# Incorporating Risk into Analysis of Alternatives Results: A Novel Methodology

RAND CORPORATION

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# Purpose & Agenda

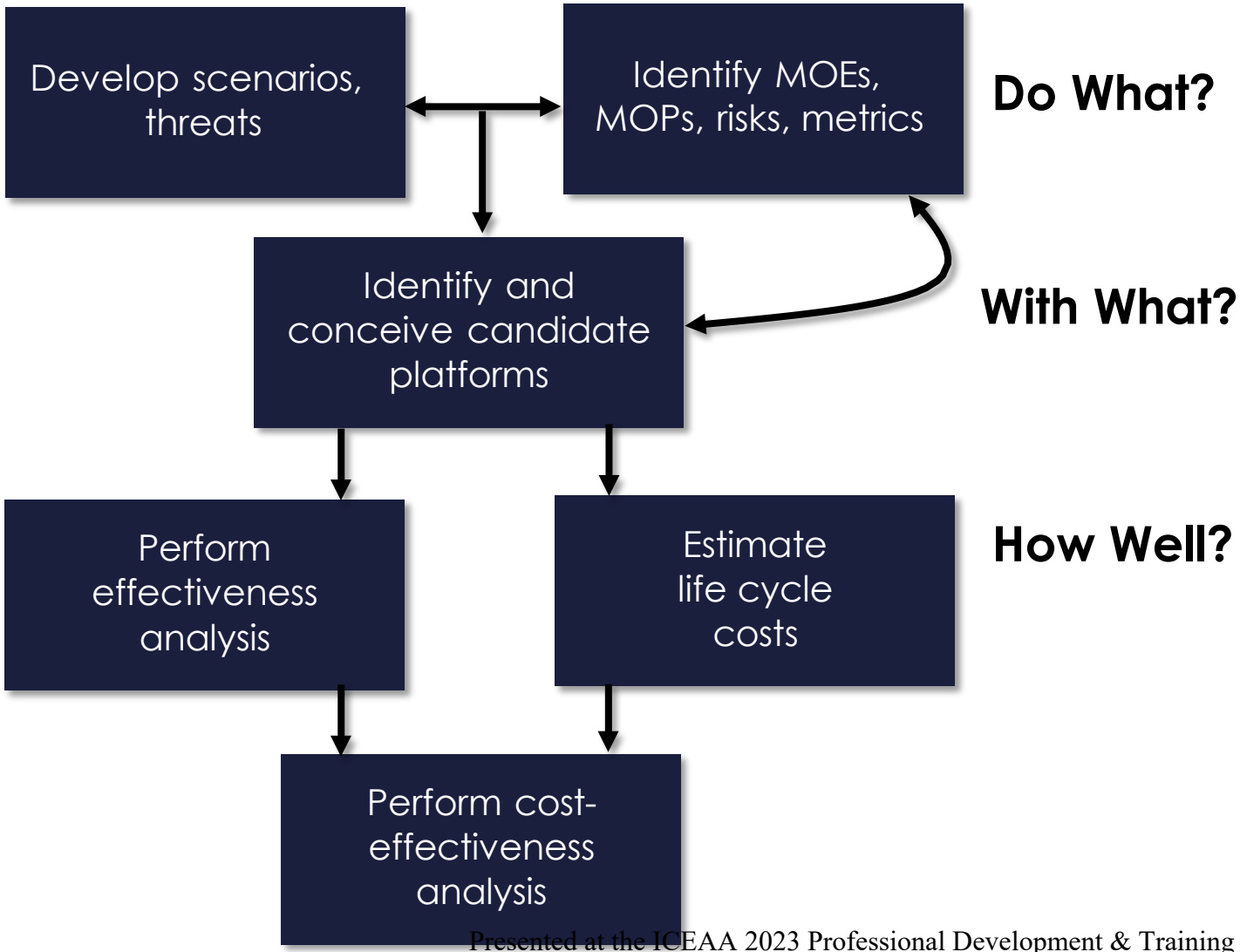
**Purpose:**

This risk methodology aims to develop a risk register, incorporate risks into the cost and effectiveness models, and evaluate cost effectiveness for each course of action (COA). This presentation provides an overview of the risk methodology.

**Agenda:**

1. Analysis of Alternatives (AoA) background
2. Overview of risk analysis methodology
3. Identification of risk assumptions
4. Categorization of collected risks
5. Discussion of cost-effectiveness analysis

# AoA informs decisions about future materiel solutions that fill capability needs given scenarios and threats




Specific example presented here supported a major weapon system

- Details not open source
- Effort spanned 3 years
- Large, multi-disciplinary team that included several stakeholders
- Multiple alternatives, or courses of action (COA), investigated
- Governed by Initial Capabilities Document (ICD)
- Capability requirements defined by threshold and objective values

