Raytheon Company (Missiles & Defense – M)
Experimental License Renewal Application
Call Sign: WI2XWW
File No: 0334-EX-CR-2021

Explanation of Experiment

Background:

Raytheon Company (Missiles & Defense – M) (Raytheon) is a US defense contractor that develops sophisticated technologies for the US government and governments around the world. Some of the development of new technologies is conducted under contracts with federal agencies; however other technology development is done for independent research and development (IRAD) which leads to innovation and new products.

The Advanced Security and Directed Energy Systems product line at Raytheon is focused on developing security solutions for critical infrastructure protection, homeland security, high value target security, etc. The current system under development is an advanced technology security system that uses millimeter wavelength electromagnetic energy to stop, deter, turn back, and otherwise discourage a pirate, trespasser or other threatening person at relatively long distances. The system consists of an electrical power source, a device producing millimeter wavelength electromagnetic energy, an energy director projecting a narrow energy beam towards a target, and mounting and connecting equipment. This application seeks to renew authorization for testing on inanimate carbon-loaded Teflon targets to advance the development of the technology.

This proposed testing is being conducted under a US Army Contract: H94003-04-D-0006, Delivery Order 0331

New Testing is required to meet contractual requirements of the US Army

Raytheon has been working on the development of its active denial technology using carbon-loaded Teflon targets for years. The US Army customer is requesting that Raytheon continue its testing and development of the system using a phased array antenna that will allow different types of focusing of the radio energy. The relevant contract number is: H94003-04-D-0006, Delivery Order 0331.

The testing will strictly adhere to RF safety standards.

The currently proposed testing will use infrared imaging of patterns on a sensitive Carbon Loaded Teflon (CLT) target – also known as black targets. There will be NO HUMAN TESTING conducted under the requested license.

The purpose of the currently proposed testing is to develop additional data on how the directed RF energy affects the black targets, how to build safety controls into the directed energy device while giving the device the flexibility to work in ways that might be useful, and to learn more about the characteristics of directed radio waves and how they propagate and perform under a variety of circumstances.

Technical Synopsis:

The energy will be highly directed.

- Frequencies: 91.0 to 96.0 GHz, primary use is on 92.75 GHz
- ERP: 7 kW
- Azimuth: limited at each location
- Beamwidth: The RF Energy is a focused RF beam
  - Almost all energy is directed in front of the antenna
  - At 1.5 degrees off bore sight, the signal is 20 dBi down
  - At 5 degrees off bore sight, the signal is 35 dBi down
- Pulse width: algorithms built in only allow transmission for 3 seconds at a time

Operations are similar to those authorized under Raytheon's experimental license WG2XHU

The proposed testing is an adaptation of testing that is currently authorized under WG2XHU. The key differences from the existing authorization include:

- Spectrum: this application requests use of 5 GHz of spectrum from 91-96 GHz
- Lower power: **previous** ERP was 50 MW, the **current** request is for an ERP of only 7 kW
- Two additional locations: This application requests the ability to test at another location on the Raytheon plant site and at a location near Florence, AZ.

The operations are otherwise consistent with those that are currently authorized.

Nature of the Engineering Experimentation Required:

There are a number of engineering parameters that the program needs to test in its development of this directed energy technology. Raytheon has been testing to determine how to properly focus and defocus its system. This application seeks authorization for the use of a phased array antenna that may be able to change the beam form as the system is in use. The phased array antenna will affect how can the beam be focused or de-focused at various distances to minimize the resulting energy to

safe levels, and second, testing the safety interlock in the device in the unlikely event that some obstruction was to get into the energy concentrator in the device.

1. Testing Focus and Distance: This experimental device uses directed RF energy to create heat in a target. Targets are acquired using a visual camera. The device incorporates an infrared range finder that measures the distance to the target. This range finder is actually a commercially available class 1 laser, which is safe. The range finder feeds the distance-to-target into the control system, which then sets the focus distance for the RF device. The device focus is modified to ensure that any operation directed to that target is properly powered to achieve the heating goal, without creating unsafe results. The testing required will allow the program to analyze the focus and defocus mechanisms to improve the integration of the targeting and ensure properly powered operation.

   This testing will also allow the program to align the signal concentrators (horns) to fine tune the focus of the RF beam. Because the technology requires very precise measurements, it is essential to test how the components work with one another. Being able to experiment with the focusing and defocusing of the beam using a changing target distance allows the program to ensure that the RF energy is limited to only that which would be needed. Setting the parameters for how the pieces of this technology work together is dependent on the information derived from the heat profiles captured at the targets.

