

Tools and Techniques for Developing Robust Policies for Complex and Uncertain Systems

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RAND

Evolving Logic

Policy Analysis for Complex Adaptive Systems Requires New Tools

- Naive Policy Analysis:
 - Develop best model of policy system
 - Determine recommended policy by calculating optima of some cost function on that model
- Does not work well for complex systems because
 - Classical simulation modeling techniques do not exploit the information that is available about the behavior of complex systems
 - “Best estimate” models **cannot predict** the behavior of complex systems
 - “Optimal” policies often perform poorly - **not robust**
 - Complex adaptive systems require **adaptive policies**
 - Knowledge, learning, and information processes undervalued in most policy studies
 - Complex Open Systems imply **Deep Uncertainty**

Deep Uncertainty

*“Uncertainty --
in the economy, society, politics --
has become so great as to render futile,
if not counterproductive,
the kind of planning most companies still practice:
forecasting based on probabilities”*

Peter Drucker
(WSJ Editorial)

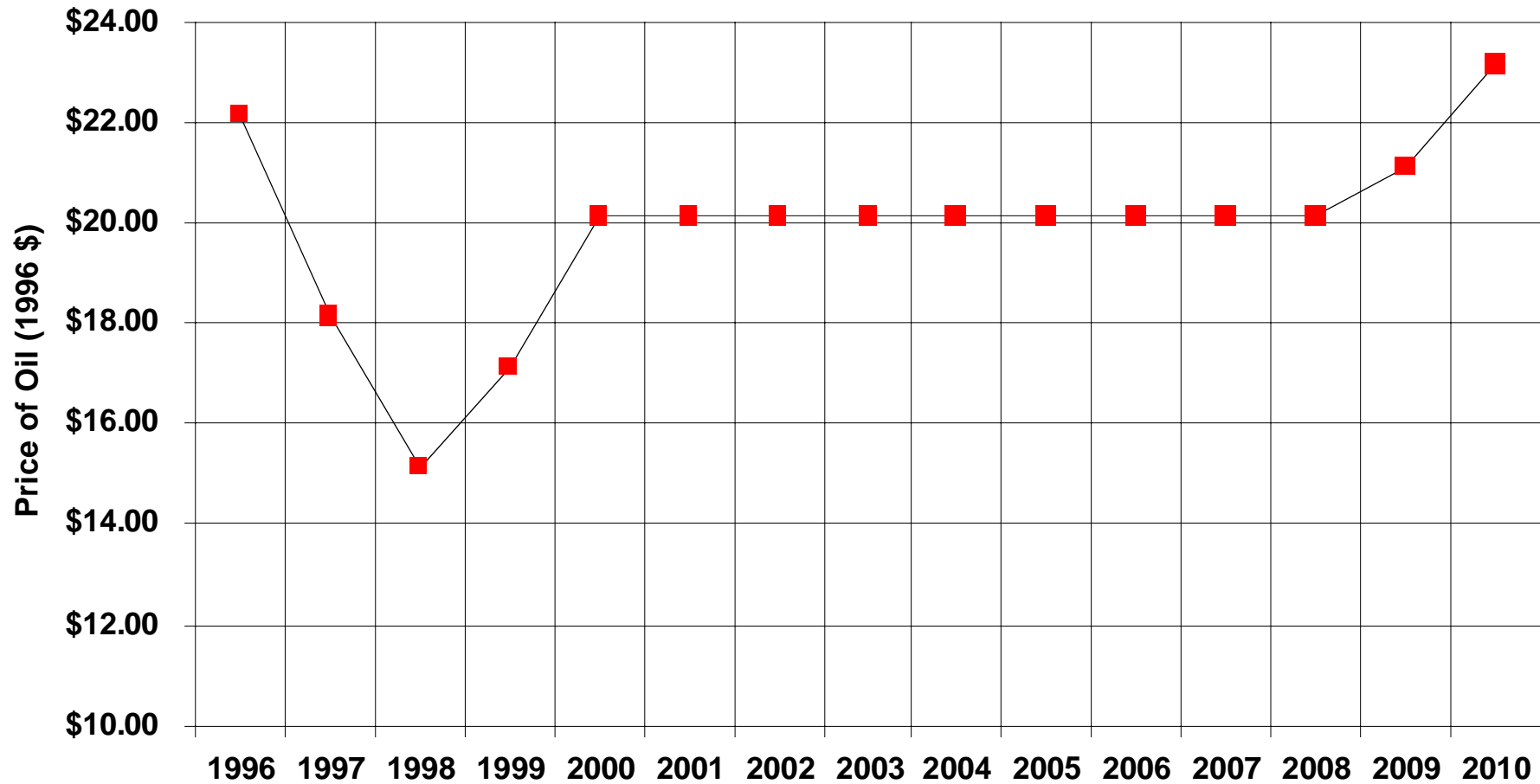
New Tools for Reasoning about Complex Adaptive Systems

- Technology for reasoning with **ensembles** of models, scenarios, and plans
- **Landscapes of plausible futures** and policy region analysis to reveal important scenarios
- **Level sets** to develop satisficing options
- **Robust region analysis** to develop options good enough for all possibilities
- **Challenge sets** to develop **adaptive policies**

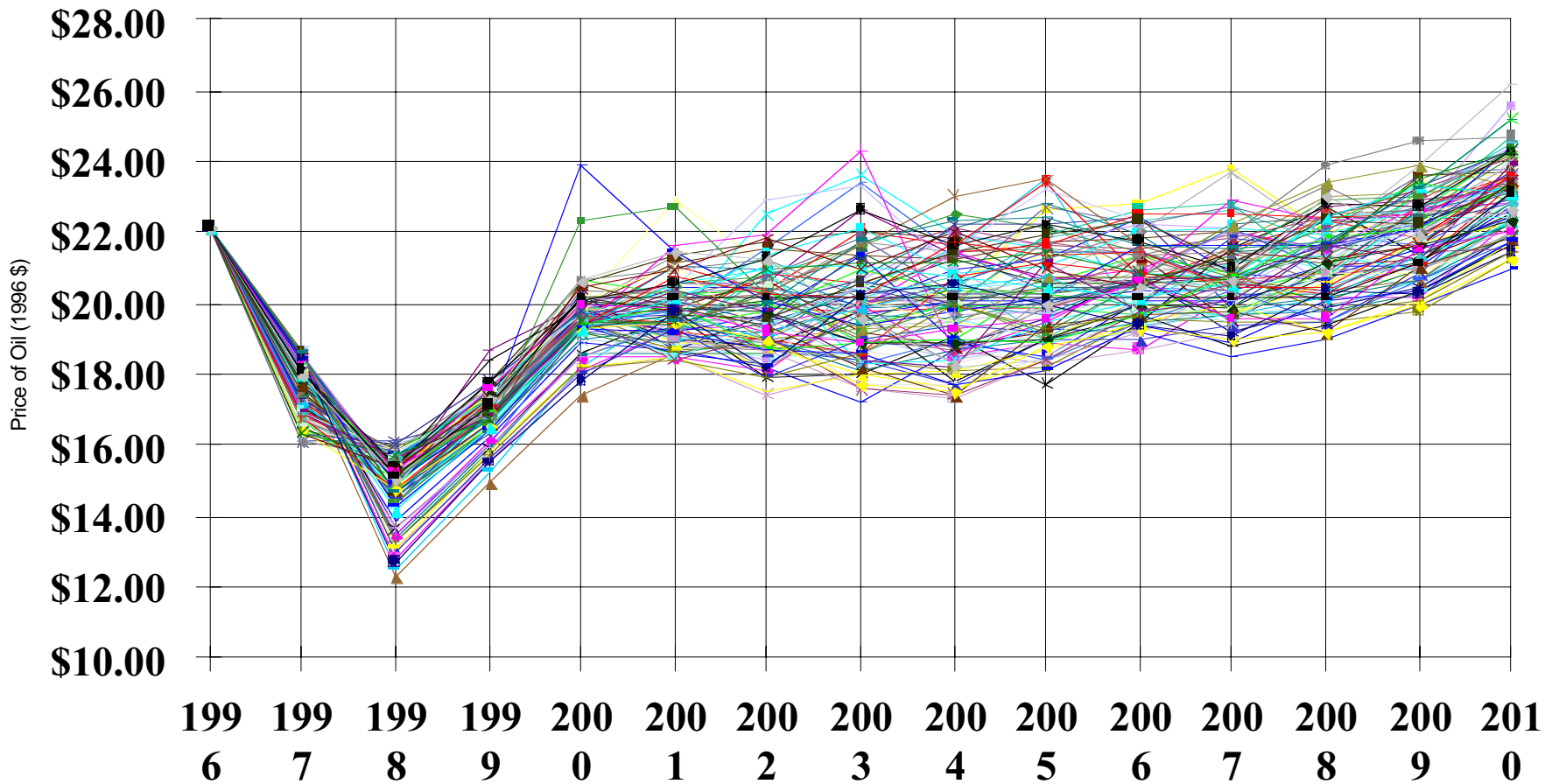
Landscapes of Plausible Futures: Beyond the Base Case

