This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

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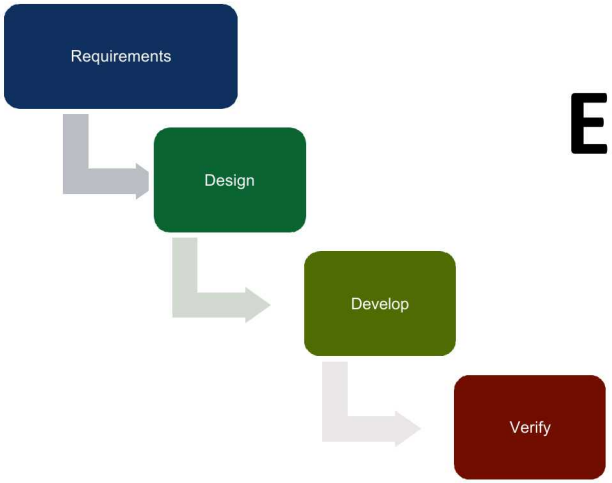


# Requirements Efficiency: External Questionnaire Results

*September 25, 2018*

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

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# Study Basis

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

***To reduce organizational impacts, schedule delays, and costs***

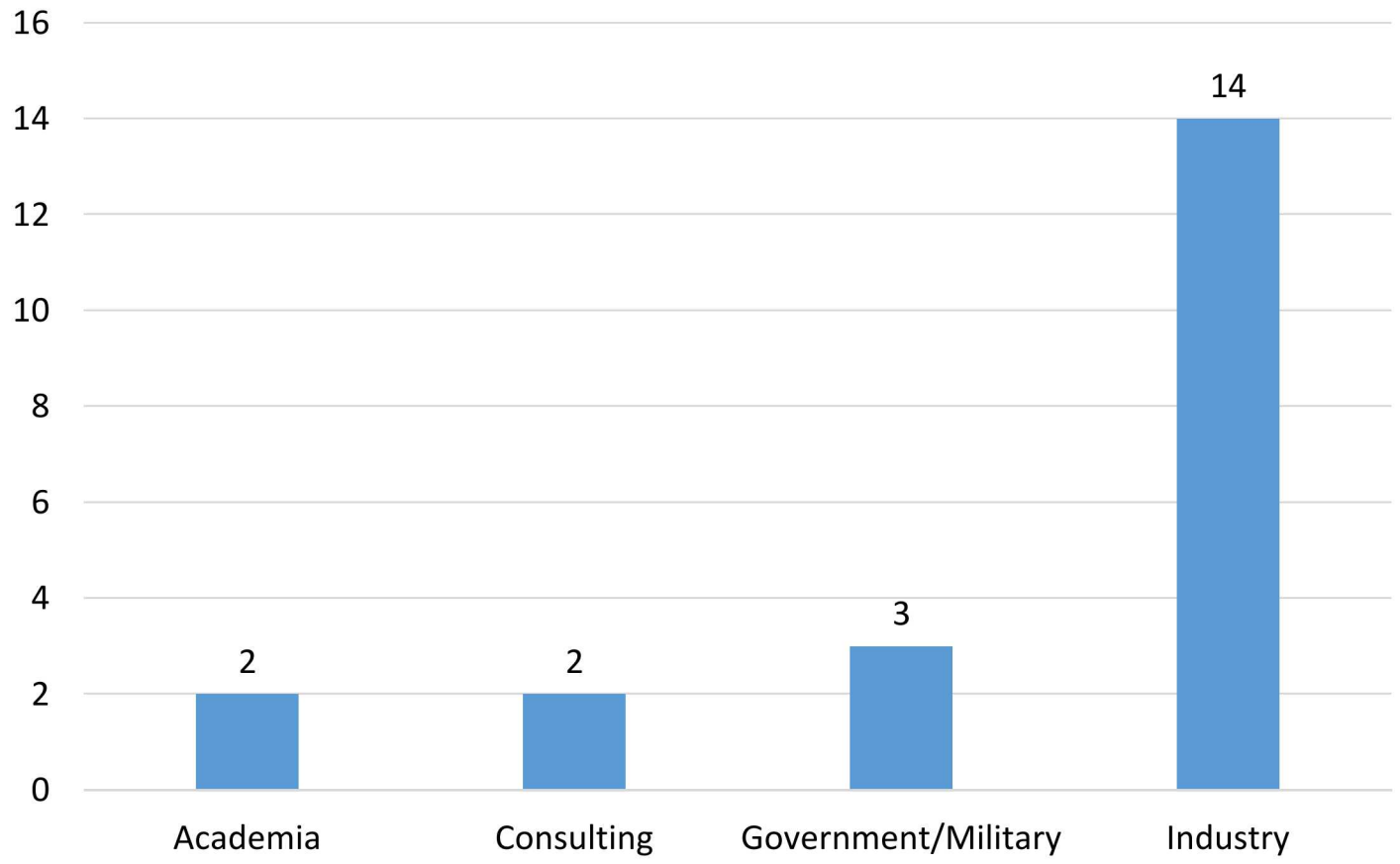
Goals:

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

- Approach (3 parts)
  - Internal SNL state-of-the-practice
  - Literature review
  - External investigation

# Participants

- Fourteen of twenty-one participants were from industry, including aerospace, automotive, manufacturing, automation/controls



