Course Overview/Systems Engineering

- Course Overview
  - Goals
  - Web-based Content
  - Syllabus
  - Policies
  - Project Content
- Tools of Systems Engineering
  - History
  - Project Organization
  - Task-based Management

Contact Information

Dr. Dave Akin

Space Systems Laboratory

Neutral Buoyancy Research Facility/Room 2100D

301-405-1138

dakin@ssl.umd.edu

http://spacecraft.ssl.umd.edu

Goals of ENAE 483/484 (and 788D)

- Learn the basic tools and techniques of systems analysis and space vehicle design
- Understand the open-ended and iterative nature of the design process
- Simulate the cooperative group engineering environment of the aerospace profession
- Develop experience and skill sets for working in teams
- Perform and document professional-quality systems design of focused space mission concepts

Outline of Space Systems

- ENAE 483 (Fall)
  - Lecture style, problem sets and quizzes
  - Design as a discipline
  - Disciplinary subjects not contained in curriculum
  - Engineering graphics
  - Engineering ethics
- ENAE 484 (Spring)
  - Single group design project
  - Externally imposed matrix organization
  - Engineering presentations
  - Group dynamics
  - Peer evaluations

Web-based Course Content

- Data web site at spacecraft.ssl.umd.edu
  - Course information
  - Syllabus
  - Lecture notes
  - Problems and solutions
- Interactive web site at www.ajconline.umd.edu
  - Communications for team projects
  - Surveys for course feedback

Syllabus Overview

- Fundamentals of Spacecraft Design
- Level 1 Design: Vehicle-Level Estimation
- Level 2 Design: Systems-Level Estimation
- Level 3 Design: Component Detailed Design

Syllabus 1: Fundamentals of Space Systems

9/3 - Systems Engineering

9/5 - Space Environment

9/10 - Orbital Mechanics

9/12 - Engineering Graphics

9/17 - Engineering Ethics

9/19 - Engineering in Teams

Syllabus 2: Design Levels 1 and 2

- Level 1: System-Level Parametric Design
  - 9/24 - Rocket Performance
  - 9/26 - Parametric Analysis
  - 10/1 - Cost Analysis
- Level 2: System-Level Parametric Design
  - 10/3 - Mass Estimating Relations and Budgets
  - 10/8 - Advanced Costing Analysis
  - 10/10 - Reliability and Redundancy
  - 10/15 - Confidence, Risk, and Resiliancy

Syllabus 3: Design Level 3

- Loads, Structures, and Mechanisms

  10/17 - Loads Estimation

  10/22 - Structural Analysis

  10/24 -Structures and Mechanisms Design
- Propulsion, Power, and Thermal

  10/29 - Propulsion System Design

  10/31 - Power System Design

  11/5 - Thermal Design and Analysis

11/7 - Midterm Examination

- Avionics Systems

  11/12 - Attitude Dynamics/Proximity Operations

  11/14 - Data Management; GN&C

  11/19 -Communications

Syllabus 4: Design Level 3 (continued)

- Crew Systems
  - 11/21 - Space Physiology
  - 11/26 - Human Factors and Habitability

11/28 - Thanksgiving Break

  - 12/3 - Life Support Systems Design
- Other Topics
  - 12/5 - Scheduling Margin

12/10 - Team Project 2 Presentations

Policies

- Grade Distribution
  - 30% Problems
  - 15% Midterm Exam
  - 10% Team Project 1*
  - 15 % Team Project 2*
  - 30% Final Exam

* Team Grades

- Late Policy
  - On time: Full credit
  - Before solutions: 70% credit
  - After solutions: 20% credit

Projects for ENAE 483 - Fall 2002

Project Diana

- Minimum cost and time system for resuming human lunar exploration
- "Pathfinder" project to illustrate techniques and applications this term
- Single-person project (me!)

