Decision and uncertainty management for human and human/agent teams

Dr. David Ullman
President
Robust Decisions, Inc.
www.robustdecisions.com

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Topics

- What is Decision Management and why is it important?
  - Key to removing the waste in Lean Project Management
  - Required for effective use of Theory of Constraints (TOC) and Critical Chain Project Management
- Use of Decision Management software at Boeing, Space and Communications Division
- NASA funded research on decisions made by Human/ Agent Teams

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What do these processes have in common?

- Acquisition planning
  - Concept selection
  - Project planning
  - Portfolio management
  - Product development
  - Trade studies
  - Proposal evaluation
  - Strategic planning
- Homeland security
  - Bad actor identification
  - Target identification
- Courses of Action (COA) decisions
- Analysis of Alternatives
- Business strategy development

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They all require choosing a course of action and committing resources based on information that is:

- Incomplete
- Uncertain
- Evolving

from stakeholders or agents who:

- Know part of the information
- Are distributed in time and location
- Represent many different viewpoints, areas of expertise, and organizational functions

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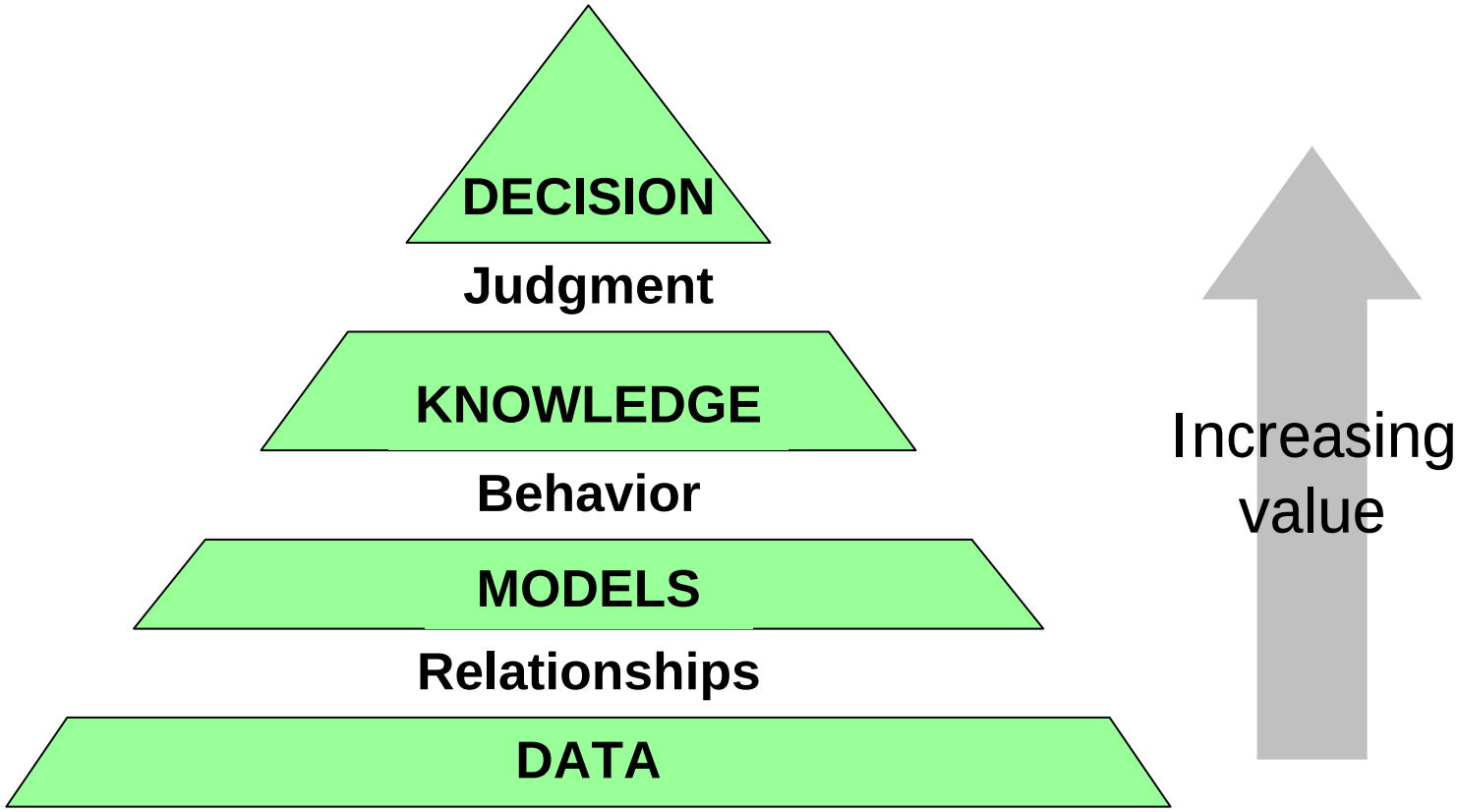
The Value of Information



