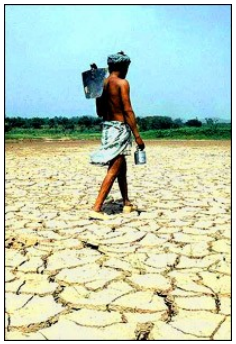
Exploiting Complexity

The abaci Partnership

Is Agent-based Modelling 'Real-world-ready'? - A Systematic Analysis



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A presentation to: UCL / Global System Dynamics Project

Date: 25 Nov 2009

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Aim, Context and Assumptions

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- Aim - to examine the assertion:

  Agent-based Modelling (ABM) is not yet 'real-world ready'

  - sub-aim: to consider what may have to be 'done differently' if the assertion proves to be justified
- Context - UK National Infrastructure for the 21st Century
- Assumptions, that the audience is:
  - fully familiar with ABM
  - also familiar with terminology and concepts from complexity science
- Given, that:
  - we all know models are wrong but that some are useful!
  - no one disputes Gödel's 'Incompleteness Theorem'

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[References are provided at the end of the Presentation]

1-1 Real-world ready (RWR) is what?

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- To be real-world-ready is to be able to meet the needs of ***Practitioners*** - defined as:

  "Those who have to engage with the *Complex Realities* of day-to-day life in their work"

- ***Complex Realities*** being defined as:

  "Real-world situations which co-evolve with humans in some environment in a dynamic manner which cannot be stopped and which can only be changed through engagement and influence."

- Assertions:
  - "To be RWR, Agent-based Modeling (ABM) must be able to deal with the consequences of these Realities."
  - "Real-world 'systems' are open and cannot be bounded".

1-2 Describing Complex Realities - a Thought Experiment

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- Think of a fast-flowing river:
  - your task is to navigate down it to win a race,
  - the river contains rocks, rapids and whirlpools,
  - other people are already on the river, exploiting its dynamics to speed their journey
  - you can't get left behind, you must engage.
- How do you approach this task?
  - stand on the bank and measure and plan? That's not enough
  - do you have the capabilities to engage - to get on the river?
- The River is a metaphor for the kind of dynamic and complex operational environment we Practitioners face

1-3 Practitioners' view of Complex Realities

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- To make effective decisions in complex environments requires us Practitioners to understand:
  - what causes (complex) phenomena to come about - we have to deal with the realities - can't 'assume' them away
  - how to engage with, shape and influence various types of dynamic phenomena
  - what we (and our partners) need to do differently when decision-making and acting in complex environments
  - how to specify capabilities which are suitable for use in complex environments - such that they are 'complexity-worthy' [in the way we expect things to be sea-worthy]
- We Practitioners do NOT need complexity science tutorials - but we do need to know how to put complexity to work more effectively. Can ABM help? Is it RWR?

1-4 Characterising Real-world Readiness

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- What are the potential dimensions of RWR? Measured against the ability to address / deal with:
  - the past, the now, the future
  - scales and variety of contexts:
    - over time - milliseconds to millenia
    - over size - micro to macro
  - various degrees of certainty / knowability
  - various degrees of variety / homogeneity
  - dynamic, emergent 'on-the-fly' phenomena
  - various natures of interdependency / connectedness
- All too complicated - suggest assess RWR in terms Practitioners would understand . . .

1-5 Dimensions of Real-world Readiness

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- This presentation will assess ABM against four dimensions - examining their ability to address a range of:
  - information qualities
  - problem solving and decision-making styles
  - types of phenomena
  - time horizons
- This will provide a framework for systematic analysis
- In addition, this presentation will touch on previous research which has:
  - documented the level of performance of agents in general
  - indicated the challenges to be addressed

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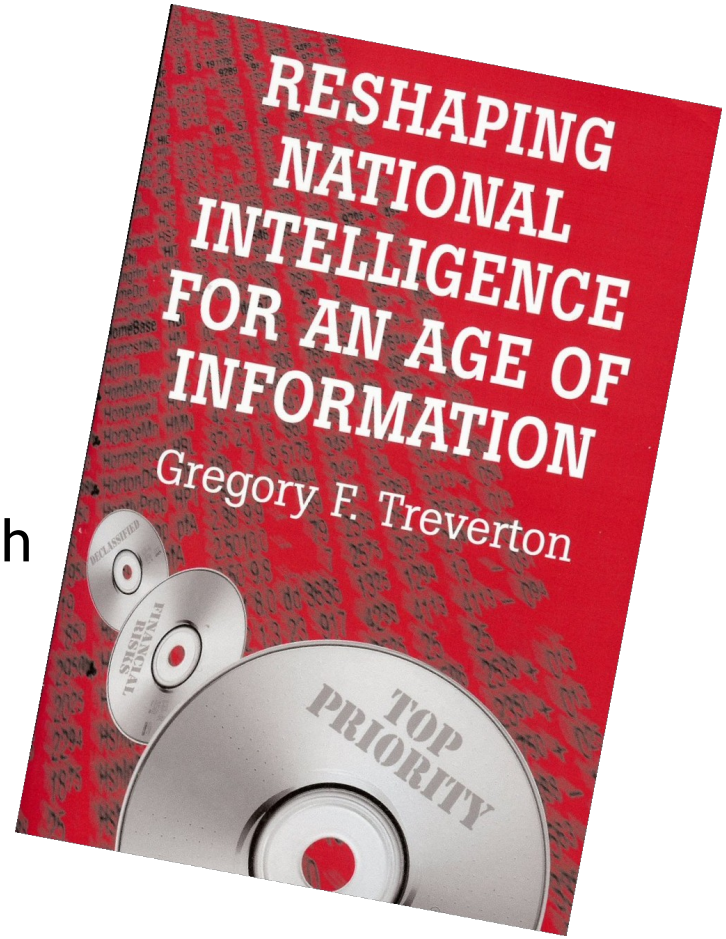
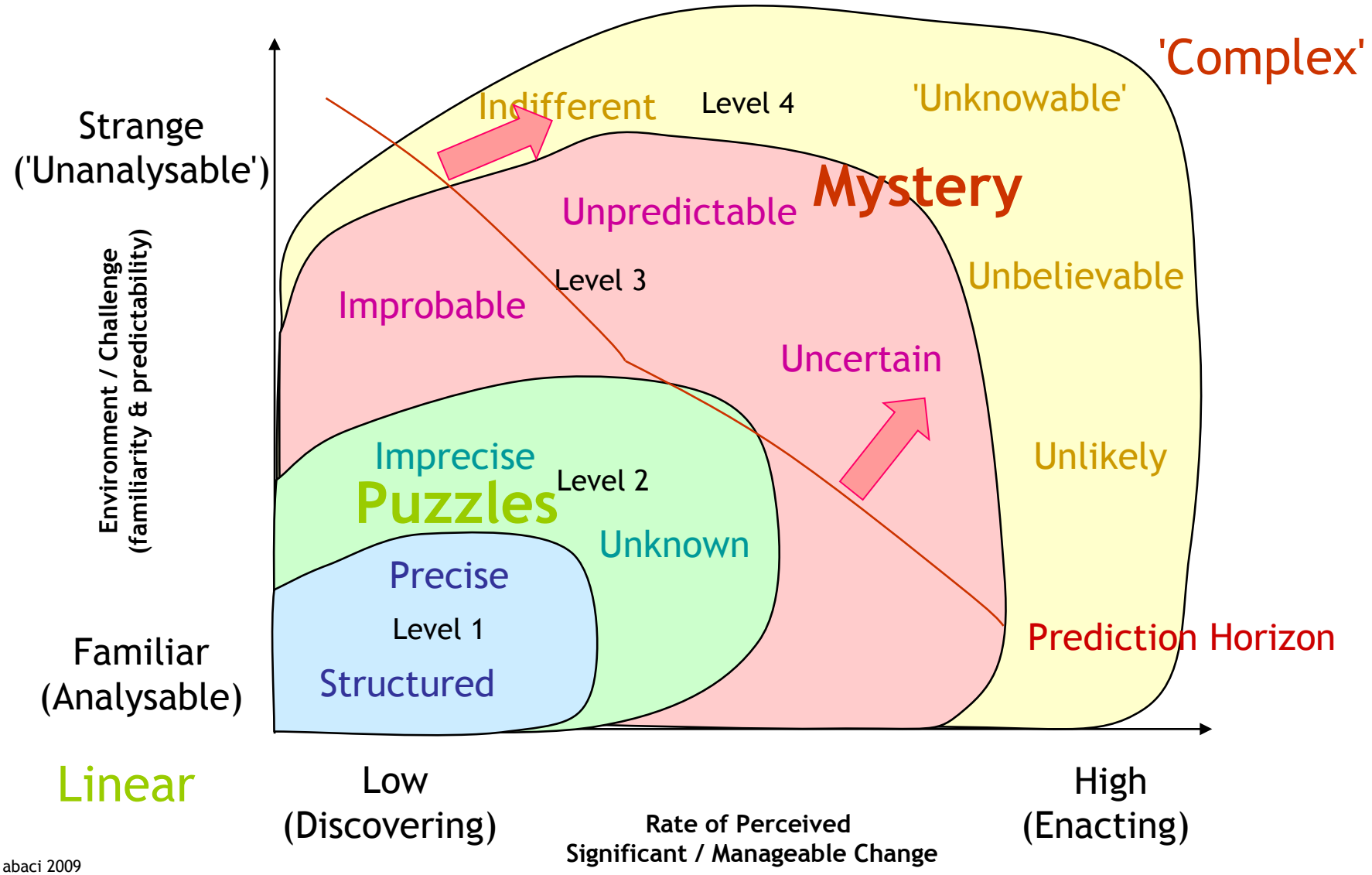


