A Few Words First

Audio Connection – Please mute phone (*6 toggle) – or your GM left-side name

Upcoming Meetings:

- **Jul 18: Summer Social, 6:00-9:00pm, Shark Reef Café, register HERE**
- **Aug 8: Chapter Challenge Event, 5:30-7:00pm, Nexus Brewery, details soon**
- **Sep 12: Agile SE Processes 201: Basic Principles – Sense, Response Evolve**
  Rick Dove, INCOSE Chair Agile SE Working Group
- **Sep 20-22: Western States Regional Conference, Ogden, Utah**
  Website: https://incose-wsrc.eventbrite.com, Presentation call open all of March

CSEP Courses by *Certification Training International:*
Course details
Upcoming Course Schedule (close by, but many more locations and dates):
2018 Jul 16-Jul 20 | Austin, TX
~~2018 Oct 15-Oct 19~~ | ~~Albuquerque, NM~~ -- CANCELED

Chapter SEP mentors: Ann Hodges alhodge@sandia.gov, Heidi Hahn hahn@lanl.gov

First slide, not recorded but retained in pdf presentation.

And Now - Introductions

Enchantment Chapter Monthly Meeting

13 June 2018 – 16:45-18:00

Requirements Efficiency: Challenges and Best Practices

Cheryl Bolstad, Sandia National Laboratories, Human Factors,
cbolsta@sandia.gov

Abstract: As requirements engineering and management processes (REMP) for complex hardware systems continue to mature, a major goal is to reduce the long timelines for generating and distributing requirements to system and component engineers. This literature review draws from external sources, such as peer-reviewed journal and conference proceedings, to reveal inefficiencies, challenges and problems experienced in REMP and seek recommendations and solutions for overcoming them and reducing lengthy REMP timelines while ensuring quality in the process. The purpose is to understand where gains in efficiency might be realized. Best practices and lessons learned for general requirements management and for requirements elicitation, specification, analysis, derivation and decomposition, validation and verification, and change control are reviewed.

Download slides today-only from GlobalMeetSeven file library or anytime from the Library at www.incose.org/enchantment

NOTE: This meeting will be recorded

Today's Presentation

Things to Think About

How can this be applied in your work environment?

What did you hear that will influence your thinking?

What is your take away from this presentation?

Speaker Bio

Dr. Cheryl Bolstad recently joined the Human Factors department at Sandia National Laboratories as a Principal Systems Research and Analysis Engineer.

Previously Dr. Bolstad worked as a principal scientist with Touchstone Evaluation and SA Technologies both small women-owned businesses specializing in human factors.

Dr. Bolstad is a Certified Professional Ergonomist and has a Ph.D. in Psychology specializing in cognition and human factors from North Carolina State University.

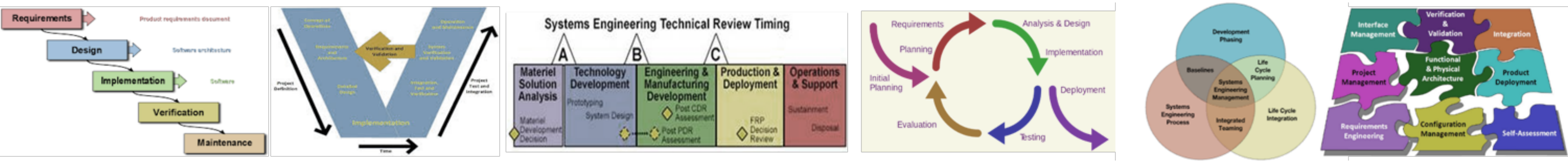
Dr. Bolstad has over 25 years of experience working with the DoD and within the commercial sector. She has worked extensively in situation awareness (SA) research, human automation integration, user interface design, team training and performance.

During her career Dr. Bolstad has worked on projects for DoD weapons programs, military and commercial aviation, CDC emergency response operations, military health services, regional power companies, commercial automakers and several large computer and technology corporations.

Dr. Bolstad has authored over 100 publications, is a member of multiple professional organizations, and has served on professional review committees.

Exceptional service in the national interest

Sandia National Laboratories



Requirements Efficiency: Challenges and Best Practices

Cheryl Bolstad
Human Factors Org.
Celeste A. Drewien, Patricia Hubbard
Systems Analysis Org.
Raymond Wolfgang
System Surety Engineering Org.

