From Human-Subject Experiments To Computational-Agent Experiments

(And Everything In Between)

Presenter

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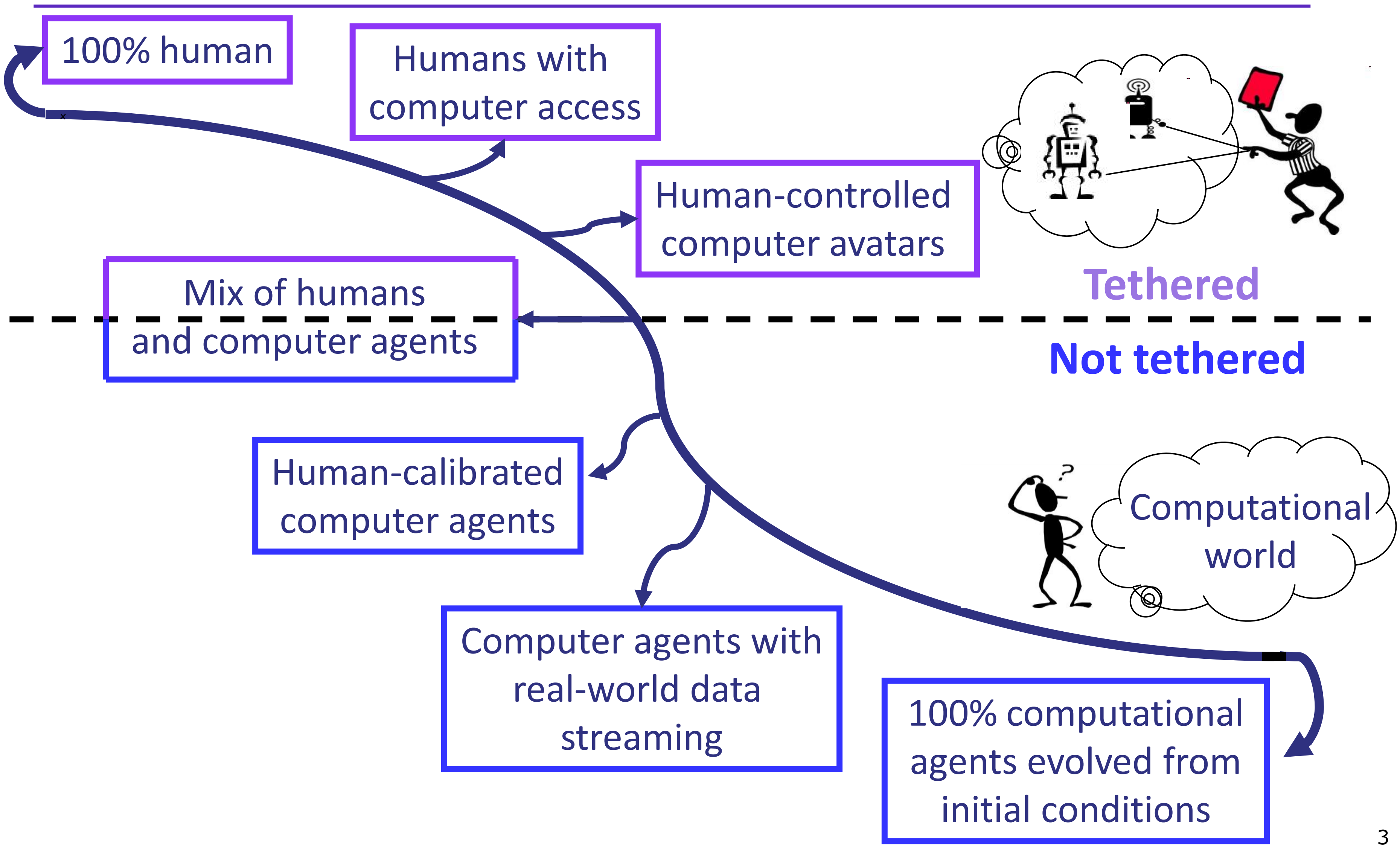
Presentation Outline

- Spectrum of Possible Experiments
  - 100% human → 100% computational agents
- What is Agent-based Comp Econ (ACE)?
  - 100% computational agents
  - ***Example:*** Electric power market test bed
- Towards Integrated Human-Computational Test Beds
  - Parallel experiments with humans and comp agents
  - Platforms permitting human & comp-agent participants
  - https://www2.econ.iastate.edu/tesfatsi/aexper.htm

Spectrum of Possible Experiments



What is ACE ?

- **Agent-Based Computational Economics (ACE)**

- Computational modeling of economic processes (including whole economies) as open-ended dynamic systems of interacting "agents".

- ***Goal:*** Development of empirically-grounded dynamic economic theories in which equilibrium is a possible outcome rather than a constraint imposed in advance.

Meaning of "Agent" in ACE

Agent =: Encapsulated bundle of data, attributes, and/or methods within a computationally constructed world

