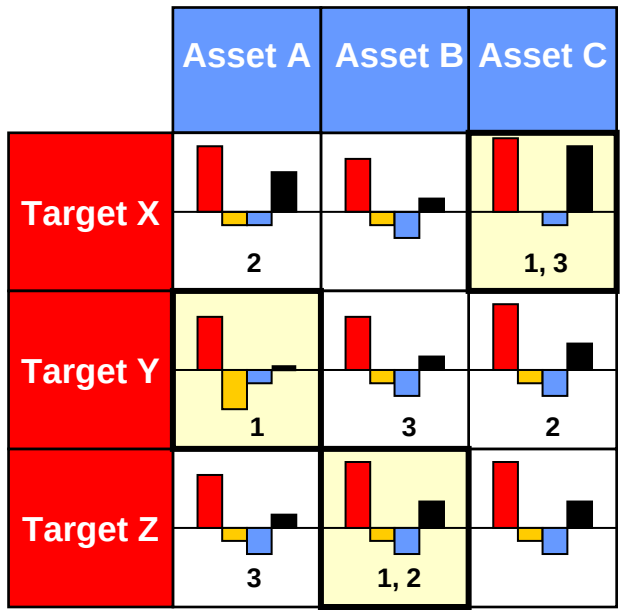
Structure Mapping in Visual Displays for Decision Support

Kevin Burns
Craig Bonaceto



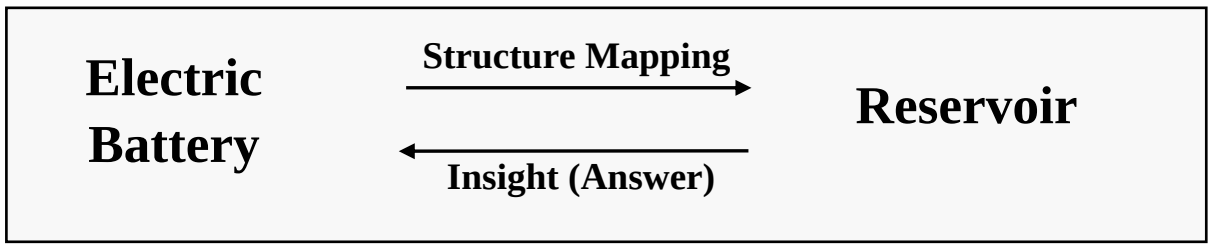
MITRE

The Problem

- Computerized decision support systems for C2 are often designed without adequate attention to the psychology by which decisions and other human inferences are made.
- Operators may not use these systems, and performance may actually be degraded by such systems.
- In this briefing, we:
  - Present an approach to decision support design founded on a cognitive theory of analogy called Structure Mapping.
  - Analyze the C2 problem of time-sensitive targeting and present a support system designed in accordance with Structure Mapping.
  - Summarize guidelines for generalizing the approach to other systems.

A Solution in Structure Mapping

- In Structure Mapping, a body of knowledge in one domain is mapped to a body knowledge in another domain based on common structures shared by the two domains.
- Example: “An electric battery is like a reservoir.”



- We are interested in constructing visualizations that support C2 decisions by mapping the structure of a C2 problem to the graphical features of a visual display.

Structure Mapping: The Missing Link

C2 Problem ⟷ **C2 Picture**

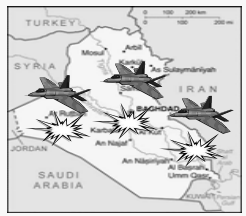
Structure Mapping →

← Insight (Answer)