- Prediction or forecasting is an important and powerful form of model use
- Computational poverty meant that until recently, it was often the only feasible form of model use
- Frequently, models are used as though they predict, even when they have not been experimentally validated
- This can result in misleading conclusions (and other ills)

Firms Use Analytical Planning Tools Simply, With Only Part of Their Data...



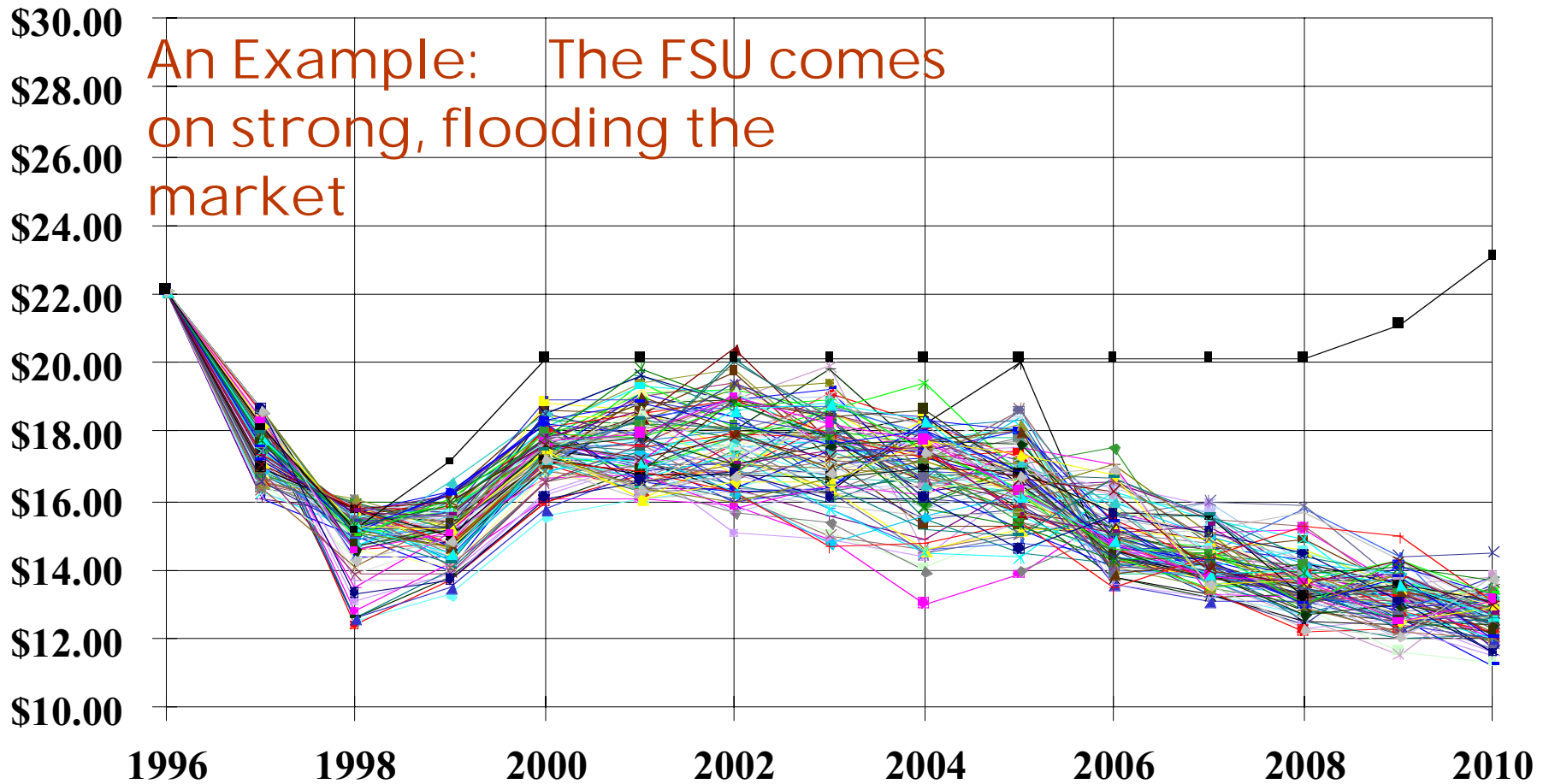
What Exists May Be Leveraged, Providing a Wider View with Available Data



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PROPRIETARY -- DO NOT DUPLICATE

