Dr. Robert Hauge
Special Projects Office (SPO)
New Optical Sensors

I am Rob Hauge from DARPA's Special Projects Office. I'm here to tell you about our work in new optical sensors. One of our programs in this category is managed by Lt Col Greg Vansuch, and addresses the emerging threat of non-RF air defenses. As shown in the plot, our adversaries are increasingly turning to EO/IR defenses that are RF-silent. Our program to address this threat is named MEDUSA, after the mythical creature who turned anyone who looked at her into stone. The name was chosen to convey the goal of our program: to take out any air defense system that tracks our aircraft. It takes the paradigm we use to protect our aircraft from radar-guided surface-to-air missiles and applies it to protection against optical and infrared guided missiles. For years, we have had ways to find and target the radar trackers that are attempting to lock on and attack our aircraft. MEDUSA will attempt to do the same to infrared and optical guided missiles, which are much harder to find since they are often passive tracking systems.

There are a wide variety of these types of missiles. Some are handheld with infrared seekers. Some are seekerless and ride a laser beam that is pointed at the aircraft. Some are command guided by a tracking system that uses optics or infrared, perhaps with a radar too. The attribute they share is that they can all kill aircraft with little or no use of a radar.

Historically, aircraft have dealt with these threats in relatively passive ways. Dispensing flares and, more recently, using laser jammers to defeat them are the most advanced technical approaches. But, more often than not, we deal with these threats by avoiding them completely, which limits our freedom in the air.

The MEDUSA Program takes a more active approach, searching for these types of threats and dealing with them before they launch or immediately after launch. It combines active and passive optical systems and includes multiple modes of operation: search, track, classify, and optical defeat. The goal is to break the enemy air defense kill chain at multiple points, not just at the endgame. For example, if we can break track and avoid a missile launch, it's far superior to waiting until the missile is seconds away and then jam, jink, or deploy flares while crossing your fingers. It also clears the way for other aircraft in the same strike package. As senior officers at Air Combat Command said, they want to break the enemy air defenses as early in the chain as possible, to establish air dominance over the largest envelope of altitudes and locations.

The technical challenges for MEDUSA are to find these systems at long ranges, with a low false alarm rate, and to successfully disable the threats. The program is organized into three concurrent efforts:

- A measurements effort
- A set of component technology developments
- A system development.

There is a critical interplay between the three efforts. The data gathered in the measurements program will drive the system designers. Component technology maturity will determine the menu that system designers have to choose from. System designers will decide which components are most critical to their designs. We are actively encouraging communications among the three parts of the program through workshops and joint program reviews.

The first effort is to make a series of measurements and develop techniques that will establish some of the design boundaries for a MEDUSA system. Most of this work will be done by Government labs and their in-house contractors. There are four main work areas. We will measure the characteristics of the systems MEDUSA will be looking for. We will measure the likely operating background clutter. We will explore techniques for distinguishing targets from clutter. And we will develop techniques for optically defeating the targets. These efforts will establish a fundamental knowledge base for the rest of the MEDUSA Program. This database will be available to other U.S. Government agencies interested in using the data for other programs.

The second major effort is to develop the key component technologies required to build a MEDUSA system. In a study we did to determine the feasibility of MEDUSA, we identified some key technologies that would need development. At the top of the list are lasers that could provide enough energy or power at the right wavelengths to give MEDUSA a useful operational range. Our analysis pointed to lasers in the 20-30 watts range in the short-, medium-, and long-wave infrared bands, with various pulse formats for the search, classify, and countermeasure functions. We need detectors to work with lasers in a laser radar. Conventional direct detection techniques are not sufficiently sensitive to detect the few photons we expect to get back from targets, so we are exploring avalanche photodiodes, optical amplifiers, and coherent detection schemes to give the sensitivity we seek. We identified passive, multiwavelength infrared detector arrays as a key enabling component. In addition, there were some technologies required to make the MEDUSA system possible to fit on tactical aircraft. To avoid large gimbals that would destroy the aerodynamics and observability of modern aircraft, we need nonmechanical beam-steering techniques that provide large fields of view from a small aperture. And we need some way to move large amounts of infrared laser power around an aircraft, using some type of waveguide. To address these technical demands, we published a program research and development announcement (PRDA) this past fall. We awarded 11 contracts to various companies to begin work on all these critical technologies.

