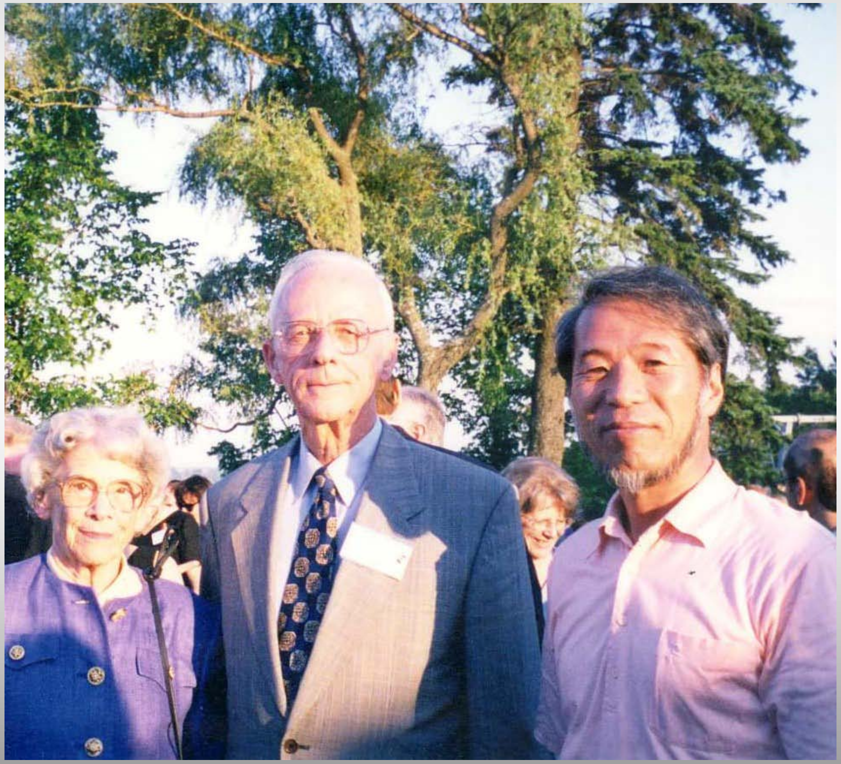
The 1st Nano-Satellite Symposium
Takeda Hall, University of Tokyo
June 10 – 11, 2010

System Dynamics - A Method for Sustainable Project

Prof. Kaoru Yamaguchi, Ph.D.
Doshisha Business School
Kyoto, Japan

Prof. Jay Forrester

At MIT, Sept., 1999



At the 16th International SD Conf.
Quebec, Canada, July 1998

Prof. Jay Forrester

- A Brief Biography (1) -

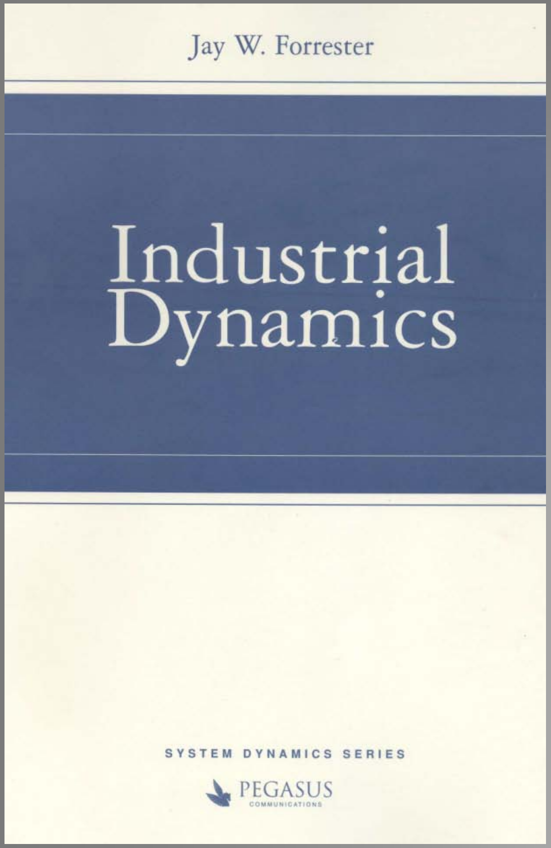
- Forrester grew up on a cattle ranch in Nebraska
  "A ranch is a cross-roads of economic forces. Supply and demand, changing prices and costs, and economic pressures of agriculture become a very personal, powerful, and dominating part of life."
- 1939: Forrester arrived at MIT for graduate study in electrical engineering under Prof. Gordon Brown: founder of MIT Servomechanism Laboratory
  - ✓ Pioneering research in feedback control mechanisms for military rader system in the aircraft carrier Lexington, Pearl Harbour, WWII, (which was torpedo bombed in the retaking of the Marshall Islands in 1943)
- 1947: MIT Digital Computer Laboratory was founded under his direction
  - ✓ WHIRL WIND I - MIT's first general purpose digital computer
    He patented "coincident-current random-access magnetic computer memory" - the industry standard for computer memory for 20 years. (USA National Inventors' Hall of Fame in 1979)
- 1950s: A division of MIT's Lincoln Laboratory was lead by him.
  - ✓ Computers for the North American SAGE (Semi-Automatic Ground Environment) air defence system - remained in service for 25 years.

Prof. Jay Forrester

- A Brief Biography (2) -

- 1956: A professorship in the newly-formed MIT School of Management (founded in 1952 with a grant of ten million dollars from Alfred Sloan- founder of General Motors Corporation).
  - ✓ "After talking with them (people from General Electric) about how they made hiring and inventory decisions (in Kentucky), I started to do some simulation. This was simulation using pencil and paper on one notebook page. ・・・ That first inventory control system with pencil and paper simulation was the beginning of system dynamics."
- 1958: "Industrial Dynamics- A Major Breakthrough for Decision Makers" Harvard Business Review; chapter 2 of Industrial Dynamics (1961)
  - ✓ SIMPLE (Simulation of Industrial Management Problems with Lots of Equations by Richard Bennett
  - ✓ DYNAMO by Jack Pugh
- 2006: Operational Research Hall of Fame
  International Federation of Operational Research Societies.

Industrial Dynamics(1961)



- Corporate modeling (Enterprise Design)

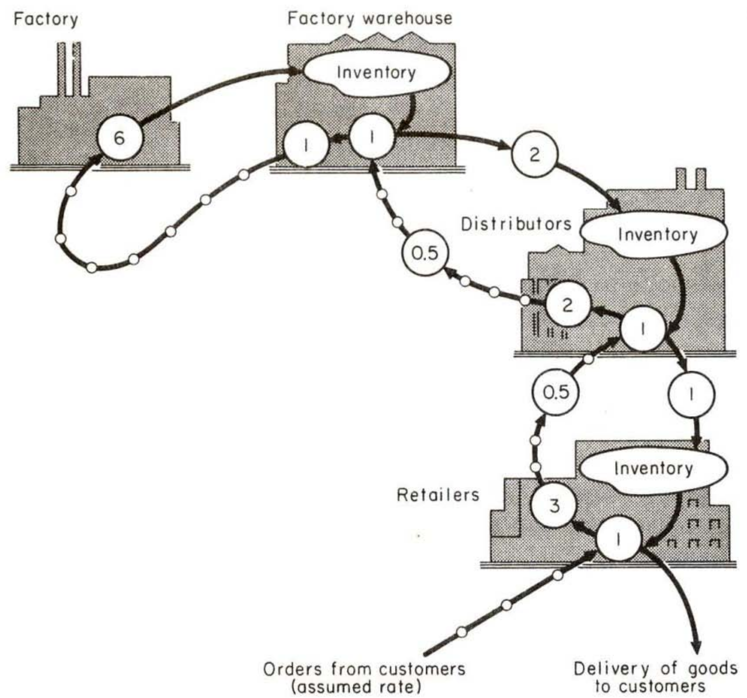
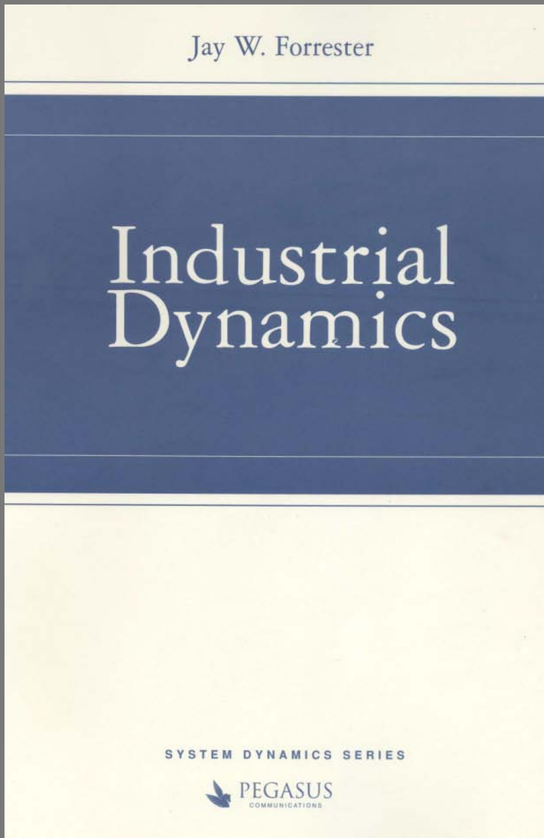


Figure 2-1 Organization of production-distribution system.

Industrial Dynamics, P. 22

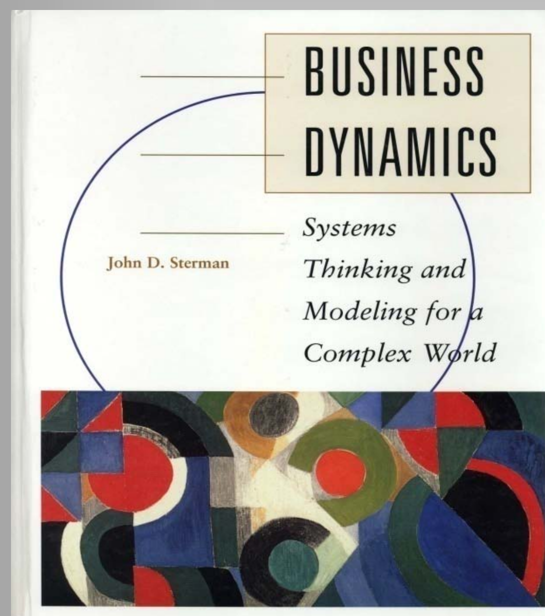
1958: "Industrial Dynamics- A Major Breakthrough for Decision Makers"
Harvard Business Review; chapter 2 of Industrial Dynamics (1961)



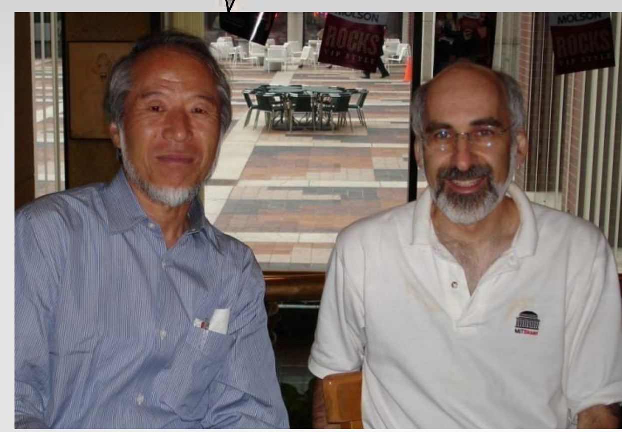
Industrial Dynamics(1961)

- Corporate modeling (Enterprise Design)

Jay Forrester Award 2004



2000 by The McGraw-Hill Companies

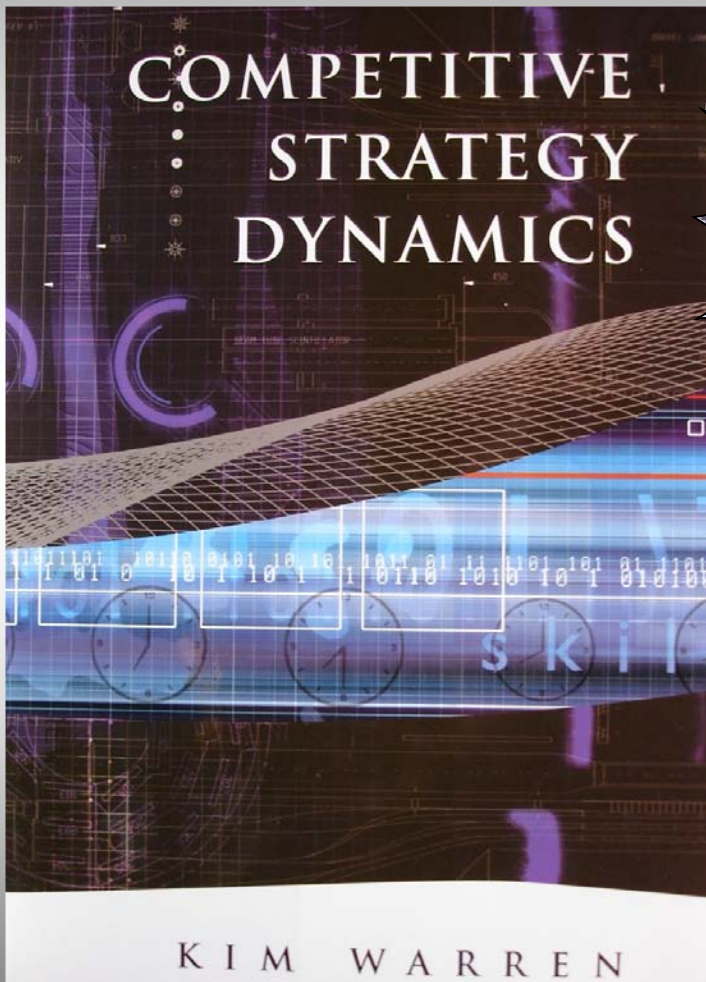


Prof. Sterman, MIT
Sept. 16, 2005

Competitive Strategy Dynamics

by Kim Warren

John Wiley & Sons Ltd,
England, 2002



Jay Forrester
Award 2005

**At the 22nd SD Conf., Oxford Univ.
July 27, 2004**

Urban Dynamics(1969)

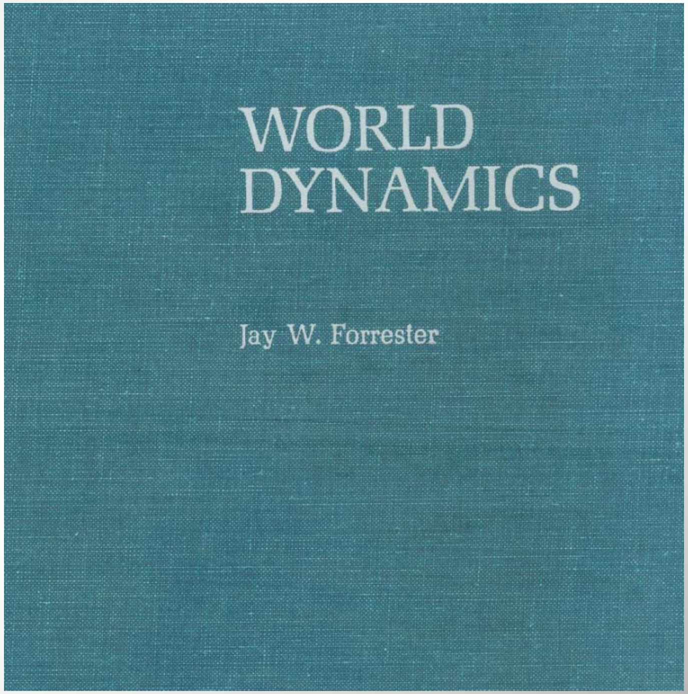
- Broader social systems
  With John F. Collins (former mayor of Boston for eight years
  "Urban Dynamics" was the first of my modeling work that produced strong, emotional reactions."

Many applications to
Public Policies

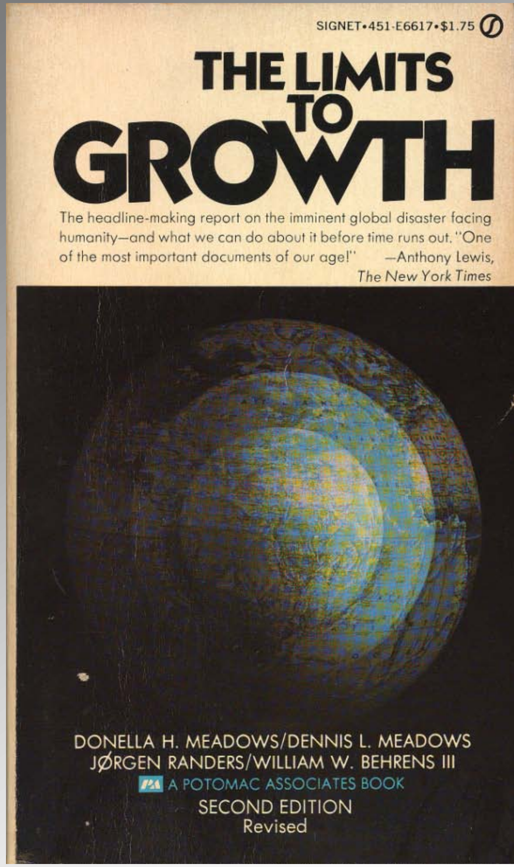
U.S. Department of Energy 's
Introduction to System Dynamics
A Systems Approach to Understanding Complex Policy Issues
Version 1.0
http://www.systemdynamics.org/DL-IntroSysDyn/inside.htm

World Dynamics(1971)

- "At Lake Como in Italy, I first met Aurelio Peccei, founder of the Club of Rome. Later I was invited to a meeting of the Club in June, 1970, in Bern, Switzerland, which became another turning point in my career with system dynamics.・・・(On the plane back from the Bern meeting, Forrester created the first draft of a system dynamics model of the world's socioeconomic system. He called this model WORLD1.

