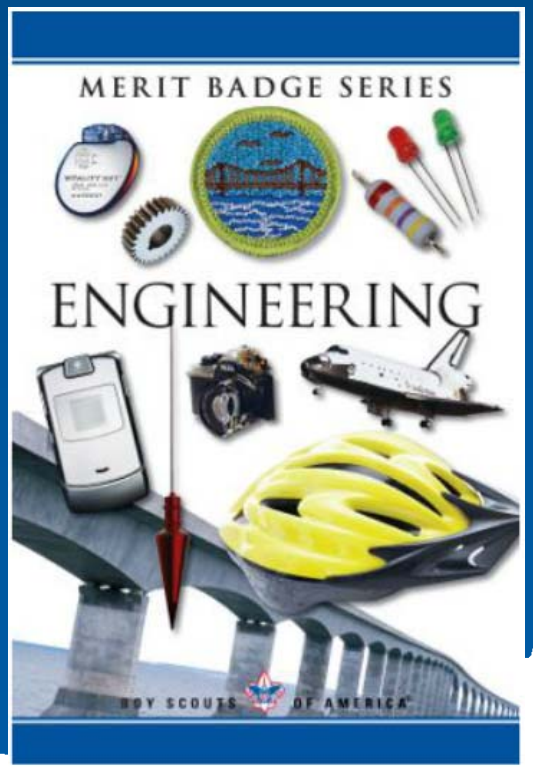
Engineering Merit Badge
PART THREE

Eric Cutright, ASM Troop 1028, Oct - Dec 2015



Engineering Merit Badge Plan
October - December 2015

Your Troop 1028 Merit Badge Counselor

Eric Cutright, Ph.D. EE (UVA)

Oct 5 – Introduction to Engineering, Problem Solving, Patrol Bridge Building Competition

Oct 12 – (UVA Observatory) Scout Presentations (Sami & G. Michael), Star Wars Force Awakens Project

Oct 19 – (UVA) Field Trip to UVA Engineering School

Visiting three engineering labs – Materials, Robotics, Radios

Oct 26 – (STAB) Apple Harvest Catapult Construction

Dec 7 – (STAB) Triumphs/Disasters in Engineering. Careers in Engineering, Interview an Engineer

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The Plan for Today
Part Three – Engineers Rule !

- **Refresher:**
  - Engineering Approach to Problem Solving (Requirement 5)
  - Professional Engineer (P.E.) Certification (Requirement 7)
  - Engineer's Code of Ethics (Requirement 8)
- **Great Accomplishments and Terrible Disasters in Engineering (Requirement 2)**
- **Becoming an Engineer – Do you have what it takes? (Requirement 9)**
- **Patrol Competition: Energy Hogs !! (Requirement 6b)**
- **Interview an Engineer (Requirement 4)**

Engineering Approach to Problem Solving

(Requirement 5)

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Engineering Approach to Problem Solving

1. Make a plan showing approach, resources, required tools, and schedule
2. Describe the project requirements
3. Plan the project's activities and task schedules
4. Conduct research – get ideas
5. Develop the best ideas for alternative solutions
6. Analyze the best ideas and compare them
7. Select the best idea
8. Perform the construction or solution of the project
9. Check the solution

Professional Engineer (P.E.) Certification

(Requirement 7)

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Professional Engineer (P.E.) Certification

- **For some careers or particular projects, it may be necessary to get a Professional Engineering (PE) license in your state or the project's state**
- **Obtaining a license is typically a four-step process**
  1. Earn an approved 4 year engineering degree
  2. Complete 4 years of qualifying work experience
  3. Pass the Fundamental of Engineers (a.k.a. Engineer-in-Training) exam
  4. Pass the Principles and Practice of Engineering (PE) exam (which is quite difficult)
- **Typically must periodically renew the PE license**

Engineer’s Code of Ethics

(Requirement 8)

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Engineer's Code of Ethics

- **The Engineer's Code of Ethics has three fundamental principles that guide the work of the engineering profession**
- **Engineers uphold and advance the integrity, honor, and dignity of their profession by**
  - Using their knowledge and skill for the enhancement of human welfare
  - Being honest and impartial, and faithfully serving the public, their employers, and their clients
  - Striving to increase the competence and prestige of the engineering profession
- **How is this similar to the Scout Oath & Scout Law?**

Great Accomplishments in Engineering

(Requirement 2)

