Defense display strategy and roadmaps *

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ABSTRACT

The Department of Defense (DoD) is developing a new strategy for displays. The new displays science and technology roadmap will incorporate urgent warfighter needs as well as investment opportunities where military advantage is foreseen. Thrusts now ending include the High Definition System (HDS) program and related initiatives, like flexible displays, at the Defense Advanced Research Projects Agency (DARPA). Continuing thrusts include a variety of Service-led programs to develop micro-displays for virtual image helmet-/rifle-mounted systems for pilots and soldiers, novel displays, materials, and basic research. New thrusts are being formulated for ultra-resolution, true 3D, and intelligent displays (integration of computers and communication functions into screens). The new strategy is Service-led.

Keywords: defense, electronic displays, high definition, micro-display, 25-megapixel, true 3D, novel and intelligent displays

1. INTRODUCTION

Prior to 1989 defense display research was led by the services. During this period several flat panel display (FPD) and light-valve projection technologies were invented. The active matrix liquid crystal display (AMLCD) was created under research projects funded by the Air Force with the goal of creating a better cockpit display than the cathode ray tube (CRT) could ever become. The Air Force succeeded and the AMLCD technology is now economically viable for cockpit and military applications because it has spawned several high-volume consumer products (notebook computers, information appliances, flat monitors, hang-on-the-wall television, etc.). Other service investments in plasma and light-valve projectors were applied in several fielded systems but are now being replaced with improved projection, and 22-53 in. direct-view AMLCD, technologies. The Army invested in inorganic electroluminescent (IEL) display technology for land combat systems; many were fielded and continue to be fielded; however, the lack of full color capability has led to the use of AMLCDs for most ground and sea applications as well as for tri-Service cockpits. [1]

During the 13-year period from 1989 through 2001 the DoD strategy for displays was driven by DARPA's HDS program. This program and its accomplishments have been reviewed by Tulis, Hopper, Morton and Shashidhar.[2] The original HDS goal was to develop digital high definition display technology. This goal was achieved by early 1995 with the invention and delivery by Texas Instruments of a 100% digital, 2.1 megapixel full motion video (60 Hz) projection display system. However, the DARPA program continued and morphed into an industrial preparedness program from 1994-1999. [3] In 1999 the HDS program morphed once again into an effort to create flexible displays and roll-to-roll infrastructure. The last year of DARPA HDS funding was FY2001. Efforts awarded under the DARPA HDS flexible display initiative will complete execution by June 2003. As of FY2002 defense display research is once again a service-led technology area.

In March 2001 the Secretary of Defense sent a report to Congress, per its direction, outlining DoD's intention to create a new strategy to adjust to DARPA's decision to stop investing in displays. [4] The report noted that the original goals of the DARPA program to create a 2-megapixel high definition display technology had been met. Furthermore, the FPD industrial preparedness goals subsequently pursued by DARPA since 1994 had been (a) overcome by the development in 1999 of FPD manufacturing industries in Korea and Taiwan willing to sell fab-time to DoD integrators (even for military-unique custom display designs for combat cockpits, which the Japanese were not willing to touch for culture reasons) and (b) determined by the director of DARPA to be too near-term in nature for DARPA. The report identified two new thrusts for DoD display research: 25-megapixel and true 3D devices. The approved roadmap is illustrated in Figure 1.