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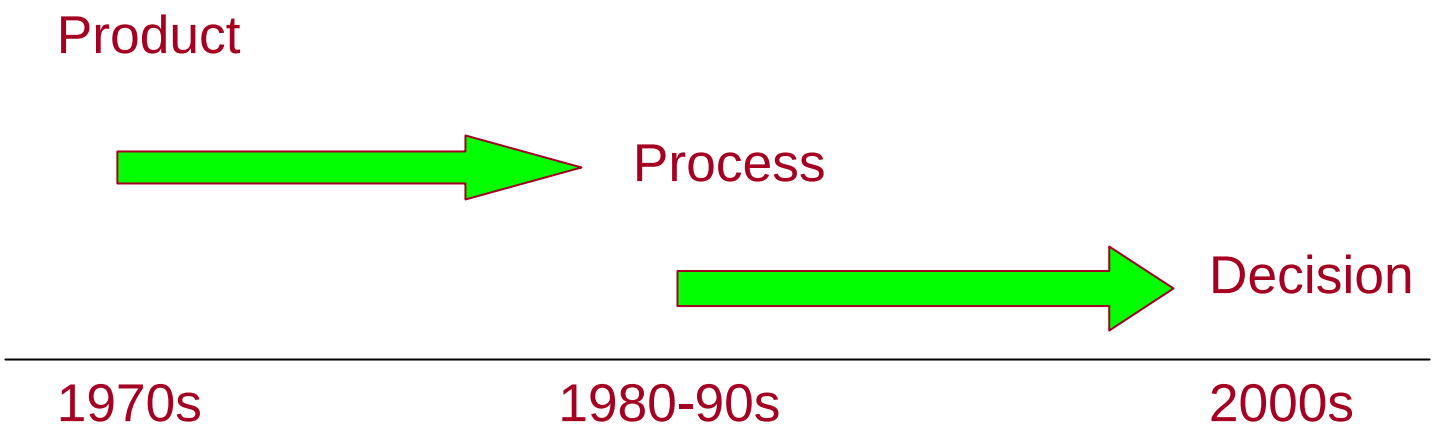
Historical View



Projects are the evolution of information punctuated by decisions!

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The goal is to make decisions with:

- Best use of available information
- Confidence
- Stakeholder buy-in
- Measured expectations
- Risk awareness
- Efficient processes
- Reports, documentation, and reuse

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Meeting this goal requires decision management

Decision management is a process that ensures stakeholders' perspectives and their uncertain knowledge and information are effectively used in determining what to do next to make the best possible decisions with measured satisfaction and risk

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Symptoms of poor decision management

- Projects are late or over budget
- “Final” decisions are later revisited
- Poor stakeholder buy-in
- Decisions made by edict or the most forceful
- Expertise is underutilized
- Low confidence in decisions
- Decisions are not justified, recorded, reused

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The Lean Project Management Puzzle

Profound Knowledge
- System
- Variation
- Psychology
- Theory of Knowledge

Underlies

Requires

Decision Management
- Uncertain Information
- Fragmented knowledge
- Honored viewpoints
- Managed decisions
- What to do next?

Lean	TOC/CCPM
Specify customer value	Satisfy Customers Now & Future
Value stream	System thinking
Flow	Throughput
Pull.	Rope
Perfection	POOGI

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Lean Project Management requires the elimination of waste

- Wasted time in making a decision
  - Poor use of resources and expertise
- Wasted time and money resulting from a poor decision
  - Rework and wasted materials
  - Later firefighting
  - Discarded work that was focused on “the wrong task”

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Trade Studies and Decision Making at Boeing, Space and Communications Division

Must select a Delta Rocket nozzle modification to propose in an uncertain environment.

- Unrefined information: *some even qualitative*
- Conflicting information: *evaluation and importance varies across team members*
- Evolving information: *problem is changing with time*
- Incomplete information: *evaluation is incomplete*

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Boeing's traditional Trade Study Approach

Modified Pugh Tool (Decision Matrix)

1. Identify trade parameters (criteria)
2. Assign weight to individual criteria
   - Pairwise comparisons
3. Evaluate criteria against design concepts
   - Use scale 1-5 in matrix form
4. Multiply weight and rating
5. Add total scores and compare

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Traditional method of assigning weight to criteria

Pair-wise comparison approach for criteria weight development

	Cost	Schedule	Risk	Performance	Turn Around	Inspectability	Process Variability	Hardware Robustness	Failure Mode Count	Materials
Cost	**1.00**	4.00	2.00	2.00	2.00	4.00	4.00	2.00	2.00	2.00
Schedule	0.25	**1.00**	0.50	0.50	1.00	2.00	2.00	1.00	2.00	2.00
Risk	0.50	2.00	**1.00**	0.50	1.00	4.00	4.00	1.00	4.00	2.00
Performance	0.50	2.00	2.00	**1.00**	2.00	4.00	4.00	1.00	4.00	2.00
Turn Around	0.50	1.00	1.00	0.50	**1.00**	2.00	2.00	0.50	2.00	2.00
Inspectability	0.25	0.50	0.25	0.25	0.50	**1.00**	1.00	0.25	0.25	0.50
Process Variability	0.25	0.50	0.25	0.25	0.50	1.00	**1.00**	0.50	0.10	0.50
Hardware Robustness	0.50	1.00	1.00	1.00	2.00	4.00	2.00	**1.00**	2.00	2.00
Failure Mode Count	0.50	0.50	0.25	0.25	0.50	4.00	2.00	0.50	**1.00**	0.50
Materials	0.50	0.50	0.50	0.50	0.50	2.00	2.00	0.50	2.00	**1.00**
Sum	4.75	13.00	8.75	6.75	11.00	28.00	24.00	8.25	19.35	14.50
Product vector	0.4	1.0	0.7	0.5	0.9	2.5	2.1	0.7	1.3	1.2
	4%	9%	6%	5%	8%	22%	19%	6%	11%	11%

