SYSTEMS ENGINEERING RESEARCH CENTER | AIRC ACQUISITION INNOVATION RESEARCH CENTER | SERC RESEARCH REVIEW 2026

Improving and Assessing Architectures and Architecture Decision Making

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WRT-1078

Dr. Bryan Mesmer

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE®

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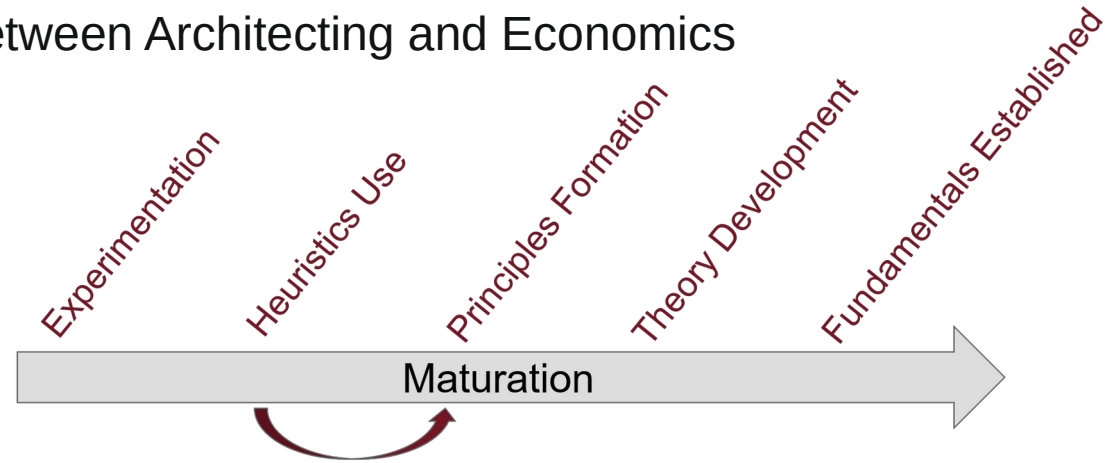
Moving Architecting from Art to Science

- Motivation: It is critical that decisions concerning architectures be **rigorous, justifiable, and easily communicated** throughout the architecture's lifecycle to decision makers and stakeholders.
- Research Question: What decision-making process modifications result in improved decision making in architectural contexts?
- Sub-Task 1: Human Study on Architecting
- Sub-Task 2: Relationship between Architecting and Design Space Exploration
- Sub-Task 3: Relationship between Architecting and Economics



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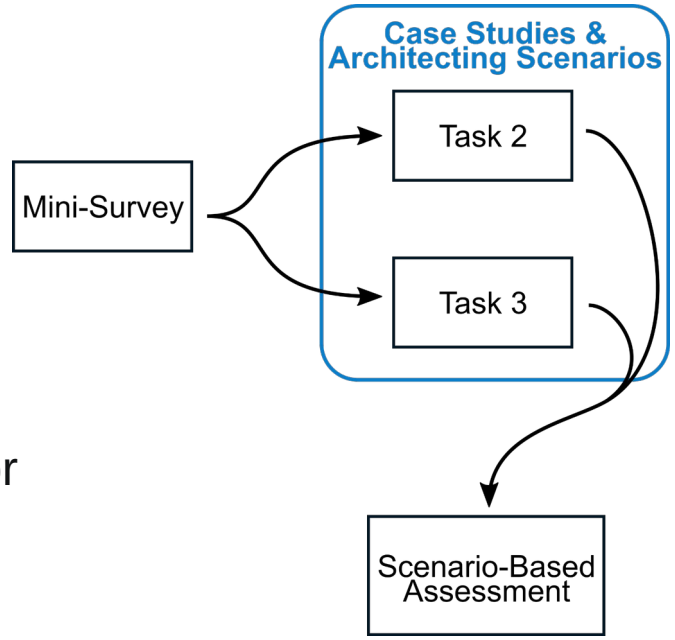
Sub-Task 1: Human Study on Architecting

- Mini-Survey developed to inform Sub-Task 2 and 3
  - Focused on how engineers and architects approach complex architecture problems
- Results from tasks will lead to Scenario-Based Assessment
  - Focused on how architects actually perform their roles
  - Established in this project but for future work



Mini-Survey

Estimated time: 12-15 Minutes.

[Consent Form Information Inserted Here]

This survey explores how engineers and system architects' approach complex system architecture problems (e.g., defense, aerospace, large-scale systems etc.).

For this survey, architecting can be thought of as early lifecycle decisions where tradeoffs are made related to competing goals, general capabilities, systems tasks, etc.

I. Problem Space

Please answer the following questions based on your experience with architecting problems, describing how you understand, define, and approach the problem space.

