Using System Dynamics to Model Risk Perception and Communication in Response to Threat

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Mathematical Modeling in Social Science

- Physical sciences as ideal for social science
- Social science evolved from case studies
  - Margaret Mead
  - Clark Hull
- Advantages of models
  - Forces precision
  - Hypothesis testing
- Work at PNNL in Motivation and Intent
  - Aid analysts in assessing group propensity for violence
  - Model social science theories after the fact of their construction
  - Can serve as a blue print for collaboration between modelers and social scientists in research on Dynamics of Risk Perception.

System Dynamics

- Used to model complex systems in which there are feedback loops
- There are two types of variables:
  - Stocks or levels; e.g. inventory, perceived risk
  - Flows or rates; e.g. production rate, deaths per thousand per year.
- Invented by Jay Forrester at MIT
- Used to model social systems including business models, ecological systems, diffusion of fear following catastrophe (Burns and Slovic)

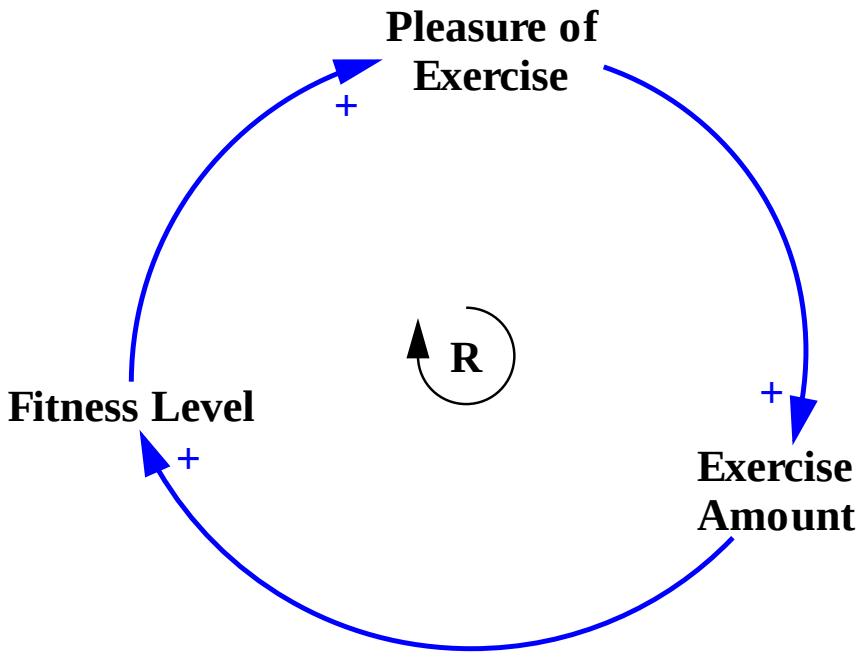
The System Dynamics Paradigm

- Emphasizes insight and understanding over prediction
  - Predicts patterns of behavior
  - Point predictions are more problematic
- Concept of cause and effect is central to model
  - Typically build causal loop diagrams first
  - Data can be used to establish specific functional relationships
- Verification and Validation is more than fitting data
  - Clarity of purpose—fulfills intended function
  - Documentation—transparency
  - Conceptually valid—relationships among variables are theoretically and empirically compelling
  - Behaviorally valid—behaves in a reasonable manner
  - Data consistency

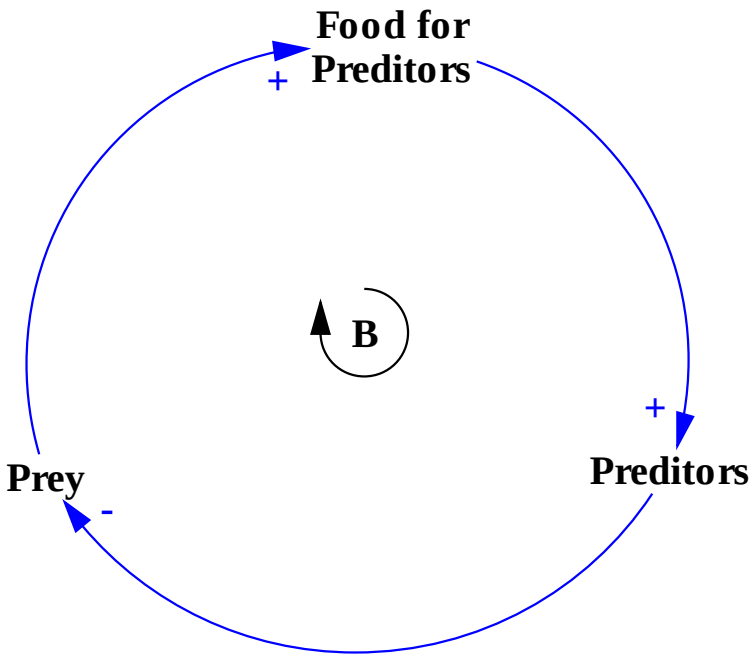
The System Dynamic Method

- Method
  - Identify *major* factors.
  - Identify cause and effect relationships.
  - Characterize the relationships as direct or inverse.
  - Diagram relationships.
  - Build stock and flow computer model.
  - Validate the model.
  - Analyze behavior of system through simulations.
- Value: It shifts the focus from one aspect of a system to the behavior of the system as a whole.

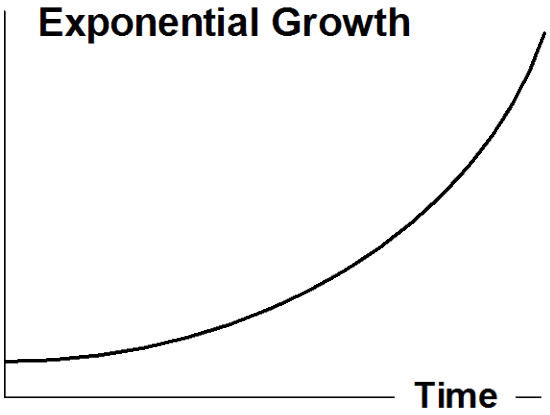
Some Simple Loops:
Reinforcing or Positive Loop

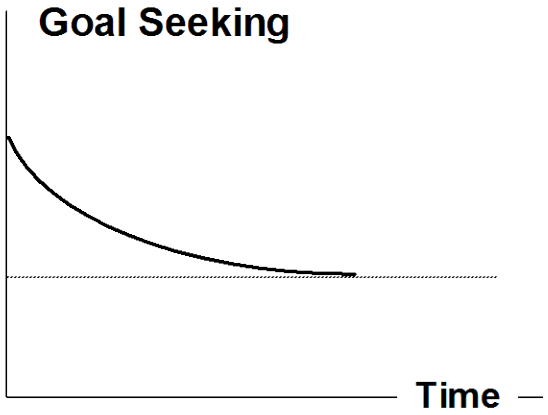


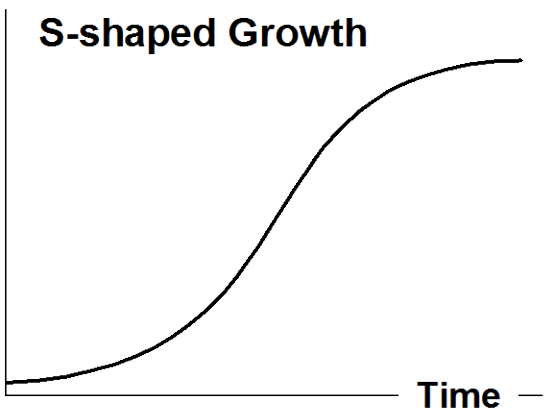
Some Simple Loops:
Balancing or Negative Loop

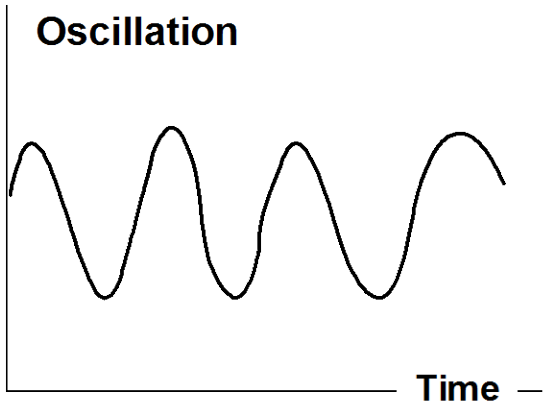


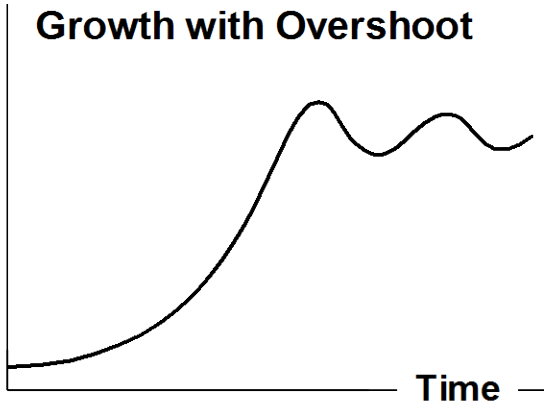
Common Modes of Behavior in Dynamic Systems

