

## Inner Armor

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### *Teleprompter script*

“ Thanks Dan. DARPA has responded to the enemy’s new and improvised weaponry with novel solutions which have already saved countless lives. We have made extraordinary advances in the *external, physical armor* that protects our Soldiers from most of the enemy’s weapons. Our job is however, incomplete. There is one flank that remains unprotected, and it is this gap that is responsible for continued unacceptable levels of morbidity, illness, injury and death.

Not ALL of the threats encountered by our deployed Soldiers are inflicted by the enemy. The dramatic increase in the number of exotic, primitive and tropical battlefields brings the modern military into extreme contact with the world’s most hostile environments—and most dangerous threat agents. As a DARPA program manager and physician-scientist, it is my vision to address all of these threats, and to leave NO PART of the soldier unprotected. My mission is to provide comprehensive protection for the warfighter. It is my goal to provide our men and women with an unfair advantage over the enemy.

In the next 2 years, I am developing technologies that will extend the soldier’s personal protection beyond bullets and bombs, to include protection against environmental threats, infectious diseases and chemical, biological and radioactive weapons. The effort will require orthogonal strategies to harden the warfighter against extremes of temperature, ...to rapidly adapt Soldiers to high altitude, to blue water operations, to prevent infection before it occurs, and to protect the soldier against new-generation weapons of mass destruction.

The objective is to fortify the entire soldier against attack from the enemy--or from the environment. I call this comprehensive protection *Inner Armor*. In the next several minutes I will talk to you about the two focus areas of Inner Armor—Environmental Hardening, which will allow Soldiers to excel in the worlds harshest environments, and Kill-Proofing, which will protect them against chemical, biological and radioactive weapons.

...Let’s begin with Environmental Hardening.

Today’s wars require our military deploy with minimal delay, to far-off, remote and austere environments. These operations often require small, lightly provisioned, fast moving teams capable of engaging an enemy that is fleet, camouflaged, skilled and insidious. Under these conditions, casualties resulting from hypothermia, heat and altitude illness can have devastating consequences to life, to limb, and to mission success.

Let’s look at one of the most challenging of today’s war zones: the mountains of Central Asia.

In Afghanistan, our Soldiers are pursuing a seasoned, acclimatized and battle-hardened enemy on **their** home turf. Our Army Rangers who train in the mountains of Georgia at elevations less than 4000 ft must engage an enemy superbly conditioned to fighting on the 16000 ft peaks of the Kashmir. Our Soldiers must pursue the enemy while wearing 100 lb packs.

Soldiers arriving to the alpine battle theatre must also battle the triad of altitude illnesses: acute mountain sickness which causes headache, nausea, and insomnia, ...and the 2 more deadly ailments, *high altitude pulmonary edema* which prevents the lungs from delivering oxygen to the blood, and *high altitude cerebral edema* which causes swelling of the brain. Our team at DSO has recently uncovered a new and natural compensatory strategy for preventing all 3 types of altitude illness. The discovery holds the promise of allowing the war-fighter to immediately adapt to high alpine conflict zones.

Let's talk about that.

Meet Apa Sherpa. Apa Sherpa is a middle-aged Nepalese highlander who lives above 15,000 feet.... and... *who likes to drink beer*. Apa Sherpa also set the world speed record for ascending Mount Everest, which is 11,000 feet higher than the mountains of Afghanistan. He set this ascent record without using supplemental oxygen.

On the summit of Everest, Apa was breathing only one-FIFTH of the oxygen that we have in this room. This feat is accomplished by triggering the local production of a natural molecule called nitric oxide, which increases organized blood flow in the lungs, thus improving total oxygen transfer capacity to the blood. This adaptation is *also found* in non-Sherpas who ascend to altitude... but the effects may take weeks to become elevated.

...We do not as of yet, know how beer contributes to this achievement.

My job is to prove that high altitude acclimatization can be transplanted to Soldiers arriving from sea level, allowing them to immediately engage the enemy in the vertical environment. Such a capability would radically advance high altitude military operations, and perhaps air combat safety and performance, by accelerating the natural physiologic changes of altitude acclimatization currently found in the worlds most elite alpinists, the Sherpas.

