University of North Carolina at Wilmington Center for Marine Science SOCON Project

A. Overview of the SOCON Project

The University of North Carolina at Wilmington Center for Marine Science ("UNCW/CMS") is requesting FCC experimental authority for implementation and operation of the Sustained Ocean Color Observations with Nanosatellites ("SOCON") project. UNCW/CMS was awarded a grant from the Gordon and Betty Moore foundation to carry out the SOCON project as a "proof-of-concept" on-orbit mission for testing and validating the viability of producing scientific quality ocean color data using CubeSat technology that will allow for sustained, high spatial and temporal resolution information about surface ocean processes. Working together with NASA through a Nonreimbursable Space Act Agreement ("SAA") between UNCW/CMS and the NASA Science Mission Directorate, the goal is to develop next generation ocean color data collection methods via low-Earth orbiting satellites and expanding accessibility to the SOCON science data through free distribution to the international research community.

The ocean color sensor developed for the SeaHawk spacecrafts has been designed to help meet the *International Ocean-Colour Coordinating Group's* requirement for a continuous time series of observations to estimate ocean properties such as phytoplankton chlorophyll-a with the radiometric accuracy of SeaWiFS (Sea-viewing Wide Field-of-view-Sensor), or to gain better insight into climate variability and change. SeaWiFS' legacy, which flew for 13 years, is a well-calibrated data record giving scientists one of the best benchmarks available to study the planet's biological response to a changing environment. SeaWiFS enabled us for the first time to monitor the biological consequences of that change - to see how the things we do, and how natural variability, affect the Earth's ability to support life. *This "Game Changer" satellite* is *130 times smaller, 45 times lighter, 8+ times better resolution (120-m vs 1-km) at 10% of development time and construction costs as SeaWiFS.*

Specifically, UNCW/CMS requests authority to construct, launch and operate two low- Earth orbit CubeSats, SeaHawk-1 and SeaHawk-2, on an unprotected, non-interference basis using the space-to-Earth downlink frequency band of 400.725 MHz – 400.825 MHz for TT&C communications and the data downlink frequency of 8100 MHz. NASA's Near Earth Network ("NEN") ground stations at Wallops Flight Facility in Virginia and the Alaska Satellite Facility at the University of Alaska Fairbanks will be scheduled for routine downlinks of the X-band science data which will then be transmitted directly to the NASA Ocean Biology Processing Group ("OBPG") at NASA Goddard Space Flight Center ("GSFC").

Clyde Space of Glasgow, Scotland, a leader in cutting-edge CubeSat technology, is constructing the satellites for the UNCW/CMS SOCON project. The satellites will be transported

to California for launch on the SpaceX Falcon 9 Launch Vehicle from Vandenberg Air Force Base. SeaHawk-1 is expected to be launched during 2Q2018 with an estimated launch date for SeaHawk-2 in 1Q2019.

Clyde Space is also under contract to UNCW/CMS to provide Telemetry, Tracking and Command (TT&C) services to monitor the status of the spacecraft and all its subsystems via its ground station in Glasgow, Scotland. UNCW/CMS, however, will at all times maintain operational control of the satellites and will provide a 24-hour contact to the FCC for any interference issues that may arise. The TT&C will routinely receive tasking requests from UNCW/CMS, appropriately format those requests, upload them to and have the spacecraft execute them. On direction from UNCW/CMS, the TT&C will execute command and control capability required by regulatory authorities to ensure that UNCW/CMS has the responsibility for and control of the spacecraft and its operation. For normal SOCON satellite operations (imaging scenes of ocean color), UNCW/CMS, in consultation with its NASA partners, will identify the specific scenes to be captured for downlinking to the NASA NEN and the OBPG. UNCW/CMS will then supply weekly updated image capture control information to Clyde Space for uplink to the spacecraft.

UNCW/CMS received a Grant of License from NOAA on October 26, 2017 "to Operate a Private, Space-Based, Remote Sensing System" for SeaHawk-1 & 2. After "thorough interagency review" NOAA waived the legal requirement that TT&C operations be maintained in the United States and approved TT&C operations by Clyde Space in Scotland. An Orbital Debris Assessment Report ("ODAR") was part of the application documents submitted and reviewed by NOAA prior to issuing its license.

B. The Specific Objectives Sought to be Accomplished

UNCW/CMS

- Working with Cloudland Instruments of Santa Barbara, CA, develop a miniaturized low-cost, multispectral, Ocean Color Sensor using Commercial Off-The-Shelf (COTS) parts capable of flight on a CubeSat, with spectral characteristics comparable to SeaWiFS collection of near-synoptic color data in open-ocean to coastal-margin to near-shore terrestrial environment.

- The sensor should have the capability of collection of the 8 SeaWiFS bands and be designed with form factor fit into a custom 3U (i.e., 3 Units or $10cm^3$ or 10 X 10 X 30 cm) CubeSat; have spatial resolution of 128 m and swath of 230 km in a 575 km LEO orbit.

