SERC RESEARCH REVIEW 2023 | NOVEMBER 15, 2023

Improvements in Architecting Decision Making and Training

ART-016: IME Architecture Process for Vertical Lift Systems

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Project Overview

- Title: ART-016: IME Architecture Process for Vertical Lift Systems
- Period of Performance
- 11 March 2020 - 1 March 2023
- PI: Bryan Mesmer; Original PI: Paul Collopy

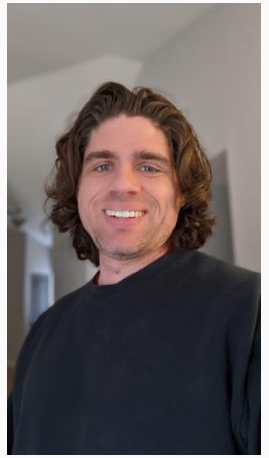
- Research Objective: The Systems Engineering Research Center (SERC) will assist U.S. Army Combat Capabilities Development Command Aviation & Missile Center in maturing the existing Comprehensive Architecture Strategy (CAS) approach by developing methods for consistently applying it across multiple programs.

Research Team

- Just some of the many who worked on this project



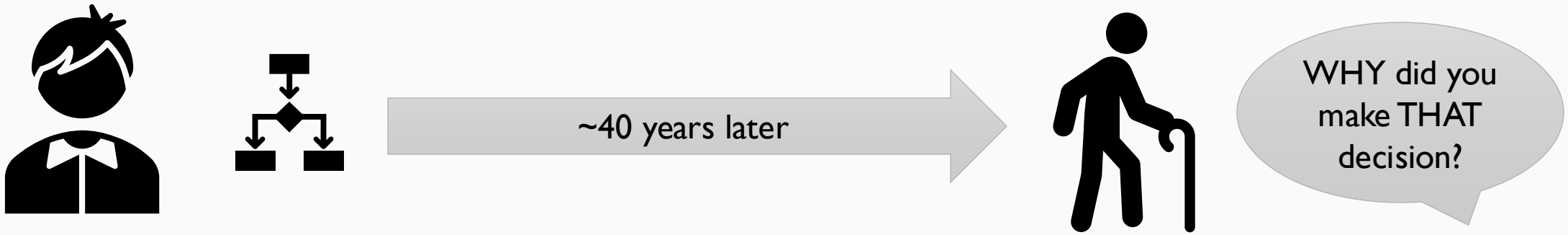





Motivation

- A rigorous, repeatable, systematic approach to architecting is needed to:
  - Provide justification for decisions to present stakeholders
  - Provide justification for decisions to future stakeholders
  - In general, improve architectures



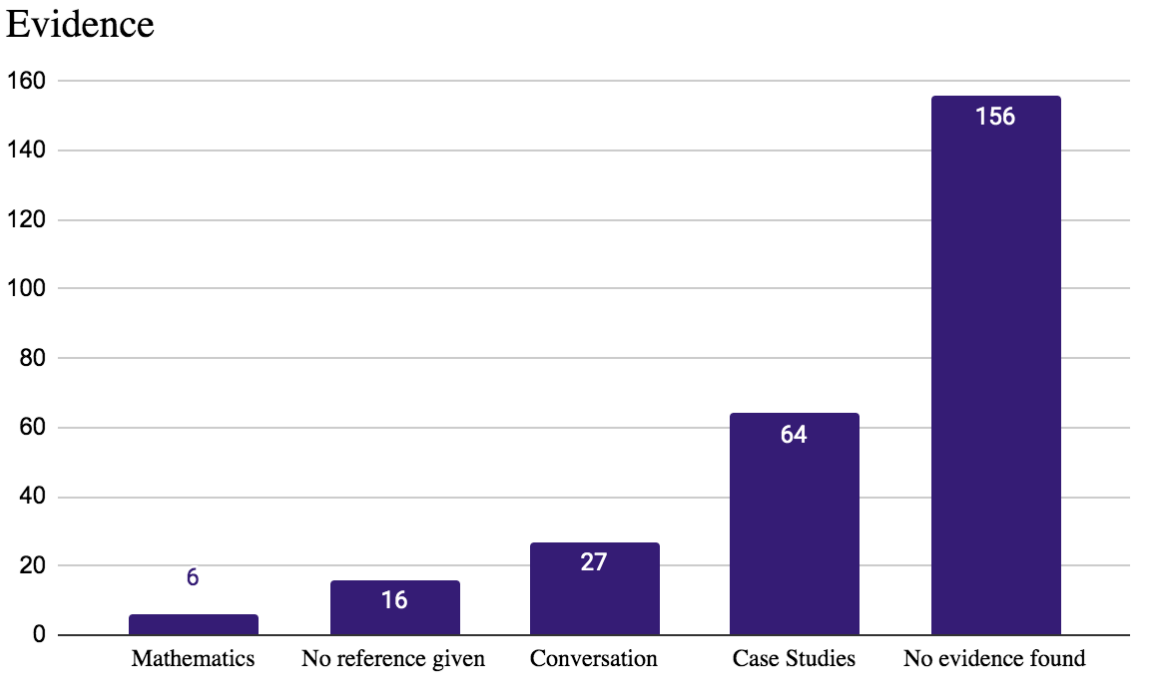
Project Overview

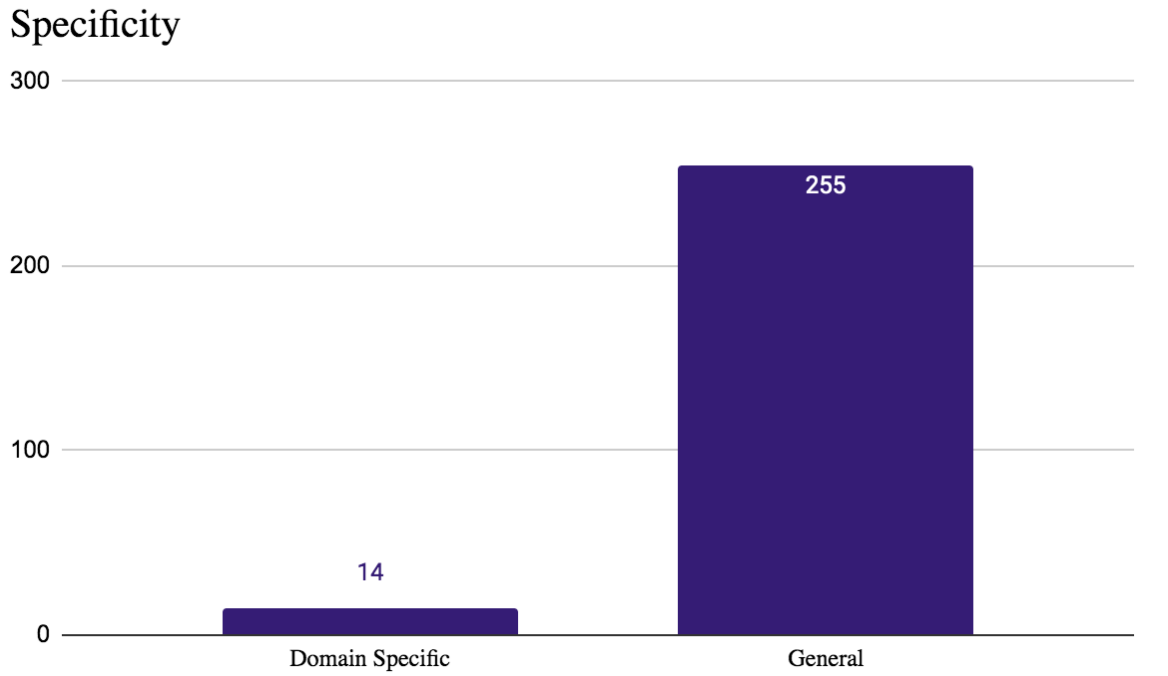
- Project had many sub-tasks and deliverables, we will focus on the primary tasks of the last year of the project:
  - Biases in Architecting
  - Deferring Decisions in Architecting
  - Data Selection Challenges in Architecting
  - Making Good Architecting Decisions
  - Decision Making Framework
  - Training Architects