For this survey, problem space can be thought of as the set of characteristics and considerations, and the relationships within that set, that describes the architecting problem, both given directly and formed by the architect

1. When you are given an architecting problem, what does that typically look like? *Describe the inputs, information, constraints, stakeholders, context, etc. you receive. Include as much detail as possible*
2. How do you personally define or structure the problem space? *List and describe the elements, interactions, relationships, factors, etc. you consider. Include how you think about uncertainty, dependencies, constraints, and system boundaries.*
3. Which types of inputs do you typically receive when beginning an architecting effort? Select all that apply

- Mission objectives
- Stakeholder requirements
- Threat/Competitors
- Environment

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Sub-Task 2: Architecting and Design Space Exploration

- A engineered architectures fundamentally have a problem to be addressed and a solution that is chosen
- Past work on problems and solutions in systems engineering have definitions that are difficult to apply in architecting, or that convolute the spaces
  - Many assume a one to one relation between problem and solution
- Architecting is unique in its imperfect knowledge of the problem
  - Hard to elicit from stakeholders
  - Ever evolving context
  - Intelligent systems that learn
- Approach:
  - Define spaces and critical elements
  - Describe architecting solution types using framework

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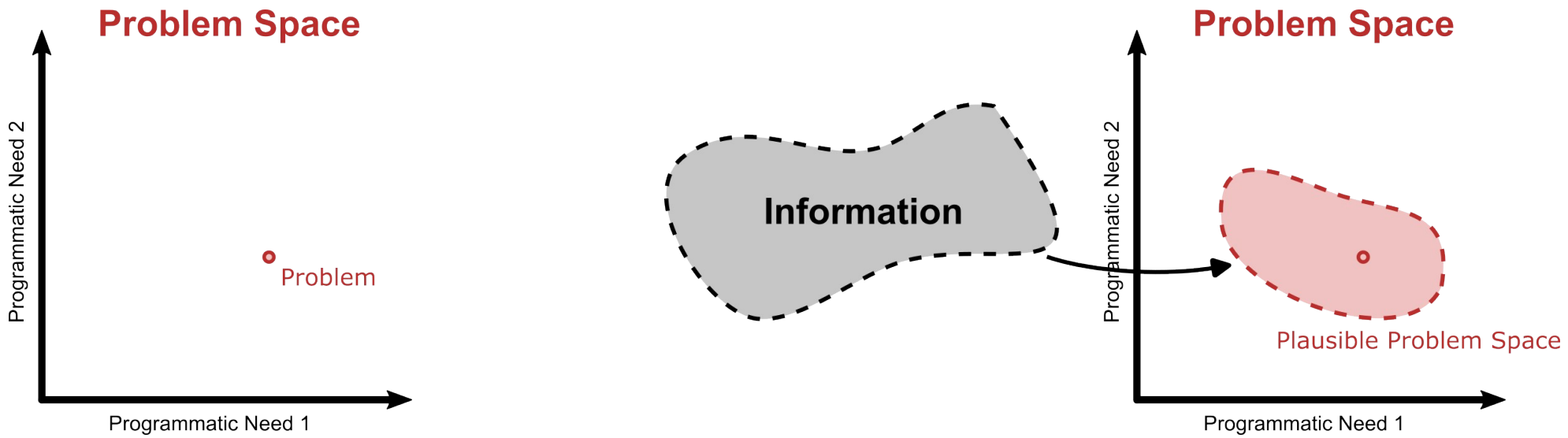
Sub-Task 2: Architecting and Design Space Exploration

- Problem Space - Multi-dimensional representation of potential architecture problems as characterized by programmatic needs.
- Problem - A particular point in problem space. A particular combination of programmatic needs.
- Plausible problem space - Region of problem space containing problems with non-zero likelihood of occurring based on present information



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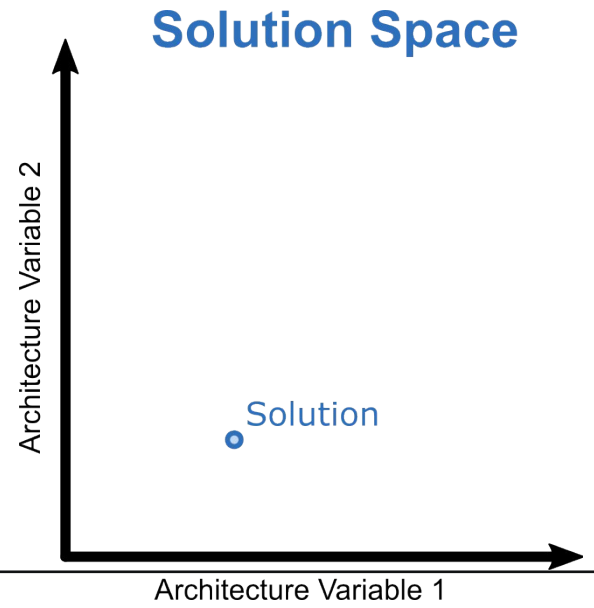
Sub-Task 2: Architecting and Design Space Exploration

- Solution Space - Multi-dimensional representation of potential solutions as characterized by architecture variables.
- Solution - A particular point in solution space. A particular architecture.
- Solution Acceptability Criteria - Metric to determine if a potential solution “solves” a particular problem.
- Acceptable Solution Space - The region of solution space which meets or exceeds the acceptability criteria for a particular problem.



