Lean Aerospace Initiative

# The Lean Aerospace Initiative At MIT

June 2002

*Presented By:*
Dr. Joyce Warmkessel
Dr. Hugh McManus
MIT

Research Sponsored By LAI

web.mit.edu/lean

Lean Aerospace Initiative

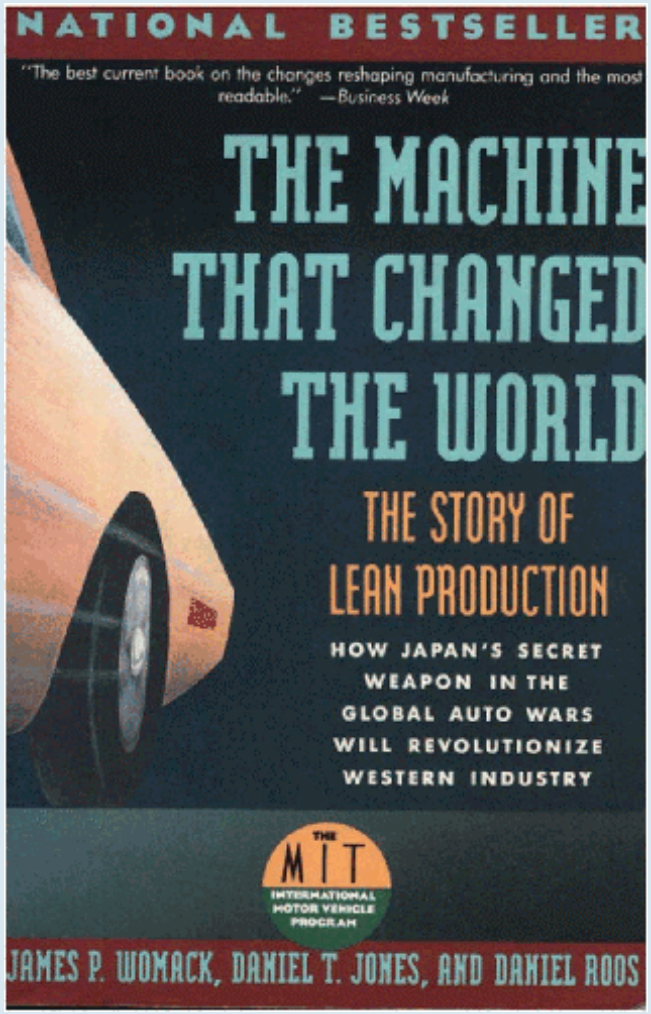
# Outline

- Origins of LAI
- Products
- Current Research
- Lean Engineering

# LAI Consortium

Lean Aerospace Initiative

# 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!***

Lean Aerospace Initiative

# LAI Mission

***"To enable fundamental change within industry and government operations that supports the continuing transformation of the US aerospace enterprise towards providing aerospace systems offering best life-cycle value"***

A system offering best life-cycle value delivers best value in mission effectiveness, performance, affordability and sustainability at the right time and right price—advantages retained throughout product life.

Lean Aerospace Initiative

# The LAI Community

## Avionics/Missiles

BAE SYSTEMS North America
Northrop Grumman Electronic Systems
Raytheon Systems
Raytheon Systems and Electronics Sector
Rockwell Collins
Textron Systems

## Space

Boeing Space & Communications
GenCorp Aerojet
Lockheed Martin Space Systems
Northrop Grumman Space Systems
TRW Space and Electronics
*Spectrum Astro*

## Airframe

Boeing Military Aircraft & Missile Systems
Boeing Commercial Airplane Group
Boeing Phantom Works
Lockheed Martin Aeronautics
Lockheed Martin Technology Services
Northrop Grumman Integrated Systems
Raytheon Aircraft Company
Sikorsky
*Avcorp*

## MIT

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

## Other Participants

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

## Propulsion/Systems

Hamilton Sundstrand
Pratt & Whitney
Rolls Royce (North America)
*Curtiss-Wright Flight Systems*
*Harris Government Comm.*

## US Air Force

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

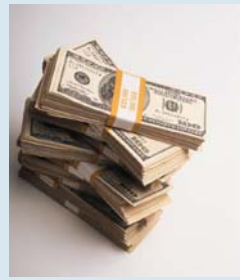
## Other Government

DCMA
NASA
NAVAIR
AMCOM
OUSD(AT&L)
NRO

Lean Aerospace Initiative

# Industry, Government, Labor Lean Implementation - Selected Examples

- F-16 production rate decreased 75% while sales price maintained and order-to-delivery time decreased by up to 42%.
- C-17 unit priced decreased from $260M to $178 M for final 80 aircraft of 120 aircraft buy.
- JDAM unit price of $15K compared to initial estimate of $68K.
- Northrop Grumman ISS lean enterprise implementation reduced throughput times for major systems by 21 to 42%.



# Products

# Lean Aerospace Journey And LAI Products

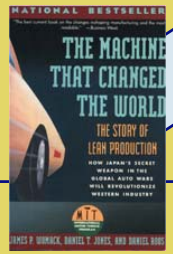
Lean Aerospace Initiative

Lean Enterprise

Lean Factory

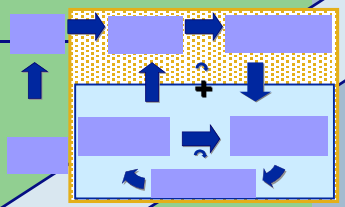
Lean Auto Factory

Toyota Production System



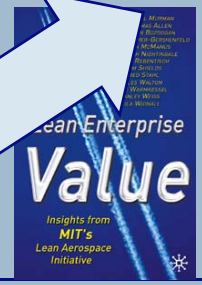


Lean Enterprise Model



Transition to Lean Roadmaps (TTL)


Lean Enterprise Self Assessment Tool (LESAT)




LAI Book

LAI Phase I

LAI Phase II

LAI Phase III

1993

1996

1999

2002

Lean Aerospace Initiative

# Student Development
# Graduate Students in LAI

## 16 current MS & PhD students

- 8 Aeronautics-Astronautics
- 4 Technology & Policy
- 2 Technology & Management
- 1 Mechanical Engineering
- 1 Sloan School

## 1 USAF Research Fellow

## 57 graduated MS & PhD students

- 12 entered government service
- 10 entered aerospace industry
- 15 entered consulting industry
- 18 entered other professions
- 2 continuing studies at MIT

## 25 affiliated MS & PhD students

Sep '01-May '02

Lean Aerospace Initiative

LEM

# Lean Enterprise Model

## Practices and Benchmark Data

**Meta-Principles/Enterprise Principles**

**Enterprise Level Metrics**

## Overarching Practices

| | | | |
|---|---|---|---|
| Identify & Optimize Enterprise Flow | Assure Seamless Information Flow | Optimize Capability & Utilization of People | Make Decisions at Lowest Possible Level |
| Implement Integrated Product & Process Development | Ensure Process Capability and Maturation | Develop Relationships Based on Mutual Trust & Commitment | Promote Lean Leadership at all Levels |
| Maintain Challenge of Existing Processes | Maximize Stability in a Changing Environment | Nurture a Learning Environment | Continuously Focus on the Customer |