# Traditional risk approaches to AoAs vary, but often includes two phases

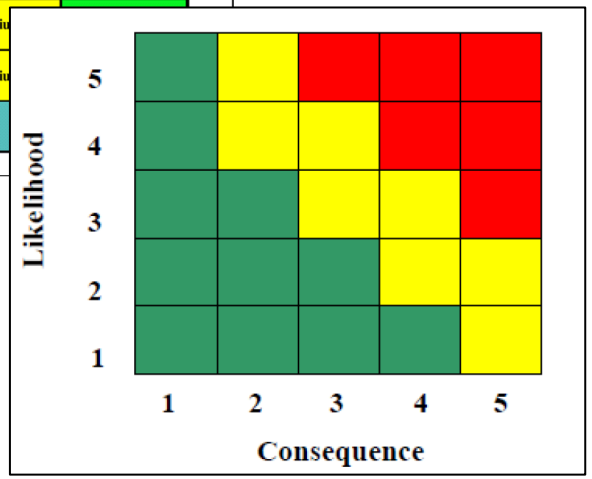
1. Unstructured discussions with various subject matter experts (SMEs) to brainstorm risks: cost, schedule, interoperability, technical, programmatic
2. Likelihood and consequence values estimated by SMEs and plotted on a separate risk matrix

Results of this analysis are often summarized as having low, medium or high risk.

RISK ASSESSMENT MATRIX

| SEVERITY / PROBABILITY | Catastrophic (1) | Critical (2) | Marginal (3) | Negligible (4) |
|---|---|---|---|---|
| Frequent (A) | High | High | Serious | Medium |
| Probable (B) | High | High | Serious | Medium |
| Occasional (C) | High | Serious | Medium | Low |
| Remote (D) | Serious | Medium | Mediu | |
| Improbable (E) | Medium | Medium | Mediu | |
| Eliminated (F) | Eliminated | | | |

Risk Assessment Matrix, MIL STD 882




Risk Reporting Matrix, Joint Agency Cost Schedule Risk and Uncertainty Handbook

# Motivation for a new methodology stems from limitations with traditional risk analysis practices

## Traditional Approach Limitation

If risk analysis is treated separately in cost and effectiveness, results could be misleading, or risks could be double-counted

Omitting distribution information (often to simplify dimensionality) results in decisionmakers not fully comprehending the risk and uncertainty surrounding results

Unstructured discussions used to identify risks may unknowingly result in important risks being overlooked

## Goal of New Methodology

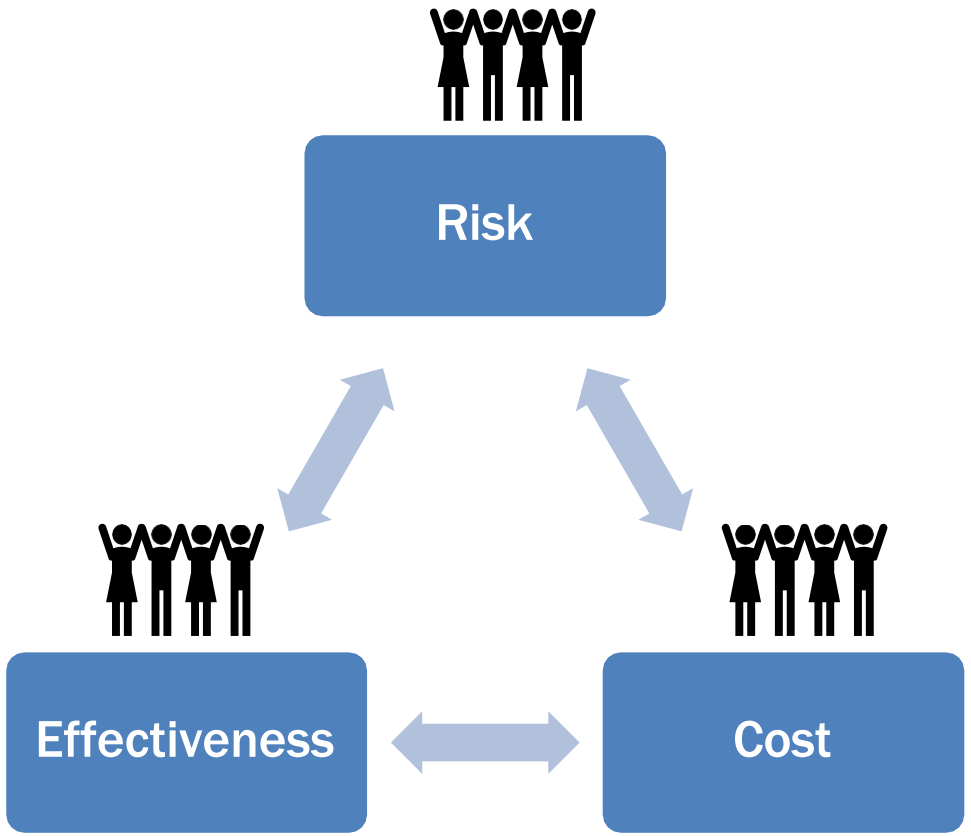
Risks must be managed and integrated into both cost and effectiveness results

Include distribution information as much as possible, to enable decisionmakers to fully comprehend the risk and uncertainty surrounding results