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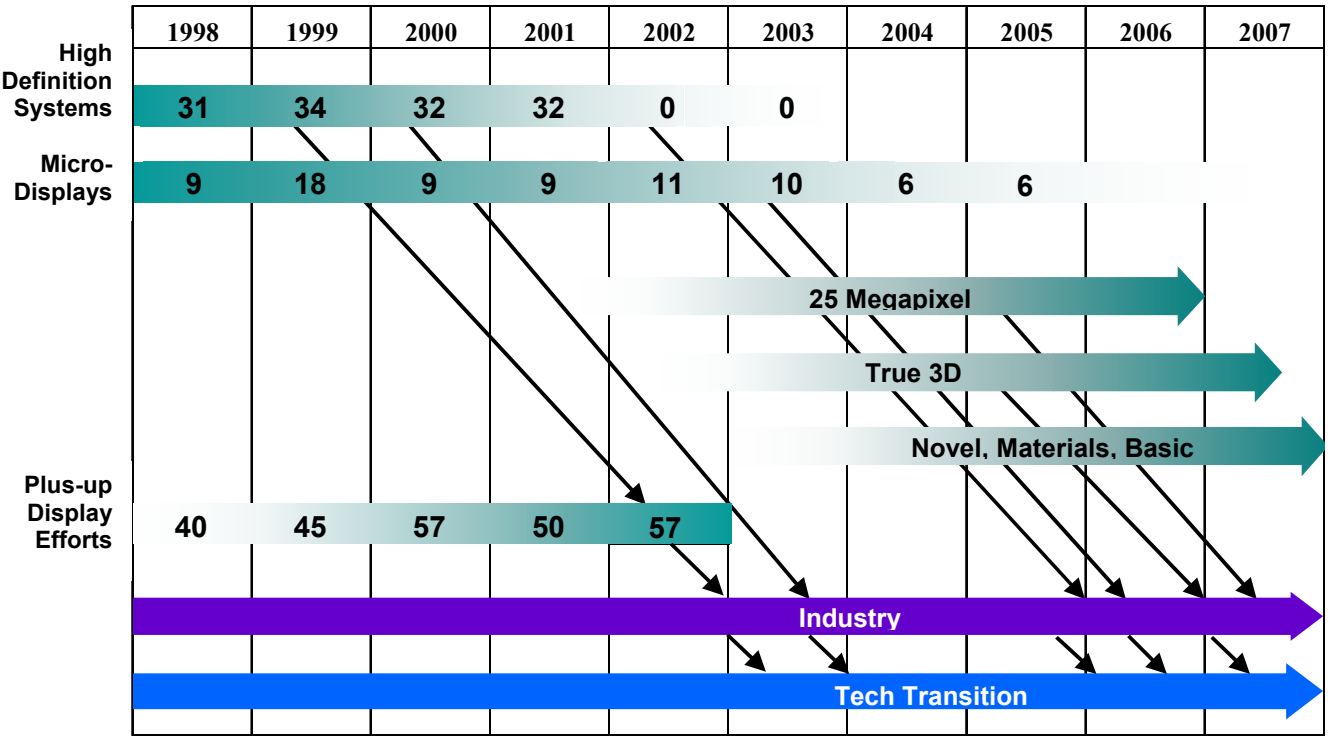

Figure 1. "Research and Development Roadmap for Defense Displays" from 21 March 2001 DoD Report to Congress.[4] Two additions are made here: (a) the 2002 Plus-up thrust amount is from the FY2002 defense appropriation act;[12] (b) the novel, materials, and basic research bar is added to aggregate budgeted efforts in the services beyond the other thrusts. Zeros in FY02-3 for the HDS thrust refer to the fact that efforts funded in earlier years will complete execution in FY03.

2. PROCESS FOR DEVELOPMENT OF NEW STRATEGY

The displays roadmap is being developed and maintained under the cognizance of a cross-agency process known as the Joint Director of Laboratories Reliance Process, Electronics Subpanel. This process was initiated some years ago by the services in response to pressure to combine the Army, Navy, and Air Force labs into a single organization, a defense research laboratory. In the electronics area this Reliance process is conducted by the Technology Panel on Electron Devices (TPED). The roadmap is also overseen by the DoD Advisory Group on Electron Devices (AGED), an industry-led federal advisory group chartered by the Under Secretary of Defense for Acquisition, Technology and Logistics, USD(ATL); AGED reports to the Director, Defense Research & Engineering (DDR&E). The roadmap for displays is similar to those recently developed for other electronics component technologies, such as radiation hardened electronics and wide bandgap materials.

The initial roadmap document for displays was briefed to the DoD Reliance TPED and to AGED in 1998-9, and to warfighters, industry, and academia in 1999-2000. This is the process that led to the inclusion of the two new technology needs in the 2001 report to Congress: 25 megapixel devices and true 3D displays. Basic research needs were also identified.[7]

The new strategy is represented in the summary roadmap illustrated in Figure 1. New second and third tier roadmaps are now being re-developed to describe specific technology creation efforts, goals, processes, and maturation efforts, based on the combined judgment of government and industry. Specific system technology needs and schedule constraints are to be analyzed. Acquisition and industrial base activities will be included as appropriate. Programmed funding, official funding shortfalls (unfunded priorities), and "opportunities" are to be included. The revised roadmap will be presented for review by program offices and industry. Briefings and meeting are to be held with relevant program offices, joint working groups, and developers in the Services and industry. Program offices and industry will be asked to verify their needs and/or requirements and identify additional needs, within the structure of the roadmap. The Reliance roadmap is a living document to be revised annually. Figure 2 illustrates the requirement and intent to harmonize the display strategy with users and other S&T needs.