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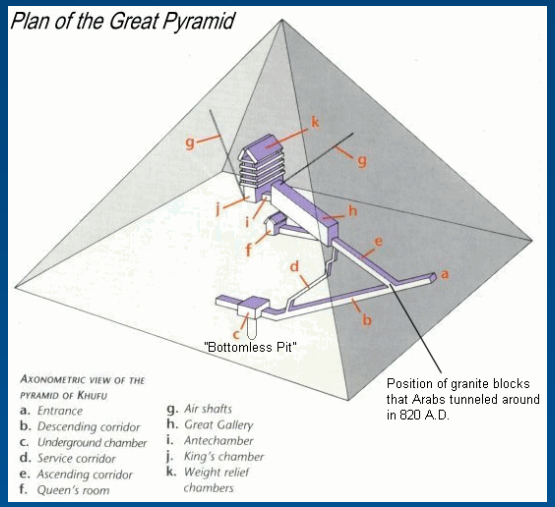
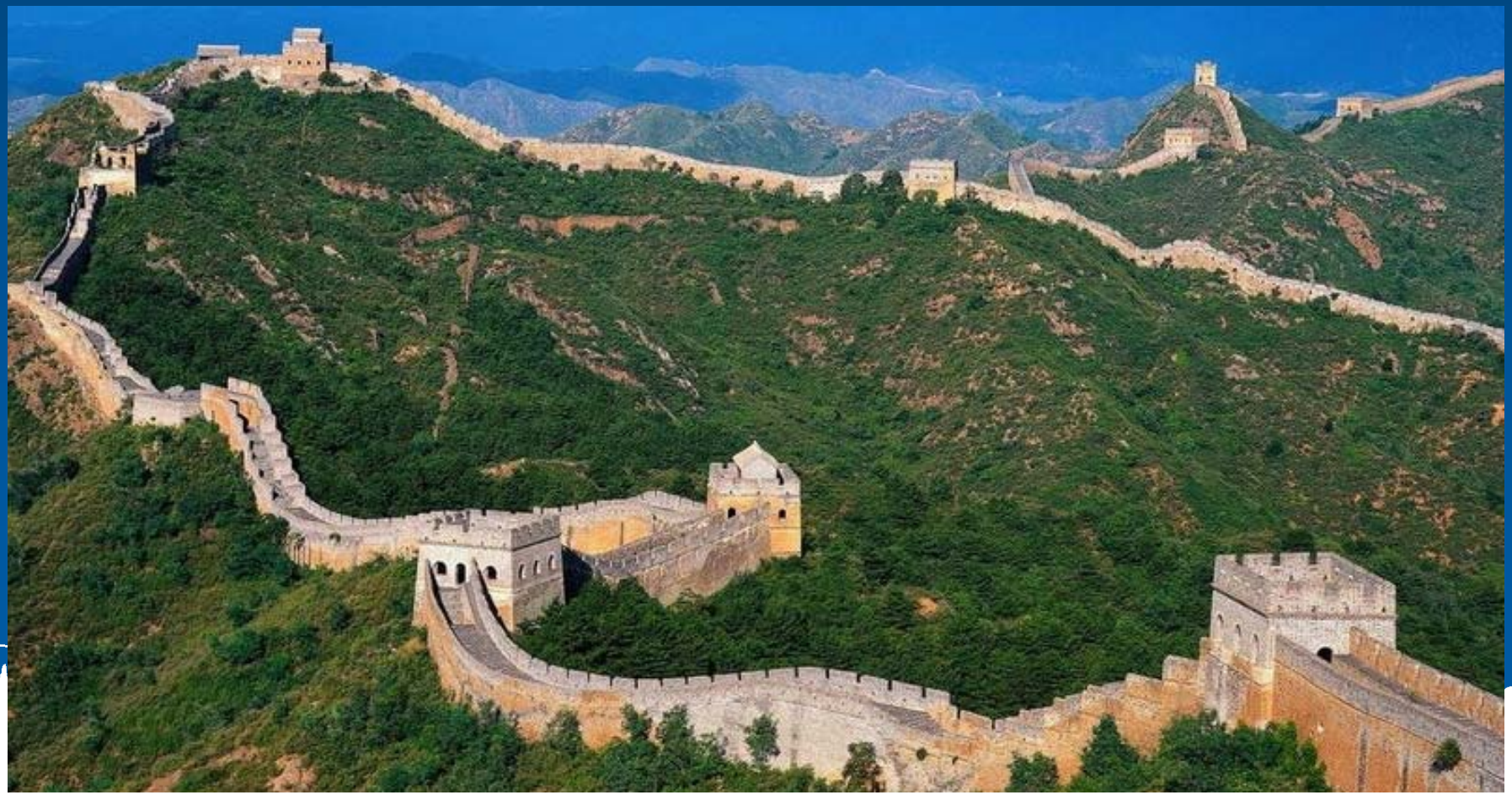
Ancient Egypt – Pyramids of Giza (2500 BC)

<u>Engineering Facts:</u>
500 feet high, each base side 756 feet long
2.3 million blocks, total weight of 6 million tons
Tallest man-made structure in world until 1300AD
Base is perfectly flat and level to ½ inch
Four sides average error of 2 inches
Ratio of perimeter to height = 2π to 0.05% accuracy

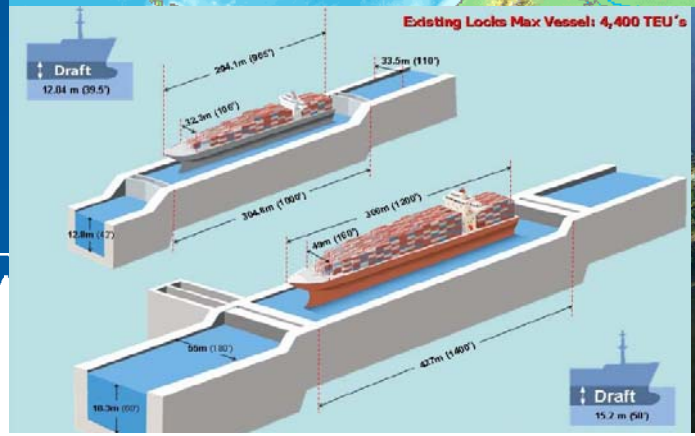


Great Wall of China (300 BC)

- **Stretches 4,000 miles across northern China averaging 25 feet high and 15-30 feet wide**