**Metrics - Barriers - Interactions**

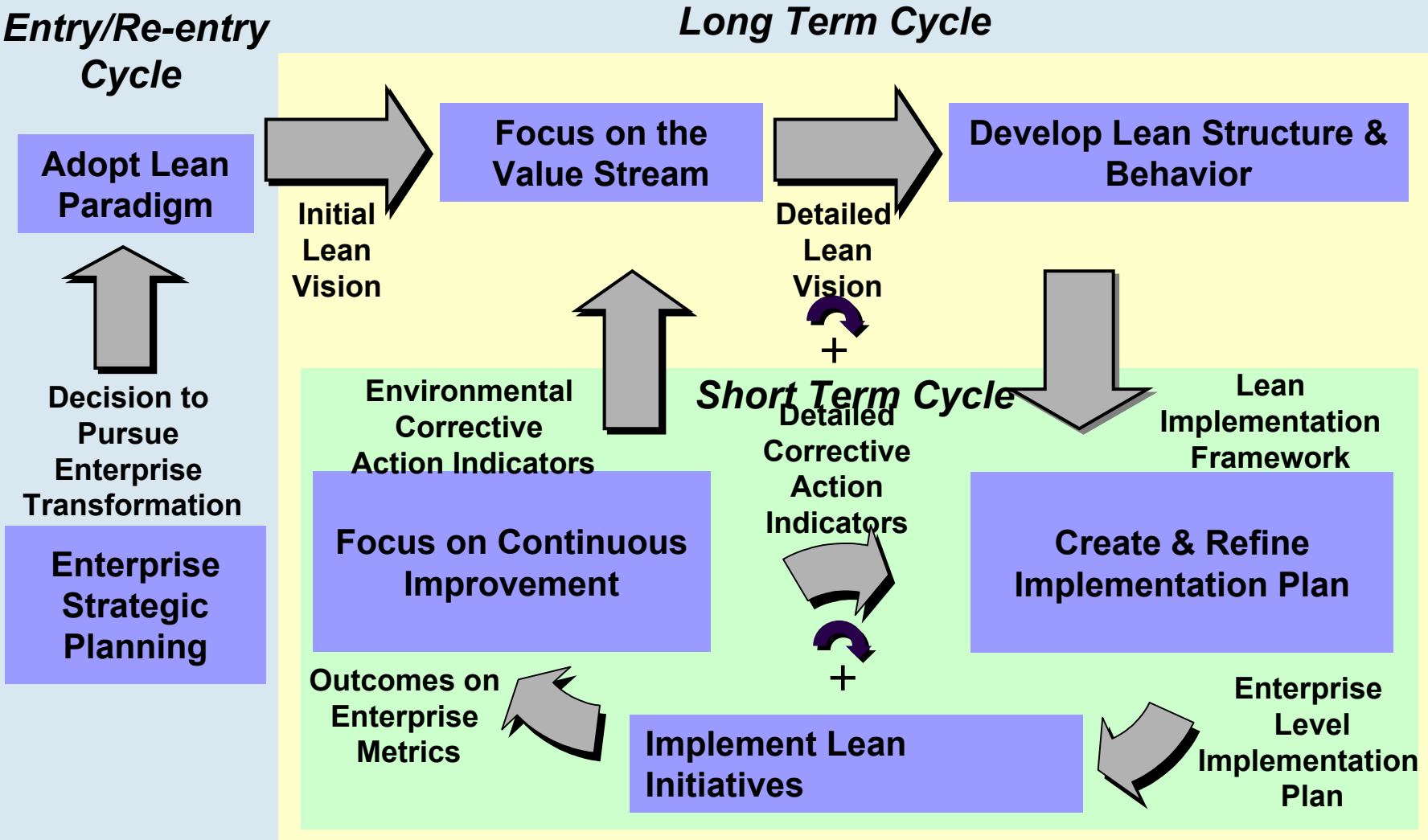
**Enabling Practices (~ 60)**
Metrics -Data - Barriers - Interactions

**Supporting Practices(~300)**

*Internet Links (~600)*

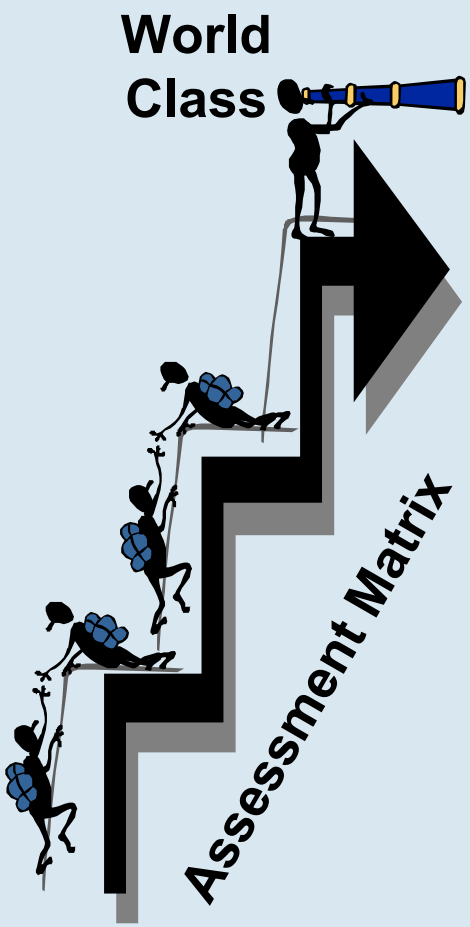
# Enterprise Transition To Lean (TTL) Roadmap

