Application

HawkEye 360, Inc. ("HE360") seeks Federal Communications Commission authorization to conduct on-the-ground testing at its facility located at 485 Springpark Place, Herndon, VA 20170, USA. Testing is required to ensure the validity and reliability of the radio frequency ("RF") systems that will fly on the HawkEye 360 Constellation ("HE360 Constellation").

Purpose and Objectives

HE360 is a Delaware corporation providing geospatial analytics, with its headquarters and operations located in Herndon, Virginia. The HE360 Constellation is used to receive and sense RF spectrum and survey and map usage of certain radio frequencies within the electromagnetic spectrum. The satellites that comprise the HE360 Constellation, in part, have Assembly, Integration, and Testing ("AI&T") performed at HE360's Herndon manufacturing facility.

Part of the AI&T process involves over-the-air testing of the hardware to be used for the constellation communication links: 2025-2110 MHz; 2200-2290 MHz; and 8025-8400 MHz. In addition to the communications links, HE360 also seeks authority to conduct over-the-air testing of its RF-sensing hardware (25 MHz to 18 GHz), and to re-radiate the Global Positioning System ("GPS") L1 signal inside its cleanroom. The testing is necessary to verify the expected performance and characteristics of the hardware used for the communication links and RF sensors prior to spacecraft launch. HE360 requests authorization to conduct the testing for a period of two years.

Facility Description

All testing will take place indoors within the HE360 cleanroom at 485 Springpark Place, Suite 400, Herndon, Virginia, 20170. The office building walls are comprised of a layer of cinder blocks and a layer of masonry blocks, approximated as two layers of masonry blocks, and the office roof is comprised of corrugated metal, with insulation backing and a rubber-rock membrane. According to the National Institute of Standards and Technology (NIST) Report on Electromagnetic signal attenuation in construction materials,[1] a two-layer cinder block building has typically greater than 15 dB of attenuation in the 500-2000 MHz range,[2] and greater than 20 dB of attenuation in the 3000-8000 MHz range.[3] Due to the metallic roof, the RF transmissivity through that plane is approximated to be zero.

System Technical Description

The process for the testing of each system is detailed below.

Communication Systems: To validate the receive chain of the S-band receivers (see, Table 1, Bus TT&C Receive and Payload Receive), HE360 will use a signal generator and tripod-mounted antenna at approximately 1.5 meters height, pointing at 0 degrees elevation, emitting a low-power, modulated signal at the receiver set up approximately 1 meter away on a table at the same height. To validate the transmit chain of the S-band and X-band transmitters (see, Table 1, Bus TT&C X Transmit, Bus TT&C S Transmit, Payload Transmit 1, and Transmit 2), HE360 will use the tripod-mounted transmitters located approximately 1.5 meters off the ground to emit

[1] *See* United States Department of Commerce Technology Administration National Institute of Standards and Technology, *NIST Construction Automation Program Report No. 3, Electromagnetic Signal Attenuation in Construction Materials* (Oct. 1997), https://doi.org/10.6028/NIST.IR.6055

[2] *Id.* at Figure 4.12b.

[3] *Id.* at Figure 4.12d.

a low-power, modulated signal from a table at approximately 1.5 meters height, pointing at 0 degrees elevation to a tripod-mounted receiver at the same height set up approximately 1 meter away. HE360 will transmit at the frequencies listed in Table 1 for approximately 2 minutes each per test.

