CS 597: Ph.D. Seminar - fall 2005

A Socio-Technical Foundation for Collaborative Engineering

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a campus-wide research and education initiative on

Collaboration Science and Technology

University of Southern California

iMPACT LABORATORY

Improving
Productivity with
Advanced
Collaboration
Technology

Decision-making Productivity of Engineering Design Teams:

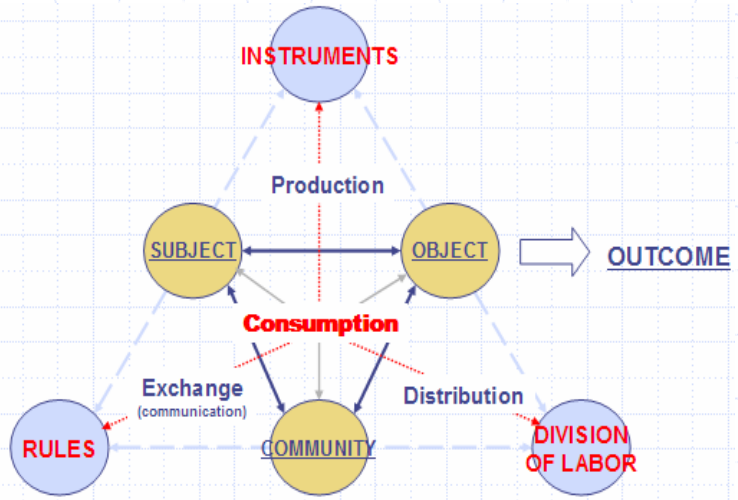
- quality
- speed
- cost

Key Points of This Presentation

- With globalization, collaborative engineering (CE) is in!
  - What is collaboration, and what is collaborative engineering?
- CE research needs a new intellectual foundation
  - The determinism versus constructionism philosophy
  - The purely technical versus socio-technical paradigm
- Group decision is the key challenge of CE research
  - Many types of group decisions
  - A old myth of group decision making
- A socio-technical foundation (STF) for participative joint decisions in collaborative engineering (CE)
  - Organization behavioral theory to model engineering teams
  - Social construction theory to achieve common understanding
  - Social choice model to rate continuous alternatives
  - Collaborative negotiation to support joint decisions
- STF/CE posts many challenging CS research questions

What is Collaboration?

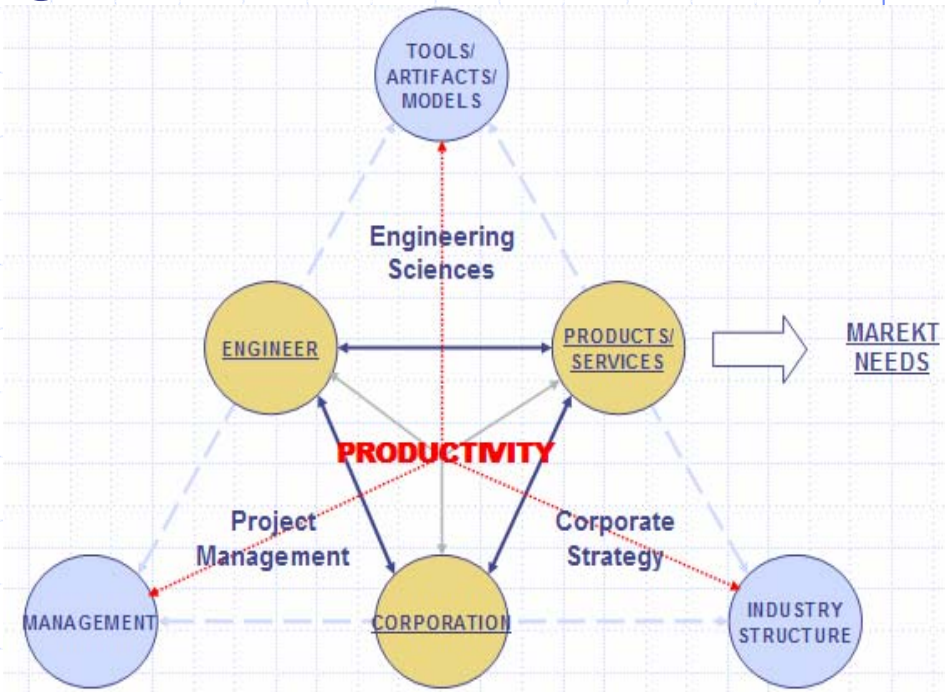
- Collaboration is a human **Activity**
  - The Cultural and Historical Activity Theory (CHAT)
    - Activity is the basic unit of analysis to study human endeavor
    - Subject, Object, and Community
  - Three types of Collaboration Activity
    - Coordination
      - Uni-directional dependencies
    - Cooperation
      - Muti-directional dependencies
    - Co-construction
      - Un-defined dependencies



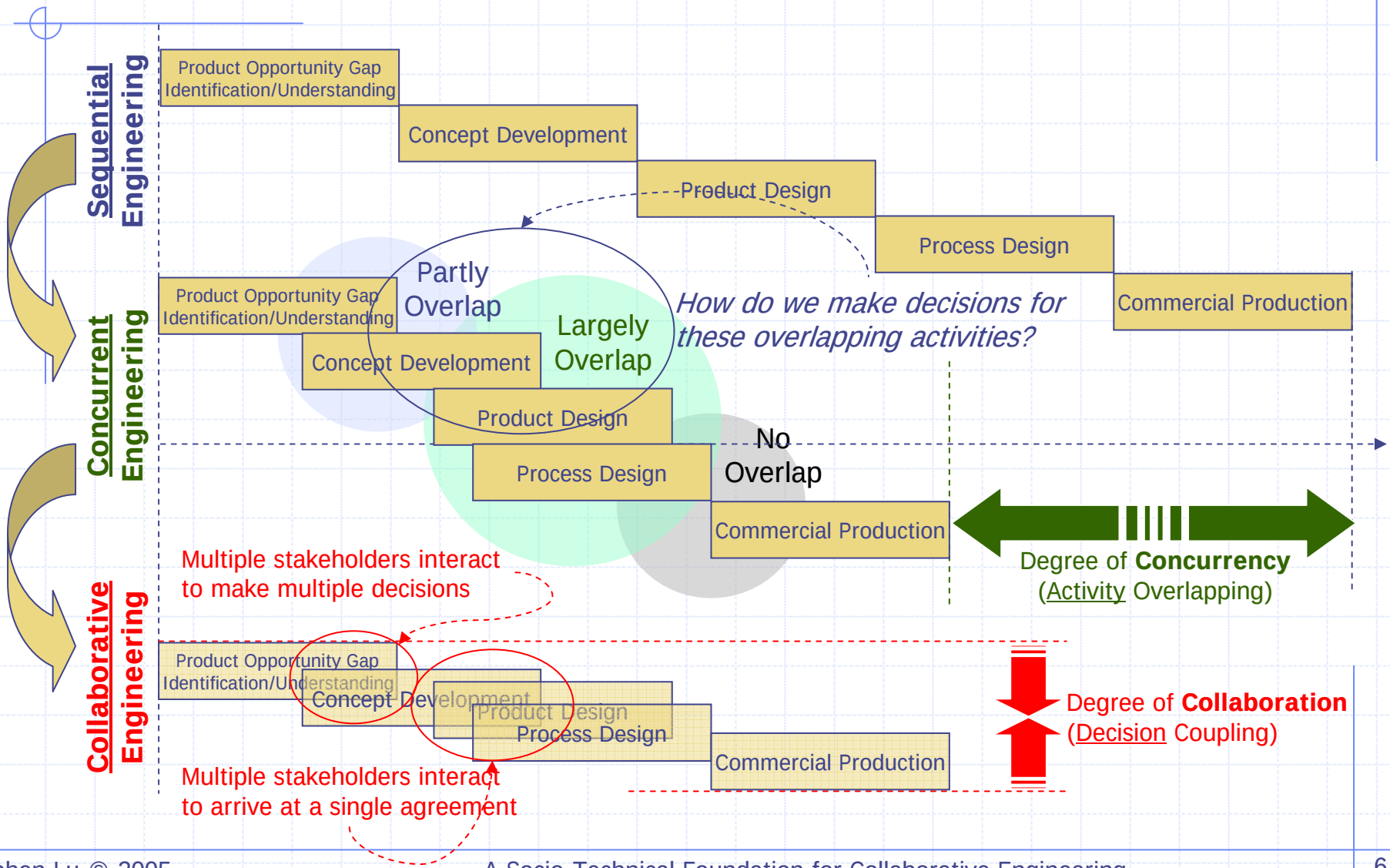
Level	Oriented Towards	Carried Out by
Activity	Motives (long-term)	Community
Action	Goals (short-term)	Individual (or united group)
Operation	Conditions	Routinized human (or automated machines)

