27th annual INCOSE international symposium

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Storytelling as a Key Enabler for Systems Engineering

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Storytelling is a Powerful Tool

- Stories help us communicate and make sense of the world
- Our brains are wired for stories
- Evidence of storytelling goes back to prehistoric times
- Storytelling is a tool we can apply with positive effect in systems engineering

Cave Painting

Photo credit: Enric Fontvila / CC BY 3.0

Benefits of Stories in SE

- A good complement to data
  - Provide contextual information
  - “Storytelling converts quantitative results into qualitative understanding.”
- Facilitate communication
  - Make the information relatable
  - Help convey complex concepts
- Capture attention, stir emotions
  - Improve engagement, retention
  - Increase influence

Storyteller Jay O’Callahan

Photo credit: NASA / Public domain

Stories

- What we mean by story
  - A connected series of events, a narrative
  - Begins in one place and ends in another
  - It has a point
- What we don't mean by story
  - Software user stories
  - *As a <type of user>, I want <some goal> so that <some reason>*

Grandfather Tells a Story

Image credit: Wikimedia Commons / Public domain

Agenda

- Storytelling in the SE process
- Storytelling in projects and organizations
- Storytelling to build a profession
- Final thoughts

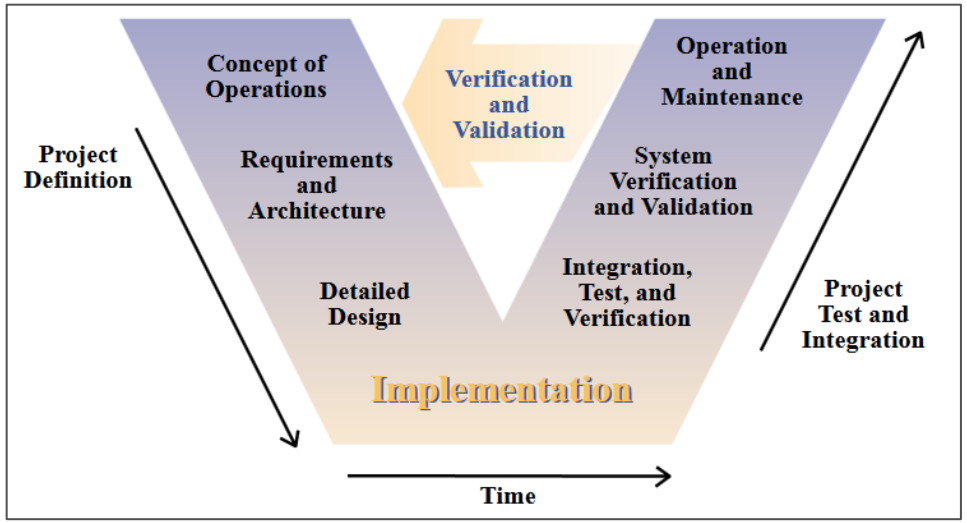
The Storyteller

Image credit: The Saleroom / Public domain

Storytelling in the SE Process

Storytelling in the SE Process

- The value of storytelling
  - Requirements
  - Design
  - Test



Systems Engineering V-Model

Image credit: FHWA / Public Domain

Storytelling in Requirements

- Stories first used by software with Extreme Programming (XP)
- Storytelling can help improve elicitation (vs. interviews)
- Stories help provide context
- Stories also useful in defining non-functional requirements