Leverage risk elicitation techniques*

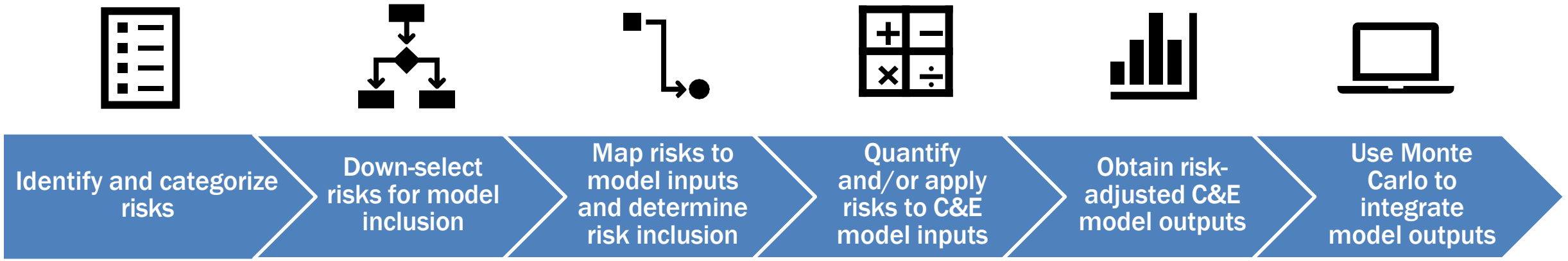
**For a review of risk elicitation techniques, see Chapter 9 in Morgan, M. Granger. Theory and Practice in Policy Analysis. Cambridge University Press, 2017.*

# Collaboration is key in risk analysis activities



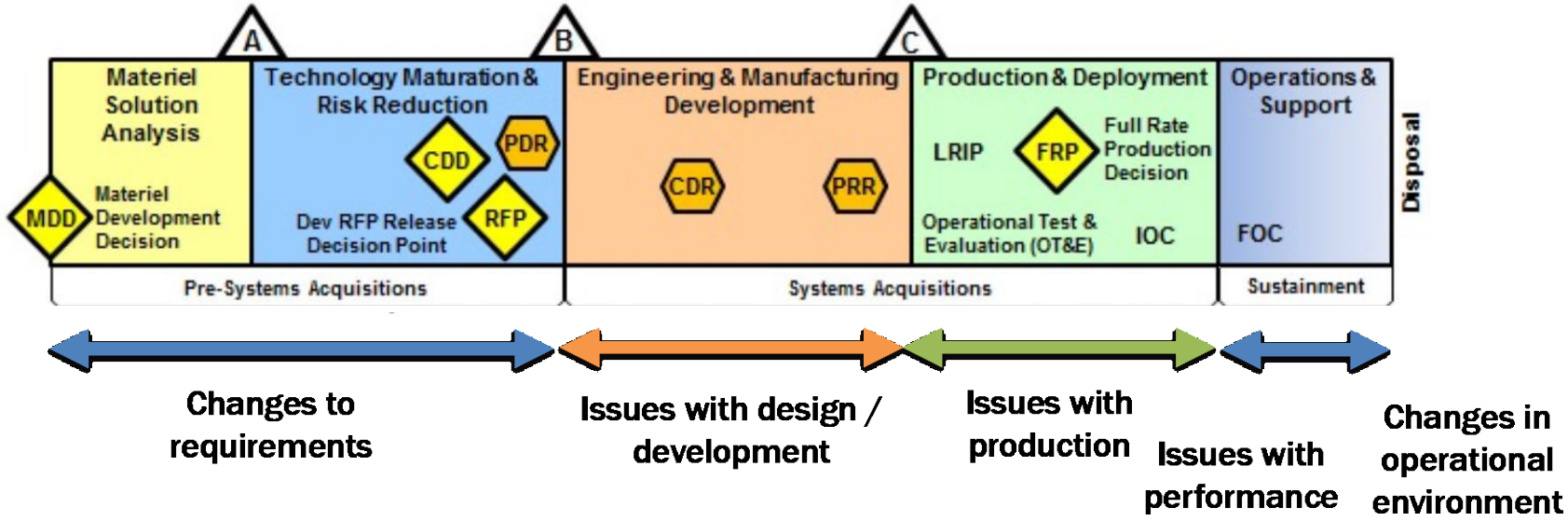

- Effectiveness, cost, and risk analyses work in parallel
- Teams collaborate throughout the AoA effort, but much done independently
- Several key products will result from these analysis
- Cost analysis also included an uncertainty analysis, in alignment with the JCSRUH guidance
- Other analyses also supported these, including interoperability analysis, DOTMLPF, sustainment analysis, logistics assessment

# Risk methodology includes several steps to identify and incorporate risks into cost and effectiveness analyses




- Identified risks triaged for quantification and/or inclusion in cost and effectiveness (C&E) model inputs as distributions or parametric assessments
- Risk-adjusted results from the C&E models integrated using Monte Carlo analysis to develop cost-effectiveness distributions for each COA

# Categorization of identified risks aligns to the acquisition lifecycle




| Category | Risks Collected | Subcategories |
|---|---|---|
| Requirements | 36 | Change in scenarios, inaccurate scenario definition, new regulatory requirements, technical maturity of systems |
| Design/development | 32 | Capability, technical maturity, integration/DT&E, interoperability/OT&E, dependencies |
| Production | 13 | Manufacturing capability/capacity, supply, material availability, issues with T&E |
| Performance | 32 | Operator performance, maintenance, technical issues not caught/mitigated during acquisition, physical constraints of system |
| Operations | 12 | Scenarios, threats, environmental conditions |

# Risk Analysis will make a few key assumptions that have an impact on how risks are categorized

- Risks equally applicable to every COA will be identified within a risk register but may not be modeled within the risk analysis
- Risks realized during acquisition will result in increased cost or schedule
- Risks realized during operation will result in decreased effectiveness
- Schedule risk is quantified in the cost model. Longer schedules result in increases in labor hours and program administration costs
- Interoperability may be handled in a few ways (scenario analysis, introduction of decision delays, etc.)

