Market Design as Social Policy: An Agent-Based Modeling Approach

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Outline

- **What is Agent-based Computational Economics (ACE)?**
- **ACE Market Design as Social Policy Analysis:** A simple wholesale power market illustration
- **A Real-World Policy Project**: Testing the efficiency and market power impacts of a newly implemented wholesale power market design
- **Taking a Companion Modeling Approach**: Operational validation issues

What is ACE?

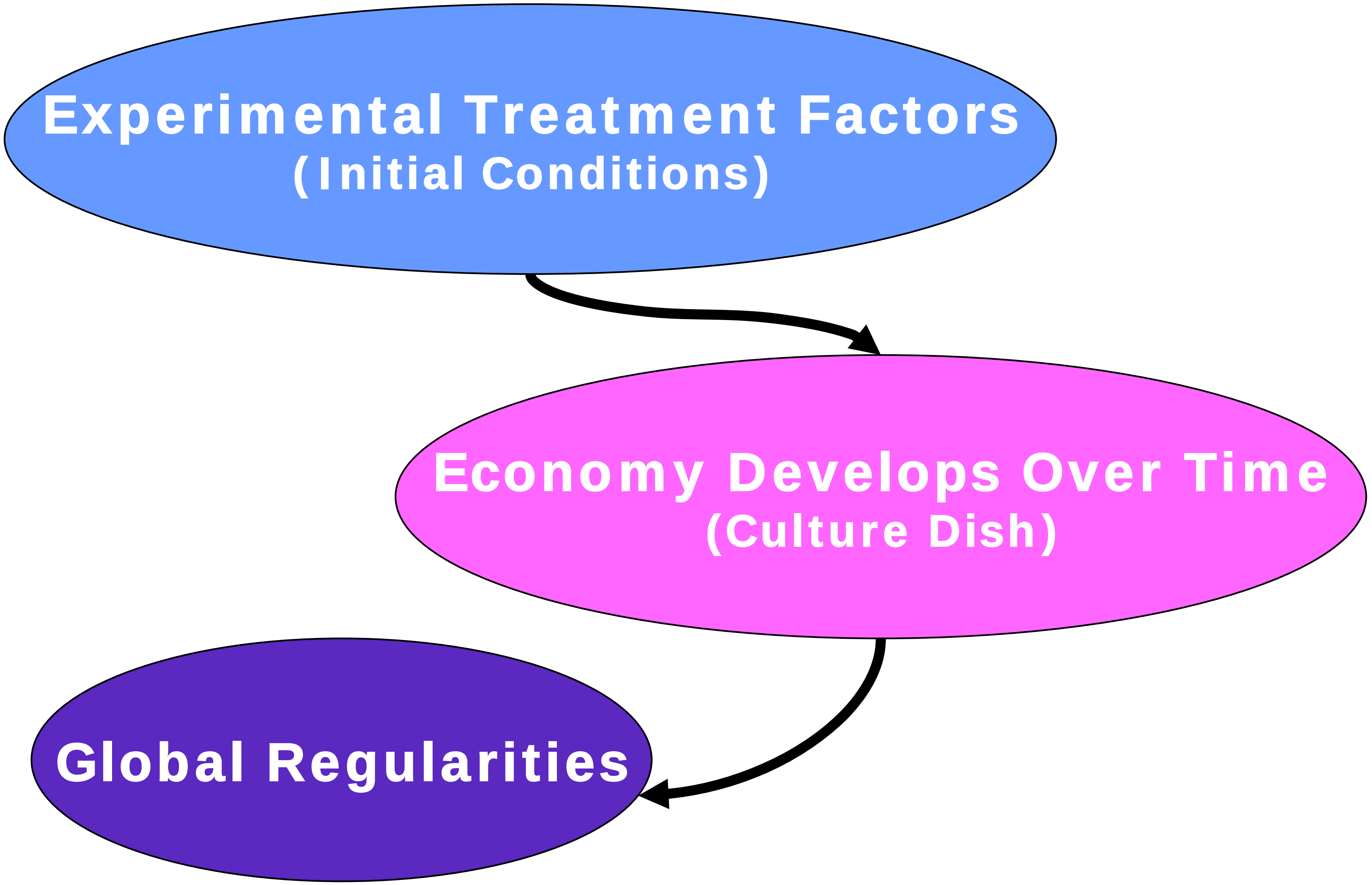
- **Constructive approach** to the study of decentralized market processes
- **ACE** = Computational study of economies as dynamic systems of interacting agents
- **Agent** = Bundled methods and data representing an individual, social, biological, or physical entity in a computationally constructed world

ACE Modeling: Culture Dish Analogy

- Modeler constructs a **virtual economic world** populated by various agent types
- Modeler sets **initial world conditions**
- Modeler then steps back to observe how the **world develops over time** (no further intervention permitted)

World events are driven by agent interactions (***dynamic completeness***)

ACE World:
Culture Dish Analogy



Four Strands of ACE Research

- **Empirical Understanding**
  (e.g., possible explanations for macro regularities)
- **Normative Understanding**
  (e.g., market design as social policy)
- **Qualitative Insight/Theory Generation**
  (e.g., self-organization of decentralized markets)
- **Methodological Advancement**
  (e.g., agent representation and visualization)