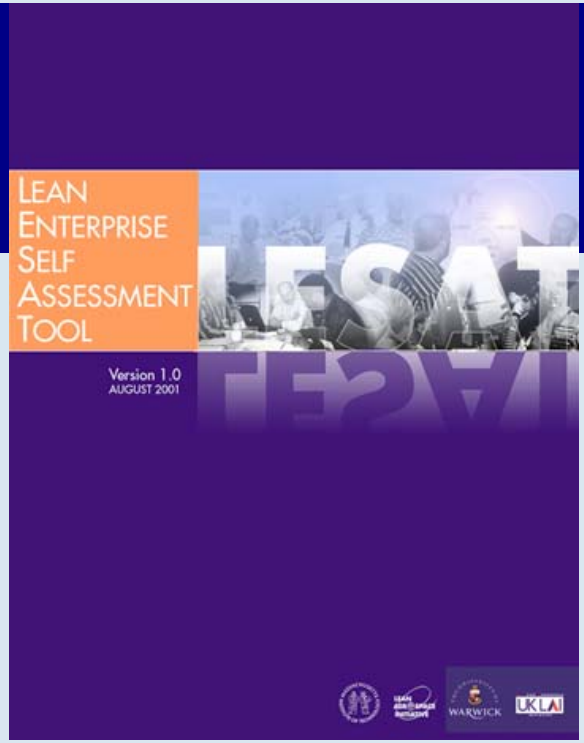
Lean Aerospace Initiative



Lean Aerospace Initiative

# What Is LESAT?



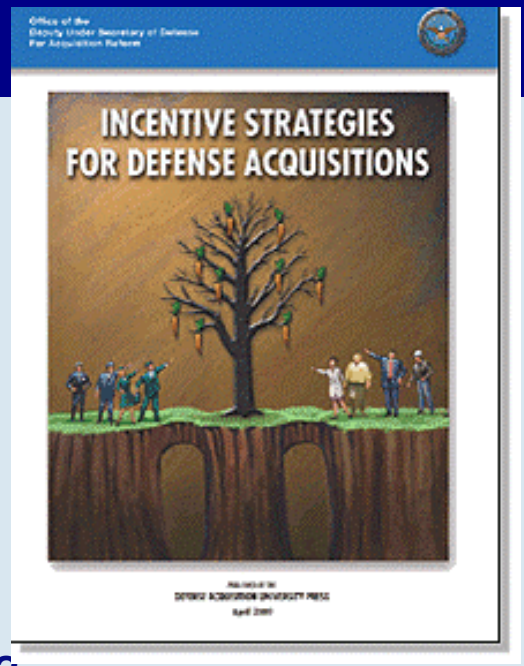

**Tool for executive self-assessment of the present state of "leanness" of an enterprise and its readiness to change**

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

**Capability maturity model**

**Supporting materials**

# Incentives Guidebook

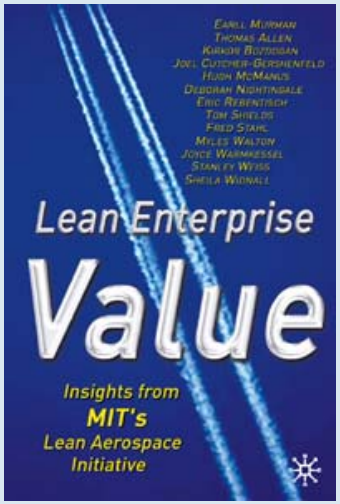



- Developed by OUSD(AT&L), DAU,USAF, MIT, LMI, SAIC
- Outgrowth of LAI research on Economic Incentives for Acquisition
- Organized around 5 questions:
  - Why are we concerned with contractual incentives?
  - What elements contribute to an effective incentive strategy leading to a successful business relationship that maximizes value?
  - How do you build and maintain an effective environment for the successful business relationship?
  - How do you build the acquisition business case?
  - How do you build an incentive strategy that maximizes value?

Lean Aerospace Initiative

# Lean Enterprise Value Concepts




*"The core challenge for industry in the 21st century involves identifying and delivering value to every stakeholder. Meeting that challenge requires lean capability at the enterprise level."*

- Stakeholders
- Creating Value
- The Three Levels of Enterprise
- Value Creation Framework
- Enterprise Level Lean Principles

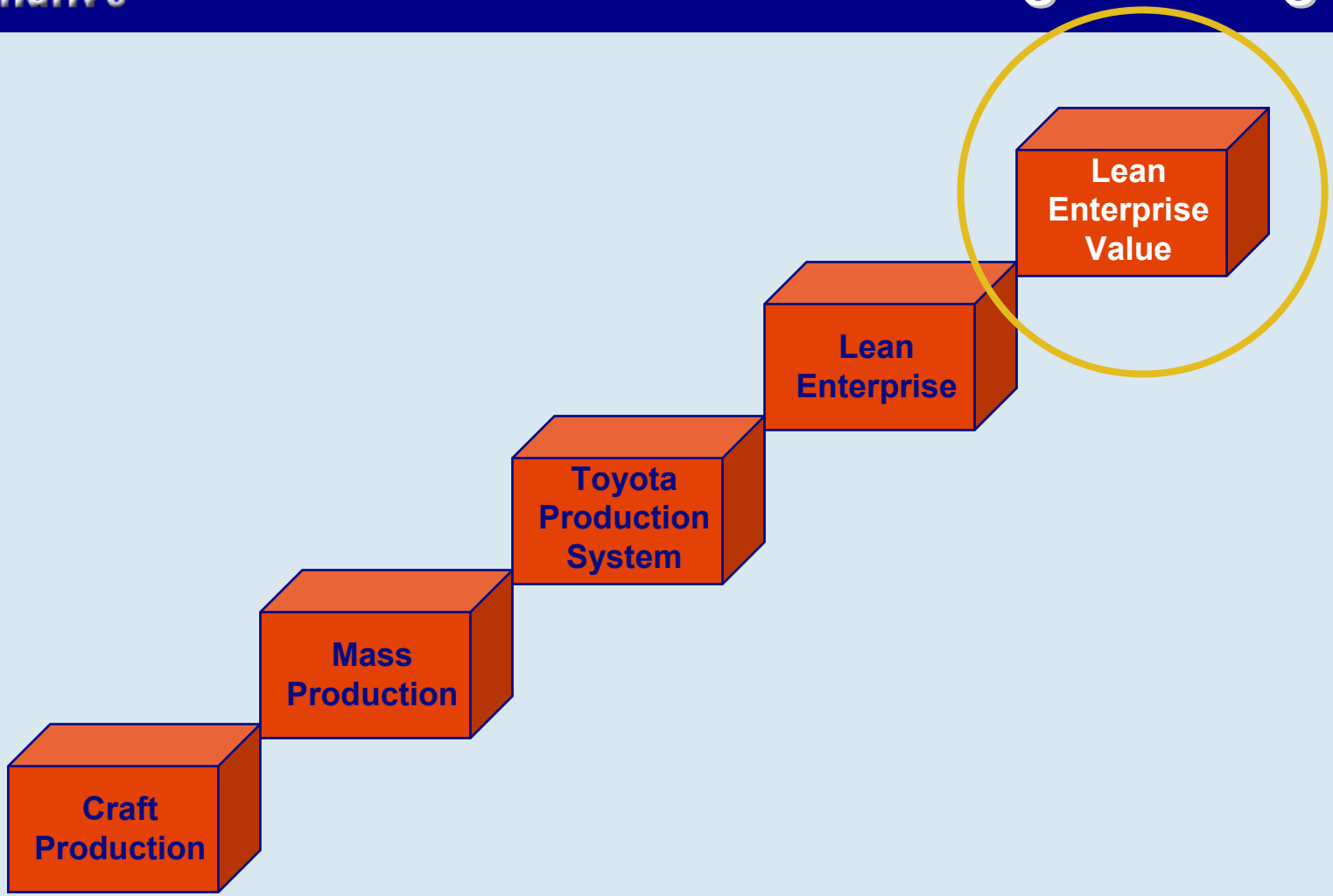
 

# Enterprise Value Creation

Lean Aerospace Initiative

# New Lean Thinking: Evolving Paradigms



Lean Aerospace Initiative

# Lean Enterprise Value: The New Lean Thinking

**Lean is not just a matter of eliminating waste, rather becoming lean is a process of eliminating waste with the goal of creating value for enterprise stakeholders.**

-**Lean Enterprise Value, Palgrave Publishing**

Lean Aerospace Initiative

# Three Levels of an Enterprise

| | |
|---|---|
| **Program** | **F22** |
| **Corporate or Government** | **Boeing, Lockheed Martin, USAF** |
| **National or International** | **Primes, Government, Suppliers** |

