Atmospheric and Space Technology Research Associates
Experimental License Modification Application
File No.: 0339-EX-CM-2023
Call Sign: WN2XPI

Explanation of Requested Modification to License
(Technical changes are highlighted in yellow)

Atmospheric and Space Technology Research Associates (Atmospheric) is seeking to modify its experimental license WN2XPI for the operations of a rapid revisit cloud imaging satellite, known as RROCI-2[1]. This satellite is an experiment being conducted for the US Space Force to determine how the satellite can improve in-theater weather imagery over the currently available technologies. The RROCI-2 satellite is a 12U satellite which is scheduled to launch in February 2024 on SpaceX's Transporter 10.

Atmospheric has been in the business of science and engineering for over 18 years. Atmospheric will own, operate, and control RROCI-2 for the duration of its mission.

Atmospheric recognizes that the federal review process of satellite applications can be lengthy, however, the launch slot in February 2024 was available, and Atmospheric is trying to finish the regulatory steps needed in time to meet the December 2023 integration date for the launch in February 2024.

Reason for Modification Request: On October 18, 2023, the RROCI-2 team at Atmospheric learned that SpaceX has changed the orbital altitude at which the RROCI-2 satellite will be released into orbit. The new release altitude will be 590 km. Upon learning of the altitude change, the team working on RROCI-2 instructed counsel to consult with the Federal Communications Commission on the recommended process for addressing the change. This modification request is being submitted to comply with the FCC's recommended process.

Technical Synopsis

- Spectrum Needed: 8025-8225 MHz – primary downlink, 100 Mbps data rate
  2217 MHz – backup downlink, 2 Mbps data rate, and
  1618.75 -1626 MHz – beacon
- Time of Use: downlink transmissions expected once per orbit
- Orbital Period: about 96.5 minutes, sun-synchronous, polar orbit
- Satellite Elevation: 590 km
- Orbital Inclination: 97.75 °
- Federal Contract #: SSC FA8808-23-9-0001
- Emission Designators: X band: 200MG1D – downlink of payload data
  S band: 4M00G1D – downlink of payload data, back up link
  Beacon: 35K0G1D – beacon transmissions

[1] Pronounced "Rocky".

Information Regarding Federal Contract

Federal Contract Number: SSC FA8808-23-9-0001
Federal Contracting Agency: US Space Force

Point of Contact on Contract: Lieutenant Allen Shadan

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Description of Experiment

Atmospheric has been developing advanced capabilities of imaging weather. This technology is of great interest to the US Air Force and US Space Force as they plan for future in-theater weather imagery support. After several successful rounds of research and development working under SBIR grants, Atmospheric developed the RROCI system to advance the science of cloud imagery for weather predictions. RROCI-2 is a 12U satellite which has been designed to incorporate multiple cameras with a satellite downlink and an electronic propulsion system. RROCI-2 will be orbiting the earth in a sun-synchronous orbit and capture still imagery at a rapid framerate. Atmospheric secured an imagery license from CRSRA at the Department of Commerce, which allows it to use its earth sensing imaging equipment. A modified imagery license that covers the operations of RROCI-2 is attached to this application.

RROCI-2 is scheduled to launch on SpaceX Transporter 10 and be released into orbit at 590 km.

X Band downlink operations: The cameras generate imagery files totaling about 12 gigabits of data on every orbit around the globe. The polar orbit will take RROCI-2 over an earth station operated by Kongsberg Satellite Systems (KSAT) in Svalbard which is expected to be used for early commissioning operations. This use is subject to the conditions that NASA has put on the license. Additional passes over the RBC Signals near-polar ground stations in Deadhorse, Alaska will be used for downlinking of imagery. RROCI-2 is expected to downlink an orbit's worth of imagery each time it passes over one of these earth stations, in accordance with the conditions that NASA has put on the license. Typical downlink operations are expected to take approximately 5 minutes, out of a 10 minute window when the satellite can see the receiving earth station. RROCI-2 is programmed so that its X band downlink radio is turned off unless it is downlinking images to an earth station. The radio link is essential to the demonstration of this innovative technology developed by Atmospheric.

