Applications of Lean Ideas to the Aerospace Industry

Professor Deborah Nightingale, MIT

Lean Thinking Strategies and Applications

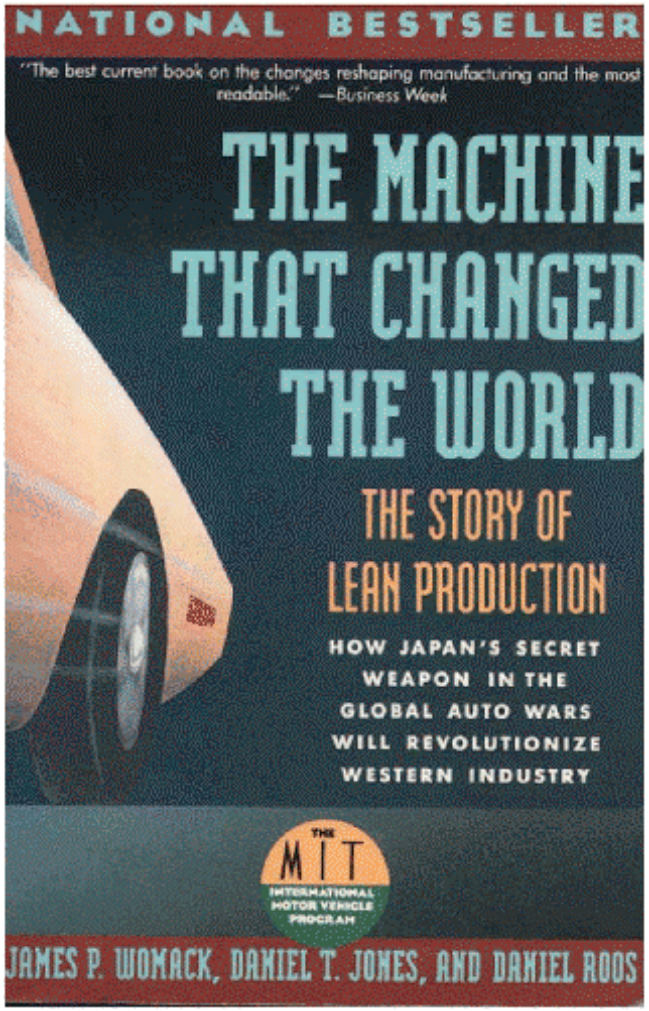
June 25, 2004

Outline

- Lean Aerospace Initiative origin and mission
- Functional lean successes
- Successes through interaction between functions
- Success through enterprise integration and value creation
- Total enterprise integration of all stakeholders
- Enterprise transformation insights

Lean Aerospace Initiative (LAI)

1993 Genesis of the Lean Aerospace Initiative



US Air Force asked:

Can the concepts, principles and practices of the Toyota Production System be applied to the military aircraft industry?

Yes!

Historical Industrial Paradigms

1885	1913	1955-1990	1993-...
Craft Production	**Mass Production**	**Toyota Production System**	**Lean Enterprise**
Machine then harden Fit on assembly Customization	Parts inter-changeability Moving production line Production engineering "Workers don't like to think"	Worker as problem solver Worker as process owner enabled by: -- Training -- Upstream quality -- Minimal inventory -- Just-in-time Eliminate waste Responsive to change	"Lean" applied to all functions in enterprise value stream Optimization of value delivered to all stakeholders and enterprises in value chain
Highly skilled workforce Low production rates High cost	Unskilled labor High production rates Low cost Persistent quality problems Inflexible models	Low cost Improving productivity High quality product	Low cost Improving productivity High quality product Greater value for stakeholders

"Lean" is elimination of waste and efficient creation of enterprise value

Lean Aerospace Initiative

Consortium

- Airframe, engine, avionics, missile and space companies
- Air Force agencies and System Program Offices (C-17, F-22)
- NASA, Army, Navy
- Pentagon—OSD, AF Secretariat
- International Association of Machinists
- Massachusetts Institute of Technology

LAI Consortium

… a venue for collaboration on Aerospace challenges

Avionics/Missiles

BAE SYSTEMS North America
Northrop Grumman Electronic Systems
Raytheon Co.
Raytheon RMS, NCS, SAS
Rockwell Collins, Inc.
Textron Systems Corp
Lockheed Martin Systems Integration Group
L3 Com

Space

Aerojet-General Corp.
Lockheed Martin Space Systems Co.
Northrop Grumman Space Technology

Airframe

Boeing Integrated Defense Systems
Boeing Commercial Airplanes
Boeing Phantom Works
Lockheed Martin Aeronautics Company
Northrop Grumman Integrated Systems
Sikorsky
Bell Helicopter

MIT

Center for Technology, Policy, and Industrial Development
School of Engineering:
Aerospace
Mechanical
Sloan School of Management

Other Participants

IAM
AIA
DAU
IDA
International Collaborations:
Linköping University
Warwick, Bath, Cranfield
Nottingham Universities

Propulsion/Systems

Rolls Royce (N.A.)
Pratt & Whitney
Hamilton Sundstrand
Curtiss-Wright Flight Systems
Harris Government Comm.
United Defense Ground Systems Div.
Aerospace Testing Alliance

US Air Force

SAF/AQ
Aeronautical Systems Center
Air Force Research Laboratory
(Materials and Manufacturing Directorate)
Space and Missile Center
Electronic Systems Center
SPOs: F-22, C-17

Other Government

DCMA
NASA
NAVAIR
AMCOM
OUSD(AT&L)

LAI Mission and Goals

LAI Mission: Research, develop and promulgate knowledge, principles, practices and tools to enable and accelerate the envisioned transformation of the greater US aerospace enterprise through people and processes.

1. **Support the on-going lean transformation of industry**
2. **Enable lean value-creating supplier base**
3. **Support lean transformation of the government**
4. **Educate and train stakeholders in value-creating lean principles and practices**
5. **Improve effectiveness of organizations and all the employees across the total enterprise**
6. **Support member lean implementation efforts by sustaining tools and knowledge base and by sponsoring outreach events**

LAI Has Expanded to a Total Enterprise Focus

Functional Lean Successes
- **Manufacturing**
- **Product Dev.**
- **Supplier Network**

"Islands" of Success

Successes Through Interaction Between Functions

Lean Applied to Enabling Processes
- **HR**
- **IT, etc.**

Transition from Waste Minimization to Value Creation

Success Through Enterprise Integration

Success Through Total Enterprise Integration of All Stakeholders
- **Industry**
- **Government**
- **Suppliers**
- **Employees**

Functional Lean Successes

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Lean Works Everywhere

- **Export licensing:**
  - 56 steps to 21 steps
  - 52 handoffs to 5 handoffs
  - Cycle time from 60 days to 30 days
  - 50% 1st pass yield to >90% 1st pass yield
- **Payroll:**
  - Reduced non-value added steps by 50%
  - 15 forms to 1 form
  - Reduced signatures/ approvals by 25%
- **Recruiting:**
  - Cycle time from 14 days to 48 hours
  - 50% reduction of paper resumes
- **Proposal:**
  - Cycle time from 30.6 days to 7 days
- **Program support:**
  - $3M savings
- **Interface management:**
  - Proposal, contract, billing, and collection steps
  - Generated $21M additional cash
- **Engineering order release:**
  - Cycle time from 76 to 4 days
  - Total queue time from 56 days to 60 minutes
- **Process definition:**
  - Work package completion cycle from 4 months to 3 wks
- **Financial reporting:**
  - 13 weeks to 3 weeks

Lean Engineering Case Studies

Lean Engineering Requires a Process

- **"Invention is 1% inspiration and 99% perspiration" - TA Edison**

- Engineering processes often poorly defined, loosely followed
  (LAI Case Studies)
- 40% of design effort "pure waste" 29% "necessary waste"
  (LAI Workshop Survey)
- 30% of design charged time "setup and waiting"
  (Aero and Auto Industry Survey)

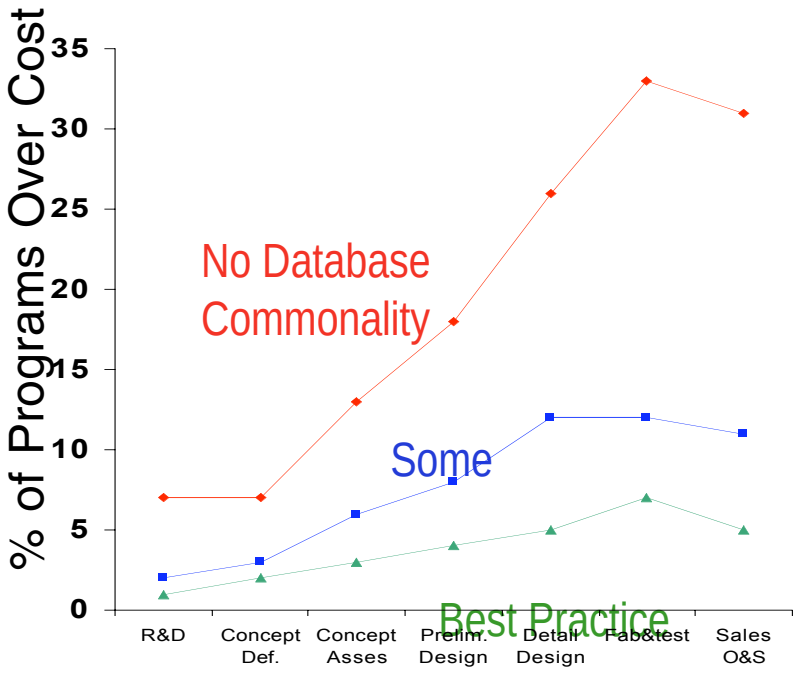
Engineering & Manufacturing Have Similarities and Differences

	Manufacturing	Engineering
Define Value	Visible at each step, defined goal	Harder to see, emergent goals
Identify Value Stream	Parts and material	Information & knowledge
Make process flow	Iterations are waste	Iterations often beneficial
Customer pull	Driven by Takt time	Driven by needs of enterprise
Perfection	Process repeatable without errors	Process enables innovation and cuts cycle time

The Seven Info-Wastes

1. Over-production	Creation of unnecessary data and information; Information over-dissemination; Pushing, not pulling, data
2. Inventory	Lack of control; Too much in information; Complicated retrieval; Outdated, obsolete information
3. Transportation	Information incompatibility; Software incompatibility; Communications failure; Security issues
4. Unnecessary Movement	Lack of direct access;Reformatting
5. Waiting	Late delivery of information; Delivery too early (leads to rework)
6. Defective Products	Haste; Lack of reviews, tests, verifications; Need for information or knowledge,data delivered
7. Processing	Unnecessary serial production; Excessive/custom formatting; Too many iterations

Engineering Requires the Seamless Flow of Information and Knowledge

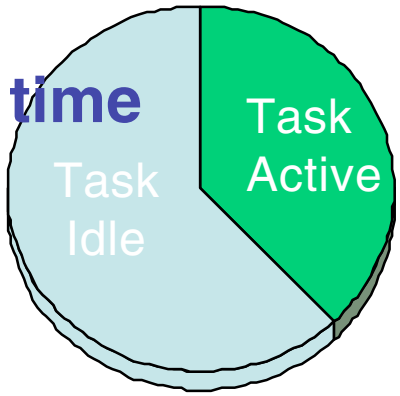


- **Information can be an IT problem - solutions exist, but are not easy**
- **Knowledge is a people problem - requires communication - this is hard!**

From Hoult et al., "Cost Awareness in Design: The Role of Data Commonality", 1995.

Communication Key to Flow and Pull

- **Flow cannot be achieved until engineering processes move and communicate without errors or waiting**
  - **62% of *tasks* idle at any given time** *(detailed member company study)*
  - **50-90% task idle time found in Kaizen-type events** *(case studies)*



Co-Location Improves Integration

Scope: *Class II , ECP Supplemental, Production Improvements, and Make-It-Work Changes Initiated by Production Requests*

Value stream simplified, made sequential/concurrent

Single-piece flow implemented in co-located "Engineering cell"

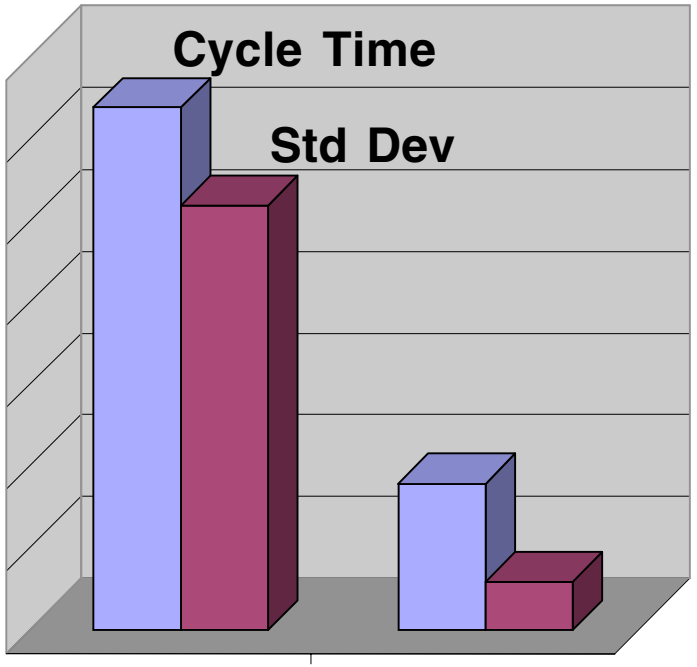
Priority access to resources

Category	% Reduction
Cycle-Time	75%
Process Steps	40%
Number of Handoffs	75%
Travel Distance	90%

Source: Hugh McManus, Product Development Focus Team LAI

Case Results for Engineering Release Process

- Value stream mapped and bottlenecks found
- Process rearranged for sequential flow
- Waiting and delays removed
- Reduced Cycle time by 73%
- Reduced Rework of Released Engr. from 66% to <3%
- Reduced Number of Signatures 63%