**Life Cycle Processes** **Enabling Infrastructure Processes** **Enterprise Leadership Processes**

Lean Aerospace Initiative

# Enterprise Example: JSF Mega Program

Centralized Control

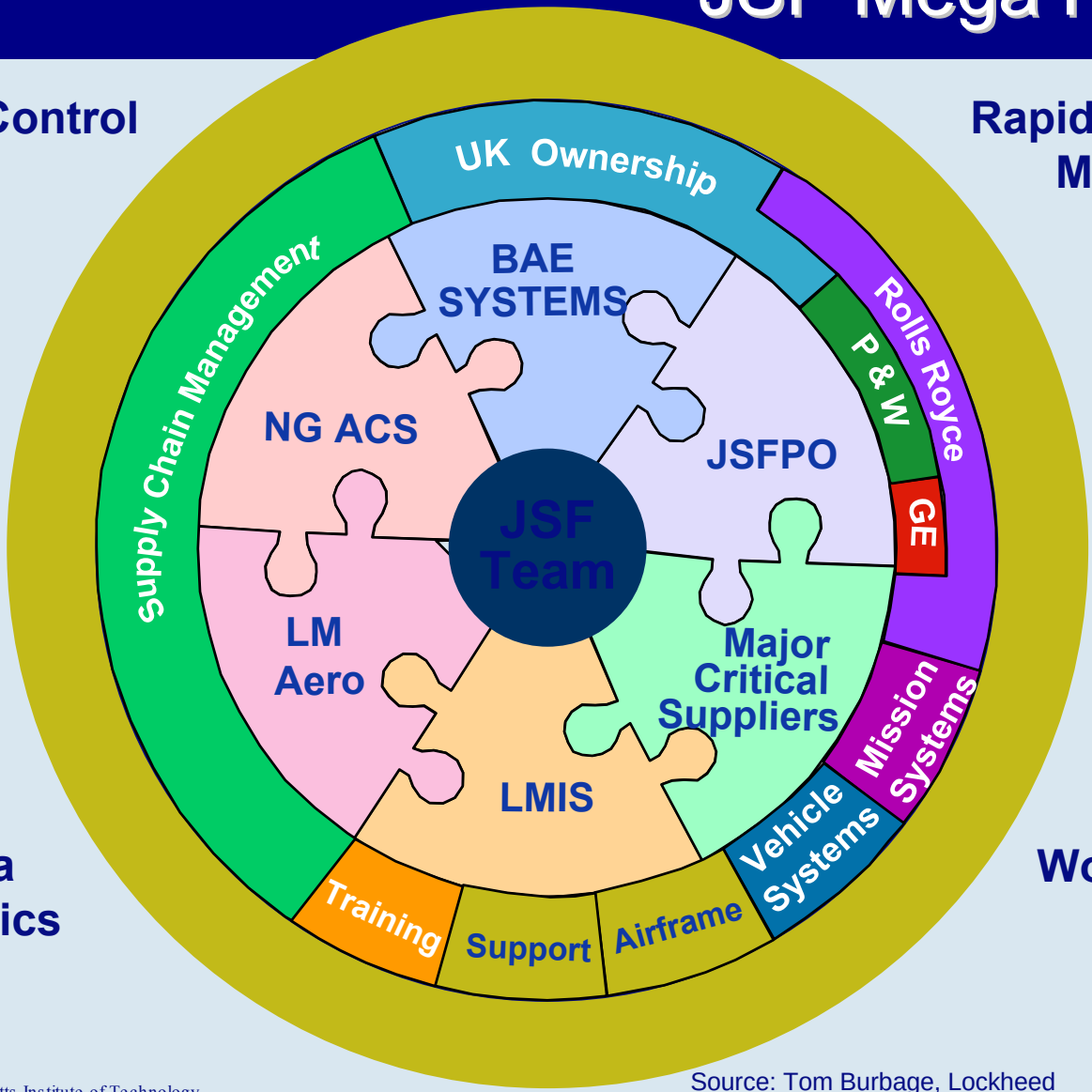
Rapid Decision Making

Decentralized Execution

Flexible Repositioning

Status at a Glance Metrics

World Class Team

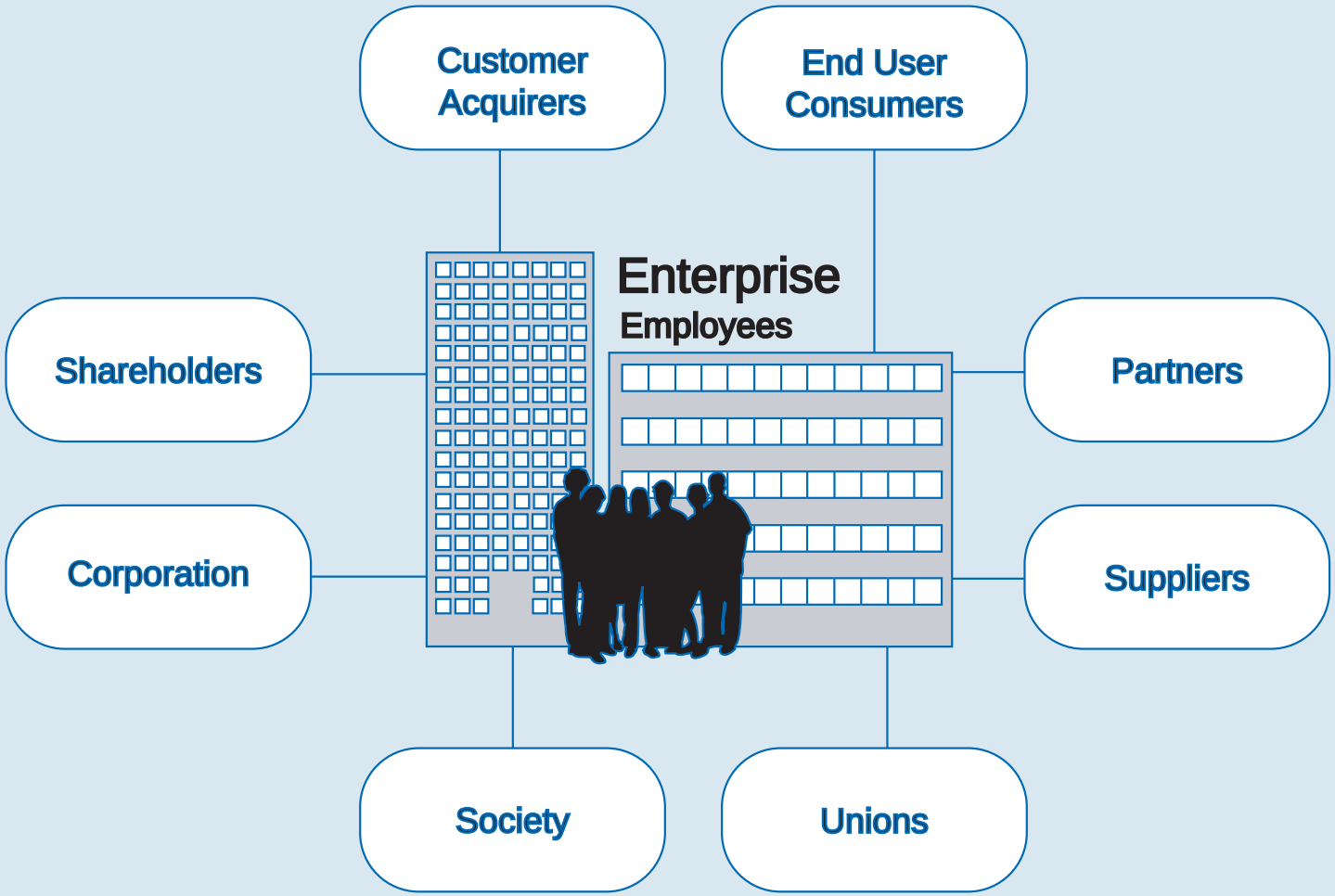





Source: Tom Burbage, Lockheed Martin Aeronautics

Lean Aerospace Initiative

# Enterprise Stakeholders



Lean Aerospace Initiative

# Lean Enterprise Value Principles

I. Create lean value by doing the right job and doing the job right

II. Deliver value only after identifying stakeholder value and constructing robust value propositions