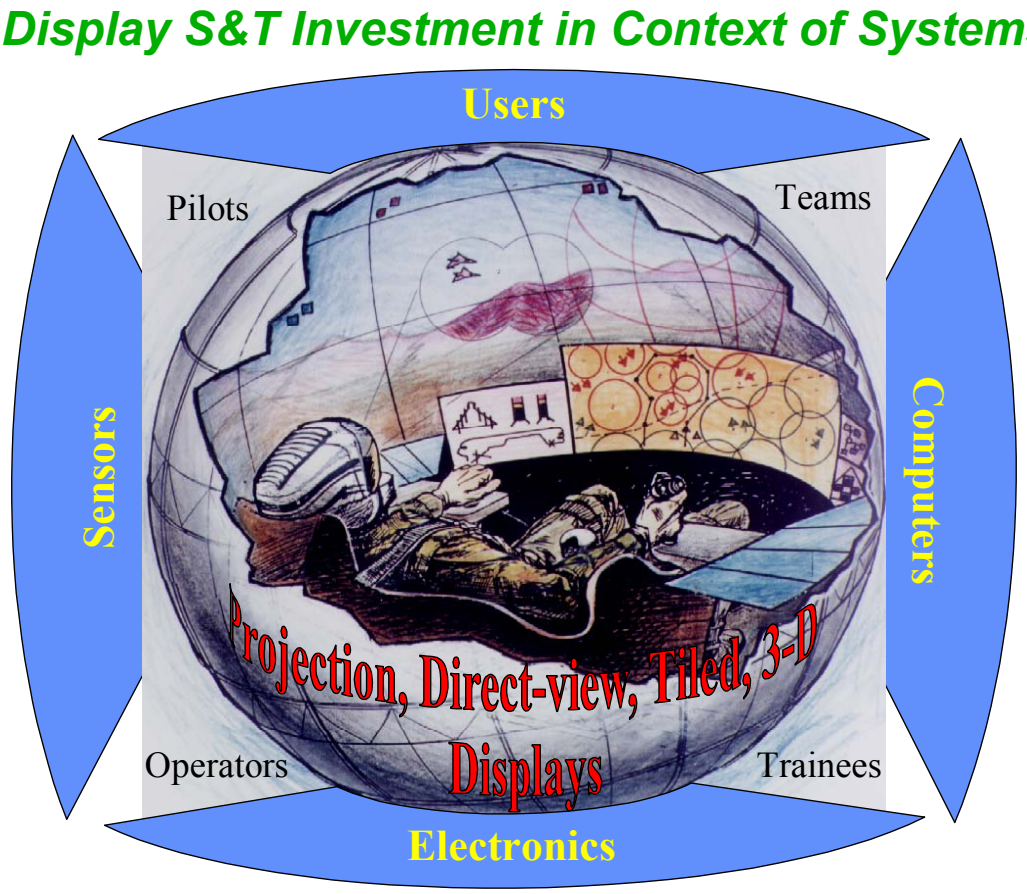

Figure 2. Defense display strategy must be synchronized with roadmaps for other technologies and for weapons systems.

3. SPECIAL TECHNOLOGY AREA REVIEW

Display transition to weapons systems typically occurs in conjunction with other electronics technologies. The timeliness of proposed investments must be consistent with the plans of weapon systems operators and on-going activities in other research areas that must be integrated along with the display to bring value to users. One way of ensuring that display investments and opportunities are made in the context of other needs is to vet the roadmap within the services and industry; this vetting is continual. Another way is to conduct an aperiodic special technology review.

In electronics areas the AGED is chartered to conduct Special Technology Area Reviews (STARs) for DoD. The last AGED STAR on Displays was conducted in 1992.[5] In 2002 AGED initiated a new special review. The objective of the 2002 STAR is to provide information that will allow the AGED to assist the DoD in defining and pursuing a defense-wide science and technology (S&T) strategy for displays. Information sought bears on (a) the potential of advances in display technology to drive revolutions in military affairs; (b) particular improvements in display technology needed for advanced applications; and (c) the technology performance trends amongst consumer, ruggedized, and custom grades of displays. AGED also seeks to define the likely evolution of non-military display technology in order to identify military S&T investment opportunities where warfighting advantage is foreseen, and contributions of past defense display S&T investments (over $1B FY89-FY01) to current systems so as to assess the actual pace of technology creation and transition to weapons. The anticipated outcome of the 2002 AGED STAR on Displays is a detailed report to be signed out by USD(ATL) that describes AGED's recommendations on the anticipated needs for display S&T investments in all facets of national security over three terms: Near: < 5 years; Mid: 5 to 10 years; Far: > 10 years. [6]

