SeaHawk-1 and SeaHawk-2

Technical Information

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1. Ownership, Operations and Construction. The University of North Carolina at Wilmington Center for Marine Science ("UNCW/CMS") is the owner and operator of the SeaHawk satellites. UNCW/CMS has selected Clyde Space Ltd., headquartered in Glasgow, Scotland as the manufacturer of the satellites and Spaceflight Industries of Seattle, Washington as the launch provider. SeaHawk-1 is expected to be launched on a SpaceX Falcon 9 launch vehicle from Vandenberg, AFB in California (geographic coordinates 34.5762°N; 4.2803°W) in the 1st Quarter of 2018. The estimated launch date for SeaHawk-2 is in the 1st Quarter of 2019. Pursuant to Part 5 §5.64 of the Commission's Rules, construction of the proposed experimental satellites and associated facilities will begin prior to the Commission's grant of an authorization. This is necessary given the nature of satellite construction and technical requirements over long lead times. Such construction is entirely at UNCW/CMS' risk without any assurances that its proposed experiment will be subsequently approved.

- **Space Station Name:** SeaHawk-1 and SeaHawk-2
- **SeaHawk-1 Estimated Construction Completion Date:** September 2017
- **Spaceflight Final Certification of Licenses (Go/NoGo):** October, 2017
- **Estimated Launch Date for SeaHawk-1:** 1st Quarter 2018
- **Purpose:** Experimental, non-Common Carrier basis
- **Orbital Type:** NGSO

2. Orbital Requirements. The satellites are designed to operate in circular sun-synchronous orbits. The satellites are based on COTS technology that allows for small, lightweight and low-cost spacecraft.

SeaHawk-1	
Total Number of Orbital Planes:	1
Celestial Reference Body:	Earth
Inclination Angle (degrees):	97.7
Orbital Period (seconds)	5778
Apogee	575 km
Perigee	575 km

Table 1

SeaHawk-2 (estimated launch date 1Q2019)	
Total Number of Orbital Planes:	1
Celestial Reference Body:	Earth
Inclination Angle (degrees):	97.5
Orbital Period (seconds)	5718
Apogee	525 km
Perigee	525 km

Table 2

3. **Service Area:** United States

4. **Satellite Payload.** For the SeaHawk satellite mission (Sustained Ocean Color Observations with Nanosatellites ("SOCON"), each of the 2 SeaHawk CubeSats will be outfitted with a low-cost, multispectral, ocean color sensor with spatial characteristics comparable to SeaWiFS capable of collection of near-synoptic color data in open- ocean to coastal-margin to near-shore terrestrial environment. UNCW/CMS has consulted with NOAA on the SOCON mission and after NOAA approval of a draft application, has submitted a license application which is currently under review. An Orbital Debris Assessment Report ("ODAR") has also been submitted with the NOAA application. The sensor has the capability of collection of the 8 SeaWiFS bands and designed with form factor fit into a custom 3U (i.e., 3 Units or $10cm^3$ or 10x10x30 cm) CubeSat; have spatial resolution of approximately 120 km and swath of 230 km in a 575 km LEO orbit. The Hawkeye sensors are designed to measure ocean, lake and river reflectivities in 8 spectral bands with high signal to noise ratio, 149 to 487 (.032 to .098 of SeaWifs), at typical radiances. The 8 bands follow SeaWiFS heritage with the center wavelength and bandwidths provided in the table below:

Band	Wavelength in nm	Bandwidth in nm
SeaWiFS 1	412	20
SeaWiFS 2	443	20
SeaWiFS 3	490	20
SeaWiFS 4	510	20
SeaWiFS 5	555	20
SeaWiFS 6	670	20
New 7	750.9	14.7
SeaWiFS 8	865	40

Table 3

The HawkEye Ocean Color Camera is approximate 10x10x10 cm with a mass of approximately 900 grams with 4 linear array CCDs in individual packages, one for each two bands. A picture of the completed sensor is presented in Figure 1.

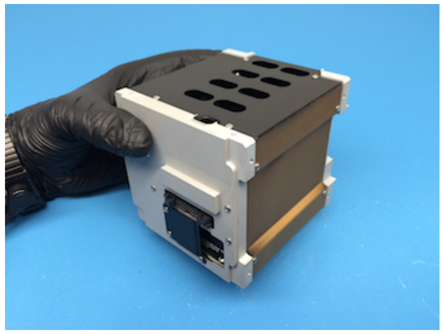

Figure 1. HawkEye Ocean Color Scanner

5. Principle Specifications. The UNCW/CMS SeaHawk satellites are identical. Each CubeSat measures 10 cm x 10 cm x 34 cm with a total mass of less than 4.8 kg. It has 4 double sided deployable solar panels, two 3U deployable panels and two 2U deployable panels that generate approximately 22 watts of power in sunlight. The Standalone 40Wh Battery consists of two lithium polymer pouch cells in a 2s3p arrangement with a typical capacity of 3900mAhr at a nominal 7.6V (full battery operational voltage range from 6.0 - 8.4V). The X-Band patch antenna is located in the long side of the satellite body (picture below). Two UHF and two VHF monopole whip antennas are deployed from the ADM (Antenna Deployment Module). The spacecraft has an estimated design lifetime of 18 months at a nominal orbit altitude of 575 km.

