Randy's Bio

- Woolley Consulting randy.woolley@engineer.com
- BSEE CSU Sacramento, BS Biochemistry UC Davis
- Retired from Caltrans Division of Research (25 years)
- Successfully completed 50+ transportation research projects
- Developed and taught (>40x) a 2 day SE fundamentals class for Caltrans
- Taught 3 day classes for UC Irvine- Fundamentals, Requirements, Design, Verification & Validation (>20 x)
- Member of INCOSE, ITE, IEEE, ITS America, ITS Ca
- Worked in Electronics Design and Manufacturing more than 26 years
- Using SE Techniques more than 20 years

The Value of Systems Engineering and Transportation System Examples

INCOSE Los Angeles Chapter

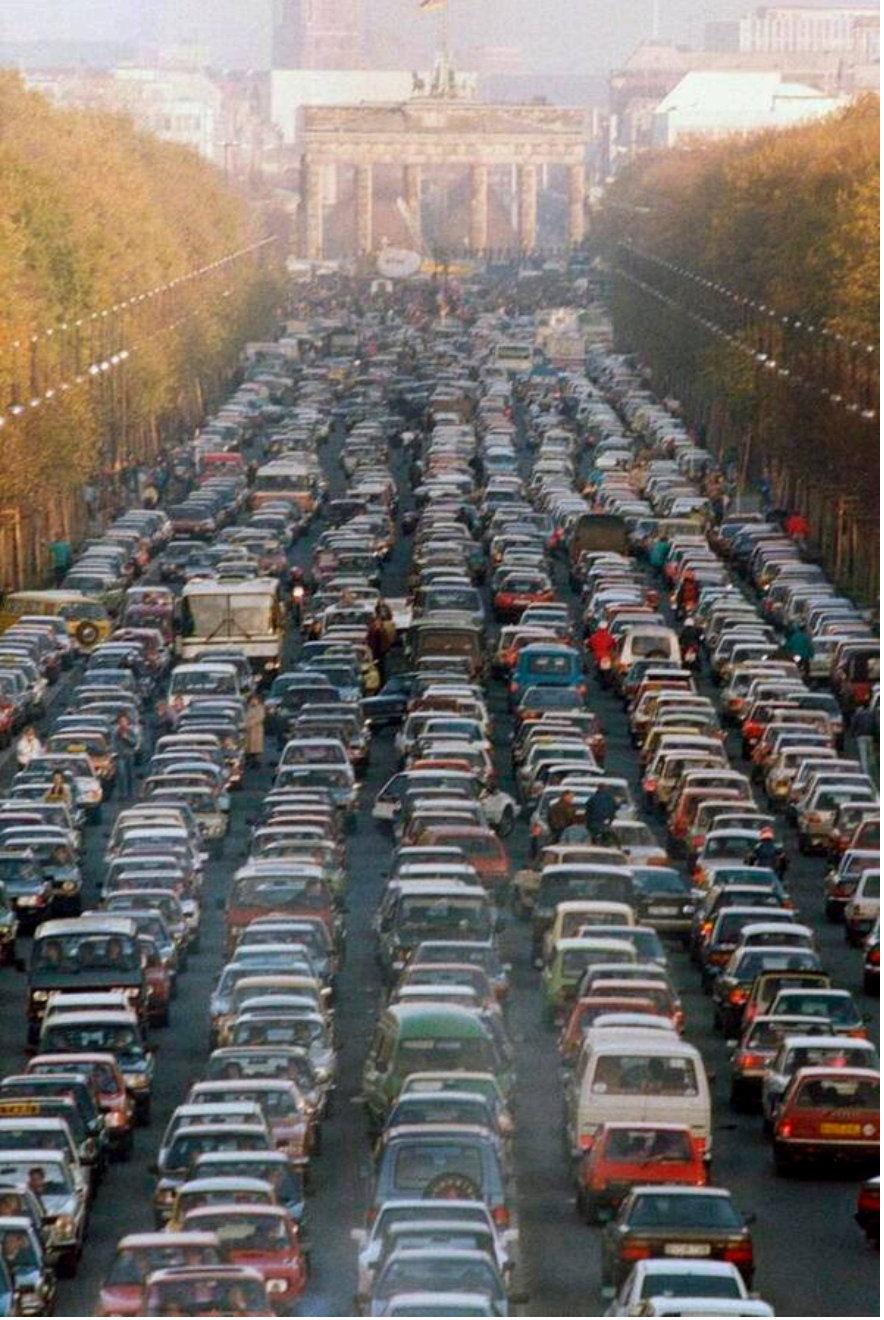
June 13, 2017

Membership Meeting Presentation

Randy Woolley, CSEP, PE

Ice Breaker

An Engineer, a Surgeon and a Priest are playing golf …



Does this look familiar?

Traffic jam in Berlin, Germany, on the first Saturday after the fall of the Wall on November 9, 1989, ~**28 years ago.**

Topics to Discuss

- My Interest in SE/ My History
- Basics- SE101
  - What is a System?
  - What is Systems Engineering?
- Some Caltrans History
- What do we mean by “Value”
- Who determines value?
- Transportation Examples

My Interest/ History

- Began in the early 1970s in flight school and while flying UH1 Huey aircraft on Medevac Missions at Ft Knox
- Nearly all missions are solo flights with critical patients on board
- Flight diversions for **perceived** mechanical or electrical problems are seldom in the patient's best interest
- Few pilots have any training to determine what is a critical problem and what is a minor one
- I really wanted to know how to tell the difference

My Interest/ History

- I was privileged to attend the US Army Maintenance Test Pilot School where they teach these things
- Most military aircraft have redundant system indicators for critical items such as oil pressure and temperature
- When a problem is perceived, you must be able to interpret all the system indicators to determine if you have a major problem, a minor problem or an indicator problem
- This led to my interest in understanding all the **aircraft systems**, how they operated, and what the indicators actually told me
- **My interest really started more than 40 years ago**

My Interest/ History

- After my time in the service, I obtained a degree in Electronics Engineering, and went to work for General Electric Medical Systems Ultrasound Division assigned to investigate and solve equipment field problems
- This again required a detailed understanding of the entire system
- I learned similar details of processes when transferred to manufacturing, responsible for vendor quality
- I continued at System Integrators as the Quality Assurance Manager, implementing SE and Just-in-Time into their manufacturing process (was not called SE at that time)