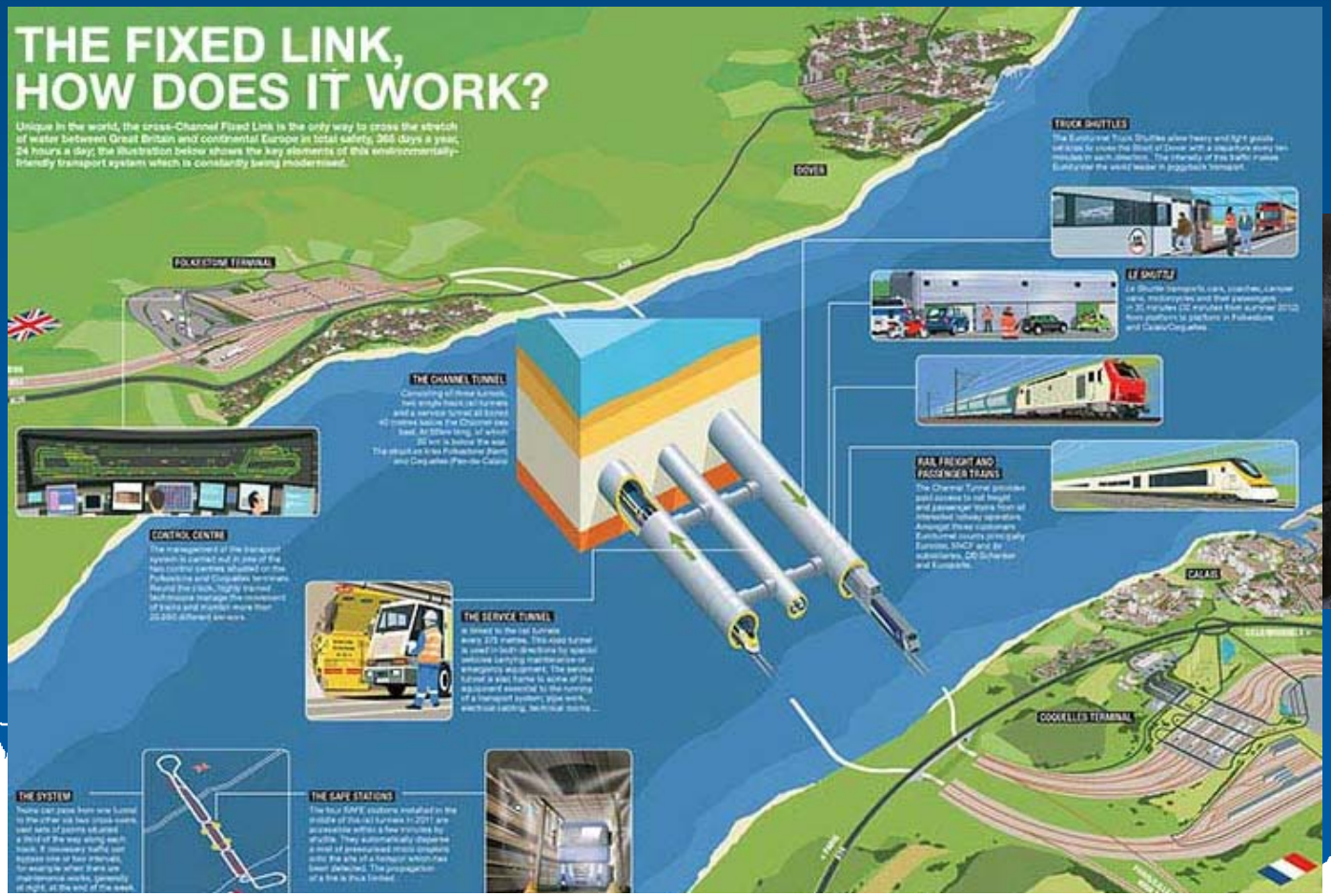


Panama Canal (opened 1914) – 48 miles long, 85 feet above SL



Channel Tunnel (1994)