Presentation: INCOSE Enchantment Chapter
June 13, 2018

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

About Sandia

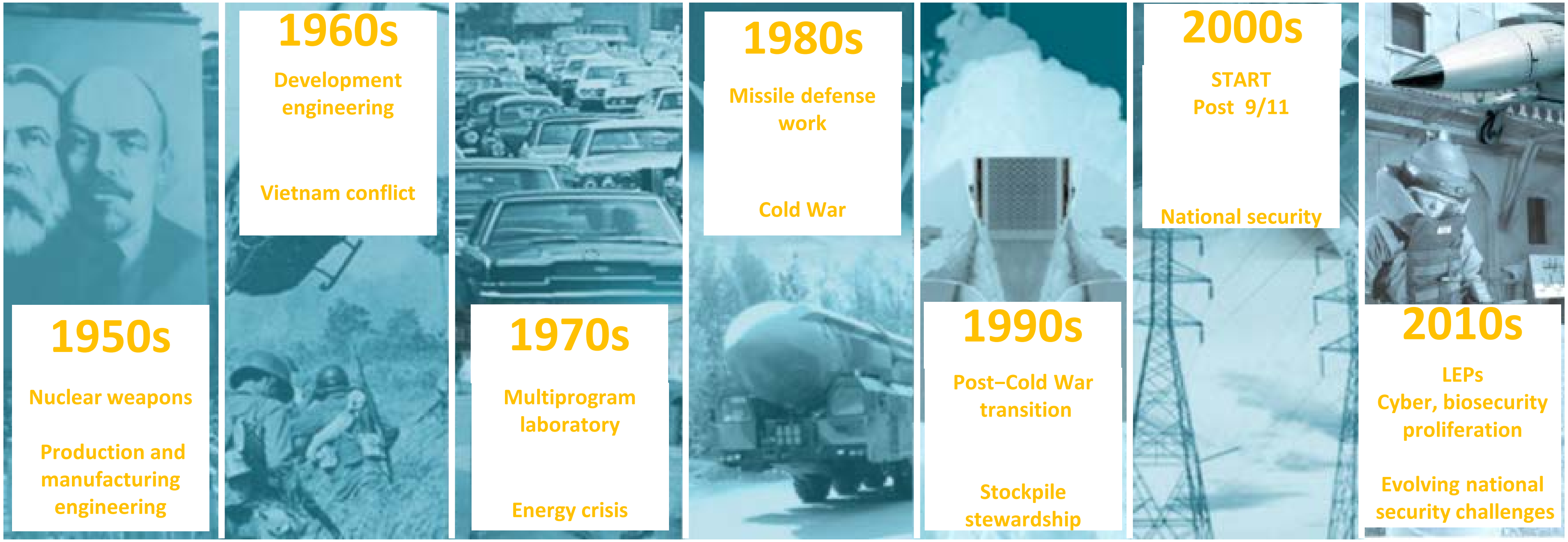
- Operated and managed by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc.

- Operates as a contractor for the U.S. Department of Energy's (DOE) National Nuclear Security Administration (NNSA)

- **National security programs**
  - We work with other government agencies, industry, and academic institutions to accomplish our missions in the following strategic areas:
    - Nuclear Weapons
    - Defense Systems & Assessments
    - Energy & Climate
    - Global Security

- http://www.sandia.gov/about/index.html

Sandia Has a 70 Year History in Working National Security Challenges



1950s

Nuclear weapons

Production and manufacturing engineering

1960s

Development engineering

Vietnam conflict

1970s

Multiprogram laboratory

Energy crisis

1980s

Missile defense work

Cold War

1990s

Post–Cold War transition

Stockpile stewardship

2000s

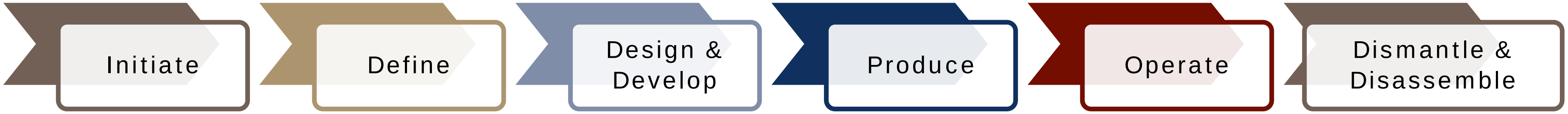
START
Post 9/11

National security

2010s

LEPs
Cyber, biosecurity proliferation

Evolving national security challenges



Initiate

Define

Design & Develop

Produce

Operate

Dismantle & Disassemble

Sandia National Laboratories

Albuquerque, New Mexico

SNL works National Security programs with other government agencies, industry, and academic institutions to accomplish missions in the following strategic areas:

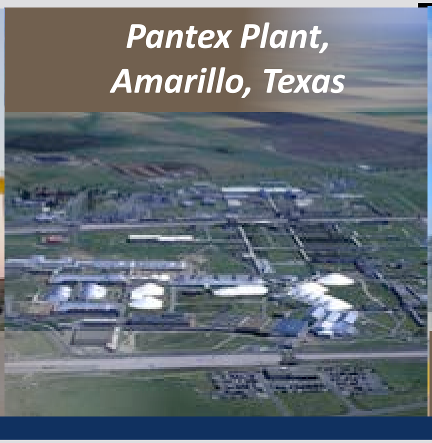
Nuclear Weapons
Defense Systems & Assessments
Energy & Climate
Global Security

Livermore, California

For more information, please see: http://www.sandia.gov/about/index.html

Kauai, Hawaii

United States Department of Energy
Waste Isolation Pilot Plant
Waste Isolation Pilot Plant, Carlsbad, New Mexico


Pantex Plant, Amarillo, Texas

Tonopah, Nevada

Our Study Basis

Where can a program gain efficiency in its system engineering requirements processes?