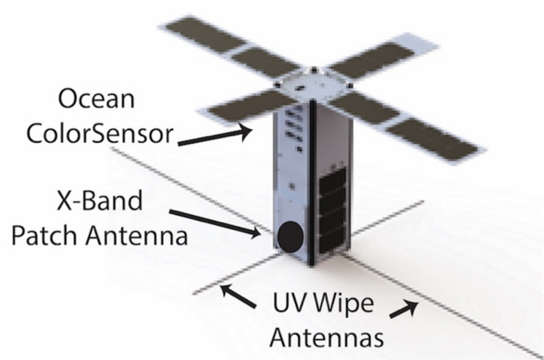

Figure 2. Location of the Spacecraft Antennas

6. Telemetry, Tracking and Command. Under the direction and control of UNCW/CMS, the UNCW/CMS satellites will receive TT&C communications from a gateway earth station located at Clyde Space in Glasgow, Scotland using the uplink band of 140-150 MHz licensed by Ofcom. UNCW/CMS commands will be communicated to the TT&C from the mission operations center in Wilmington, North Carolina, and then uplinked to the satellites. The satellites will transmit TT&C data to the earth station using the downlink band of 400-440 MHz. The science data collected by the satellites' ocean color sensor, will be downlinked via the X-Band 8100 MHz frequency to NASA's Near Earth Network ("NEN"). The primary receiver for the SOCON data will be Wallops Flight Facility Ground Station in Virginia. There are three NASA NEN secondary receivers for the SOCON data in Fairbanks, Alaska and a backup receiver located at NASA NEN in McMurdo, Antarctica.

7. Radio Equipment.

UHF/VHF Transceiver: F'SATI VUTRX CubeSat Radio: UHF downlink, VHF uplink

- Primary transceiver capability for telecommand, telemetry, and redundant payload data, uses an off-the-shelf VUTRX (UV Transceiver), providing a UHF uplink and VHF downlink both using 9600 bit/s GMSK using CCSDS packets.
- When not transmitting, the transceiver shall operate in a Morse code beacon mode for broadcasting identification and basic health data for tracking.
- The VUTRX interfaces to UV monopole whip antennas deployed from the ADM (Antenna Deployment Module).

Downlink: UHF Transmit

- DC Power 4 – 10 W (27 – 33 dBm)
- Frequency 400 - 440 MHz RF
- Power 27 – 33 dBm (3 dBm steps)
- Channel Spacing 25 kHz
- Spurious Response < -65 dBc F
- Frequency Deviation 3 kHz (FM)
- Frequency Stability ± 50 ppm

Uplink: VHF Receive

- DC Power < 250 mW
- Frequency 140 – 150 MHz
- -120 dBm for 12 dB SINAD
- Channel Spacing 25 kHz
- Noise Figure < 1.5 dB
- Spurious Responses < -65 dB
- Dynamic Range -120 dBm to -70 dBm
- Frequency Stability ± 50 ppm

X-Band Transmitter: Syrlinks EWC27 X-BAND Transmitter
RF transmitting power: 2W (33 dBm*)*

- Secondary transmitter capability for high-resolution science data including payload data and mission housekeeping data, providing a X-band downlink using 100Mbps air data rate (after convolutional coding), OQPSK modulation and CCSDS packets.

- The transmitter will be switched on according to the on-board schedule to match a ground station pass.

Downlink: X-Band Transmit

- Transmit Frequency: 8100 MHz
- Bandwidth: 90 Mhz
- Flexible RF Output Power: 27 – 22 dBm, with 1-dB steps
- Power Consumption:
  - < 7 W for 1 W RF Output Power
  - < 10 W for 2 W RF Output Power
- Useful data rate from 2.8 to 50 Mbps with Variable Bit Rate (up to 100 Mbps in Constant Bit Rate)
- Configurable data rate (in flight up to 50 Mbps

Antenna Systems

- Clyde Space VHF/UHF; Model 01-02766 Antenna Deployment Module
- PCL Model PCL-MSA-74-12-1 X-band Patch Antenna

Lower Frequency	Upper Frequency	Frequency Units	Power	Power Units	Output Power/ERP	ERP Units	Mean/Peak	Frequency Tolerance	Station Class
8100	8100	MHz	2.0W	W	33	dBm	32/33	+/-5 ppm	Mobile
400	440	MHz	0.5W	W	27	dBm	27/33	+/-2.7 ppm	Mobile