- **31 mile tunnel runs under English Channel to connect England and France**



Tunnel Boring Machine

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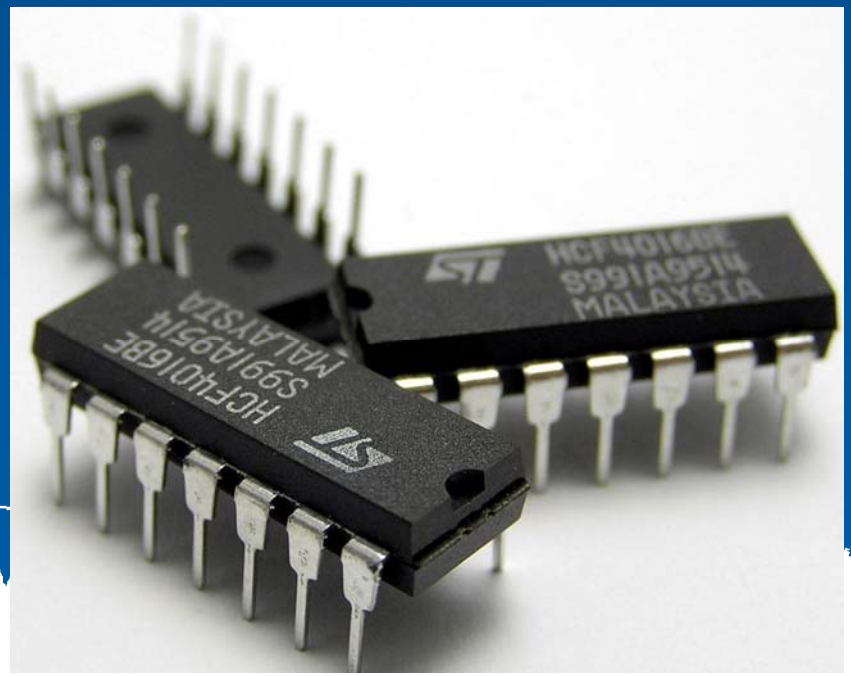
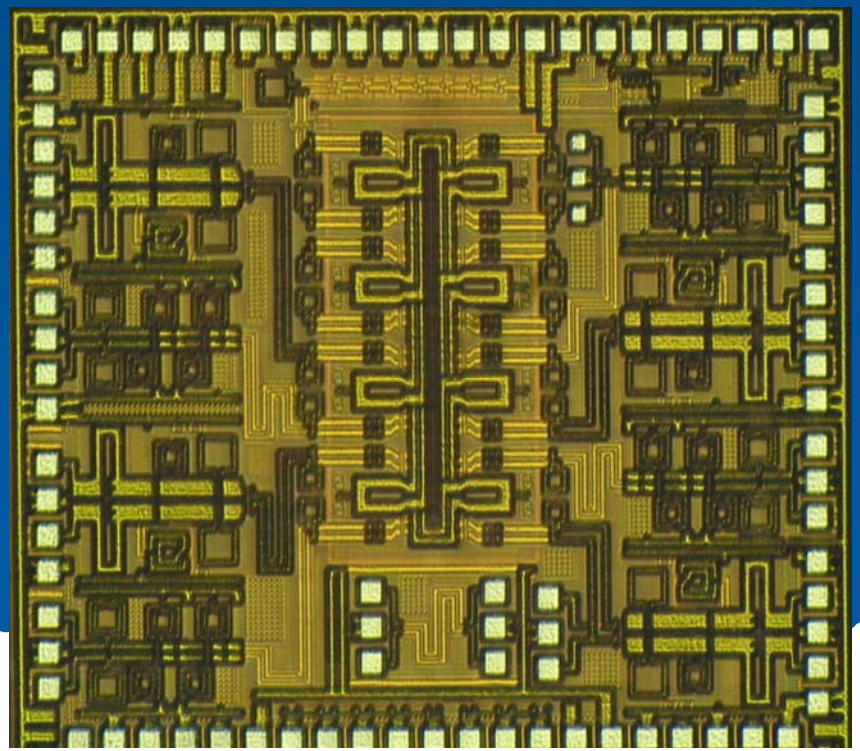
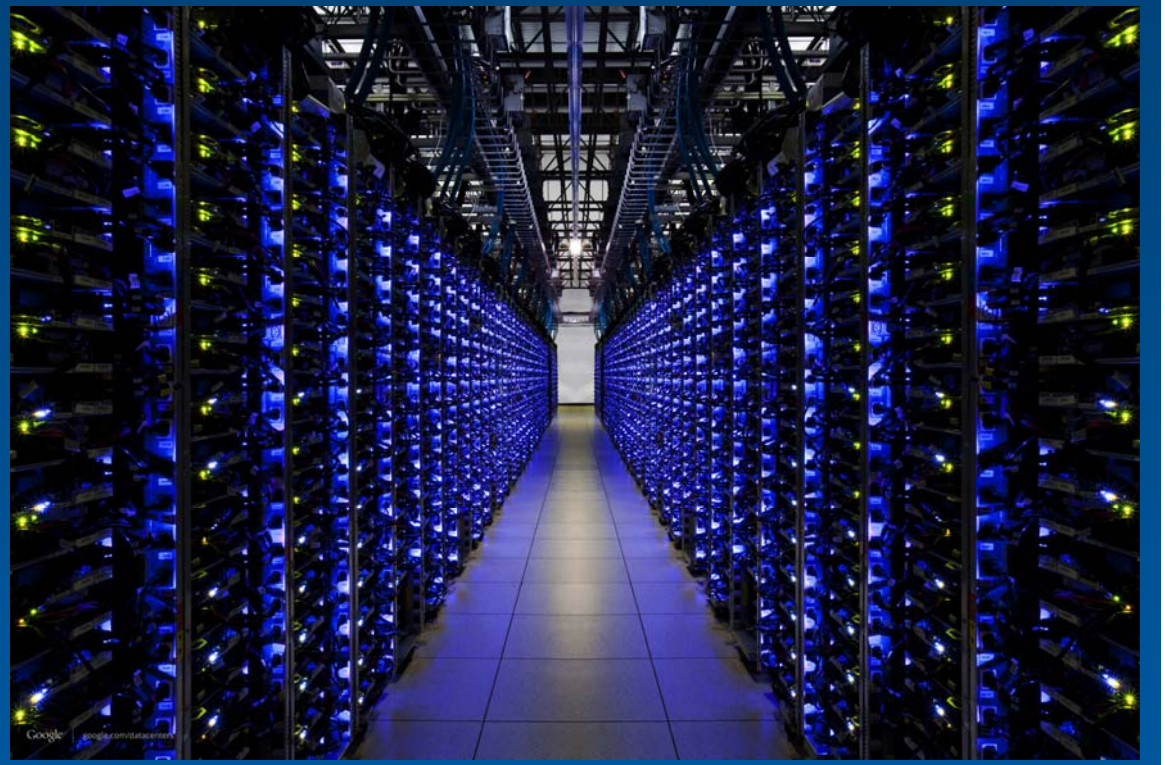
Integrated Circuit (1958)

- Invented by Jack Kilby to manufacture multiple electronic components together on the same piece of semiconductor material
- Paved the way for modern computers and electronics





Modern Computers



Modern Vehicles

Terrible Disasters in Engineering
(Requirement 2)

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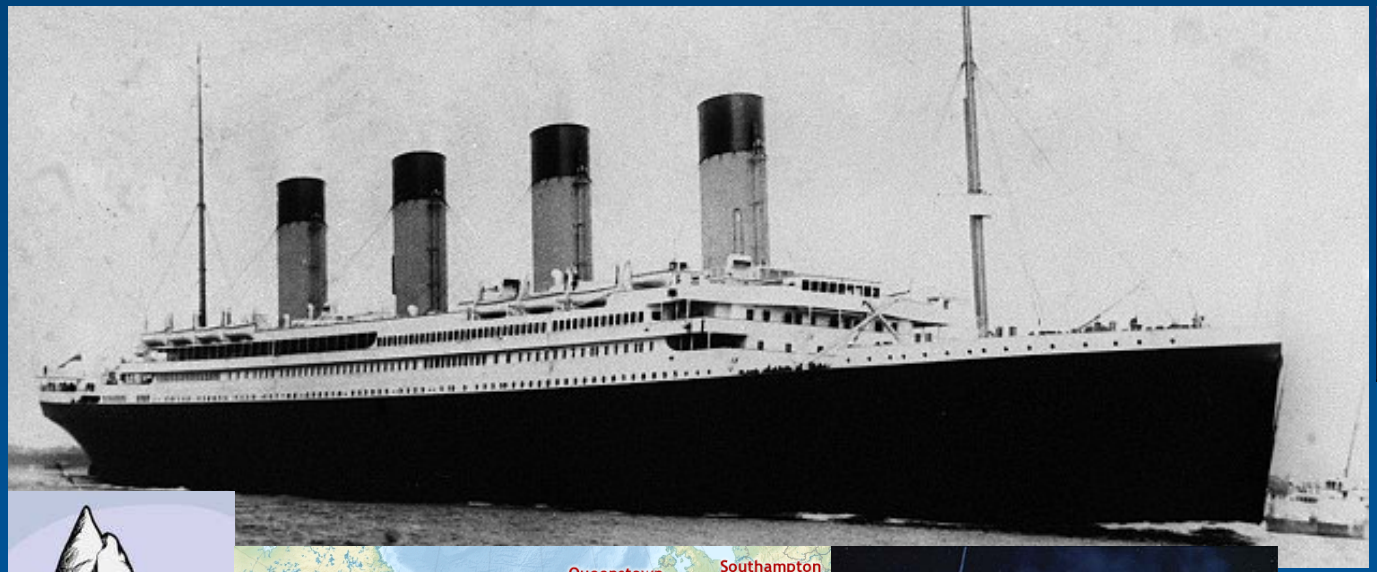
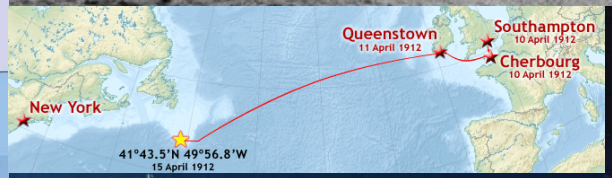
Wreck of the RMS Titanic (April 15, AD 1912)






The Boston Daily Globe.