My Interest/ History

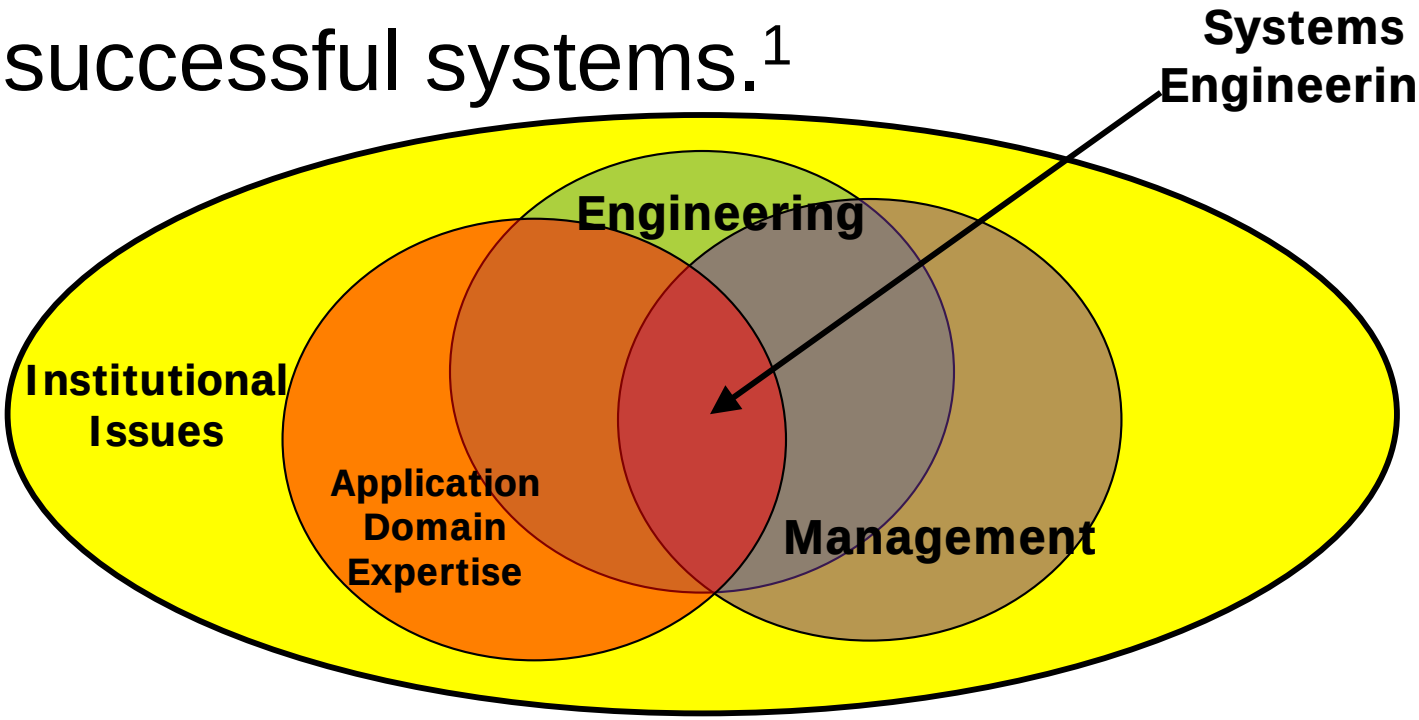
- I was assigned similar problem solving responsibilities at Caltrans in the Research Division
- In January 2001, the Federal Highway Administration issued “The Final Rule” mandating the use of Systems Analysis for ITS Projects (23CFR940.11) (Use of Systems Engineering)
- I was assigned as the team lead for Caltrans to implement 23CFR940.11 into Caltrans ITS Project processes to insure that we continued to receive federal funds (80% of most projects) for ITS Projects.

SE 101- Formal Definition of a System

- Definition:
  - The ***aggregation*** of end products and enabling products that achieves a given purpose **(EIA 632 V1.0 April 1998)**
  - An ***integrated composite*** of people, products, and processes that provide a capability to satisfy ***a stated need or objective.*** **(INCOSE SE Handbook Version 2.0 July 2000)**

SE 101 What is Systems Engineering?

An ***inter-disciplinary approach*** and means to enable the realization of successful systems.[1]

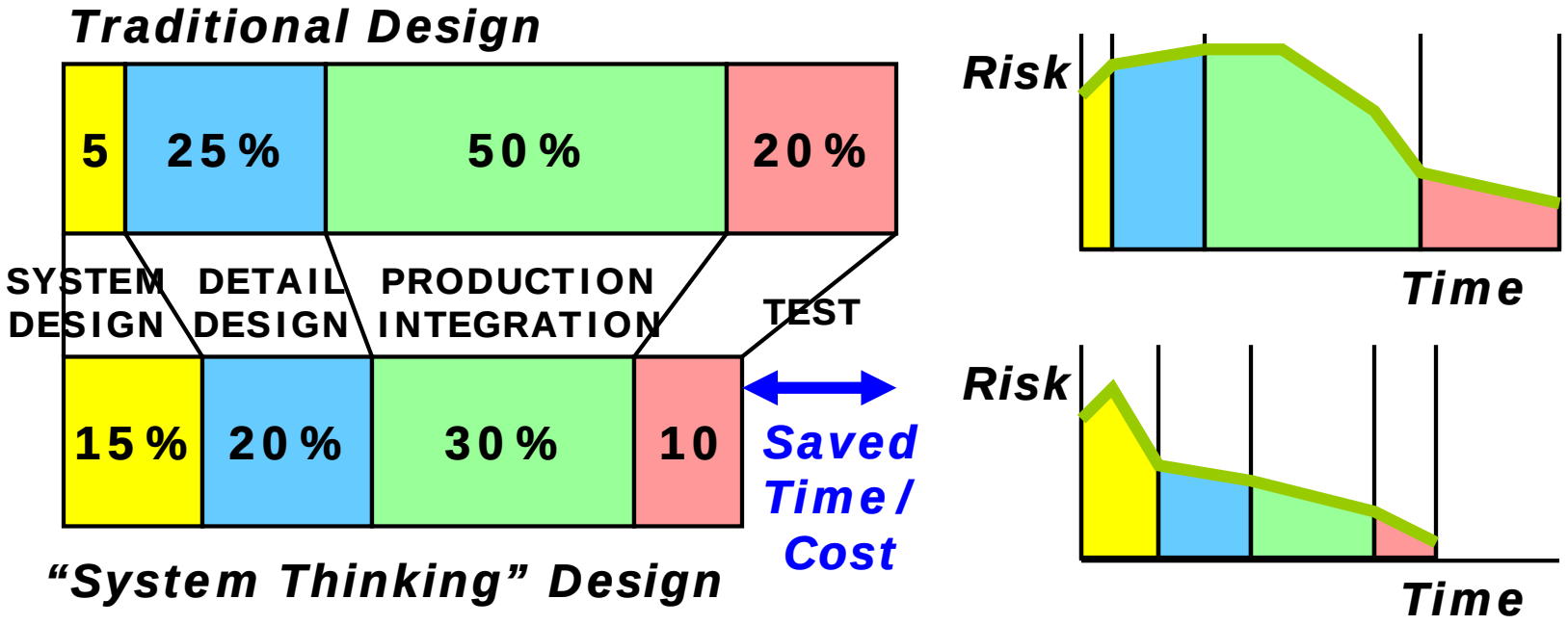


1-EIA-731 Annex B (Glossary)