Weapon-Target Pairing

Standard Mapping →

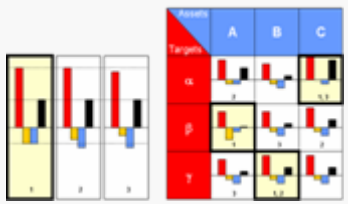
← / **A Missing Link**



Weapon-Target Pairing

Structure Mapping →

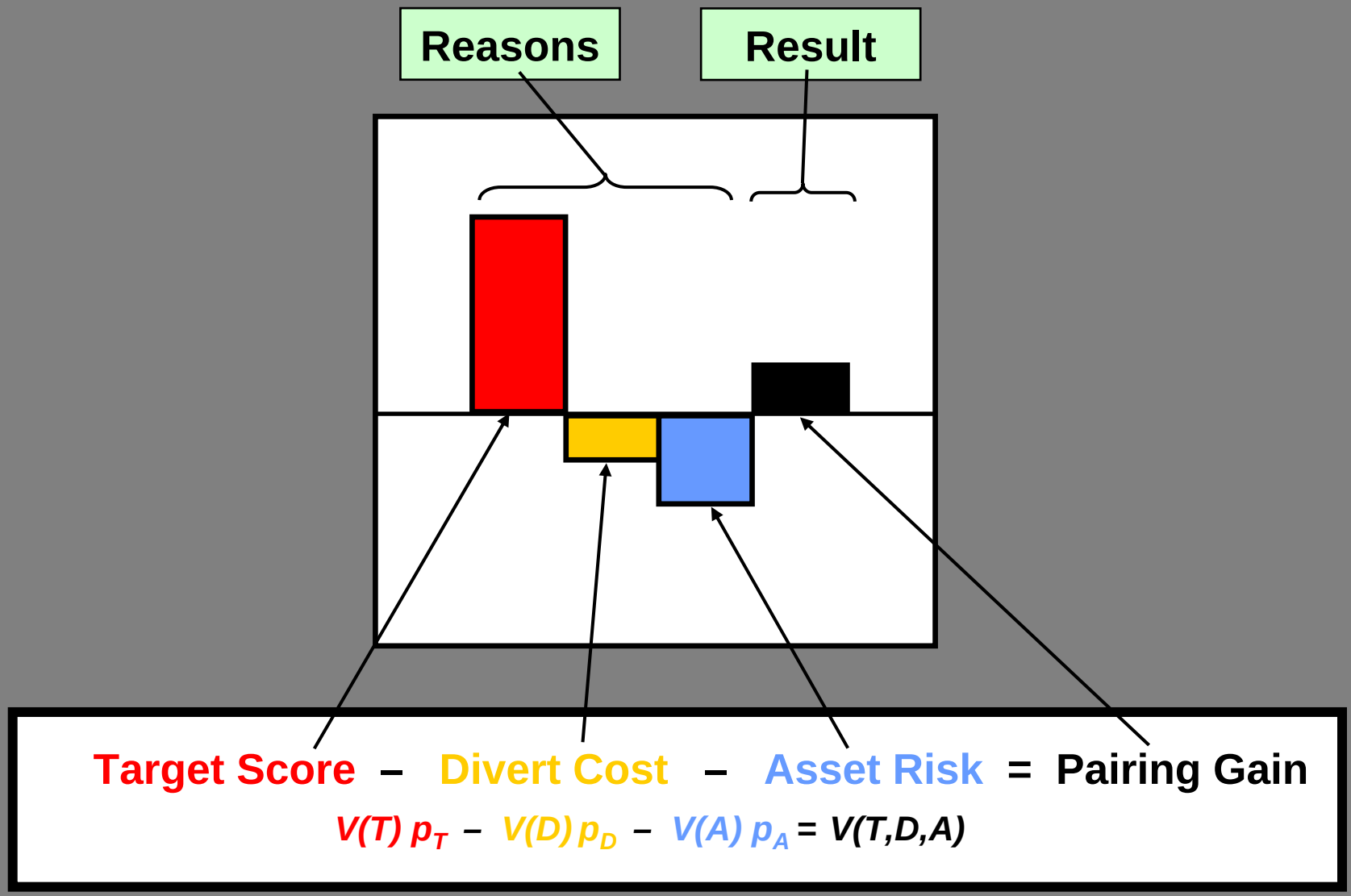
← Insight (Answer)



