DESCRIPTION OF PROPOSED EXPERIMENTATION

Pursuant to Sections 5.54 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-RL1 low-Earth orbit 1U cubesat with an Iridium 9603 modem transmitting and receiving in the 1618.725-1626.5 MHz band.

Care Weather currently holds a special temporary authorization ("STA") for the experiments described herein.[2] Conventional experimental authority is necessary to ensure Care Weather can continue its ongoing in-orbit testing and validation of the custom satellite components following testing delays with the Iridium relay. Such experimentation will be identical to the operations approved in the STA.[3]

Experimental authority to complete these experiments will enable Care Weather to establish an important milestone towards Care Weather's broader mission to fill critical gaps in U.S. weather remote sensing capabilities by enabling Care Weather to develop satellite bus technologies that can be tightly integrated with its future satellite wind-sensing radar (a "scatterometer") to produce the final, compact instrument system. Timely grant of the requested experimental authority would therefore strongly serve the public interest.

[1] *See* 47 C.F.R. §§ 5.54, 5.64.

[2] *See* Care Weather Technologies, ELS File No. 1840-EX-ST-2020, Call Sign WR9XNG (granted Feb. 18, 2021) ("STA"). Care Weather hereby incorporates by reference the information and attachments filed in the STA to the extent necessary to authorize the immediate application.

[3] Care Weather understands that when a conventional experimental license application is timely filed, STA operations may continue in accordance with the other terms and conditions of the STA pending disposition of the license application. *See* 47 C.F.R. § 5.61(c).

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. 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. In recent years, all U.S. scatterometers have reached their end of life and 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.

Significant cost reduction requires tight integration between sensor and satellite bus to the point of individual components carrying both sensor and satellite functionalities. To this end, Care Weather constructed the Veery-RL1 satellite to demonstrate custom satellite computing, power, and avionics systems designed and manufactured by Care Weather.

Verification of these systems on-orbit will provide Care Weather with the technical assurance required to further integrate them with Care Weather's nanosatellite scatterometer on later missions. Such experiments will also further continue to development of Care Weather's integrated solar panel, antenna, and radiator ("SPAR") technology to permit tight integration and miniaturization of satellite subsystems.[4] Continuation of the Veery-RL1 mission is an important

[4] Care Weather recently proposed an integrated SPAR system to the NASA Earth Science Technology Office, in partnership with NASA Marshall Spaceflight Center and Brigham Young University. When complete, this component will fill solar power, waste heat management, antenna, and radar front end functionalities. However, before developing this integrated system, Care Weather must develop and test individual component technologies such as those included in the Veery-RL1 mission.

step toward Care Weather's goal of increasing the rate of ocean surface vector wind measurement ten-fold to provide earlier warnings for hurricanes and other forms of extreme weather.

II. Discussion

A. Veery-RL1 Satellite

The Veery-RL1 satellite is a 1U cubesat designed and manufactured by Care Weather. The custom Veery-RL1 satellite is comprised of commercially available cubesat components, complies with the operational requirements of the CubeSat Design Specification Revision 13, and is otherwise consistent with cubesat manufacturing standards.

Veery-RL1 satellite subsystems include power, command and computing, communications, structures, drag, thermal control, attitude determination and control. The power subsystem includes body-mounted solar panels, lithium-polymer batteries, and power management circuit boards. The command and computing subsystem includes a watchdog, a thermal timeout system, microcontroller, and microprocessor. The drag subsystem includes four 8cm x 9cm polycarbonate panels deployed from four of the satellite faces. These panels are deployed using a whip approach wherein the panels are constrained by the deployer and are thereby released automatically upon separation from the dispenser. The attitude determination and stabilization subsystem includes an inertial measurement unit and six sun-sensing photodiodes for attitude determination and a set of three reaction wheels for attitude control.

The Veery-RL1 satellite is also equipped with an experimental AIS-gPPT3-1C Series Integrated Pulsed Plasma Propulsion Module which uses Teflon as a fuel source and does not require pressure vessels.[5] Care Weather is testing this experimental propulsion module for on-

[5] An overview of the propulsion module is available of Applied Ion Systems' website. *See* AIS-gPPT3-1C Series Integrated Pulsed Plasma Propulsion Module, *available at*

orbit performance. The propulsion system is not used for station keeping or for significant changes to orbital parameters. All thruster tests will be oriented to lower the Veery-RL1 satellite's orbit.

In conformance with the Process for Limiting Orbital Debris, NASA-STD-8719.14A, the Veery-RL1 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 is currently in a 550 km circular orbit with an inclination of 45°. The orbital lifetime of the spacecraft is therefore estimated to be approximately 3.5 years until full demise, which includes the drag effects of its deployed drag panels (well within the current 25-year benchmark).

As described in more detail in the attached Orbital Debris Assessment Report[6] and for the avoidance of doubt, Care Weather (i) has 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) has 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 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).

https://appliedionsystems.com/portfolio/ais-gppt3-1c-series-integrated-propulsion-module/ (accessed on Dec. 6, 2020).

[6] *See* Attachment 1 (ODAR). The report has been updated from the version filed in the STA to reflect a minor change to the description of under-temperature protection of the Veery-RL1 battery system.

B. Veery-RL1 Satellite Launch and Operations

Veery-RL1 was launched on March 22, 2021 in the Maxwell dispenser on Rocket Lab's Electron launch vehicle. This launch took place at Rocket Lab's Mahia, New Zealand launch site and Care Weather fully complied with New Zealand's space payload regulations.

