16.885J/ESD.35J
Aircraft Systems Engineering

September 4, 2003

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Today's Class

- Course introduction
- Course learning objectives & measurable outcomes
- 21st Century Jet: The Building of the 777
  - Interleaved video and discussion on aircraft systems engineering
- Semester case study
- Administrivia
- Grading
- Class discussion

Course Introduction

- Holistic view of aircraft as a system
  - Systems Engineering and System Level Attributes (12 lectures)
  - Subsystems: The Anatomy of an Aircraft (7 lectures)
  - System Realization (6 lectures)
- Retrospective analysis - studying existing aircraft to learn about design choices and features
- Apply knowledge to semester long case study
- Emphasis is more on “aircraft systems” than on “systems engineering”
- Learning community approach
  - We are all teachers and learners
  - Be engaged

Course Learning Objectives

At the completion of 16.885, students will have gained:

- An appreciation of an aircraft as a system, operating within a larger air transportation or air defense system, and comprised of many subsystems
- Understanding of, and ability to apply, basic concepts for:
  - Systems engineering: requirements, interface mgmt, verification & validation
  - Cost and weight analysis and estimation.
  - Performance analysis
  - Reliability and safety
  - The function, architecture and key performance issues of major subsystems
  - Risk analysis and management
  - Design closure to deliver lifecycle value
- An ability to understand complex systems and design choices through the retrospective analysis of existing aircraft systems.

Course Measurable Outcomes

- Retrospective analysis of an existing aircraft design, delivered in both written and oral forms.
- Individual contributions to case study team effort as reported by student and teammates.
- Class participation.
- End of semester interview with course faculty on achievement of learning objectives.

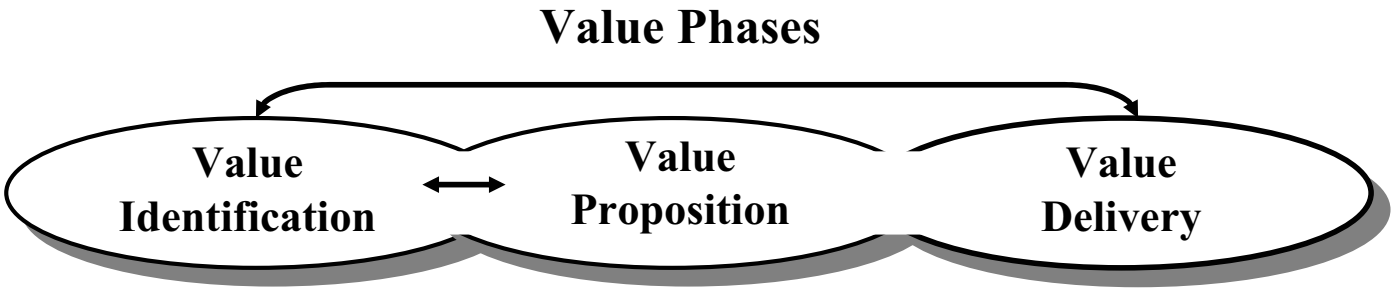
Segment from PBS Home Video *21st Century Jet: The Building of the 777*

Part I - 9:15-16:10 (6 min 50 sec)

Covers the 777 “Value Proposition” struck between United Airlines and Boeing

Value Creation Framework

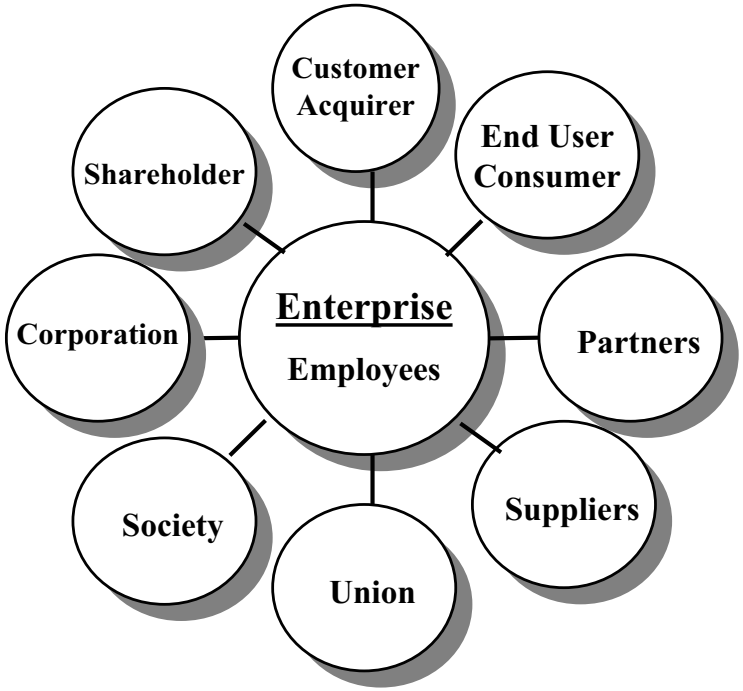
Value - how various stakeholders find particular worth, utility, benefit, or reward in exchange for their respective contributions to the enterprise.



