Raytheon Missile Systems
Experimental License Renewal Application
Exhibit 1
File No: 0102-EX-RR-2013

Tucson Test Facility
Explanation of Experiment and Use of Spectrum

Background:

This application is filed to renew an experimental license, KA2XAG, to use radio frequencies at radar cross section testing facility operated by Raytheon Missile Systems (RMS) in Tucson, Arizona. This application is for RMS to use this spectrum for independent research and development (IRAD) of products. The same facility is used for identical testing by RMS pursuant to government contracts. The use of the facility for government contractual purposes is the subject of a Navy frequency assignment request. After numerous meetings with both the Navy and the Federal Communications Commission (FCC) in 2008, 2009, and 2011, RMS was instructed that this facility requires both the Navy frequency assignment and an FCC experimental license, as it has in the past. The technical data presented here is identical to the technical data presented in parallel Navy submissions, because the facility is the same and the parameters required for its operation are the same.

Description of the Research Project:

RMS builds systems used for national security and defense. Creating products and systems that are difficult to detect is an important part of developing new technologies that keep our nation safe. While much of the company's work is performed on government contracts, some work is done independently to develop new ideas that may be useful to RMS's customers. That IRAD testing requires use of the Tucson Test Facility, and an experimental license is required for operation. The nature of the research is to determine the radar cross section of various objects under test. Radar pulses are narrowly focused to bounce off those objects, and the radar returns are evaluated to determine the profile of the object. There is no other way to determine the radar cross section of an object without using radar to test it, which is the purpose of the facility for which this license renewal is being filed.

This facility has had an experimental license, KA2XAG, from the FCC for nearly 20 years. The current renewal application proposes to continue operations at TTF exactly as they are currently authorized.

Synopsis:

- Test Range: Used for Radar Cross Section Testing
- Frequency usage: Tests step across frequency bands in 10 MHz steps
- Time of Use: 70 nanoseconds per frequency step, very short pulse duration
- Range design: Antennas are directionalized & down tilted to minimize energy dispersion

- Coordination: Past applications were coordinated with satellite providers, FAA, and other users

Technical Details of Testing:

TTF operates a low power instrumentation test range. This range operates on three discrete frequencies – 155 MHz, 815 MHz, and 1300 MHz (these frequencies are only used about 4 times per year for a day or two) – and steps across the 2-18 GHz and 32-39 GHz bands. The transmissions are made in 10 MHz steps with a pulse width of 70 nanoseconds with a beam narrowly targeted to analyze objects. Although the power level and antenna gain for these transmissions appear to be high, the narrow beamwidth and down tilt of the antenna minimize the impact of the power and antenna gain. Furthermore, the duration of the pulse is so short that it will not be processed by a typical radio receiver. The object to be tested is put on a turntable down range from the transmitters. The signals are pulsed to capture complete data on the profile of the object. The facility is searching for the returned signal. Those returns are processed to determine the profile of the object being tested.

Test Time:

The RF test time of any given object is short. An object is placed on the test range 520 feet from the antennas. For most of the testing, the transmitter is pulsed at each frequency, from 2 to 18 GHz and 32 to 39 GHz, in 10 MHz steps. The discrete frequencies, 155 MHz, 815 MHz, and 1300 MHz, are used only about two weeks a year. As noted above, each pulse is 70 nanoseconds in duration. This is repeated 128 times for the system to correlate the signal using a Fast Fourier Transform (FFT). Once this is done, the polarization is changed and the frequency stepping is repeated at the same angle. The object on the turntable is rotated thru 360 degrees in 1/10 degree increments, with the frequency stepping at both polarizations repeated at each angle. Depending upon the weather, up to 6 items, or patterns, can be tested each day. Normally only one or two patterns can be tested each day. In the rare event that six patterns are completed in a day, the RF – across all frequencies – is in use for a total of 14.8 minutes. The RF for any single frequency is on for only 387 milliseconds for the whole day, spread across the whole day. (See test time calculations, slide 10 in presentation attached.)