Table 4
Antenna Frequency Registration

Lower Frequency	Upper Frequency	Frequency Units	Emission	Modulating Signal	Necessary Bandwidth
8100	8100	MHz	G 1 D	OQPSK	90M0
400	440	MHz	G 1 D	GMSK	15K4

Table 5
Frequency Emissions Registration

8. RF Table

RF Table

Description	Transmitter 1	Transmitter 2	Receiver 1
Communication System Nominal String	VUTRX - CPUT	XTX - Syrlinks	VUTRX - CPUT
Carrier Frequency, MHz	400-440	8100	140-150
3 dB Bandwidth, MHz	0.0102	40	N/A
Necessary Bandwidth per NTIA redbook***, MHz	0.011	80	N/A
20 dB Bandwidth, MHz	-	100	N/A
60 dB Bandwidth, MHz	-	300	N/A
Receiver sensitivity, dBW	N/A	N/A	-147
Antenna gain, dBi	0	7.3	0
Modulation type and characteristics (total data rate)	GMSK, 9600 bit/s	OQPSK, 100 Mbit/s	GMSK, 9600 bit/s
Receiver Input Damage Threshold*, (line loss included), dBm	N/A	N/A	-70
Receiver span (MHz)	N/A	N/A	140-150
Intermediate frequency, MHz	-	N/A	-
Local Oscillator frequency, MHz	-	8100	-
Transmit Antenna output (EIRP), dBW	-3 (0.5 W, 27 dBm)	9.35	N/A
Receive Antenna Flux Density, dBW/m2 (receiver ON)	N/A	N/A	-
Antenna Description, Polarization	UHF dipole, linear	Patch, right	VHF Dipole, linear
Operating on PAD	No	No	No
Operating during launch	No	No	No
Ground Equipment output power, dBm	N/A	N/A	N/A

Table 6

9. Power Flux Density Calculation

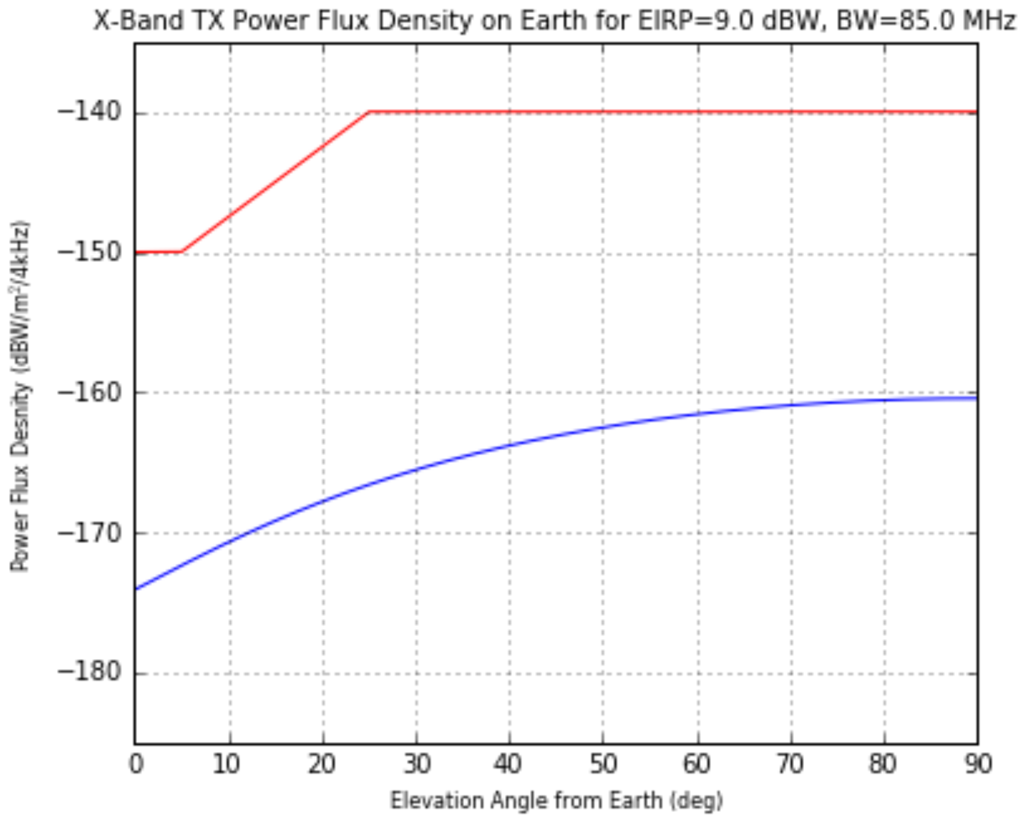

Figure 3
PDF at the Surface of the Earth produced by SeaHawk satellite Downlinks
Shown for 575 km orbit

(a) Power Flux Density at the Surface of the Earth for the 8100 MHz Frequency

ITU-R Recommendation SA-1157 specifies a maximum allowable interference power spectral flux-density level at the Earth's surface of -255.1 dB(W/(m^2·Hz)) to protect ground receivers in the deep-space research band 8400-8450 MHz. The SeaHawk satellites do not operate in this frequency range, so no special precautions are warranted.