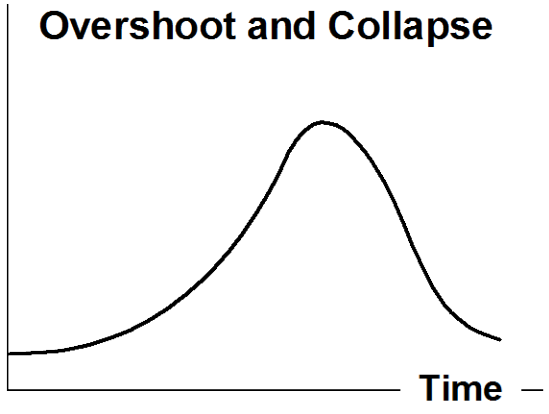




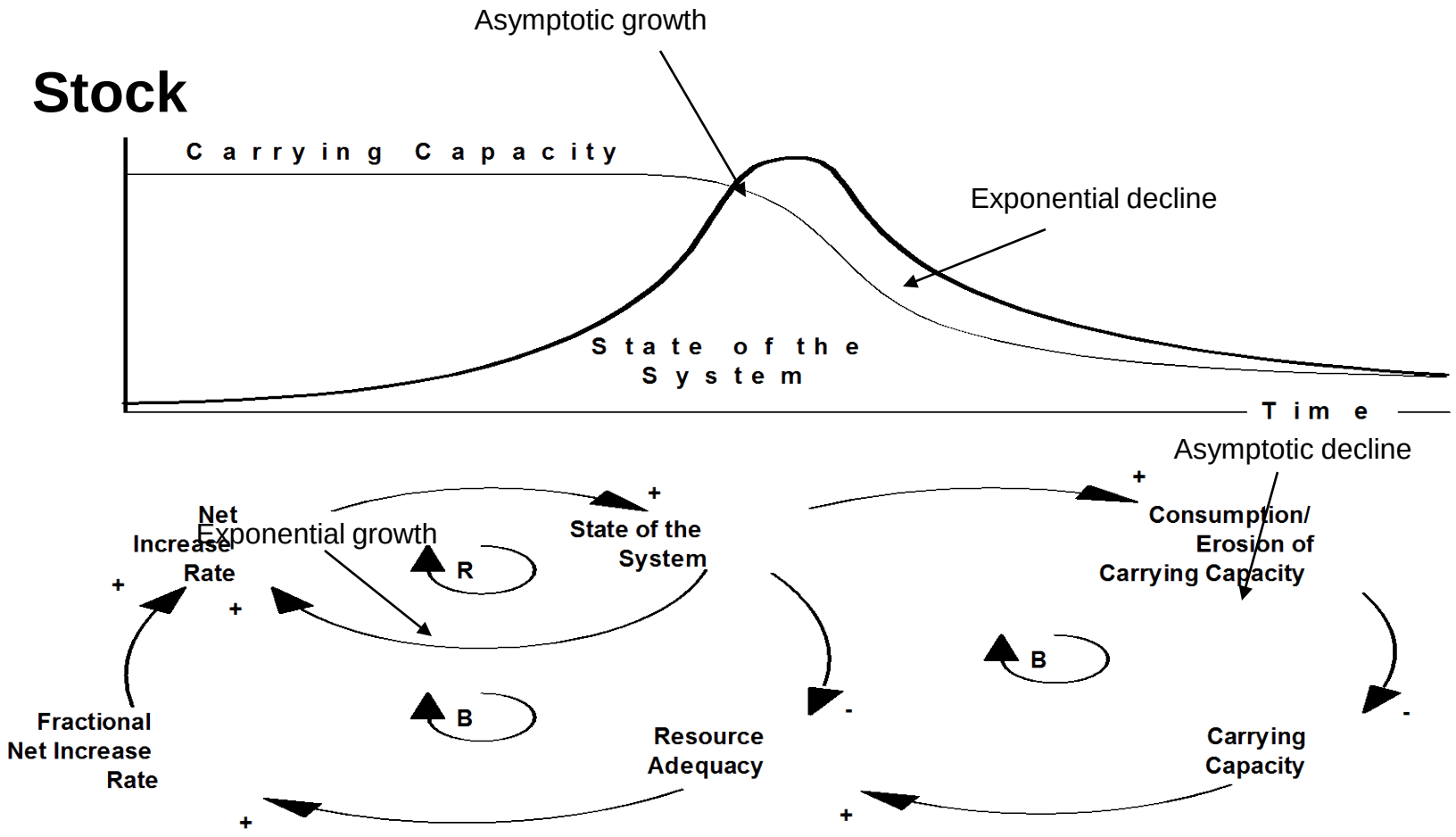


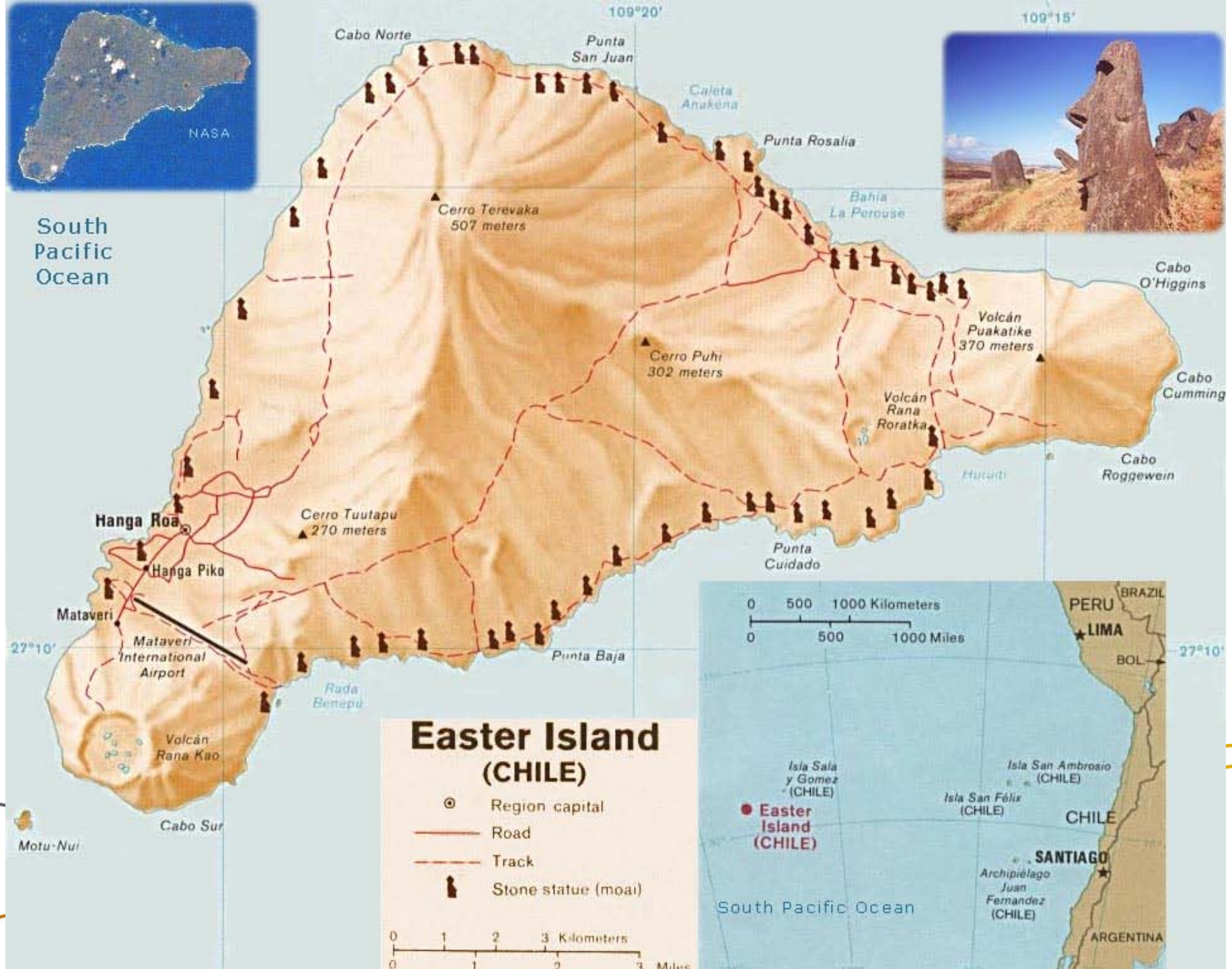






Overshoot and collapse behavior

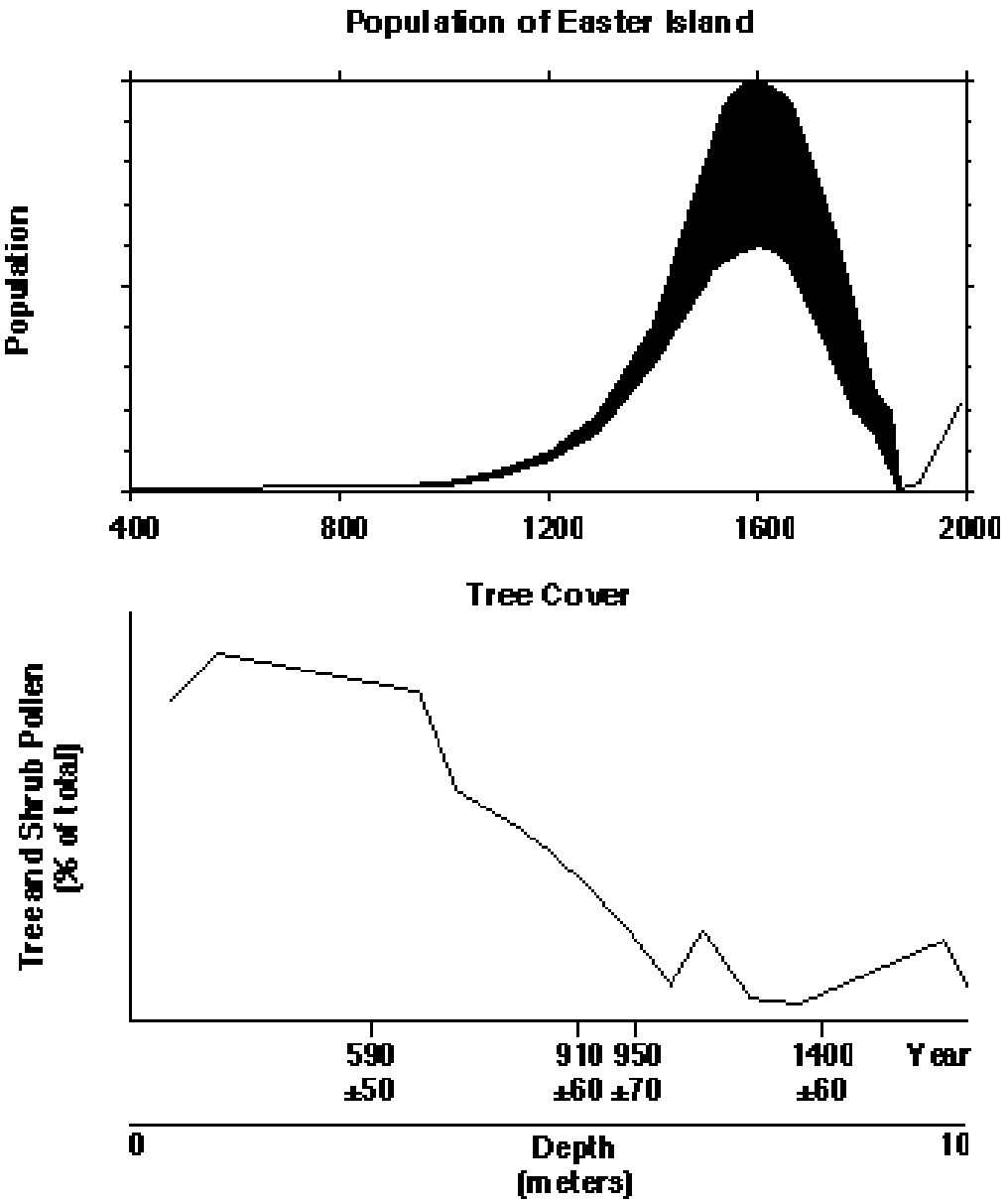



NASA
South Pacific Ocean
109°20'
109°15'
Cabo Norte
Punta San Juan
Caleta Anakena
Punta Rosalia
Bahia La Perouse
Cerro Terevaka 507 meters
Cabo O'Higgins
Volcán Puakatike 370 meters
Cerro Puhi 302 meters
Cabo Cumming
Volcán Rana Roratka
Cabo Roggewein
Hanga Roa
Cerro Tuutapu 270 meters
Hanga Piko
Punta Cuidado
Mataveri
