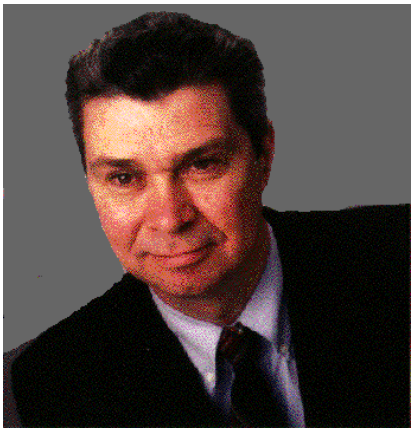
Wave Front

the Directed Energy Technical Newsletter - Summer 2001

Director's Forum



It is a pleasure to share some thoughts with the members during these very exciting times for Directed Energy and for DEPS. Within the community, the OSD HEL JTO has requested, through the President's amended FY 02 budget, a $64M increase in funding for HEL science and technology. The Army has also requested an increase in funding for HEL S& T, and the Navy has re-established an HEL Program Office. Many in the administration and in Congress are showing significant interest in HEL programs, such as THEL, ABL, and SBL, and in High Power Microwave applications (see the Feature Article). DEPS sees a major role in trying to foster communications among the government, industry, and academia and DEPS members, through symposia, workshops, short courses, through this newsletter and the DEPS web page (www.deps.org)

DEPS has also been busy. To support the growing level of activities and better serve our members and sponsors, the Board of Directors agreed to hire an Executive Director. We were very pleased to receive eighteen applications from very well qualified individuals. It was a challenging selection process, and we are very pleased to announce that Dr. Sam Blankenship has joined the DEPS team. Welcome aboard Sam!

DEPS sponsored the Solid-State Diode Laser Technology Review (SSDLTR) Conference in Albuquerque in May 2001. DEPS led a panel discussion describing DEPS and its vision. In addition, DEPS chaired a Military Applications session. DEPS is again planning an Education Workshop on September 19, 2001.

DEPS will also co-sponsor an OSD HEL JTO- Industry and Academia Roundtable in Albuquerque in September 2001. Don Lamberson presented the DEPS vision and mission to the National DE Alliance, with an offer to help the NDEA and the HEL JTO interface with the industry and academic community.

DEPS will sponsor with the US Army Space and Missile Defense Command as host, the 4th Annual Directed Energy symposium. The symposium will be held October 29 through November 1, 2001 in Huntsville, AL. The symposium, chaired by Dr. Randy Buff of SMDC, promises to be interesting with events at the NASA Space Museum and other areas of interest. Please check the DEPS web site for information and registration information and register today.

DEPS is also working on a Directed Energy Journal. We are currently planning for an electronic journal. We will be seeking articles in DE systems and sub-systems engineering as well as fundamental and applied science. Start preparing your articles. Look for information soon.

The DEPS Board has selected and announced the members of the board of Scientific and Engineering Advisors. The members: Fritz Benning, Boeing, Dr. Barry Hogge, SAIC, Keith Brown, Raytheon, Edl Schmiloglu, UNM, Darryl Greenwood, MIT/LL and AF SAB. To honor those that have made outstanding contributions to the directed energy field, the DEPS board is seeking nominations for "DEPS Fellow" candidates this fall. The selections, recommended by the Board of Scientific and Engineering Advisors, will be announced next fall at the annual symposium.

As you all know, DEPS is a volunteer organization. I want to thank all the volunteers who are making things happen within DEPS and the community. Our committee chairpersons and their members are providing an invaluable service. If you want to do more, please contact the chairs or Sam Blankenship, or the board. Thanks again.

Edward A Duff
Member of the Board

Active Denial Technology

By: Dr. Kirk E. Hackett, AFRL/DEHA
LtCol Dennis Scholl, AFRL/HED

A field demonstration of non-lethal antipersonnel directed energy weapon technology, Active Denial Technology (ADT), is ongoing at Kirtland AFB, NM. This field test is designed to demonstrate critical enabling technology for a vehicle-mounted repel system, prove the ability to propagate an energy beam to tactically significant ranges, conduct large spot size human repel effects testing, and allow the assessment of the operational utility of ADT.

ADT represents a new class of weaponry which not only uses directed energy, but which is also non-lethal. The ADT demonstrator produces a powerful beam of mm-wave energy that heats the target's skin, causing intense pain. The pain repels adversaries. There are many reasons why a military capability exploiting this effect is interesting.

A Brief History

In the mid-80s, Strategic Air Command published a statement of need for non-lethal weapons to guard high value national assets. Air Force Research Laboratory (AFRL) scientists at Brooks AFB, TX created a concept that might provide such a capability. Funding to investigate these concepts came from the Air Force and from a physical security group in the Pentagon. An Air Force-funded repel demonstrator using a low power source was built and tested in 1994-96.

After the Cold War ended, deployments of U.S. forces in peace support operations increased dramatically, and new concerns of asymmetric warfare emerged. Incidents in Somalia, and peacekeeping operations in the Balkans and elsewhere, re-stimulated the development of non-lethal weapons technologies.

In 1996, Congress directed the Defense Department to create a joint organization to develop non-lethal technology and capabilities. The Marine Corps was chosen as the Executive Agent on behalf of the Defense Department. In Mar 97, the Joint Non-Lethal Weapons program funded AFRL to produce two vehicle-mounted repel demonstrators.