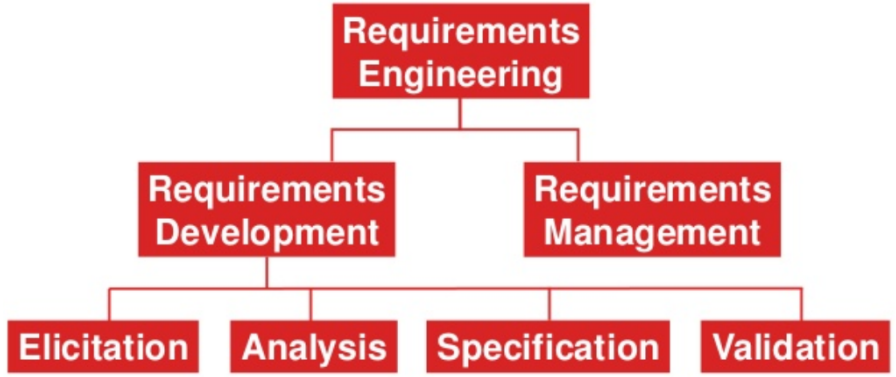


Image credit: Dr. Dagmar Monett Diaz

Story of the Tree Swing

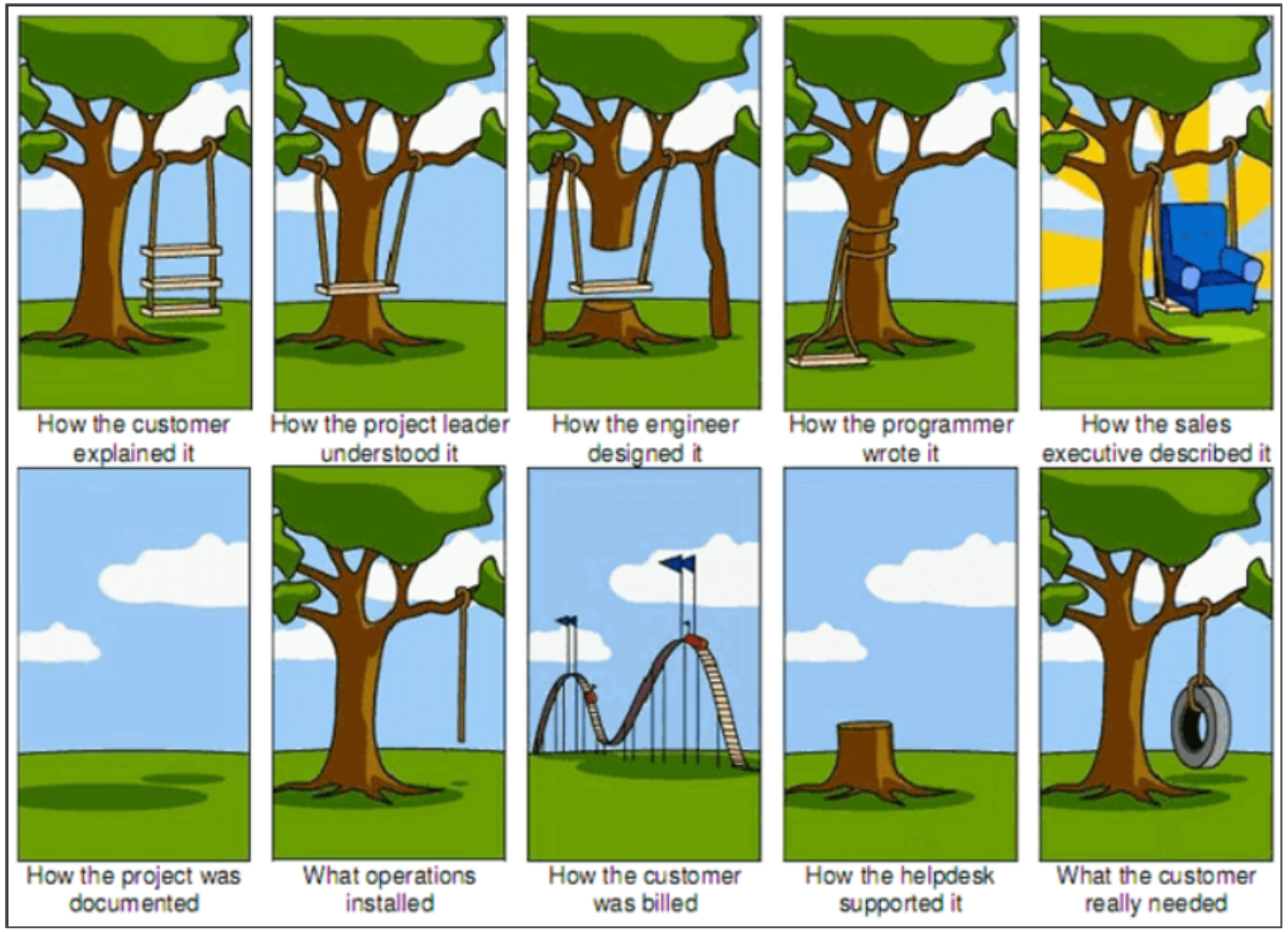
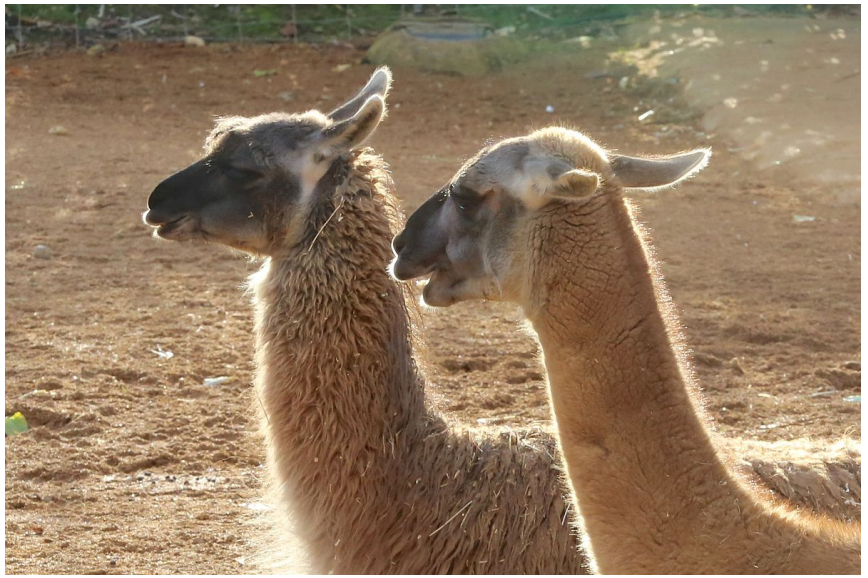


Image credit: Taming Data

Llama Dung Story

- US Army needed a dependable supply of llama dung
  - Apply to leather seats in airplanes
  - Submarine threat made shipments from South America unreliable
  - Started raising llamas in New Jersey
- Only after this failed did they question the requirement
  - US Army had copied a British Army requirement
  - Originally for cavalry saddle leather
  - Smell of leather made horses skittish