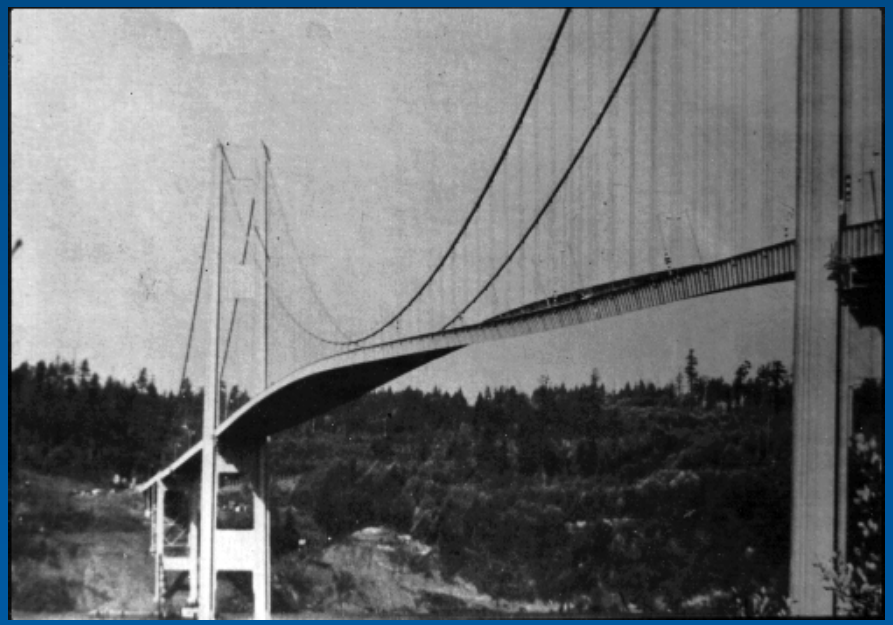
TITANIC SINKS, 1500 DIE

Carpathia Picks Up 675 Out of 2200---Races for New York---Survivors Mostly Women and Children.

POLICE ORDER DORR'S ARREST

Tacoma Narrow Bridge Collapse (1940)

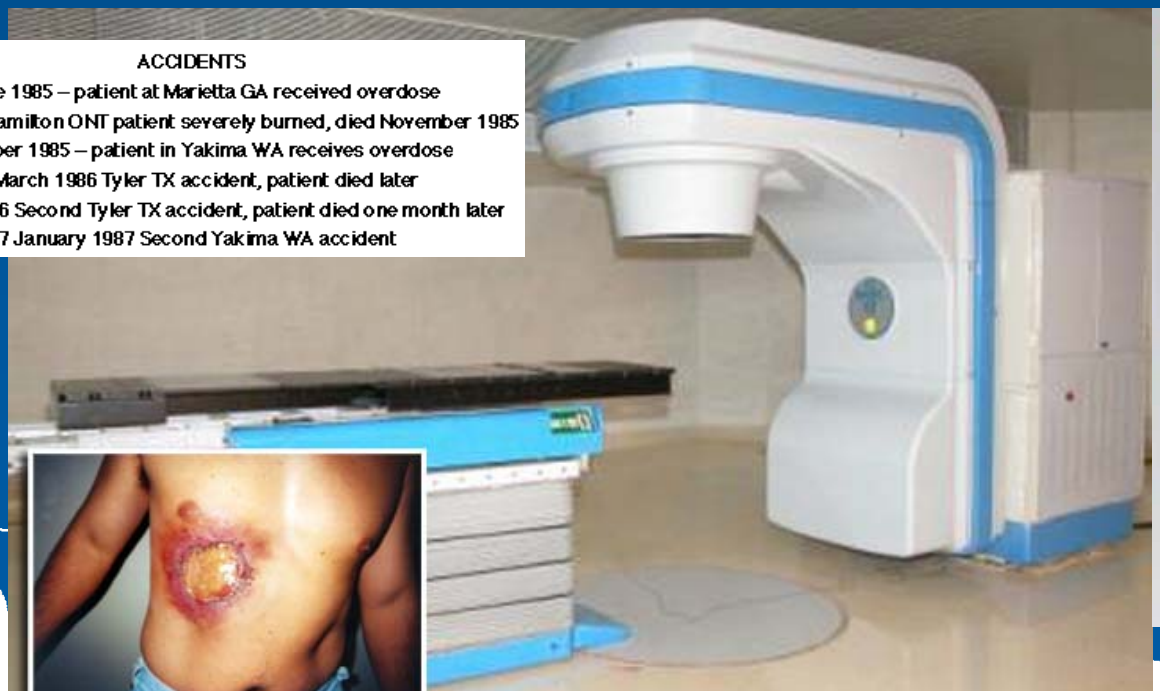
- **Bridge destroyed by harmonic action from wind – design was too flexible and used shorter girders to cut costs – luckily no loss of life**



Therac-25 (1976)

- Radiation therapy machine gave patients massive overdoses of radiation due to concurrent programming errors
- Led to advances in software control of safety-critical systems like medical devices and transportation

ACCIDENTS
3 June 1985 – patient at Marietta GA received overdose
26 July 1985 Hamilton ONT patient severely burned, died November 1985
December 1985 – patient in Yakima WA receives overdose
21 March 1986 Tyler TX accident, patient died later
11 March 1986 Second Tyler TX accident, patient died one month later
17 January 1987 Second Yakima WA accident



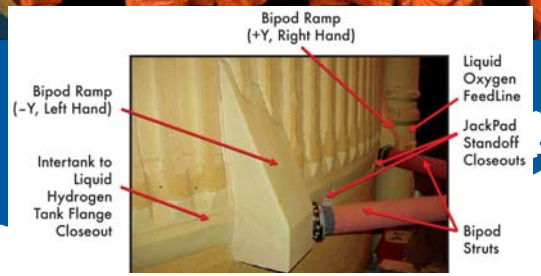
Therac-25 Radiation Therapy Disaster

Early Theracs machines had hardware interlocks to prevent activating a high-power electron beam, rather than the intended low-power beam. The later version did not have the hardware and relied instead on software. When the software failed, three people died of excess radiation.