Identify the stakeholders and their value expectations	Develop a robust value proposition to meet the expectations	Deliver on the promise with good technical and program performance

Source: *Lean Enterprise Value: Insights from MIT's Lean Aerospace Initiative,* Murman, et. al 2002

The Challenge of Architecting and Engineering Aircraft Systems



Stakeholders

A fundamental challenge of any program is to satisfy multiple stakeholders expectations for product

- Performance/quality
- Schedule/availability
- Cost/financial return

with acceptable risk.

Segment from PBS Home Video *21st Century Jet: The Building of the 777*

Part I - 17:12-20:32 (3 min 30 sec)

Addresses the technical complexity of aircraft with its many components which interact, requiring the use of mockups, originally physical and now digital, to visualize the interactions.

Technical Dimension

6 Level Hierarchy

0 - Physical environment of the world

1 - The air transportation system or the air defense system

2 - The aircraft and/or related systems

3 - Major subsystems or subassemblies: both hardware and software

4 - Components or major software units

5 - Parts or lines of code

The "Inters"

- Interrelationship: "mutual or reciprocal relation or relatedness".
- Interrelationships take various forms with increasing degrees of relatedness
  - Interconnections (or interfaces): "a state of being connected reciprocally"
  - Interactions: "mutual or reciprocal action or influence"
  - Interdependencies: "mutual dependence"
- Large-scale systems are characterized by many elements which, through their interrelationships, deliver greater capability than the sum of the individual elements alone.

Source: http://www.dictionary.com/

Examples of Technical Dimension Inters

6 Level Hierarchy

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- Emissions from engines (3) multiplied by size of a/c fleet (1) impacts global environment (0).
- Engine (3) provides thrust for wing (3) which provides lift for engine, both coupled through aerodynamics
- AA Flight 261 accident
  - Stripped elevator lead screw (5) caused loss of a/c system (2)
  - Maintenance system (2) interacted with a/c system (2)

Segment from PBS Home Video *21st Century Jet: The Building of the 777*

Part I - 22:05-27:45 (5 min 40 sec)

Introduces Design Build Teams (or Integrated Product Teams) and shows one in action sorting out solutions to crack formation and growth in a passenger door

Social Dimension

6 Level Hierarchy

0 - Society, nations, communities, etc.