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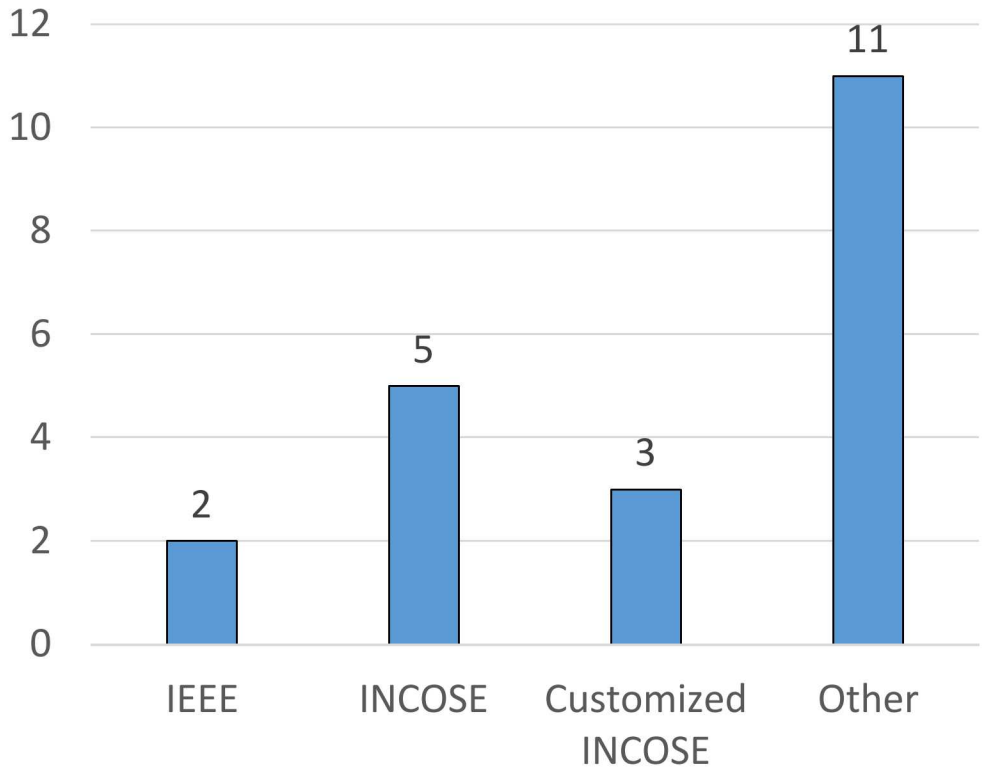
# Topics

- Requirements Process
- Requirements Team
- Requirements Timeline
- Requirements Approach
  - Architecture
  - Rigor
  - Speed
  - Lean
  - Agile
- Requirements Management
  - Level of design
  - Product specifications
  - Safety critical
  - Attributes
  - Evidence
- Tools
- Skill set and training
  - Skills
  - Training available inhouse
  - Roles
- Best Practices
  - Requirements management
  - Change process
  - Verification

# Requirements Process




- IEEE 15288
- INCOSE Handbook
- Customized INCOSE and Other:
  - Effective requirements/verification assurance
  - More structure for aerospace needs
- Other:
  - FAA process
  - Rapid prototyping—requirements process was not applied
    - Verification was negotiated as part of contract

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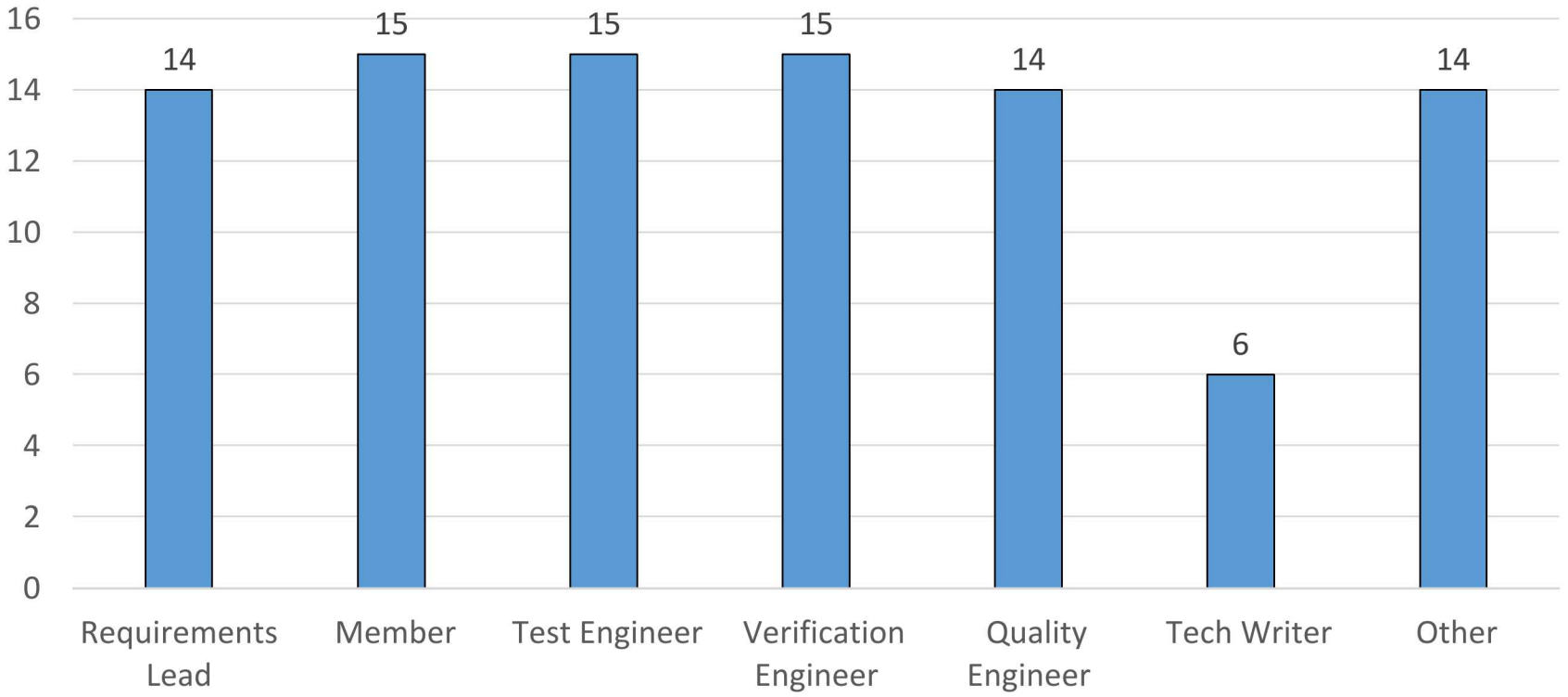
# Requirements Team Composition




- Requirements and quality engineers are not roles separate from a system engineer for several respondents.
- “Other” involved many differing responses.
  - Human Factors conspicuously absent