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Issues With Traditional Approach

- Laborious
- Assumes all criteria initially known. Any changes requires extensive work.
- Must have team agreement on comparisons

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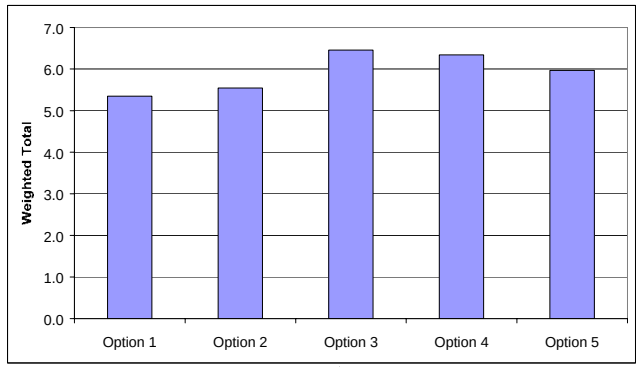
Traditional Trade Study Approach

Pugh Matrix

Weights

Category	Criteria	Weight	Option 1	Option 2	Option 3	Option 4	Option 5
Safety - 50%	Inspectability	15%	5.0	5.0	6.4	6.4	3.6
	Process Variability	40%	3.0	4.4	4.7	4.7	3.3
	Hardware Robustness	25%	3.5	4.7	5.8	5.6	4.3
	Failure Mode Count	15%	5.6	5.6	6.3	6.3	5.0
	Materials	5%	5.0	5.0	5.0	5.0	5.0
	Weighted Total	50%	3.3	3.7	4.2	4.2	3.2
Programmatic - 40%	Cost	60%	4.0	4.0	5.4	5.2	4.6
	Schedule	20%	5.0	5.0	5.0	5.0	4.0
	Risk	20%	4.3	4.3	5.6	5.6	6.9
	Weighted Total	40%	8.0	8.0	9.6	9.5	9.3
Integration - 10%	Performance	50%	4.0	4.0	4.0	4.0	6.0
	Turn Around	50%	6.0	6.0	6.0	5.0	7.0
	Weighted Total	10%	5.0	5.0	5.0	4.5	6.5
	Weighted Total	100%	5.3	5.5	6.5	6.3	6.0

Final Comparison



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Issues With Traditional Approach

- Assumes all alternatives have the same level of knowledge for each criteria
- Ignorance is bliss - uncertainty often not dealt with
- Assumes all experts have same experience base for the options
- Hard to achieve consensus - strong voices dominate
- Difficult to determine best option when final comparison is close