[References are provided at the end of the Presentation]

2-1 Four Information Qualities



2-2 Information Qualities in Detail

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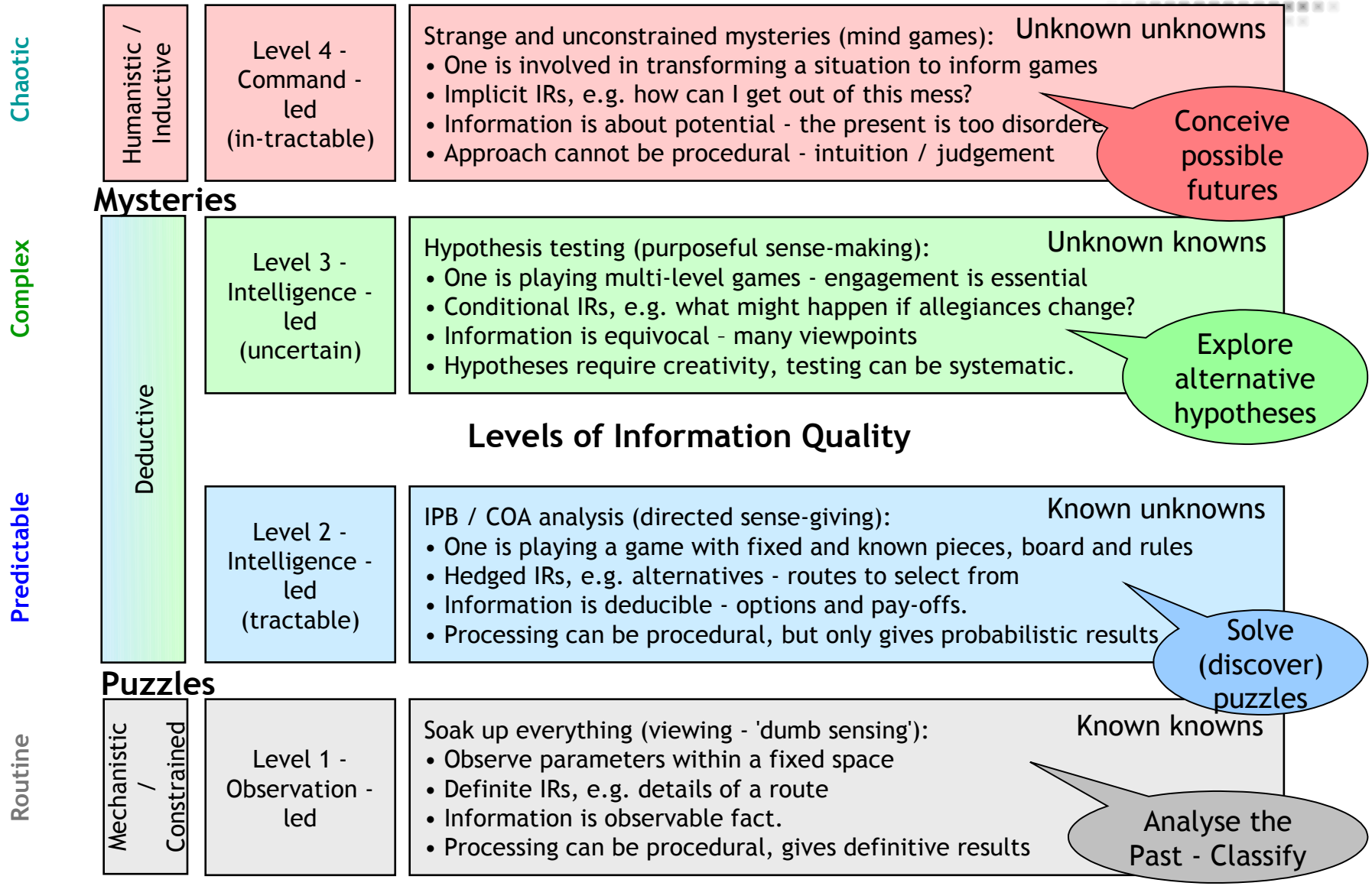

Adapted from Marsay & Green - QinetiQ 2005

2-3 ABM and Puzzles and Mysteries

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- Mystery: eg Resilience across CNI (involves emergence, imaginati… reativity)
  - Have no / little knowledge of the nature or extent of t…
  - Build theories / hypotheses or 'fantasies' (… nets of evidence / patterns)
  - Project the 'models' in to th… compare to the (multiple) perceptions of the world - inconsis… ontradiction' must be allowed to co-exist
  - Consid… indicators / weights of evidence that might exist / be required
  - …serully direct the sensing (may shake the tree first) to support / refute etc
  - No 'final, correct' answer, instead: judgement, assessment, probability etc
- Puzzle: eg, Logistic scheduling (can be a procedure)
  - Know the puzzle (bound the problem) an… thing is missing
  - Able to classify the missing i… escribe it in 'fact-like' terms
  - Able to search f… the missing item(s)
  - Ab… that search result or item collected is the missing one
  - …le to fit the new fact in the puzzle and confirm it is the 'right' piece