III. Fully realize lean value only by adopting an enterprise perspective

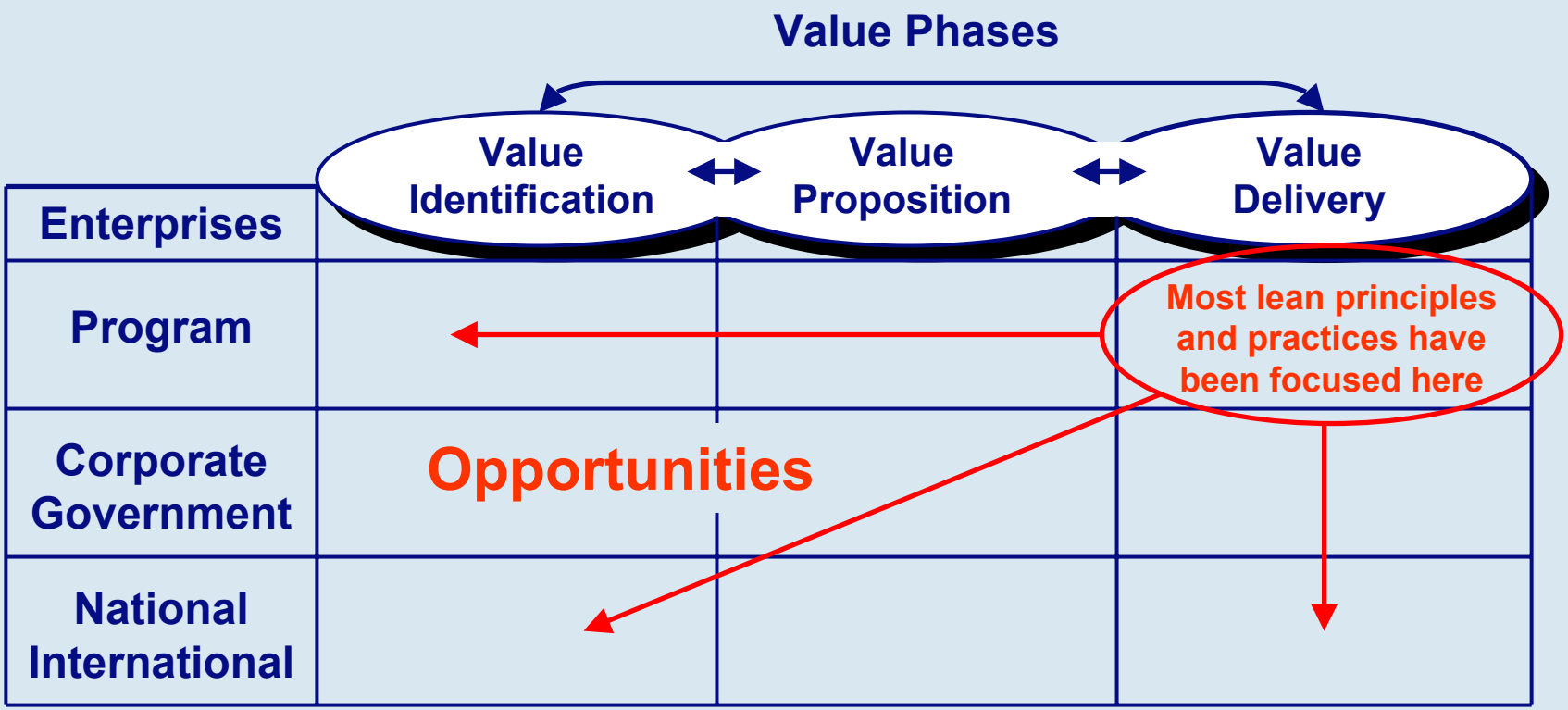
IV. Address interdependencies across enterprise levels to increase lean value

V. People, not processes, effectuate lean value

Lean Aerospace Initiative

# A Value Creation Framework

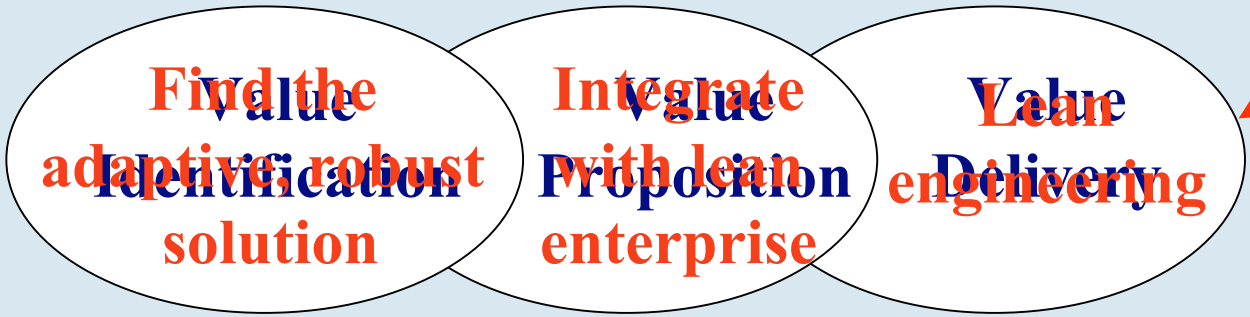


# Lean Engineering

# Value Creation Framework




Most lean done here

Challenge for PD: apply lean to existing processes to "do the job right"

Find stakeholder value

Agree to and develop the approach

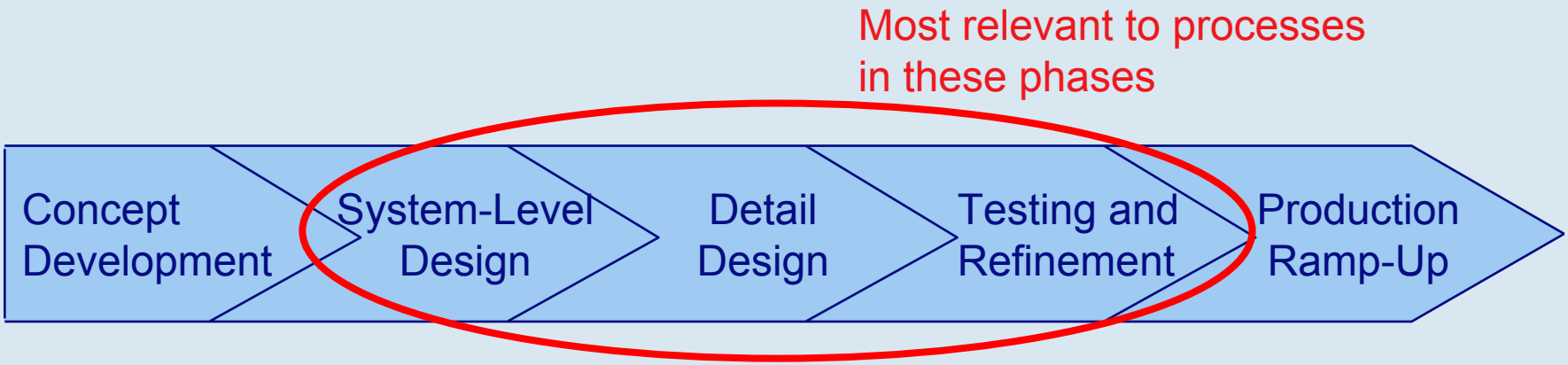
Execute on the promise

Want to drive lean upstream

"Do the right job"

