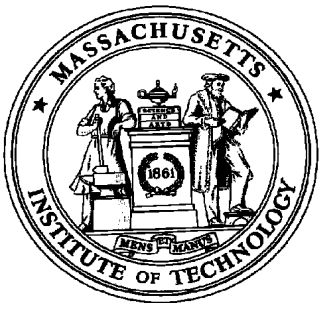
# LEAN EFFECTS ON AEROSPACE PROGRAMS (LEAP) PROJECT

# AMRAAM CASE STUDY REPORT




## LEAN AEROSPACE INITIATIVE

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**March 1, 2002**

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# Acronym List

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| AMRAAM | Advanced Medium-Range Air-to-Air Missile |
| BVR | Beyond visual range |
| DCMA | Defense Contract Management Agency |
| ECM | Electronic countermeasures |
| FMS | Foreign military sales |
| GD | General Dynamics |
| IPT | Integrated Product Team |
| JSPO | Joint System Program Office |
| LAI | Lean Aerospace Initiative |
| LEAP | Lean Effects on Aerospace Programs |
| MRB | Material Review Board |
| NASAMS | Norwegian Advanced Surface-to-Air Missile System |
| PO | Purchase Order |
| POM | Proof of Manufacturability |
| RMS | Raytheon Missile Systems |
| SAP | Standard Accounting Practice/Procedure |
| SNADS | Surface Navy Air Defense Systems |
| TI | Texas Instruments Inc. |
| TSPR | Total System Performance Responsibility |
| U.S. | United States |
| USAF | United States Air Force |
| USN | United States Navy |
| WIP | Work in Progress |

# 1. INTRODUCTION AND OVERVIEW

## 1.1. Introduction

The AIM-120 Advanced Medium-Range Air-to-Air Missile (AMRAAM) is an advanced active radar-guided air-to-air missile that allows an aircraft to launch multiple missiles at multiple enemy aircraft from beyond visual range (BVR) in any weather. AMRAAM is dependable with a low cost of ownership.

AMRAAM is in full rate production at the Raytheon Company in Tucson, Arizona. Formerly, the AMRAAM was produced at both the heritage Raytheon Company in Andover, Massachusetts and the heritage Hughes Aircraft Company Tucson facility. AMRAAM production operations were consolidated at the Tucson facility after Hughes sold its defense-electronics business to Raytheon.


**Figure 1: An AMRAAM in flight after launch**
(Raytheon Company Photo)

AMRAAM is a joint Air Force/Navy program with the Air Force as the lead service. The Joint System Program Office (JSPO) at Eglin Air Force Base, Florida manages the AMRAAM program. AMRAAM has been a flagship in United States Air Force Acquisition Reform.

The AMRAAM is flown by the air forces of 20 nations. For example, the AMRAAM is operational on the F-15, F-16, F/A-18, the German F4F, and the United Kingdom's Sea Harrier. In addition, the Norwegians use AMRAAM in their Norwegian Advanced Surface-to-Air Missile System (NASAMS).

## 1.2. Main Findings

Numerous items are of interest in the AMRAAM story. One of the most interesting items is the cooperative relationship Raytheon has with their U.S. Government customer. The

accomplishments the AMRAAM program in Tucson made using lean enabled them to have an improved, trusting relationship with their U.S. Government customer. With strong, insightful leadership from both the contractor and the government, this cooperation enabled an even higher level of lean and even more cost reduction.

The AMRAAM program has overcome hurdles. When the AMRAAM program at the Tucson facility first began their lean transformation under the Agile program, significant improvements were made. The Raytheon-Hughes consolidation was a slight setback, but the AMRAAM program overcame the challenges. They continue their lean efforts using Raytheon Six Sigma. Agile and Raytheon Six Sigma have created a culture where the six sigma/lean tools are institutionalized.

Strong leadership at all levels has provided the motivation and support for continued change. People are empowered at all levels, and there is teamwork across the organization. There is an extreme pride and enthusiasm for AMRAAM.

Among other factors, the government relationship, the lean transformation and continuation, the strong leadership and the emphasis on people have transformed the AMRAAM program into a benchmark of what is possible in the aerospace industry.

