George Mason University

SYST 101: Intro to Systems

Lecture 28

April 29, 2004

C. Wells, SEOR Dept.

Announcements

- FINAL EXAM
  - May 11
  - 1:30 – 4:15
  - Open book, open notes

Agenda

- Finish course review

Why Systems?

- The universe is too big and too complicated
  - Too much to do or understand
  - Divide and conquer
    - Artificial non-unique partitions
    - Every system is someone else's subsystem
    - It's the structure and interaction
- Combine and simplify for the system view
  - The big picture at the expense of detail
  - Relationships between parts is the focus

Events vs Systems

- So far, we've discussed systems
  - Implied that they interact with each other
  - Implied that they do things themselves
- Brings us to how systems interconnect, and the topic of events
  - The structure and interaction

Events

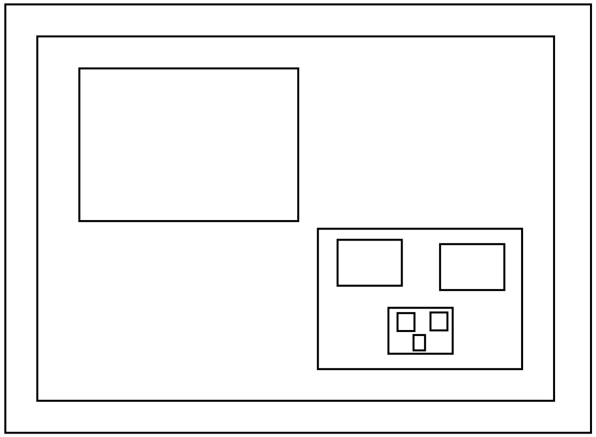
- Events are things that happen in or to your system
- Events usually have relatively short time durations.
  - Functions, on the other hand, can take a long time to perform

Events vs Functions

- A common modeling technique:
  - Envision systems as responding to events by performing a function.
  - Events “trigger” functions
  - Biology: Stimulus-response

Internal vs External Events

- Systems are made up of sub-systems.
  - And often a system can be viewed as a sub-system to some larger system



Systems inside systems inside systems ...

Every system is somebody else's subsystem

Internal vs External Events

- A system can experience events that come from external systems, or can experience events that come from one of its internal systems
  - When you get hungry, your brain sub-system is responding to low-sugar signals from your endocrine system.

Events & Interfaces

- Systems relate to each other through their interfaces
  - Events are often “transmitted” through some sort of interface.
  - Interfaces are much easier to see in man-made systems
  - Sometimes not so easy to see in natural systems.
    - That’s what makes medicine so hard...

Note!

- A System's interfaces will exist whether or not they are connected to anything!!
- A system's interfaces and what information they carry to and from the system are a key part of system design, and a key element in understanding natural systems.

Why Doesn’t It Work?

- The model is wrong
- The model is not sufficiently accurate
- The entity doesn’t match the model
- The entity is broken

- So what’s wrong, the model or the entity? Or both?
- What to you do about it?

The Secret Ingredient

- There is a critical element in the evaluate block essential to explaining reality vs the model
  - ***OBSERVE*** the operation of the entity
    - Note the differences between reality and the model
    - Identify the (possible) cause of the differences
  - Formulate (guess) a "solution" that addresses the causes for the differences
  - Analyze the solution
  - Interpret the analysis to see if the solution is adequate

Quality of the Observation

- Sufficient detail to hypothesize what is causing the observed anomalous behavior
  - Why is it doing what it is doing
  - As usual, the needed quality of observation depends on the situation

Observe – Think - Do

- Think before you make changes
  - Do you have a rationale for what caused the difficulties? Really?
  - Does the “fix” address the cause?
  - Should the “fix” solve all the problems?
- Only then apply the fix
  - Document the fix
- Observe and document the results

And the Answer --

- Depends on the situation
- You have to cultivate the ability to observe accurately and adapt
  - Critical element of intelligence
  - Difference between academic exercise and real world engineering
    - observation → possible cause → improved solution
  - 30 years of experience or 1 year experience 30 times

Software Can Be Tricky

- Validation and verification of software is problematic at best
  - Impossible to test all conditions
- Failure modes are harder to identify
  - Failure sources can be computer hardware, logic, or coding
- Compilation and optimization can exacerbate the problem

A Basic Problem

- Knowing you're right
- Leads to
  - Dead ends
  - Being stuck
  - Conflict with others who know they're right too.