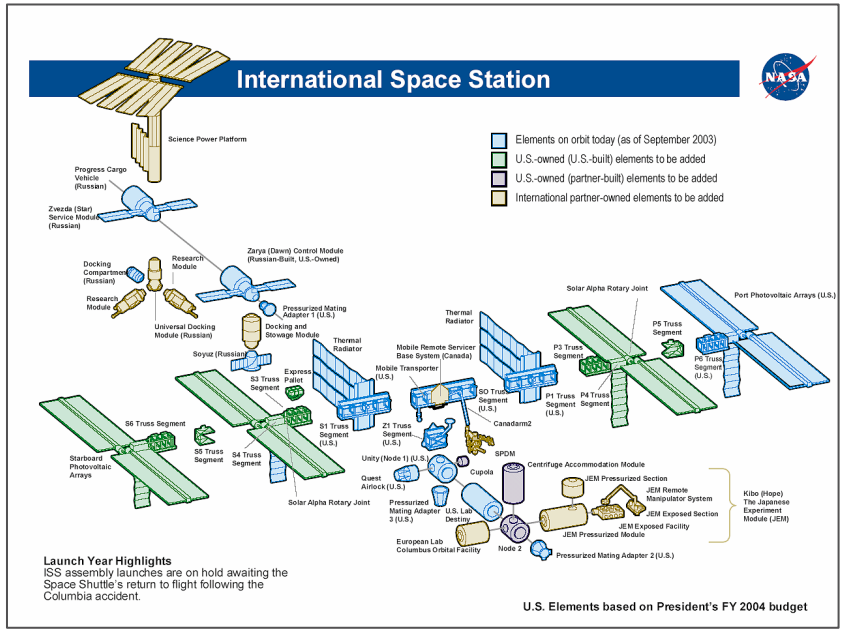


Llamas

Image credit: Ronnie Macdonald / CC-BY-2.0

Storytelling in Design

- Stories facilitate communication between users and designers
- Also useful with MBSE, diagrams can be hard for users to understand
- Storytelling can help drive creativity and innovation
- Stories useful for design reviews



International Space Station Design

Image credit: NASA / Public domain

International Space Station Design Story

- ISS has a “two-in-one” design
  - Part US, part Russian
  - Two different design philosophies
  - Provides extra measure of redundancy
- Example - attitude control system
  - US system - control moment gyroscopes
    Russian system - thrusters
- Critical system failure (2001)
  - All three US computers failed, crippling US control system
  - Russian system used to maintain system attitude control

ISS Crew for Expedition 38 (2014)

Image credit: NASA / Public domain

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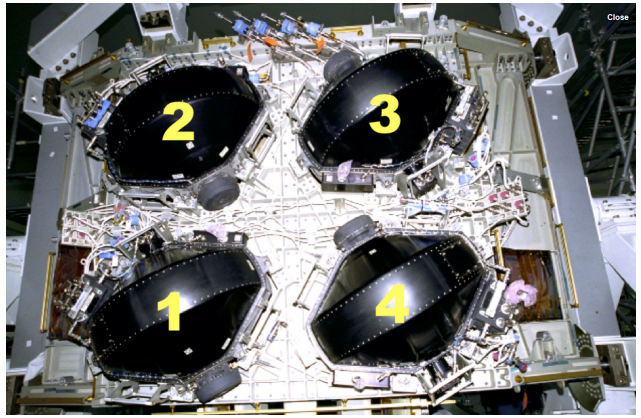
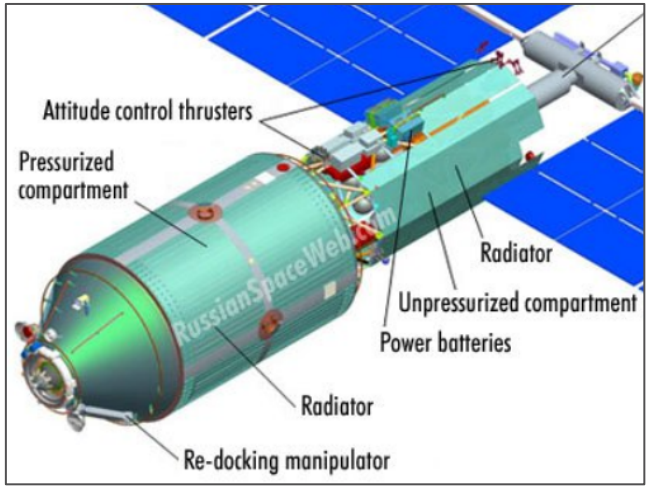


Control moment gyroscopes



Thrusters

Image credit: NASA / Public domain

Storytelling in Test

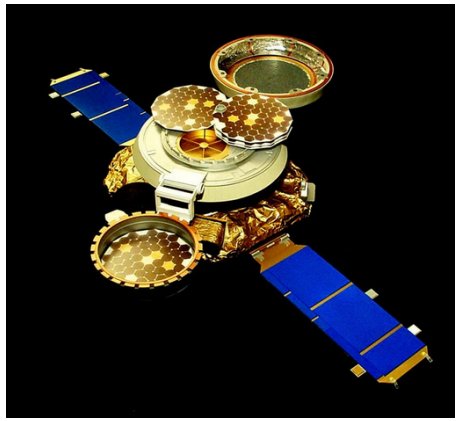
- Stories useful for advocating for testing resources
  - Share horror stories about projects that skimped on testing
  - Tell stories about problems that were difficult to diagnose and fix
  - Bug advocacy – tell a story about a bug's potential impact