Uplink operations: Atmospheric's instructions to the satellite will be sent over secure VPN from Atmospheric's headquarters (mission control) to one of the global KSAT ground stations or to the RBC Signals ground station in Deadhorse, Alaska. Those instructions will be uplinked to RROCI-2. Atmospheric will not operate its own uplink to its satellite. Atmospheric is seeking this license for

downlink operations only. The downlink operations are an essential component of the technology demonstration it is conducting for the US Space Force. The uplink frequency will be 2085.5 MHz.[2]

Atmospheric reviewed the conditions requested by NASA, which have been incorporated into its license WN2XPI, and it has agreed to the NASA limitations. This application does not seek to alter any of the previously authorized operations.

S band downlink operations: RROCI-2 has been designed with a backup downlink capability. That link operates in the S band with a center frequency at 2217 MHz. The capacity of the link is much lower, making it less appealing as a downlink solution. Nevertheless, the radio was incorporated into RROCI-2 to ensure that there is a failsafe system that can show the performance of the satellite if the X band link does not work properly. RROCI-2 is only expected to use the S band link about 20 times during the life of the experiment, presuming the X band link works as expected. The S band link is expected to send information down to the ground stations as well. RROCI-2 will use its S Band link in accordance with the conditions on its license.

Beacon Operations:

RROCI-2 will have a satellite beacon radio that communicates with the Iridium satellite constellation. The purpose of the beacon is to make the satellite easier to track. This beacon replaces the Globalstar beacon that was incorporated into RROCI.

The Iridium system is configured such that the radios use dynamic channel selection. The band specified in this application will allow the beacon to use any available channel within the band, in accordance with the protocols built into the Iridium system. The radio signals use only 460 mW of output power, with gain of 4.5 dBi, resulting in an ERP of 1.91 W.

Downlink Protocol for Imagery Data:

The cameras generate imagery files totaling about 12 gigabits of data on every orbit around the globe. The downlink operation is expected to take approximately 5 minutes, out of a 10 minute window when the satellite can see the earth station. Most downlink operations will use high latitude earth stations because of the frequency of orbital passes over those earth stations. RROCI-2 is programmed so that its X band downlink radio is turned off unless it is downlinking images to the earth station.

[2] Atmospheric anticipates that any uplink authorizations will have the same conditions that are on its experimental license WN2XPI. It will comply with all applicable conditions.

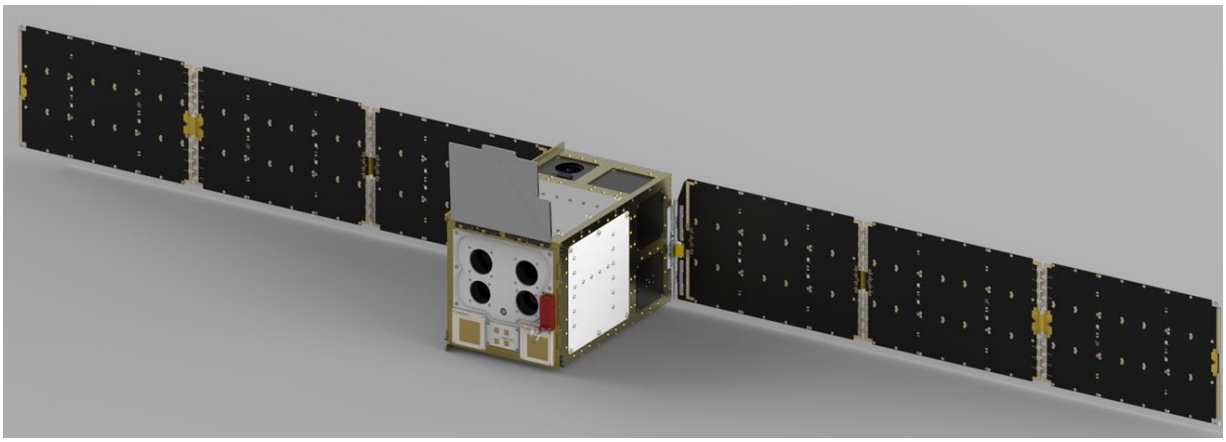

Figure 1: an image of RROCI on the workbench at the Atmospheric facilities

Length of Satellite Operations

Atmospheric has a contract to operate this satellite for a year after launch. The application seeks authorization for a full two-year experimental license. The reason that Atmospheric is seeking a 2-year license is that there is some possibility that its DoD customers will want to extend the contract for some additional period, whether a few weeks or months.