Mataveri International Airport
27°10'
Punta Baja
Rada Benepú
Volcán Rana Kao
Cabo Sur
Motu-Nui
Easter Island
(CHILE)
Region capital
Road
Track
Stone statue (moai)
0 1 2 3 Kilometers
0 1 2 3 Miles
0 500 1000 Kilometers
0 500 1000 Miles
PERU
BRAZIL
LIMA
BOL
Isla Sala y Gomez (CHILE)
Isla San Ambrosio (CHILE)
Isla San Félix (CHILE)
Easter Island (CHILE)
CHILE
SANTIAGO
Archipiélago Juan Fernandez (CHILE)
South Pacific Ocean
ARGENTINA

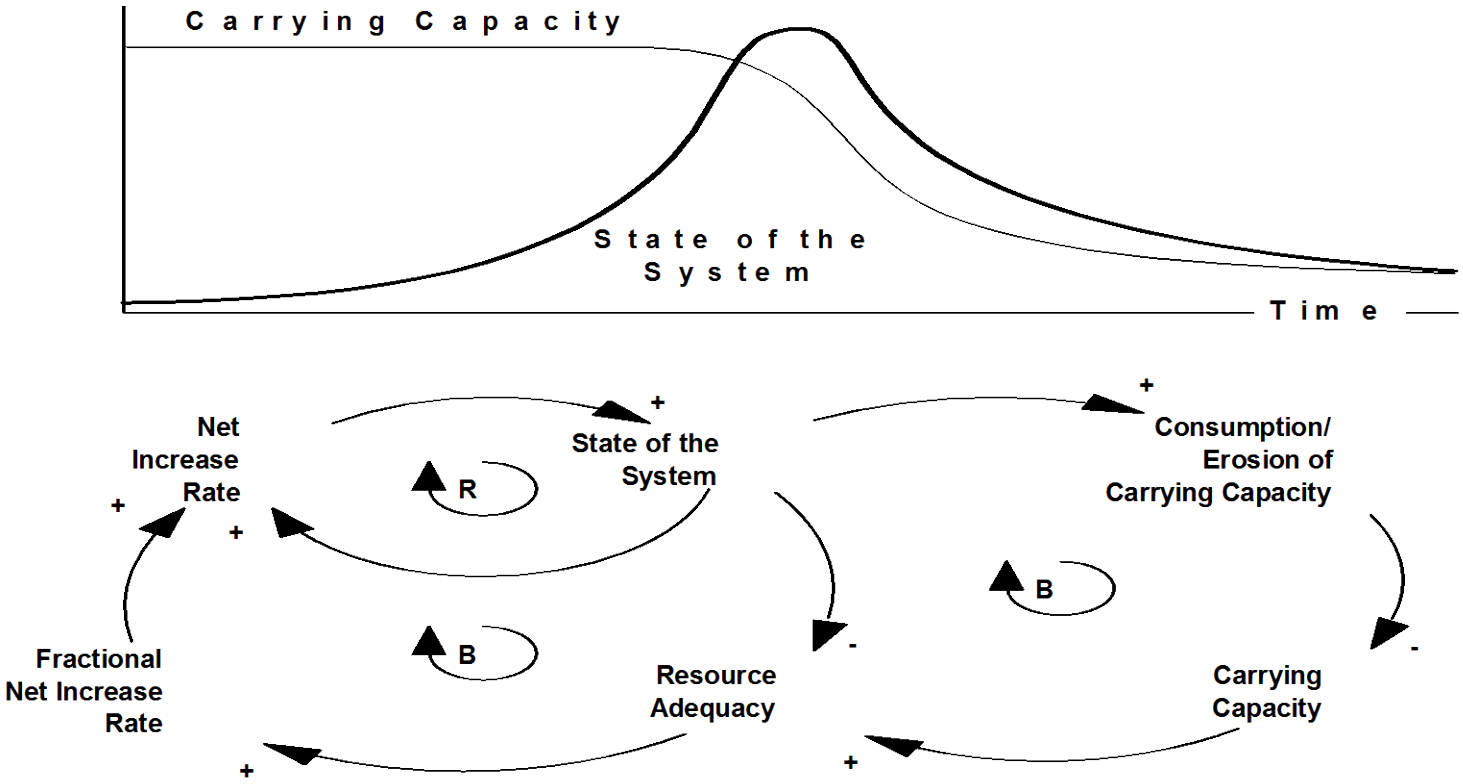
Estimated population and tree cover of Easter Island