# Process is Important in Engineering

- **For this discussion, Engineering is defined as preliminary and detailed design and analysis, process design, and validation and verification**




**Phases of Product Development**

From Ulrich & Eppinger, ***Product Design and Development***, 1995

# Focus on Process Can Eliminate Waste

- **Effort is wasted**
  - **40% of PD effort "pure waste", 29% "necessary waste"** *(workshop opinion survey)*
  - **30% of PD charged time "setup and waiting"** *(aero and auto industry survey )*
- ***Time* is wasted**
  - **62% of *tasks* idle at any given time** *(detailed member company study)*
  - **50-90% task idle time found in Kaizen-type events**



***Industry experience shows improved process cuts waiting time and improves information flow***

Lean Aerospace Initiative

# Engineering & Manufacturing have Similarities and Differences

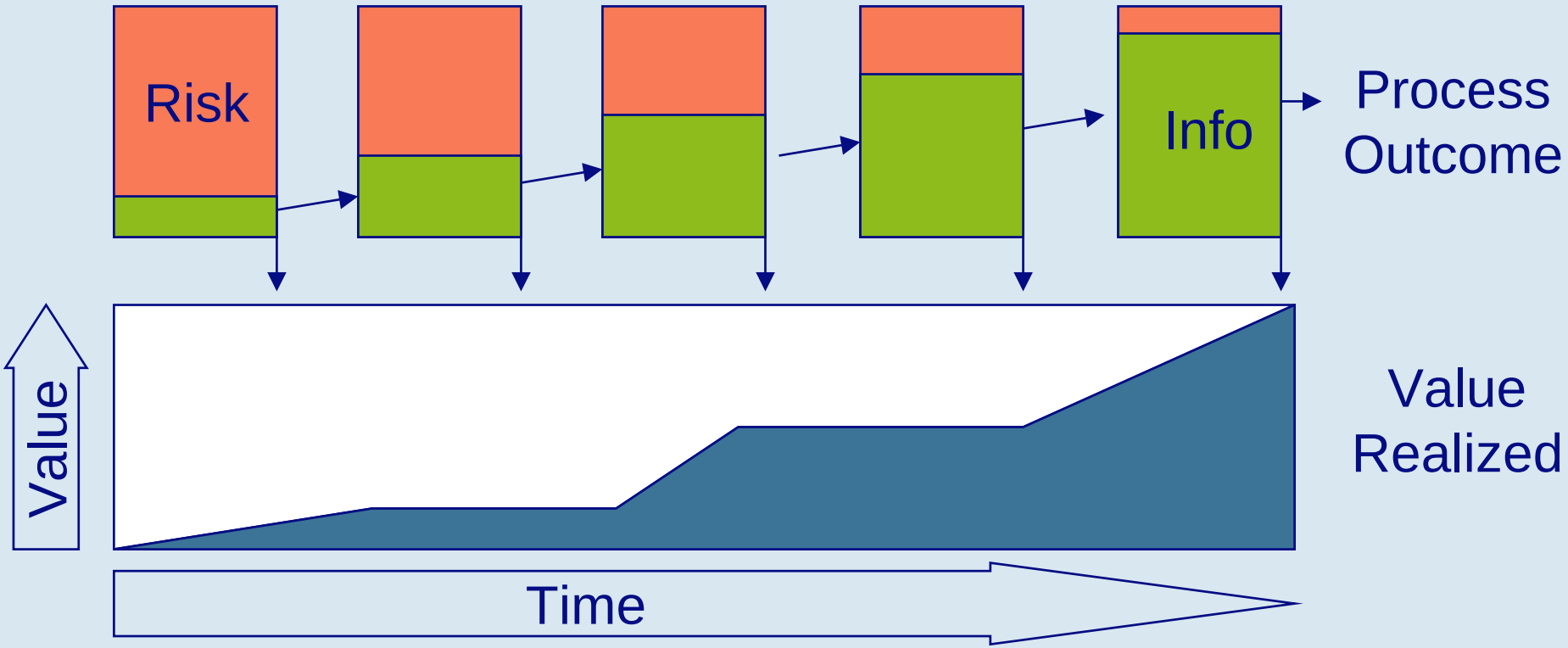
| | Manufacturing | Engineering |
|---|---|---|
| Define Value | Visible at each step, defined goal | Harder to see, emergent goals |
| Identify Value Stream | Parts and material | Information & knowledge |
| Make process flow | Iterations are waste | Iterations often beneficial |
| Customer pull | Driven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

Lean Aerospace Initiative

# Engineering Value is Emergent

Activities accumulate information, eliminate risk, use resources

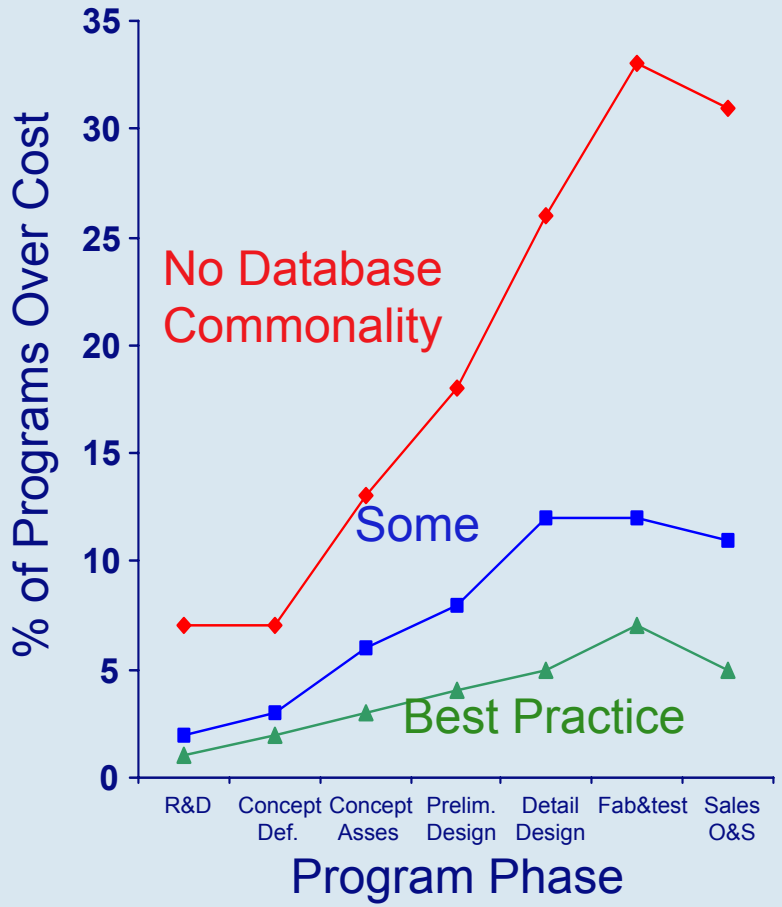



**Adapted From Chase, "Value Creation in the Product Development Process", 2001.**

Lean Aerospace Initiative

# Engineering Requires the Seamless Flow of Information *and Knowledge*




## Two Requirements

- **Easy availability of information**
- **Communication of emerging knowledge to enable learning and innovation**