## 1.3. Approach

The core of this case study was a site-visit to the Raytheon Company in Tucson, Arizona on January 22, 2002 by two LAI personnel. Five structured in-person interviews and several informal conversations were held with a cross-section of personnel at the case study host organization. The host organization also provided a tour of the AMRAAM production facility. Materials from the host organization were analyzed, along with supplemental information from publicly available data sources. Primarily, the supplemental data sources used were reports from The RAND Corporation, an Industry Week article, and a previous MIT Master's thesis on the AMRAAM program.

## 1.4. Organization of the Report

The organization of this report is shown in the Table of Contents. This report has a summary of the case study profile and the larger organizational context. Highlights are given of the lean transformation through both Agile and Raytheon Six Sigma. Major achievements of both the AMRAAM program and the general Tucson facility are presented. A discussion

of the key enablers, processes and practices follows. The external factors and developments section expounds on the relationship between Raytheon and the government. The final section addresses the remaining challenges and opportunities for AMRAAM. Concluding observations are then discussed.

# 2. CASE STUDY PROFILE

## 2.1. Summary Case Study Profile

The AIM-120 Advanced Medium-Range Air-to-Air Missile (AMRAAM) is an advanced active radar-guided air-to-air missile that allows an aircraft to launch multiple missiles at multiple enemy aircraft from beyond visual range (BVR) in any weather. After launch, the pilot can break away immediately and engage other targets. Other capabilities include look-down/shoot-down, resistance to complex electronic countermeasures (ECM), and interception of high-flying, low-flying, and maneuvering targets.

**Figure 2: Navy personnel on a carrier working on an AMRAAM system**
(United States Navy photo)

Among the benefits listed by Raytheon, AMRAAM has the "highest dependability at lowest cost of ownership." Production AMRAAMs currently exhibit mean-time-between-failure of more than 1500 hours. The AMRAAM performance and reliability have been proven in combat, with combat victories over the skies of Iraq, Bosnia, and Kosovo.

The requirements for AMRAAM were originally envisioned in 1975-6 (Robbins, p. 31), and the AMRAAM was deployed in September 1991. As a follow-on to the AIM-7 Sparrow missile, the AMRAAM is faster, smaller and lighter than its predecessor. AMRAAM has a length of 12 feet, a diameter of only 7 inches, and a weight of 345 pounds.

Since the AMRAAM is flown by the air forces of 20 nations, sales are roughly 60-70% foreign military sales (FMS) and 30% domestic sales. The FMS are good for the business position but are variable due to politics. There is an AMRAAM AIM-120A, AIM-120B and AIM-120C, with the AIM-120C for the U.S. government. Unit cost is $386,000

**Figure 3: An AMRAAM Arsenal**
(FAS Military Analysis Network photo)
(www.fas.org/man/dod-101/sys/missile/aim-120.htm)

according to USN and USAF materials.

Currently, Raytheon has a Total System Performance Responsibility (TSPR) contract with the U.S. military. AMRAAM contracts are by lot number, with one production lot lasting approximately one year. Lot 12-15 was one long-term pricing agreement. Lot 16-21 is the next agreement, which was awarded at the end of March 2002. They produce four missiles per day now. Volumes are about 450-600 missiles per year. In the past, they had been producing 1463 missiles per year. Raytheon also has the AMRAAM sustainment contract of $8 million per year. They repair 100-150 missiles per year through the sustainment contract. Over 600 missiles have been repaired, which includes a government backlog they initially had to work down.

## 2.2. Larger Organizational Context

According to the 2000 Annual Report, the Raytheon Company had $16.9 billion in net sales, with 93,700 employees (Raytheon Company, p. 25). The Raytheon Company core businesses are: (1) defense, government and commercial electronics and (2) business aviation and special mission aircraft. The Raytheon Company has an Electronic Systems division with a Missile Systems business unit. Raytheon Missile Systems (RMS) is headquartered in Tucson, Arizona, with three facilities in the Tucson area. As of 11/2001, Raytheon Missile Systems as a whole had 10,361 employees and 4.2 million square feet. This includes the 2.6 million square feet at the Airport Site in Tucson that LAI representatives visited. The Air-to-Air Missiles group within RMS houses the AMRAAM program.

