

*Benefits of Implementing Lean Practices
and the
Impact of the Lean Aerospace Initiative
in the
Defense Aerospace Industry and Government Agencies*

A White Paper

Background

In the 1980's, many United States industrial organizations started developing new production processes to improve quality, reduce cost, and better respond to customer needs and the pressures of global competition. This new paradigm was coined Lean Production (or simply "Lean") in the book *The Machine That Changed The World* published in 1990 by researchers from MIT's International Motor Vehicle Program. In 1993, a consortium of US defense aerospace firms and the USAF Aeronautical Systems Center, together with the AFRL Materials and Manufacturing Directorate, started the Lean Aircraft Initiative (LAI) at MIT. With expansion in 1998 to include government space products, the program was renamed the Lean Aerospace Initiative. LAI's vision is to "*Significantly reduce the cost and cycle time for military aerospace products throughout the entire value chain while continuing to improve product performance.*" By late 1998, 23 industry and 13 government organizations with paying memberships, along with MIT and the UAW were participating in the LAI.

At its November 13, 1998 meeting, the LAI Executive Board members agreed to submit letters by December 4, 1998 summarizing:

- The benefits which have been realized from implementation of lean practices in their organization, with an emphasis on specific and quantitative results, and
- The contributions of the LAI to achieving these benefits.

This white paper captures the major points synthesized from the 28 letters received from 16 industry organizations, 11 government agencies and MIT, as listed in Attachment 1. Citations have been taken verbatim and without attribution or verification.

Implementation of Lean Practices

The LAI industry partners are committed to implementing Lean throughout their organizations, citing three drivers: reductions in DoD budgets following the end of the Cold War; competitive pressures; customer desires. Many companies started their efforts before the advent of LAI, some started after 1993, and a few have just begun their "journey to Lean". Most companies have formulated a program with stretch goals which embrace Lean principles and practices. Typical thrusts cited in the letters include: Single Quality Systems (SQS), Single Process Initiative (SPI), Integrated Product Teams (IPT), Integrated Product and Process Development (IPPD), High Performance Work Organizations (HPWO), supplier certification and partnership programs, Design for Manufacturing and

Assembly (DFMA), Kaizen events, parts kitting, factory flow, modular factories, cellular manufacturing, benchmarking other organizations, integration of information systems and business processes, implementing best commercial practices, use of 3D digital design tools, and process/product variability reduction. The primary emphasis has been on production operations, with upstream links to design. A few respondents cite the implementation of Lean in product prototyping efforts. Several respondents refer to pilot efforts “above the factory floor”.

Letters from government agencies relate increasing emphasis and activities on implementing lean practices in their operations and the acquisition process, citing the need to reduce organizational size and cycle time. Efforts appear to have started more recently than those in industry, although few starting dates are given. Representative lean practices being implemented in government agencies include: integrated product teams, organizational goal setting, identification of critical processes, tracking of metrics, focusing on customer needs, and workforce training. A frequent target for Lean has been reducing the cycle-time for procurement actions. Another major target is seamless information systems (databases, internet procedures, integrated software systems). Agencies are also supporting contractor’s implementation of lean practices, and in some cases working closely with them.

Benefits of Implementing Lean Practices

Fifty percent of the industry and forty percent of the government respondents cited specific quantitative improvements from the implementation of lean practices. Most of the remaining letters cited qualitative improvements in the same general categories. The quantitative citations have been collected in Attachment 2 using five different categories: Complete Products; Major Components or Sub-assemblies; Production Operations; Product Development; Procurement Processes. The data has been tabulated in Attachment 3 as a series of metrics with cited ranges of values.

The data in the attachments as well as the letters themselves reveal that indeed, reductions in cost and cycle time have been realized with improvements in product performance. Significant improvements are reported for several major products/programs. And many improvements are cited for sub-processes or sub-assemblies. Substantial improvements are reported for all metrics, often exceeding 50%. As one might expect, the most pervasive impact has been in production operations. Fewer citations are reported for product development and procurement processes which have only recently begun to be “leaned out”.

Several letters make reference to the fundamental change underway and others caution that many years will be needed to completely realize the benefits of Lean.

