NPS-AM-19-006

ACQUISITION RESEARCH PROGRAM
SPONSORED REPORT SERIES

Active Matrix Liquid Crystal Display: A Case Study

12 October 2018

William R. Fast, Senior Lecturer

Graduate School of Business and Public Policy

Naval Postgraduate School

Prepared for the Naval Postgraduate School, Monterey, CA 93943.

Acquisition Research Program
Graduate School of Business & Public Policy
Naval Postgraduate School

The research presented in this report was supported by the Acquisition Research Program of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

To request defense acquisition research, to become a research sponsor, or to print additional copies of reports, please contact any of the staff listed on the Acquisition Research Program website (www.acquisitionresearch.net).

Acquisition Research Program
Graduate School of Business & Public Policy
Naval Postgraduate School

Abstract

This research investigates the reasons for the failure of Optical Imaging Systems, Incorporated (OIS), Northville, Michigan, and the lessons learned from that failure. In 1993, OIS was the recipient of $48 million from the Advanced Research Projects Agency for the development of a manufacturing capability for active matrix liquid crystal, flat panel displays. Invoking Title III of the Defense Production Act of 1950, defense contractors were directed by the Department of Defense (DoD) to use OIS to fulfill their flat panel display requirements. When OIS shut its doors in 1998, it was the supplier for more than 80 percent of DoD's flat panel displays. The collapse of OIS threatened the production lines of several important weapon systems, to include the AH-64 Apache helicopter, the F-16 fighter jet, and the M1 Abrams main battle tank. This research uncovers a fascinating web of interrelated causes of the failure, including: overly optimistic production yield rates, inadequate market analysis, conflicting stakeholder interests, poor profitability analysis, and flawed public policy. Finally, this research reinforces the use of existing tools to help the DoD make better investment decisions in emerging technologies and their suppliers.

This case study was prepared for the Navy Director of Acquisition Career Management (DACM) as sponsored research for the Acquisition Research Program (ARP), Project #18-34. Research for the case study was conducted during the period of February 20 through September 30, 2018.

Students preparing for class discussion of this case study should first read the AMLCD [active matrix liquid crystal display] Case Study Discussion Questions at Appendix B. These questions will help students focus on key aspects of the case study as they prepare for class discussion of the case. The glossary at Appendix A, the Form BIS-999 at Appendix C, and the Department of Commerce (DoC) briefing on the Defense Priorities and Allocations System (DPAS) at Appendix D will also be helpful to students who do not have past experience, training, or education in these topics.

Instructors may elect to facilitate this case study over two separate class meetings. Using this approach, the first four chapters would be discussed in the first class meeting,

followed by the last two chapters in the second class meetings. Students should not be provided with the last two chapters until after they have discussed the first four in class.

Key words: Dual Use Technology, Production, Markets, Profitability, Policy.

NPS-AM-19-006

ACQUISITION RESEARCH PROGRAM
SPONSORED REPORT SERIES

Active Matrix Liquid Crystal Display: A Case Study

12 October 2018

William R. Fast, Senior Lecturer

Graduate School of Business and Public Policy

Naval Postgraduate School

THIS PAGE LEFT INTENTIONALLY BLANK

Table of Contents

THIS PAGE LEFT INTENTIONALLY BLANK

List of Figures

THIS PAGE LEFT INTENTIONALLY BLANK

List of Tables

THIS PAGE LEFT INTENTIONALLY BLANK

Introduction

It was a sunny day in late August 1998 when I took command of ***Defense Contract Management Agency (DCMA)***[1] Springfield. The command was headquartered at the U.S. Army's Picatinny Arsenal just outside of Dover, NJ. The command had responsibility for the administration of all Department of Defense (DoD) and National Aeronautics and Space Administration (NASA) contracts in the northern New Jersey geographic area. One of my subordinate commanders was Major Steve Griffith, U.S. Air Force. Steve commanded DCMA Allied Signal, and he was collocated with about 30 other government personnel at the Allied Signal facility in Teterboro, NJ.

I hadn't even had time to get my feet on the ground in this new command when Steve informed me that we had a problem with the ***Multi-Purpose Display (MPD)*** being produced by Allied Signal for the Army's Apache Longbow helicopter program. Early one morning, Steve called to give me a "heads-up" about a potential line-stopper for the Apache Longbow MPD. Specifically, the company making the ***flat panel display*** screen glass for the MPD (called an ***Active Matrix Liquid Crystal Display***, or ***AMLCD***), was shutting its doors. The company was Optical Imaging Systems (OIS), Inc., located in Northville, MI, and was a subcontractor to Allied Signal. Not only were we having problems producing the MPD at Allied Signal's facility in Teterboro, but there was also a real possibility that the lack of MPDs could stop the Apache Longbow production line in Mesa, AZ, as well!

[1] Terms in ***bold italics*** are defined in the glossary at the end of the case study.

THIS PAGE LEFT INTENTIONALLY BLANK

Background

Flat Panel Display (FPD) technology (shown in Figure 1) was largely developed in American laboratories; however, the United States has not had a significant capability to manufacture FPDs. Companies capable of manufacturing displays either decided not to do so or, lacking the necessary financial resources, were unable to persuade other organizations to fund their efforts. In the early 1990s, U.S. firms had only a small fraction of the FPD world market (U.S. Congress Office of Technology Assessment, 1995, p. 62).

Figure 1. Multi-Purpose Displays in the Cockpit of an Apache Longbow Helicopter. Source: Lockheed Martin (2018).