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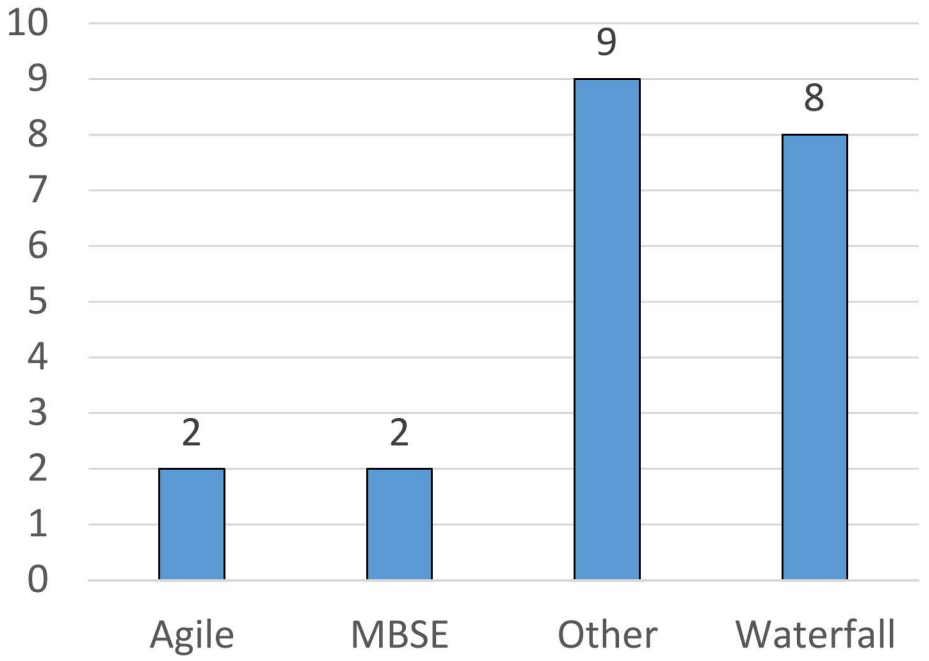
# Requirements Timelines

- Configuration Management (CM) start
  - Rigid from start of program (process already in place); OR,
  - After conceptual design, thorough needs analysis, and indication that requirements are stabilizing
- Change Process formalized
  - Early; OR,
  - When requirements are formalized → at contractual boundary
- Requirements "chilled"
  - Not practiced; OR,
  - At baseline design
- Requirements "frozen"
  - Not practiced—allowed to evolve; OR,
  - Before production start or contract signing

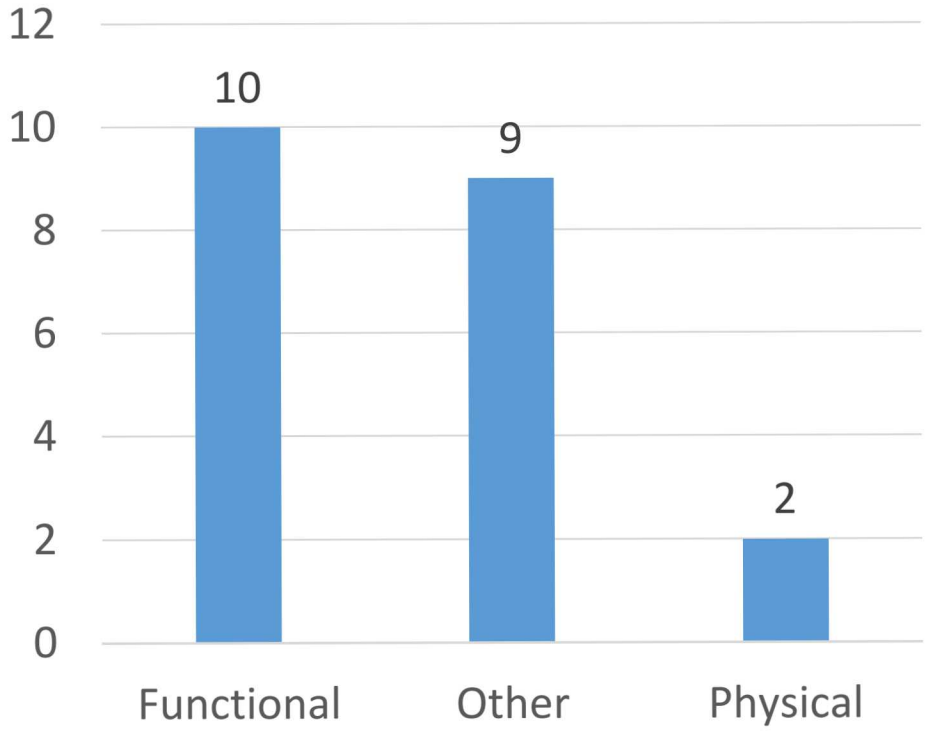
# Requirements Approach

- Agile
  - Some practice on program subset
  - Not used with safety critical designs
  - Used:
    - On focus projects, not main projects
    - By SW teams
    - Early in creative part
    - Inside of a boundary
  - Causes challenge in merging with EVM
- Six responses of using or moving towards MBSE
- Other
  - Waterfall with Agile within stages or components
  - New term emerging—"rapid"