Successes Through Interaction Between Functions

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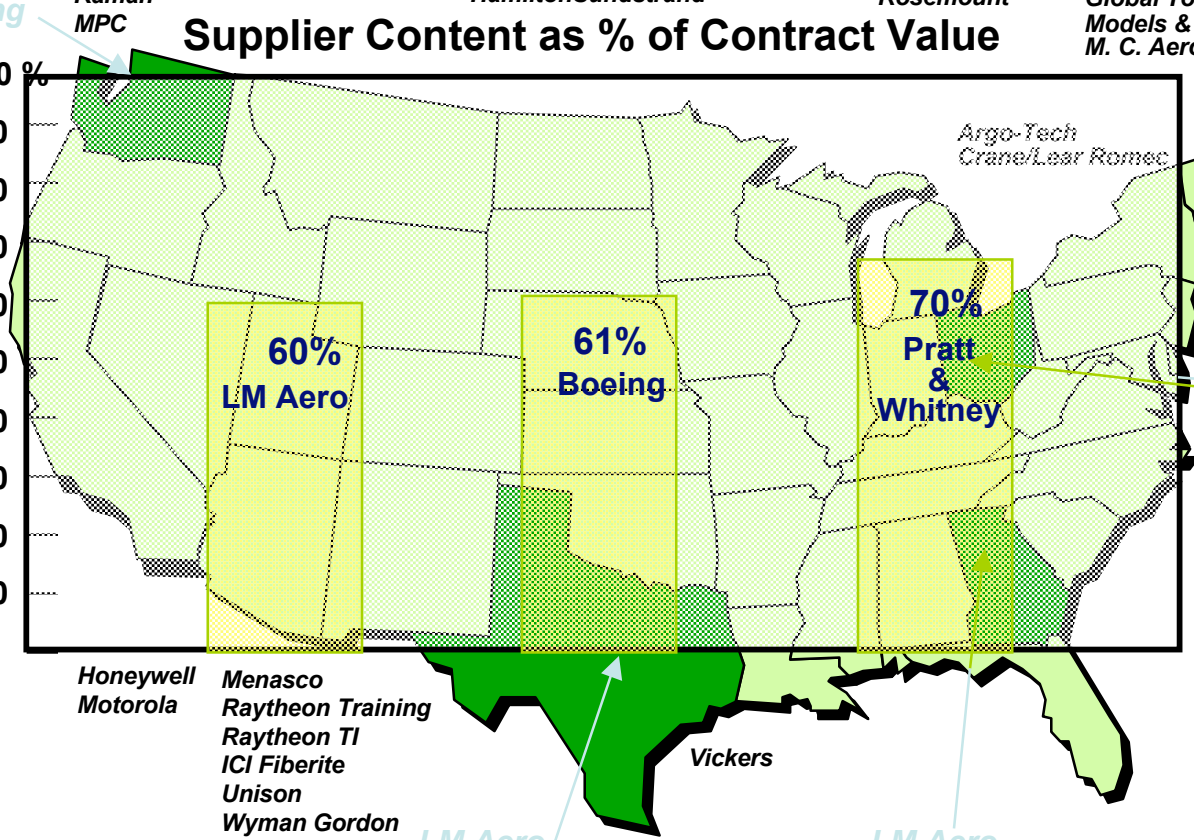
- Industry
- Government
- Suppliers
- Employees

Supplier Network Case Studies

F/A-22 Raptor Supplier Network Illustrates Central Challenge

F/A-22 is supported by an extensive multi-tiered supplier network



Alliant TechSystems
Kaman
MPC

Electrodynamics
HamiltonSundstrand

Honeywell
Rosemount

NWL
Global Tooling
Models & Tools
M. C. Aerospace

Interval
Hughes Treitler
Amphenol Bendix

GD Armament
BAE Systems
Fenwal Safety Syst
Litton Itek
Wyman Gordon

Boeing Defense
GKN Westland
Hamilton Sundstrand
Sermatech-Lehr

EDO
Lucas Aerospace
Honeywell

Curtiss Wright
Hexcel, AlliedSignal
Smiths Ind.

Northrop Grumman
Orbital Sciences

Brunswick, Walter KIDDE
Howmet, Alliant TechSystems,
Unison

BAE Systems

Harris
Intellitec
LMEM
Pall Aero
Trilectron

BAE Systems
Avionics - UK

Helmet Integrated
Systems - UK

Normalair Garrett-UK

Kidde Graviner
Ltd - UK

Dowty Decoto
Primex
Schlosser
Timet
PCC

Aerojet
Aircraft Eng
Avica
Chem-tronics
Circle Seal
Eaton
Hexcel
Honeywell
Kaiser
LM Aero - Palmdale
Litton
BAE Systems
Marvin Eng
OEA Aerospace
Pacific Scientific
Parker Bertea
Parker Hannifin
Raytheon
BF Goodrich (Rohr)
Sierracin/Sylmar
Sterer
Superform USA
Sweeney Eng
Symetrics
Telair Int'l
Teledyne
Vickers
TRW

Honeywell
Motorola

Menasco
Raytheon Training
Raytheon TI
ICI Fiberite
Unison
Wyman Gordon

Vickers

It is estimated that 60% of supplier costs are also procured
That puts 36% of the F/A-22 Program cost in sub-tier suppliers

SOURCE: From Don Handell, "F-22 War On Cost Update," Lean Aerospace Initiative Plenary Conference, March 26, 2002.

Lean Supply Chain Management Differs Sharply from Conventional Practices

ILLUSTRATIVE CHARACTERISTICS	CONVENTIONAL MODEL	LEAN MODEL
Number & structure	Many; vertical	Fewer; clustered
Procurement personnel	Large	Limited
Outsourcing	Cost-based	Strategic
Nature of interactions	Adversarial; zero -sum	Cooperative; positive -sum
Relationship focus	Transaction -focused	Mutually -beneficial
Selection criteria	Lowest price	Performance
Contract length	Short-term	Long-term
Pricing practices	Competitive bids	Target costing
Price changes	Upward	Downward
Quality	Inspection -intensive	Designed-in
Delivery	Large quantities	Smaller quantities (JIT)
Inventory buffers	Large	Minimized; eliminated
Communication	Limited; task -related	Extensive; multi -level
Information flow	Directive; one -way	Collaborative; two -way
Role in development	Limited; build -to-print	Substantial

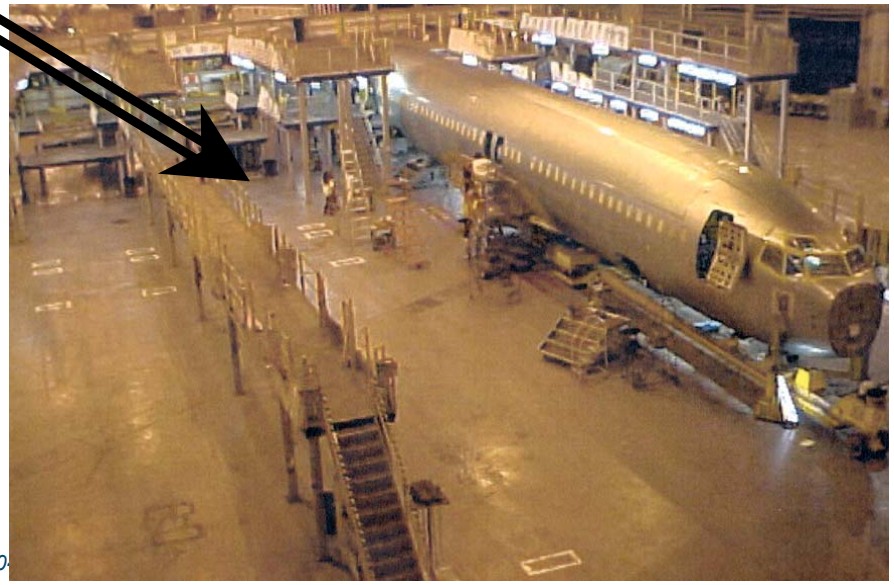
Boeing 737 "Next Generation"-- Synchronized Work Flow throughout the Enterprise Value stream to Support Moving Line

- Focus on pull, not push
- Quality ➠Process Kaizen ➠ System Kaizen
- Value stream focus;Nine step lean process
- Breakthrough process redesign
- Entire system synchronized to support moving line

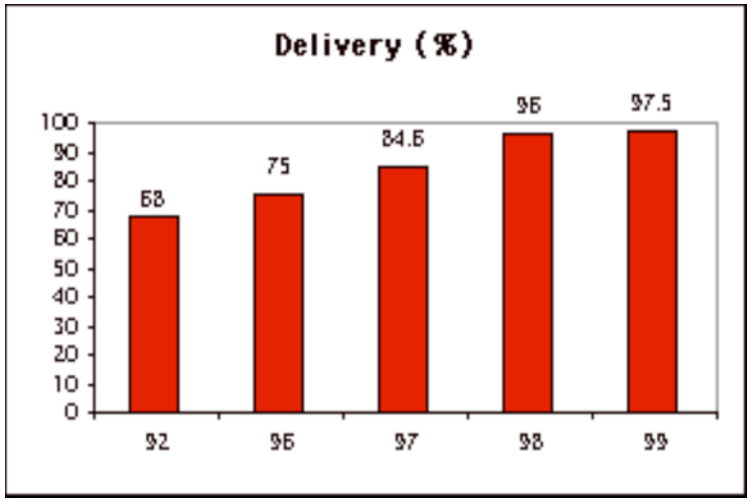
BEFORE

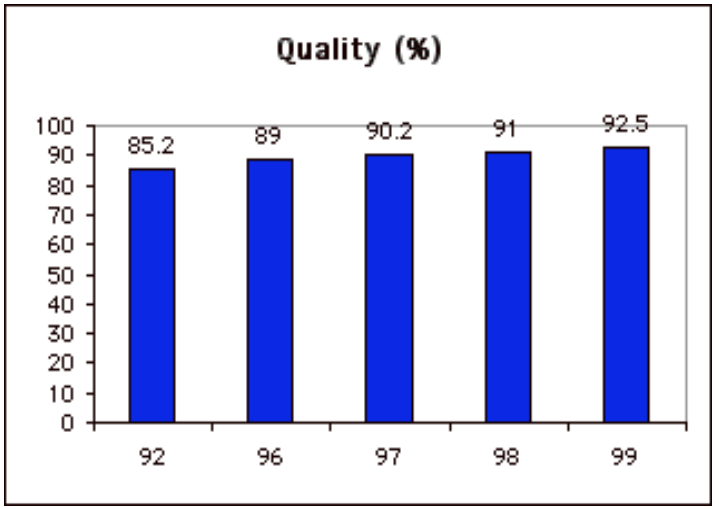
- Reliable & delivered on time, but at what cost?
- Quality emphasis; push system; point solutions
- Imperative (1996): Increase production from 10 to 28 planes per month to keep up with jump in demand & meet delivery commitments -- never before done

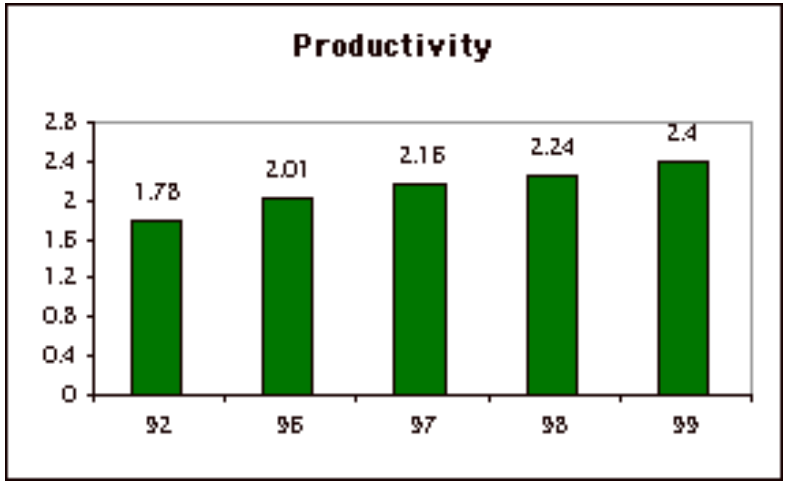
AFTER

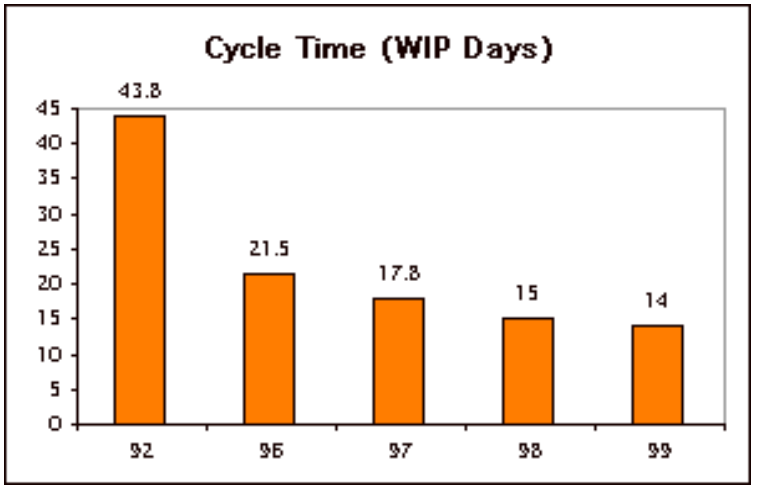


Another Example: Engine Parts Casting Supplier Worked with Customer Company to Achieve Synchronized Flow





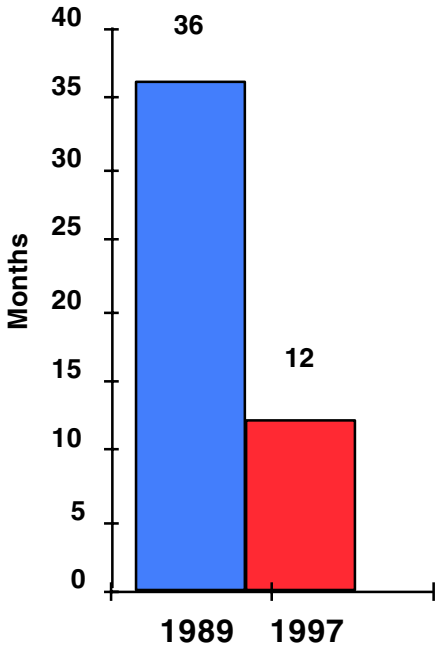




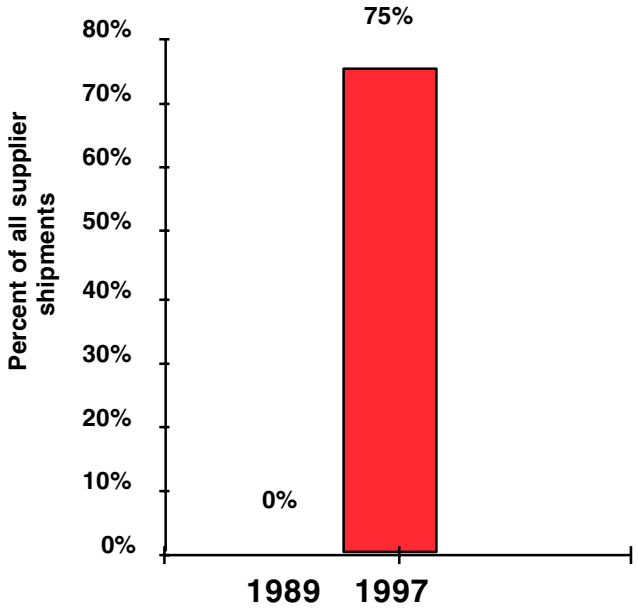
Case Study Shows Significant Performance Improvements through Supplier Partnerships

Case study: Major producer of complex airframe structures

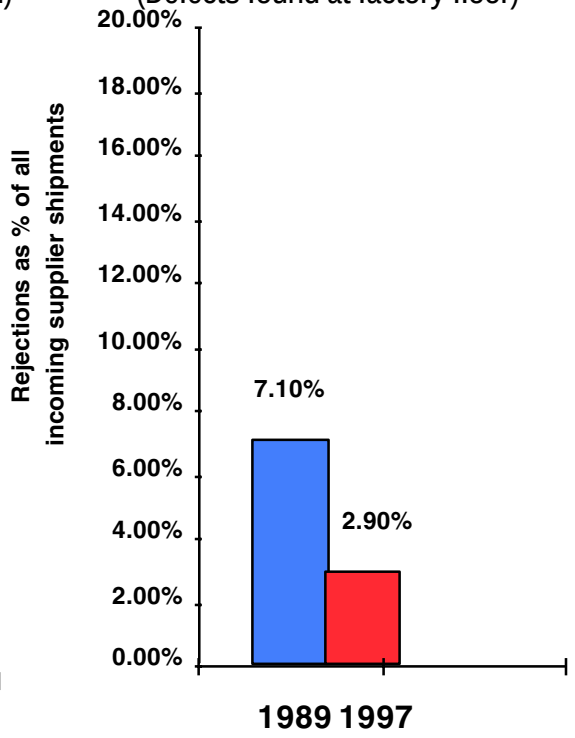
REDUCED CYCLE TIME
(Main Product
Order-to-Shipment, months)