Heuristic Claims of SE- SE 101

- Better systems engineering leads to
  - Better system quality/value
  - Lower cost
  - Shorter schedule

RISK IS REDUCED EARLIER



Mar, Honour Value of Systems Engineering 2002 INCOSE Symposium

Developing the Systems Engineering Guidebook (SEGB), SE Training

- FHWA Final Rule mandated use of Systems Analysis for ITS Projects (23**CFR**940.11 January 2001) (Use of Systems Engineering)
- The Code of Federal Regulations specified seven steps, all of which are common in Systems Engineering
- Randy led the Caltrans development of the *Systems Engineering Guidebook (SEGB) for ITS Projects,* partnering with FHWA and private industry
- Hosted at https://www.fhwa.dot.gov/cadiv/segb/
- Used by most state DOTs in the US and many around the world

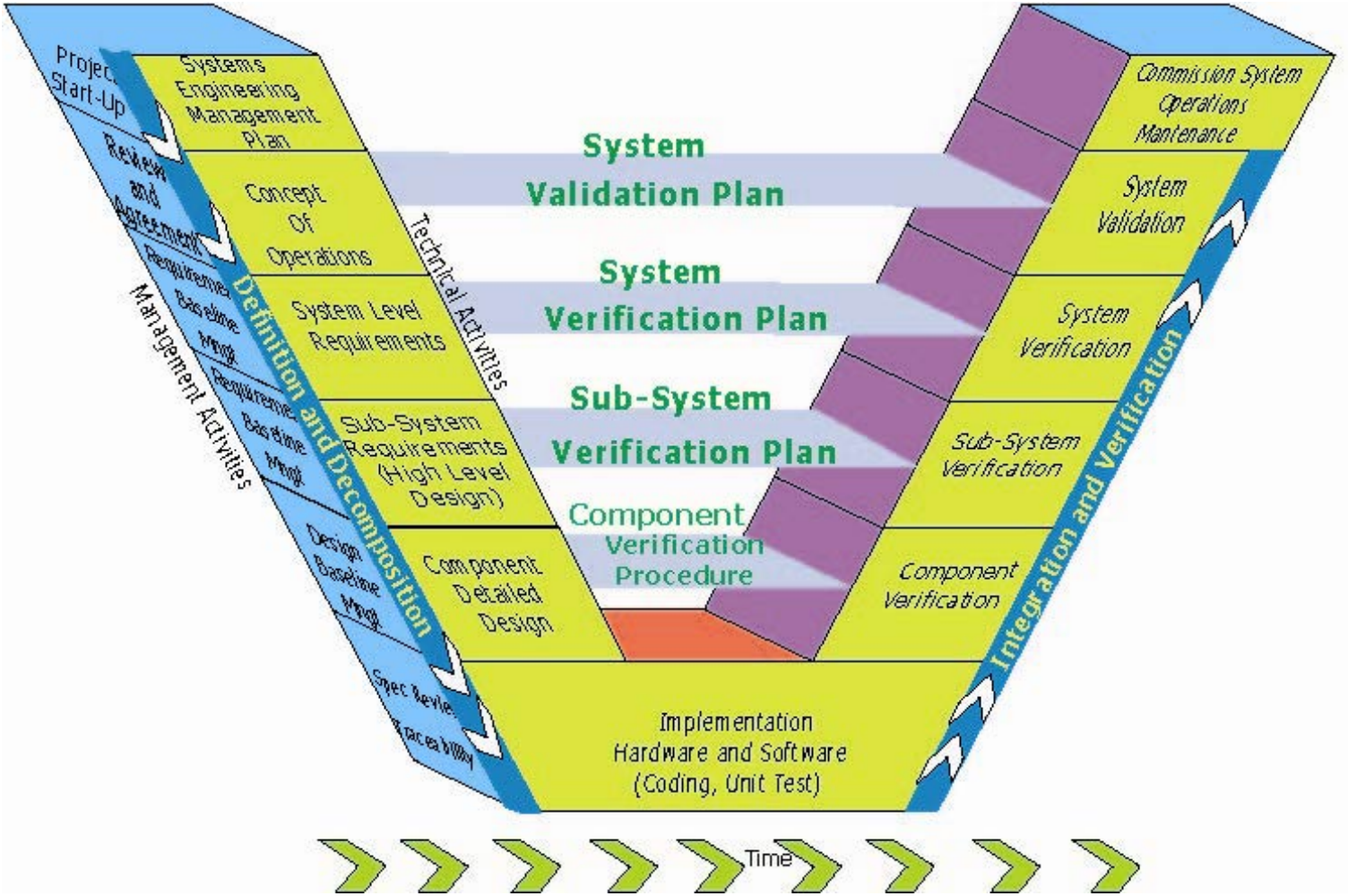
Developing the Systems Engineering Guidebook (SEGB), SE Training

- Randy was also the Contract and Project Manager to develop a two day Systems Engineering Fundamentals class (SE101)
- This two day class was taught >40 times to Engineers and Planners throughout Caltrans, as well as multiple counties and cities in California. We focused on those developing Intelligent Transportation System Projects.
- I later updated this to four 3 day classes for UC Irvine and taught them in the corporate world.
- These included: Fundamentals, Requirements, Design, Verification & Validation. I taught this series more than 20 times.