What is Collaborative Engineering?

- Collaborative engineering is
  - a socio-technical group decision-making process whereby a team of engineers, who share a common commitment, engage in collaborative activities to:
    - resolve conflicts,
    - bargain for individual or collective advantages,
    - agree upon courses of action,
    - craft joint decisions that serve their mutual interests



Engineering Lifecycle Activities



An Old Myth of Group Decisions

- Arrow's theorem of ImPossibility
  - Kenneth Arrow proved the intransitivity of individual preferences to a group preference, which led to the traditional myth of group decision making.

Customers express their preferences via ordinal ranking of discrete alternatives

Individual Customer	Preference Rankings
I	a > b > c, and a > c
II	b > c > a, and b > a
III	c > a > b, and c > b

Democratic decision making (or social choice) by simple preference aggregations

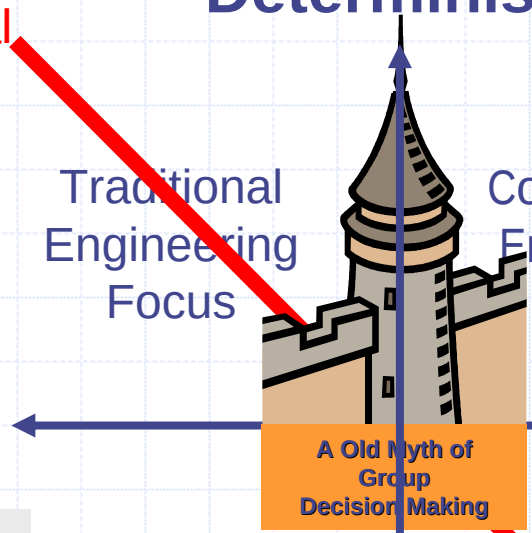
Customer	Decisions		
(when asked)	a vs. b	b vs. c	c vs. a
I	a	b	a
II	b	b	c
III	a	c	c
Group Result	a > b	b > c	c > a

Demystify the Old Myth!

- If group decisions are indeed irrational, then a true collaborative engineering is impossible
  - let the leader to make autocratic individual decisions
    - Become multi-objective, multi-attribute decision problems
- We challenge this old myth with a new approach

		Old Thinking	New Approach
Collaborative Engineering	**Philosophy**	Scientific Determinism	Social Constructionism
	Paradigm	Pure-Technical	Socio-Technical
Group Decision Making	**Style**	Autocratic	Participative
	Decision	Individual	Joint