This area largely intractable for ABM - human dimension critical

This area tractable for ABMs - knowable and collectable

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[References are provided at the end of the Presentation]

3-1 Types of Phenomena

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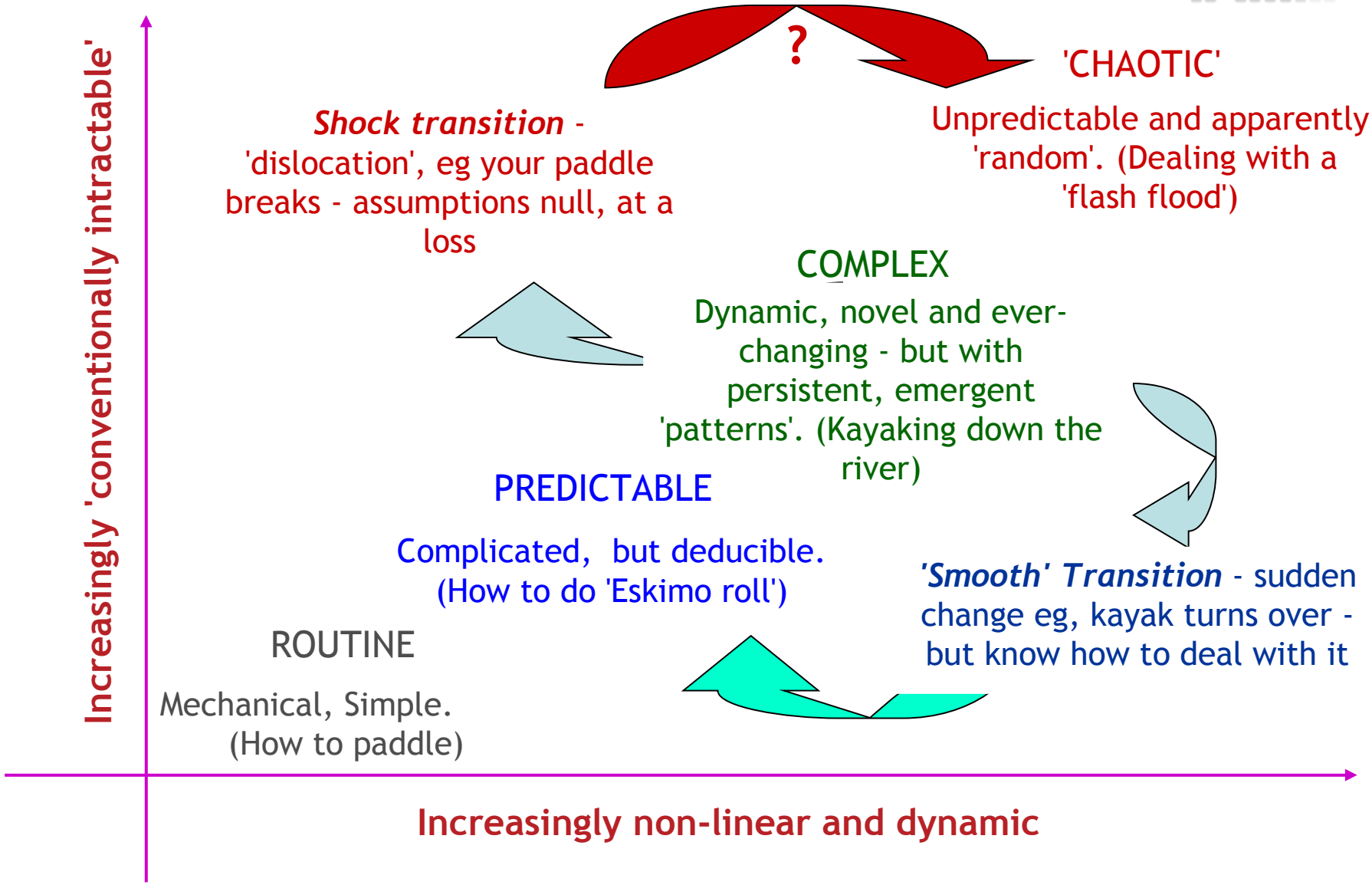

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4-1 Decision-making strategies

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- Group 4 - Consider possible futures:
  - Enact: conceive futures, probe, hypothesise, seed
- Group 3 - Engage and influence:
  - Explore: engage, perceive, adapt, influence
- Group 2 - Planning and control:
  - Discover: sense, analyse, plan, respond
- Group 1 - Analysis of the past:
  - View: sense, recognise, react

4-2 Match Approach to Phenomena

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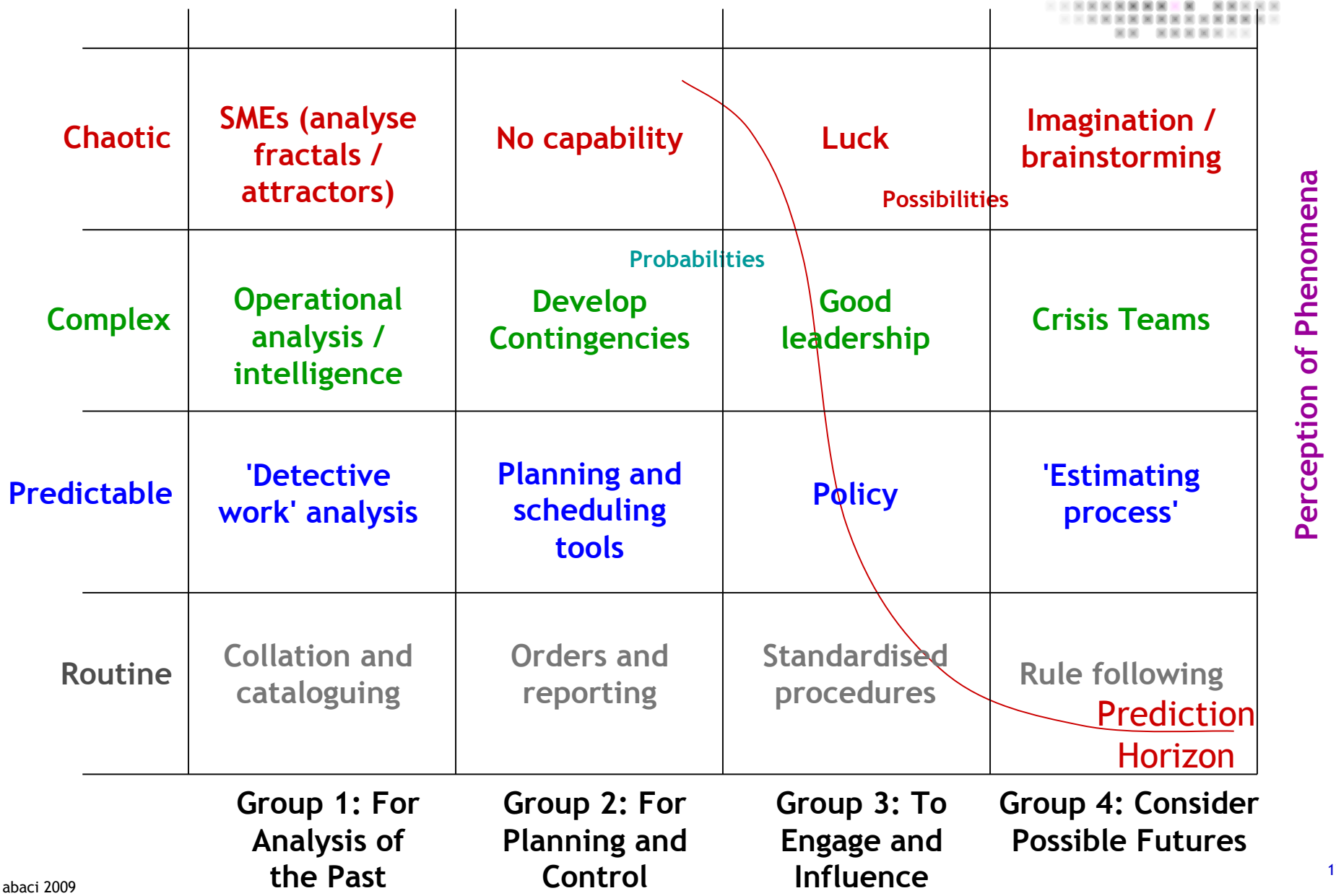