Currently, the status of all systems onboard the Veery-RL1 are nominal. The initial operational lifetime of the satellite was estimated to be six (6) months. However, considering the good health of the satellite and the need for more time to perform experimental operations, the operational lifetime of the Veery-RL1 is estimated to be at least two (2) years.

C. Iridium Satellite Relay

The Veery-RL1 satellite utilizes an Iridium satellite relay to communicate with Care Weather mission control. The communications subsystem includes an Iridium 9603 satellite modem and body-mounted 25mm Iridium single-feed, non-deployable ceramic patch antenna manufactured by Taoglas, Model: CGIP.25.4.A.02.[7] 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 filed by Iridium was granted on March 5, 2021 authorizing the communications from the Iridium satellite system to the Veery-RL1 satellite,[8] and Iridium has filed for a renewal of its experimental authority under the same parameters (together the "Companion Applications").[9] Care Weather incorporates by reference all operational information pertaining to the Iridium satellite relay as filed in the Companion Applications to the extent necessary to grant the immediate application.

[7] *See* STA, Attachment 2 (Antenna Beam Pattern). Note that the beam pattern information is pulled directly from the Taoglas data sheet, which 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.

[8] *See* Iridium Satellite, LLC, ELS File No. 1931-EX-ST-2020, Call Sign WR9XSF (granted Mar. 5, 2021).

[9] *See* Iridium Satellite, LLC, ELS File No. 1323-EX-ST-2021, Call Sign WR9XSF (filed Mar. 13, 2021).

To date, there have been no cases of interference in the experimental operations of the Veery-RL1 satellite. Of course, Care Weather will continue operate on a non-protected, non-harmful interference basis. If harmful interference to an established radio service occurs, Care Weather will cease all communications until it is demonstrated that no further harmful interference will occur.

D. Experimental Subsystem Descriptions

To achieve the Veery-RL1 cubesat system integration and low-cost objectives, the Veery-RL1 satellite features subsystems and software of Care Weather's own design and manufacture which must be spaceflight tested, including:

- *Care Weather solar panels*: The solar charge current and voltage will be measured over time. The effect of thermal cycling and UV degradation of the cells over time on the solar panels will be evaluated.
- *Care Weather solar charge controller*: Measurement of solar charge current and voltage confirm the combined effect of varying solar conditions, battery charge states, and thermal cycling on the solar charge controller's performance.
- *Care Weather battery charge/discharge controller*: Measurement of the battery voltage, charge current, and discharge current will confirm the combined effect of varying input solar power, system power draw, and thermal cycling on the performance of the controller in regulating charge and discharge.
- *Care Weather electrical power manager*: Measurement of solar charge current, solar voltage, battery state, battery voltage, battery charge current, battery discharge current, and software state will confirm the effect of various combinations of system conditions (solar illumination, thermal cycling, UV, charge currents and voltages, discharge currents and voltages) on the success of the electrical power manager in maintaining appropriate power characteristics and ensuring the satellite is only operated under the appropriate thermal and power conditions.
- *Care Weather coarse sun-sensors*: Measurement of tumble by the inertial measurement units ("IMU") along with solar charge currents and system temperatures will be used to verify the performance of the coarse sun sensors over various combinations of solar illumination, rotation rates, and thermal cycling.
- *Care Weather watchdog*: The performance of the watchdog in resetting the system over time in the event of solar energetic particles or state errors will be observed by saving a log of software states and bootup operation.

- *Care Weather reaction wheels*: measurements from the gyroscope on the IMU and the coarse sun sensor array will be used to measure the rotation of the satellite and reaction wheel output. These measurements will be compared with attitude measurements and drag estimations to evaluate the performance of the reaction wheels and attitude control software.

- *Care Weather flight software*: software state will be logged over time to confirm software performance under various combinations of the measured system and environmental conditions measured above.

These systems continue to be extensively tested on the ground and require further on-orbit testing to further evaluate performance and achieve final design parameters.

As discussed above, Care Weather is also carrying an experimental propulsion module for performance, as well as for conjunction avoidance in the unlikely event that maneuvering may be necessary during the satellite's brief orbital lifetime. Measurement of discharge current and acceleration, combined with tracking of the satellite from the ground, will confirm the capabilities and power consumption of this experimental first-generation nanosatellite thruster developed and manufactured by Applied Ion Systems.

E. Points of Contact

Primary contact who can terminate ALL satellite transmissions.

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Secondary contact who can terminate ALL satellite transmissions.

Point of Contact Name:	Alex Laraway
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F. International Telecommunications Union ("ITU") Compliance

The Commission has submitted filings to the ITU on behalf of Care Weather pursuant to international obligations for the coordination and registration of space network systems and Care Weather will continue to engage with the Commission regarding coordination to the extent required.[10]

G. Public Interest Considerations

The Veery-RL1 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 to increase ocean surface vector wind measurements exponentially in order to enhance weather forecasting for safety of life and other purposes. Care Weather is partnering with and has received support from a range of U.S. government agencies and affiliated academic institutions, including NASA, the Air Force, the U.S. Forest Service and the University of Utah.[11] Thus, there is a strong government interest in conducting the Veery-RL1 mission.

III. Conclusion

In view of the foregoing, Care Weather respectfully requests a conventional experimental license to continue testing of the Veery-RL1 satellite for a period of two years in accordance with the specifications described herein.

[10] The ITU Advance Publication Information submission along with the applicable Space Capture V.9 information for the Veery-RL1 satellite are attached to the STA and are incorporated herein to the extent necessary. STA, Attachments 4-5. Moreover, Care Weather has agreed to pay any cost recovery fees associated with its application. *Id.*, Attachment 3.

[11] *See id.*, Attachment 6.