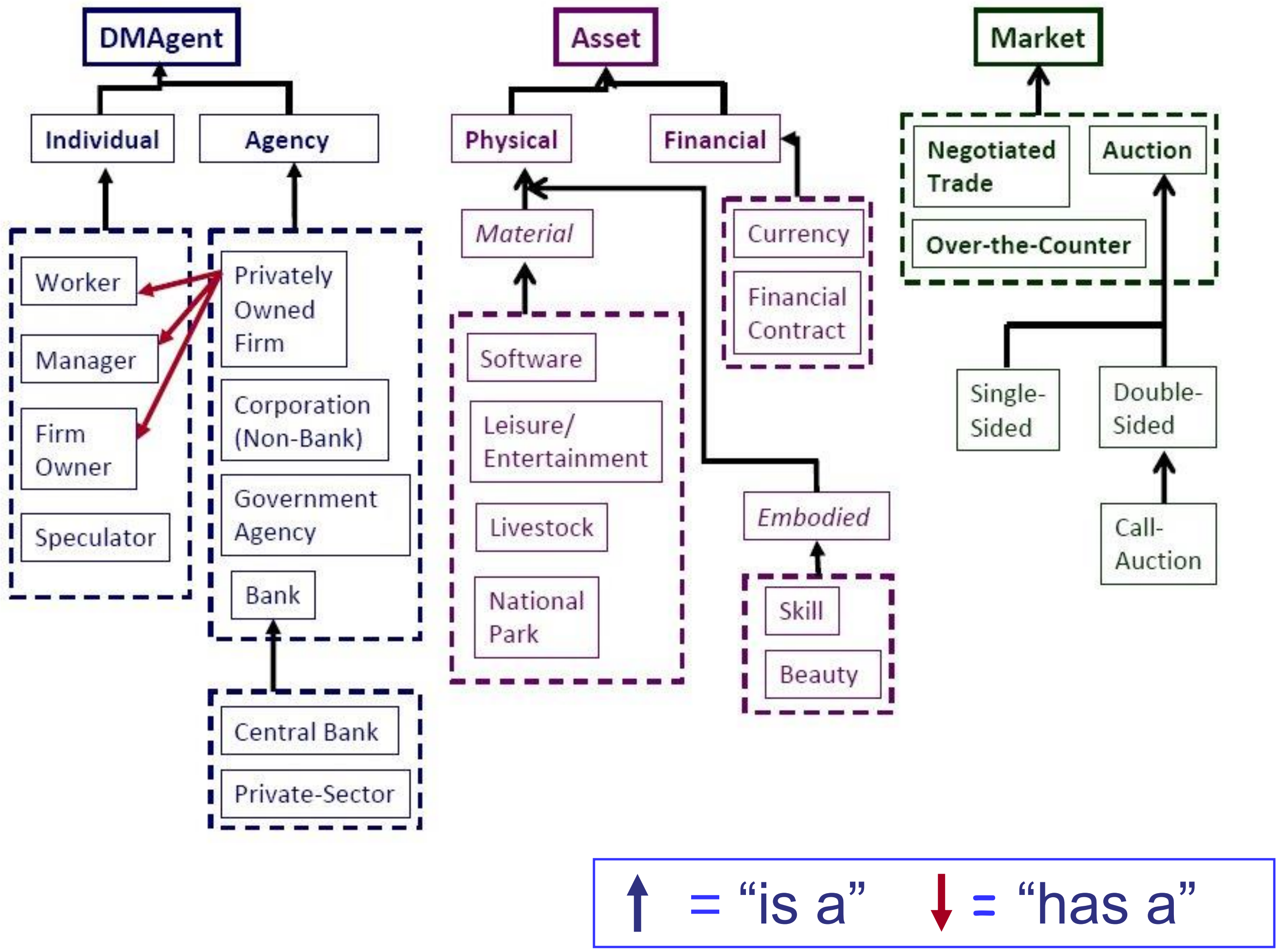
- Agents can represent
  - ***Individuals:*** consumers, traders, entrepreneurs, …
  - ***Social groupings:*** households, communities, …
  - ***Institutions:*** markets, corporations, gov't agencies, …
  - ***Biological entities:*** crops, livestock, forests, …
  - ***Physical entities:*** weather, landscape, electric grids, …

Meaning of "Agent" in ACE …

Decision-making agents can exhibit:

- Behavioral adaptation
- Goal-directed learning
- Social communication (talking with each other!)
- Endogenous formation of interaction networks
- **Autonomy:**
  Self-activation and self-determination based on private internal data and methods as well as on external data streams (including from real world)

Illustration: Partial UML Diagram for Agent Relationships in an ACE Macroeconomic Model



Importance of Agent Encapsulation

- Real-world economies consist of distributed entities with limited information & computational capabilities.

- **ACE modeling forces adherence to this constraint.**

  - An ACE model is a collection of computational "agents," i.e., encapsulated bundles of data, methods, and/or attributes.

  - An intended action of an agent at any given instant is completely determined/constrained by the data, methods, and/or attributes of this agent at this instant.

- **In principle, any decision-making agent in an ACE model can be replaced by a human being who is constrained to use this agent's input/output interfaces.**

Example: Power Generation Company (GenCo)

Public Access:

// Public Methods

Methods for receiving data;
Methods for retrieving GenCo data;

Private Access:

// Private Methods

Methods for gathering, storing, and sending data;
Methods for calculating own expected & actual net earnings;
Method for updating own supply offers **(LEARNING)**.

// Private Data

Own capacity, grid location, cost function, current wealth… ;
Data recorded about external world (prices, dispatch,…);
Address book (communication links);

ACE Culture-Dish Analogy

- ACE modeler constructs a **virtual economic world populated by various agent types.**
- Modeler sets initial agent **states** (data, attributes, and/or methods).
- Modeler then steps back to observe how the **world develops in real (CPU) time without further intervention from the modeler** (i.e., no externally imposed coordination constraints such as demand=supply, fulfilled expectations, etc.)
- World events are **driven by agent interactions.**

ACE and Market Design

Key Issues:

- Will a proposed or actual market design promote **efficient, fair, and orderly social outcomes over time**?
- Will the design give rise to **unintended consequences**?

ACE Culture-Dish Approach:

- **Develop a computational world (test bed)** embodying market design, physical constraints, decision makers, …
- **Set initial world conditions** (agent data & methods).
- **Let the world evolve** with no further intervention, and observe and evaluate the resulting outcomes.