Improve the efficiency of the requirements engineering and management processes and thereby reduce organizational impacts, product realization delays, costs, and schedule delays due to requirements processes

Goals:

- Understand existing requirements processes
- Analyze inefficiencies in processes
- Identify opportunities for consistency in processes
- Identify opportunities to streamline processes

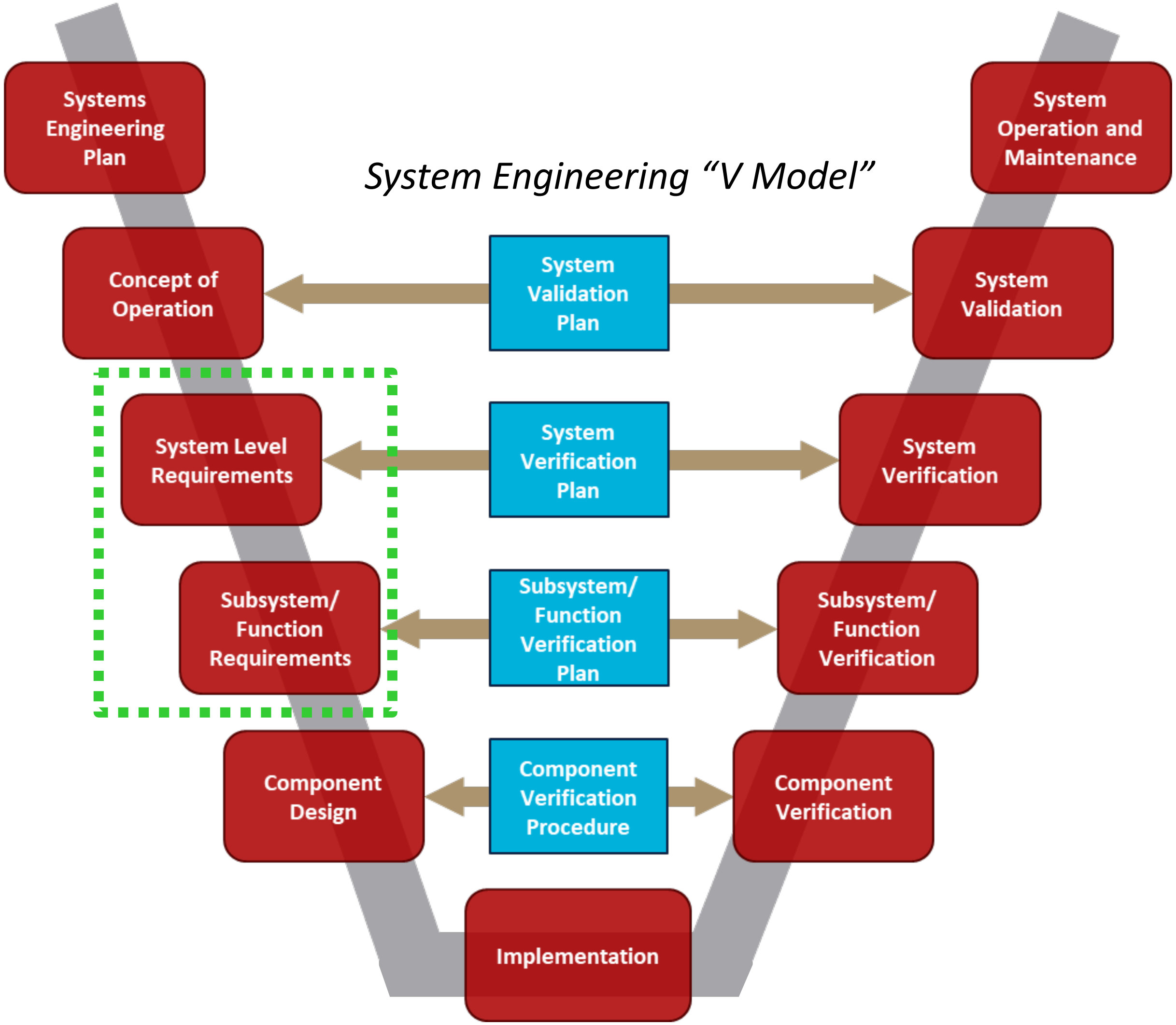
- Approach (3 parts)
  - Literature review → Current Presentation
  - Internal interview - ongoing
  - External benchmarking - ongoing

Requirements Management
Elicitation
Specification
Derivation and Decomposition
Validation and Verification (V&V)
Change

Model Based Systems Engineering (MBSE)

INCOSE defines Model Based Systems Engineering as:

“formalized application of modeling to support system requirements, design, analysis, verification, and validation, beginning in the conceptual design phase and continuing throughout development and later life cycle phases."


System Engineering “V Model”
Systems Engineering Plan
Concept of Operation
System Validation Plan
System Validation
System Operation and Maintenance
System Level Requirements
System Verification Plan
System Verification
Subsystem/ Function Requirements
Subsystem/ Function Verification Plan
Subsystem/ Function Verification
Component Design
Component Verification Procedure
Component Verification
Implementation

Summary of Quality Results & Other Findings

- Reviewed Over 65 Articles
  - Mostly journals and conference proceedings
  - Recent publications (last 10 years)
  - Peer-reviewed
- High Relevance Articles
  - 44% Journals
  - 48% Conference proceedings
  - 67% Academia
  - 57% International authors
- Majority of Articles Addressed:
  - General requirements overviews
  - Requirements validation and verification

Requirement Topic	Count
Change	4
Decomposition/Derivation	7
Elicitation	4
General	13
Management	18
Metrics	1
Tracking/Allocation	4
Validation/Verification	13

