2009 Mini-Conference

Brief Introduction to Lean Enablers for Systems Engineering

INCOSE-LA Miniconference Feb 7, 2009

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Lean Systems Engineering Working Group

Bio of Bohdan "Bo" W. Oppenheim

<u>The product was developed by the Lean SE WG. I am only presenting.</u>

- Professor of Mechanical and Systems Engineering, LMU, Los Angeles
- Coordinator of the Lean Aerospace Initiative Educational Network at MIT
- Founder and Co-Chair of the Lean Systems Engineering Working Group of INCOSE
- Education:
- PhD, 1980, U. Southampton, U.K., in System Dynamics
- Naval Architect, 1974, MIT
- M.S., 1972, Stevens Institute of Technology, in Ocean Systems
- B.S.(equivalent), 1970, Warsaw Technical University, Mechanical Engineering and Aeronautics (MEL)
- Northrop-Grumman (2007-2008), Aerospace Corporation (1990-1994), Northrop (1985-1990), Boeing SD (2004)
- IAE Fellow.

Full Version

- **Full version will be presented during the INCOSE-LA Tutorial on March 21, 2009 at LMU**

1. History
2. Lean Fundamentals
3. Lean Systems Engineering = synergy of Lean + SE
4. Development of LEfSE
5. The Product: LEfSE
6. “Validation”
7. Summary

