The Developing Science & Technologies List (DSTL)

ABSTRACT:
The Militarily Critical Technologies Program (MCTP), a DoD responsibility directed by Congress, provides a systematic, ongoing assessment and analysis of goods and technologies to determine those technologies that would permit significant advances in the development, production and use of military capabilities of potential adversaries and those that are being developed worldwide that have the potential to significantly enhance or degrade US military capabilities in the future. The program's objective is to characterize the technologies, including quantitative values and parameters, and assess worldwide technology capabilities. This paper describes the Militarily Critical Technologies Program's (MCTP) Developing Science and Technologies List (DSTL) sponsored by the Office of the Director, Defense Research and Engineering (DDR&E). This paper outlines the unique Technology Working Group (TWG) process developed by the Institute for Defense Analyses (IDA) to support the MCTP and specifically the DSTL. It also outlines the approach used to determine the technologies that are included as well as how worldwide technology capability assessments are incorporated into the review process. As an example, this paper outlines the technology parameters associated with Deformable Mirrors and identifies how both military and commercial applications have an input into the TWG process.

BACKGROUND: Militarily Critical Technologies Program (MCTP):

The Department of Defense (DoD) Militarily Critical Technologies Program (MCTP) provides an ongoing assessment and analysis of goods and technologies to determine those that are mature and critical to the U.S. military (the MCTL) and those which are developing and could improve our military capabilities once mature (the DSTL). The program's objectives are to characterize these critical technologies, including quantitative parameter values and assessments of worldwide technology capabilities.

The MCTL technologies are ones that are mature and would permit significant advances in the development, production and use of military capabilities of potential adversaries... The DSTL technologies are developing technologies and scientific research efforts which have the potential to significantly enhance or degrade U.S. military capabilities starting 5 years into the future. Both are products of the MCTP TWG process; however the MCTL is used as a guide by the export control community in the development of international controls on both technology and products of that technology.

The DSTL is primarily used by DDR&E and other government organizations and agencies to aid in understanding and applying new technologies being developed worldwide. The DSTL is therefore used as a reference document as well as a guide for

international cooperation programs. Both programs are part of the MCTP, which is under the direction of the Deputy Under Secretary of Defense for International Technology Security (DUSD/ITS) in the Office of the Director, Defense Research and Engineering (DDR&E). This office furnishes program guidance to IDA, which is under contract to DoD to support the MCTP endeavors.

MCTP BASIS:

The basis of the MCTP stems from the Export Administration Act (EAA) of 1979[1], which assigned responsibilities for export controls to protect critical technologies and weapons systems. The EAA established the requirement for the DoD to compile a list of militarily critical technologies. The EAA and its provisions, as amended, have been extended by Presidential Executive Orders on a continuing basis.

MCTP PROCESS:

The MCTL and DSTL are both products of the MCTP process (see Figure 1 below). This process utilizes inputs from technical experts within Technical Working Groups (TWGs) to provide a systematic, ongoing assessment and analysis of goods and technologies to determine those that are or could be critical to U.S. military force activities and defense efforts.

Technologies are selected for the MCTL and DSTL through the deliberation and consensus of TWG members. TWG chairpersons continually screen technologies and nominate items to be added or removed from the MCTL and DSTL. Working within an informal structure, TWG members strive to produce precise and objective analyses across the technology areas and to periodically update these assessments. TWG members provide these inputs based on their experience and knowledge of the specific technology area and from observations made within the R & D community developing these technologies.

Once the TWGs have developed the MCTL and DSTL, these products are circulated within DoD for coordination. Once final approval is received from DoD, these products are distributed, placed on the Defense Technology Information Center (DTIC) web sites and used by all interested parties. They are located on the Web[2] in one of two venues, one version on the public web at www.dtic.mil/mctl/dstl and another version on the Private STINET web site: https://dtic-stinet.dtic.mil/ which is restricted to the US Government and their contractors.

DSTL data sheets are continually being updated. The currently approved optics and the many other developing science and technology data sheets can be reviewed at: http://www.dtic.mil/mctl/DSTL/DSTL_Sec19.pdf.