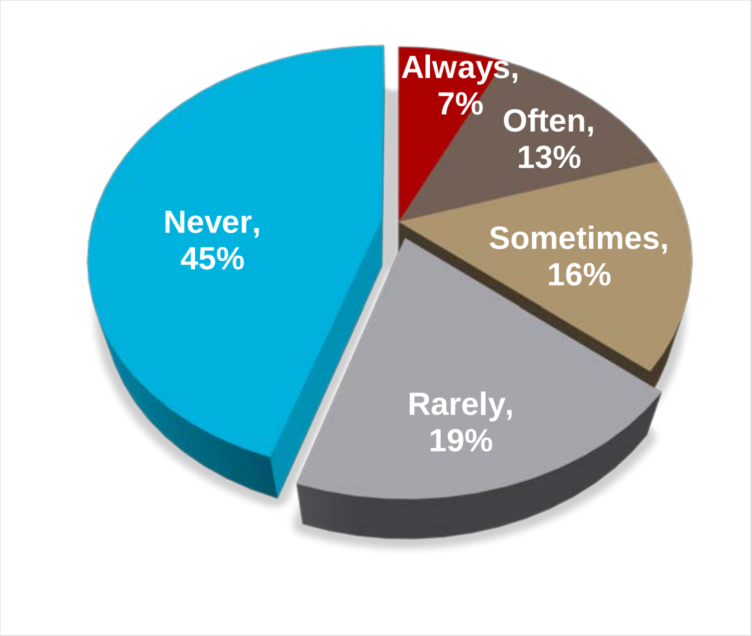
Articles By Topic

Acknowledgment: Missy Hess and Jadyn Vigil

Main Findings:
Avoid Big Requirements Up Front (BRUF)

- Large, detailed set of requirements developed from customer interactions and source documents by requirements engineers early in a program and then issued to design team
  - Usually used in a 'Waterfall' development process
- Challenges
  - Very hard to think through all the requirements up front
  - Can result in over-engineering*
  - Makes process less agile
  - Can result in less team communication – communication by documentation instead
  - Very costly to implement later requirement changes → changes may require rework of design, verification and deployment plans