Mars Mariner Testing (1964)

Image credit: NASA / Public domain

Genesis Space Probe Test Story

- Sample-return space probe
  - Designed to collect solar wind data
  - Send back samples in return capsules
- Critical failure - parachute fails to open – hard landing
  - G-switch sensors were upside down
  - Design reviews failed to catch error
  - Verification process failed to catch error
  - Red Team review did not catch verification process failure



Genesis Space Probe

Return Capsule

Image credits: NASA / Public domain

Storytelling in Projects and Organizations

Storytelling in Projects

- Stories create a shared language that enhances communication
- Use project's story to complement the project plan
- Stories help build team cohesion and engagement

NASA X-48B Flight Test Team

Image credit: NASA / Public domain

Storytelling in Organizations

- Xerox copier repairmen (1980s)
- Sharing tacit knowledge and wisdom
- Sharing norms and values
- Developing trust and commitment
- Socializing new members

Copier Repairman

Storytelling to Build a Profession

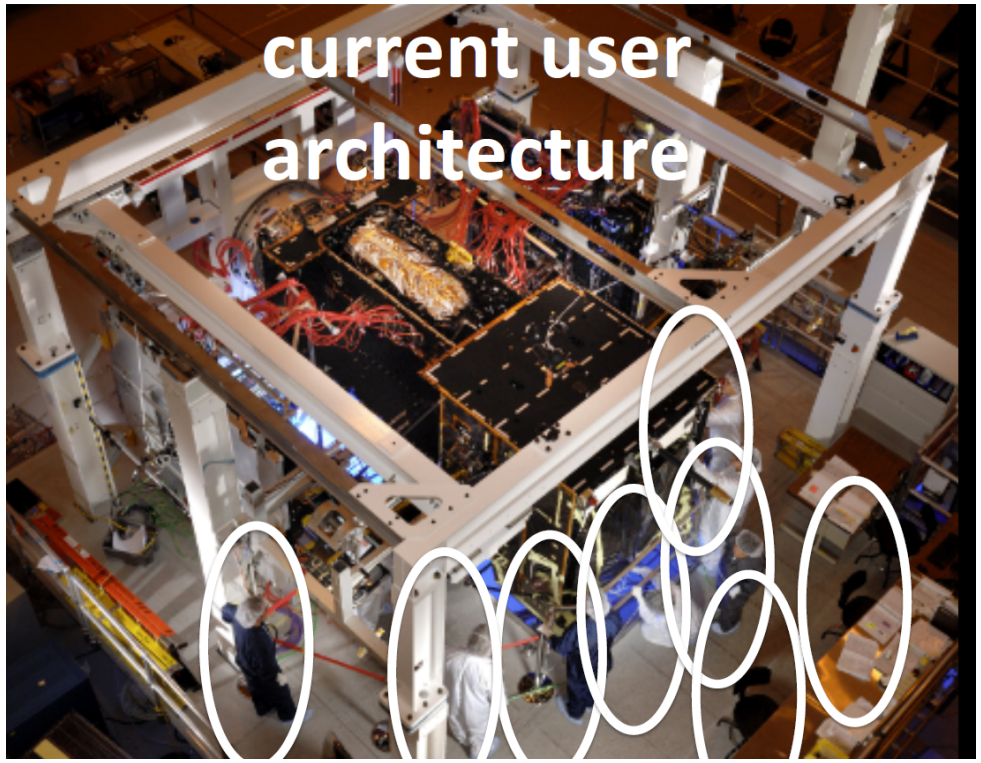
Use Storytelling to Promote SE

- Success stories
- Origin stories

Image credit: INCOSE

Success Stories - Design Thinking

- Satellite testing
- Difficult work
- Teams of 6-12
- 3 shifts, 24/7 operation
- 12-24 months