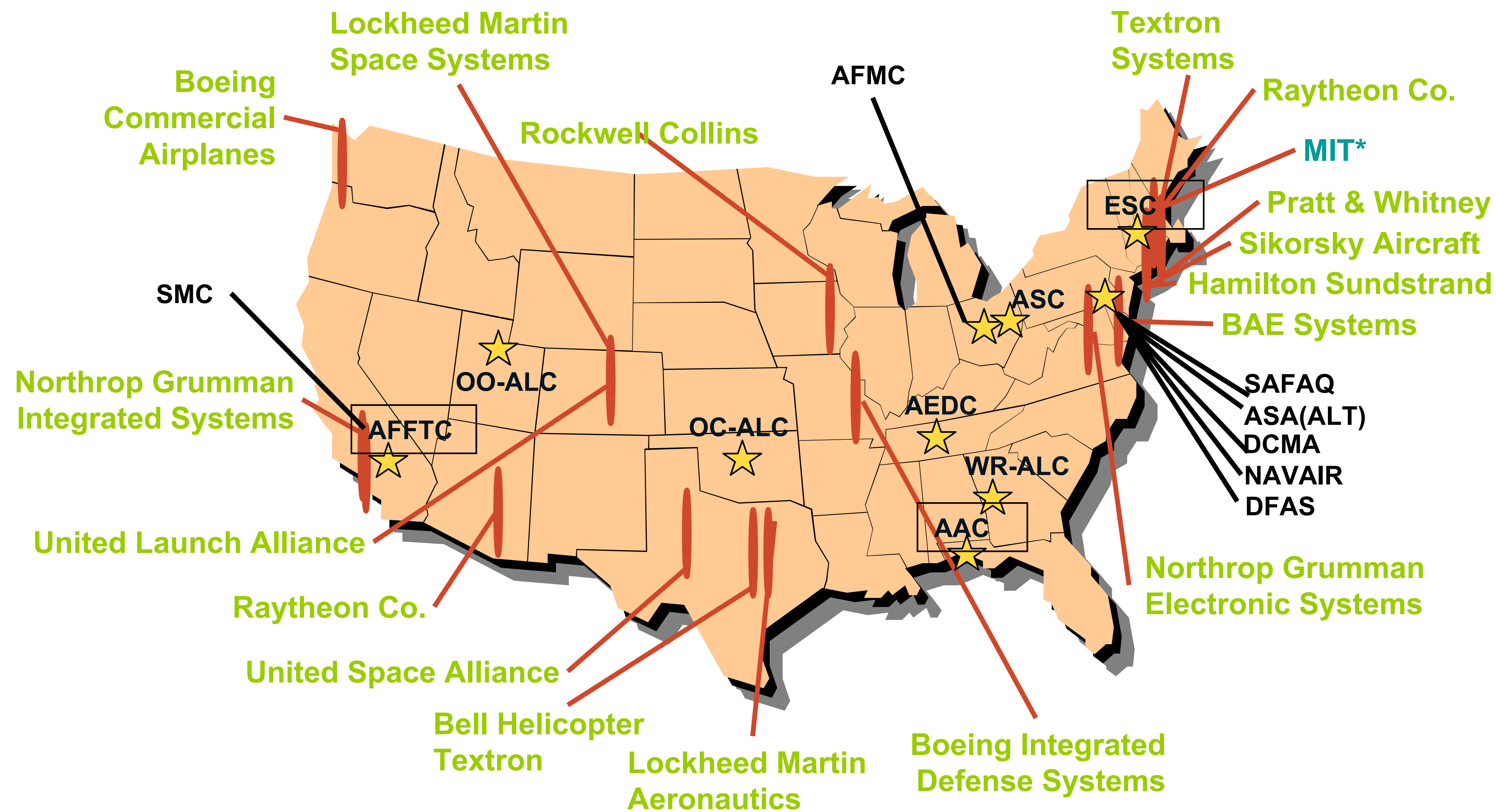
Part 1. History
From LAI to INCOSE

Origins at the MIT LAI

- 1992 Lean Aerospace Initiative consortium started at MIT
- 1992-present major research by the LAI community in various areas of Lean
- 2003: LAI invited other universities to join the LAI Educational Network, some active in Lean research
- 2004 – Lean SE working group was formed within the EdNet, migrated to INCOSE in 2006
- 2007 – LAI renamed to Lean Advancement Initiative (//lean.mit.edu)

LAI Membership 2008

U.S.Military



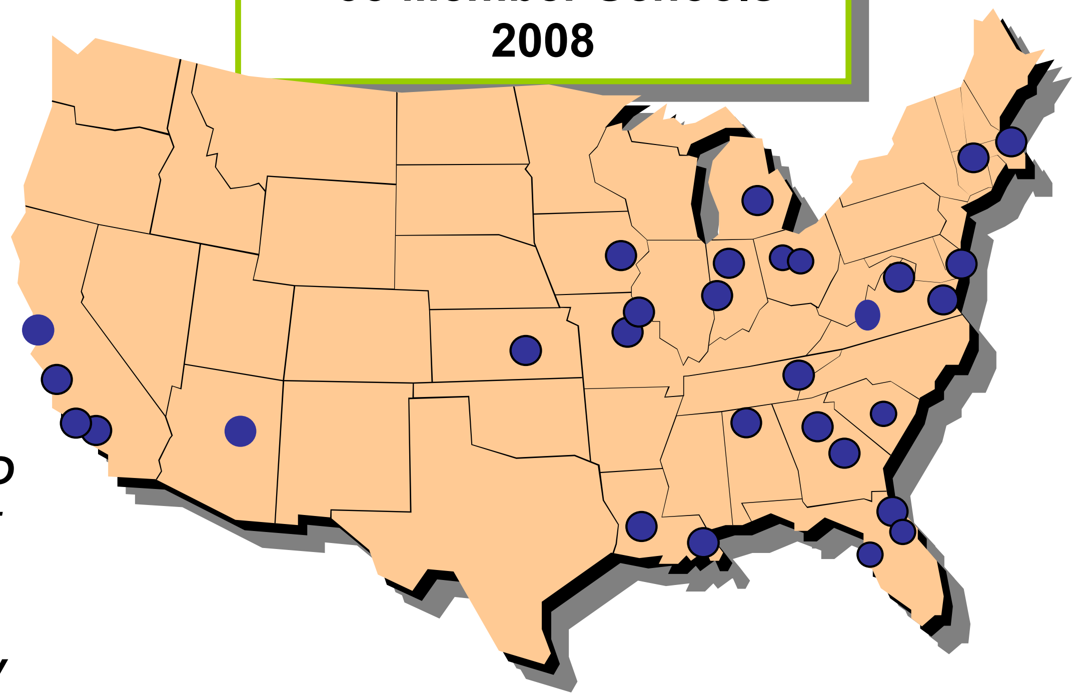
LAI Lean Academy™

http://lean.mit.edu

LAI Educational Network "EdNet", 2008

AFIT
AZ State U
Cal Poly SLO
Cranfield (UK)
DAU
Embry-Riddle
Georgia Tech
Indiana State Univ
Jacksonville Univ
Loyola College, MD
Loyola Marymount
Macon State Col
MIT
Old Dominion Univ
North Carolina State
Purdue Univ
St. Louis Univ, MO
San Jose State Univ

35 Member Schools 2008



3 UK

2 Mexico

Tecnológico de Monterrey (MX)
Universidad Popular Autónoma del Estado de Puebla (MX)
U of AL, Huntsville
U of Iowa
U of Michigan
U MO Rolla
USC
U of Bath (UK)
U of South Florida
U of Tenn, Knoxville
U of New Orleans
U of Louisiana, Lafayette
University of VA
U of Warwick (UK)
Wichita State Univ
Wright State Univ
WPI

The INCOSE Lean SE Working Group

- Initiated in Jan. 2006 in ABQ
- In order to draw on the collective wisdom of INCOSE members
- November 2008: 100+ names and growing
- Major current effort: Development of Lean Enablers for Systems Engineering (LEfSE)
- Co-chairs:
  - Ray Jorgensen*, Rockwell Collins, IA
  - Earll Murman, MIT, ret.
  - Bo Oppenheim*, LMU, Los Angeles
  - Deb Secor*, Rockwell Collins, IA