Biases in Architecting

Biases in Architecting - Motivation

- Heuristics in System Architecting
  - Over 250 heuristics examined



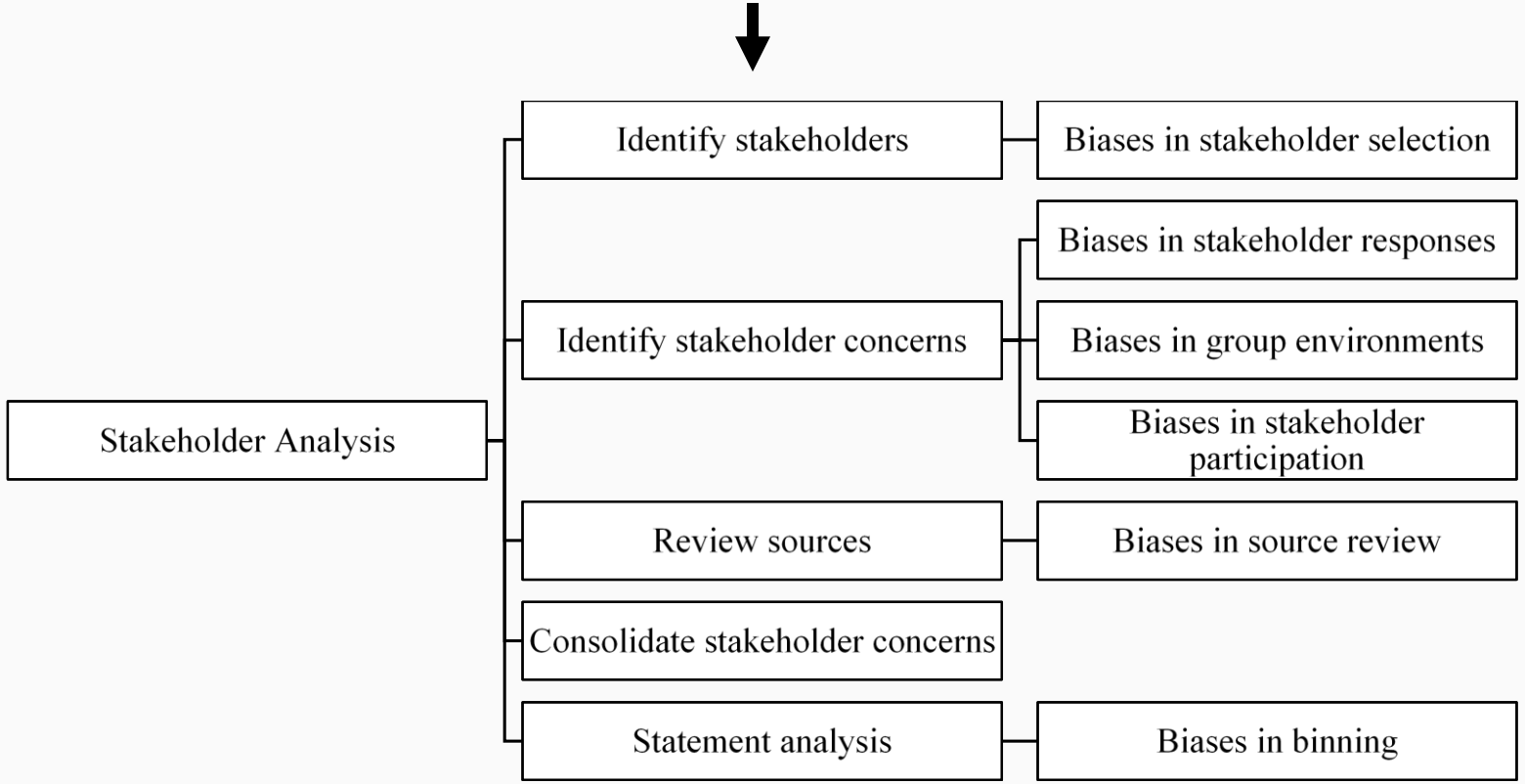


Biases in Architecting - Motivation

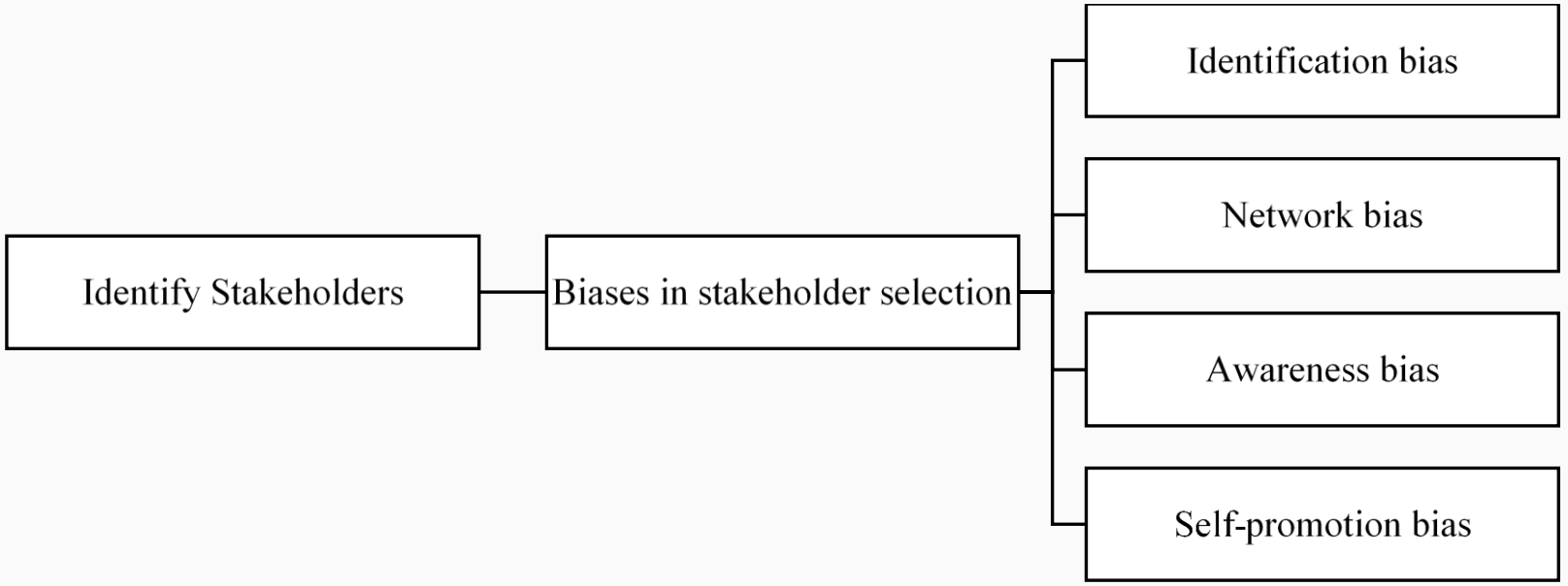
- If using a heuristic, architects should understand key information about the heuristic including
  - The heuristic's effectiveness
  - Where the heuristic is sourced from
  - Why the heuristic works
  - Relevance to how the architect wishes to use it

