Alternative COA Selection Methodologies: The Quantum Command and Control Theory

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Purpose

- This briefing provides an introduction to alternative COA selection methodologies
- Several alternative COA methodologies are presented that offer the commander quantitative alternatives that eliminate some of the drawbacks with the standard WNC methodology
- This briefing also provides an introduction to Quantum C2 Theory. While clearly there is an art component of C2, there is a need for a sound mathematics-based science of C2 as well

Background: WNC Methodology

COA Selection Decision Matrix

Criteria	Weight	SLBM	Bomber	Cruise Missile	Weighted Results SLBM	Weighted Results Bomber	Weighted Results Cruise Missile
Pd	20	0.6	0.9	0.8	20	60	40
Execution Time	20	36	128	300	60	40	20
Collateral Damage	20	Low	High	Med	60	20	40
Fratracide Risk	20	Low	Med	Med	60	40	40
Economy of Force (Risk to our Forces)	20	Low	Med	Low	60	40	60
Anti-Access (Ability to Defeat)	20	High	High	Med	60	60	40
Threats (against this option)	20	Low	Med	Med	60	40	40
Total					380	300	280

Recalculate

- Example
- Data Intensive
- Uncertainty
  - ✓ Criteria
  - ✓ Weights
  - ✓ Values
  - ✓ Risk vs Success

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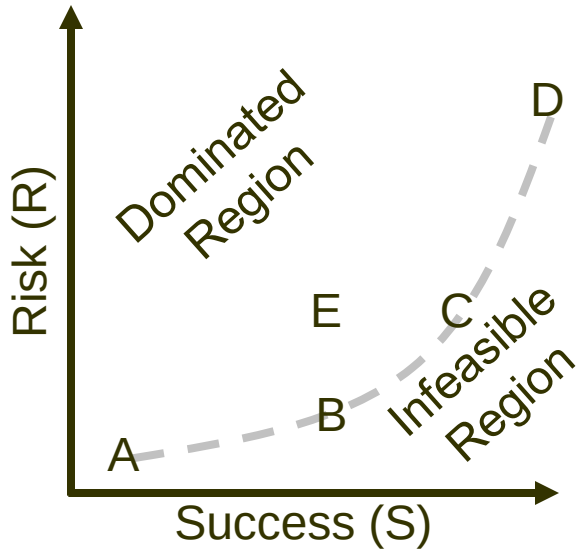
Objective – Develop a Theory of C2

- There is a need for an accepted, useful theory of C2
- Current theories are not satisfactory
- We've looked at metrics associated with the theory
- We've looked at the simplifying cases, where the general theory simplifies into a known class of problem

Command and Control:
(DOD) The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission. Also called C2.

Tradeoff Between Risk and Reward



Well known in investment strategy.

Multiple mission objectives can each contribute to defining Success and Risk

- The efficient frontier is the boundary between the dominated region and the infeasible region
- COAs A, B, C, and D lie on the efficient frontier and a commander might choose any of them depending on the risk/reward tradeoff
- E should never be chosen, because B and C are both strictly better than E

An Different Approach to Risk : Quantum C2 Theory

- There is uncertainty about achieving the mission
- There is uncertainty about bad things happening
- I call this the “Quantum Physics” approach (or Quantum C2), because in quantum physics an electron exists as a probability cloud that describes the likely location if you try to detect it
- Likewise, the future outcome of an operation can be described as a two-dimensional probability distribution
- When the operation actually happens, then that probability distribution “collapses” into a single event

Three Alternative COA Selection Methodologies

- Alternative 1: Use the WNC data but divide into risk and mission success factors
- Alternative 2: Define the "successful" outcome space and estimate the probability of achieving it for each COA
- Alternative 3: Define a "catastrophic" outcome space as well as the "successful" outcome space and present the commander with a risk/mission success tradeoff