Each Projection Depends on Explicit Recognition of Underlying Assumptions

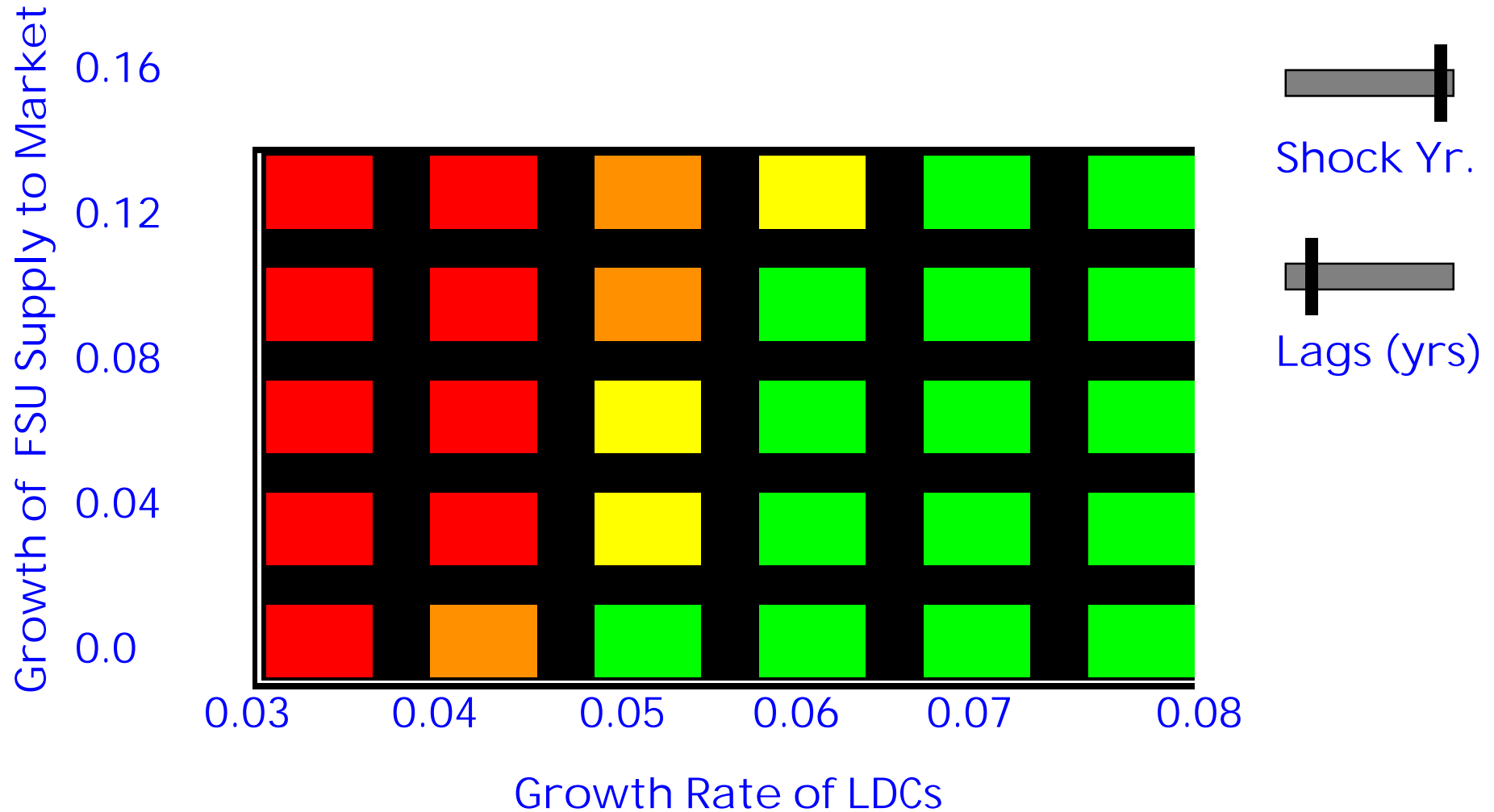


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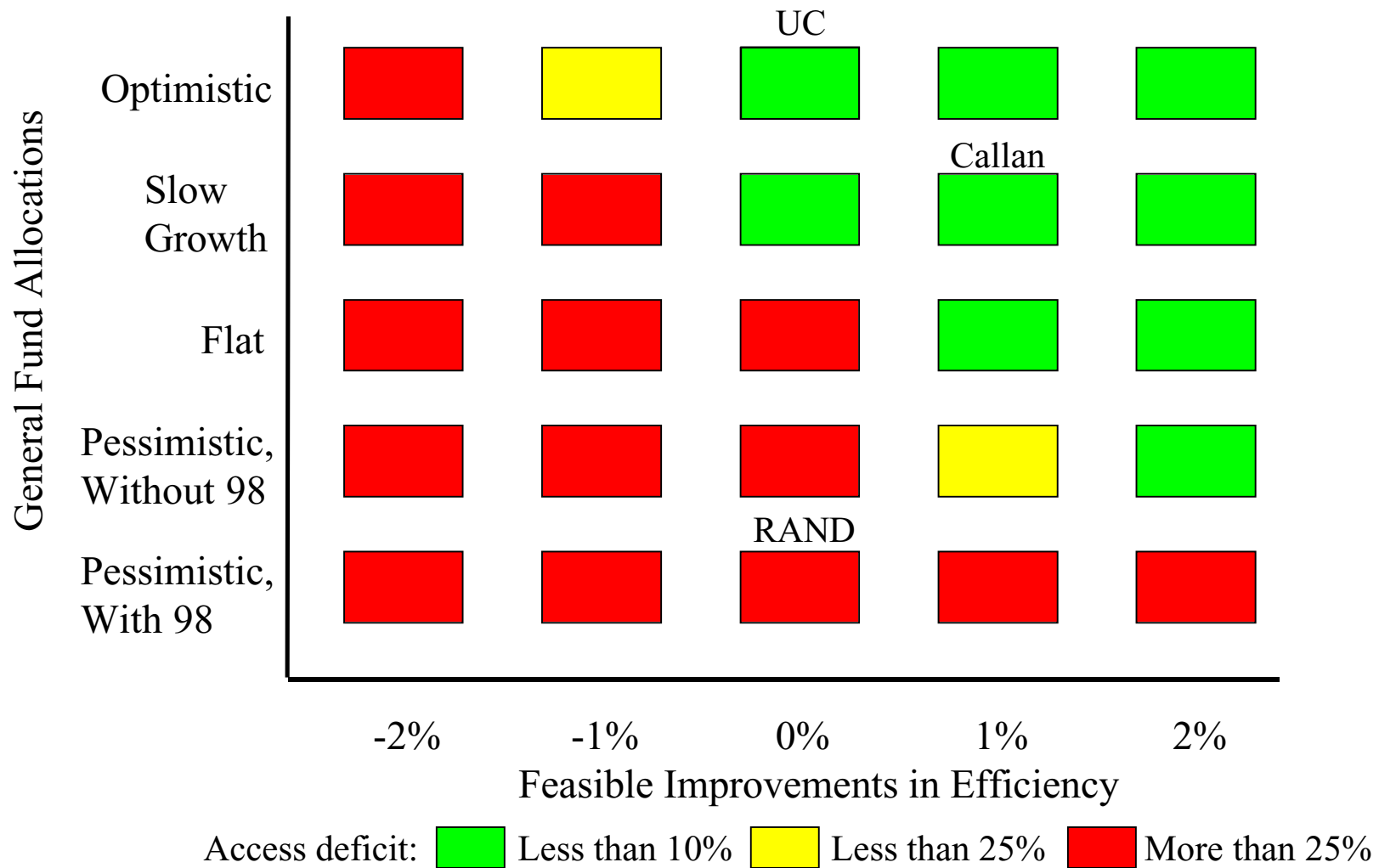
PROPRIETARY -- DO NOT DUPLICATE

The Landscape View Summarizes the Range of Possibilities

Return on an Investment



Access Deficits at University of California



Using Level Sets to Find Satisficing Options and Trade Spaces

- Selecting a Policy by Optimizing some Cost Function on a best estimate model and best estimate case results in
 - fragile solutions that are efficient for the best estimate case, but may fail catastrophically for other possibilities
 - Result in point solutions that decision makers must either accept or reject
- Instead, develop level sets of policy candidates that perform “well enough”
 - provides a foundation to look for robust candidates
 - provides a bridge to combine qualitative and quantitative knowledge

The Weapon Mix Problem: Minimize Time to Complete Campaign

- Assess the services' deep attack systems to determine the appropriate weapon mix and force size

For any given scenario:

- [Targets](#) • [Weapons](#) • [Platforms](#) • [Test Data](#) • [Special Features](#) ...