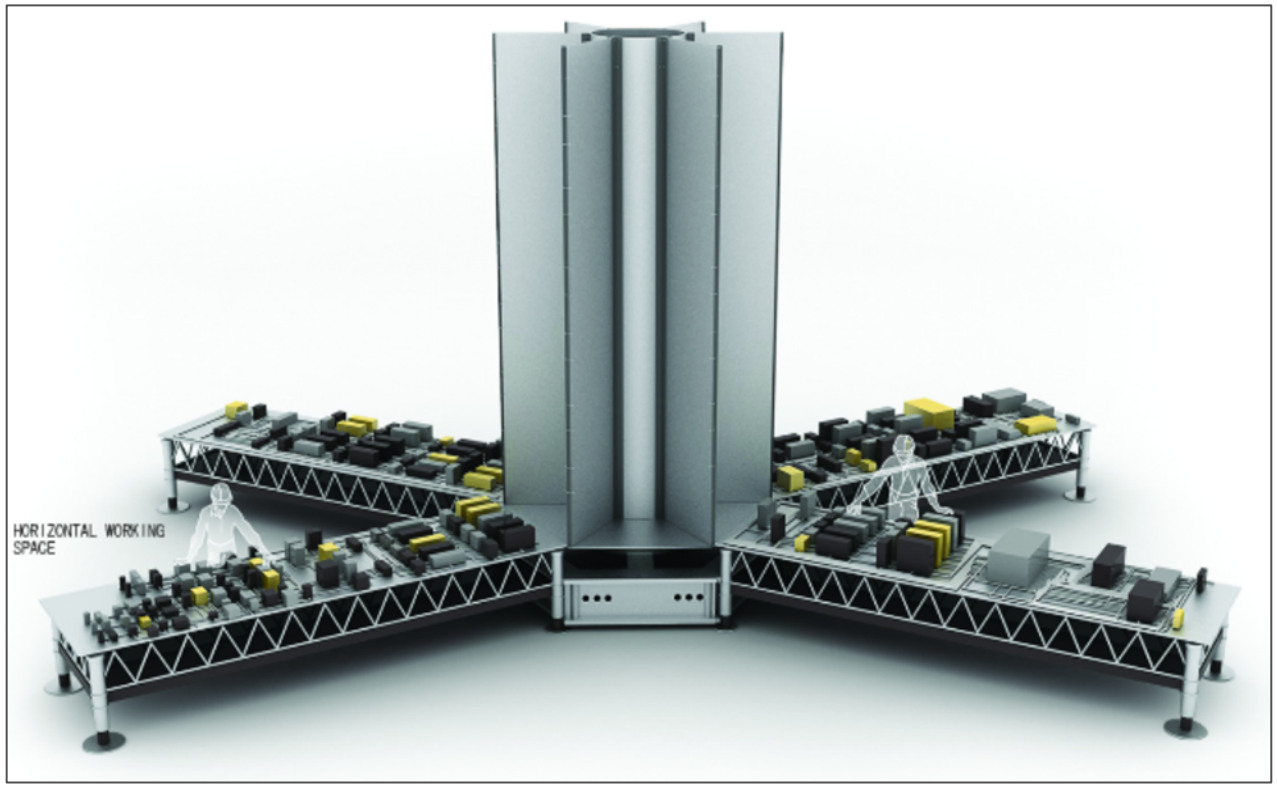


Lockheed Martin Satellite

Image credit: Stanford d.school

Success Stories - Design Thinking

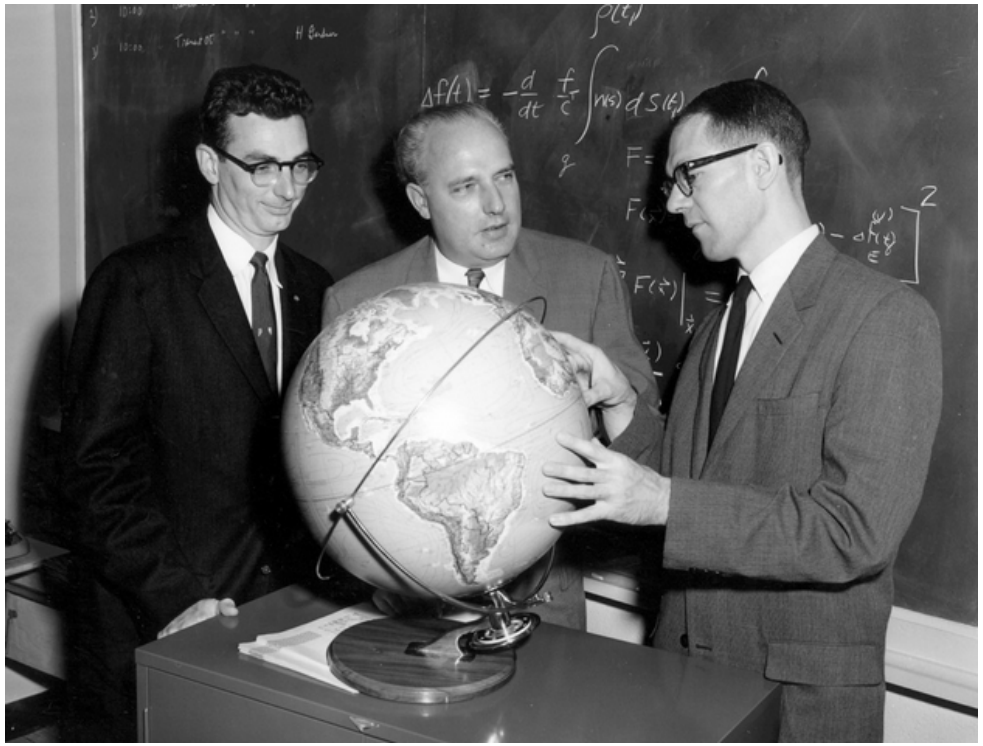
- Develop horizontal workbench design
- Save $25M / satellite
- Save $150M / year