Projects for ENAE 483 - Fall 2002

- Team Project 1 (2-3 person teams)
  - Research a spacecraft from history (real or planned)
  - Prepare an engineering overview presentation
  - Emphasis on research and graphics skills
- Team Project 2 (4-5 person teams)
  - Perform preliminary design of a space vehicle
  - Should follow along with lecture syllabus
  - Presentations at end of term
  - Lead-in to ENAE 484

Team Project 1

- Intended to give you a start at systems engineering and group dynamics
  - Picking and operating in small teams
  - How to perform research
  - Engineering graphics
  - Technical presentation preparation
- Prepare a viewgraph presentation describing a space vehicle - Could be past, present, or planned for future, flown or unflown - but *not* science fiction! (Note: vehicles, not missions: e.g., "Apollo lunar module", not "Apollo 17")
- Details linked to course syllabus

Team Project 2

- Crew Rotation/Rescue Vehicle
  - Rotate crews to/from International Space Station
  - Based on ISS for emergency "bail-out"
  - Launch on Delta IV Heavy
  - Cost-effective compared to Space Shuttle
- Design process should proceed throughout the term
- Formal design presentations at end of term

Class Rosters

- ENAE 483
  - Aymergen, Cagatay
  - Baker, Meghan Briana
  - Beres, Matthew Christian
  - Bowen, Christopher L
  - Catlin, Kathryn Anne
  - Christy, Jason Thomas
  - Colville, Jesse Ryan
  - Edery, Avi
  - Frank, Wendy Elizabeth
  - Hintz, John Charles
  - Hollingsworth, Kirstin Mic
  - Hoskins, Aaron Bradley
  - Jones, Robyn Michelle
  - Langley, Alexandra Bliss
  - Long, Andrew Michael
  - Michael, Sadie Kathleen
  - Miller, William Martin
  - Moulton, Nathan Lee
- ENAE 483 (cont.)
  - Noyes, Thomas Vincent
  - Parker, John Michael
  - Pierson, Lynn Kathryn
  - Reilly, Jacqueline Marie
  - Richeson, Justin Arthur
  - Rodriguez, Eric Raymond
  - Sadorra, Oliver John
  - Silva, Ernest Surendra
  - Stamp, Gregory Carlton
  - Work, Christopher Eric
  - Yoshimura, Yudai
- ENAE 788D
  - Chauffour, Marie-Laure
  - Clough, Joshua Alan
  - Evanson, Justin J
  - Horne, Rebecca Leigh
  - Rodriguez, Arthur Steven
  - Shapiro, Elisa Gail
  - Shoup, Gregory James

Project for ENAE 484 - Spring 2002

Mars Scout-Class Mission

- Robotic mission to precede human mission
- Science objectives are to sample, survey, and verify surface environment as safe for human exploration mission, and to develop necessary infrastructure
- Develop to NASA requirements for Scout-class missions
- Design as a university-built mission
- Final output is a Scout proposal to NASA

Akin's Laws of Spacecraft Design - #3

Design is an iterative process. The necessary number of iterations is one more than the number you have currently done. This is true at any point in time.

Overview of Systems Engineering

- Developed to handle large, complex systems
  - Geographically disparate
  - Cutting-edge technologies
  - Significant time/cost constraints
  - Failure-critical
- First wide-spread applications in aerospace programs of the 1950's (e.g., ICBMs)
- Rigorous, systematic approach to organization and record-keeping

The Space System Development Process

Pre-Phase A

<u>Conceptual Design Phase</u>

Development of performance goals and requirements

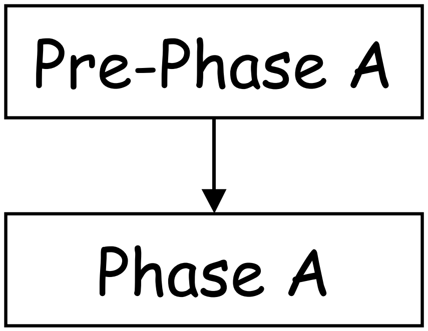
Establishment of Science Working Group (science missions)

