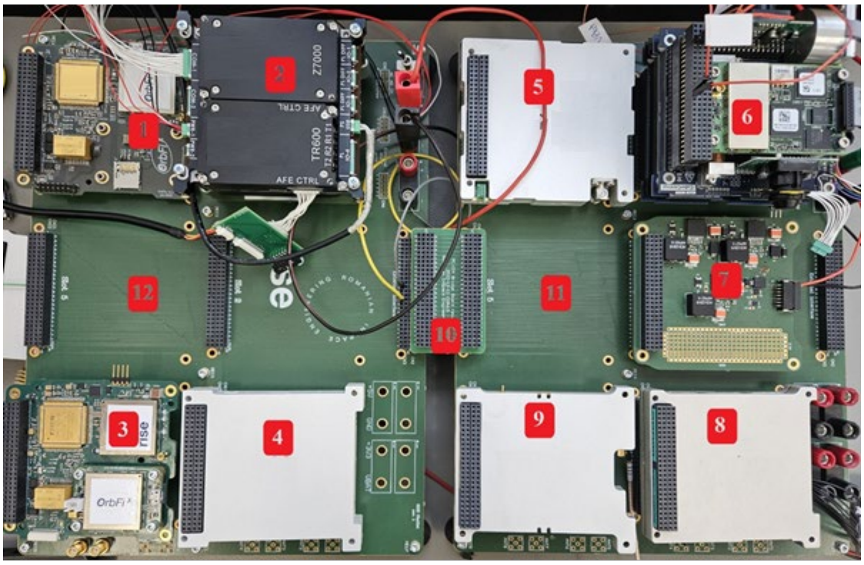

Figure no. 4: *CORVUS (flatsat configuration)*

The preliminary validation of the satellite and main functional verifications were performed during the flatsat integration, a phase that includes software development as well. The flatsat configuration, presented in Figure no. 4, includes the following subsystems: 1. OrbFIX (payload unit), 2. Software Defined Radio, 3. OrbFIX (system unit), 4. S-band transceiver, 5. S-band transmitter, 6. ADCS, 7. EPS (electrical power supply), 8. OBC (on board computer), 9. UHF transceiver, 10. development board extension.

Following integration of the subsystems, the verification and validation campaign plan includes thermal vacuum tests and mechanical vibration tests.

3. VHF/UHF Antenna Design

One of the challenges of a wide-band monitoring satellite is the antenna system that needs to be sensitive for the range of frequencies of the mission objectives. The development of the antennas operating in the VHF/UHF band is presented in this section, together with the results of the analyses conducted.

The main constraint was keeping within the mechanical dimensions of the 6U CubeSat and designing a suitable stowage configuration that can allow in-orbit deployment and orientation for detection.

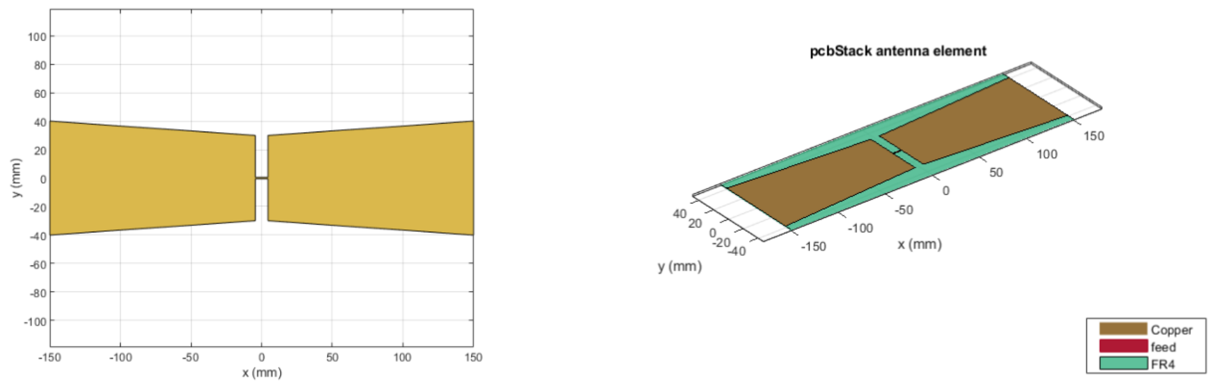

Figure no. 5: *Antenna design*
(credit: CORVUS consortium)

The proposed antenna is defined by a dipole with a bow-tie shape, as can be observed in Figure no. 5. The length of the antenna is 30 cm and the width is 8 cm. This shape was chosen to design an antenna that requires easy integration into the satellite chassis. Multiple dielectric substrates can be used depending on the application.