IMPROVED SUPPLIER DELIVERY
(Dock-to-Stock, w/o prior inspection)



REDUCED SUPPLIER DEFECTS
(Defects found at factory floor)



Supplier Partnerships Driven by Strategic Corporate Thrust to Develop Integrated Supplier Networks

KEY PRACTICES	BEFORE	AFTER
Reduced and streamlined supplier base		
• Number of direct production suppliers	**542**	**162**
Improved procurement efficiency		
• Procurement personnel as % of total employment (%)	**4.9**	**1.9**
• Subcontracting cycle time (days)	**13**	**7**
Improved supplier quality and schedule		
• Procurement (dollars) from certified suppliers (%)	**0**	**75**
• Supplier on-time performance (% of all shipments)	**76.4***	**83.0**
Established strategic supplier partnerships		
• Procurement dollars under long-term agreements(%)	**0**	**95**
• "Best value" subcontracts as % all awards	**50.0**	**100.0**

BEFORE: 1989 AFTER: 1997

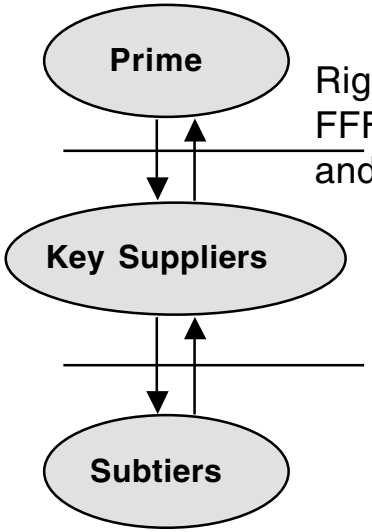
*Refers to 1991

Early supplier integration into design delivers best value to the customer

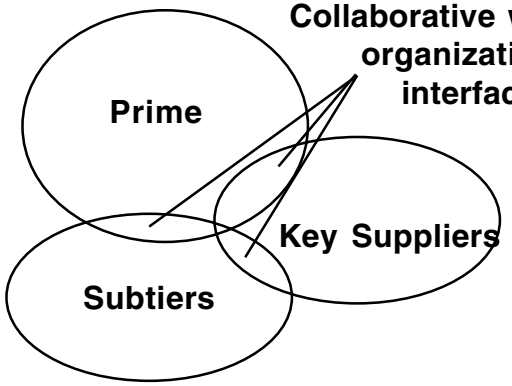
- Early and major supplier role in designing complex products with integral system architecture in a collaborative design process -- IPTs; joint configuration control
- Up-front integration of product development, manufacturing processes and supplier networks
- Delegation of progressively greater responsibility for designing, testing and producing more and more complex parts/components
- Leveraging a wealth of in-depth supplier-based technical knowledge and innovative capacity
- Value analysis and target costing to achieve substantial cost reductions
- Product lifecycle commitment & incentivized contracting

Evolution of Early Supplier Integration in Aerospace

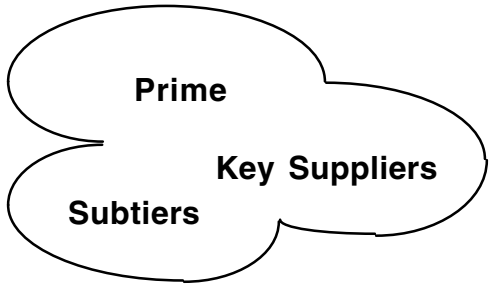
"Old" Approach → **"Current" Lean** → **"Emerging" Lean**



Rigid vertical FFF interfaces and control



Collaborative with rigid organizational interfaces



Virtual Team w/o boundaries

Arm's length; interfaces totally defined and controlled

Collaborative; but constrained by prior workshare arrangements

Collaborative and seamlessly integrated, enabling architectural innovation

ARCHITECTURAL INNOVATION: Major modification of how components in a system/product are linked together

- **Significant improvement in system/product architecture through changes in form/structure, functional interfaces or system configuration**
- **Knowledge integration over the supplier network (value stream perspective ; prime-key suppliers-subtiers; tapping supplier technology base)**

Fostering Innovation across Supplier Networks Ensures Continuous Delivery of Value to all Stakeholders

- **Research:** Case studies on F-22 Raptor avionics subsystems -- what incentives, practices & tools foster innovation across suppliers?
- **Major finding: Innovation by suppliers is hampered by many factors. This seriously undermines weapon system affordability.**
  - **Excessive performance and testing requirements that do not add value**
  - **One-way communication flows; concern for secrecy; "keyhole" visibility by suppliers into product system architecture**
  - **Little incentive to invest in process improvements due to program uncertainty; limited internal supplier resources**
  - **Yearly contract renegotiations wasteful & impede longer-term solutions**
- **Recommendations:**
  - **Use multiyear incentive contracting & sharing of cost savings**
  - **Improve communications with suppliers; share technology roadmaps**
  - **Make shared investments in selected opportunity areas to reduce costs**
  - **Provide government funding for technology transfer to subtiers**

Case Study on Electronic Integration of Supplier Networks

Challenge: Electronic integration of supplier networks for technical data exchange as well as for synchronization of business processes

- **Important success factors include:**
  - **Clear business vision & strategy**
  - **Early stakeholder participation (e.g., top management support; internal process owners; suppliers ; joint configuration control)**
  - **Migration/integration of specific functionality benefits of legacy systems into evolving new IT/IS infrastructure**
  - **Great care and thought in scaling-up *experimental* IT/IS projects into *fully-functional operational systems***
- **Electronic integration of suppliers requires a process of positive reinforcement -- greater mutual information exchange helps build increased trust, which in turn enables a closer collaborative relationship and longer-term strategic partnership**

Lean Effect on Aerospace (LEAP) Case Studies

Purpose and Approach

- **Purpose: Conduct an exploratory study to respond to an LAI Executive Board request:**
  - What has been the impact of lean on the US aerospace industry?
  - To what degree have lean principles diffused through the industry?
- **Approach:**
  - **Survey:** Broad overview -- both impact & diffusion
  - **Focused case studies:** Selected cases of lean transformation; diverse set of programs & products; site visits & structured interviews; common method

Assess accomplishments

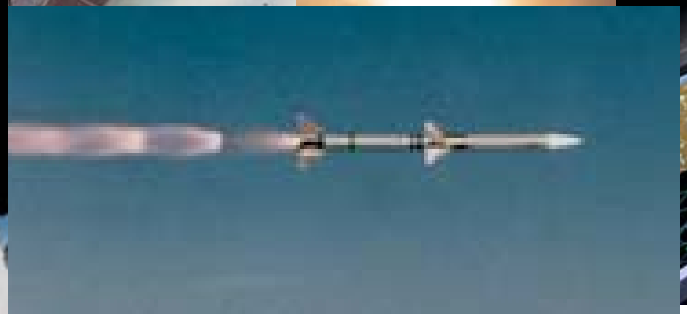
Identify key enablers and future challenges

Case Studies

Boeing 737 Fuselage

Atlas

F-16



Phalanx

AMRAAM

Commercial Aviation Electronics

Sources: www.lockheedmartin.com, www.boeing.com, www.rockwellcollins.com, www.raytheon.com

737 Fuselage

Boeing Commercial Airplane Group, Wichita, KS
1996-2001

Results:	**25% decrease in unit cost**
	50% decrease in labor hours/unit (1998-2000)
	Reduced flow time by 21% (from "classic" to "Next Generation" models)
1996 Imperative:	**Keep up with jump in demand –from 10 to 28 planes/mo.**
Challenge:	**Reliability & on-time delivered, but at what cost? Need to reduce flow time.**

- **Quality ➠Process Kaizen ➠ System Kaizen**
- **Value stream focus – Nine step lean process**
- **Breakthrough process redesign**
- **Senior leadership commitment**
- **Worker education – Knowledge at all levels**
- **Lean maturity assessment**
- **Supply chain partnerships**

F-16 Falcon

Lockheed Martin Aeronautics Company, Ft. Worth, TX
1992 - 2001

Results: **Constant price with decreasing production rates (180/yr to 24/yr) and significantly improved capability**

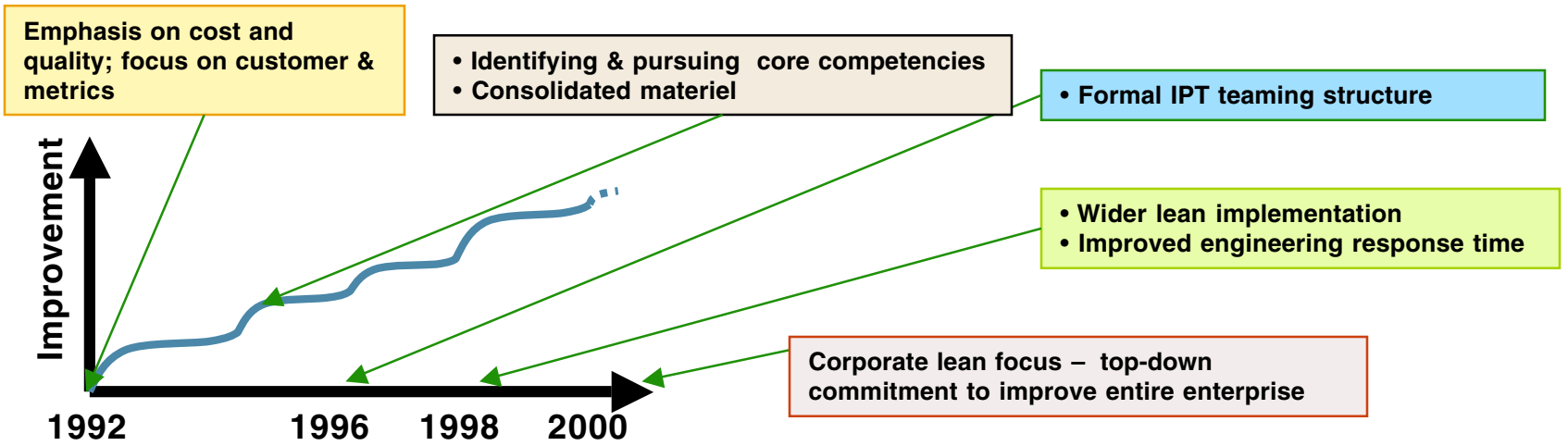
Continuous customer-focused improvements

Turning Point: **1992**

Quality problems; cost-overruns

Pressure from Air Force customer for change

Need to reduce number & cost of non-conformances



Commercial Aviation Electronics

Rockwell Collins - Melbourne, FL
2000-2002

Results: 1st test yield improved by as much as 50%

37% increase in labor productivity

Turning Point:
Oct 1998-Sept '99

98% responsiveness & customer acceptance no longer good enough

Challenge: Improve cycle time & cost beyond what current processes could deliver; respond to competitive pressures

- Value stream mapping – Enterprise-wide
- Creation of single-piece flow in product work cells
- Work cells for simple products, then for more complex products – learning feedback
- Committed leadership & worker solidarity
- Closely-linked relationships with suppliers

Aggressive learning process in lean implementation leading to significant productivity improvements

Phalanx

Raytheon Missile Systems, Louisville, KY
1999 - 2000

Results:	**Integration of repair and upgrade with new system delivery**
	50% reduction in cycle time
Turning Point: 1996	**Production & profitability problems**
Challenge:	**Make program more than marginally profitable complex product; difficult to produce; high % of parts produced internally; long lead times**

1996-'98: Overcame initial hurdles; built on Agile basics

- Phalanx adopts Hughes Agile program; Raytheon acquires Hughes
- Navy privatizes depot; production moves from Tucson to Louisville

1999-'02: Integration of program enterprise

- Combined new production & sustainment at the same site
- Fusion of Agile/Six-Sigma/Lean principles
- Cultural transformation – trust-based relationships

Expanding Raytheon Six Sigma throughout the enterprise (to customers and sustainment infrastructure)

AMRAAM

Raytheon Missile Systems (RMS), Tucson, AZ 1992-2001

Results: **"…cut cost of a missile from $1 million to $250,000 in 7 years, doubled deliveries in 12 months, improved reliability to three times what RMS contracted for."***

Integration of production and sustainment

1996
Turning Point: **Tough competition between Hughes & Raytheon; need to eliminate waste & create capability to quickly react to changing environment**

- **Collocated development, production, repair & upgrade operations**
- **Six Sigma/Lean**
- **Enterprise-wide transformation focus; empowered workers; extensive training**
- **Parts count reduction; closely-linked relationships with suppliers**
- **Trust-based relationship with customer**

Six Sigma/Lean tools institutionalized enterprise-wide

Source: * Miller,W. Industry Week Best Plant Award (1999)

Atlas

Lockheed Martin Astronautics, Littleton, CO

1995-2000

Results: Production cycle time reduced by 50% (from 48 mo. to 24)
Booster of Atlas III has 11,000 fewer parts than booster of Atlas IIAS

1995
Turning point: Customer demand to reduce cycle time (48 to 24 mo.)

Challenge: Double production capacity without doubling the facility
Reduce cycle time & cost while maintaining mission success

- Emphasis on cycle time reduction
- LM-21 Initiative; Kaizen events;value relationships with suppliers
- Committed & engaged leadership
- Reorganization around value streams
- Significantly reduced parts count
- Engaging workforce in self-reinforcing learning process
- Continued efforts to evolve high-performance supplier network
- Pulling LAI tools/knowledge

Synthesis

- Strong evidence of successful lean transformation in aerospace -- acceleration of progress since 1997
- Significant progress made on factory floor but also noticeable diffusion of lean beyond the factory floor
- Based on survey, diffusion of lean to supplier base seriously lagging
- Case studies show that common achievements embrace quality improvements, cycle time reduction, improved customer satisfaction and COST REDUCTION – significant benefits of lean even across enterprise boundaries
- Case studies underscore importance of enterprise-wide systemic change initiatives & committed top-down leadership
- Customer engagement in change process as a key stakeholder shown to accelerate change process
- Lean and Six Sigma – two mutually complementary change initiatives – merging across the industry into a unified enabler for systemic change

Future Challenges

- Wide recognition of need to continue expanding achievements beyond the factory floor -- engineering, human resources, finance, IT/IS
- Need for greater integration across functional groups & organizational interfaces throughout the program value stream (e.g., with customers, supplier networks)
- Challenge of greater integration within multi-program enterprises along multiple value streams (e.g., design commonality, process standardization)

Success Through Enterprise Integration and Value Creation

Functional Lean Successes
- **Manufacturing**
- **Product Dev.**
- **Supplier Network**

"Islands" of Success

Successes Through Interaction Between Functions

Lean Applied to Enabling Processes
- **HR**
- **IT, etc.**

Transition from Waste Minimization to Value Creation

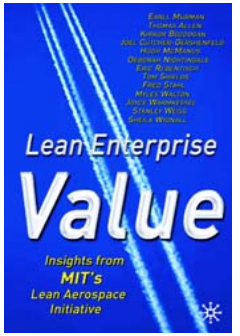
Success Through Enterprise Integration

Success Through Total Enterprise Integration of All Stakeholders
- **Industry**
- **Government**
- **Suppliers**
- **Employees**

Lean Journey: From the Factory Floor to the Total Enterprise

"A lean enterprise is an integrated entity that efficiently creates value for its multiple stakeholders by employing lean principles and practices."