1 - Extended multi-organization enterprises, including partners and suppliers

2 - Single organizations

3 - Organizational units

4 - Working groups/teams

5 - Individuals

Examples of Social Dimension Inters

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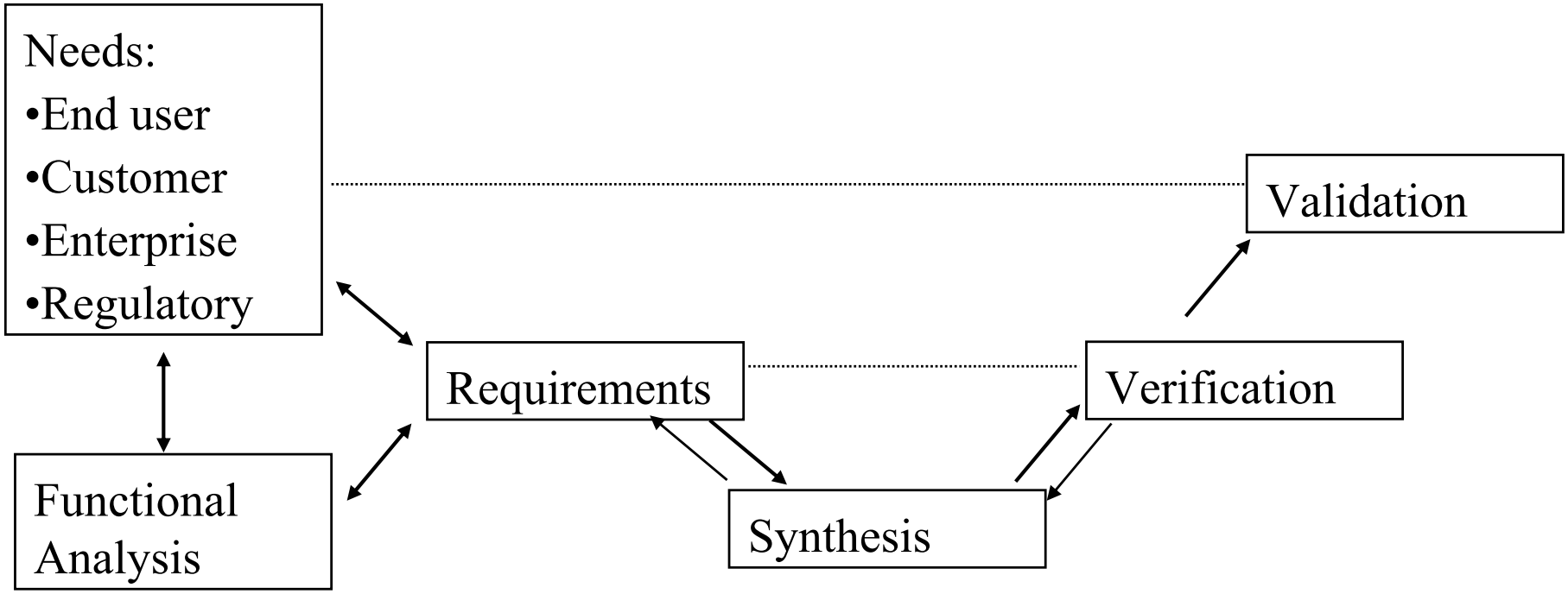
- Enterprise leader (2) affects lives of many employees (5).
- Employee productivity (5) affects enterprise success (2).
- Airbus & Boeing (2) mutually dependent upon competition.
- International terrorism (0) impacts future of entire US aerospace enterprise (1-5).
- Creative genius of individual (5) like Kelly Johnson affects fate of enterprise (2) and nation (0).

Segment from PBS Home Video *21st Century Jet: The Building of the 777*

Part I - 27:45-30:50 (3 min 5 sec)

Shows a verification test of passenger door opening with 1/2” of ice - a step in the systems engineering process

Simplified System Engineering Process Steps



Verification is assuring the system meets the requirements

Validation is assuring the system meets the needs

Source: Adapted from Jackson, S. *Systems Engineering for Commercial Aircraft*

Segment from PBS Home Video *21st Century Jet: The Building of the 777*

Part I - 40:36-43:56 (3 min 20 sec)

Covers Working Together, the new approach used by the 777 for open and honest communication.

Learning Community

- Establish and maintain program credibility
- Open and honest communication
- Encourage and reward asking for help
- Utilize knowledge regardless of where it originate
- Share responsibilities for decisions using a well-defined process
- Maintain two way dialog in working relationships, do both listening and talking
- Value people for the skills they contribute to the program with mutual respect and appreciation

Source: Adapted from Stanke, A. "A Framework for Achieving Lifecycle Value in Product Development"

Segment from PBS Home Video *21st Century Jet: The Building of the 777*

Part I - 52:30-55:40 (3 min 10 sec)

Covers the task ahead to design and produce a product that takes several years and lasts decades, all in an uncertain world market and environment