The Repel Effect

ADT uses a 95 GHz beam of energy to heat the skin. There are several reasons for this choice. Powerful, efficient mm-wave source technology exists. As frequency increases, the ability of an antenna to concentrate energy increases as the square of the frequency in the far field. There is an atmospheric transmission window near 95 GHz, and energy penetration in tissue at 95 GHz is 0.3 mm. Nerves in the skin that cause pain are located at the same depth.

ADT exploits intolerance of thermally-induced pain. Pain is a primitive part of the nervous system that has evolved to help keep us from being damaged. Pain makes us react quickly to avoid damage.

We have all touched a hot surface or received a blast of very hot air in the face from an open oven. If the heat is low, we can pull away from it without experiencing pain, but when the heat is high, our skin temperature can rise above 45 degrees Centigrade, where the pain threshold is crossed.

Pain intolerance depends on the intensity of pain and duration. At pain threshold, pain intolerance takes about seven hours. At higher temperatures, the intensity of pain increases rapidly until at skin temperatures above 50 C, pain intolerance takes less than a second. At 55 C, the maximum intensity of pain is experienced.

For legal and ethical reasons, ADT is designed to avoid burning or other effects that could be considered as causing prolonged or unnecessary suffering, permanent damage or long-term effects.

A burn is caused by high skin temperature and duration. The relationship between skin temperature and duration to cause a burn is well understood. At a skin temperature of 50 C, about 250 seconds is required to cause a burn, while at 55 C, it requires 20-30 seconds to cause a burn.

In the operational range of ADT, there is ample margin between causing intolerable pain and causing a burn. This allows exploitation of pain intolerance while avoiding damage.

Two common questions about ADT concern the possibility of eye damage and cancer. The eye has many pain receptors and an aversion response protects the eye before it is damaged. The aversion response is usually a combination of turning the head, protecting the eyes with a hand or arm, or simply closing the eyelids. The same aversion response also happens when an oven door is opened and a blast of heat hits the face. The photon energy of mm-waves is low – less than a 5000th that of visible light: these photons cannot damage DNA. Experiments have demonstrated that mm-wave energy does not promote cancer that has been initiated by chemicals. There is over 100 years of experience with electromagnetic energy in the environment. Despite searches there has been no link established (nor is one expected) between these low energy photons and cancer.

We are confident in the safety of our human volunteers. Repel has now been safely demonstrated on several dozen volunteers who have been exposed to weapons level beam parameters. All human experimentation is conducted in strict accord with approved laws and regulations requiring informed consent and approval by an Institutional Review Board and the AF Surgeon General's Research Oversight Council.

Technology

An ADT system consists of an electrical power source, a device producing a beam of mm-wave energy, an antenna directing energy towards a target and a beam transport connecting the source and antenna. The system, built by Raytheon AET of Rancho Cucamonga, CA, (Figure 1) is a full-power, full range demonstration system for

vehicle-mounted technology that integrates these elements. The system is not self-contained and little effort has been expended to package the technology.

The mm-wave source is a gyrotron, designed and built by CPI of Palo Alto, CA. In the gyrotron, a rotating electron beam is created in a strong magnetic field (~34,000 Gauss) generated by an electrically cooled superconducting magnet. The electrons interact resonantly with electromagnetic waves in a cavity. This interaction bunches the electron beam and electron energy is converted into mm-waves. The mm-wave energy is extracted from the cavity and mode-converted to a quasi-gaussian beam. The energy beam is shaped by mirrors and passes through a window made of polycrystalline diamond, which has low loss, high thermal conductivity, and high mechanical strength.

The antenna is similar in configuration to satellite TV receivers. The secondary mirror is shaped to uniformly illuminate the 2-meter primary reflector. This allows high aperture efficiency and increases energy density on target. The primary aperture, designed and built by Malibu Research, is based on FLAPSTM (FLat Aperture Parabolic Surface) technology. The FLAPSTM surface is a large Fresnel mirror and achieves high gain with less stringent mechanical tolerance requirements.

The antenna is mounted on an azimuth-elevation turret. Spatial stabilization allows antenna operation in high velocity buffeting winds. A boresighted low-light video camera and thermal imager are mounted on the antenna. The operator maneuvers the antenna with a joystick and depresses a trigger to fire the beam. Since the operator sees the target and surrounding area, he knows exactly what the beam will hit when he fires it.

The mm-wave beam is slightly absorbed in the atmosphere and heavy rain can degrade performance.

The Demonstration

Since spring 2001, the system demonstrator has been field tested at Kirtland AFB, NM. This was the final phase of a Force Protection Battlelab demonstration. The exit criteria required peak power density on target at range, dwell time, and spot size. These criteria were met or exceeded in late March 2001. Earlier phases of the battlelab demonstration used modeling and simulation and live force-on-force exercises to assess the operational benefits of ADT. These exercises showed significant potential in operational scenarios.

The demonstration system has also been used in a series of experiments to study the repel effect on people. At the time of writing, the repel effect has been safely demonstrated on several dozen volunteers.

After a review of the Vehicle-Mounted Active Denial System (VMADS) (Figure 2) program, it will transition to Electronic Systems Center at Hanscom AFB, MA for further development and weaponization. The system demonstrator will be used as a technology testbed and for additional effects studies.