Satellite Horizontal Working Space Design

Image credit: Stanford d.school

Success Story - GPS

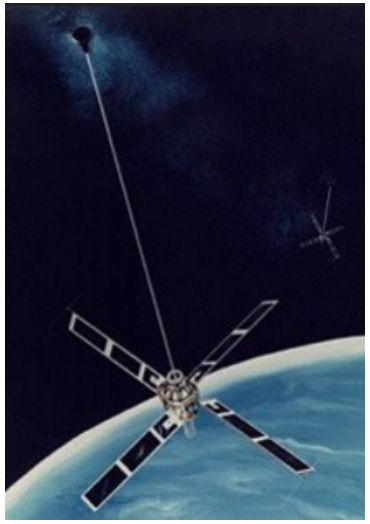


Guier, McClure, Weiffenbach

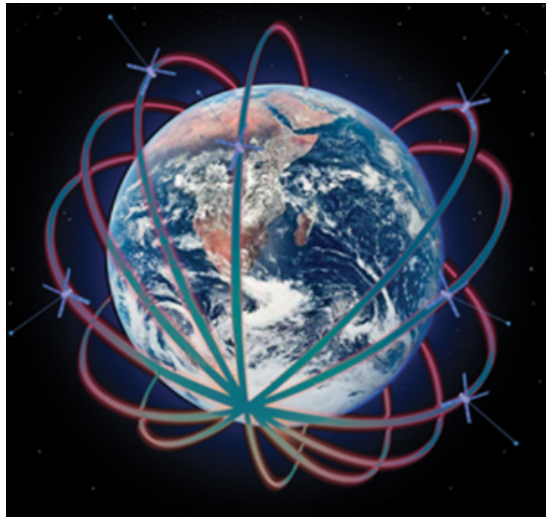
- GPS inspired by Sputnik (1957)
  - US scientists at JHU APL (William Guier and George Weiffenbach) realize they can track Sputnik position using Doppler
  - Frank McClure of JHU APL asks Guier and Weiffenbach to solve inverse problem

Image credit: GPS World

US Navy Transit System (1960's)



Transit Satellite



Transit Constellation

- JHU APL proposes satellite based navigation system
  - Development began in 1958
  - First satellite launched in 1959
  - System operational in 1964
- Primary application was geolocation for Polaris submarines
  - Also used for surface ship navigation and hydrographic surveys
  - Civilian applications as well
- System accuracy (200 m) not adequate for US Air Force applications (planes, missiles)

Image credit: US Navy / Public domain

US Air Force NAVSTAR

NAVSTAR Satellite

Getting Nakamura Woodford

Image credit: US Air Force / Public domain
GPS World

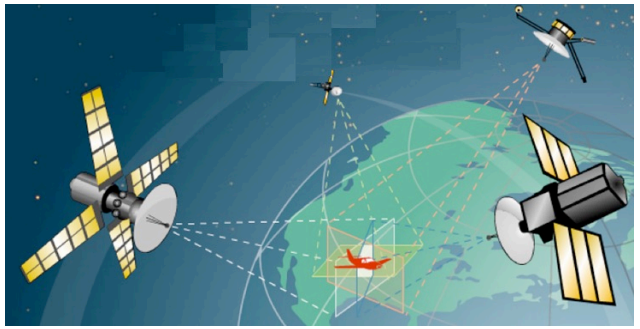
- Developed Requirements

Characteristic	Performance
Accuracy (relative and repeatable)	5–20m (1 sigma)
Accuracy (predictable)	15–30m (1 sigma)
Dimensions	3D + time, 3D velocity
Time to acquire a fix	Real time (for stated accuracies)
Fix Availability	Continuous
Coverage	Global

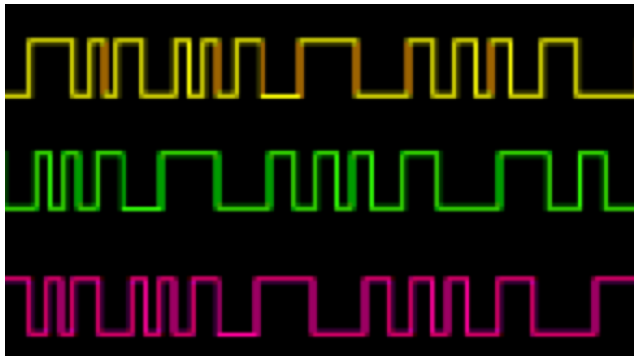
- Did a trade study (1964-66)
  - Commissioned by Ivan Getting of The Aerospace Corporation
  - Led by Hideyoshi Nakamura, James Woodford
  - Studied 12 different design options for satellite-based navigation

Key GPS Innovations

Four Satellites



CDMA Signal



Atomic Clock

- Four simultaneous ranging measurements to find 3 dimensional position
- Unique GPS signal – code division multiple access (CDMA)
- Space-hardened atomic clocks