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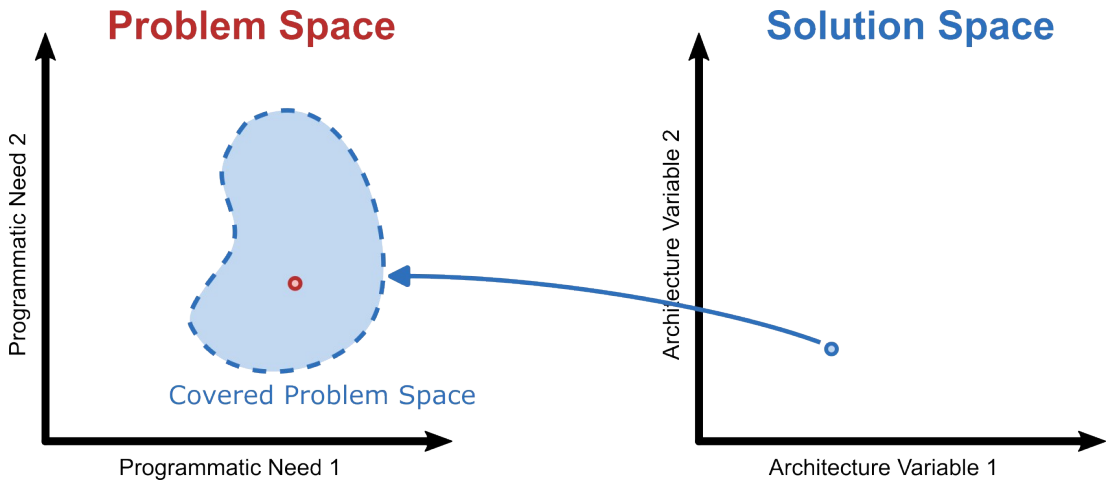
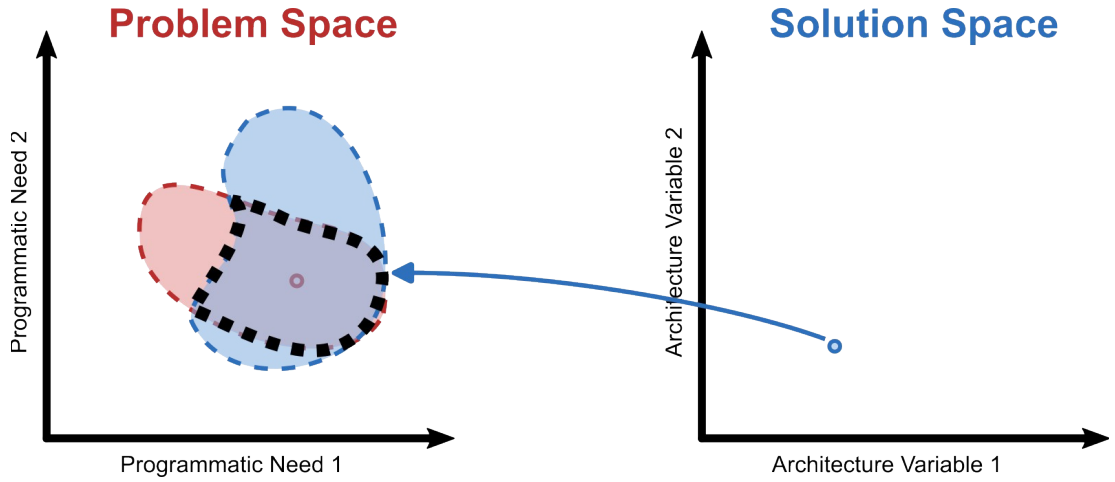
Sub-Task 2: Architecting and Design Space Exploration

- Covered Problem Space - Region of problem space for which a particular solution would be acceptable.
- Solution Completeness - Amount of plausible problem space covered by a solution.