Table 1: Communications Links

		Communications Links					
System	Description	Bus TT&C Receive	Bus TT&C X Transmit	Bus TT&C S Transmit	Payload Receive	Payload Transmit 1	Payload Transmit 2
Transmitter	Manufactuerer	Rigol	UTIAS-SFL	UTIAS-SFL	Ettus Research	Syrlinks	Syrlinks
	Model	DSG836	SFL-GEN-COM-XFE v1	SFL-GNB-COM-STX A2.3	N310	EWC-27	N-XONOS
Antenna	Manufactuerer	RFSpace	UTIAS SFL	UTIAS-SFL	RFSpace	Endurosat	Endurosat
	Model	TSA900	SFL-GNB-COM-XPA	SFL-GNB-COM-SPA	TSA900	X-Band 2x2 Patch Array	X-Band 4X4 Patch Array
Antenna Characteristics	Directional? (Y/N)	Y	Y	Y	Y	Y	Y
	HPBW (Deg)	60	90.5	90.5	60	40	18
	Peak Gain (dBi)	6	3.4	6	6	13	17
Frequency & Emissions	Lower Frequency (MHz)	2025	8025	2200	2025	8025	8025
	Upper Frequency (MHz)	2110	8400	2290	2110	8400	8400
	Carrier Frequencies (MHz)	2052.1 2053.0 2053.7	8291 8297 8303	2242 2254 2260	2046.5 2049.3 2075	8075 8165 8255	8090 8210
	Station class (Fixed/mobile)	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
	EIRP (dBW) (Peak)	-34	-2	-1.42	-34	11.91	17
	Emission Designator	180KF1D	4M00G1D	4M00G1D	2M00G1D	80M0G1D	105MG1D
	Modulating Signal	QPSK	QPSK	QPSK	QPSK	OQPSK	QPSK / 8PSK

GPS Receivers: To validate the systems that utilize GPS, HE360 will re-radiate GPS L1 signals within the cleanroom (see, Table 2). A schematic of the GPS re-radiation system in the HE360 facility is detailed in Figure 1, below. For this testing, HE360 has an active GPS receiver on the roof of its office building, with a low noise amplifier ("LNA") and an omnidirectional passive repeater antenna inside the cleanroom. The antenna and LNA can be set up at a work bench location in the cleanroom, at approximately 1.5 meter height. This system will only be enabled when utilizing the GPS links and can be disabled by the operator in the facility.

Table 2: GPS L1 Re-Radiation

		GPS
System	Description	GPS L1
Receiver	Manufactuerer	NovAtel
	Model	GPS-702-GG-HV
Antenna	Manufactuerer	MIKROE
	Model	DLGPS/GLONASS-C1-PASSIVE
Antenna Characteristics	Directional? (Y/N)	N
	HPBW (Deg)	N/A
	Peak Gain (dBi)	2.5
Frequency & Emissions	Lower Frequency (MHz)	1574
	Upper Frequency (MHz)	1577
	Carrier Frequencies (MHz)	1575.42
	Station class (Fixed/mobile)	Fixed
	EIRP (dBm) (Peak)	-75.9