Potential Biases in Elicitation Process

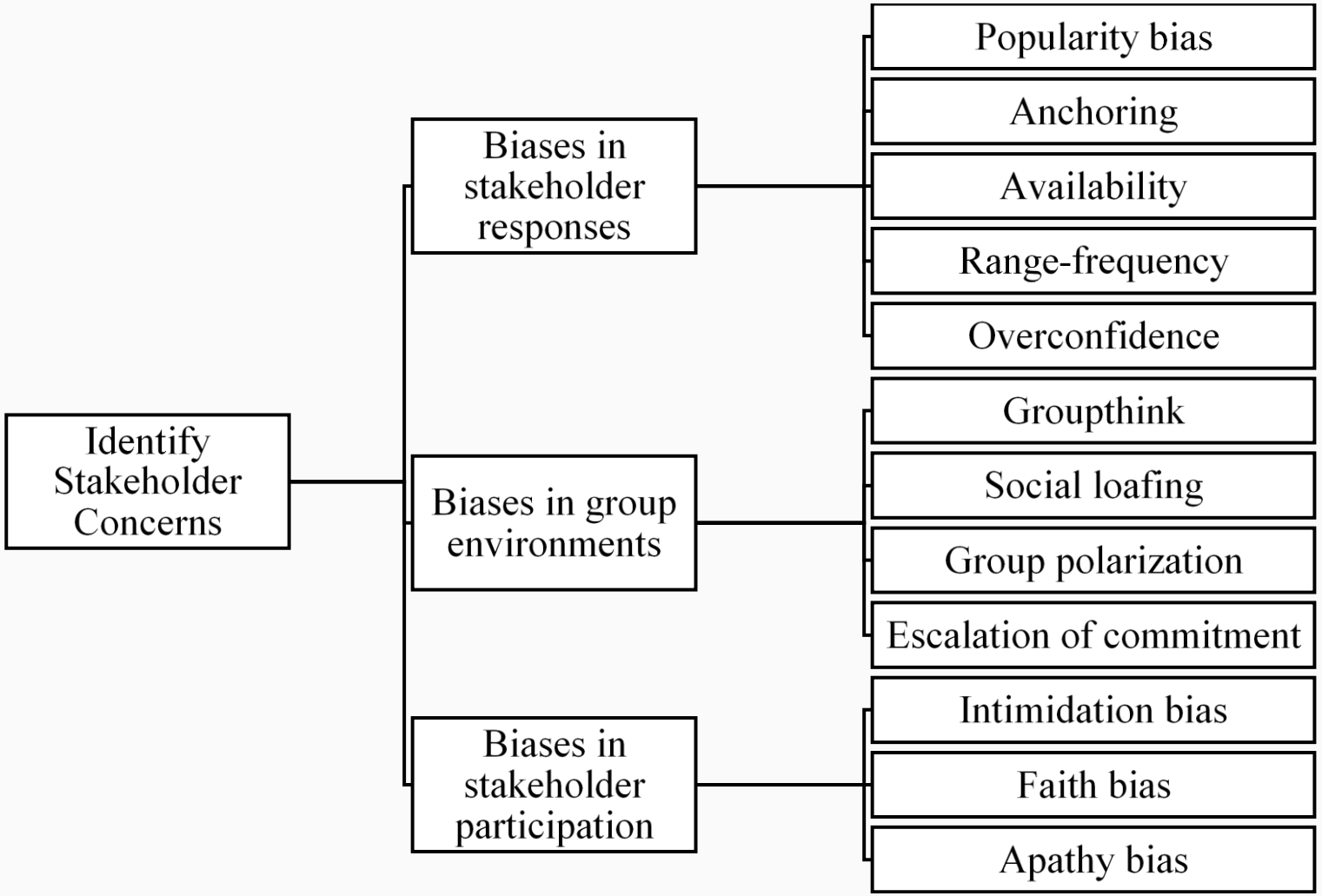
- Task Objective: Identify potential biases in architecting processes associated with stakeholder preference elicitation.



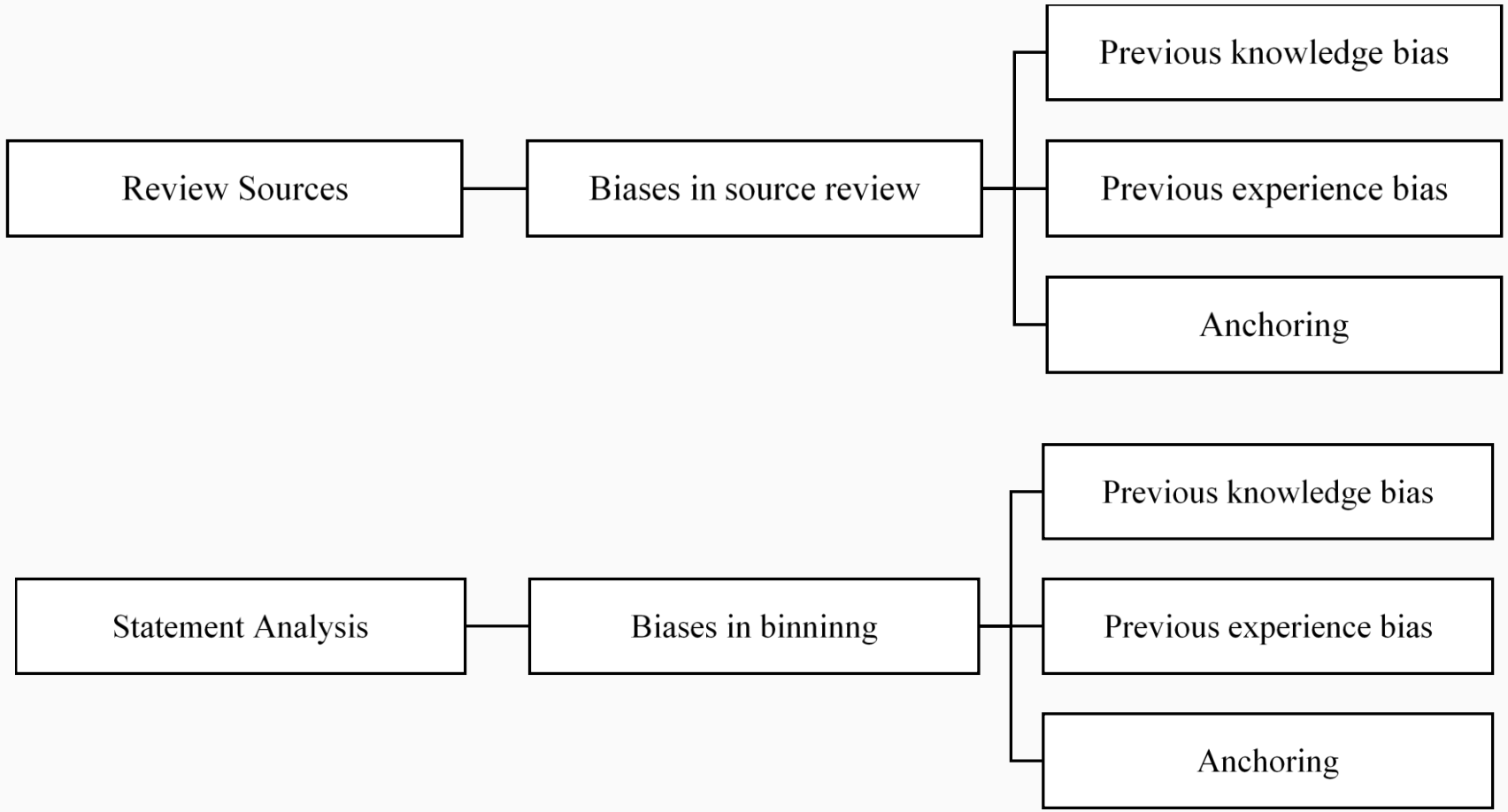
Potential Biases in Elicitation Process



Potential Biases in Elicitation Process



Potential Biases in Elicitation Process



Potential Biases in Elicitation Process

Bias	Organizational Strategies for Mitigation
Groupthink	• Create a conducive, open climate at all levels; giving and accepting criticism encouraged by leaders • Foster open debate and inquiry; group leaders refrain from stating personal preferences at start of discussion • Establish multiple groups to work on decision-making in parallel; groups may be divided into subgroups
Social Loafing	• Increase identifiability to avoid "hiding in the crowd"; group decision making tasks can be divided • Limit group size • Strengthen group cohesiveness through social solidarity and bonding among group members • Increase autonomy among group by allowing task choice
Group Polarization	• Encourage group participants to take perspective of other members • Form work groups from a variety of specialisms or disciplines
Escalation of Commitment	• Structure incentives so group members are not penalized for inconsistency • Reduce incentive among members to defend a previous faulty decision; inform group that adverse outcomes beyond individual control • Ensure group-decision makers are aware of cost of subsequent withdrawal before committing further resources

Potential Biases in Elicitation Process

- Task Takeaways:
  - There are many biases that can influence the elicitation of stakeholder preferences.
  - Ideally those biases would not exist, however this is not realistic.
  - The eliciting organization can establish protocols to aid in the reduction of impacts of biases.
  - Elicitors can be educated on the potential biases that exist and ways to mitigate impacts.