Figure no. 6: *Antennas manufactured*
(credit: CORVUS consortium)

The analysis was carried out in the 100 – 600 MHz frequency band due to project constraints. The AntennaDesigner interface of the MATLAB R2021a development environment was used to simulate the results below. Further optimizations were also performed using a suite of MATLAB programs. The design refinement and analysis were followed by manufacturing and validation in the laboratory using specialized equipment. The design was manufactured for several configurations (shown in Figure no. 6). The main radiating characteristics of the flight model antenna were measured in the anechoic chamber of the Special Telecommunications Service. The results of the gain measurements are presented in Figure no. 7.

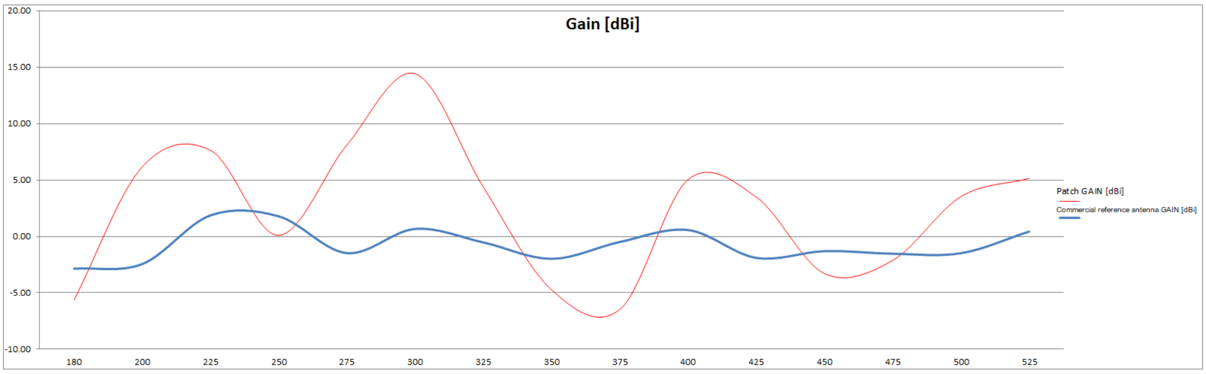

Figure no. 7: *Measured gain for the proposed antenna overt the frequency bands of interest* (credit: CORVUS consortium)

The payload module allows the detection of emissions as well as the measurement of associated parameters (e.g. center frequency, level, occupied band). Also, each measurement has the associated time stamp at which it was performed and the scan sequence number. Detection can be performed either on a fixed band of 2MHz, around the frequency entered by the operator ("Fixed Frequency Scan") or on a wide frequency band, defined by the operator ("Spectrum Scan").

The method consists of tuning the SDR receiver to the frequency of interest and continuously acquiring the received waveforms. Upon completion of the measurement (reaching a maximum waveform threshold or interrupting the process) the obtained data is saved as a binary file that can be accessed offline for analysis. The data is structured in groups of 4096 complex values, each group representing the IQ components of the received waveform.

Given the limitations of the SDR storage capacity, between 10 and 1,000 waveforms can be saved. To avoid exceeding the SDR storage capacity, it is recommended to delete the binary file stored on the SDR after its transfer to the ground. The specific measurement parameters are configurable (SDR gain, tuning frequency, detection threshold, averaging, etc.). To avoid losing the results, they are automatically saved in JSON format, either when a predefined number of scans is reached or when the process is interrupted.

In order to be able to represent the data obtained from the scans, a WEB application was developed with graphic elements that specifically expose the system's facilities. The application can represent the data obtained for each scanning mode and can make comparisons between multiple files.

Secondary to the antenna design and critical to the in-orbit demonstration of the mission objectives is the detection of the RF source and the estimation of its location. These are dependent on the algorithm of determining the point of closest approach (PCA). The process consists of measuring the central frequency, which is affected by the Doppler effect. Also, each measurement is associated with a sequence number and a time stamp. Thus, by obtaining a sufficient number of frequency measurements, the Doppler curve can be obtained.