There has been significant transition at RMS. In an article about RMS (Miller, p.3) William Miller states that, "Altogether, RMS has had to assimilate the cultures of five separate companies (Hughes, General Dynamics, Raytheon, TI, and E-Systems) and eight manufacturing sites." Hughes Aircraft Company opened the Tucson facility in 1952. When Hughes acquired the General Dynamics Corporation (GD) missile business in 1992, Hughes

transferred some GD product lines to Tucson. In December 1997, Hughes sold its defense-electronics business to Raytheon. This included the Tucson facility. Also, Raytheon had acquired the Texas Instruments Inc. (TI) defense and electronics group and a defense-electronics firm named E-Systems Co. Raytheon consolidated all its missile operations in Tucson. AMRAAM production from the heritage Raytheon plant in Andover, Massachusetts was consolidated with the former competitor's heritage Hughes Tucson plant.

Started in June 1995, the Agile program was the beginning of lean at the Tucson facility. Significant progress was made using Agile. During the Raytheon-Hughes AMRAAM consolidation, many challenges arose. AMRAAM representatives believe they have recovered from the consolidation. Currently, the Agile tools are wrapped into the corporate-wide Raytheon Six Sigma initiative.

# 3. EVOLUTION OF LEAN IMPLEMENTATION

## 3.1. Highlights of Lean Transformation

### 3.1.1. Introduction of Agile

In 1996, the AMRAAM was in production at both the heritage Raytheon plant in Andover, Massachusetts and the heritage Hughes plant in Tucson, Arizona. AMRAAM was a mature program, and the program had already been significantly value engineered. The AMRAAM Producibility Enhancement Program (APREP) had already reduced the overall program cost. In harsh competition, Hughes kept adding capability by enhancing the design. "The two competitors almost drove each other out of business," as one interviewee stated. In order to survive this "life and death struggle," the AMRAAM program turned to Agile. As the beginning of lean at Tucson, the Agile program was an adaptation of GM's and Toyota's competitive manufacturing principles. The focus was on eliminating waste and creating the capability to quickly react to a changing environment. Agile was first introduced in Missile Systems in June 1995, though it was not used in the AMRAAM program until 1997.

Agile training began for AMRAAM employees. The core team received additional training and took a trip to a facility where lean was in work. Some people worked on Agile full-time, with their efforts supplemented by IPT leaders. They had high management visibility and regular reviews. This sent the signal that Agile was an important initiative.

Inter-relationships between the teams were better defined, so workers understood the linkages and their role. Workers better understood who their customer was.

Initially, there were problems implementing Integrated Product Teams (IPT). A consultant helped them work through some of the cultural issues, and now the IPTs have been embraced. In 1996, the factory had no flow. It was grouped according to the classification of how secret the hardware was. Using spaghetti diagrams, they tracked the flow of the hardware and discovered there was considerable waste. The IPTs, that included the line workers, reorganized the factory layout and removed walls. Agile helped reduce the part travel distance from 5 miles to 2.5 miles.

The concept of "pull" was utilized by working to the contract numbers. Kanbans and color-coding were used. A blue utility grid was installed overhead to improve flexibility. AMRAAM is continually being upgraded, so they wanted to be able to easily change things around. As new products were developed, they tried to use current production equipment. The contractor repair facility (the depot) was brought into the same building as the production factory to help integrate the operations. The wall between production and repair was removed, but some union issues must be resolved before full integration can occur between repair and build.

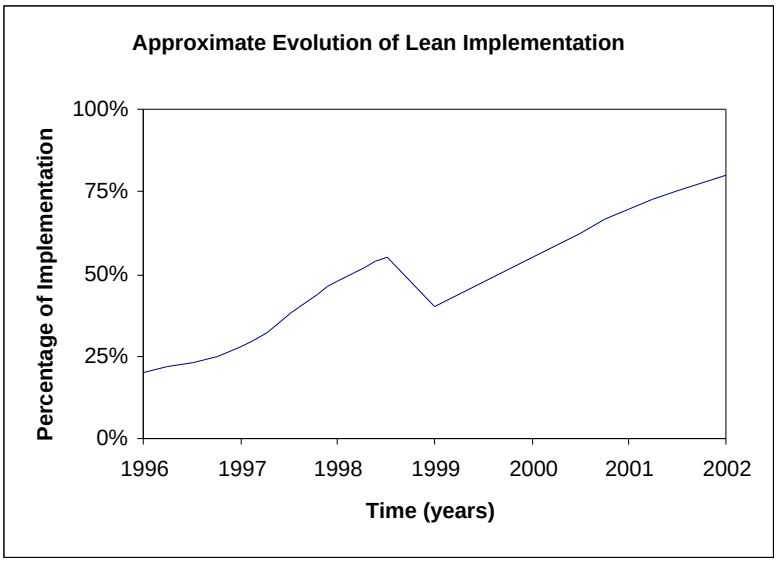
Initially, there was resistance to lowering WIP, since "WIP was life, " as one employee stated. However, the AMRAAM team did "reduce the WIP from 40/50 units to 25 basically overnight." This forced the team to focus and fix things rather than get a new kit. They had to focus on their problems. The WIP reduction made a big difference, since everything looked more organized.