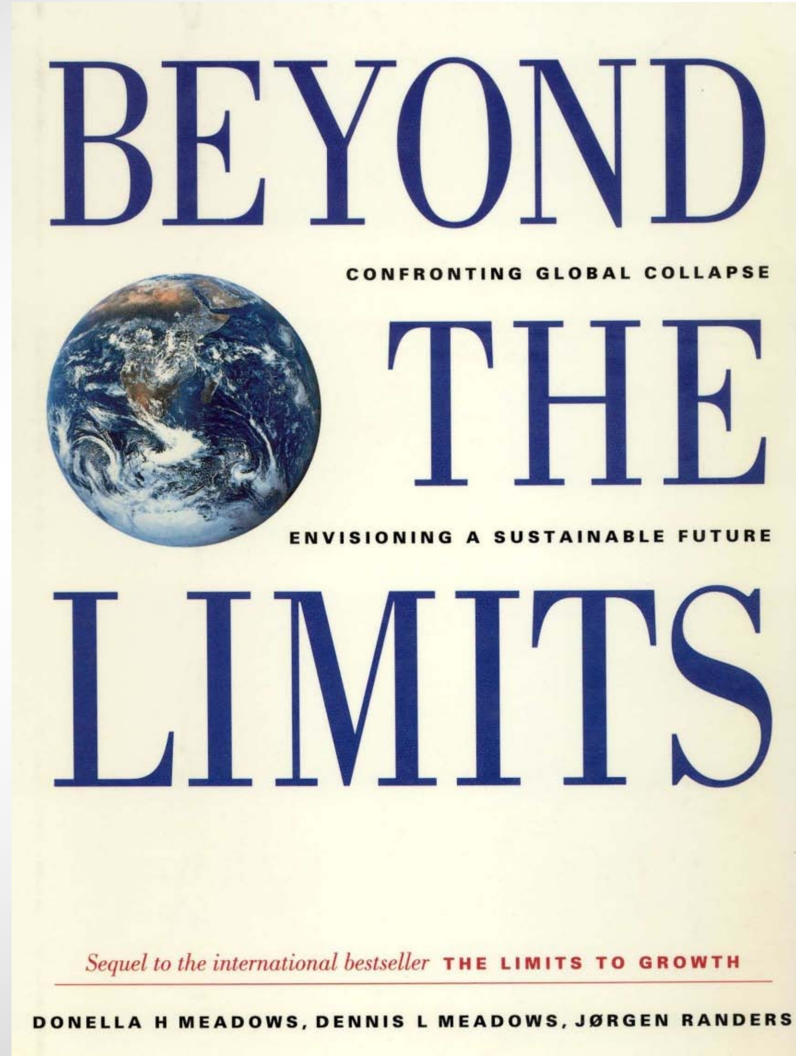


- The world problem discussed at the Bern meeting became the basis for the model in World Dynamics (called WORLD2), which was used in a two-week meeting with the executive committee of the Club of Rome at MIT in July 1970.
- Nine months after World Dynamics, Limits to Growth was published in which his former Ph.D. students (Dennis Meadows and his associates) created WORLD3 model.



(1972)

(1991)

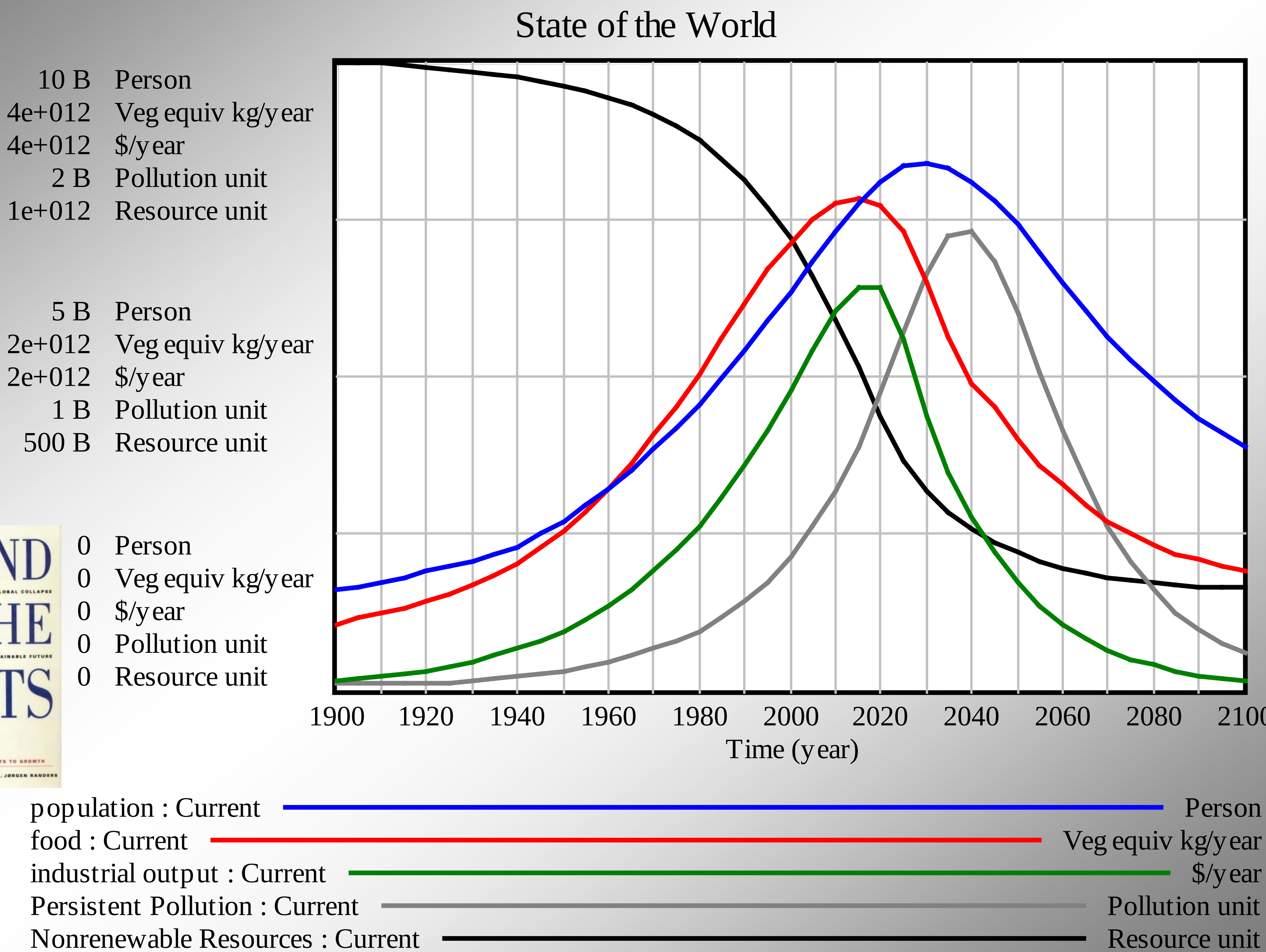


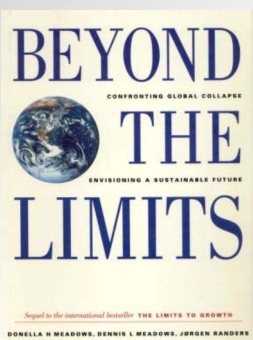
- This book was published by the three original authors of ”The Limits to Growth” in preparation for the twentieth anniversary of the book’s publication. The model is called WORLD3-91.

By Chelsea Green Publishing Company

Beyond the Limits(1991)

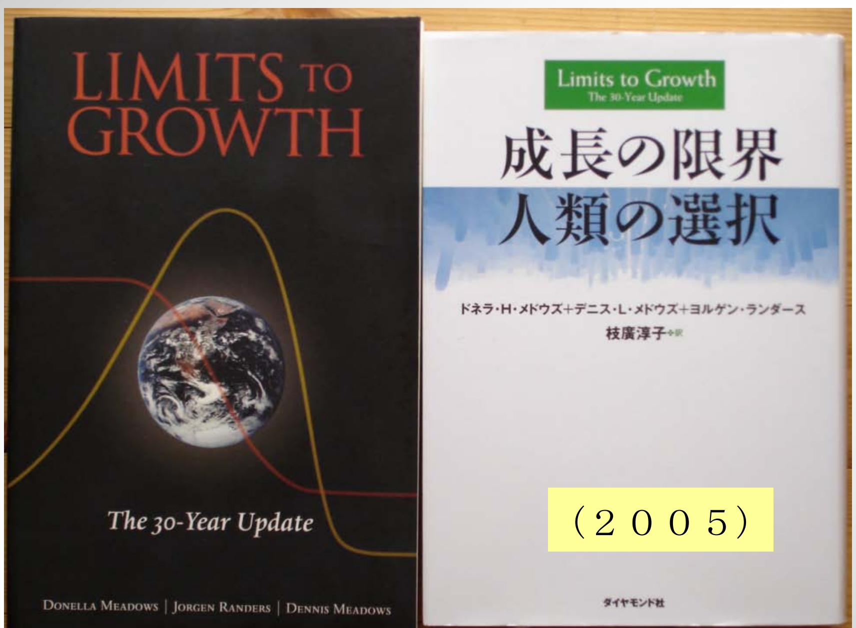
-WORLD3-91:Standard Run -

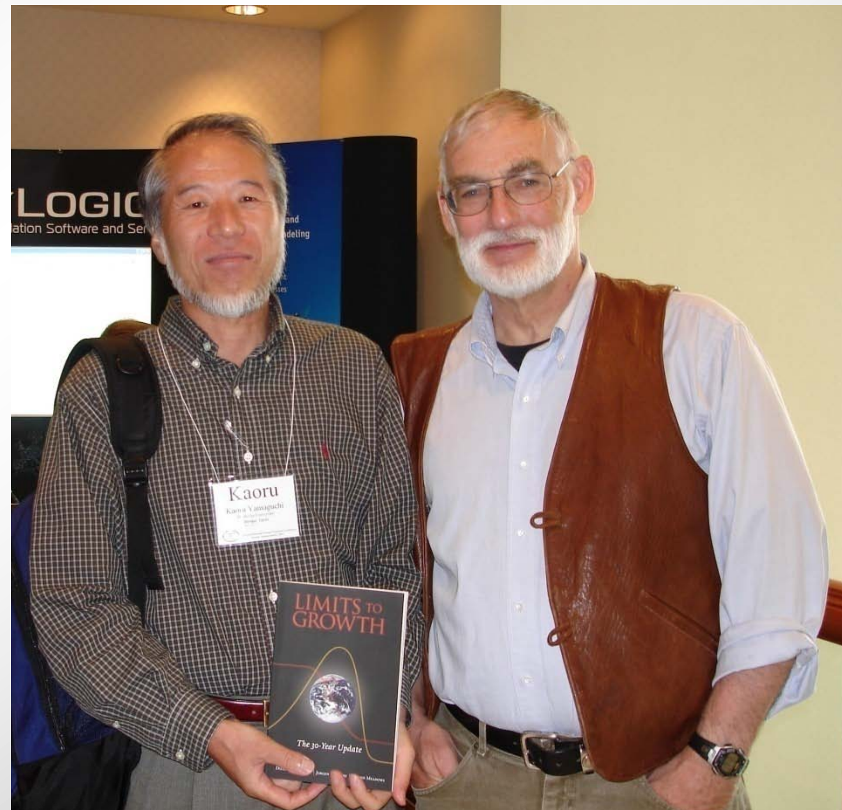




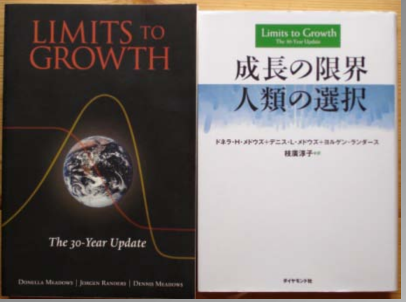
Limits To Growth (2004)
- The 30-Year Update -

- This book was published by the three original authors of ”The Limits to Growth” as the 30-year update of the. The previous model World3-91is renamed World 3.



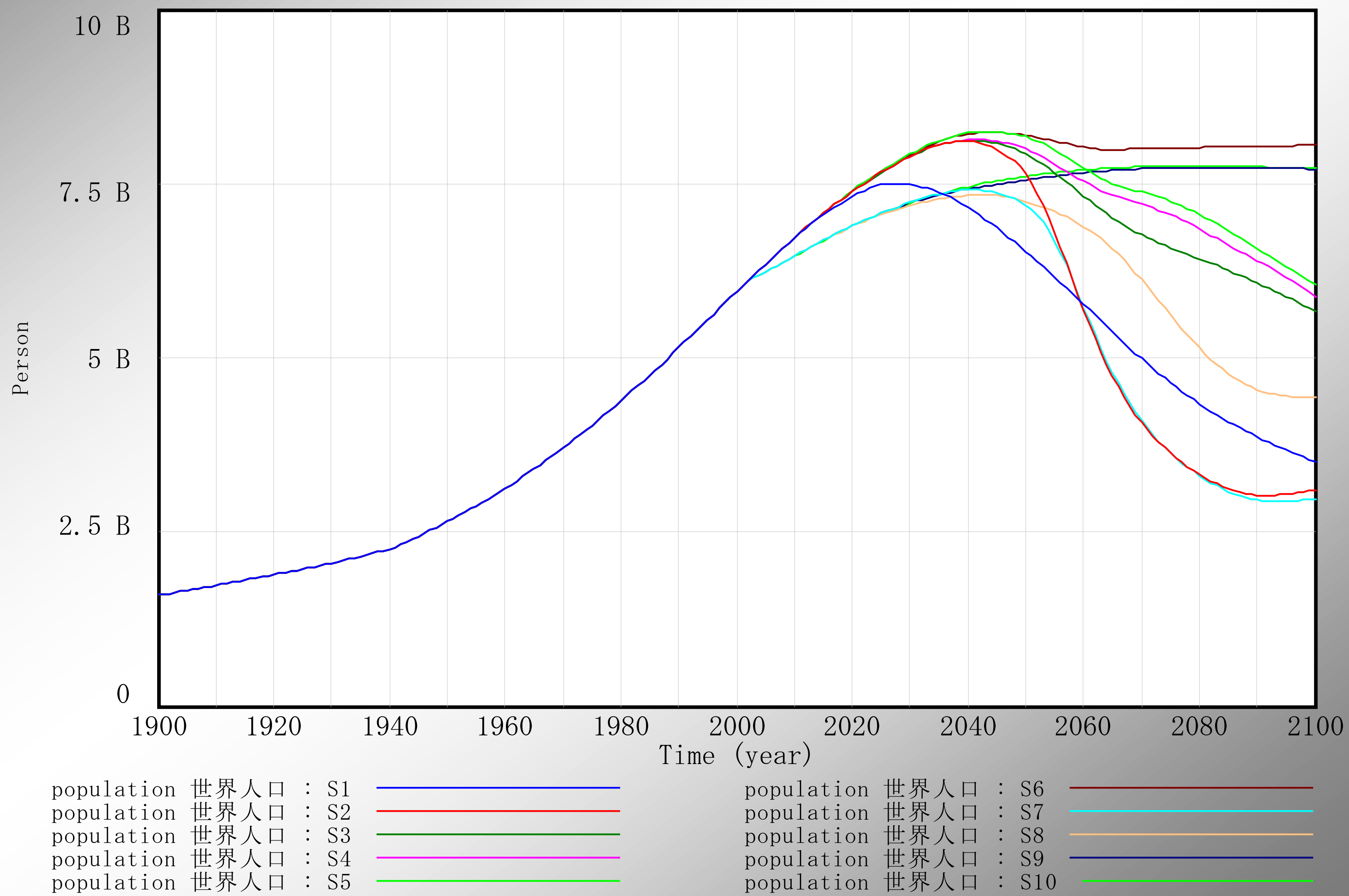


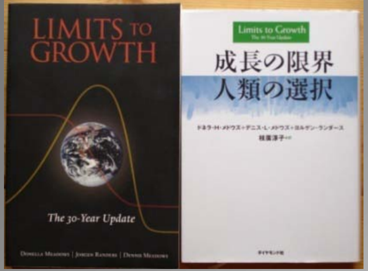
Prof. Dennis Meadows at the 23rd SD Conference, Boston, USA, July 25-29, 2005



Limits To Growth (2004)
- World3-03: 10 Scenarios -

population 世界人口





2009 (25th) Japan Prize Laureate

http://www.japanprize.jp/en/prize_this_year_prize01.html

Dr. Dennis L. Meadows served as Research Director for the project on "The Limits to Growth," for the Club of Rome in 1972. Employing a system simulation model called "World3," his report demonstrated that if certain limiting factors of the earth's physical capacity - such as resources, the environment, and land - are not recognized, mankind will soon find itself in a dangerous situation. The conflict between the limited capacity of the earth and the expansion of the population accompanied by economic growth could lead to general societal collapse. The report said that to avert this outcome, it is necessary that the goals of zero population growth and zero expansion in use of materials be attained as soon as possible. The report had an enormous impact on a world that had continued to grow both economically and in population since World War II.

The report sparked a great debate worldwide about the value of the zero growth theory that it proposed. The report was extremely significant in that it sounded a loud alarm about global society's urgent need for sustainable development, and it engendered broad interest throughout the world. Since its initial publication, Dr. Meadows has continued to study the causes and consequences of physical growth on a finite planet. He co-founded the Balaton Group, a famous environmental research network. He has published many educational games and books about sustainable development that are used around the world.