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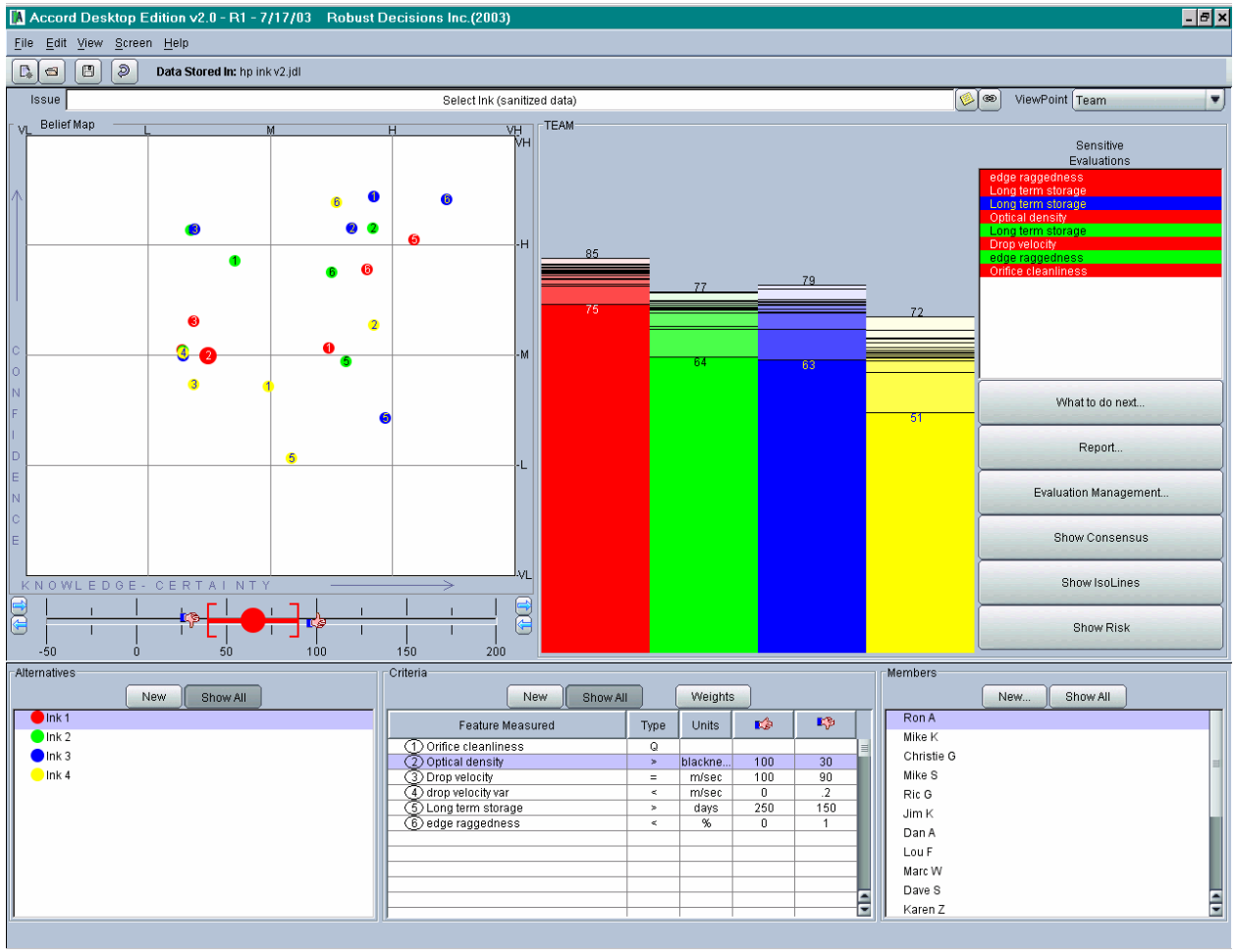
New Trade Study Approach

Decision Management and the *Accord*™ Tool



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Underlying model

- **Utility Theory augmented by Bayesian Model**
- **Manages uncertain information from multiple stakeholders**
  - Allows uncertainty to be a major factor in the analysis
  - Allows multiple preference (weighting) models
  - Allows simple model of team members' beliefs
- **Fuses distributed team information:**
  - Satisfaction from multiple viewpoints
  - The value of information (risk and what to do next)
- **Patented algorithms**

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Identify trade parameters (criteria)

Decision management methods help team develop a set of robust criteria

Criteria

New | Show All | Weights

Feature Measured	Type	Units		
1 Total cost (inc Raps)	<	$M	.5	1.5
2 Delta Weight	>	lb	230	0
3 Capital Cost	<	$M	4.8	8.3
4 Performance	>	sec	10	5
5 Recurring Tooling Cost	<	$K	0	100
6 Development risk	Q			
7 Quality Cost	Q			