(b) Power Flux Density at the Geostationary Satellite Orbit

No. 22.5 of the ITU Radio Regulations specifies that in the frequency band 8025-8400 MHz, which the EESS (using non-geostationary satellites) shares with the fixed-satellite service

(Earth-to-space) and the meteorological-satellite service (Earth-to-space), the maximum PFD produced at the geostationary satellite orbit ("GSO") by any EESS space station shall not exceed –174 dB(W/m2) in any 4-kHz band. The calculation below shows that the PFD produced by the transmissions from the proposed SeaHawk satellites does not exceed the limit in No. 22.5, even in the worst possible hypothetical case.

The PFD at the GSO produced by the SeaHawk satellite transmission is:

PFD [dBW/m2 /4 kHz] = EIRP (dBW) - 71 - 20log10(D) - 10log10(BW) – 24

Where:

- EIRP is the Maximum EIRP of the transmission, in dBW;
- D is distance between the UNCW/CMS satellite and GSO, in km;
- BW is the symbol bandwidth of the transmission, in MHz.

The minimum possible distance between a SeaHawk satellite and the GSO is 35,786 - 575 = 35,211 km for the highest possible SeaHawk satellite orbit of 575 km. Under a hypothetical assumption that the SeaHawk satellite antenna is radiating at its peak EIRP toward the GSO, the X-Band transmission with the peak EIRP = 9.35 dBW and BW = 90 MHz produces a PFD at the GSO of -196.122 dBW/m^2/4 kHz.

10. Interference Analysis

<u>8100 MHz (Primary Data Downlink)</u>

The 8025-8400 MHz band is allocated for a number of uses including non-Federal use for EESS (Earth-to-space) subject to such conditions as may be applied on a case-by-case basis. Further, transmissions from the satellites operating in this band shall not cause harmful interference to Federal and non-Federal stations operating in accordance with the U.S. Table of Frequency Allocations. UNCW/CMS will coordinate with Federal and non-Federal operators in this band to ensure compliance with this requirement.

UNCW/CMS has taken time to understand and include mitigation techniques outlined in the ECC Report 155, for operating its satellite downlink in the 8100 MHz frequency. Below are the key steps taken to minimize risk of interference.

- UNCW/CMS satellites operate in a non-broadcast mode, only radiating when transmitting data to one or more of the NASA NEN ground stations. The transmitter will be switched on according to the on-board schedule in order to match a ground station pass.
- UNCW/CMS satellites operate in the lower portion of the 8025 – 8400 MHz band.
- UNCW/CMS satellites operate well within the power flux density requirements.

- UNCW/CMS has initially been performing pre-flight with the NASA NEN. When SeaHawk is on orbit we will schedule test contacts with each of the NASA NEN stations and apertures to perform "on orbit certification" in lieu of a pre-launch compatibility test. Once the NEN has certified/demonstrated their ability to successfully receive our signal and have accurately configured the grounds station, we will enter an operational phase.
- The Syrlinks X-Band Transmitter is in conformance with the NTIA and ITU-R PFD limits and in conformance with the DSN protection criteria – clearing the 8100 MHz frequency for potential use for this mission.

(a) Interference between EESS systems operating in the band 8025-8400 MHz

Interference between the SeaHawk satellites and those of other systems is unlikely because EESS systems operating in the 8025-8400 MHz band normally transmit only in short periods of time while visible from the dedicated receiving earth stations (typically less than 10 minutes for a single pass). SeaHawk satellites are designed to be non-broadcast satellites. For interference to happen, satellites belonging to different systems would have to travel through the antenna beam of the receiving earth station and transmit at the same time and at same frequency. In such a very unlikely event, interference can be still be avoided by coordinating the satellite transmissions so that they do not occur simultaneously.

(b) Interference with the Fixed Service and the FSS in the band 8025-8400 MHz

SeaHawk satellite transmissions will meet the limits specified by the ITU for protection of the Fixed Service in the 8025-8400 MHz band, as well as the geostationary FSS satellites using this band for their uplinks. See Section 9(b) above.

400-440 MHz (TT&C Downlink)

Interference with U.S. federal and amateur assignments in the 400-440 MHz band is unlikely as they will only be transmitting when over the associated TT&C ground station in Glasgow, Scotland. When not transmitting, the transceiver shall operate in a Morse code beacon mode for broadcasting identification and basic health data for tracking.

A 24-hour contact for interference issues is provided in Section 13 below.

11. SeaHawk Satellite Link Budgets. The coverage area diameter from an altitude of 575 km is approximately 5,000 km. Each satellite will pass over the U.S. about 4 times a day for approximately 7 minutes. The satellite transmitters are only active while communicating with user terminals. Following are the SeaHawk Satellite Link budgets.