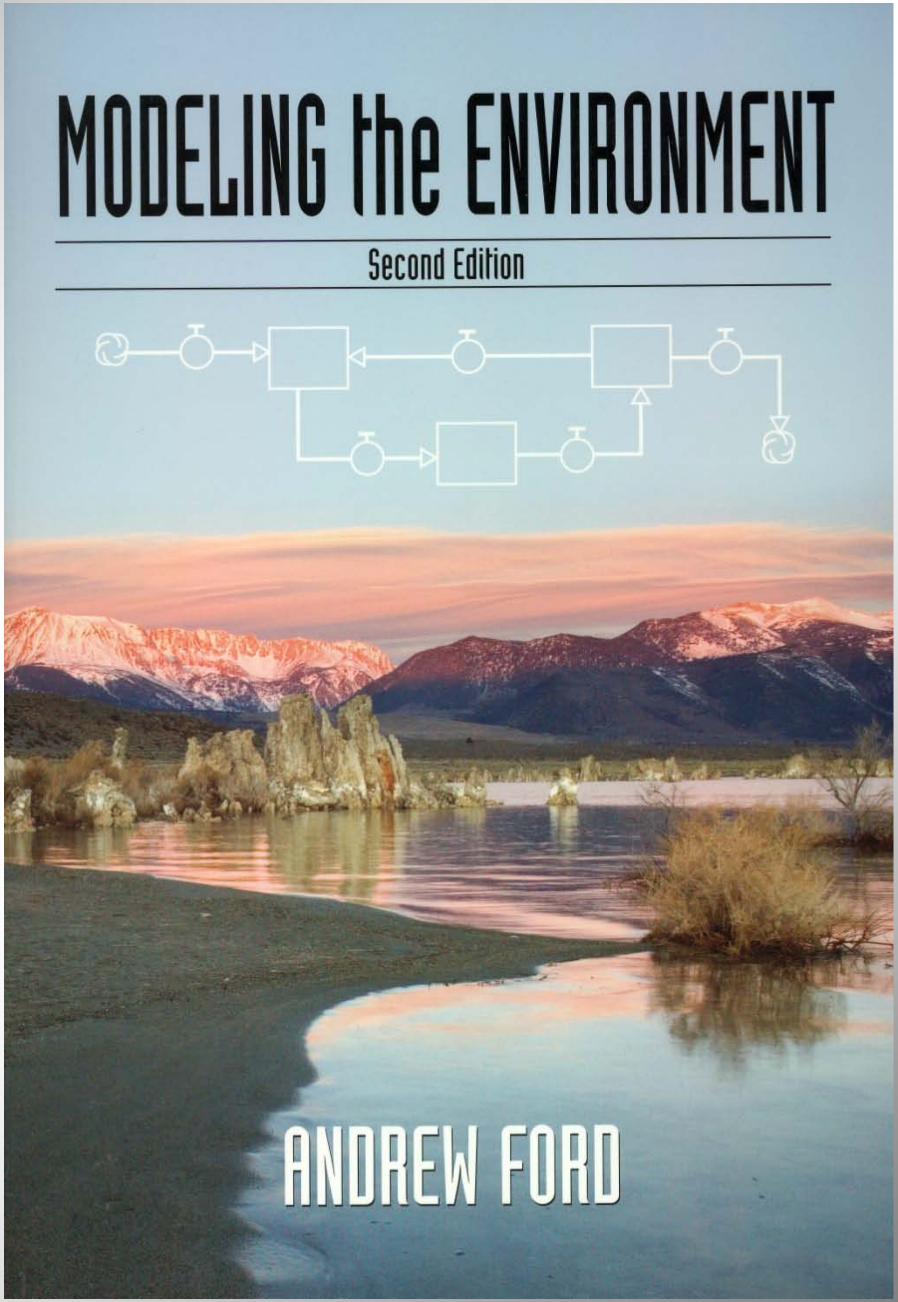
Together with his wife, the late Dr. Donella Meadows and Dr. J. Randers, he has twice co-authored updates to " The Limits to Growth", in 1992 and 2004. In these updates, an improved world model was used to point out that the limiting features of the earth's physical capacity, about which " The Limits to Growth" had sounded a warning, have continued to deteriorate, and that the time left for solving the problem is growing short; the authors also urged that mankind not delay in taking the measures necessary to address the situation.

This series of reports, especially the first "The Limits to Growth," presented the conflict between the earth's physical limitations and the growth of mankind in clear, logical terms, and marked the beginning of mankind's efforts to achieve a sustainable society. "The Limits to Growth" also became a major underpinning of "The Global 2000 Report to the President," a famous report presented by a US presidential commission in 1980. Moreover, we may take note of the UN's World Commission on the Environment and the Development (commonly known as the Brundlandt Commission). This commission is famous for a 1987 report titled "Our Common Future." The Commission was created based on a proposal made by the Ad hoc Group on Global Environmental Problems, a deliberative body of the Japanese Government operated under the auspices of the Secretary of the Environment Agency. The Ad hoc Group's establishment was inspired by "The Limits to Growth" and "The Global 2000 Report to the President." Thus it could be said that Dr. Meadows' "The Limits to Growth" provided the spark that ignited mankind's movement towards sustainable development.

Based on the foundations established in "The Limits to Growth" over the past 30 years Dr. Meadows has consistently proposed, through model analyses, efforts aimed at forming a sustainable society. He has continued to exert a large influence on the entire world. This, it is believed, is highly praiseworthy and deserving of the 2009 Japan Prize, which is intended to honor contributions in the area of "Transformation towards a sustainable society in harmony with nature."

Environment and Ecology Modeling

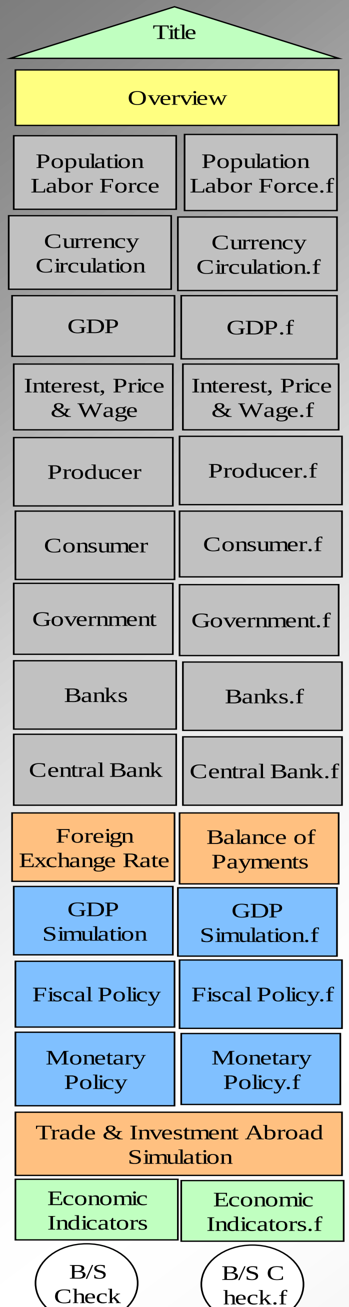
Awaji Island, June 7, 2010



1999 by Island Press

National Model

- A creation of a system dynamics model of the United States economy - a project as leading to a new approach to economic science and a fundamental understanding of the way macroeconomic systems work.
- Although his national economic model remains unfinished, the most noteworthy intermediate result is that the model generates a 40- to 60 year economic cycle or "long wave (or Kondratiev cycle)" that not only explains the Grerat Depression of the 1930s, but also shows that deep economic slumps are a repetitive feature of capitalist economies.



Macroeconomic Dynamics Model

< *MacroDynamics 2.2* >

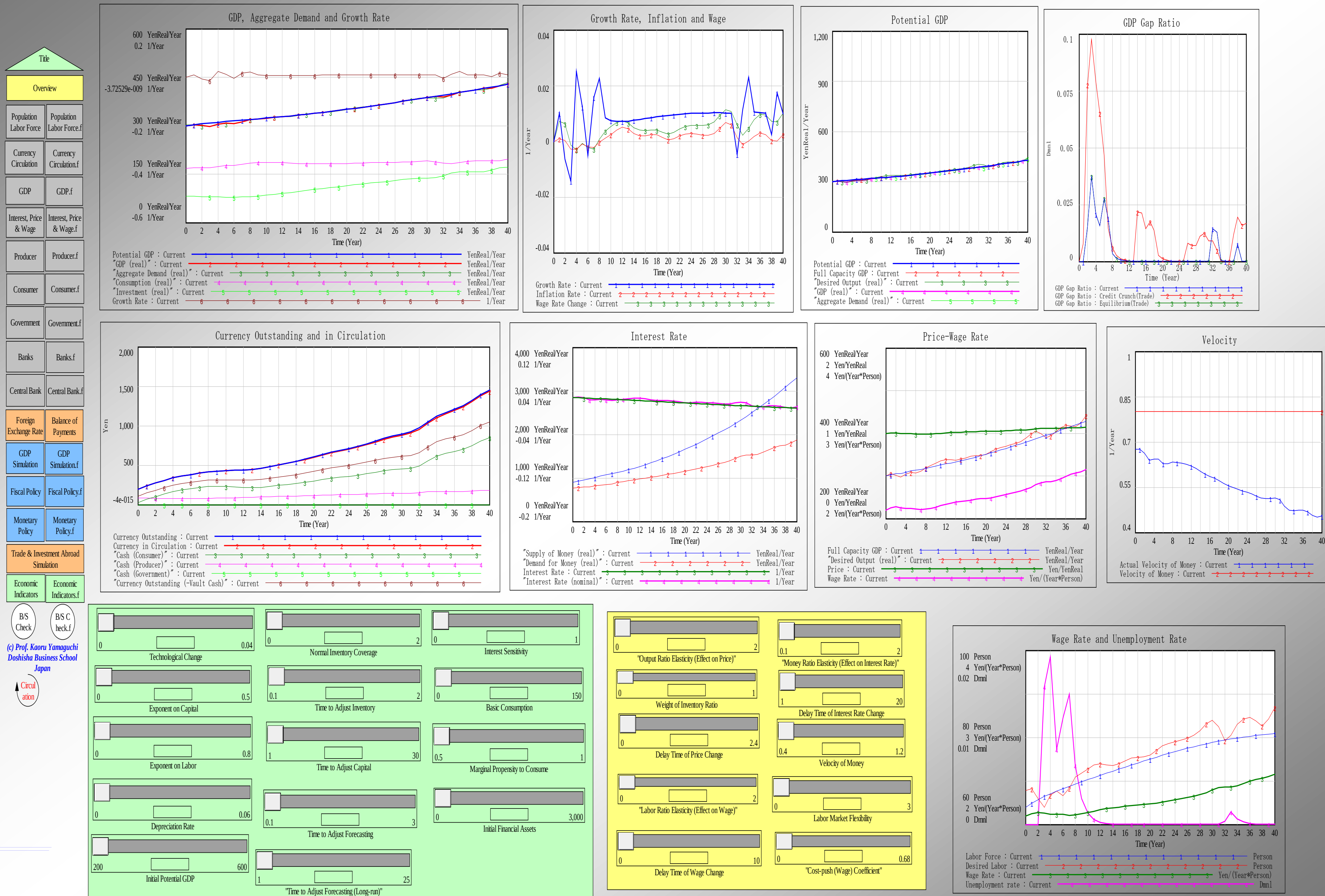
- Accounting System Dynamics Approach -

Porf. Kaoru Yamaguchi, Ph.D.

Doshisha Business School
Doshisha University
Kyoto, Japan

kaoyamag@mail.doshisha.ac.jp

This model provides a generic system on which various schools of economic thoughts can be built. Your comments and suggestions are most welcome.



Title
Overview
Population Labor Force
Population Labor Force.f
Currency Circulation
Currency Circulation.f
GDP
GDP.f
Interest, Price & Wage
Interest, Price & Wage.f
Producer
Producer.f
Consumer
Consumer.f
Government
Government.f
Banks
Banks.f
Central Bank
Central Bank.f
Foreign Exchange Rate
Balance of Payments
GDP Simulation
GDP Simulation.f
Fiscal Policy
Fiscal Policy.f
Monetary Policy
Monetary Policy.f
Trade & Investment Abroad Simulation
Economic Indicators
Economic Indicators.f
B/S Check
B/S C heck.f
(c) Prof. Kaoru Yamaguchi Doshisha Business School Japan
Circulation
GDP, Aggregate Demand and Growth Rate
Potential GDP : Current
"GDP (real)" : Current
"Aggregate Demand (real)" : Current
"Consumption (real)" : Current
"Investment (real)" : Current
Growth Rate : Current
Growth Rate, Inflation and Wage
Growth Rate : Current
Inflation Rate : Current
Wage Rate Change : Current
Potential GDP
Potential GDP : Current
Full Capacity GDP : Current
"Desired Output (real)" : Current
"GDP (real)" : Current
"Aggregate Demand (real)" : Current
GDP Gap Ratio
GDP Gap Ratio : Current
GDP Gap Ratio : Credit Crunch(Trade)
GDP Gap Ratio : Equilibrium(Trade)
Currency Outstanding and in Circulation
Currency Outstanding : Current
Currency in Circulation : Current
"Cash (Consumer)" : Current
"Cash (Producer)" : Current
"Cash (Government)" : Current
"Currency Outstanding (-Vault Cash)" : Current
Interest Rate
"Supply of Money (real)" : Current
"Demand for Money (real)" : Current
Interest Rate : Current
"Interest Rate (nominal)" : Current
Price-Wage Rate
Full Capacity GDP : Current
"Desired Output (real)" : Current
Price : Current
Wage Rate : Current
Velocity
Actual Velocity of Money : Current
Velocity of Money : Current
Technological Change
Normal Inventory Coverage
Interest Sensitivity
Exponent on Capital
Time to Adjust Inventory
Basic Consumption
Exponent on Labor
Time to Adjust Capital
Marginal Propensity to Consume
Depreciation Rate
Time to Adjust Forecasting
Initial Financial Assets
Initial Potential GDP
"Time to Adjust Forecasting (Long-run)"
"Output Ratio Elasticity (Effect on Price)"
"Money Ratio Elasticity (Effect on Interest Rate)"
Weight of Inventory Ratio
Delay Time of Interest Rate Change
Delay Time of Price Change
Velocity of Money
"Labor Ratio Elasticity (Effect on Wage)"
Labor Market Flexibility
Delay Time of Wage Change
"Cost-push (Wage) Coefficient"
Wage Rate and Unemployment Rate
Labor Force : Current
Desired Labor : Current
Wage Rate : Current
Unemployment rate : Current

K-12 Education

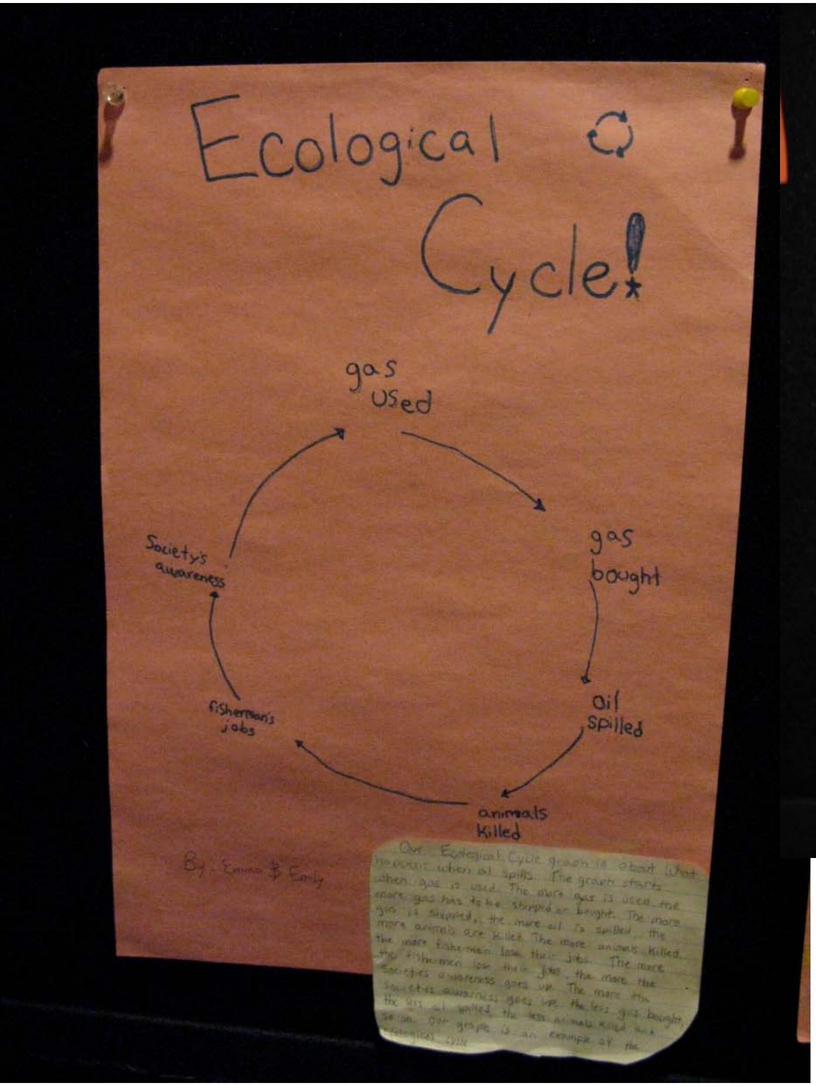
- An extension of system dynamics training to kindergarden through high school education - a crucial project not only for the future health of the field of system dynamics, but also for the future health of human society.
- His mentor Gordon Brown retired from MIT in 1973 and began wintering in Tucson, Arizona. During the late 1980s, Brown introduced system dynamics to teachers in the Tucson school district. The result were remarkable. It spread, not only through the original junior high in which it was introduced, but through the entire school district. Subjects as diverse as Shakespeare, economics, and physics are today taught in the school district, wholly or in part, via system dynamics.
- The future of system dynamics in K-12 education appears promising. Today, an international clearinghouse for K-12 system dynamics materials exists and Web sites have been created to disseminate information.