The satellite can function properly, maintaining its designated orbit for a full two years. Further, the satellite's propulsion system is adequate to support any necessary collision avoidance maneuvers during the operational period and still have sufficient capacity to deorbit the satellite at the end of its mission, whether that will be at the one-year mark or beyond.

Time of Use is Limited; Area of Operations is Limited

The satellite will orbit over the north pole every 96.5 minutes. The X band downlink may be in use 4-6 times per day over the ground stations, as needed. The X band radio will only be in use for about 5 minutes of each pass over a ground station. RROCI-2 will not downlink images on each pass over each ground station, and its X band radios will be turned off when it is not passing over a ground station. The ground stations selected give RROCI-2 the best opportunity to demonstrate that it is capturing key information and sharing that information promptly. RROCI-2 will operate in accordance with the limitations specified in the conditions added to the license by NASA.

The S Band link is expected to be used about once a week for demonstration of its capabilities, for testing the backup system, and for supplemental information downloads, if needed. This would be over one ground station, about once a week, if the X band link is working properly. If the X band link fails, for some reason, the S band link is the backup system for downloading imagery, and, in the event of the X band failure, the S band link would be used regularly at each pass over each ground station. This is not expected. Atmospheric would be glad to update the FCC in the event of some issues with the X band link.

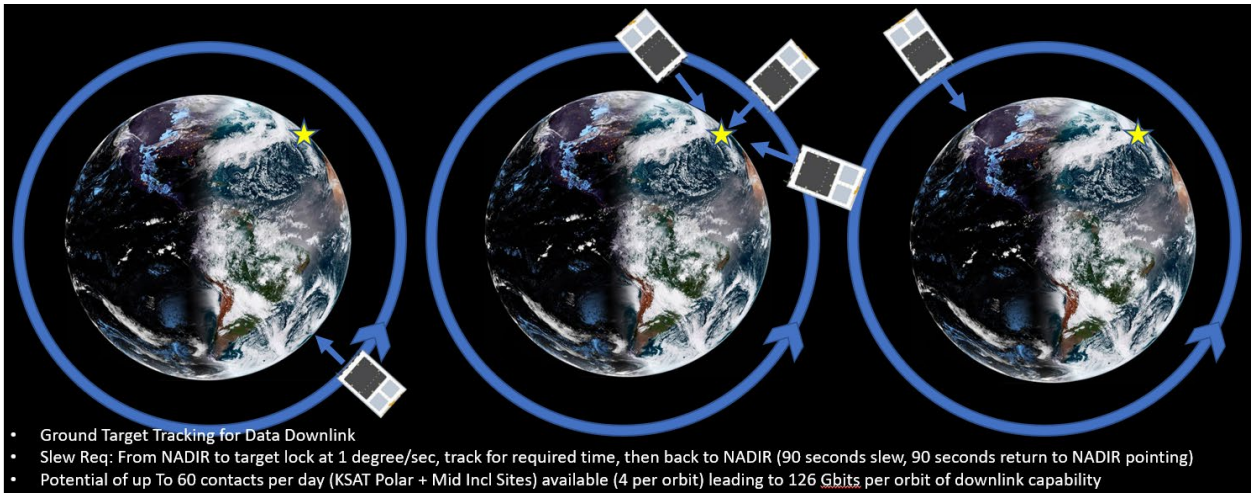

Figure 2. Theoretical image of the anticipated orbit of RROCI

All of the ground stations are listed in Table 2, below.

Satellite launch schedule

Atmospheric's RROCI-2 is scheduled to launch on a SpaceX rocket in February 2024. As noted elsewhere in this exhibit, the integration date will be in December 2023. Therefore, Atmospheric must have a modified license in hand in time for the satellite to be integrated into the rocket.