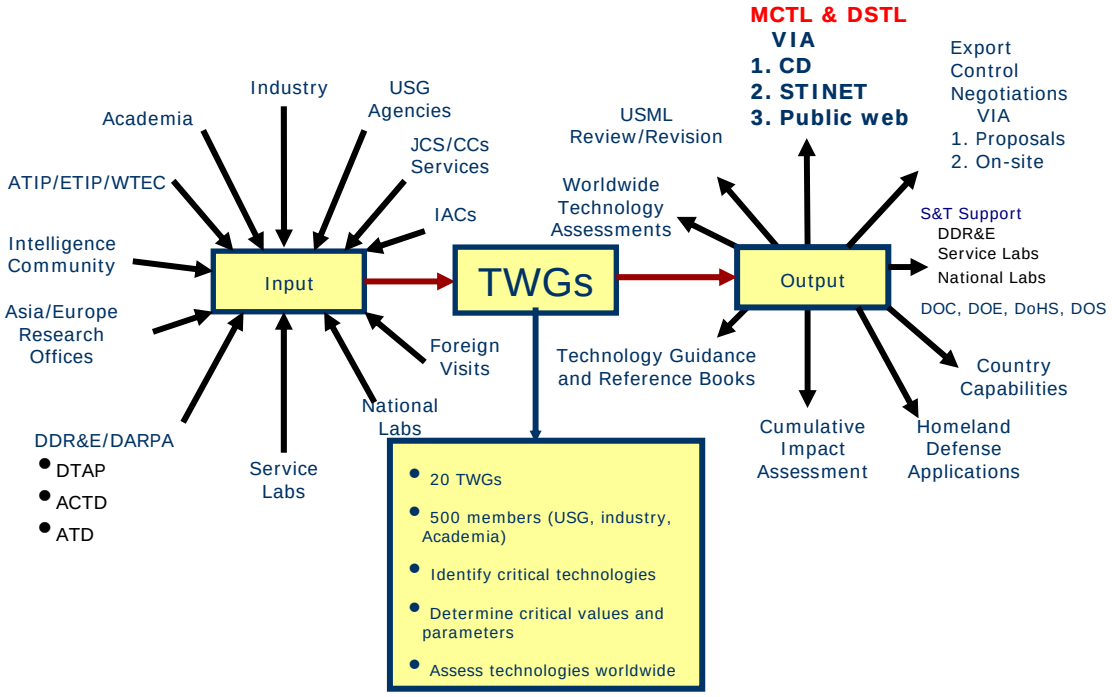

Figure 1. Diagram of the MCTP Process showing the inputs and outputs.

COMPOSITION OF THE MCTP:

There are 20 technology areas and 20 respective TWGs, established for the MCTP DSTL program, that evaluate both current technologies and technology trends. Based on military requirements, the TWGs establish militarily critical parameters and critical levels of those parameters for the technologies in these 20 technology areas. These technology areas are as shown below in Table 1 below:

TABLE 1. The 20 MCTP DSTL Technology Areas

Aeronautics	**Information Systems**
Armaments & Energetic Materials	**Lasers, Optics & Imaging**
Biological	**Processing & Manufacturing**
Biomedical	**Marine Systems**
Chemical	**Materials & Processes**
Directed Energy Systems	**Nuclear Systems**
Electronics	**Positioning, Navigation & Time**
Energy Systems	**Signature Control**
Ground Systems	**Space Systems**
Information Security	**Weapons Effects**

USES OF THE MCTP PRODUCTS:

The US government uses the MCTP products (both MCTL & DSTL) for various purposes. The key ones are listed below.

- Worldwide Technology Capability & Forecasts
- International Cooperative R & D
- Independent R & D
- S & T Planning
- Advanced Concepts and Technology Development
- Guidance for export control issues
- Development of US proposals for the international Wassenaar Arrangement
- Guidance for Small Business Innovative Research (SBIR)
- Technical Guide for Independent Review Teams

COMPOSITION AND ROLE OF TWGs:

The TWGs review and recommend developing science and technology (S&T) items for the DSTL and mature militarily critical technology items for the MCTL. The TWGs are comprised of technical representatives from the Department of Defense (including the Service Laboratories), National Laboratories, US Government agencies, Intelligence Community, academic research organizations, educational institutes and industry. Each TWG is chaired or co-chaired by an IDA technical staff member.

The TWGs review the known worldwide technology capabilities of all countries for each technology. In addition, the TWGs must assess technical parameters to determine which parameters and what levels of those parameters are critical for our military or homeland defense. Therefore, the TWG members have quite a few responsibilities. The key responsibilities include:

- Define, in quantitative technical terms, which technologies contribute to, or have the potential to threaten US national security;
- Evaluate the global state-of-the-art and trends that affect the availability of such technologies and the ability of the US and cooperating countries to control the dissemination of such technologies.
- Provide a resource for S&T planning.