Part 2.
Lean Fundamentals

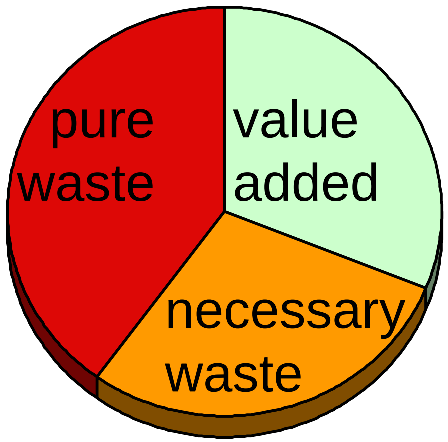
Lean Thinking

- **Lean = The thinking** credited for the extraordinary success of Toyota
- Toyota's Product Development process (including Systems Engineering) is widely recognized as the best in the world
- Example: Prius designed in 9 months
- Three concepts are fundamental to the understanding of Lean:
  - Value
  - Waste
  - The process of creating Value without Waste

Definition of Value in Lean SE

"Flawless Mission Assurance or product success delivered without waste, in the fastest possible time"

Huge Waste Exists in Programs



- **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**

Source: McManus, H.L. "Product Development Value Stream Mapping Manual", LAI Release Beta, April 2004

Ohno's Categorization of Waste into Seven Types

1. Over-production	Creating too much material or information
2. Inventory	Having more material or information than you need
3. Transportation	Moving material or information
4. Unnecessary Movement	Moving people to access or process material or information
5. Waiting	Waiting for material or information, or material or information waiting to be processed
6. Defective Outputs	Errors or mistakes causing the effort to be redone to correct the problem
7. Over-processing	Processing more than necessary to produce the desired output

An example in Backup slides

Lean Thinking Captured into Six Lean Principles

1. Capture customer value
2. Map the value stream: prepare for and plan all end-to-end linked actions and processes necessary to realize value, streamlined, after eliminating waste
3. Make value flow continuously: without stopping, rework or backflow (valid iterations OK)
4. Let customers pull value: Customer's "pull/need" defines all tasks and their timing
5. Pursue perfection: all imperfections become visible, which is motivating to the continuous process of improvement
6. Respect people