The ***Defense Advanced Research Project Agency (DARPA)*** took on the challenge to improve AMLCD manufacturing techniques so that U.S companies could supply affordable AMLCDs to both military and commercial systems. Beginning in 1993, DARPA launched an effort to build manufacturing knowledge and drive towards affordable display production. This program combined industry and government funding, with a minimum industry share of 50%. As the first part of this effort, two AMLCD demonstration facilities were established. The first demonstration program was at Optical Imaging Systems, Inc., and was to respond to military requirements for AMLCDs and also serve as a dual-use entry into the large commercial market. The second AMLCD demonstration program was a joint effort between Xerox, AT&T, and Standish Industries. This manufacturing test bed focused on advanced packaging technologies and very high resolution displays suitable for intelligence-related applications. The ***National Flat Panel Display Initiative*** continued emphasis on manufacturing over the next several years (Hartney, 1995, p. 10).

The news article shown in Figure 2 explains many of the details associated with AMLCD work at OIS, Inc.

OIS UNVEILS AMLCD PRODUCTION PLANT
Electronic News, Nov 14, 1994

Northville, Mich. - OIS Optical Imaging Systems, Inc. this week will open what it claims is the first facility located in the United States for the volume manufacture of active matrix liquid crystal displays (AMLCDs).

Curtis Casey, OIS's vice president of business development, said the new $102 million OIS plant has 115,000 square feet of floor space and a capacity to produce annually 44,000 6x8-inch, or 10-inch diagonal, displays. The plant also would have the capacity produce over 100,000 smaller displays, Mr. Casey said. He said the displays are being built on 17-inch substrates. The new facility will employ 300, he said.

About 70 percent of the AMLCD production equipment, which is being bought under a $48 million contract from the Pentagon's Advanced Research Projects Agency (ARPA) in 1993 (EN, Aug. 30, 1993), is of U.S. manufacture, with 20 to 25 percent coming from Germany, Mr. Curtis said. OIS, which was founded in 1984, manufactures displays for a wide range of military, avionic and commercial applications. It also is developing new custom-made displays for commercial avionic upgrade programs, NASA's space shuttle and the military.

The subsidiary of Guardian Industries earlier this year entered into an agreement with Apple Computer, Inc. to develop high-performance AMLCD's for Apple's next generation notebook computers (EN, June 13). At the time, OIS said Apple was paying for the development. No terms of the accord were disclosed.

Apple currently buys its flat panel displays (FPDs), including AMLCDs, from Japanese suppliers, according to an Apple spokeswoman.

AT&T, Standish Industries and Xerox also have joined in a $100 million two-year Defense Department effort (EN, July 11) to lay the groundwork for the U.S. production of AMLCDs. Government funding of $50 million will be matched by the three companies over the two-year span.

The $100 million will be spent over two years; but the contract is for five years in the sense that the Pentagon will have call on the three companies for FPDs for an additional three years.

The award to the three companies was part of a $587 million, five-year government effort to encourage U.S. manufacturing of FPDs and foster U.S. national security in the face of Japanese dominance of the world FPD market (EN, May 2).

The $48 million ARPA award to OIS was made outside of and prior to the new U.S. display manufacturing policy.

Last month, (EN, Oct. 3), OIS reported a net loss for fiscal 1994 of $5.9 million, or 19 cents per share, versus a loss of $5.3 million, or 20 cents per share, a year ago. Revenues jumped to $11.7 million from $7.2 million.

Figure 2. News Article: OIS Unveils AMLCD Production Plant. Source: Electronic News (1994).

THIS PAGE LEFT INTENTIONALLY BLANK

DCMA Allied Signal Takes Action

Later that day, Steve called me to explain that the Apache Longbow helicopter program was eligible to apply for ***Special Priorities Assistance (SPA)*** since it was a ***DX rated program***. (Note, in the time frame of this case, DoD DX rated contracts were called "BRICKBAT" and DoD DO rated contracts were called "CUECAP." These terms are now obsolete, and DoD rated contracts are either DX or DO, the ratings used to describe all contracts under the ***Defense Priorities and Allocation System [DPAS].*** DX rated programs are considered "highest national defense urgency," and ***DO rated programs*** are considered "critical to national defense." Only Major Defense Acquisition Programs [MDAPs] may receive a DX rating). When suppliers receive a DX or DO rated contract, work on that contract is to take priority over all other commercial contracts.

Steve went on to explain that the DPAS that provides for DX and DO ratings is designed to be largely self-executing (see DPAS website: http://www.bis.doc.gov/dpas/default.htm). The Department of Commerce (DoC) has authorized several other federal government organizations to place rated orders on contracts; these organizations are the DoD, Department of Energy, Department of Homeland Security, and General Services Administration. In the event that formal assistance is required, SPA should be sought from the delegate agency (e.g., the DoD) through the contract administration or program office via a FORM BIS-999 to the Department of Commerce for action (see Appendix C for a copy of FORM BIS-999). SPA may be provided for any reason in support of the DPAS, but is usually provided in these situations:

1. Sorting out difficulty obtaining delivery against rated orders by the required delivery date
2. Rectifying inabilities to locate suppliers to fill rated orders
3. Ensuring rated orders receive preferential treatment by suppliers
4. Resolving production or delivery conflicts between various rated orders
5. Assisting in placing rated orders with suppliers
6. Verifying the urgency of rated orders
7. Determining the validity of rated orders

Steve told me that situation 1 appeared to apply to the Apache Longbow MPD predicament; however, situation 2 might also apply since the contractor didn't want to continue production.

Steve advised me that his staff was working with Allied Signal to complete an SPA request using BIS-999, Request for Special Priorities Assistance Form, and that he would hand carry it to Headquarters (HQ), DCMA, in Alexandria, VA, so it could be forwarded to the DoD DPAS office and then on to the DoC. Steve's hope was that the DoC could influence OIS, not to close its doors. I asked if ***privity*** of contract between Allied Signal and OIS was a problem. Steve said that from the perspective of the DoD Program Office, privity of contract is not a consideration in the SPA process and is not a requirement to initiate the SPA process.