As one interviewee said, "New material used to come in 12 miles down the road at the Rita Road facility. It would be counted, entered into a computer, trucked to the production building, counted again, entered into a computer again, and so on. We put that out of business." Now, some suppliers are delivering directly to the stockroom. Access to parts was improved. With projected use on-hand, they have kits and also some free stock on the floor. They outsourced re-supply of the smaller stock. There are bar codes that get scanned when the stock is low. Previously, they also had a MRB "parts jail". Considering this waste, since these parts were not flowing, they kept making this room smaller and smaller. "With Agile, you could really see the results," stated one interviewee.

### 3.1.2. The Raytheon-Hughes Consolidation

In December 1997, the Raytheon takeover was announced. The AMRAAM work from Andover was moved to Tucson. As one interview said, "When Andover was added, it was like hitting a brick wall." During the consolidation, the rate doubled in six months. There were communication and cultural difficulties between the two plants, though they have an excellent working relationship today.

There were material issues that had to be resolved between the Andover configuration and the Tucson configuration. Andover would buy parts in bulk, so when the transition happened Andover had 3-4 years in stock. When all that material was moved to the Tucson facility, they basically had two separate inventories. The Andover parts were designated with an R (for Raytheon) at the end of the part number, and they slowly started using up these materials to reduce the inventory. During the transition, the purchase orders (PO) were transferred from Andover to Tucson. It was a challenge to close out these PO's. Some suppliers still shipped hardware to Andover. They were trying to set up supplier agreements for Lot 12-15 at the same time.




It was frustrating, and it took 1-2 years to resolve the consolidation issues. The AMRAAM program had a good transition plan and took the best practices from both locations. Through teamwork with the government and Raytheon, schedule impacts to the warfighter were minimized during the consolidation.

### 3.1.3. Raytheon Six Sigma

Raytheon Six Sigma was introduced in 1999. Part of Raytheon Six Sigma is lean manufacturing (Agile), but Raytheon Six Sigma brings in the business assessment piece. Raytheon Six Sigma uses ideas such as value, value stream, pull, customer, and so on, with a

six-step improvement process model. In order to promote the continuous improvement environment, there is a Raytheon Six Sigma meeting area right in the middle of the AMRAAM production floor. At first, the Raytheon Six Sigma projects came from a business assessment. In the second year, they started focusing on specific projects, such as tolerance problems or a problem with a cart. Now, ideas for projects come directly from the teams. "Once you foster a culture of change, people realize they can use this to solve everyday problems," as one interviewee stated.

## 3.2. Major Achievements

The Tucson facility has won various awards for their lean efforts, including the Arizona Governor's Award for Quality in 1997 and the Industry Week Best Plant Award in 1999. They also had multiple citations in the 1998 Navy COE Best Manufacturing Practices Survey. The AMRAAM program has delighted their customer also. In 2000, they received a "Lightening Bolt Award" for AMRAAM Engineering Support. AMRAAM has "cut the cost of a missile from $1 million to $250,000 in seven years, doubled deliveries in 12 months, and improved reliability to three times what RMS contract for," states William Miller in his article discussing the Industry Week Best Plant Award (Miller, p. 5). Documents provided by Raytheon in 2002 show even more dramatic unit cost reductions, from $1.8 million to $250,000.