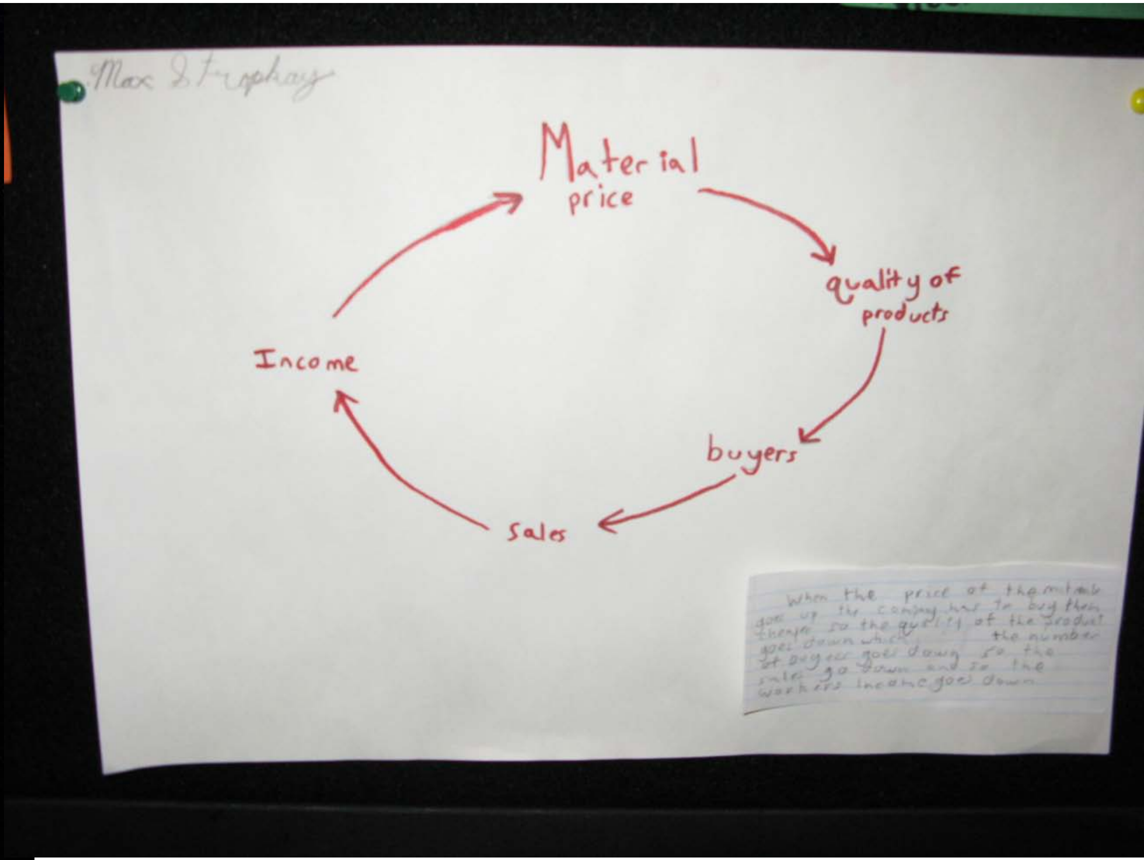
Road Map Project

At Sloan School of Management, MIT
Sept. 17, 1999

http://sysdyn.clexchange.org/road-maps/rm-toc.html

The 27th International Conference of the System Dynamics Society
Albuquerque, New Mexico, USA
July 26 – 30, 2009

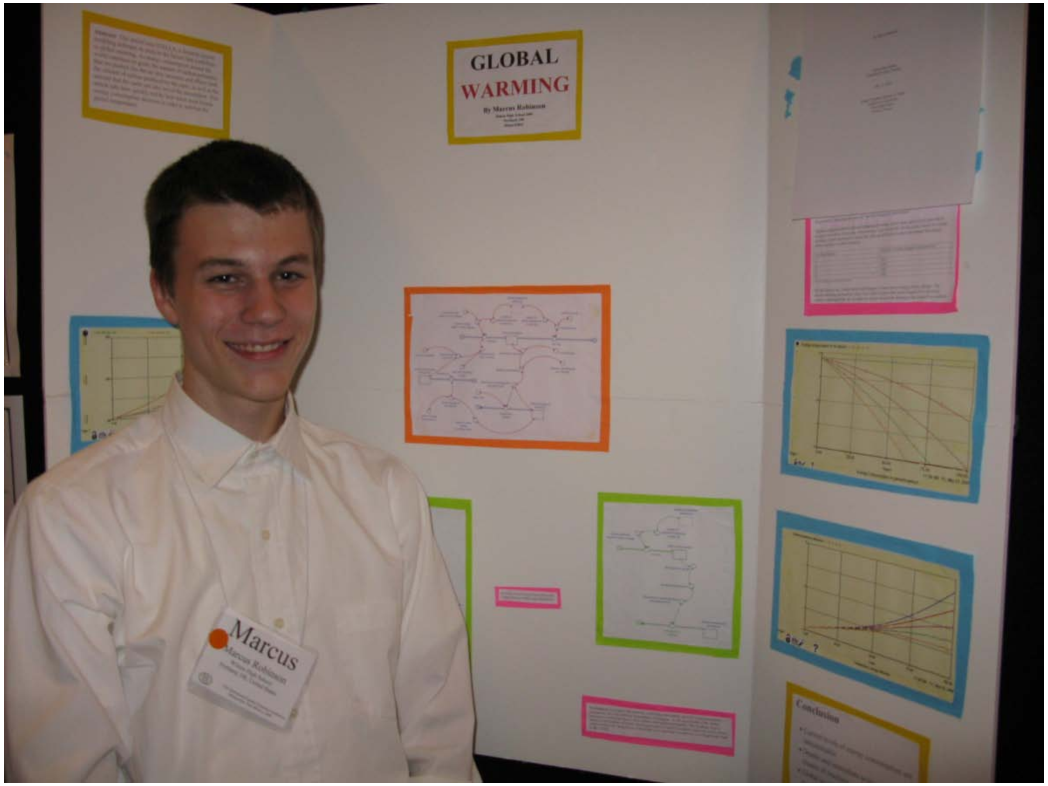


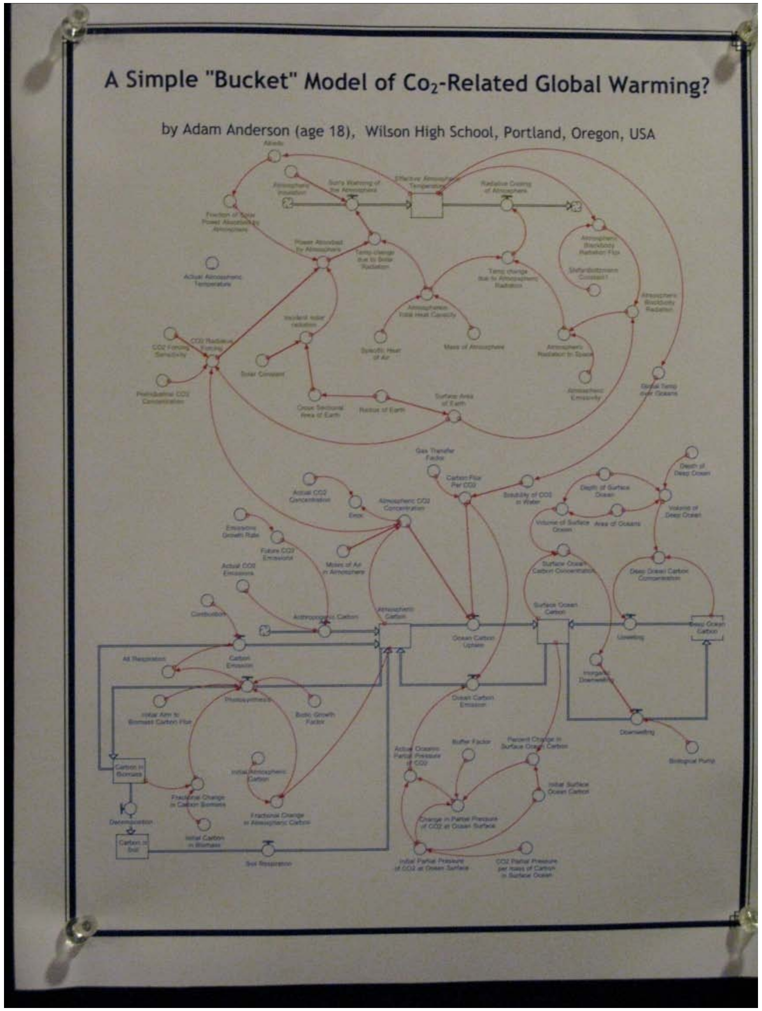


K-12 Poster Session

The 27th International Conference of the System Dynamics Society
Albuquerque, New Mexico, USA
July 26 – 30, 2009

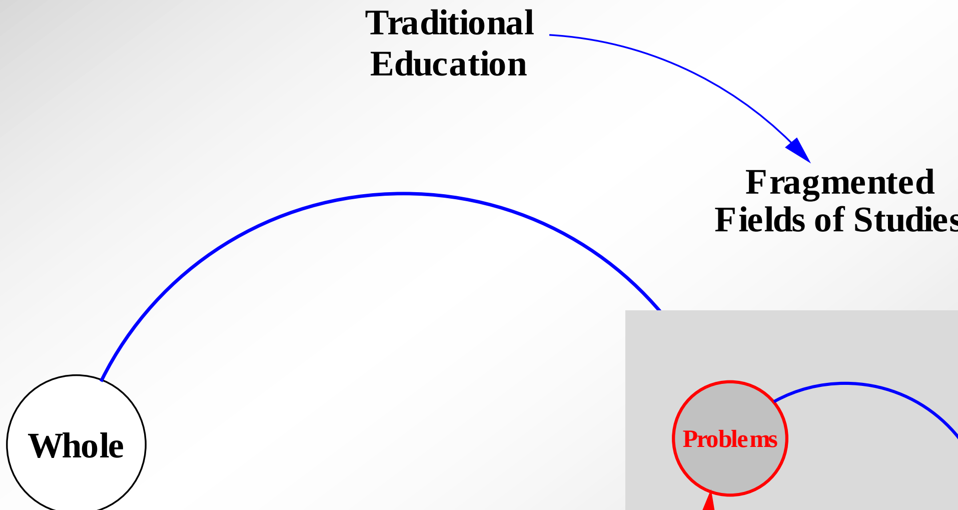
Winner of Dana Meadows Award!

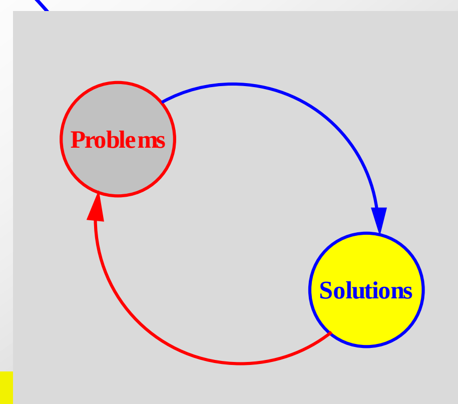


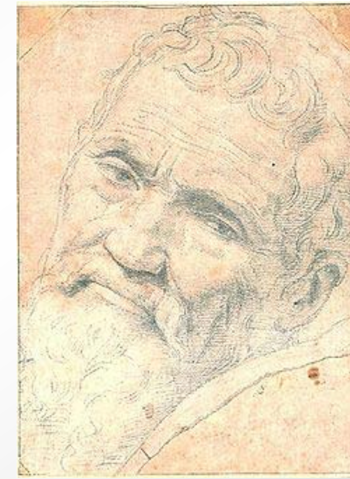


K-12 Poster Session

“Renaissance man”





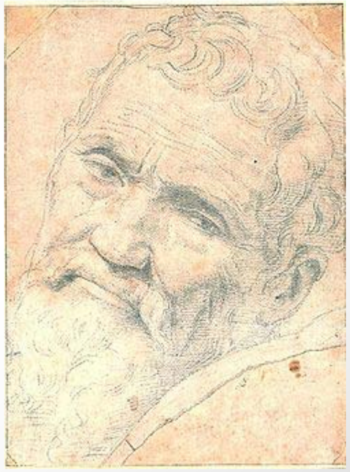


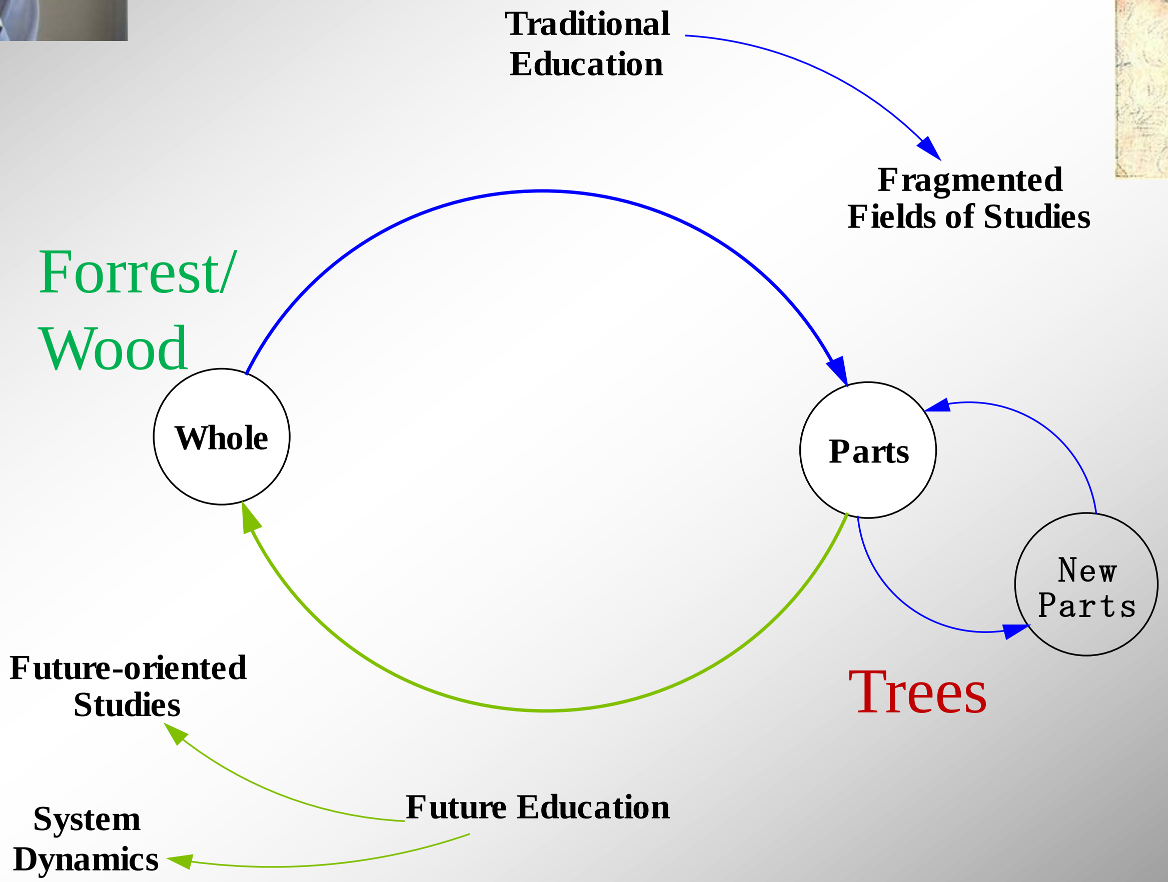
Michelangelo
1475 - 1564

Lenardo de Vinci
1452 - 1519

the trend of the last century
that has been moving away from the
“Renaissance man”
toward fragmented specialization.

"Renaissance man"





There is now a promise of reversing the trend of the last century

“Renaissance man”

- Such transfer of insights from one setting to another will help to break down the barriers between disciplines.
  It means that learning in one field becomes applicable to other field.

There is now a promise of reversing the trend of the last century that has been moving away from the “Renaissance man” toward fragmented specialization. We can now work toward an integrated, systemic, educational process that is more efficient, more applicable to a world of increasing complexity, and more compatible with a unity in life.

--- The Beginning of System Dynamics, p.15
Jay Wright Forrester ---

The 27th International Conference of the System Dynamics Society (Program by Thread) Albuquerque, New Mexico, USA July 26 – 30, 2009

You can see the wood (whole) for the trees (parts)!

- Business
- Challenges of Terrorism & Military
- Economics
- Education (K-12)
- Energy & Resources
- Environment & Ecology
- Health Policy
- Information Science
- Infrastructure & Resiliency
- Methodology in SD
- Operations Management & Supply Chains
- Organization
- Psychology
- Public Policy
- Strategy