4-3 Corresponding 'Tools'

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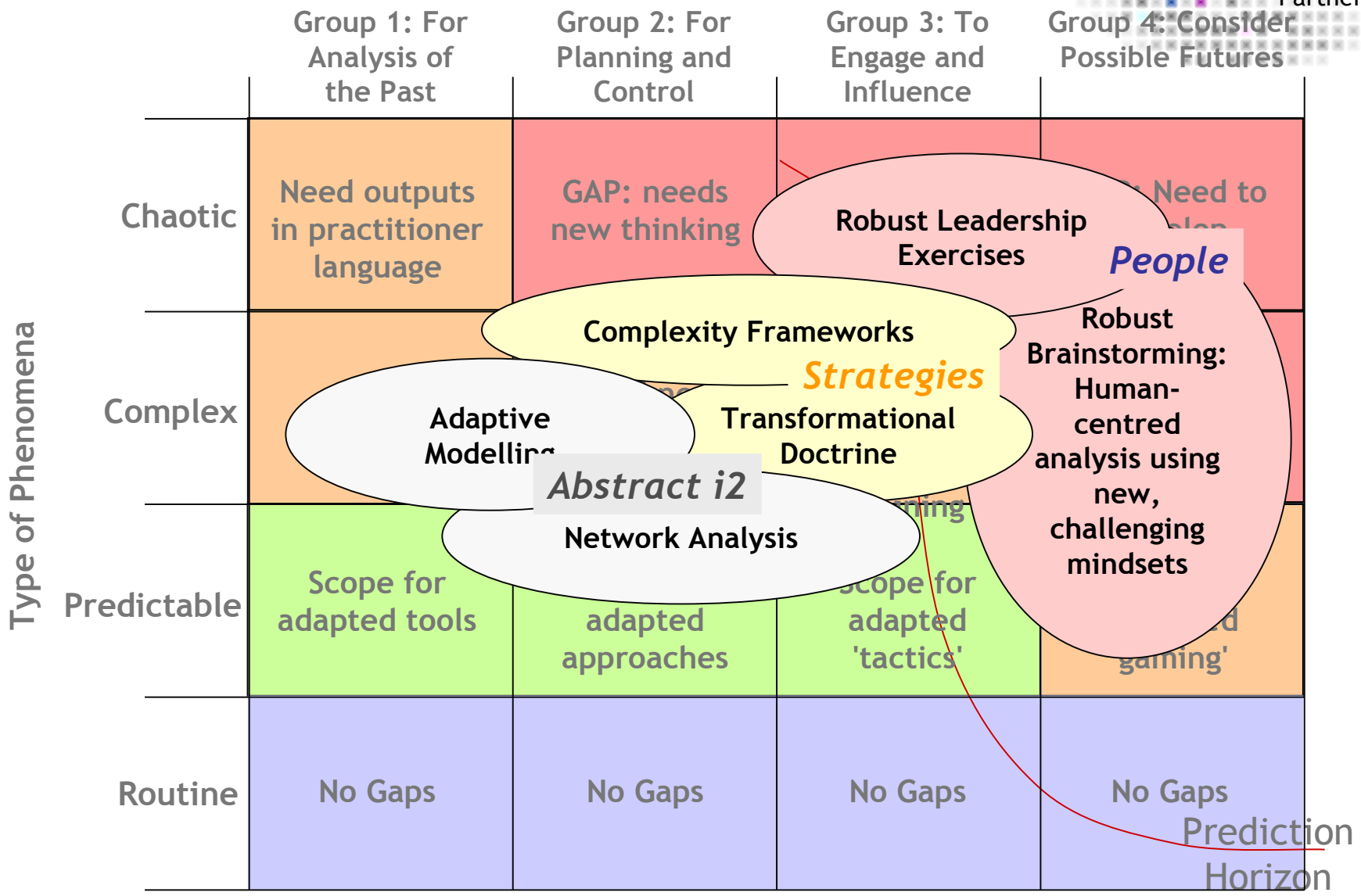

4-4 Complex realities - Assessment Cube

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National Infrastructure for the 21st century is where?

