ETLS 509 - Validation & Verification
University of St. Thomas

John Engelman

ETLS 509 - Session 1

- **Systems Engineering, like all engineering fields is evolving**
  - *Best practices are not perfect or all that they can be*
  - *Many different approaches to all aspects of systems engineering*
    - *Texts will not agree, senior systems engineers will not agree*
    - *Different approaches work well for different types of systems*
- **Student introductions – course expectations**
- **Syllabus**
- **Good reading / viewing: Twenty-First-Century Jet: The Making and Marketing of the Boeing 777**
- **https://www.youtube.com/watch?v=0oyWZjdXxlw**

Texts, etc.

International Council on Systems Engineering (INCOSE) Systems, Engineering Handbook, INCOSE-TP-2003-002-03.2.2.

Members can download the handbook from www.incose.org free of charge. Non-members can purchase the handbook from the same site. Selected readings from web sites as defined in the detailed course outline below.

Guide to the Systems Engineering Body of Knowledge (SEBoK), Version 1.3 released May 2014.

The Systems Engineering Book of Knowledge can be downloaded free of charge at:

http://www.sebokwiki.org/w/downloads/SEBoKv1.3_full.pdf

The Engineering Book of Knowledge can also be viewed via its wiki interface at:

http://www.sebokwiki.org/wiki/Main_Page

"Technical Measurement; A collaborative Project of PSM, INCOSE and Industry," December 2005, INCOSE-TP-2003-020-01, which can be downloaded free of charge at:

https://www.incose.org/ProductsPubs/pdf/TechMeasurementGuide_2005-1227.pdf

There may be some additional web based material added throughout the course

Syllabus summary

Week	Class Activity	Student Activity
1	Introduction to course / course objectives, Review of Systems Engineering	
2	The System Design Processes, Define Validation & Verification	SEBoK, Medical Radiation Case Study (pp 850-853)
	Systems Engineering Body of Knowledge (SEBoK), Medical Radiation Case Study	SEBoK FBI Virtual Case File System Case Study (pp 853-856)
	SEBoK FBI Virtual Case File System Case Study	
3	Validation & Verification Processes	INCOSE 4.8
4	System Test & Evaluation – Analytical & Simulation Testing / Type 1 / 2 testing	"Technical Measurement; A collaborative Project of PSM, INCOSE and Industry" – Sections 1-3.
5	System Test & Evaluation – Type 3 testing	
	System Test & Evaluation – Type 4 testing	