The third effort in MEDUSA is to actually build a system. We just awarded three contracts for a full design effort. Assuming the designs look promising and feasible, we will progress into a system development effort, followed by system demonstration. The candidate platforms for MEDUSA are fighter aircraft such as the F-22 and Joint Strike Fighter, although our final demonstration will probably be on a testbed aircraft. While we assume that the three contractors in the design phase will be the prime contractors for the development and demonstration phases, there is no assumption about their subcontractors or teammates. There are many difficult problems to solve, ranging from the high power lasers and sensitive detectors discussed earlier, to issues of integration on low visibility aircraft with limited volume, weight, and surface area. There is ample room for new, innovative ideas for the MEDUSA Program to solve these and other problems. If you have some novel technology or design ideas that would help us build a MEDUSA system, please see me during or after this meeting. Special areas of concern to me are high sensitivity infrared laser radars and compact optical beam steering.

In addition to MEDUSA, we are exploring other novel optical sensors to provide tactical sensing from both air and space. The same drivers of timeliness, responsiveness, and coverage apply to both air and space systems. Some constraints, however, are less stringent for aircraft deployment. We are interested in very lightweight optical systems for on-demand launch to orbit. We envision a launch platform such as a RASCAL or Pegasus, where the payload capacity constrains the technical solutions. The driver is really extremely lightweight optics and, as with space systems, we are interested in Fresnel lenses, membrane mirrors, and similar optical components. Lightweight optics, however, have their own challenges in manufacturing and aberration compensation.

Let's talk about a different approach for tactical optical sensing to provide both wide-area optical moving target indication and high-resolution imaging on the same platform. The goal is to give the battlefield commander both a wide-area surveillance mode and a narrow high-resolution imaging mode from the same optical sensor. Today's optical systems are used primarily to give the commander high-resolution images, but if a novel sensor can also give theatre-wide surveillance, it would be a big benefit.

There are two main performance goals for the dual-mode optical sensor. First, to find unresolved moving targets in high background clutter. We are looking at both software signal processing and novel hardware to be able to find moving targets. The second challenge is to design an optical system that can give this multifunction capability.

While it is relatively easy to build sensors to do either, it is not clear how best to get both functions from the smallest possible sensor. Obviously, one could put two sensors on the same platform or a single sensor with a zoom capability. What we're seeking is technology that produces both modes simultaneously (or nearly simultaneously), much like the human eye. This concept is known as foveated imaging.

For battlefield commanders, a wide-area surveillance mode would be used to look for troop and vehicle movements. We are conducting a study of what kind of optical sensor system is needed to obtain high confidence moving target indications that would detect vehicles moving at reasonable speeds in a typical clutter environment, using multiframe space- and time-based algorithms. The problem is challenging, but appears to be feasible using state-of-the-art signal processing, tracking, and some novel hardware.

A question that arises is whether it makes most sense to carry this type of dual-resolution system on an aircraft or a satellite. Each platform has its advantages. For instance, space is farther away so the signal level there is much smaller, and the satellite is moving much more quickly than an aircraft so the dynamics of pointing the optical system are somewhat harder. However, from space, we can expect to look down directly onto the targets, which reduces the geometric distortion of the pixels in the image plane. Because of the complex trades and technical challenges involved in a space-based sensor design, we are also investigating possible deployment of a foveated imaging system on airborne platforms.

The bottom line is that, next fiscal year, we anticipate investing in this area of novel optical sensors for airborne- and/or space-based applications. We are looking for your ideas to help us make these dreams a reality. Keep your ear to the ground for a BAA.