**Highlights of Raytheon Missile Systems Awards**

- 2000 "Lightening Bolt Award" for AMRAAM Engineering Support
- 2000 OSD Acquisition Reform Recognition Award
- 1999 Industry Week America's Best Plants Award
- 1999 AMRAAM Defense Life-Cycle Cost Reduction Award
- 1998 Navy COE Best Manufacturing Practices
- 1997 Arizona Governor's Award for Quality

Here are highlights from the metrics provided during this study. Average actual elapsed manufacturing flow time decreased 71%. Defects per unit for integrated assembly/test dropped 48%. The percent of total dollar value of purchased direct production materials, parts or components obtained under long-term purchase agreements or supplier

partnerships with certified suppliers almost tripled. 100% of all production workers are participating in empowered or self-directed teams.

## 3.3. Key Enablers, Processes and Practices

Recurring themes about key enablers resounded throughout the interviews. Leadership and people are extremely important in the AMRAAM program. There is strong, involved enterprise leadership by Louise Francesconi, along with strong leadership at all levels. All interviewees spoke highly of all levels of leadership. Leadership was a key enabler to overcoming the transition period of Raytheon-Hughes consolidation. These leaders provide the motivation, incentive and support for continued change.

Consistent responses from all levels were heard. There is an extreme pride and enthusiasm for AMRAAM. Employees appear empowered at all levels. There is teamwork across the organization. There is also strong discipline in place. "The senior staff in AMRAAM have known each other for a long time. There is an underlying network that really makes it work. There is a formal organization and an underlying network." People enjoy working in this program.

The emphasis on people extends into a personalization of the product. The leadership team focuses on the warfighter. One Raytheon presentation states, "Warfighters' Lives Depend on Us Meeting Our Commitments." Repeatedly interviewees used the quote, "The warfighter comes first." At the entrance to the factory, there are military flags and stars with the names of various "hits" that used the AMRAAM. There are pictures of pilots in planes and pictures of the AMRAAM in use. A fighter pilot came to talk to the factory workers and others on the program. Along with a map showing where the AMRAAM is used internationally, there is a showcase with samples of the missile components and the component evolution over time.

**"Warfighters' Lives Depend on Us Meeting Our Commitments"**

The Raytheon Six Sigma/lean tools are institutionalized. IPPD is in action. There is extensive use of IPTs. New development and production are combined. The walls are removed between repair and production operations, with a plan to combine these in the future. There are common parts, processes, and practices.

Another important enabler is the relationship with the customer. According to Raytheon, the customer does not want to go elsewhere. There is trust between the AMRAAM program and their customer. Raytheon is trying to work that into other programs, but that relationship depends on the customer also.

## 3.4. External Factors and Developments

Once the AMRAAM contractor costs were reduced, the government costs were driving the missile cost. The AMRAAM Vision 2000 Operating Guide states that in 1997, "over 50% of government program dollars were being expended on infrastructure, products, and services other than the missile." In an exercise called Task Destination, Raytheon and the government looked at all the AMRAAM tasks to see who ***is*** doing what, and who ***should be*** doing what, in order to reduce the total procurement cost. This streamlined the government and supplier process, eliminating duplicate and "cross checking" tasks. For example, missile simulation was in triplicate and was moved completely to Tucson. Reliability testing used to be performed by the government. Now, Raytheon runs reliability tests itself in Tucson, with equipment brought from Andover. Raytheon now interfaces directly with the user community. The Task Destination document says,

> "In this business venture, the Government is a partner with insight to the actions of the contractor versus a product recipient with oversight and total control. The Government transfers responsibility for control and verification of the product to the contractor, allowing the AMRAAM JSPO to function with much less manpower."

**"Contractor Self-Oversight, Government Insight"**

Indeed, this exercise enabled the government to reduce their support office from 300 people to 60 people. The process took 6 months to 1 year. AMRAAM helped set the groundwork of acquisition reform.

Currently, AMRAAM has a Total System Performance Responsibility (TSPR) contract. With this interesting contracting relationship, AMRAAM does not have the government oversight that other programs do. There is no DCMA oversight. There are no progress payments, and they are not paid on inventory. Instead, they have performance-based payments in their contract. Raytheon maintains change control below the Missile Performance Specifications, so they can be more agile. With additional responsibility though

comes increased risk, including the fact that the contractor is now responsible for obsolete parts.