Note: **Time axes for top and bottom graphs differ.**

Source**: Bahn and Flenley (1992, p. 174).**

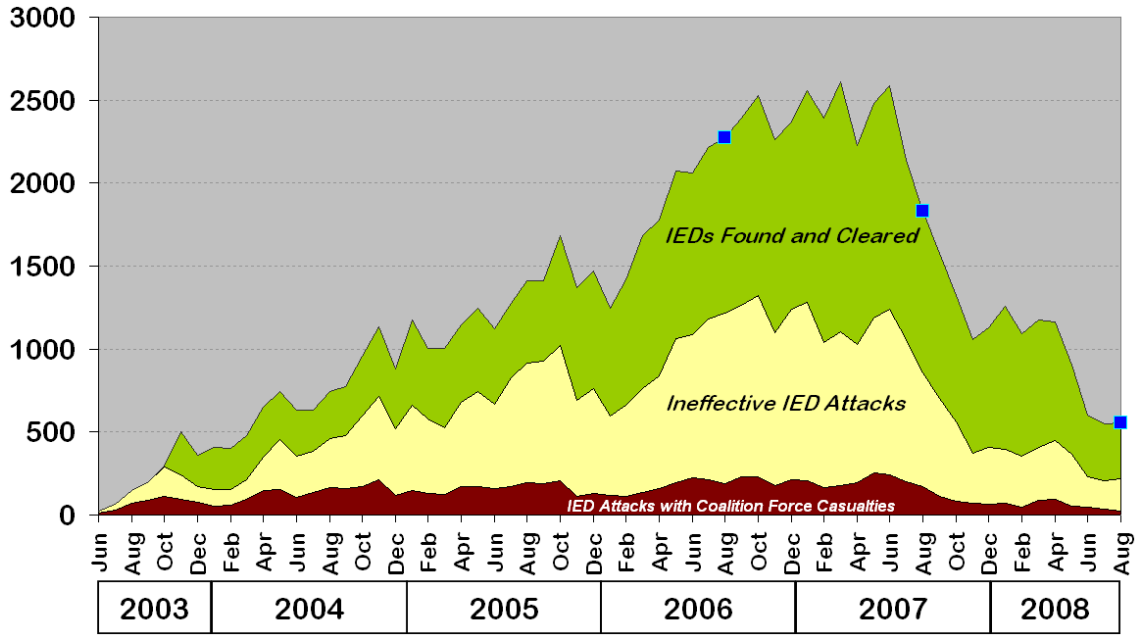


Generic structure that generates overshoot and collapse



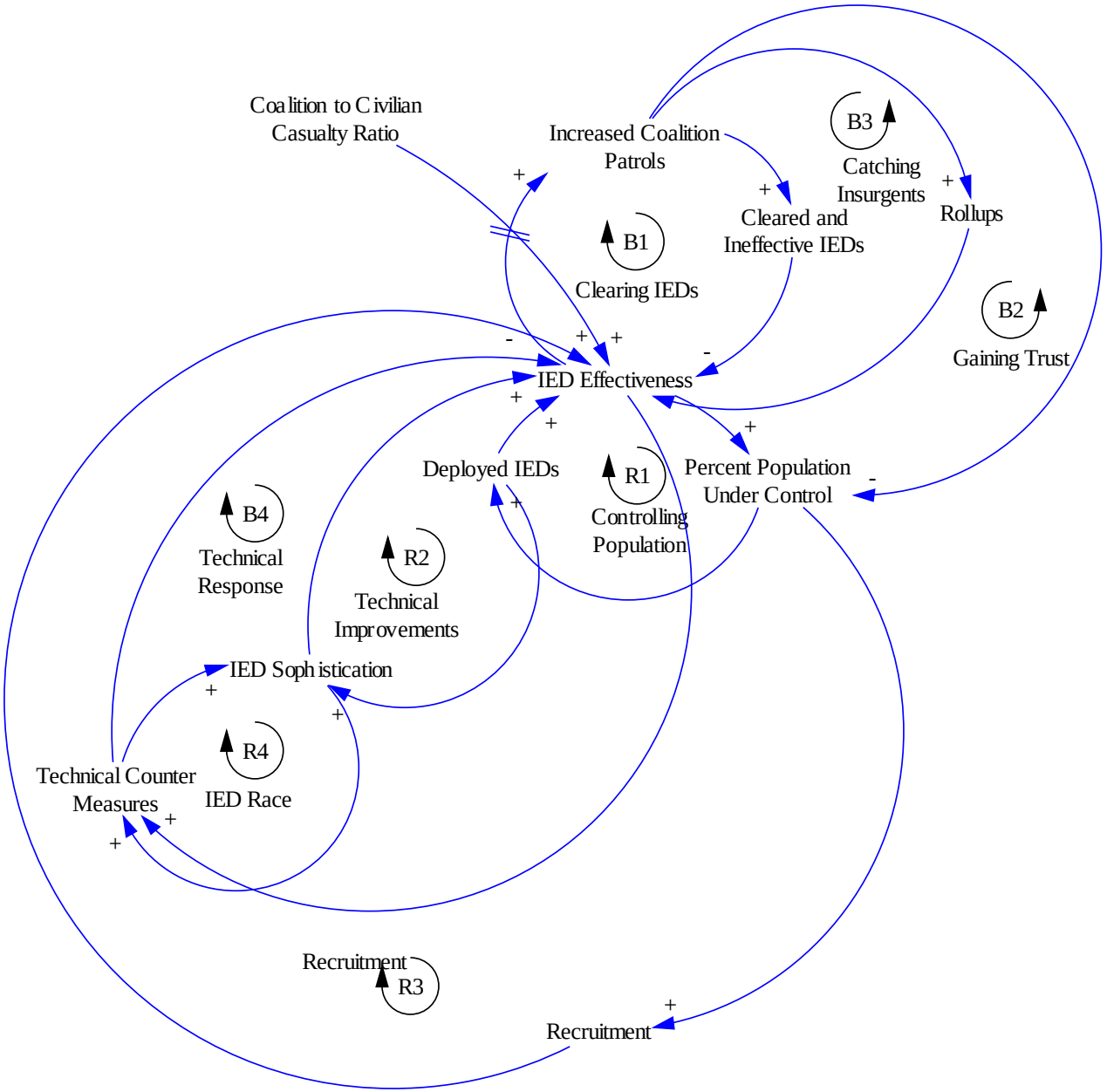
A System Dynamics model of IED Effectiveness

Monthly IED incidents in Iraq (JIEDDO)

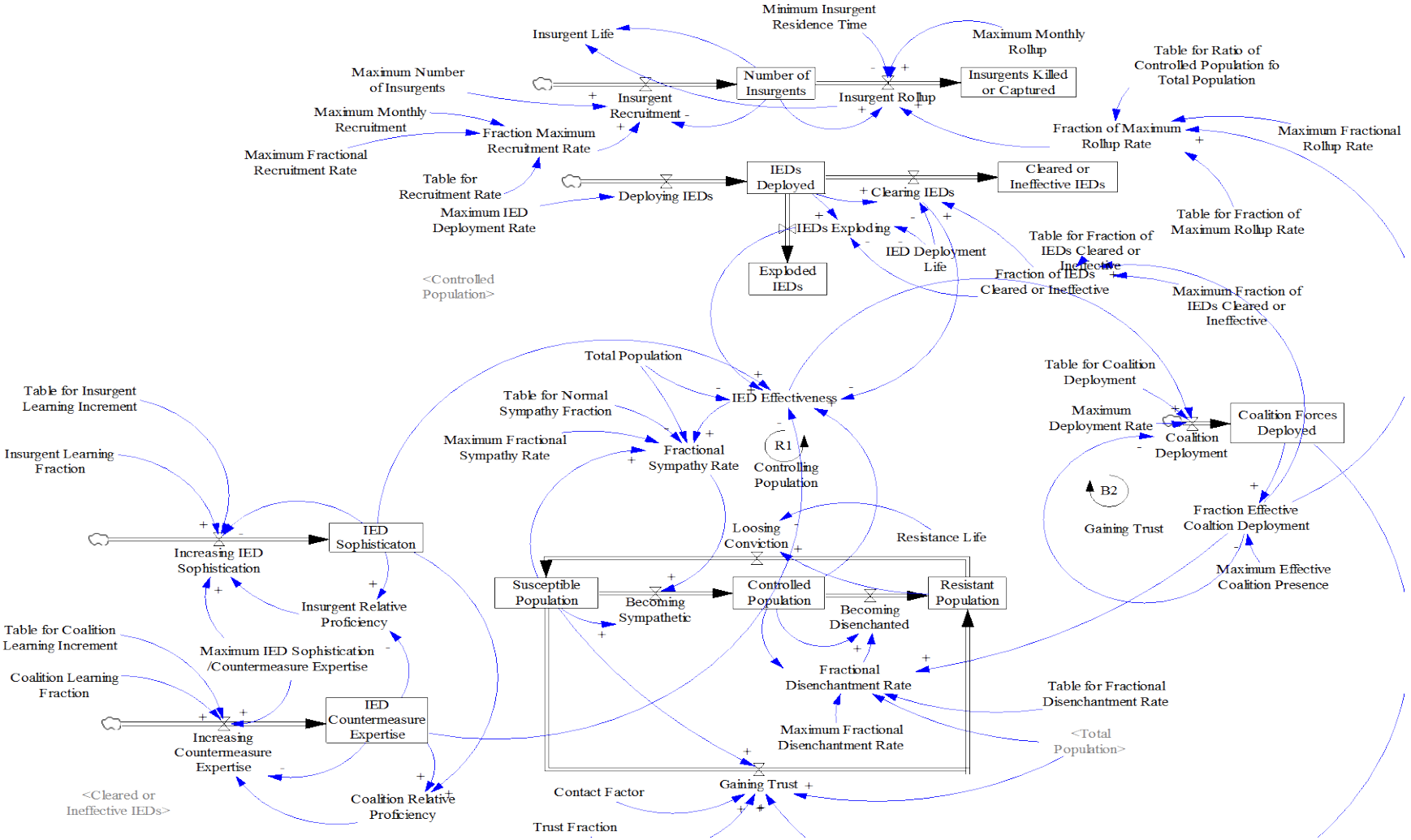


- **Build model based on subject matter expertise that is consistent with data.**

Two Types of SD Models: (1) Causal Loop Diagram (CLD)