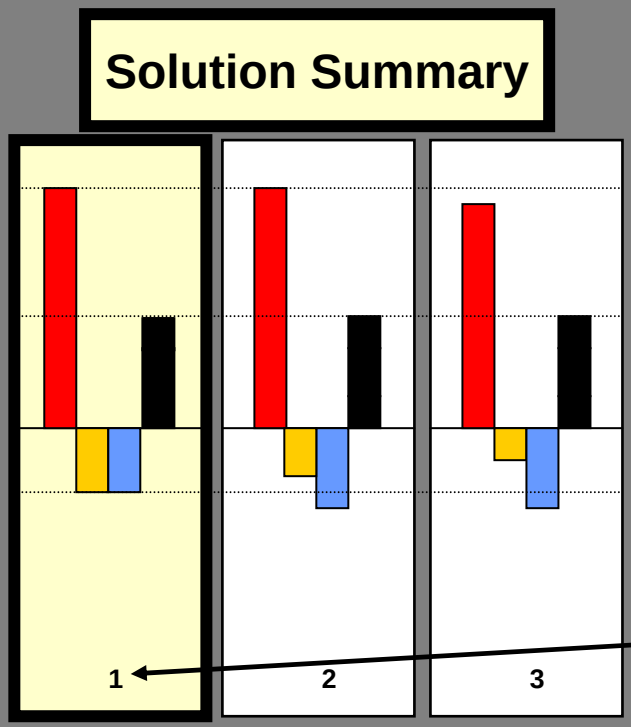
The Example: Weapon-Target Pairing for Time-Sensitive Targeting

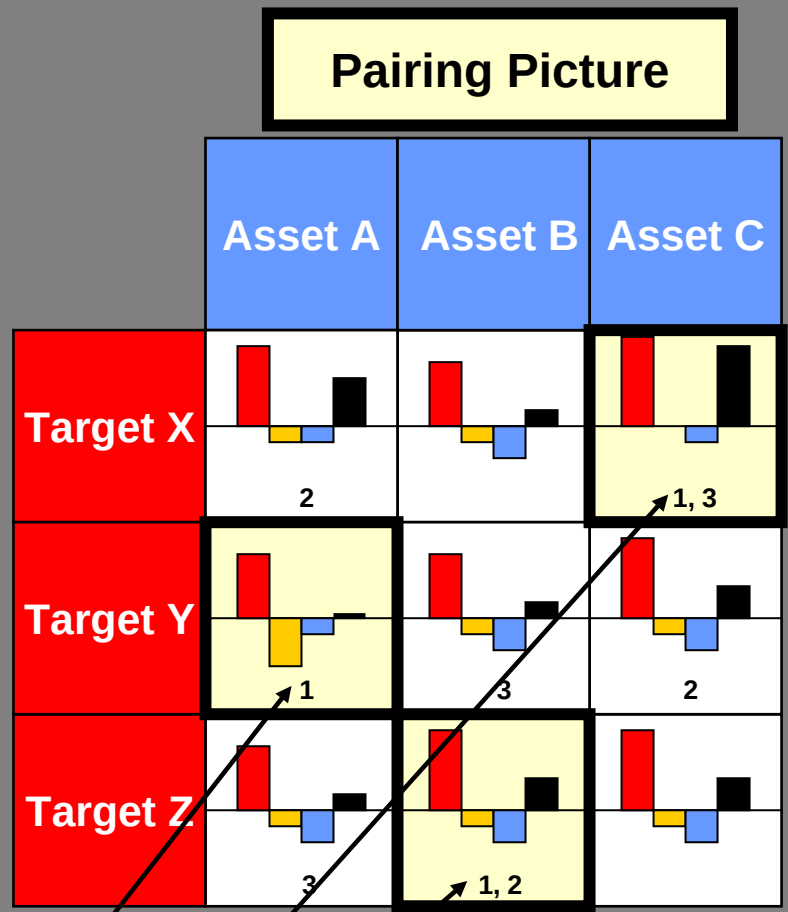
- **The C2 Problem: Which weapons (assets) should be diverted from their originally scheduled targets to attack time-sensitive targets?**
- **A Solution:**
  - **Given asset/target priorities and loss/kill probabilities, compute the value of pairing each asset against each target.**
  - **Compute a set of asset/target pairings with maximum expected value.**
- **The Structure Mapping Problem: How to construct a visual display to show what assets should be assigned to what targets and why?**

Mapping the Value Function



Mapping the Problem and Solution Spaces





Numbers in the Problem Space matrix correspond to the solution they're part of.