- Nano-Satellite Applications

Common modes of behavior in dynamic systems

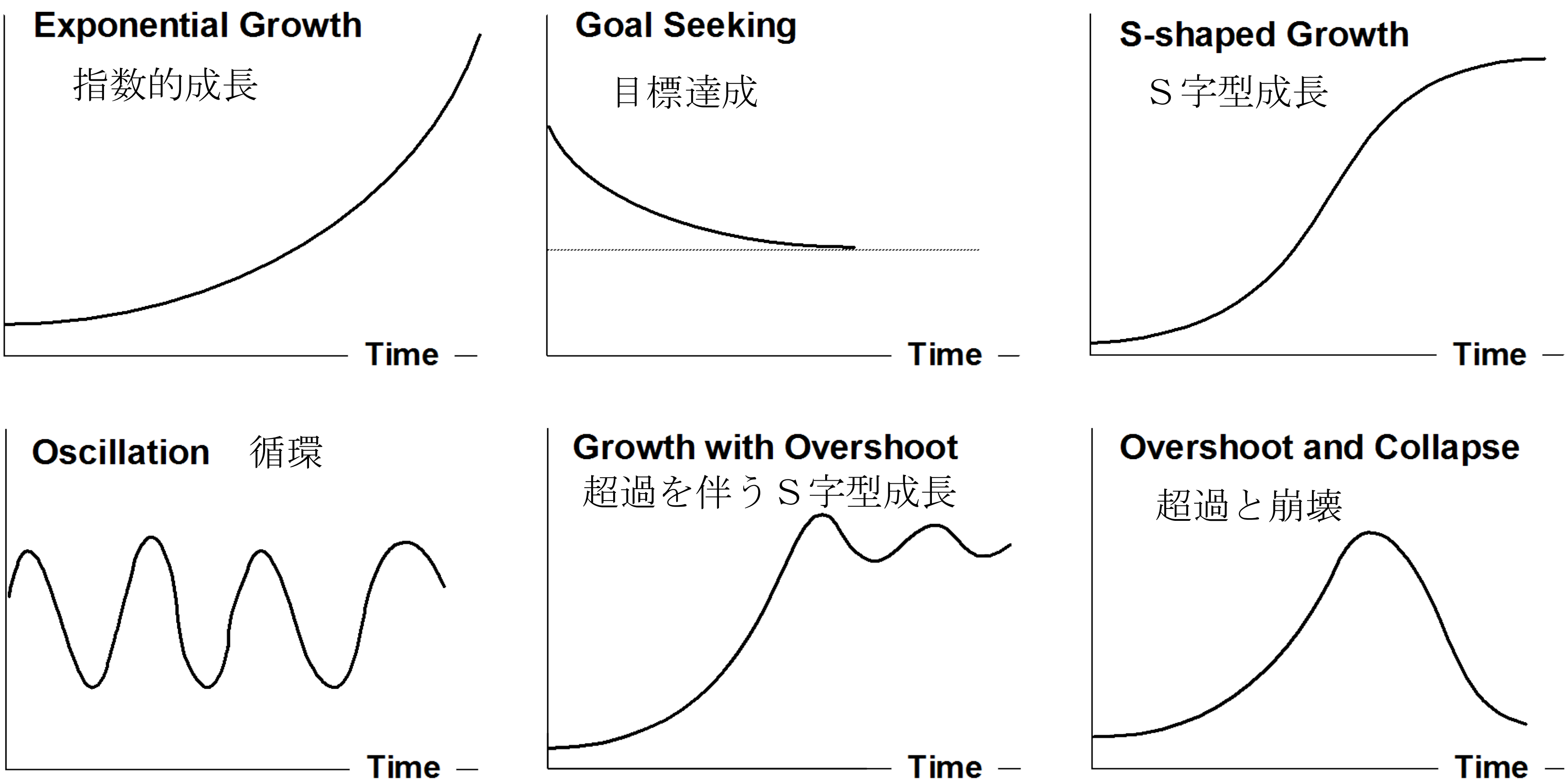
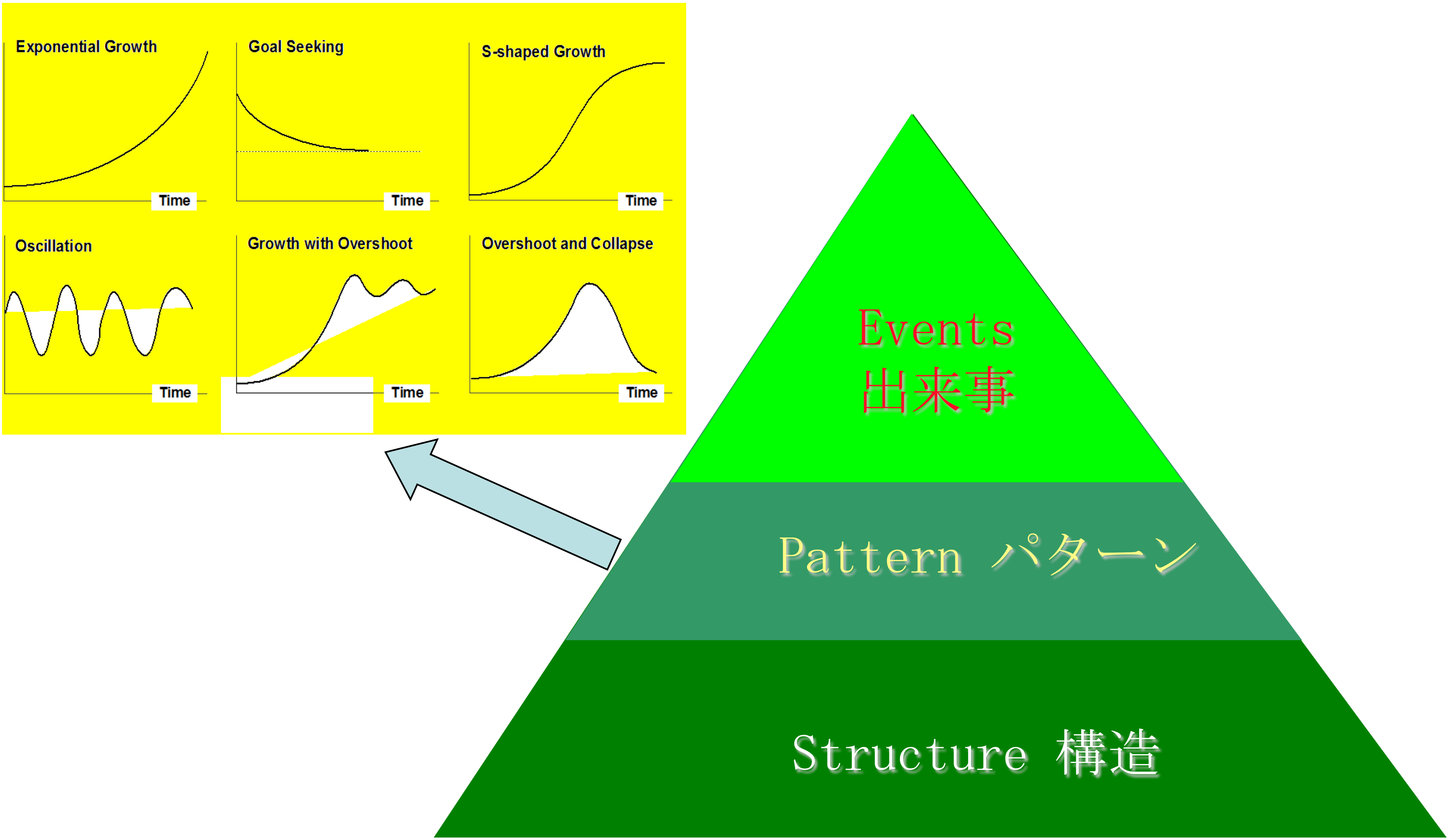
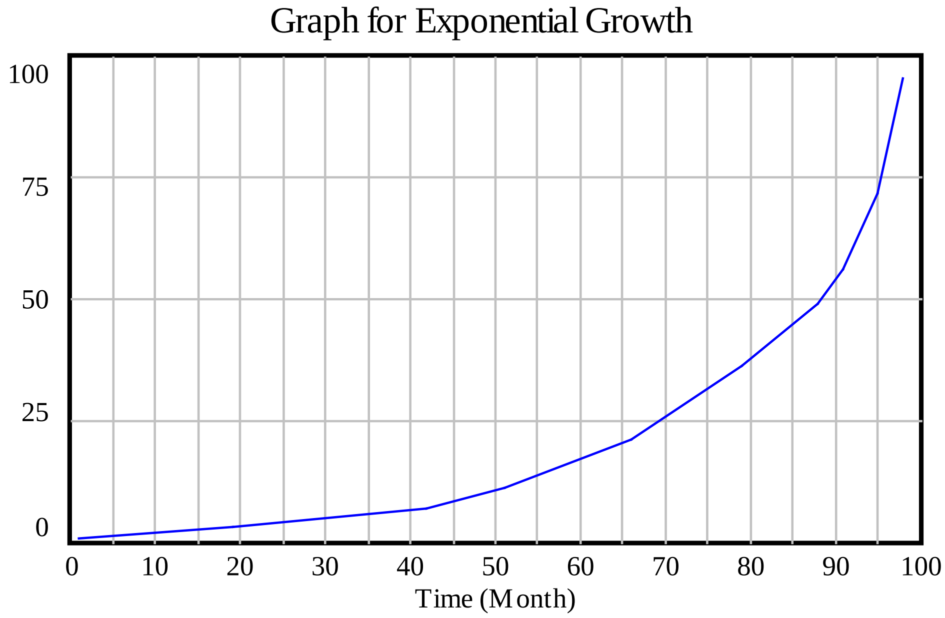


Figure 4-1, p.108

Pyramid Structure

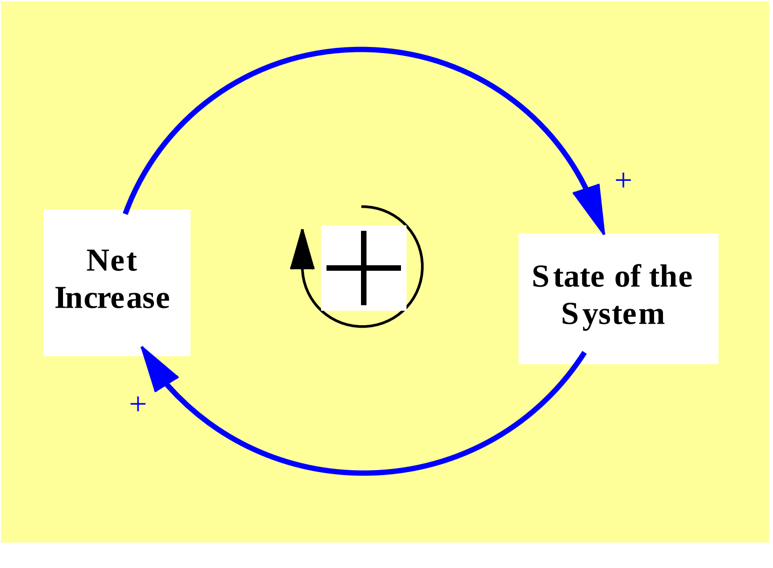


Exponential Growth 指数的成長

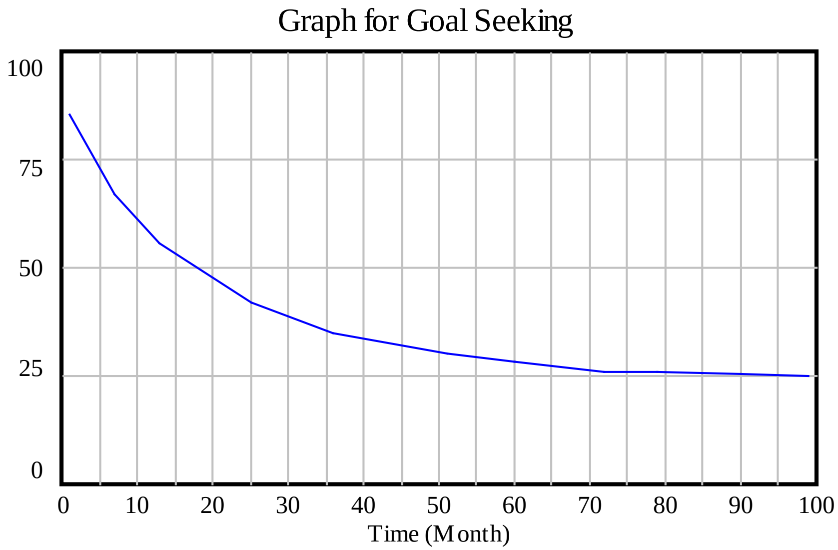


Pattern (Behavior)

System Structure

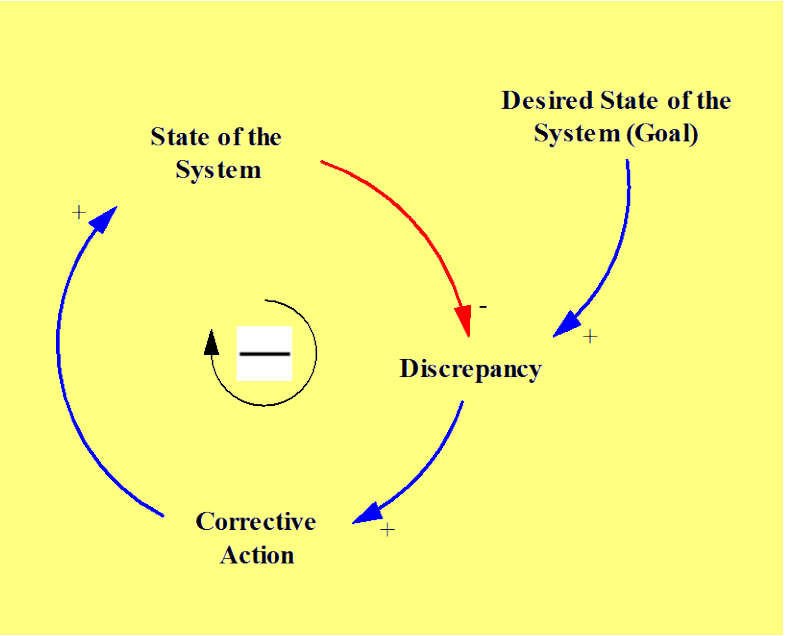


Goal Seeking 目標達成

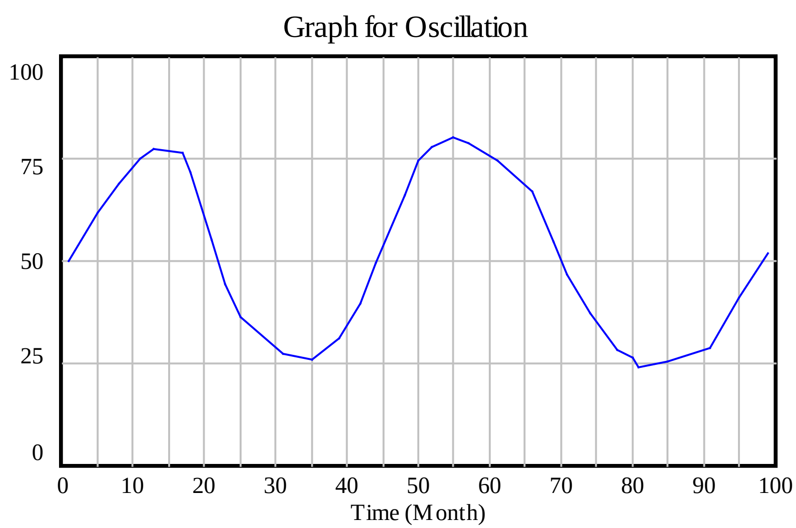


Pattern (Behavior)

System Structure



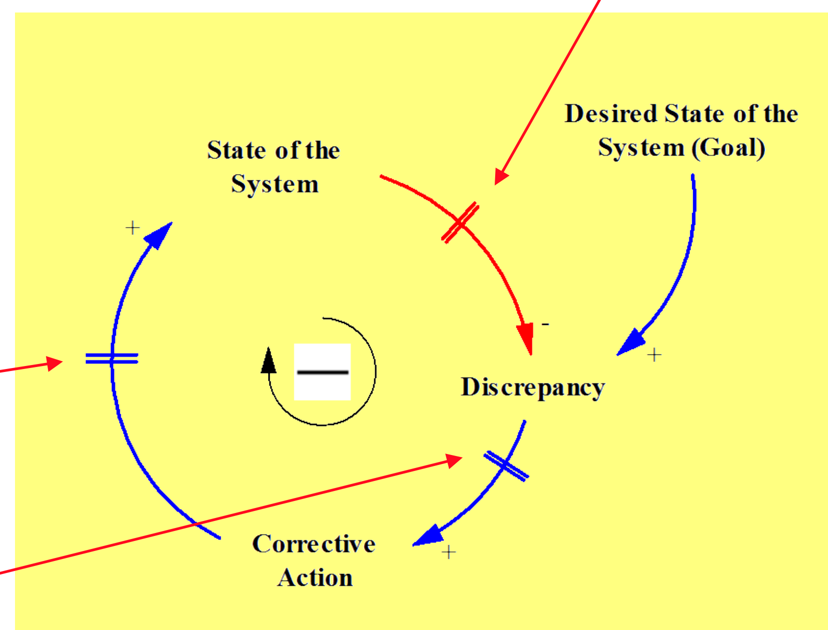
Oscillation 循環



Pattern (Behavior)

Measurement, Reporting, and Perception Delays

System Structure

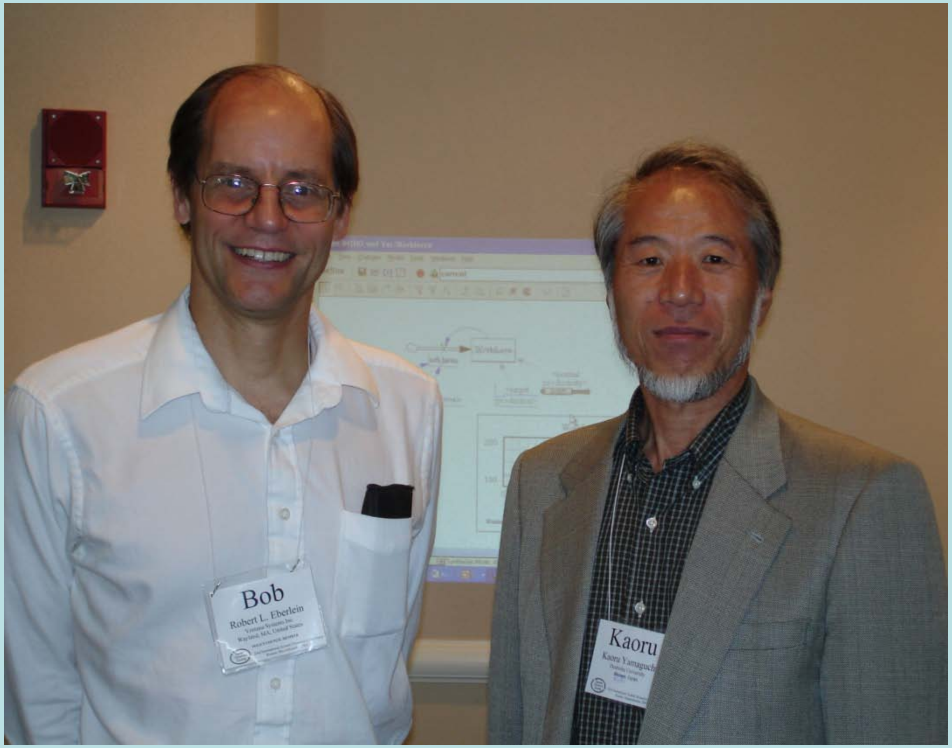


Action Delays

Administrative and Decision-Making Delays

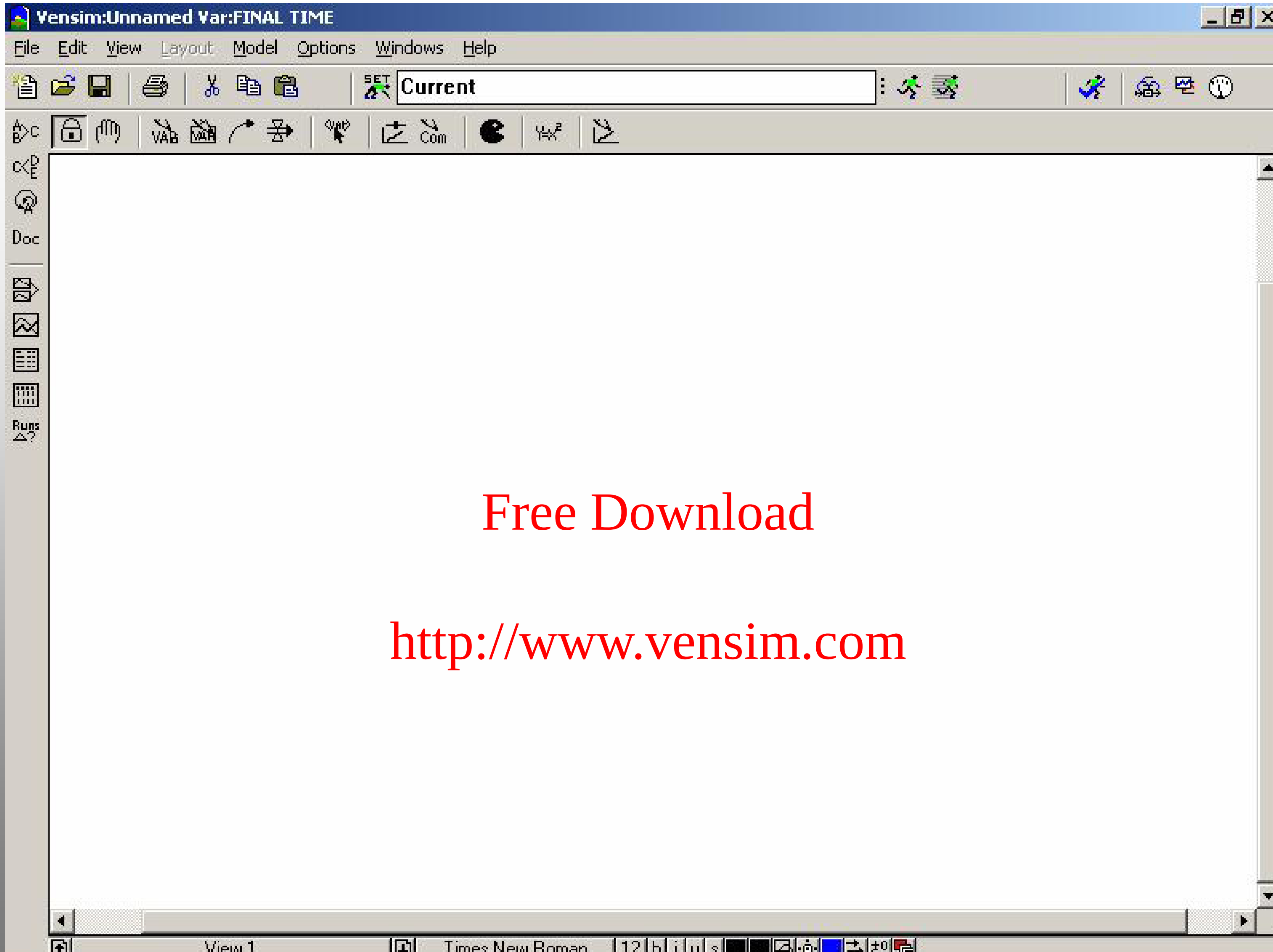
SD Softwares

- Dynamo
- Stella iThink
- Powersim
- Vensim
- Mystrategy
- Simile
- Simulink - MATLAB
- GoldSim
- Agent-based…
  - AnyLogic