Seahawk -1 Link Budget

Property	Uplink 1		Downlink 1		Downlink 5		Comments
Mission Geometry							
Altitude (km)	**575**		**575**		**575**		Launch Orbit
Earth Radius[km]	**6378.0**		**6378.0**		**6378.0**		
Angular radius of the Earth [deg]	**66.52**		**66.52**		**66.52**		
Orbit inclination [deg]	**97.70**		**97.70**		**97.70**		
Orbital Period [min]	**96.30**		**96.30**		**96.30**		
General							
Central Frequency (MHz)	**149.15**		**400.775**		**8100**		**UL1**: VHF, **DL1**: UHF, **DL5**: X-band
Transmitter Bandwidth(Mhz)	**0.0154**		**0.0154**		**90**		
On Air Bit Rate (Mbit/sec)	**0.0096**		**0.0096**		**100**		Downlink 5 sym rate 50 due to
Platform Tx							
Platform Tx Power (W)			**0.5**		**1.6**		
Spacecraft antenna pointing loss [dB]	**0.5**		**0.5**		**0.5**		Total feedline loss of 1.5dB
SC Transmission line loss [dB]	**0.5**		**0.5**		**0.5**		Total feedline loss of 1.5dB
Impedance Mismatch loss [dB]	**0.5**		**0.5**		**0.5**		Total feedline loss of 1.5dB
Antenna pattern ID	**1**		**2**		**3**		
Antenna pattern: Elevation/Nadir angel/Gain	**NA**	**G**	**NA**	**G**	**NA**	**G**	UL1-DL1 use omnidirectional antennas - DL5-HPBW 40 deg half angle
0	**67**	**0**	**67**	**0**	**67**	**-0.2**	
10	**65**	**0**	**65**	**0**	**65**	**0.3**	
20	**60**	**0**	**60**	**0**	**60**	**1.6**	
30	**53**	**0**	**53**	**0**	**53**	**3**	
40	**45**	**0**	**45**	**0**	**45**	**4.3**	
50	**36**	**0**	**36**	**0**	**36**	**4.9**	
60	**27**	**0**	**27**	**0**	**27**	**5.4**	
70	**18**	**0**	**18**	**0**	**18**	**6.1**	
80	**9**	**0**	**9**	**0**	**9**	**6.7**	
90	**0**	**0**	**0**	**0**	**0**	**7.3**	Peak gain DL5 7.3, UL1/DL1 use omnidir
Platform Rx							
Rec Min dynamic range/Rec sensitivity [dBW]	**-144**						
Receiver Max dynamic range [dBW]	**-100**						
Path							
Polarisation loss [dB]	**CP-LP**		**Matched**		**Matched**		Matched 0dB loss, Mismatched 3dB loss.
Atmospheric attenuation [dB/km]	**0.007**		**0.007**		**0.013**		
Groundstation Tx + Rx							
Tx Power Ground Station (W)	**200**						
Pointing Accuracy	**1**		**1**		**0.05**		
Antenna	**52**		**30**		**0.23**		
Antenna Gain[dB]	**10.2**		**[OPTIONAL]**		**[OPTIONAL]**		for DL captured in G/T figure
GS Trans line loss[dB]							
sky noise[K]			**[OPTIONAL]**		**[OPTIONAL]**		for DL captured in G/T figure
rec noise[K]			**[OPTIONAL]**		**[OPTIONAL]**		for DL captured in G/T figure
interf noise[K]			**[OPTIONAL]**		**[OPTIONAL]**		for DL captured in G/T figure
Total System Effective Noise Temp[K]			**[OPTIONAL]**		**[OPTIONAL]**		for DL captured in G/T figure
GroundstationG/T [dB/K]			**-2.31**		**34.5**		
Receiver bandwidth to Signal bandwidth ratio			**1.5**		**1.5**		
Receiver Bandwidth(Mhz)			**0.0231**		**135**		

(continued on next page)

Link Evaluation				
Modulation Type	GMSK	GMSK	QPSK	For DL5 OQPSK-doesn't affect overhead
Convolutional Coding implemented		Yes	Yes	
Convolutional Coding code rate		0.50	0.50	
Reed-Solomon Implemented		Yes	Yes	
Reed-Solomon code rate		0.87	0.87	
Reed Solomon Interleaving Depth		4	4	
CFDP Implemented	Yes	Yes	Yes	
Ax.25 implemented	Yes			
Desired FER		1.00E-07	1.00E-07	
Req Eb/No Threshold to meet desired FER [dB]		2.7	2.7	
Implementation loss [dB]		1	1	
Desired Link Margin	3.0	3.0	3.0	