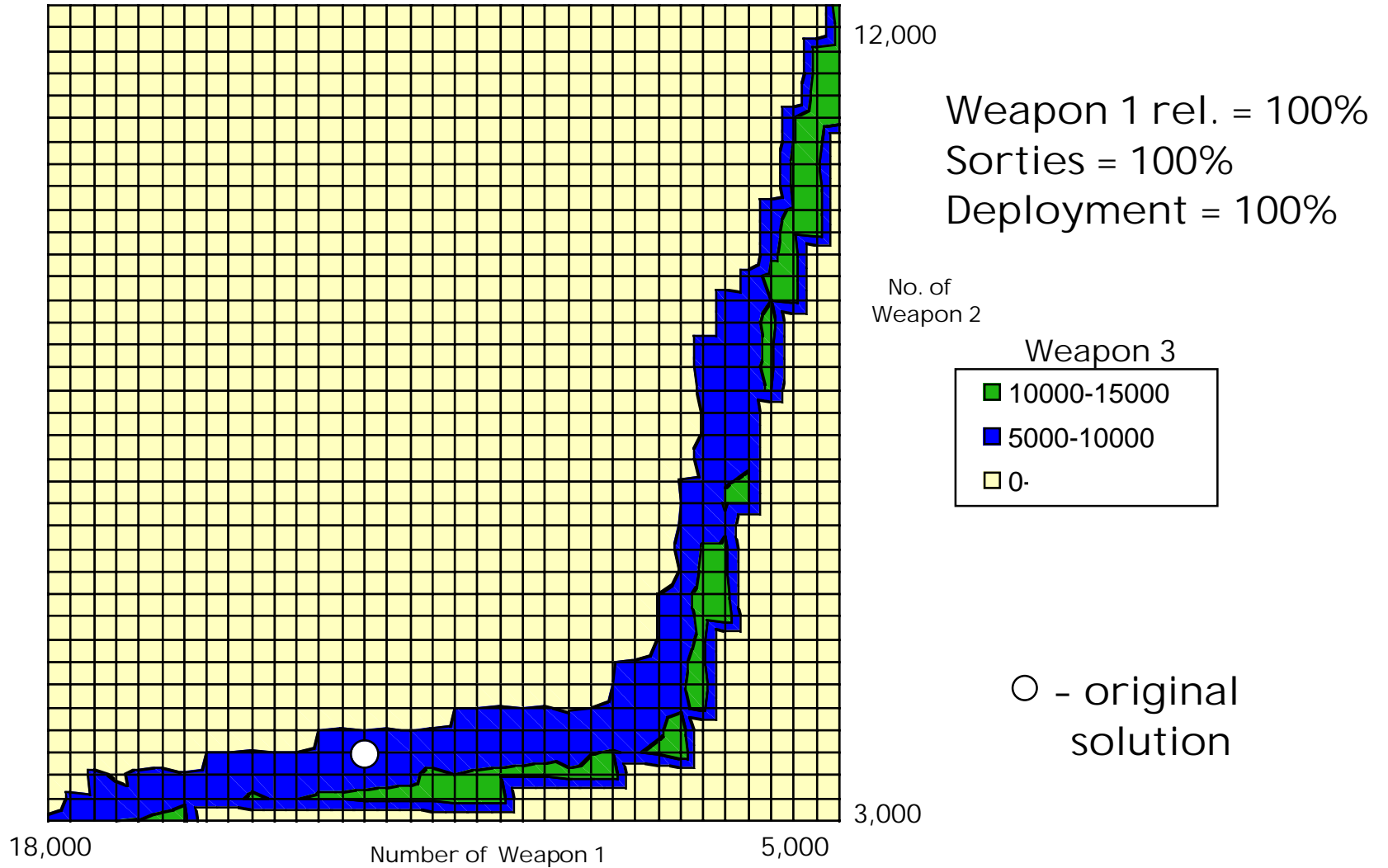
Find Optimal Solution:

Example: Campaign in Country X in Year Y is completed in
22 days

Using:

- TOTAL Weapon 1 USED: 15,502
- TOTAL Weapon 2 USED: 6,960
- TOTAL Weapon 3 USED: 5,003