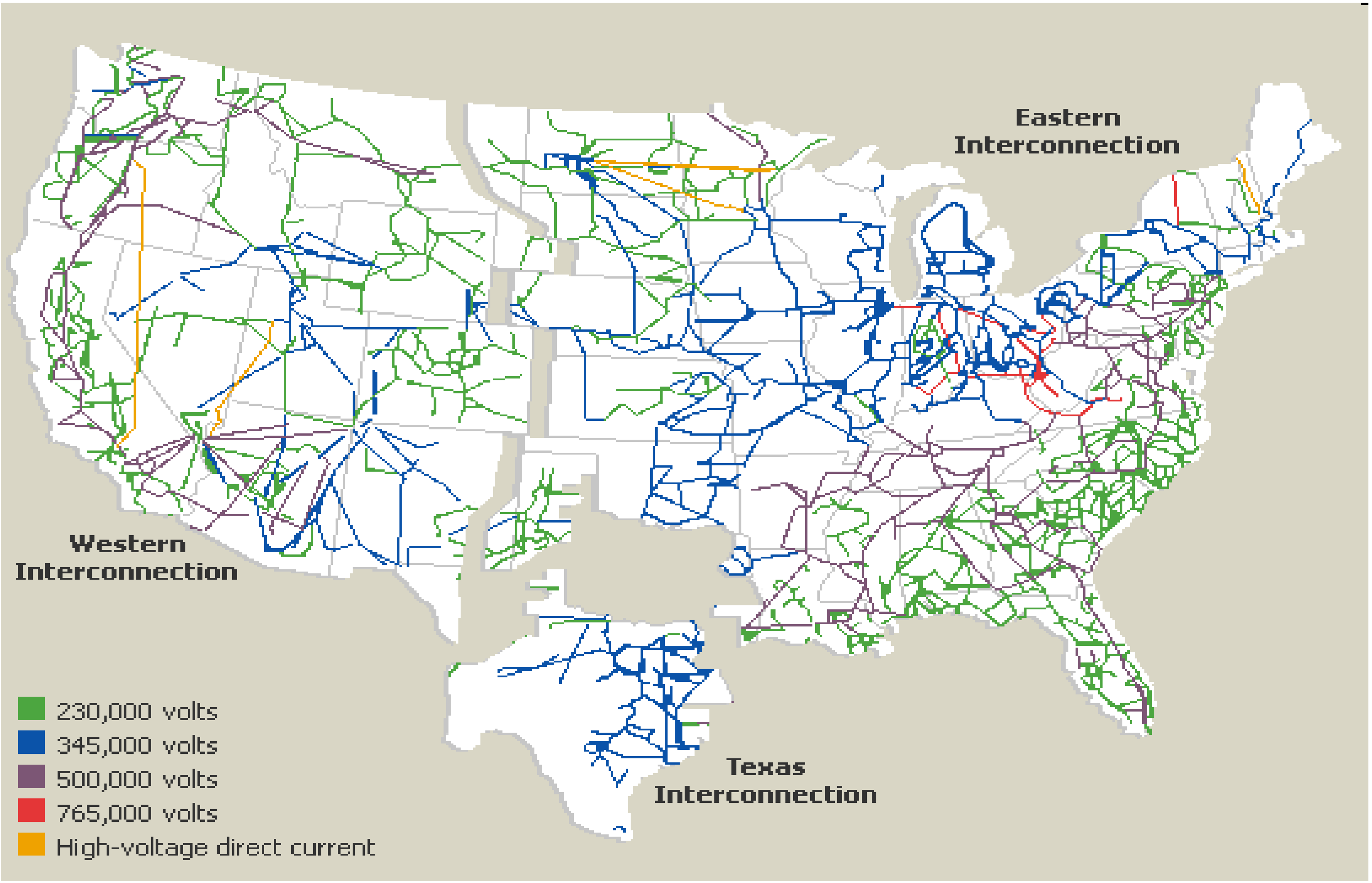
Example: Using ACE Test Beds for the Study of Electric Power Market Designs

- The **restructured electric power markets** that are being implemented in many industrialized economies around the world are immensely complex.

- They involve increased systematic consideration of
  1) **Physical constraints & ancillary service needs**
  2) **Institutional arrangements & incentives**
  3) **Behavioral responses of human traders/operators**

- To be useful and informative, power market studies need to consider all three elements 1) thru 3).

U.S. Wholesale Electric Power Transmission Grid

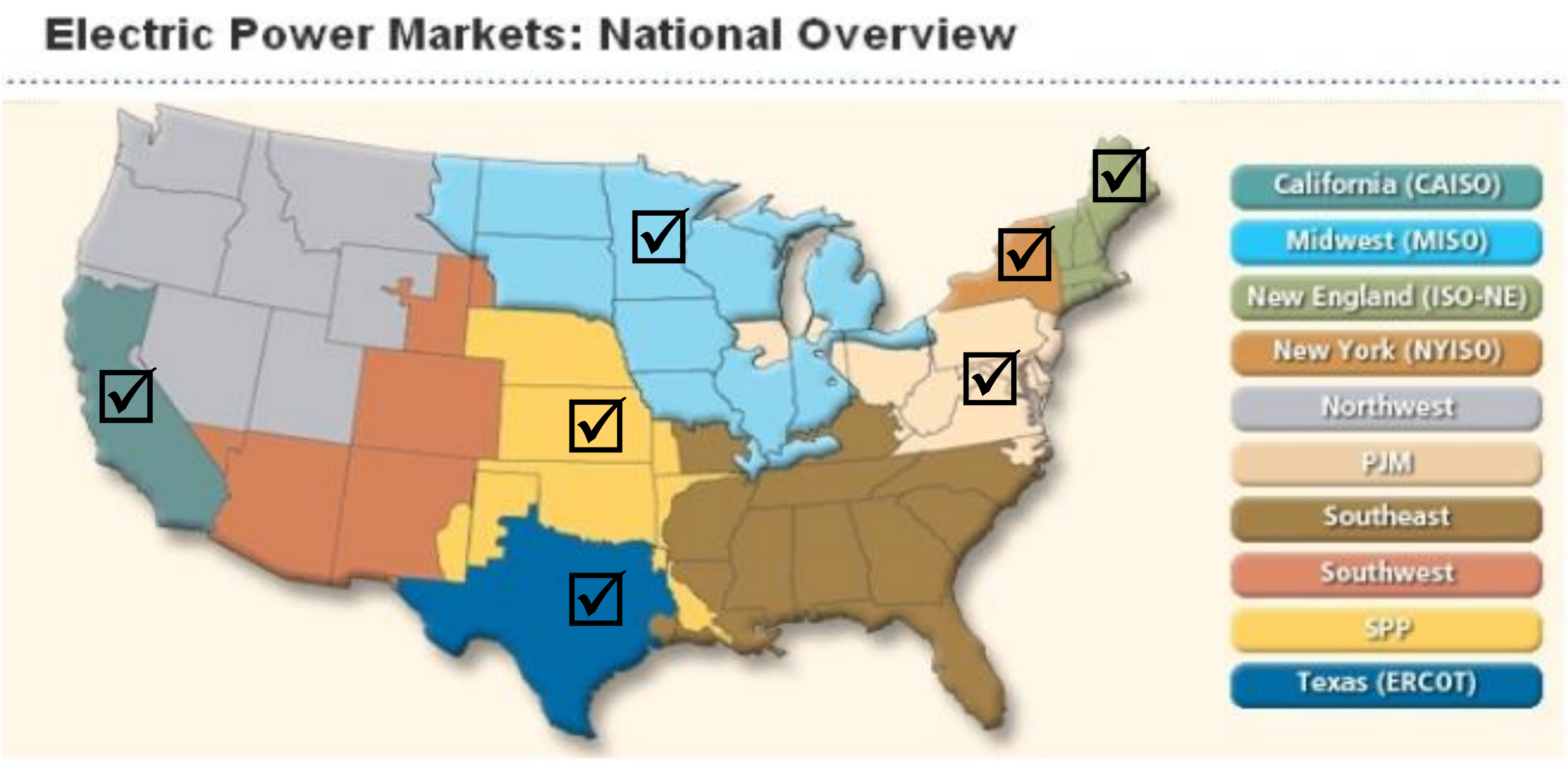


Market Design Proposed in 2003 by the U.S. Federal Energy Regulatory Commission (FERC)

