Application for Conventional Experimental Authority

Produced by Care Weather Technologies, Inc. for the Veery-0E Mission

Narrative Description

CAREWEATHER

Revision History and Signatures

Revision	Notes	Produced By	Date
A	First Version	Patrick Walton CEO, Care Weather Veery Mission Manager	4/19/2023

DESCRIPTION OF PROPOSED EXPERIMENTATION

Pursuant to Sections 5.54, 5.61, and 5.64 of the rules of the Federal Communication Commission ("Commission")[1], Care Weather Technologies ("Care Weather") respectfully requests conventional experimental authority for a period of two years to operate its Veery-0E (Hatchling Veery) low-Earth orbit 1U cubesat with an Iridium 9603 modem transmitting and receiving in the 1618.725-1626.5 MHz band.

Experimental authority will enable Care Weather to make significant progress in its mission to address critical gaps in U.S. weather capabilities by testing its third satellite, Veery-0E. This experiment focuses on the evaluation and validation of new satellite subsystems, such as a high-reliability electronic deployables release mechanism, software for enhanced satellite relay communication over the Iridium network, and an improved attitude determination and control system to ensure accurate Earth-pointing control. Veery-0E also supports re-flight of Veery-FS1 experiments that were impeded by anomalies on Momentus Vigoride. This experiment is essential to advance the readiness of Care Weather's satellite bus technologies for seamless integration with its future satellite-based weather sensing instruments.

By testing and refining these critical subsystems on orbit, Veery-0E will lay the foundation for the integration of future weather sensing payloads, such as wind-sensing radars (scatterometers). Ensuring the reliability and performance of these subsystems is crucial before investing in Care Weather's weather sensing satellite constellation. This constellation will significantly improve global weather forecasting, maritime safety, and hurricane monitoring.

[1] *See* 47 C.F.R. §§ 5.54, 5.61, and 5.64.

This will help mitigate the dramatically rising cost of hurricanes to American infrastructure. A timely grant of the requested experimental authority would therefore strongly serve the public interest and contribute to advancements in weather monitoring and prediction in a professional and efficient manner.

I. Background

Of all the satellite datasets incorporated into global numerical weather forecasts, ocean surface vector winds measured by scatterometers improve forecast accuracy more than measurements from any other satellite sensor.[2] Unfortunately, these measurements are one of the least available by quantity of measurements.

In the 1980s and 1990s, the United States led the world in satellite scatterometer development and operation with the NSCAT and SeaWinds scatterometers. While recent dramatic growth in hurricane damages has underscored the need for improved weather forecasting, the U.S. has fallen behind in scatterometry, decommissioning its last scatterometer in 2016. The United States has become fully reliant on foreign governments for this critical dataset. The development and operation of new scatterometer systems is a priority for national security, weather and maritime safety, and for U.S. leadership in space and weather forecasting. Many follow-on missions have been proposed, but all have been too cost prohibitive for limited national Earth science budgets.

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[2] See "Impact per observation" in Giovanna De Chiarra, et al. "On the impact of scatterometer winds in coupled and uncoupled DAS: preliminary results." International Ocean Vector Winds Science Team Meeting. 2017.

Care Weather's mission is to reinstate U.S. leadership in scatterometry by significantly reducing the cost of scatterometers. Achieving this cost reduction involves optimizing the volume and performance of satellite bus technologies, which will eventually enable seamless integration with advanced sensors. To accomplish this, Care Weather must develop and verify in-house technologies through on-orbit testing.

To this end, Care Weather is building the Veery-0E satellite to conduct on-orbit testing of custom satellite bus subsystems, which are crucial for the success of its future nanosatellite scatterometer, "Veery." The tests to be conducted during the mission include fully Earth-pointing control, radio data rate stress testing, and validation of the enhanced attitude determination and control system. Moreover, the mission will feature the first orbital testing of Care Weather's high-voltage radar power system, paving the way for future radar testing.