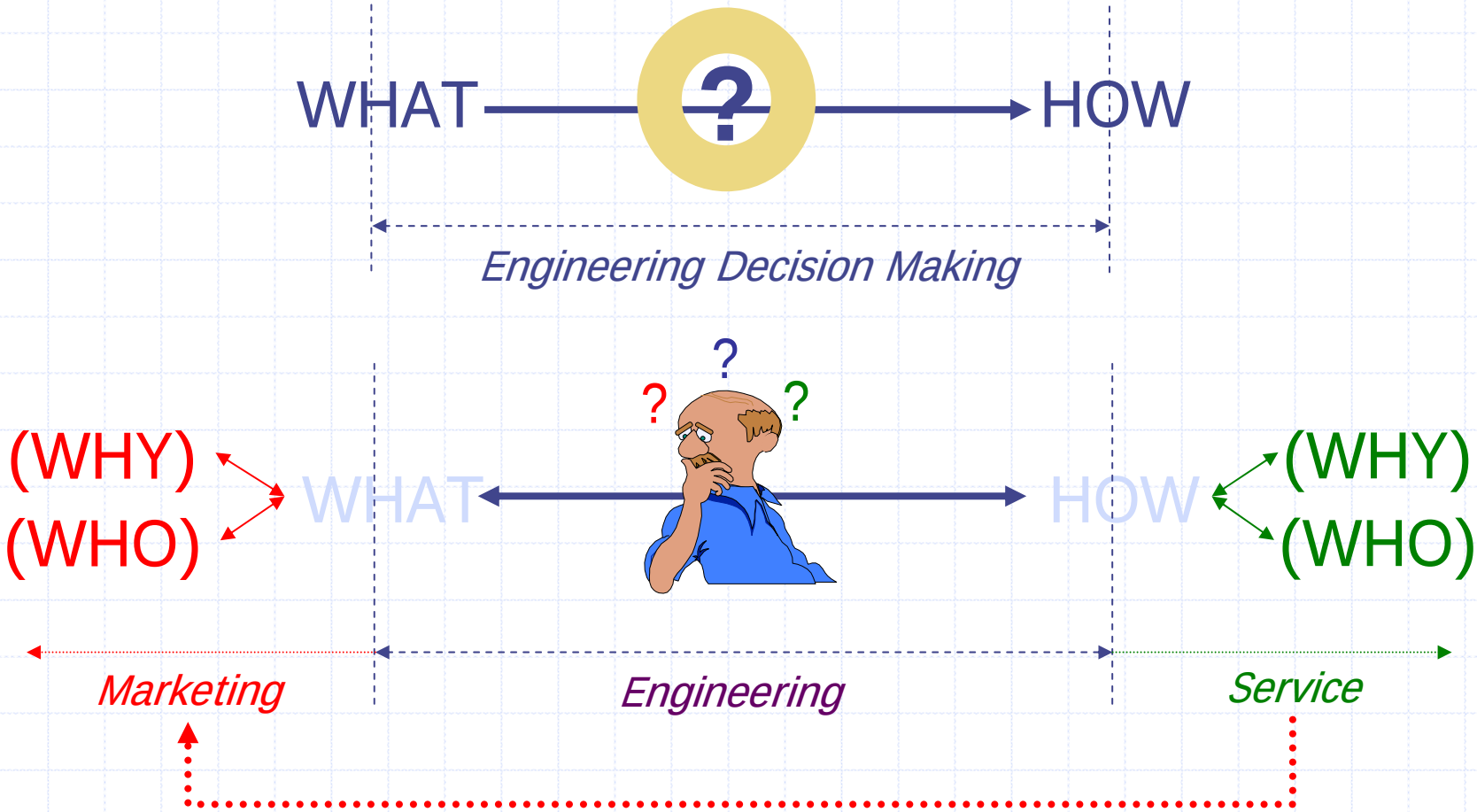
Determinism vs. Constructionism



Any event can be rationally and precisely predicted, if a complete and accurate description of the event with all the needed laws of nature is given.

An idea which may appear to be obvious to those who accept it, but in reality is just a creation or artifact of a particular culture or society. Social constructs are human choices, rather than laws of the nature.

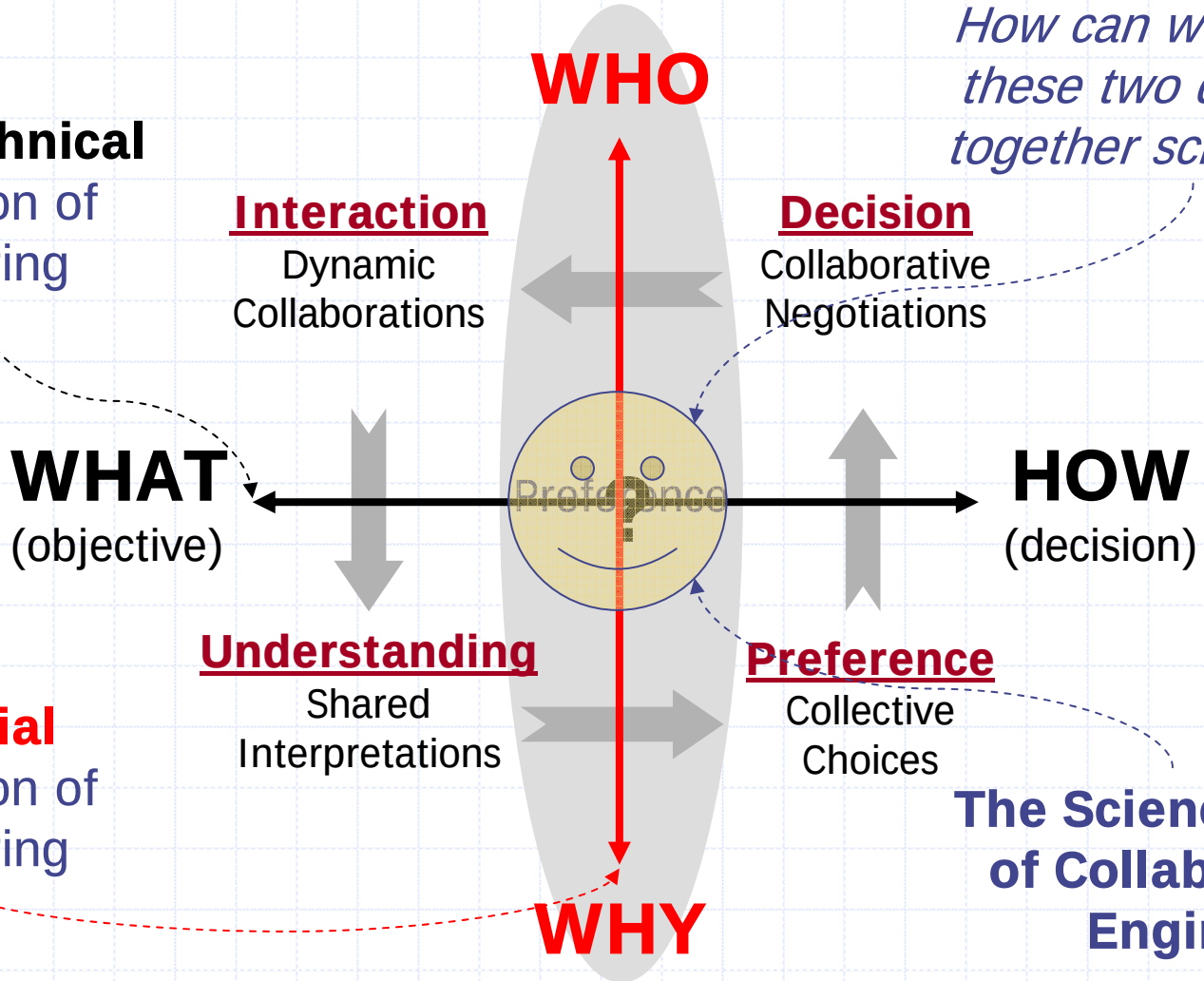
Traditional Technical Paradigm



New Socio-Technical Paradigm

How can we integrate these two dimensions together scientifically?