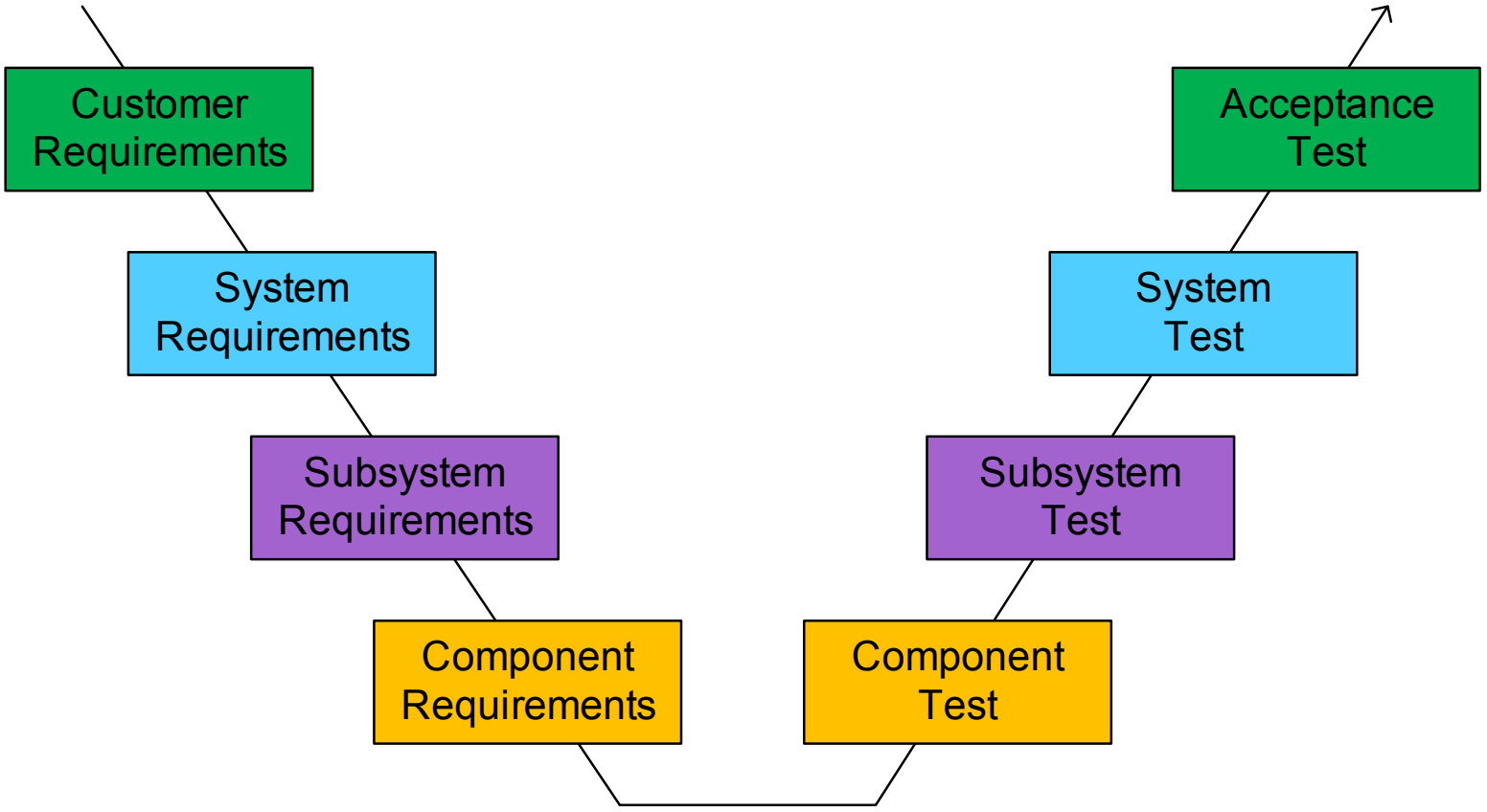
Syllabus summary (continued)

6	Voice of Customer / Requirements Definition
7	Mid-term Presentations
8	Requirements Definition – Human Factors Engineering
9	Requirements Definition RM&A
10	Requirements Definition Logistics & Supportability
11	Producibility, Disposability, and Sustainability
12	Requirements Definition Affordability (life-cycle costing)
13	Putting it all together – Integrating Requirements with Validation / Verification / Cost
14	Student Project Presentations

What this class is all about?

- Integrate V & V into systems engineering process
- Understand how different kinds of requirements impact V & V strategies – we will look at requirements in many disciplines around an in-class system, and your project system
- Come away with a working model of how to V & V a system – a test & evaluation master plan (TEMP)
- 21st Century Jet - Making the Boeing 777

Systems Engineering V-diagram



Development of a New System

- **Identify the customer problem**
  - The customer/user problem **IS NOT** the technical problem(s) being solved
- **How is the problem solved today**
  - If a customer/user has a problem, there is some approach being taken to solve that problem
  - Understanding how something is done today is key to being able to articulate advantages and issues
- **What is the "new idea"**
  - What is the new method for solving the problem
  - How will this resolve issues with the current methods being used
- **What are the metrics**
  - How will the new method be judged
- **What are the milestones and metrics associated with the milestones**
- **How much will it cost**
- **How long will it take**