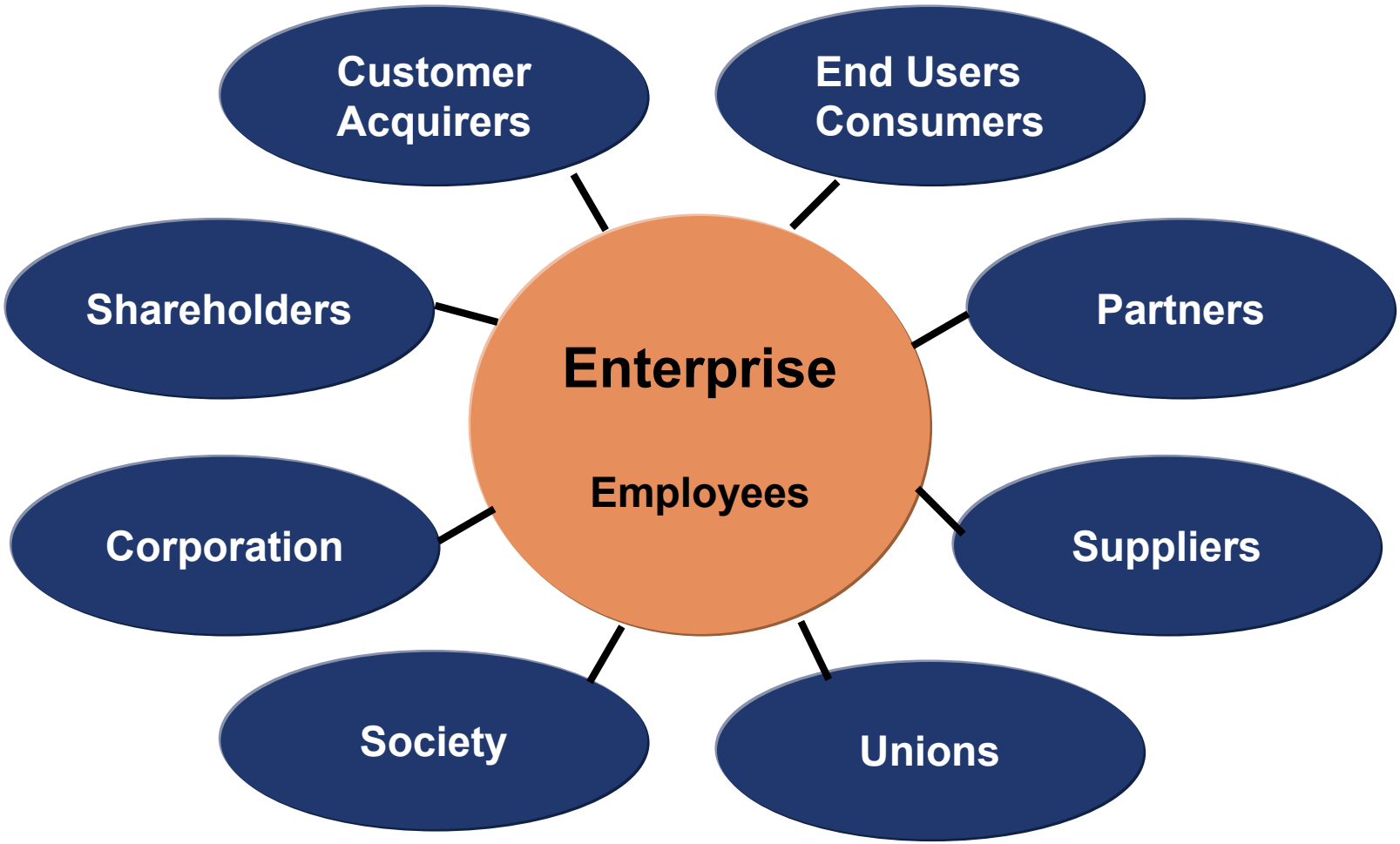
– *Lean Enterprise Value*,
Murman et al.



Lean Enterprise Value Principles

- Create lean value by doing the right job and doing the job right
- Deliver value only after identifying stakeholder value and constructing robust value propositions
- Fully realize lean value only by adopting an enterprise perspective
- Address interdependencies across enterprise levels to increase lean value
- People, not just processes, effectuate lean value

Enterprise Stakeholders



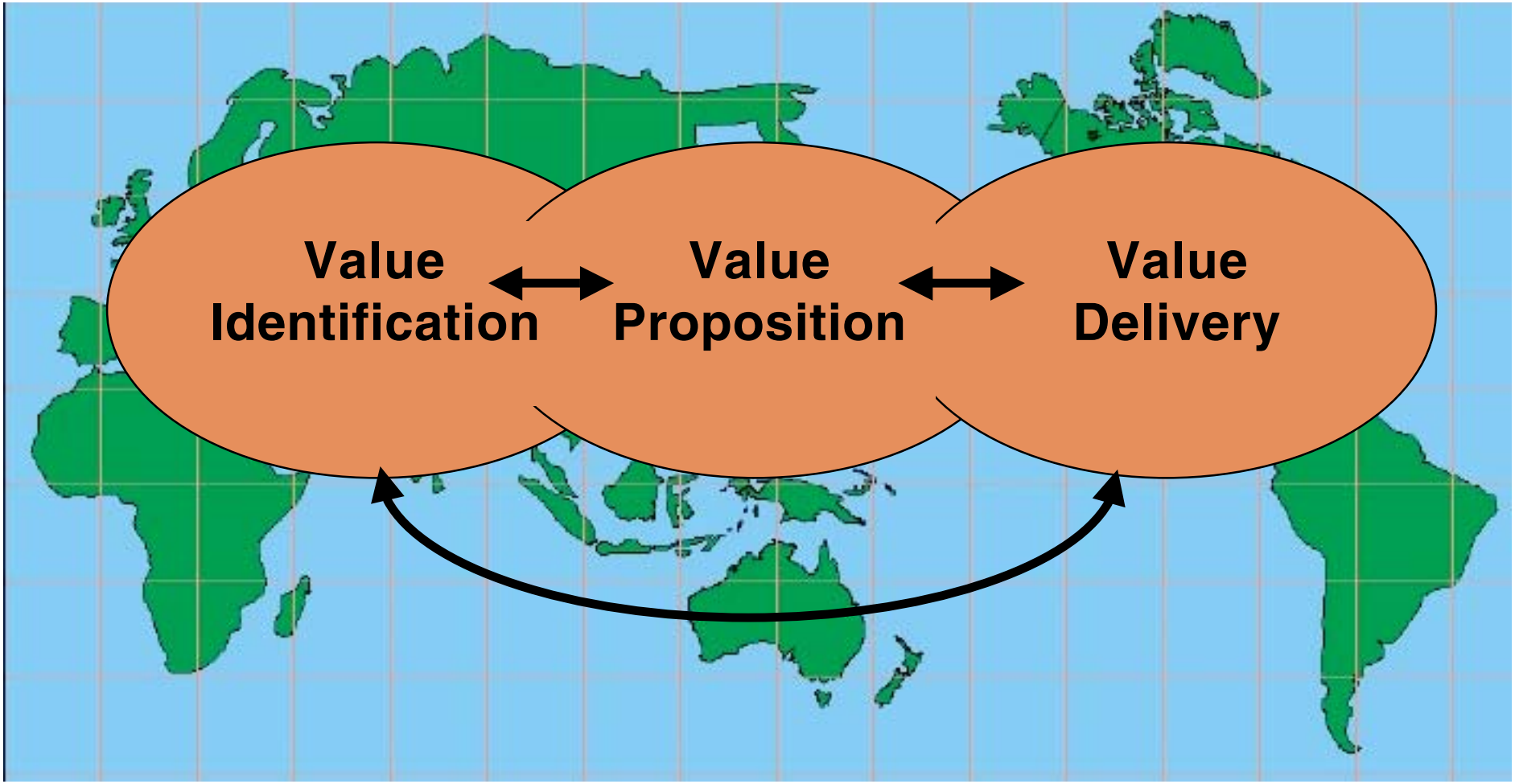
Creating Value

Delivering what stakeholders want and need.

For example:

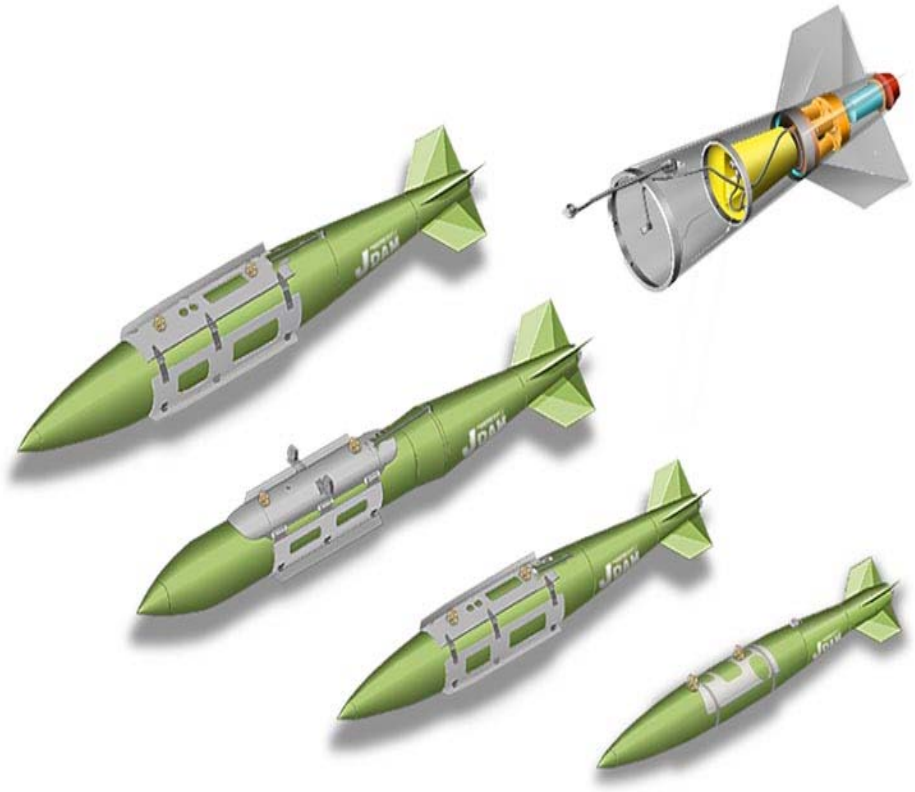
- **Timely, quality products at a reasonable price to customers**
- **Competitive returns on investments to shareholders**
- **Rewarding work environment, stable jobs for workforce**
- **Early and informed involvement of suppliers**
- **Environmental and civic responsibility to the public**

Value Creation Framework



Taking Stock - JDAM Lean Enterprise

From the Beginning...



- Acquisition Reform Pilot Program
- Minimum Requirements
  - Performance Related - Few Specs, CDRLs
- Waivers from Most FARs Allowed Commercial Suppliers to Join the Team
- Strong Integrated Product Team with Boeing, SPO and Suppliers

Lean Goes in First

Suppliers

- **Supplier Team Helped Refine Partitioning of Design (Traded Work Share for Team Benefit)**
- **Big Picture Look at Kitting**
  - **Batteries Shipped to Actuator Supplier**
  - **Containers Shipped to Strake Supplier**

Total System Design (Product and Process) Supports Lean

New Start on Factory Design

Performance Characteristic		"Business-As-Usual" Forecast
Cycle Time	Hrs	48
Touch Labor	Min	300
Floorspace	Ft^2	60,000
People Travel	Ft	1600 *(to/from dock)*
Two-Man Ops	Min	36
Inventory Turns	-	3
Safety & Health	-	Heavy Lifts

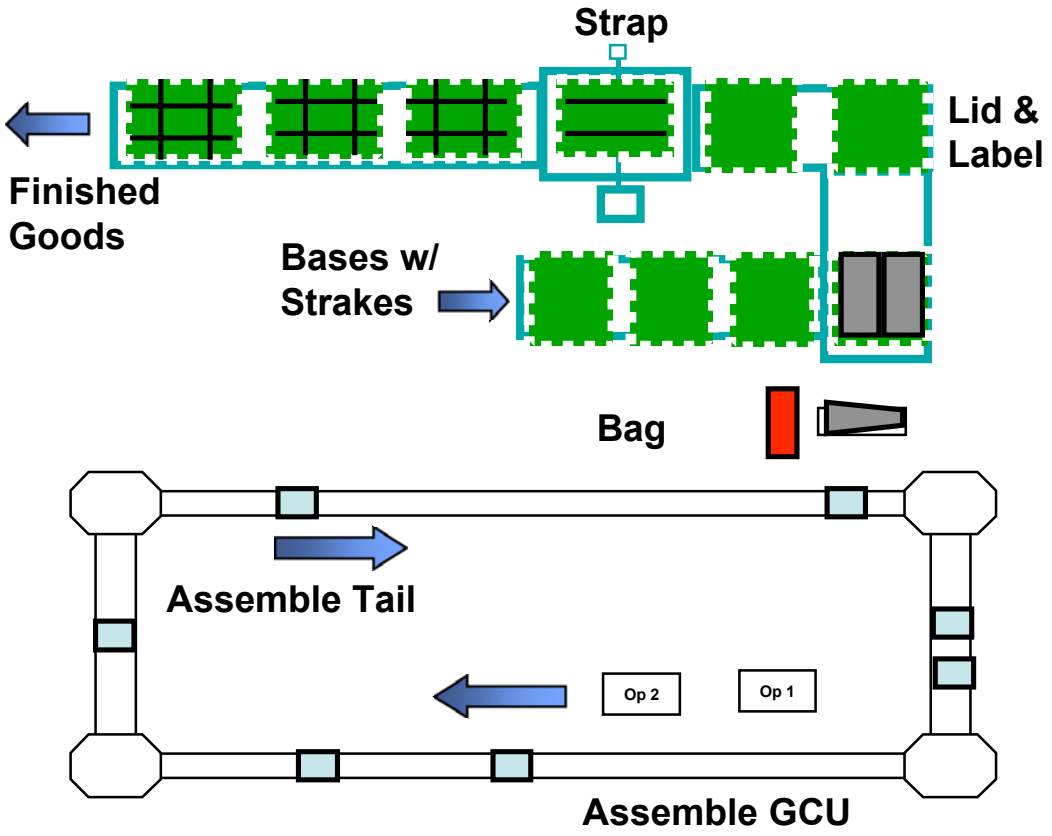
Dismal Forecasts Prior to New Production System

- **EMD Hardware Produced in Batch & Queue Factory**
- **"Just-in-Time" Learning Used To Set Up New Factory**

People	**Single Classification** **Co-Located Support**
Material	**Point Of Use Delivery** **Returnable Containers**
Equipment	**Moving Line** **Ergonomic Lift Assists**
Flow	**Continuous with Kanbans** **Daily Plans & Measures**

Boeing Factory Today*

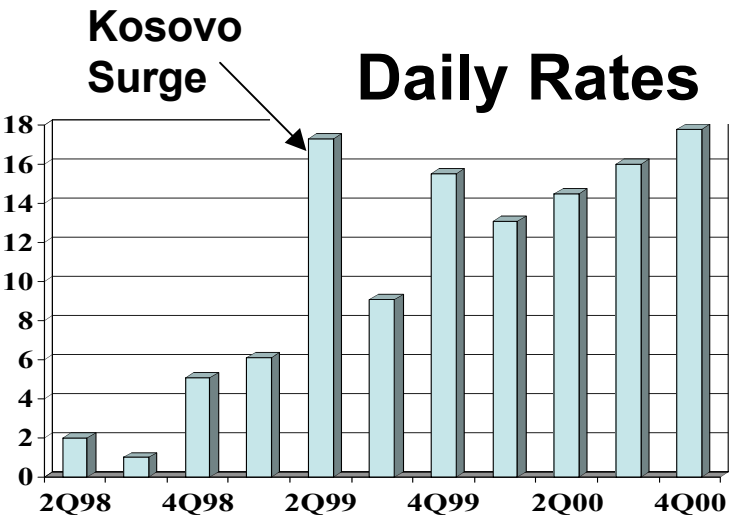
Performance Characteristic		"Business-As-Usual" Forecast
Cycle Time	Hrs	19 (48)
Touch Labor	Min	200 (300)
Floorspace	Ft^2	14K (60K)
People Travel	Ft	0 (1600)
Two-Man Ops	Min	0 (36)
Inventory Turns	-	10 (3)
Safety & Health	-	Lift Assists!