Finally, Steve cautioned me about getting my hopes up. He went on to say that there were lots of constraints in implementing SPA. One of the keys to overcoming these constraints is to involve the DoD DPAS office and, if necessary, the DoC early in the process—not at the 11th hour when options become more limited (and, unfortunately, Steve said we had reached the 11th hour with OIS). He went on to say that the government cannot require indefinitely that a company produce an item that it no longer wants to produce, presuming that the company has retained the capability to produce the item and that an acceptable substitute can be identified or developed in a reasonable period of time. The bottom line is that SPA may not be able to fix the problem entirely, but it may buy Allied Signal and the government enough time to come up with viable alternatives (Hagan, 2010, p. 9).

Outcome

Both the DoD and Allied Signal knew that OIS, was having financial problems years before the contractor announced it was ceasing operations. News reports such as the one shown in Figure 3 should have prompted earlier action.

NORTHVILLE, Mich., Nov. 12, 1997 /PRNewswire/ -- OIS Optical Imaging Systems, Inc.

OVON announced its unaudited financial results for the first quarter ended September 30, 1997. Revenues increased 176% during the first quarter and were $6,478,728 as compared with $2,344,683 in the preceding fiscal year. The Company's net loss available to common shareholders was $6,682,496 or seven cents per share (cents per share the amount of a mutual fund's dividend or capital gains distributions that a shareholder will receive for each share owned, based on a weighted average of 97,467,920 shares outstanding), as compared with $8,277,036 or nine cents per share (based on a weighted average of 97,137,140 shares outstanding) in the preceding fiscal year. The following are condensed operating results for the three months ended September 30, (in thousands):

OIS Operating Results	Three Months Ending September 30,	
	1997	1996
Revenues	$6,479	$2,345
Cost of Sales	$11,689	$6,862
Gross Margins	$(5,210)	$(4,517)
Operating Expenses	$1,837	$2,168
Other Expenses	$951	$886
Income Tax Benefit	(2,801)	---
Preferred Stock Dividends	$1,485	$706
Net Loss Available to Common Shareholders	$(6,682)	$(8,277)
Net Loss Per Common Share (in dollars)	$(0.07)	$(0.09)
Source: OIS Optical Imaging Systems, Inc.		

Figure 3. News Article: OIS Announces First Quarter Results Source: PRNewswire (1997).

Unfortunately, and due to no fault on the part of Steve or his Team, the DoC didn't receive the SPA request until *three days* before the company closed its doors on September 18, 1998. On September 28, 1998, 10 days after shut down, the DoC directed OIS to reopen and continue producing the AMCLDs as required by its contracts. This government action was in accordance with the ***Defense Production Act (DPA) of 1950*** and the Selective Service Act of 1948, both of which have provisions for the president of the United States to take steps to assure the availability of goods considered vital to

national defense. This was also the first time in history that the federal government had ordered a closed manufacturing facility to restart operations ("Optimal Imaging Systems," 1998). In addition, the DoC press release announcing the order stated that a group of defense contractor customers who use the AMLCD had offered to help pay the OIS facility operating costs ("OIS Optical Preparing," 1996). Most importantly, the DoC press release added that "Commerce's order is contingent upon the availability of that funding for OIS" and that "civil injunctions or criminal penalties may be imposed for failure to comply with the order" ("OIS Optical Preparing," 1996).

The offer made by the group of defense contractor customers to pay OIS operating costs was never accepted by OIS. Responding to the press about the DoC order to reopen production, Rex Tapp, OIS president and CEO said,

> I think there is strong contention about whether they have the power to order us back into production. I have some questions as how the Commence Department handled this from a press-relations standpoint, but I can assure you that I don't think anyone is going to jail. There are alternative sources for our products, and we wish everyone well. There's not much else we can do, because we are no longer in production. (Roush, 2006, p. 1)

The Department of Justice (DOJ) refused to issue a court injunction to keep the doors of the plant open. The best that the DoC could do was to extract a promise from the OIS management that, with customer assistance, they would keep the facility open and operating with enough people to complete work on 750 pieces of work-in-process (WIP; Hagan, 2009, p. 1). Later follow-up with DoC officials confirmed that, in fact, OIS voluntarily agreed to remain open to complete the 750 pieces of WIP. In a phone call with the author on September 13, 2018, Liam C. McMenamin of the Bureau of Industry and Security, DoC said that no actions could be taken by the DoC because OIS received a DX rated contract and OIS performed on that contract.

Fortunately, the 750 pieces of WIP turned out to be enough AMLCDs to support, without substantial delay, a number of weapons systems, to include the MPD for the Apache Longbow helicopter. With the help of Colonel Tony Love, commander, DCMA Atlanta, Steve and his team found another vendor and introduced that company to Allied Signal so it could become a qualified supplier of the AMLCD for the Apache Longbow MPD. But for the 750 pieces of WIP, this matter would have been a disaster, and there is

not much that the government would have been able to do about it. Neither the DoD nor the DoC could force OIS to remain in business while it was suffering a financial loss. The news article shown in Figure 4 details the impact on the DoD.

FAILED FLAT-PANEL DISPLAY FIRM LEAVES PARTNERS HIGH AND DRY

February 1999, National Defense
by Joshua A. Kutner

Several major U.S. defense industry layers were hindered late last year when the Pentagon's contracted supplier of flat-panel displays suddenly closed down shop. OIS Optical Imaging Systems Inc., Northville, Michigan, once the foundation of the Defense Department's national flat panel display initiative, had failed to find new investors or a potential buyer after suffering substantial losses. Its market consisted primarily of government contracts, and it had been unable to achieve success in the commercial sector.

The demise of OIS delayed the production schedules of specific prime contractors that required flat-panel display applications. The firm was the supplier of more than 80 percent of the Pentagon's full-size flat displays.