Ground Station Information

As noted above, Atmospheric has entered into contracts with KSAT and RBC Signals for ground station operations. KSAT, a Norwegian company with a US subsidiary, operates satellite ground stations worldwide. Its polar ground stations have limited use, so ground station services were secured in Deadhorse, Alaska. The ground stations that Atmospheric will use are listed in Table 2, below, with the caveat that Svalbard and Troll will only be used for commissioning the satellite:

Name of station, city and country	Lat	Long	X band	S band	#of contacts w/satellite per day, time of each
Svalbard, Norway	78-13-47 N	15-23-53 E	Beamwidth = 0.69 ° Gain: 47.01 dBi	Beamwidth = 2.56 ° Gain: 37.13 dBi	Satellite commissioning use only
Awarua, New Zealand	46-31-45 S	168-22-52 E	Beamwidth = 0.69 ° Gain: 47.01 dBi	Beamwidth = 2.56 ° Gain: 37.13 dBi	Contacts = ~ 1 x / day Duration - ~ 10 min / contact – subject to NASA conditions
Punta Arenas, Chile	52-56-17 S	70-51-28 W	Beamwidth = 0.69 ° Gain: 47.01 dBi	Beamwidth = 2.56 ° Gain: 37.13 dBi	Contacts = ~ 1 x / day Duration - ~ 10 min / contact – subject to NASA conditions
TrollSat, Queen Maud Land, Antarctica	72-00-06 S	2-31-32 E	Beamwidth = 0.69 ° Gain: 47.01 dBi	Beamwidth = 2.56 ° Gain: 37.13 dBi	Satellite commissioning use only
Deadhorse, Alaska, USA	70-11-27 N	148-26-07 W	Beamwidth = 0.69 ° Gain: 47.01 dBi	Beamwidth = 2.56 ° Gain: 37.13 dBi	Contacts = 10 x / day Duration - ~ 10 min / contact

Table 2. Ground Station details

LTAN
01:00 (13:00 pm LTDN)

Information Being Submitted with this Application

Deorbit Plan: An updated deorbit plan is attached to this exhibit as **Attachment A**, which accounts for the updated orbital altitude.

Conjunction Warnings Response Plan: On May 27, 2022, in response to inquiries from the FCC regarding the proposed operations of RROCI-1 while its application 0867-EX-CN-2021 was under review, Atmospheric submitted a conjunction warnings response plan to explain in detail how it would react to warnings regarding potential on-orbit collisions with space particles, orbital debris, or other satellites. Atmospheric will follow that plan. The Conjunction Warnings Response Plan is attached hereto as **Attachment B** to this exhibit.

ODAR: Atmospheric has rerun the NASA DAS program for operation of RROCI-2, using the latest version of the software. The RROCI-2 satellite is in compliance.

The change in orbital elevation does not change the results of the ODAR analysis. An updated ODAR showing the proper orbital altitude is attached.

ITU API: Atmospheric is submitting an updated API for the operations of RROCI-2, with updated orbital altitude, inclination, and orbital period.

NTIA Space Record Data: Atmospheric has prepared a new NTIA Space Record Data Form that changes the orbital altitude, inclination, and orbital period.

ITU Cost Recovery Letter: Atmospheric is submitting an additional ITU Cost Recovery Letter with this application, confirming its commitment to cover any costs that the ITU might impose for its evaluation of RROCI-2 or the publication of information regarding RROCI-2.

Stop Buzzer POC

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Conclusion

Atmospheric is seeking to modify its experimental license, WN2XPI, for its RROCI-2 satellite operations, for operations at an orbital elevation of 590 km in a circular, sun synchronous orbit.

The proposed spectrum use will be the same as the operations authorized. The only changes relate to the updated orbital altitude, which is now 590 km. That change has increased the orbital period to 96.5 minutes. The orbital inclination has changed to 97.75°. The deorbit plan has changed because of the additional altitude.

Atmospheric holds an imagery license from NOAA. The imagery license covers the operations of RROCI-2.

RROCI-2 will be deorbited at the end of its mission. The deorbit planning shows that the satellite will burn up completely upon reentry.

For questions about this application, please contact Anne E. Cortez, Esq., Washington Federal Strategies, 520-360-0925 or alc@conspecinternational.com.