Trade studies of mission concepts

Feasibility and preliminary cost analyses

Request for Phase A proposals

The Space System Development Process



<u>Preliminary Analysis Phase</u>

Proof of concept analyses

Mission operations concepts

"Build vs. buy" decisions

Payload definition

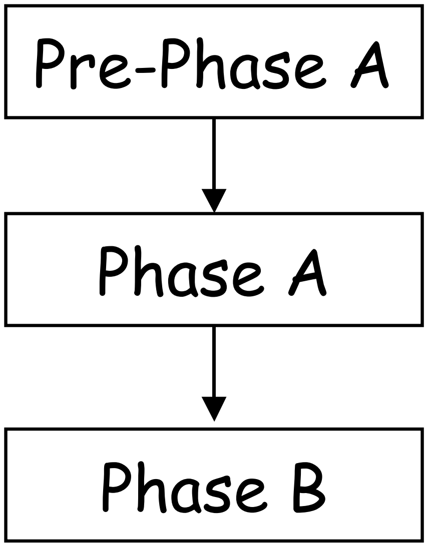
Selection of experimenters

Detailed trajectory analysis

Target program schedule

RFP for Phase B studies

The Space System Development Process



Definition Phase

Define baseline technical solutions

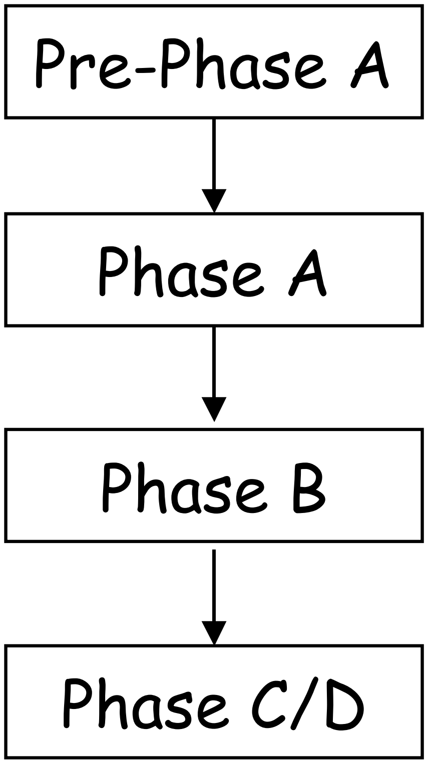
Create requirements document

Significant reviews:

- Systems Requirements Review
- Systems Design Review
- Non-Advocate Review

Request for Phase C/D proposals

The Space System Development Process



<u>Development Phase</u>

Detailed design process

"Cutting metal"

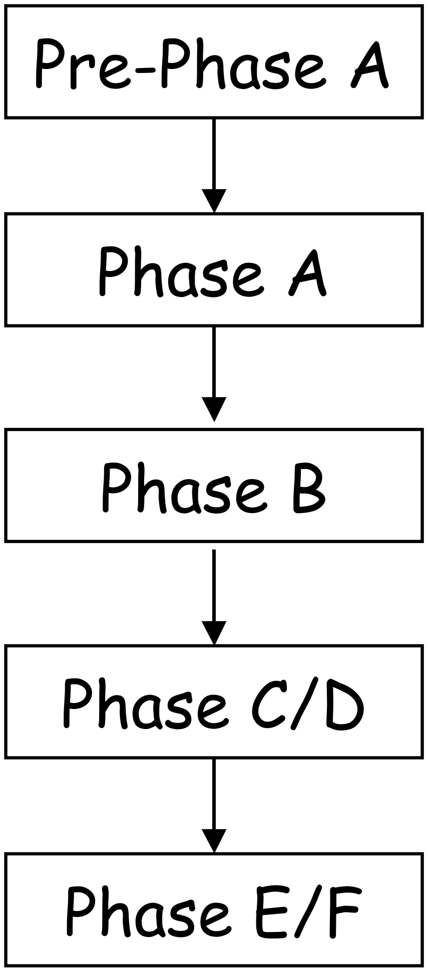
Test and analysis

Significant reviews:

- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Test Acceptance Review
- Flight Readiness Review

Ends at launch of vehicle

The Space System Development Process



Operations and End-of-Life

Launch

Check-out

Mission Operations

Maintenance and Troubleshooting

Failure monitoring

End-of-life disposal

Requirements Document

- The “bible” of the design and development process
- Lists (clearly, unambiguously, numerically) what is required to successfully complete the program
- Requirements “flow-down” results in successively finer levels of detail
- May be subject to change as state of knowledge grows
- Critical tool for maintaining program budgets

Project Diana Mission Statement

Project Diana

Presidential address to a joint session of Congress, January, 2003:

"I believe this nation should commit itself to achieving the goal, before this decade is out, of returning humans to the lunar surface, for exploration and eventual permanent habitation."