The company's shutdown "hindered our ability to meet some deadlines," said John Bernaden, director of public affairs for Allied Signal Electronic and Avionics Systems. Allied Signal's corporate headquarters is located in Morristown, New Jersey.

The Defense Department, under Title III of the Defense Production Act, required companies such as Allied Signal to enlist the services of OIS in applying active matrix liquid crystal displays to systems and weaponry, according to industry sources.

Title III of the Defense Production Act stipulates that its "mission is to establish, expand, and maintain domestic capability for technologies and industrial resources critical to the Defense Department. It achieves this by partnering among service acquisition, support, and laboratory programs and industry."

The national flat panel display initiative was designed to provide incentives for companies and military establishments who enlist the services of domestic manufacturers such as OIS.

The company had initially signed a production agreement for delivery of its advanced CQ6363 high reliability active matrix liquid crystal display to be used in the U.S. Army AH64 Apache helicopter to Allied Signal Government Electronic Systems in Teterboro, New Jersey. Allied Signal was to then apply the displays to instruments used in the helicopter. Allied Signal paid approximately $15 million to OIS under the terms of the agreement. As of April 1998, this was OIS Inc.'s largest single production order.

When OIS folded, Allied Signal was left without the necessary means to complete its part of the agreement.

One official from Allied Signal said, "We were directed by the Defense Department to use OIS because the military needed this flat display ... There was a lot of political help in getting [OIS] started. $50 million—OIS Inc.'s total government endowments—was spent in taxpayers' money ... It just smelled from the beginning."

Following the shutdown of OIS, Allied Signal went to court to try and keep the company running, or to at least obtain any leftover or half-built supplies, said Bernaden.

"The Defense Department asked us to use this supplier, then the supplier decided to go out of business," he said. "Our job is to satisfy our customers."

Allied Signal is currently seeking substitute flat-panel display suppliers in order to get back on schedule, said Bernaden.

OIS Inc.'s collapse also threatened to delay production and delivery of systems such as Lockheed Martin Corporation's F-16 fighter jet. Other companies affected by the shutdown include

General Dynamics, Warren, Michigan, which at the time, was about to go into production on the new Abrams tank; the Honeywell Defense Group, Albuquerque, New Mexico; and the McDonnell Douglas-Boeing Company team that manufactures the U.S. Army AH-64 Apache helicopter.

Some officials accuse the government of not wanting to pay for these necessary systems. In an opinion piece published by CMP Media Inc., David E. Mentley, vice president of Stanford Resources, said, "The solution is to face the reality that the true cost of advanced cockpit-display technology must be paid by the customer [the government]. It is not fair to ask a business to subsidize the development of such a unique technology. When the aircraft makers needed special materials for radar-absorbing coating and lightweight composite wings, they paid for the development and the full price of the materials. For some reason, the U.S. government does not want to pay the real price for the most important electronic system in the airplane—the cockpit display."

Mentley said the only workable solution is to build the displays in government-operated labs in spite of high costs and inefficiencies.

The only other U.S. manufacturer of full-size flat-panel displays is dpiX Inc., Palo Alto, California. Pentagon program managers quickly turned their attention to dpiX following the shutdown of OIS, said officials.

"OIS is a good supplier to the Defense Department, and we don't like to see it leave the field," said Bruce Gnade, high definition display program manager for the Defense Advanced Research Projects Agency, in a related press report. "It's not good for the Defense Department, for the U.S. industry, or for the country. However, dpiX offers an alternate source of supply for military programs."

Malcolm Thompson, president and chief executive officer of dpiX, is confident that his company can pick up the slack.

Industry figures estimate that production could be set back 18 months to two years.

"We are still trying to assess some of our costs negotiating with the Defense Department," said Allied Signal's Bernanden.

Figure 4. News Article: Flat-Panel Display Firm Leaves Partners High and Dry. Source: Kutner (1999).

Anatomy of a Bad Investment Decision

DARPA's Research Support Center was asked for information regarding the decision to provide the $48 million AMLCD manufacturing grant to OIS in 1994. In response to an email request from the author, Mr. Howard Ho of the Research Support Center searched DARPA's internal database and repository but couldn't find anything related to OIS or the decision to award the grant. Mr. Ho said that the lack of findings might be attributed to the records management systems in the 1990s, where many files were archived in print and not every paper was digitalized.

Regardless, there are at least three lessons learned from OIS and the DARPA grant decision: (a) lack of profitability was already a known problem at OIS and should have been considered before awarding the $48 million grant; (b) the fact that AMLCD manufacturing processes were unproven and the fact that OIS management knew that ramping up to the necessary volume production would be a significant challenge should have been considered; and, (c) in the market environment at the time, the DARPA strategy of promoting the AMLCD as dual-use technology was flawed. In the remainder of this case study, we address each of these problems, in order.

Profitability. Under federal securities laws, public companies are required to annually disclose information on their business, investments, sales, and assets. On September 26, 1996, OIS filed Form 10-K with the U.S. Securities and Exchange Commission (OIS Optical Imaging Systems, Inc., 1996). Information extracted from that filing is displayed in Table 1. From this information, it is clear that, over a five-year period, profitability at OIS was steadily declining and the company's stockholders were losing money on their investments.

Table 1. OIS Profitability. Source: OIS Optical Imaging Systems, Inc. (1996).

