Prediction Of Human Behavior

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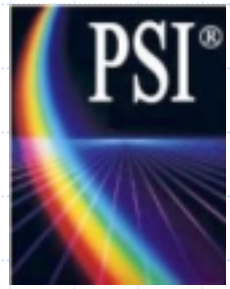


Introduction

- Prediction of Human Behavior can be approached in various ways and is a complex, challenging problem.
- PSI sought appropriate methods for modeling this.
- We evaluated model architectures for suitability.
- Models should evolve with new knowledge.
- Recent research suggests need to incorporate knowledge of experts in human behavior, and who may not have experience with M&S.
- **Our Goal**: Provide an intuitive environment that facilitates capture of expert knowledge, and can serve as a framework for easily expanding models.

Problem Statement

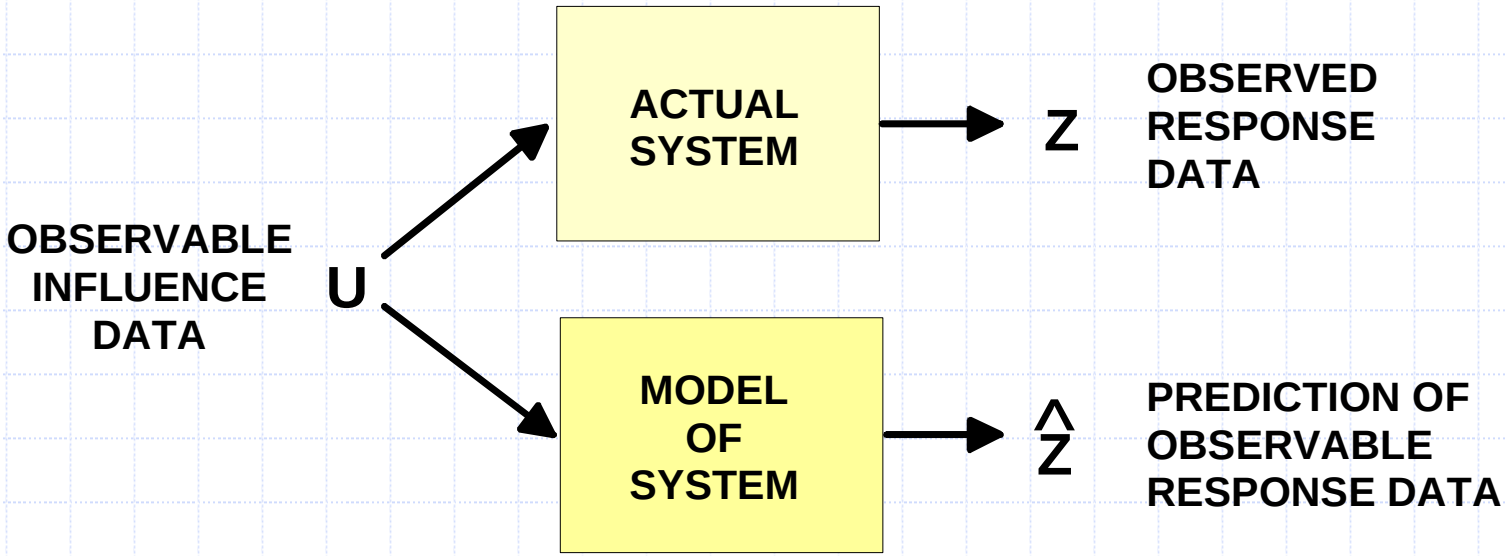
- **Predicting the behavior of an individual or group, e.g., small cell or whole society.**
  - ***This is a complex problem***
- **Which framework or approach works best?**

Approach to the Problem

- Treat each individual or group as a ***system***.
- Develop an approach that leverages knowledge of experts, and is flexible.
- Apply and extend traditional Control Theory to the problem.

General Form of a Prediction Model

(Discrete State Space)