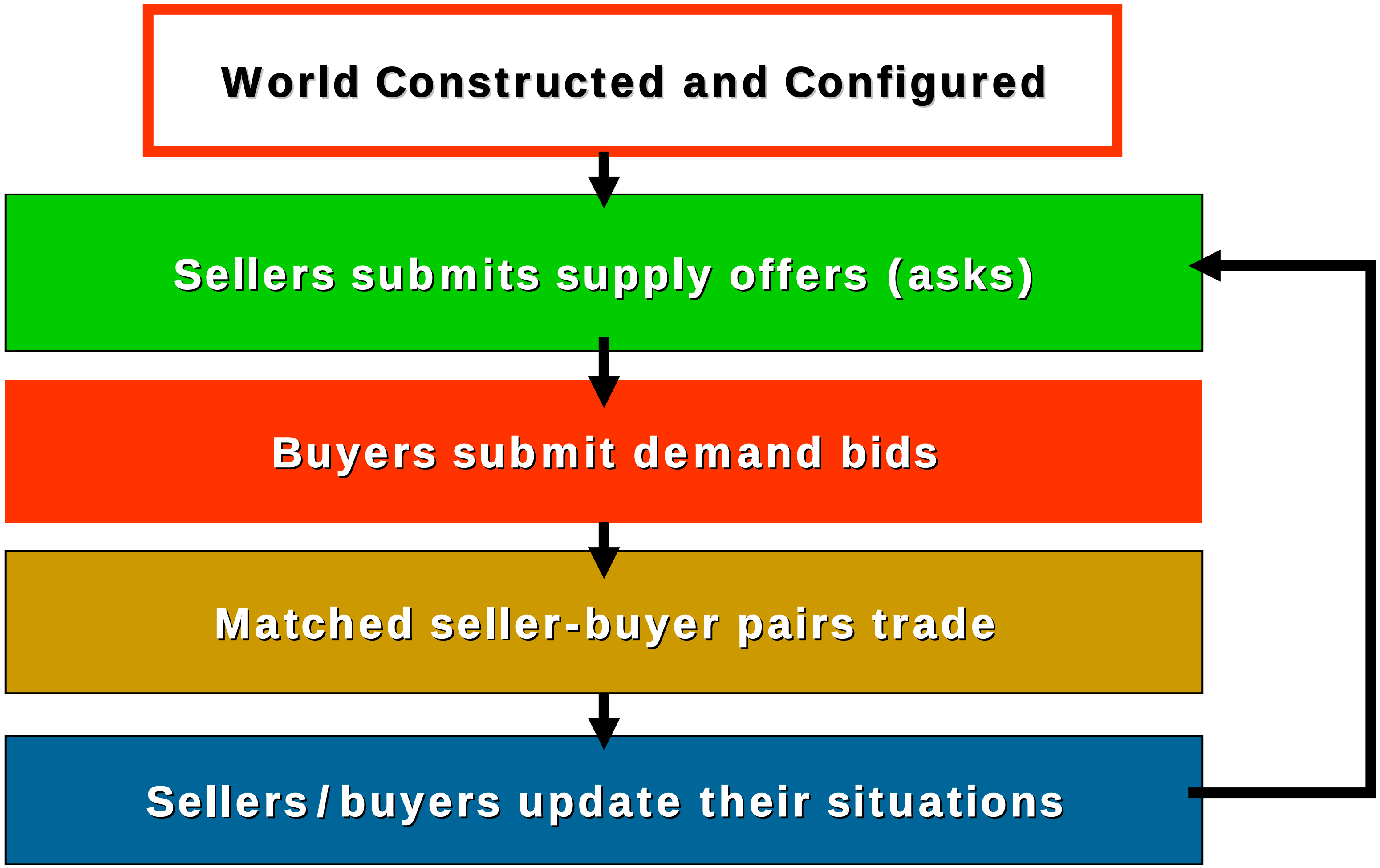
ACE Market Design as Social Policy Analysis

- Construct an ACE World capturing salient aspects of a proposed or actual market design.
- Introduce traders with preferences and learning capabilities, and let ACE World develop over time.

◆ **Key Issue:** Does the design ensure efficient, fair, and orderly social outcomes over time despite attempts by traders to exploit the design for their own individual advantage?

Double-Auction Wholesale Power Market

(Nicolaisen, Petrov, Tesfatsion, IEEE-TEC, Vol. 5, 2001)



Key Issue Addressed

Relative role of **structure vs. learning** in determining double-auction performance.

- Sensitivity of market efficiency and market power outcomes to changes in market structure

  RCON = Relative seller/buyer concentration

  RCAP = Relative demand/supply capacity

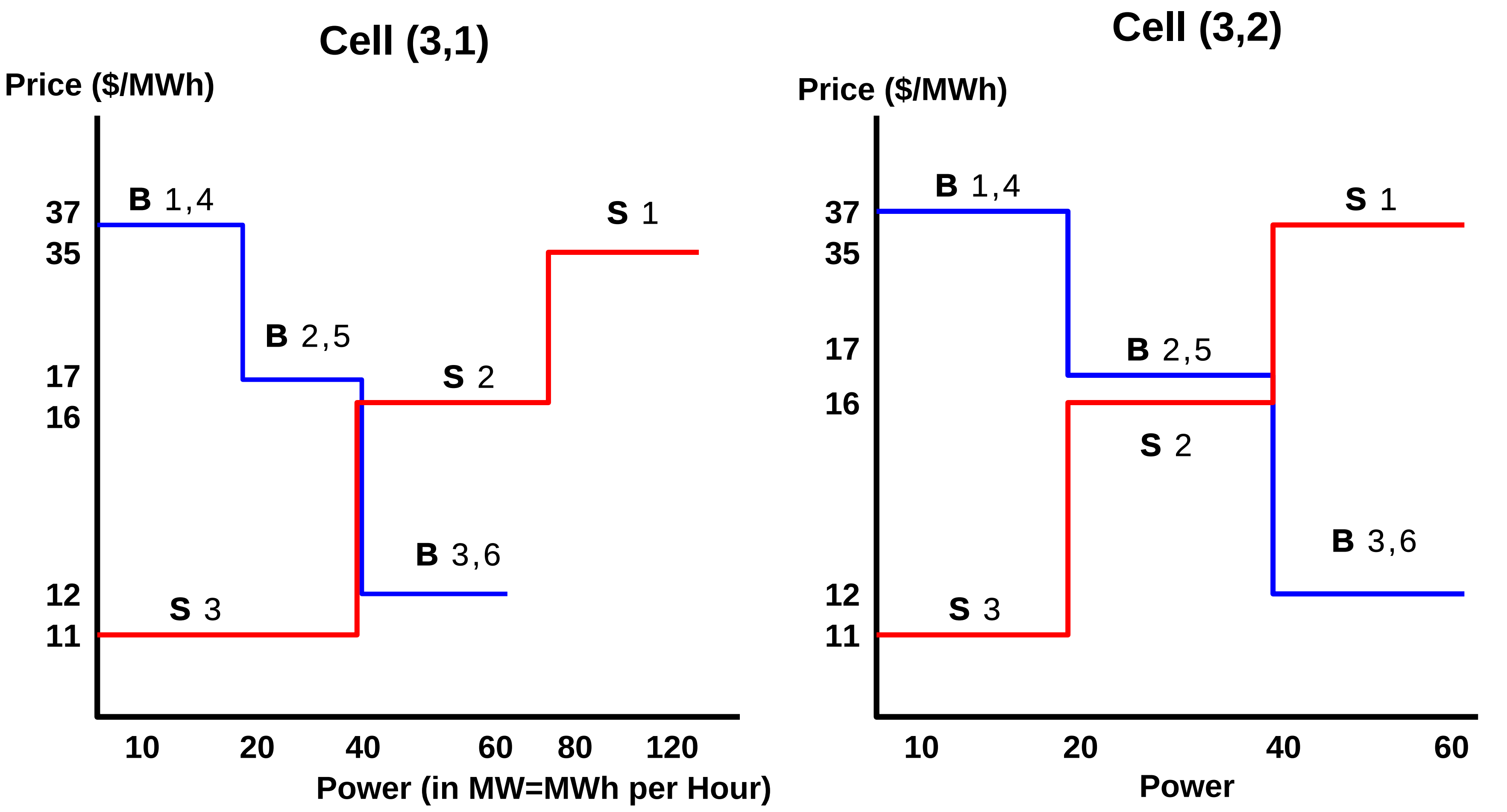
- Sensitivity of market efficiency and market power outcomes to changes in trader learning representations (RL vs. GA social mimicry).