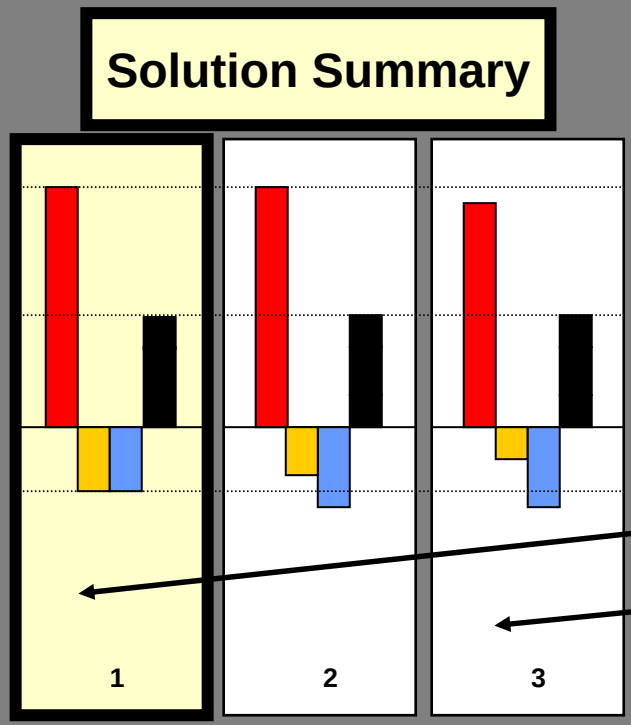
Is This a Better System?

Question: But why is this system better than just giving operators the “optimal” answer?

Answer: Operators realize there are many assumptions and uncertainties behind system solutions, and there may be many sub-optimal solutions that are almost as good as the so-called optimal solution.

Let’s see some examples…

Commander's Guidance: "Minimize Divert Cost!"



Solutions 1 and 3 have the same overall score (black bar) but different divert costs and asset risks. Solution 1 is actually sub-optimal if the commander's guidance includes a desire to minimize divert cost.

I Know Something You Don't Know

Target Score (+)
Divert Cost (-)
Asset Risk (-)
Pairing Gain

An operator may know that Asset C's effectiveness against Target X is sensitive to weather. Thus, he may choose to avoid any solution that includes this cell.

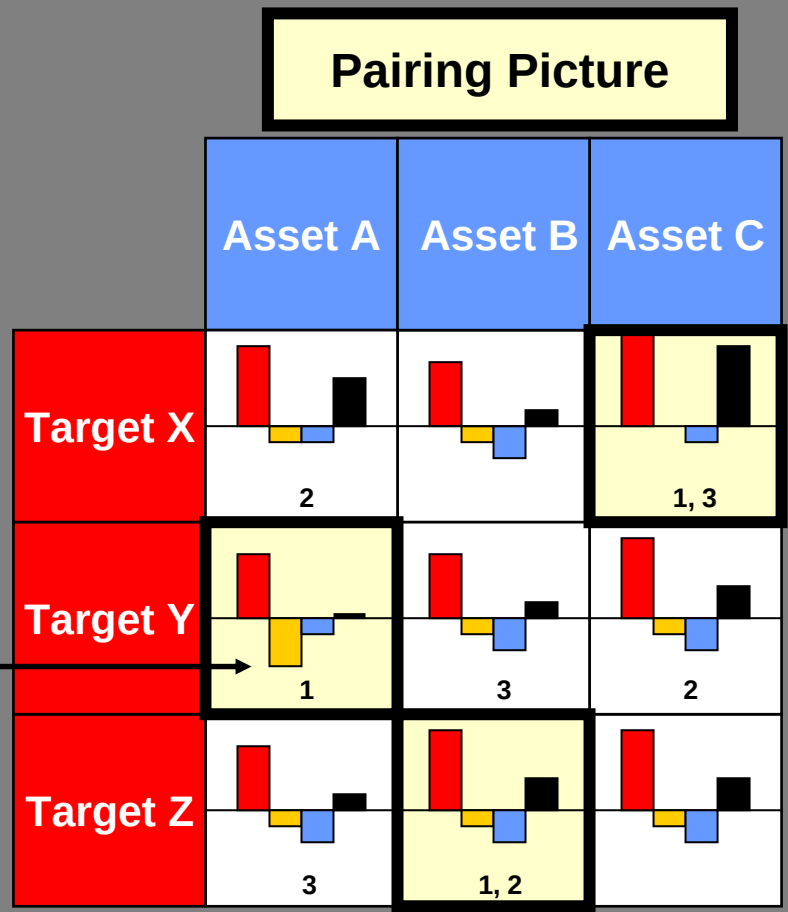
Pairing Picture

	Asset A	Asset B	Asset C
Target X	2		1, 3
Target Y	1	3	2
Target Z	3	1, 2	

Do I Really Want to Re-task Maverick?