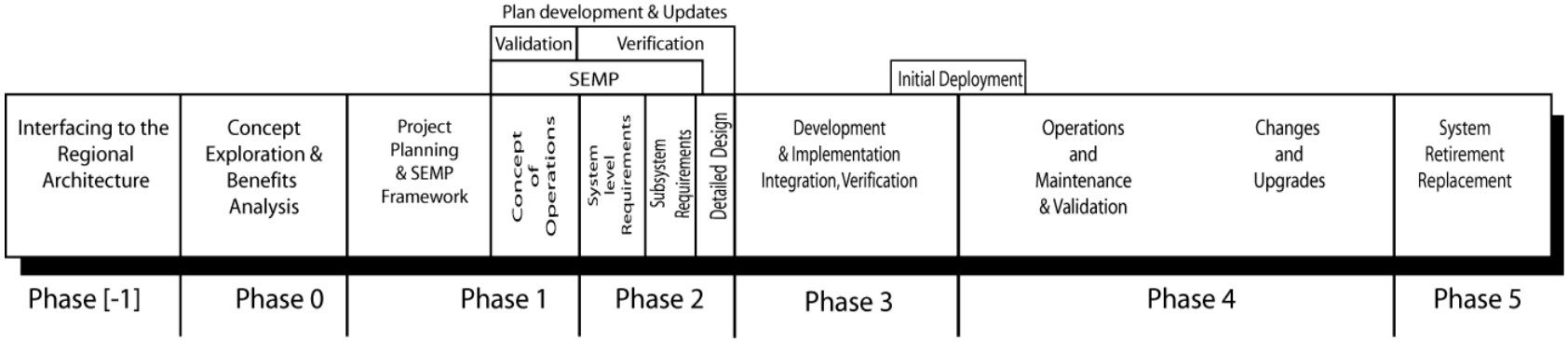
Changes in the Research Process

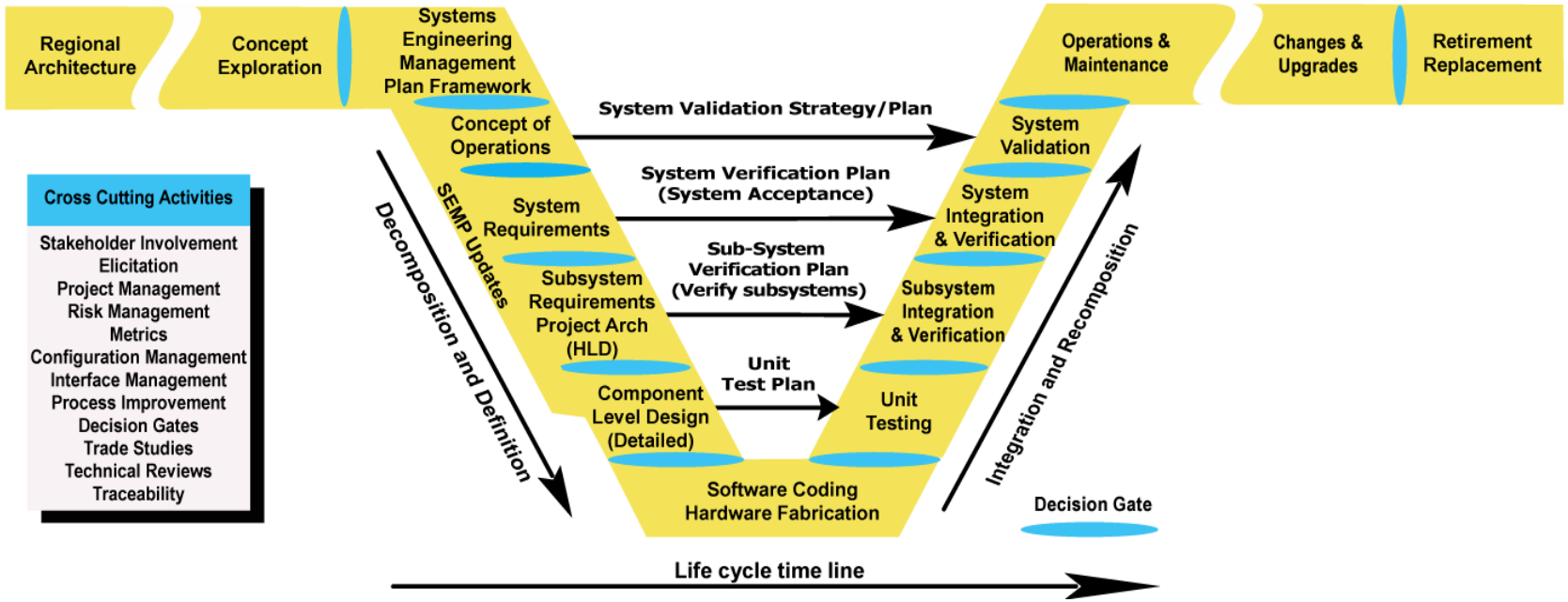
- **Communication with the customer became key at all stages of the research**
- **Focus on Customer Needs**
- Research **projects needed a customer champion** to start
- Champion customer must **commit to implementing** when an affordable solution is found
- Began use of systems engineering Vee model
- SE and PM training provided
- My team mandated use of SE Vee model for our projects
- **Engineers, Planners and first level supervisors** managed contracts (rather than higher level managers)