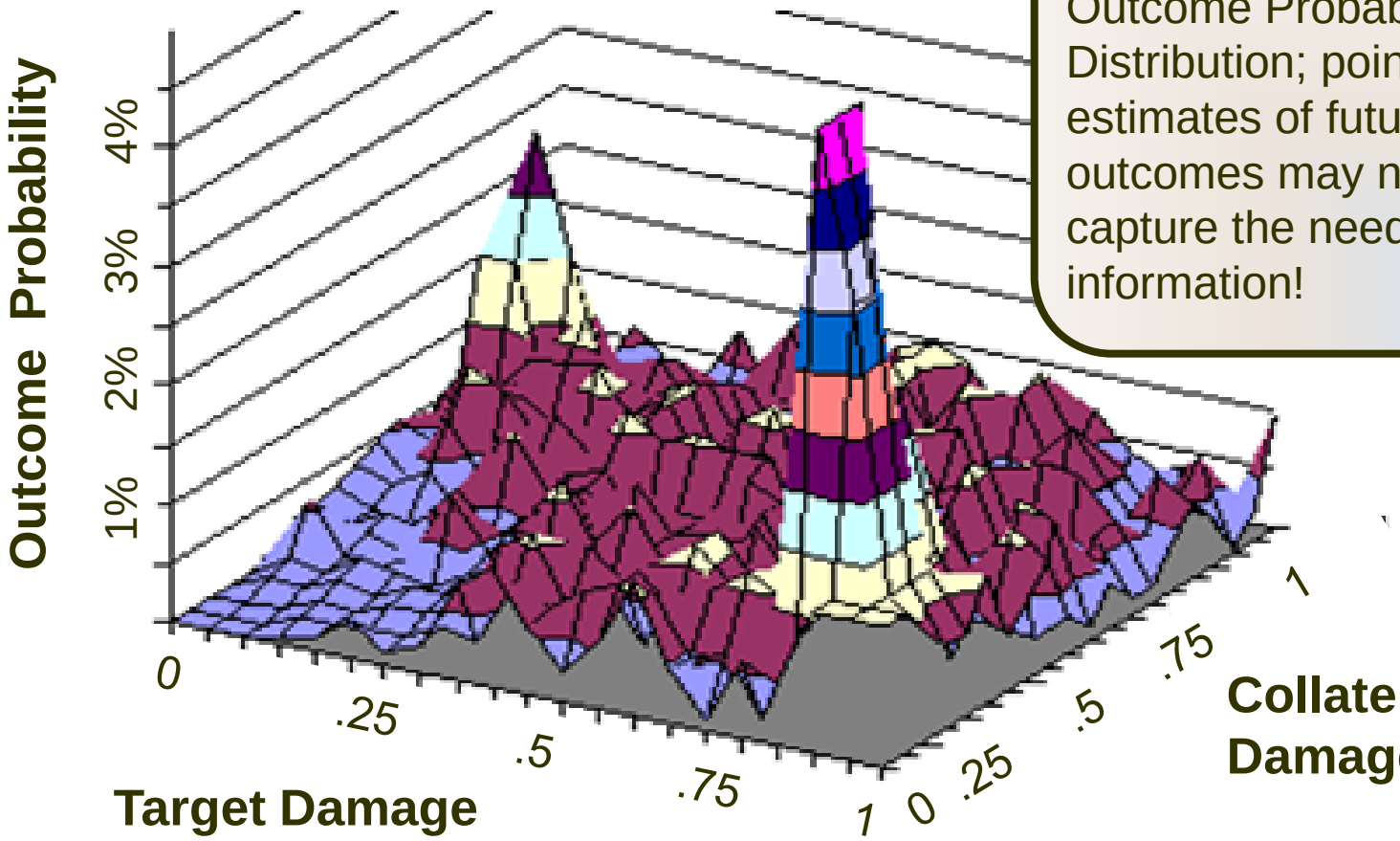
Alternative 1: Make Explicit the Risk vs Mission Success Tradeoff

- Hidden in the previous example is an implicit statement about the risk vs mission success tradeoff
- Treating the COA selection problem as a two dimensional problem
  - ✓ One dimension is “risk”
  - ✓ The other dimension is “Mission Success”
- Assigning each of the criteria as risk or mission success, each COA can now be plotted on an XY plot
- The Commander can now make the appropriate command decisions regarding risk

The Two Dimensional COA Outcome Space

Notional Example of Risk vs. Mission Success Tradeoff

Limitations of Alternative 1 Probability Distributions of Future Outcomes



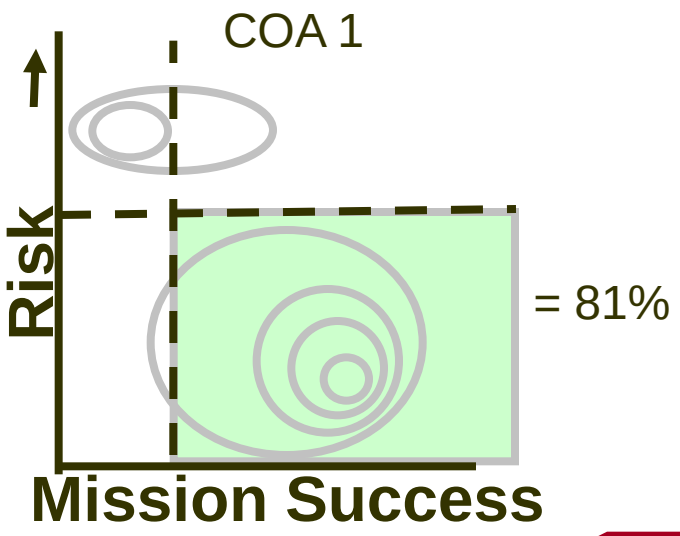
Notional Bi-modal Outcome Probability Distribution; point estimates of future outcomes may not capture the needed information!