Fiscal Years Ending June 30	**FY92**	**FY93**	**FY94**	**FY95**	**FY96**
Total Revenues (Sales)	$5,481,869	$7,162,035	$11,700,389	$8,423,041	$10,595,207
(-) Cost of Goods Sold	$4,894,526	$9,262,815	$13,078,919	$17,810,224	$26,106,953
(-) General and Admin Expenses	$6,644,735	$3,935,699	$3,789,061	$2,834,330	$6,167,353
(-) Internal Research & Development	$517,348	$372,242	$688,094	$1,306,843	$1,971,513
(-) Depreciation	Not Available	Not Available	Not Available	$7,111,928	$9,300,731
(=) Operating Income (OI)	-$6,574,740	-$6,408,721	-$5,855,685	-$20,640,284	-$32,951,343
Operating Profit Margin = OI/Sales x100	***-119.94%***	***-89.48%***	***-50.05%***	***-245.05%***	***-311.00%***
Total Assets	$10,288,994	$7,088,883	$38,146,868	$57,263,779	$70,513,934
Return on Assets = OI/Total Assets x100	***-63.90%***	***-90.41%***	***-15.35%***	***-36.04%***	***-46.73%***
Source: U.S. Securities and Exchange Commission, OIS Optical Imaging Systems, Inc. Form 10-K, September 26, 1996.					

Moreover, it is clear that OIS was not profitable well before DARPA awarded the $48 million grant in 1994. From fiscal year (FY) 1992 to FY1993, the cost of goods sold almost doubled, while sales increased by only 30%. Elliott Schlam, principal analyst and consultant at Elliott Schlam Associates in Wayside, NJ, also discovered that OIS had a problem with cost of goods sold:

> There's a big disconnect between their [OIS] cost structure and pricing. For the Abrams tank displays, OIS locked itself into a fixed-cost contract before it actually had product, leaving it to sell displays for $5,000 when, based on costs, they should have been a minimum of $14,000 to $15,000, and Litton was charging about $35,000 [for essentially the same display]. (Lieberman, 1998, para.11).

Even more telling is that fact that by FY1996, only 46% of sales were from manufactured displays. The majority of revenues (sales), especially in the FY1992 and FY1993 timeframe, were from customer-funded engineering activities, not production line work. DARPA should have requested an Industrial Capabilities Analysis on OIS from the Office of the Deputy Assistant Secretary of Defense for Industrial Affairs. DoD Handbook 5000.60-H (Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics [OUSD(AT&L)], 1996) provides guidance for performing such an analysis, to include how to conduct a financial analysis of OIS (as detailed in Appendix A to DoD Handbook 5000.60-H).

Unproven Manufacturing Processes. Under the terms of its agreement with DARPA, OIS received $48 million over two years (FY1994 and FY1995) to purchase and install new manufacturing equipment for high volume production in the new Northville, MI, facility. The equipment purchased was property of the U.S. government and "OIS was entitled to use this equipment without charge until August 1998" (OIS Optical Imaging Systems, Inc., 1996, p. 21), at which time OIS could "purchase the Government owned equipment at its then Fair Market Value" (OIS Optical Imaging Systems, Inc., 1996, p. 21). Prior to establishing the Northville facility, limited manufacturing was done at the OIS facility in Troy, MI; however, the Troy facility was originally designed only for customer-funded engineering of limited numbers of AMLCDs, not high-volume production (OIS Optical Imaging Systems, Inc., p. 25).

By the end of June 1996, OIS had only established baseline manufacturing processes at the Northville facility. Several problems had prevented the ramp-up of that facility to volume production. First, there was a fire at the Northville facility in March 1995 that required extensive clean-up and repairs. The Troy facility had to continue its limited manufacturing during that time. During this same time frame, OIS discovered that AMLCD "design and manufacturing tolerances were too narrow for efficient manufacturing as production volumes increased" (OIS Optical Imaging Systems, Inc., 1996, p. 25). In response, OIS restructured the management of product design and manufacturing and "implemented design rules more suitable for higher production volume" (OIS Optical Imaging Systems, Inc., 1996, p. 25). In some cases, OIS had to renegotiate specifications with its customers (OIS Optical Imaging Systems, Inc., 1996, p. 25).

In its annual Form 10-K filed with the U.S. Securities and Exchange Commission for FY1996, OIS admitted to two other problems in AMLCD volume production at the Northville facility. First, manufacturing process problems were limiting production, and second, low manufacturing yield rates were resulting in product defects. OIS management did not believe that these two problem areas would improve in FY1997 (OIS Optical Imaging Systems, Inc., 1996, p. 22).

It is unknown if DARPA ever assessed the manufacturing readiness of OIS, either at the Troy facility or at the Northville facility. However, within defense acquisition

programs, assessments of manufacturing readiness levels (MRLs) for key manufacturing process and key product characteristics are considered essential to the transition from design to production. Organizations such as the Navy's Best Manufacturing Practices Center of Excellence (BMPCOE) or the Lean Aerospace Initiative (LAI) could have helped assess manufacturing readiness and provided recommendations for solving manufacturing process problems.

Dual-Use Technology Strategy. In a 2001 review of defense display research programs, Robert W. Tulis, Microsystems Technology Office, DARPA, Darrel G. Hopper, Air Force Research Laboratory, David C. Morton, Army Research Laboratory, and Ranganthan N. Shashidhar, Naval Research Laboratory (2001) write,

> Two facilities were funded via DARPA to provide a supply of U.S. manufactured active matrix liquid crystal displays (AMLCD) for U.S. military-unique application – especially aircraft cockpits. Neither of the U.S. AMLCD manufacturing facilities, one at OIS and the other at Xerox (now dpiX), succeeded in developing a non-defense customer base and ceased production in August 1998 and March 2001, respectively. However, the DoD received a significant return on its investment [from] the OIS and Xerox avionics AMLCD facilities during the period of their operation, 1995-2001. (p. 7)

Tulis et al. (2001) go on to explain that without these AMLCD pilot demonstration programs, the F-22A Raptor, F-18E/F Super Hornet, and AH-64D Apache Longbow programs could not have made it through their engineering and manufacturing development (EMD) phases and into their low rate initial production (LRIP) efforts. What was the purpose of this explanation? Was DARPA trying to put a positive spin on these failed pilot demonstration programs?