Structural treatment factor values (tested for each learning treatment)

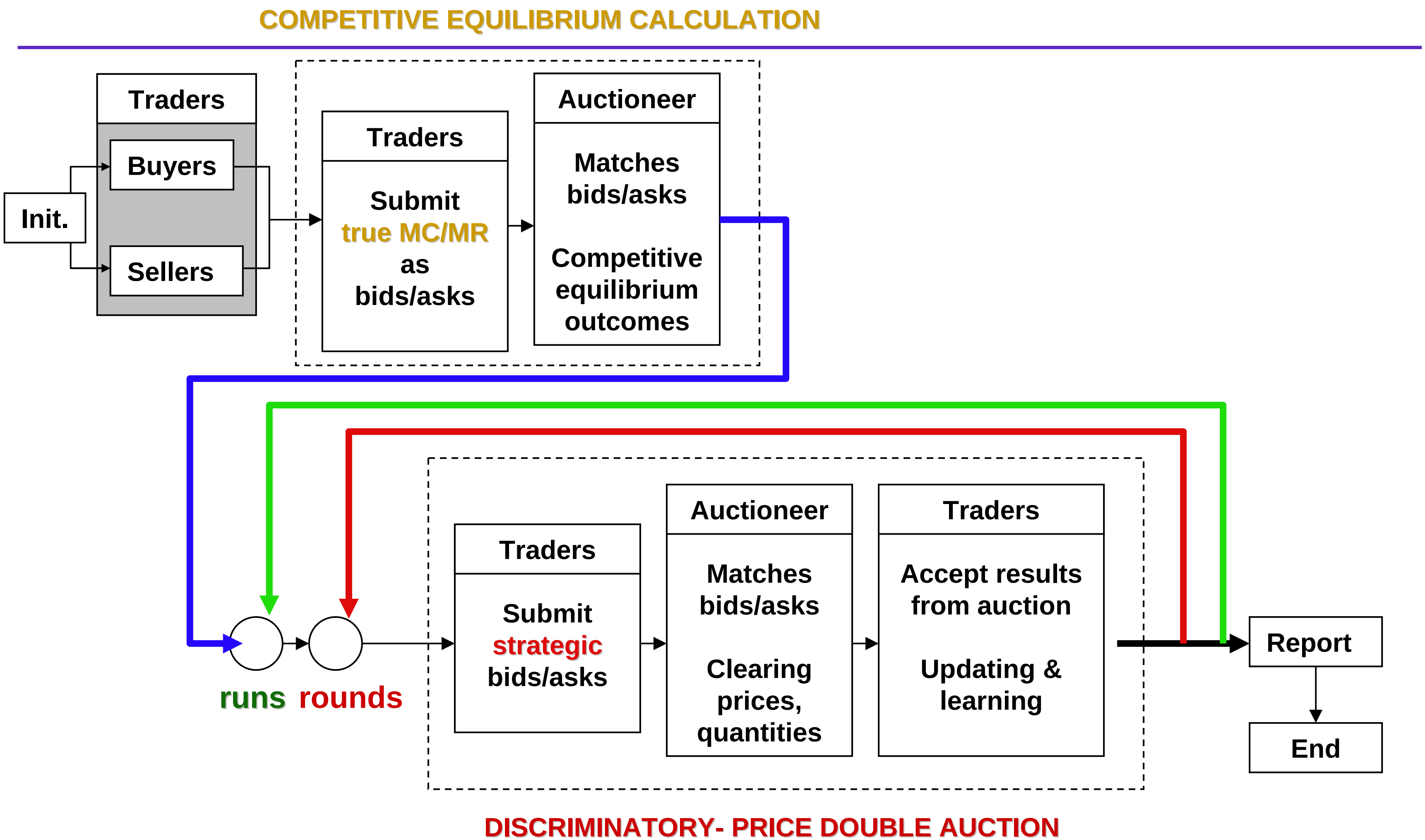
Ns = Number of Sellers
Nb = Number of Buyers
Cs = Seller Supply Capacity
Cb = Buyer Demand Capacity

		RCAP		
		1 / 2	1	2
RCON	2	Ns = 6 Nb = 3 Cs = 10 Cb = 10	Ns = 6 Nb = 3 Cs = 10 Cb = 20	Ns = 6 Nb = 3 Cs = 10 Cb = 40
	1	Ns = 3 Nb = 3 Cs = 20 Cb = 10	Ns = 3 Nb = 3 Cs = 10 Cb = 10	Ns = 3 Nb = 3 Cs = 10 Cb = 20
	1 / 2	Ns = 3 Nb = 6 Cs = 40 Cb = 10	Ns = 3 Nb = 6 Cs = 20 Cb = 10	Ns = 3 Nb = 6 Cs = 10 Cb = 10

Aggregate "True" Demand and Supply per Hour



Detailed Activity Flow for the Double Auction



The Computational World

Public Access:

// **Public Methods**

The ***World Event Schedule,*** i.e., a system clock that permits inhabitants to time and synchronize activities (e.g., submission of asks/bids into the DA market);

Protocols governing trader collusion;

Protocols governing trader insolvency;

Methods for receiving data.