Alternative 2: Use the Probability of Minimum Mission Success for Each Criteria

- The commander frequently specifies the minimum acceptable (or maximum risk acceptable) level for each important criteria
- Instead of using a value function and weights, simply calculate the probability of each COA alternative achieving the desired levels for all criteria
- Advantages of this approach are:
  - ✓ Uses information normally available
  - ✓ No subjective value functions
  - ✓ No subjective weights

Alt 2 Example

- Evaluate each COA in terms of the probability of achieving desired mission success and risk levels
- Can be n-dimensional with the probability that the COA achieves all the desired levels. This method avoids using utility weights for trading off positive and negative outcomes

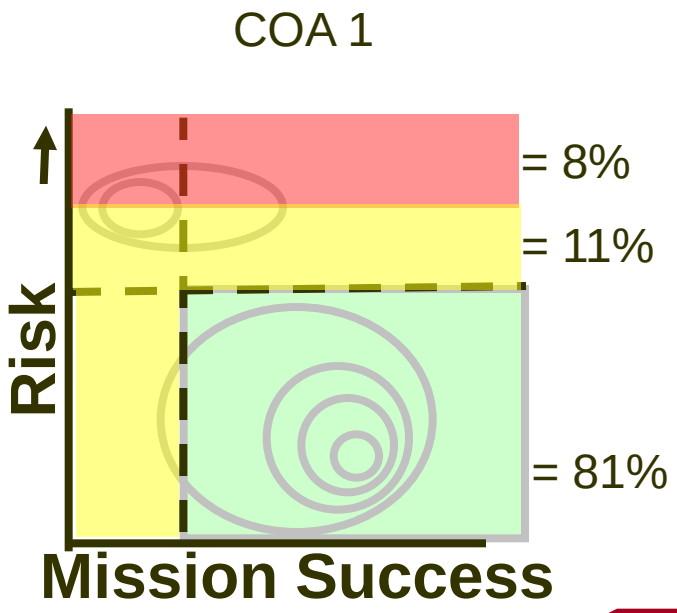


Alternative 3: Expand Alt 2 by Considering "Catastrophic" Outcomes to be Avoided

- In some cases, the unlikely events are the ones that are of most concern
- The commander specifies regions in the outcome space that are not only undesired, but so bad as to be considered "catastrophic"
- In addition to selection Criteria to maximize the probability of mission success, the commander may also want to avoid COAs that have a high potential for catastrophic outcome
- Once again, there may be a Risk vs. Mission Success tradeoff
- Advantages of this approach are:
  - ✓ Same as Alt 2, plus
  - ✓ Considers the tails of the probability distribution to estimate the likelihood of a catastrophic outcome

Alternative 3 Example

- Evaluate each COA in terms of the probability of achieving desired mission success and risk levels
- Evaluate each COA in terms of the probability of avoiding catastrophic mission success and risk levels