The **Technical** Dimension of Engineering



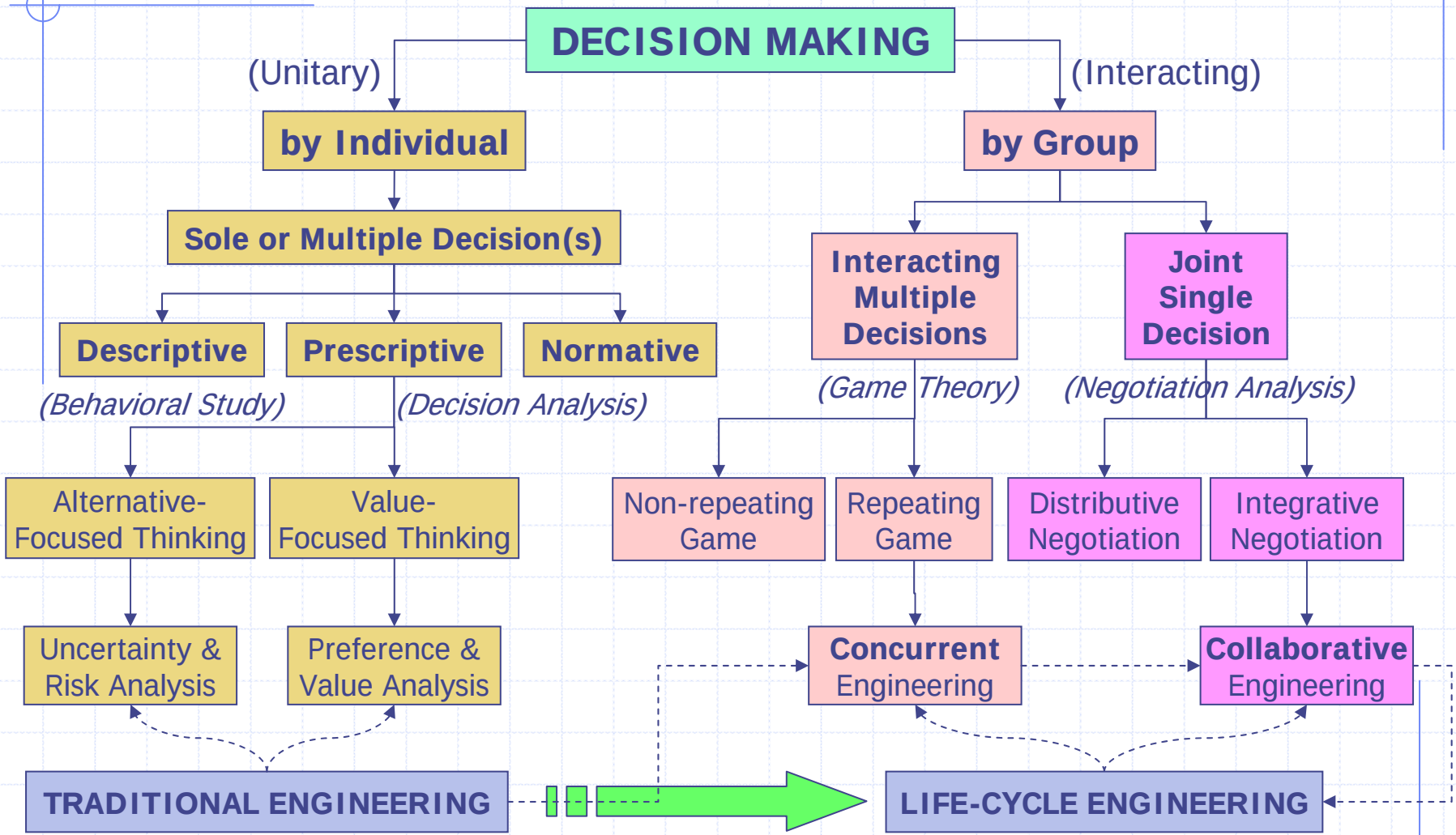
The **Social** Dimension of Engineering

The Science Base of Collaborative Engineering

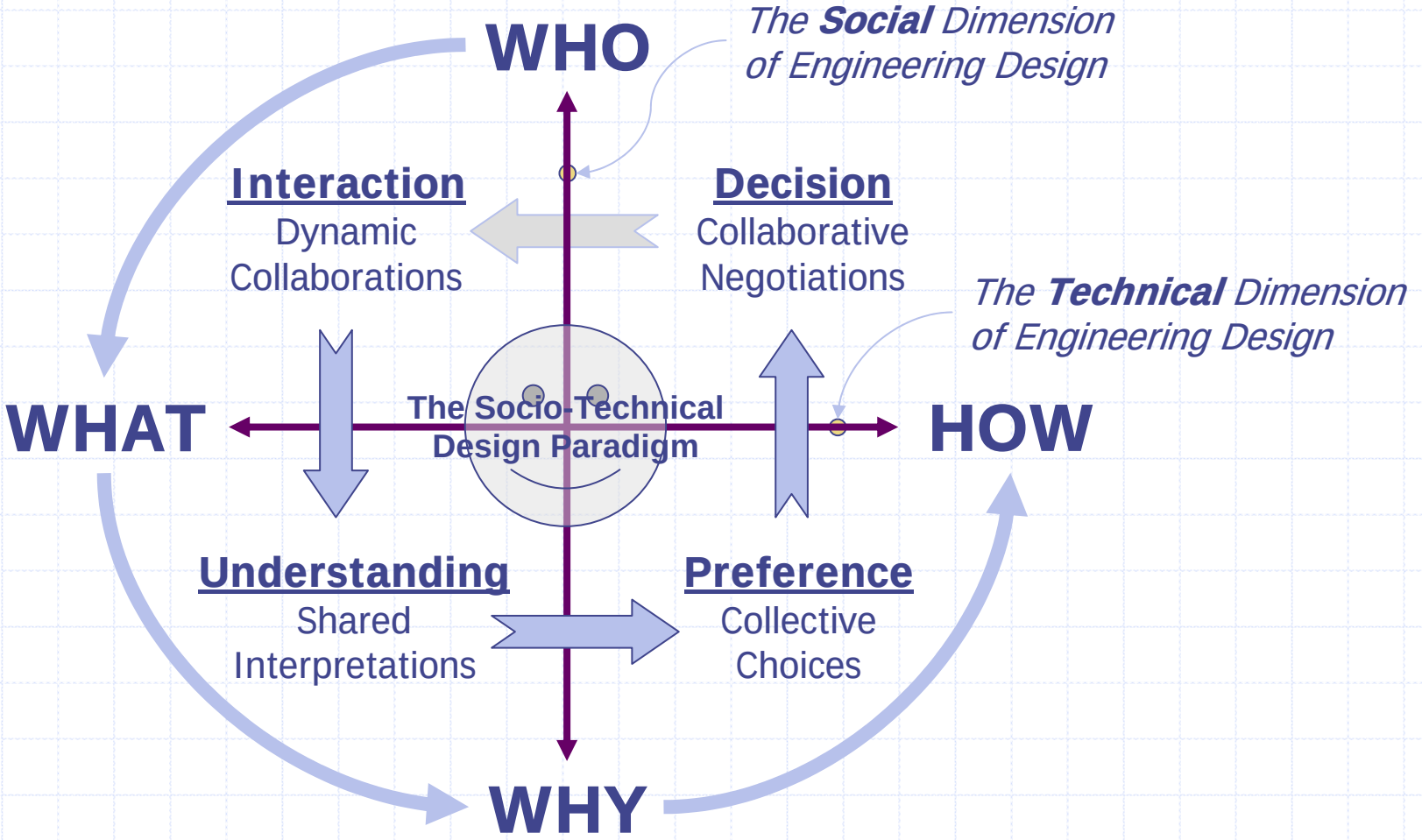
Different Decision Making Styles

- The Leader Decides
  1. Autocratic or directive style of problem solving
  2. Autocratic with group information input
  3. Autocratic with group's review and feedback
  4. Individual Consultative Style
  5. Group Consultative Style
- The Group Decides
  6. Group Decision Style (based on leader's definition)
  7. Participative Style (by all interested stakeholders) Our Focus
  8. Leaderless Team
- CE research must support the "Group-decide" styles
  - Classical decision theory is only good for styles 1 – 5
  - Our research is targeted at styles 6, 7 and 8