Summary

In the final analysis, ADT is meant to save lives. Active Denial is a revolutionary force protection technology that will help fill the U.S. non-lethal capability gap. ADT systems

will provide field commanders with a non-lethal force option in situations where the use of force is authorized, but lethal force is not the preferred response.

One of the attractive features of ADT is that, since ballistics is not an issue, the probability of hit is 100%. The energy beam travels at the speed of light (nearly a billion feet per second muzzle velocity). As long as electricity is supplied, a continuous or pulsed beam of energy can be projected. This beam can be directed towards individual targets, swept across many targets, or dwelled to, for instance, suppress snipers or help form a barrier. The range of ADT considerably exceeds the ranges of conventional non-lethal technologies and is meant to out-range small arms fire. Since the system is powered electrically, it has a deep magazine – as long as power is supplied the system can fire the energy beam.

Many applications of ADT are possible, including airborne, maritime, fixed site, or man-portable. All of these applications are being studied for their operational benefits and technical feasibility.

Figure 1. The System 0 demonstrator

Figure 2. Vehicle-mounted ADT

High-Power Diode Laser Arrays, Overview

Alan Paxton
Air Force Research Laboratory
Kirtland AFB, NM

Semiconductor diode lasers can be extremely compact and efficient. They provide the pump light for fiber lasers and for the most efficient solid-state lasers. Thus, they are used in all of the electric lasers that are under development for directed energy applications. Arrays of diode lasers are also applied directly for industrial applications such as light welding, ablating, drilling, cutting, and heat-treating various materials. The electrical efficiency of near-infrared high-power diode laser arrays is usually in the range, 30% to 50% (not counting the power that is expended in cooling the arrays). No other type of electric laser comes close to their efficiency.

A 1-D array is usually fabricated by growing a number of lasers, side-by-side, onto a strip that will be cleaved from a wafer, as shown in Fig. 1a. This type of array is called a bar. The lasers are contacted in parallel, sharing one pair of electrical contacts. The output power of the bar can be changed as a whole, but the output power of one laser cannot be adjusted individually. A popular format for a bar consists of 19 lasers equally spaced along a bar that is 1 cm long. Each laser has a current-injection contact that is 100 to 150 micrometers across. Values of the output power available from CW bars mounted on water-cooled heatsinks can exceed 40 W.

Output beams, from wide-stripe lasers of the type usually found in bars, are far from diffraction limited in the dimension parallel to the plane of the wafer (the slow axis). The divergence angle is typically about 10 degrees (FWHM). Because the emitting surface of a laser is so narrow in the direction normal to the junction plane (the fast axis) the beam divergence is greater, typically about 40 degrees (FWHM), but it can be drastically reduced by incorporating a lens. Figure 1 b shows the pattern of the light from one laser, projected on a plane between the observer and an unlensed bar which is shown edge-on. The light beams emitted by the lasers in a bar are completely mutually incoherent with respect to each other. For pumping slab lasers, arrays may be unlensed or may include fast-axis lenses. Array systems that are used for most other applications include a number of sophisticated optical elements to shape and focus the laser beams.

Bars are assembled into 2-D arrays to obtain yet higher power. A distinction can be made between two types of assemblies. In one type, the bars are mounted directly over the cooling channels of a cooler. These are often referred to as “microchannel” coolers, although some designs have cooling channels that are 100s of micrometers across. A common design involves mounting each bar on a cooler. The cooler-bar assemblies are stacked, making a 2-D array, as is shown in Fig. 1c. Arrays of this type are available with CW output power up to about 60 W per bar. Alternatively, bars are sometimes mounted on monolithic substrates that have cooling channels.

The second general type of 2-D array consists of a stack of bars with solid spacers. A cooler with circulating coolant is soldered to the back plane of the stack. A variation involves mounting the bars in slots cut in a block of solid material, which is soldered to the planar surface of a cooler.

There is active research in array development. Individual lasers with improved beam quality, and improved lensing and beam shaping optics are under development for use in array systems to increase the power that can be focused into a given spot. Packaging materials and techniques are undergoing improvements to more effectively remove heat and to minimize damage caused by thermal cycling, leading to higher reliability under stressful operating conditions. In order to open new markets there is a strong push to find ways to decrease the price per watt of unlensed arrays and of arrays with beams that focus to small spots. A decrease in cost would be a very desirable contribution to electric-laser, directed-energy programs. A very high total power from diode lasers is required for a directed-energy weapon.

As diode arrays are improved, they are capturing a share of the market for industrial lasers that has been occupied by Nd:YAG and CO2 lasers. Their added compactness and electrical efficiency are significant advantages for these markets as well as for military applications. Their continued development is crucial to the development of directed-energy electric lasers.