Part 3.
Lean Systems Engineering

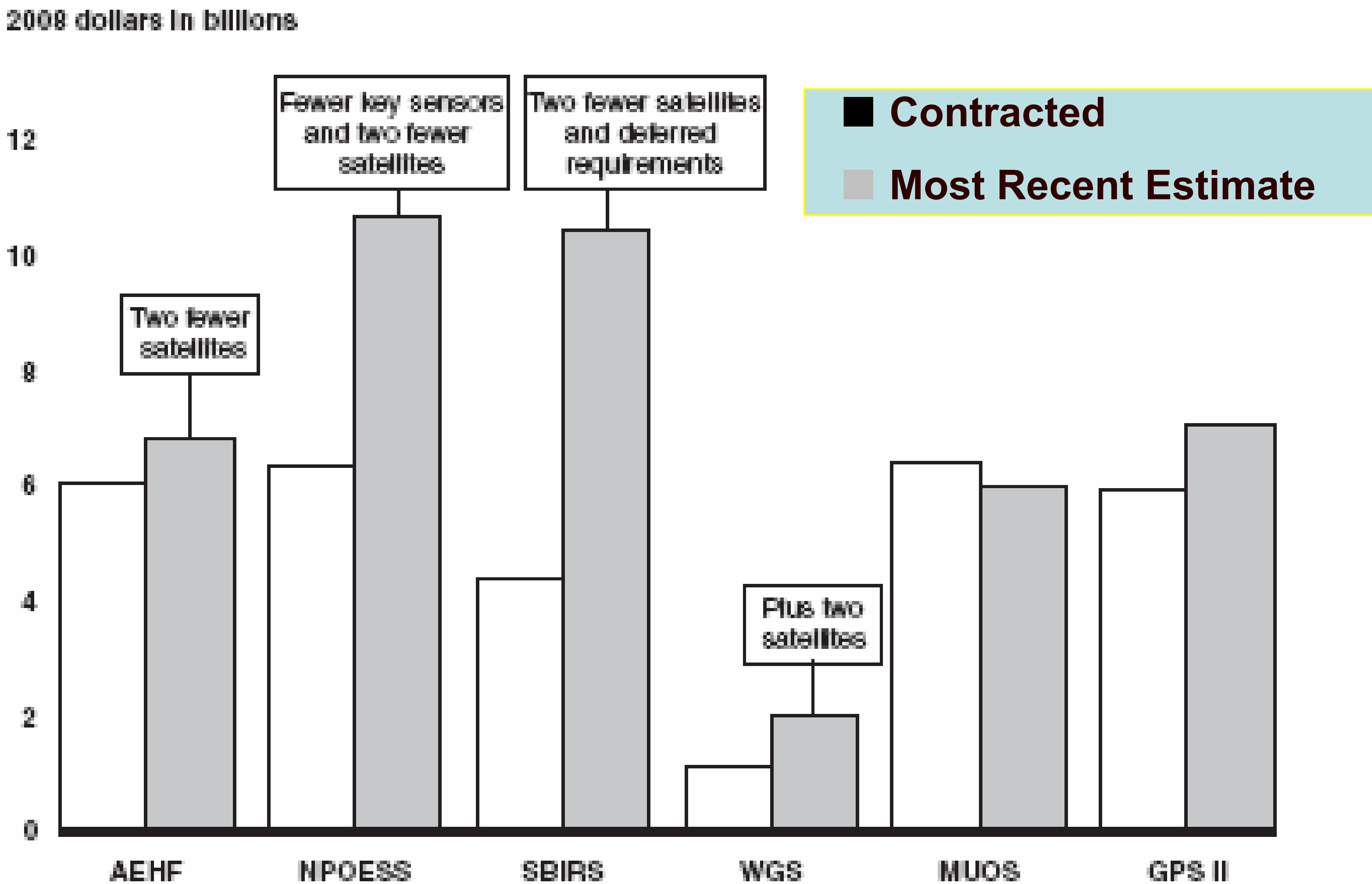
Laud calls for Improving SE

- **Recent Programs provided Mission Assurance but are notorious for schedule and budget overruns**

- **Numerous NASA and GAO studies call for improvements of the SE process**

Need for Better SE: Cost Overruns

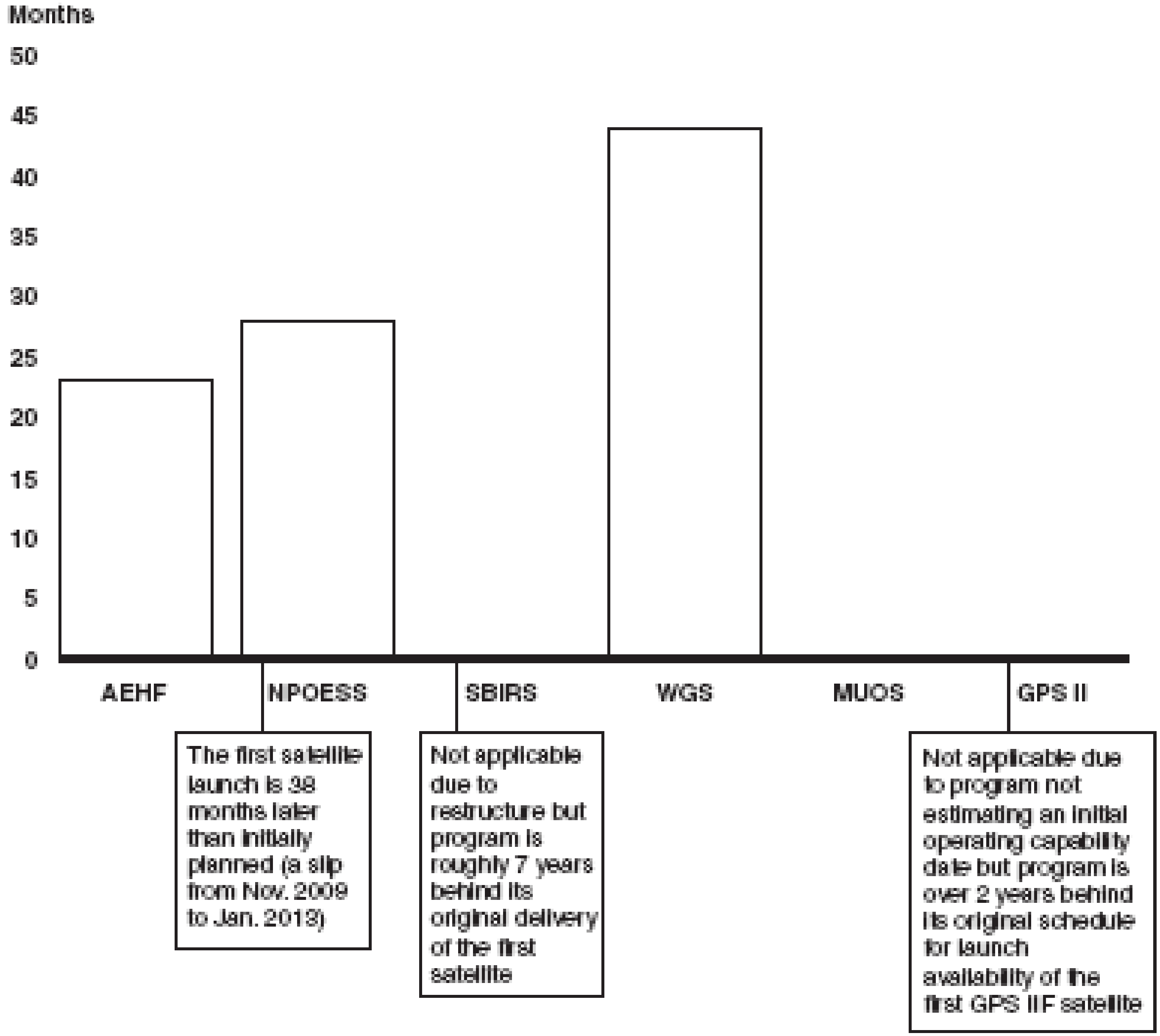
Figure 1: Differences in Total Program Costs from Program Start and Most Recent Estimates



GAO: Space Acquisitions, 2008

Schedule Overruns

Figure 2: Additional Months Needed since Program Start



Source: GAO analysis of DOD data.