Image credits: Avionics West, GPS World

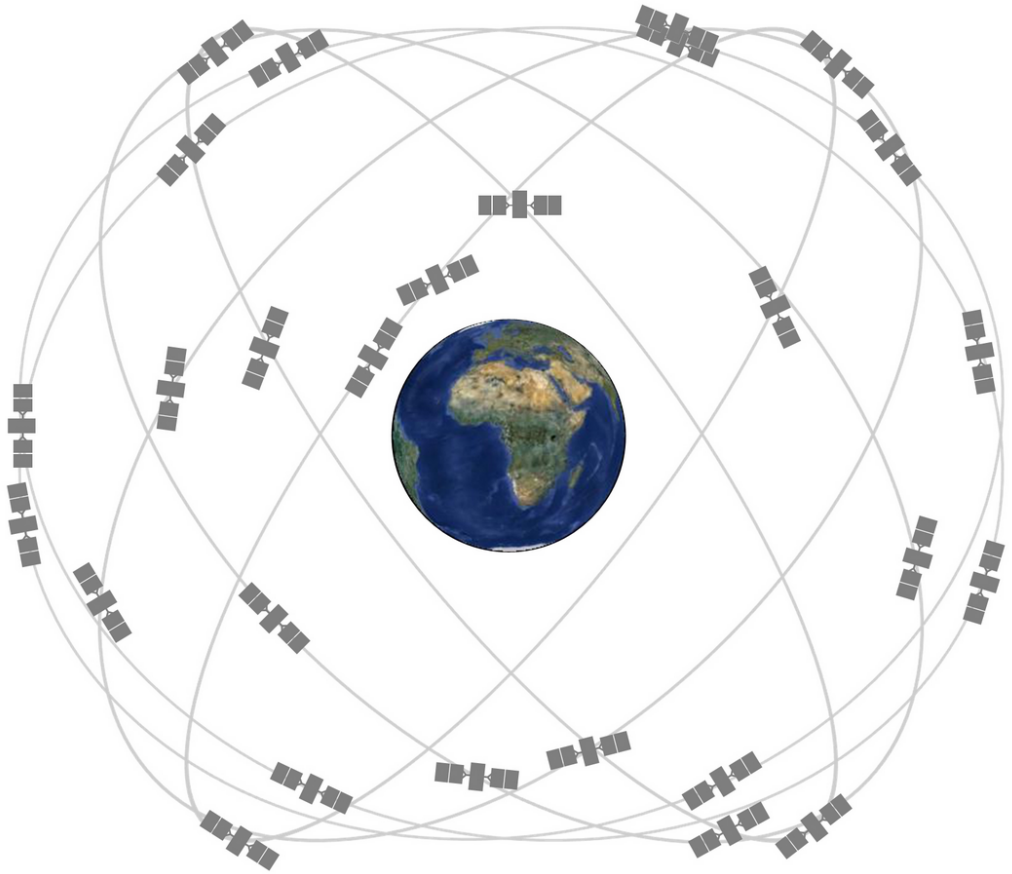
Key GPS Success Factors

Block IIR Satellite

Image credit: Hugo Fruehauf

- Staff key positions with domain experts
- Rigorously maintain program baselines
- Consistent and stable support from high-level authorities
  - Stabilizes funding and system engineering process
- Apply disciplined risk management throughout the life cycle

GPS Program Highlights



GPS Satellite Constellation

- First satellite launched in 1978
- President Reagan orders GPS available for public use in 1983
- First major combat test in 1990 Persian Gulf War
- 24 satellites and fully operational in 1995
- President Clinton orders SA turned off in 2000

Image credits: GPS.gov / Public domain

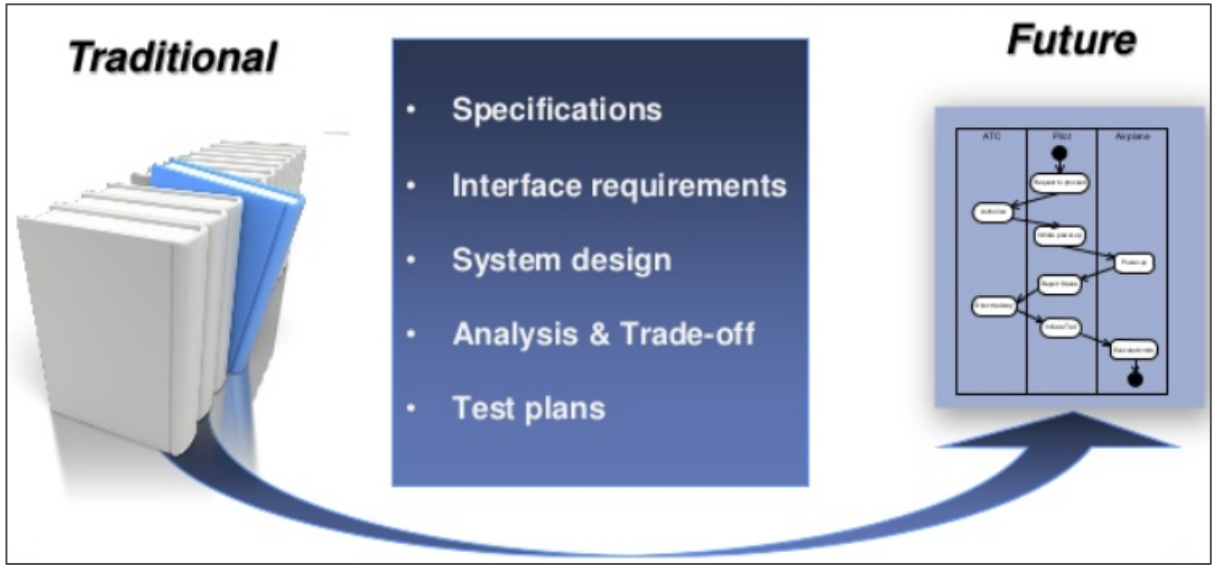
GPS a Part of Everyday Life

THINGS THAT ARE EASIER BECAUSE OF GPS	THINGS THAT ARE HARDER BECAUSE OF GPS
Finding friends and family via location apps	Avoiding friends and family
Cross-country skiing in the wilderness	Keeping people out of your favorite backcountry skiing spot
Driving	Driving if your phone has died
Bass fishing	Bass fishing without a damn computer
Getting to a bar everyone's at	Discovering a bar no one's been to
Sending creepy advertisements	Avoiding creepy advertisements
Synchronizing atomic clocks	Having a convincing excuse for being late