Criteria are usually a mix of qualitative and quantitative

Targets usually are uncertain

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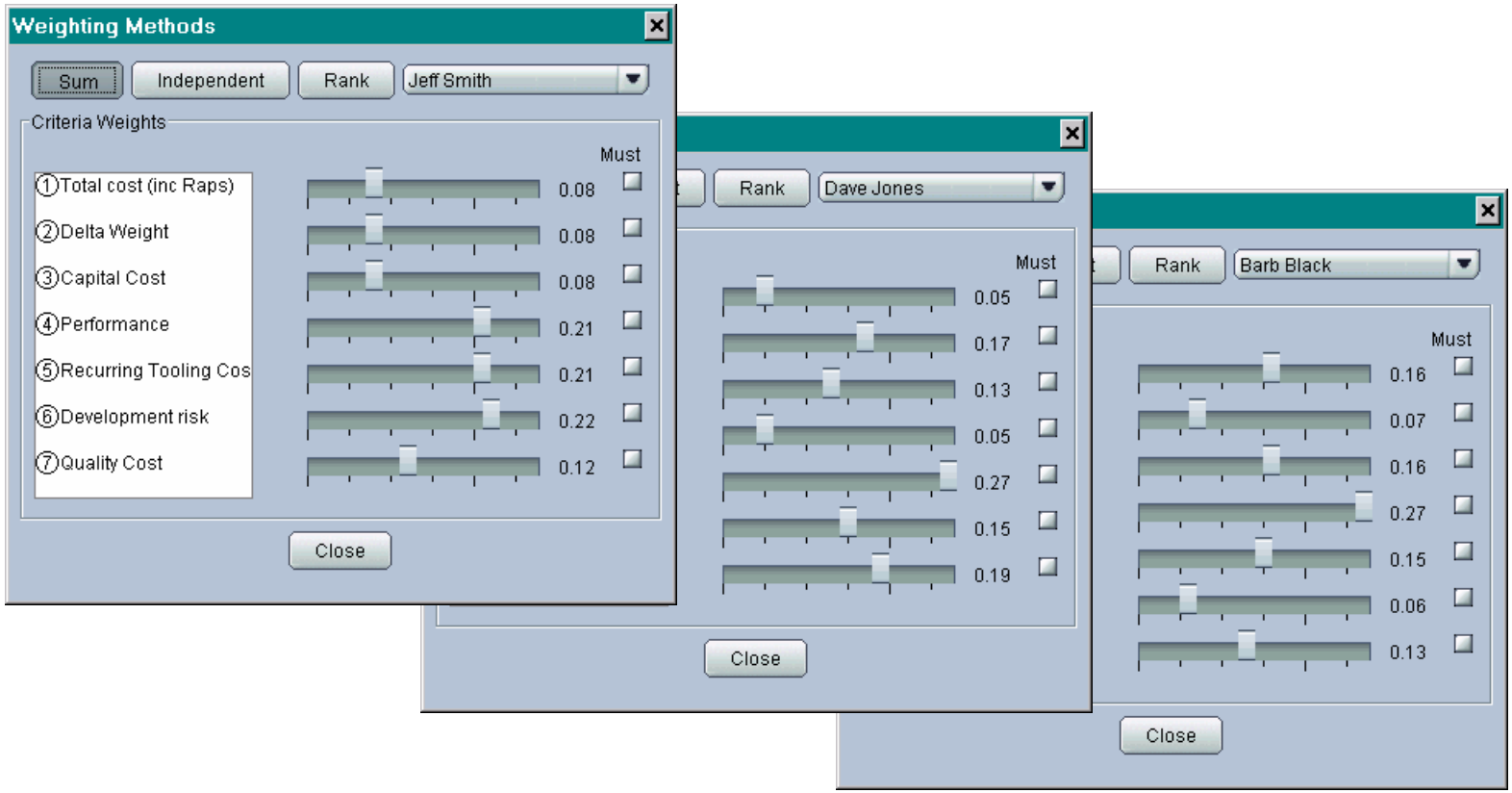
Decision management method of assigning weight to criteria

Dependent on viewpoint in the organization



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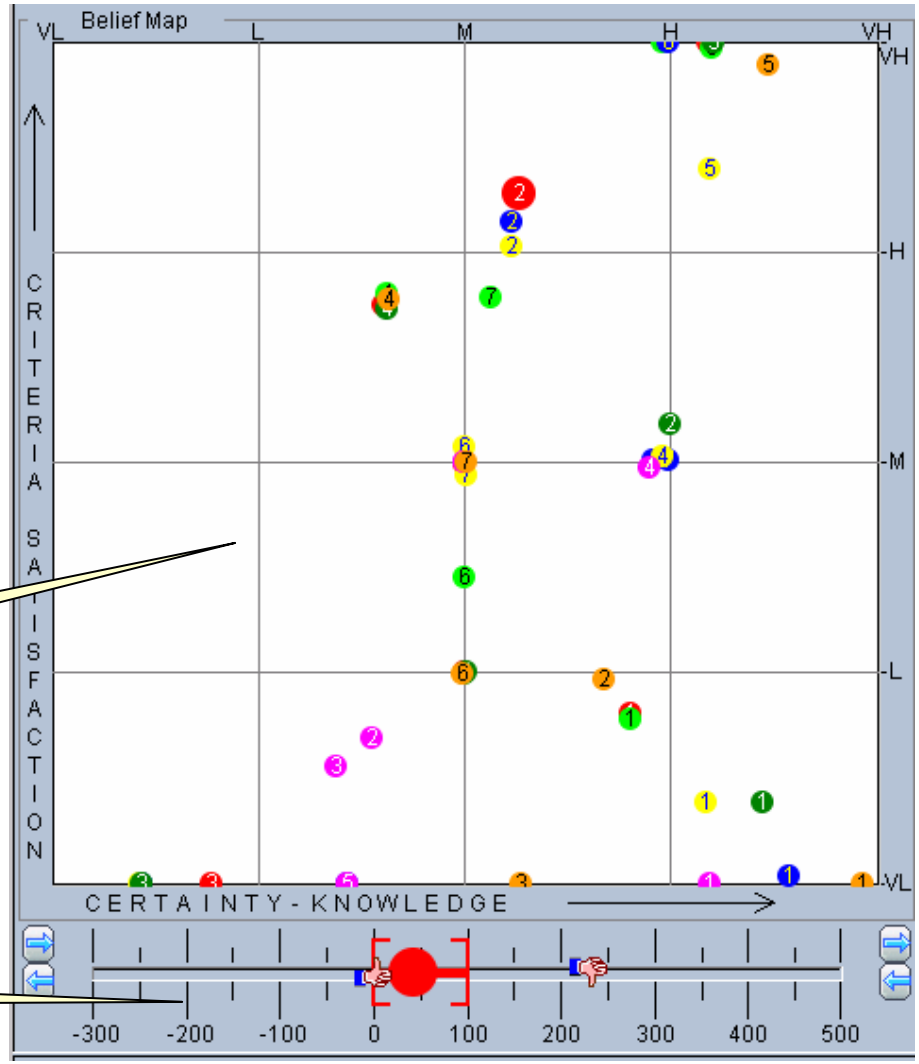
Evaluation must include uncertainty