Dr. Eberlein (developer of Vensim and former president of SD Society) at the 23rd SD Conference, Boston, USA July 25-29, 2005

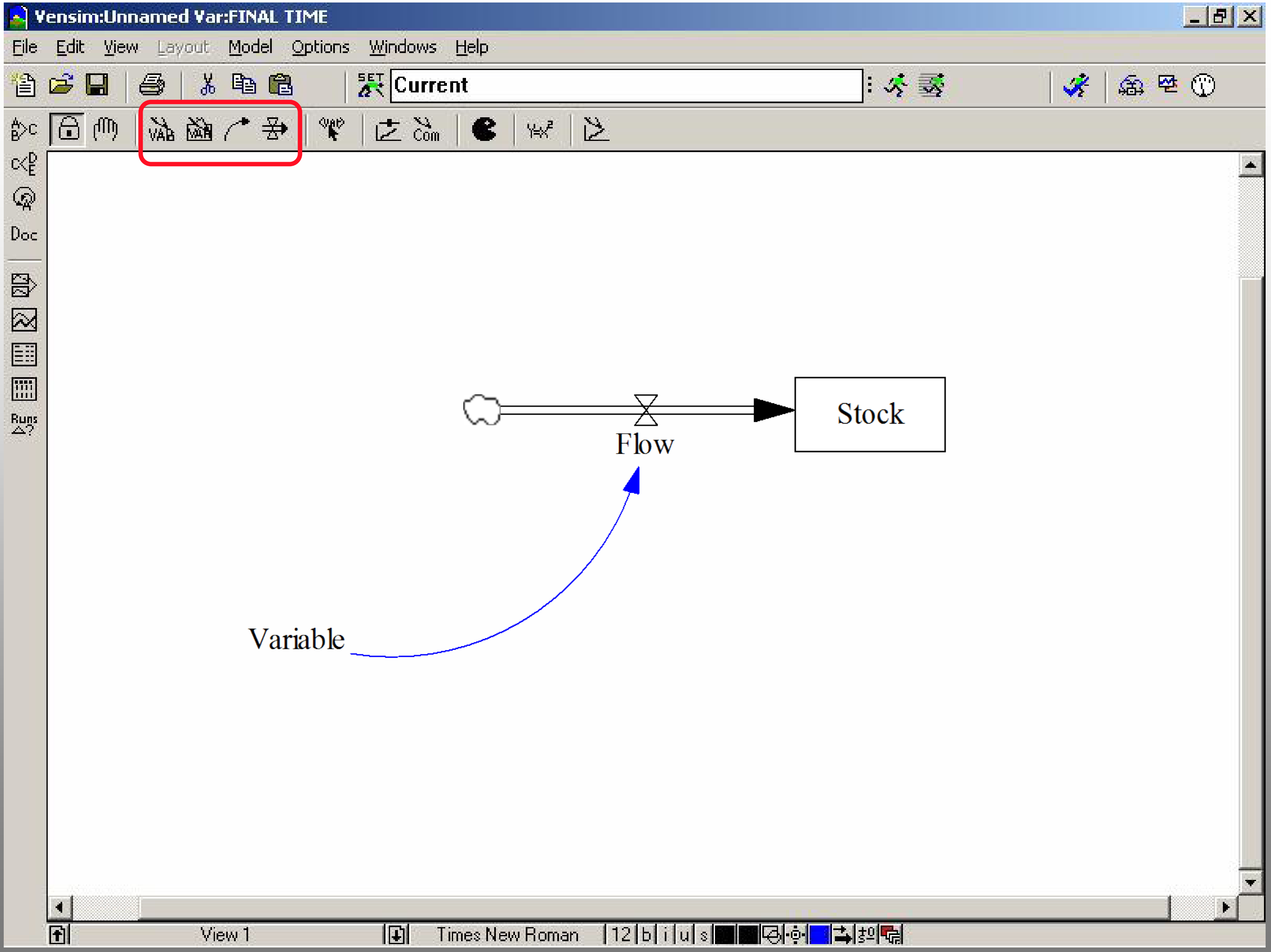
Vensim PLE



Free Download

http://www.vensim.com

Vensim PLE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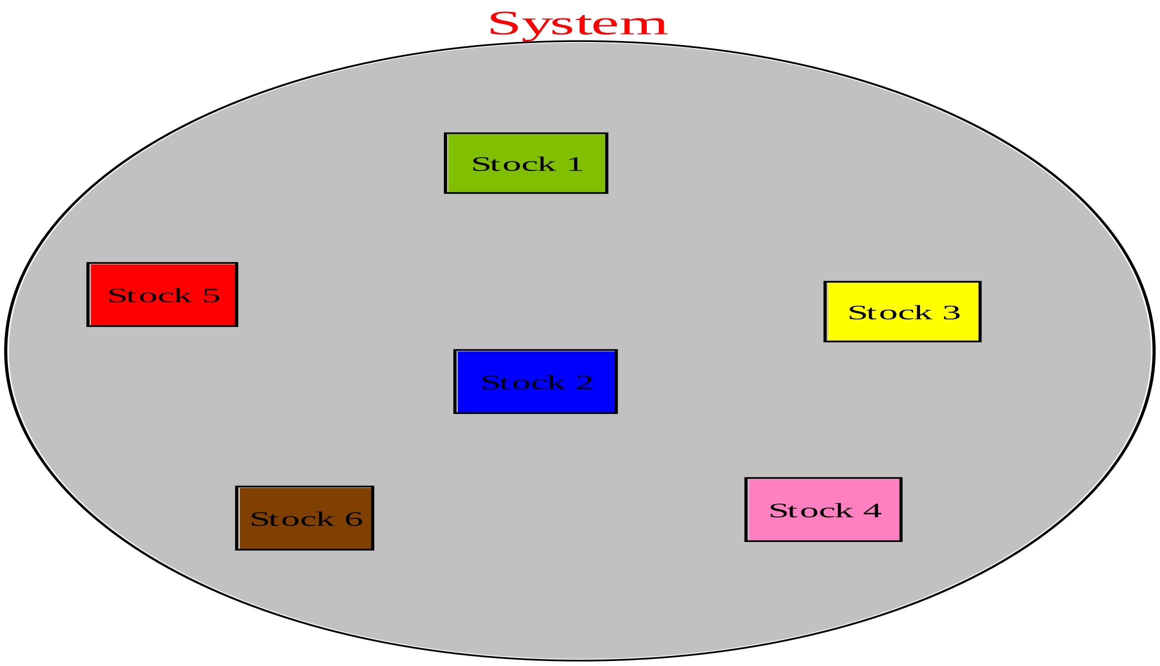
12 b i u s

What is a system?
- Definition by System Dynamics -

Principle 1. System as a Collection of Stocks

System can be described by a collection of state variables, called *stocks* in system dynamics, whose levels or volumes are measured at a *moment in time*.

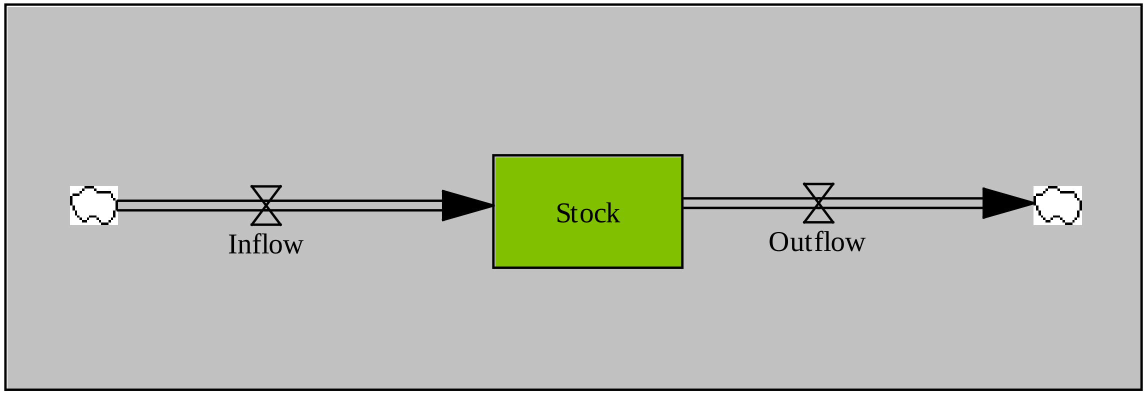


What is a system?

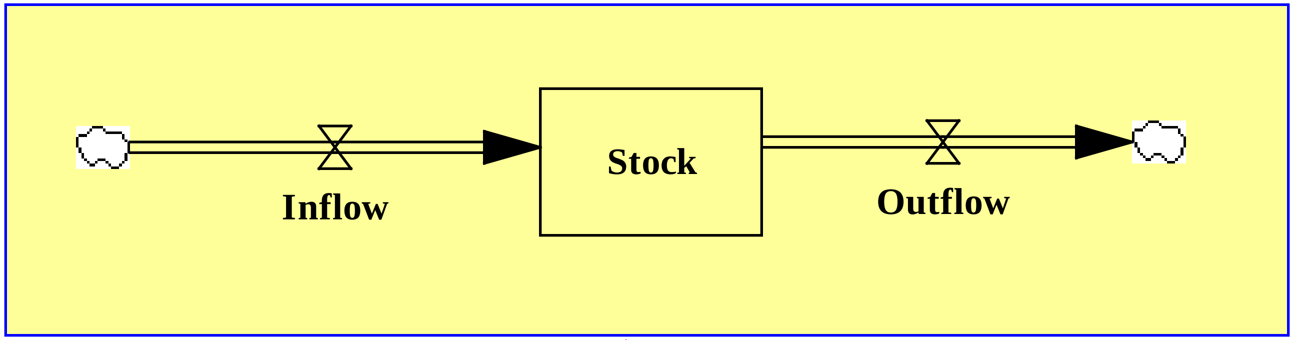
- Definition by System Dynamics -

Principle 2. Stock-Flow Relation

Levels of a stock can only be changed by the amount of ***flows*** measured for a *period of time*.
The amount of flow that increases the stock is called *inflow*, while the one that decreases it is called *outflow*.



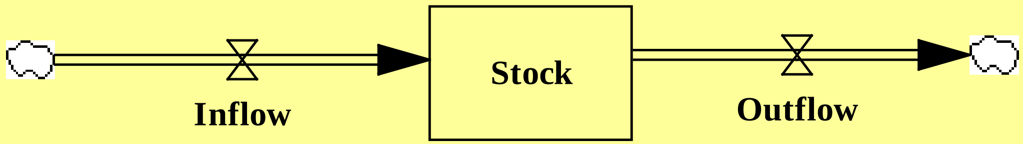
Stock-Flow and Differential Equation



Stock= INTEG (Inflow-Outflow, Initial Stock Value): Vensim Program

Stock(t) = Stock(t - dt) + (Inflow - Outflow) * dt : Stella Program
INIT Stock = Initial Stock Value

Differential Equation (Contd)



Integral Equation： 積分方程式

$$Stock(t) = Stock(t_0) + \int_{t_0}^{t} (Inflow(s) - Outflow(s))ds$$

Differential Equation： 微分方程式

$$\frac{d(Stock(t))}{dt} = Inflow(t) - Outflow(t)$$

$$\begin{cases} \Rightarrow d(Stock(t) = (Inflow(t) - Outflow(t))dt \\ \Rightarrow Stock(t+dt) = Stock(t) + (Inflow(t) - Outflow(t))dt \end{cases}$$

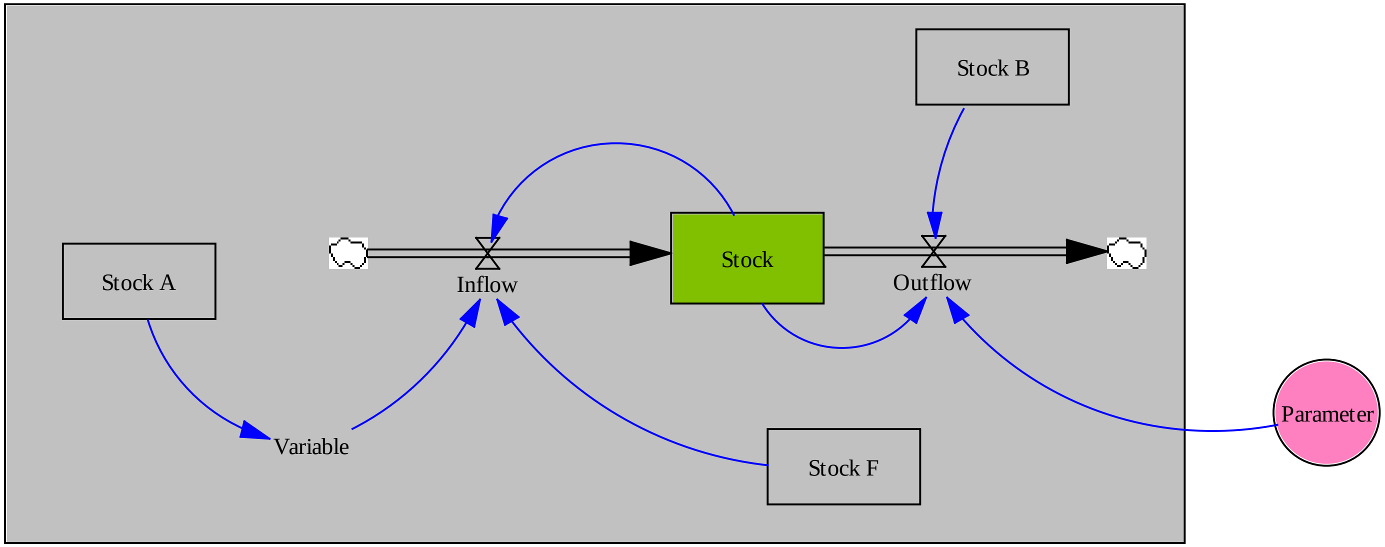
System Dynamics Programming

What is a system?

− Definition by System Dynamics −

Principle 3. Information Feedback

The amount of inflows and outflows is directly or indirectly determined either by the information obtained from the stocks through their feedback loops, or parameters obtained outside the system.



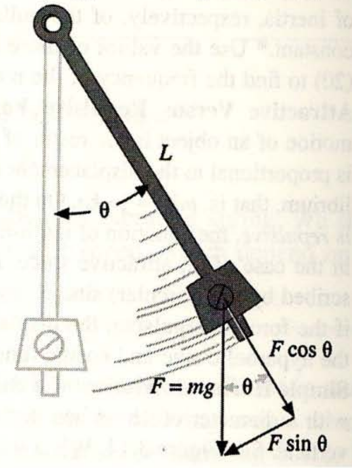
A Simple Pendulum

16. A Pendulum Experiment A rod of length L is suspended from the ceiling so that it can swing freely. A weight (the bob) is attached to the lower end of the rod, where the weight of the rod is assumed to be negligible compared to the weight of the bob. Let θ (radians) be the angular displacement from the vertical (plumb line), as shown in Figure 3.12. It can be shown that the differential equation that describes the motion of the pendulum is the **pendulum equation**

$$\ddot{\theta} + \frac{g}{L}\sin\theta = 0 \qquad (19)$$

Determine the natural period for a pendulum of length L for small oscillations by approximating $\sin\theta \doteq \theta$.