The Users Problem

- **Consider - An individual would like to view TV shows/movies at home**
  - Let's take a step back in time
    - How was the problem solved in the 1960's & 1970's?
      - Broadcast TV
      - Cable TV
        - » Pay TV – i.e., Channels available via extra cost without commercials
      - Large satellite dishes
  - How did this model for satisfying the users need evolve?
    - Broadcast – some (small number) of additions networks, local TV stations, etc.
      - This happened throughout the 1960's & 1970's
    - Cable TV
      - Large increase in the number of channels, specialized channels, etc.
    - Directed Broadcast – Specialized networks broadcast via towers/ building tops in large metropolitan areas, specialized box required
    - Satellite TV
      - Direct TV, DISH TV, etc.

Time progresses

- **User problem remains the same**
  - New solutions to the problem (dramatically simplified)
    - Sony develops Betamax VCR – Started gaining popularity in early-mid 1970's
      - Significant issue – cost - >$1200 in 1976 (>$5000 in 2014 $)
    - JVC develops VHS, many companies marketing units
      - Open standard
      - Lower cost
  - VCRs give way to new solution to problem
    - Purchase TV shows/movies on tape
    - Video rental stores
      - The rise of Blockbuster and the like

Current Home Entertainment Solution & Issues

- **VHS Tape Issues**
  - Quality of video with emerging larger TVs
  - Analogue media
    - Tape tends to stretch with usage causing poorer video quality
    - Manufacturing quality control
    - Manufacturing time
  - Sound
- **Next generation technologies address issues**
  - DVDs
    - Digital
    - Manufacturing is a “stamped” e.g., high speed, operation
    - Significant increase in picture & sound quality

User Problems vs Technical Problems

- **Standard method of delivery for VHS - video rental store (user problems)**
  - Had to go to physical store for typical 1-2 night rental of VHS tape
  - Late fees were quite high (part of the business model for the VHS rental store's profit)
  - When tape quality was poor (not uncommon), inconvenient to return for a good one.
  - A hassle to get newly released films – best case reserve via phone, typical case, see if it happened to be on the shelf
- **Separate User Problems from Technical Problems/business problems**
  - Tape quality was a technical problem with the delivery mechanism
  - Delivery mechanism of a physical store was in part a technical problem due to the size/weight of a VHS tape, e.g., shipping was high relative to rental cost for "mail type service"
  - The rest of the problems were fundamentally business problems associated with the video rental store business models

Addressing Fundamental Technical Problems

- **Data density**
  - A fundamental technical problem for computer and entertainment industries
  - The magnetic methods of storage are fundamentally related to surface area, as such tape provides large amounts of surface area at low cost (also essential to both industries)
- **Disruptive low cost data storage**
  - Instead of magnetic storage, utilize light, e.g., CDs/DVDs/ Blu-ray
  - Fundamentally, put rectangular bumps holes in a layer of media which can then be read by looking at the reflection when a laser is shined on the media, a completely different technique than magnetic storage utilizing different physics.
- **Net result, a dramatic increase in highly producible storage**