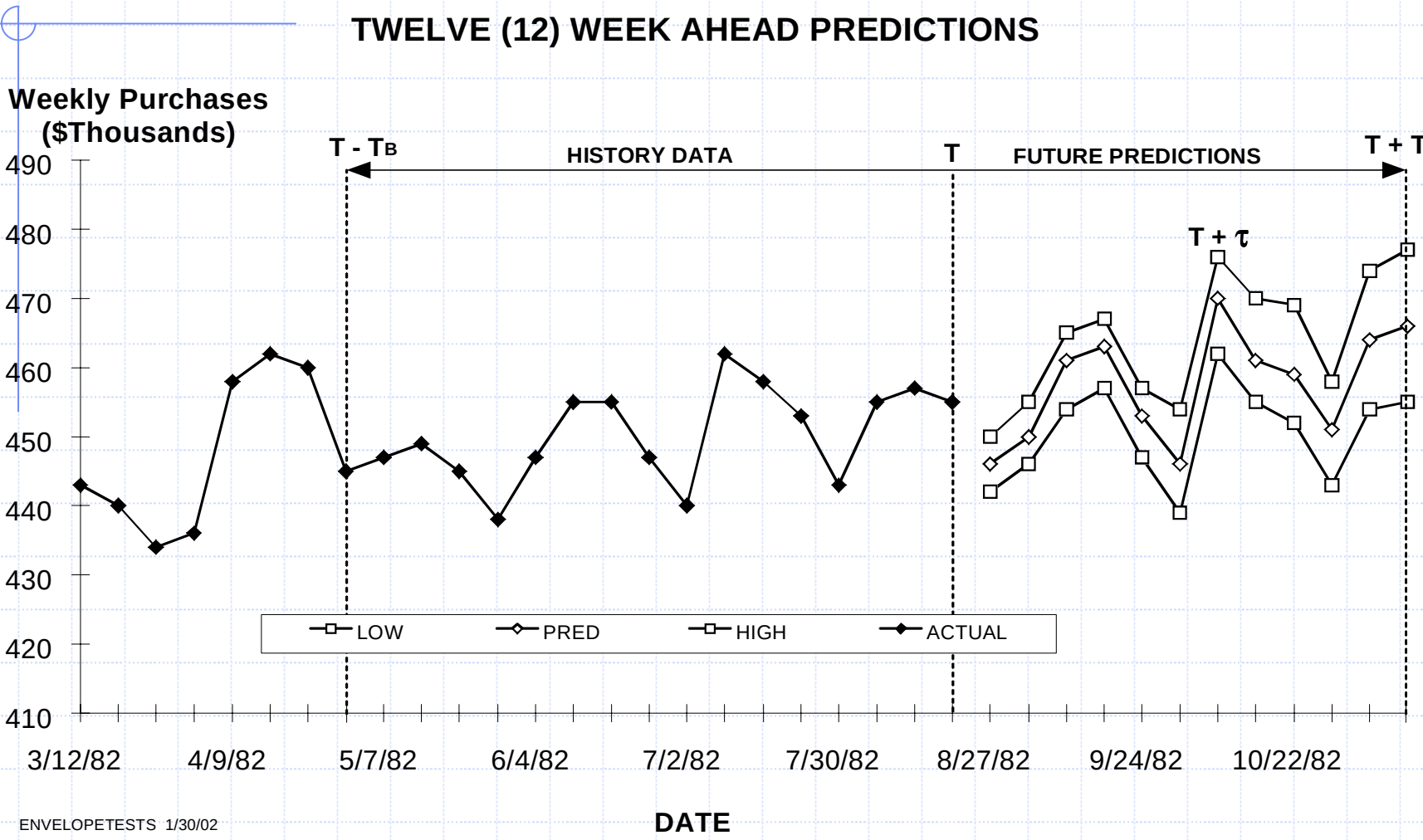


System Response @ Time T: $Z(T) = [Z_1(T), Z_2(T), \ldots, Z_m(T)]$

Driving Force: $U(T) = [U_1(T), U_2(T), \ldots, U_k(T)]$

Want to Predict $\hat{Z}$

History & Time Horizons



General Modeling Approaches

- Prediction problem has been shown to be difficult, and is often misunderstood.
- Constructing accurate models that reflect system behavior falls into two categories:
  - Naïve Models
  - Structured Models
  - Hybrid Models (Naïve + Structured Models)

Naïve Models

- Use generic approaches, e.g. neural nets.
- Linear regression models using historical data & trained

Structured Models

- Use the "physics" of the system
- Build on prior knowledge of internal dynamics of system.
- Draw on knowledge of experts.
- Require far less data.
- Can have naïve (empirical) components to account for behavior that can not be described by "physical" mechanics, and that may be used to optimize prediction accuracy.