- Wholesale power markets to be managed by ***independent system operators (ISOs)*** without any ownership/financial stake
- ***Two-settlement system:*** Concurrent operation of day-ahead (forward) & real-time (intra-day) markets
- Transmission grid congestion managed via ***Locational Marginal Prices (LMPs),*** where LMP(b,T) at grid bus b for operating period T =: Least system cost of delivering 1 additional energy unit (MWh) at b during T
- ***Market power mitigation*** by price caps & other controls

→ Has led in practice to complex systems difficult to analyze using standard analytical & statistical tools or standard (100% human) laboratory experiments.

Seven US Energy Regions Have Adopted FERC's Market Design to Date (2011)

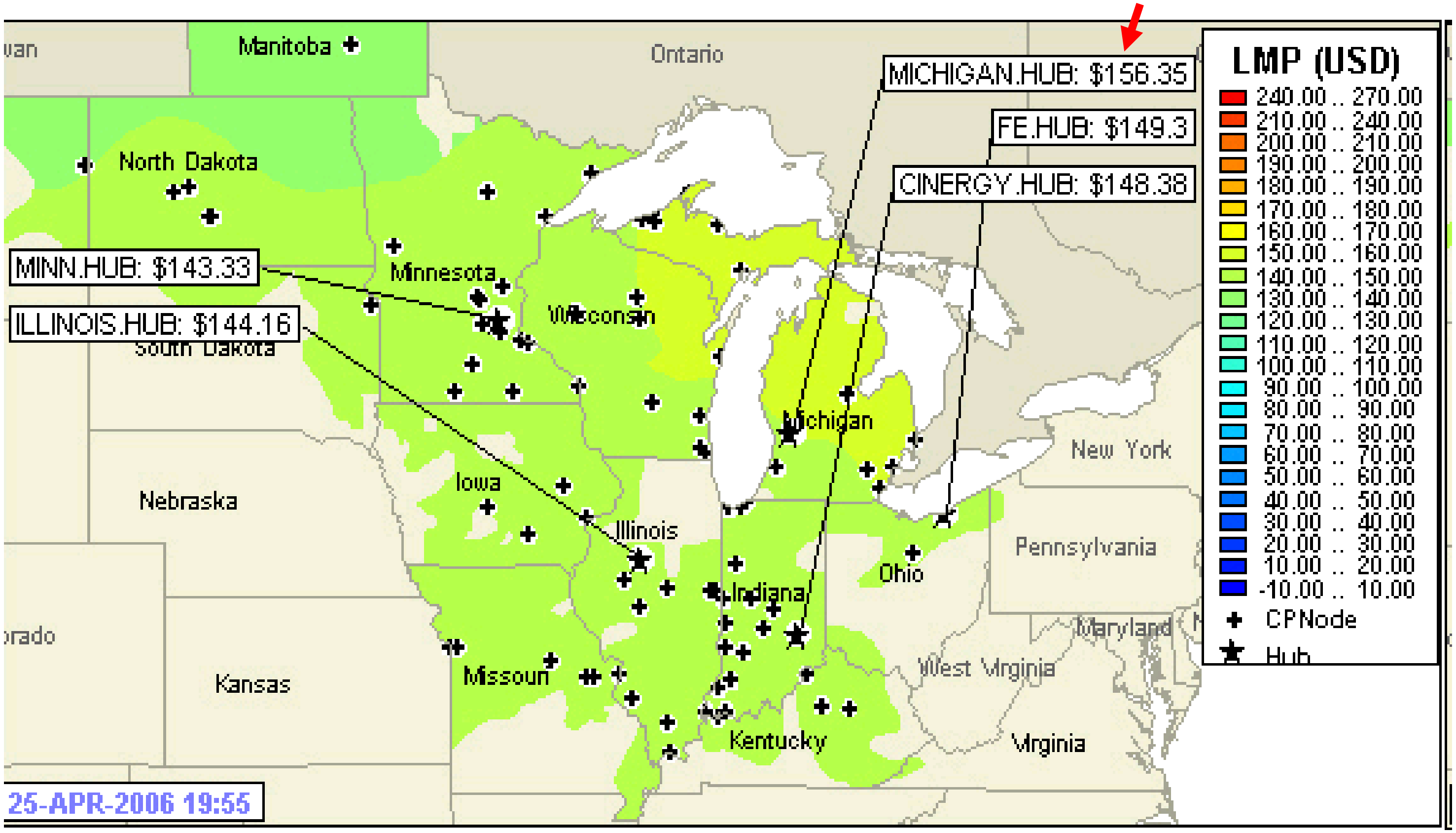


☑ = FERC Market Design Adopted

Actual Electricity Prices in Midwest ISO (MISO)