High altitude environments also impact other physiologic processes which degrade mission readiness. At higher elevations, soldier's have a reduced ability to fight infection, maintain muscle mass, and to think clearly. Insomnia reduces alertness, saps strength and degrades morale. This is unacceptable for those that must respond quickly and decisively during life and death situations. Preventing this deterioration requires inspiration from some unusual places. For example, my DSO team is working to replicate the solutions provided by animals that excel in these extreme environments.

Meet the Male Bar Headed Goose. This is a species known to crash into jet aircraft at altitudes over 34,000 feet. In April this male goose took off from the lowland swamps of Southern China.

Over the next 3-days, he was tracked by transmitter as he flew continuously, increasing altitude to cross over a 22,000 ft pass near Mount Everest. Two days later he reached the lakes of Central Siberia. You might be impressed to know he flew this distance for 5-days without eating or drinking, and crossed the highest mountains on the planet.

...and after landing 3000 miles later, ...he *started looking... for ...a **Date***. Now That's Conditioning!

Scientists have only now started to understand how the bar-headed goose is able to transiently adjust his hemoglobin, the red cell protein which carries oxygen, for high altitude flight, and alter his metabolism to allow for continuous physical activity without rest.

In my programs to improve physical performance during high altitude and high atmosphere operations, I will be looking deeply into the clues provided by Apa Sherpa and the bar-headed goose. I will borrow from their success to develop transferable, transplantable acclimatization that speeds the body's natural adaptive process in a manner that allows an Army Ranger from Georgia to deploy to Afghanistan, and immediately give chase and engage the enemy without delay, limitation, or health consequence.

There are many other extremes of environment and our Soldiers see them all. Military operations underneath the water pose even more daunting challenges. Water is 11-15x more effective than air at pulling heat from the body. Also, the metabolic activity required for underwater operations results in limits set by oxygen supply, the onset of cold, dehydration and consumption of energy stores. Attempts to extract oxygen from water have been limited by the energy requirements and the poor efficiency of current systems.

Meet the Steller sea lion. During deep dives, the sea lion has developed the capacity to redirect blood flow away from non-critical organs, thus reducing oxygen demand. One strategy then, to improving oxygen use by our navy divers, may *not* be to increase oxygen supply, but rather to do what the sea lion does: *reduce total body oxygen DEMAND*.

The sea lion does more than preserve oxygen for use by the most critical organs such as the brain, heart, and lungs; he is also able to slow the heart rate during deep dives. Recent studies show that humans also have a residual capacity to slow the heart rate and redirect blood flow during dives, however, this response is unstable, blunted, and difficult to control. What has recently been discovered is that both the sea lion and human oxygen-preservation dive reaction or "dive reflex" is in part neurally-controlled.

Imagine the advantages of reproducing the natural compensation mechanisms of diving mammals to conserve oxygen by 30-45% during military dive operations. In a time not too distant, our military divers might wear a device that provides a push button controlled "dive reflex" allowing for a reduction in the total oxygen consumption during loiter activities but which is turned off when divers need to perform at high levels of exertion.

Let's now move on to places hot and dry.

In desert battlefields our military carry out operations limited by the threat of heat exhaustion and heat stroke. In middle eastern operations, our foot patrols are limited by the heat tolerance of the soldier and the water capacity of their camelbacks. The reason for this is that the human body sheds heat *primarily* through evaporative cooling of perspiration from the skin. During extreme exertion, water loss can exceed 1.25 liters/hour ...or 2.3 lbs/ hr. Therefore, one soldier on an 8-hr patrol requires up to 10 liters ...or 25 lbs of water. Imagine the advantages over the enemy of reducing this demand. Our soldiers could go farther, operate at higher levels of exertion and carry less water than the enemy.

Meet the archaen. This is a microorganism that uses enzymes that deflect heat away from critical physiologic functions. What if we were to develop designer-enzymes based on this microbe to create materials that have the same heat transfer capabilities, ....thus dramatically increasing **radiant** rather than Non-evaporative, heat loss? Imagine the value of a technology that would separate **water** demands from **cooling** demands?