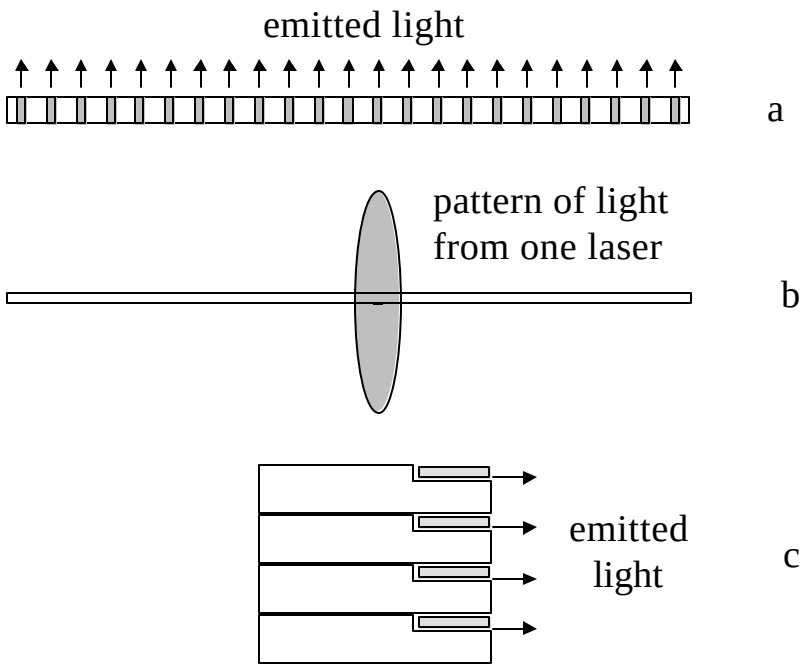


Figure 1. ***a) Diode laser bar, top view. Locations of current injection stripes are shown as hatched rectangles. b) Edge view of diode laser bar showing the pattern of the light, from a single laser, projected on a plane between the observer and the bar. The light has a larger divergence angle in the fast-axis direction, shown as vertical, than in the slow-axis direction, shown as horizontal. c) side view of bars mounted on microchannel coolers and stacked.***

Programmatic Update

The HEL Joint Technology Office (JTO):

In accordance with the recommendations from Congress, Section 244 of the Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001 (Public Law 106-398], the High Energy Laser, Joint Technology Office (JTO) has finalized plans to move its headquarters to Albuquerque, New Mexico. The office will be headed by Mr. Ed Pogue, formerly from Los Alamos National Lab. The office will continue to be under the auspices of the (DUSD (S&T)) Director of Plans and Programs) and will have representation from the Military Services and other Defense participants. The physical office complex will be located in the Science and Technology Park at the University of New Mexico approximately 1 mile from the Albuquerque airport (901 University Street). An official ribbon-cutting ceremony for the new facility is scheduled for the near future. More good news is the move of the JTO location has not stopped their work. The JTO is still planning to announce the release of a Broad Area Announcement for technology/academic proposals in the Fall.

Navy setting up a DE shop:

The Navy is reviewing its role in directed energy and appears to be considering opening a dedicated office for directed energy at the Navy Ship Yard. More information to follow.

BMDO gets a new role:

An excerpt from: Ballistic Missile Defense Organization's Director's testimony to House Armed Services Committee Amended Fiscal Year 2002 Budget July 19, 2001.

The mission of the Ballistic Missile Defense (BMD), Boost Defense Segment (BDS) is to define and develop boost phase intercept (BPI) missile defense capabilities.

The capabilities defined and developed in the BDS will progressively reduce the "safe havens" available to a hostile state. A "safe haven," is formed by geographic and time constraints associated with BPI. It is the region of a state from which it can launch a missile safely out of range of a potential boost phase intercept. To engage ballistic missiles in this phase, quick reaction times, high confidence decision-making, and multiple engagement capabilities are needed. The development of higher power lasers and faster interceptor capabilities are required to reduce the size of safe havens, whereas development of viable space-based systems could potentially eliminate them entirely. Thus, resources have been allocated to develop both kinetic and directed energy capabilities in an effort to provide options for multiple engagement opportunities and basing modes to address a variety of timing and geographic constraints.

There are four principal objectives for the BDS. First, it will seek to demonstrate and make available the Airborne Laser (ABL) for a contingency capability in Block 2004 with a path to an initial capability in Block 2008. Second, it will define and evolve space-

based and sea-based kinetic energy Boost Phase Intercept (BPI) concepts in the next two to four years, supporting a product line development decision in 2003-2005. This effort will include concept definition, risk reduction activities, and proof-of-concept demonstrations. For example, the sea-based boost program is considering a high-speed, high-acceleration booster coupled with a boost kill vehicle. This same booster will be evaluated (with a different kill vehicle) for sea-based midcourse roles. Third, the BDS will execute a proof-of-concept Space-Based Interceptor Experiment (SBX). Fourth, the BDS will also continue Space-Based Laser (SBL) risk reduction on a path to a proof-of-concept SBL Integrated Flight Experiment (SBL-IFX) in 2012. At appropriate times, BMDO will insert mature system concepts and technologies into product line development and deployment. Planned tests within the Boost Segment include a ground test of the ABL project and a ground test of the sea-based boost concept in 2002.

Cooperation Highlights

Education Update:

DEPS Receives $100k HEL Joint Technology Office Educational Funding

DEPS received a $100,000 contract from the HEL Joint Technology Office to explore a variety of approaches to attract students to HEL technologies and then to identify and implement academic programs to accomplish this. The objectives of the contract are to increase students enrolling in and completing Science and Technology programs related to HEL. The effort will initially focus on K-12 and undergraduates. A broad spectrum of mid-, high school and undergraduate programs are envisioned. For high schools funding will be provided for science fairs, subsidizing hard science classes with HEL labs, awarding competitive scholarships and subsidizing summer employment with government and industry. University programs include projects to increase student participation in HEL related classes and research. The DEPS Board of Directors provided an additional $50,000 of DEPS money for this project.

The DEPS Board has approved the funding of three efforts thus far for training mid- and high school teachers in HEL technology and having them in turn develop HEL materials for other teachers.