Delivery Mechanism

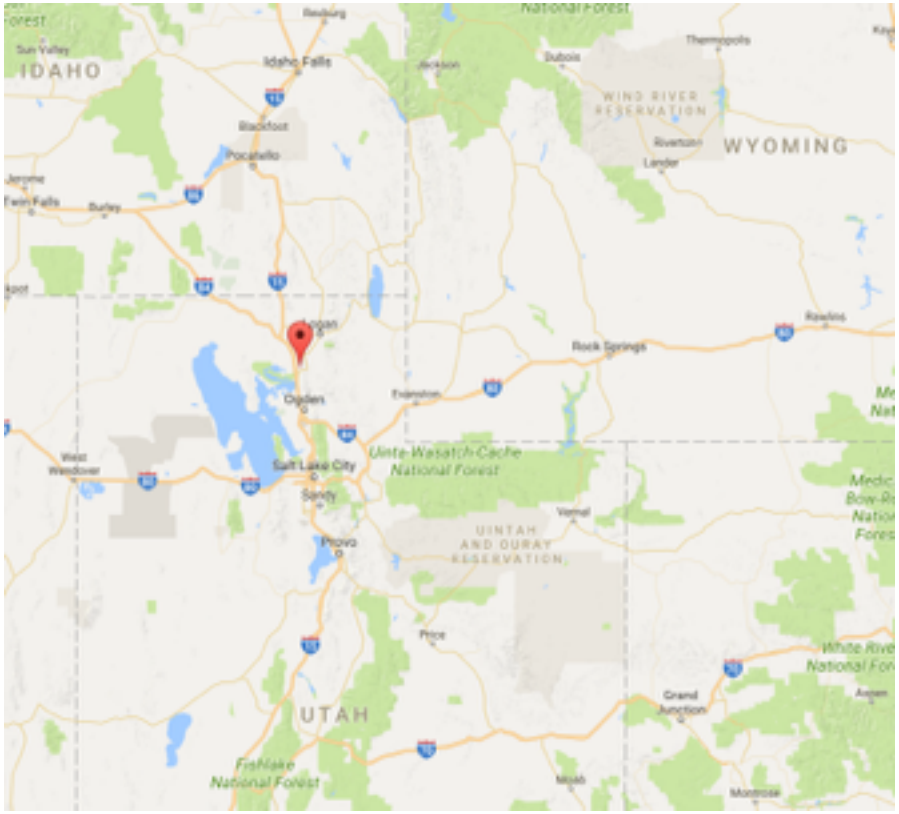
- **Idea – with new media, use the post office and a warehouse**
  - In 1997 a pair of entrepreneurs, Reed Hastings and Marc Randolph, founded Netflix.
    - Provide DVDs for “untimed” rental – experiences with late fees from video rental stores provided this guiding business principal
    - Ship via single first class stamp, include prepaid return mailer
    - Provide method for customers to select and prioritize DVDs they wanted prior to the DVDs being released
  - Netflix business model/service is generally sited with putting former video rental giants such as Blockbuster in bankruptcy
- **The technical problems associate with delivery continue to cause new solutions to be introduced**
  - Streaming

U.S. Space Shuttle System

- Orbital Vehicle - crew and operations
- External Tank - main engine fuel
- 2 Solid Rocket Boosters
  - preliminary thrust assist (1st 2 minutes of flight)
  - Most powerful rocket motors ever flown
  - Half the mass of the entire system at liftoff

Solid Rocket Booster

- 12.17 foot diameter (3.71 m)
- Manufactured by Thiokol (now ATK)
- Manufacturing facility in Brigham City, Utah



Shuttle Launch System Assembly

- Space shuttle component parts are transported to mission launch facility for assembly for integration and assembly
  - Kennedy Space Center, Florida
- 7 day freight train route from Utah to Kennedy
  - Train runs through multiple tunnel segments during journey

U.S. Train Tunnels

- Creating tunnels through mountains terrain is expensive
  - ~$6,700 / linear foot (2016 dollars) (based on Moffat tunnel cost)
- Make the tunnel only large enough for what moves through it.

U.S. Rail Gauge

- Gauge is the distance between the 2 wheel sets of a train.
- U.S. Standard Gauge is 4’ 8.5”
- U.S. Standard is based on English standard

European Rail Gauge

- Rail lines were built by same people who built pre-railroad “tramways”
- Used the same jigs and tools for building wagons
- Rail gauge is approx. equal to wagon wheel width

Wagons

- Wagon wheel spacing was built to match the existing rutted roads the wagons travel on
- Original roads were built by Romans
- First travelers were likely Roman war chariots
- Wagons were only as wide as the animals pulling the wagons

Thus,

- **One of the most sophisticated machines every designed and built by humans has a design requirement that can be traced back to the Romans and is approximately the width of 2 horses' rears.**