In April 1998, Allied Signal awarded a $15 million contract to OIS for 1,400 AMLCD head assemblies for the Apache Longbow. This was OIS' largest single production order. The period of performance of that contract was to be October 1998 through September 2000 (Chinnock, 1998, p. 4); however, deliveries on that contract never started because OIS terminated production in August 1998. Allied Signal, with the help of DCMA, had to find and qualify another supplier to fulfill the needed AMLCD head assemblies. Likewise, other military aircraft cockpit display manufacturers who had depended on OIS AMLCDs were in the same predicament—they also had to find and qualify other suppliers. Clearly,

the DARPA demonstration pilot at OIS, which only produced AMLCDs for about two years, did not sustain these military aircraft programs through EMD and into LRIP.

The production of AMLCDs from the OIS Northville facility was supposed to reach 40,000 pieces per year. According to Rex Tapp (1997), OIS president and CEO, by August 1997 the Northville facility was producing 400 displays (17 types) per month; however, when OIS announced it was shutting down, there were only 750 pieces in process. Assuming that these 750 pieces represented about one month of production, only 22% of its annual production goal had been achieved. While the OIS Northville facility was Mil-Q-9858 compliant, it didn't receive its International Standards Organization (ISO) 9001 Quality Management System certification until February 1998 (Chinnock, 1998, p. 4). Six months later in August 1998, OIS went out of business, never using its ISO 9001 certification in support of volume production of commercial computer displays.

The OIS and Xerox AMLCD pilot demonstrations really show that the dual-use model developed under the National Flat Panel Display Initiative was flawed. The model called for the use of the same resources, to include factories, machines, and workers, for both commercial computer displays and military cockpit displays; however, both companies found it impossible to break into commercial computer display markets while simultaneously meeting more stringent display specifications for defense avionics applications.

Tulis et al. (2001) also explained,

> Currently, combat avionics AMLCDs are manufactured in high volume facilities in Korea, Taiwan, and Japan (Japan will only participate in dual use, custom designs). Avionics AMLCDs are still all custom design albeit manufactured at opportunity cost in high volume facilities. Such facilities did not exist in the early-mid 1990s outside of Japan and the Japanese companies; which both then and now refuse to work military-unique program like F-22, F-18, and AH-64. The Koreans and Taiwanese companies now exist and will work with military-unique programs. (p. 8)

With this explanation, DARPA is admitting that the AMLCD portion of the National Flat Panel Display Initiative was a failure. The DARPA grants to OIS and Xerox did not enable these companies to break into either the military or the commercial AMLCD markets. While DARPA was working through the failures at OIS and Xerox, companies in

Korea, Taiwan, and Japan were successful in manufacturing custom-designed AMLCDs for military applications; however, domestic dual-use production of AMLCDs that satisfy both military and commercial requirements and demands was not achieved.

Conclusions

This case study investigated what happened when the U.S. government, in an effort to take FPD market share from the Japanese, used defense program contracts to try to help two U.S. companies mature their AMLCD manufacturing processes. This case study uncovered the reasons for the failure of one of those companies, OIS, and identified several lessons learned from that failure. The reasons for failure weave a fascinating web of interrelated causes, including overly optimistic production yield rates, inadequate market analysis, conflicting stakeholder interests, poor profitability, and a flawed public policy. This case study has also revealed challenges in AMLCD technology readiness and transition to production, contracting, execution of the Defense Priorities and Allocations System (DPAS), contract administration, and manufacturing management. More importantly, this case study emphasizes what can happen when taxpayer dollars are given away to public companies without first investigating profitability and manufacturing readiness. Finally, this case study reveals some of the pitfalls and false hopes of dual-use technologies, embodied in the failed attempt to manufacture AMLCDs simultaneously, for both commercial and defense markets.

THIS PAGE LEFT INTENTIONALLY BLANK

References

Boeing. (1997, September 23). *Apache Longbow helicopter lifts off for first time with full-color multi-purpose displays* [News release]. Retrieved September 20, 2018, from http://boeing.mediaroom.com/1997-09-23-Apache-Longbow-Helicopter-Lifts-off-for-First-Time-With-Full-Color-Multi-Purpose-Displays

Chinnock, C. (1998, July). OIS turns corner: Wins Apache Longbow contract. *Military and Aerospace Electronics*, *9*(7), p.4.

Defense Acquisition University. (2017). *Glossary of defense acquisition acronyms and terms*. Retrieved from https://www.dau.mil/glossary/Pages/Default.aspx

Defense Advanced Research Projects Agency (DARPA). (2018, September 30). About DARPA. Retrieved September 30, 2018, from https://www.darpa.mil/about-us/about-darpa

Defense Production Act (DPA) of 1950. Pub. L. No. 81-774, 50 U.S.C. Appendix §2061 et seq. (1950, September 8)

Hagan, G. (2009). *Defense Priorities and Allocation System (DPAS) examples of Department of Commerce involvement.* Fort Belvoir, VA: Defense Acquisition University (DAU).

Hagan, G. (2010). *Exercise 9 instructor support plan* (PMT 352B). Fort Belvoir, VA: Defense Acquisition University (DAU).

Hartney, M. (1995). ARPA display program and the national flat panel display initiative. Retrieved 30 September 2018, from: https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=540949

John S. McCain National Defense Authorization Act for Fiscal Year 2019, Pub. L. No. 115-232, § 1791, 132 Stat. 1636 (2018, August 13).

Kutner, J. A. (1999, February). Failed flat-panel display firm leaves partners high and dry. *National Defense*(Vol. LXXXIII; p. 30). Arlington, VA: National Defense Industrial Association.