Level 1 Requirements

1) Perform a mission equivalent to a NASA J-class Apollo mission before January 1, 2010
2) No programmatic resources may be used for launch vehicle development
3) Any single mission shall have a 90% chance of mission success
4) Any single mission shall have a 99.9% chance of crew survival
5) The program will maximize the opportunities to engage and involve the U.S. and world public, especially K-12

Level 2 Requirements

1.1) At least two astronauts will form the lunar landing crew

1.2) Lunar surface stay time will be at least 72 hours

1.3) Lunar surface activities will be comparable to Apollo J missions

Level 3 Requirements

1.3.1) Landed lunar equipment mass will be TBD kg

1.3.2) Returned lunar sample mass will be TBD kg

1.3.3) Surface activities will include 3 EVAs of 7 hours duration each

Akin's Laws of Spacecraft Design - #13

Design is based on requirements. There's no justification for designing something one bit "better" than the requirements dictate.

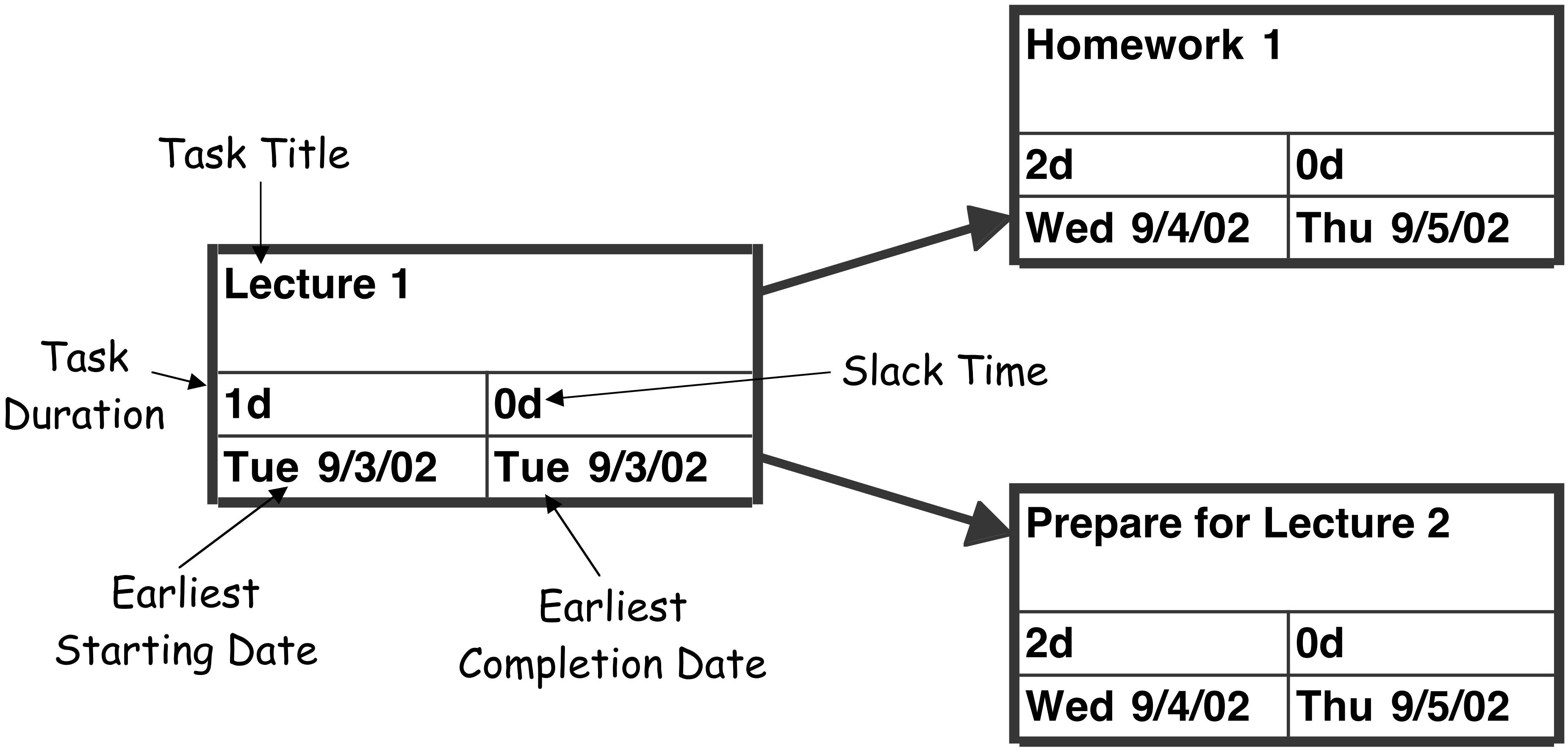
Work Breakdown Structures

- Detailed “outline” of all tasks required to develop and operate the system
- Successively finer levels of detail
  - Program (e.g., Space Transportation System)
  - Project (Space Shuttle Project)
  - Mission (Earth-LEO Transportation)
  - System (Shuttle Orbiter)
  - Subsystem (Main Propulsion)
  - Assembly (High Pressure LOX Turbopumps)
  - Subassembly, Component, Part, ...