MCTL ROLE & FUNCTIONS:

The role and functions of the MCTL are outlined to provide a direct comparison with the subject of this paper; the DSTL. The MCTL is a compendium of existing goods and technologies that DoD assesses would permit significant advances in the development, production and use of military capabilities of potential adversaries. It includes goods and

technologies that enable the development, production, and employment of weapons of mass destruction. Goods and technologies are considered critical if their acquisition and exploitation by a potential adversary would either significantly negate or impair a major military capability of the United States or significantly advance a critical military capability of the adversary.

The MCTL is not an export control list. It is published as a separate technology document with separate volumes for each critical technology area and appropriate technology data sheets for each technology within a given technology area. There may be items on the MCTL that are not on an export control list; and there may be items on an export control list that are not on the MCTL. The MCTL should be used as a reference for evaluating potential technology transfers and for reviewing technical reports and scientific papers for public release. The information must be applied using good technical judgment. It should be used to determine if the proposed transaction would result in a transfer that would give potential adversaries access to technologies whose specific performance levels are at or above the characteristic levels identified as militarily critical, not whether a transfer should or should not be approved.

DSTL ROLE & FUNCTION:

The DSTL is a compendium of scientific and technological capabilities being developed worldwide which have the potential to significantly enhance or degrade U.S. military capabilities starting 5 years out and further into the future. It includes basic research, applied research and advanced technology development in support of DDR&E, specifically in the area of S&T. The DSTL, like the MCTL, is also not an export control list and stands alone, published as a separate technology document with separate volumes for each technology area. Appropriate technology data sheets are included for each technology within a given technology area. The focus of the DSTL is primarily on assisting in the evaluation of S&T; SBIRs; advanced R&D; and as a technical guide for independent review teams (IRTs) and cooperative international technology programs.

AN EXAMPLE OF DSTL TECHNOLOGY:

There are many technologies which could have been used as examples for this paper. One can review the current data sheets at the DTIC web site referenced previously: www.dtic.mil/mctl/dstl The following draft data sheet , Figure 2 below, is an example of a DSTL optics technology which is currently under review by the Lasers, Optics and Imaging Technology Working Group (LOITWG) for the Optics subsection of the DSTL. As such, the LOITWG is interested in feedback as to the parameters and the level of those parameters chosen. Therefore, any constructive comments concerning this draft data sheet are welcome. Please contact one of the POCs listed at the end of this paper for comments.

Deformable Optics are also referred to as Smart Optics, Adaptive Optics or Active Optics. They include any optical component whose optical surface can be controlled or adjusted dynamically to enhance the optical system performance. It should be noted that (quasi-static) errors in optics such as telescope optics are usually controlled by a low bandwidth optical system referred to as "Active Optics." The (high dynamic) controlled optics typically required for correcting atmospheric turbulence inside and above the telescope are usually referred to as "Adaptive Optics" and in the case of a closed loop system they are sometimes referred to as "Smart Optics".

Data Sheet: "DEFORMABLE / ADAPTIVE OPTICS (ACTIVE OPTICS)"

Technology Parameter(s)	Any continuous or multi-element optical component surface, and specially designed components, which dynamically provide: 1. Positioning at > 500 Hz or, 2. Repositioning accuracy and precision to < 20 nm.
Critical Materials	• Improved piezo electric actuators with less histeresis and higher piezo coefficients. • Improved bonding techniques for actuators to face plates. • Higher bandwidth actuators with lower voltages. • Improved nulling techniques for the control surface. • Increased bandwidth electronic components and actuators.
Unique Test, Production, Inspection Equipment	• Production: None identified. • Testing: None identified. • Inspection: None identified.
Unique Software	Critical Software / Software Parameters: None identified.
Major Commercial Applications	Ground-based Optical Telescopes. Developmental items such as artificial eyes, high-speed telecommunication links, ophthalmic instrumentation as well as semiconductor lithography, and industrial laser system optimization components. Systems of deformable mirrors and wavefront sensors to correct for optical disturbances in the atmosphere through which large ground based telescopes must peer. Other possible application areas include commercial laser beam correction, laser beam forming, laser materials processing, scanning optical systems, optical probes and confocal microscopes, coupling of micro-optics, and several areas of optical imaging, including imaging of the retina in vivo.
Affordability Issues	Lower cost will result with further development work, which should improve performance, decrease complexity and increase the bandwidth substantially. This will reduce the cost for the next generation of giant telescopes.