Deferring Decisions in Architecting

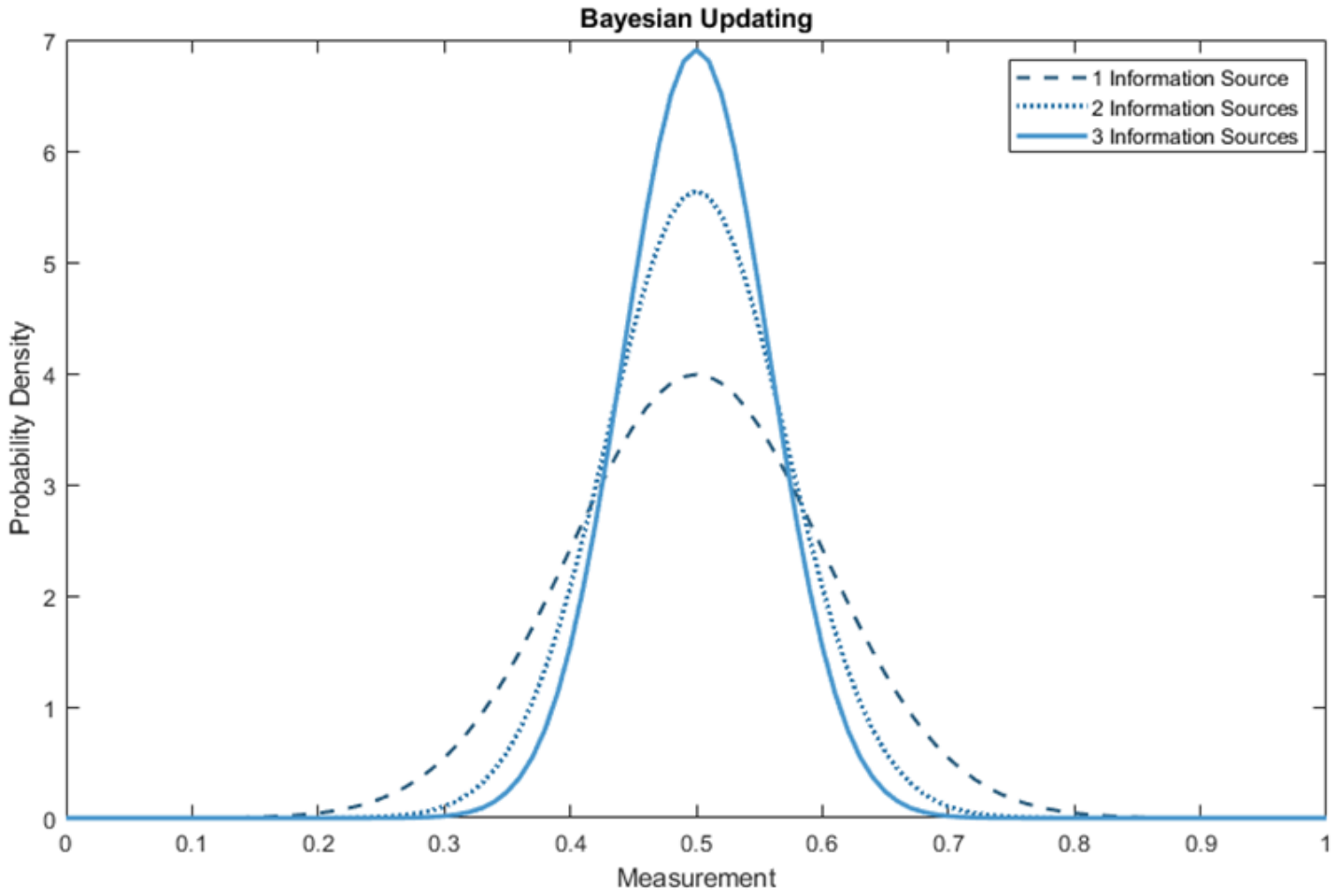
Deferring Decisions in Architecting

- Task Objective: Identify techniques relevant to architects as they work to gather information to inform typically highly uncertain decisions.
  - Summaries of research areas typically not employed by the architecting community.

- Two categories of methods for determining when to stop gathering information for a decision:
  - Convergence-based stopping rules
  - Threshold-based stopping rules