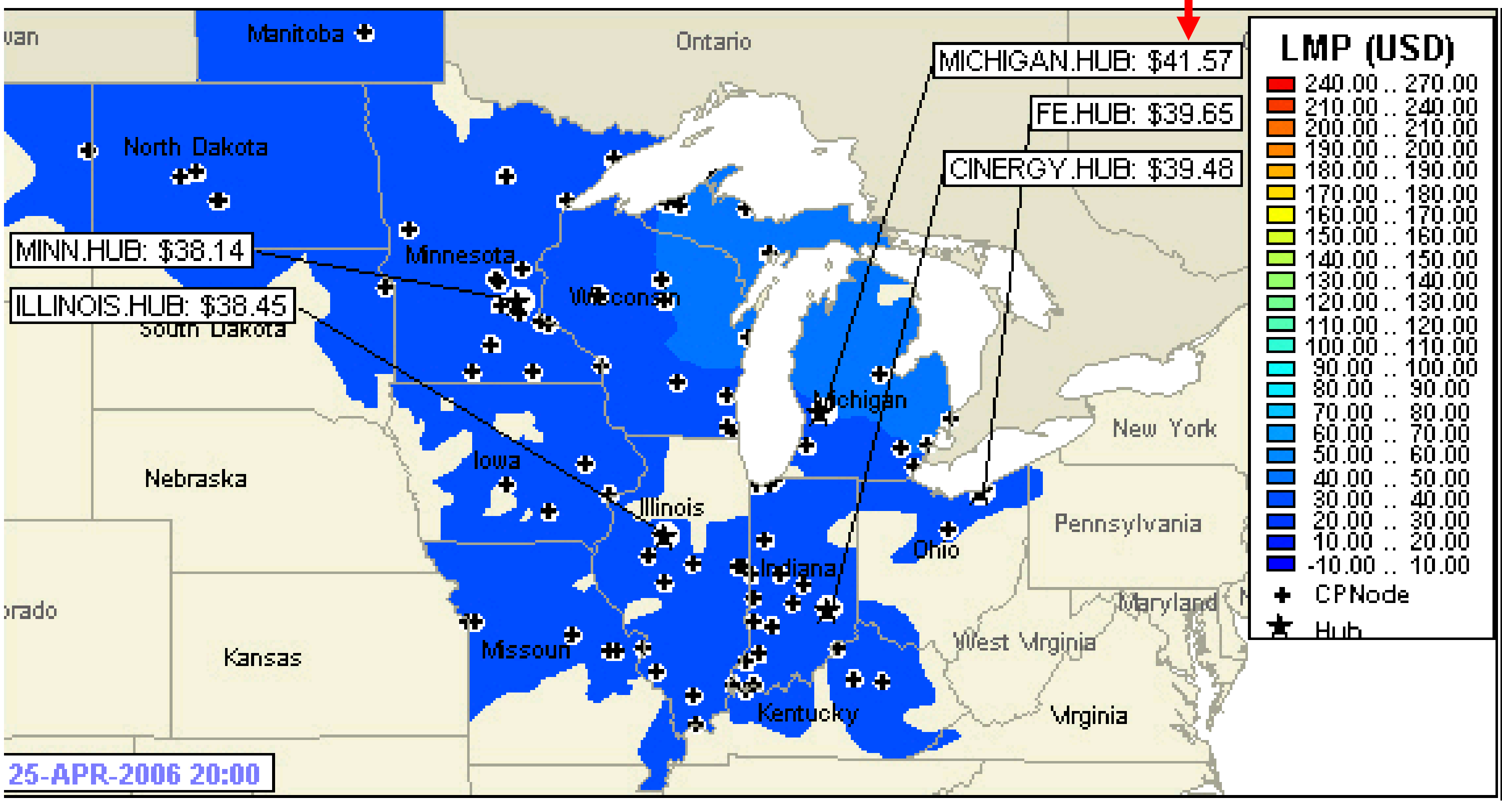
April 25, 2006, at 19:55

Note this price,$156.35



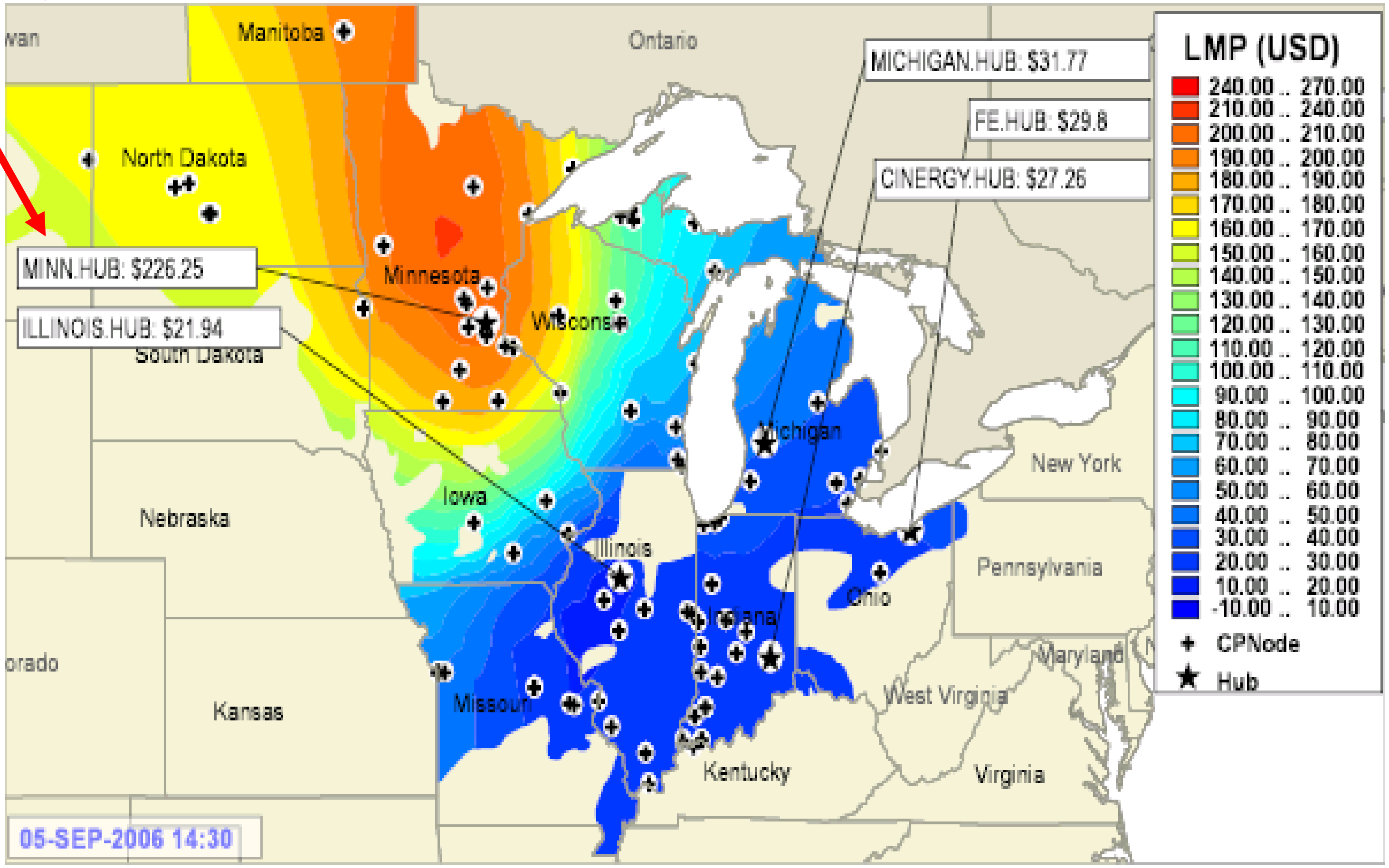
Five Minutes Later…

73% drop in price in 5 minutes !