Image credit: Bloomberg Businessweek

Success Stories - MBSE

- Collect and share MBSE success stories
- Project success stories
- Adoption success stories



MBSE Transformation

Image credit: INCOSE

Origin Stories

Florence Nightingale

- Origin stories can help build and promote a profession
  - Explain how the profession came to be
  - Share early history and founders
  - Help understand its place in the world
  - Share the profession's culture and core values
  - Instill pride in the profession

Image credit: Florence Nightingale Museum / Public domain

Nursing Profession Origin Story

Florence Nightingale

- Story highlights
  - Florence Nightingale, mother of nursing
  - Cared for people in her village in her youth
  - Knew by age 16 that nursing was her calling
  - Heroic effort leading a team of nurses to care for wounded soldiers in Crimean War (1854)
- Key lessons
  - Cleanliness a key to promoting healing
  - Model of selfless caring and compassion

Image credit: National Institute of Health / Public domain

Origin Stories for Systems Engineering

- Develop origin stories for systems engineering
  - Share history, culture and core values
  - Instill pride in the profession
  - Help promote the profession
- Hold a storytelling contest
  - Tell stories about the founders of systems engineering
  - Share stories from significant projects in history
  - Recognize the best stories at INCOSE IS 2018

Image credit: INCOSE

Brian Mar, Founding Father of INCOSE

Brian Mar

Image credit: INCOSE

- Dr. Brian Mar
  - University of Washington professor
- Attended first meeting in 1989
  - Mused: “I wonder if a systems engineering society could be founded on these principles”
- Founding member of INCOSE
  - One of initial co-chairs of INCOSE
  - Second president of INCOSE (1993)
  - Wrote over 200 papers
  - Wrote textbook, “The Engineering of Complex Systems”
  - Received Founders Award (1997)

Places to Look for Origin Stories

INCOSE Chapters and Countries

Domain Areas

Companies

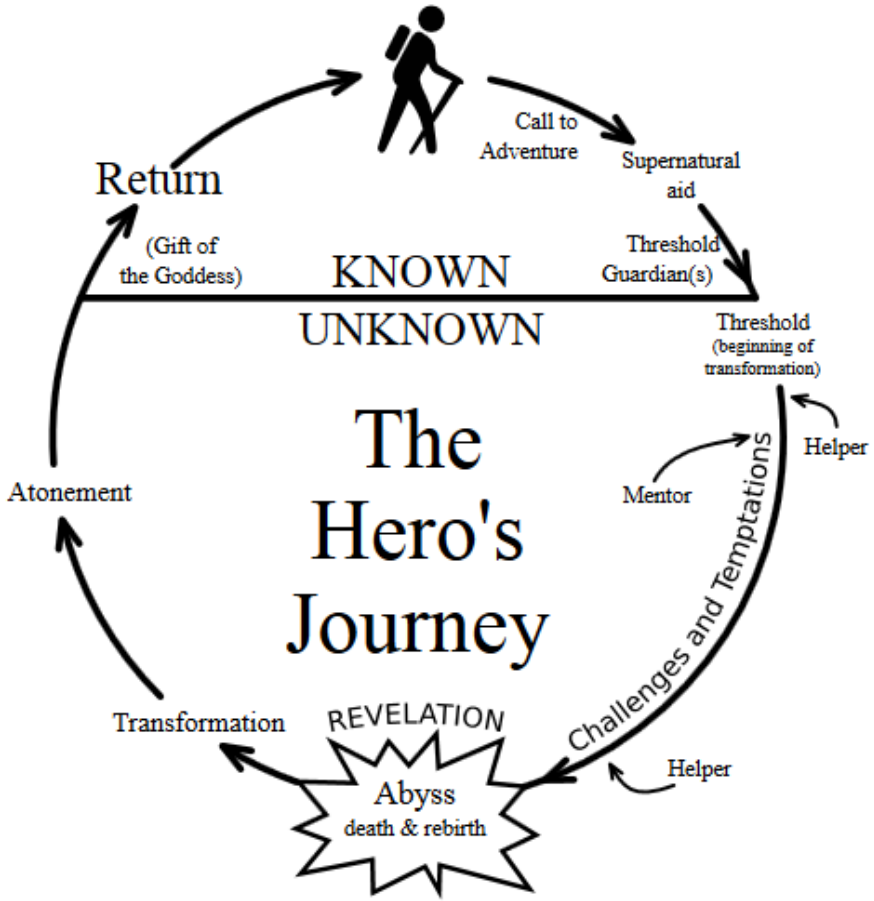
Final Thoughts

Conclusion

- Storytelling is a powerful tool
- Storytelling has value in the systems engineering process
- Storytelling has value at the project and organizational level
- Storytelling can help to build and promote the systems engineering profession

Image credit: langwitches.org

Learning How to Tell Stories



- Joseph Campbell's Hero's Journey is a good model
- Ira Glass (This American Life) suggests starting with anecdotes
- Share success stories and war stories from your projects
- Put stories into your presentations

Image credit: 4chan.org / Public domain

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www.incose.org/symp2017