Weapon 1/2/3 Mix Trades

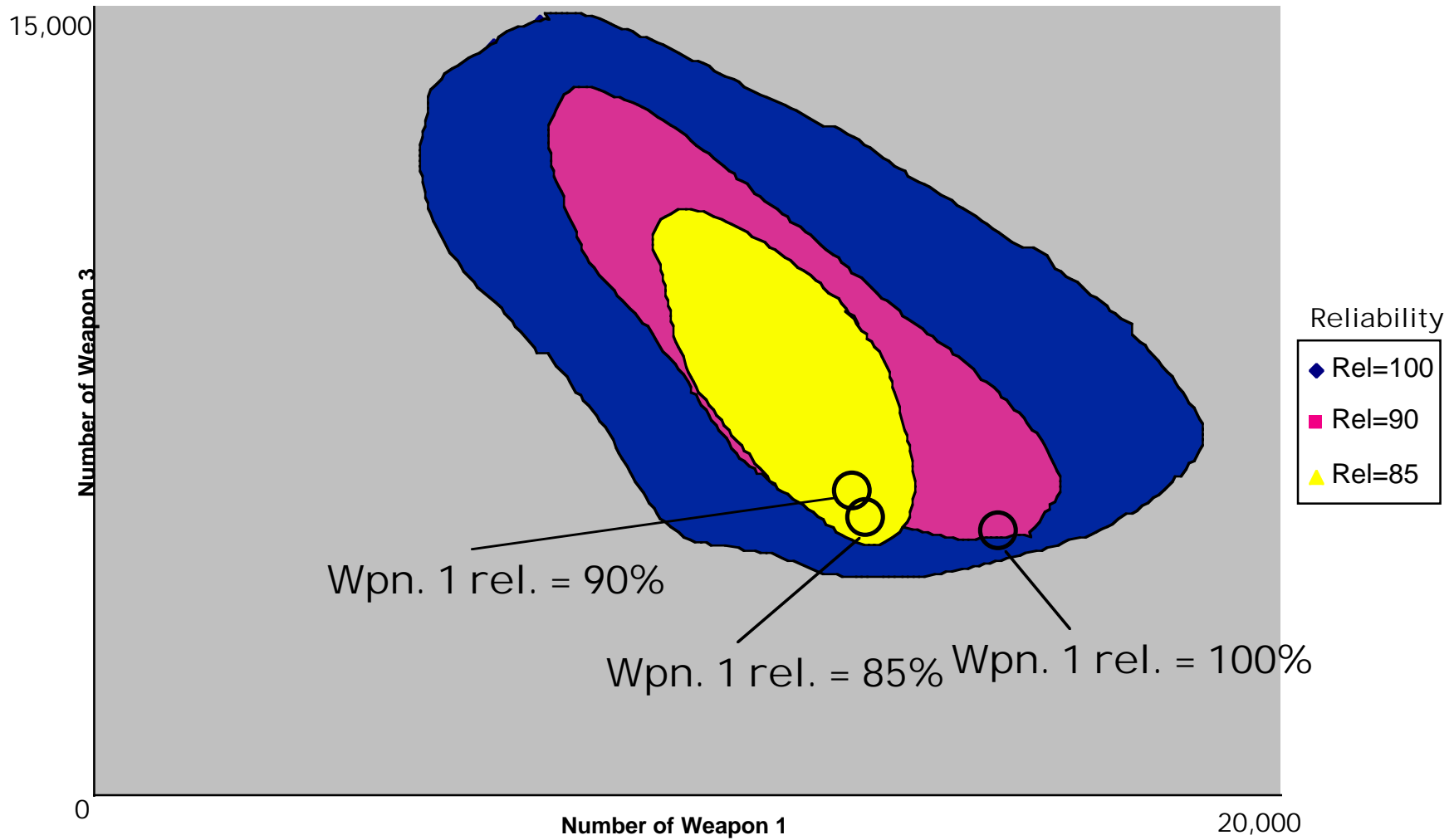


Regret Region Analysis to Find Robust Decisions for Deeply Uncertain Problems

- Intersection of level sets for all plausible scenarios is set of options performing satisfactorily on all of them
- Calculate Regret (Savage, 1950) for policies across scenarios
- Search for cases for which proposed decisions fail to perform well.
- Display minimal regret policy across scenarios
- Support human/machine collaboration in devising compound policies robust across wider ranges of cases

Weapon 1/3 Mix Trades

Weapon 1 Reliability = 100%, 90%, 85%



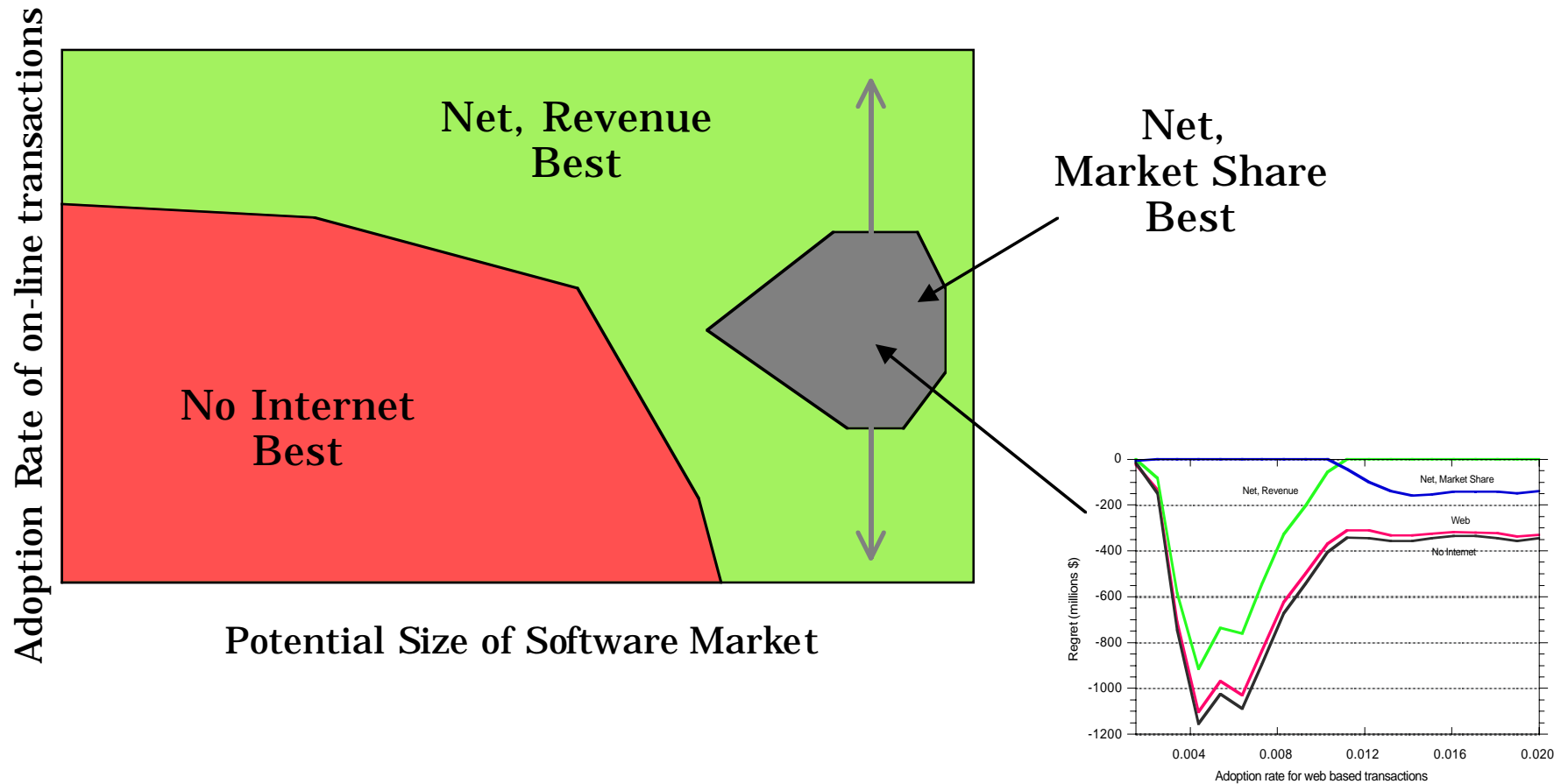
Compare Four Alternative Strategies for Internet Commerce

Results of Monte Carlo sample over uncertainty space:

•	Mean Profit	Mean Regret	Worst Regret
•			
• Net, Revenue	\$236	-\$14	-\$1,290
• Net, Market Share	\$231	-\$16	-\$254
• No Internet	\$217	-\$45	-\$938
• Web	\$205	-\$46	-\$1,308