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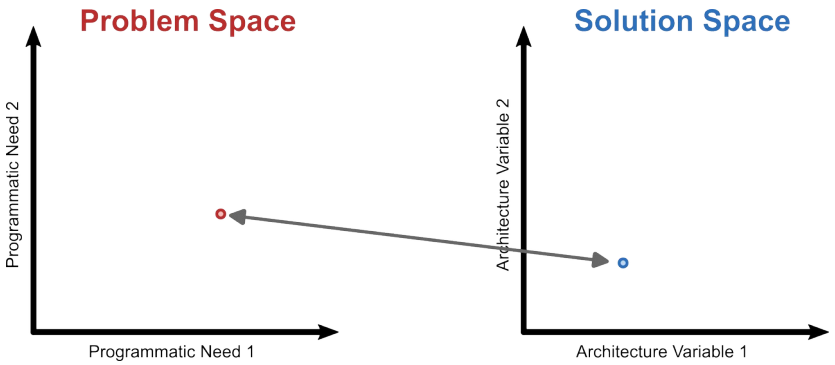
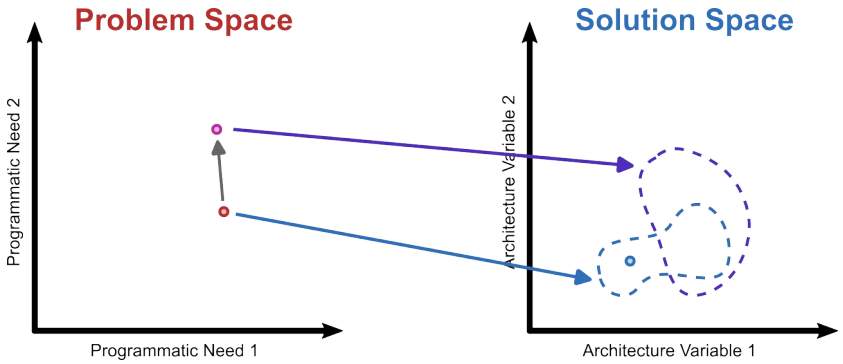
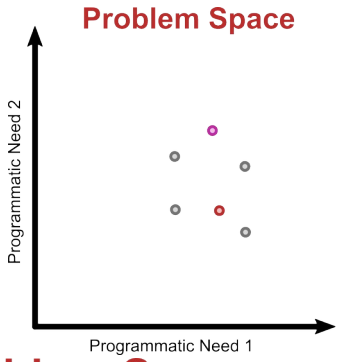
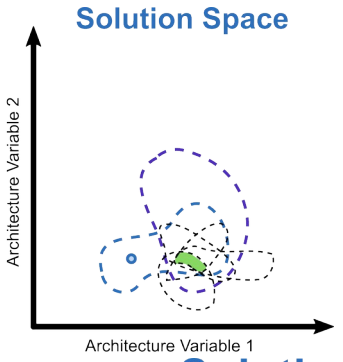
Sub-Task 2: Architecting and Design Space Exploration

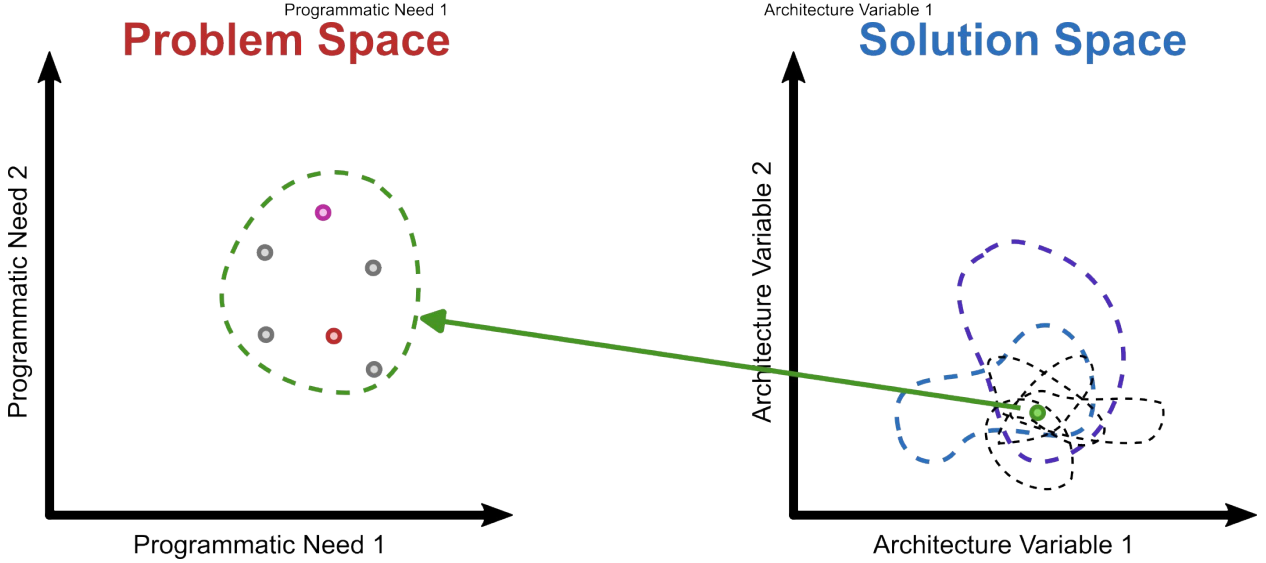
- Target-Coverage Solutions
  - Useful when there are multiple known points in problem space which all need to be potentially solved by a common solution.