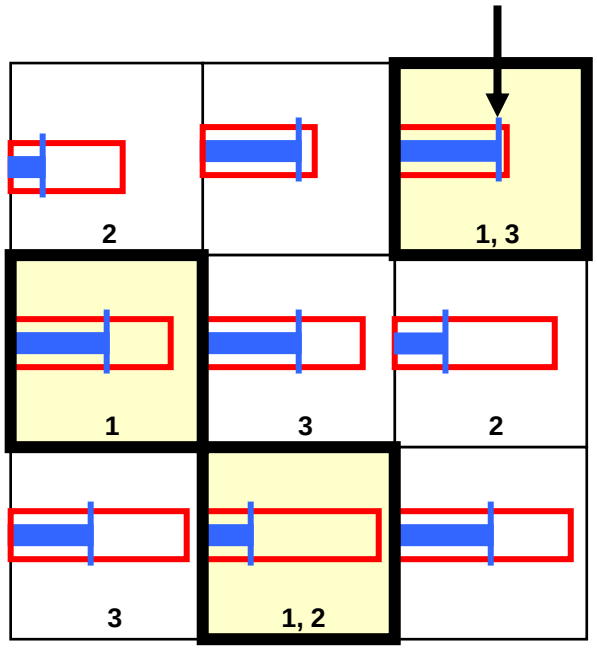
Target Score (+)
Divert Cost (-)
Asset Risk (-)
Pairing Gain

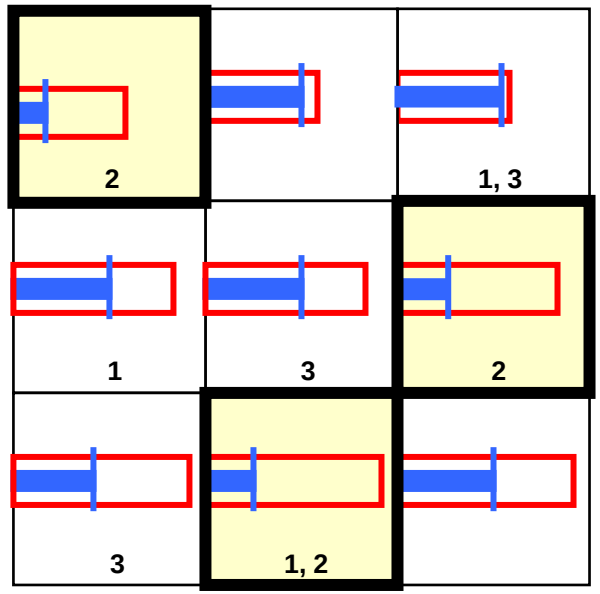
Most of the gain in Solution 1 comes from pairing Asset C against Target X and Asset B against Target Z. Even though this cell is part of the optimal solution, an operator might choose not to send Asset A to Target Y since the pairing gain is nearly 0.



Will Iceman Get There in Time?