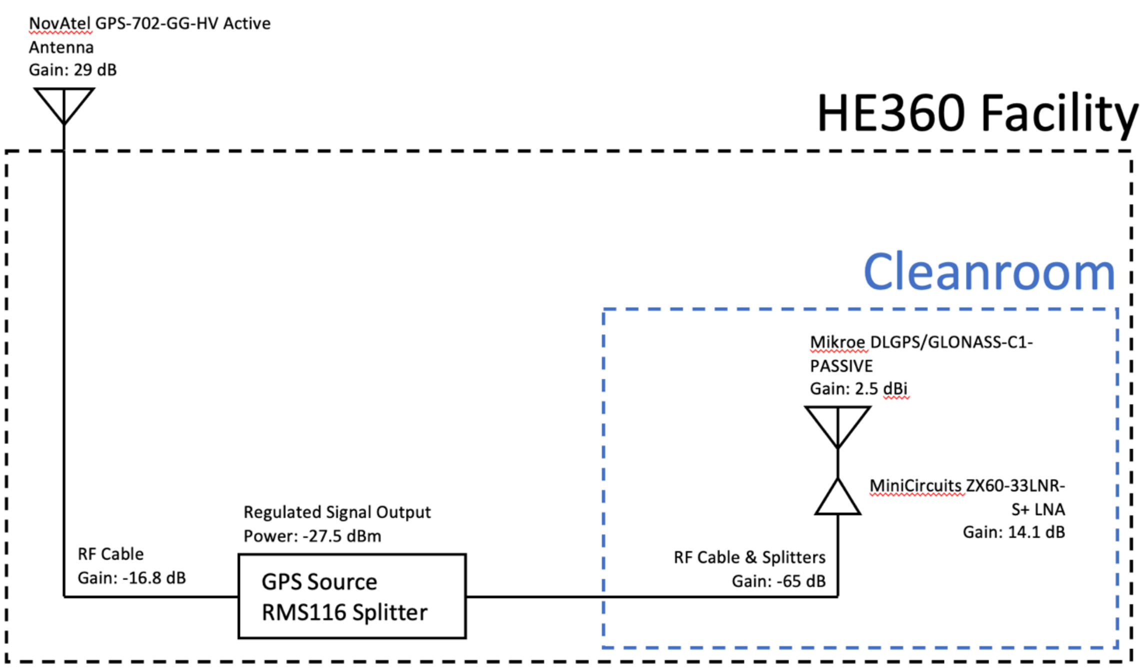

Figure 1: GPS Re-Radiation Schematic

Compliance with NTIA Requirements: HE360 will comply with all requirements in section 8.3.28 of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency

Management (Redbook), which provides federal guidelines for fixed devices that re-radiate signals received from GPS satellites.[4]

a. **Individual authorization is for indoor use only, and is required for each device at a specific site.** As stated above, the GPS re-radiation system will be located indoors in the HE360 cleanroom**.**

b. **Applications for frequency assignment should be applied for as an XT station class with a note indicating the device is to be used as an "Experimental RNSS Test Equipment for the purpose of testing GPS receivers" and describing how the device will be used.** As discussed above, this application is for an experimental license to test GPS devices, complying with this requirement.

c. **Approved applications for frequency assignment will be entered in the GMF.** HE360 would have no objections to recording grant of this application in the Government Master File, if appropriate.

d. **The maximum length of the assignment will be two years, with possible renewal.** HE360 seeks authorization for two years and may renew the request at the appropriate time.

e. **The area of potential interference to GPS reception (e.g., military or contractor facility) has to be under the control of the user.** Given the low power of operations and the test set up, the area of potential interference will be limited to the HE360 cleanroom and other nearby areas under HE360's control.

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[4] National Telecommunications and Information Administration, *Procedures and Principles for the Assignment and Coordination of Frequencies*, Chapter 8 (2008), https://www.ntia.doc.gov/legacy/osmhome/redbook/8.pdf

f. **The maximum equivalent isotropically radiated power (EIRP) must be such that the calculated emissions are no greater than -140 dBm/24 MHz as received by an isotropic antenna at a distance of 100 feet (30 meters) from the building where the test is being conducted. The calculations showing compliance with this requirement must be provided with the application for frequency assignment and should be based on free space propagation with no allowance for additional attenuation (e.g., building attenuation.).** The EIRP calculations for the proposed GPS re-radiation system are provided in Table 3, below, and are in compliance with the NTIA regulations.

Table 3: GPS Re-Radiation EIRP

GPS Repeater Link Calculations			
		Units	**Comments**
Target Level	-140	dBm	NTIA Requirement -140 dBm/24MHz @ 30m
Target level range	30	m	NTIA specified range
Frequency	1575.42	MHz	L1 frequency
Output Power Calculation			
Signal level from Satellite	-125	dBm	Standard GPS signal at earth surface
Active Antenna Gain	29	dB	Input
GPS Splitter Output Power	-27.5	dBm	Input
Cable Loss	-65	dB	Input
LNA Max Gain	14.1	dB	Input
Repeater Antenna Max Gain	2.5	dBi	Input
Maximum EIRP	**-75.90**	**dBm**	**Calculation**
Signal power at 30 meters	**-141.84**	**dBm**	**Calculation**
Link Compliance Margin	1.84	dB	Calculation

g. **Applications requesting consideration of non-zero building attenuation in order to meet the -140 dBm/24 MHz limit at 30 meters from the building must provide detailed justification and measured values for the building attenuation for agency review.** The above calculations assume zero building attenuation.