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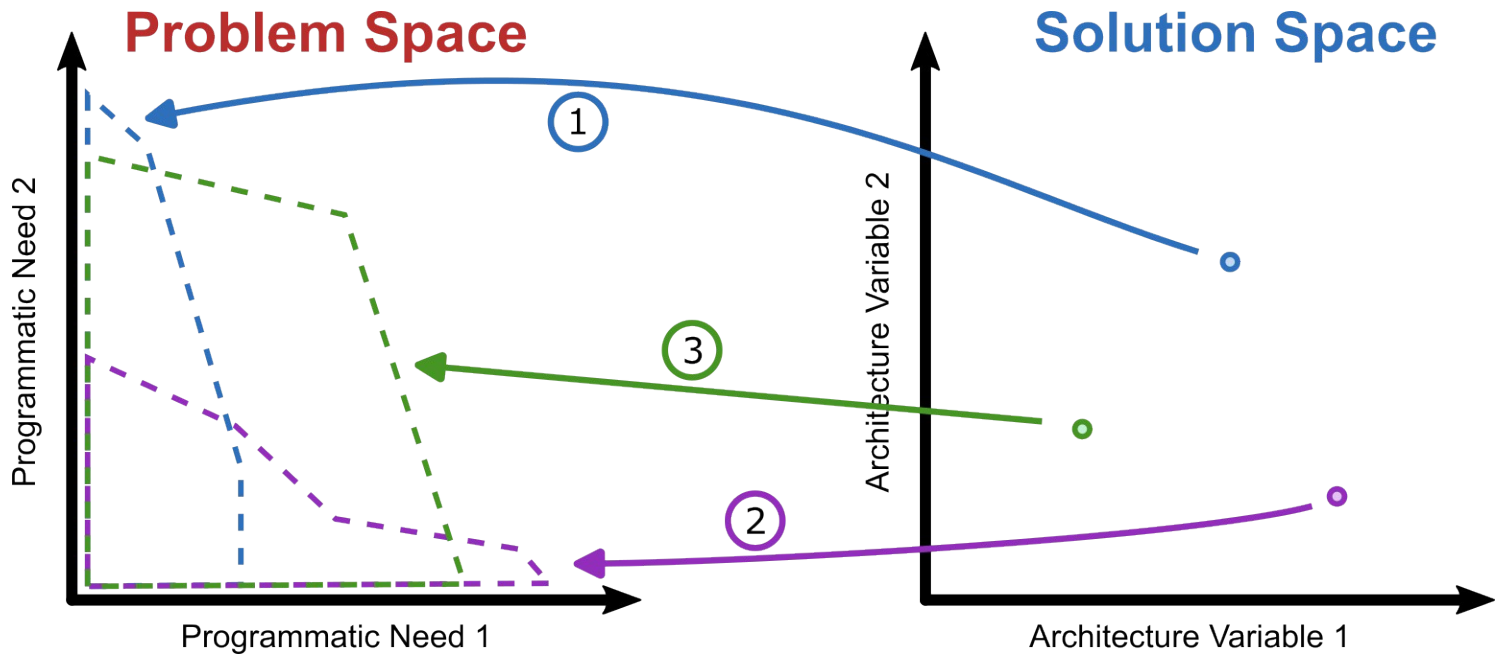
Sub-Task 2: Architecting and Design Space Exploration

- Broad Coverage Solutions
  - Relevant in situations where high uncertainty prevents the definition of a reasonable plausible problem space.