But we have much more information than in these simple summaries

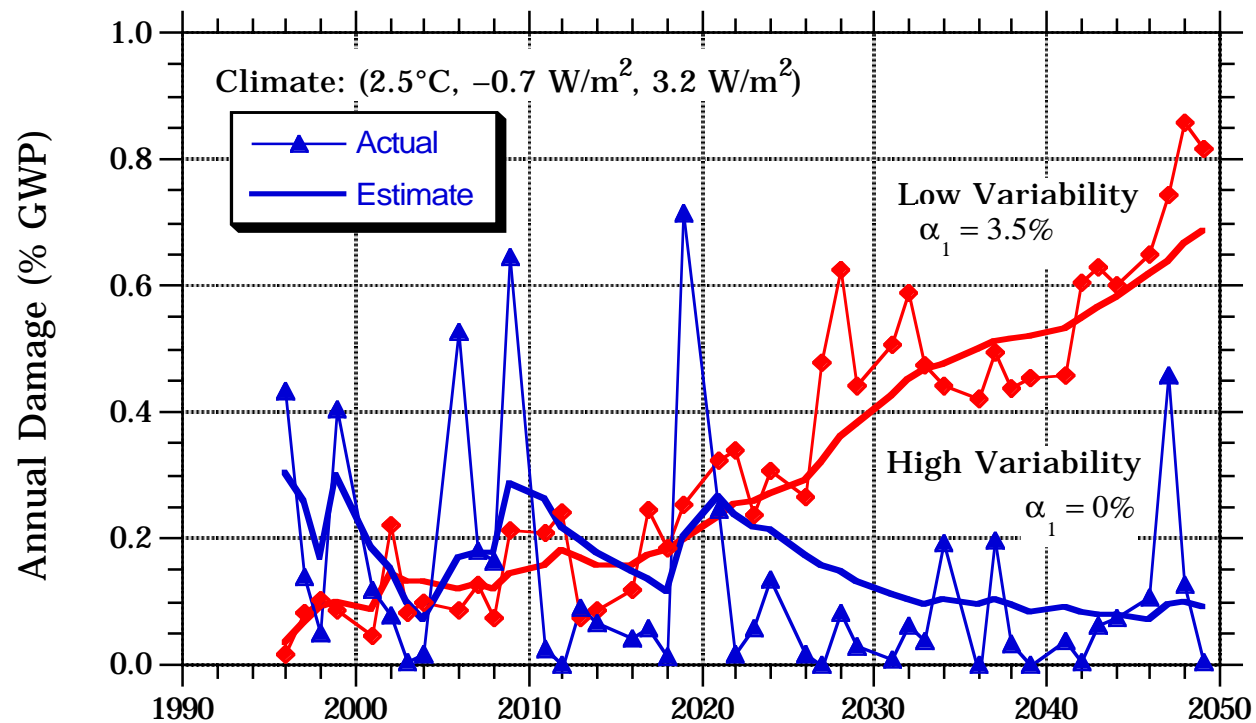
Search for High Regret Cases Yields Regime with Qualitatively Different Behavior



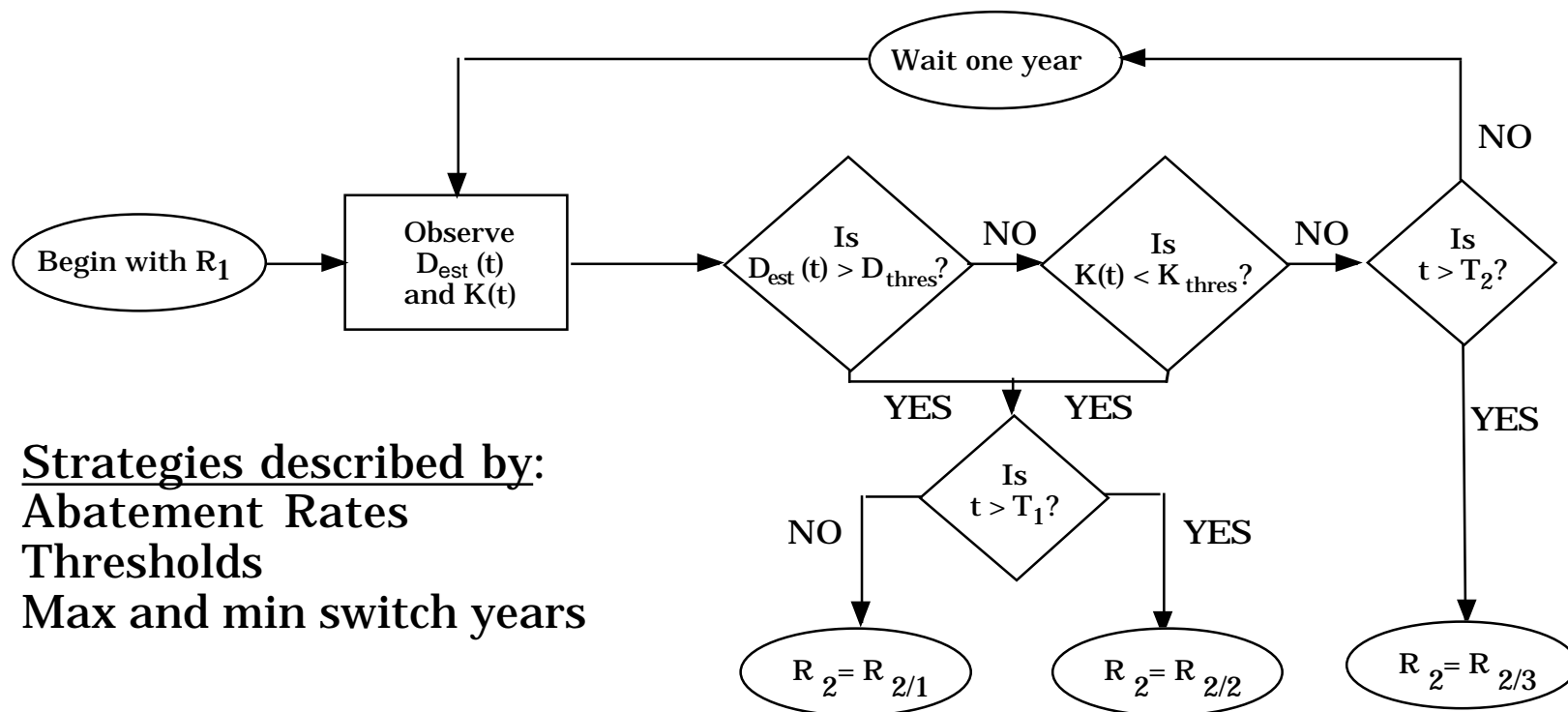
Adaptive Policies

- Combine policies that perform well under differing circumstances with logic that picks among them based on future information
- Test ensembles of alternative adaptive policy options against ensembles of possible future conditions (challenge sets)
- Search for cases that break candidate policies
- Use Robust Region Analysis to identify limits of candidate adaptive policies
- Iterate, combining human and machine resources to devise the most robust adaptive mechanism