Comparing Prediction Accuracy
(Measures of Error)

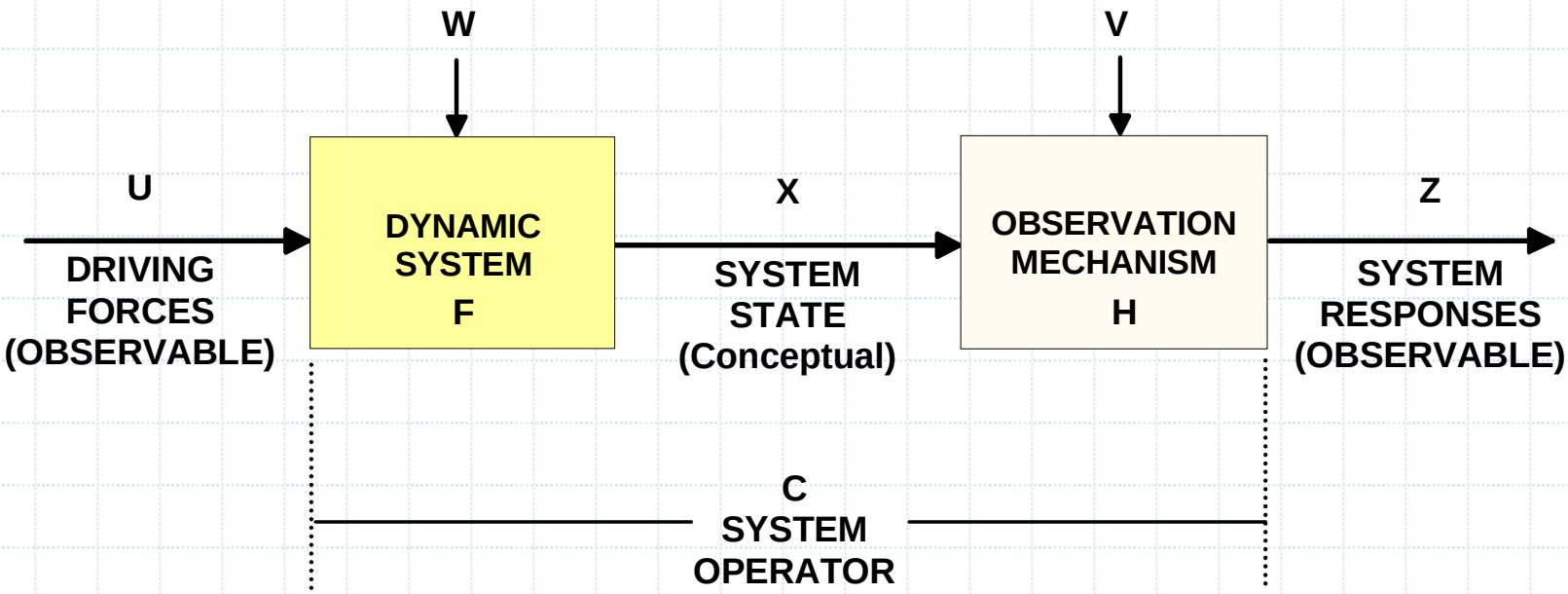
Sequence of normalized residuals:

$$RN[Z(T\hat{+}\tau)] = \frac{\hat{Z}(T+\tau) - Z(T+\tau)}{Z(T+\tau)}$$

$$\varepsilon_Z = E\{RN[Z(T+\tau)]\} = \frac{1}{T_T - T_B} \sum_{T=T_B}^{T_T} \left| \frac{\hat{Z}(T+\tau) - Z(T+\tau)}{Z(T+\tau)} \right|$$

Generic Modeling Framework

State Space Framework



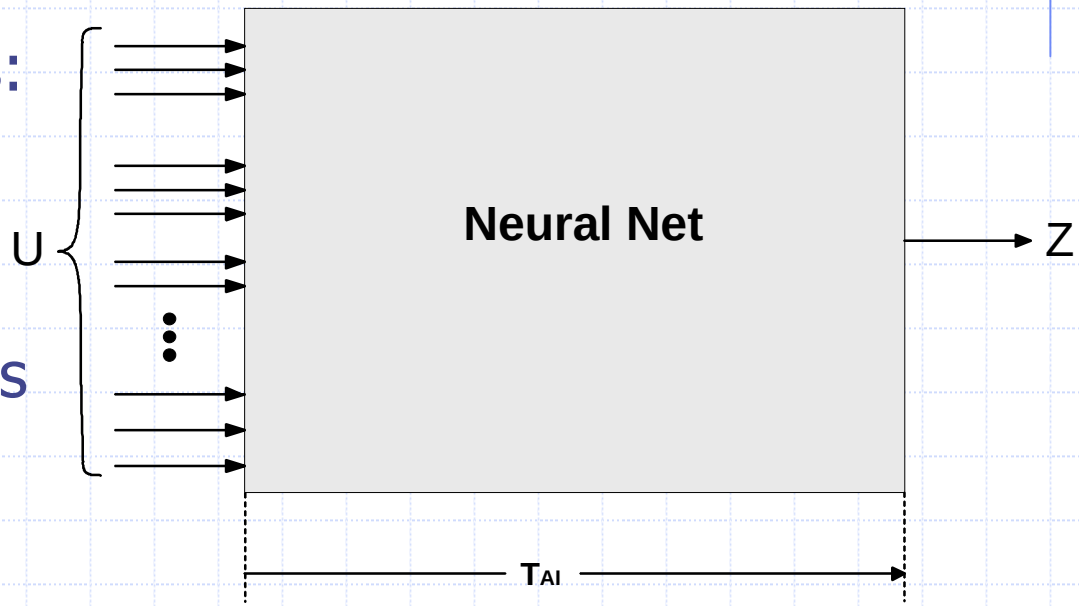
State of System $X(T) = [X_1(T), X_2(T), \ldots, X_n(T)]$