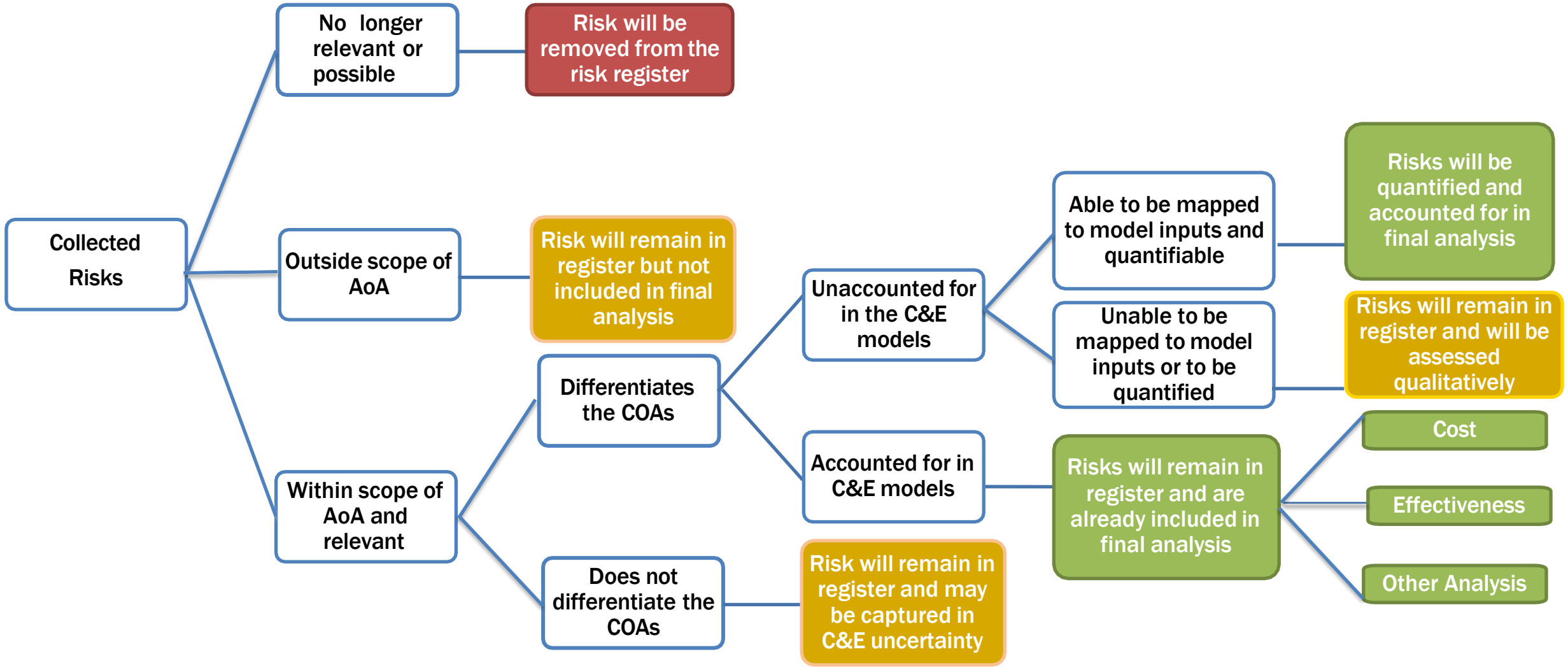
# Risk Register developed to help Program Office track and mitigate risks

- 100+ risks included in risk register, collected from all working groups
- Identify if and how the risk is accounted for and which COAs are impacted
- Allows the program office to continue tracking applicable risks as program matures

| | | | | Unaccounted | | | Accounted | | | | | | | | | COA Impacted | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Risk Event | Event Description | Category | Out of scope | Solution agnostic | Unable to quantify | Cost Model | Effectiveness Model | Interoperability | Logistics | Sustainment | DOTMLPF | Sensitivity | Excursion | Qualitative | 1 | 2 | 3 | 4 | 5 |
| 1 | Risk 1 | Risk 1 Description | | | | | | | | | | | | | | | | | | |
| 2 | Risk 2 | Risk 2 Description | | | | | | | | | | | | | | | | | | |
| 3 | Risk 3 | Risk 3 Description | | | | | | | | | | | | | | | | | | |
| 4 | Risk 4 | Risk 4 Description | | | | | | | | | | | | | | | | | | |
| 5 | Risk 5 | Risk 5 Description | | | | | | | | | | | | | | | | | | |
| 6 | Risk 6 | Risk 6 Description | | | | | | | | | | | | | | | | | | |
| 7 | Risk 7 | Risk 7 Description | | | | | | | | | | | | | | | | | | |
| 8 | Risk 8 | Risk 8 Description | | | | | | | | | | | | | | | | | | |
| 9 | Risk 9 | Risk 9 Description | | | | | | | | | | | | | | | | | | |
| 10 | Risk 10 | Risk 10 Description | | | | | | | | | | | | | | | | | | |
| … | … | … | | | | | | | | | | | | | | | | | | |
| n | Risk n | Risk n Description | | | | | | | | | | | | | | | | | | |