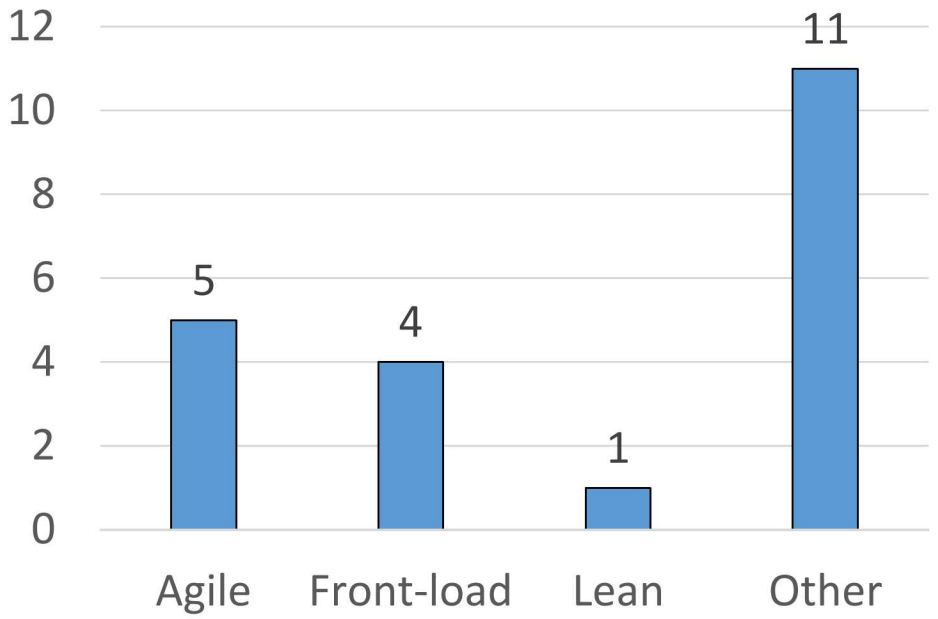
# Requirements Architecture Approach

- Other responses
  - "All of the above"
    - Seven responses
    - Most start with functional
  - "Depends on project"
  - "Does not apply"
- A few use MBSE, letting the architecture be the basis of the requirements



# Balancing Speed and Rigor

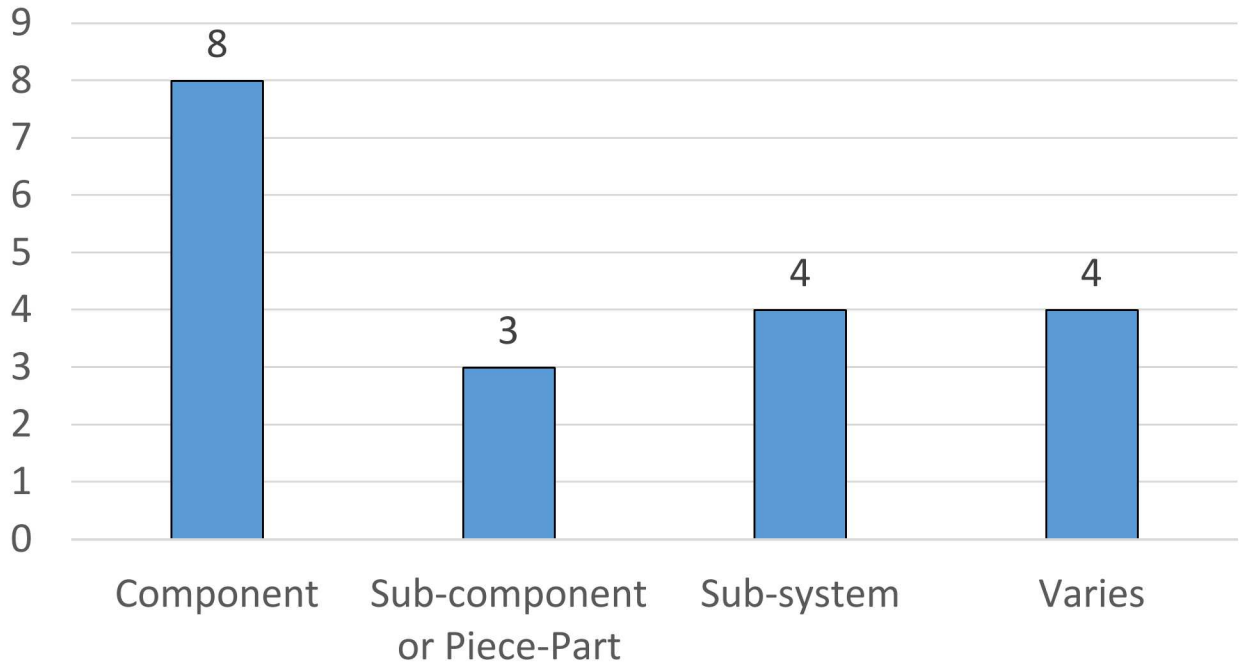
- Responses for speed
  - MBSE to speed up the requirements process
  - Front load—staff early
  - Use natural language tools
  - Review each requirement when it is ready
  - Use Agile and Lean approaches
- Responses for rigor
  - Use MBSE to identify gaps
  - Ensure customer involvement




Don’t write requirements too soon—get validated needs first.

Use flexibility in design until requirements solidify.