Group 1: For Analysis of the Past

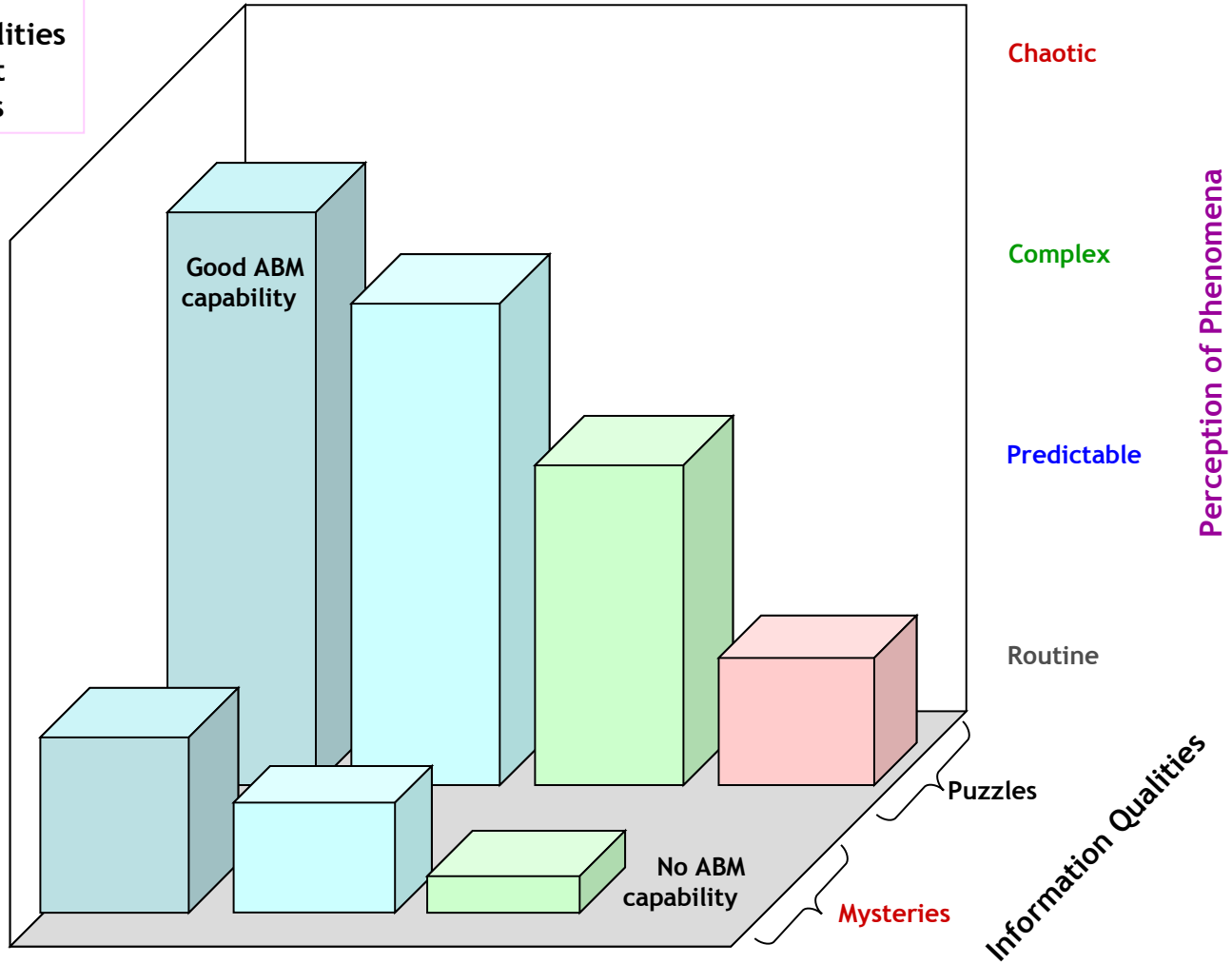
Group 2: For Planning and Control

Group 3: To Engage and Influence

Group 4: Consider Possible Futures

Volume of Cube = Space of Complex Realities Practitioners must be able to address

Height of Bar = ABM's Degree of Real-world Readiness



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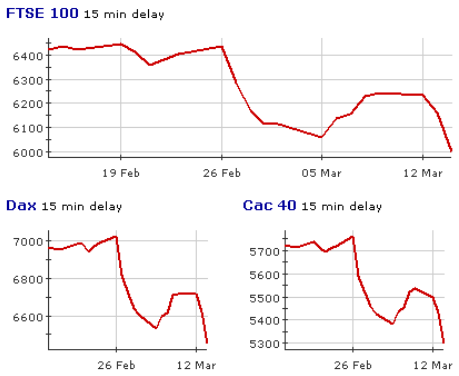

[References are provided at the end of the Presentation]

5-1 Temporal Aspects

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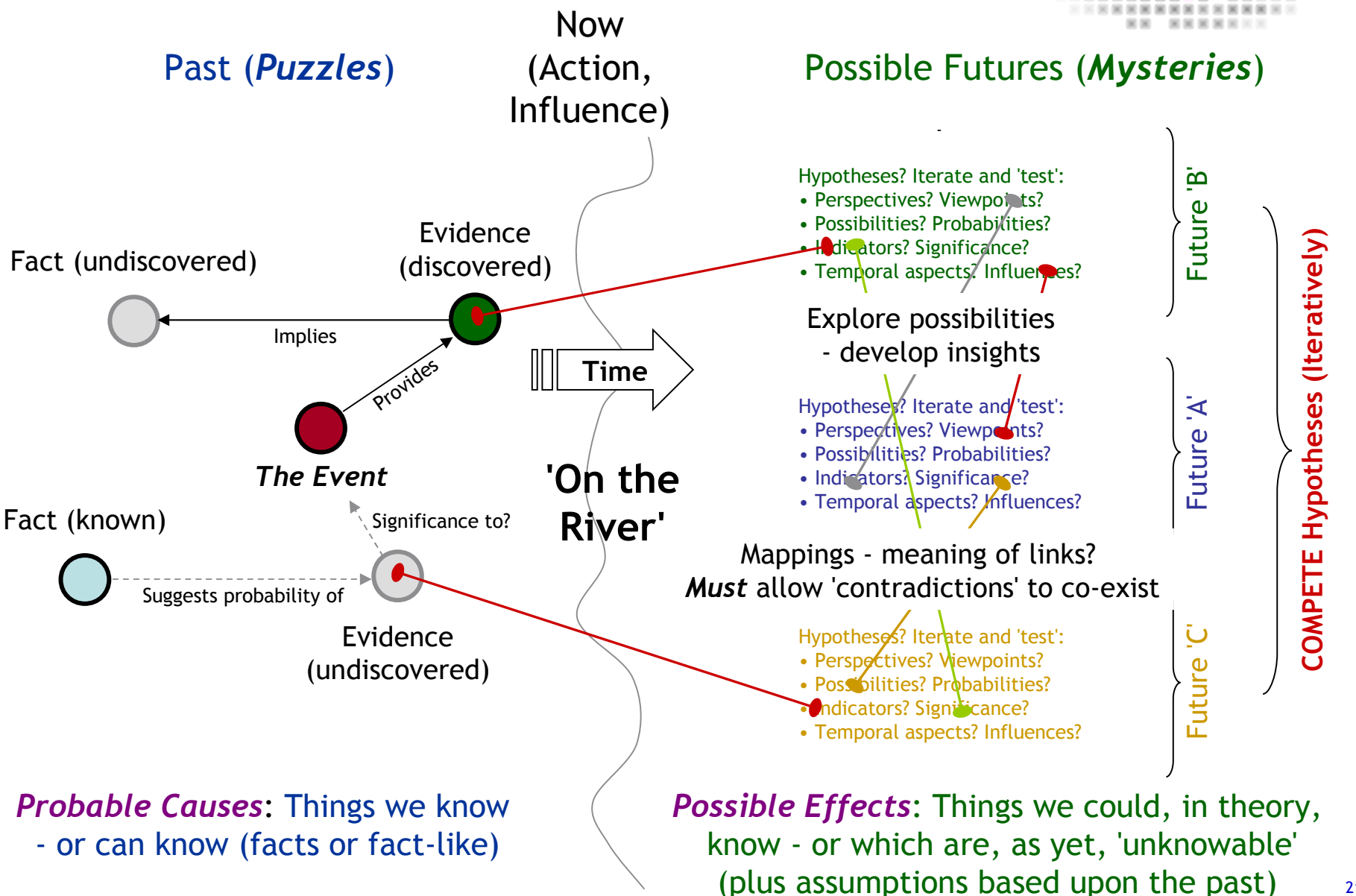

Probable Causes: Things we know - or can know (facts or fact-like)

Possible Effects: Things we could, in theory, know - or which are, as yet, 'unknowable' (plus assumptions based upon the past)

5-2 Practitioners' Complex realities - which parts can ABM address?