Akin's Laws of Spacecraft Design - #24

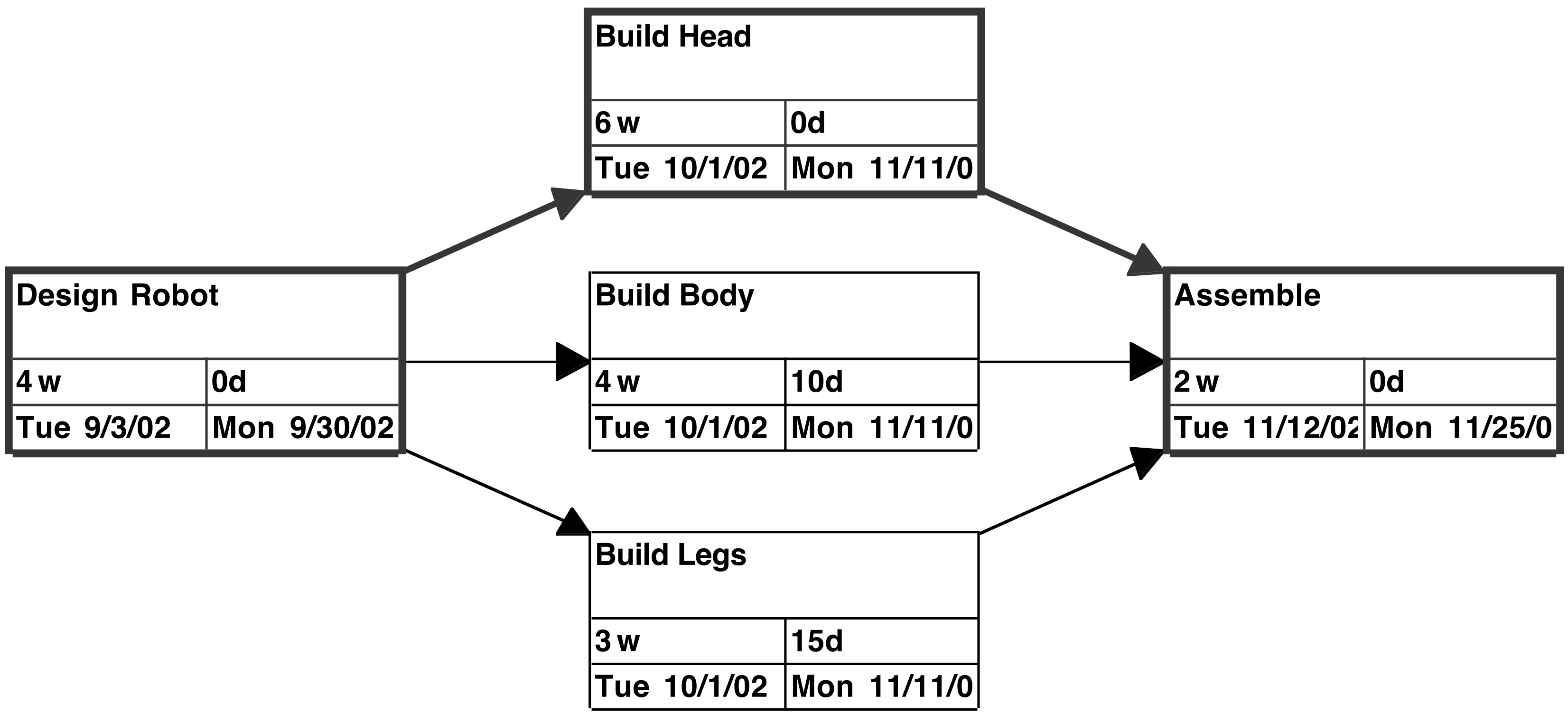
It's called a "Work Breakdown Structure" because the Work remaining will grow until you have a Breakdown, unless you enforce some Structure on it.