Huge Improvements from Business-As-Usual!!!

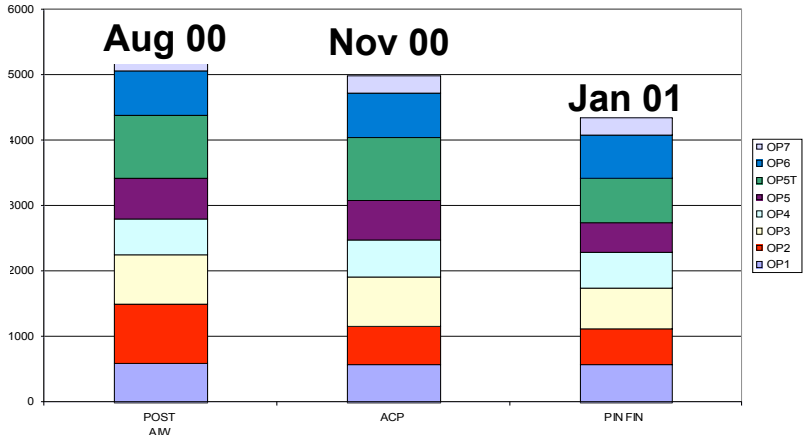
** Until Next Accelerated Improvement Workshop*

Improve It Again



August Workshop Results

Work Content



- 40% Increased Throughput
- Removing Work Content & Balancing Line

Accelerated Improvement Workshop Tackled Challenge of Meeting Production Rates


AIR ARMAMENT CENTER
Stremel
MANUFACTURING CO.
EASER
WOVEN ELECTRONICS
WOVEN ELECTRONICS CORPORATION
CEPA
CE Precision Assemblies, Inc.
IAMS
Manufacturing
Solutions
PRECISE
MACHINING
& MANUFACTURING
Plastics
Research
Corporation
BOEING
GP05403001.ppt

Improving Downstream

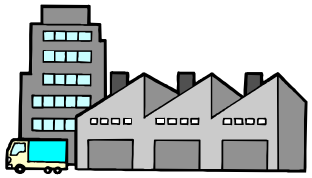
- Mantech Provided Contract Support to Drive Lean Through the Value Stream
- Small and Medium Enterprise Initiative (SMEI)
  - Six JDAM Suppliers Participate in 4-Year Program
  - Training, Action Plans, Metrics
- Pilot Supplier Development Tools
- Incentive for Commercial Suppliers to Take a Risk on DoD Contract
- "Success" Means Supplier Owns the Vision

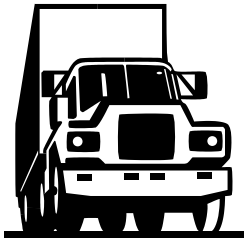
JDAM Lean Lessons Learned

- Lean is a Long Term Commitment
  - Cannot Let Job Rotations Weaken the Drive
- We Will Never Be Lean Enough
- Lean Gains Importance as Complexity Increases
- Lean is Not a Launch and Leave Tool
  - With a Lean Factory, Scrap Can be Created at Alarming Rates if Suppliers Lose Their Edge or Process Control Moves to the Back Burner
- Lean is not for the Feint of Heart
  - Trust and Relationships Matter

Traditional Value Chain

Material Flow





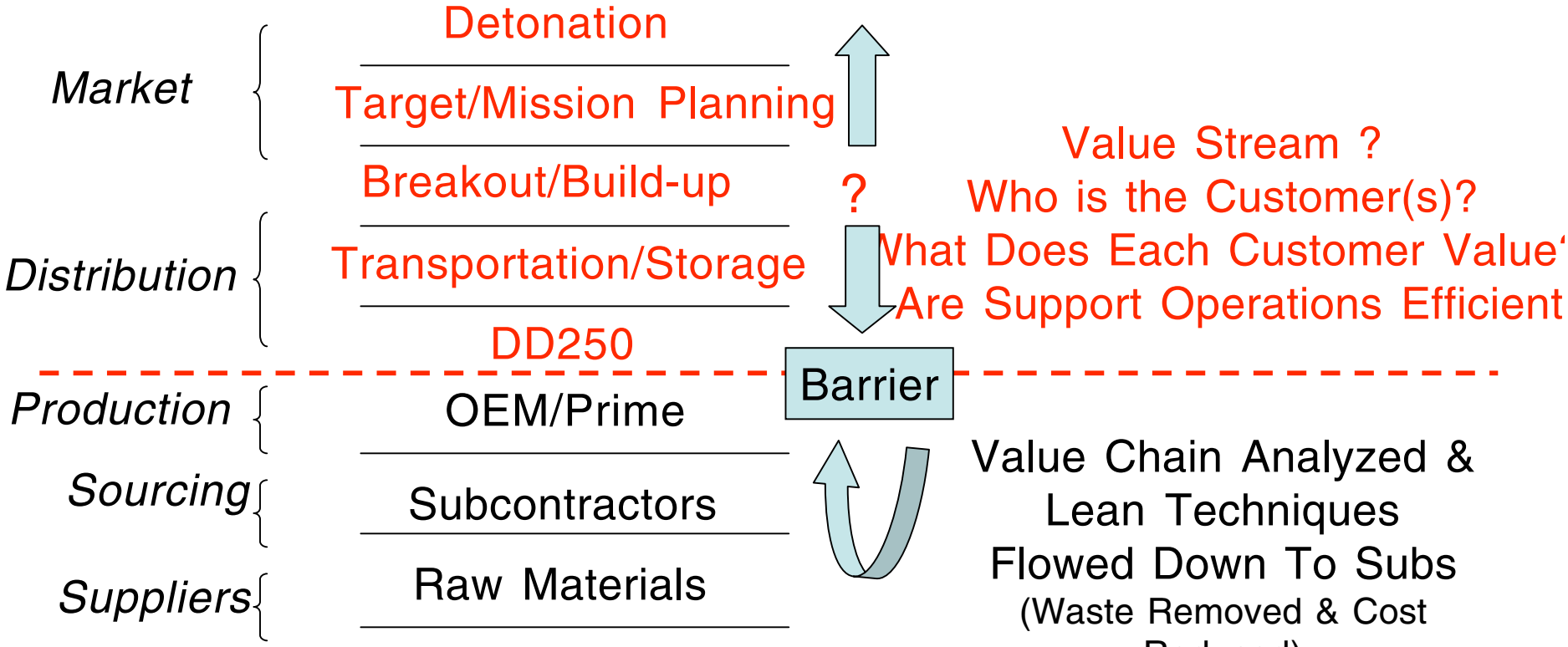
Suppliers | Raw Material Sourcing | Production | Distribution | Markets

Information Flow

JDAM

Raw Materials to Detonation

"What is the Value Stream beyond the Factory?"



Establish A Lean JDAM Enterprise

JDAM ENTERPRISE

Detonation

Target/Mission Planning

Breakout/Build-up

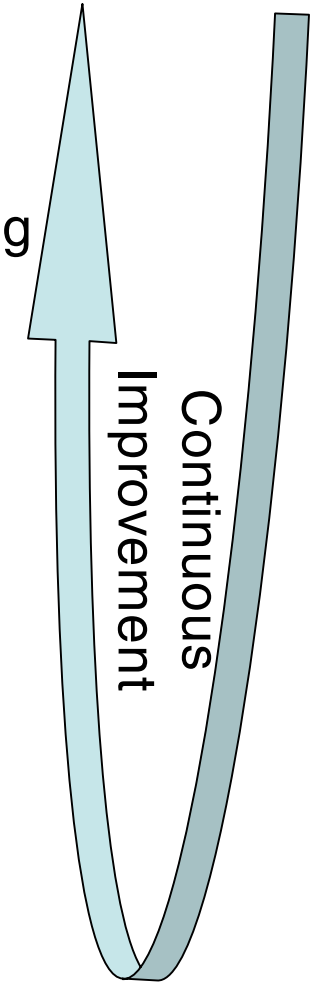
Transportation/Storage

DD250

OEM/Prime

Subcontractors

Raw Materials



- ID Value Stream/Customers
- Maintain Alignment Across Organizations
- Est. Performance Metrics to Gage Improvements
- Eliminate Non-Value Tasks
- ID Value to All Customers
- Eliminate Casual Interactions
- Pursuit of Excellence

Total Enterprise Integration of All Stakeholders

Functional Lean Successes
- **Manufacturing**
- **Product Dev.**
- **Supplier Network**

"Islands" of Success

Successes Through Interaction Between Functions

Lean Applied to Enabling Processes
- **HR**
- **IT, etc.**

Transition from Waste Minimization to Value Creation

Success Through Enterprise Integration

Success Through Total Enterprise Integration of All Stakeholders
- **Industry**
- **Government**
- **Suppliers**
- **Employees**

Air Force Lean Now Initiative Established in Collaboration with LAI

- What: Lean Transformation of Air Force Material Command
- Why: Provide On Time, Effects Based Capability to the War Fighter
- Who: Lean Aerospace Initiative Consortium Members Teamed with AFMC within the LAI venue

LAI Has Provided Lean Now Deployment Venue

- AFMC Leadership
- Industry Members Provided Strong Support
  - Many Members Provide Near "Full time" SMEs at no cost

Supporting LAI Members
- Boeing, Lockheed Martin, MIT, Northrop Grumman, Pratt and Whitney, Raytheon, Rockwell Collins, Rolls-Royce, Textron

- Lean Now Workshop Developed by LAI Industry Members, MIT and Air Force Team … The Best of the Best!
- One Week Facilitator Course Developed…LAI Industry Members, MIT, Air Force…The Best of the Best!
- LAI Developed Tools Deployed
  - LESAT, GLESAT, PDVSMA, LEV Simulation Game, Enterprise TTL
  - MIT Process to develop feedback of tools and methods

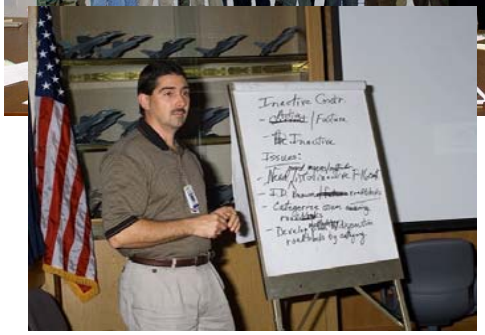
Prototype Focus…the Interfaces

CTF (F/A-22)
LAI SME
F/A-22 SPO
MIT LAI
LM Aero
Boeing
Discipline Experts

ITSP (ESC)
LAI SME
Discipline Experts

Turbine Engine Test (AEDC)
LAI SME
MIT/LAI
AEDC, AFMC, ASC, AFRL, ALC, AFFTC, NAVAIR, GE, RR and P&W

Alpha Contracting (Global Hawk)
Northrop-Grumman
Raytheon
MIT LAI
Global Hawk SPO



Contract Closeout (F-16)
LAI SME
MIT/LAI
F-16 SPO
DCMA, DCAA, DFAS
LM Aero

Procurement Request (Ogden ALC)
MIT LAI
Discipline Experts

Local Results and Behavior Change… New Capabilities and Skills,

CTF OFP Load (F/A-22)

- Selected improvements within processes:
  - Software Install Time Reduced from 97 hours to 46 hours
    - Validated on the F/A-22
  - 50-95% Span Time Reduction
  - 56% reduction in non-value added steps
  - 91% reduction in part traveled distance
- Implemented web based spares ordering system
- Process improvements:
  - Parts purging within CTF compound
  - Dedicated parts research
- CTF deploying lean (VSM, Kaizens, Internal Coaches, etc…)

Alpha Contracting (Global Hawk)

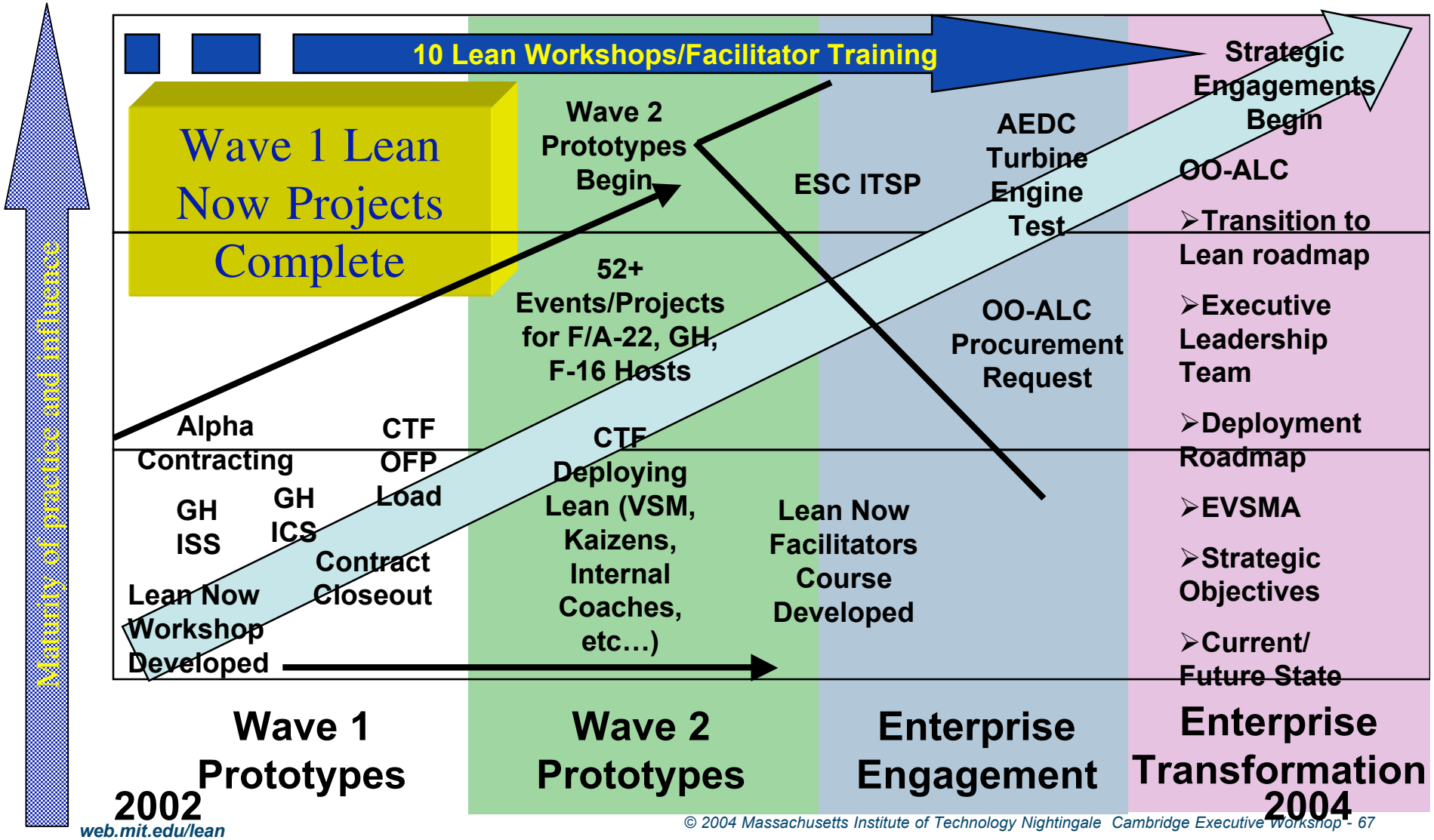
- 37% Initial cycle time reduction for Alpha Contracting
- Created Enterprise Level Tier I and Production Tier II VSM's
- Project Plans Ongoing (10 Major Events Completed):
  - ISS $2M savings per ship set / $49M life cycle savings
  - AICS/GICS $33.8M life cycle savings
  - 38% Production delivery cycle time reduction per BL-10
  - Additional $5M Est. Savings for Producibility Initiatives