“...[We] have been proactive in implementing the lean practices of waste elimination, production flow, customer pull, and continuous pursuit of perfection. This has involved a revolution in how we conduct work in our factories.” - Industry letter

“It is now visibly apparent to all of us in the U.S. Aerospace Industry that we are not really as efficient as we thought we were! If we compare ourselves to the really efficient Japanese/Swedish/German companies in automotive/electronics/industrial areas, we realize that we have just ‘scratched the surface’ on our journey towards ‘Lean’” - Industry letter

“Two kaizen events at a major casting supplier by contractor/SPO team resulted in significant span time reductions necessary for achievement of EMD schedules. The also provided the sobering details of how a successful lean journey requires top management commitment and investment of a minimum of 5 years.” - Government letter

Impact of the Lean Aerospace Initiative on implementing Lean

The LAI is contributing to organizations’ implementation of lean practices in several major ways which can be characterized as providing:

- A **Forum** for information exchange
- **Facts** from research and benchmarking
- A **Focus and Framework** for implementation

A short paragraph on each of these with representative quotations follows. Beyond these major themes, other contributions mentioned in more than one letter are recorded.

Forum for information exchange

The LAI workshops, meetings, and information channels provide the consortium members with opportunities to learn about the latest research findings, find out about other’s experiences with Lean, exchange ideas with members from other industry, government and labor organizations, participate directly in the research process, and an opportunity to network.

“One of the most challenging aspects of implementing lean principles is establishing a critical mass of knowledgeable people. The LAI has served as a wonderful forum for getting people engaged and educated in the details of lean thinking” - Industry letter

“ Our program managers, purchasing managers and design engineers participate in LAI events and bring back approaches and ideas on how to deploy lean to the entire enterprise.” - Industry letter

“The LAI is a teaching forum to help me maintain mission effectiveness during a period of declining resources.” - Government letter

“The LAI is an outstanding vehicle for bringing us together with our contractors to try and stimulate improvement through use of lean practices.” - Government letter

Facts from research and benchmarking

The biggest LAI contribution mentioned in the majority of the letters is the Lean Enterprise Model (LEM) which incorporates research findings and benchmark data. LAI's research is providing the foundation for fundamental understanding of effective lean practices in the aerospace field. Benchmarking studies, both with member and non-member organizations provide valuable data. Organizations are using the LEM in a variety of ways, including: as a framework or template for formulating their organization's strategy; as one of several tools for implementation; as a reference source for comparing with others; as a tool for educating their personnel.

"The contribution of the LAI to our direct effort has primarily been the LEM, which we use as a template to assure that we are addressing all areas of the enterprise. We have also made use of MIT research, such as, supply chain management." - Industry letter

"Our sector ... has modeled its lean implementation after the Lean Enterprise Model (LEM), and has used the LEM extensively in the development of metrics to monitor progress towards lean." - Industry letter

"The LAI lean framework with its twelve overarching principles is a valuable tool to use when exploring and implementing lean practices" - Government letter

"LAI provides a shared network of information and knowledge. This has been captured in the Lean Enterprise Model which serves as a research tool to help find best practices and benchmarking." - Government letter

Focus and Framework for implementation

The LAI consortium provides a focus and a framework to government and industry organizations for understanding and adopting Lean. LAI serves as a catalyst for accelerating the transition to Lean, a framework for common understanding of Lean, a focus for developing policy recommendations, and a vehicle for gaining top level commitment to Lean.

"Lean is a concept, an attitude, a philosophy if not a culture involving the total enterprise in relentless pursuit of increased competitiveness and sustained long-term profitable growth. The Lean Aerospace Initiative has provided a framework to characterize and help understand the multiple initiatives necessary to achieve these objectives." - Industry letter

"In effect, the LAI is responsible for taking years off our changeover from traditional to lean practices..." - Industry letter

"...we have used James Womack's *Lean Thinking* and MIT's Lean Aerospace Initiative as the headlights for our journey." - Industry letter

“One of the greatest benefits of the LAI is the opportunity to interact with the government acquisition representatives and to develop a mutually beneficial operating environment for future procurements based upon common principles and expectations” - Industry letter

“LAI has also forged an effective team of industry, academia, unions, and government working toward a common goal in a disciplined and informed manner.” - Government letter

“The initiative has clearly proven that the conversion to lean principles and practices will lead to dramatic improvements ... for our customers. The initiative is aimed at accelerating the pace of the conversion and has led the way in many areas...” - Government letter

Other LAI Benefits

Other LAI benefits cited in two or more letters were:

- The LAI website as a valuable source of information
- The Evidence of Lean site visits organized by ManTech
- The ManTech sponsored Industrial Base Pilot programs
- Training material developed by ManTech

Benefits to MIT

Although the primary intent of the LAI Consortium is to reduce the cost and cycle time for military aerospace products, a valuable side benefit is impacting academia which represents the source of future talent and knowledge for the field. MIT cites seven ways that the LAI is impacting its institution:

- Some 50 graduate students have undertaken research. 11 graduates have been hired by consortium members and 6 by consulting groups.
- At any time, 13-18 faculty are engaged, most of whom knew little about lean practices before LAI
- Engineering and Management School collaboration, a linkage sadly lacking in most US universities, is being positively impacted at MIT
- MIT faculty and students are gaining first hand knowledge of “real world” priorities through participating in focus teams and workshops
- MIT degree programs and curriculum are benefiting directly from the LAI
- The LAI is serving as a new model for collaborative research with academia, industry and government working on interdisciplinary problems
- The LAI is affording MIT an opportunity to make a recognized impact on a intellectual area of national importance

The Future

Although not specifically asked to comment about the future, many of the letters contained a statement about their organizations intent to continue their participation in LAI, some offering suggestions for future priorities, including: implementation of lean practices and overcoming systemic barriers; applying Lean “above the factory floor” such as in engineering, finance, administration; short run spacecraft products; engaging the supplier base.

Summary

The organizations participating in the Lean Aerospace Initiative consortium are undertaking their “journey to Lean”. Substantial progress has already been made in several major programs and many processes. The LAI research and products are contributing to this systemic change, and the LAI is providing a needed focus and a valuable forum for sharing knowledge and experiences. The organizations participating in the LAI plan to continue, implying that they value the benefits they are receiving. This includes MIT who reports that the LAI is benefiting students, faculty, education and providing the academic participants an opportunity to impact a major national priority.

“The USAF / MIT Lean Aerospace Initiative has provided us with the focus, the “benchmarking”, the sense of urgency and the ability to exchange “best practices” which accelerate our lean implementation progress.” - Industry letter

“Everyone in the defense establishment shares the benefits of LAI. Through mutual **commitment** to improvement, shared **knowledge**, and leveraged **implementation**, we have raised the level of competency in the US defense industry and fueled the acquisition reform process.” - Industry letter

“We believe that LAI efforts are consistent with DoD policy and acquisition reform initiatives, and will eventually provide a valuable contribution to the revolution in business affairs.” - Government letter

“We recognize the potential organizational payoff from implementing lean practices. We are embarked down that path internally but have only begun in earnest. Our contractor partners are improving but we believe there are many more gains to be made. The LAI is an important part of realizing significant benefits in both arenas.” - Government letter

“In the end, MIT’s goal as an institution is to develop fundamental knowledge and educate students in a way that has real impact on important national issues. Its resources, devoted to this end, are the time and energy of its faculty and students. LAI has been a leading-edge partnership, a new way of working between government, industry and universities.” - MIT letter

Organizations Submitting Letters

Industry

Boeing Military Aircraft and Missile Group
Boeing Space and Communications Group
Boeing Phantom Works
GE Military Engines Operation
GenCorp Aerojet
Hughes Space and Communications Company
Lockheed Martin Aeronautics Sector
Lockheed Martin Space and Strategic Missiles Sector
Northrop Grumman Corporation
Pratt and Whitney Large Military Engines
Raytheon Company
Raytheon Systems Company
Rockwell Collins
Sunstrand Aerospace
Textron Systems
TRW Space and Electronics Group

Government

Aeronautical Systems Center
Air Force Research Laboratory, ManTech Program
Defense Contract Management Command
Deputy Undersecretary of Defense for Acquisition and Technology
C-17 Systems Program Office
F-22 Systems Program Office
Flight Training Systems Program Office
Joint Strike Fighter Systems Program Office
National Reconnaissance Office
Space and Missiles Systems Center
US Army Aviation and Missiles Command

Academia

Massachusetts Institute of Technology

Quantitative Savings Cited by LAI Consortium Members

Complete Products

- Product order to delivery time reduced from 24 to 10 months with 15% annual price reduction and performance exceeding goals for a munitions product
- 50% fewer cycle days for lightweight airframe product
- Production hours under budget by 11% for EMD and 16% for LRIP for major airframe product
- 50% reduction in cycle time for production and launch of commercial launch vehicle
- For a major aircraft system, production rate doubled with same workforce, repair and rework reduced by 88%, last 30 units delivered to field early.