Systems Engineering Vee Diagram

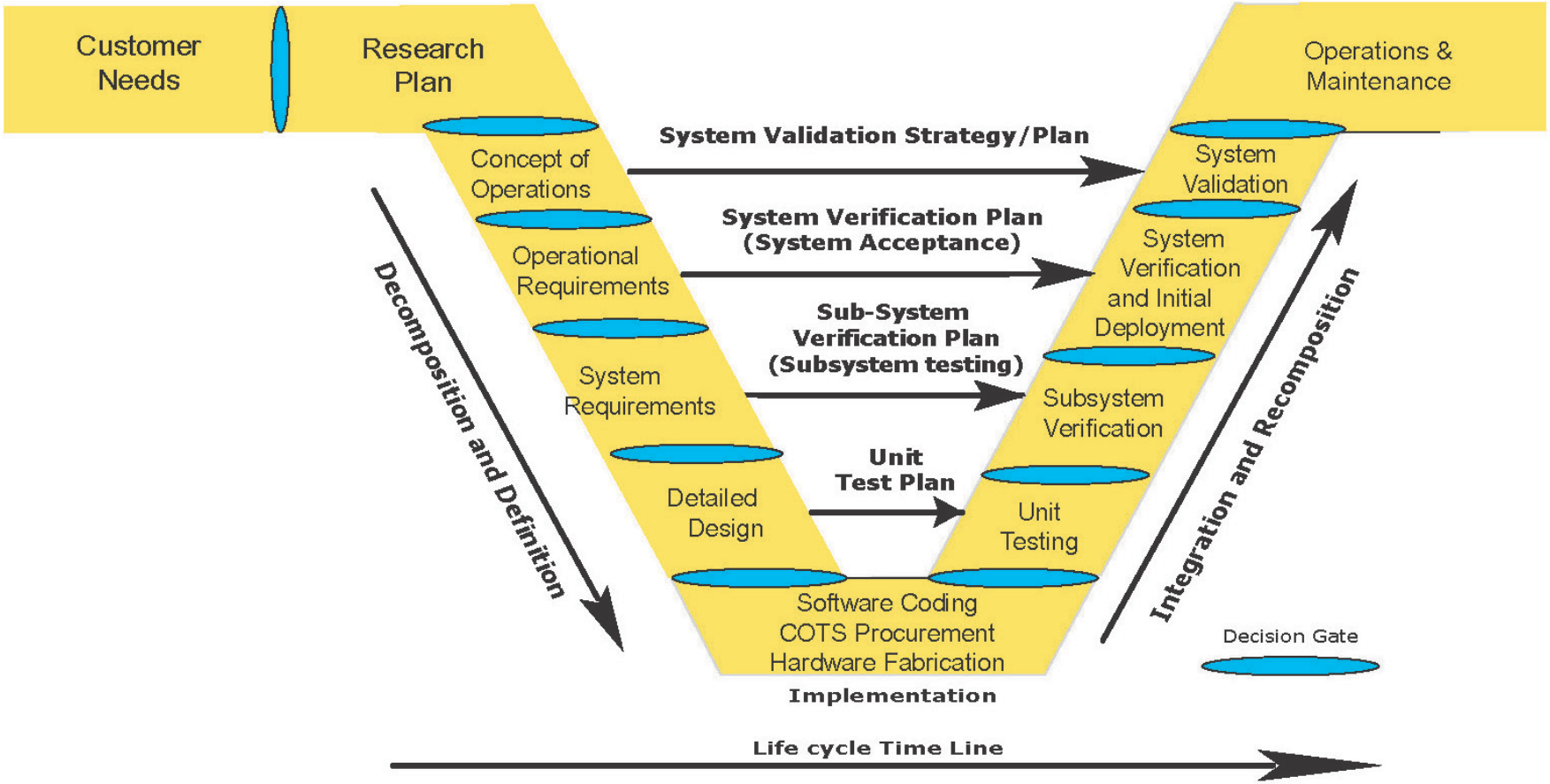


Vee Diagram for Transportation





Vee Diagram for Transportation Research



The Results

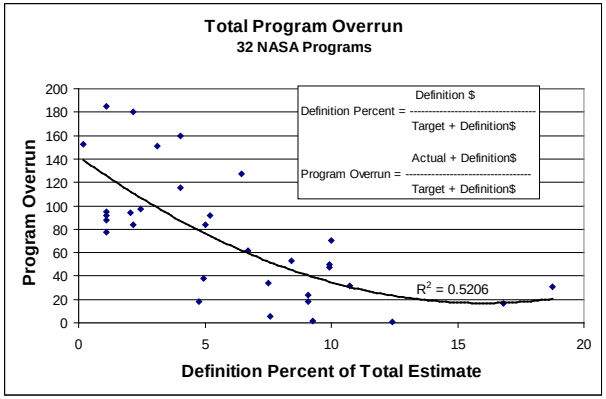
- **Research projects only started when the customer was on board.**
- Higher Quality Research, Quality Control by customer and Contract Manager
- Payment only **after** an accepted delivery
- Change orders made very difficult
- CM and PM **MANAGED** the project
- Weekly and monthly status with CM/PM, **customer** and researchers
- Nearly all projects completed on time/ in budget
- **Each of these things contributed to better quality or higher value product**

What is Value?

- First, a Look at Webster (2 nouns, 2 verbs)
  - "A fair return or equivalent in money, goods, or services for something exchanged"
  - "The monetary worth of a thing"
  - "To estimate the worth of: Appraise"
  - To rate in usefulness, importance, or general worth"

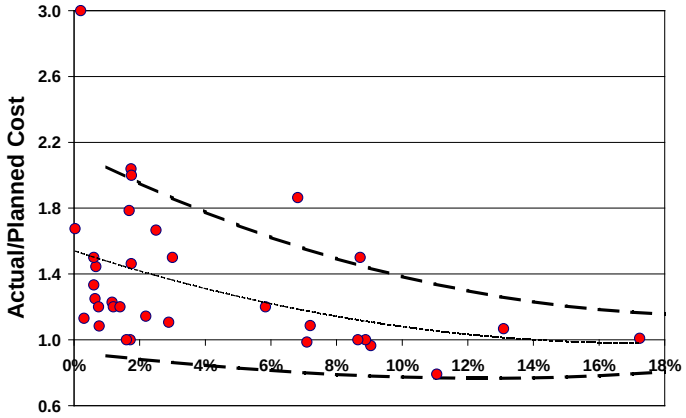
Value of Systems Engineering Effort

NASA Tracking 1980s

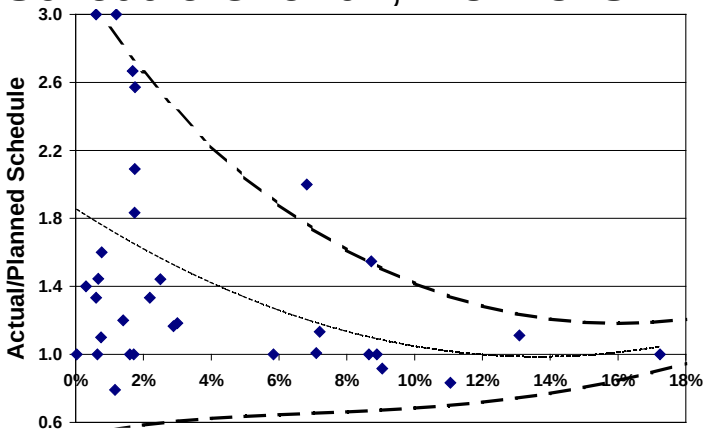


Source Werner Gruhl
NASA Comptroller's Office

Cost Overrun, Risk vs. SEE



Schedule Overrun, Risk vs. SEE



Source: SECOE 01-03
INCOSE 2002

- Program Overrun
- Actual/Planned Cost/ Risk
- Actual/ Planned Schedule

All Plotted Against Systems Engineering Effort

Value of Systems Engineering

- The Questions to Ask-
  - **Did the system work as the customer envisioned it**?
  - Was the **cost** what the **customer expected**?
  - Was the system **delivered on time**?
  - Do the customer's users **use the system**?
  - Does the system work as the **users needed it to work**?
- If your customer answers favorably to these questions, then Systems Engineering was likely of significant value to the project

Who Determines Value of SE

- Ultimately comes down to: How does your **Customer, Owner, User, Funder** Value the system, ie: What is is it worth to them
- **These people** determine whether or not SE was of value for the project
- Ultimately, the PM, SE, CM and engineers on the job do not make the final determination of the value of SE on a project.

Sample Research Projects

- * Snowfighter Communication
- * Using Highway Patrol in Workzones- COZEEP/MAZEEP
- Advanced CMS Sign Specification
- New Barrier Designs
- Alternative Fuel Vehicle/ Maintenance Fleet tracking
- Airborne GPS for Photogrammetry
- 1997 Automated Highway Technology Demonstration
- Placing travel times on CMS Signs
- Reducing backing accidents
- Numerous workzone safety investigations

Snowfighter Communication Project

Sample Research Projects - Snowfighter Communication

- In mountainous areas, there is little or no line of sight radio communication, few cell towers, often miles without communication
- We installed a test bed with additional radio repeaters
- We developed a store/forward software mechanism between all vehicles to pass messages, including a moving map with last known location
- Used Radio, Cell and Satellite communications as necessary
- Employed identical systems in all vehicles
- **First 12 months** developing user needs and requirements (more extensive than any previous project)

Sample Research Projects - Snowfighter Communication

- Minimal new development, nearly all the work was integrating existing COTS products
- Tests conducted on highway 88 near Caples Lake (Kirkwood Ski Resort), the w**orst communications area** in California (South and East of Lake Tahoe)
- Prototype testing successful
- Included a near real time moving map and text messaging system (available in the truck and at the maintenance station or District Office)
- Project put on hold when a similar commercial product was found to be under development and already patented- the product is being evaluated