Individual vs. Group/Joint Decision



Socio-Technical Paradigm for CE



Alternative Theories and Models

The Nature and the Modeling of:	Current Approach	New Approach	New Paradigm and Procedure:
Team Behavior	Neo-Classical Economic Man in Open Large Groups	Modern Organizational Man in Small Teams with Incentives	**(WHO) Interaction**
Social Interaction	Self-Interested Rationality with Static Perspective	Social Construction Theory with Dynamic Perspective	**(WHAT) Understanding**
Group Preference	Ordinal Ranking with Discrete Social Choice Models	Cardinal Rating with Spatial Continuous Social Choice Model	**(WHY) Preference**
Joint Decision	Classic Decision Analysis, and Game Theoretic Approach	Collaborative Win-win Negotiation Framework and Analysis	**(HOW) Decision**

Economic vs. Organizational Man

- Economic Man (and Rational Man)
  - Based on neoclassical economic theory (and decision theory)
    - Economic Man has a complete/consistent system of preferences to choose correctly among entire set of available alternatives
      - all the alternatives of choice are given,
      - all of the consequences of each alternatives are known, and
      - a complete utility ordering for all possible set of consequences
- Organizational Man
  - Based on modern organization theory (Simon, Cyert, March)
    - While Economic Man optimizes, Organizational Man satisfices to look for a course of action that is satisfactory or good enough
      - choice is always exercised with respect to limited resources, time, information, and approximate model of the real situation, and
      - the elements of alternatives are not given but are the outcome of a psychological and sociological processes, including the choosers' own activities and the activities of others in the choosers' environments
- Our research is based on organizational behavior theory
  - "satisficing" and "bounded rationality"

Social Construction of Reality

- Social construction of reality is an interactive and dynamic process of socially shape an agreement and/or artifact by a group of interested stakeholders
  - Interpretive Flexibility
    - SC (e.g., CE) results are always under-determined
  - Relevant Social Group
    - All members of a social group share the same set of meanings (i.e., interpretations) attached to a specific design
  - Closure and Stabilization
    - The SC process continues until all conflicts are resolved, and the artifact no longer posts a problem to any relevant social group
  - Wider Context
    - Background conditions of social interactions matter
- We use this process to achieve a common understanding among team members
  - Preferences are expressed w.r.t a common understanding

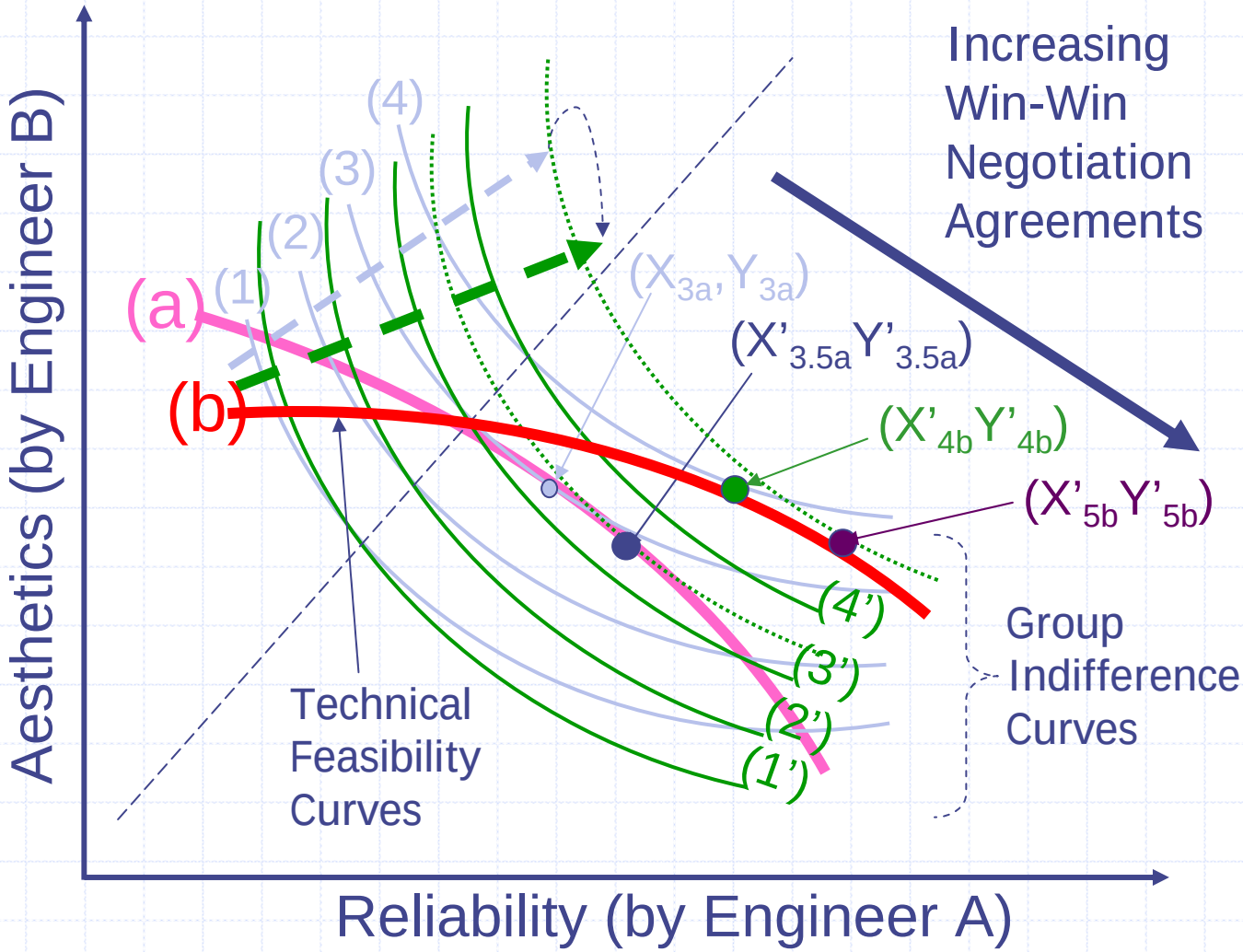
Spatial Social Choice Model

- Group preference **can be** rational and consistent
  - Ordinal rankings of discrete alternatives of individual preferences leads to the Arrow's paradox of group decisions
  - Ordinal ratings of continuous (spatial) alternatives of individual preferences can result in rational and consistent procedures of aggregating preferences of many to a group preference
- Spatial model of social choice draws on concepts from geometry, real analysis, and topology to describe the set of continuous alternatives of individual preferences
  - Alternatives are drawn from an ordered set, represented by points in a continuum
- Our CE research is based on ratings of continuous alternatives of individual preferences
  - Rating contains richer preference information than ranking
  - It is possible to obtain spatial social choice models (i.e., ratings of continuous alternatives) for most engineering problems

Collaborative Engineering via Negotiation (ECN) with a consistent group preference