The Pencil Point Analysis

- All the steps were right, so why isn't the answer right?
  - An assumption was invalid, but was overlooked.
  - An inadvertent error exists but is repeatedly missed because the mind sees what it expects to see

Getting Unstuck

- Become an independent observer
  - Observe your system operating, without following your mental model
  - Watch what it does, and only what it does
  - Preconceptions about what is wrong can keep your attention away from the real difficulty

"Pride of Ownership"

- A phrase often heard in the real world.
- Meaning: "I built this, and if you criticize what I built, you're criticizing me, and I will take it personally."
- Effects: Criticisms dismissed as "stupid" or "ignorant". "They really don't understand what's going on if they can make comments like that".

“NIH” - Not Invented Here

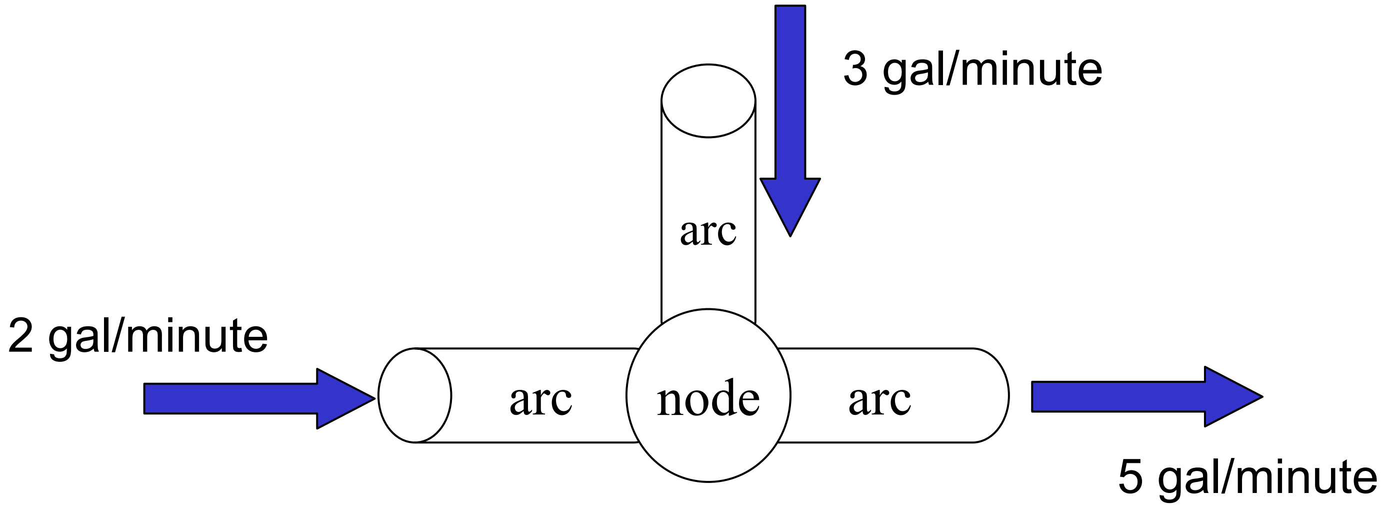
- Translation: “If we didn’t invent it, then it can’t be any good”.
- Allows a team to dismiss others’ ideas and criticisms without truly considering them.

Utility of Lifecycles

- Had they been good systems engineers....
- Consider the full lifecycle of the system, from a variety of viewpoints
- Take the viewpoint of different participants in the system

"What Goes In, Must Come Out"

- In electrical engineering, it's known as Kirchoff's Current Law:
  - The sum of the flows entering a node must be equal to the sum of the flows exiting the node.