Lean Deployments Have Matured To Large Enterprise Deployments

AEDC Groundbreaking Initiative:

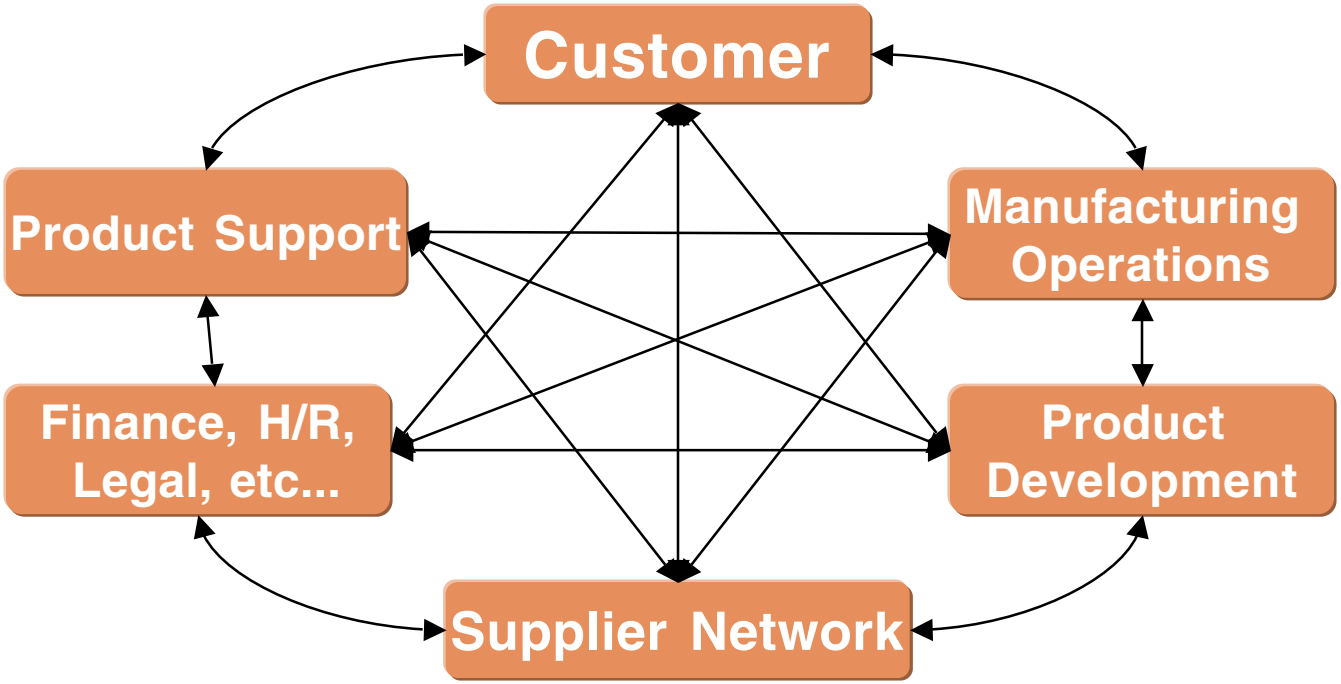
- Total Enterprise Approach - Not Program Specific
- Numerous Organizational Interfaces
  - Government-industry
  - Tri-service: Army, Navy, And Air Force
  - Cross Functional: S&T, Ground Test, Flight Test, Program Office, Depot Maintenance, Logistics, OEM Design And Manufacture
- Embedded Contractor (ATA) In AEDC Daily Operations
  - Recently Joined LAI as Full Member