LESSON: High-risk operations should always have many layers of protection systems. Theracs' hardware and software were not tested jointly until the machine was resembled at the hospital—far too late in the development process.

Space Shuttle Challenger (1986), Columbia (2003)

- Challenger disaster caused by failed O-ring in booster rocket
- Columbia disaster caused by wing tile damage from foam insulation breaking off external tank



Hubble Space Telescope (1990)

- Main mirror was ground to wrong specifications and had to be replaced (but has since been amazing)

Engineering: Do you have what it takes?

(Requirement 9)

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Studying Engineering: Do you have what it takes?

- **"Required" skills and interests for Engineering**
  - Math
  - Science
  - 3D visualization / shapes
  - Writing / communication (more later)
  - Creative thinking, thinking outside of the box
  - Ability to see the big picture and not get lost in details
  - Designing new things
  - Working as part of a team
  - Computer skills
- **If you absolutely <u>hate</u> any of the above then Engineering may not be right for you !!**

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Engineering: Oh snap – why writing and communication?

- **Writing and communication are HUGE parts of almost every engineering career**
  - You have to write requirements, detailed design, and testing documentation for every engineering project so that other engineers will clearly understand it and agree with you
  - You often have to "pitch" your ideas to your team, boss, or clients to get funding to work on new projects or design new things
  - Must be able to write well and speak well to do this effectively !!
  - Poor writing or communication erodes confidence in your engineering skills even if you are an amazing engineer !!
- **A sales pitch like this will not get you anywhere:**
  - Me project is gud it works wheel nice, gimme money to deezin it

Getting into an Engineering School

(Requirement 9)

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Getting into a Competitive Engineering School

- **Eric's tips / advice for getting into a competitive university engineering school program**
  - From UVA Admissions office and Legacy program experience
  - Also applicable to any competitive university

- **Have a challenging, well-rounded high school career**
  - Planning starts in middle school to get on right course track
  - Looking for consistent, challenging course load
    - 5 academic solids: math, English, language, hard science, soft sci
  - Advanced Placement (AP) courses are <u>absolutely critical</u>
  - Consistent good grades, good score on SAT / ACT
  - Extracurricular activities (Scouting, sports, jobs, etc.)

High School Course Selection for Engineering

- **Count the "pinnacle" AP classes to judge rigor**
  - Seniors: AP Govt, AP English, AP Calculus, AP Physics, AP foreign language (take highest offering)
  - Competitive schools are looking for at least 5 or 6 pinnacle AP classes by end of high school, <u>with good grades in each</u>
  - College application: early decision versus regular decision ?
    - Early decision more competitive, need stronger Junior program since they can't judge on Senior grades
- **AP or Dual Enrollment (DE) ? Pick AP.**
  - Some high schools offer DE classes with local community colleges where you <u>might</u> be able to earn transfer credits
  - AP classes are based on national standards and are viewed as more challenging, so if you have a choice <u>always</u> stick with AP

What to Expect in Engineering School

(Requirement 9)

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What to Expect in Engineering School

- **First two years concentrate on core math and science and basic engineering skills**
  - Course load is VERY heavy compared to other majors, lots of homework and labwork
  - Classes are difficult and schools “weed out” poor students
  - Few electives

- **Second two years have more focus on technical skills for your major**
  - Specialized classes - electrical engineering, mechanical engineering, etc.
  - More electives, finalize your major

Engineering School (EE, 5 year Acc BS/MS): Year 1

- **Eric's schedule – First Year, Fall Semester**
  - Intro Calculus
  - Intro Chemistry + Lab
  - Intro to Scientific Programming
  - Engineering Concepts
  - Humanities: Language Communication in a Technical Society
- **Eric's schedule – First Year, Spring Semester**
  - Calculus II
  - Advanced Chemistry for Engineers + Lab
  - Engineering Graphics
  - Physics I + Lab
  - Humanities: Technology, Aggression, and Peace

Engineering School (EE, 5 year Acc BS/MS): Year 2

- **Eric's schedule – Second Year, Fall Semester**
  - Math Analysis 2
  - Electrical Science
  - Physics 2 + Lab
  - Principles of Economics
  - Elective: Intro to Archaeology
- **Eric's schedule – Second Year, Spring Semester**
  - Differential Equations I
  - Intro to Computer Science
  - Dynamic Electrical and Magnetic Fields
  - Digital Logic Design + Lab
  - Physics 3 + Lab

Engineering School (EE, 5 year Acc BS/MS): Year 3

- **Eric's schedule – Third Year, Fall Semester**
  - Electronic Circuits + Lab
  - Solid State Devices
  - Linear Systems
  - Microcomputers
  - Elective: Intro Anthropology
- **Eric's schedule – Third Year, Spring Semester**
  - Applied Probability & Statistics I
  - Communications
  - Electronics
  - Electric Machines
  - Elective: Intro Classical Archaeology
  - Thermodynamics (summer)

Engineering School (EE, 5 year Acc BS/MS): Year 4

- **Eric's schedule – Fourth Year, Fall Semester**
  - Linear Control Systems
  - Computer Organization and Design
  - Intro to Robotics
  - Humanities: Technology and Society
  - Elective: Archaeology of Prehistoric Mediterranean
- **Eric's schedule – Fourth Year, Spring Semester**
  - Digital Control Systems
  - Microwave Communications + Lab (graduate level)
  - Electrical Engineering Projects
  - Fault Tolerant Computing (graduate level)
  - Math Probability (summer)