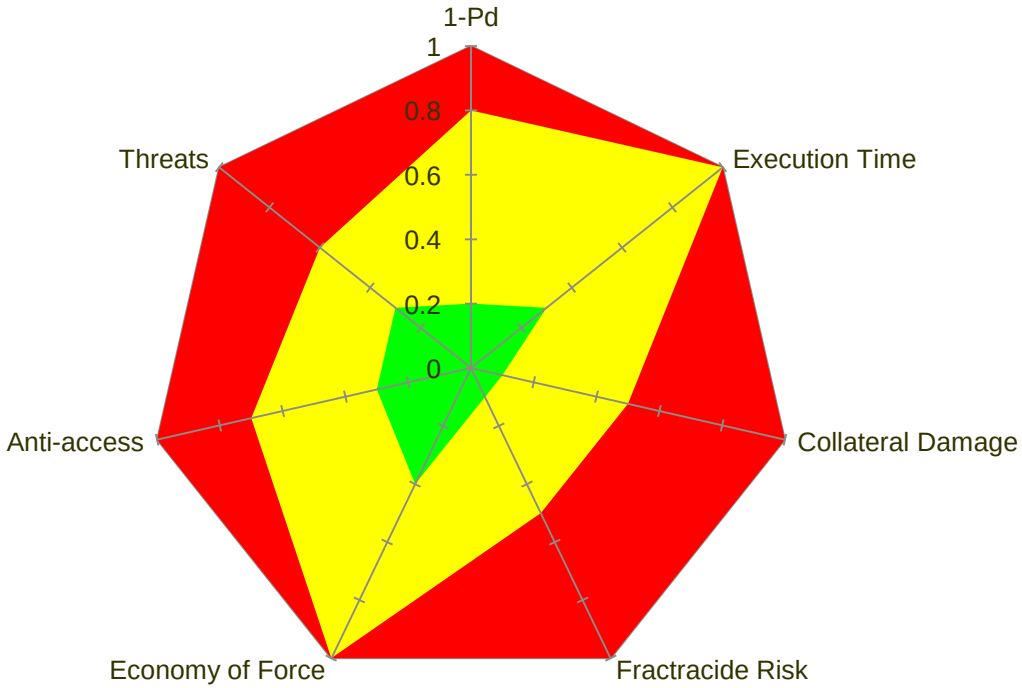


- Can be n-dimensional.
- Probability that all criteria are “green”
- Probability that ANY criteria are “red”

Multidimensional COA Analysis

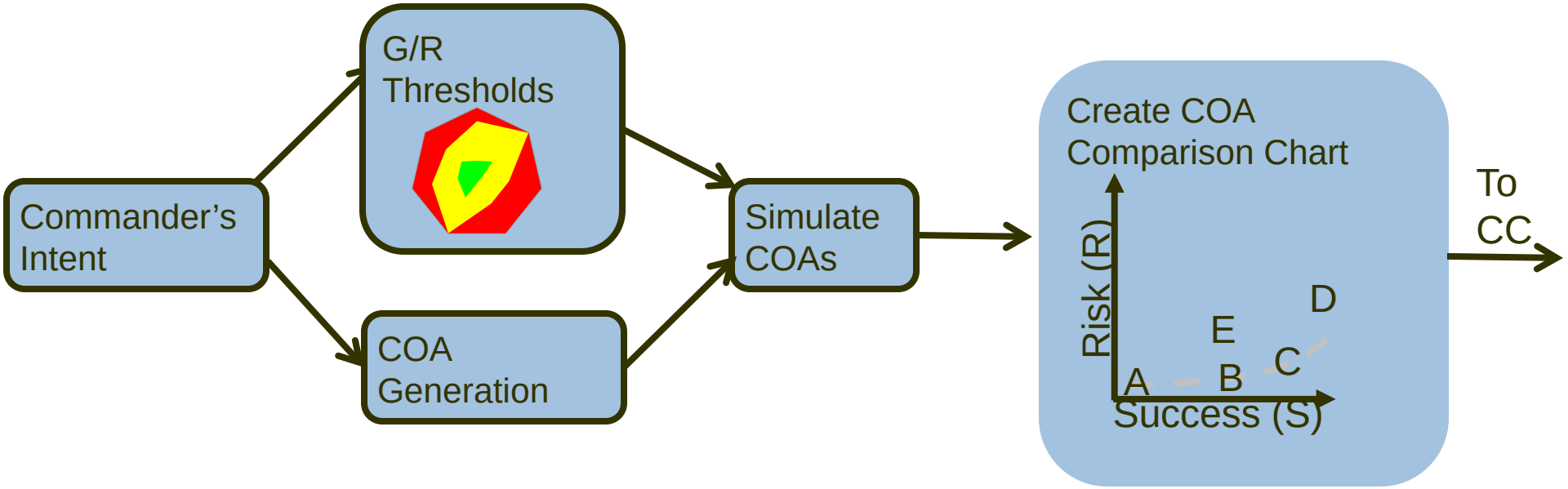
- **Each COA selection criteria has two values**
  - ✓ Desired value (green threshold)
  - ✓ Catastrophic value (red threshold)
  - ✓ An outcome that is between the two thresholds is yellow
- **Each run of a simulation is given a R/Y/G score**
  - ✓ If all the criteria are green, then the outcome is green
  - ✓ If any criteria is red, then the outcome is red
  - ✓ If neither, it is yellow
- **This approach allows an estimate of the relative probabilities of a R/Y/G outcome**
- **SMEs could also contribute to estimates of the probability of various outcomes**

Graphical Depiction of Commander's Intent



- The green region represents the desired outcome space
- The red region represents the catastrophic outcome space

Simulations Role in Multidimensional COA Analysis Process



- **COAs will need to be simulated 1000's of times to get good probability estimates of low probability catastrophic events**

What M&S Environment is Needed?