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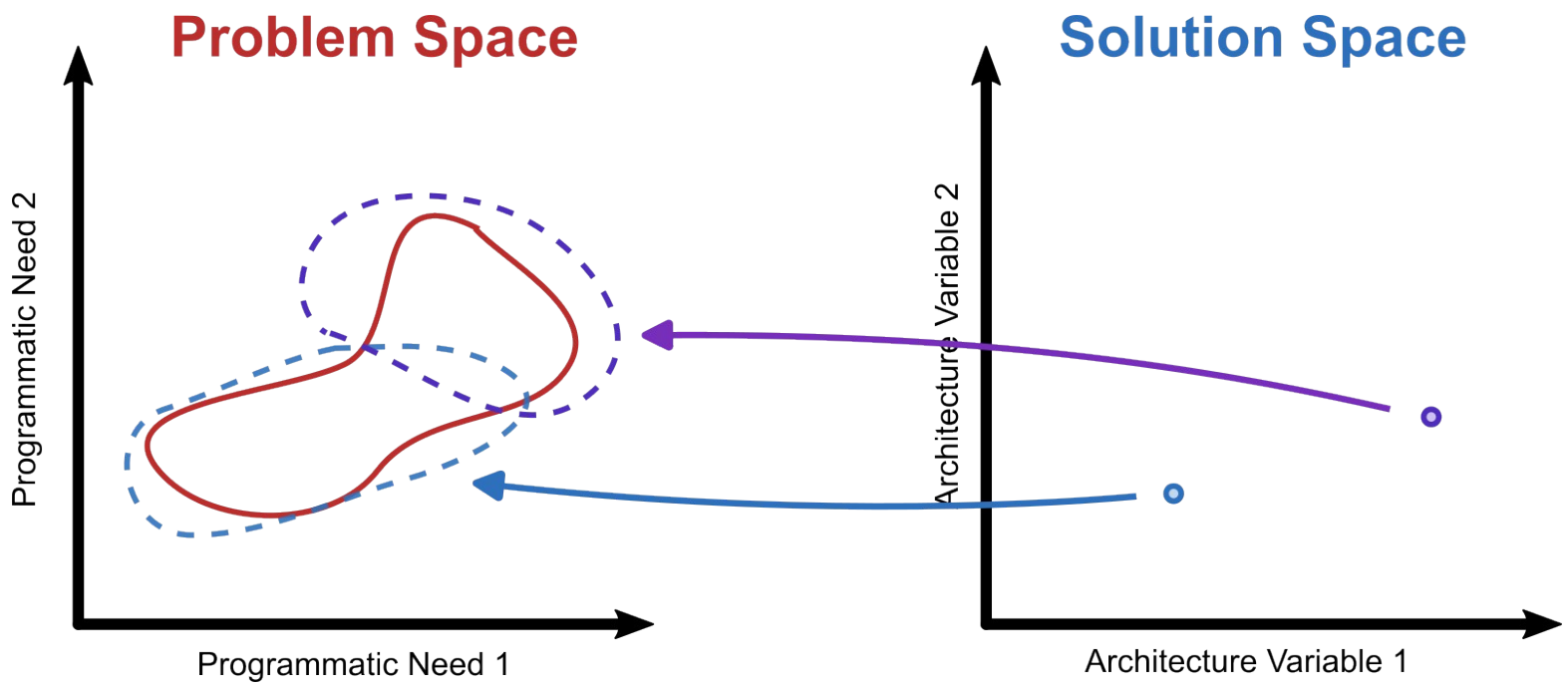
Sub-Task 2: Architecting and Design Space Exploration

- Complementary Solutions
  - Sets of solutions provide full coverage of plausible problem space through the union of their coverage spaces.



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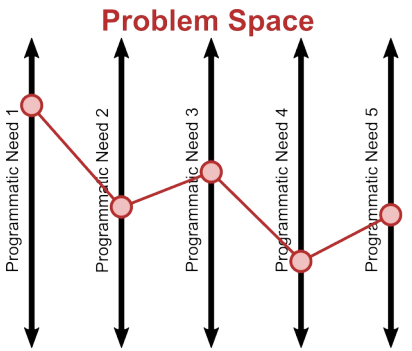
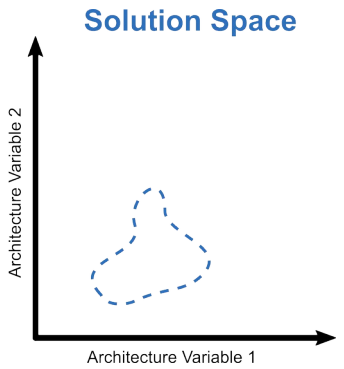
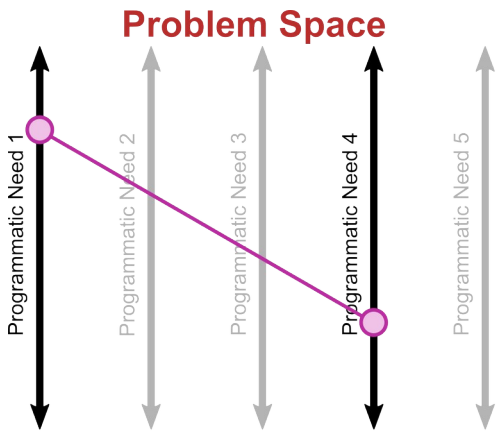
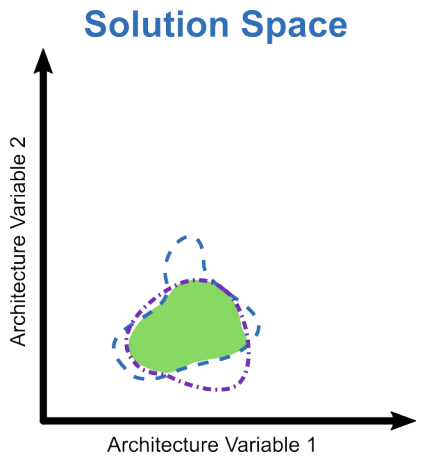
Sub-Task 2: Architecting and Design Space Exploration