Belief map

Number line

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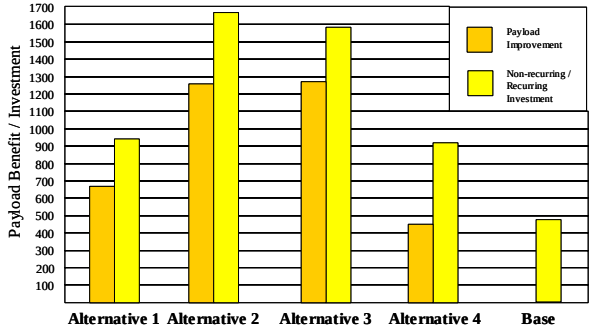
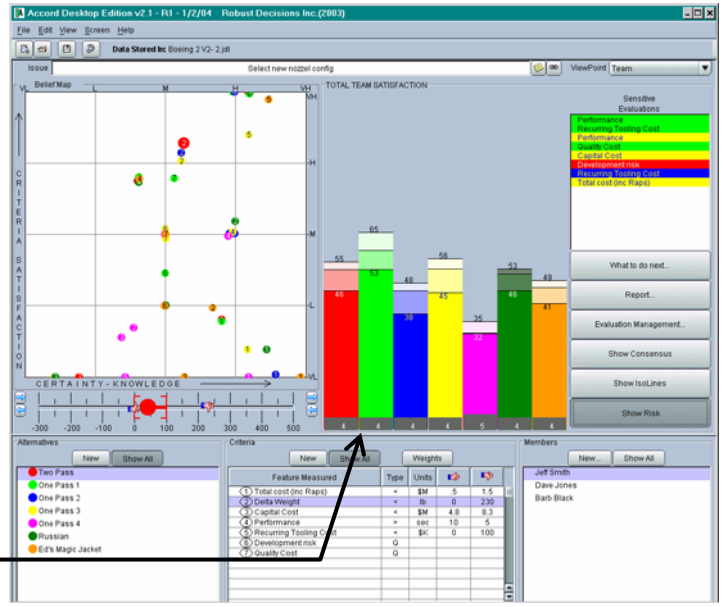
Rocket Nozzle Case Study
New designs compared to current

Using traditional approach results achieved in one month



Using *Accord* - Results reached with-in a few hours with multiple strong personalities



Selected Alternative

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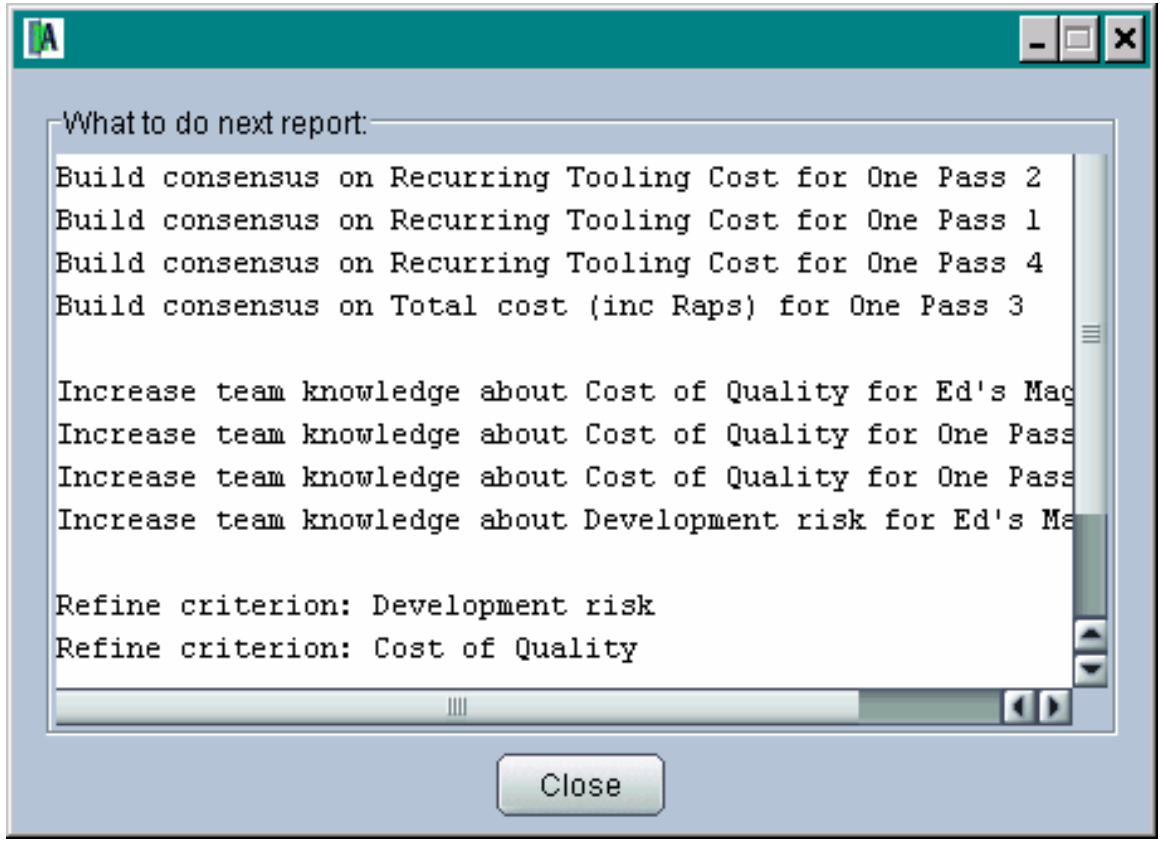
What to do next