Synergy of Lean and Systems Engineering

- **Systems Engineering:** **Deliver flawless complex systems**
  - **Focus:** technical performance **and** risk management
  - **Poor focus:** business success

- **Lean:** **Deliver quality products at minimum cost**
  - **Focus:** waste minimization, short schedules, low cost**,** flexibility, quality

- **Common goal: Deliver system lifecycle value to the customer**

- **Lean Systems Engineering: is the area of synergy of Lean and Systems Engineering**
  - Deliver best lifecycle value for technically complex systems with minimum waste.

Adopted from Murman, 2006

Part 4.

Development of Lean Enablers for SE (LEfSE)

Overall Strategy for the Lean Enablers

- The underlying philosophy:
  - Produce a checklist of do's and don'ts of SE and EM
  - Aim for “the asymptote of excellence”
  - Ignore present regulations, policies, etc.
  - Capture collective wisdom and experience of practicing experts
  - Formulate for Industry SE practitioners
  - Utilize academic depth, breadth, and rigor.
- Lean Enablers not intended as a regulation or mandatory procedure.
- LE for SE should not repeat information already covered in the SE handbooks– which are considered sound, but lacking Lean Thinking

Development of LEfSE

- **The 15-months Development Followed the Established Process**
  - **Concept (Oct. 2007)**
  - **Alpha**
  - **Beta (including survey)**
  - **Prototype (including survey)**
  - **Version 1.0 released Feb.1, 2009**
  - **Online Change Process for future changes**

LEfSE

- **Result**
  - 194 practices
  - Full text:

    http://www.incose.org/practice/techactivities/wg/leansewg/
  - Paper submitted to Journal for SE
  - Massive dissemination (6 tutorials scheduled in 2009), more in planning

Part 5

The Product: Lean Enablers for Systems Engineering

EXAMPLE: Lean Principle 2: Map the Value Stream (Plan the Program)

3. **Plan for Front-Loading the Program. (U 0.33)**
   Examples: Toyota, Rockwell Collins
   1. **Plan to utilize cross-functional teams made up of the most experienced and compatible people at the start of the project to look at a broad range of solution sets. (U 0.36)**
   2. **Explore trade space and margins fully before focusing on a point design and too small margins. (U 0.36)**
   3. **Anticipate and plan to resolve as many downstream issues and risks as early as possible to prevent downstream problems. (U 0.40)** *Examples: F/A-18 E/F, B-777*
   4. **Plan early for consistent robustness and "first time right" under "normal" circumstances instead of hero-behavior in later "crisis" situations. (U 0.12)**

Lean Principle 1: Value

1. Follow all practices for the requirements capture and development in the INCOSE Handbook. In addition: (U 0.29)
2. Establish the Value of the End Product or System to the Customer. (U 0.60)
3. Frequently Involve the Customer. (U 0.92)

Lean Principle 2: Map the Value Stream (Plan the Program)

1. Plan the Program according to the INCOSE Handbook Process. In addition: (U 0.23)
2. Map the SE and PD Value Streams and Eliminate Non-Value Added Elements. (U -0.40)
3. Plan for Front-Loading the Program. (U 0.33)
4. Plan to Develop Only What Needs Developing (U -0.13)
5. Plan to Prevent Potential Conflicts with Suppliers. (U 0.40)
6. Plan Leading Indicators and Metrics to Manage the Program. (U 0.25)

Lean Principle 3: Flow

1. Execute the Program according to the INCOSE Handbook Process. In addition: (U 0.17)
2. Clarify, Derive, Prioritize Requirements Early and Often During Execution. (U 0.08)
3. Front Load Architectural Design and Implementation. (U 0.44)
4. Systems Engineers to accept Responsibility for coordination of PD Activities. (U 0.11)
5. Use Efficient and Effective Communication and Coordination. (U 0.22)
6. Promote Smooth SE Flow. (U 0.38)
7. Make Program Progress Visible to All. (U 0.18)
8. Use Lean Tools. (U 0.25)