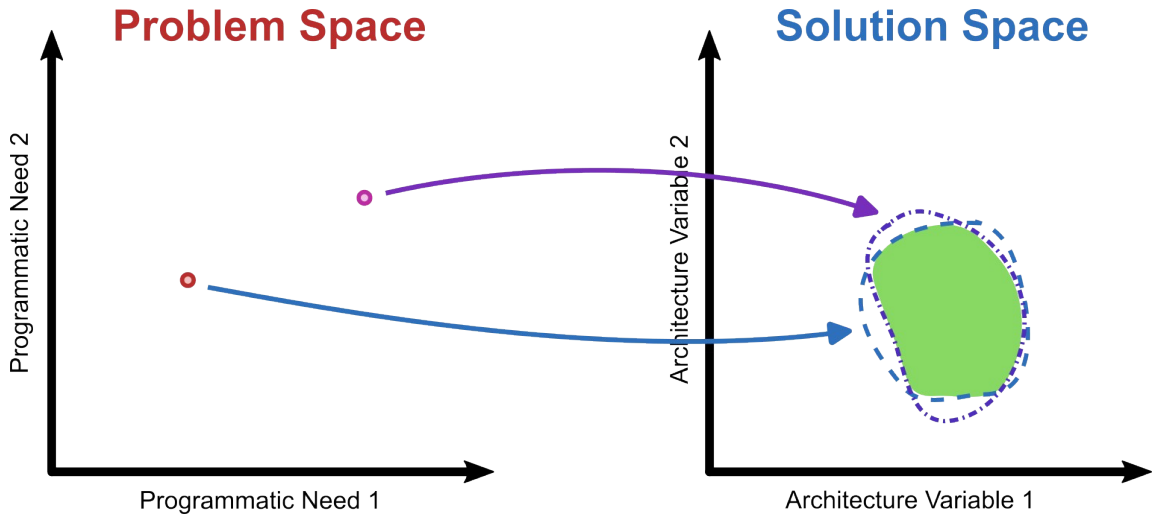
- Proxy Problems and Solutions
  - Alternate problem forms which yield a highly similar region of acceptable solution space.











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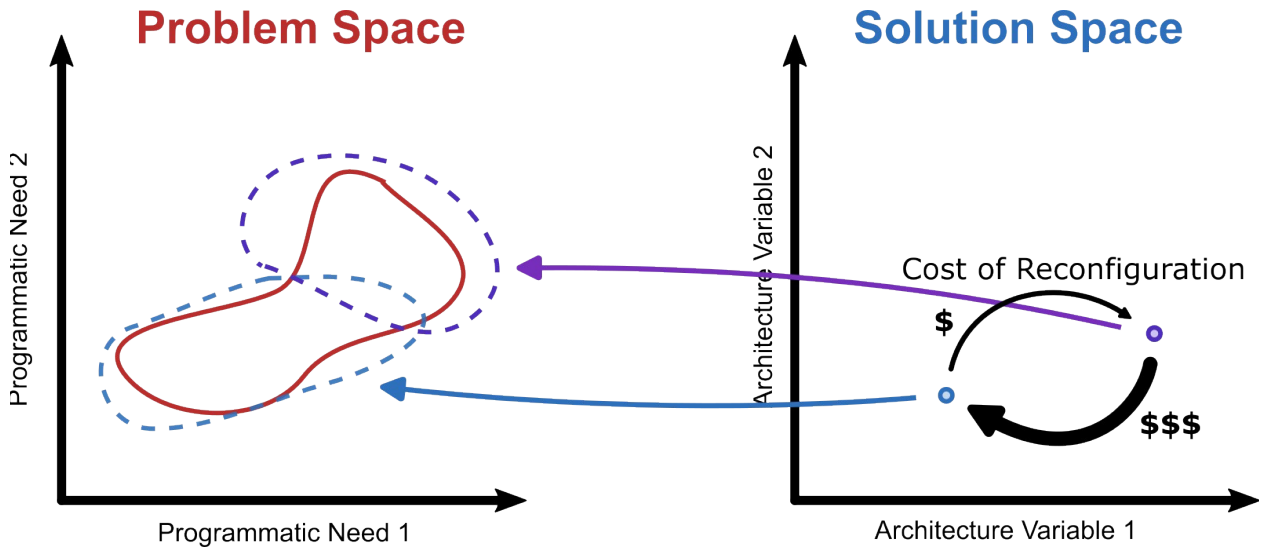
Sub-Task 2: Architecting and Design Space Exploration

- Problem Space Coverage
  - Framework can be used to determine what regions of problem space would be covered by that solution.
  - Shifts conversations from broad notions of more versatile “jack-of-all-trades” solutions to an understanding of exactly what problem states could be solved by that solution to the satisfaction of particular acceptability criteria.
- Complementary Solutions and Expected Rework



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Sub-Task 3: Relationship between Architecting and Economics

- Architecting is inherently incorporating distant time horizons, uncertainty, changing stakeholders, and shifting contexts.
- Economics has methods to handle these types of problem challenges
  - Time Discounting
  - Utility Theory
  - Game Theory
- Past work established key attributes and relationships in architecting preference representation.
- A tool is needed to enable a simple justification for complex architecting decisions.