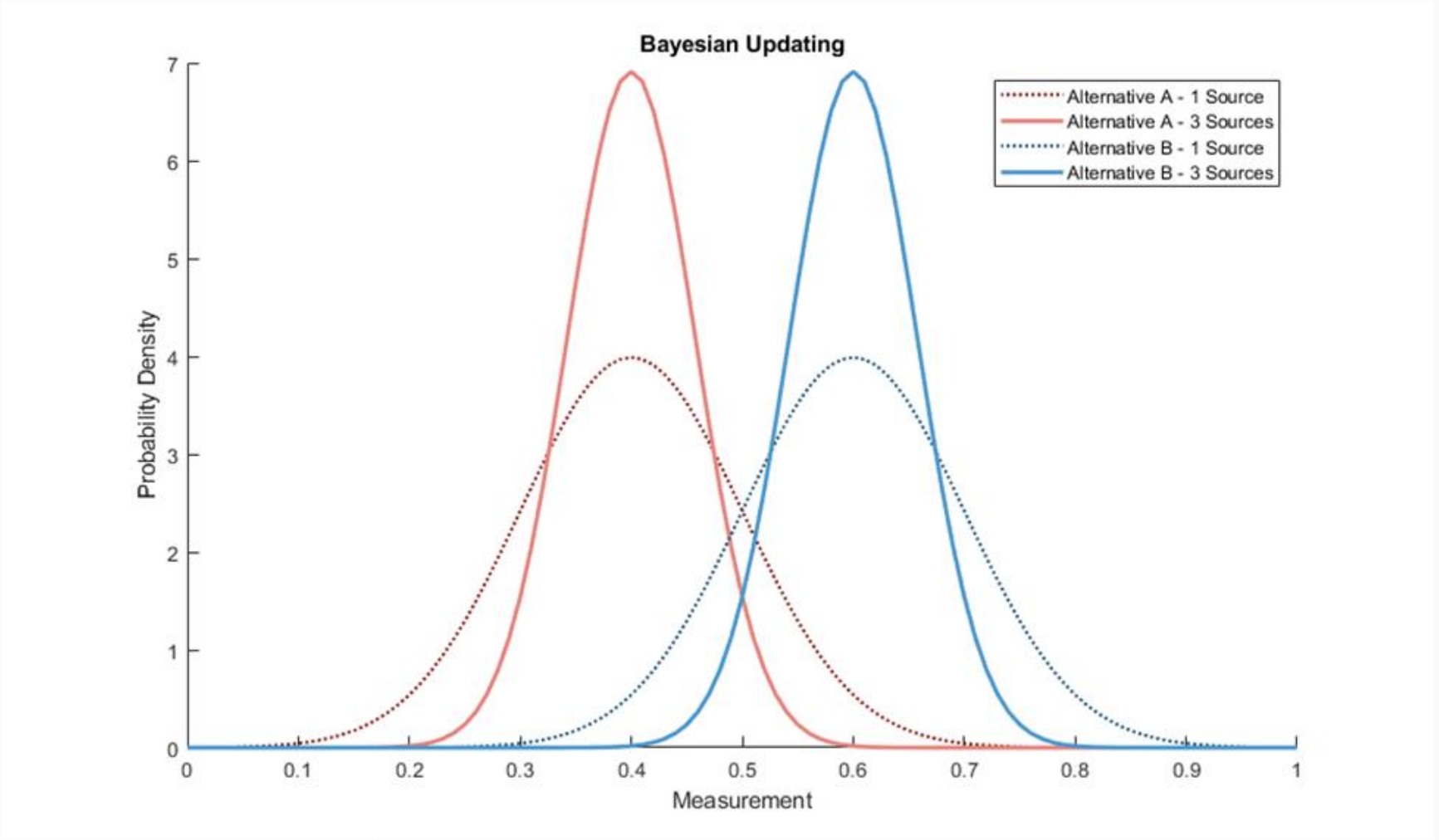
Deferring Decisions in Architecting

- Convergence-based stopping rules



Deferring Decisions in Architecting

- Threshold-based stopping rules



Deferring Decisions in Architecting

- Open research questions:
  - How do decision makers assess how useful a potential piece of information is?
  - What information is currently known?
  - What information sources are available?
  - How valuable those information sources are likely to be?
  - How to determine the costs of accessing those information sources?
  - What information sources may be available in the future?
  - What are the potential effects of deferring the decision to a later point?

Data Selection Challenges in Architecting

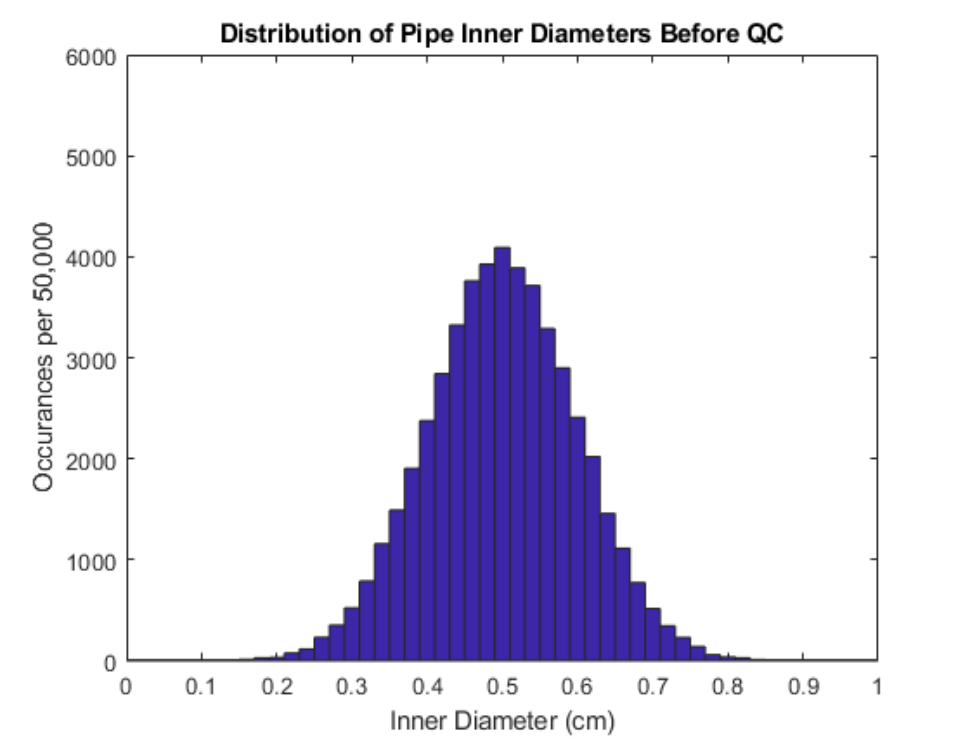
Data Selection Challenges in Architecting

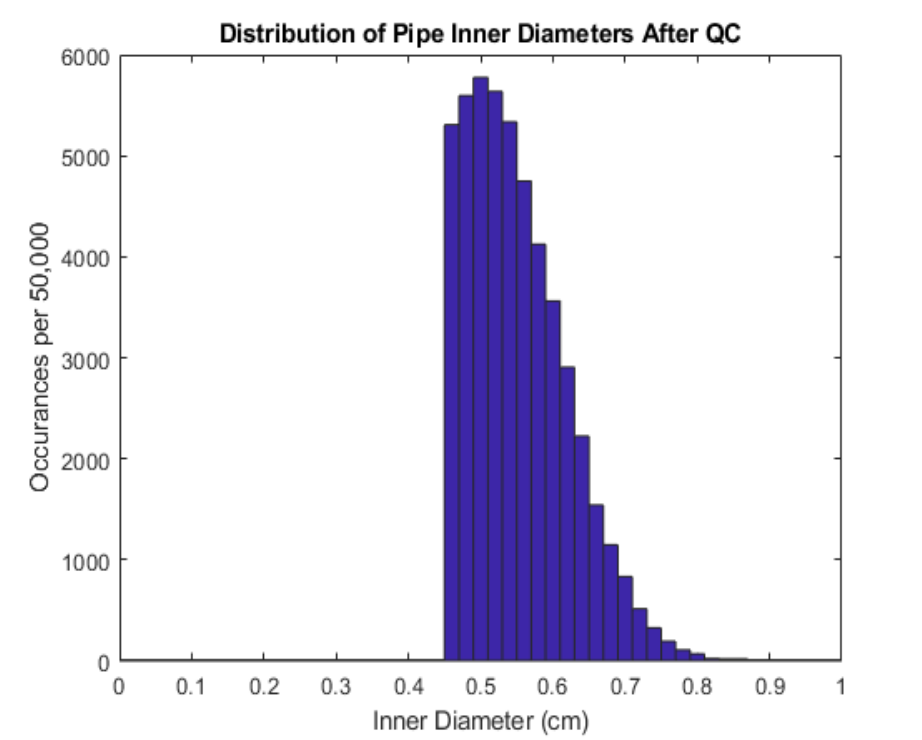
- Task Objective: Illuminate a potential data selection challenge that architects can face when making decisions.

- Two examples created illustrating the challenge of survivorship bias on forming beliefs on engineering decision outcomes as well as techniques to mitigate the challenge's impacts.