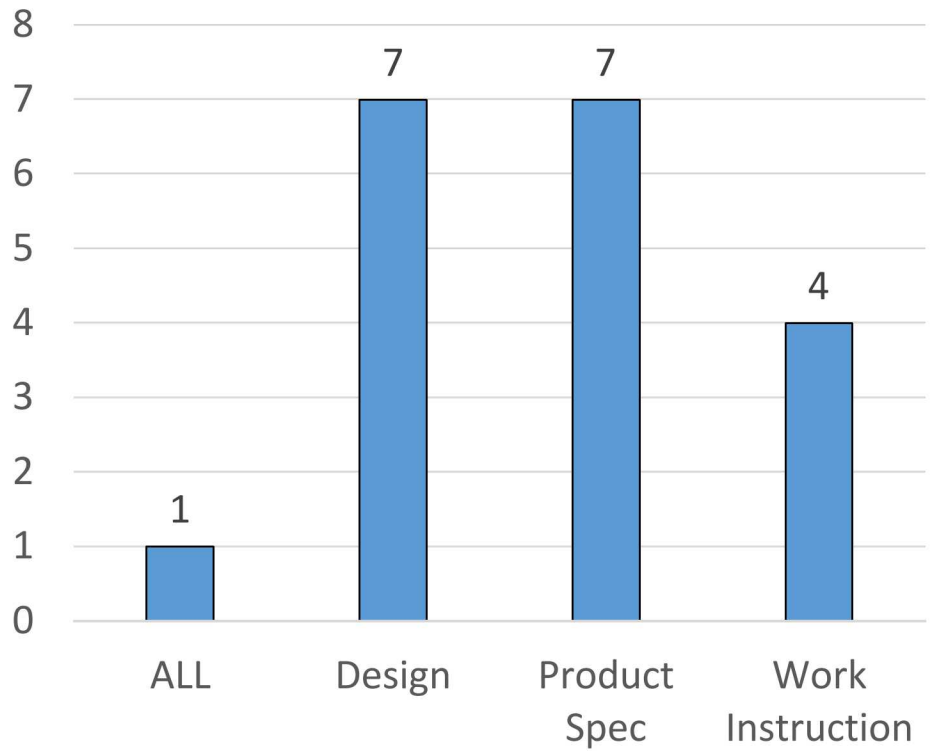
# Lowest Level of Requirements Tracking



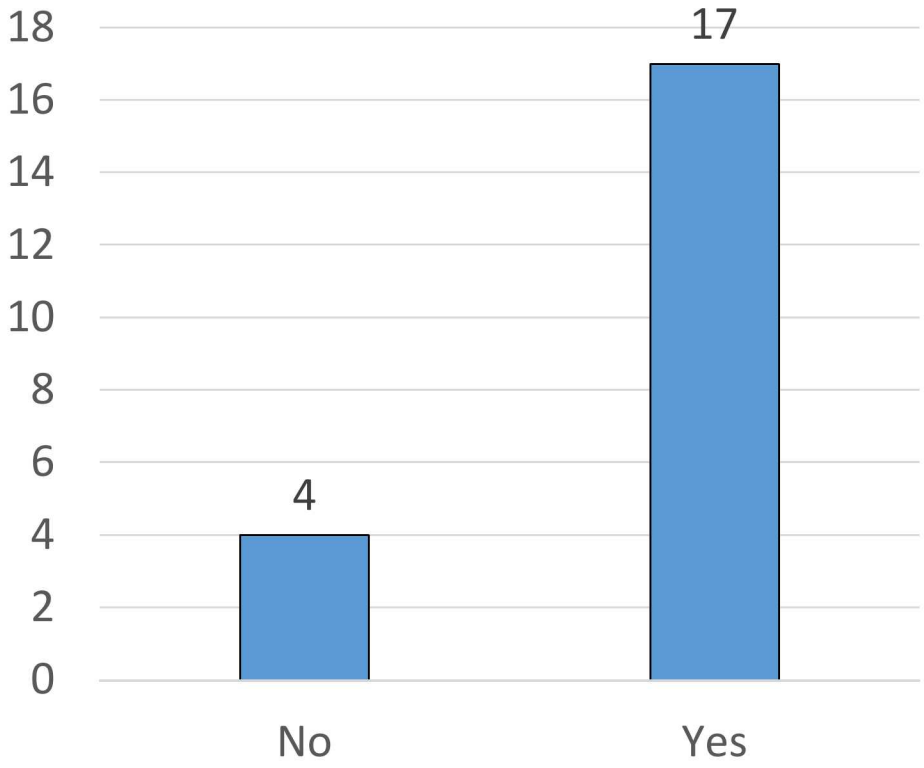

- Lowest level depends on risk, speed to market, other factors
  - Most often component—some caveating that “it depends”
  - To contractual boundary
  - To lowest level that they can be controlled
  - To lowest level of concern

# Depth of Requirements Management

- Requirements engineering and management can extend beyond design, to the Product Specification level and even the Work Instruction.
- Risk used to determine depth



# Most use Safety Critical Requirements




- Safety requirements varies by industry
  - Aerospace: ARP, FAA
  - Commerce/industry: ISO, FDA, automotive
  - Military: SAR, Mil-Std 882
- Fault trees, Failure Modes and Effects Analysis (FMEA), safety working groups, safety assessment reports were used in conjunction with defining safety requirements

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# Managing Requirements Attributes

- Recommendation:
  - Try to standardize—including module sets
  - Basic set that can be tailored for program needs
- Suggested attributes were as follows:

| Attribute Name | | |
|---|---|---|
| ID | Parent | Risk |
| Requirement Text | Child | Uncertainty |
| Requirement Type | Linked Functions | Verification Requirement |
| Rationale | Interface Linkages | Verification Rationale |
| Priority | Safety Critical | Evidence |
| Requirement Status | Change history / version # | Verification Status |
| Owner | Designer owner | Stakeholder |
| Subsystem | Comments | Classification |

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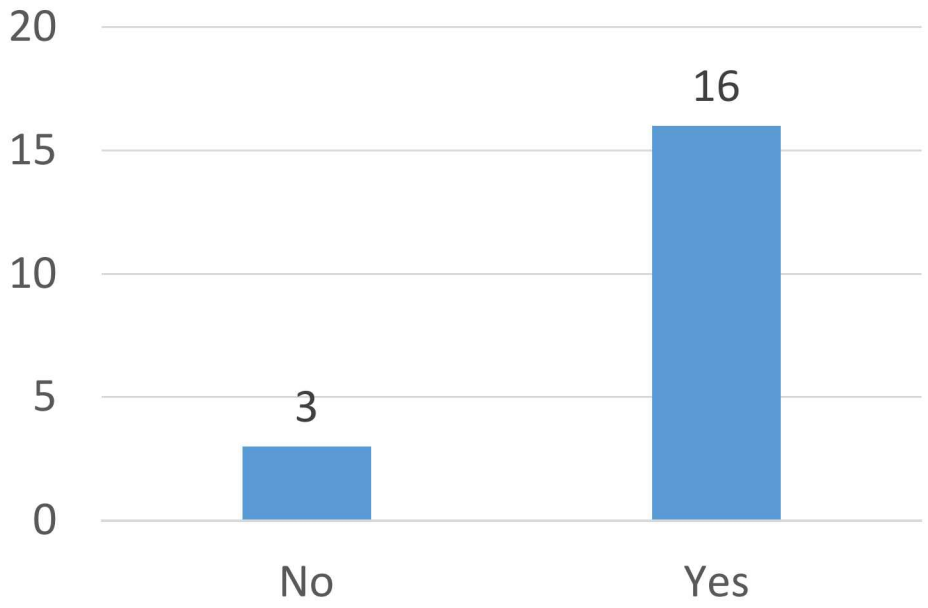
# Evidence for Meeting Requirements