4. STRATEGY

The new defense displays S&T strategy is beginning to emerge. A top-level summary is illustrated in Figure 3. It should come as no surprise that many key elements of the strategy are common with other technologies with which displays must be integrated and transitioned to weapons systems and platforms. These elements are: (1) leverage the commercial display market to the maximum extent possible; (2) continually assess the display needs of currently deployed defense capabilities and envision display requirements of notional future systems; (3) ascertain what defense research investments are required to address element (2) consistent with element (1). The strategy assumes a process of continual coordination within and among services, other government agencies, industry and academia.

A worldwide perspective is adopted due to the current international nature of electronics industries in general and display manufacturing in particular. Display component fabrication facilities are located almost exclusively in Asia for mass market technologies (AMLCD, CRT). Some display device fabrication facilities exist in North America (US, Mexico, Canada) in the mature (CRT) and new niche (DMD, GLV, LCOS, TFEL) technologies and more may be added over the next 5-10 years (in AMLCD) due to commercial market and economic forces.

Integration of display components into line replaceable units installed into weapons systems and platforms is performed by defense companies located primarily in the US, but also in the UK, Canada, Israel, and France. New display technology is created primarily in the US, with significant contributions too from the UK and other European countries. National research programs have recently been undertaken in several Asian countries (including Korea, Japan, Taiwan, China, and Singapore) to boost their displays research activity. Thus, the current status quo of research and integration in the West and display component manufacturing in Asia may change over the next 10-20 years with research, manufacturing, and integration occurring in a more balance manner in both hemispheres.

Figure 3. Overview of the defense display strategy summarizing key elements of the planning process.

5. ROADMAP STATUS

5.1. Top Level Roadmap Circa 2001

The top level roadmap issued by DoD in March 2001 (see Figure 1) is organized into several thrusts entitled High Definition Systems, Microdisplays, 25 Megapixel, True 3D, and Plus-up Display Efforts. An additional thrust—entitled Novel, Materials, Basic—has been added here comprising miscellaneous planned efforts. This is the current, official defense displays roadmap.[4,7]

The HDS thrust is a DARPA program for which funding ended in FY2001. However, previously funded HDS efforts will not complete execution until FY2003, as indicated by the zeros entered in the roadmap for FY2002 and FY2003. Emerging flexible plastic display technology based on organic light emitting diode (OLED) materials and structures has been the focus of recent HDS efforts since 1999. These flexible displays are made on substrates other than glass to reduce weight and cost; one day they may enable products for defense needs that other technologies do not address.

The Microdisplays thrust encompasses planned, budgeted efforts by the Air Force, Army, and Navy to develop near-eye virtual image systems including helmet-mounted displays for pilots and dismounted warriors and rifle- or vehicle-mounted sighting systems for riflemen and gunners. Service-planned and funded efforts include the creation of miniaturized versions of FPD technologies (AMLCD, AMOLED) to replace micro-CRTs and to enable new applications like indirect sights for rifles and improved panoramic night vision goggles.[8]

The 25 Megapixel thrust represents a variety of defense needs for ultra-resolution (10-1000 megapixel) display systems. These needs have been reviewed by Hopper[9a] and by Hopper et al.,[9b] and are based on the situational awareness and visualization requirements of advanced sensors, cockpits, training systems, dismounted warriors, intelligence workstations, operational control information centers, and combatant command posts. The current goal is a 10X increase of resolution from current 2 megapixel devices, developed in the 1990s for high definition television, to 21-36 megapixel devices. A second goal is a dramatic refinement/expansion of tiling and image generation technologies to enable these higher resolution devices to be integrated to create color video systems with aggregate resolutions of 100-300 megapixels.

The True 3D thrust represents a variety of defense needs for actual depth, or true, three-dimensional visualization systems, as contrasted to current-day digital 3-D computer models rendered on normal, 2D display hardware. The technology challenges and defense opportunities for True 3D devices have been reviewed by Hopper.[10] The current goal is a new generation of devices to address situational awareness and visualization requirements in which sparse symbol set, pre-computed true 3D graphical systems could dramatically enhance the effectiveness of mission/training pre-and post-flight debriefs, and the situational awareness for decision making in combat information centers and in cockpits.