Private Access:

// **Private Methods**

Methods for gathering, storing, and sending data;

// **Private Data**

World attributes (e.g., spatial configuration);

World inhabitants (DA market, buyers, sellers);

World inhabitants' methods and data.

The Computational DA Market

Public Access:

// **Public Methods**

getWorldEventSchedule(clock time);
Protocols governing the public posting of asks/bids;
Protocols governing matching, trades, and settlements;
Methods for receiving data.

Private Access:

// **Private Methods**

Methods for gathering, storing, and sending data.

// **Private Data**

Data recorded about sellers (e.g., seller asks);
Data recorded about buyers (e.g., buyer bids);
Address book (communication links).

A Computational DA Trader

Public Access:

// **Public Methods**

getWorldEventSchedule(clock time);

getWorldProtocols (collusion, insolvency);

getMarketProtocols (posting, matching, trade, settlement);

Methods for receiving data.

Private Access:

// **Private Methods**

Method for calculating my expected profit assessments;

Method for calculating my actual profit outcomes;

Method for updating my ask/bid strategy (**LEARNING**).

// **Private Data**

Data about me (history, profit function, current wealth,...);

Data about external world (rivals' asks/bids, ...);

Address book (communication links).

Summary of Policy-Relevant DA Findings

- **Market Efficiency:** Generally high when traders use reinforcement learning **but not** when traders use social mimicry (***type of learning can matter***).

- **Structural Market Power:** Microstructure of the DA market is strongly predictive for the relative market power of traders (***rule details matter***).

- **Strategic Market Power:** Traders are **not** able to change their relative market power through learning (***importance of countervailing power***).

Real-World Policy Project

"An Agent-Based Computational Laboratory for Testing the Economic Reliability of FERC's Proposed Wholesale Power Market Platform"

Joint research by

Deddy Koesrindartoto

(Centre For Comp. Finance and Economic Agents, U of Essex)

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(Economics Ph.D. student, ISU)

and

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2005 Work in Progress

Wholesale Power Market Platform - WPMP

U.S. Federal Energy Regulatory Commission (FERC), White Paper, April 2003

Policy Objectives:

- Customer-based competitive wholesale power markets providing reliable service
- Fair/open access to the transmission grid at reasonable prices
- Good price signals to encourage appropriate investment in new generation and transmission
- Market power oversight and mitigation

FERC's WPMP Design Adopted?

- **Mid-Atlantic States** (PJM) implement similar plan (1998)
- **New York** (NYISO) implements similar plan (1999)
- **New England** (ISO-NE) implements similar plan (2003)
- **California** (CAISO) files to adopt similar plan (2003)
- **Midwest** (MISO) **files to adopt** similar plan (7/2003), **withdraws filing** (10/2003), **refiles** (3/2004), and then **adopts and implements** design (4/2005)
- **Opposition** from states in Southeast and Northwest

Why Resistance to FERC's WPMP Proposal?

- **Stakeholders in Midwest**

  Key cited problem:

  Lack of sufficient reliability testing.

- **Stakeholders in Southeast and Northwest**

  Key cited problems:

  Lack of sufficient reliability testing;

  Questions about suitability given special local conditions (TVA, hydroelectric power…).

Our Wholesale Power Market Model

- **Modeling Goal: Operational Validity**

Model architecture based on operation/training manuals issued for the *Standard Market Design (SMD)* implemented by New England, March 2003

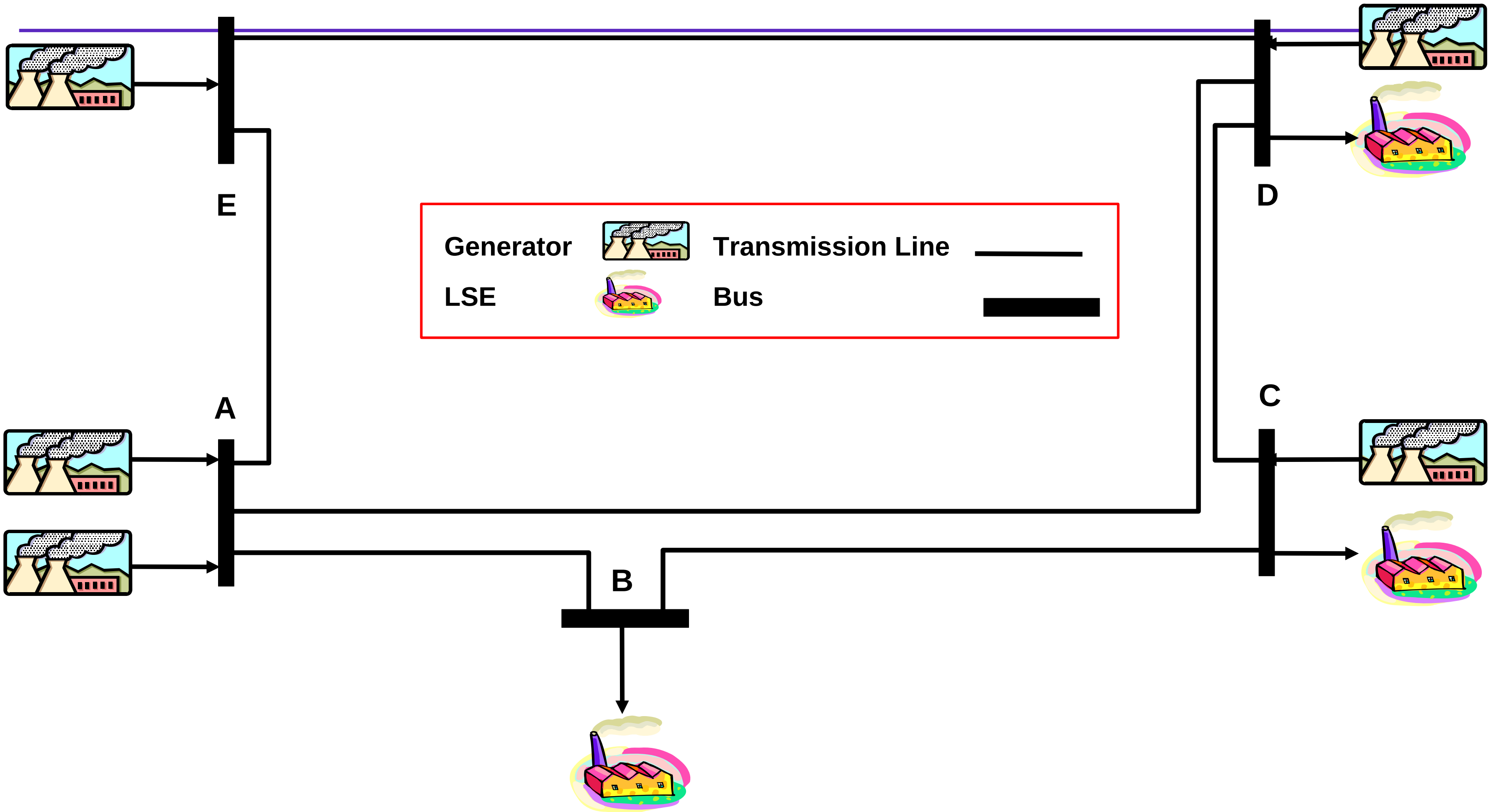
The New England SMD meets FERC's core WPMP architectural requirements