**"Win-Win Strategies in an Atmosphere of Teamwork and Trust"**

Raytheon and the government currently have a very cooperative relationship with open communication. "Win-Win Strategies in an Atmosphere of Teamwork and Trust," is a quote from a Raytheon presentation. The government, as Raytheon's teammate, is proactive in managing schedules, so that where possible, any schedule deviation does not impact the user. The government also views the schedule in terms of the total program, rather than by each individual contract line item, when assessing contractual consideration for any unmitigated deviation. When there is an issue with AMRAAM, Raytheon sits down with the government to see what the best thing is to do. They jointly develop goals and monitor to those goals. Once a week they have a quick meeting to go over issues. The government enablers are there to get barriers out of the way. Raytheon has open books with the government, so the government is not out getting cost and pricing data from suppliers. This cooperation has serious cost implications. 30-40% of the cost has been taken out by the increased government efficiency. The government is getting improved missiles at reduced prices. A quote from one of the government presentations states the vision of a "Lean government team partnered with industry to meet our commitments to develop, deliver, warrant, and support affordable, combat ready products and services."

**"Lean Government Team Partnered With Industry"**

The accomplishments AMRAAM made using lean enabled them to have an improved relationship with their U.S. Government customer. This enabled an even higher level of lean. Since the program was performing, they could build trust with the government. Trust follows performance. AMRAAM has delighted their customer to the point where Raytheon managers can use government charts to sell the program.

It is interesting to note that AMRAAM did not always have such a mutually beneficial relationship with their government customers. A 1993 report by RAND (Rand N-3620-AF, p. vii) states that,

> "When the system encountered serious technical problems in 1983-4, the gap grew between what had been promised and what was being achieved. OSD and congressional oversight increased, and external authorities (particularly Congress) became 'hypervigilant,' focusing on development and testing problems—common to any program—to the point where even the most minor difficulties (failure of a single test, for example) put the program at risk of cancellation."

It is ironic and encouraging that a program that suffered extreme external scrutiny can now function under the independence and trust of a TSPR contract. The cost growth and schedule slips of the early days of the program seem like ancient history now. Both the 1993 RAND paper and the James Robbins thesis can be referenced for more details of the early development of the AMRAAM program.

Not all the Raytheon Tucson facility enjoys this type of trusting, win-win relationship with their government customer. Others in the Air-to-Air Missile division have this type of relationship; however, other groups still have customers with huge support offices. Improving this is in the vision the Acquisition Center of Excellence.

# 4. REMAINING CHALLENGES AND OPPORTUNITIES

## 4.1. Remaining Challenges

With as much progress as the AMRAAM program has made, there are still challenges to overcome such as new developments and new designs coming in. This is a barrier to being fully lean like the Toyota Production System.

One AMRAAM Raytheon Six Sigma project currently in process is to "develop the capability to produce a missile in 12 months and deliver Lot 15 two months early." Currently, there is a 22-month to 16.8-month lead time when working with suppliers. There is a structured supplier Raytheon Six Sigma Blitz Process established to get suppliers involved with Raytheon Six Sigma. They try to get the supplier to take on a challenge and sign up for a goal. Raytheon and the supplier then sign for an agreement for shared savings. The supplier keeps the difference if more savings result.

Sustaining the progress they have made is also a challenge. They are the incumbents and targets for others. The Union has shown great flexibility in understanding the need to change. AMRAAM must compete for scarce things such as skilled people, resources, and

square feet. Also, the functional organizations have been given power, when it used to be programs that held the power. The complexity of the missile is a challenge also.

In addition, since people and leadership have been so important in this program, there is concern about new leadership and new employees joining the program. There are materials given to all new government and contractor employees when they join AMRAAM. This information tells how they do contracts, what the mutual areas of concern are, and how they will continue to do business. In the development area for the next phase, there is a certain amount of double-checking going on due to new engineers coming on board. They do have a mentoring program, and new engineers are taught design for manufacturing.

## 4.2. Future Opportunities

Since the two competitors for AMRAAM are now consolidated in one company, the motivation for lean is different now. The current motivation to continue lean is financially driven. Raytheon and the government share data regarding their independent financial obligations, and help each other to execute to the commitments each has made to their respective management organizations. They must keep executing so customers are delighted with them. They also plan on working capital reduction. They will be incorporating an SAP system.