The verification of these systems on-orbit equips Care Weather with the technical assurance required to further integrate them with the full Veery scatterometer on later missions. The Veery-0E, "Fledgling Veery", mission is an essential step towards Care Weather's goal of increasing the rate of ocean surface vector wind measurement ten-fold, providing earlier warnings for hurricanes and other forms of extreme weather.

II. Discussion

A. Veery-0E Satellite

Veery-0E subsystems include power, command and computing, communications, deployment mechanism, attitude determination, and attitude control. The power subsystem has been upgraded to 12V to support a future radar and features several reliability improvements. It includes solar panels, lithium-polymer batteries, and power management circuit boards. The command and computing subsystem consists of enhanced reliability computing hardware, a significant amount of software improvements for increased controllability, and over-the-air scripting capabilities. The communications subsystem includes an Iridium 9603 satellite modem with a body-mounted patch antenna (not deployed), as well as an amateur radio payload, which will be discussed in more detail below, with deployed dipole antenna.

The deployment mechanism subsystem has been updated with an electro-permanent magnet deployment system, replacing the servo-driven latch of Veery-FS1 for improved reliability. The attitude determination subsystem now features fine sun-sensors, an inertial measurement unit, and a magnetometer. The attitude control subsystem incorporates improvements for greater reliability in the 3-axis reaction wheels and magnetorquers.

In conformance with the Process for Limiting Orbital Debris, NASA-STD-8719.14A, the Veery-0E satellite does not generate debris as part of normal operations, there is no material probability for on-orbit breakup, no debris will survive re-entry, and there is very low probability for an on-orbit conjunction and human casualty risk. The satellite will be launched into a 550 km circular orbit with an inclination of 97°. Veery-0E's control system points it in a low-drag orientation that can extend orbital life up to 12 years. However, when the mission is completed, this control system will be powered off, allowing Veery to passively drag-stabilize in its high-drag orientation, passively disposing of Veery within 2 years.

As described in more detail in the attached Orbital Debris Assessment Report[3] and for the avoidance of doubt, Care Weather has (i) assessed and limited the amount of debris released in a planned manner during normal operations, and has assessed and limited the probability of the space station becoming a source of debris by collisions with small debris or meteoroids that could cause loss of control and prevent post-mission disposal; (ii) assessed and limited the probability of accidental explosions during and after completion of mission operations; (iii) limited the probability of the space station becoming a source of debris by collisions with large debris or other operational space stations; and (iv) detailed the post-mission disposal plans for the space station at end of life, including an assessment of the probability of human casualty as a result. Thus, this application conforms to the requirements of Section 5.64(b) of the Commission's rules, 47 C.F.R. § 5.64(b).

B. Veery-0E Satellite Launch and Operations

Veery-0E is flying in the Exolaunch Exopod dispenser on the SpaceX Falcon 9 Transporter 10 launch. This launch will take place in the United States. The mission authorization and operation timeframes are included in the Table 1 below.

Table 1. Mission Authorization and Operation Timeframe	
Authorization grant-by date (integration):	November 1, 2023
Launch date:	January 1, 2024
Date for initiation of on-orbit operations:	0-3 days after launch
Expected mission duration:	2 years

[3] *See* Attachment 1 Veery0E Orbital Debris Assessment Report.

Upon release, Veery-0E's power system will be reconnected to its batteries by its separation switches. This will power the microcontroller system, which will initiate timers that ensure deployables are released and radio transmissions begin at a safe separation distance from the upper stage. When the deployment timer is completed, the microcontroller will initiate deployment of solar panels and the dipole antenna. When the radio timer is completed, the radios will begin communications with the Iridium satellite network.