Solution 1 has a cell with close timing

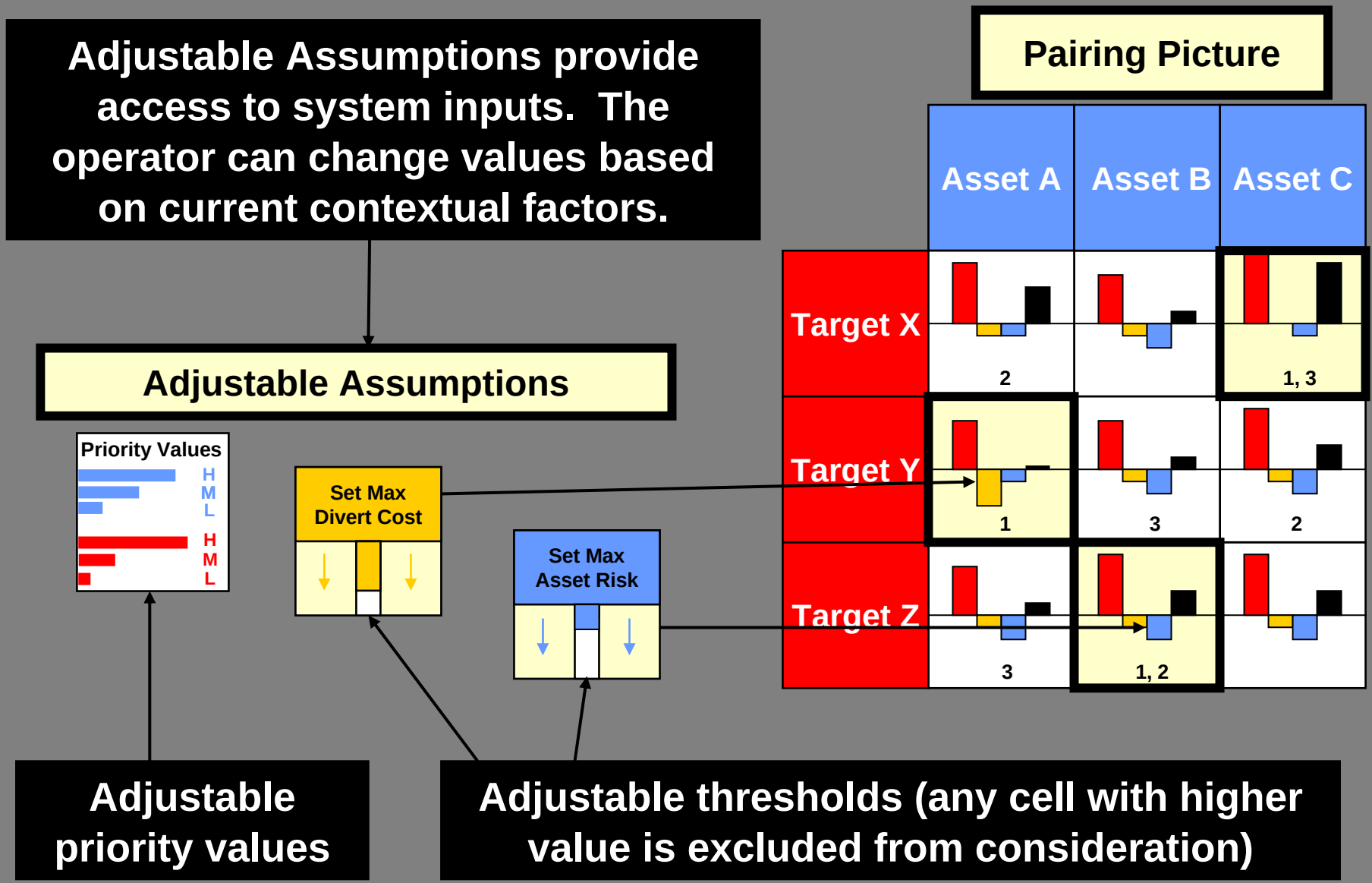




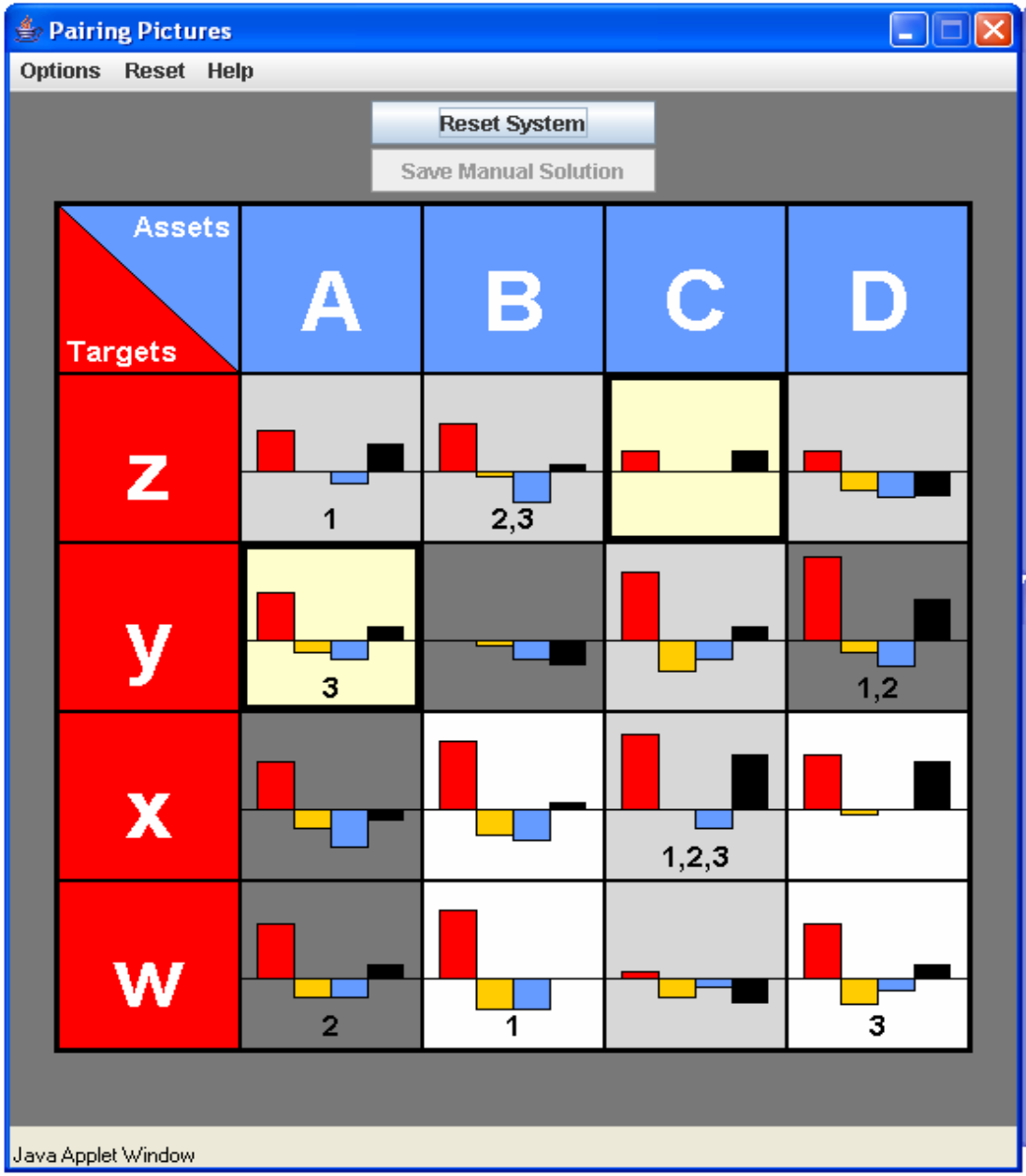