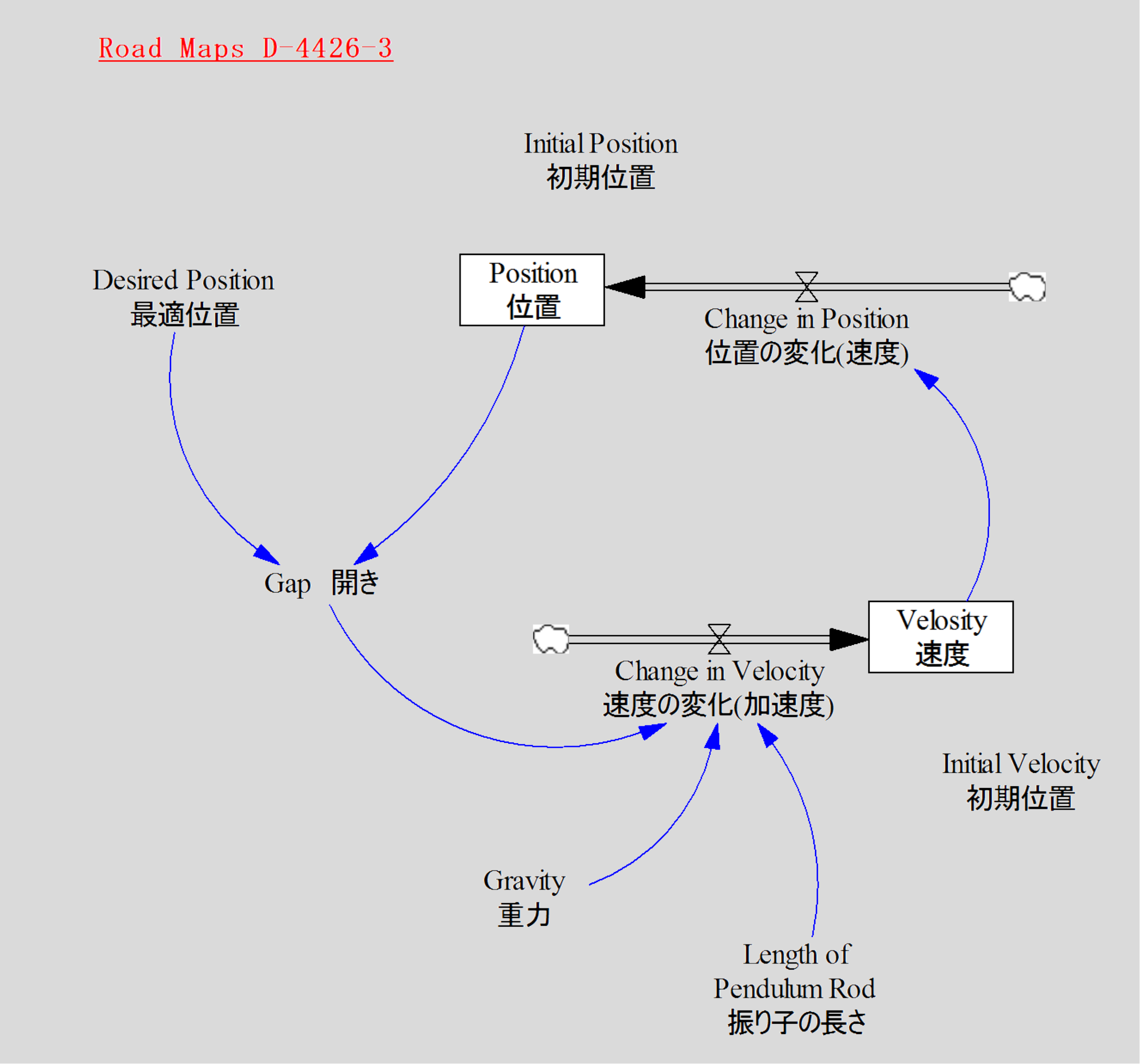
Figure 3.12
A simple pendulum



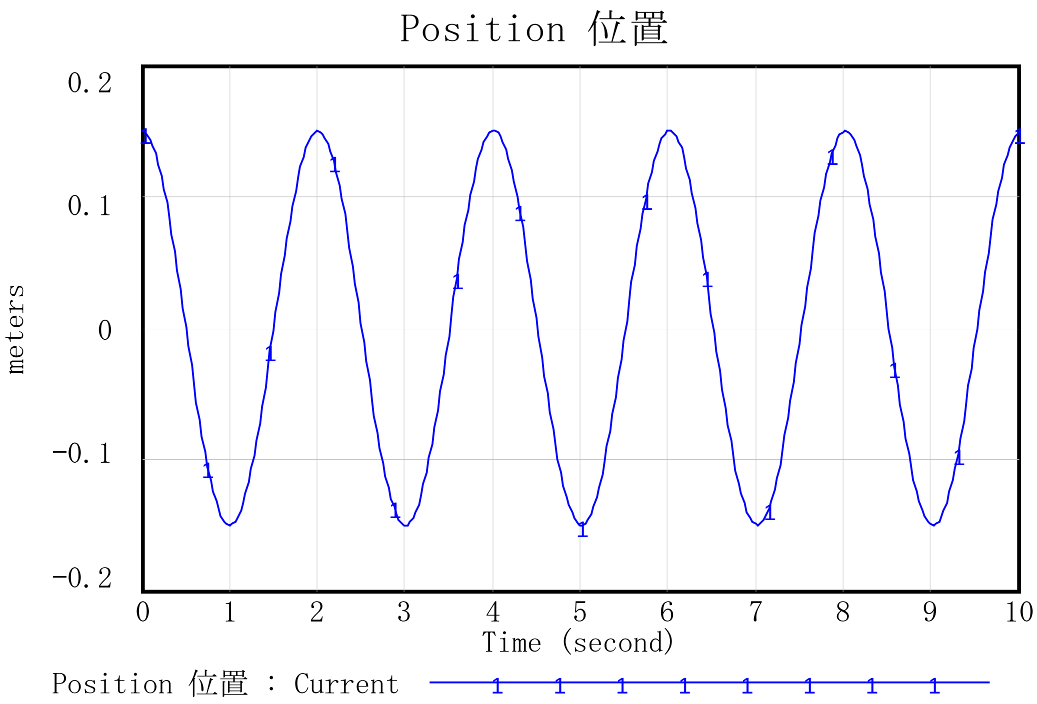
An Introduction to Differential Equations and their Applications

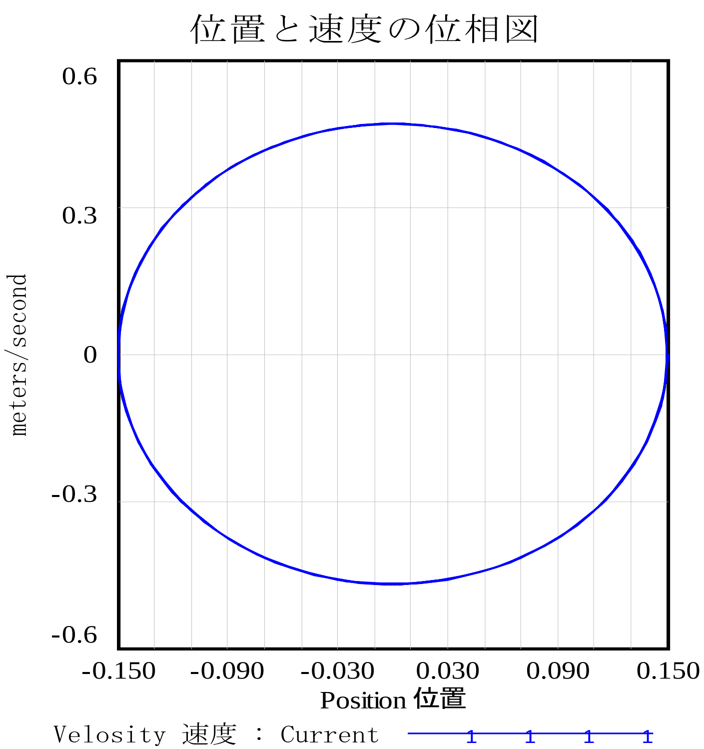
By Stanley J. Farlow
Dover Publications, Inc.,
New York, 1994, p.171

A Simple Pendulum

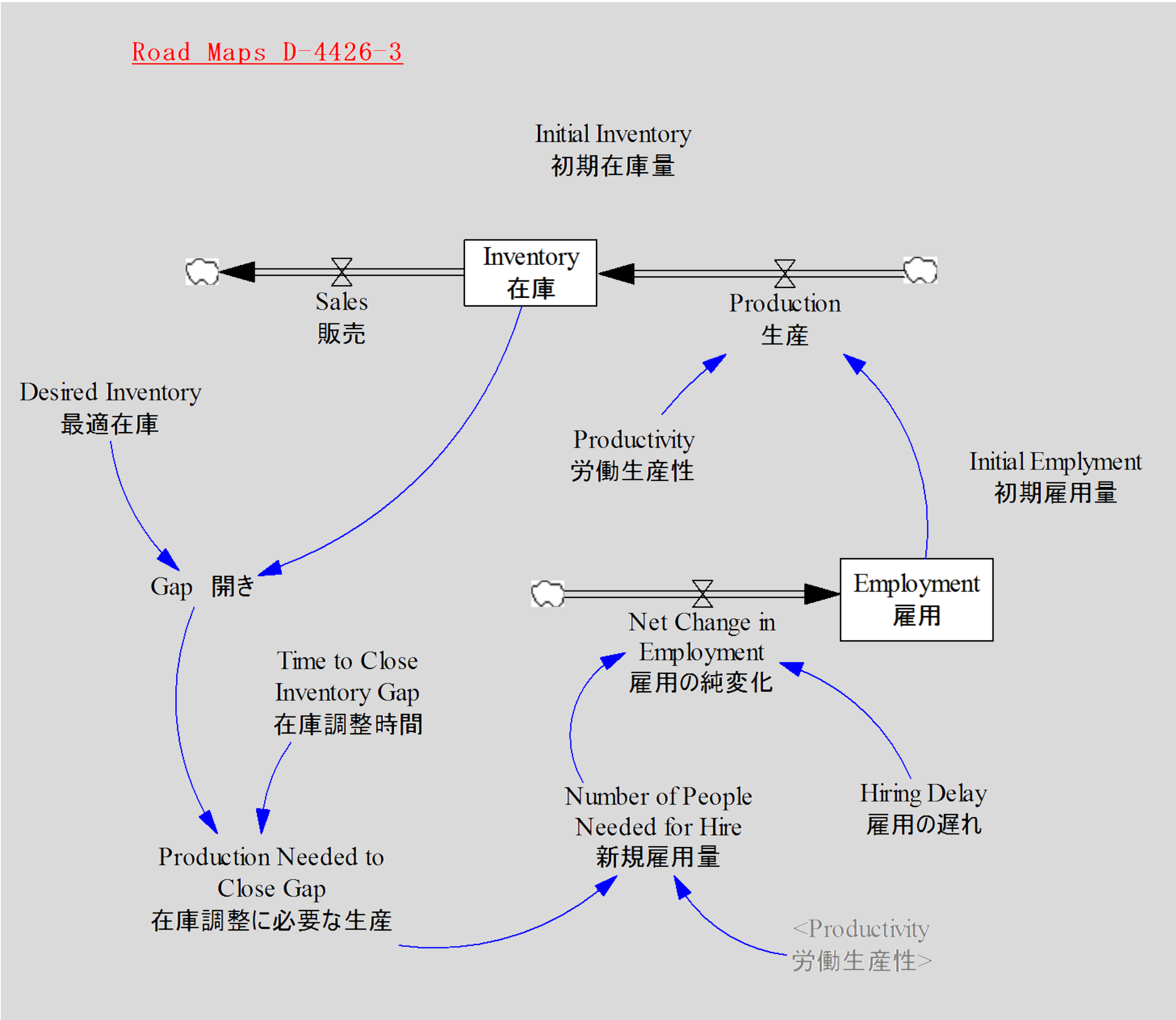


Oscillation Model (Figure)

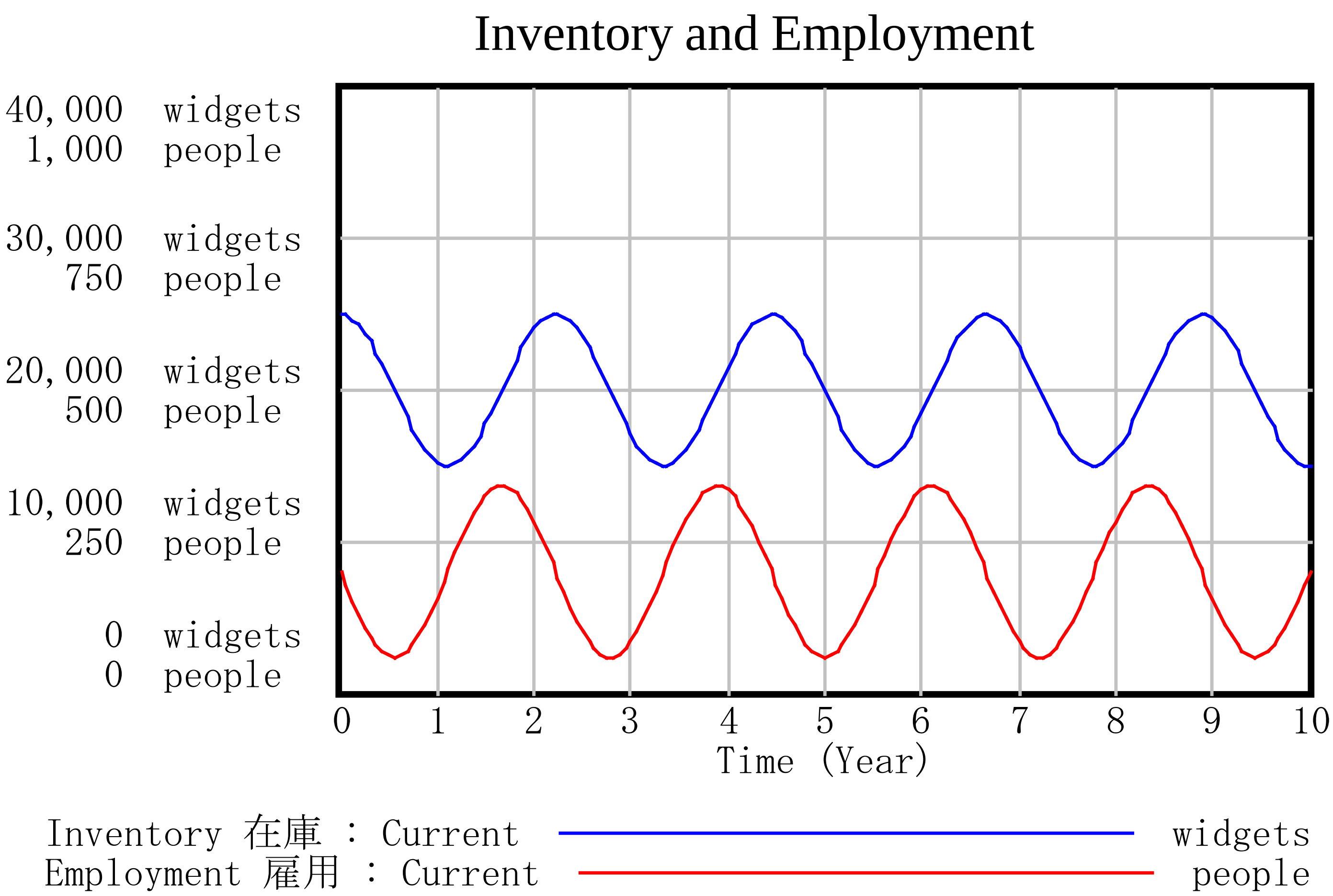




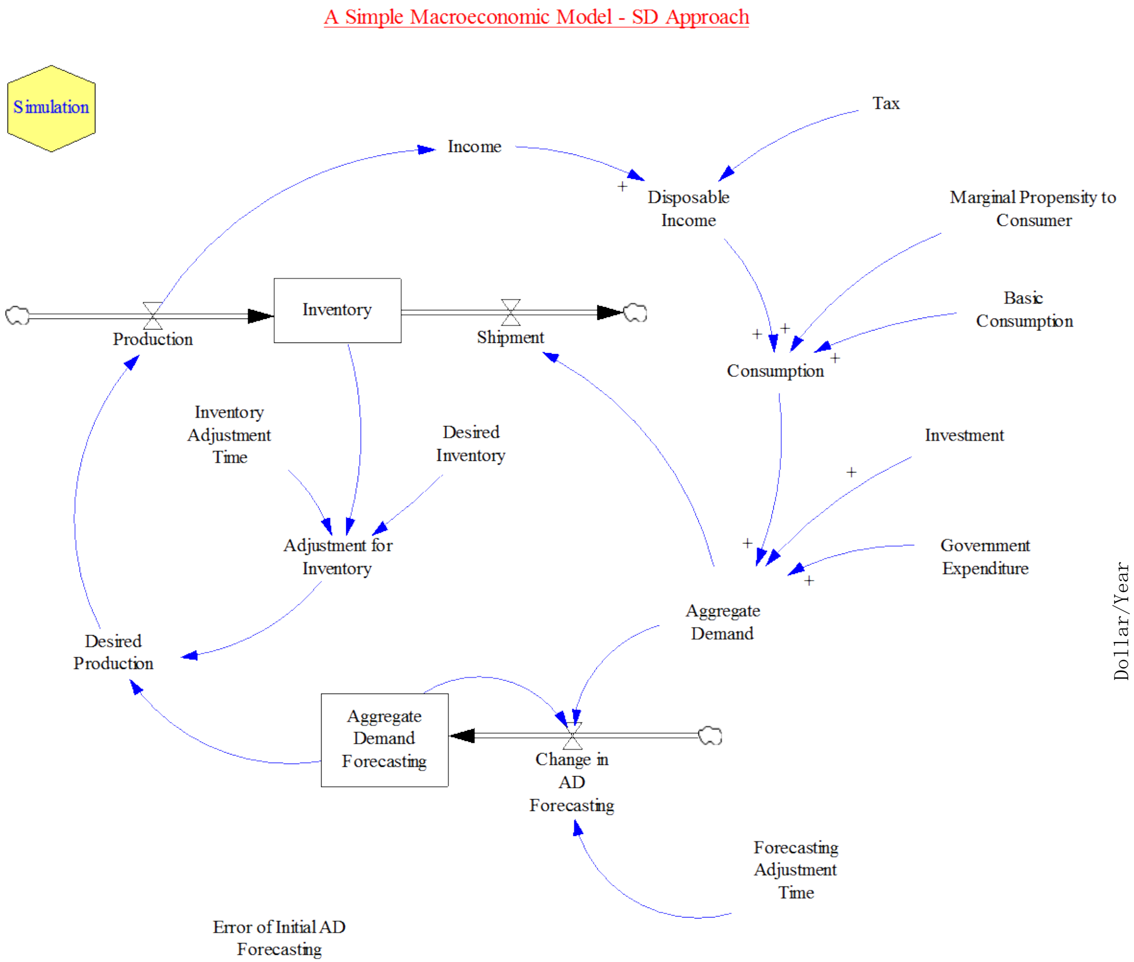
Employment Instability Model

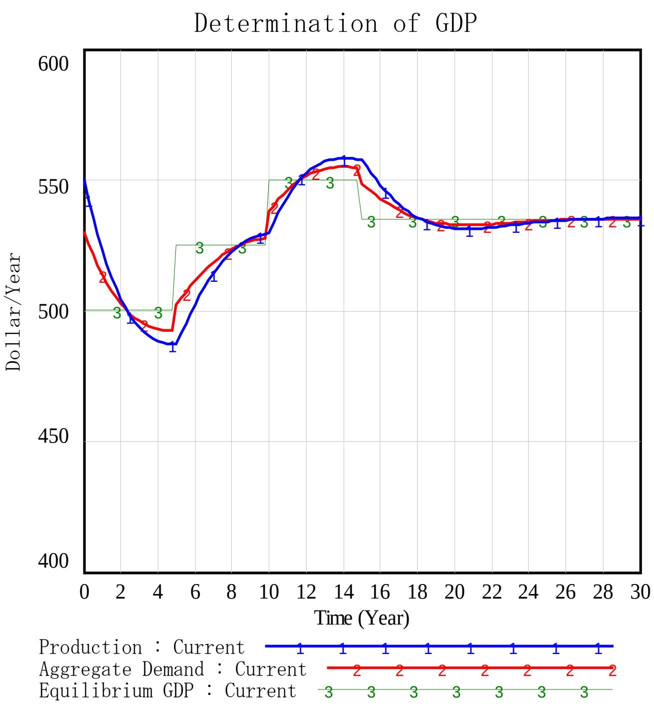


Employment Instability Model (Figure)