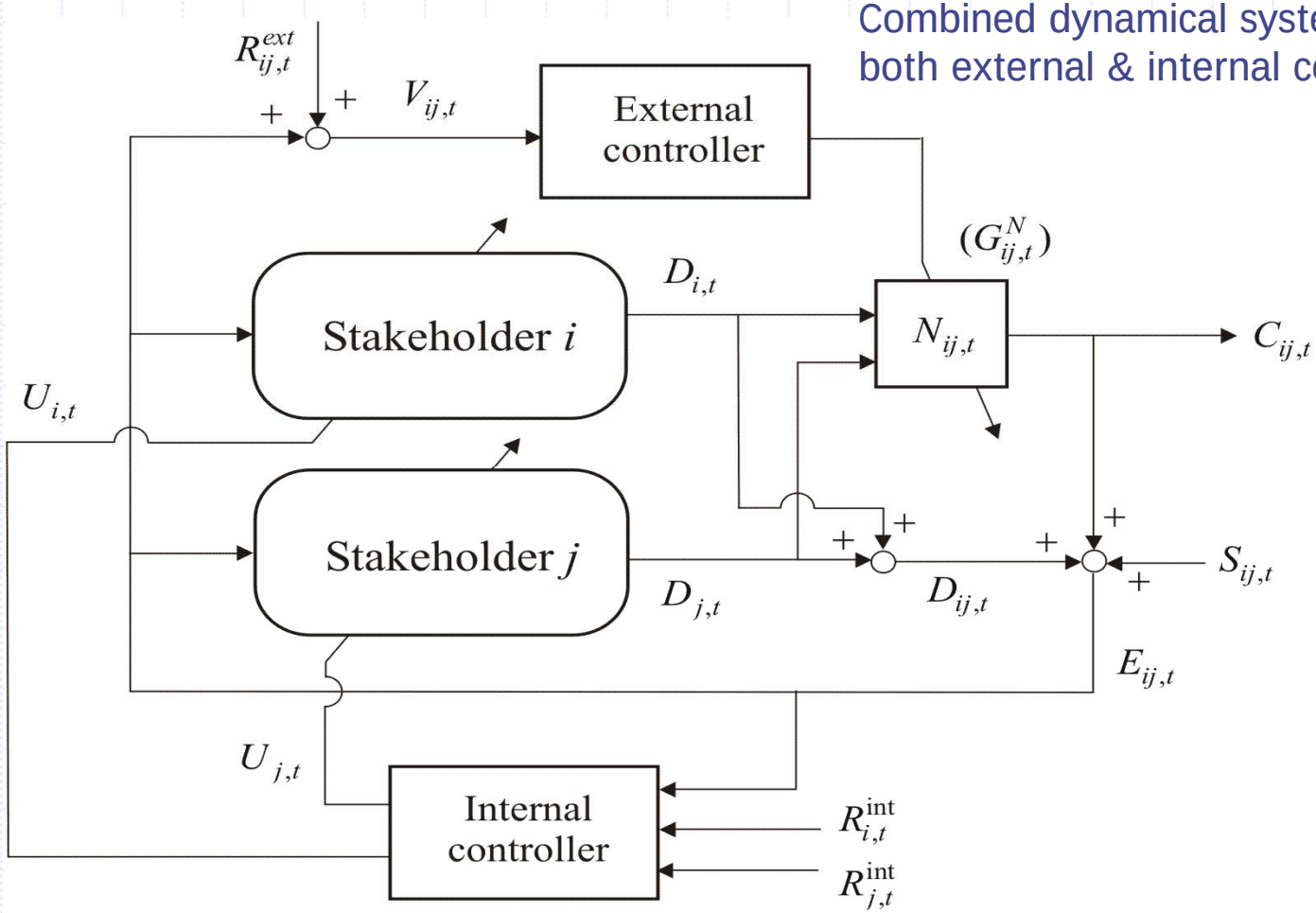
1. **Individual Analysis:** each party thinks alone to decide their respective BATNA – organizational behavior theory
2. **Communal Analysis:** two parties get together to establish their initial ZOPA – social construction theory
3. **Mutual Exploration:** both parties jointly explore maximal technical feasibilities – social construction theory
4. **Establish Preference:** parties jointly & collaboratively establish a value structure – spatial social choice model
5. **Initial Agreement:** parties locate initial agreements along the Efficient Frontier within the negotiation feasibility region
6. **Joint Co-construction:** parties work together to dynamically and collaboratively modify their previously constructed value structure to improve initial agreements **ECN**
7. **Collective Invention:** parties collaboratively probe each other's knowledge to expand, or invent, new technical feasibilities for even more improved agreements
8. **Collaborative Innovation:** parties simultaneously perform Steps 6 and 7, which is the ultimate goal of ECN