Raytheon is also working to reduce the Lot 16-21 AMRAAM pricing by working with suppliers. For Lot 12-15, the material strategy was to not change the Tucson supply base. They had tried to reduce the Lot 12-15 cost more. Since the price was pre-established, they brought the price down with long-term agreements and established pricing. For the past 15 years, they tried to not change suppliers. However, many supplier options expire with Lot 15. It is a challenge to keep up quality and margin when suppliers change. The whole team is involved when verifying that new suppliers are performing satisfactorily. Post-award audits are performed. Cross-functional Raytheon teams visit suppliers to understand the technical data and see that the processes are in place. They must audit all suppliers with this process to continue on with a good product, particularly since some suppliers will change parts without telling Raytheon.

With the incorporation of the heritage TI and heritage Raytheon locations, very similar parts had unique part drawings and supplier requirements. One screw might have forty

drawing numbers across the different programs and heritage companies. Raytheon is trying to standardize across the programs. As an example, the commodity managers are looking to see what is different among the gyros being used. Cables and harnesses across the company are also being examined. They want to change the suppliers for things like cables and harnesses to drive down the price, but not sole-source. They want to get corporate-wide agreements for the suppliers. It is hard to get all the suppliers involved in this.

The next big development is the Phase 3 missile, which is currently preparing for Proof of Manufacturability (POM). The production team talks to the designers of the new products. During development, they build in the manufacturing area so that the development process trains people for future production. When production comes, it is not a cold startup. They also use the same suppliers in development and in production. They prove the manufacturing systems and suppliers during the development phase. The POM build is treated like a production build and is under formal change control at the Tucson plant and at suppliers. Success in development is measured by how production starts up.

## 4.3. Lessons Learned

In the initial implementation of Agile, the biggest barriers were cultural issues. They convinced the union workers that these initiatives were to compete with the competition and get more work, not for fewer jobs. At first, the workers were not as risk-taking. Empowerment was the key. They also got the managers there to reassure workers that it was acceptable to do this. Leadership was also critical during the consolidation. During the consolidation, a good transition plan was essential. Also, taking the best practices from both locations was helpful.

## 4.4. Concluding Observations

Though this report primarily addresses the most recent history of the program, the AMRAAM program has had quite a journey since the mid-1970s -- early cost growth and schedule slips, extreme oversight by external authorities, risk of program cancellation, the APREP initiative, the F-15 captive carry reliability problem, fierce competition by two contractors, Agile, the Raytheon-Hughes consolidation, and Raytheon Six Sigma. Nonetheless, the AMRAAM program has driven through these challenges and changes to rise to a new level of excellence.

Throughout the program, leadership and people have been key enablers. Strong leadership at all levels has provided the motivation and support for continual improvement. Leadership and organizational discipline was critical in overcoming the transition period of consolidation. People are empowered at all levels, and there is teamwork across the organization. There is an extreme pride and enthusiasm for AMRAAM. People enjoy working on AMRAAM.

When the AMRAAM program at the Tucson facility first began their lean transformation under the Agile program, significant improvements were made. The Agile (lean) experience in 1996 helped the organization overcome the challenges of the Raytheon-Hughes consolidation. Agile also set the stage for current progress using Raytheon Six Sigma. Agile and Raytheon Six Sigma have created a culture where the Raytheon Six Sigma/lean tools are institutionalized. IPPD is in action. There is extensive use of IPTs. New development and production are combined. The walls are removed between repair and production operations, with a plan to combine these in the future. There are common parts, processes, and practices. Suppliers are actively engaged in the improvement process.

The accomplishments the AMRAAM program in Tucson made using lean enabled them to have an improved, trusting relationship with their U.S. Government customer. With strong, insightful leadership from both the contractor and the government, this cooperation enabled an even higher level of lean and even more cost reduction. Raytheon and the U.S. Government have a cooperative relationship through the TSPR contract. There is no DCMA oversight. The processes have been streamlined.

There is a plethora of statistics on the improvements the AMRAAM program has made. One is that the average actual elapsed manufacturing flow time decreased 71%. The bottom line is that costs have decreased dramatically, from $1.8 million to $250,000 per unit. Strong leadership, emphasis on people, lean transformation and continuation, and a cooperative government relationship are key elements in the AMRAAM success story.

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