Lean Principle 4: Pull

1. Tailor for a given program according to the INCOSE Handbook Process. In addition: (U 0.00)

2. Pull Tasks and Outputs Based on Need, and Reject Others as Waste. (U -0.22)

Lean Principle 5: Perfection

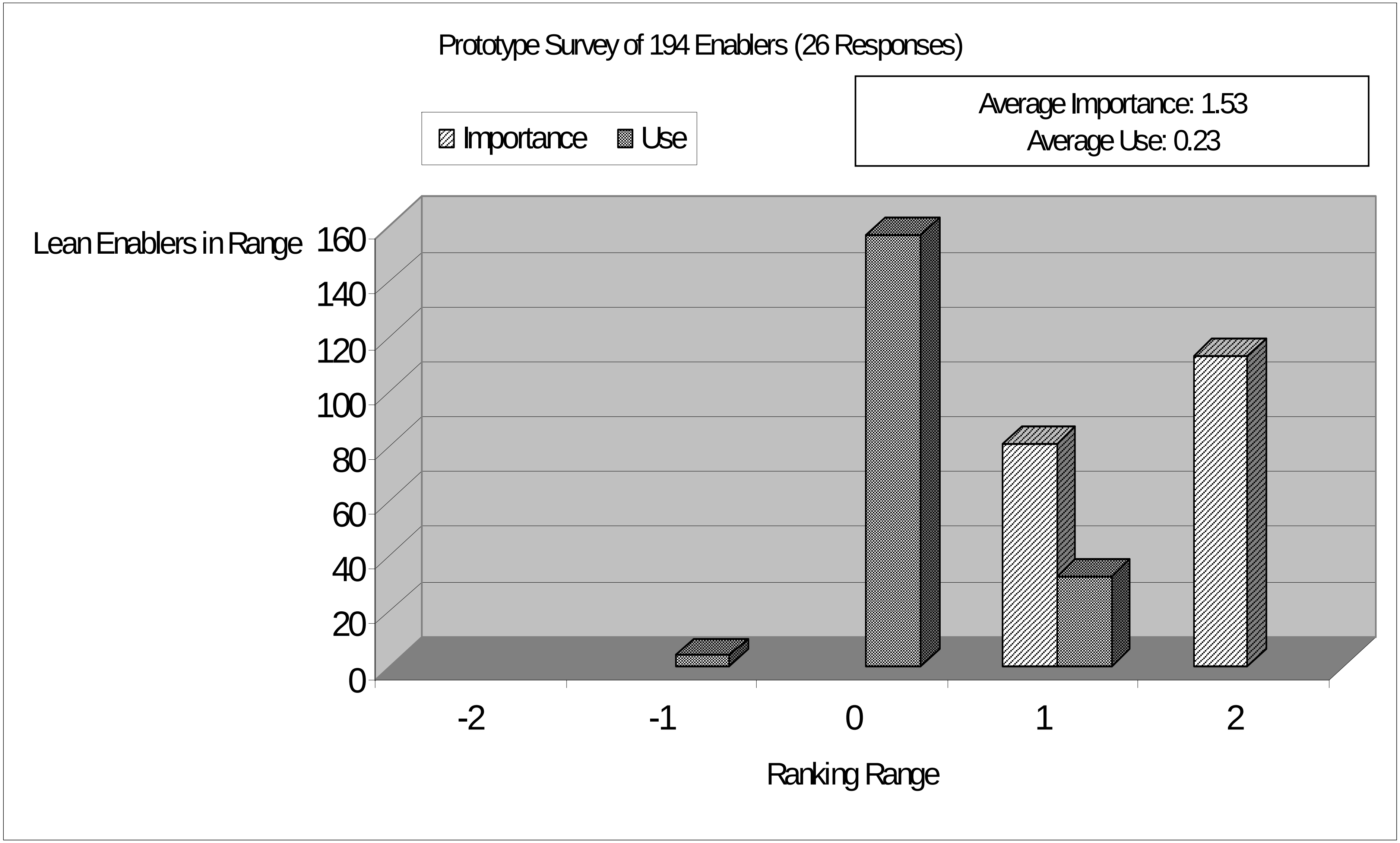
1. Pursue Continuous Improvement according to the INCOSE Handbook Process. In addition: (U 0.20)
2. Strive for Excellence of SE Processes. (U 0.44)
3. Use Lessons Learned from Past Programs for Future Programs. (U 0.11)
4. Develop Perfect Communication, Coordination and Collaboration Policy across People and Processes. (U 0.11)
5. For Every Program Use a Chief Engineer Role to Lead and Integrate Development from Start to Finish. (U 0.00)
6. Drive out Waste through Design Standardization, Process Standardization, and Skill-Set Standardization. (U 0.56)
7. Promote All Three Complementary Continuous Improvement Methods to Draw Best Energy and Creativity from All Employees. (U 0.63)

Lean Principle 6: Respect for People

1. Pursue People Management according to the INCOSE Handbook Process. In addition: (U 0.36)
2. Build an Organization Based on Respect for People. (U 1.00)
3. Expect and Support Engineers to Strive for Technical Excellence. (U 0.60)
4. Nurture a Learning Environment. (U 0.00)
5. Treat People as Most Valued Assets, not as Commodities. (U 0.70)