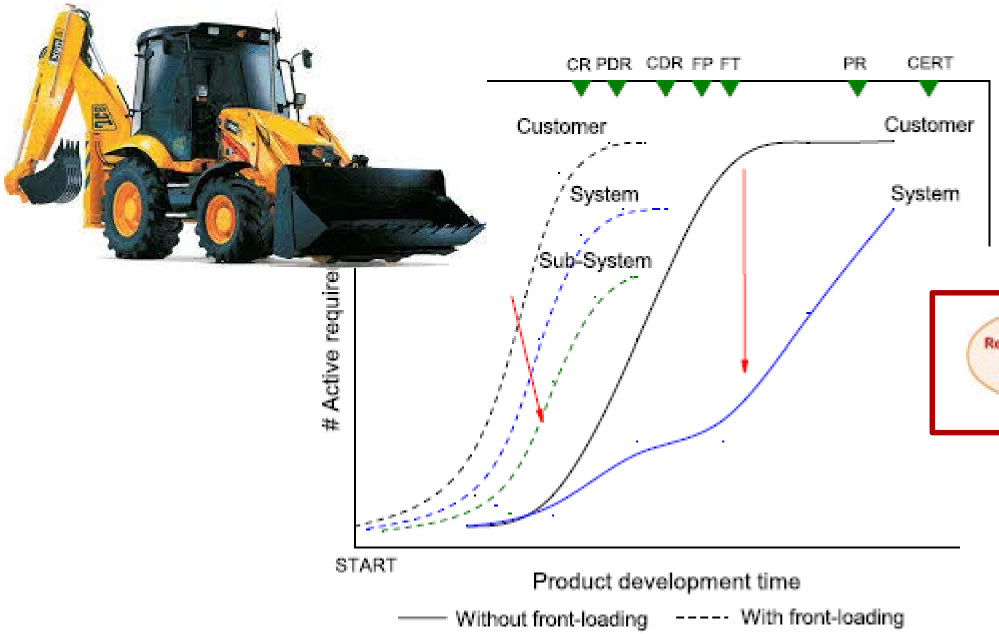
BRUF Can Lead to Significant Waste



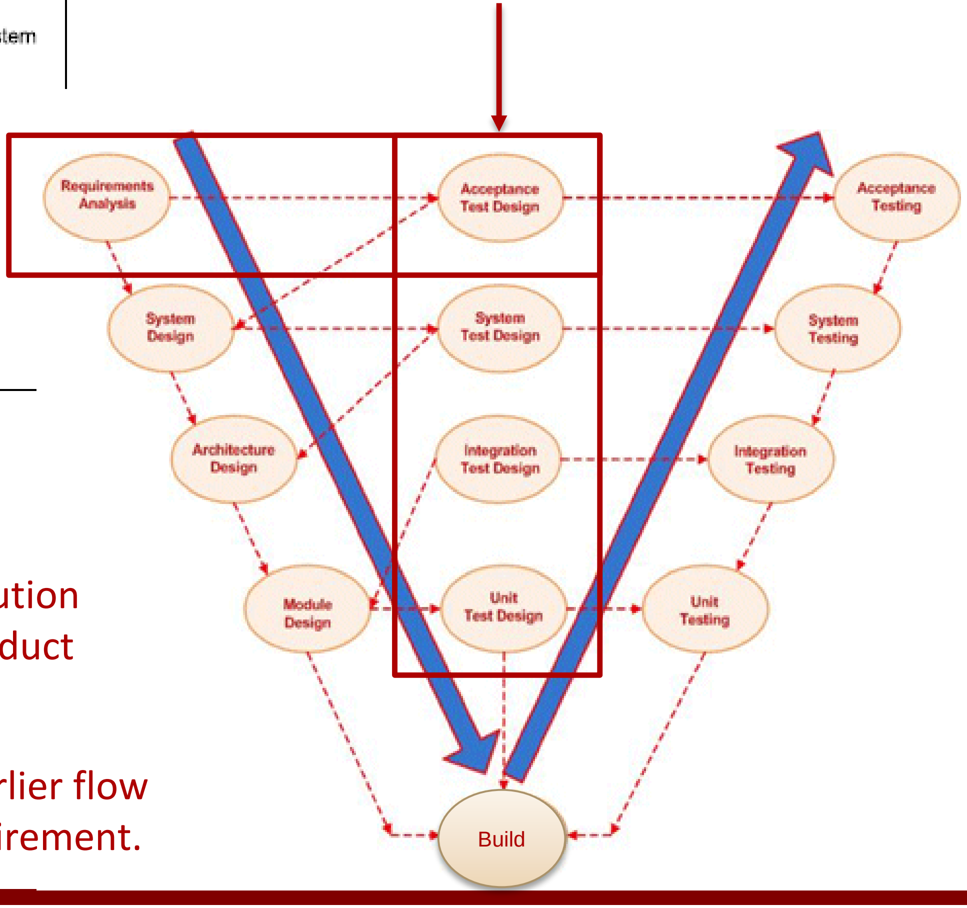
An example of a successful software project's feature usage.

Source: Jim Johnson (2002) Keynote Speech XP 2002

Main Findings:
Front Load the Requirements Process



Link requirements and testing up front



Shift (load) the problem identification and solution (verification) efforts to earlier phases of a product development process

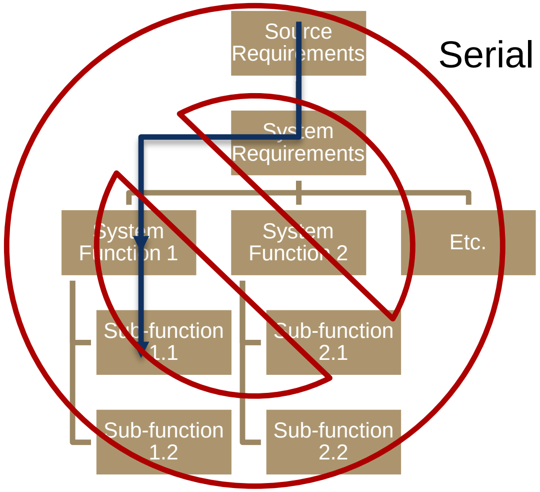
Reduce impact of late requirement changes → Earlier flow down of technical specifications into system requirement.

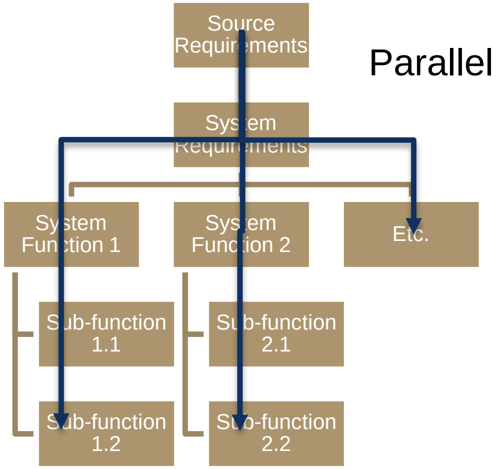
Comparison and Contrast of BRUF with Front-Loading of Critical Requirements

	BRUF	Front-Loading Critical Requirements
Requirements Elicitation	Customer(s) Requirements Team	Customer(s) and other stakeholders, such as design and test engineers Requirements team
Requirements Approach	May be serial or parallel All source to all system requirements	Parallel Source to functional requirements
Requirements Management	Detailed from start	Detail limited to only what was needed immediately by design and test engineers, followed by more detail later on
Requirements Derivation and Decomposition	Performed by Requirements Team	Worked by key stakeholders and overseen by Requirements Team
Requirements Validation	Performed at Requirements Review	On-going validation
Requirements Verification	Verification requirement may be developed in conjunction or after the fact	Verification requirement developed in conjunction with requirement

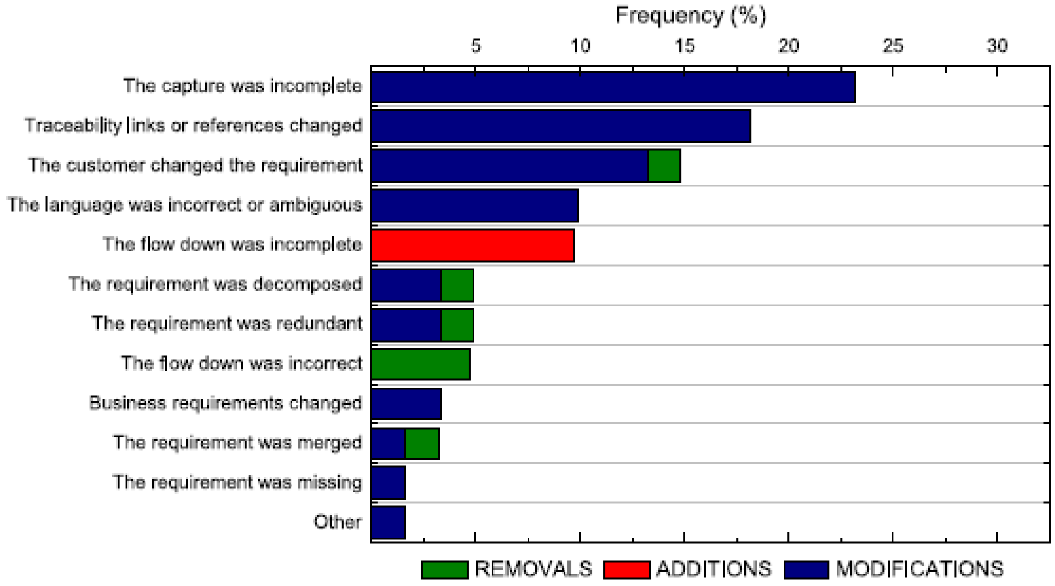
Main Findings: Implementing Front Loading