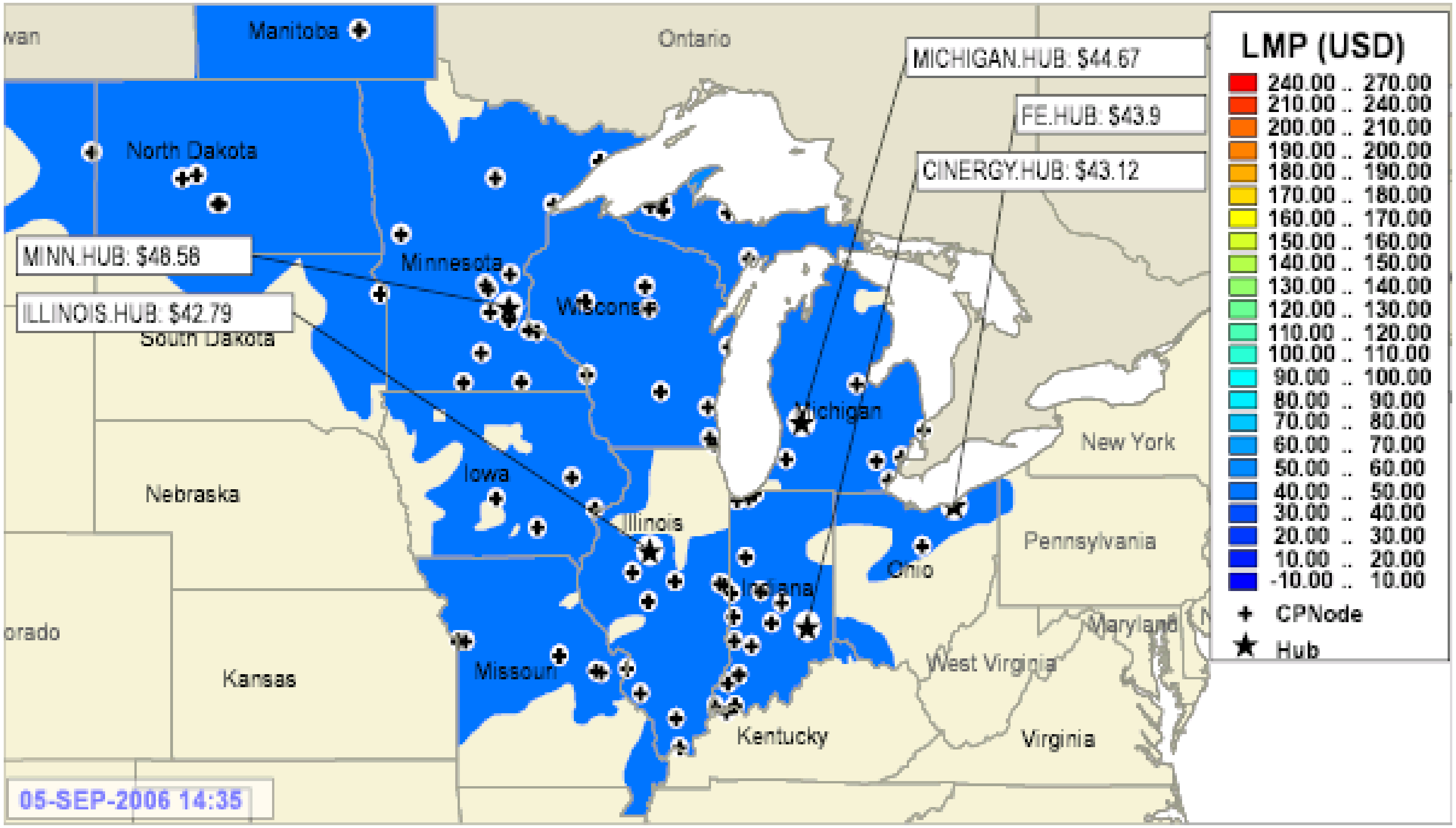
Actual Electricity Prices in Midwest ISO (MISO) September 5, 2006, 14:30

Note this price, $226.25



Five Minutes Later …

79% drop in price in 5 minutes!



ACE Test Bed Project: Integrated Retail/Wholesale Power System Operation with Smart-Grid Functionality

https://www2.econ.iastate.edu/tesfatsi/irwprojecthome.htm

Project Directors: **Leigh Tesfatsion** (Prof. of Econ, Courtesy Prof. of Math, & ECpE, ISU)
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Current Government & Industry Funding Support:

PNNL/DOE, and the Electric Power Research Center (EPRC), an industrial consortium

Industry Advisors: PNNL/DOE, XM, RTE, MEC, and Midwest ISO

Wholesale Power Market Design Proposed in 2003 by the U.S. Federal Energy Regulatory Commission (FERC)

- Market to be managed by an ***Independent System Operator (ISO)*** or ***Regional Transmission Organization (RTO)*** with no ownership or financial stake in market operations

- ***Two-settlement system:*** Daily concurrent operation of a separately settled day-ahead (forward) market & a real-time (intra-day) market

- Transmission grid congestion managed via **Locational Marginal Prices (LMPs),** where:

  – ***LMP(k,T) ($/MWh) at a grid bus k during an operating period T*** is the least incremental ("marginal") system cost of servicing a 1MW <u>increase</u> in the power level (MW) to be <u>maintained</u> at b during T, starting from a currently planned maintained power level at b during T