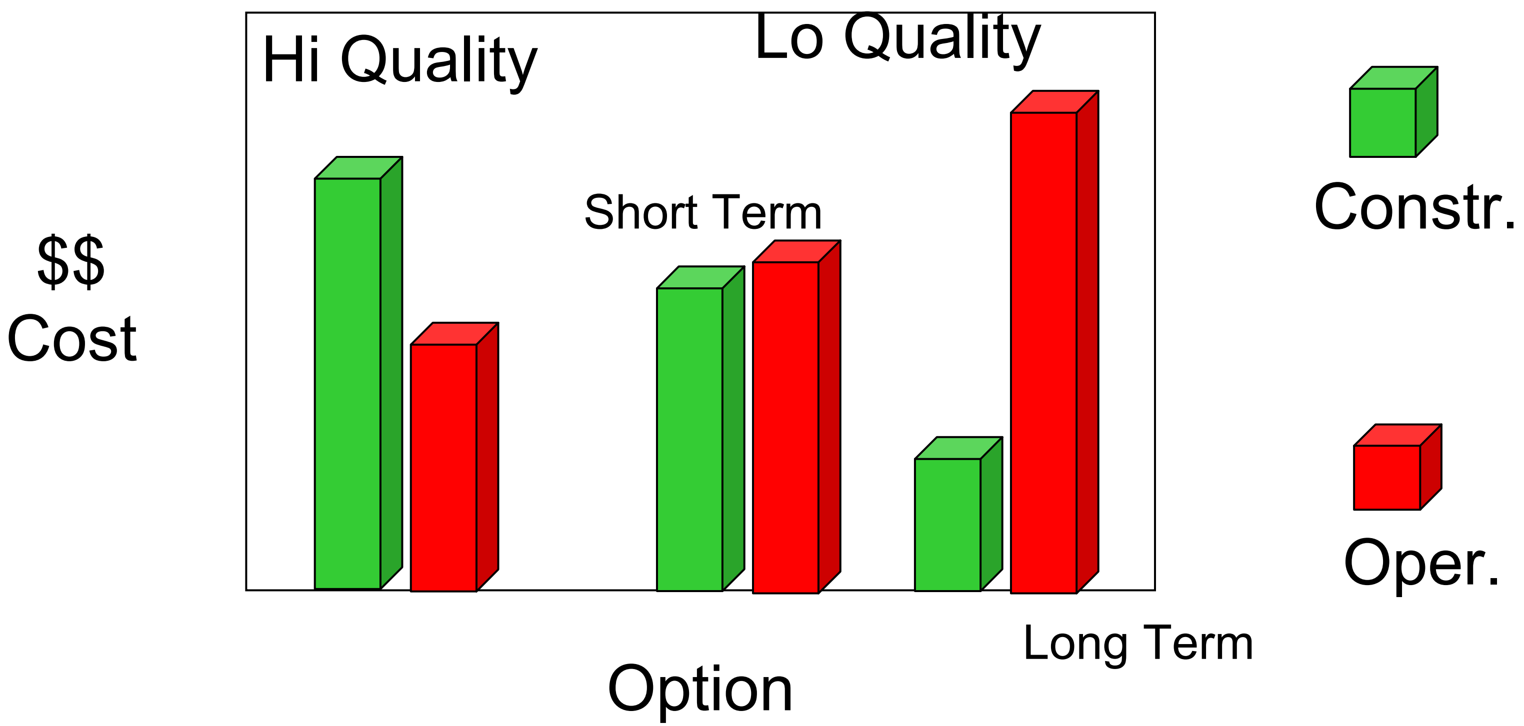


Project Phases

- Design Phase
  - Competitive Designs
  - Relatively Inexpensive
  - Relatively Little Opposition
  - Drives total costs
- Construction Phase
  - Must Have Only One Design
  - Expensive
  - Opposition Prior to Start

Construction/Maintenance Tradeoff

- Another classic tradeoff



Components of Tradeoff Analyses

- At least two components, and a +/- relationship between them
- In the previous example:
  - The higher we decide to pump, the shorter the tunnel needs to be
- Calculate (or look up) the cost functions of each

Optimization Procedure

- Sum the costs (as a function of the single independent variable, pumping height)
- Look for minima in the curve
  - inflection points
    - Slope = 0 ($\frac{d}{dx} f(x) = 0$)
  - endpoints