Figure 2. Sample: Developing Technology Data Sheet for Adaptive Optics

Adaptive Optics Technology Background Information:

A significant technological development in the field of laser optics is deformable optics (also called adaptive optics). Developed to minimize the effects of fluctuations in air, caused by temperature gradients and the consequent atmospheric turbulence that bends and scatters the laser's beam, adaptive optics concepts rely on deformable mirrors, sometimes called a "rubber mirror," to compensate for tilt and phase distortions in the atmosphere on a pixel to pixel basis depending on the number of actuators on the deformable mirror.. The mirror typically has hundreds of actuators that change hundreds to thousands of times per second when driven by a wavefront sensor, enabling the mirror to modify the laser beam so that it can travel further through turbulent air.

This technique of deforming optical surfaces has succeeded in producing even sharper and clearer images from terrestrial telescopes than the Hubble Space Telescope. To better understand the mechanisms and techniques involved in deformable or adaptive optics, one first needs to know the basics of an adaptive optics system. The most distinctive component of an adaptive optics system is the "deformable mirror" itself which actually makes the optical corrections in reflection, and then followed in importance is the "wave front sensor", which measures the turbulence at a few Hertz to thousands of Hertz. These two key systems function in concert via the control of a high-speed computer and appropriate algorithms. But, there are many other components such as the actuators, processors and the control electronics, which are required to complete the system.

Today, deformable mirrors for astronomy and space surveillance are usually made of a very thin sheet of glass or low thermal expansion material with a diameter of several inches to a few meters in size. Attached to the back of the glass are various kinds of "actuator" devices which expand or contract in length in response to a voltage signal, bending the thin sheet of glass locally to the intended wavefront correction. A deformable mirror is able to correct a distorted beam of light from a star or any distant object, by straightening out the incoming wavefront.

Light is incident on the mirror and is reflected back toward a secondary or focal plane. If the deformable mirror has a depression that is half the depth of the initial distortion in the wavefront's shape, then by the time the light has reflected from that portion of the mirror, the rest of the wavefront will have caught up with the "notched" section and the wave front will be flat, or nearly "perfect."

Future deformable mirror technology will involve mirrors that are both much larger and much smaller than those of today. Smaller mirrors are being developed using small piezo-electric actuators in MEMS (micro-electro-mechanical systems) in concert with liquid crystal displays (LCDs). Larger deformable mirrors, that sometimes replace the telescope's secondary mirror, are being developed at the University of Arizona and other institutes.

SUMMARY & COMMENTS:

Neither the MCTL nor the DSTL are export control lists. These two lists are DoD directed products of the MCTP for the identification of militarily critical and potentially critical technologies. The export control lists are: (1) the Commerce Control List (CCL) (*Dual Use)* maintained and enforced by the DOC and (2) the US Munitions List (USML) maintained and enforced by the DOS.

However, the MCTL is one of many inputs used in the development of these control lists. On the other hand, the DSTL is a list of developing technologies intended to be a guide for technology research as well as a reference source for international cooperative S&T programs. The DSTL includes technologies arising from basic research, applied research and advanced technology development.

The MCTP TWG process reviews worldwide technologies from all countries and assesses the technical parameters of each technology to determine which, if any, of those technologies have attributes and parameter levels which are militarily critical (for the MCTL). The TWGs also evaluate technologies (for the DSTL) which could be critical to our defense when mature. Therefore, the Technology Working Group members have significant responsibilities in this review and evaluation process.

Anyone who wishes to join one of the TWGs and help in the current and future reviews and drafting of appropriate sections of the MCTL and DSTL should contact one of the points of contact (POC) listed below. We believe that this can be beneficial, both to the TWG process itself and to the individual involved, by way of exploring new and developing technologies and networking, which could provide utility to your organization in the future.

MCTP POCs at IDA

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REFERENCES:

1. Export Administration Act (EAA) of 1979 and its provisions, as amended, and extended by Presidential Executive Orders
2. MCTL and DSTL listing at: www.dtic.mil/mctl/dstl