- **Use Increased Level of Concurrent Requirements Engineering**
  - Frequent coordination/integration between requirements engineering teams
  - Parallel flow down of requirements across system functions
  - Standard procedures for how higher-level requirements teams engages with dependent lower-level requirements teams
- **Invest in Initial Increase in Allocation of Resources**
  - Especially during preliminary design stages
  - To prevent requirements activities from becoming serialized (not concurrent)
  - Increases parallel requirement flow downs
- **Critical Requirements Up Front (CRUF)**
  - Confirm required versus desired operational needs
  - Identify critical functionality
  - Establish Measures of Effectiveness (MOE) for critical requirements (success criteria)
  - Establish KPPs needed to verify critical requirements
- **Delay Non-Critical Requirement Details That May Change**





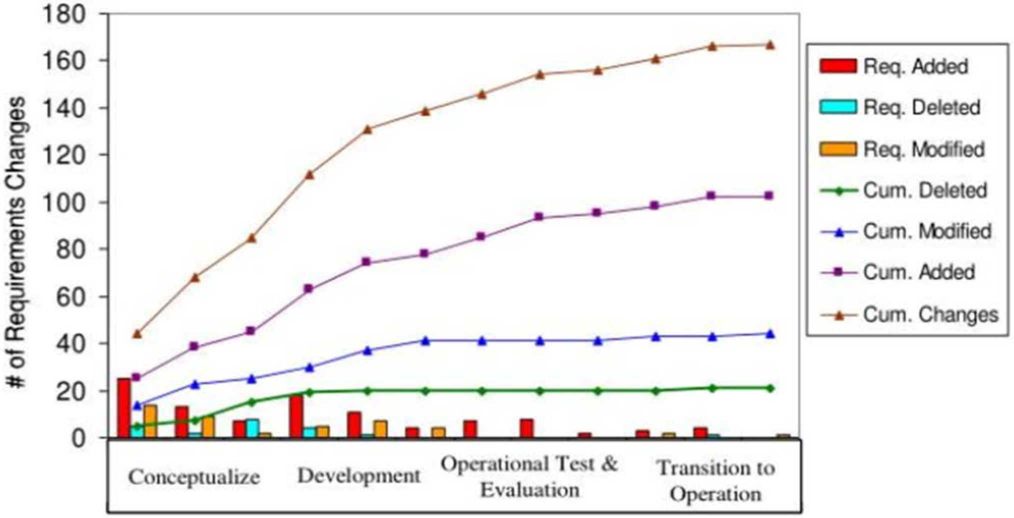
Main Findings: Anticipate Changing Requirements



Reasons for requirements changes are well documented

Requirements change across the lifecycle phases

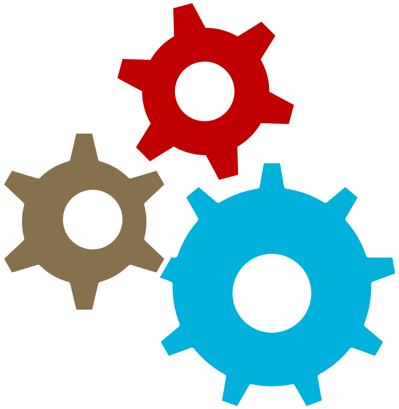
Phase transitions tend to generate requirements changes



Fernandez et al, (2015); Pena, (2015)

Improving Requirements Management

- Challenges of Requirements Management
  - Establishing adequate requirements
  - Requirements engineer is not an expert in the domain
  - Inadequate communication between requirements engineer, developers, stakeholders
  - Unstable requirements



- Best Practices
  - Avoid BRUF (Big Requirements Up Front)
  - Good communication is needed throughout
  - Use consistency and uniformity
    - In plans, products, processes from system-level to lower level
    - Requirements specification template and reporting
    - Common taxonomy (e.g. SEBok)
  - Utilize requirements management plan and requirements management tool (such as DOORS)
  - Use tracking metrics (e.g. Count, Traceability, Volatility) to communicate trends

Improving Requirements Elicitation

- Challenges of Requirements Elicitation
  - Multiple methods exist for requirements gathering
  - No method is perfect method
  - Missing requirements