Two Types of Models: (2) Stock and Flow Model



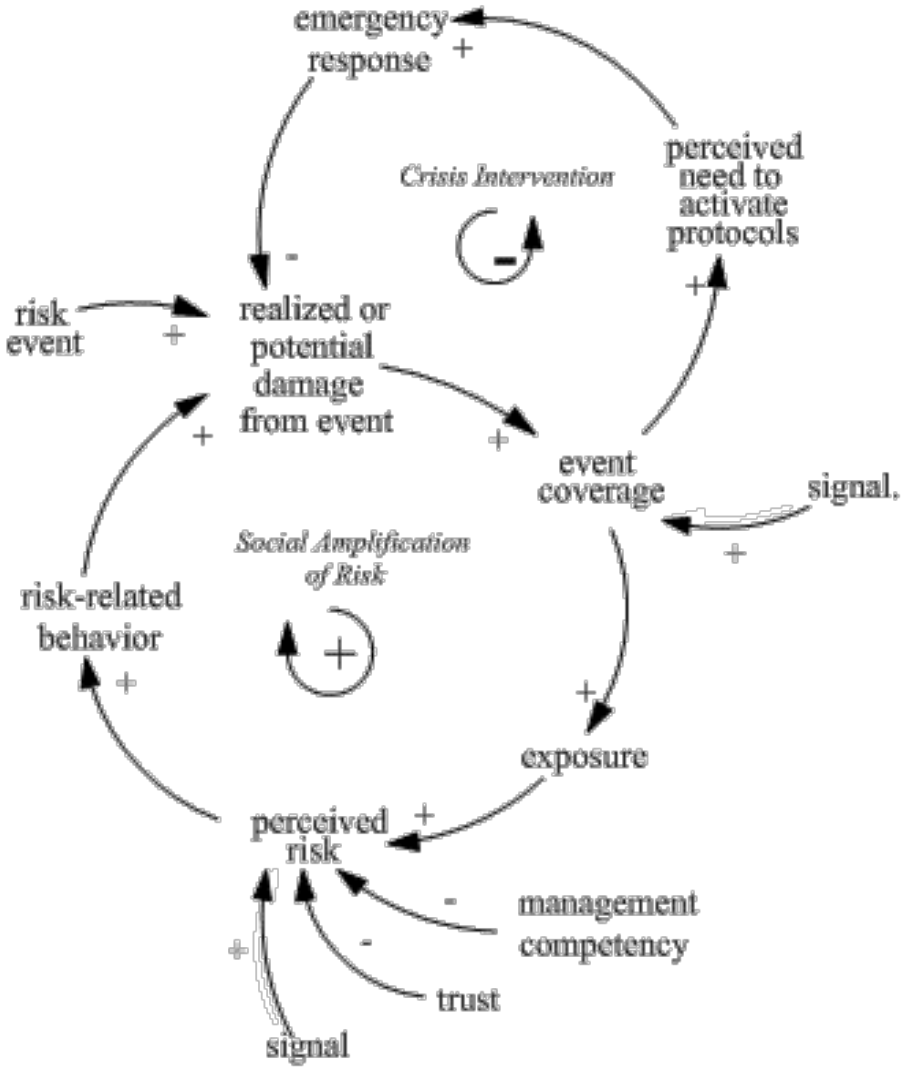
Escalation Module

Infection Module

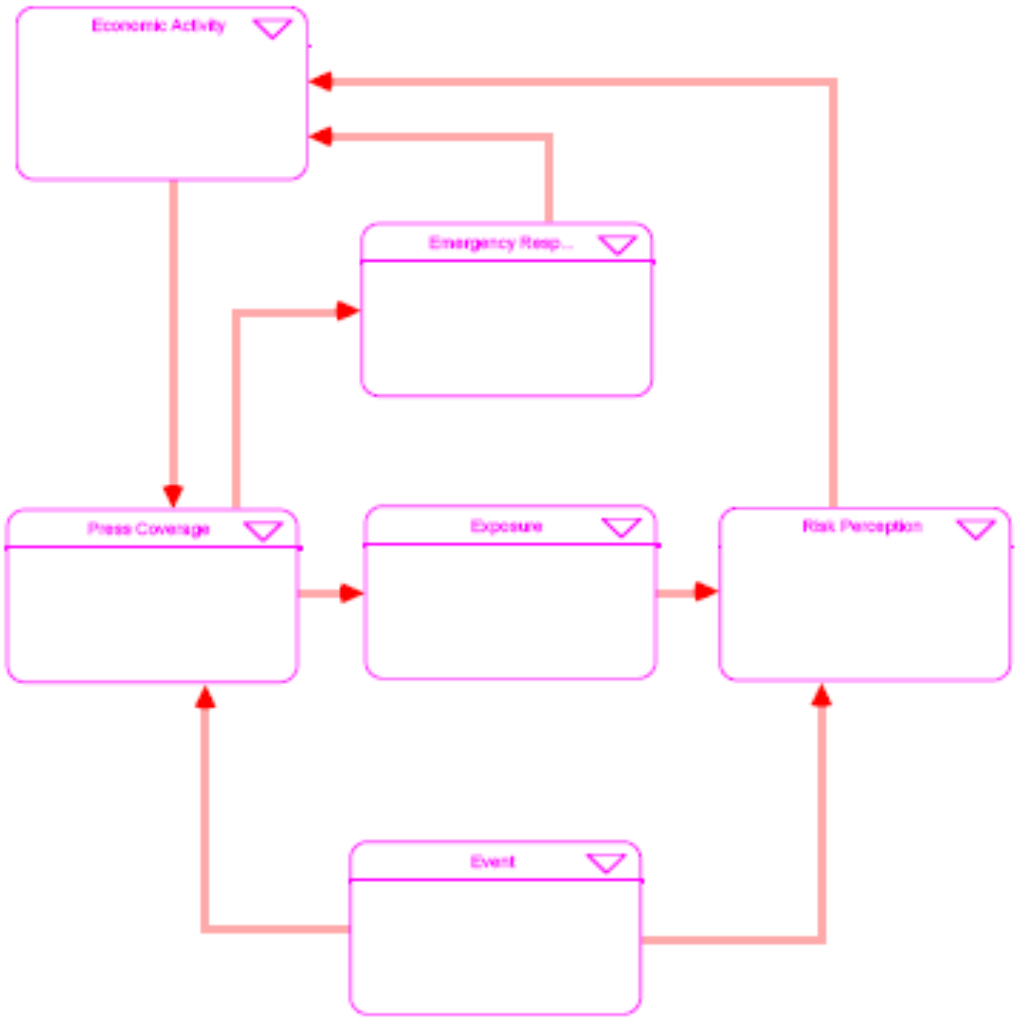
A New Paradigm of Risk Perception

- Risk perception had been static
  - The focus of past research has been on factors that influence perceptions of risk and how layman conceptions differ from experts.
  - Perception of risk following terrorist events or natural disasters evolve quickly as events unfold.
  - There is a need for dynamic models of how risk perceptions evolves following catastrophic events and how it is impacted by government actions and the media.
- System dynamics is well suited to model these changes over time
  - complex interactions and feedback loops.