Table 7

VHF Up Link Budget: 140 - 150 Mhz											
Mission Geometry	Units										
Elevation	deg	0	10	20	30	40	50	60	70	80	90
Pho 66.5 deg											
Nadir angle	deg	67	65	60	53	45	36	27	18	9	0
Slant Range	km	2769	1874	1343	1034	847	730	655	609	583	575
Groundstation Tx											
Transmission power	dBW	23.0									
GS transmission line loss	dB	4.0									
Gs Antenna gain	dBi	10.2									
Effective Isotropic Related Power	dBW	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Path											
Groundstation pointing loss	dB	0.0									
Path loss	dB	144.8	141.4	138.5	136.2	134.5	133.2	132.2	131.6	131.2	131.1
Polarisation matching loss	dB	3.0									
Received power at receiver	dB	7.93	3.34	1.94	1.37	1.08	0.91	0.81	0.74	0.71	0.70
Platform Rx											
Received power at Platform antenna	dBW	-126.49	-118.51	-114.21	-111.37	-109.35	-107.88	-106.84	-106.14	-105.73	-105.60
Platform antenna pointing loss	dB	0.50									
Platform Antenna gain	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SC Transmission line loss	dB	0.50									
Mismatch loss	dB	0.50									
Received power at receiver	dBW	-128	-120	-116	-113	-111	-109	-108	-108	-107	-107
Link evaluation											
Receiver Lower limit dynamic range (Receiver sensitivity)	dBW	-144	-144	-144	-144	-144	-144	-144	-144	-144	-144
Receiver Upper limit of dynamic range (Max receiver input)	dBW	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
Link Margin lower limit	dB	16	24	28	31	33	35	36	36	37	37
Link Margin upper limit	dB	28	20	16	13	11	9	8	8	7	7

Table 8

UHF Link Budget - Downlink: 400 - 440 Mhz											
Mission geometry	Units										
Elevation	deg	0	10	20	30	40	50	60	70	80	90
Rho	deg ---- 66.5										
Nadir angle	deg	67	65	60	53	45	36	27	18	9	0
Slant range	km	2769	1874	1343	1034	847	730	655	609	583	575
Satellite Tx											
Transmission power	dBW	-3.0									
SC Transmission line loss	dB	0.5									
Mismatch loss	dB	0.5									
Antenna gain	dBi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Effective Isotropic Radiated Power	dBW	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
Path											
Spacecrafe antenna pointing loss	dB	0.5									
Path loss	dB	153.3	150.0	147.1	144.8	143.1	141.8	140.8	140.2	139.8	139.7
Polarisation matching loss	dB	0.0									
Atmospheric Attenuation	dB	7.9	3.3	1.9	1.4	1.1	0.9	0.8	0.7	0.7	0.7
Groundstation Rx											
Received power ground station antenna	dBW	-165.79	-157.81	-153.51	-150.67	-148.65	-147.18	-146.14	-145.44	-145.04	-144.90
G/S antenna pointing loss	dB	0.01									
Boltzman's Constant	dBW/K/Hz	-228.60									
Groundstation Figure of merit (G/T)	dB/K	-2.31									
C/No at Rx input	dBHz	60.49	68.47	72.76	75.61	77.63	79.09	80.14	80.84	81.24	81.37
Eb/N0	dB	24.28	32.26	36.55	39.39	41.42	42.88	43.92	44.62	45.03	45.16
C/N	dB	18.61	26.60	30.89	33.73	35.75	37.22	38.26	38.96	39.37	39.50
SNR	dB	16.87	24.85	29.15	31.99	34.01	35.47	36.52	37.22	37.62	37.75
Illumination level	dBW/m2	-143.85	-140.46	-137.56	-135.29	-133.56	-132.27	-131.33	-130.69	-130.32	-130.20
PFSD	dBW/m2/Hz	-185.72	-182.33	-179.44	-177.17	-175.44	-174.14	-173.20	-172.56	-172.19	-172.07
PFSD	dBW/m2/4kHz	-149.70	-146.31	-143.42	-141.15	-139.42	-138.12	-137.18	-136.54	-136.17	-136.05
Link Evaluation											
Link Margin for Eb/N0 desired WER/FER	dB	20.58	28.56	32.85	35.69	37.72	39.18	40.22	40.92	41.33	41.46
Shannon limit	Mbps	0.087	0.127	0.149	0.164	0.174	0.181	0.187	0.190	0.192	0.193

