Raytheon Missile Systems Experimental License Exhibit 1
File No: 0144-EX-ML-2008

Tucson Test Facility
Explanation of Experiment and Use of Spectrum

Background:

This application is filed 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), 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 in the Navy submission, 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. The 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, which is the purpose of the facility for which this license modification is being filed.

This facility has had an experimental license, KA2XAG, from the FCC for years. The reason for this requested modification is to add to the license some frequencies that the FCC has carved out of the continuous spectrum needed for the radar testing done at this facility.

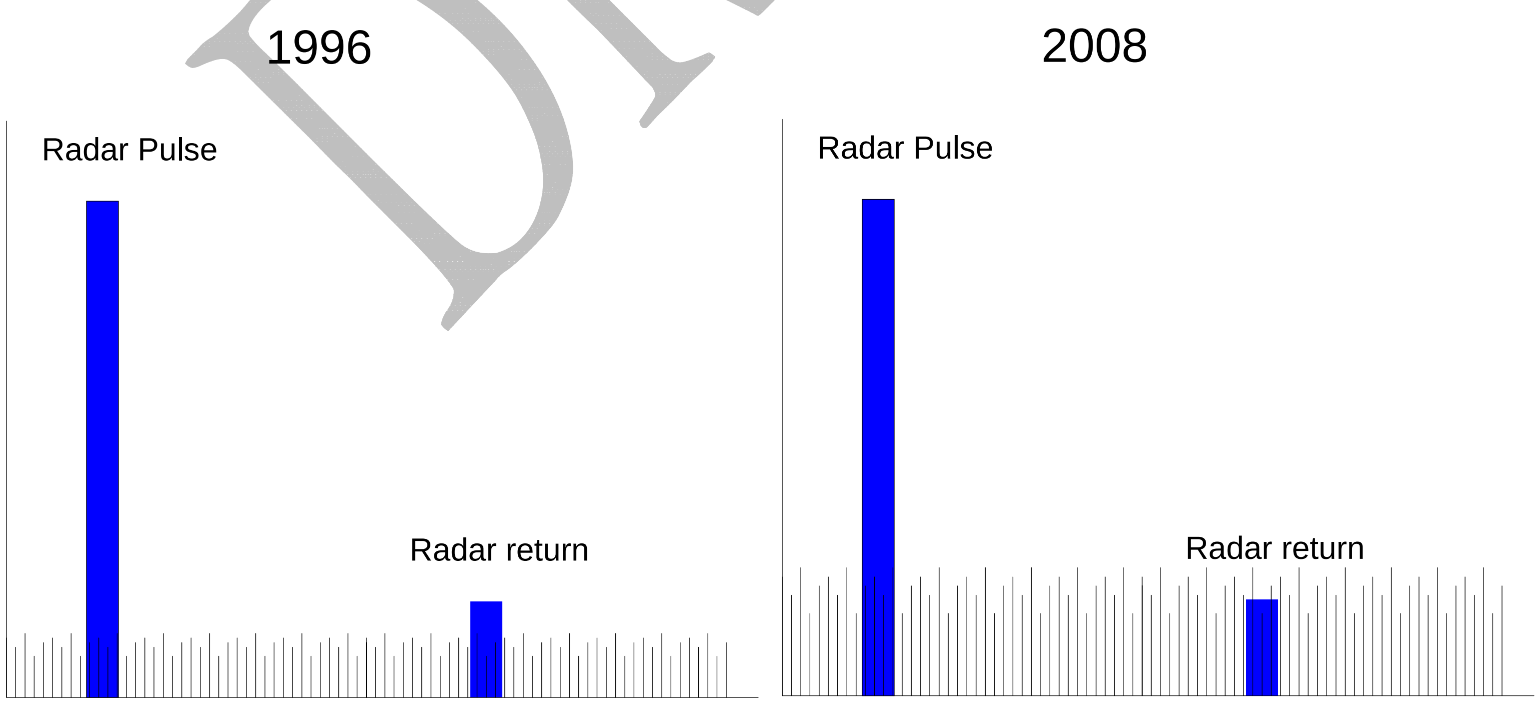
The frequencies requested to be added to this license are in the last column of the table below.