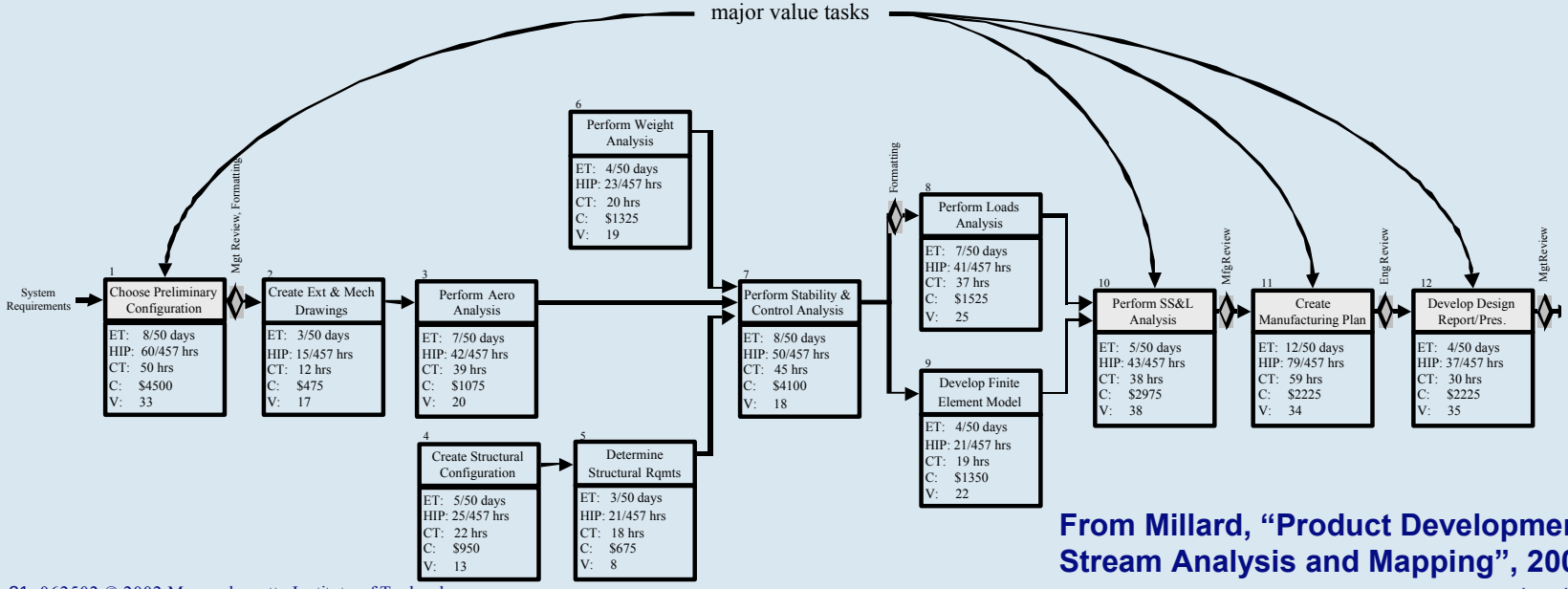
**From Hoult et al., "Cost Awareness in Design: The Role of Data Commonality", 1995.**

Lean Aerospace Initiative

# Making Processes Flow

- Value Stream Mapping and Analysis required for understanding
- Process mapping and Design Structure Matrix methods most powerful for process improvement
- Process mapping customized for Product Development developed - planned LEV product

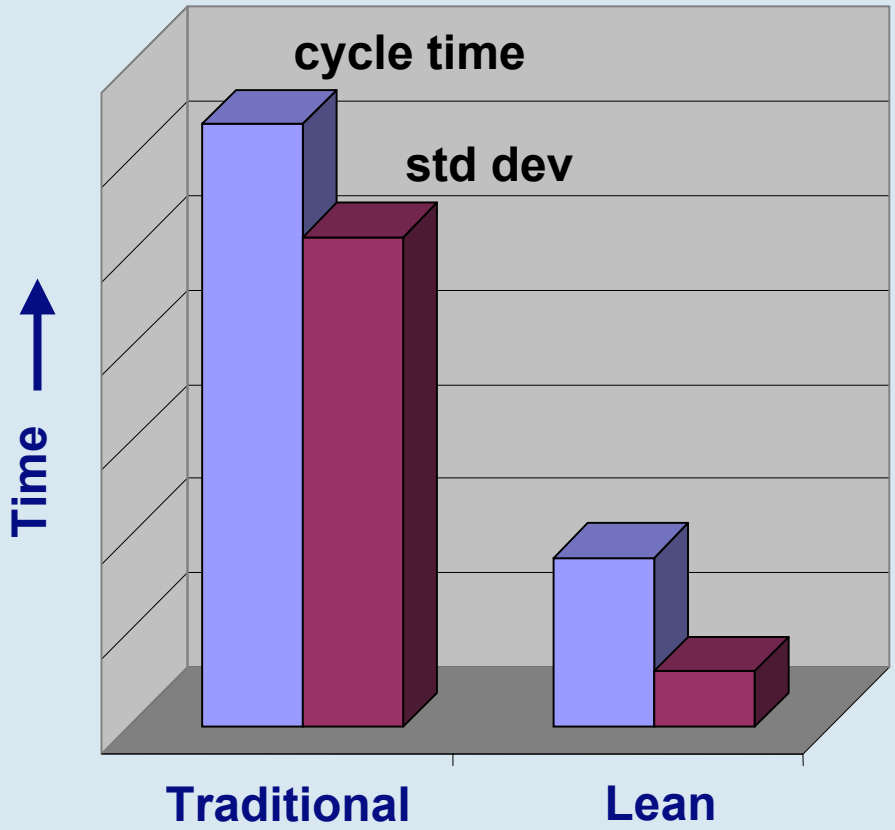



From Millard, "Product Development Value Stream Analysis and Mapping", 2001

# Engineering Release: Taking out Waste and Cycle Time

- Value stream mapped and bottlenecks found
- Process rearranged for sequential flow without iteration
- Waiting and delays removed

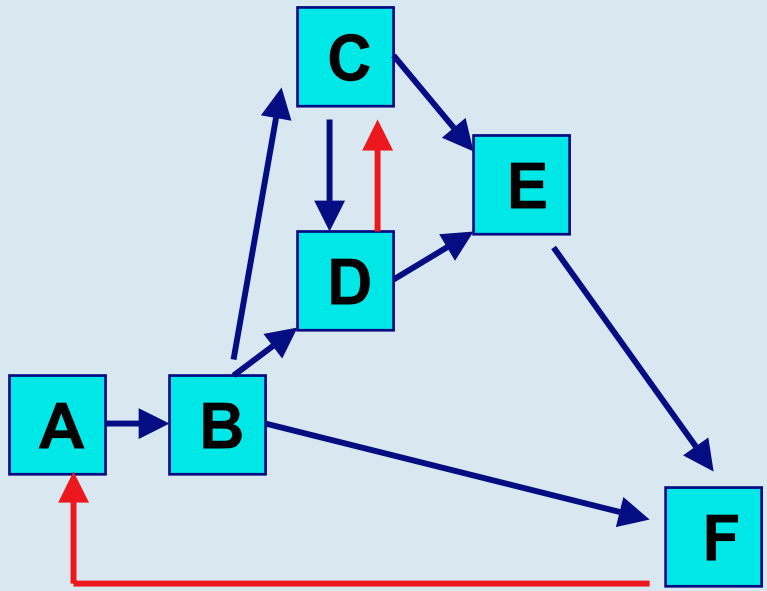



- Reduced Cycle time by 73%
- Reduced Rework of Released Engr. from 66% to <3%
- Reduced Number of Signatures 63%