Table 9

X-Band Down Link Budget - 8100 Mhz											
Mission geometry	Units										
Elevation	deg	0	10	20	30	40	50	60	70	80	90
Rho	66.5 deg										
Nadir Angle	deg	67	65	60	53	45	36	27	18	9	0
Slant Range	km	2769	1874	1343	1034	847	730	655	609	583	575
Satellite TX											
Transmission power	dBW	2.0									
SC Transmission line loss	dB	0.5									
Mismatch loss	dB	0.5									
Antenna gain	dBi	-0.2	0.3	1.6	3.0	4.3	4.9	5.4	6.1	6.7	7.3
Effective Isotropic Radiated Power	dBW	0.8	1.3	2.6	4.0	5.3	5.9	6.4	7.1	7.7	8.3
Path											
Spacecraft antenna pointing loss	dB	0.5									
Path loss	dB	179.5	176.1	173.2	170.9	169.2	167.9	166.9	166.3	165.9	165.8
Polarisation matching loss	dB	0.0									
Atmospheric Attenuation	dB	14.7	6.2	3.6	2.5	2.0	1.7	1.5	1.4	1.3	1.3
Groundstation Rx											
Received power at ground station antenna	dBW	-193.89	-181.43	-174.64	-169.90	-166.33	-194.12	-162.49	-161.04	-160.01	-159.26
G/S antenna pointing loss	dB	0.57									
Boltzman's Constant	dBW/K/Hz	-228.60									
Groundstation Figure of merit (G/T)	dB/K	34.50									
C/No at Rx input	dBHz	68.65	81.10	87.90	92.63	96.20	98.41	100.04	101.49	102.53	103.27
Eb/N0	dB	-7.74	4.71	11.51	16.24	19.81	22.02	23.65	25.10	26.14	26.88
C/N	dB	-10.90	1.56	8.35	13.09	16.66	18.87	20.50	21.95	22.99	23.73
SNR	dB	-12.64	-0.19	6.61	11.34	14.91	17.12	18.75	20.21	21.24	21.98
Illumination level	dBW/m2	-139.04	-135.11	-130.91	-127.24	-124.21	-122.32	-120.88	-119.54	-118.57	-117.84
PFSD	dBW/m2/Hz	-218.58	-214.65	-210.46	-206.79	-203.75	-201.86	-200.42	-199.08	-198.11	-197.39
PFSD	dBW/m2/4kHz	-182.56	-178.63	-174.44	-170.76	-167.73	-165.84	-164.40	-163.06	-162.09	-161.37
Link Evaluation											
Link Margin for Eb/N0 for desired WER/FER	dB	-11.44	1.01	7.81	12.54	16.11	18.32	19.95	21.40	22.44	23.18
Shannon limit	Mbps	6.883	87.233	223.275	348.300	450.033	514.423	562.403	605.392	636.032	658.051

Table 10

12. Antenna Patterns and Beam Contours

VHF/UHF:

- POLARIZATION Linear
- ORIENTATION (NB = NARROW BEAM) (EC=EARTH COVERAGE) EC
- ANTENNA GAIN 0dB
- ANTENNA BEAM WIDTH Omnidirectional