Comparison of Models

Artificial Intelligence (AI) Models

- Naïve Models -

- General Pattern Recognition
- Need to be Trained
- Good for some problems:
  - Moving 3D Objects
  - Fuzzy Images
  - Encryption
  - Homogeneous models
  - Stationary Problem
- U are input patterns



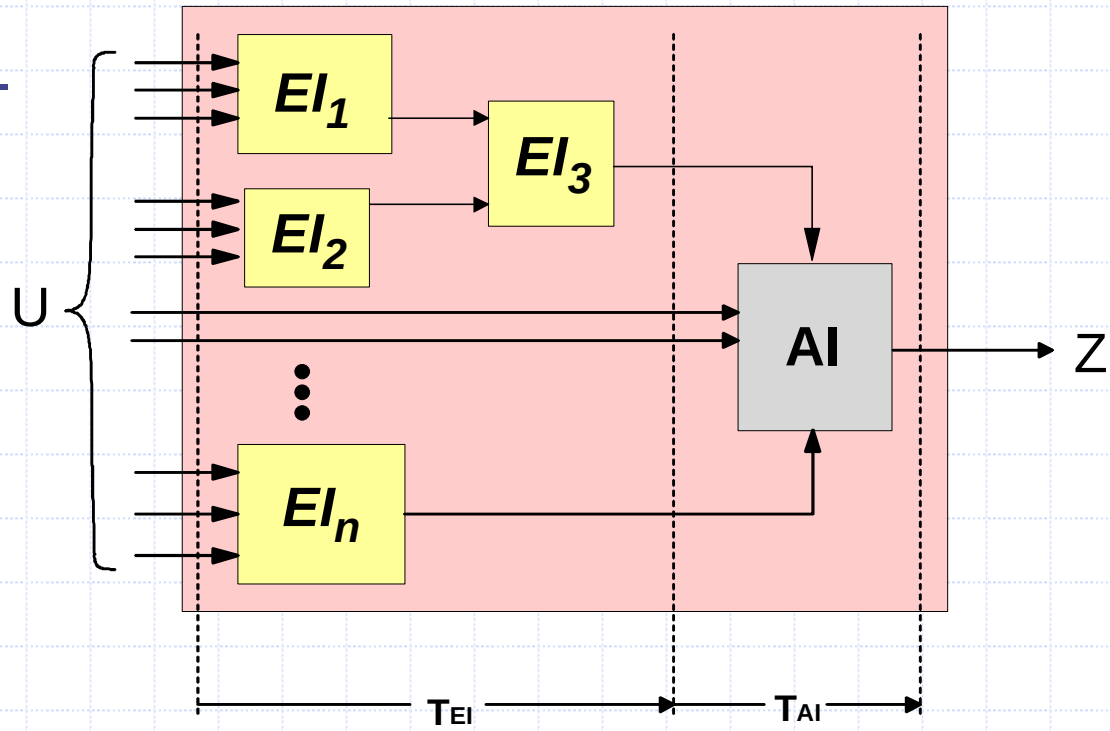
- Less suited to non-stationary problems
  - Require non-homogeneous models

Expert Intelligence (EI) Models

- Use more of the "physics" of the problem.
- A discrete event environment based on the state space framework.
  - Vector spaces can contain discrete states
  - Experts translate behaviors into simple rules with small number of parameters.
- Leverages subject area experts.
- Basic example built using GSS…