Attachment A: Deorbit Plan

Atmospheric and Space Technology Research Associates

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Background:

Atmospheric and Space Technology Research Associates (Atmospheric) provided detailed information on a deorbit plan in its application for operations of RROCI-2. The only changes to that plan at in Step 1, because the orbital altitude starts now at 590 km, rather than 525 km, and therefore the number of days for Step 1 has increased.

The timing of various stages of the deorbit process, and the use of propulsion, are shown in Table 1, below. It is a three step deorbiting process, with two steps using thrust (Steps 1 and 3) and Step 2 using drag to decay RROCI-2's orbit.

Stage		Delta V	Engine	Duration (days)
Step 1	Thrust down from 590 km to 430 km	52.8	MPPT	27
Step 2	Natural coast arc from 430 km to 380 km	28.3	Drag	453
Step 3	Thrust from 380 km to Deorbit	179.4	MPPT	29

Table 1. Deorbit stages for RROCI-2

Atmospheric took heed of the need to avoid thrust (and so simplify tracking for NASA) when RROCI-2's deorbiting process passes through the orbit of the International Space Station. Therefore, the deorbiting process uses drag where appropriate.

The MPPT is a "continuous thrust" thruster. It will be used at the altitudes noted in Table 1, above, during the deorbit period.

Launch Information:

Launch date: SpaceX has set the launch date for this rideshare rocket, Transporter 10, in February 2024.

Orbital Apogee: SpaceX will release the rideshare satellite at an orbit of 590 km.

Conclusion:

If the FCC needs further details, please contact Anne Cortez, Esq. 520-360-0925 or alc@conspecinternational.com, counsel for Atmospheric as soon as possible.

Attachment B: RROCI-2 Conjunction Warnings Response Plan

Atmospheric and Space Technology Research Associates (Atmospheric)

Experimental License Modification Application: 0339-EX-CM-2023

This Conjunction Warnings Response Plan was originally prepared and submitted to the FCC and approved by the FCC for experimental license WN2XPI. This license modification request does not change the approved conjunction warning plan. The question and answer format below provides the information that Atmospheric submitted to address questions raised by the FCC previously.

To ensure the best possible outcomes for RROCI-2 and all other satellites and objects in the same orbit, this plan anticipates a thorough and prompt response to all conjunction warnings that are issued for RROCI-2 by 18 SDS.

Commanding the thruster:

The spacecraft has the explicit ability to command the MPPT to fire after commanding the ADCS to achieve an appropriate orientation. I.e., the operation / firing of the MPPT is independent of other SC operations, and is contingent only on power being available to energize the MPPT.

The command is the following:

mutation { fireThrusterCycle(numCycles: 1) }@192.168.1.70:8400

The `numCycles` defines how many firing cycles to execute.

The `MPPT-service` configures the MPPT unit parameters on startup to be:

- Preferred firing cycle of 1,6,2,5,4,3
- Firing rate of 1000 ms
- Inductor Charge Time of 60uS (for vacuum operation)

FCC Questions:

Please indicate that in the event the RROCI-2 will need to perform collision avoidance that you will send the necessary commands to the spacecraft for it to propulsively maneuver to a safe location. Will the trajectory of any maneuvers also be screened for possible conjunctions prior to execution of any maneuver?

Atmospheric will send the necessary commands for it to propulsively maneuver to a safe location.

Atmospheric will have the 18th SDS screen the trajectory of the proposed maneuver to ensure that the maneuver will not cause any further possible conjunctions.

FCC Question:

Please define the risk thresholds and lead time limits that inform whether and when an avoidance maneuver is required, the sequence of events from when a CDM is received to the time a collision avoidance maneuver is executed, etc. with expected timeframes.