2. Safety Interlock Testing: The RF device being developed is being designed with power monitors built in. The device uses a klystron to put forth the RF energy. The power monitoring is being designed to monitor the energy coming out of the klystron. If there is an interruption to the beam, from some foreign object entering the series of horns, then the safety interlock is intended to shut down the power to the whole device. The idea here is that if something such as a bird or an object were accidentally to get into the machine, the safety interlock would shut down the power before there could be any unintended consequences – within the machine or at a target site. To ensure the proper installation and functioning of the safety interlock technology, it is necessary to test the device as a whole. For this reason also, Raytheon is seeking this experimental authorization.

Black Target Testing, Not Human Testing:

The proposed testing will use a CLT board as the target for the directed radio frequency energy. These boards have RF absorption characteristics that mimic the absorption rate of human skin, and the RF absorption results in heating of the board, just as if the board were skin. The proposed testing will use an infrared camera to measure the temperature change on the Teflon boards. The information gathered from how much the temperature changes at the target, where the temperature

changes, and by how much and how quickly the temperature changes are all parameters that need to be tested to ensure that the technology under development could be used safely and reliably.

Only with an experimental authorization can Raytheon's engineers explore how to make the technology work effectively and safely.

Effective Area of Radio Beam:

Raytheon is also working on ways to control, shape, and size the RF beam at various distances. Most commonly, the expectation is that this device would be used at a greater distance, rather than at close range. This is why most testing is conducted with the target 50 meters down range from the transmitter. This is also why it is so important to test how to focus and defocus the RF beam, because it will be important to adjust to different distances, for moving targets. The goal is to create a beam that is narrow enough not to cause any harm to the target, while ensuring the effective operation of the technology.

Previous experimentation with DOD customers has generated a beam that is about 28-30 cm in diameter. The diagram below shows the signal concentration in the beam's target area, and it shows how rapidly the signal strength falls off outside the main beam. Further experimentation is required to determine if a smaller target area is possible and safe and to determine how to reach that goal.

Time of Use:

In target testing, the expectation is that the beam would be directed to the target for three seconds. The heating of the target would be measured, and those measurements will deliver information about how the beam is working at the particular distance and focus set for the test. Then, the device will have to remain off until the target cools down again. This is estimated to be about a two minute waiting period.

Location of Experimentation:

Raytheon is requesting authorization to test at three locations.

Location 1: a Raytheon facility at 3292 E. Hemisphere Loop, Tucson, AZ. At this location, all operations will be conducted indoors. The operations will be in a 20-degree arc from azimuth 170 to azimuth 190.

Location 2: Raytheon plant site test area, this is the current site of testing for this device under WG2XHU. The testing is outdoors, between buildings, across a 15-degree arc from azimuth 225 to azimuth 240. The energy is directed across unpopulated desert.

Location 3: Area adjacent to the Florence Military Range. The operations will be outdoors, directed across unpopulated desert. Operations will be across an arc between azimuth 0 and azimuth 90. In this instance, the operations will be directed across a range of elevation from 0 to 60 degrees. This will test the tracking of the system to see if it can acquire and target flying unmanned objects.

The experiments will only be conducted in a very limited area which will be cordoned off with signs posted in advance of testing.

The actual beam is quite narrow. Raytheon is seeking authorization to transmit across an arc at each location because the program needs to explore the tracking ability of the technology. The ability to track a target is an important component to the developed product, but it is impossible to determine how to use the tracking, and effectively test the focus and defocus of the device when it is tracking a moving target unless there is some ability to test on the black targets simulating the expected real-world conditions.