- Automated tools to Speed Process:
  - Easy to generate COA alternatives for M&S
  - Post-processing tools to gather data and build charts
  - Fast run times in order to estimate outliers accurately
- Reach-back capability to support the warfighter
- Automated search of the COA alternatives to generate COAs that lie on the efficient frontier
- Models must capture all the key factors of COA evaluation or automated tools must allow assessments of these other factors to be combined with the model-based factors.

Request

- If you have experience with COA selection problems and were unsatisfied by the WNC methodology
- And you have a COA selection problem that you have the COA selection brief
- And you would like us to apply Multidimensional COA analysis (Alternative Three) to your COA problem
- Then, please contact us!

The next logical step is to conduct a series of case studies to evaluate the usefulness of these alternatives

Summary

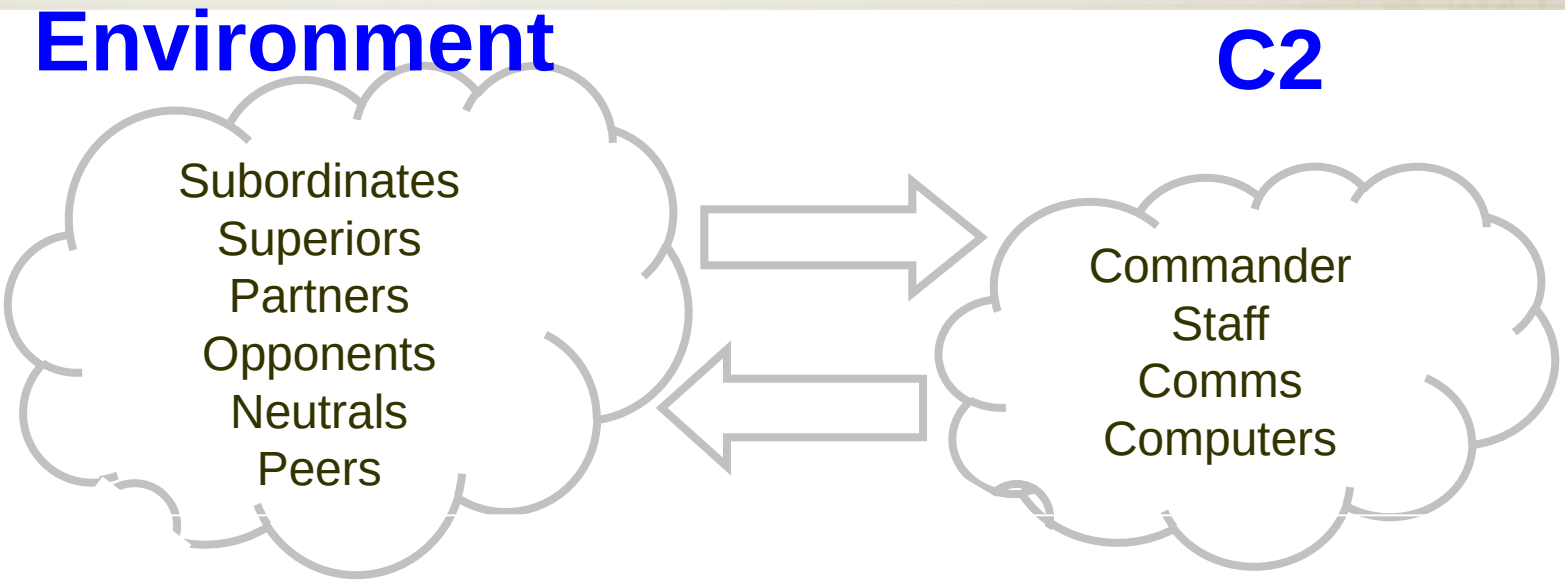
- The standard NWC methodology for COA selection has limitations

- Three alternative methodologies proposed:
  - ✓ Alt 1: Separate Risk and Mission Success
  - ✓ Alt 2: Don't use value functions, but rather acceptable thresholds
    - Can be two-dimensional Risk vs Mission Success
    - Can be n-dimensional with n criteria
  - ✓ Alt 3: Include a catastrophic threshold for each criteria as well as the acceptable threshold

- Looking for COA selection problems for future case studies for these alternative

QUESTIONS

The C2 Boundary: What isn't C2?



- C2, C3, C3I, C4ISR…Difficult to define C2
- Difficult to even set boundaries for C2
- C2's fractal nature makes it challenging to isolate C2 functions
- The commander (and staff) receive information, make decisions, and communicate those decisions
  - ✓ This suggests that communications mark the beginning and end of the C2 process boundaries