- Independent System Operator (ISO)
- Day-ahead and real-time markets for power
- Congestion managed via Locational Marginal Pricing (LMP)
- Financial transmission rights
- ISO market oversight and market power mitigation

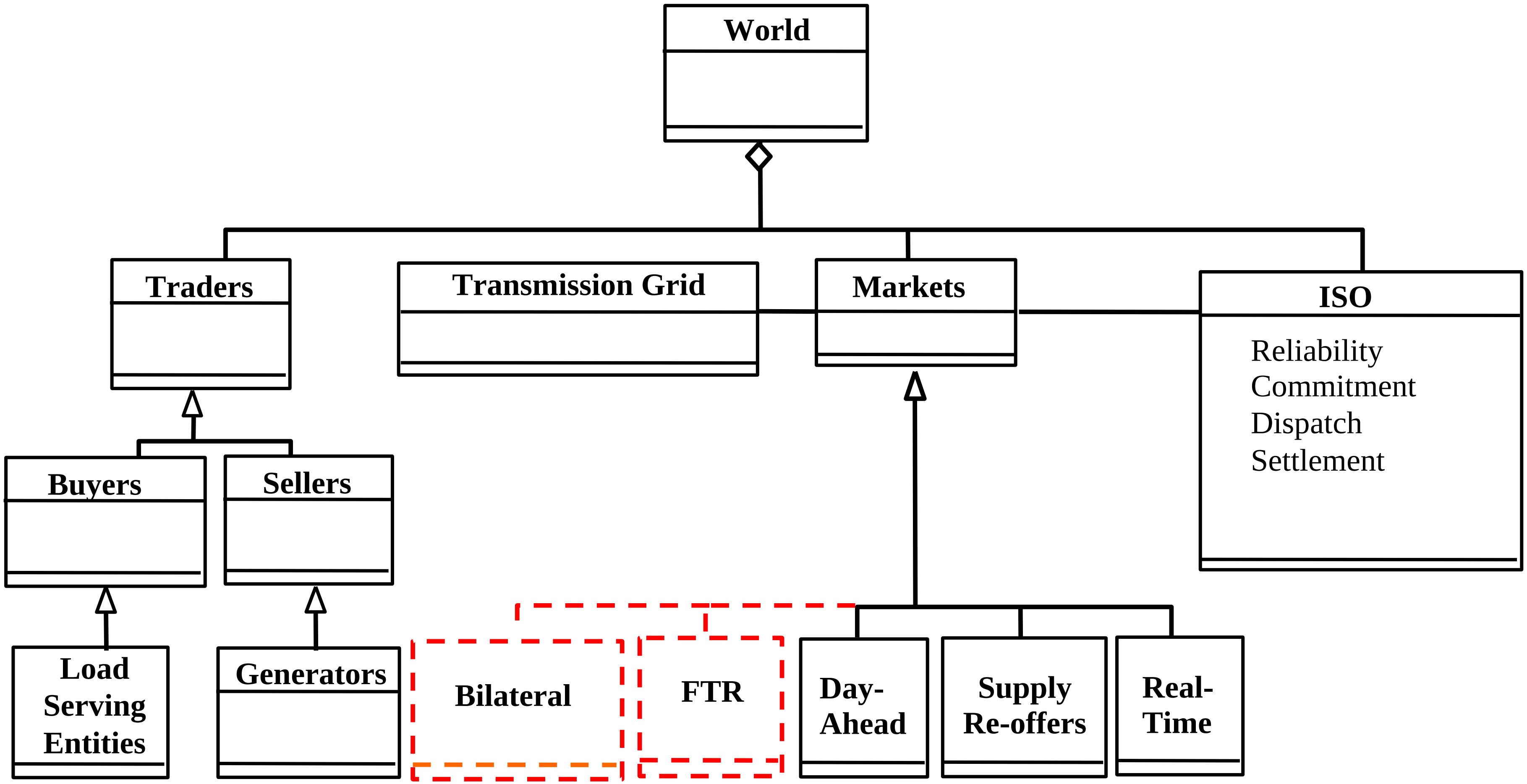
Core Features of Our Model

- **Traders**
  - Sellers and Buyers
  - Follow market rules
  - **Learning abilities**
- **Independent System Operator**
  - System reliability assessments
  - Day-ahead security-constrained bid-based unit commitment
  - Real-time settlement
- **Multi-Settlement Process**
  - Day-ahead market (double auction, financial contracts)
  - Real-time market (settlement of differences)
  - Supply re-offer period
- **AC Transmission Grid**
  - Congestion managed via Locational Marginal Pricing (LMP)
  - 5-bus demo model (scalable to a more complex grid)

5-Bus Transmission Grid (Demo Model)



Model Architecture: Agent Hierarchy



A Computational Seller (Generator)

Public Access:

// **Public Methods**

getMarketProtocols(posting, trade, settlement);
getMarketProtocols(ISO market power mitigation);
Methods for receiving data.