NAVY Frequency Bands	RMS Current Frequencies **KA2XAG**	Additional Frequencies needed for **KA2XAG**
155 MHz	155 MHz	
815 MHz	815 MHz	
1300 MHz	1300 MHz	
2000-4000 MHz	2000-2290 MHz	
		2290-2300
	2300-2360 MHz	
		2360-2390
	2390-2690 MHz	

NAVY Frequency Bands	RMS Current Frequencies **KA2XAG**	Additional Frequencies needed for **KA2XAG**
		2690-2900
	2900-3700 MHz	
		3700-4400
4000-8000 MHz	4400-4990 MHz	
		4990-5250
	5250-5600 MHz	
		5600-5650
	5650-5925 MHz	
		5925-8500
8000-12400 MHz	8500-9000 MHz	
		9000-9200
	9200-10000 MHz	
		10000-13400
12400-18000 MHz	13400-14000 MHz	
		14000-15700
	15700-17700 MHz	
		17700-18000
32000-38000 MHz	32000-39000 MHz	

After meetings with the FCC in April and July, and based upon the information included in the exhibits to this application, (and the fact that these same frequencies are authorized for use by the same facility at the same power levels) we believe that KA2XAG can be modified without any prospect of harmful interference to any governmental or commercial user in the area.

The power levels requested in this application are required by the facility because an increase in the ambient radio noise in the vicinity of the Tucson Test Facility (TTF) has made testing at lower power levels ineffective. (See diagram below for a visual representation of the current conditions.)



Background noise has increased during last 12 years
Power increase is needed to see radar return

<u>Technical Details of Testing:</u>

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. The increase in ambient noise due to nearby arc welders and other industrial facilities has made those returns impossible to detect. RMS's need for continuous spectrum is the reason for this license modification request.

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 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 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. (See attached calculations of test time.)

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.

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.

<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. Thus, KA2XAG currently does not allow for accurate measurements of the profile of those objects. Grant of this modification request will allow for an accurate study of the radar profile of objects being tested. The frequencies requested here are for use of the spectrum on a secondary basis.

The spectrum requested is identical to that authorized to the Navy for its use at the same facility. The Navy's frequency assignment is already in the federal coordination process, and we expect that the Navy will support this application. We are requesting that the IRAD testing be permitted according to the same parameters already under consideration, therefore we do not anticipate any new interference concerns. The only difference between operation under the Navy authorization and the RMS experimental license, if this modification is approved, 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 attached antenna gain chart shows the power levels used for these analyses.

The Hertz Warfare plots indicated that the signal strength of the proposed TTF operation is never stronger than -70 dBm off RMS's TTF range. Analyzing the spectrum plots along with the 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 above, the radar returns are buried 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.

<u>Satellite earth stations:</u> There are no site-licensed satellite earth stations southwest of TTF, which is directed at 237 degrees from the azimuth, or pointed to the southwest. A driving survey of the area found two Very Small Aperture Terminal (VSAT) dishes approximately 2.5 miles from TTF. RMS

consulted with the FCC's satellite division experts regarding various satellite networks, including VSAT networks and other non-site licensed satellite networks. They are 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. The duty cycle of the transmission for VSAT networks is greater than any of the others at 3.5 microseconds of pulsing on the VSAT spectrum out of a 161 microsecond sweep across all of the spectrum being used, or a 2.17% duty cycle. As noted, this did not cause concern to the FCC's satellite division engineers. (See attached e-mail from Scott Kotler, FCC.)

<u>Satellite Radio:</u> 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. A statement from XM is attached hereto. (See attached e-mail from Craig Wadin, VP of RF Solutions, XM Radio.)

<u>Occupied Bandwidth and Pulsewidth:</u> Several officials have expressed concern about the calculated occupied bandwidth, of 10 MHz, being 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 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."

<u>Conclusion:</u> 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 following pages, which are taken from the filing submitted to the Navy to support its frequency assignment request, contain additional information in support of this application:

- Total RF On-time – for any day that the facility is in use.
- Antenna parameters –
- Hertz Warfare Spectrum analysis – which does not account 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.