Lieberman, D. (1998, September 16). Demise of OIS said to loom as “crisis” for big defense contractors—Top military display maker could go lights out. Retrieved September 30, 2018, from https://www.siliconinvestor.com/readmsgs.aspx?subjectid=14766&msgnum=78&batchsize=10&batchtype=Previous

Lockheed Martin. (2018). Target Acquisition and Designation Sight (TADS) Electronic Display and Control (TEDAC). Retrieved September 30, 2018 from https://www.lockheedmartin.com/en-us/products/tedac.html

Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD[AT&L]). (1996, April 26). Assessing defense industrial capabilities (DoD Handbook 5000.60-H). Washington, DC: Author.

OIS Optical Imaging Systems, Inc. (1996, September 26). *Form 10-K: Annual report pursuant to section 13 or 15(d) of the Securities Exchange Act of 1934 for fiscal year ended June 30, 1996*. Washington, DC: Securities and Exchange Commission (SEC).

OIS Announces First Quarter Results. (1997, November 12). *PR Newswire*. p.1112DEW024

OIS Optical preparing response to U.S. government. (1996, September 30). Reuters Detroit. Retrieved September 30, 2018, from https://www.siliconinvestor.com/readmsgs.aspx?subjectid=14766&msgnum=78&batchsize=10&batchtype=Next

OIS unveils AMLCD production plant. (1994, November 14). *Electronic News* (Vol. 40 (2040)). Oak Brook, IL: Reed Business Information.

Optical imaging systems to reopen. (1998, September 29). Associated Press. Retrieved September 30, 2018, from https://www.apnews.com/8f72af87bef29cf6356ac21a32c59f06

Roush, M. (2006, March 29). OIS says it won't reopen despite government order. *Crain's Detroit Business*. Retrieved September 30, 2018, from https://www.crainsdetroit.com/article/19981005/SUB/810050865/ois-says-it-wont-reopen-despite-government-order

Selective Service Act of 1948. Pub. L. No. 80-759, 50 U.S.C. Appendix §§ 451-473 (1948, June 24)

Shields, S. E. (1994, March 1). The allure of liquid crystal displays. *Optics & Photonics News* (Vol. 5, Issue 3, pp. 12-18). Washington, DC: The Optical Society.

Tapp, R. (1997, August 25). Opinion/letters. *Electronic Engineering Times, 968*, p44. Manhasset, NY: CMP Publications.

Tulis, R., Hopper, D., Morton, D., & Shashidhar, R. (2001). Cockpit displays VIII: Displays for defense applications. In *Proceedings of SPIE* (Vol. 4362; pp. 1–25). Bellingham, WA: Society of Photo-Optical Instrumentation Engineers.

U.S. Congress Office of Technology Assessment. (1995, September). *Flat panel displays in perspective* (OTA-ITC-631). Washington, DC: Government Printing Office.

Appendix A. Glossary

(Note: Unless otherwise cited, definitions are taken verbatim from the ***Defense Acquisition University Glossary of Defense Acquisition Acronyms and Terms***, updated as of February 9, 2017. Other definitions are also taken verbatim from the cited references.)

Active Matrix Liquid Crystal Display (AMLCD)—Liquid crystal displays LCDs are the most prevalent type of Flat Panel Display (FPD), and are used in notebook computers, pocket televisions, and personal digital assistants. LCDs use a material that acts like a shutter—blocking, dimming, or passing light unobstructed, depending on the magnitude of the electric field across the material, LCDs are lightweight and require little operating power. However, since LCDs only modify light, they require an external source of light; while ambient light is used in simple displays, complex, rapidly changing color displays require a bright light, typically mounted behind the LCD screen. There are two primary types of LCDs *passive matrix* and *active matrix* LCDs (PMLCDs and AMLCDs, respectively). The PMLCD is the basic type of LCD; it is made by sandwiching liquid crystal material between two glass plates, each of which contains a parallel set of transparent electrical lines. The plates are arranged so that, looking through the display, the lines cross to form a checkerboard pattern, or matrix. Every intersection of two lines forms a pixel, and the voltage across that pixel determines the shade of that pixel. PMLCDs are commonly used for gasoline pump displays, pager screens, digital wristwatch readouts, and other applications that require a simple, inexpensive display; recent manufacturing improvements, however, have led to the application of PMLCDs to more complex display functions. AMLCDs use an electronic switch at every pixel, which provides faster switching and more shades. With the addition of filters that pass only certain colors, AMLCDs produce vivid color graphics in portable computer and television screens. The added complexity of manufacturing the switches results in a large, but diminishing, price premium compared with PMLCDs. (U.S. Congress Office of Technology Assessment, 1995, p. 6)

Flat Panel Display (FPD)—FPDs are electronic displays that are much thinner than their screen size, measured diagonally. Like the most common type of electronic display, the cathode ray tube (CRT), FPDs visually present electronic information, including text, graphics, and video. FPDs are also used as displays for computers, cameras, televisions, and other video systems. The FPD presents information in a thin, lightweight package that can operate on a modest amount of power, whereas the CRT requires a large package—typically as deep as the display is wide-that is heavy and consumes large amounts of power. (U.S. Congress Office of Technology Assessment, 1995, p. 6)

Multi-Purpose Displays (MPDs)—The MPDs—two in each cockpit—are at the heart of the Apache Longbow's pilot and copilot/gunner's fully integrated crew stations that bring together a wide array of advanced avionics and weapon systems. The Apache Longbow's multipurpose displays are the cornerstone of the information management system since

they give the crew the ability to control the aircraft's advanced avionics, sensors and weapon systems. (Boeing, 1997, para. 9)

Defense Contract Management Agency (DMCA; City/Area)—A DCMA contract administration office located in a city or area having cognizance over all government contractors in that city/area, unless they are covered by a team located within a specified contractor's plant.