- Best Practices
  - Develop a plan for the requirements gathering process
  - Ensure proper stakeholders are included
  - Agree on prioritizing requirements through verbs or designated priority levels
  - Identify interface requirements
    - Analyze the requirement across both sides of the interface
    - Define inputs and response
    - Agree on who owns the interface requirements and has verification oversight
  - Study existing products and information for functional requirements
  - Utilize various modeling techniques for requirements identification
  - Use standard format/template and if possible requirements patterns

Improving Requirements Specification

- Challenges of Requirements Specification
  - Using inconsistent/ambiguous wording
  - Difficulty separating needs from solutions
  - Writing requirement with a sound verification pathway
  - Removing/avoiding redundancy

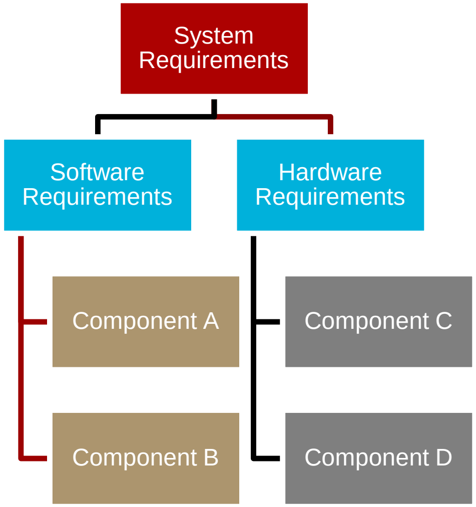
SMART *(requirements authoring mnemonic)*

- **Specific**—is the requirement specific to one thing or does it target an explicit area
- **Measurable** – quantifiable, a recognized method of verification exists
- **Attainable** – achievable design and verification solution, appropriate, actionable
- **Realistic** – on timeline and within constraints of program (follows from user needs)
- **Time-bound** – traceable, timing issues specified

- Best Practices
  - Take advantage of patterns
    - Use standard format/template and if possible requirements patterns
  - Consider using automation tools (e.g. Requirements Authoring Tool, Natural Language Parsing Tools)
  - Couple verification testing and acceptance criteria with the requirements
  - Assign responsibility for standards and authority documents, including revisions
  - Use component databases for commonly used or already qualified parts

Improving Requirements Derivation and Decomposition (1/2)

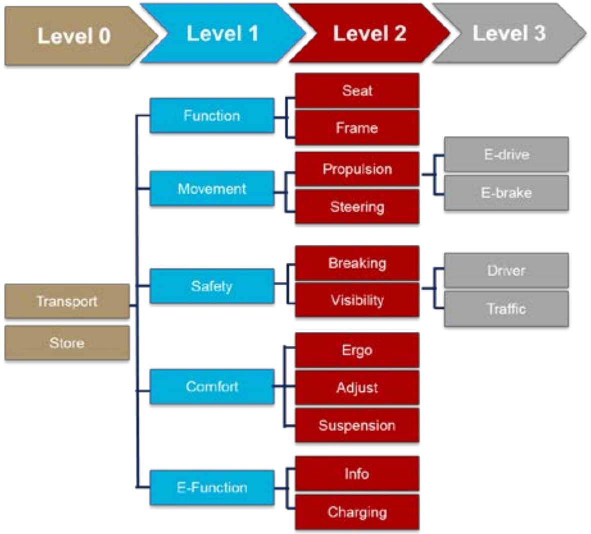
- Challenges of Requirements Derivation and Decomposition
  - Requirements derivation is highest in early design stage
    - Detailed requirements may not be generated until a design is selected
  - Derived requirements may not include explicit state constraints (only implied)
  - Non-functional requirements may receive less attention
  - Requirement decomposition can lead to flow down errors
  - Designers/engineers as they work out the design
    - May estimate requirements
    - Base requirements on feelings or intuitions
    - Skip some steps or sequences
    - Place prioritization/value on certain requirements



These can lead to requirement changes

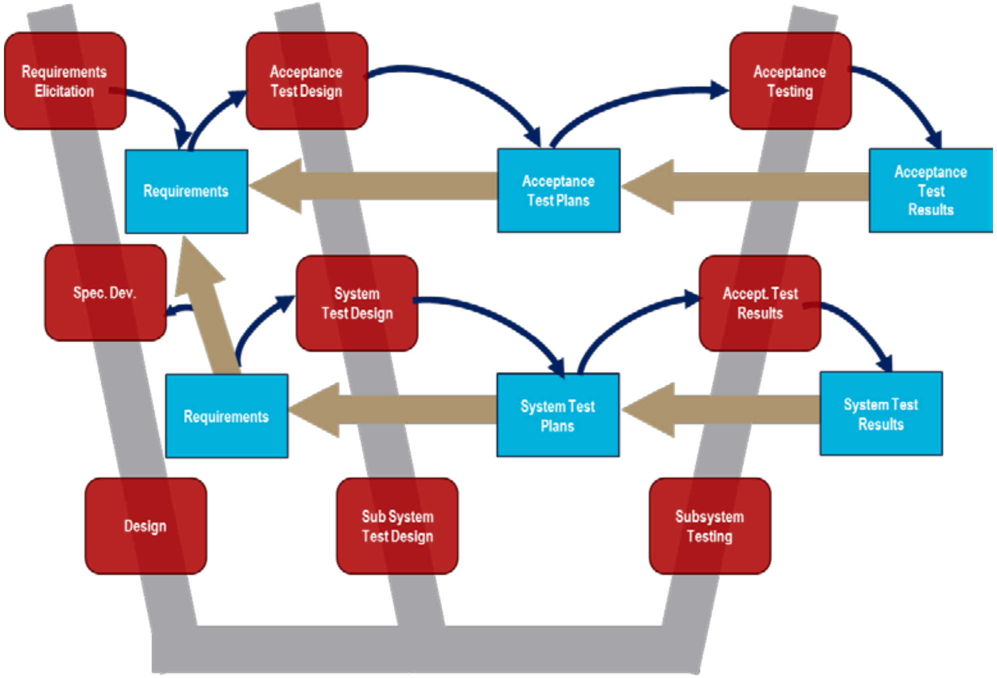
Improving Requirements Derivation and Decomposition (2/2)