- Agreement that verification should be performed up front/early, included in proposal and requirements review process
- Verification method and requirement written with each design requirement
- Verification engineer works with test engineers and collects (chain of) evidence, tying back to requirement

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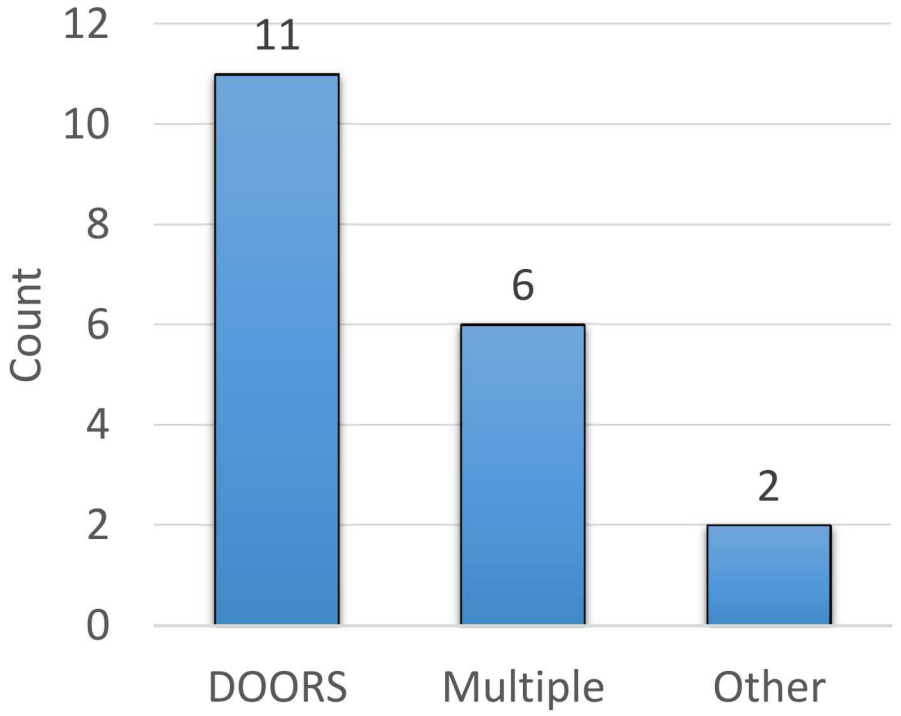
# Requirements Tools

- DOORS most widely used, because
  - Maturity
  - Number who know how to use it
  - Extensibility with other applications
  - Requirements tracing capability
- EXCEL used for small projects or as an export/import to DOORS




Use naming convention in tools, common schema for formatting, standardized attribute set, templates for requirements creation, V&V template, and tool user access rules

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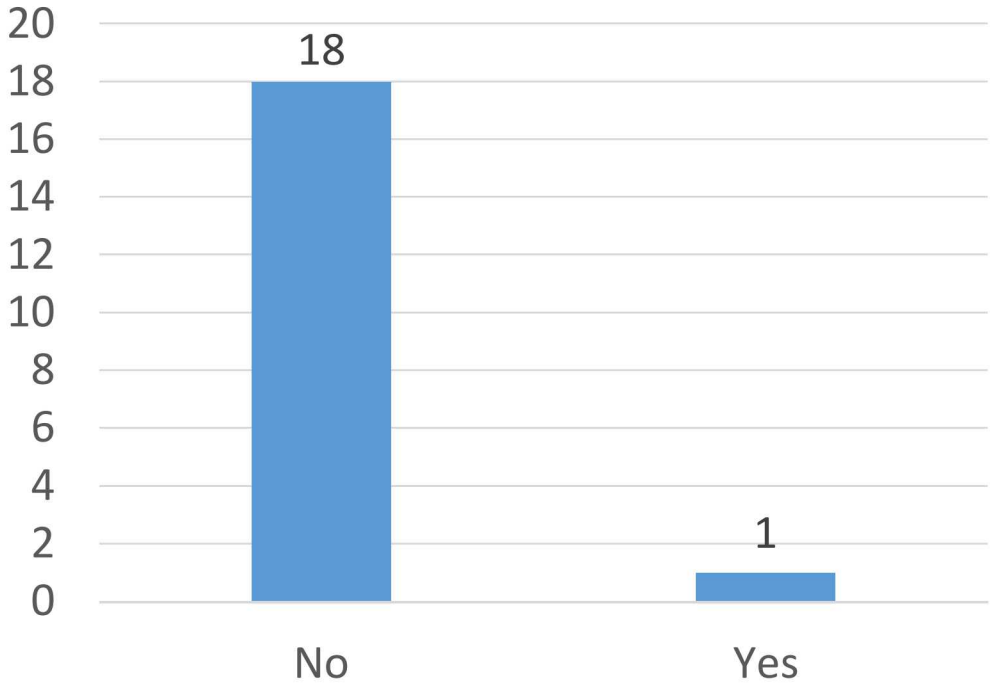
# Do Tools Become Burdensome?

- ***Yes, burdensome at some point***
  - Agile processes too fast
  - Without standardization up front, database format confusion
  - Large number of modules create an administrative problem
  - With too much information and too many links to documents, tools fail and links get lost
  - Insufficient resourcing
    - Problem if one person is superuser
  - Overkill for small projects
  - Integrating into corporate processes like EVM
  - Cut-and-paste usage from last program without tailoring to needs of new program
  - Customer has unrealistic expectations of tool performance
- ***No, not experienced as burden***
  - Required/mandatory
  - MBSE tools were not viewed as overly burdensome when used with management support and multiple users

Process should drive tool—tool should not drive process!

# Capture Requirements from Drawings?




- While only one respondent answered “yes”, some others did have limited efforts in digitizing requirements capture

Using digital capture tools offers potential time savings. Recommended for consideration.