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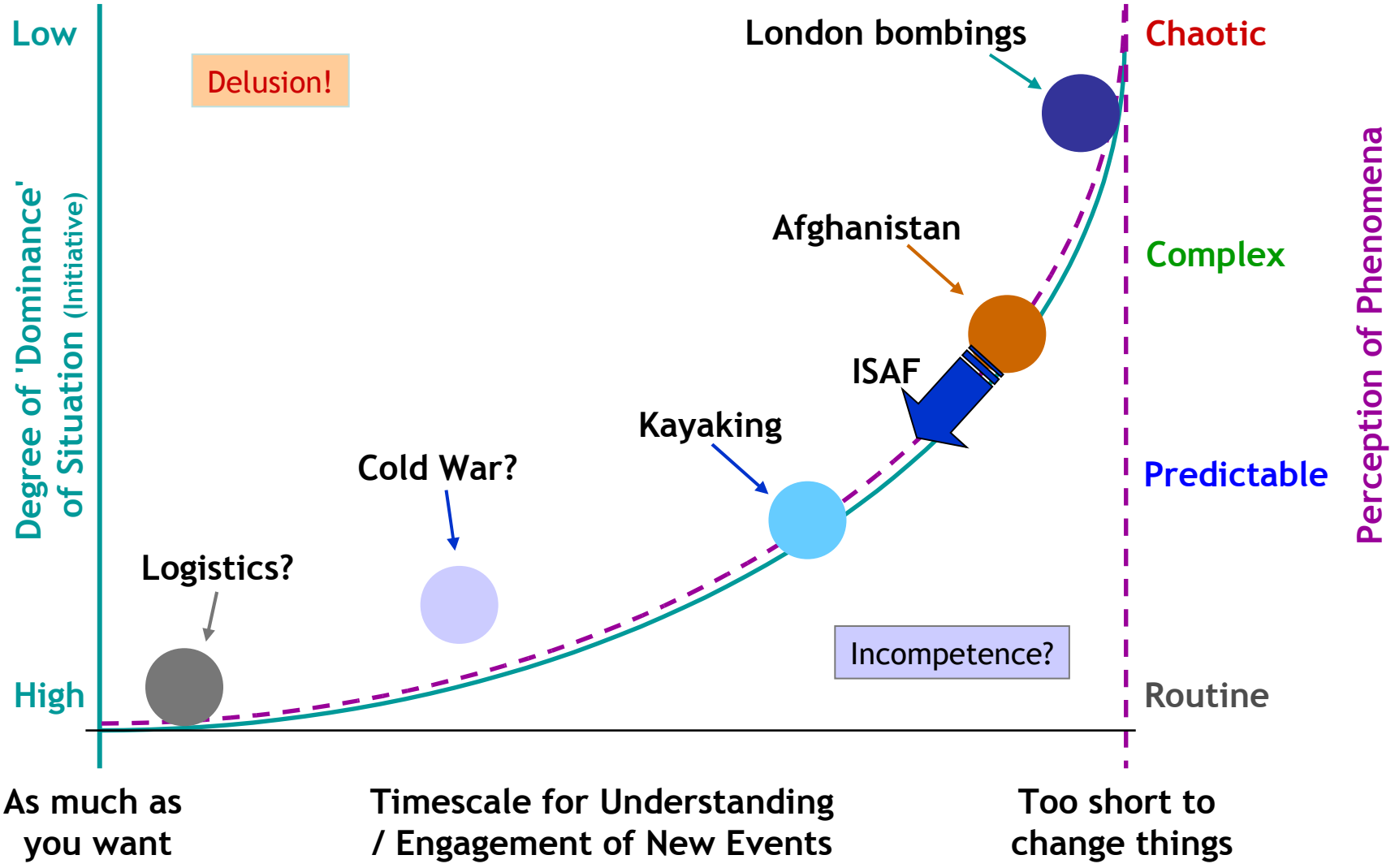

5-3 Issues of cross-scale Interactions

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- Human-machine 'symbiosis' (extend into cyberspace)
- Human society, structures and machines
- Socially intelligent beings who conceive futures
- Tribal, co-operative creatures
- Stereo-vision air-breathing creatures
- Fast 'pack' land animals
- Purposeful creatures
- 'Sensible', free-moving creatures
- Self-*, cell-based forms
- 'Stable' biological environment
- 'Stable' geo-chemical environment
- Large-scale to sub-nano-scale structures and forces

All are, potentially, significant actors in Real-world Complex Realities

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[References are provided at the end of the Presentation]

6-1 Some Relevant Research

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- DAMAS: Defence Applications of Multi-agent Systems:
  - Beautement, P. Allsopp, D. Greaves, M. Goldsmith, S. Spires, S. Thompson, S. Janicke, H. 'Autonomous Agents and Multi-agent Systems (AAMAS) - Issues and Challenges' published in “Lecture Notes in Computer Science”. From: http://dx.doi.org/10.1007/11683704_1. Applications of Multi-Agent Systems: International Workshop, DAMAS 2005, Utrecht.
- NASA / AMES:
  - Making Agents Acceptable to People. Bradshaw, J. M., Beautement, P., Breedy, M. R., Bunch, L., Drakunov, S. V., Feltovich, P., Hoffman, R. R., Jeffers, R., Johnson, M., Kulkarni, S., Lott, J., Raj, A. K., Suri, N., & Uszok, A. (2003). In N. Zhong and J. Liu (Eds.), Handbook of Intelligent Information Technology. Amsterdam: IOS Press / Springer, 2004.
  - Bradshaw, J M, Boy, G, Durfee, E, Gruninger, M, Hexmoor, H, Suri, N, Tambe, M, Uschold, M, and Vitek, J., editors. Software Agents for the Warfighter. ITAC Consortium Report. 2002. Cambridge, Massachusetts, AAAI Press/The MIT Press.
- DARPA:
  - The Coalition Agents Experiment: Network-enabled Coalition Operations. M Kirton et al. In Journal of Defence Science (Special edition), Vol 8, No 3, Sep 2003.
  - Coalition Agents Experiment: Multi-Agent Co-operation in an International Coalition Setting. David N. Allsopp et al. In a special edition of the IEEE, Intelligent Systems Journal, 2002.

6-2 USA JFCOM Comments on EBO

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- Effects-based approaches try (by exhaustive analysis in advance) to predict the future effects of interventions.
- Comd JFCOM has ***rejected*** EBO / ONA (operational network analysis) approaches because they:
  - assume a level of *unachievable* predictability
  - *cannot correctly anticipate* reactions of complex systems (e.g. leadership, societies, political systems, etc)
  - call for an *unattainable level of knowledge* of opponents
  - are *too prescriptive*, focussed on 'facts' and over engineered
  - *discount the social and human dimensions* of conflict (eg: passion, imagination, loyalty, willpower, variability, culture and power)
  - *promote centralisation* and lead to micro-management from HQs
  - are *staff-led* [ie, controlled by process-followers], not Command led [ie, hypothesis-led by active problem-solvers]
  - *fail to deliver clear and timely direction* to subordinates

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7-1 Is ABM Real-world ready?