C. Iridium Satellite Relay

The Veery-0E satellite uses an Iridium satellite relay to communicate with Care Weather mission control. The Iridium satellite relay system uses an Iridium 9603 satellite modem, which has been routinely granted in other circumstances,[4] and body-mounted 25mm Iridium single-feed, non-deployable ceramic patch antenna manufactured by Taoglas, Model CGIP.25.4.A.02.[5] The antenna has a peak gain of 5 dBi and operates with a bandwidth of 7.275 MHz (the 1618.725 – 1626.5 MHz band). A companion application for experimental authority will be filed by Iridium authorizing the communications from the Iridium satellite system to the Veery-0E satellite.

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[4] *See, e.g.*, Care Weather Technologies, Inc., ELS File Nos. 1840-EX-ST-2020 and 1838-EX-ST-2021 (authorizing communication with the Iridium 9603 modem); *see also* Capitol Technology University, ELS File No. 0033-EX-CN-2017 (authorizing communication with the Iridium 9603 modem); *see also* Thomas Jefferson High School Partnership Fund Inc., ELS File No. 0950-EX-CN-2018) (authorizing communication with the Iridium 9602 modem).

[5] See Attachment 2 Antenna Beam Patterns. Note that the Taoglas antenna beam pattern information includes antenna performance at 1575.42 MHz for GPS/Galileo reception. However, only the radiation pattern at 1621 MHz for communication with the Iridium system is relevant to this application. There are no Earth stations in this filing, so no Earth station antenna diagrams are included.

D. Hosted Radio Payload

The Veery-0E satellite will include an amateur radio system capable of communication in the 435-438 Mhz amateur band. This radio will be switched off unless our amateur partners at BYU obtain authorization for its use.[6] Primary operation of this payload will be conducted by Brigham Young University. This payload will be coordinated with the IARU separately by BYU. Care Weather will require proof of IARU coordination before enabling this radio payload to operate. BYU will coordinate with others in the amateur community to provide access to all necessary connection details and retrieved data. The amateur radio communications system includes a Care Weather Trill radio and tape-spring dipole antenna, both manufactured by Care Weather.

D. Experimental Subsystem Descriptions

Care Weather's custom satellite bus and radar support technologies on Veery-0E require in-flight testing to advance their readiness for integration with the full satellite scatterometer. These systems include:

1. *Reflight of Veery-FS1 experiments:*
    a. *High-accuracy, integrated attitude determination system:* attitude determination software will integrate the fine sun sensor array, magnetometer, and inertial measurement unit ("IMU") measurements to estimate the spacecraft attitude. Raw measurements from these systems will be downlinked to ground for evaluation of

[6] An arrangement for deferral of use until authorization of this nature has been granted by the FCC previously. See *e.g.*, Care Weather Technologies, Inc., ELS File No. 1371-EX-ST-2021.

attitude determination performance. In addition, Iridium signal strength will be used to verify the performance over various combinations of orientations and rotation rates.

b. *Integrated attitude control system:* estimations of attitude generated by the attitude determination system will be used to measure strength and settling time of the reaction wheel attitude control system and control software.

c. *Next-generation computing, power, instrumentation, and software systems:* Informed by the Veery-RL1 mission, the new computing, power, instrumentation, and software systems contain many refinements over past iterations. The computing system incorporates more flexible computing capabilities, the power system has improved efficiency, the instrumentation system is more extensive providing more thermal and power measurements of the satellite with greater detail, and the software is more capable of managing the many added systems of Veery-0E.

2. *High-voltage radar power system*: The upgraded 12V power system will be evaluated by monitoring the voltage levels and current consumption to ensure sufficient power is provided to satellite systems while maintaining overall efficiency.
3. *Improved Earth-pointing control*: The enhanced attitude determination and control system performance will be assessed by analyzing data from the fine sun-sensor array, magnetometer, and IMU. Pointing accuracy, stability, and response time to control commands will be evaluated on orbit.

4. *Electronic antenna release mechanism*: The electro-permanent magnet deployment system's reliability and effectiveness will be tested by measuring the deployment time, antenna position, and the system's ability to maintain a locked state during the mission.
5. *On-orbit re-programming*: The Veery-0E satellite's computing capabilities will be tested by executing on-orbit software updates and analyzing the satellite's ability to adapt to new commands, ensuring improved mission adaptability and responsiveness.