Accord suggests evaluations which have the greatest likelihood of changing the satisfaction ranking of the alternatives.



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Boeing's Stated Advantages For Design Decisions

- Ability to manage uncertainty of knowledge
  - Increases confidence in decisions
  - Helps target areas for risk mitigation
- Significant potential time saving due to lowering the risk of repeating a design cycle in the development process.
- Ability to manage strong personalities
- Facilitates team consensus
  - Allows productive discussion of different views

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Advantages for all Decisions

- Manage uncertainty and help eliminate waste
  - Support your Lean initiative
  - Support your TOC/CCPM efforts
- Make decisions knowing the answers to:
  - What is the best alternative course of action?
  - Do we know enough to make a good decision yet?
  - What do we need to do next to feel confident about our decision within our limited resources?
  - What is the risk that our decision will not turn out as expected?

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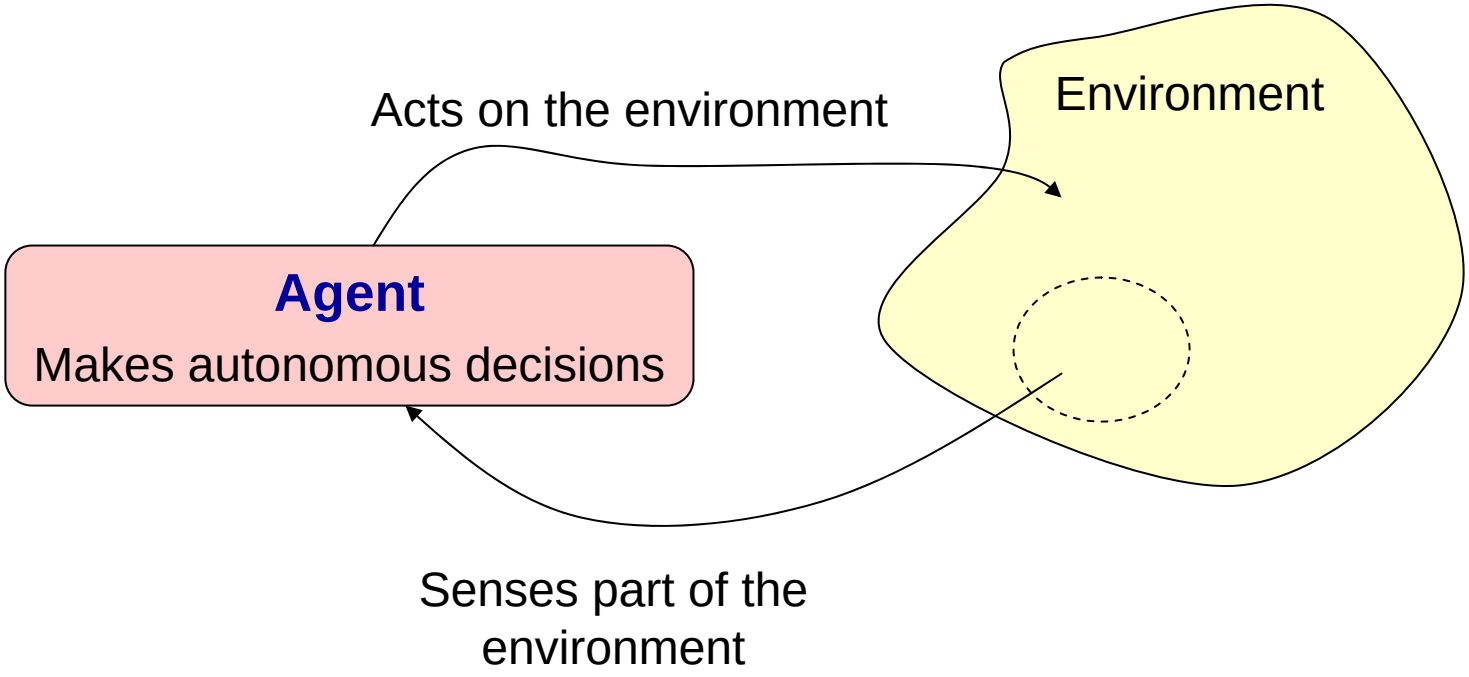
Human/Agent Team Decision Management