Engineering School (EE, 5 year Acc BS/MS): Year 5

- **Eric's schedule – Fifth Year, Fall Semester**
  - Linear Automatic Control Systems (graduate level)
  - Advanced Switching Theory (graduate level)
  - Digital System Design (graduate level)
  - Master's Research
- **Eric's schedule – Fifth Year, Spring Semester**
  - Operating Systems (graduate level)
  - Very Large Scale Integration (VLSI) circuit design (graduate level)
  - Humanities: Thesis and Research Presentation
  - Master's Research
- **Degrees: Bachelor of Science + Masters of Science in Electrical Engineering**

Engineering School (EE, Ph.D.): Years 6 & 7

- **Eric's Ph.D. Classes (over 2.5 years)**
  - Digital Control Systems
  - Reliability & Risk
  - Computer Networks
  - Stochastic Systems
  - Behavioral Synthesis
  - Discrete Event Stochastic Simulation
  - Real Time Systems
  - Advanced Networks
  - Ph.D. Research
- **Degree: Doctor of Philosophy (Ph.D.) in Electrical Engineering**

Patrol Competition: Energy Hogs !!

(Requirement 6b)

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Patrol Competition: Energy Hogs !!

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Patrol Competition: Energy Hogs !!

- **Part 1: Using the provided list of home appliances, pick the 10 that you think use the most electricity per year. The biggest energy hog list wins !**
  - Pick your top ten, show to Eric
  - Eric will provide an answer key
  - Add up your annual energy cost to get a grand total

- **Part 2: List five ways you can conserve electricity to become less of an energy hog**

So What the Heck Does Eric Do?

(Requirement 4)

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Interview an Engineer !

- **Eric works for TUV Rail Safety Consulting (RSC) as a Reliability and Safety Engineer**
- **RSC is focused on all safety-related control equipment for the rail industry, covering railroads as well as metro systems like WMATA and NYCT MTA**
- **Our work is in four main areas:**
  - Helping suppliers design new safety-related equipment
  - Acting as an Independent Safety Assessor for railroads and metro system operators to make sure equipment is safe
  - Performing formal safety certification of safety-related equipment
  - Analyzing reliability, availability, and maintainability of railroad and metro systems

Computer Technology in Railroads and Metros

– State-of-the-Art computer technology is extensively used in rail systems for wayside, on-board, and Central command/control

Microprocessor-based Automatic Train Control On-Board System

Microprocessor-based Coded Track Circuit

Microprocessor-based Vital Interlocking Controller

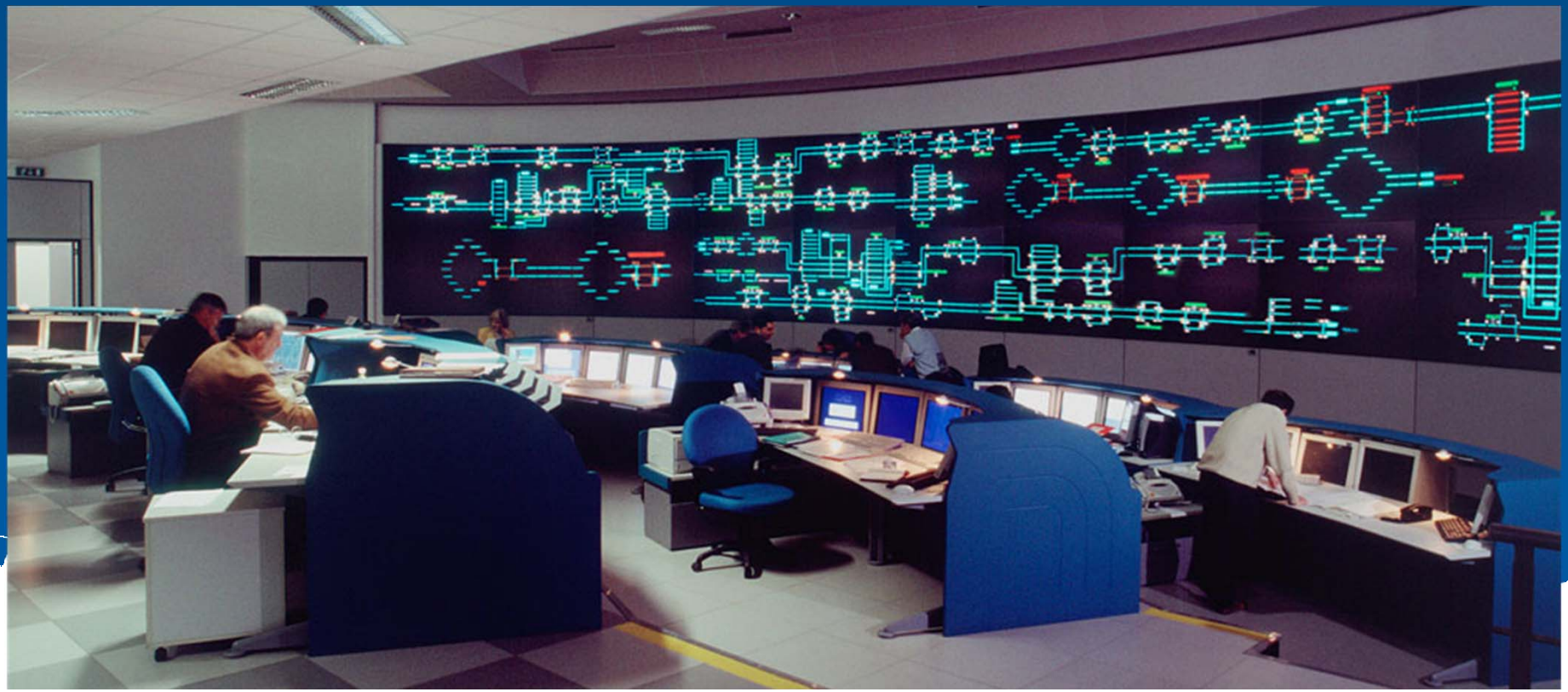
Microprocessor-based Code Relay

Microprocessor-based Wayside Interface Unit (PTC)