Data Selection Challenges in Architecting

- Manufacturing Tolerances

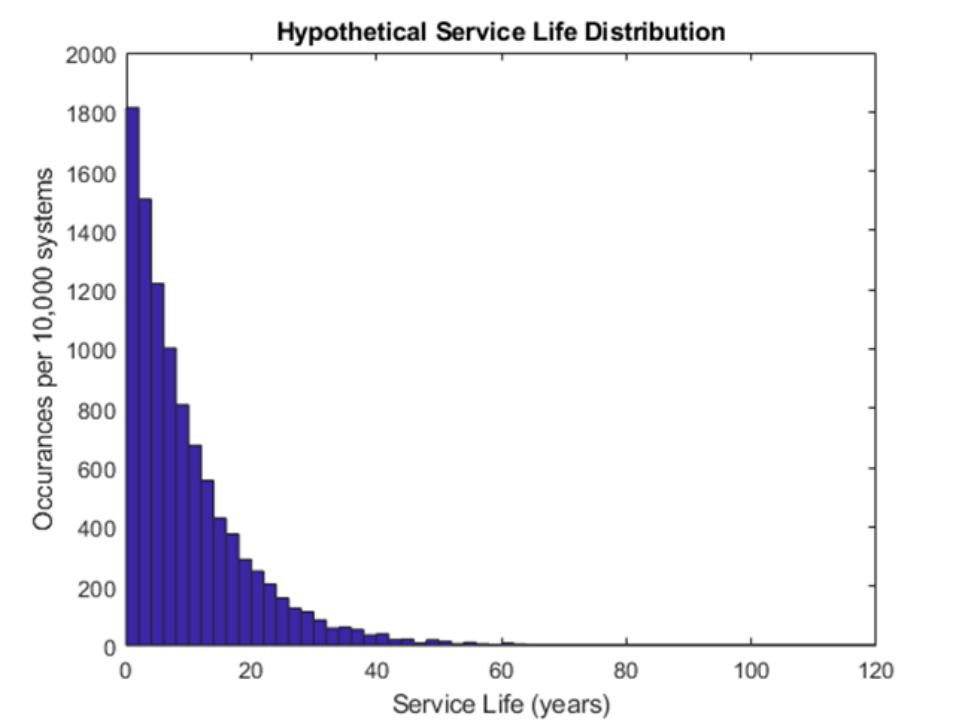


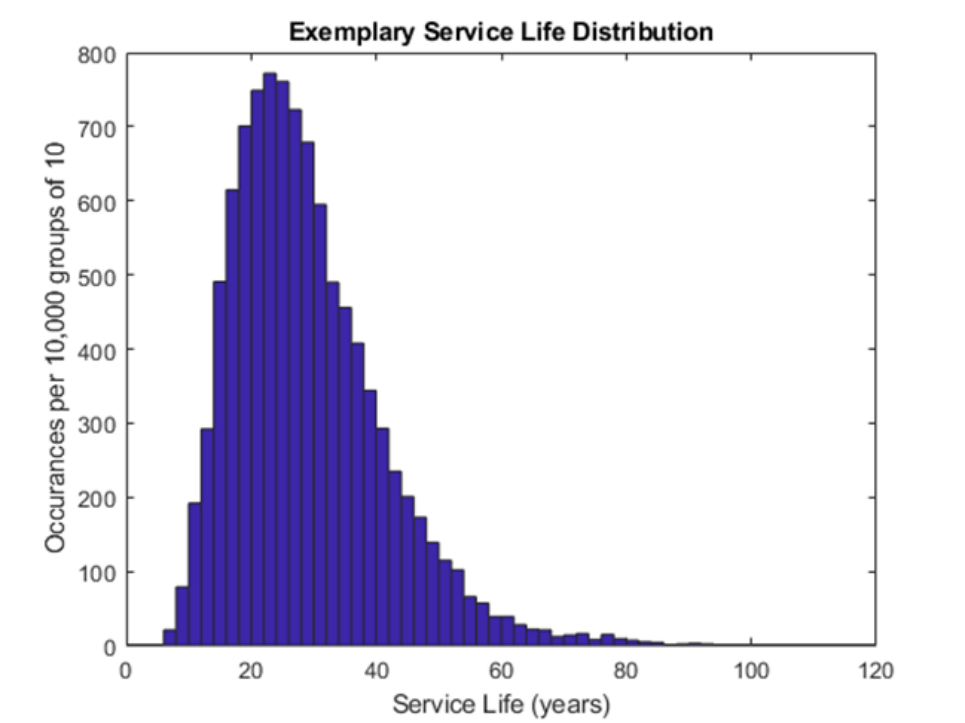


	Mean	Median	Std. Dev.
Before QC	0.5000	0.5001	0.0994
After QC	0.5511	0.5399	0.0697
Difference	0.0511	0.0398	0.0297

Data Selection Challenges in Architecting

- Bias introduced to the estimates if case studies are only performed on successful, long-serviced systems.
  - Sample 10 systems keep the best





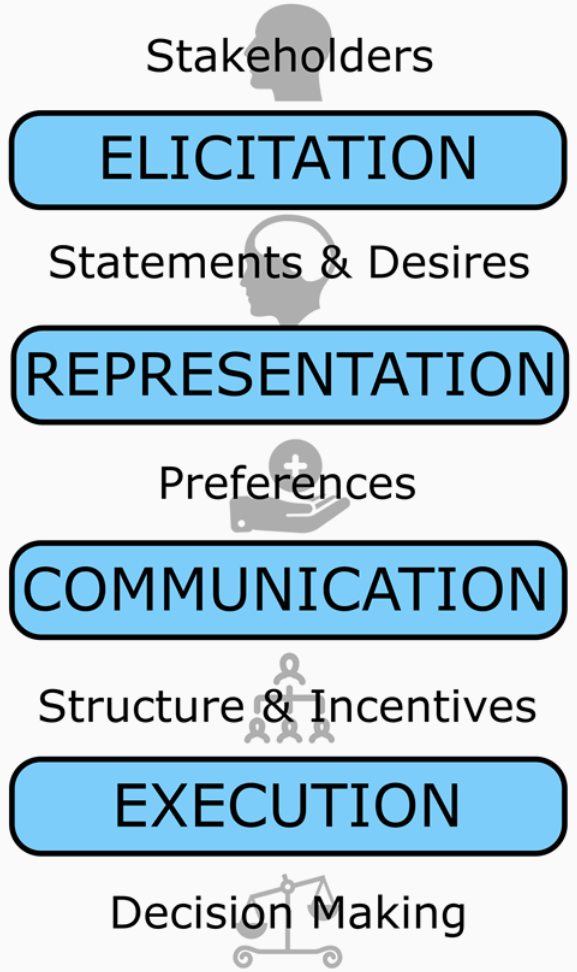
Data Selection Challenges in Architecting

- Mitigation
  - Robust statistics provides several possible options for more reliable estimation from non-ideal data sets.
  - Despite the prevalence of the mean as a predictor in engineering applications, the mean is a non-robust estimator.
  - The relatively small methodological change of replacing mean values with median values can result in greater robustness to outliers in data sets.
  - Median-based decisions have been shown to be less sensitive to order-preserving errors in systems engineering value scales than mean-based decisions.

Making Good Architecting Decisions

Making Good Architecting Decisions

- Task Objective: Provide a menu of techniques to architects that they can use in their decision making process.
- A guide to decision making in architecting, decomposing decision making into four processes which are further decomposed into techniques



Making Good Architecting Decisions

- Elicitation Techniques

Evaluation	Category	Example Techniques	References
OK	Archival	Body of Knowledges	SEBoK, PMBok
		Data Scraping	Bradley and James, 2019, Chen and Wojcik, 2016 Landers et al., 2016, Weber 1990
		Experience	Disterer, 2002, Argote and Miron-Spektor, 2011, Maier and Rechtin, 2009
OK	Stakeholder Statements	Interviews	de la Croix et al., 2018, Knott et al., 2022
		Surveys	Fink, 2015, Taherdoost, 2018
		Workshops	Ørngreen, 2017, Rosner et al., 2016
Good	Participation and Observation	User-Centered	Bixler, 2011, Cardoso et al., 2022
		Observational Studies	Zhang, 2007
		Behavioral	Liu, et al., 2017
Better	Controlled Comparisons	Experimentation	de Carvalho, et al., 2021
		Prototyping	Zamfirescu-Pereira et al., 2021

Making Good Architecting Decisions

- Alternative Representation Techniques

Evaluation	Form	Architecting Example	References
OK	Name Only	Ring Topology	Strandh Tholin, 2021
Good	Qualitative Description	A Ring Topology has edges and nodes	Sormaz et al., 1999
Better	Quantitative Description	A Ring Topology has 2 edges for each node	Scothern, 1991

Making Good Architecting Decisions

- Belief Representation Techniques

Evaluation	Form	Architecting Example	References
Poor	Name Only	Modification Cost from Baseline	
Poor	Direction	Modification Cost from Baseline is negatively impacted	Ricci et al. 2014
OK	Certain Outcome	Modification Cost from Baseline = $400 Million	Collopy & Hollingsworth 2011, Keller & Collopy 2013
Good	Range of Outcomes	Modification Cost from Baseline between $200 Million and $600 Million	Renou & Schlag 2010, Tuan et al. 2019
Better	Probability Distribution	Modification Cost from Baseline is a triangular probability distribution with a lower of $200 Million, a Mode of $300 Million, and an upper of $600 Million	Pinsky & Karlin 2011, Malak et al. 2015