Geography limits interference potential:

TTF is located in a relatively unpopulated area without many radio receivers operating in this spectrum, which also minimizes the possibility of any potential interference. At the request of the FCC and others, RMS researched several questions, including whether there are satellite earth stations that would be affected by this operation and what the possible impact might be on satellite radio customers. RMS was also requested to provide additional theoretical analyses of the signal strength in the surrounding area.

Voice Communications Equipment Receives No Interference:

Research shows that voice communication equipment will not respond to 70 nanosecond signals because the signal duration is too short for a standard receiver to process the signal.

Additionally, FM receivers normally reject pulsed signals. Additionally, the squelch on most standard receivers dampens out any signal that is shorter than a millisecond in length. One pulse train from the TTF has less effect on a voice communication radio than a lightning strike. FM receivers are designed to reject amplitude variations in the received signals, which further reduce the likelihood of interference. Motorola makes a variety of handheld and fixed-location voice communication products. Their engineers stated that voice communication equipment will not respond to 70 nanosecond RF bursts.

To verify that TTF does not interfere with voice communication equipment, RMS engineers conducted a test using a Motorola handheld radio on the TTF range. The engineers tuned the radio to 155 MHz and placed it in the TTF main beam on the range with the TTF transmitter also set to 155 MHz. As expected, the radio did not respond to the maximum-power emissions from TTF. RMS engineers repeated the tests on 815 and 1300 MHz. In all cases, the radios had absolutely no response to the transmitted signals.

The signals will not cause interference to Wi-Fi systems. Furthermore, there are no Wi-Fi systems at the test range which could experience interference.

<u>Need for Continuous Spectrum:</u>

RMS needs continuous spectrum for its testing to be valid. When its testing is constrained by bands of spectrum being carved out, RMS is unable to gain essential information on the radar cross section of its new products. Carve outs do not allow for accurate measurements of the profile of those objects. The frequencies requested here are for use of the spectrum on a secondary basis.

The Navy's frequency assignments have been approved through the federal coordination process. We are requesting that the IRAD testing be permitted according to the same parameters already approved for use under those frequency assignments, and in accordance with the testing parameters previously approved for this experimental license. Raytheon has not had any complaints of harmful interference, and it does not anticipate any new interference concerns. The only difference between operation under the Navy authorization and the RMS experimental license will be the absence of a federal official in the test facility during IRAD operations.

<u>Spectrum plots show very weak signals beyond the test range:</u>

To illustrate the rapid drop off of the signal in all frequency bands, RMS ran theoretical spectrum analyses using Hertz Warfare software. Those spectrum plots illustrate that the signal levels are never higher than -70 dBm beyond the test range. The signal levels shown, unattenuated by buildings, are very low, and with the short pulse width, the possibility of harmful interference to any other radio use is minimal. Moreover, because the spectrum analyses do not take into account the attenuating effects of buildings, they predict much stronger signals than will actually be present during a test. The antenna gain chart in the attached presentation shows the power levels used for these analyses. Two of the plots are also included in the attached presentation.

The Hertz Warfare plots indicate that the signal strength of the TTF operation is never stronger than -70 dBm off RMS's TTF range. Analyzing the spectrum plots along with Raytheon studies of radio noise floor data, the TTF signal will blend into the radio noise. The TTF signals are no stronger than the surrounding radio noise, and thus will not create any additional harmful interference due to the proposed power increase. As shown in previous applications, the radar returns are down in the noise, which has led to the extensive testing performed to use correlation data to discern the real signals from the radio noise. Given the predicted weakness of the proposed radio signals, grant of this request will not lead to harmful interference to any of the surrounding area.