Major Components or Sub-assemblies

- Horizontal stabilizer reductions of 20% in weight, 90% in parts, 81% in fasteners, 70% in tools, and 50% in cost
- Horizontal tail reductions of 61% in parts and tools, 48% in design cycle time, 38% in design hours, 50% in assembly, 62% in defects
- Engine pylon reductions of 10% in cycle time, 10% in labor hours, 89% in people travel with all safety issues eliminated and 5S score improved by 58%
- Nose installation reductions of 60% in cycle time, 85% in set-up time, 77% in people travel distance and with increase in productivity of 60% and elimination of 2 safety issues
- Landing gear pods reduction of 32% in cycle time, 17% in set-up time, 16% in lead time, 42% in people travel distance, 83% in product travel distance with 32% increase in productivity

Production Operations

- Enterprise-wide 35% improvement in productivity
- After 1 year of Kaizen workshops, average improvement of 27% in productivity and reductions of 50% in inventory, 25% in floor space, 50% in lead-times with significant improvement in quality and reductions in set-up time
- After several Kaizen workshops, reductions of 47% in cycle time, 31% in inventory, 34% in floor space, with 100% improvement in throughput in certain areas
- HPWO led to reductions of 28% in scrap, 20% in rework, 60% in cycle time
- Kaizen workshops led to reductions of 47-71% in labor hours, 76-92% in travel distance, 54-80% in setup time, 65-81% in floor space and 20-97% in cycle time for certain production operations

- Reductions of 51% in space, 79% in travel distance, 80% of work in progress, 36% in direct labor, 50% in defects, 66% in capital equipment requirements, 80% in thru-put time
- Reduction from several thousands to 420 defects per million opportunities
- 50/60/70% reductions in implementing critical processes are being proposed and achieved on several major space related products
- Selected demonstration projects for new aircraft program documented reductions of 67% in manufacturing cycle time, 80% in inventory and 60% in cycle time variations.
- Kaizen workshop with supplier led to reductions of 28% in unit cost, 70% in floor space, 98% in work in progress, 95% in distance traveled, 38% in cycle time
- Just-in-time delivery of titanium billet reduced inventory by \$8-10M, lead time by 50%, suppliers to 2 from 31

Product Development

- Pilot efforts in improved information flow between engineering and manufacturing resulted in cost reductions of approximately 30% in engineering, 15% in manufacturing with a 25% reduction in overall cycle time
- IPPD led to reductions in hours of 80% for design, 50% for NC programming, 50% for inspection and 67% for fabrication of flying testbed
- For prototype development, 1/3 less time for 90% drawing release milestone

Procurement Processes

- Material release order processing time reduced from average of 6 days to one day or less
- Contract change proposals process managed by 50% fewer people (3 compared to 6)
- 36% improvement in total negotiated savings / cost avoidance due to SPI
- Newest contracts on a major system awarded in record time due to successful use of one-pass negotiations.
- Complex high dollar contracts executed in significantly less time than normally required, while customer needs met or exceeded for price, delivery and timeliness of service
- 50% reduction in cycle time for reviewing Engineering Change Proposals
- 50% reduction in lead time with 0.02% cost increase to program with fixed-price purchase orders before final sizing completed

Summary of Measurements Cited by LAI Consortium Members

<i>Metric</i>	<i>Range of Measurements of Relative Improvement</i>	<i>Number of Measurements</i>
Production/manufacturing		
Costs	11% to 50%	5
Labor hours	10% to 71%	6
Productivity	27% to 100%	5
Cycle time	20% to 97%	13
Factory floor space	25% to 81%	6
Travel distances (people or product)	42% to 95%	8
Inventory or Work in progress	31% to 98%	5
Scrap, rework, defects or inspection	20% to 80%	7
Set up time	17% to 85%	4
Lead time	16% to 50%	3
Design/engineering/EMD		
Labor hours or cost	30% to 80%	3
Cycle time	48% to 50%	2
Enterprise		
Cycle time, price, productivity	15% to 58%	4
Business/Acquisition Processes		
Cycle time or labor for orders, proposal processing	50% to 83%	4