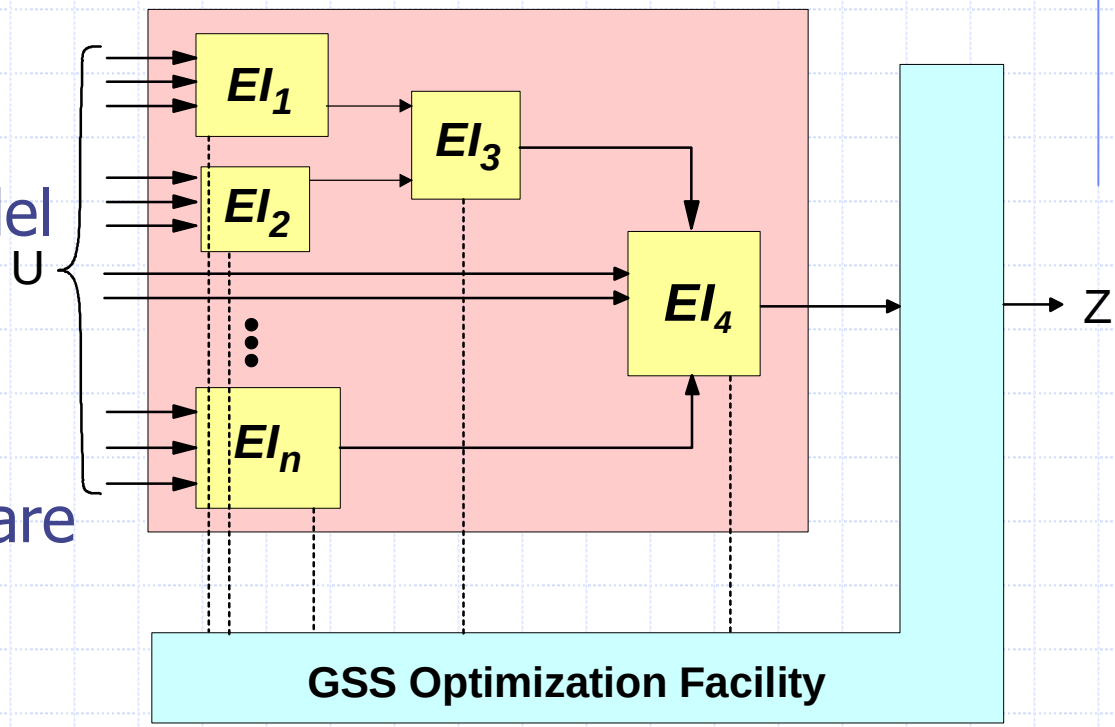
EI-AI Hybrid Models

- Combine EI and AI
- Small amounts of non-repeating data improve accuracy.
- Introduces "physics"
- U are input patterns
- EI Models are:
  - Simpler than AI
  - Faster than AI
  - Require less data
  - More accurate
  - Require no (or much less) training
- Overall more effective (faster and accurate) than pure AI.



EI with Optimization

- Introduce Optimization to model environment
- Replace AI with EI model
- EI parameters:
  - account for lack of knowledge
  - are selected with care
- U are input patterns



- Optimization is built into PSI's GSS modeling environment

General Simulation System (GSS™)

- A discrete event-based simulation development environment built by PSI.
- Uses Computer Aided Design (CAD) technology.
- Supports large scale simulations.
- Has a simple, high-level language for describing rules and data.
- Is easily used by experts to codify rules without need of complex programming languages.

Accuracy Considerations

- Additional accuracy can be obtained by modeling the driving forces.
- Two aspects of a model represent additional information not generally contained in response data:
  - Expression of the structural properties of the system
  - Modeling the driving forces.
- We want to develop models without violating the rules of parsimony.
  - Minimize unknown parameters (e.g., curve fitting coefficients).
  - Use structural knowledge of the system.

Summary

- Recent literature stresses the need for subject matter experts (SMEs) when modeling human behavior.
- AI, EI, EI-AI Hybrids and EI Optimization were compared.
- The CAD approach of the General Simulation System (GSS) allows SMEs to apply knowledge without deep computer knowledge.
- The EI approach with optimization provides a framework for SMEs to apply their expertise on human behavior, and an architecture that can easily support new knowledge.
- This investigation merely scratches the surface of modeling human behavior.
- The acceleration of technological advances in related areas will aid this work.