PERT Charts

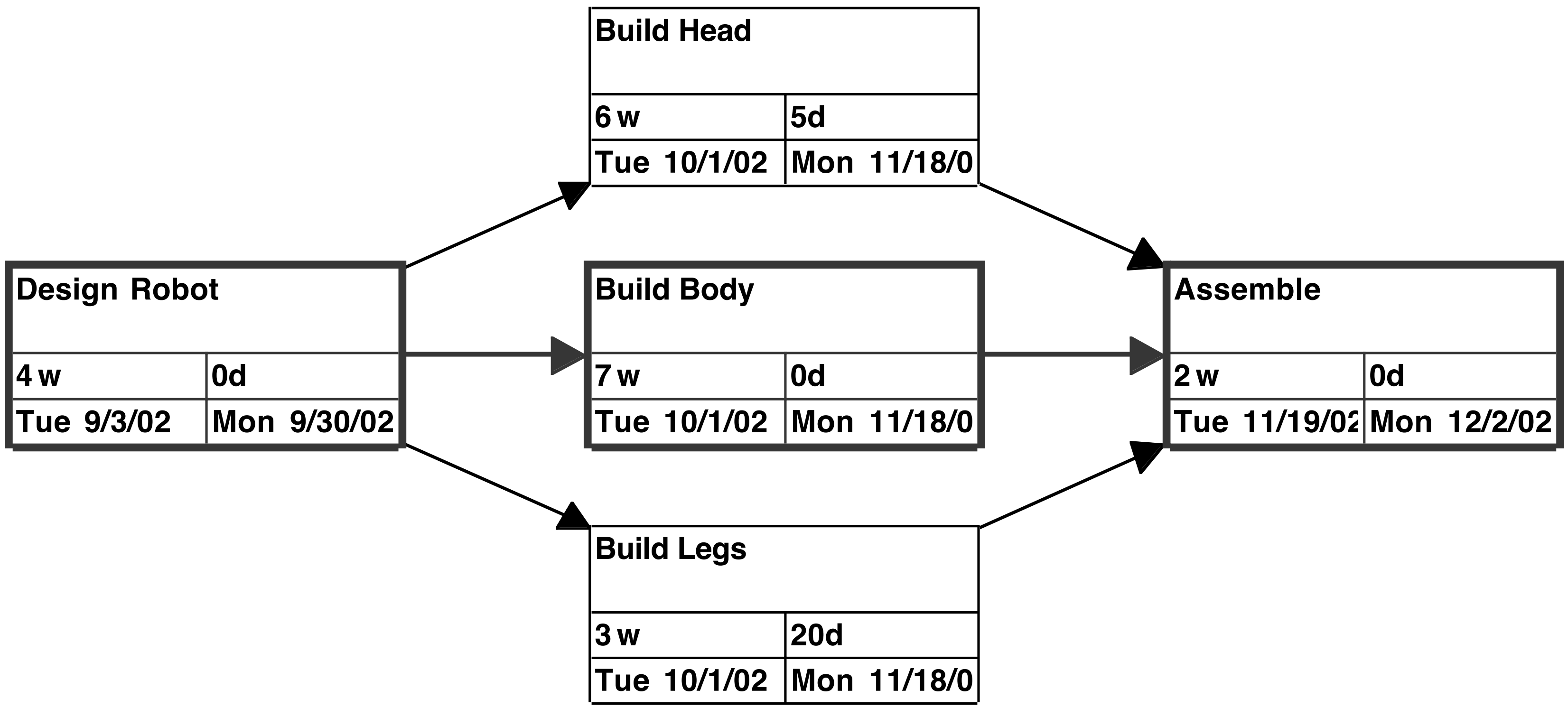


Task Title
Lecture 1
1d
0d
Tue 9/3/02
Tue 9/3/02
Task Duration
Slack Time
Earliest Starting Date
Earliest Completion Date
Homework 1
2d
0d
Wed 9/4/02
Thu 9/5/02
Prepare for Lecture 2
2d
0d
Wed 9/4/02
Thu 9/5/02