Variability Can Mask Trends

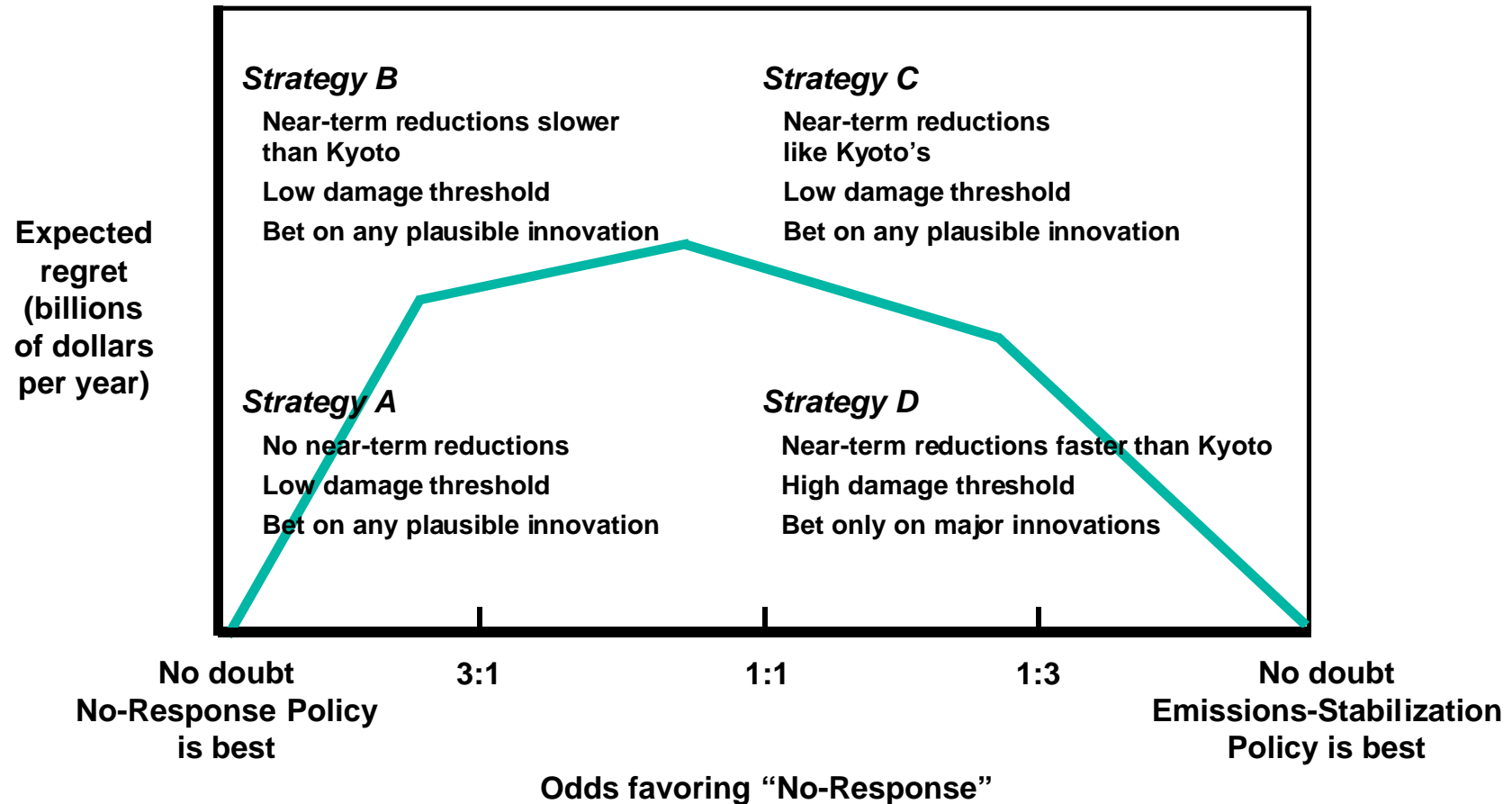


Adaptive-Decision Strategy Responds to Dangers and Opportunities



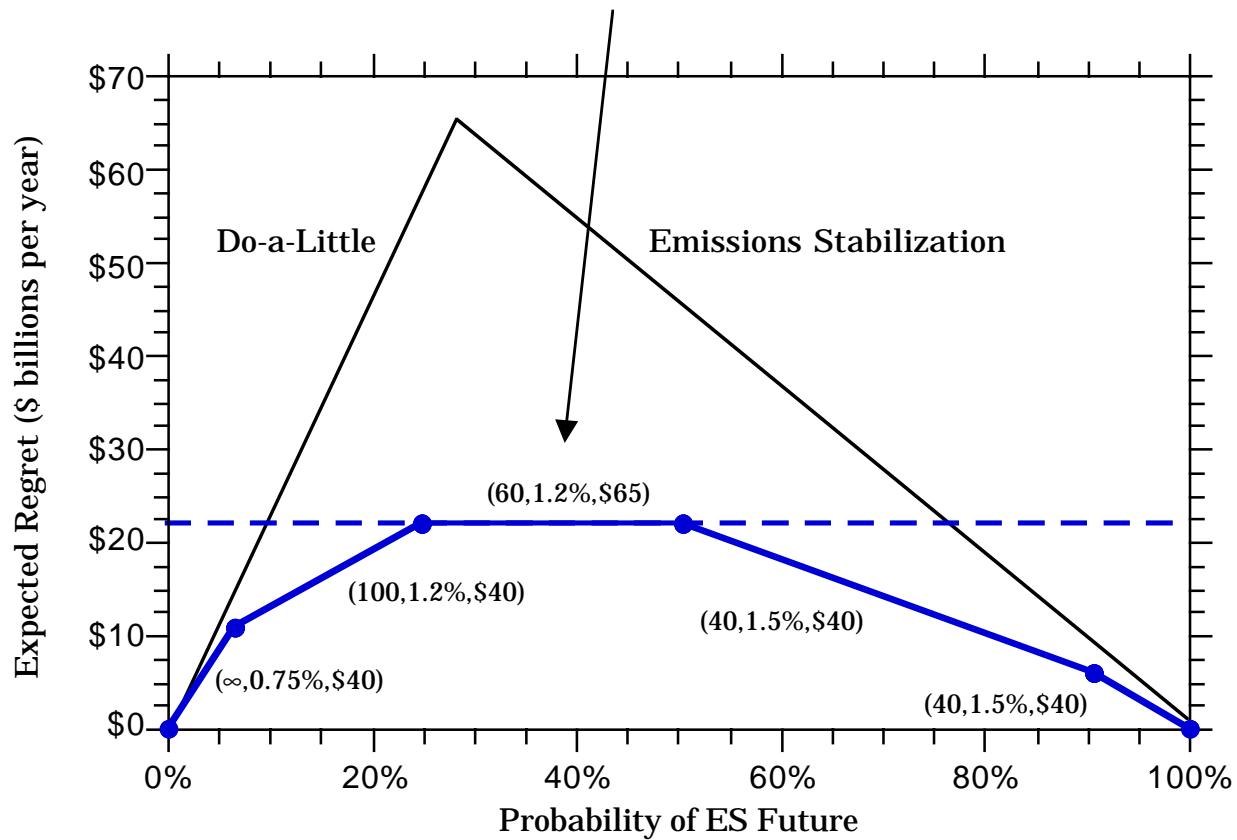
Strategies described by:
Abatement Rates
Thresholds
Max and min switch years