Grant Awarded to two Albuquerque Middle School Teachers

A grant was awarded to two Albuquerque Public School middle school teachers participating in the Air Force Research Laboratory Directed Energy Directorate PETE's program to develop lesson plans and materials to integrate laser and other directed energy concepts for teaching middle school students about lasers. The outcome of this effort will be the development of a high energy laser outreach "student toolbox" which will be mastered by participating middle school students. The students will use the toolbox for demonstrations performed for their own schools as well as for mentoring elementary

school children in order to develop student interest in laser and other directed energy fields of study.

Grant to University of Florida

High Schools in Florida's Okaloosa County, home of the University of Florida Graduate Engineering & Research Center and Eglin AFB, are embarking on an innovative science and math program to assist teachers in the development of application related instructional material and lesson planning. Directed Energy is one science and technology area that will now be included through a DEPS grant.

The Science and Technology Education Enrichment Project (STEEP) is a Math and Science content-centered program aimed at assisting teachers in developing content-specific instructional materials that will be used as a foundation for technology based coursework for the student population in grades 6-12. This three-year program exploits opportunities for cooperative development of a unique educational program, consisting of academic and practical applications of Math and Science. STEEP is facilitated through a cooperative effort among educational, business, and governmental organizations in Okaloosa County. Workshops are conducted on various subjects to give the teachers a background and examples for classroom presentation. These applications are then transformed into teacher lesson plans. STEEP will incorporate Directed Energy technology applications as one of it science areas. Selected teachers will participate in educational technology workshops, subject specific workshops, e.g., Directed Energy, internships with various companies and government facilities, and lesson-planning development meetings. These meetings, where the teachers share their experiences and lesson plans with the other participating teachers, will provide a broad base for teacher presentation. STEEP provides a model suitable for state and national replication. The project's bottom line is to invigorate science and math teaching leading to increased student interest in being part of science and math work force.

A Directed Energy segment would be included in STEEP through a specific workshop and appropriate lesson planning support for a group of 10 teachers to take back to the classroom. Attempts would be made to find appropriate government or business organizations that could provide selected teachers an internship opportunity in Directed Energy. The teachers are paid to attend the workshops, seminars, and internships.

Grant to New Mexico Institute of Mining and Technology (NMT)

New Mexico Tech offers a Master of Science Teaching (MST) degree. In this program teachers take a series of hands-on classes with an emphasis on science content. New Mexico Tech is developing an optics course to be part of the MST program.

Courses in the MST program meet all day, five days per week, for two weeks. Their optics course will have twenty segments, each consisting of a lecture and a lab. The course will then be offered in subsequent summers. NMT will develop the twenty segments and tailor them to high-school teachers in the MST program. The course would include lesson plans for teaching optics in the high schools. DEPS will fund the purchase of an optics kit for each teacher, to be used in the MST course and then be taken back to the teacher's home school.

Potential units include: Lab practices for safe use of small lasers, Basics of refraction, Snell's Law Basics of reflection from planes and curves, Thin lenses Aberrations in optical systems, Imaging Systems, Vision, Use of digital cameras, Effects of atmospheric propagation, Prisms, Gratings, Measuring the wavelength of light with a ruler, Vacuum coating, and making a front-surface mirror.

It is the intent of DEPS to make all the curriculum programs available to other schools and teachers across the country to encourage new students into Directed Energy fields of study.

Wave Packets

As we all know from the announcement on the DEPS webpage, this year's theme for the DE symposium is the *New National Defense Policy*. In preparation for that symposium, the reader may find some of the following selections useful. [Three dots (…) within the text indicates that not all of the article was copied here since the intent was to highlight portions of interest to directed energy and related research programs. Please refer to the reference at the beginning of the excerpt for the full articles and their references.]

An excerpt from http://www.csbaonline.org/:

The Bush Administration's Call for Defense Transformation: A Congressional Guide

By: Andrew Krepinevich Published 06/19/2001
Highlight

The Bush Administration has declared its intention to transform the American military to meet the challenges of a new century. President George W. Bush recently observed that

> We are witnessing a revolution in the technology of war. Power is increasingly defined not by size but by mobility and swiftness. Advantage increasingly comes from information . . . Safety is gained in stealth and force is projected on the long arc of precision-guided weapons . . .

With respect to modernizing US military, the president stated

> We will modernize some existing weapons and equipment . . . but we will do this judiciously and selectively. Our goal is to move beyond marginal improvements to harness new technologies that will support a new strategy . . . .Our defense vision will drive our defense budget, not the other way around.[1]

The principal means the president has chosen for implementing his defense vision is through "a comprehensive review of the United States military, the state of our strategy, the structure of our forces, [and] the priorities of our budget," undertaken by Defense Secretary Donald Rumsfeld. Indeed, a veritable cottage industry of speculation has emerged as to what this review will portend for the military services, individual programs, the disposition of forces, and demands on the nation's resources.

…What follows is an attempt to provide a series of first-order metrics by which to evaluate whether the forthcoming defense strategy represents an improvement over the current defense posture, as laid down by the Clinton Administration's 1997 Quadrennial Defense Review (QDR).

Metric Number 1: Why transform the world's best military?