Congress adds in areas it considers the President's Budget Request (PBR) to be deficient. Displays is such an area. The Congress views the PBR as just that, a request. The Plus-up Display Efforts thrust in Figure 1 comprises multiple individual additions made by the Congress across various of the DoD research accounts. Each such effort tends to receive such an add for several consecutive years with cumulative funding of some 20 to 40 million dollars. Recent examples of display research efforts that resulted from Congressional adds include awards to Micron/Pixtech for field emission display technology, Microvision for virtual retinal scanning displays, eMagin for miniature active matrix organic light emitting diode displays, CTC for a 3D table viewer using LC-shutter glasses, MCNC for display performance and environmental evaluation, the United States Displays Consortium for fleshing out domestic display infrastructure, and the Army Research Laboratory for a new, competitive program in advanced display technology.[8,11,12]

5.2. New Roadmap Circa FY2003

In February 2002 the Air Force, Army, Navy, and OSD began development of a new defense displays roadmap. In April 2002 it was agreed that the top level of this more detailed roadmap would be provisionally divided into six sub-areas as shown in Figure 4. During the remainder of 2002 the services plan to develop databases of their funded efforts to populate this new structure. Also, these agencies will separately and collectively identify opportunities and areas ripe for advancement, where defense advantage is foreseen, but in which commercial industry expects government to make some or all of the necessary S&T investment. The plan is to complete this new, more detailed roadmap by early FY2003.

STRUCTURE of DoD ROADMAP for DISPLAYS

Area	Subarea	*(Notes and Examples)*
Direct View		*(real image: user can touch screen on which eye focuses)*
	Cockpits	*(aircraft, land and sea combat vehicles)*
	Hand-held or worn	*(excludes virtual image systems; viewable by N persons)*
	Consoles/Workstations	*(air, land, sea, space vehicles; mobile platforms and fixed facilities)*
	C2 Posts/Centers	*(example technology classes: EM, large CRT, large FPD, projector)*
	Simulators, Trainers	*(used to show real world or synthetic visual environments)*
Virtual Image		*(virtual image: user can **not** touch screen; nothing at eye focus point)*
	Helmet/Head	*(special training required for safe and effective use)*
	Weapons Sights	*(viewable by only one person; restricts field of view at the head/eye)*
	Head Up	*(example technology classes: mini- projector, PNVG)*
True 3-D	Multiplexed 2-D	(virtual/real, mux across horizontal view points or depth planes)
	Volumetric	*(real image, direct-write)*
	Holographic	*(virtual image, e-holography)*
Novel Concepts		*(examples: resonant microcavities, intelligent pixels, acoustic)*
Materials		*(e.g. OLED, LC, EP, EC, inorg. EL, pyro, micro-, nano-)*
Basic Research (6.1)		*(e.g. Multi-disciplinary University Research Initiatives (MURIs), service OXR (ARL/ARO, ONR/NRL, AFRL/AFOSR) programs)*

Figure 4. Proposed structure for new defense roadmap for display science and technology.

6. DISCUSSION

A new era has dawned in defense display research. Until 1989 the program was based on joint service-led processes including the Tri-Service Avionics Working Group. From 1989-2001 DARPA mounted several programs having annual aggregate investment levels that averaged $80M per year and dwarfed the previous aggregate service investments.[1,2] The services reacted by decreasing their planned programs. Beginning in 2002 the DoD displays program is again service-led, coordinated via the Reliance process, and at a planned annual funding level of about $10M per year. The Congress continues to add some $40-60M each year for research and some $100-200M per year for development efforts in displays.

The current defense-wide display S&T roadmap is the one shown in Figure 1 and reported to Congress in 2001. A new, updated roadmap is being developed, which is scheduled to be completed and vetted by early FY2003. The vetting will begin with the services, defense agencies, industry, and the DoD Advisory Group on Electron Devices. AGED is conducting a Special Technology Area Review on displays in 2002-2003 to provide its recommendations on how to shape the revised roadmap. Another vetting in conjunction with all other electronics technologies will occur as part of the 2003 DDR&E Technology Area Review and Assessment (TARA) for Sensors, Electronics, and Electronic Warfare (SEEW).

The new roadmap is a path to the future from the present. Analyses of all current military displays and of the current industrial base for addressing specialty applications, including especially defense, are available. [1, 13]

Defense transformation requires productivity growth for each combatant. The primary means of information assimilation is visual, so warfighter requirements continue to expand and to impose demands on display devices far beyond those of consumer commercial markets. For over a decade the defense Service departments (Air Force, Army and, Navy) have relied primarily on the large DARPA program to address their needs for display technology. Now it will be necessary for the Services to reconsider their S&T investment posture in light of the DARPA departure from the displays area.

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