Using Highway Patrol in Workzones

Using Highway Patrol in Workzones

- Construction and Maintenance Zone Enhanced Evaluation Program (COZEEP and MAZEEP)
- Evaluated using 1, 2 and 3 CHP units in the work zone
- 34 tests in 12 urban and rural sites
- Day and Night tests
- Was most effective in long work zones where the driver can see multiple CHP units
- Initial results were that traffic slowed just over 5 mph- Does not seem like much

Using Highway Patrol in Workzones

- We evaluated the data using an FHWA microsimulation called *PC Crash*
- The outputs of *PC Crash* show all crash forces, including those which would result in fatalities, only injuries, and only likely property damage
- We used 3 years of actual crash data and entered it into the simulation, 1,860 Work Zone crashes: 35 fatalities. We ran the simulation again, with a 5 mph speed reduction
- **Showed a 27% reduction in fatalities (9)**

Using Highway Patrol in Workzones

- Statistical cost of a fatality is $5.8 M
- Reduction of 9 fatalities -->$52 M savings in cost alone, as well as lives and a reduction in injuries
- CT Maintenance immediately asked for a $2M increase in budget for MAZEEP, CT Construction asked for $10M for COZEEP
- **The most successful project in my career**

Using Agile SE in Software Development

Using Agile in Software Development

- Caltrans uses a modified Vee Model combined with a modified Agile process for ATMS Software (Advanced Transportation Management System) in the Transportation Management Centers (TMCs)
- Start with the User Needs, ConOps, Requirements from the left side of the Vee and have the customer approve it. (Requirements left at the highest level possible)
- At the bottom of the Vee, they take the functions and create a **Product Design Case (PDC)** document (Backlog) that can be split into sprints

Using Agile in Software Development

- Each sprint is two weeks with a demonstration for the customer and a review/ buyoff by the customer
- Changes/ additions are allowed if needed, but the customer must agree to use contingency funds to do so and they either sprint again, or include it in the next sprint
- On approval, take the next PDC feature into a sprint
- So far, this has been tested on small software projects, each requiring only 2 or 3 sprints to complete

Using Agile in Software Development

- This has been a game changer
  - After the initial sprint, the User Needs, ConOps, Requirements and the PDC are updated, and the next sprint initiated.
  - There is a product to demo/ review every 2 weeks
  - Customer/ stakeholders involvement **required** every 2 weeks
  - During sprints, the customer can do more extensive evaluation on the last version on their own test server while the next development is in progress

Using Agile in Software Development

- Previous efforts to develop the entire software package in one pass typically took 1-2 years, with customer involvement only at the beginning and end
- Customers now engaged every 2 weeks
- Changes/ mistakes usually caught after 2 weeks, not 2 years
- Changes in needs/ requirements caught quickly
- Testing of each function as it is developed results in the final integrated approval test using already tested/ approved pieces. Usually approved quickly.

Using Lean Techniques in Construction-

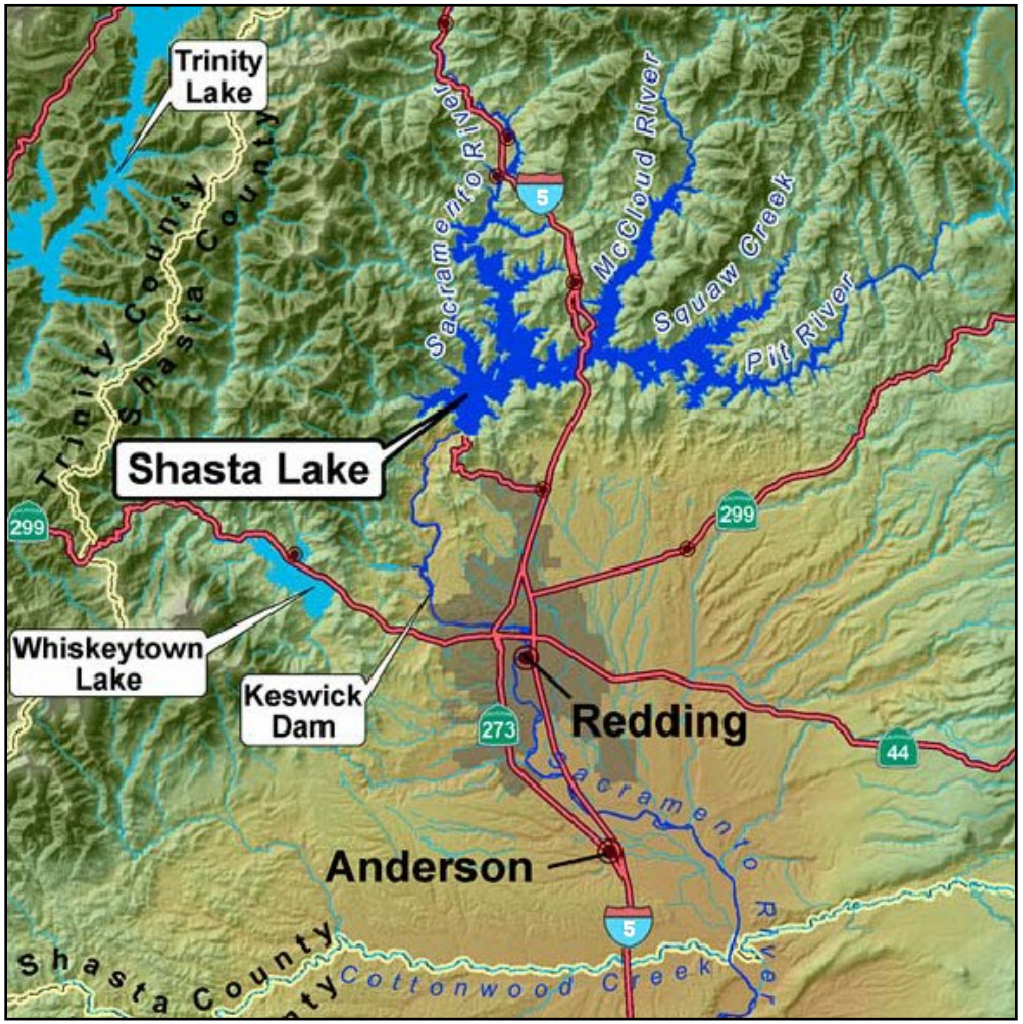
Antlers Bridge Replacement

Using Lean Techniques in Construction- Antlers Bridge Replacement

- Use of Lean actually began after the early design effort
- Caused some concern among engineers
- **Managers** were on a “use lean” agenda, and mostly forced its use, even though it was not well understood
- “Lean” expert brought in to help the project
- Lots of early ‘learning’ problems
- Lots of early issues with BLM, Forrest Service, Agriculture Department and other federal agencies
- Took a year or so to really get it going