Part 6
"Validation"

Prototype Survey



Benchmarking with NASA's "Key Enablers for Systems Engineering"

NASA "Key Enablers of Successful Programs"	LSfSE Enabler #
Visionary Leadership - Role of organizational leadership in establishing a clear overarching purpose, deriving and articulating a compelling but credible vision to fulfill that purpose.	1.2.6, 1.3.1, 3.4, 5.5, 5.7, 6.2
Capability Maturity – Organization attainment of high levels of "Capability Maturity" to support and facilitate the undertaking of complex systems development	2.2, 2.3, 2.5, 3.3, 3.5, 3.6, 5.2, 5.3, 5.4, 5.6
Systems Engineering Culture – A pervasive mental state and bias for Systems Engineering methods applied to problem solving across the development lifecycle and at all levels of enterprise processes.	1.2, 1.3, 2.2.3, 2.6, 3.4, 3.6, 5.2
Design Robustness Mindset – High levels of focus on system safety and reliability driven by a bias toward achieving robustness, supported by the cultural attitude of "Failure is not an Option".	2.5, 5.2, 5.3, 5.4, 5.6, 5.7, 6.3
Accountability Structure - Effective decision making accomplished through clearly defined structures of assigned responsibility and accountability for decisions at appropriate levels and phases of system development.	5.2, 6.2, 6.3

NASA Pilot Benchmarking Initiative: Exploring Design Excellence Leading to Improved Safety and Reliability, October 2007

Additional Benchmarking with GAO Report

GAO Commercial Best Practices during Program Development	Lean Enabler #
• Use quantifiable data and demonstrable knowledge to make go/no-go decisions, covering critical facets of the program such as cost, schedule, technology readiness, design readiness, production readiness, and relationships with suppliers.	2.5, 2.6, 3.2, 3.3–3.7
• Do not allow development to proceed until certain thresholds are met—for example, a high proportion of engineering drawings completed or production processes under statistical control.	2.6.4, 5.2
• Empower program managers to make decisions on the direction of the program and to resolve problems and implement solutions.	1.2.5, 2.5, 3.5.7, 5.5, 6.2.8
• Hold program managers accountable for their choices.	5.5
• Require program managers to stay with a project to its end.	5.5
• Hold suppliers accountable to deliver high-quality parts for their product through such activities as regular supplier audits and performance evaluations of quality and delivery, among other things.	2.5
• Encourage program managers to share bad news, and encourage collaboration and communication.	3.5, 3.7

Part 7.

Summary

Summary

- Lean SE does not mean less SE
  - Lean SE usually means more SE
  - For less waste during the subsequent program execution
  - But the SE must be of an excellent quality
  - With more RAA (Responsibility, Accountability, Authority)
  - So, Lean SE is not a repackaged FBC
- Emphasis on frontloading of programs
  - Better capture of customer needs
  - Better preparations and better planning
- Emphasis on "right the first time"
  - This does not mean "leave mistakes uncorrected"
  - It means "prepare, plan and coordinate to avoid mistakes"
- Emphasis on best engineering and business practices
- Emphasis on best coordination and communication among all stakeholders (customer, suppliers, teams)

Summary- Cont.

- In Lean SE, Mission Assurance is not negotiable!
- Any task which legitimately is needed for Mission Assurance must be included
- Mind boggling number of opportunities to improve our programs without sacrificing quality
- Many of present tasks taking months can be done in one week
  - with better quality
  - without speeding up any Value-Adding activity
  - just by cutting the waiting and mindless repetitions

Backup slides

Credits for the Work on LEfSE

- Concept-through-Beta Team (Oct 07- Jan 08)
  - Earll Murman*, MIT, Core Team Co-lead
  - Col. Jim Horejsi, SMC
  - Mike Schavietello, Boeing
  - Jim Zimmer, Toyota
  - Larry Earnest, NGIS
  - Deb Secor, Rockwell Collins
  - Ray Jorgensen, Rockwell Collins
  - Bo Oppenheim*, LMU, Core Team Co-lead

    * Prepared Alpha and Beta versions
- Beta survey (29 respondents)
- Prototype Team (Jan. 28 – June 19)
  - Larry Earnest (Northrop Grumman-IS) larry.earnest@ngc.com
  - Roy Jorgensen (Rockwell Collins) rwjorgen@rockwellcollins.com
  - Ron Lyells (Honeywell ABQ) ron.lyells@honeywell.com
  - Bo Oppenheim** (LMU) boppenheim@lmu.edu
  - Uzi Orion (ELOP) uzio@elop.co.il
  - Dave Ratzer (Rockwell Collins) dlratzer@rockwellcollins.com
  - Deb Secor (Rockwell Collins) dasecor@rockwellcollins.com
  - Hillary G. Sillitto (UK MoD Abbey Wood) hillary.sillitto@incose.org
  - Stan Weiss (Stanford Univ.) siweiss@stanford.edu
  - Avigdor Zonnenshain avigdorz@rafael.co.il