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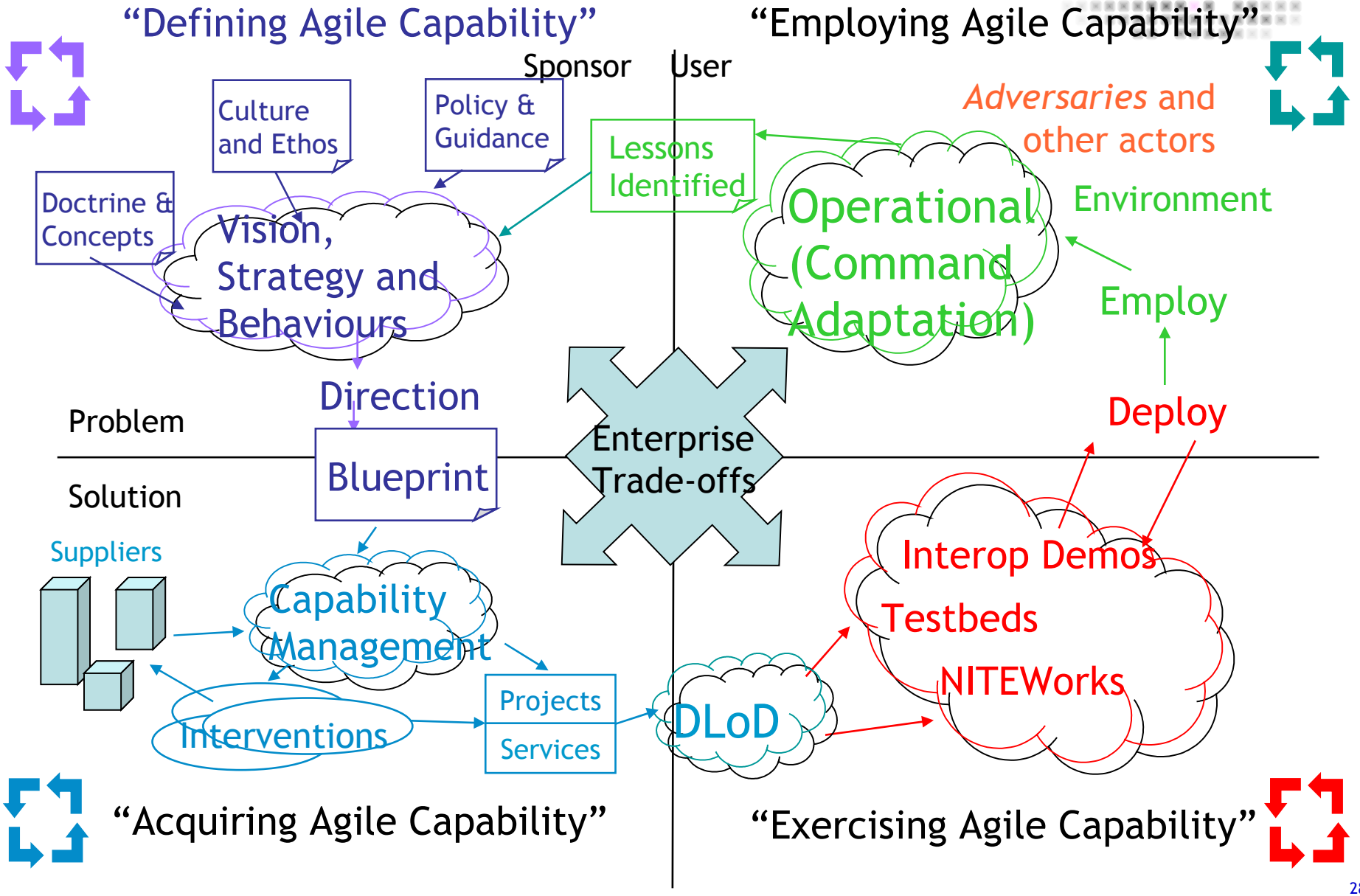
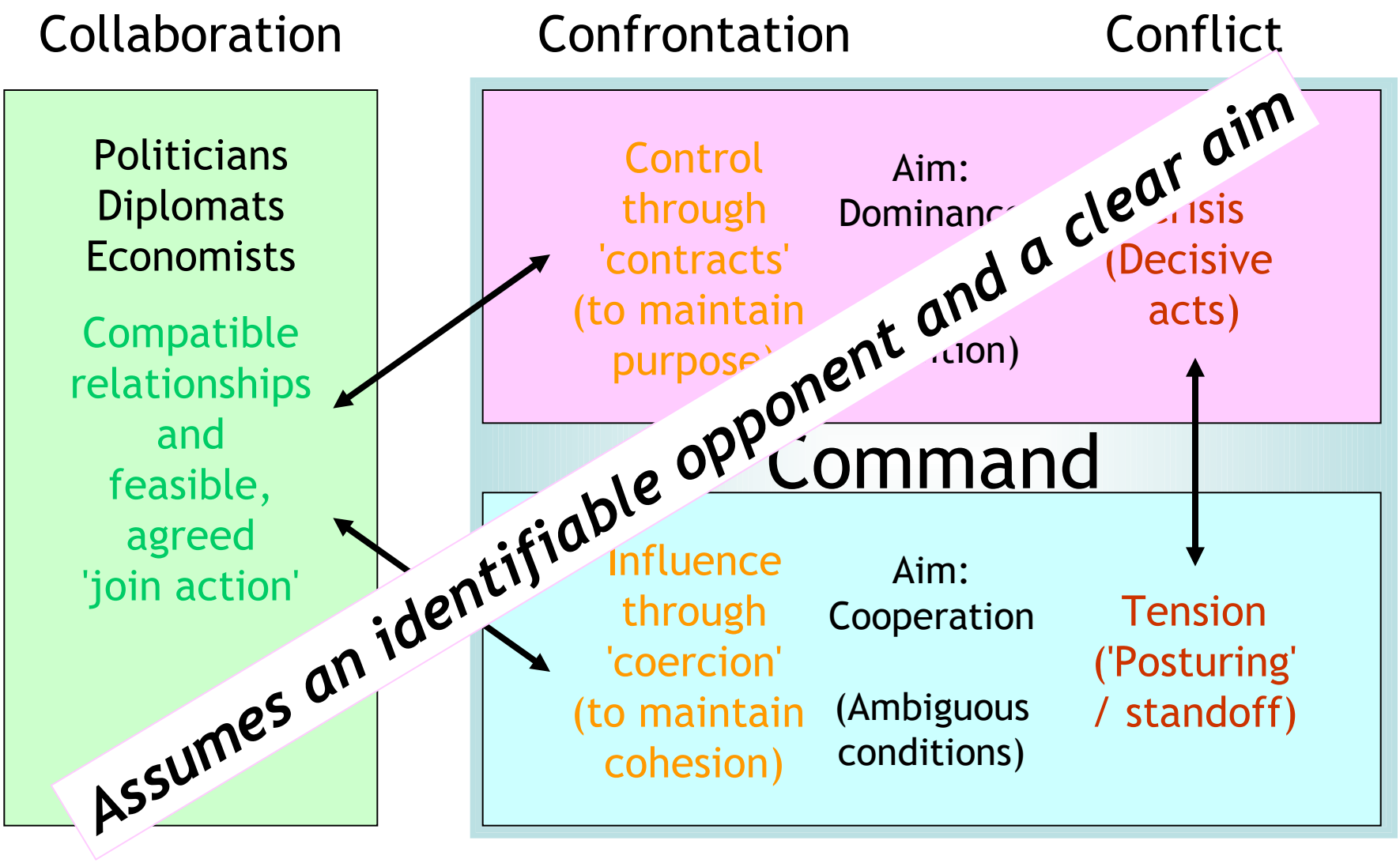


7-2 Heterogeneous Realities



7-3 Is ABM Real-world ready?

