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.

Value Phases

- **Value Identification**
  - Identify the stakeholders and their value expectations

- **Value Proposition**
  - Develop a robust value proposition to meet the expectations

- **Value Delivery**
  - 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

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

<table>
<thead>
<tr>
<th>Level</th>
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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 Interests

6 Level Hierarchy

0 - Society, nations, communities, etc.

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

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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

Needs:
- End user
- Customer
- Enterprise
- Regulatory

Functional Analysis

Verification

Synthesis

Validation

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

### 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**
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