Application for Conventional Experimental Authority

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

Narrative Description

CAREWEATHER

Revision History and Signatures

Revision	Notes	Produced By	Date
A	First Version	 Patrick Walton CEO, Care Weather Veery Mission Manager	4/16/23

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-0F low-Earth orbit 1U cubesat with the following spectrum allocations:

- Iridium 9603 modem transmitting and receiving in the 1618.725-1626.5 MHz band,
- Care Weather custom radar transmitting and receiving in the 5255.1-5260.0 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 fourth satellite, Veery-0F. This experiment builds on Care Weather's recent small satellite radar to demonstrate pathfinder measurement of ocean surface wind speed. This requires evaluation and validation of new satellite subsystems, as well as refinement of existing satellite and radar subsystems, including refined radar hardware, upgraded solar and antenna deployment actuators. Veery-0F also includes a suite of new software, including a flight operating system for A-scale processor command and control, full attitude determination and control software, Iridium pointing software for improved inter-satellite connectivity, and radar calibration with built-in data transfer.

By testing and refining these critical subsystems on orbit, Veery-0F will lay the foundation for the enhancement of its wind-sensing radars (scatterometers) and the addition of other weather payloads. Ensuring the reliability and performance of these subsystems is crucial

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

before investing in Care Weather's full vision for a weather sensing satellite constellation capable of 10X more frequent mapping of global sea winds. This constellation will significantly improve global weather forecasting, maritime safety, and hurricane monitoring, which will help mitigate the dramatically rising cost of extreme weather 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

[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.

follow-on missions have been proposed, but all have been too cost prohibitive for limited national Earth science budgets.

Care Weather's mission is to reinstate U.S. leadership in scatterometry by significantly reducing the cost of scatterometers. Achieving such cost reduction requires substantial volume optimization through tight integration of the satellite bus and sensor, necessitating the development and on-orbit verification of in-house technologies.

To this end, Care Weather is building the Veery-0F satellite to conduct on-orbit testing of a radar system as a precursor to its future small scatterometer, "Veery." Veery-0F will also flight qualify custom satellite bus subsystems. The primary objective of this satellite is to demonstrate measurement of ocean surface winds using Care Weather's in-house systems. Tests of refined software, communications, and attitude control will precede and lay the way for this objective.

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-0F 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-0F Satellite

Veery-0F subsystems include radar, power, command and computing, communications, deployment mechanism, attitude determination, and attitude control. The radar subsystem includes a refined, in-house radar backend system and a patch array antenna. This radar has

improved noise performance, enabling successful measurement of ocean surface winds.The power subsystem includes solar panels, lithium-ion 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. 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 shape-memory alloy deployment system, improving on past deployment systems with repeatability and reliability. The attitude determination subsystem includes hardware tested on Care Weather's previous satellites with a new suite of integrated software enabling Earth pointing. This hardware includes 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-0F 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 sun-synchronous low-Earth orbit (below 590 km). Veery-0F passively drag-stabilizes in its high-drag orientation, passively disposing of Veery within 5 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-0F Satellite Launch and Operations

Veery-0F is flying in the Exolaunch Exopod dispenser on the SpaceX Falcon 9 Transporter 12 launch. This launch will take place in the United States. The mission authorization and operation timeframes are included in Table 1 below.

Table 1. Mission Authorization and Operation Timeframe	
Authorization grant-by date (integration):	August 1, 2024
Launch date:	October 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-0F'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. After commissioning of the Iridium communications system and the attitude determination and control system, Care Weather will initiate testing of the radar.

C. Weather Radar Pathfinder

The Veery-0F satellite is equipped with a C-band weather radar system operating in the 5.255.1-5.260.0 GHz band, which has been granted previously.[4] The radar is a scatterometer, a coarse imaging radar system that utilizes Linear Frequency Modulated Interrupted Continuous Wave (LFM-ICW) range-doppler processing to segment Veery-0F's footprint into long, thin slices for coarse wind measurement. When passing over Care Weather's receiver in Utah, the radar transmits an FSK radar calibration signal with integrated data. The radar system uses a body-mounted, 10 cm by 10 cm, non-deployable patch array antenna. The antenna has a peak gain of 11 dBi.