The United States has by far the world's best military, by practically any conceivable measure. The Bush Administration must present a convincing case that, in effect, "what is seemingly *not* broken, must be fixed." To make its case, the Rumsfeld Review must do two things. It must show

how changes in the threat environment require transformation, and how opportunities exist, thanks to the military revolution ("revolution in military affairs") to effect a transformation:

- The threat environment is changing (or likely to change) in location, scale or form in such a way that an improved version of today's military (i.e., an in-kind modernized version of our current military) will be far less effective in dealing with tomorrow's challenges than today's. … A case can be made that the shifting form of military competitions—such as defeating anti-access/area-denial threats, controlling space and homeland defense—requires major changes in US military doctrine, force structures, capabilities, and investment patterns.

- … The administration must make the case that it is possible for the US military to exploit rapidly advancing technologies to deal with both existing and nascent threats, before they are capable of posing a serious risk to our security. Can the US military deploy, support and operate forces that are highly distributed, yet also highly networked through advanced information technologies? Is it possible to conduct effective sustained operations from extended ranges? How much can we leverage space and cyberspace to enhance the effectiveness of our forces? Perhaps most important: How might such capabilities be integrated into a warfighting concept that enables the US military to play its role in dissuading, deterring or (if need be) defeating would-be aggressors?

Metric Number 2: Does the prescription fit the diagnosis?

… Can we be confident that the defense strategy and program called for by the Rumsfeld Review is appropriate to deal with existing and emerging challenges to our security?…. Dealing with the anti-access/area-denial threat will argue for a vigorous effort to exploit the potential for highly distributed, highly networked force deployment, sustainment, and operations. This would seem to favor, among other things, greatly increased emphasis on a range of potential capabilities, such as the so-called Streetfighter concept linked to Network Centric Warfare, advanced C4ISR, unmanned combat aerial vehicles (UCAVS), highly dispersed ground forces with the ability to scout and engage at extended-ranges (e.g., employing attack helicopters, rocket artillery and UCAVs), and long-range bomber aircraft. Significantly, one would expect less emphasis would be placed on heavy ground forces, fixed forward assets (e.g., land-based tactical aviation), and large, relatively slow-moving surface combatants than was called for in the 1997 QDR. …

Metric Number 3: If transformation is warranted, does the new defense program have a process for effecting it?

Transformation can be defined as innovation on a grand scale, sufficient to bring about a discontinuous leap in military effectiveness, and thus cannot be effected through processes established by the Defense Department to support and sustain the existing ways of operating. Therefore, a transformation strategy must be an integral part of any overall defense plan and program that emerges from the Rumsfeld Review.

An effective transformation strategy would almost certainly comprise the following:

- *A future warfare vision to provide direction to transformation efforts*. The administration must provide a clear vision to focus the military on the kinds of threats and opportunities that are the foundation of its call for transformation.

- *Selection of senior leaders based on their ability to effect transformational change*. …

- *Robust funding for leap-ahead technologies*. At present, there are few opportunities to field a significantly different kind of military in the near term. Realistically, transformations usually take a decade or more to take effect. However, one would expect to see a vigorous effort to increase funding for the science and technology (S&T) accounts over the Future Years Defense Program (FYDP) to develop capability options to deal with an uncertain future.

- *Joint and Service field exercises and experimentation*. …

- *A new procurement strategy.* Will the defense review set a new course with respect to modernization, one that corresponds to its vision of the new security environment? The president has called for new thinking with respect to defense modernization, to include "skipping a generation" of weapon systems where possible. Thus one would expect the Rumsfeld Review to yield a procurement strategy in the near- to mid-term that places

somewhat less emphasis on costly next-generation weapons programs that represent essentially linear improvements over existing systems (e.g., the three new tactical fighter programs). At the same time, one would expect to see greater emphasis placed on procuring advance versions of current-generation systems (e.g., the latest, Block 60 versions of the F-16); service-life extensions of existing weapon systems, and, most importantly, limited production runs of promising new kinds of weapon systems (e.g., converted Trident SSGNs).

- *Divestment strategies to eliminate capabilities that are a poor fit with the emerging strategic environment and to free up resources to support transformation.* This requires making tough choices and balancing near- and long-term risk. It also would send an important signal that the administration understands that successful transformation is not only comprised of new initiatives, but also involves reducing reliance on capabilities that are likely to decline in effectiveness, perhaps precipitously….

Metric Number 4: Is the defense program that emerges from the Rumsfeld Review supported by realistic budget estimates?

America's wealth, great as it is, is not unlimited. Given the Bush Administration's priorities, and those of Congress, it seems unlikely that major increases in defense spending will be realized. Even more sobering, the current defense program suffers from a plans-funding mismatch of some $120 billion over the next six years, with even greater shortfalls thereafter. … Given the likely trade-offs the Rumsfeld Review confronts, sustaining the force structure at it current levels runs a high risk of producing a stillborn transformation effort. …

Speech, President George W. Bush, Norfolk Naval Air Station, February 13, 2001. Http://frwebgate6.access.gpo.gov.

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An excerpt from http://web.mit.edu/ssp/db21/breakthroughs.html :

"Can We Afford a Revolution in Military Affairs?"

By: Cindy Williams and Jennifer M. Lind

Breakthroughs (Spring 1999), pp. 3-8

The Department of Defense and a wide array of scholars, analysts, and visionaries outside the military assert that the U.S. military is on the threshold of a revolution in military affairs (RMA). … Little has been said, however, about the long-term affordability of these proposals. How much will it cost to exploit a revolution? Where will the money come from? …[F]uture defense budgets are difficult to predict with any accuracy. Yet an examination of just a few of the proposals on the table shows that capitalizing on the so-called revolution could add tens of billions of dollars to annual defense budgets a decade from now. …

How Much Will It Cost?