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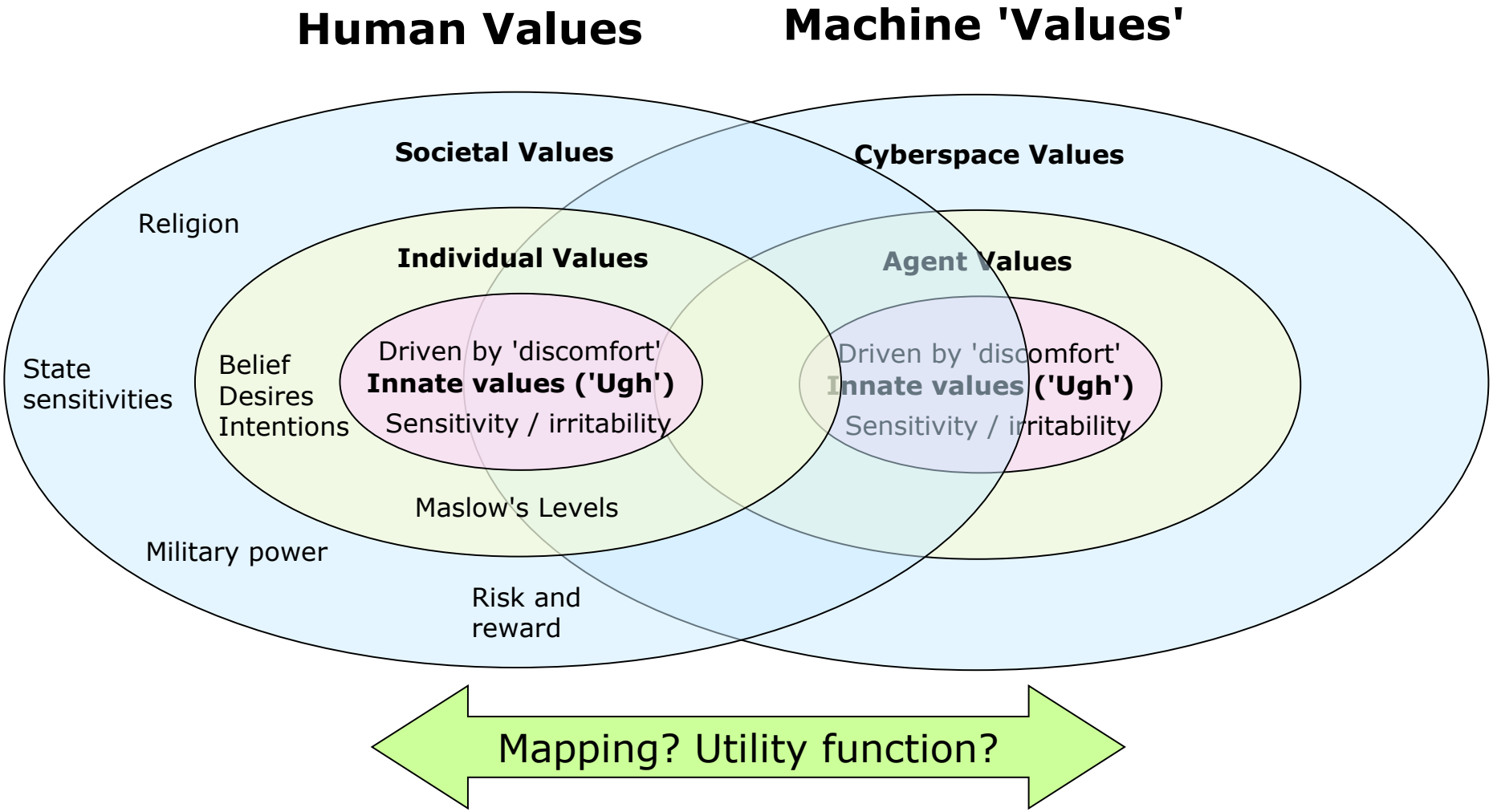

The machine 'value-space' has its own drivers which, innately, are not the same as those in human-space. For agents to reason on our behalf, it is necessary to perform some mapping. The question is, what are the meaningful equivalents in terms of what can be sensed / perceived / reasoned about / effected etc?

7-4 Is ABM Real-world ready?

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- In Practitioners terms?
  - ***No, ABM is not RWR***
- In academic terms?
  - ***Yes, for certain applications***
- Impediments:
  - The space of Complex Realities extends into that part which is inaccessible to machines / machine representations
  - ABMs lack the necessary requisite variety for RWR solutions
  - Lack of appropriate data (knowability / collectability)
  - Computability - impossible across scope, level, scale
    - The 'Deep Thought' / "The answer is 42" effect*
    - The 'Prediction Horizon', Gödel's 'Incompleteness Theorem',

* See Douglas Adams "The Hitchhikers Guide to the Galaxy"

7-5 What needs to be done differently?

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- For agent-based modellers:
  - acknowledge the consequences of the Complex realities:
    - be pragmatic about the bounds on modelling
  - in terms related to the Practitioners' context / perceptions:
    - clearly express assumptions, limitations and constraints
    - engage in a dialogue about the relevance of the model
- For Practitioners, be able to understand:
  - the scope / relevance of the model's 'results'
  - their options / request appropriate techniques
  - apply 'common sense'
- For both: a toolset 'Symptom Sorter' is required:
  - work going ahead ***based on the four dimensions*** described

Questions?

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1 What does 'Real-world-Ready' (RWR) mean?

2 ABM and Information Qualities

3 ABM and Types of Phenomena

4 ABM and Decision-making styles

5 ABM, Time and Scale

6 ABM maturity - previous Research

7 ABM - Is it Real-world-Ready?

* Mark Ho

[References are provided at the end of the Presentation]

0-0 Some References

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0-0 Michael Batty - ECCS'09

We do not have any idea how the people in our models will adapt to change and this is not new. The very fact a generation ago we though that we could treat cities in equilibrium is testament to the limits to our knowledge.

But I believe that what all this is showing is that we need new forms of intelligence system to deal with the future where we will have many different models running in parallel, mediated in a context that seeks to 'inform' rather than to 'predict'. The quest is to find the appropriate milieu in which to act in this way.