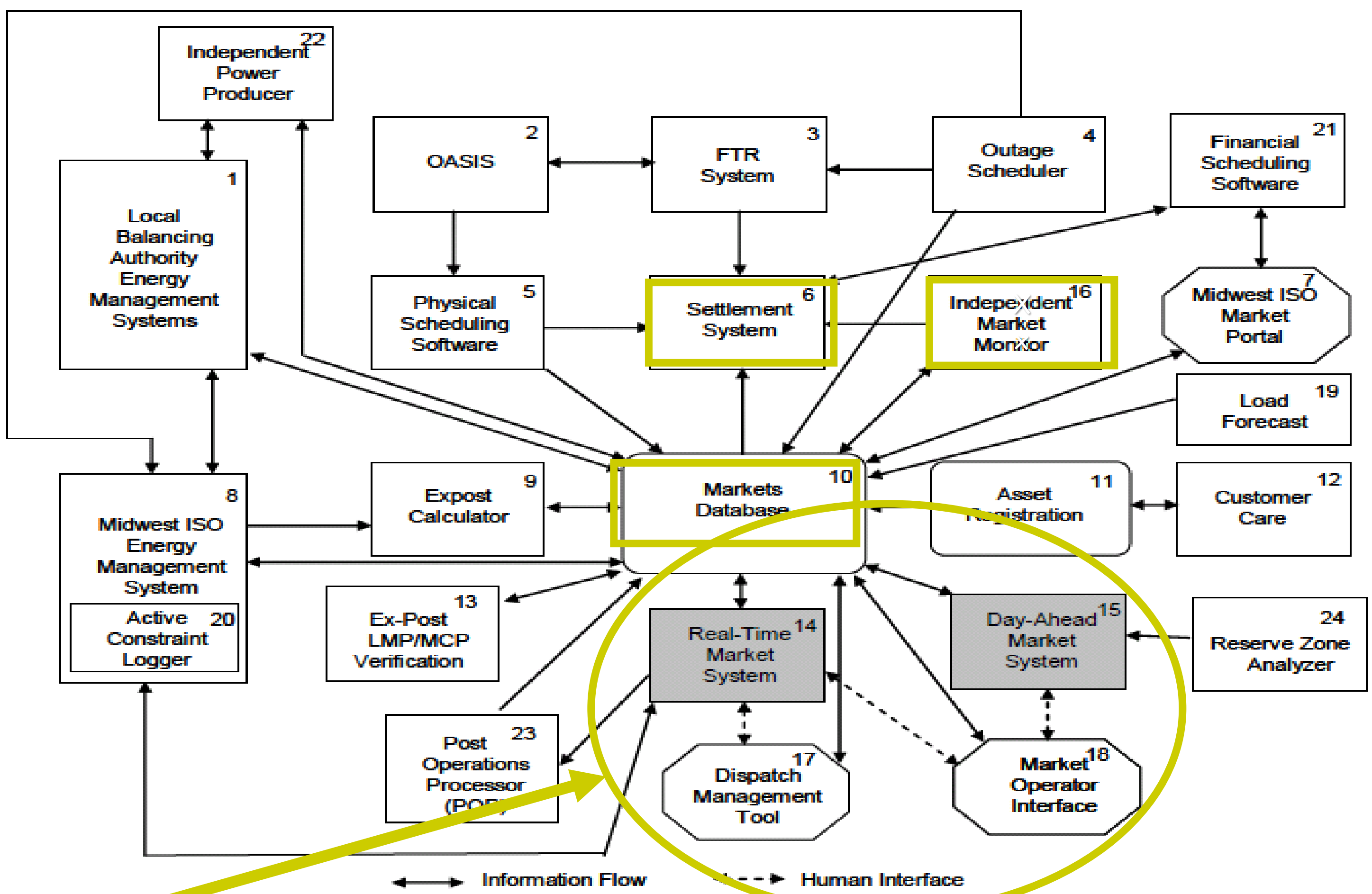
- Oversight & market power mitigation by outside agency