DART (Digital Architecting Twin)

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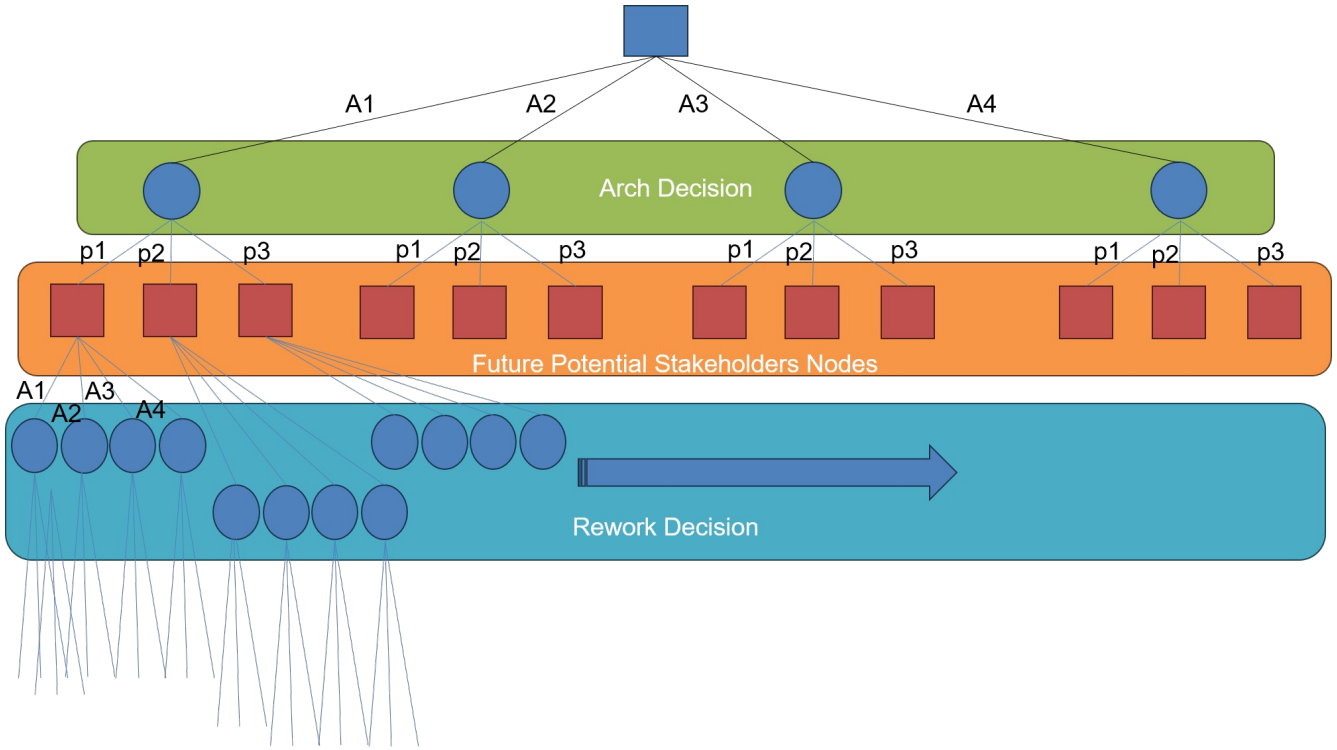
Sub-Task 3: Relationship between Architecting and Economics

- DART
  - Current focus area of work
- Hypotheses to explore:
  - Critical to ensure traversing the decision tree/matrix doesn't result in a dead end
    - Important to avoid overcommitting to transient current needs
    - External changes can lead to unrepairable architectures
  - Super pattern architectural decision reduces overall costs



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Conclusion

- Architecting is hard, which has led it to be thought of as Art.
- BUT, there is science to this hard challenge:
  - Human studies to ground current state
  - Problem/solution space framework
  - Classification of architecting problem types
  - Utility, Game Theory, NPVs
  - Digital twin representations
- Building a scientific basis to the architecting challenge will enable decisions concerning architectures be **rigorous, justifiable, and easily communicated** throughout the architecture's lifecycle to decision makers and stakeholders.

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Thank you!

Email the presenter

✉ Dr. Bryan Mesmer

Email the research team

✉ Christopher White

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