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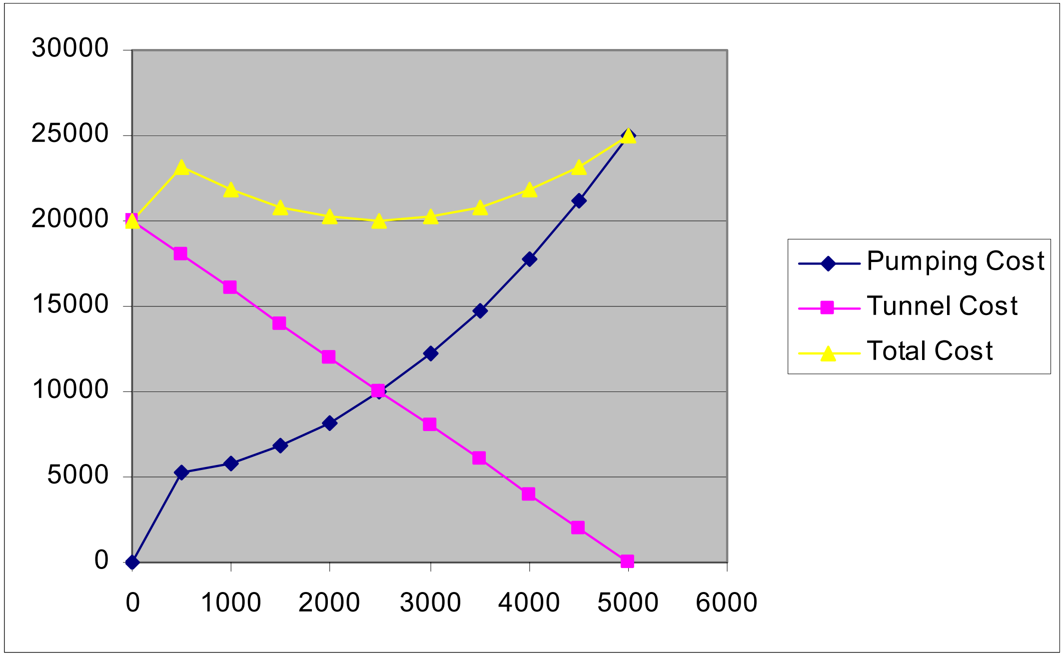
Tradeoff Optimization

Pumping Cost	Tunnel Cost	Total Cost
0	20000	20000
5200	18000	23200
5800	16000	21800
6800	14000	20800
8200	12000	20200
10000	10000	20000
12200	8000	20200
14800	6000	20800
17800	4000	21800
21200	2000	23200
25000	0	25000



An N^2 Diagram

			ground					power			attitude				TT&C		comm.		
		orbital dynamics/launch	antennas & pointing	receivers	transmitters	command & control	networks	generation	storage	thermal control	determination	control	structures	propulsion	commanding	telemetry	antennas & pinting	receiver	transmitter
	orbital dynamics/lanch	--	X	X	X	X	X	X		X	X	X	X	X			X	X	X
ground	antennas & pointing	X	--														X	X	X
	receivers	X		--													X		X
	transmitters	X			--												X	X	
	command & control					--									X	X	X	X	X
	networks	X					--										X	X	X
pwr.	generation	X						--	X	X	X	X	X		X	X		X	X
	storage							X	--	X		X	X		X	X	X	X	X
	thermal control	X						X	X	--	X	X	X	X	X	X	X	X	X
att.	determination	X						X		X	--	X			X	X	X	X	X
	control	X						X	X	X	X	--	X	X	X	X	X	X	X
	structures	X						X	X	X		X	--	X	X	X	X	X	X
	propulsion	X								X		X	X	--	X	X			
TTC	command					X		X	X	X	X	X	X	X	--	X	X	X	X
	telemetry					X		X	X	X	X	X	X	X	X	--	X	X	X
comm.	antennas & pointing	X	X	X	X	X	X		X	X	X	X	X		X	X	--	X	X
	receivers	X	X		X	X	X	X	X	X	X	X	X		X	X	X	--	X
	transmitters	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	--

Readings

- The final will also cover the readings
- Petroski: “To Engineer Is Human”
  - Chapters 4, 5, 7, 8, 9, 15
- Petroski: “Invention By Design”
  - All chapters

Tips

- Simple answers
  - Necessary and sufficient
    - Same detail as viewgraph
    - Short and direct paragraphs
- Organize your notes and study
- Get some rest
- Good Luck
  - (if you depend on luck to pass)