Private Access:

// **Private Methods**

Method for calculating my expected profits;
Method for calculating my actual profit outcomes;
Method for updating my supply offers (**LEARNING**).

// **Private Data**

My capacity, grid location, cost fct., current wealth... ;
Data recorded about external world (dispatch schedule...);
Address book (communication links).

A Computational Buyer (LSE)

Public Access:

// **Public Methods**

getMarketProtocols(posting, trade, settlement);
getMarketProtocols(ISO market power mitigation);
Methods for receiving data.

Private Access:

// **Private Methods**

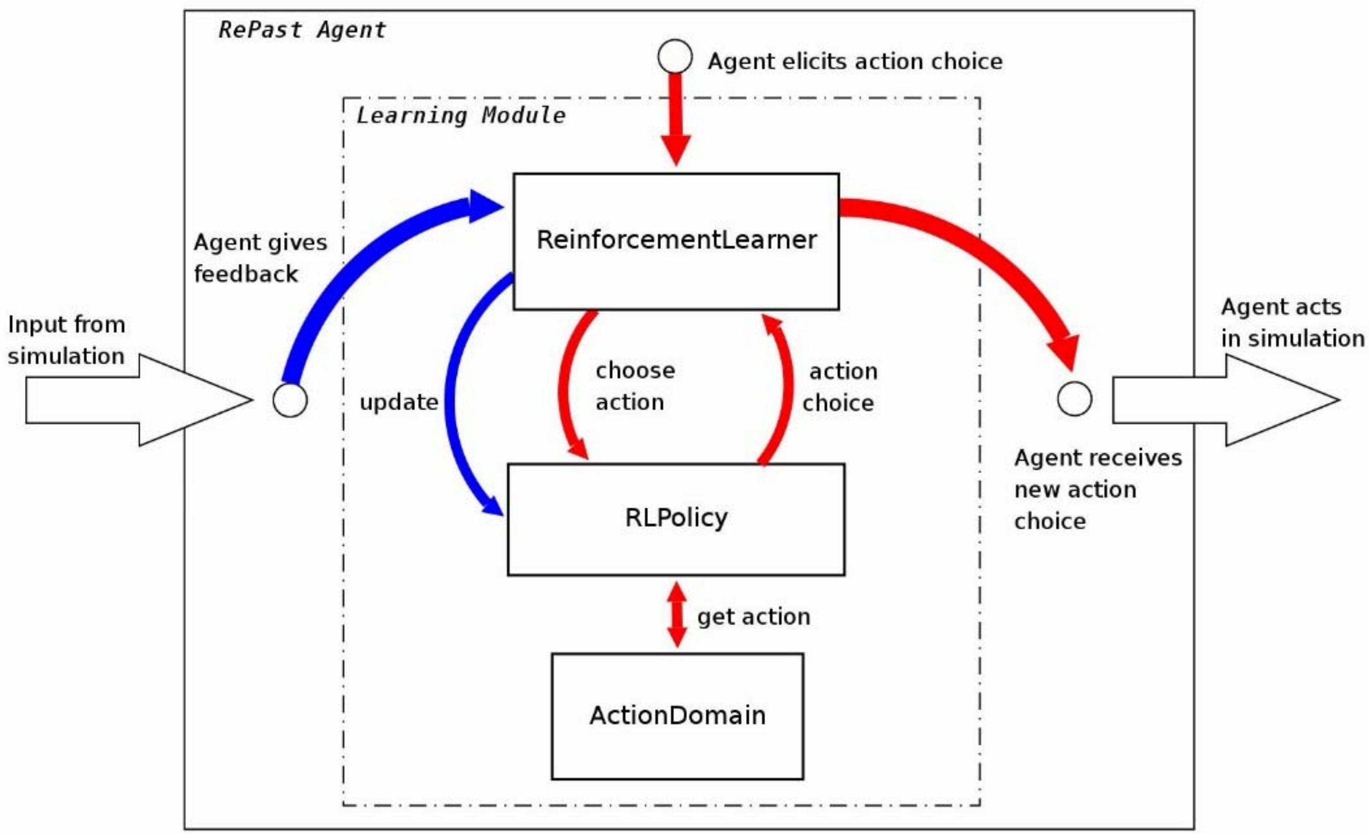
Method for calculating my expected profits;
Method for calculating my actual profit outcomes;
Method for updating my demand bids (**LEARNING**).

// **Private Data**

My downstream demand, grid location, current wealth…;
Data recorded about external world (dispatch schedule…);
Address book (communication links).