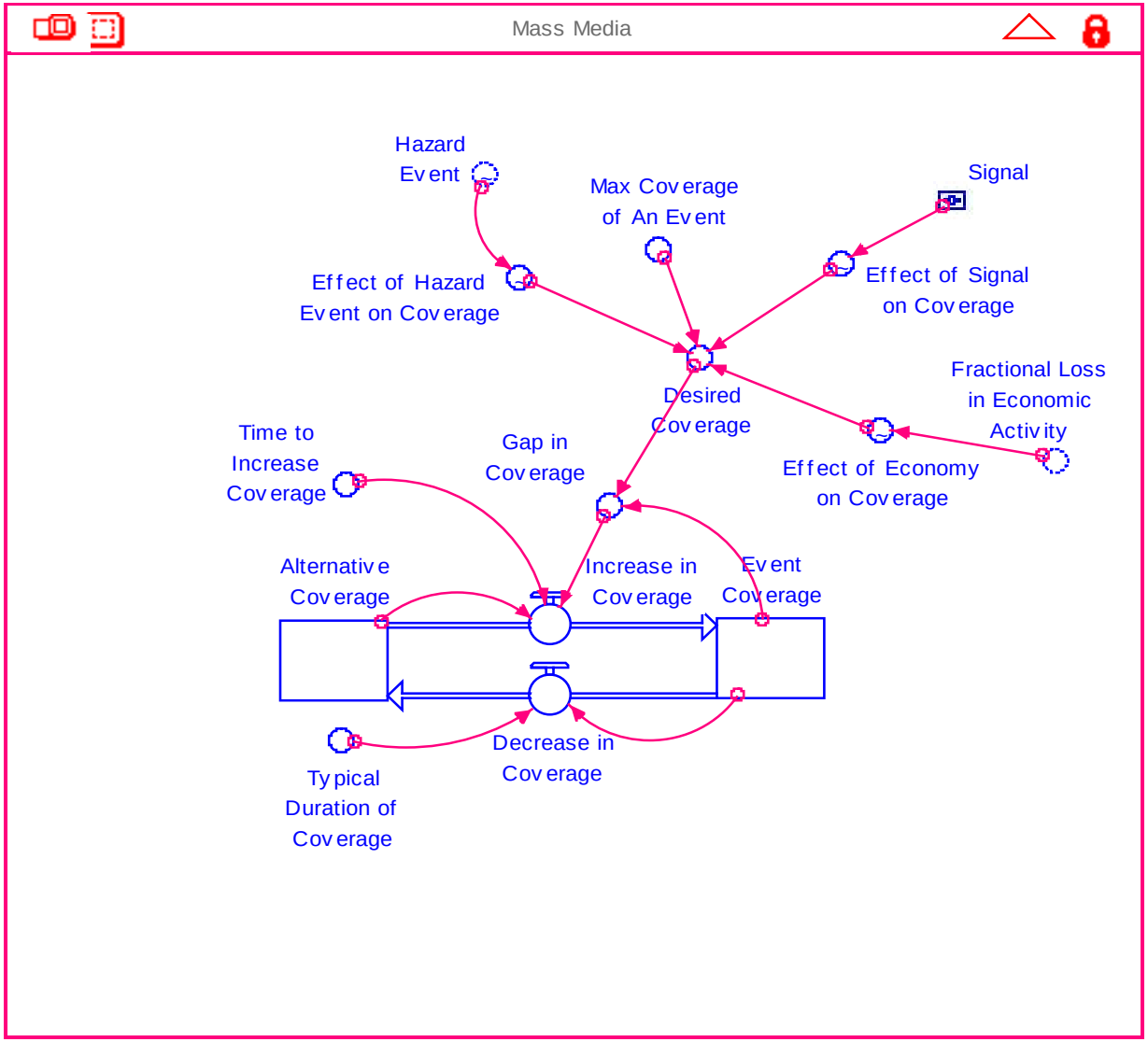
Dynamic Hypothesis



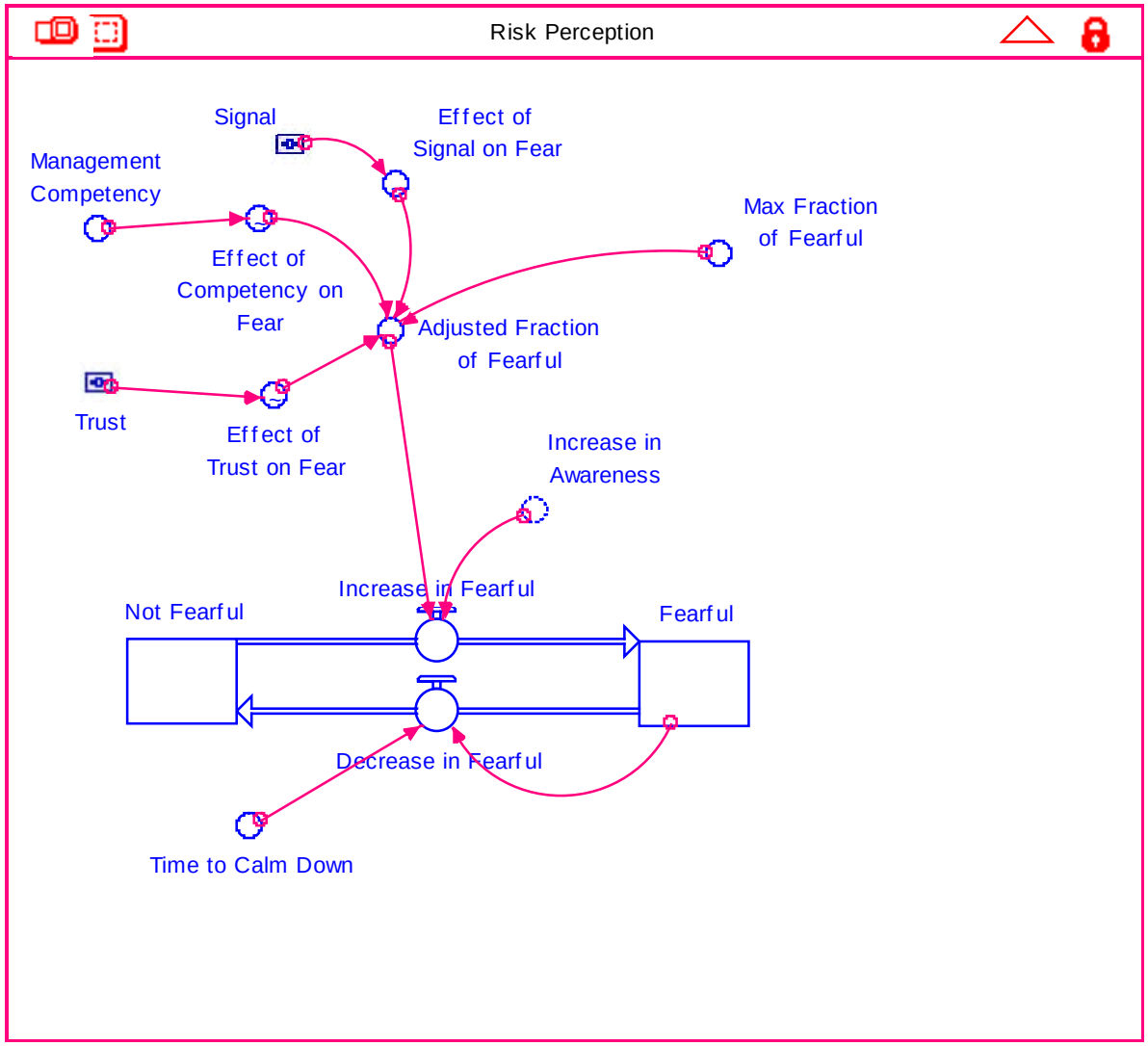
Model Sectors



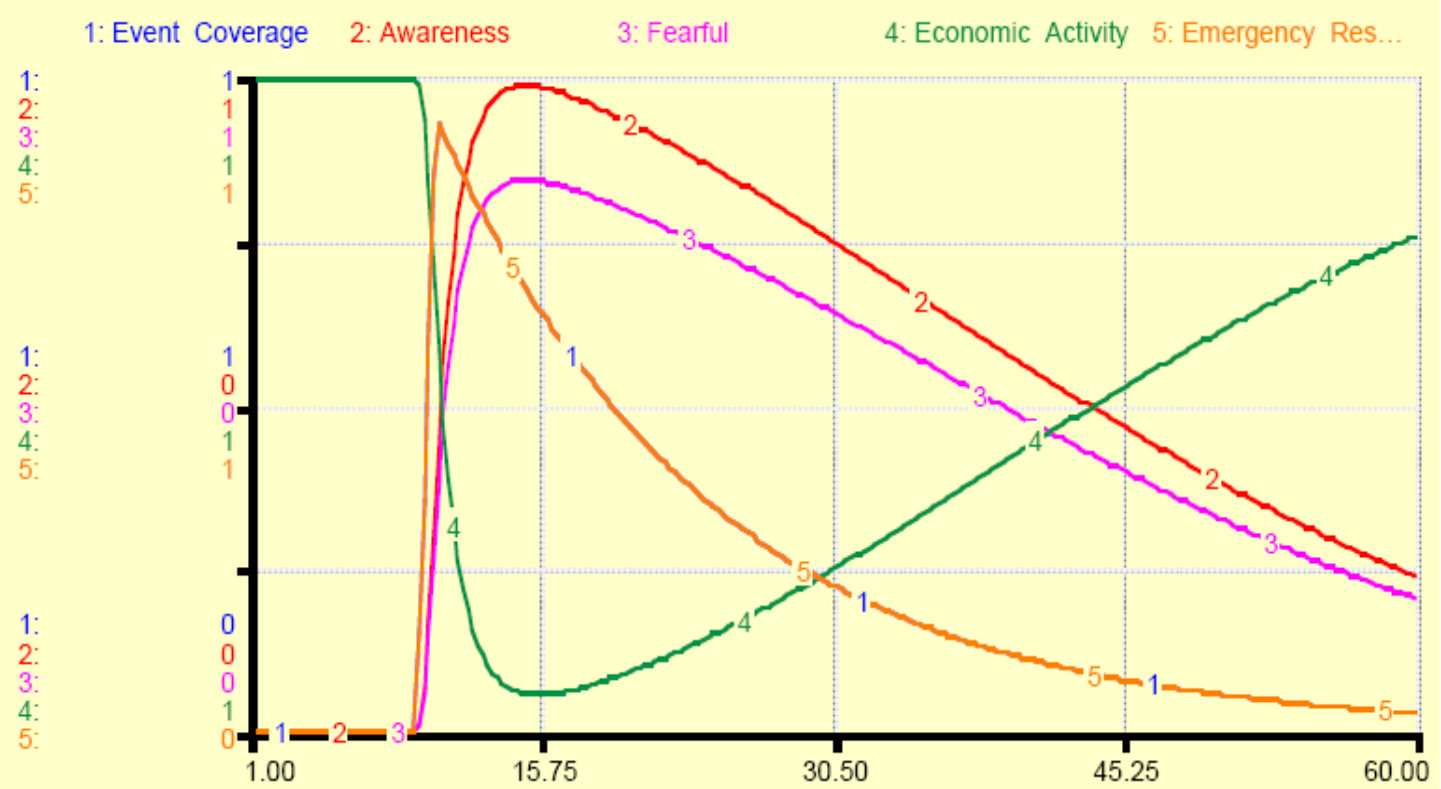
The Mass Media Sector



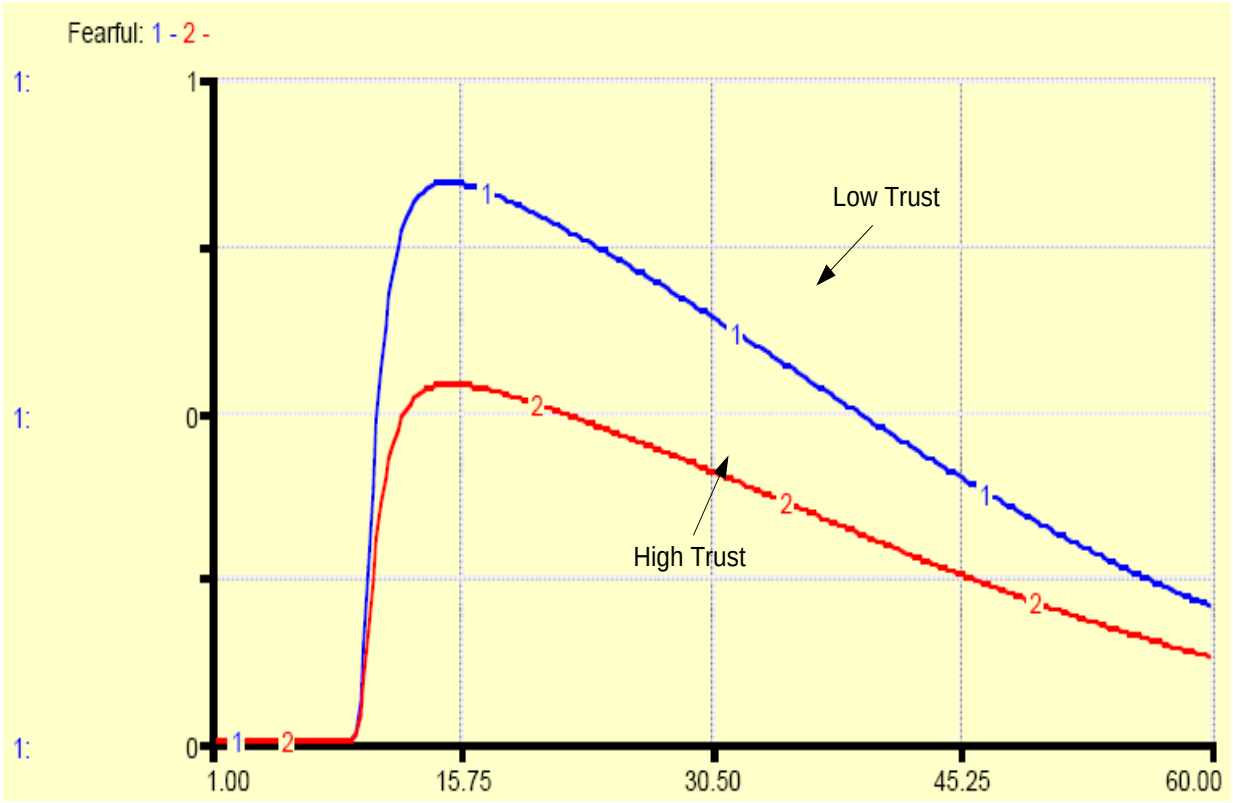
The Risk Perception Sector



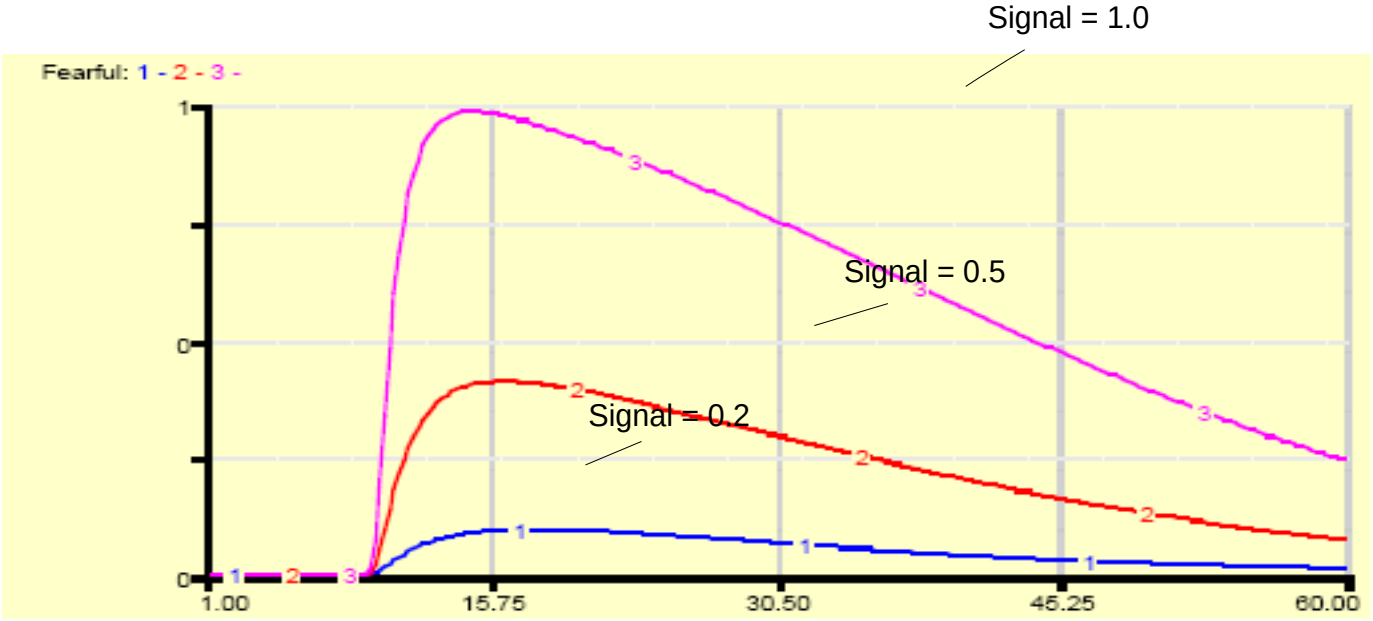
Base Run


1: Event Coverage
2: Awareness
3: Fearful
4: Economic Activity
5: Emergency Res...
1.00