Satellite earth stations:

A search of the FCC database of commercially licensed earth stations shows that there are no site-licensed satellite earth stations within 30 miles southwest of TTF. As shown above, the range is directed at 237 degrees from the azimuth, or pointed to the southwest. RMS consulted with the FCC's satellite division experts regarding various satellite networks, including VSAT networks and other non-site licensed satellite networks. They were not concerned about harmful interference to satellite earth station operations because of the directionalized signal, the narrow beamwidth, the shortness of the radio pulse, and the low duty cycle. Even though the duty cycle of the TTF transmission is greater on VSAT networks than for any other service or network – TTF is on for 3.5 microseconds of pulsing on the VSAT spectrum out of a 161 microsecond sweep across all of the spectrum being used, which is a 2.17% duty cycle – this time of spectrum use did not cause concern to the FCC's satellite division engineers.

Satellite Radio:

Additionally, RMS researched the prospective impact of this transmission on use of satellite radios in the vicinity of TTF. Tests of these radios while TTF was operational did not result in any interference. Two other factors are worth noting: both Sirius and XM Radio have buffers built into their systems to protect against signal outages. Those buffers are four seconds long. The use of any single frequency at TTF is merely 387 milliseconds per day, significantly shorter than the 4 second buffer. Second, RMS consulted with the chief RF engineer at XM Radio to discuss the proposed testing. He does not anticipate any harmful interference will result from the proposed use of spectrum at TTF.

Occupied Bandwidth and Pulsewidth:

The calculated occupied bandwidth of 10 MHz is used for most of the transmissions at TTF. The system was designed to ensure that each test gives an accurate picture of the radar cross section of the object for the specified 2 MHz of spectrum. The system is configured using a signal generator controlled by a computer that creates a signal pulse that is then sent through a cable to the transmitter, which in turn feeds the pulse to the transmit/receive antenna. The pulsed transmissions were tested to show that the pulses use very narrow bandwidth, about 1 MHz at 3 db down from peak power and less than 2 MHz at 20 db down from the peak power. If the bandwidth was any greater, it would not be possible to design or redesign objects under test as necessary. The test range measurements of the occupied bandwidth are shown in attached plots. Any signal wider than the 2 MHz bandwidth shown here would negate the need to step in 10 MHz increments. The pulsewidth, 70 nanoseconds, was selected to ensure an accurate measure of the object being tested. The pulsewidth needs to be just large enough to create an RF envelop that covers the profile of the object. It must be small enough to ensure that the return signals arrive within a specified time window. All of the calculations presented in this filing are based upon a pulsewidth of 70 nanoseconds. There are some objects for which the pulsewidth used is actually shorter, as little as 30 nanoseconds. Typically, the pulsewidth is 60 ns, but we based our calculations on a "worst case scenario."

Stop Buzzer Point of Contact:

Should there be any instances of interference, the stop buzzer point of contact is:

Thomas J. Fagan, Spectrum Manager
Raytheon Missile Systems
520-794-0227 (office)
520-465-7087 (cell)

Conclusion:

Finally, any receiver would have to be looking for this directionalized transmission – located downbeam from the transmission, facing toward TTF. The receiver would also need to be seeking the pulsed transmission at just the frequency and instant that it is pulsing and be sufficiently sensitive to perceive the short duration, extremely attenuated signal (correlated signal). Standard radio receivers cannot perceive and process these signals at the pulse width used by TTF, thus any RF signal detected will be filtered out by receivers sensitive enough to detect signals that low.

The attached powerpoint presentation contains additional information in support of this application:

- Total potential RF On-time – for any day that the facility is in use (worst case).
- Antenna parameters –
- Hertz Warfare Spectrum analyses – not accounting for the attenuating effects of buildings
- Correspondence from the FCC's satellite division, showing their concerns have been addressed
- Correspondence from XM Radio, showing that the company has no interference concerns
- Test results from the measurements taken to determine the occupied bandwidth
- Measurements of radio noise in the vicinity of TTF showing why the power levels requested are necessary to conduct the tests and experiments at this facility.

For questions about this application, please contact Tom Fagan, 520-794-0227 or tjfagan@raytheon.com, or Anne Linton Cortez, 520-360-0925 or alc@conspecinternational.com.