- Best Practices
  - Refine requirements → make explicit; subdivide by functions or elements
  - Plan sufficient time for deriving non-functional requirements
  - Sequencing or separate requirements to describe how the system behaves from one state to the next
  - Understand and avoid common flow down errors
    - Non-KPPs overlooked
    - Duplicated requirements with differing performance parameters
    - Parameter mismatches (e.g. units of measurement)
    - Dangling requirements (parentless, child missing)
    - Unwarranted assumptions



Improving Requirements Validation and Verification

- Challenges of Requirements Validation and Verification
  - Failure to understand extreme loadings/environments
  - Inadequate review of test cases against requirements
  - Assuming similitude with other designs/projects
    - Similar circumstances in which the underlying statistics were obtained
    - Similar environment in which the system operates.



System Engineering "W Model" Incorporates Verification Requirements, Planning, and Test Results into the Traditional "V Model" (A.J.J. Dick, 2012)

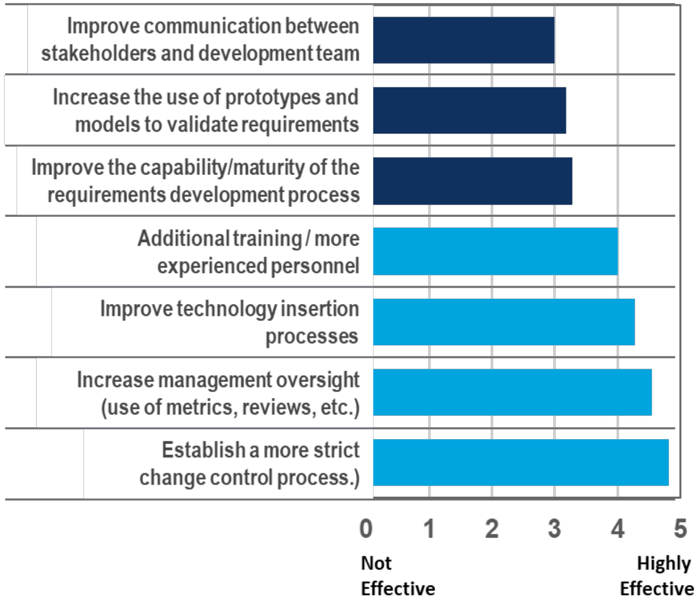
Improving Requirements Validation and Verification

- Best Practices
  - Validate requirements with variety of means
    - Use rapid prototyping – particularly useful for early validation efforts
    - Communicate with stakeholders
  - Review all requirements including validation and verification plans
    - Include multiple organizations
    - Confirm traceability of all requirements (matrix)
    - Ensure full test coverage
    - Identify and quantify limit states or constraints
  - Use structured argumentation or assurance case for requirements verification
    - Capture context and assumptions

Effectively Managing Requirements Change

- Challenges of Managing Requirements Change
  - Requirements can change between project phases
  - Greater impact later in the system life cycle
- Best Practices
  - Understand origins of requirements change
    - Change in stakeholder needs
    - Scope reduction or expansion
    - Verification issue
    - Part change or functionality enhancement
    - Defect fixing
  - Set requirements chill and freeze dates
  - Establish "critical no change" date
  - Improved communication between requirements engineers, test engineers, quality, and designers
  - Changes can be positive → increased quality, reduced costs or time

Mitigation Factor Effectiveness Rating



Pena, M. (2014). Mitigation Factor Effectiveness: Survey Results (CSSE ARR Survey, 2010). From https://www.slideserve.com/morwen/requirements-volatility

Conclusion: Efficiency Gains Might be Realized by

- Avoiding BRUF
- Front-loading the requirements process to ensure earlier V&V and avoid late requirements changes
  - Allocate resources to ensure inclusion of all stakeholders—customer(s), domain experts, design and test engineers, etc.—in requirements
  - Specify verification requirement along with the requirement and ensure flow down
  - Have database for commonly used or reusable parts and for standards and authority documents to share across projects
- Managing requirement volatility and change
  - Understand major drivers of requirements change
  - Include stakeholders, design and test engineers, etc. in requirements change control process
  - Determine who owns and must verify interface requirements
  - Avoid common flow down errors

Today’s Presentation

Things to Think About

How can this be applied in your work environment?

What did you hear that will influence your thinking?

What is your take away from this presentation?

Please

The link for the online survey for this meeting is

www.surveymonkey.com/r/2018_06_MeetingEval

www.surveymonkey.com/r/2018_06_MeetingEval

Look in GlobalMeet chat box for cut & paste link.

Slide presentation can be downloaded now/anytime from:

The library page at: www.incose.org/enchantment.

Recording will be there in the library tomorrow.