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# Requirements Skill Set

| Skill | Count of Responses |
|---|---|
| **Domain expertise** | **10** |
| **System engineering/ requirements engineering** | **10** |
| Soft skills | 3 |
| Use of tools | 3 |
| Big picture thinking | 3 |
| Ask questions | 3 |
| Detail oriented | 2 |
| Communication | 2 |
| Writing | 2 |
| Organization | 2 |
| Impact analysis | 1 |

- Most consistent responses:
  - Domain expertise
    - Experience on past programs
  - System engineering knowledge, and/or requirements background
- Soft skills: such as customer relations

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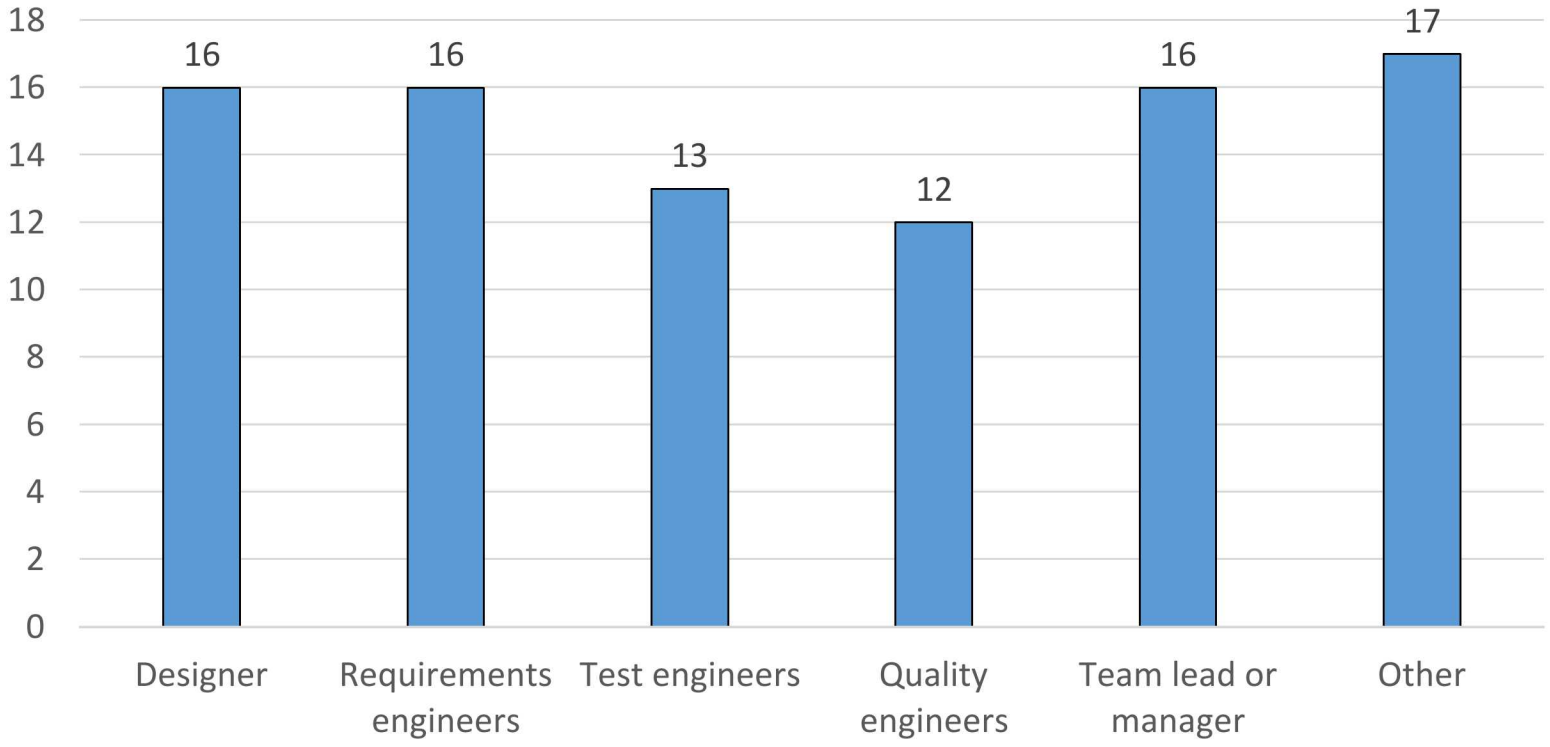
# Requirements Training

- Most offer training inhouse (16 out of 21 responses)
  - Most common courses
    - Tool usage
    - Writing requirements
- Informal training (1-on-1, OJT) also acknowledged
- A few companies encourage MS in System Engineering

| Inhouse Training Offered | Number of Responses |
|---|---|
| **Tools training** | **11** |
| **Writing requirements** | **6** |
| System requirements management | 2 |
| Intro to System Engineering | 2 |
| SAFe/Agile | 2 |

Training is a substantive part of the whole process

# Many Involved in Requirements Change Process




- Others = Stakeholder, Change requestor, Supplier, SEMP author, Manufacturing, Mission engineers, Compliance, Customer rep.
- Change Control Board (CCB) may be run by an assurance team

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# Best Practices for Requirements Management

- Involve customer(s) in elicitation and validation
- Validate customer needs and develop a design architecture prior to flowing requirements
- Have requirements engineer integrated with rest of product team
- Manage and force definitive proof on boundaries/interfaces
- Be conscious of level of requirements; write requirements appropriate to level of system. Focus on “black box” requirements.
- Write verification requirements early
- Have a verification plan and strategy for each requirement
- Verification engineers review requirements before product build
- Once requirements are reviewed and released, enforce CM and CCB

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# Best Practices for Change Management

- Expect change
- Understand impact of the changes
- Stay at the right level of abstraction to minimize change
  - Write *WHAT* is needed, not *HOW* to implement
- Ensure adequate response to requirements change
  - Must be managed
  - Communicate change; implement change in design, test, etc.
- Tailor change process to program
- Integrate change process with configuration management

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# Best Practices for Verification

- Involve verification engineer early
- Verify from system perspective
- Include verification details in proposal and bid
- Write verification plan/strategy for each source requirement
- Assign source requirement owner responsible for life of requirement, including verification
- Test as you go—collect evidence along the way
- Insert compliance artifacts into Product Lifecycle Management system so verification is closed out and CM manages info
- Ensure verification linked to source drawing

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# Summary - Recommendations for Action