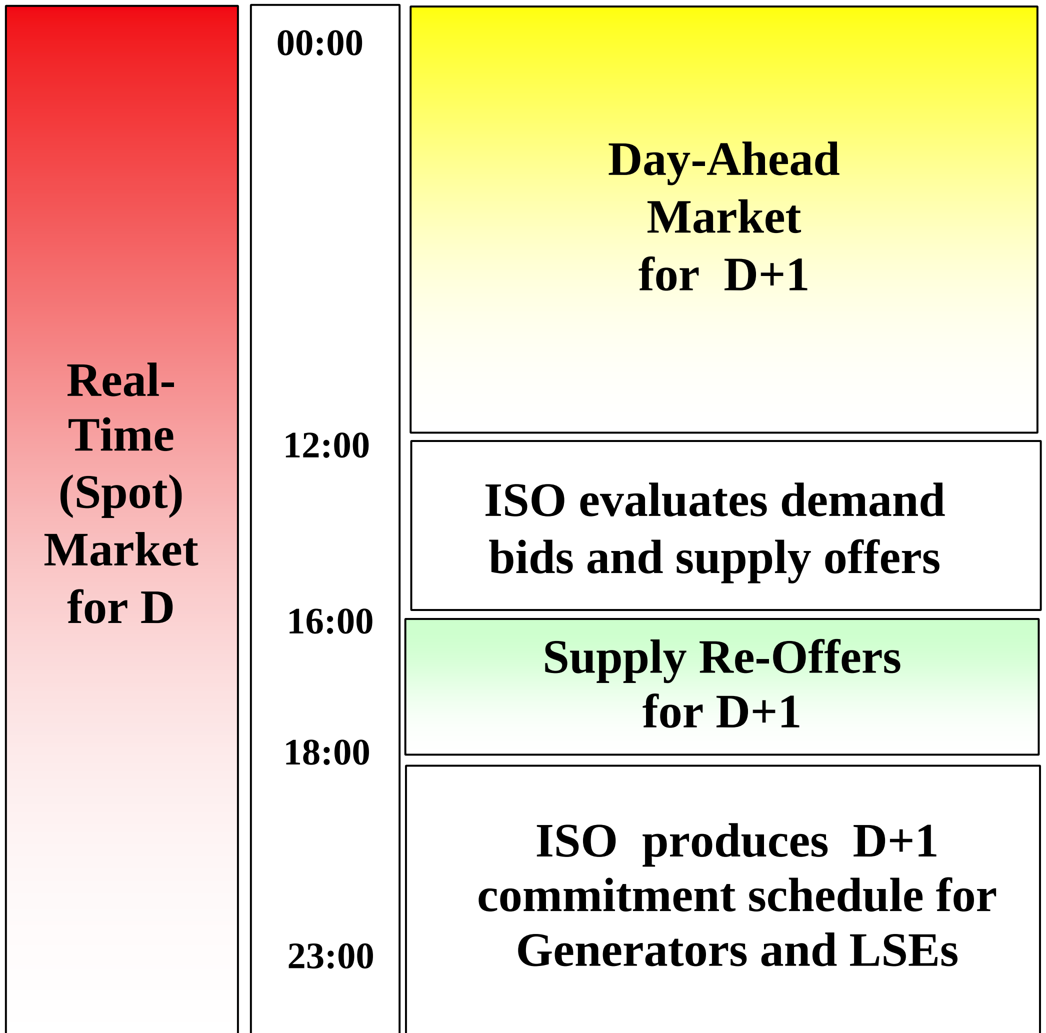
GenBots / LSEBots Use Reinforcement Learning

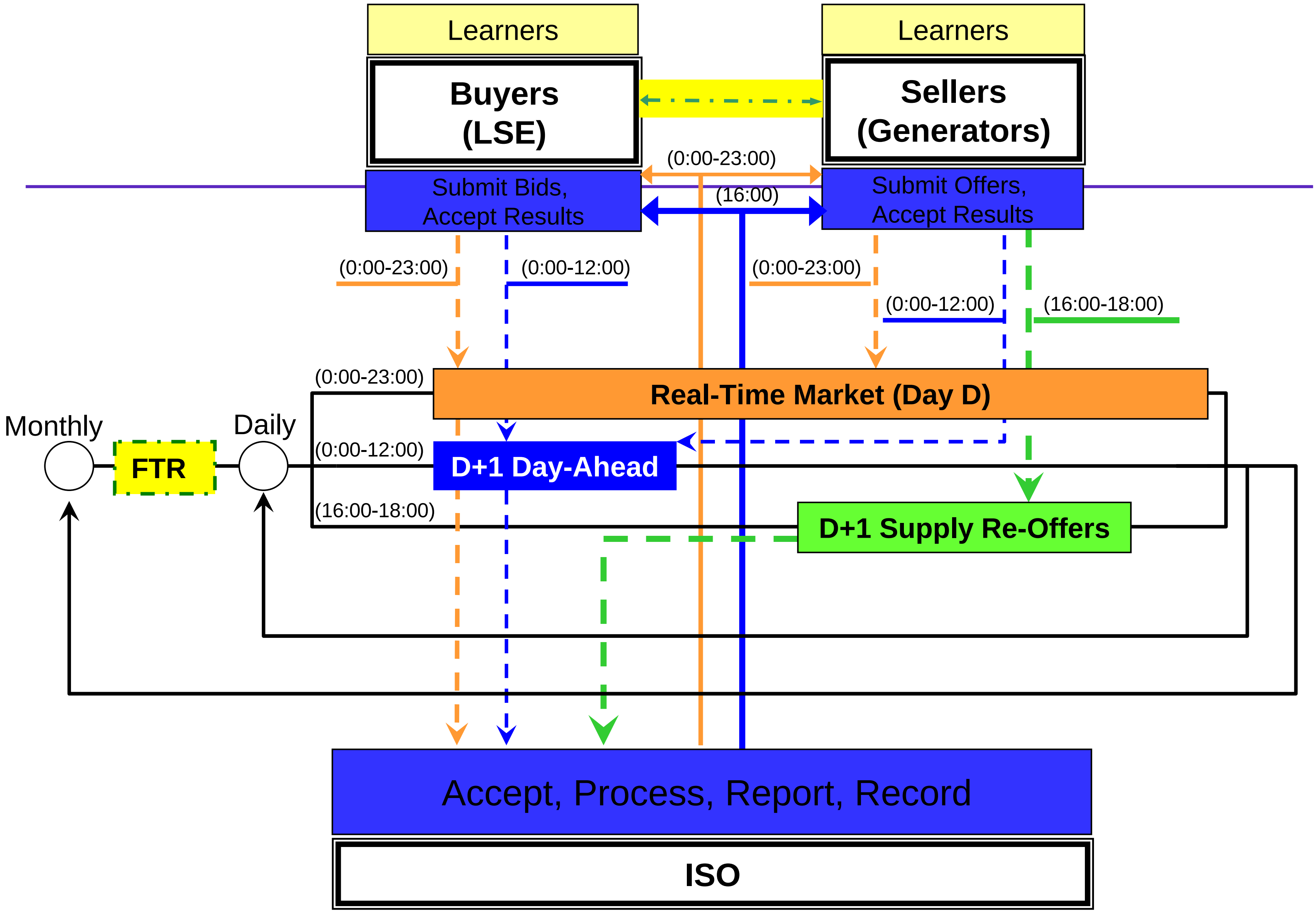
[C. Gieseler, Repast/Java Learning Module, M.S. Thesis, 2005, in Progress]