Inside and outside the U.S. military, much of the discussion of a revolution in military affairs centers on the exploitation of information technologies to achieve information superiority on and off the battlefield. The technologies that underlie the so-called revolution are those related to command, control, communications, intelligence (C3I) and information. The prevailing view is that these technologies are cheap compared to the major weapon platforms that they support, and that they will be even cheaper as the military capitalizes increasingly on commercial off-the-shelf systems (COTS).

The truth is that these technologies, taken as a group, are not cheap. The Defense Department currently devotes 20 percent of its budget — up from 15 percent in 1985 — to C3I and information systems. Spending for these areas comes to about $54 billion in the fiscal year 2000 budget … And the migration to COTS is not saving as much money as proponents once hoped. Using COTS lowers the price of individual components and software, but it raises problems of hardware and software integration and replacement cycles for which the government still finds it difficult to plan.

$54 billion a year is a lot of money by anybody's standards. It exceeds the entire defense budget of every country in the world with the exception of the United States and Russia. It is just $10 billion lower than Russia's total budget for defense. …

To be fair, not all of that money can be attributed to exploiting a revolution in military affairs. … But it does pay for the information superiority that supporters say is the backbone of the revolution.

How much more would the U.S. military need to spend to exploit the revolution that advocates posit? It is not easy to determine an amount, in large part because the changes that people have in mind are far from well defined. Advocates argue that much of the transformation they seek will come from changes in doctrine, operational concepts, organization, and training rather than through specific technologies or systems. They assert that a good deal of the technology needed is already at hand; exploiting it requires changes in culture and attitude more than additional investment in equipment.

… The Pentagon's advanced warfighting experiments and advanced concept technology demonstrations are aimed at exploring new operational concepts and changes in doctrine. The Defense Department will spend less than $1.5 billion a year on them through 2005. If these experiments and demonstrations represent the main path to transforming the culture, then transformation is relatively cheap and already covered in the Pentagon's budget plans. … The Pentagon asserts that its current plans already support a transformation of the military by funding information technologies as well as a number of "leap-ahead" enabling technologies. …

Proposals for new systems run the gamut from the familiar to the completely new. … [I]deas would add weapons to platforms that today are used for communications or sensing rather than as combat vehicles: unmanned aerial vehicles outfitted with conventional weapons, projectile weapons based in space. Still other proposals offer concepts that would be quite new to military arsenals, for example trans-atmospheric vehicles that carry precision guided munitions, combat vehicles that require no fuel or ammunition, directed energy weapons launched from platforms not yet invented, infrasonic weapons, and computer viruses used as weapons. Estimating the costs of items in the last category is a tricky business. The best cost estimates for a new system are based on a clear understanding of the system's design. They often incorporate comparisons with similar systems that have been purchased or at least attempted in the past. For the more futuristic concepts, the designs and their analogs for comparison are difficult to come by. Cost estimates for types of systems with which the military already has some design experience are more feasible. For example, one RMA supporter recommends that the military explore technologies for precision weapons, smaller and more mobile computers and communications

systems, information warfare, stealth, unmanned vehicles and robots, and space-based systems, including weapons in space. Technologies on this list lend themselves to cost estimation, using analogs like the canceled Brilliant Pebbles program that would have put weapons into space under President Reagan's Strategic Defense Initiative. The author of that list urges boosting research and development spending by $100 billion over the coming decade to explore the technologies on the list. … If just one program in each of those areas makes it into engineering and manufacturing development and then production, costs could rise an additional $15 billion a year by 2010. Moreover, operating and support costs for the new systems will be far from free. In short, it is hard to pin a specific price tag on exploiting a revolution in military affairs. … One recommendation offered by an advocate outside the military calls for $10 billion a year above current Pentagon plans, but focuses on exploratory research and development. Over time, programs that grow out of that exploration could add another $15 billion a year in acquisition and more for operation and support. Thus a conservative estimate for a sustained program of technology exploration and force modernization based on just a few of the new technologies comes to $25 billion a year by the end of the next decade.

Where Will the Money Come From?

… The F-22 fighter will cost at least twice as much per airplane as the F-15 that it replaces and 20 percent more than the Air Force currently admits. On the support side, per-troop spending for operation and maintenance has grown in real terms by an average of more than three percent a year over the past 25 years. O&M now eats up more than 37 percent of the Defense Department's budget, compared with 28 percent in the mid-1980s.

… New weapons cost increases are on the way, and O&M spending will shoot to 39 percent of the budget for fiscal year 2000. The upshot is that retaining the current force structure at current levels of readiness, and equipping it as the Defense Department currently plans, will cost as much as $40 billion more each year in the coming decade than we are paying today.…If Americans are not willing to boost defense spending significantly, then the gap between plans and money will have to be closed the other way by reducing defense expectations. The main choices for reducing defense plans can be grouped into four categories: reprioritize and reduce existing programs in the areas of C3I and information technologies, constrain other modernization plans, slice military force structure, or cut back on military infrastructure. The Pentagon has tried for several years to get the owners and acquisition agents of so-called "legacy" command and control systems to migrate to newer systems. … Many of them were designed in what the military refers to as a "stove-pipe" fashion to handle a single function within a single military service or command. As a result there are numerous systems, and their functions often overlap. Moreover, some of them are quite cumbersome to use. Since they were designed years ago, the technology that they incorporate is generally not up to date.