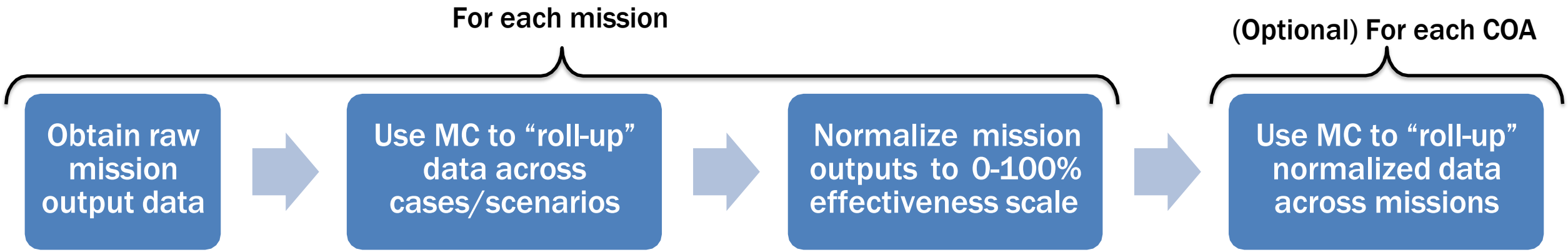
# Risks mapped to cost and effectiveness model inputs to determine risk inclusion

*Legend:*
- Included in analysis
- Included in Register
- Excluded



# Risk-adjusted cost-effectiveness analysis aims to investigate differences between COAs

- Objective is to preserve risk/uncertainty and magnitude of COA differences in data, while providing a high-level summary across missions analyzed
- Building a Monte Carlo (MC) model to "roll-up" effectiveness model data will combine cases and scenarios, and (possibly) finally missions
- Results can be visualized as a trade-space between cost, effectiveness and uncertainty



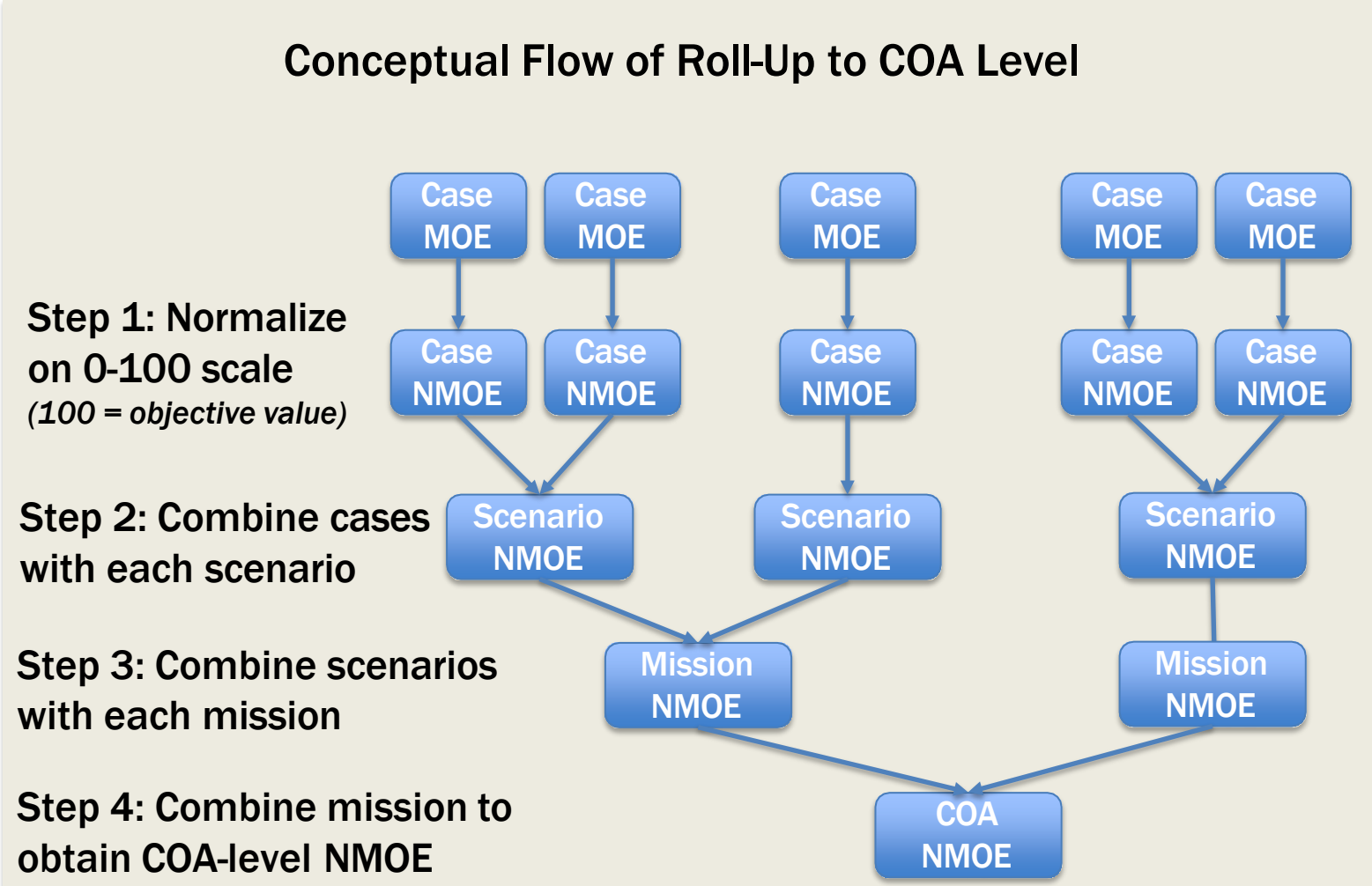
# Effectiveness outputs from each scenario and case is normalized and rolled-up at the mission-level