Need to Choose an Entire Strategy Not Just Debate Near-term Reductions

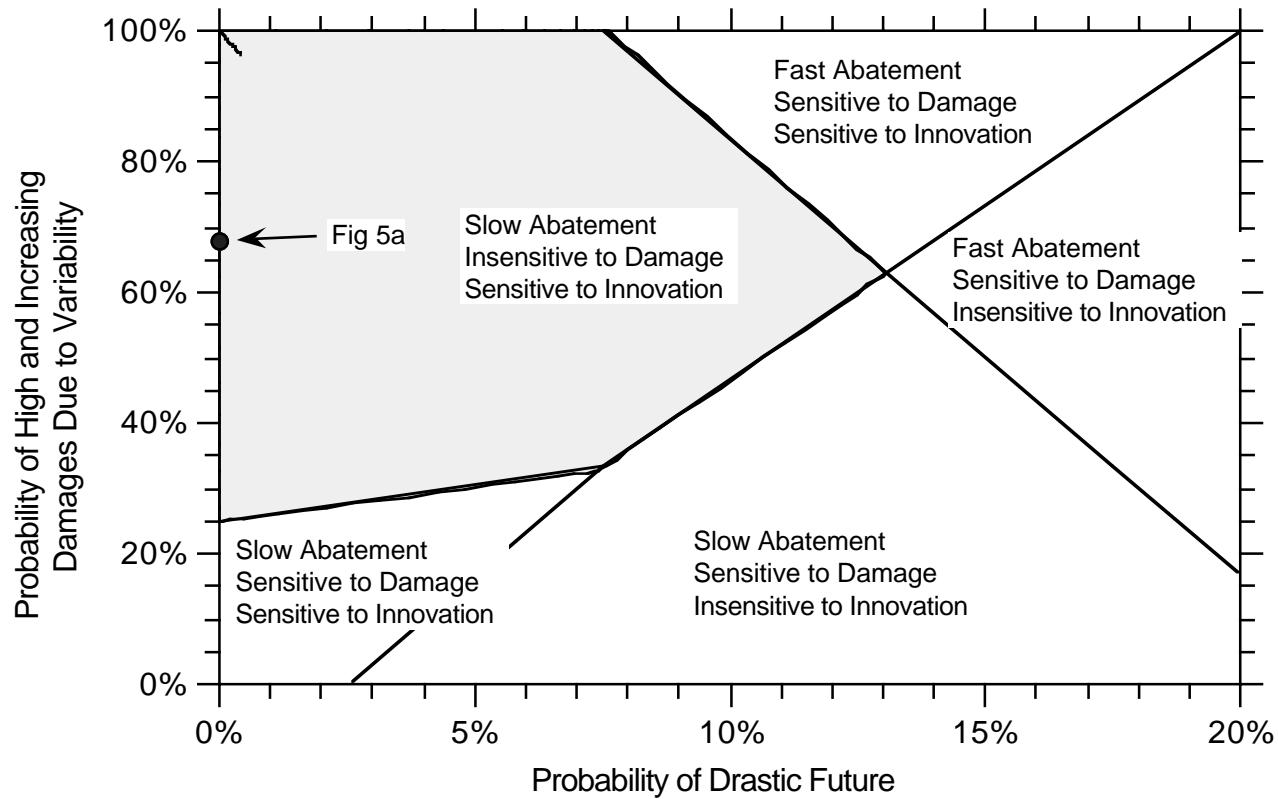


Search for most robust strategies

Most robust strategy has moderate near-term reductions, is insensitive to damages, and is sensitive to trends in "innovation."

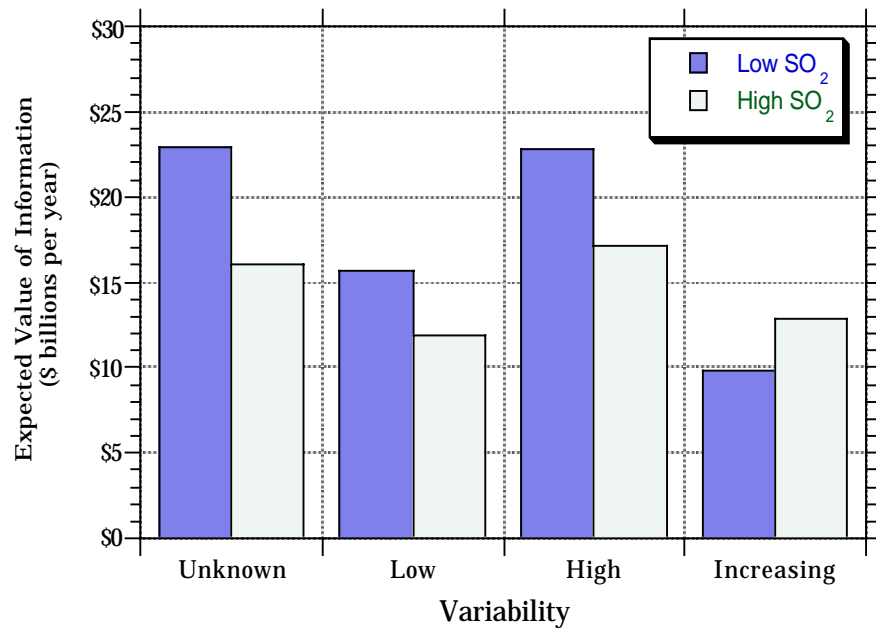


A Map for Creating Scenarios

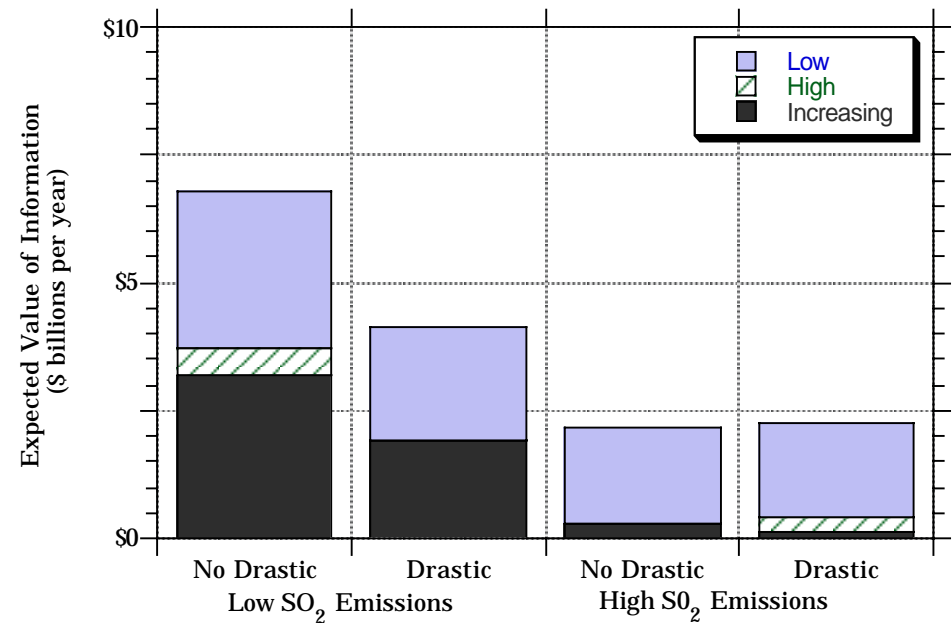


Value of Information on Variability 1/3 to 1/8 as Valuable as Information That Determines Optimum Long-Term Policy

Value of Information Distinguishing DAL and ES Futures



Value of Information about Variability



CAS Provides General Improvement to Decision Support Software

- Powerful Computer Assisted Reasoning requires an appropriate division of labor
 - machines do what they do best
 - logically trace the implications of complex information and relationships
 - humans do what they do best
 - reason about pragmatics rich social contexts and deep uncertainties that are difficult to automate
 - recognize patterns in the outcomes of constellations of computational experiments