In humans, core body temperature can be controlled by the temperature applied to superficial veins in the arms and legs. Thus, "heat dumping" materials comprised of designer proteins, could be worn as "venous radiator patches" over the 8 anatomic locations where major blood vessels lie close to the skin.

The second focus area in Inner Armor that I want to share with you is Kill-Proofing.

As of today, our Soldiers are vulnerable to diseases to which the enemy is immune. When a single soldier is infected, the mission is jeopardized and often, terminated. The medical evacuation of ill and injured casualties places comrades and medical corpsmen at risk of bullets from snipers and infection from contagious casualties.

Let's first look at ways to "kill-proof" our Soldiers against chemical and radioactive weapons. Over the last 2 years, surveillance studies of the world's most toxic places, including nuclear waste and chemical weapons dumps, reveal that these ecological niches are teeming with life. The organisms growing in these areas have developed compensatory biological mechanisms to deal with radiation and chemical toxins. Many enzymes produced by these microbes and fungus provide wide-ranging protection for DNA and for critical physiologic processes.

Many of the enzymes under study share properties with drugs the physician uses to treat the side effects of radiation or chemotherapy. It is our intention to mimic these natural successes in the human body by producing synthetic vitamins and safe preventive drugs that will forestall the onset of radioactive and chemical injury.

Throughout recorded history there has been no greater natural threat to the soldier than infectious diseases. Currently, we prevent infections from exotic and tropical diseases through daily or weekly doses of microbial inhibitors and poisons, such as those used to prevent

malaria. Today's military vaccines only protect our Soldiers against 7 of the 44 highly dangerous pathogens that our Soldiers encounter in today's conflict zones.

We can do better.

There is an opportunity to radically transform this situation. I envision that we will pre-position universal immune cells that are capable of making antibodies that neutralize tens, perhaps hundreds, of threat agents.

Imagine that in the future, a universal immune cell can be quickly given to any non-immune soldier who is going into harms way, which will provide stand-by protection against any tropical infection, or agent of bioterrorism.

Over the last 15 years, 16 new killer pathogens have emerged, and most of these occur on foreign soil, including in regions which harbor terrorists. Our current methods for developing vaccines require access to these pathogens, which poses problems if these microbes are controlled by unfriendly nations.

Additionally, today's vaccines work only for diseases that are already here and already causing infections, illness and death. What we need is to **preempt** a pathogen's emergence with a effective vaccine.

...But how do we prepare for tomorrow's pathogen or anticipate which genetically engineered biological agent will be used?

One effort we are pushing is to develop technologies for predicting pathogen *evolution* in advance of its occurrence. This prediction capability will work for naturally-occurring pathogens ...and those engineered at the hands of man. Our intention is to couple this program to the first vaccine manufacturing platform that does NOT require access to the pathogen. My team at DSO is currently working to develop an extraordinary flexible, transportable, vaccine system capable of producing 3 million doses of any vaccine or therapeutic within 12 weeks at pennies per dose. Once we have identified which pathogen will threaten our Soldiers,... natural or man-made, we will develop and refine vaccines, and test their safety and effectiveness in "humans" without a patient ever being injected.

I want to be clear: we will prove that tomorrow's vaccines will actually protect our Soldiers, without jeopardizing human safety during clinical testing. The reason for this is that our Soldiers are not little white mice, and when mice are tested with human vaccines, they often become *lying little liars*. DARPA is correcting this weakness in drug and vaccine testing by replacing animal testing with a high throughput, human immune system which is grown, trained and tested entirely in the laboratory.

I want to end with this. I DO NOT accept that our Soldiers cannot physically outperform the enemy on his home turf. My DARPA vision is that we have the drive, motivation and resources to environmentally harden our Soldiers to allow them to outperform native combatants in the

harsh environments in which they were born, raised and now wage terror. We must also work to make our men and women Kill-Proof against infectious disease, radioactive and chemical threats delivered from intentional man-made or natural sources. I need your help and ideas to close the remaining gaps and complete my vision of inner armor.

Next, to conclude our DSO set of speakers, is our Deputy Director, Barbara McQuiston.