Computer-based Transportation Management System

Computer Aided Dispatching (CAD) Systems

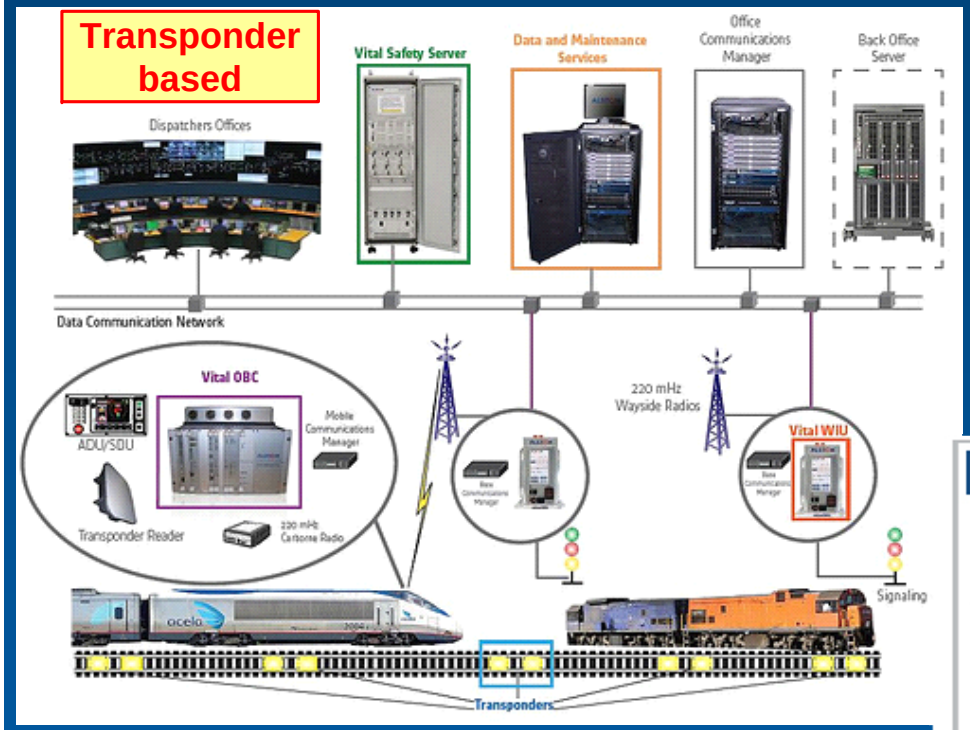
- CAD Systems allow dispatchers to set signals and route trains from a Central Office controlling many miles of track
- CAD commands are safety checked by the vital wayside interlocking control logic before they are accepted/processed

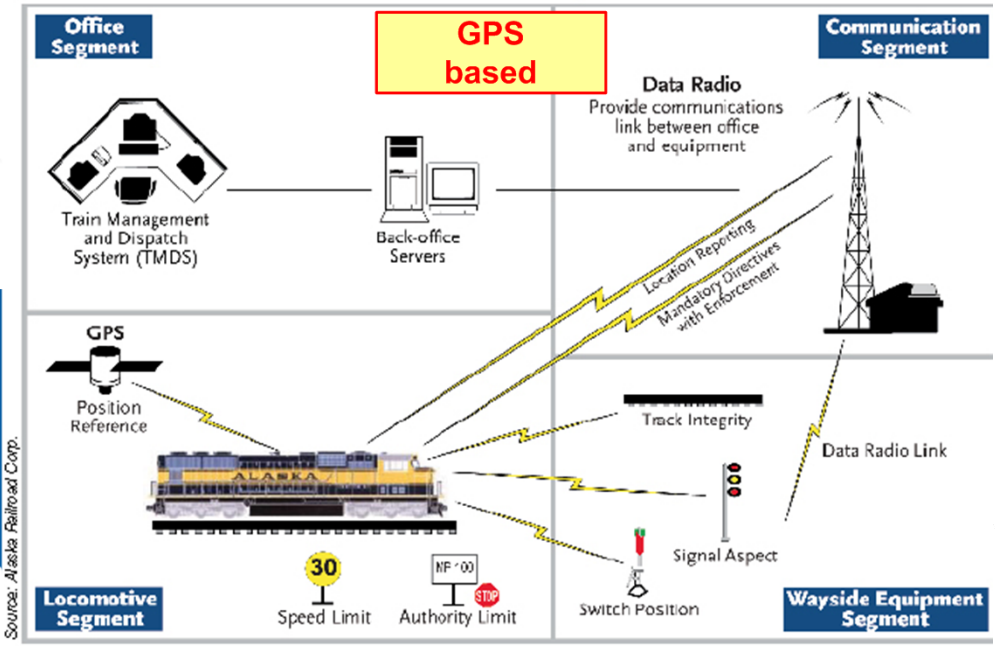


Positive Train Control (PTC) Introduction

- **In 2008, Congress passed a law that all railroads in the US (with some exceptions) must install Positive Train Control (PTC) systems to enhance system safety by preventing human errors from causing train accidents**
- **PTC must reliably and functionally prevent the following:**
  - Train-to-train collisions
  - Over-speed derailments
  - Incursions into established work zones
  - Movement of a train through a mainline switch in an improper position

Positive Train Control (PTC) System Overview





Source: Alaska Railroad Corp.

Example System Design: Interlocking Controller

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Example Safety Analysis: Axle Counter System

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Example Safety Analysis: Axle Counter System

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Example Reliability Analysis, On-Board Computer - Top

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Example Reliability Analysis, On-Board Computer - TMC

- (Slide removed)

Careers in Engineering

- **There are many exciting career opportunities in all fields of engineering across many industries:**
  - Civil engineering
  - Chemical engineering
  - Electrical/Computer engineering
  - Mechanical engineering
  - Mining/Metallurgical engineering
  - Aerospace engineering
  - Agricultural engineering
  - Architectural engineering
  - Biomedical engineering
  - Material engineering

The End !!

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