15.75
30.50
45.25
60.00

High and Low Values of Trust



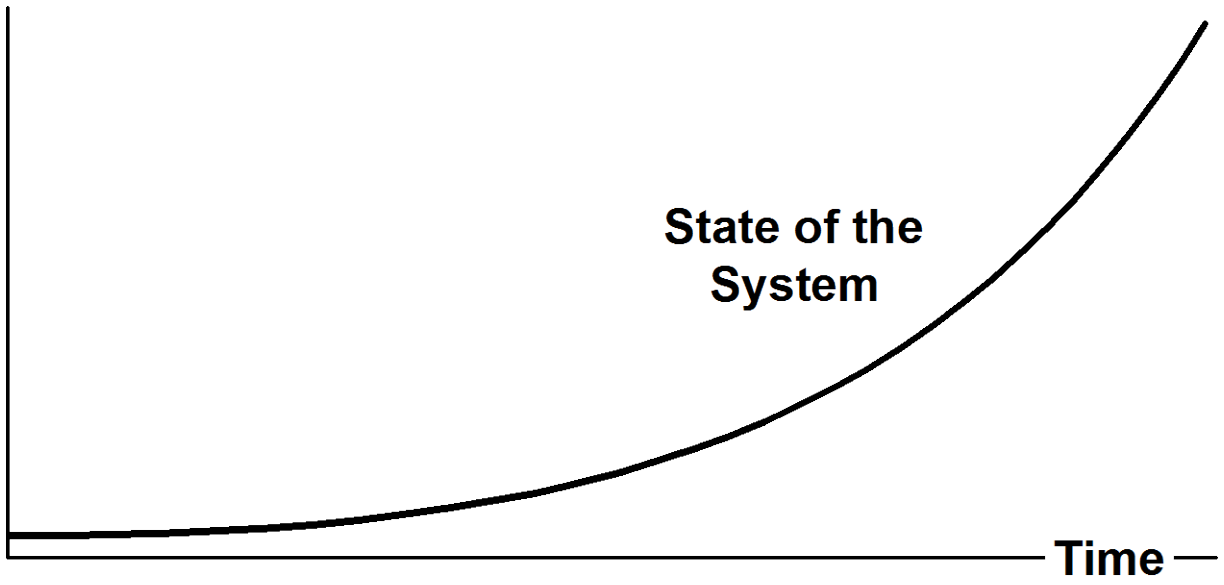
Amplification of the Signal



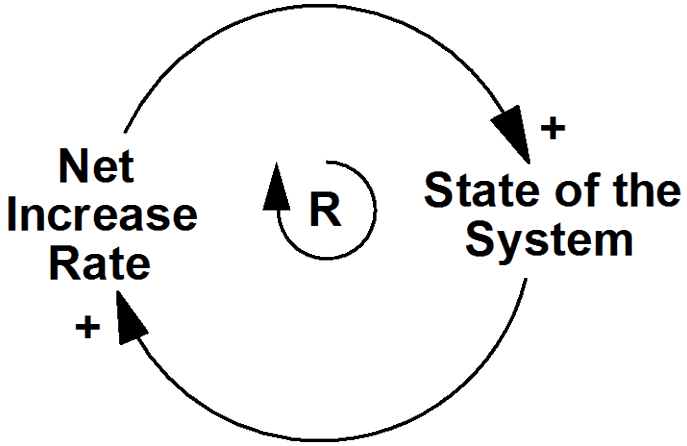
What Causes Dynamics?

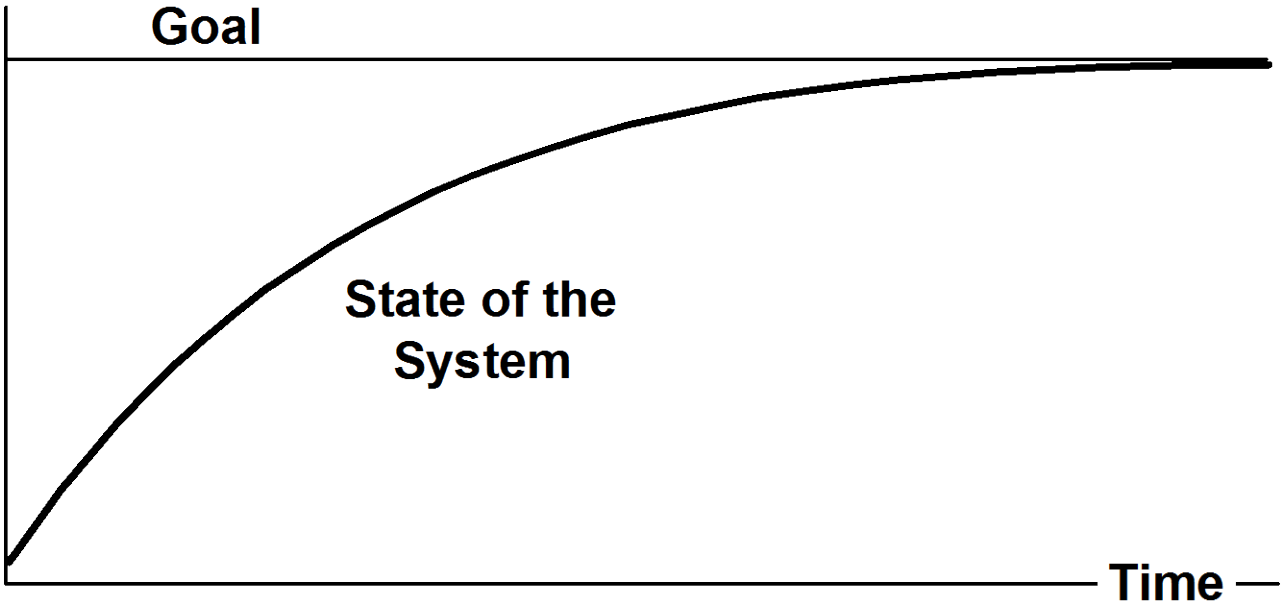
- All dynamics are driven by –
  - Feedback processes
  - Accumulation processes

The generic behavior modes can be produced by relatively simple generic structures.