- Working with Clyde Space, construct two 3U CubeSats to meet projected mission requirements, including mechanical interface design for accommodating the Ocean Color Sensor payload, a mission orbit of 575 km and a design lifetime of 18-24 months.

- Integrate sensor data into NASA's SeaWiFS Data Analysis System (SeaDAS) for processing, display, analysis, and quality control of ocean color data which can then be distributed worldwide to the scientific research community.

- Develop an engineering model of the sensor that will be constructed and retained at the Cloudland Instruments to evaluate and resolve potential questions or problems which might arise during sensor integration or while the first unit is in orbit.

NASA

- Provide pre-launch NASA/GSFC Code 618 Calibration Facility support in order for the Ocean Color Sensor instrument to have its spectral calibration verified with a monochromator and its absolute radiometric calibration checked against a Goddard integrating sphere prior to integration with the spacecraft bus. This radiometric calibration will improve the utility of data that it subsequently returns from orbit, and will allow direct comparison with other GSFC missions past and present.

- The NEN ground stations at Wallops Flight Facility in Virginia and the Alaska Satellite Facility at the University of Alaska Fairbanks will be scheduled for routine downlinks of the X-band science data at 8100 MHz which will then be transmitted directly to NASA Goddard Space Flight Center ("GSFC").

- The ocean color data downloaded from the SeaHawk satellite by the NEN will be supplied directly to the OBPG at NASA's Goddard Space Flight Center. OBPG's responsibilities will include the processing, calibration, validation and archive. This will include the development of Level 0-to-1 processing software and necessary changes to the SeaDAS (comprehensive image analysis package for the processing, display, analysis, and quality control of ocean color data). The OBPG will also provide assistance in developing targeted scheduling for the ocean color data collection.

- All data from the Ocean Color Sensor will be available free of charge to the international research community under the guidelines described in NASA's standard Earth Science Data Policy (https://science.nasa.gov/earth-science/earth-science-data/data-information-policy) via the Ocean Biology Distributed Active Archive Center (https://oceancolor.gsfc.nasa.gov/) which is co-located with the OBPG at NASA's Goddard Space Flight Center.

- Identify, via the CubeSat Launch initiative (CSLI), upcoming launch opportunities for SeaHawk where CubeSats are flown as auxiliary payloads on previously planned missions with a target circular, sun-synchronous, low-Earth orbit of 575 km, and an equatorial crossing of Noon +/ 90 min: 10:30AM – 1:30PM.

C. How the program of experimentation has a reasonable promise of contribution to the development, extension, expansion, or utilization of the radio art, or is along line not already investigated.

A report from the National Academy of Science *(National Research Council 2011)* discussed the need for sustaining and advancing ocean color research and operations. This report shows that ocean color satellites provide a unique vantage point for observing the changing biology in the surface ocean. Space observations have transformed biological oceanography and are critical to advance our knowledge of how such changes affect important elemental cycles, such as the carbon and nitrogen cycles, and how the ocean's biological processes influence the climate system. In addition, ocean color remote sensing allows scientists to assess changes in primary production, which forms the base of the marine food chain. Thus, continuous satellite observation of ocean color is essential to monitoring the health of the marine ecosystem and its ability to sustain important fisheries, especially in a time of global change and acidification.

It is hoped that the UNCW/CMS SOCON mission - the development and "proof-of-concept" of a miniaturized, low-cost, multispectral, ocean color sensor capable of flight on a CubeSat and with significantly higher spatial resolution than that of standard satellite systems - will lead to dramatic changes in the method of collecting and disseminating ocean color data via the use of CubeSats. High spatial resolution imagery will provide observation of sub-mesoscale variability, giving insights into mixing dynamics that are poorly understood. It will improve our ability to monitor fjords, estuaries, coral reefs and other near-shore environments where anthropogenic stresses are often most acute and where there are considerable security and commercial interests.

Due to the low volume, mass and cost, it will become practical to fly constellations of spacecraft with color sensor payloads, opening up opportunities that will significantly improve temporal sampling. The data from SOCON will have direct and significant relevance to many of NASA's programs and science objectives and could have a large impact in helping to address a number of critical societal needs, especially in the highly variable coastal regions of the world.

D. Estimated Experiment Duration

Pursuant to Part 5 of the Commission's Rules (§5.71 License Period), UNCW/CMS respectfully requests approval of a 5-year license for its experimental program due to the long lead times required for spacecraft construction, potential launch delays and a mission life for each SeaHawk satellite of between 18 and 24 months.

In summary, UNCW/CMS respectfully requests the Commission to grant its application for launch and experimental operation authority as detailed herein. To the extent possible, UNCW/CMS hopes that expedited consideration of this Application will be given in order to ensure favorable authorization in advance of the scheduled 2Q2018 launch of the SeaHawk-1 satellite.

Pursuant to the document *FCC-Guidance-DA-13-445A1*, UNCW/CMS provides the following:

Requested grant date: 20 March 2018

Critical date for shipment to launch site: 7 April 2018