Learning Module Interaction

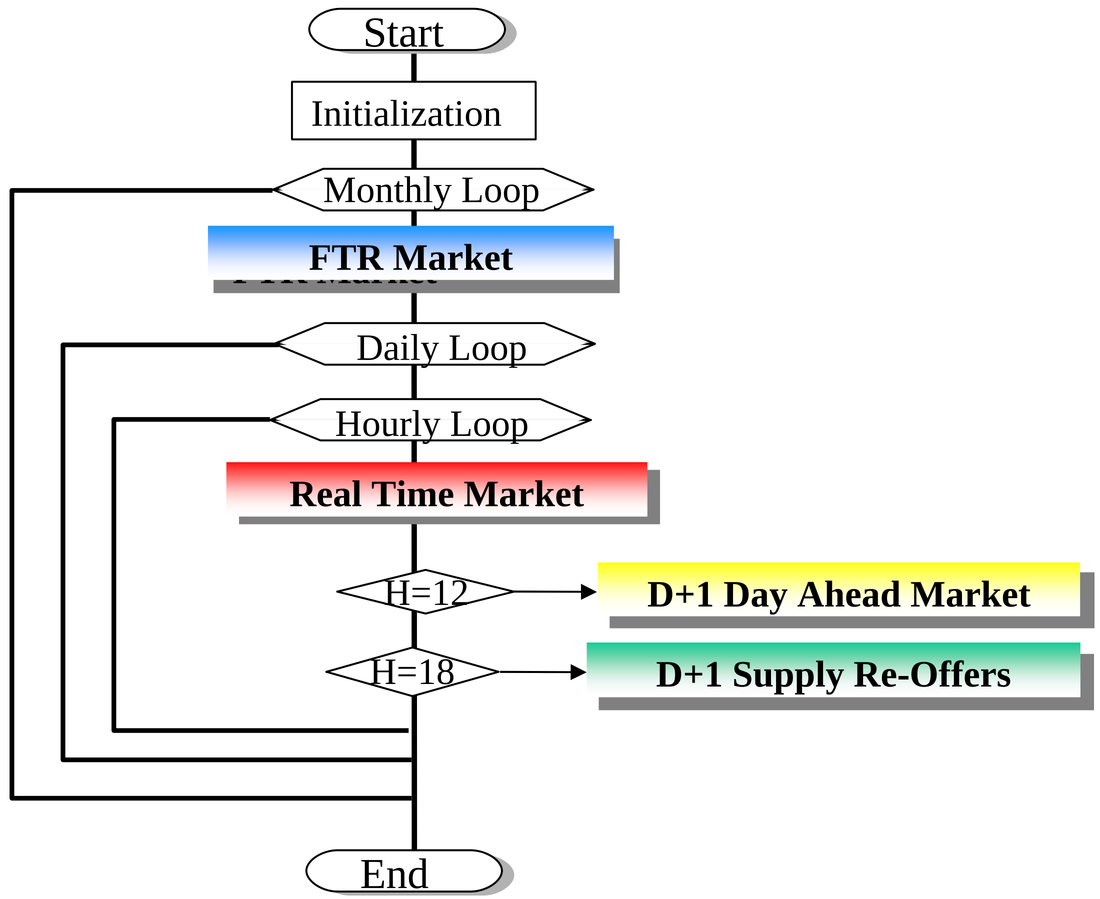
ISO Daily Activities (Day D)





Learners
Learners
Buyers (LSE)
Sellers (Generators)
(0:00-23:00)
(16:00)
Submit Bids, Accept Results
Submit Offers, Accept Results
(0:00-23:00)
(0:00-12:00)
(0:00-23:00)
(0:00-12:00)
(16:00-18:00)
(0:00-23:00)
Real-Time Market (Day D)
Monthly
FTR
Daily
(0:00-12:00)
D+1 Day-Ahead
(16:00-18:00)
D+1 Supply Re-Offers
Accept, Process, Report, Record
ISO

World Event Schedule for Our Model



Experimental Design: Treatment Factor Ranges

- DC Transmission Grid (Typical lit. assumption) → AC Transmission Grid (Actual ISO-NE situation)
- Cournot supply behaviour (Typical lit. assumption) → Learned strategic behavior (Actual ISO-NE situation)
- Passive inelastic demand (Typical lit. assumption) → Strategic DAM demand bids (Actual ISO-NE situation)
- No transmission rights (Typical lit. assumption) → Financial transmission rights (Actual ISO-NE situation)

Companion Modeling Approach

- Barreteau et al. (*JASSS* 2003)
- Iterative participatory process involving stakeholders, regulatory agencies, and researchers from multiple disciplines in a repeated looping through a 3-stage cycle:
  - Field work and data analysis;
  - Model development and implementation;
  - Computational experiments and role-playing games.

Operational Validation Issues

- **Proprietary software**
  - ISO-NE rents its commitment/dispatch software from a commercial company
  - Cannot/will not publicly release commitment and dispatch problem formulations
  - Requires challenging “missing process” inferences (inputs ⇒ ***process?*** ⇒ output)
- **Proprietary data**
  - Confidentiality agreements sought for detailed micro data

Concluding Remarks

- ACE modeling (subset of *constructive* math) is a potentially useful tool for market design policy
- as a complement for human-subject experiments, field studies, econometrics, and *classical* math.
- ACE could facilitate an iterative participatory modeling process (companion modeling).
- But **academic** (open source) research via companion modeling faces practical challenges.