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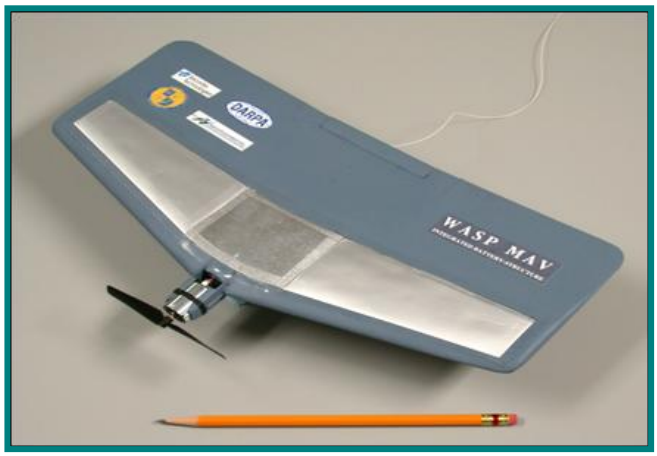
Ideas Begin Here

Dr. Tether has often referred to our office as the bottom of the food chain, the amoebas of the Agency. As life beings at the bottom of the food chain, so do ideas begin with DSO. We are equally comfortable putting capabilities directly into the hands of our Soldiers in Afghanistan and Iraq, while at the same time delving into the mysteries of quantum physics. This is an office that is developing walking robots, exoskeletons, and morphing aircraft, while examining novel materials, investigating radical approaches for maintaining the combat performance of our troops, and exploring new fundamental ideas in mathematics and biology. Ultimately, as befitting the bottom of the food chain, DSO's role at DARPA is to make everything above it more successful.

It is easy to make incremental progress in things you fully understand. However, as an office, we are always looking for ideas that will question existing beliefs about the physical sciences, biology, mathematics, and other disciplines. We consider the assertion that something can't be done to be a challenge, not an obstacle. And the more tightly held the precept, the more interested we are in dispelling it. Our approach is to go back to basics, to understand mechanisms, and then to take a new path forward that can yield breakthrough results.

In 1884, aluminum cost $1 an ounce or $16 a pound, the same price as silver at the time. This made aluminum a perfect choice for a 9-inch pyramid to crown the Washington Monument. The price of aluminum today is less that $1 per pound, driven down by a change from chemical to electrolytic manufacturing. This explains why 550,000 pounds of aluminum could be used as scaffolding in the recent restoration of the monument. However, if the monument were built today, it might well be capped with titanium, which today costs more than aluminum did in the 1800s. But despite years of trying, no one had been able to figure out how to electrolytically produce titanium at any reasonable energy cost. And so the common held belief was that titanium would always remain expensive and out of reach for most DoD applications. By going back to the fundamental thermodynamics, we were able to show there are, in fact, a number of ways to dramatically reduce the energy required to extract titanium from its cheap oxide. As we speak, DSO has several efforts underway that will make a revolutionary change in the way titanium is made and result in a cost of $4 a pound or less. This will open up myriad new Defense applications including corrosion-free pipes for Navy ships and lightweight armor.

In materials, we challenged an even wider held belief that structure is just dead weight that trades



Micro Air Vehicle with integrated battery and wing structure

against the capabilities of a platform. To dispel this precept, one only had to take a fundamental look how nature builds efficient structures. From that came the concept of multifunctional structures; i.e., structures with more than one function. For places where weight and volume are critical, this adds a dramatic new dimension to design. We now have a micro air vehicle whose battery is also its wing structure, allowing efficiencies that make it militarily valuable. Before the use of multifunctional structures, this vehicle could fly for less than 20 minutes. Today, this 175-gram vehicle can fly for over an hour at up to 30 mph with two cameras onboard. It is now being considered for use by three Services on both land and sea. This same technical approach has produced a structure that is also a heat exchanger, resulting in the possibility of designing new jet blast deflectors that will save 40 tons off the topside weight of an aircraft carrier.

In the field of robotics, it has always been understood that walking robots have an advantage over wheels in unplanned terrain. But, to make progress, we had to challenge the ineffective premise that legged robots have to be programmed by computer scientists using complex algorithms. This has led to biologically derived approaches for mobility that, for the first time, allow a four-legged robot to autonomously run and walk up a steep incline.

In other areas of biology, we challenged the belief that stopping pain meant blocking signals to the brain, thereby rendering Soldiers incapacitated. By looking at the biochemical origins of pain, we were able to develop a small molecule—an antibody—that blocks pain locally with greater effectiveness than morphine, but with no cognitive impairment. This is now in the process of being tested at Walter Reed for our wounded Soldiers.

In biological warfare defense, we contested the idea that one needs to develop a specific drug for each specific biological warfare agent that did little to handle bioengineered threats. As a result, we are on the brink of discovering approaches based on the general characteristics of a pathogen and its critical interactions with the host. This has led to a method now in clinical trials that could reduce the number of shots needed in the standard anthrax vaccination. It also might lead to a new class of therapeutics that will work against a wide range of biological warfare threats, even those that are engineered to be resistant to our current vaccines.

In mathematics, we challenged the belief that it required a supercomputer and an infinite amount of time to make full electromagnetic calculations on bodies the size of airplanes. By using novel mathematical algorithms to reduce the computational complexity, we got the problem to scale linearly with size. This now makes possible solutions that could otherwise never have been

Robot, inspired by a canine, walks on unplanned terrain.

done in our lifetime even with the largest computers we could imagine.

And in other areas, such as training, we challenged the belief that expensive, full-scale operations in places like the National Training Center are the only way to help our Soldiers train. We have been able to translate critical learning experiences into computer-based lessons and have two new laptop-based systems deployed in Iraq. The first is a basic language tool that allows a Soldier to learn simple Iraqi Arabic and, more important, the right cultural gestures such that he or she can interact with the population safely and effectively. The other, DARWARS Ambush! is a PC game based trainer that links up to 24 Soldiers to practice working as a team to prevent the ambush of a military convoy. Both systems have gotten rave reviews from Soldiers who have been in Iraq.

DARWARS Ambush!

While the previous discussion has told you some of what we have done, the real purpose of this morning is to bring you along on our next imaginative journey, guided by several of our newest program managers.

Amy Kruse will explore the fundamental world of biology and describe our next steps toward exploiting this powerful, emerging area for Defense. She will tell you how fundamental advances in less explored areas of biology such as neuroscience can lead to revolutionary new approaches to enhance the way our Soldiers learn and make decisions in the presence of environmental stress.

Ben Mann will explain that our ability to cultivate and exploit new mathematics will be critical to making the conceptual leap from description to the predictive understanding necessary to handle the increased complexity of DoD problems

Ralph Chatham will weave a tale of how to revolutionize the way military does training and simulations. He will tell you why the training of the past decades must be revolutionized for the 21st century by harnessing simulation technology from the commercial gaming world.

And Geoffrey Ling, an Army Colonel MD who spent time in Afghanistan, will talk about one of the unintended consequences of saving lives with improvements in body armor—that of young Soldiers returning home as amputees. Geoff will describe our hopeful plans in biology and engineering that can be leveraged to provide a prosthetic with the characteristics and control of a natural limb.

Finally, Brett Giroir will put everything in perspective. He will talk about specific opportunities and tell you how you can help make our visions come true.

Carl Sagan said, “Imagination will often carry us to worlds that never were. But without it, we go nowhere.” This fits the office quite well, for without imagination we cannot challenge the world.