| Mission | Scenario | # of Cases | Output Type |
|---|---|---|---|
| A | 1 | 1 | Stochastic |
| | 2 | 3 | |
| | 3 | 1 | |
| B | 1 | 1 | Stochastic |
| | 2 | 1 | Deterministic |
| C | 1 | 3 | Stochastic |
| | 1 | 4 | |
| | 1 | 3 | |
| D | 1 | 1 | Deterministic |
| | 2 | 1 | |
| E | 1 | 1 | Stochastic |
| F | 1 | 2 | Deterministic |
| G | 1 | 1 | Deterministic |
| H | 1 | 3 | Deterministic |
| I | 1 | 1 | Deterministic |

Dimensionality is a big consideration for analyses that investigate multiple COAs, missions, scenarios, cases

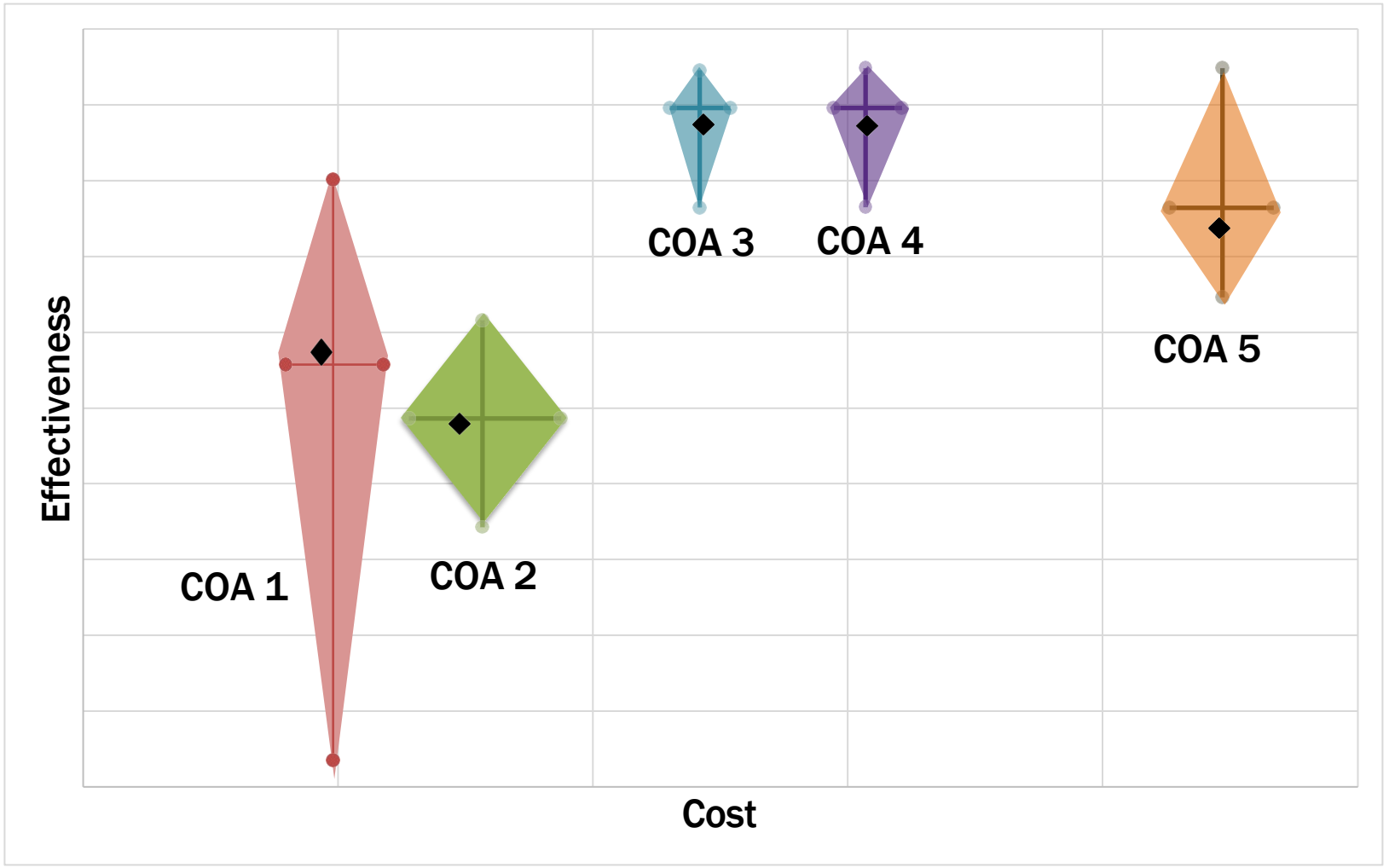
# Monte Carlo simulations used to handle dimensionality across COAs, missions, scenarios, cases