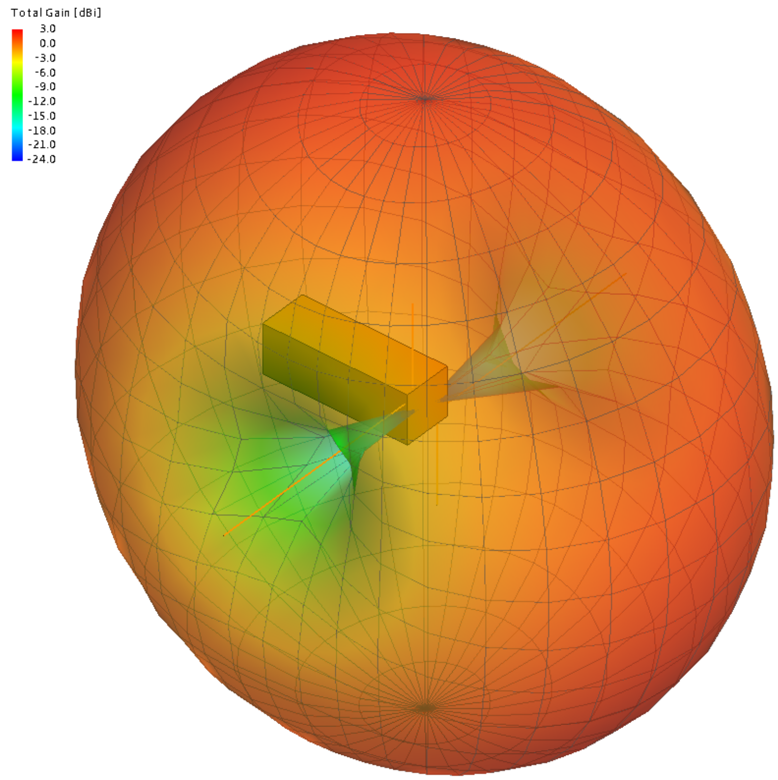

Figure 4

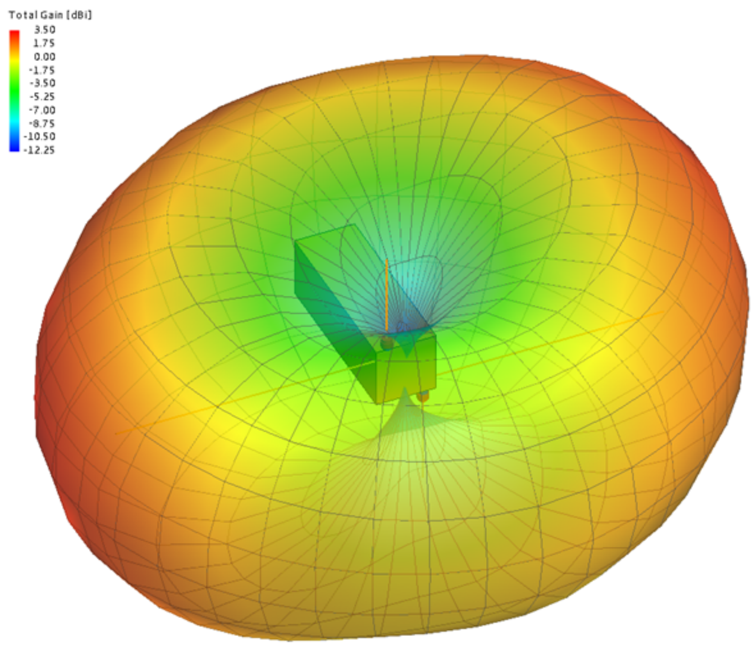

Figure 5
UHF transmit pattern

X-BAND

- POLARIZATION Right Hand Circular Polarization
- ORIENTATION (NB = NARROW BEAM) (EC=EARTH COVERAGE) NB
- ANTENNA GAIN 7.8dB peak
- ANTENNA BEAM WIDTH(3dB contour/HPBW): 41 degrees half angle , 82 degrees full beam

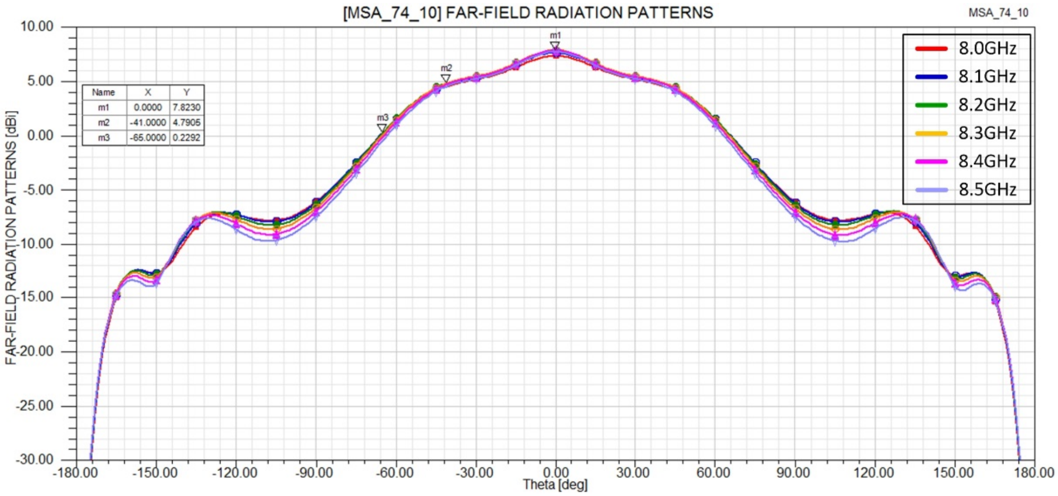

Figure 6

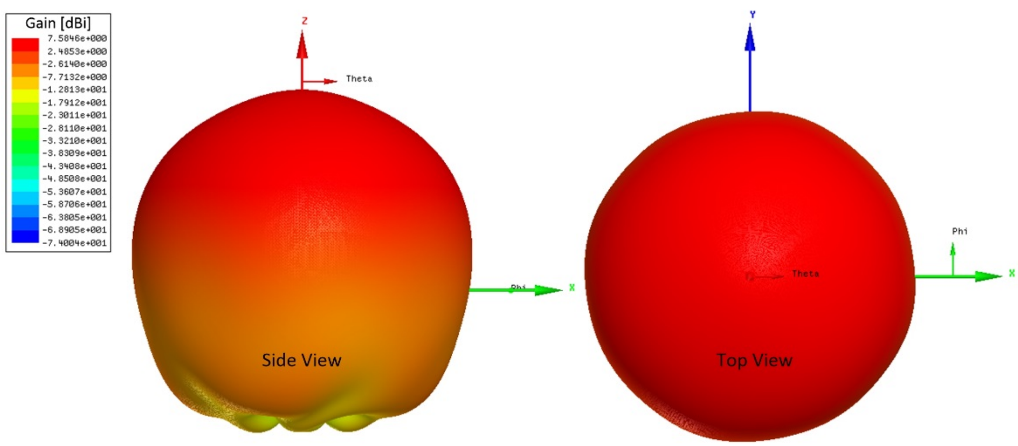

Figure 7

13. A 24-hour contact for interference issues is provided below:

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