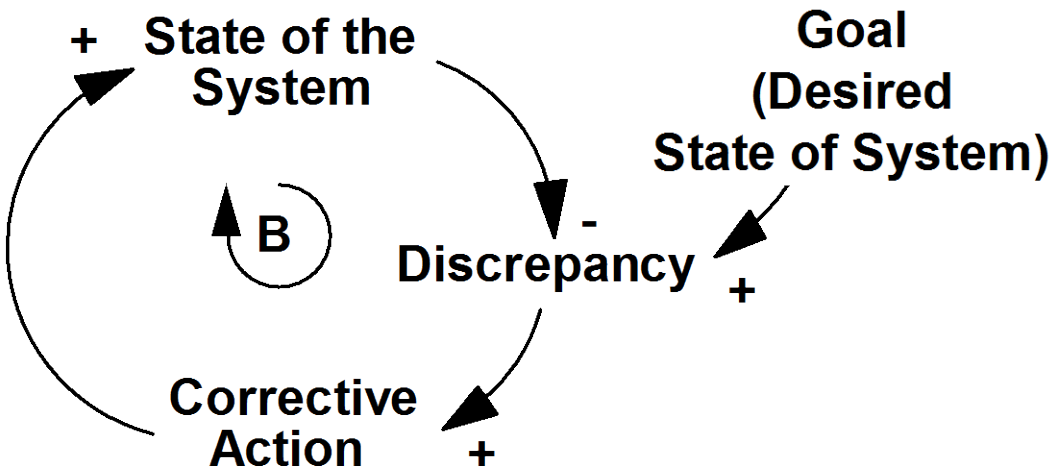


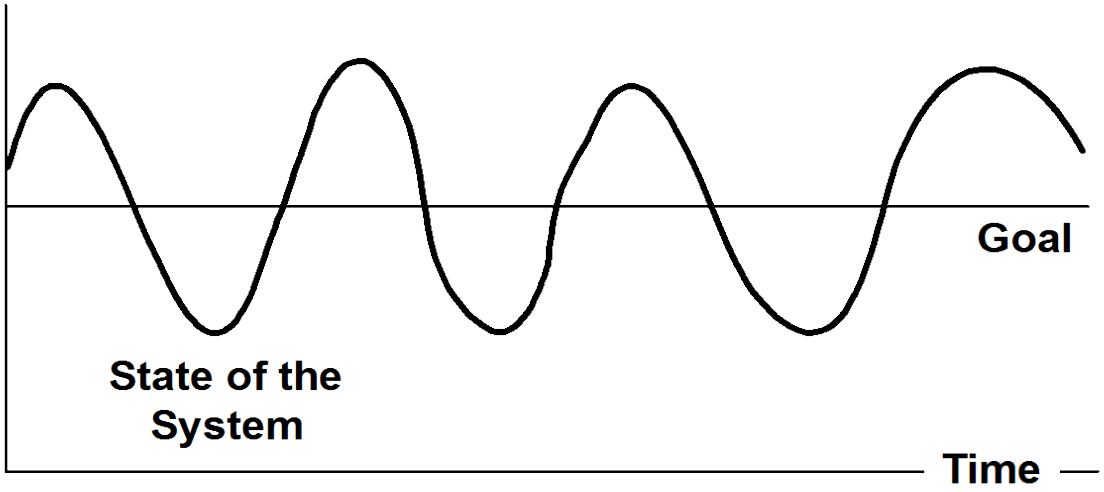
Exponential growth: Structure and behavior



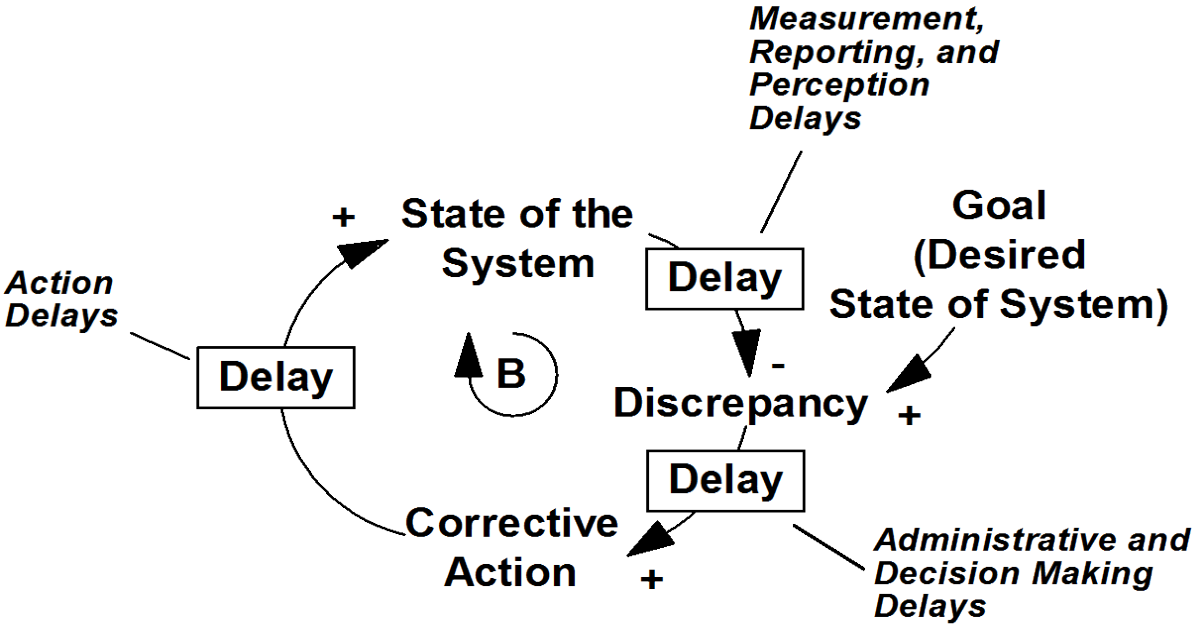


Goal seeking: structure and behavior

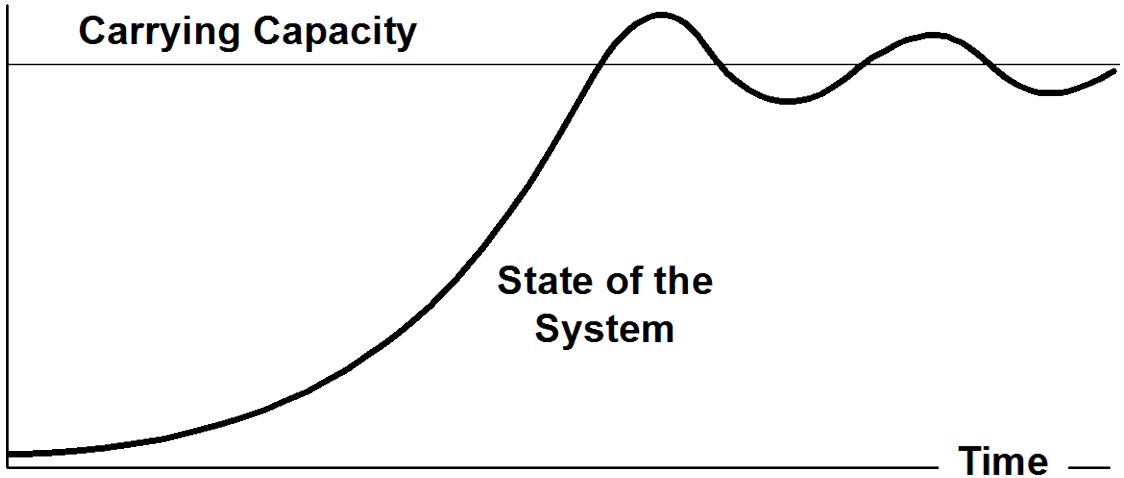


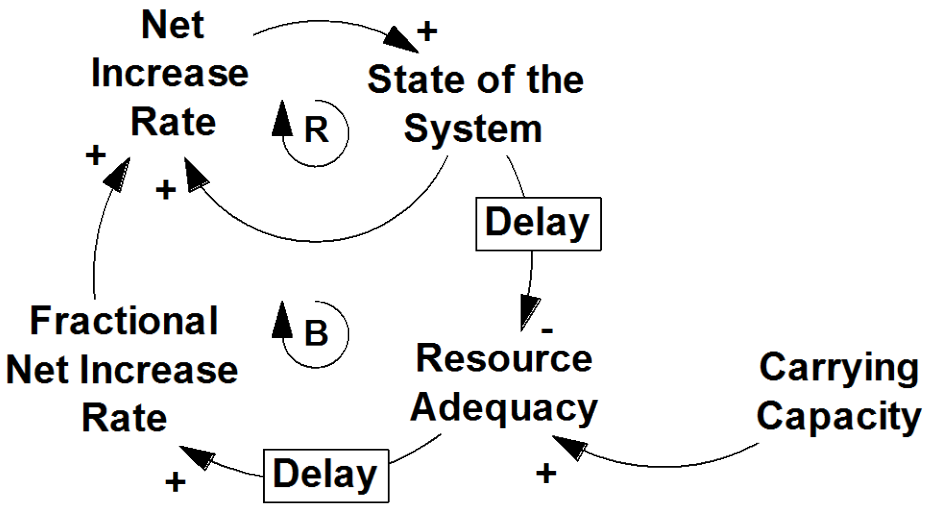


Oscillation: Structure and behavior



S-shaped growth with overshoot and oscillation: structure and behavior





S-shaped growth: structure and behavior