Agents work autonomously, most of the time



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For sophisticated agents, working in more demanding environments uncertainties quickly begin to dominate the situation

- Measurements may be noisy or outside of sensor range
- Operations may depend on uncertain projections about the future
- Operations may be beyond those programmed into agents
- Goals may be conflicting
- Information may be incomplete
- Alternative courses of action may be changing
- Knowledge about the situation may be evolving
- Decisions made about one issue may affect another issue

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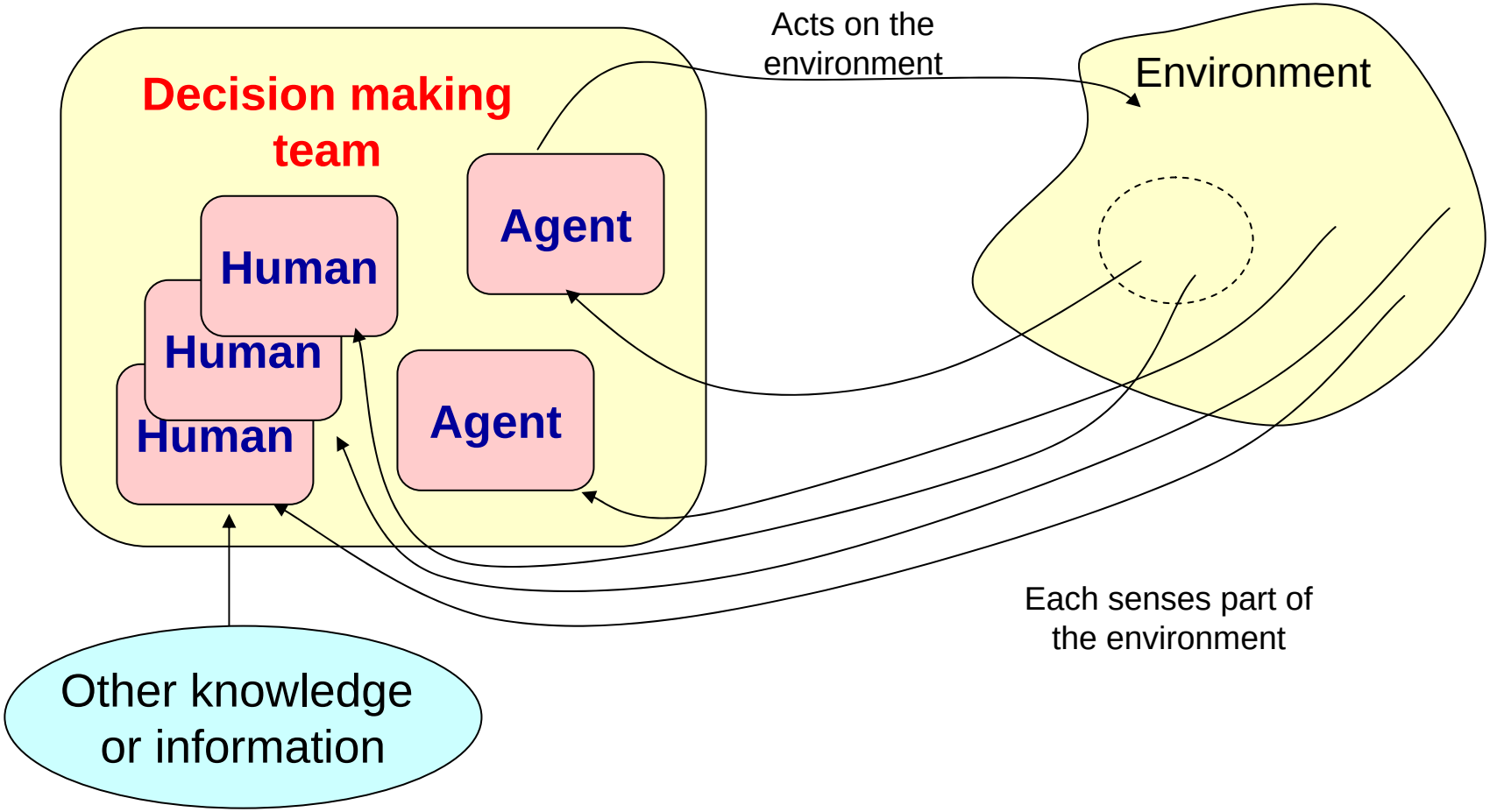
An agent may need the involvement of other agents and human partners as part of a decision making team



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This is WIP: Goals of research

- Find what the agent should do next, with high expected utility
- Find areas in which further modeling, measurements or expertise might improve an options' expected utility
- Calculate the risk involved in each option relative to key measures of success
- Monitor the level of agreement among members of the team, identify which measures they disagree on and the effect, if any, of the disagreement on the conclusion
- Monitor how the resolution of one issue and how it will affect other issues.

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Contact

Dr. David Ullman
President
Robust Decisions, Inc.
Corvallis Oregon
541.758.5088
www.robustdecisions.com
ullman@robustdecisions.com

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