Enabling Capabilities of Lean Enterprise Transformation

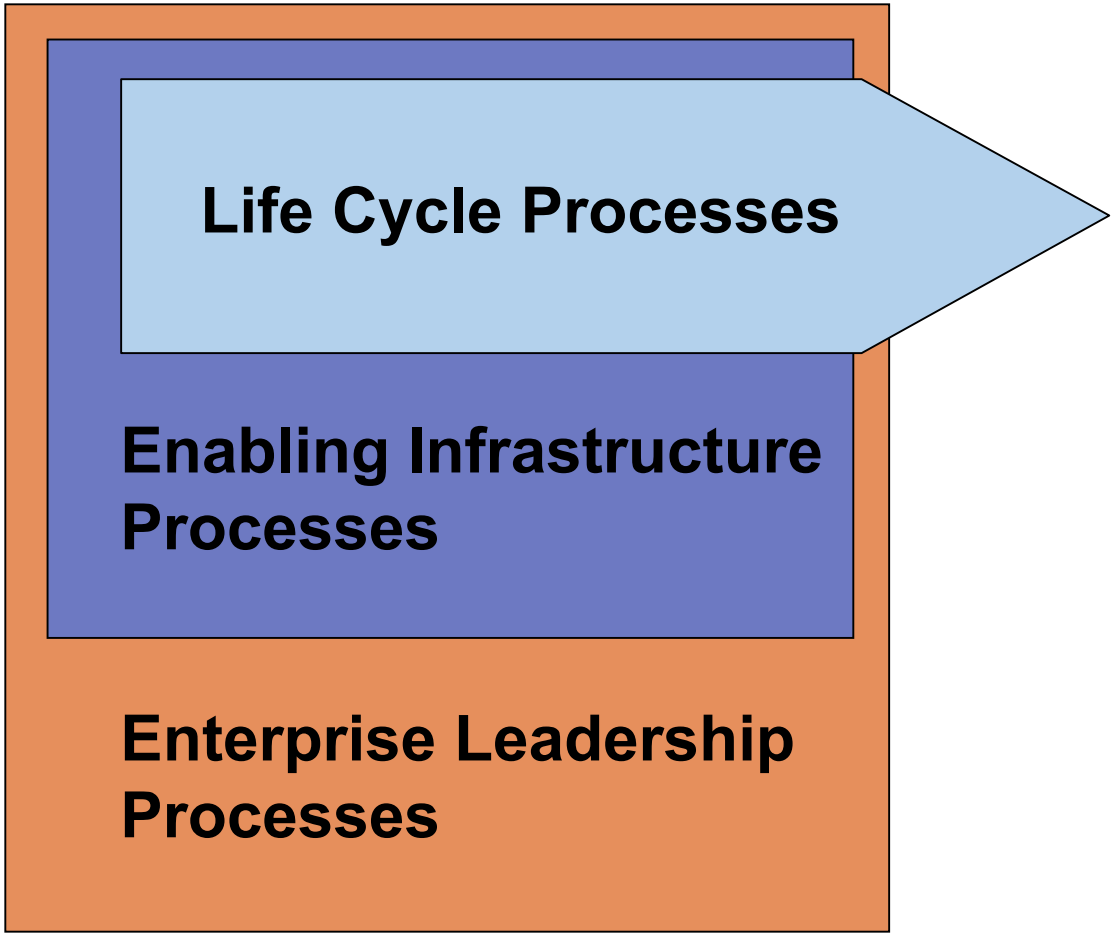


Enterprise Assessment & Implementation Insights

Integrated Enterprise

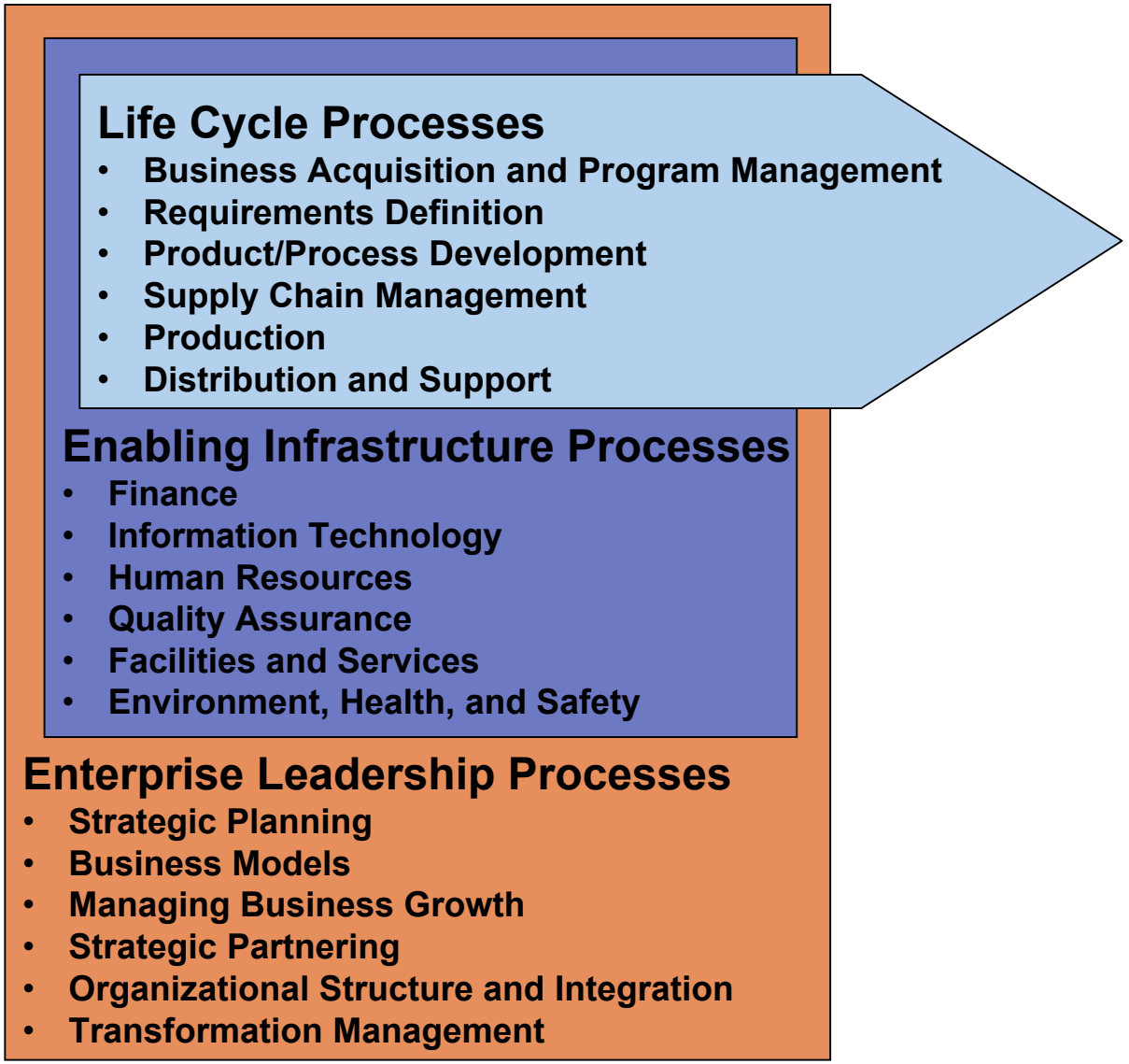


Process Architecture View of Lean Enterprise

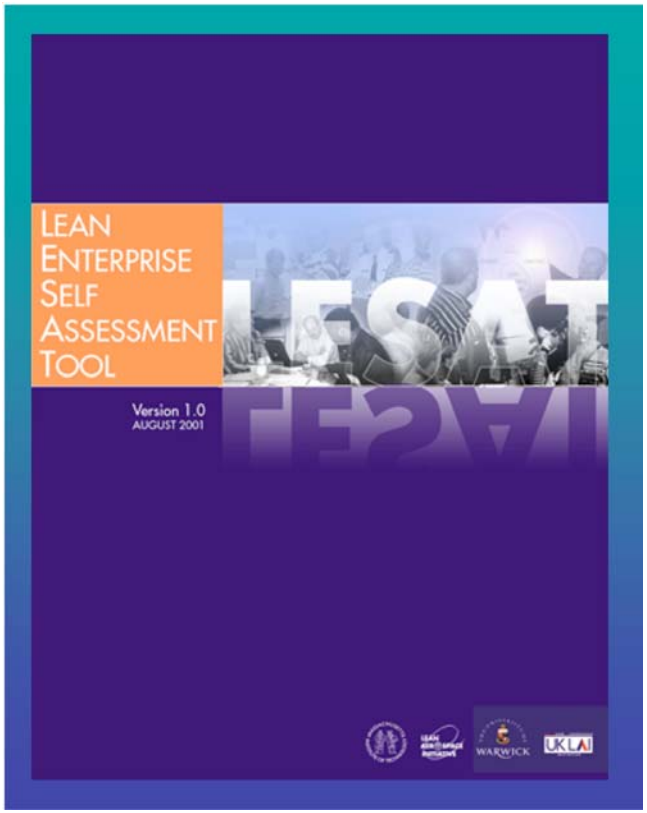


Source: Lean Aerospace Initiative, MIT © 2001

Enterprise Process Architecture



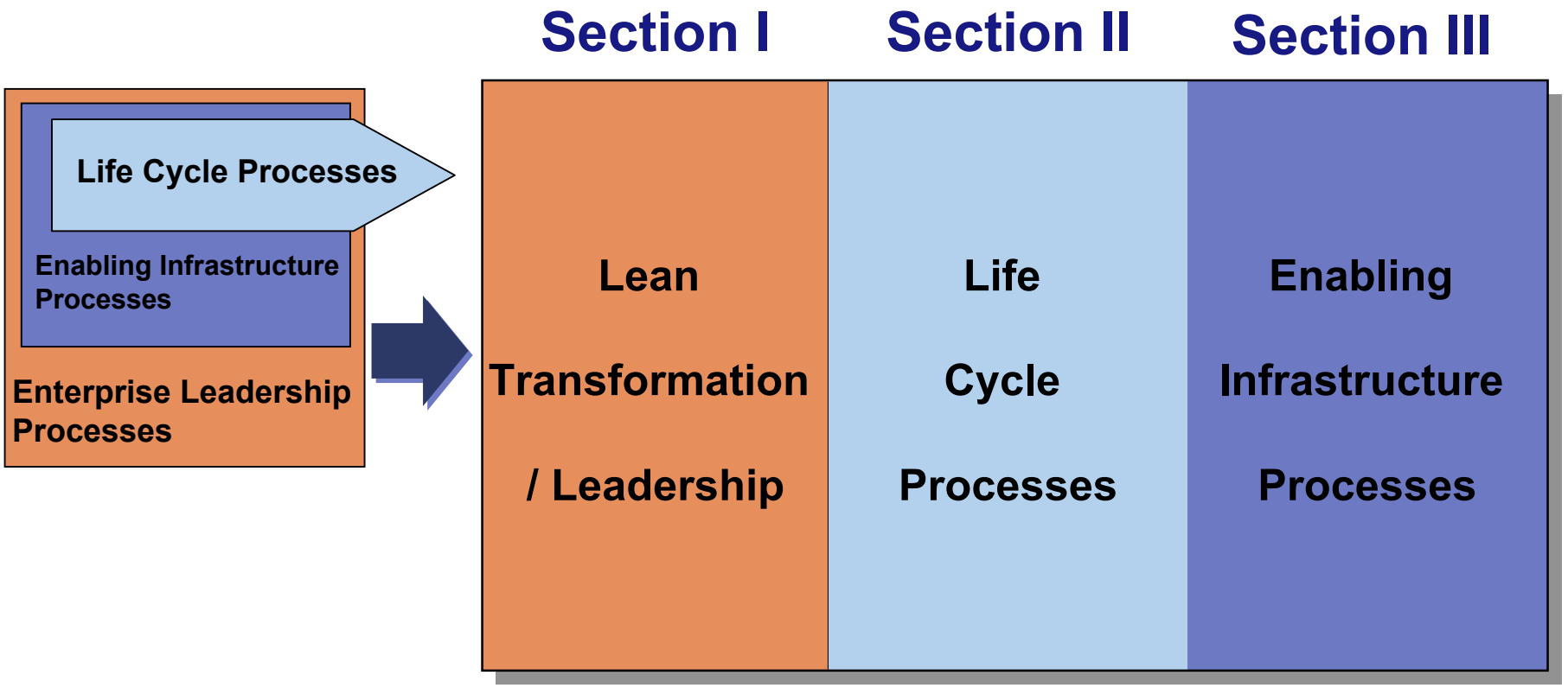
What Is LESAT?



- A tool for self-assessing the present state of "leanness" of an enterprise and its readiness to change
- Comprised of:
  - Capability maturity model for enterprise leadership, life cycle and enabling processes
  - Supporting materials: (Facilitator's Guide, Glossary, etc.)

Source: Lean Aerospace Initiative, MIT © 2001

LESAT Structure is Consistent with Enterprise Architecture

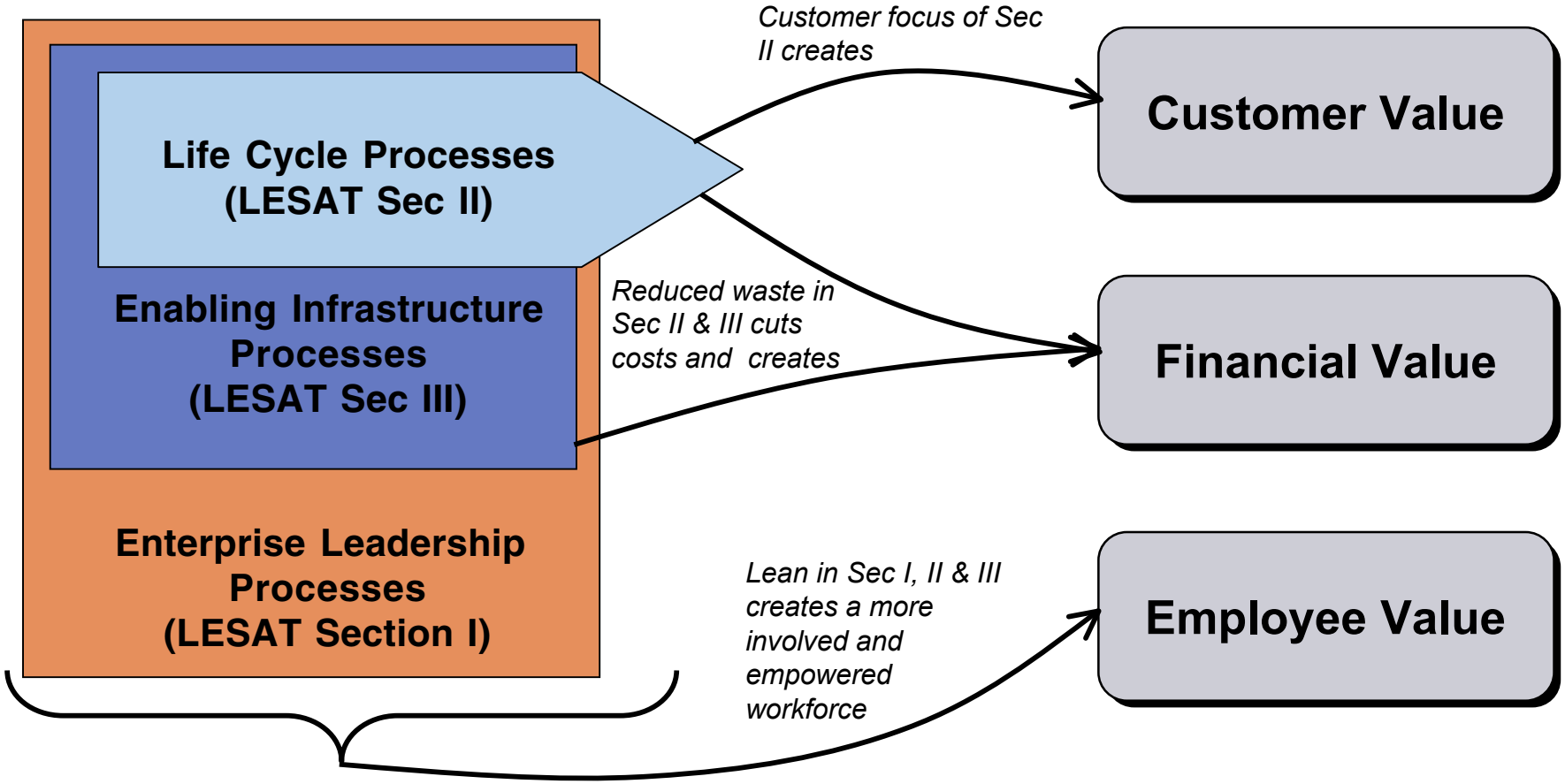


Source: Lean Aerospace Initiative, MIT © 2001

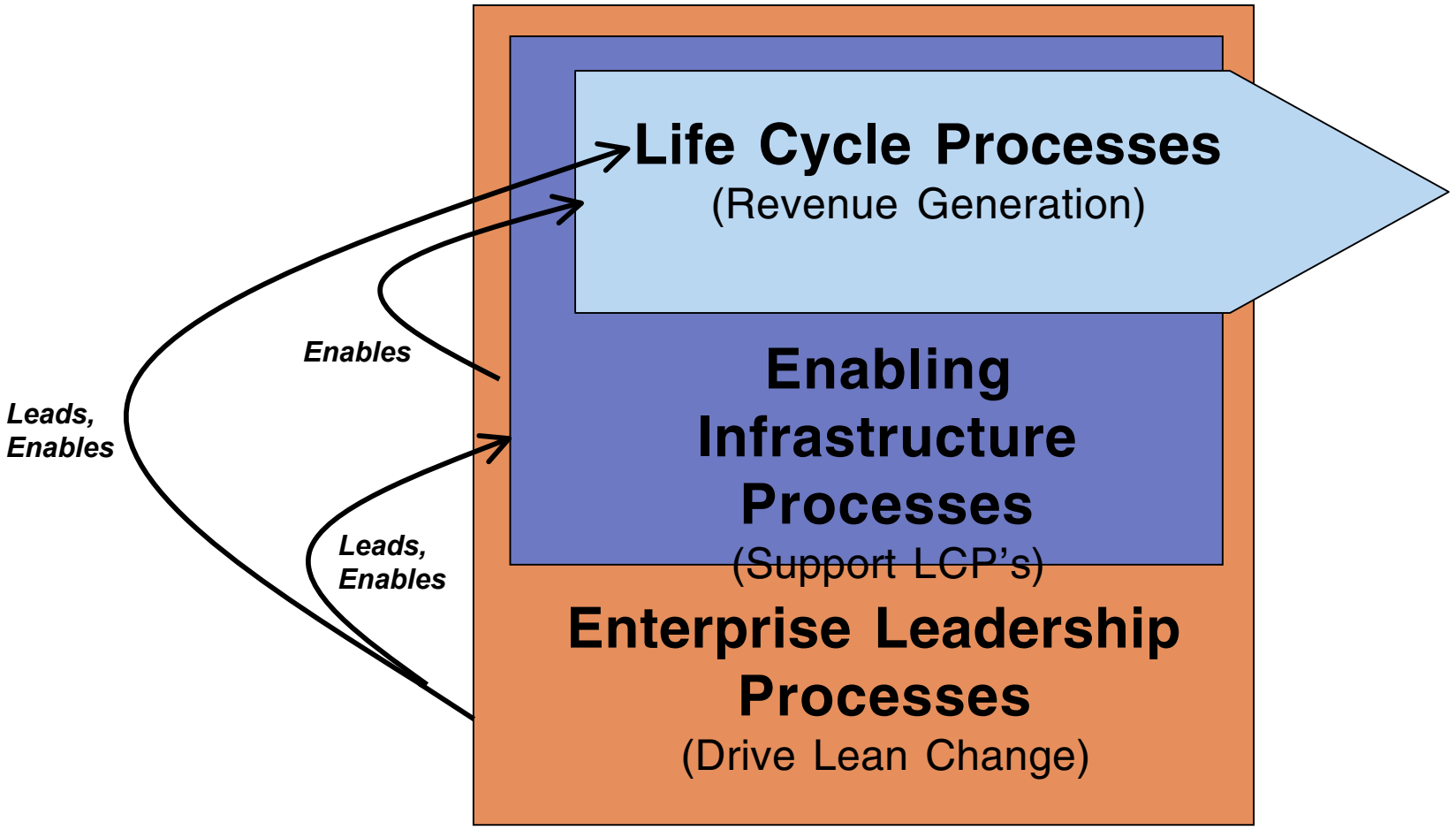
LESAT as a Leading Indicator of Improved Enterprise Value Delivery

State of Enterprise Leanness
(LESAT - Leading Indicators)

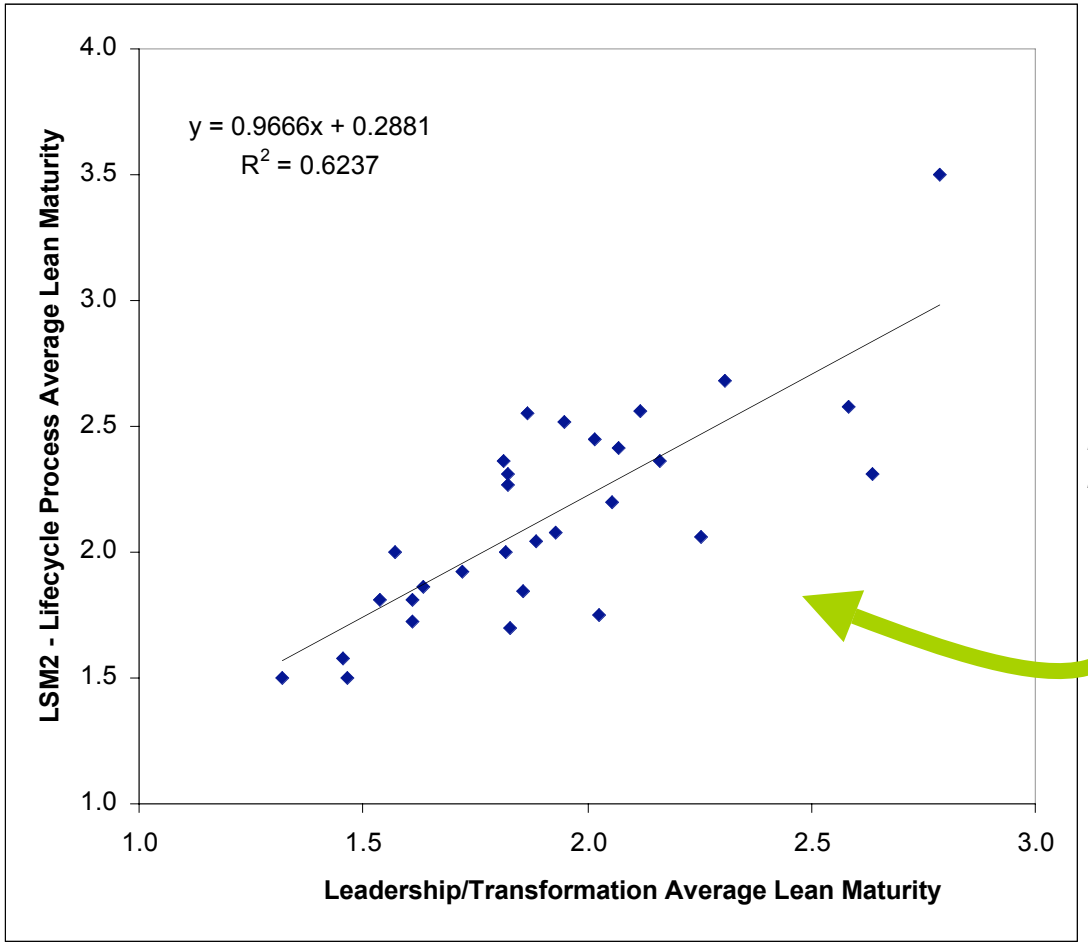
Enterprise Performance Measures
(Lagging Indicators)