Making Good Architecting Decisions

- Preference Representation Techniques

Evaluation	Form	Architecting Example	References
Poor	Requirements	Modification Cost from Baseline <= $400M and Accreditation Effort from Baseline <= 5,000 man-hours	Robertson and Roberston, 2012, Hooks, 1994
OK	Rank Order	Outcome A [Modification Cost from Baseline = $300M and Accreditation Effort from Baseline = 4,000 man-hours] is ranked 1st Outcome B [Modification Cost from Baseline = $200M and Accreditation Effort from Baseline = 10,000 man-hours] is ranked 2nd	Tsiporkova and Boeva, 2006
Good	Multiple Objective Function	F(outcomes) = w1*(Modification Cost from Baseline) + w2*(Acredication Effort from Baseline)	Roy, 1971, Hwang and Masud, 2012
Better	Value Model	V(outcomes) = (Modification Cost from Baseline) + $/man-hours*(Acredication Effort from Baseline)	Clerkin and Mesmer, 2018, Lee, Binder, and Paredis, 2014, Collopy and Hollingsworth, 2011

Making Good Architecting Decisions

- Execution Techniques

Evaluation	Techniques	References
Bad	Arbitrary	Delage et al. 2019
OK	Analytic Hierarchy Process (AHP)	Saaty 1987, Dyer 1990
OK	Expert Judgment	Shanteau 1988
Good	Pareto Frontiers	Mattson & Messac 2005
Better	Expected Utility	Abbas & Cadenbach 2018

Making Good Architecting Decisions

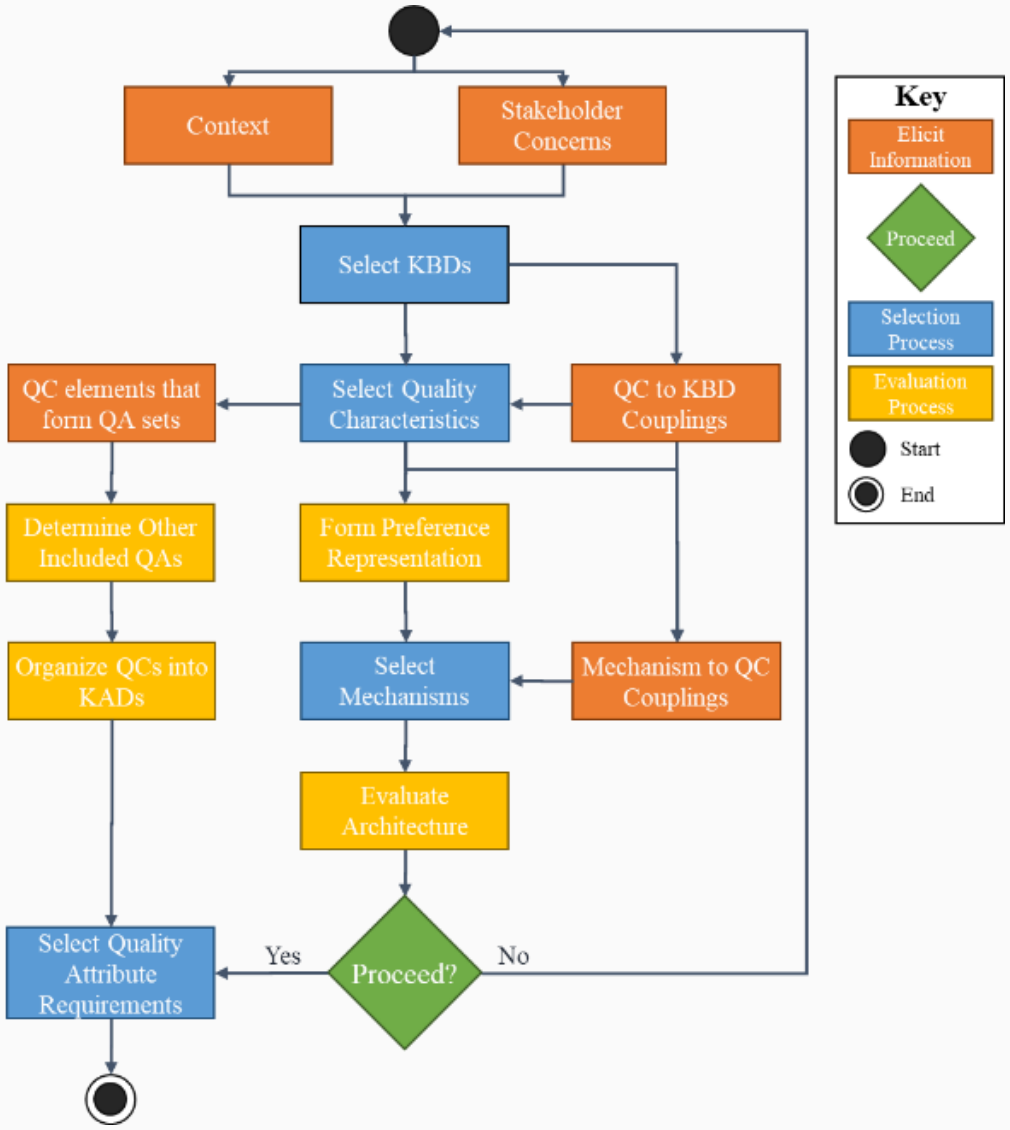
- Decision making in architecting has the same processes and components as any other decision making process. However, there are characteristics of architecting that make the application of decision making techniques challenging.
  - Architectures are not easily measured
  - Architecting informs future decision makers on how to make decisions
  - Architecture time horizon long with extremely high uncertainties
  - Architecture has many stakeholders
- All of these characteristics are manageable within the techniques, but additional analyses and elicitation is required to properly define the decision space. Architecting needs to move towards better techniques to become more rigorous and intentional in its practice

Decision Making Framework

Decision Making Framework

- Task Objective: Provide an easy representation of a proposed architecture mechanism selection process.

- Combine value-driven design approach with Army concepts.



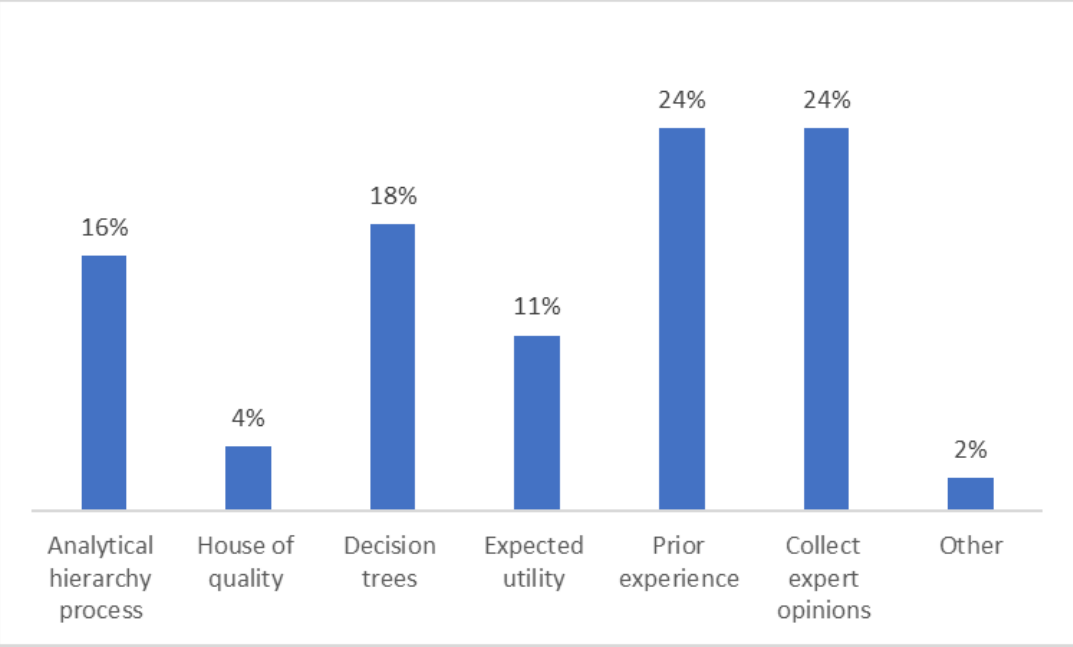
Decision Making Framework

- Use of the proposed process flow results in a **repeatable process** with **justifiable decisions** based on mathematics including sensitivities, chain rule, and optimization.
- The value model produced allows for future decision makers to have a comprehensive representation of the architect's preferences, something that requirements are incapable of communicating.