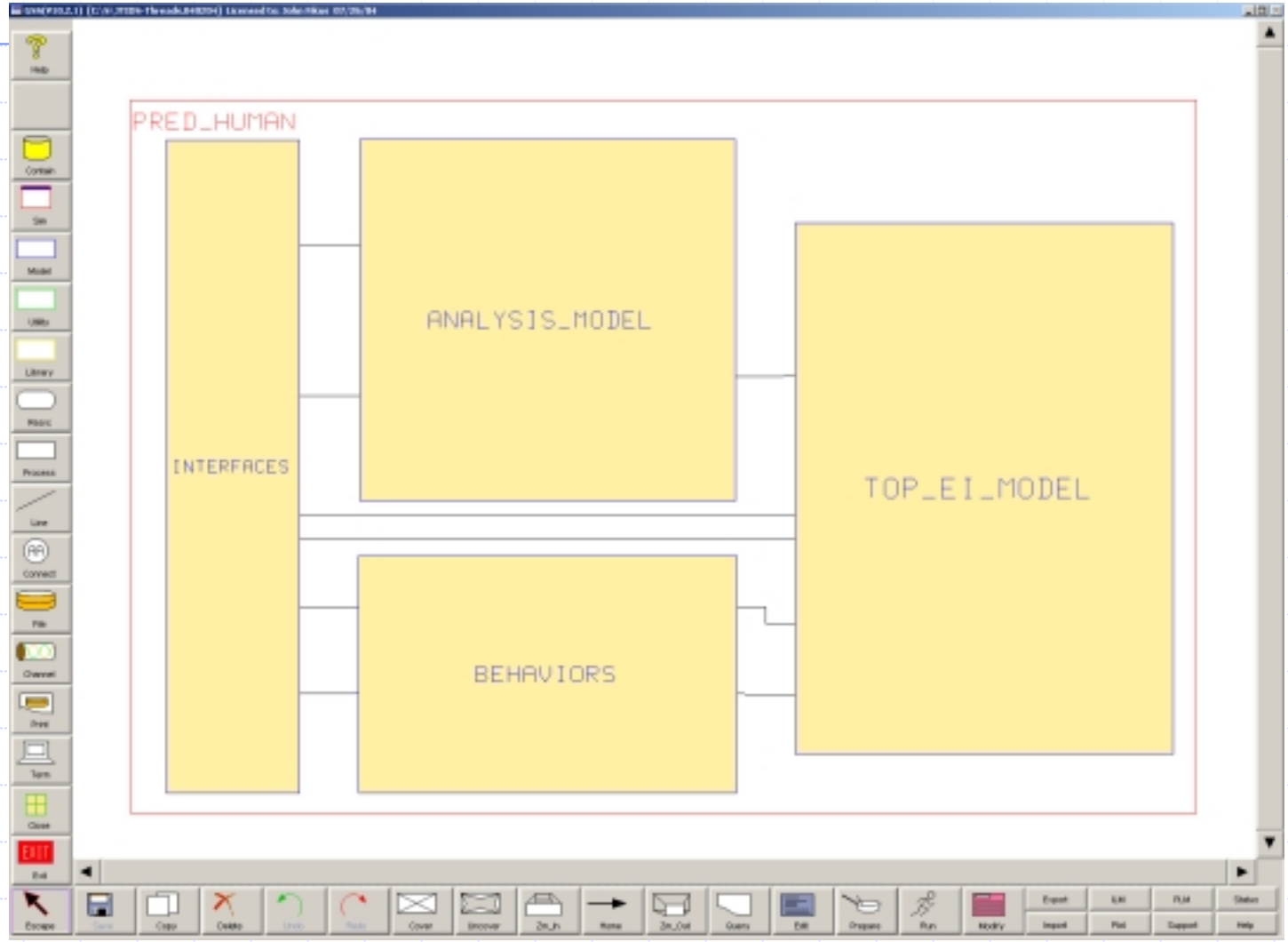
Back-up

Background on PSI

- Modeling and Simulation (M&S) company founded in 1974.
- Expertise in M&S, Planning Tools & CAD mostly for DoD.
- Founders have deep experience in Control Theory, Mathematics, SW Engineering & Design.
- In 1982, PSI created a large-scale, discrete event system environment named the General Simulation System (GSS).
- Run Time Graphics (RTG) supports fast, interactive GUI.
- Large collection of models including radio systems, network elements.
- **Work with DARPA and AFRL fostered interest in modeling human behavior.**

GSS Simulation Architecture

(Top View of Model Hierarchy)



GSS Simulation Architecture

(Deeper View – more detail on Model Hierarchy)