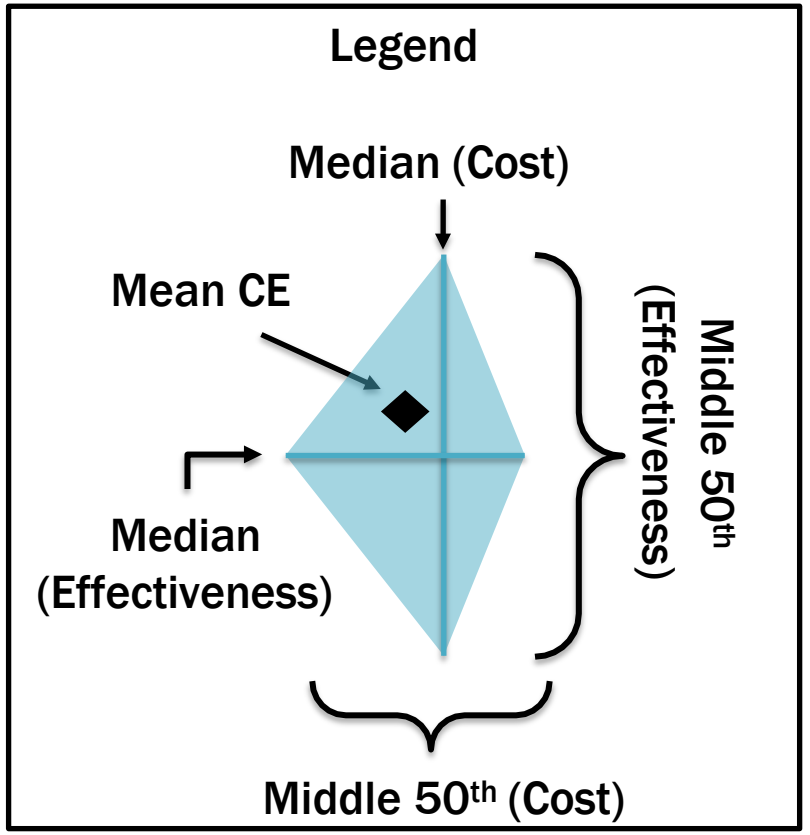
- @Risk model uses Monte Carlo simulation to:
  - Normalize to similar scale for comparability
  - Reduce dimensionality
  - Preserve risk distributions
- Simulation produces an overall effectiveness distribution for alternative
- Model developed in a way that would allow flexibility to weigh scenarios for preference or priority




*MC = Monte Carlo*
*MOE = measure of effectiveness*
*NMOE = normalized MOE*

# Cost-effectiveness rankings were assigned across all missions




*Notes: Does not represent real data, for demonstration purposes only.*

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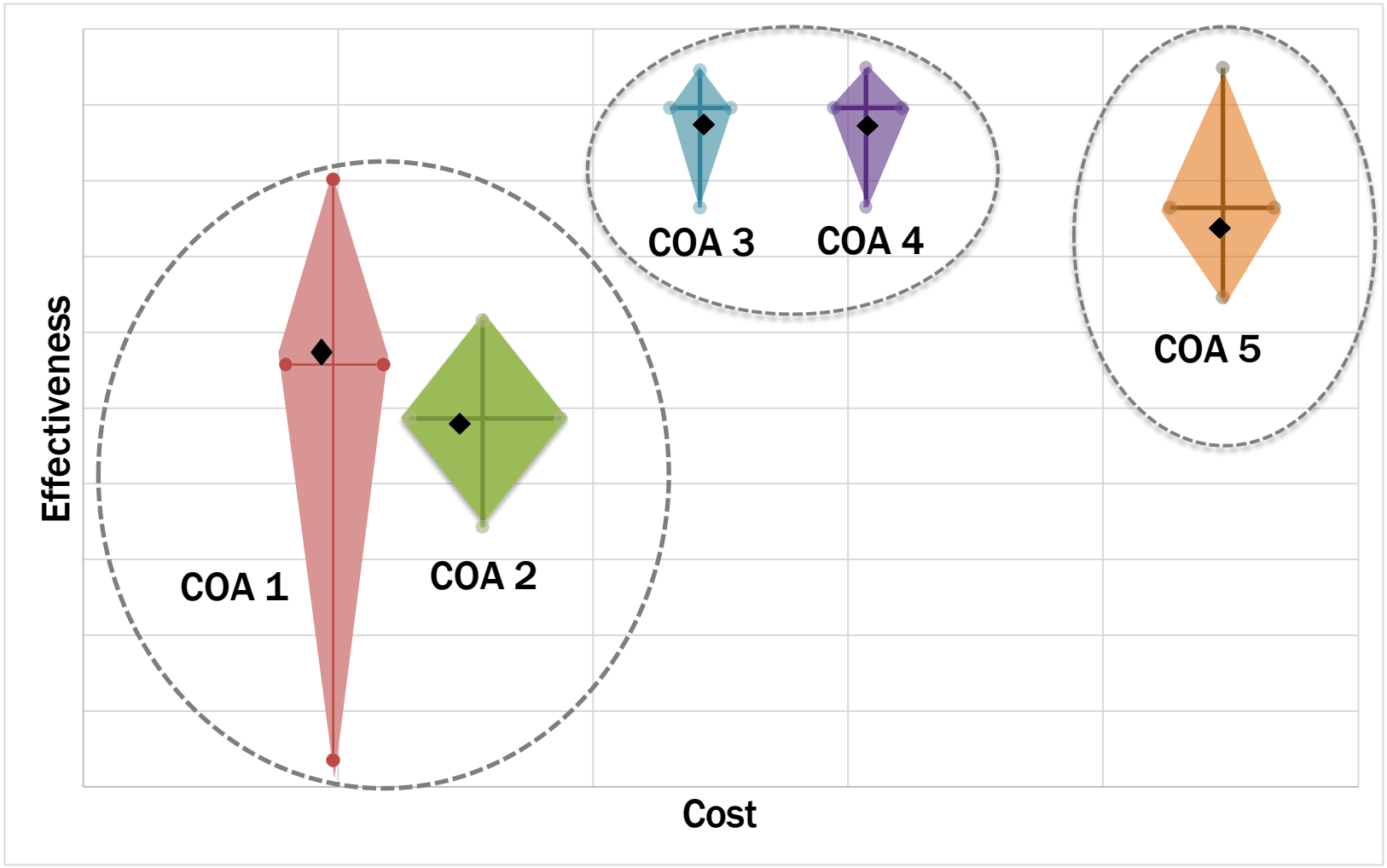