h. **GPS users in the area of potential interference to reception must be notified that GPS information may be impacted for periods of time.** HE360 will post signs in the vicinity of the testing facility stating that there is a GPS re-radiation system in use that may impact GPS information for periods of time.

i. **The use is limited to activity for the purpose of testing RNSS equipment/systems.** HE360's proposed use is limited to validating the HE360 Constellation GPS system, as discussed above.

j. **A "Stop Buzzer" point of contact for the authorized device must be identified and available at all times during GPS re-radiator operations.** See Stop Buzzer Contact information below.

Payload RF sensing systems: To validate the HE360 RF sensors, HE360 will generate a variety of low-power signals across bands from 25 MHz to 18 GHz (see, Table 4). HE360 will use a signal generator (Ettus Research B200 and Windfreak Technologies SynthHD Pro can be used interchangeably for our testing, so both systems are listed in the table) and tripod-mounted antenna at approximately 1.5 meter height emitting a low-power signal at the RF-sensor hardware sitting on a table at approximately 1.5 meter height and approximately 1 meter away. HE360 will transmit at the frequencies listed in Table 4 for approximately 30 seconds each per test.

Table 4: Payload RF Sensors

System	Description	RF Sensor Suite					
		Payload Sensing 1		Payload Sensing 2		Payload Sensing 3	
Transmitter	Manufactuerer	Ettus Research	Windfreak Technologies	Ettus Research	Windfreak Technologies	Ettus Research	Windfreak Technologies
	Model	B200	SynthHD Pro	B200	SynthHD Pro	B200	SynthHD Pro
Antenna	Manufactuerer	TEKBOX		RFSpace		A INFO	
	Model	TBMA1		TSA900		LB-SJ-60180	
Antenna Characteristics	Directional? (Y/N)	N		Y		Y	
	HPBW (Deg)	N/A		60		30	
	Peak Gain (dBi)	2		6		12	
Frequency & Emissions	Lower Frequency (MHz)	20		1000		6000	
	Upper Frequency (MHz)	1000		6000		18000	
	Carrier Frequencies (MHz)	25 55 85 140 150 162 175 300 390 400 406 440 600 800		1160 1550 1570 1590 1643 1750 2025 2700 3050 3300 6000		6000 to 18000, 50 MHz steps	
	Station class (Fixed/mobile)	Fixed		Fixed		Fixed	
	EIRP (dBW) (Peak)	-38		-34		-28	
	Emission Designator	2M00G1D	2K00N0N	2M00G1D	2K00N0N	2M00G1D	2K00N0N
	Modulating Signal	QPSK	None	QPSK	None	QPSK	None

Interference Analysis

Nominal testing is not expected to exceed 20 hours per spacecraft, and HE360 expects to test a maximum of 18 spacecraft per year. Testing is expected to be conducted in approximately 5 hour or shorter periods. Accordingly, the limited transmissions will mitigate potential interference.

Considering the relatively low powers of the emissions requested, the compliance with the GPS re-radiation NTIA Redbook requirements, the low height of the transmitter, and the building attenuation as a result of all testing occurring indoors, HE360 does not anticipate any harmful RF interference.

The RF emissions from the test equipment validating the receivers and sensors are all at very low EIRP density levels that, when coupled with expected building penetration losses, the potential for harmful interference is negligible.[5]

[5] HE360 has contemporaneously submitted a coordination request with the Federal Aviation Administration regarding testing on the 300 MHz, 390 MHz, 400 MHz, 1160 MHz, 2700 MHz, and 6000-18000 MHz frequencies, as required by the FAA. Additionally, for the frequency

The RF emissions from the radios used for the S-band (2200-2290 MHz) and X-band (8025-8400 MHz) transmitters have higher EIRP density levels but are not expected to cause harmful interference. In the S-band (2200-2290 MHz), the EIRP is 1.3 dBW. The transmitting antenna is pointing at 0 degree elevation and has a low height above the ground.