Defense Priorities and Allocation System (DPAS)—A regulation administered by the Department of Commerce (DoC) that implements the priorities and allocations authority contained in Title 1 of the Defense Production Act (DPA) of 1950 with respect to industrial resources. The purpose of DPAS is to ensure the timely availability of industrial resources to meet national defense and emergency preparedness requirements. Certain national defense, energy, and homeland security programs are approved for priorities and allocations support. The DoC has delegated authority to DoD to place priority ratings on its contracts in accordance with DPAS and DoD issues approximately 300,000 rated orders annually. DoD uses two priority ratings: DX and DO. ***DX rated programs*** and their orders are of the highest national defense urgency and are approved by the Secretary of Defense (SECDEF) or Deputy Secretary of Defense (DEPSECDEF). ***DO rated orders*** are of lower priority than DX-rated orders but take precedence over unrated orders. DPAS cannot be used to prioritize food, energy, health, water, or civil transportation resources.

Defense Production Act (DPA) of 1950—Title 1 of this act is the statutory basis for the Defense Priorities and Allocations System (DPAS). Title 1 is also one of the non-permanent provisions of the DPA that needs to be periodically reauthorized, which Congress has done in the past for periods of 1 to 5 years. The DPA provides the President with the authority to require acceptance and priority performance on contracts and orders, and to allocate materials, services, and facilities to support national defense and emergency preparedness requirements. The President has delegated his priority and allocation authority to the DoD and Departments of Homeland Security (DHS) and Energy (DoE) according to resource required. The Defense Production Act of 1950 was extended to September 30, 2025 per Section 1791 of the John S. McCain National Defense Authorization Act for Fiscal Year 2019. (National Defense Authorization Act [NDAA], 2019, § 1791)

Defense Advanced Research Project Agency (DARPA)—For sixty years, DARPA has held to a singular and enduring mission: to make pivotal investments in breakthrough technologies for national security. The genesis of that mission and of DARPA itself dates to the launch of Sputnik in 1957, and a commitment by the United States that, from that time forward, it would be the initiator and not the victim of strategic technological surprises. Working with innovators inside and outside of government, DARPA has repeatedly delivered on that mission, transforming revolutionary concepts and even seeming impossibilities into practical capabilities. The ultimate results have included not only game-changing military capabilities such as precision weapons and stealth technology, but also such icons of modern civilian society such as the Internet, automated voice recognition and language translation, and Global Positioning System receivers

small enough to embed in myriad consumer devices. DARPA explicitly reaches for transformational change instead of incremental advances. But it does not perform its engineering alchemy in isolation. It works within an innovation ecosystem that includes academic, corporate and governmental partners, with a constant focus on the Nation's military Services, which work with DARPA to create new strategic opportunities and novel tactical options. For decades, this vibrant, interlocking ecosystem of diverse collaborators has proven to be a nurturing environment for the intense creativity that DARPA is designed to cultivate. (DARPA, 2018)

DX and DO Rated Programs—DoD uses two priority ratings: DX and DO. DX rated programs and their orders are of the highest national defense urgency and are approved by the Secretary of Defense (SECDEF) or Deputy Secretary of Defense (DEPSECDEF). DO rated orders are of lower priority than DX-rated orders but take precedence over unrated orders.

National Flat Panel Display Initiative—In 1994, DOD announced the National Flat Panel Display Initiative (NFPDI). It continues existing FPD research, and introduces incentives for domestic firms to produce displays and for the armed services to purchase them. (U.S. Congress Office of Technology Assessment, 1995, p. 4)

Privity—A direct contractual relationship between the parties. A prime contractor has privity with an agent of United States and also with its subcontractors that are under contract to it. The government does not have privity with the prime contractor's subcontractors by virtue of its contract with the prime contractor.

Special Priorities Assistance (SPA)—When necessary, the Department of Commerce (DoC) may take specific official actions to implement or enforce the Defense Priorities and Allocations System (DPAS) regulation. This includes issuance of Rating Authorizations, Directives, and Letters of Understanding as noted below:

> Rating Authorization: An official action granting specific priority rating authority that permits a person to place a priority rating on an order for an item not normally ratable under the DPAS regulation, or authorizes a person to modify a priority rating on a specific order or series of contracts or orders.
>
> Directive: An official action requiring a company to deliver an item or to take other action within a specified period. A company must comply with each Directive issued; however, a company may not use or extend a Directive to obtain any items from a supplier unless expressly authorized to do so in the Directive. Directives take precedence over all DX-rated orders, DO-rated orders, and unrated orders previously or subsequently received, unless a contrary instruction appears in the Directive.
>
> Letter of Understanding: An official action that may be issued in resolving SPA requests to reflect an agreement by all parties (Commerce, Agency, the supplier, and the customer). A Letter of Understanding is used to confirm production or

shipping schedules that do not require modifications to other rated orders. It is not used to alter scheduling between rated orders, to authorize the use of priority ratings, to impose restrictions under the DPAS regulation, or to take other official actions.

Appendix B: Active Matrix Liquid Crystal Display Case Study Discussion Questions

1. From a military operations perspective, why are high definition flat panel displays important?

2. Why was the United States lagging behind Japan in the flat panel display market of the early 1990s?

3. Explain the strategy behind the decision by the Defense Advanced Research Project Agency (DARPA) to invest in OIS, Inc.

4. What was the basis for the request by Commander, Defense Contract Management Agency (DCMA) Allied Signal, for Special Priorities Assistance (SPA)? What was the result?

5. What reasons, stated or implied, are given for OIS, Inc. closing its doors and going out of business?

6. What does this case teach us about the challenges of incorporating cutting-edge, dual-use technologies into military weapon systems?

Acquisition Research Program
Graduate School of Business & Public Policy
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net