These tests, conducted during the Veery-0E mission, will help advance the development of Care Weather's custom satellite bus subsystems and new technologies, ultimately contributing to the company's goal of improving global weather forecasting, maritime safety, and hurricane monitoring.

E. Points of Contact

Care Weather remains the primary point of contact that can terminate *all* satellite transmissions, including those from the amateur radio payload, via the Iridium radio. In the unlikely event of an Iridium anomaly, Care Weather will coordinate with Dr. David Long of BYU to terminate transmissions of the amateur radio payload.

Primary contact who can terminate ALL satellite transmissions.

Point of Contact Name: Patrick Walton
Organization Name: Care Weather Technologies
Role: CEO, Mission Manager
Address: 144 W 400 N, Provo, UT 84601
Email: patrick@careweather.com
Telephone Number: (801) 227-4740

Secondary contact who can terminate ALL satellite transmissions.

Point of Contact Name: Alex Laraway
Organization Name: Care Weather Technologies
Role: CTO, System Engineer
Email: alex@careweather.com
Telephone Number: (801) 636-3388

Tertiary contact who can terminate ALL satellite transmissions.

Point of Contact Name: Dr. David G. Long
Organization Name: Brigham Young University
Role: Professor
Email: long@ee.byu.edu
Telephone Number: (801) 422-4383

F. International Telecommunications Union ("ITU") Compliance

It is understood that the commission will submit filings to the ITU on behalf of the applicant pursuant to international obligations for the coordination and registration of space network systems. Care Weather is aware that processing fees will now be charged by the ITU for satellite network filings and has attached a letter accepting responsibility to pay any cost recovery fees associated with this application.[7] Care Weather has also prepared the ITU Advance Publication Information ("API") submission along with the applicable Space Capture V.9.1 information for the Veery-0E satellite.[8]

[7] *See* Attachment 3 - ITU Cost Recovery Letter.
[8] See Attachment 4 - API Cover Letter; see also Attachment 5 - Veery0E ITU SpaceCap; see also Attachment 6 - Veery0E ITU SpaceVal Report; see also Attachment 7 - Veery0E ITU SpacePub Report.

G. NOAA Commercial Remote Sensing Regulatory Compliance

NOAA has determined that no Earth remote sensing license is required for the Hatchling Veery system.[9] Veery-0E is a Hatchling Veery system and the factual circumstances of Veery-0E match those provided to NOAA.

H. Electromagnetic Compatibility

Care Weather recognizes its limited experimental operations cannot create interference into, and must accept interference from, authorized systems (including satellite systems) in the band. Care Weather will seek to coordinate its proposed operations with co-frequency operators to the extent required. To facilitate NTIA coordination, Care Weather has attached a completed NTIA space record data form.[10]

I. Public Interest Considerations

The Veery-0E mission is an integral part of Care Weather's technology development plan and ultimate goal of developing and operating low-cost, miniaturized, satellite-based scatterometers that increase ocean surface vector wind measurements exponentially to enhance weather forecasting for the protection of lives and livelihoods. Care Weather has partnered with and has received support from a range of U.S. government agencies and affiliated academic institutions, including the National Science Foundation,[11] NASA, the Air Force, the U.S. Forest Service and the University of Utah, as well as U.S. international partners, including the U.K.

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[9] *See* Attachment 8 - Fledgling Veery NOAA Determination Letter
[10] *See* Attachment 9 - NTIA Space Record Data
[11] See NSF Award Number 2304609.

Meteorological Office.[12] Thus, there is a strong government interest in conducting the Veery-0E mission.

III. Conclusion

In view of the foregoing, Care Weather respectfully requests a conventional experimental license to operate the Veery-0E satellite for a period of two years in accordance with the specifications described herein.

[12] *See* Attachment 10 - Letters of Support.