[4] *See, e.g.*, Care Weather Technologies, Inc., ELS File No. 0675-EX-CN-2023.

D. Iridium Satellite Relay

The Veery-0F 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,[5] and body-mounted 25mm Iridium single-feed, non-deployable ceramic patch antenna manufactured by Taoglas, Model CGIP.25.4.A.02.[6] 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-0F satellite.

D. Hosted Radio Payload

The Veery-0F 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.[7] 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

[5] *See, e.g.*, Care Weather Technologies, Inc., ELS File Nos. 1840-EX-ST-2020, 1838-EX-ST-2021, and 0675-EX-CN-2023 (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).

[6] 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.

[7] Care Weather has a previous arrangement of this nature with BYU for ELS File No. 0675-EX-CN-2023, for which BYU has received IARU authorization and is working on FCC authorization. Care Weather is compliant with its responsibility to keep this radio off until BYU receives authorization.

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.

E. Experimental Subsystem Descriptions

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

1. *Scatterometer ocean surface wind sensor*: Veery-0F builds on lessons of Care Weather's previous satellite to refine the radar's noise performance to better support orbital operation. This new radar will be capable of measuring radar backscatter from the Earth's surface and process it into coarse-resolution images of ocean surface winds. The radar's performance will be assessed by comparing on-orbit measurements of ocean winds to ground-truth data.
2. *Central flight operating system:* Care Weather's previous satellite demonstrated limited operation of an A-scale processor for high-rate computing. Veery-0F builds on this experience by transferring the majority of command handling and mission management to this A-scale processor with Care Weather's spaceflight operating system. This operating system lays the groundwork for enhanced attitude control and radar software.
3. *Attitude determination and control software for nadir pointing:* Care Weather's past satellites demonstrated and characterized Care Weather's attitude determination and

control hardware. Veery-0F puts this hardware to full use, integrating it with a complete software system for nadir-pointing wind measurement operations.

4. *Shape memory deployment actuators:* Veery-0F demonstrates Care Weather's new deployment actuators that enable repeatable release of deployables, paving the way for the larger deployables that will be required for the future Veery scatterometer system.

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

F. 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. The radar only operates upon command via the Iridium link, so if Iridium contact is lost, then all radar transmissions will be terminated by default.

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

G. 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.[8] Care Weather has also prepared the ITU Advance

[8] *See* Attachment 3 ITU Cost Recovery Letter.

Publication Information ("API") submission along with the applicable Space Capture V.9.1 information for the Veery-0F satellite.[9,10]

H. NOAA Commercial Remote Sensing Regulatory Compliance

NOAA has granted an Earth remote sensing license for three satellites in the Fledgling Veery series, of which Veery-0F is the second.[11]

I. 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.[12]

J. Public Interest Considerations

The Veery-0F 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

[9] *See* Attachment 4 API Cover Letter; see also Attachment 5 Veery0E SpaceCap; see also Attachment 6 Veery0E SpaceVal; see also Attachment 7 Veery0E SpacePub; see also Attachment 11 Veery0E GIMS; see also Attachment 12 Veery0E Radar Orientation, which should be included as the first attachment to the ITU API.

[10] The SpaceVal form shows a warning for the radar pulse length exceeding 2 ms. This warning can be ignored. The pulse length for Veery0E is 3.5 ms, which is consistent with previous scatterometers, such as the ASCAT scatterometers on Europe's MetOp satellites, which use a 10 ms pulse length.

[11] *See* Attachment 8 Fledgling Veery NOAA License

[12] *See* Attachment 9 NTIA Space Record Data

and has received support from a range of U.S. government agencies and affiliated academic institutions, including the National Science Foundation,[13] NASA, NOAA, the Air Force, the U.S. Forest Service, and the University of Utah, as well as U.S. international partners, including the U.K. Meteorological Office.[14] Thus, there is a strong government interest in conducting the Veery-0F mission.

III. Conclusion

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

[13] *See* NSF Award Number 2304609.
[14] *See* Attachment 10 Letters of Support.