The band is allocated for Federal Earth exploration satellite service (EESS), Space Research, Space Operations, Fixed, and Mobile use, and for non-Federal space launch operations.[6] The satellite services (space-to-Earth) (space-to-space) allocated in this band should not be affected because they will not be susceptible to interference along the horizon. The Mobile Service and Fixed Services allocated in this band are sufficiently protected because estimated PFD for the surrounding area falls below the ITU limits[7] after approximately ~10 km, assuming there are no path losses after exiting the facility. As can be seen in Figure 2, within 1000 ft (~305 m) in all directions, at least two additional walls (and many more in some instances) exist, which provide additional attenuation. The analysis in Table 5 assumes approximately a -20 dB of building penetration loss from exiting the HE360 facility, takes into consideration the height of the antenna (1.5 meters), and considers an additional -40 dB of building penetration loss from passing through nearby facilities. This shows compliance with the ITU standard within 1 km. Additionally, the S-band testing in the 2200-2290 MHz band will cease in approximately 6-9 months.

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testing associated with the 300 MHz, 390 MHz, and 400 MHz frequencies, the ELS filing system requires that parties submit a government contract number. There is no government contract associated with the testing. HE360 submitted "0" in the Form 442 to complete the requirements of the form. Given the factors identified above, the potential for harmful interference is negligible, and HE360 submits that grant of this application is consistent with the FCC's rules.

[6] *See* 47 C.F.R. § 2.106.

[7] ITU Radio Regulations, Article 21, Table 21-4.

Table 5: S-band PFD Calculation

	S-band	Units
EIRP Density	-25.7	dBW/4 kHz
Building Exit Loss (dB)	20	dB
Building Passthrough Loss (dB)	40	dB
Link Distance (m)	**1000**	**m**
Spreading Loss (dB)	71.0	dB
PFD	-156.7	dBW/m^2/4kHz
PFD Limit	-154	dBW/m^2/4kHz

In the X-band (8025-8400 MHz), the EIRP is 17.0 dBW. The transmitting antenna is pointing at 0 degree elevation and has a low height above the ground. The band is allocated for Federal and non-Federal EESS, as well as Federal Fixed, Fixed-satellite, and Mobile-satellite use.[8] The satellite services (both space-to-Earth and earth-to-Space) allocated in this band should not be affected because they will not be susceptible to interference along the horizon. The Fixed Services allocated in this band should not be affected because estimated PFD for the surrounding area falls below ITU limits[9] after approximately 5 km, assuming no further attenuation from terrain.

However, as can be seen in Figure 2, within 1000 ft (~305 m) in all directions, at least two additional walls (and many more in some instances) exist which provide additional attenuation. The analysis in Table 6 assumes a -20 dB of building penetration loss from exiting the HE360 facility, takes into consideration the height of the antenna (1.5 meters), and considers an additional -40 dB of building penetration loss from passing through nearby facilities. This shows compliance with the ITU standard within 400 m.

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[8] *See* 47 C.F.R. § 2.106. The 8175-8215 MHz band is also allocated to the Meteorological-satellite service.

[9] ITU Radio Regulations, Article 21, Table 21-4.

Table 6: X-band PFD Calculations

	X-band	Units
EIRP Density	-27.2	dBW/4 kHz
Building Exit Loss (dB)	20	dB
Building Passthrough Loss (dB)	40	dB
Link Distance (m)	**400**	**m**
Spreading Loss (dB)	63.0	dB
PFD	-150.2	dBW/m^2/4kHz
PFD Limit	-150	dBW/m^2/4kHz

Figure 2: Image of the Area Immediately Surrounding the Test Facility

In the event that HE360 is notified that the testing is causing harmful interference to authorized operations, HE360 will cease transmissions immediately.

Stop Buzzer Contact Information

Ryan Fielder

Senior Mission Coordinator

Hawkeye 360

Phone (USA): 571-668-0042

Email: ryan.fielder@he360.com