Complexity of FERC Market Design

Example: MISO Business Practices Manual 001

DART = Day-Ahead and Real-Time Market System

Exhibit 2-3: DART Components Overview

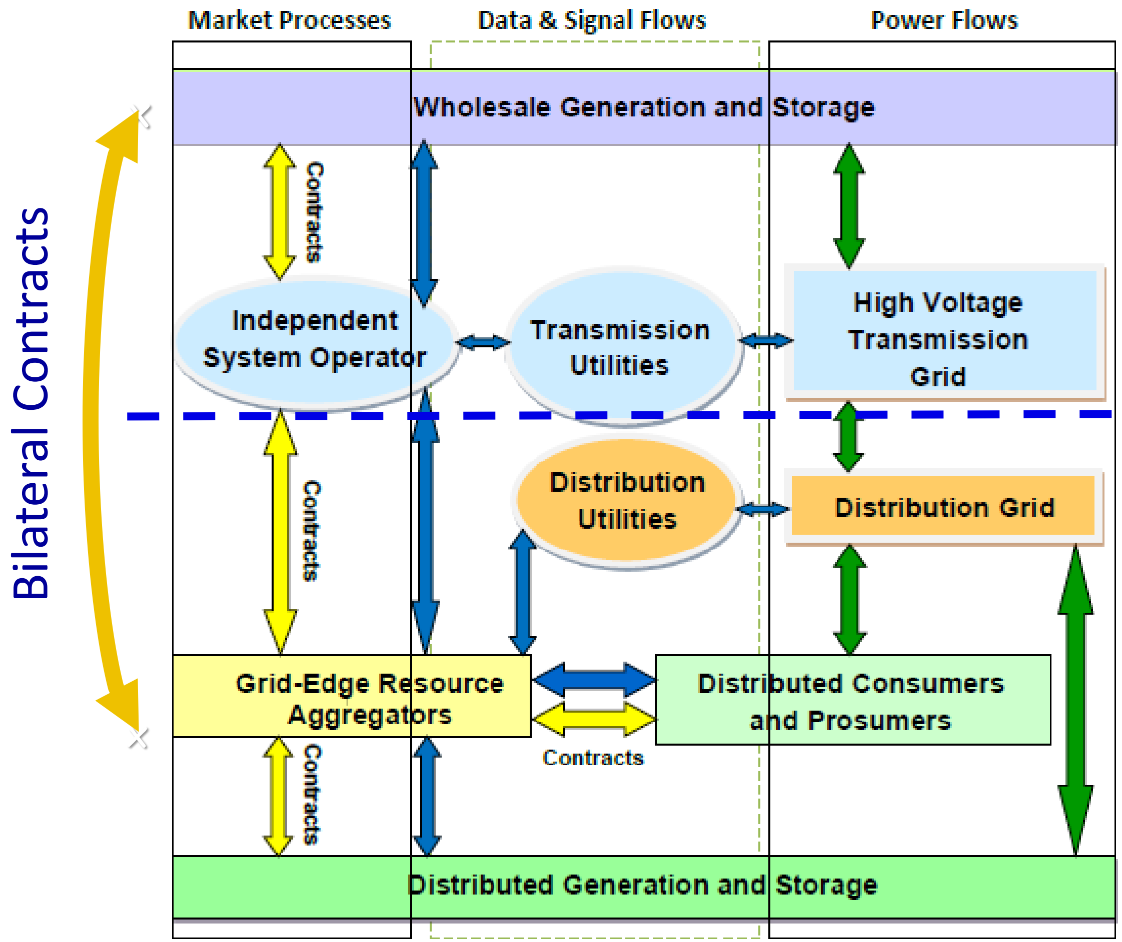


DART Two-Settlement System = Core of FERC Market Design

Project Test-System Approach

Integrated Retail/Wholesale (IRW) Power System Test Bed

https://www2.econ.iastate.edu/tesfatsi/IRWProjectHome.htm



Wholesale

AMES Test Bed

developed by ISU Team

seamed

Retail

GridLAB-D

developed by DOE/PNNL & ISU IRW Project Group

Integrated Human/Computational Test Beds for Social Science Research, Teaching, & Training

- **Integrated Test Bed (ITB)** =: Software platform permitting decision-making (DM) agents to range from 100% human to 100% computational

- Modular extensible architecture
- Open source availability
- Development of multiple application-tailored ITBs

Advantages of Integrated Test Beds for Social Science Research, Teaching, & Training

- Social systems are highly complicated.
- Global regularities arise over time from the interactions of many distributed micro entities.
- These interactions are channelled & constrained by current
  - structural conditions
  - institutional arrangements
  - behavioral dispositions

  that in turn can *change and evolve*.
- Emergence of global regularities can take a long time.

*I*ntegrated *T*est *B*eds (*ITB*s) can Facilitate the Study of Real-World Economic Processes

- ITBs permit more realistic experimental environments for human subjects by letting ***C***omputational ***A***gents (***CA***s) represent critical but complicated real-world aspects.

- ITBs permit the systematic study of human behavior within controlled group settings (small → large) because CAs can be included to represent "others" in these groups.

- ITBs permit *in situ* training of decision-making CAs to embody human decision-making behaviors, which can then be used in longer-run dynamic experimental studies not practical for human subject participation.

Existing Integrated Test Beds in Economics ?

❑ Some research combining Humans/CAs

- Roth/Murnighan 1978; Coursey et al. 1984; Brown/Kruse 1991
- Houser/Kurzban 2002;Johnson et al. 2002,Rassenti et al.2003
- Entriken/Wan/Chao 2003

❑ Not much publicly available ITB software

- Multi-Agent Simulation Suite developed by Ivanyi et al. (2007) supports "participatory simulation" (some agents can be controlled by human users)
- GEEP (Rob Goldstone, foraging project, 2009)

In Contrast ....

- **Many calls for <u>parallel</u> human-agent experiments**

  (Jager/Janssen 2003, Contini et al. 2006, Markose 2006, Duffy 2006, LeBaron/Tesfatsion 2008…)

- **Various parallel studies have already been carried out**
  - Gode/Sunder 1993; Arifovic 1993; Bousquet 1997;
  - Chan, LeBaron, Lo, & Poggio 1999; Duffy 2001; Jager/Janssen 2003;
  - Pingle/Tesfatsion 2003; Rouchier 2003, 2005; Kurzban/Houser 2005;
  - Duffy 2006; Invanyi, Bocsi, Gulyas, Kozma, & Legendi 2007;
  - Spiliopoulos 2008; Hommes/Lux 2009, …

ACE Research Area: Experiments with Real & Computational Agents

https://www2.econ.iastate.edu/tesfatsi/aexper.htm

Parallel-Experiment Synergies

- **Human-Subject Experiments ➡ ACE**
  - Empirical microfoundations for decision-making & learning
  - Empirical validation of outcomes
  - Empirical regularities in need of explanation

Parallel Experiment Synergies …

❑ ACE ➡ Human-Subject Experiments

- Benchmarks of comparison (zero-intelligence trading; control of social histories, motivations, types…)
- Intensive controlled study of necessary as well as sufficient conditions for observed human outcomes
- Extension of human-subject experiments in scope & time (wealth creation, learning dynamics, emergent types,…)

Systematic Use of Parallel Experiments

Iterative Participatory Modeling

(See F. Bousquet, O. Barreteau, et al., *JASSS* 2003)

Collect Field Data

Human-Subject Experiments

Agent-Based Computational Modeling

Additional Hypotheses for Testing

Conclusion

- ***H**uman **S**ubject (**HS**) experiments* permit careful study of micro human behaviors in controlled lab settings.

- ***C**omputational **A**gent (**CA**) experiments* permit controlled study of complex processes over extended time.

- Advantages could be jointly exploited thru ***I**ntegrated **T**est **B**eds (**ITB**s)* permitting decision-making entities to range from 100% human to 100% computational.

- Current research on parallel HS/CA implementations could be used as the basic starting point for ITB development.

On-Line Resources

- **Presentation Slides**

  https://www2.econ.iastate.edu/tesfatsi/BehExperTalk.LT.pdf

- **Key Reference Paper:** P. Borill & L. Tesfatsion, "Agent-Based Modeling: The Right Mathematics for the Social Sciences?," Elgar Volume, 2011, to appear.

  https://www2.econ.iastate.edu/tesfatsi/ABMRightMath.PBLTWP.pdf

- **Experiments with Real & Computational Agents**

  https://www2.econ.iastate.edu/tesfatsi/aexper.htm

- **Integrated Retail-Wholesale Project: Homepage**

  https://www2.econ.iastate.edu/tesfatsi/irwprojecthome.htm