ECN: a Graphical Example

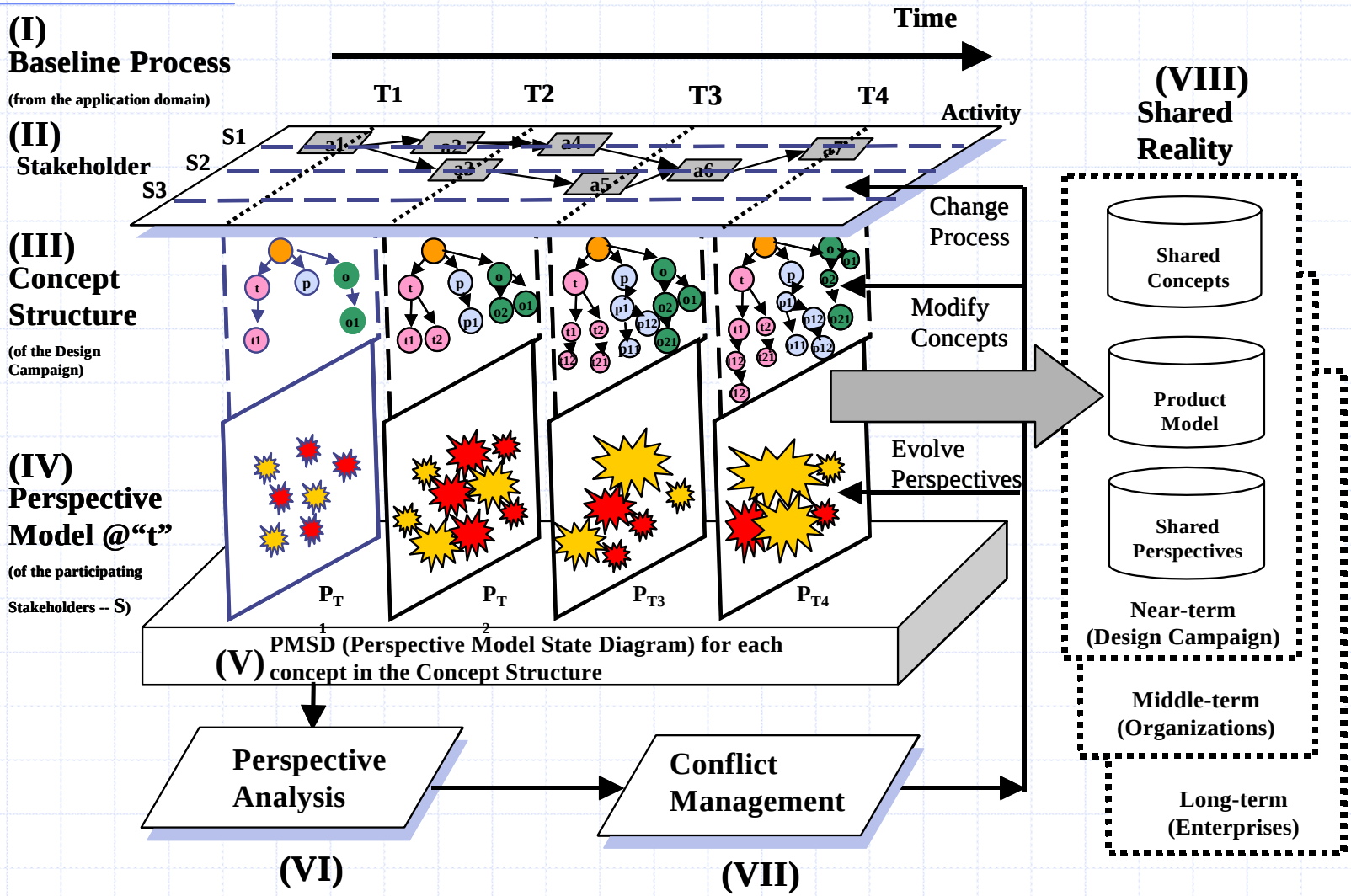


ECN: Dynamic Control System

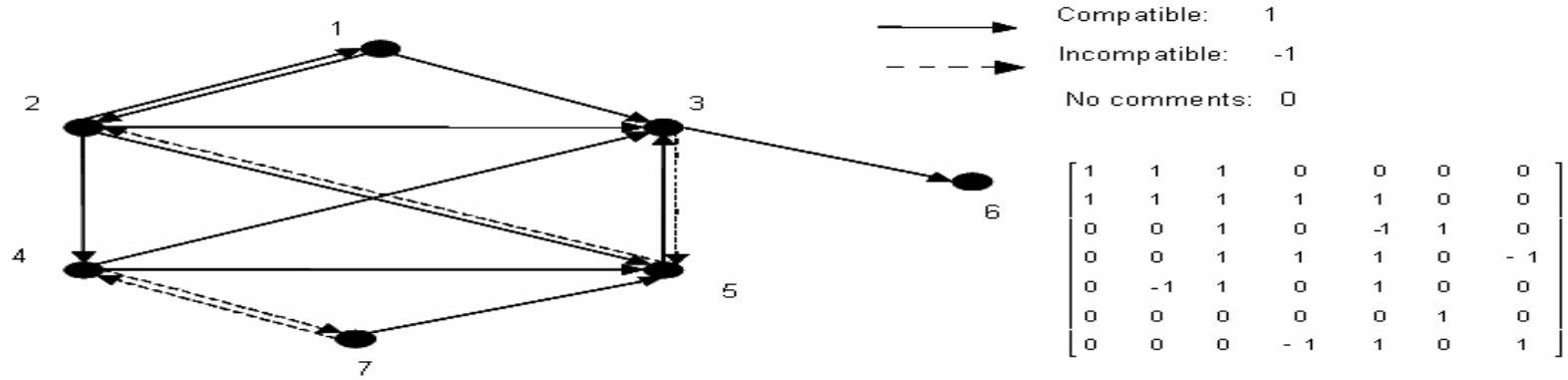
Combined dynamical system under both external & internal controls



ECN: Socio-Technical Construction



ECN: Computing the Consensus



$$\begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & -1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 & -1 \\ 0 & -1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 & 1 & 0 & 1 \end{bmatrix}$$

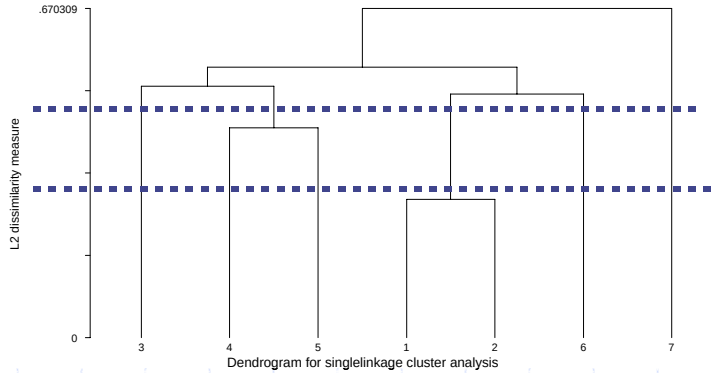
Figure 4: Perspective Model Network and Perspective Interaction Matrix

For two perspective models toward a concept:

$$d_{i,j} = \sqrt{\sum_{k=1}^{g} \left[(x_{ik} - x_{jk})^2 + (x_{ki} - x_{kj})^2 \right]}$$

For two stakeholders' perspective toward a group of concepts:

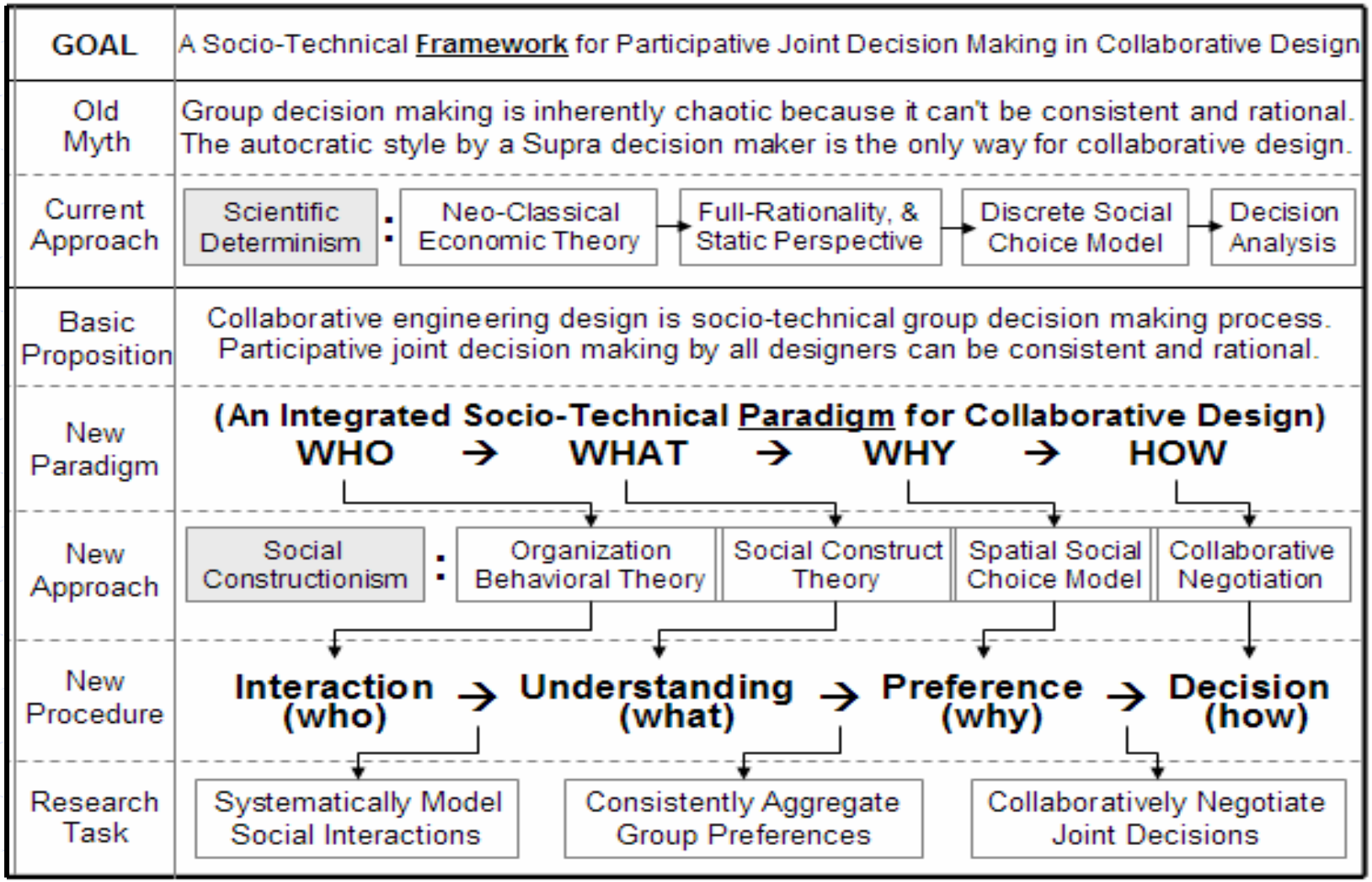
$$d_{i,j} = \sqrt{\sum_{r=1}^{R} \sum_{k=1}^{g} \left[(x_{ikr} - x_{jkr})^2 + (x_{kir} - x_{kjr})^2 \right]}$$