    ** Coordinating Editor of the Prototype
- Prototype survey (26 respondents at large)
- Lean SE Working Group (100+ members) reviewing
- Co-Chairs released Version 1.0

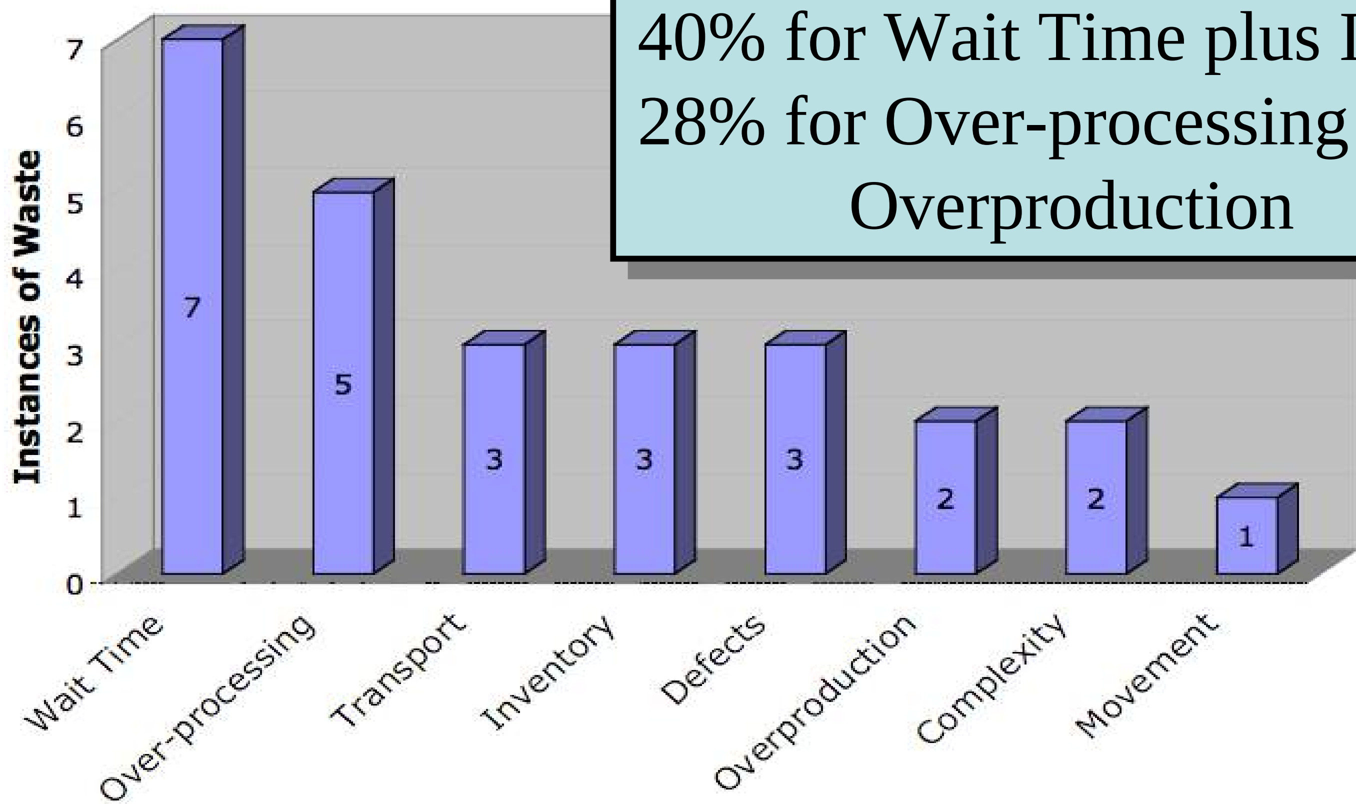
Example of Waste of Category 1: Overproduction

Adopted for PD

WASTE	EXAMPLES/DESCRIPTION
1. Overproduction	• Creating unnecessary information • Performing work which is not needed • Creating documents that nobody requested • Pushing data rather than pulling data • Over dissemination = sending information to too many people (just think of email copies) • Too much detail, administrative overhead • Sending a volume when a single number was requested • Reinventing the wheel • Needlessly repetitive development • Some meetings • Ignored expertise • Discarded knowledge (layoffs!) to be rediscovered • Measuring waste in some Six Sigma projects

Adopted by Oppenheim, with elements from LAI EdNet

Measurement of Info Waste for 25 Organizations



40% for Wait Time plus Inventory
28% for Over-processing plus Overproduction

Slack, Robert A., “Application of Lean Principles to the Military Aerospace Product Development Process,” Masters thesis in Engineering and Management, Massachusetts Institute of Technology, December 1998.