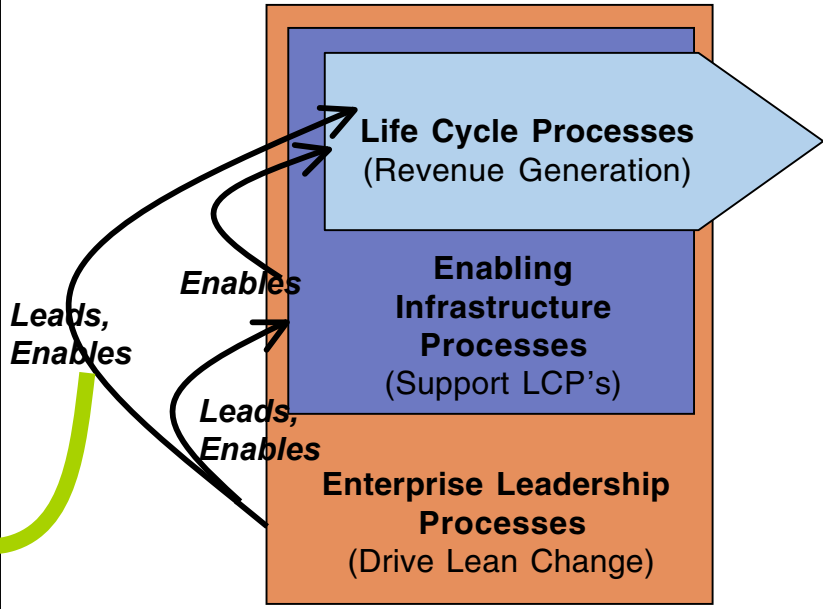


Leading Indicator Relations in Lean Enterprise Transformation



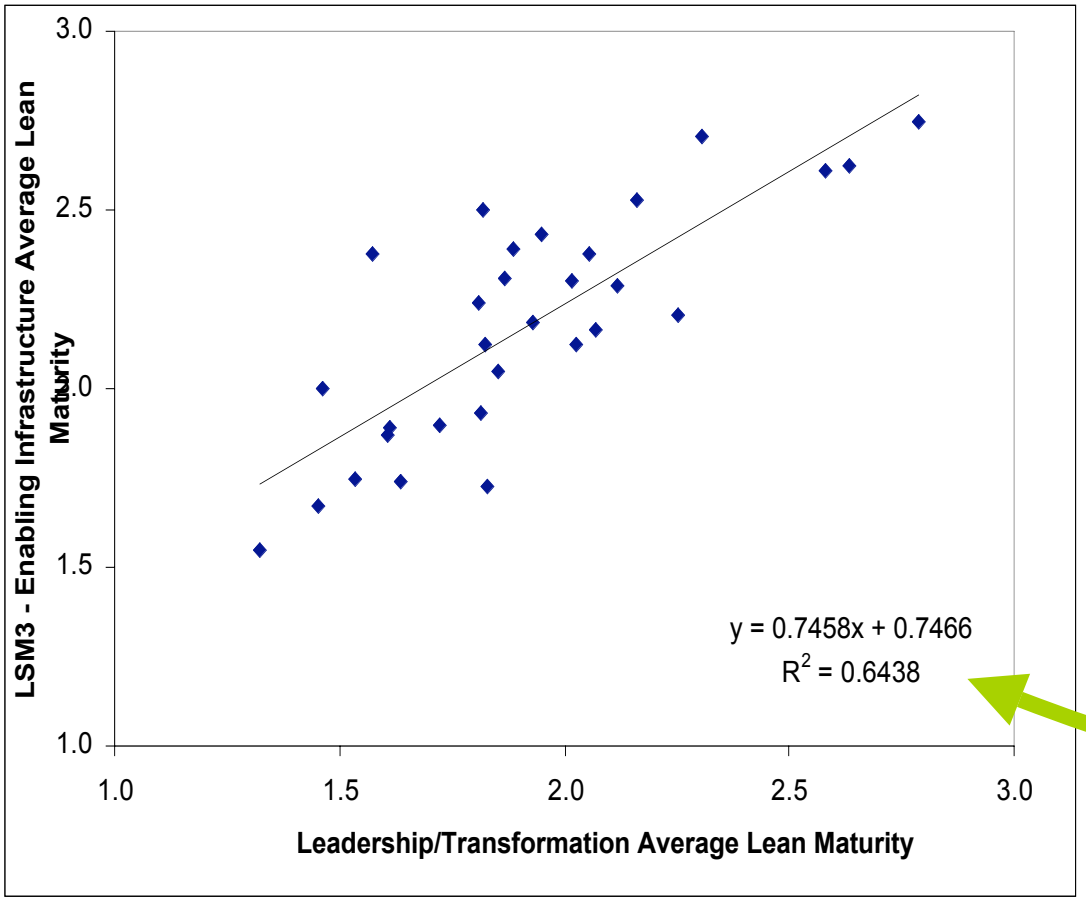
Findings: Leadership Drives Transformation of Life Cycle Processes

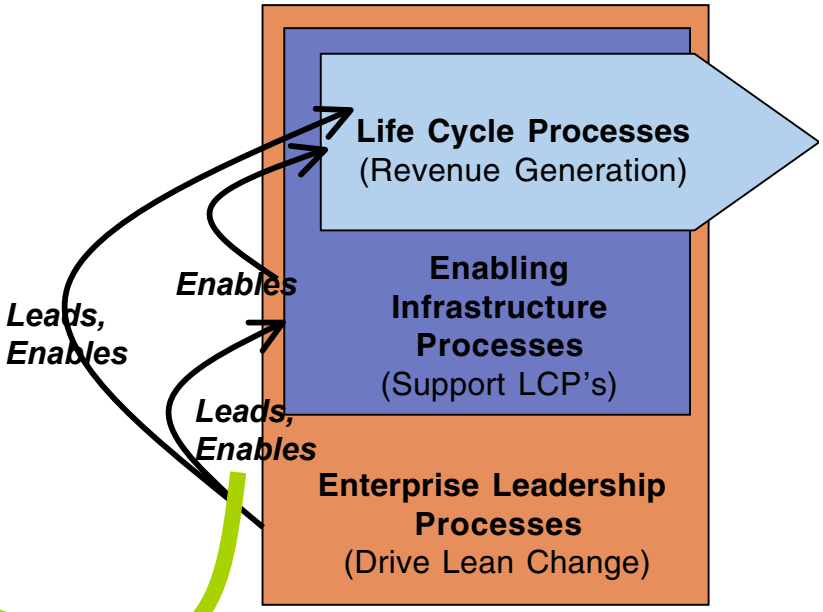




Source: Cory Hallam, 2003

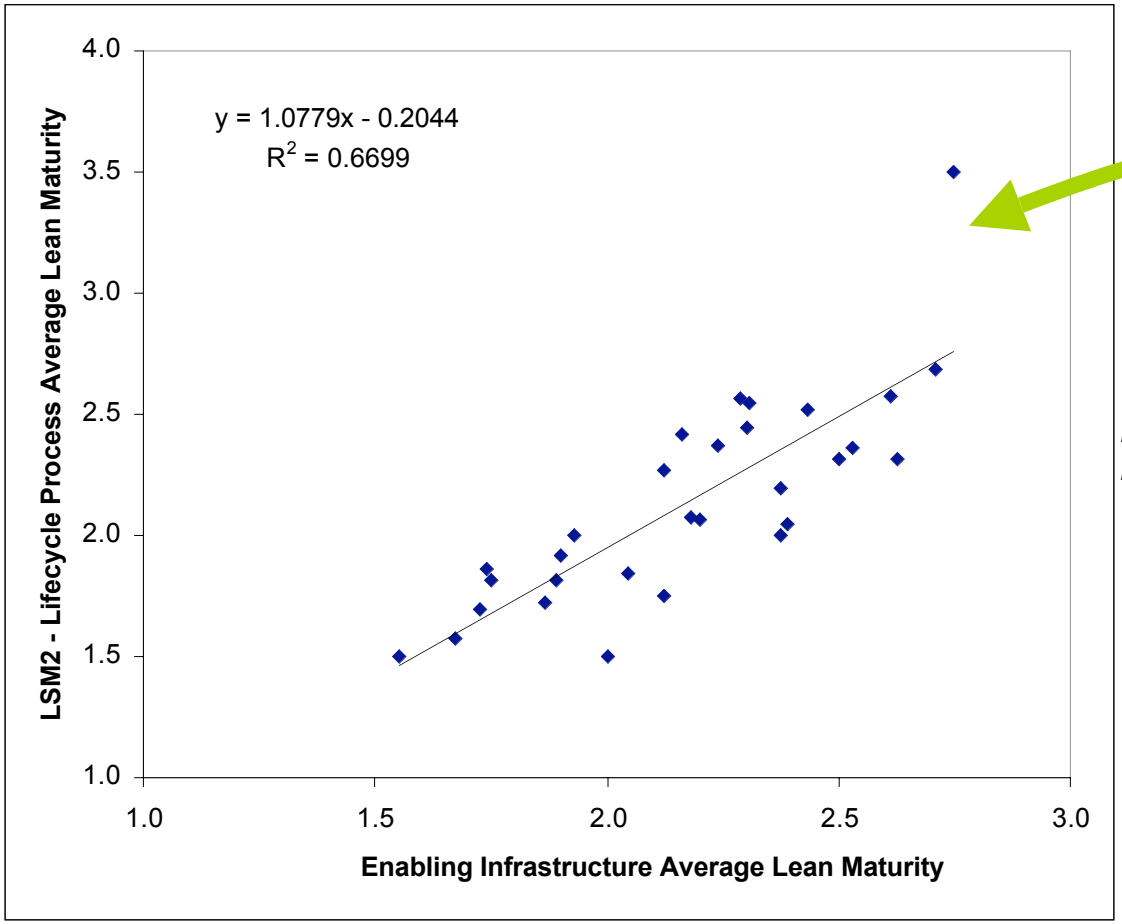
Findings: Leadership Drives Transformation of Enabling Processes

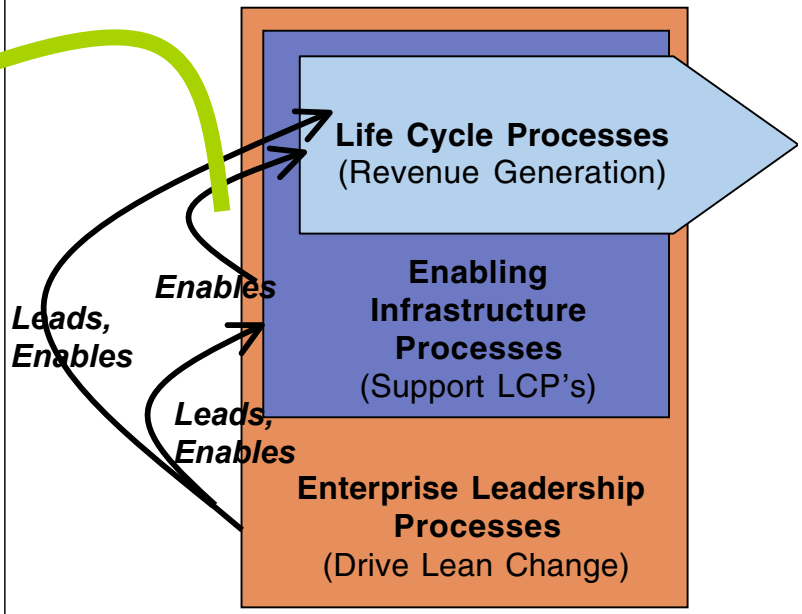




Source: Cory Hallam, 2003

Findings: Strong Infrastructure Enables Lifecycle Transformation





Source: Cory Hallam, 2003

Main Empirical Findings

- Industry is in its lean enterprise infancy
- There are significant correlations in the lean maturity of enterprise processes
- Leadership commitment is critical to lean enterprise transformation
- Infrastructure processes such as IT and HR are critical lean enterprise enablers
- Management information feedback is present in high lean maturity enterprises

"The soft stuff is the hard stuff"

-Chris Cool, VP, Lean Enterprise
Northrop Grumman, ISS Sector

Enterprise Transformation Insights

- **Transformation is continuous and takes years, not months**
- **Senior executive leadership, commitment, and involvement are critical success factors in enterprise transformation**
- **Biggest challenge is institutionalizing lean and sustaining the change**
- **Enterprises must be viewed as a holistic system**

Enterprise leader ***must*** lead a change initiative of this magnitude -- cannot be delegated!

"The notion that you can drive lean from the bottom up is 'pure bunk'."

-Mike Rother
Becoming Lean,1998

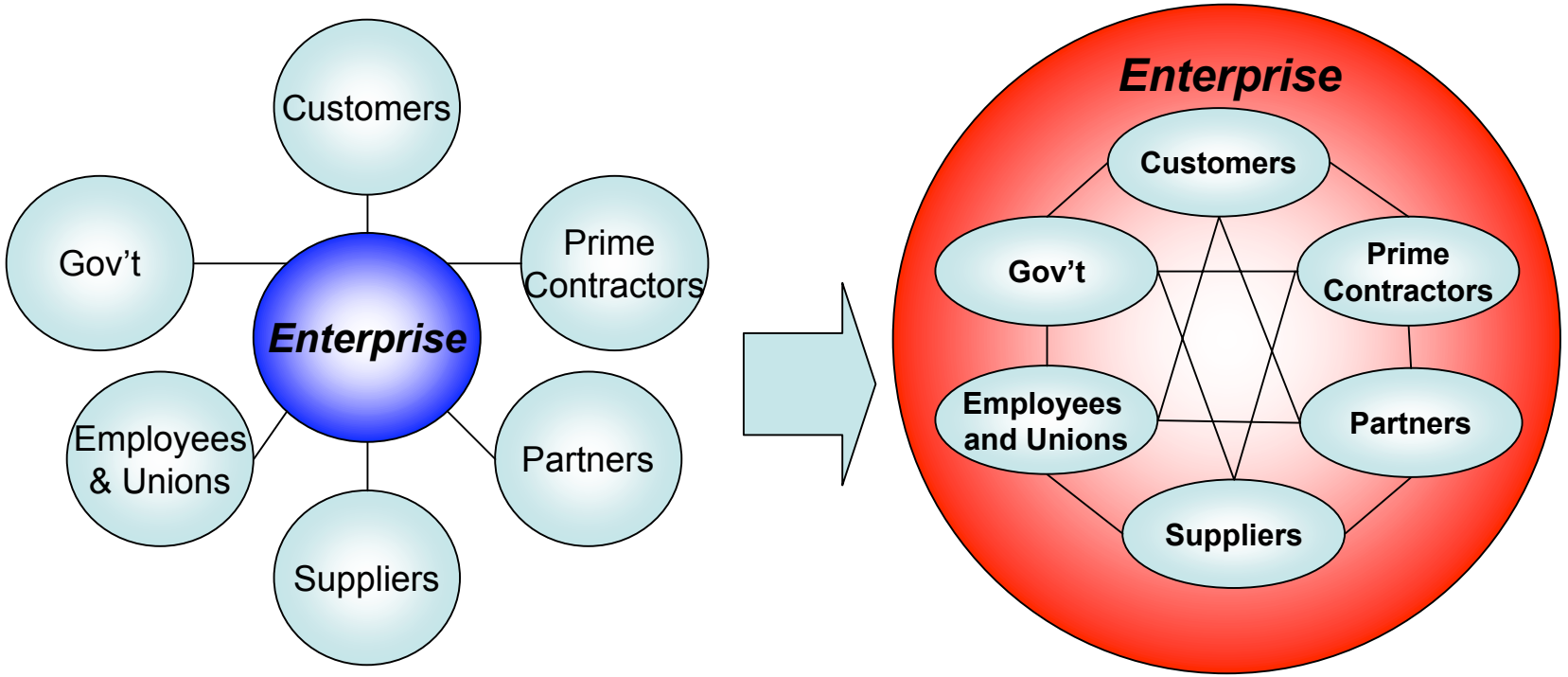
Enterprise Leadership

- Major undertaking to transform enterprise from mass-production orientation to one based on Lean
- Comprehensive change initiative - touches every person and process in the organization
- Enterprise Leader *must* lead a change initiative of this magnitude
- Success depends upon the personal involvement, understanding, and leadership of enterprise leader
- CANNOT BE DELEGATED

Implications for Industry

- Establish senior leadership commitment to begin transformation
- Improve maturity in leadership/transformation practices
- Create formal information feedback mechanisms to
  - prioritize strategically important lean improvement efforts
  - build on lean capabilities
  - build leadership support for continued lean change/operations

Evolution of Lean: Total Integrated Enterprise



Connected Enterprise **Total Integrated Enterprise**

The Journey to a Lean Total Integrated Enterprise is Extremely Challenging

Questions