Notional Lifecycle Costs

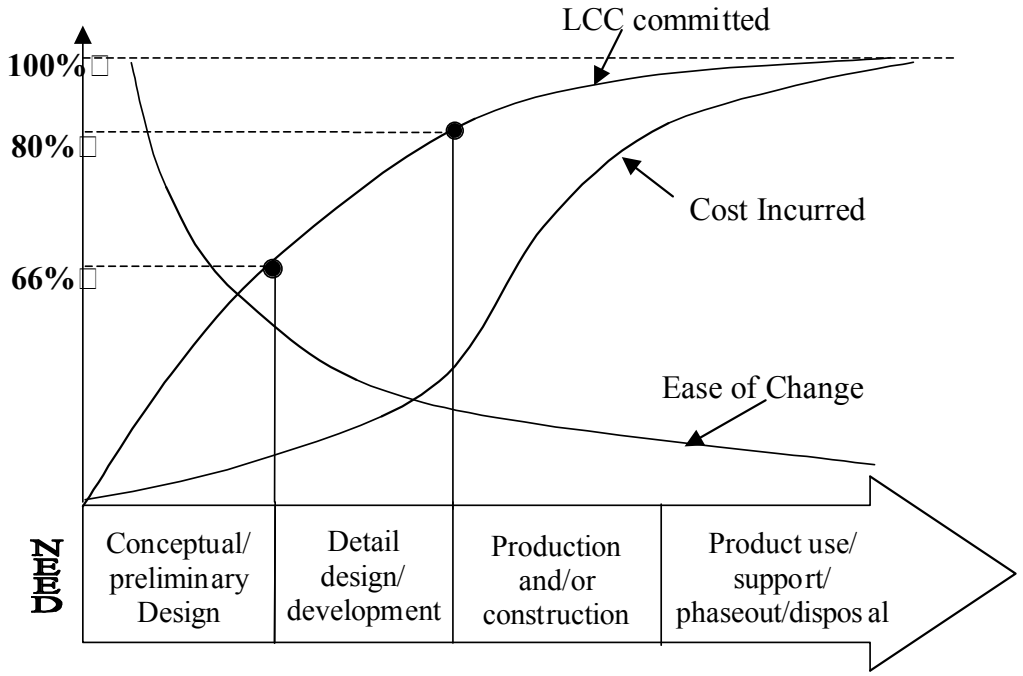


Figure 2 - Lifecycle cost committed vs incurred (Fabrycky and Blanchard, 1991)

Source: Fabrycky, W.J. and Blanchard, B.S. ***Life-Cycle Cost and Economic Analysis***

Lifecycle Issues

- Lifecycle Costs
  - ~1/3 of lifecycle cost is acquisition, 2/3 is operation
- The “ilities” dominate the life cycle
  - Reliability, maintainability, supportability, upgradeability
- Product evolution
  - E.G. B-52 was designed as a strategic bomber with predetermined missions, yet used in Afghanistan in a tactical delivering JDAMs directed by ground spotters.
- Knowledge management

Long lifecycles are a significant driver in aircraft systems engineering and architecting

Semester Case Study

- Retrospective analysis of an existing aircraft to understand key design drivers, decisions, and features
- Done in small teams
- Suggested outline in syllabus appendix
  - Last year's cases serve as models
- Will evolve during semester in written and oral versions
  - Written Versions I (9/25), II (10/16), III (11/13), IV (12/9)
  - Oral presentations scheduled near Versions II and III
- Candidate case studies with Subject Matter Experts (SMEs) available:
  - **Douglas DC-9**
  - **Saab Farchild 340**
  - **Sikorsky S-92**
  - **Cessna Citation X**
  - **USAF Boeing C-17**
  - **USAF Boeing B-52**
  - **USAF General Dynamics F-111**
  - **Space Shuttle**

Administrativia

- No formal prerequisites
- Lecture classes Tue and Thu 9:30-11:00
  - Handouts of lecture material
  - Expect class questions, discussion, participation
- Additional hour for case study team time or oral reports
- Field trip to Sikorsky in Stratford CT to be scheduled
- References many and varied
  - Books and case studies on reserve in AA library
  - Need to exploit all resources: www, SME, ….
- Course web site - see syllabus
- Turn in student profile form at end of class
- E-mail to me by Monday a one paragraph bio

Grading

Team Grades for Case Study

Written Version 1	**10**
Written Version 2	**10**
Oral presentation 1	**10**
Written Version 3	**15**
Oral presentation 2	**10**
Final Written Version	**20**
Total team grade	**75**

Individual Grades (Further guidelines will be given on these)

Midterm written assessment	**10**
End of term oral assessment	**15**
Total individual grade	**25**