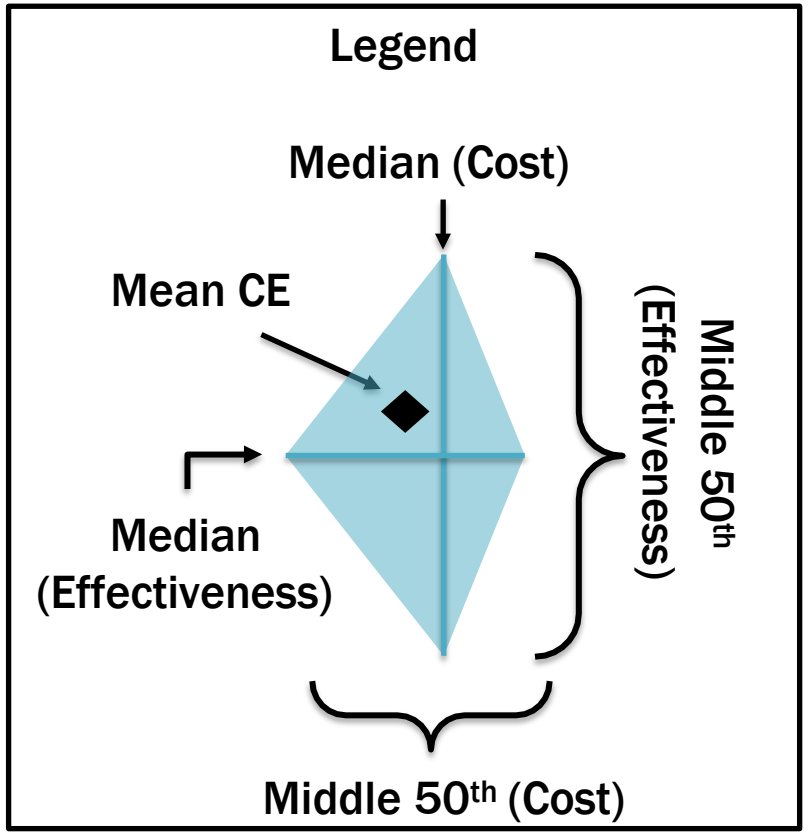


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# We see a pattern of three groups of COAs, upon which several observations can be made

- COAs 1 and 2
  - Lowest-cost alternatives, but their mission effectiveness also is considerably lower
  - COA 1 has a greater cost uncertainty score
- COAs 3 and 4
  - Provide the highest mission effectiveness of all COAs with costs in the middle of the range
  - Median effectiveness greater than the mean (indicating that most of the effectiveness values in this distribution fall above the mean)
- COA 5
  - Highest-cost alternative, but provides slightly less mission effectiveness than COAs 3, 4
  - Greater cost and effectiveness uncertainty than COAs 3, 4

**Based on decisionmakers' priorities and level of risk tolerance, COAs 1, 2, or 3 may be preferred**

# In implementing this risk methodology, the study team developed several observations and lessons learned

- Risks may be realized at each stage of the acquisition process
- Risk register is a valuable artifact that should serve as the starting point for the risk management plan
- Start early to inject risk considerations across all working groups
- Continue to track risks throughout the analysis and check if risks are still relevant
- Frequent status meetings to update leadership and working level on what risks we're identifying and how we're proposing to account for them
- Consider the intersection of risks between WGs (should be an integrated effort, not stove piped)


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