Migrating to newer, joint systems would cut the costs of operating and building multiple systems with overlapping functions and could free up some of the money that advocates of transformation would like to see spent on new technologies. But pulling the plug on legacy systems that support critical ongoing functions when the new systems are not ready has not been easy. Until new systems are in-hand and working, the military has little choice but to continue using the old ones. Some advocates of revolution have suggested that the money to pay for change should be taken from the Pentagon's ongoing modernization programs. …The most lucrative single modernization cutback would come from canceling all three of the military's new fighter aircraft programs: the Air Force F-22, the Navy F-18E/F, and the multi-service Joint Strike Fighter. The combined procurement costs of those three programs will be about $12 billion annually over the next two decades. But the fighter airplanes in the force structure today are rapidly reaching the end of their useful service lives. Unless the United States is ready to go without fighter aircraft altogether, canceling the three programs would require adding new funds to extend the service lives of existing planes or to build new ones using existing production lines. Either choice would eat into the savings achieved through cancellations. As a result, the net annual savings achieved by canceling all three new airplanes might be between $4 billion and $6 billion. Other expensive modernization targets include the Marine Corps' V-22 transport plane, the Navy's New Attack Submarine, or the Army's Comanche reconnaissance and attack helicopter systems that the Pentagon classes as "leap-ahead" but that were largely conceived during the Cold War. Canceling any of these systems would free up money for new programs, but as with the fighter programs, the savings would be significantly offset by efforts to extend the lives of the systems that they are intended to replace. Fitting new procurement programs into the defense budget when the Pentagon's purchasing accounts are already squeezed is not easy. The fiscal year 2000 budget for all of the military's weapons purchases comes to $53 billion. In contrast, the procurement bill for the modernization scheme that the Defense Department has already

embarked on comes to more than $70 billion a year during the next decade. The Defense Department wants to boost spending for procurement significantly in the coming years. But its hopes for future procurement increases have been dashed time and time again in recent years as it has confronted its must-pay bills for operation and maintenance. Some proponents of revolution argue that the right combination of air power, precision munitions and information superiority will be so effective by themselves that the United States can significantly reduce its force structure — particularly Army force structure — thereby saving billions of dollars a year. … For example, eliminating three of the Army's ten active-duty divisions would save only $4 billion a year in direct and indirect costs — far short of the $10 billion that one RMA proponent would like to add to R&D just to get things started. …The final alternative for reducing defense plans is to cut back on military infrastructure. … Taken together, these changes might save $5 billion to $6 billion a year. But each of them is extremely unpopular with some sector: communities that might lose the bases or hospitals, advocates for military families and retirees, and to some extent the Congress.
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Summary and Conclusion

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The U.S. military already spends a significant portion of its budget on the technologies and programs that support information superiority. Some advocates of exploiting an RMA would like to add more to explore new technologies. The extra annual acquisition costs incurred if just a few of those technologies lead to procurement programs could exceed $25 billion. Operating costs will add to the budget pressures. Given that the current defense program already faces a potential shortfall in the neighborhood of $40 billion a year, any new RMA-related project will face formidable competition for funds.

Money for new programs could come from adding to the defense budget, reprioritizing within the C3I category or reducing other defense programs. … Taking the money from infrastructure or from Cold War C3I programs makes good sense, but has been difficult for the Pentagon to carry out. That leaves tradeoffs against force structure and other modernization programs a solution that appeals to advocates of change but is frightening to the Services, which are deeply concerned at the prospect of giving up forces or modernization programs in exchange for unproven technologies.

An excerpt from http://www.af.mil/news/n20010803_1066.shtml

Jumper confirmed as next Air Force chief

Gen. John P. Jumper, Air Combat Command commander, testified before the Senate Armed Services Committee during his confirmation hearing on Capitol Hill in Washington Aug. 1. During the confirmation hearings, Jumper answered questions on a variety of subjects from the group…

The general said his priorities for the force in the coming years would mirror those of Secretary of Defense Donald Rumsfeld and Secretary of the Air Force James Roche. "I intend to follow the objectives put forth by Secretary Rumseld and Secretary Roche that include transformation, readiness, retention and recapitalization," he said.

"Transformation is, and always will be, a key issue because the Air Force is inherently transformational -- constantly adapting ourselves to new threats and leveraging new technology in order to posture ourselves to face the challenges of an uncertain future," he said. "Our greatest challenge remains the requirement to advance new capabilities while maintaining the robust readiness required to meet day-to-day warfighter requirements.

"It is imperative we develop our Global Strike Task Force, a kick-down-the-door force that will assure access and aerospace dominance for all our joint forces."

Calendar

19 September 2001, DEPS Education and Training Workshop, Albuquerque, NM

29 October - 1 November 2001, 4th Annual Directed Energy Symposium, Huntsville, AL

3 - 6 June 2002, Annual Solid State Diode Laser Technology Review, Albuquerque, NM

Our **Thanks** and **Appreciation** go out to all the contributors to this publication. As Mr. Duff indicated in the *Director's Forum*, all of the content contained herein came from volunteers and supporters of the DEPS. If you would like to be a future contributor, and bring your ideas and work before your fellow directed-energy colleagues, please contact me to make arrangements.

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