- Strongly couple requirements writing with verification writing
- Use customized INCOSE or inhouse requirements approach, according to assurance needs
- Standardize the approach to requirements writing
- Use a requirements management tool, limiting the attributes being tracked to ~20 or less
- Customize membership of change and process boards
- Carefully consider requirements baselining and change practices
  - Requirements are most often chilled at baseline
  - Then, frozen prior to contract award/signing.
  - If not contracting out, consider not freezing requirements until end of program – rolling revisions, per funding and schedule

# Appendix A

## Requirements Engineering and Management Process Questionnaire

The goal of our study is to identify and recommend options for achieving higher levels of efficiency while maintaining effectiveness in requirements engineering and management process. As part of this effort, we are eliciting feedback from several sources to understand the current state of the practice and collect and share lessons learned and best practices. Information from all sources will be compiled without attribution. Please respond based on your **current position** and **current program(s).**

### Requirements Process

1. What is the most recent process you used for managing and tracking requirements (not tools)? *(please check or highlight the appropriate box)*
   - ☐ INCOSE
   - ☐ IEEE (which spec's?) _____
   - ☐ PMI
   - ☐ Other _____

   Comments: _____

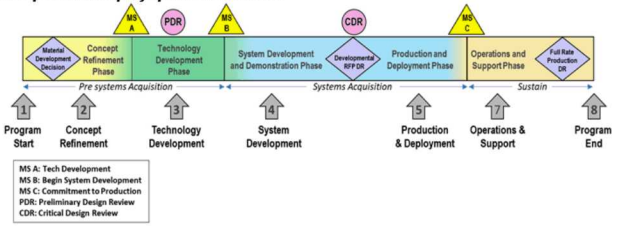
2. What are your best practices for managing requirements in general?

3. What are your best practices for managing your requirements change process (i.e., managing a change board, or other)? *(please describe)*

4. Typically, who is involved in your requirement change processes? *(please check or highlight all that apply)*
   - ☐ Designers
   - ☐ Requirements engineers
   - ☐ Test engineers
   - ☐ Quality engineers
   - ☐ Team lead or manager
   - ☐ Others *(please list)* _____

1

***Please answer questions 5 through 8 using the following image. Identify the product lifecycle location that best answers the specific question and enter the number (1 through 8) that most closely corresponds to the specific process or milestone.***




5. Typically, when is the requirements configuration management process begun? ***(Which number best represents where in the cycle)***

6. Typically, when is the change process formalized? ***(Which number best represents where in the cycle)***

7. With respect to a major milestone, when are requirements "chilled"? ***(Which number best represents where in the cycle)***

8. With respect to a major milestone, when are requirements "frozen"? ***(Which number best represents where in the cycle)***

### Requirements Approach

1. What is your requirements approach (not tools)? ***(check or highlight all that apply)***
   - ☐ Model Based Systems Engineering (MBSE)
   - ☐ Waterfall (traditional tracing/system engineering vee)

- ☐ Lean
- ☐ Agile
- ☐ Ad hoc
- ☐ Other *(please describe)* _____

_____

_____

_____

_____

2. What is your approach to architecting requirements? *(check all that apply and please describe below)*
   - ☐ Physical
   - ☐ Functional
   - ☐ Model-based, as derived from tool
   - ☐ Other *(please list)*

     _____

   Please describe: _____

   _____

   _____

3. How does your requirements process balance rigor and speed? (*check all that apply and please describe below)*
   - ☐ Agile techniques
   - ☐ Lean techniques
   - ☐ Front-load process
   - ☐ Other *(please list)*

     _____

   Please describe: _____

   _____

   _____

4. If applicable, specifically, what lean and agile practices do you apply to Requirements Engineering? (*Please describe*) _____

_____

_____

_____

5. What is the lowest level that your requirements engineering and management process maps to? *please check or highlight the appropriate box)*
   - ☐ System level
   - ☐ Sub-system level
   - ☐ Component level
   - ☐ Sub-component level or piece part level?

6. How deeply does your requirements engineering and management process extend (to production requirements (Product Specification (PS)[1] level))? (*please check or highlight the appropriate box)*
   - ☐ Design level only
   - ☐ Product specification level
   - ☐ Work instruction

7. Do you have safety critical requirements? (*please check or highlight the appropriate box)*
   - ☐ No
   - ☐ Yes. Do you couple a fault tree to the requirements management process? *(Please explain)* _____

     _____

8. Do you use evidence-based assurance (or an assurance case) approach for requirements verification? (*please check or highlight the appropriate box)*
   - ☐ No
   - ☐ Yes *(Explain your approach)* _____

     _____

     _____

9. Based upon your requirements experience, what best practices and lessons learned can you provide from your verification approach? _____

_____

[1] Product Specification is the written statement of an item's required characteristics documented in a manner that facilitate its procurement or production and acceptance.

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## Tools and Infrastructure

1. Does your organization use a Requirements Engineering and Management software tool, such as DOORS, RequisitePro, Tau, other? (*please check or highlight the appropriate box)*
   - ☐ Yes, which tool? _____
   - ☐ No→ **skip to the next section.**

   a. Why was this tool chosen? _____

   b. What attributes are used in this requirements management tool (for example, ID, text, etc.)? *Please list all that you can recall*. _____

2. Based on your experience, did the requirements tool become burdensome? At what point did this occur? How did you adapt? _____

3. Does your project capture requirements from drawings with a tool, such as DISCUS or others?
   - ☐ Yes, which tool do you use? _____
   - ☐ No, manual capture
   - ☐ Other *(list)* _____

## Requirements Skill Set and Training

1. Based on your experience with major programs, what requirements engineering and management roles were used on your program? *(check or highlight all that apply)*
   - ☐ Requirements lead
   - ☐ Team member
   - ☐ Test engineer
   - ☐ Verification engineer
   - ☐ Quality engineer
   - ☐ Technical writer
   - ☐ Other (*list all other roles*) _____

   Comment(s) _____

2. What **technical** skills do you look for in a Requirements Engineering lead on a major program? _____

3. In your organization, is requirements engineering and management training is available?
   - ☐ Yes, what training is available? _____
   - ☐ No, external training utilized *(please list)* _____
   - ☐ None *(please explain)* _____

Thank you for your time!