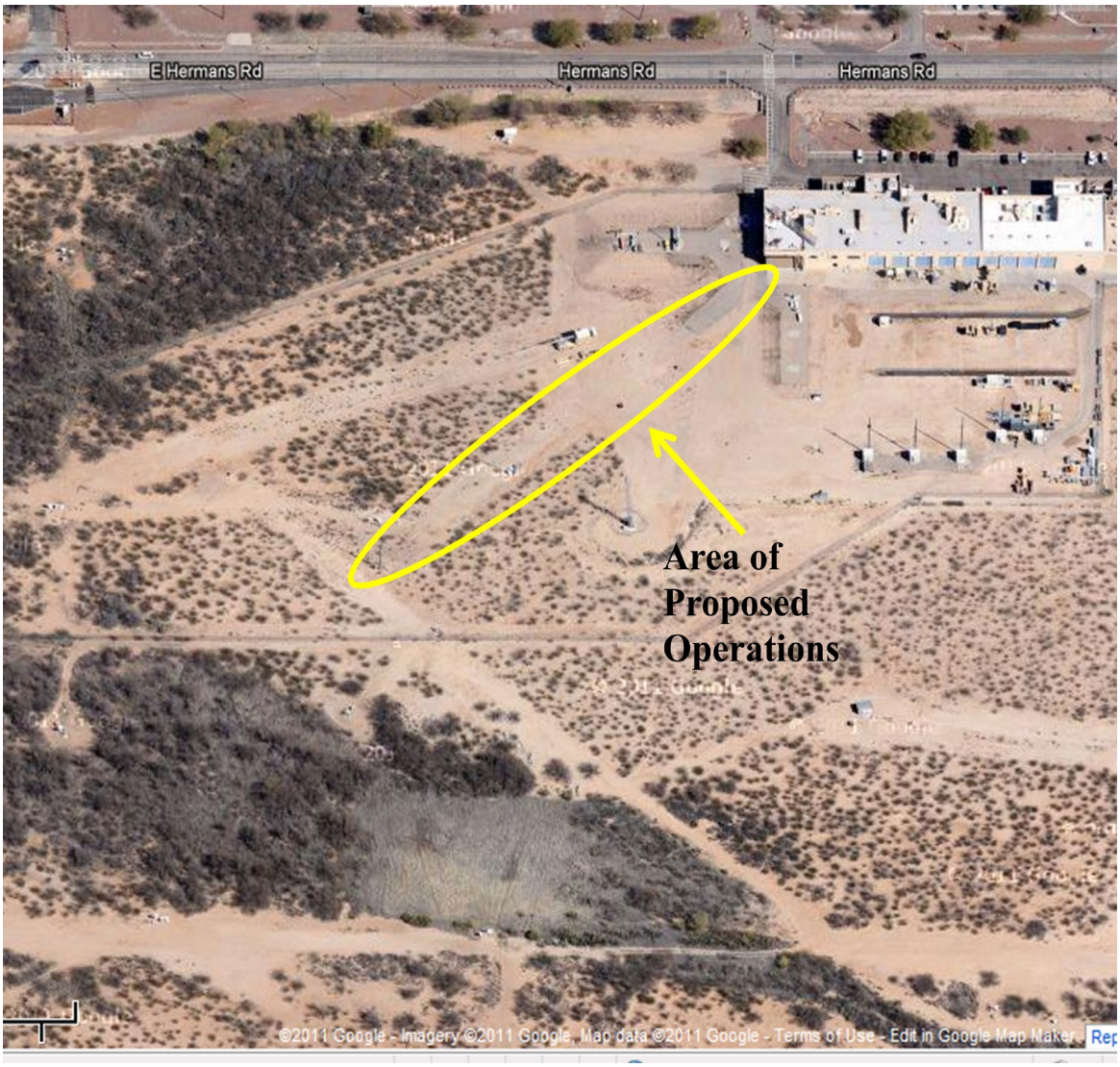

Figure 1: Area of proposed testing on RF test range at Location 2

RF Safety is of paramount importance in moving forward with testing:

Raytheon's RF Safety team has been thoroughly briefed on the proposed experimentation, and they have written a proprietary and confidential plan for the protection of the Raytheon workforce to ensure that Raytheon is in compliance with all RF safety requirements.

The RF Safety plan includes: cordoning off areas from all unauthorized personnel prior to activation of the directed energy device. The cordoned areas have signs posted at the perimeter to ensure that unauthorized personnel stay out of the area. A copy of the warning sign is attached to this exhibit.

The program has designated a RF safety officer who is responsible for ensuring that any and all operations by the program are fully compliant with the RF Safety plan. The safety officer has stop buzzer authority.

Stop Buzzer Point of Contact

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Conclusion:

Raytheon is requesting authority to continue experiments with its directed radio energy technology. The experimentation is being conducted to comply with Raytheon's US Army Contract: H94003-04-D-0006, Delivery Order 0331. The proposed transmissions are highly directed, and the beamwidth is very narrow.

The beam must be coherent, discrete, and controllable. Development of such devices requires advanced engineering and extensive testing across a wide set of parameters to ensure the safety of the device.

As Raytheon stated above, the proposed testing is to be on targets only; there will be no human testing under this proposed license.

For further information, please contact Anne Linton-Cortez, WFS, 520-360-0925, alc@conspecinternational.com.

RF Safety Warning Sign