Training

Training

- Task Objective: Develop and conduct an applied architecture workshop; develop, conduct, and analyze a survey on architecting concepts; identify workshop challenges and paths for future research and training.



Decision Process Used by Participants in their Role.

- 92% of participants were familiar with systems architecting
  - 37% performed architecting tasks for 5-9 years
  - 36% for 0-4 years, and
  - 27% for 10 or more years
- 70% consider themselves a systems architect
- 70% of the participants indicated that Army assigns them architecting roles or tasks
- 83% of participants indicated that they are aware of formal processes, standards or guidelines that exist to perform architecting work

Training

- **Example -** Module 1: Architectural Decision Process
- Objective
  - Gain knowledge to explain Modular Open Systems Approach (MOSA)
  - Differentiate between design and architecture
  - Understand the decision making process to achieve MOSA goals
- Description
  - The Architectural Decision Processes module was presented by Dr. Bryan Mesmer. The module outlined Modular Open Systems Approach (MOSA) and decision-making processes to achieve MOSA goals. Differentiation between design and architecture was discussed. This module incorporated several Activities for the participants to integrate and apply the concepts. …..
- Activities
  - The activities were spread throughout the module and comprised of a group discussion based on the lecture. The participants worked in their table groups, then generated discussion as each group shared their thoughts. See Table 5 for samples of participant discussion points.
- Facilitator Resources
  - Powerpoint, Flipchart, Notes
- Outcome
  - Participants reviewed MOSA and decision-making processes to achieve MOSA goals. …

Training

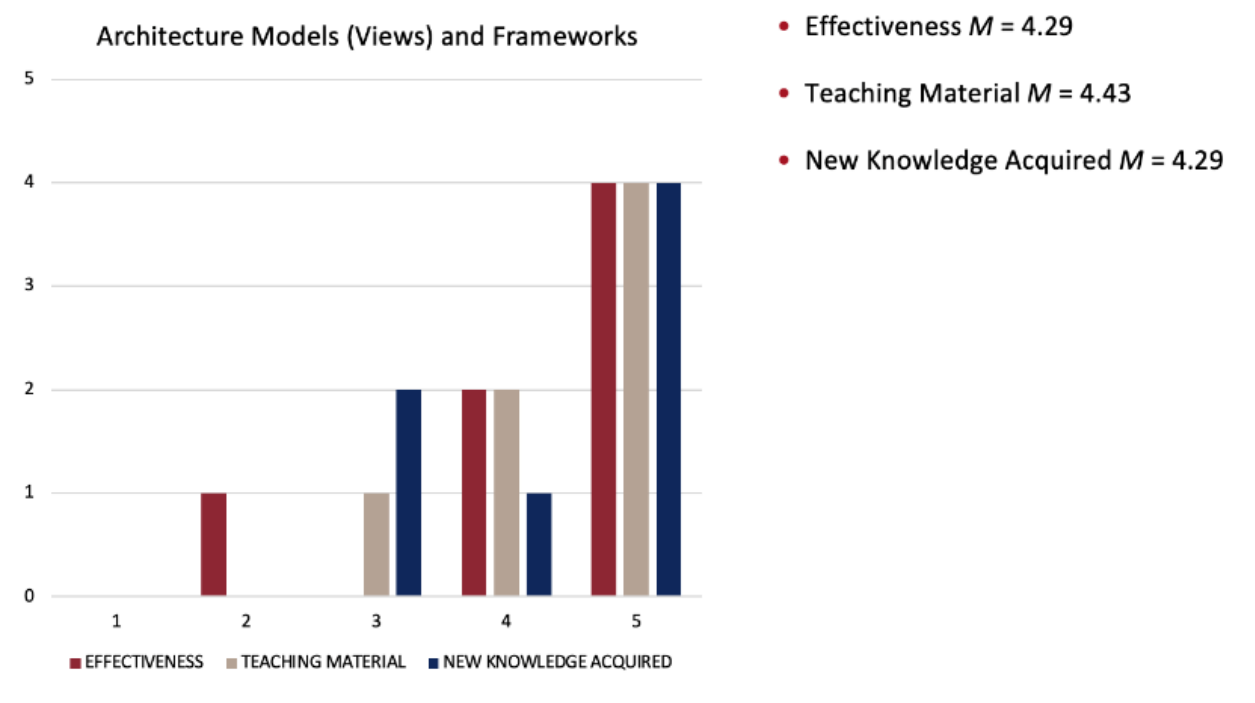
- **Example -** Module 1: Architectural Decision Process

Activity	Sample of Participant Discussion Input
How is Architecting and Traditional Design Engineering (such as designing a F-35) different?	•I can't, at top level know what the decision will be – those are variation points within process. •There is the KPP, threshold; initially you're not considered in your response if you don't consider KPPs.
Who are the stakeholders of an Architecture?	•The user, the customer gives operation requirements, cyber security, safety, systems engineers, material managers, the pyramid continues down, crossovers are the new vendor and all "his" extensions
What heuristics have you used in Architecting?	•Depends on what level arch. Mandates might lead requirements. •Depends what experts have told you; past experience from all these experts

Sample of Participant Discussion Points

Training

- Feedback



- Effectiveness *M* = 4.29
- Teaching Material *M* = 4.43
- New Knowledge Acquired *M* = 4.29

Example Feedback Comments

- *Case study should be **reviewed & better defined and implemented***; e.g, *Less time on case studies - more efficient use of time*
- *Start with some base definitions or perhaps a **preliminary slide deck that those of us with little to zero architecting experience can read through to come more prepared** - this would of course depends on your target audience*
- ***Consider examples more relevant to the audience** - allows them to focus on the architecture aspect and not have to think about the example*
- *For each section and kickoff brief, [I] **suggest including a big picture end state** - it felt like some of the briefs went straight into the details or steps*
- *Appreciated the SW Arch section - pull it in earlier*
- ***Tailor to specific audience***
- *Maybe how/suggestions **on stressing the importance of arch for our Leadership***

Conclusion

Conclusion

- **Decision making in architecting is hard.**
- The thing we are making decisions regarding is **not easily measured**
  - The architecture does not have a thrust, speed, weight, etc.
  - There is a lack of tools to analyze the architecture during the decision making process
- Architecture decisions not only restrict future decision makers on the types of architecture and design decisions they can make, but also **inform the decision makers on how** to make those decisions
  - Restrict decision space AND the decision process
- The time horizon is significantly **long with extremely high uncertainties**
- There are **many stakeholders** along the time horizon that can significantly impact architectural decisions

Conclusion

- Introducing a new architecting framework will require wide acceptance and adoption
- Training for a new framework does not just focus on architects. Need to train both the levels above and below architects in order to gain acceptance/adoption from the top and provide justification to below.

Future Work

- Persistent Question:

- Is architecting so uncertain that dominant decision strategies emerge which enable more heuristic or axiomatic -based decision processes?
  - Normative decision analysis would say that when different preferences are possible it is unlikely that dominant strategies for all of those preferences exist.
  - However, this is an open question that will be informed through experimentation.

Thank you

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