# Emergent Processes Require iteration

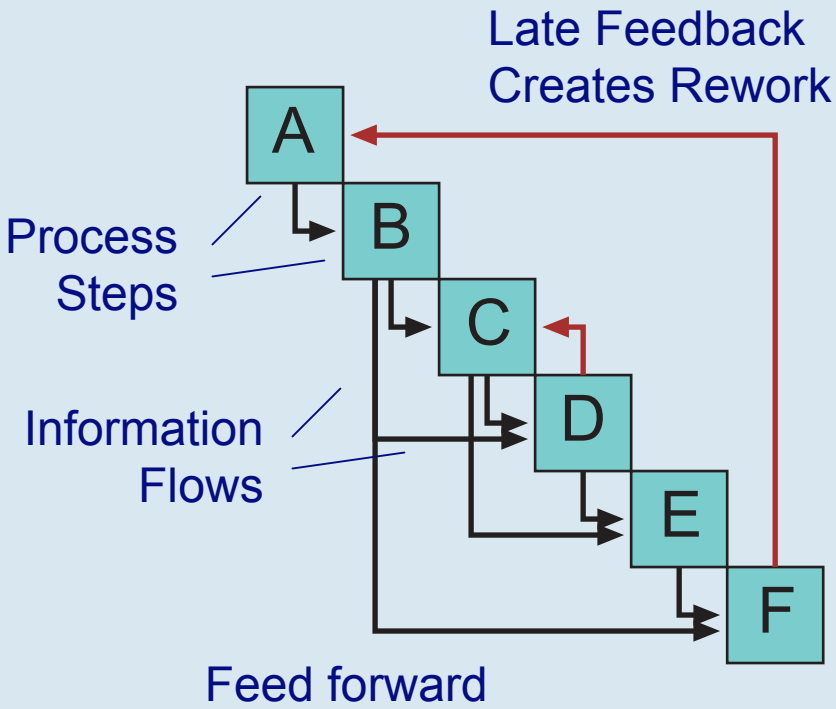
- Processes often *interdependent* (the chicken/egg problem)
- Knowledge of the best design may be *emergent* - revealed with iteration
- Risks and uncertainties may need to be driven out by iteration



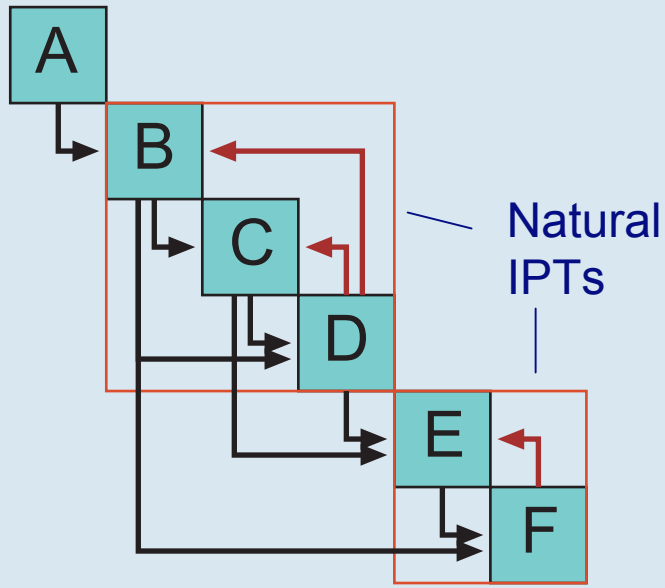

 

Lean Aerospace Initiative

# Iteration Should be Managed to Avoid Unnecessary Rework




Unmanaged Iteration



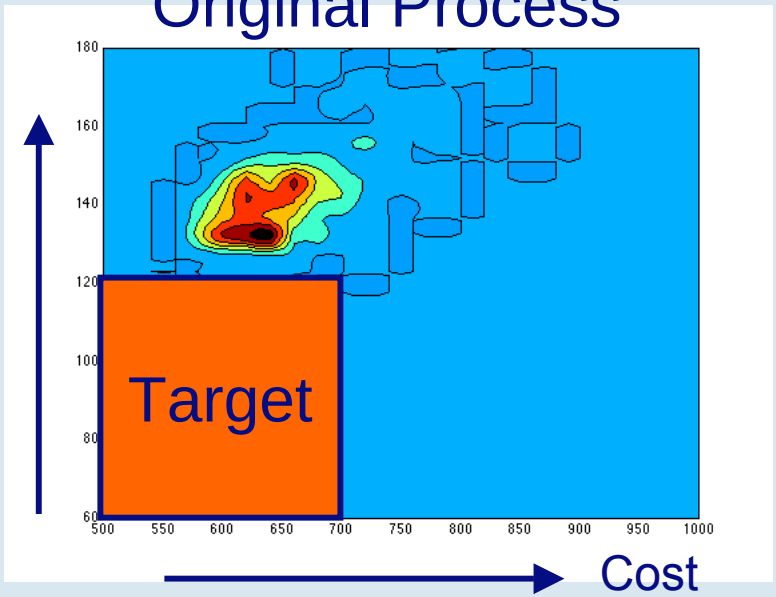

Managed Iteration

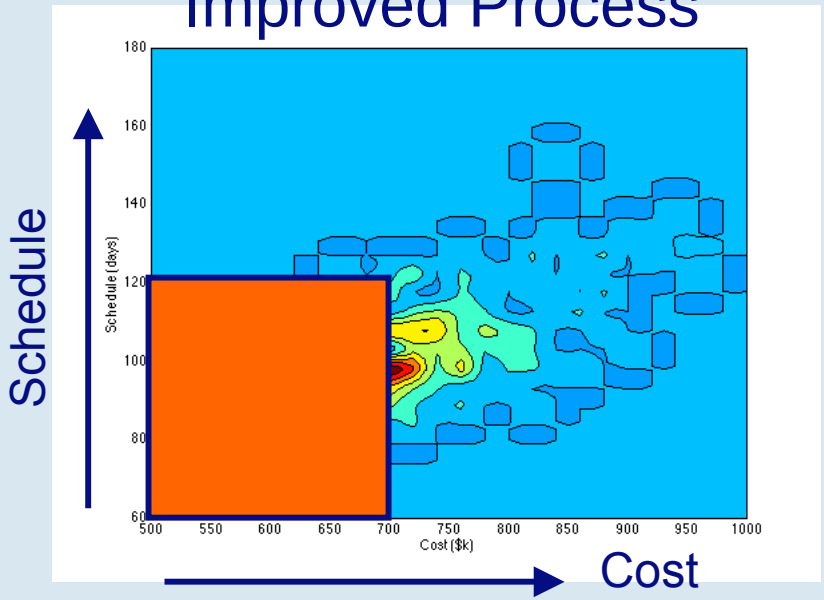
# Probabilistic Modeling Illuminates Opportunities for Process Improvement

- **Probabilistic model of preliminary design process shows original process too slow due to rework cycle**
- **Improved processes faster; *in this case*, slightly more expensive in terms of engineering hours, and slightly less predictable**

Original Process




Improved Process




From Browning, 1999

# Conclusions

- Application of Lean principles to make processes standard and efficient eliminates waste and reduces engineering cycle time
- Standard, efficient processes enables higher quality engineering, more innovation and a more producible product