Antlers Bridge Replacement

Project Location

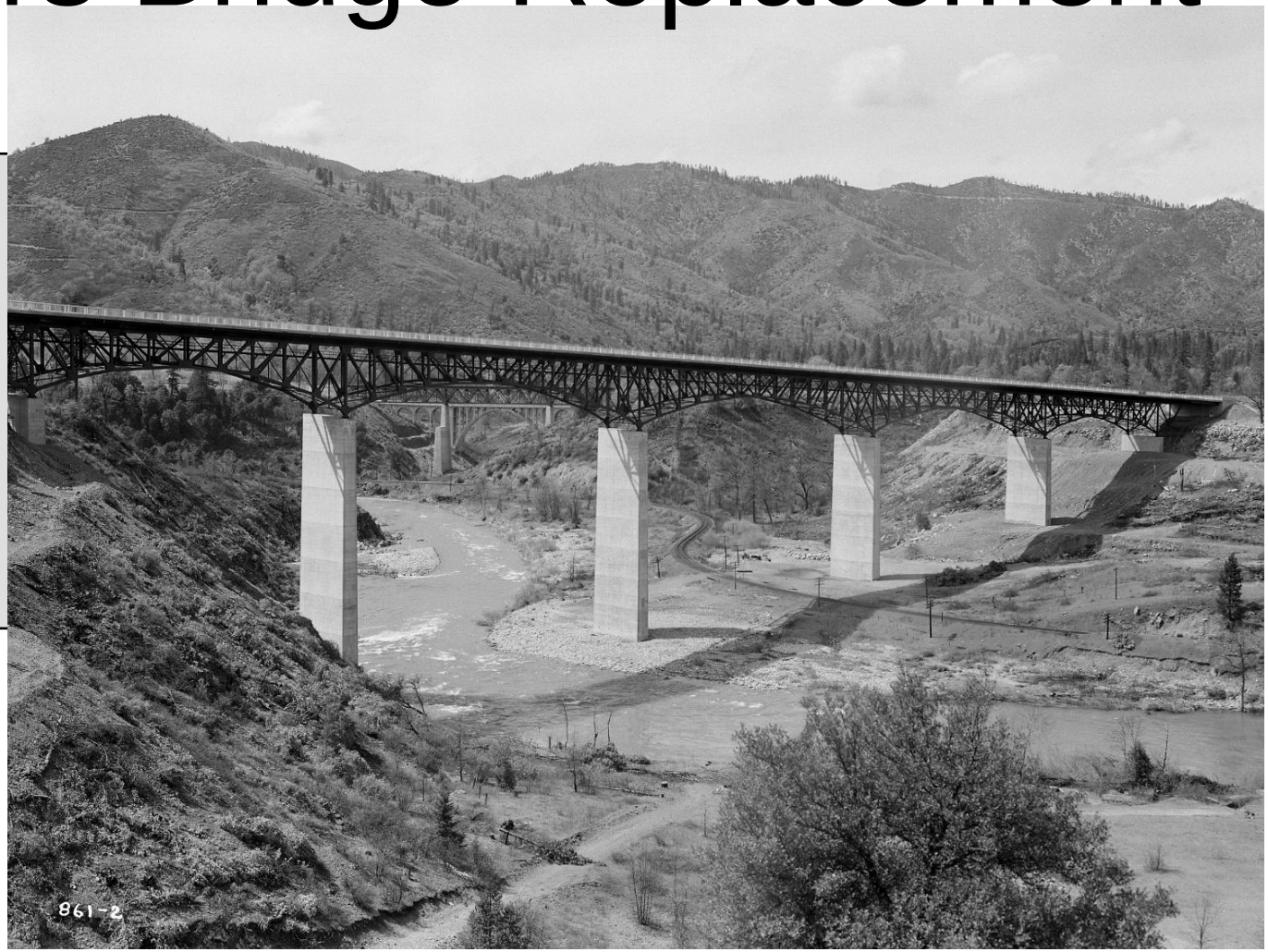


Using Lean Techniques in Construction- Antlers Bridge Replacement

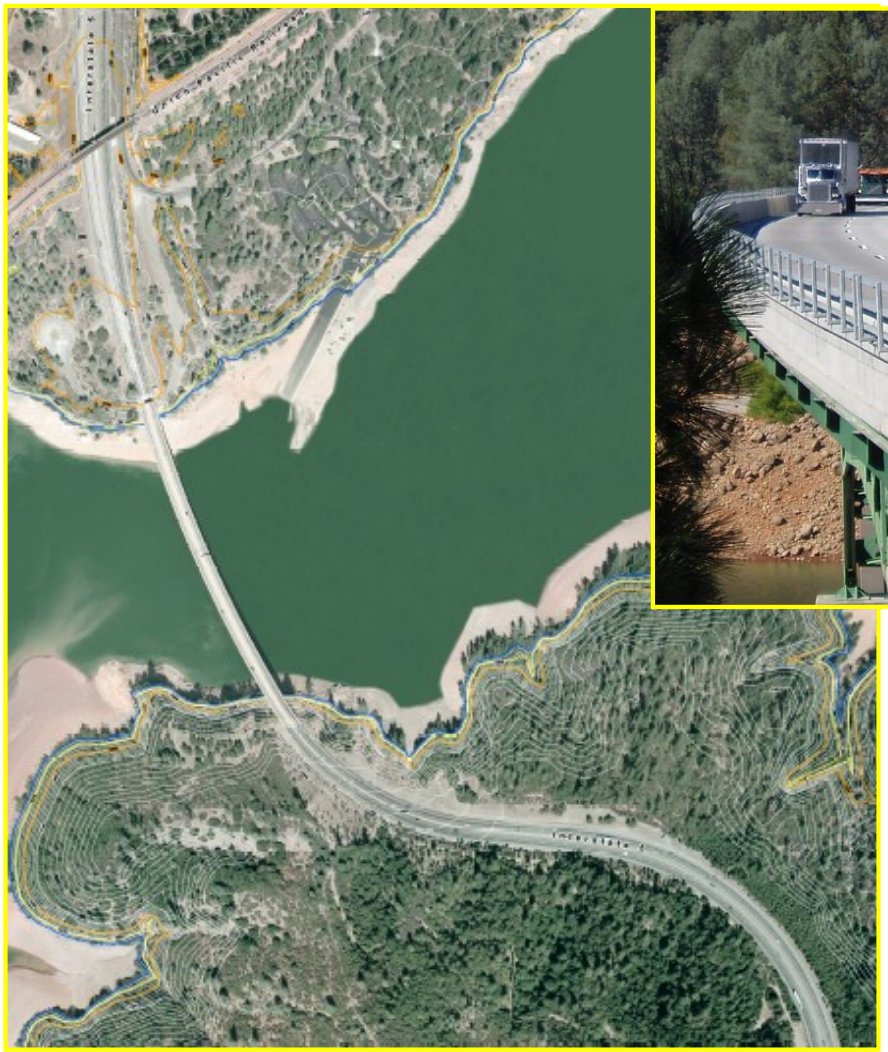
Antlers Bridge Replacement

Existing Bridge

- Built 1943
- Widened 1968
- Deck Replacement 2004



Antlers Bridge Replacement



Why Replace?