Solution 2 might be better, because it's more robust.

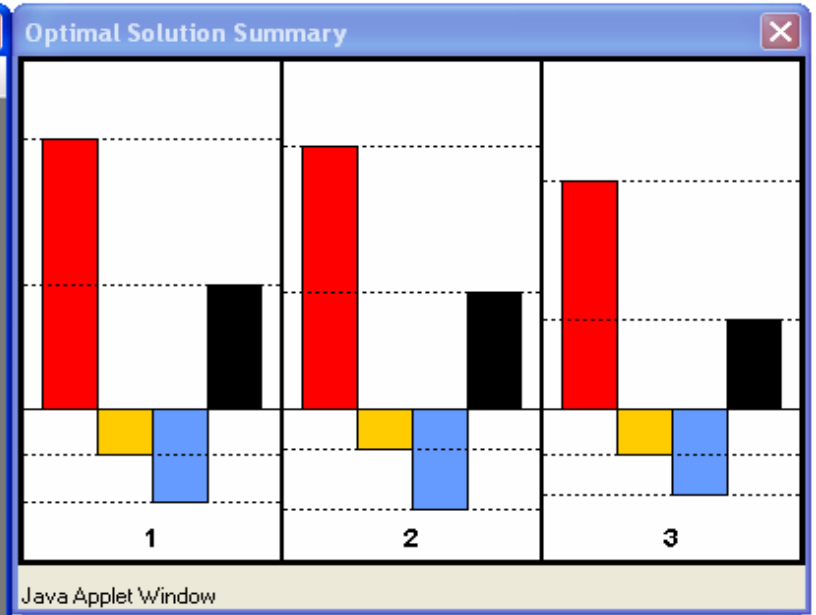
What are the Underlying Assumptions?