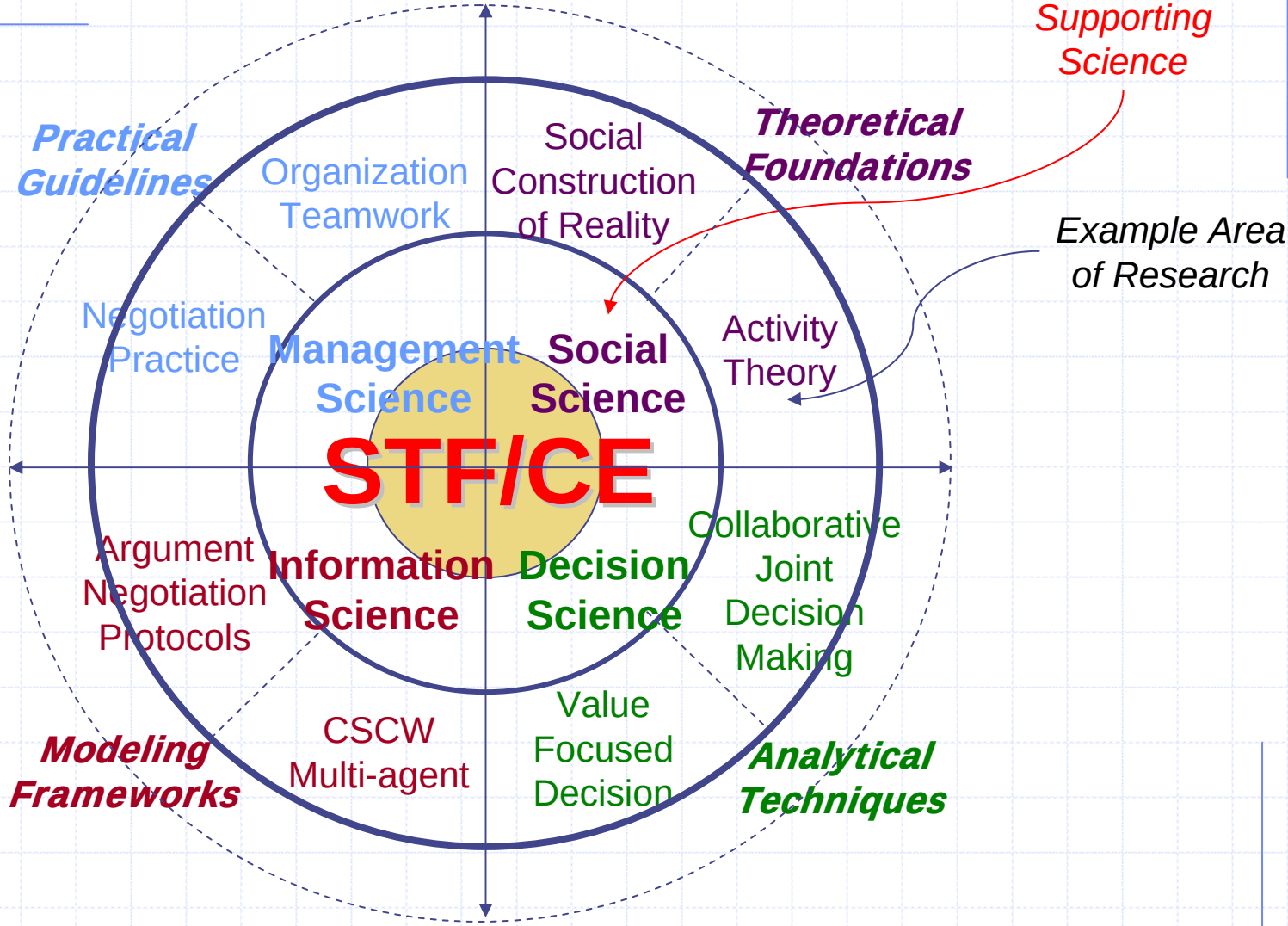
$$d(r,s) = \max(d_{i,j}),\ i \in (1,\ldots,n_r),\ j \in (1,\ldots,n_s)$$

Figure 6: Mathematical Relations for Computing Perspective Distances and Cluster Analyses

Summary of Research Journey



The BIG Picture – What's for CS?



Organization by Focus/Foci (CS)

Immersion	Interaction	Autonomy	Computation
Arbib	Boehm	Bekey	Adleman
Cohen	Diniz	Cohen	Arbib
Desbrun	Frank	Gil	Boehm
Hovy	Ghandeharizadeh	Gratch	Goel
Itti	Golubchik	Hill	Horowitz
Knight	Govindan	Johnson	Huang
Marcu	Hall	Knoblock	Itti
Medioni	Heidemann	Lu	Medvidovic
Neumann	Horowitz	Mataric	Port
Nevatia	Kesselman	Medioni	Requicha
Price	Knoblock	Medvidovic	Schaal
Szekely	McLeod	Nevatia	von der Malsburg
von der Malsburg	Medvidovic	Rickel	
	Neches	Rosenbloom	
	Neuman	Schaal	
	Papadopoulos	Shen	
	Port	Sukhatme	
	Requicha	Swartout	
	Shahabi	Tambe	
	Touch		
	Zimmerman		