- Alignment Safety
- Roadway Width
- Fatigue Cracking

Antlers Bridge Replacement

Antlers Bridge Replacement

Deck Cracking

Antlers Bridge Replacement

Antlers Bridge Replacement Foresight

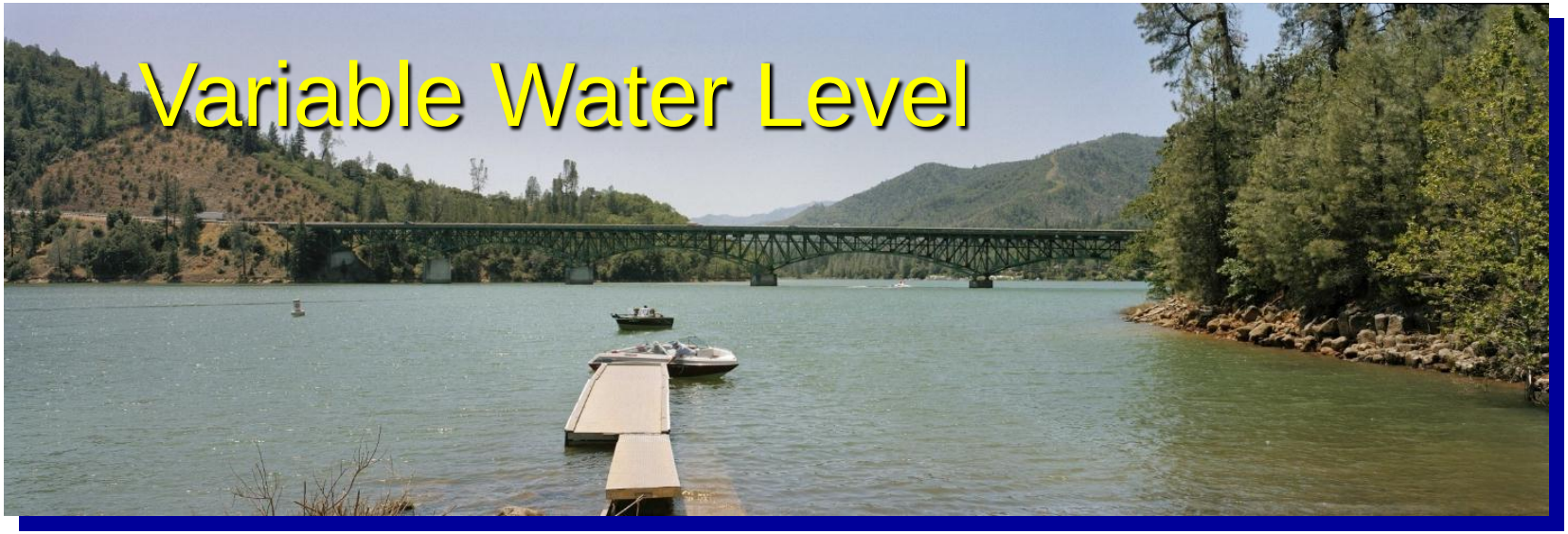
✓

That might work!

✗

That'll never work…

Antlers Bridge Replacement



Antlers Bridge Replacement

Artist’s Conception of final Bridge

Antlers Bridge Replacement

Final Cost

Bid Amount = $ 124 million
Approved CCO's = $ 5.2 million
Claims to date = $ 60 million
Total to date = $ 189 million

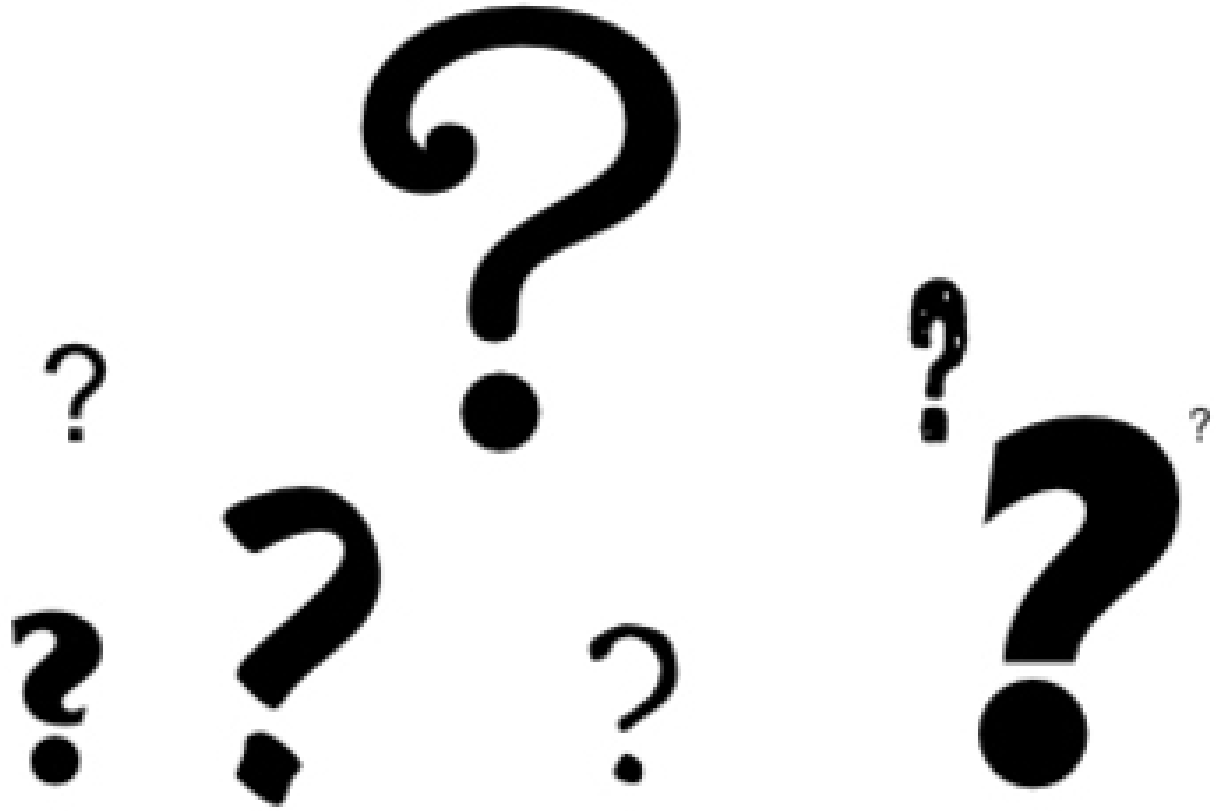
Last Working Day: May 11, 2015

Estimated Date of Completion (CPM): August 16, 2016

(Engineer's Estimate $219 million)

Antlers Bridge Replacement

Questions?



Thank You

Randy.Woolley@engineer.com