The PCA is determined by identifying the zero crossing of the Doppler curve. Also, the derivative of the frequency function will have an extreme value in the PCA (Figure no. 8). The position of a transmitter position can be estimated by associating the time stamp of the PCA with the orbital position. The projection from the PCA to the Earth model provides the location estimate.

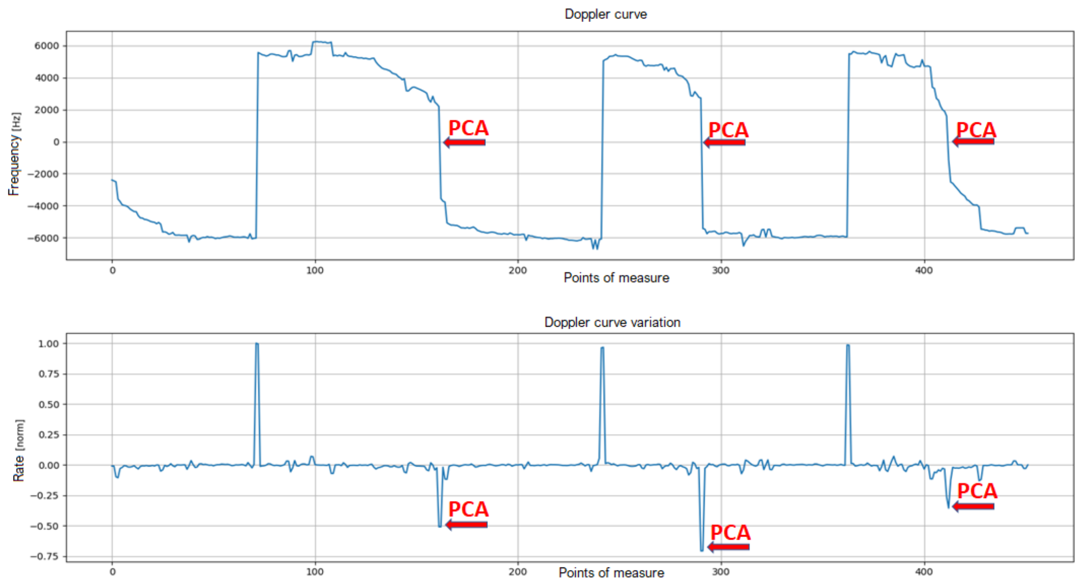

Figure no. 8: *Example of the point of closest approach in digital measurements* (credit: CORVUS consortium)

4. Conclusions

The CORVUS represents a strategic advancement in Romania's national security framework, and it is a significant step forward in Romania's ability to monitor and secure its radio frequency landscape. Its advanced signal detection, geolocation accuracy, and secure data transmission make it a valuable asset for intelligence, defense, and emergency response applications. By providing real-time radio signal detection and geolocation, it enhances these capabilities for Romania not only within its national borders, but also to share them with its allies. As satellite technology continues to evolve, further improvements and international cooperation will be essential to maximize CORVUS's effectiveness and maintain security in an increasingly complex electromagnetic environment.

Acknowledgement

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REFERENCES

Ali, I., Al-Dhahir, N., & Hershey, J.E. (1998). Doppler characterization for LEO satellites. *IEEE Transactions on Communications*, *46(3),* 309-315. Available at: https://doi.org/10.1109/26.668054.

Ball, D., Robinson, B., & Tanter, R. (2015). The SIGINT Satellites of Pine Gap: Conception, Development and in Orbit. *Nautilus Institute for Security and Sustainability*. Available at: https://nautilus.org/wp-content/uploads/2015/10/PG-SIGINT-Satellites.pdf.

HawkEye 360. (2020, January). Pioneering spectrum awareness analytics from space. *SatMagazine*. Available at: http://www.satmagazine.com/story.php?number=1983820634.

Kratos Defense. (2023, April 17). *Espionage in Orbit: Satellite or Spy?* Available at: https://www.kratosdefense.com/constellations/articles/espionage-in-orbit-satellite-or-spy1.

SatelliteObservation.net. (2016, November 6). *History of the French reconnaissance system*. Available at: https://satelliteobservation.net/2016/11/06/history-of-the-french-reconnaissance-system/.

The CubeSat Program. (2020). *CubeSat design specification* (Rev. 14.1). Cal Poly SLO. Available at: https://www.cubesat.org/s/CDS-REV14_1-2022-02-09.pdf .