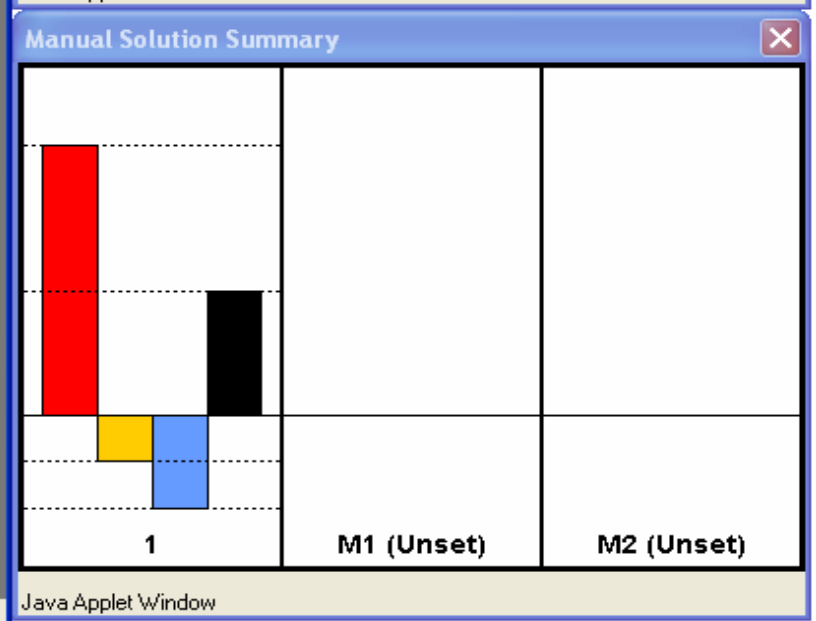
Adjustable Assumptions provide access to system inputs. The operator can change values based on current contextual factors.



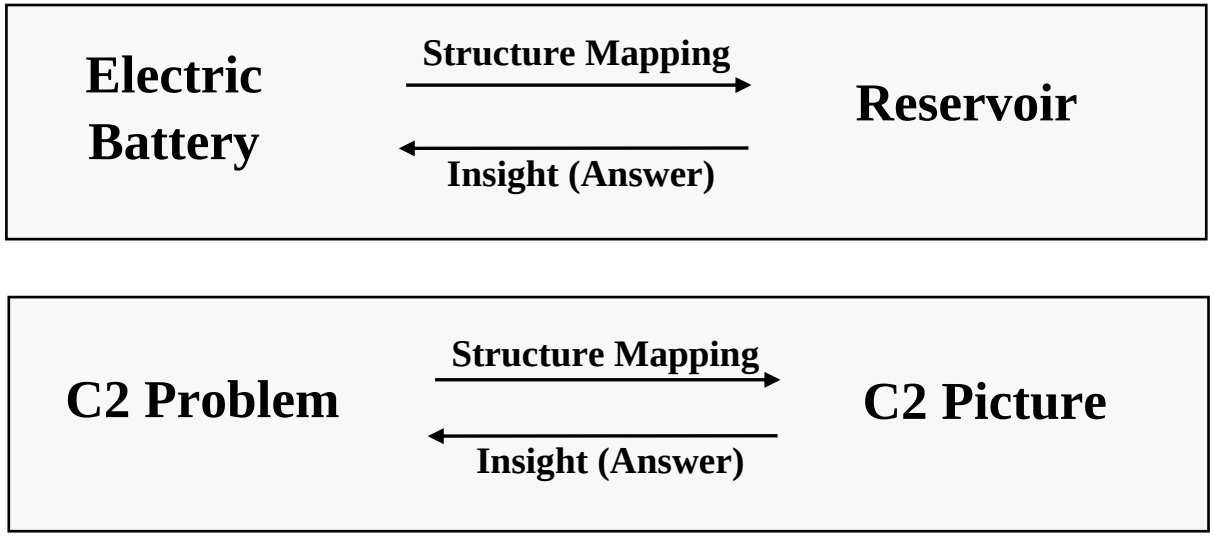
Taking Control: Manual Solutions







Applying Structure Mapping to Other Systems



- The goal of Structure Mapping is to identify *conceptual aspects* of the problem and illustrate them with *graphical attributes* of a display.
- The graphical structure of the display should be analogous to the conceptual structure of the problem and solution.
- The technique may be applied to a wide range of systems in environments that require human judgments and decisions.

Questions?

- **A working prototype of the system is available online at:**

http://mentalmodels.mitre.org/Hyperlinks/Time_Is_Critical.htm