The risk thresholds that prompt a CDM from 18 SDS will trigger the Atmospheric conjunction response plan. Here is the procedure that Atmospheric will follow when a Conjunction Data Message (CDM) is received:

a. Review the message and send the RROCI-2 ephemeris update to 18 SDS. This step is expected to be completed within one (1) hour of receipt of a CDM during regular work hours. Evenings and weekends, this step is expected to be completed within three (3) hours of receipt of a CDM.
b. If the collision avoidance message indicates that the other object has propulsion, the RROCI-2 team will contact the other satellite operator to discuss the proper response, This contact is expected to be completed within one (1) hour after the ephemeris data has been submitted to 18 SDS. Reaching a mutual plan may take additional time as the teams analyze options.
c. Calculate a new trajectory, based on analysis of options including attitude adjustment and/or propulsion to avoid the collision. This initial calculation is expected to be completed by 2-4 hours after receiving a CDM. If the other object has no propulsion, this calculation will be the starting point for response.
d. Send proposed new trajectory from maneuvers to 18th SDS for review. This step is expected to be completed approximately 2-4 hours after receiving a CDM.
e. Then, if the proposed new trajectory is approved by 18 SDS, when RROCI-2 reaches the closest ground contact time, Atmospheric will upload the corresponding commands in the minimum amount of time possible. 18 SDS specifies that its review of the new trajectories could take 8 hours or more from submission of the information. Given RROCI-2's orbital period of about 96 minutes, the earliest it might be possible to send a command to instruct the satellite to use propulsion to avoid a conjunction is about 13 hours after receipt of a CDM. Typically, the CDM provides an alert of a possible conjunction 72 hours prior to the prospective conjunction. While it may not always be possible to meet the 13 hour turnaround on a propulsion command, Atmospheric is committed to working quickly and thoroughly to ensure that its response to a CDM is promptly communicated to RROCI-2 to ensure protection of RROCI-2 and of other space vehicles.

The analysis for closest ground contact time could be on the order of hours, however there is no warm-up time for the thrusters. To summarize, the expected timeframe is a combination of the time of analysis and the time until ground contact which is on the order of hours (< 24 hours).

In the course of reviewing and responding to a CDM, if the risk of conjunction drops below the warning threshold, in other words the risk lessens to the point where the risk of conjunction would not trigger a warning because of improved data or because of some action in response, then subsequent steps may not need to be completed. For instance, if another satellite operator (whose satellite is the subject of the CDM sent to the RROCI-2 team) is responding to two CDMS and has to use propulsion to minimize its risk, and if that

maneuver eliminates the risk warning to RROCI-2, then the RROCI-2 team will note the actions taken, update 18 SDS, and not take further action with regard to that warning, because the risk has been mitigated.

FCC Question:

Please state the expected ability of the spacecraft to successfully respond to a conjunction warning which requires a propulsive maneuver. Will the spacecraft be able to avoid a predicted collision using the included propulsive system? Is there a minimum amount of time before a potential collision that the RROCI-2 would be unable to effectively respond through use of a propulsive maneuver?

The current propulsion system can change our orbit altitude 1 km for every 8 hours of thrusting.

Given the CDM response procedure set forth above, RROCI-2 would not be able to effectively respond using propulsion if it received a warning only 13 hours or fewer before the projected collision. Some of that time is required for review of the proposed trajectory, which has to be performed by 18 SDS. However, since 18 SDS expects to send CDM's 72 hours before a projected collision, it is not anticipated that this would curtail RROCI-2's propulsive response to a CDM.

If the CDM requires an orbit altitude adjustment of more than 1 km, then the time for the propulsive response will need to be increased by more than 8 additional hours. This is why the RROCI-2 team plans to initiate its response promptly.

RROCI-2's engineering team has worked on two types of collision avoidance maneuvers. Not only can the satellite use propulsion, but the satellite's attitude can be adjusted to increase drag, slowing the apparent velocity of the orbit, and thereby avoiding the potential conjunction. This type of maneuver in response to a CDM would be subject to review and approval by 18 SDS before it was selected as the conjunction response.

In all circumstances, the Atmospheric response to a CDM will be to work swiftly to plan a new flight path for RROCI-2, as needed, and secure approval for that new flight path with 18 SDS, and then implement the corrective action as quickly as the commands can be transmitted to the spacecraft.

FCC Question:

Please confirm that you will be conducting coordination with inhabitable space stations during the deorbit/orbit lowering process.

Atmospheric will be conducting coordination with the necessary parties of inhabitable space stations during the deorbit process. The deorbit process will involve continuous thrust to slow down our spacecraft in order to lower the orbit.