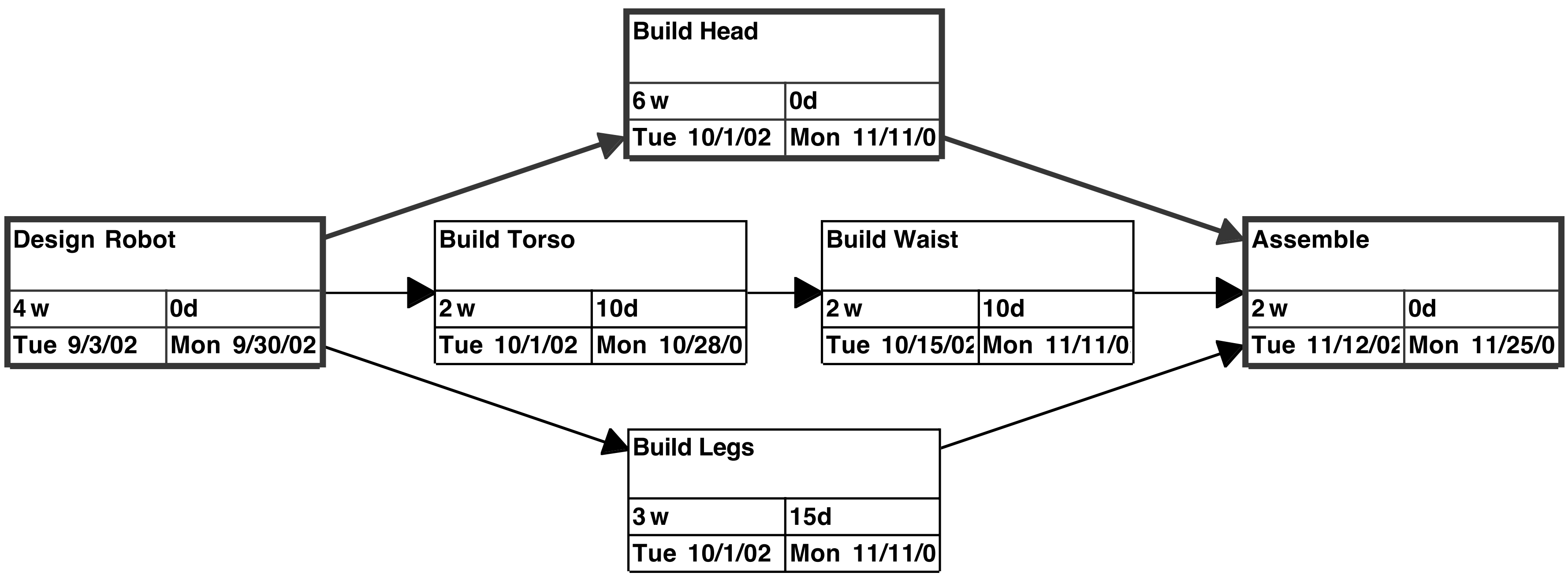
The Critical Path and Slack Time



The Critical Path and Slack Time

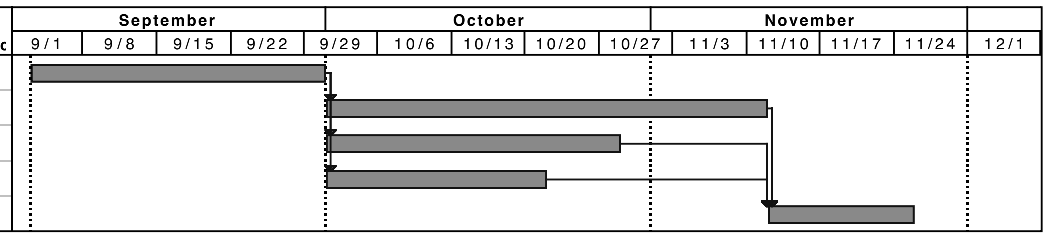


Cascading Slack Time



Gantt Charts

ID	Task Name	Duration	Start	Finish	Predec
1	Design Robot	4 w	Tue 9/3/02	Mon 9/30/02	
2	Build Head	6 w	Tue 10/1/02	Mon 11/11/02	1
3	Build Body	4 w	Tue 10/1/02	Mon 10/28/02	1
4	Build Legs	3 w	Tue 10/1/02	Mon 10/21/02	1
5	Assemble	2 w	Tue 11/12/02	Mon 11/25/02	2,3,4



Akin's Laws of Spacecraft Design - #23

The schedule you develop will seem like a complete work of fiction up until the time your customer fires you for not meeting it.

Akin's Laws of Spacecraft Design - #1

Engineering is done with numbers. Analysis without numbers is only an opinion.