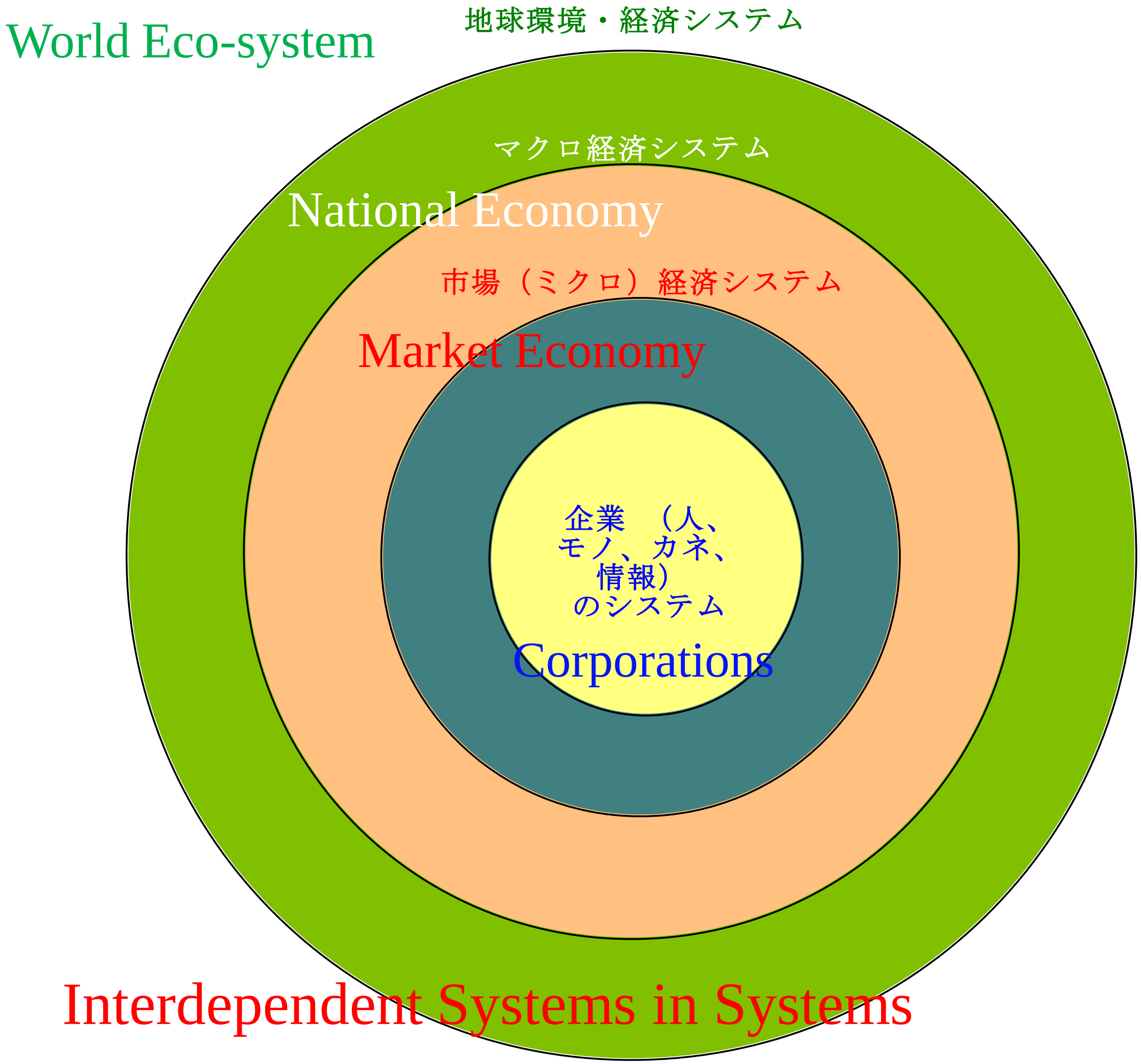


An Example of System Dynamics Model

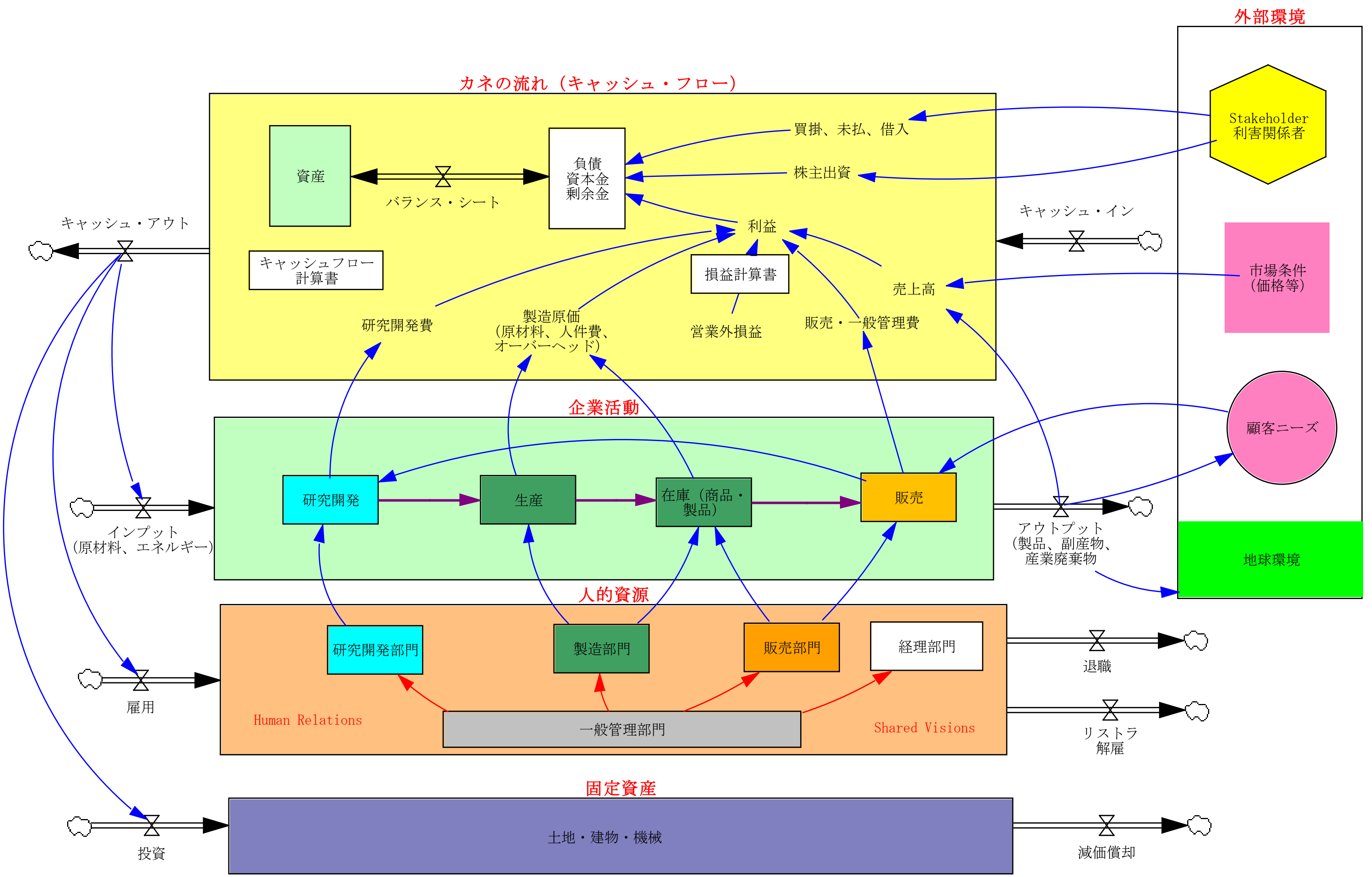




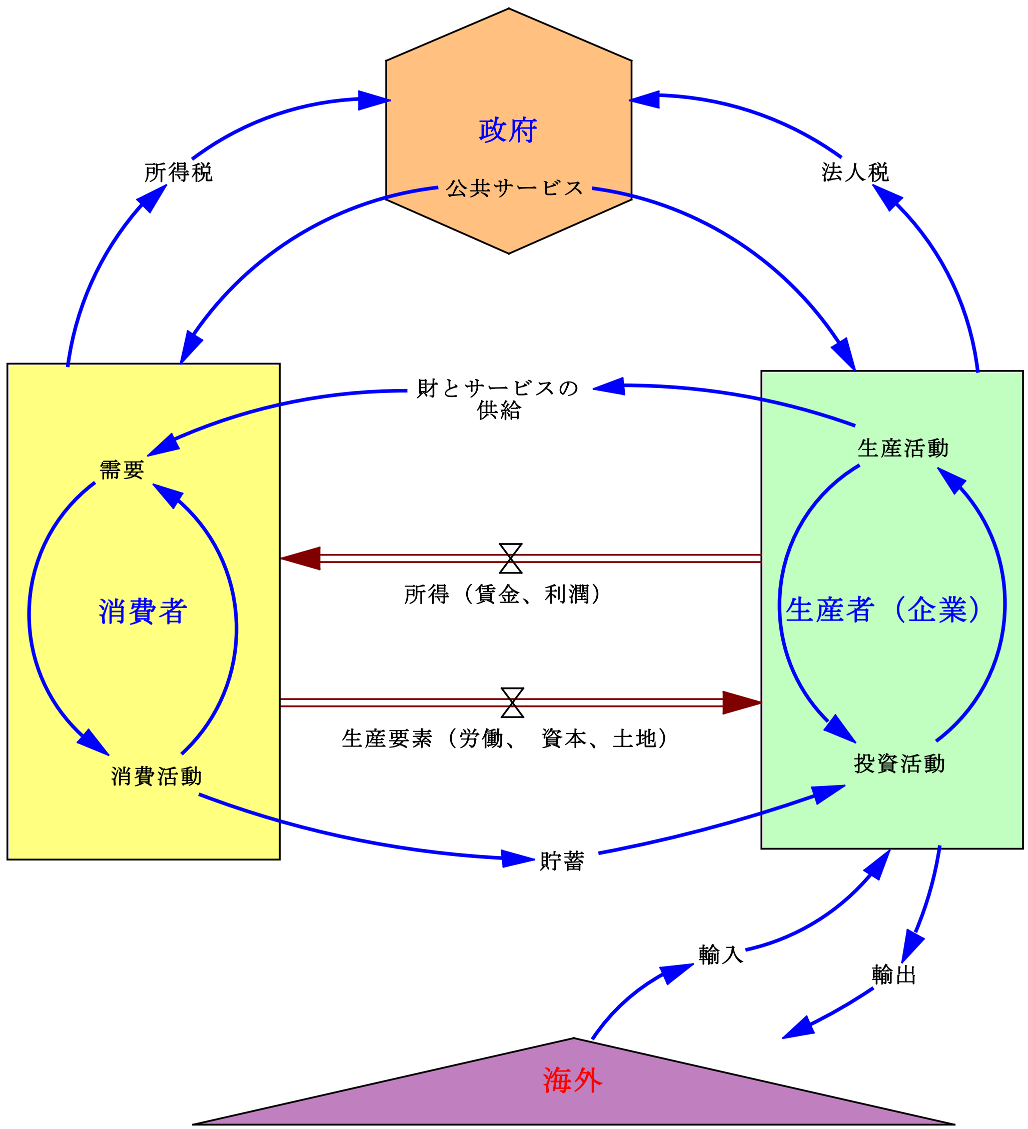
Complex & Overlapping Systems)



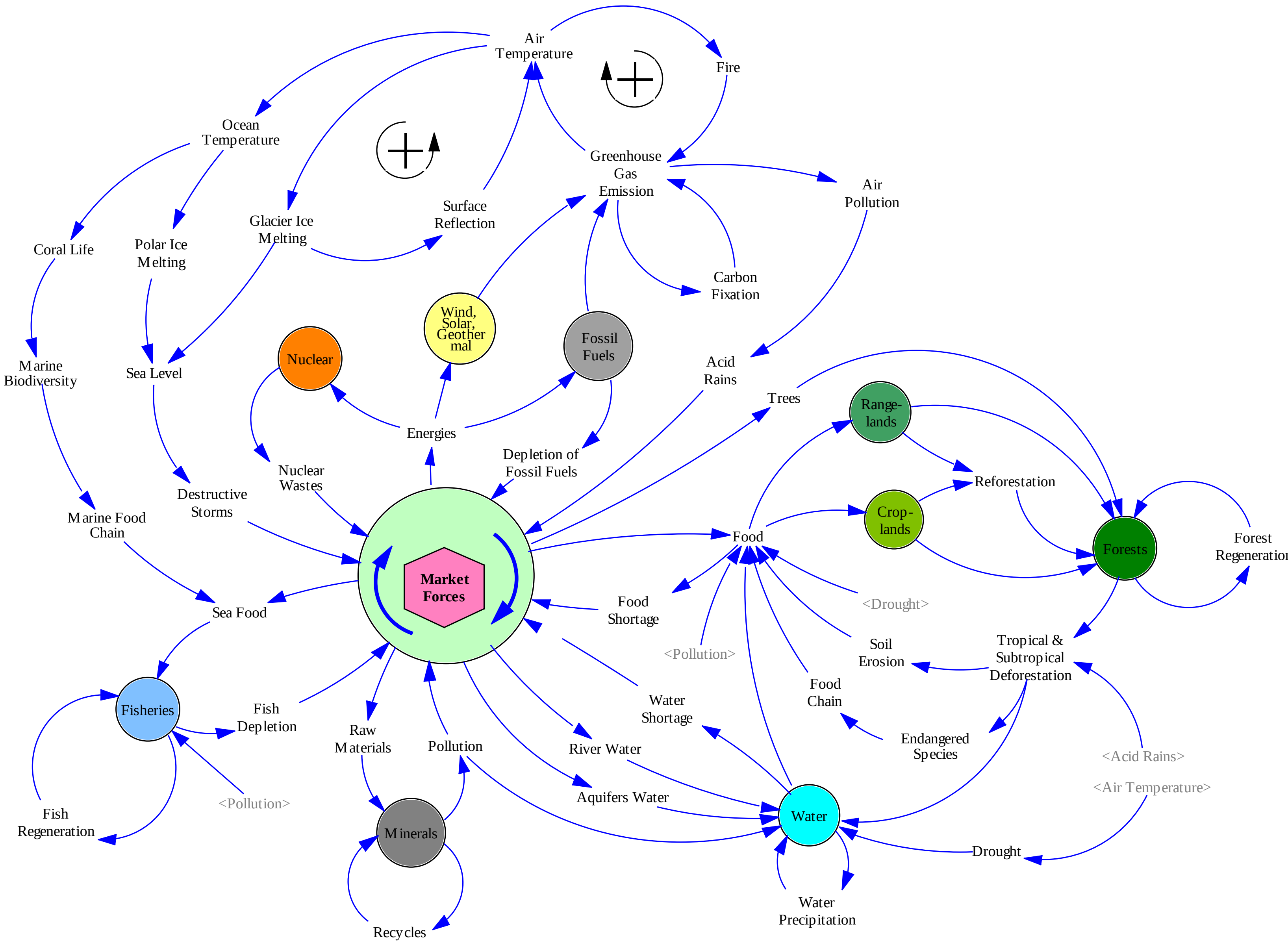
Corporate System (People, Materials, Cash, Information)



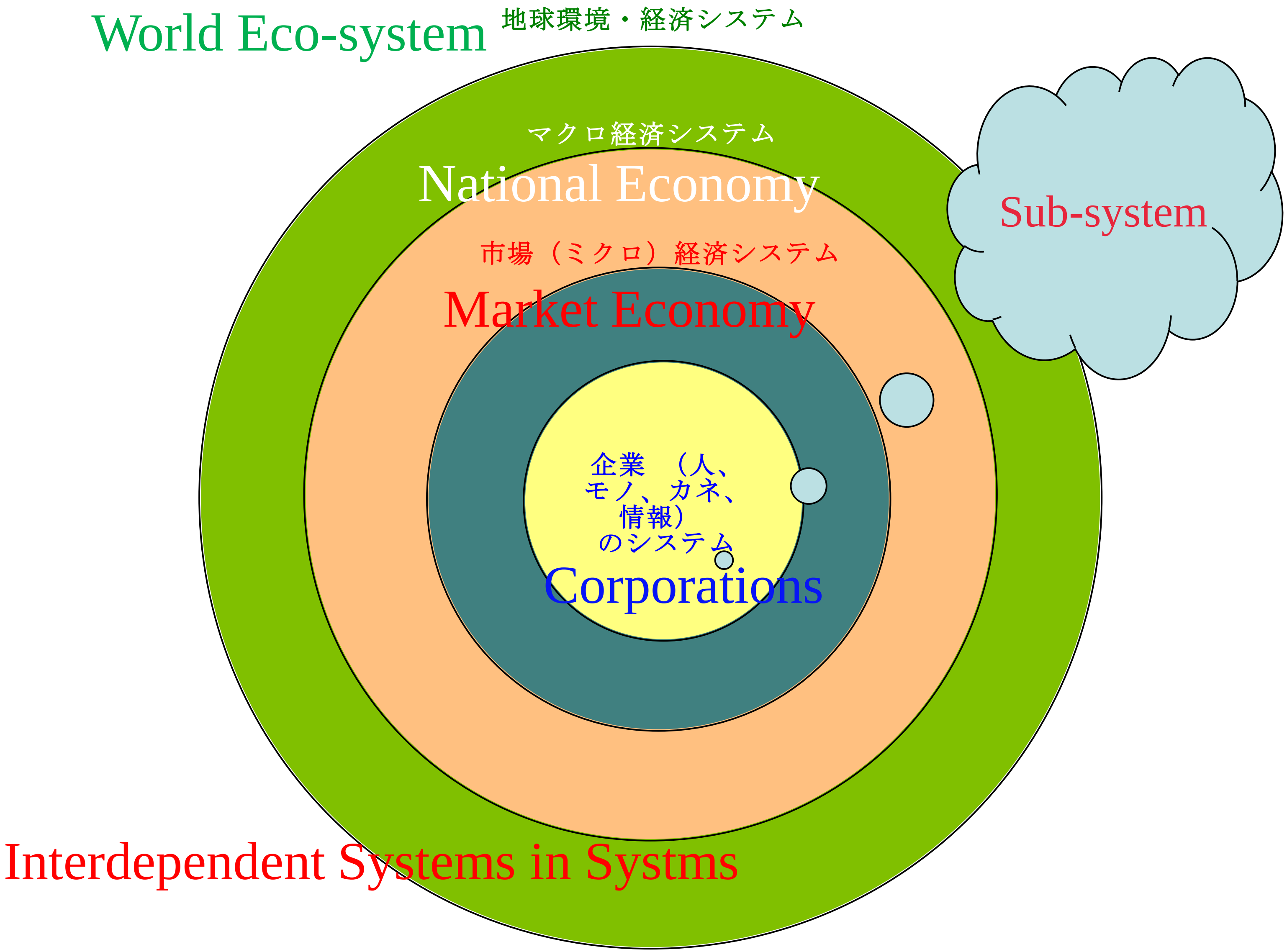
Macroeconomic System



Global Environment & Eco-Economy System

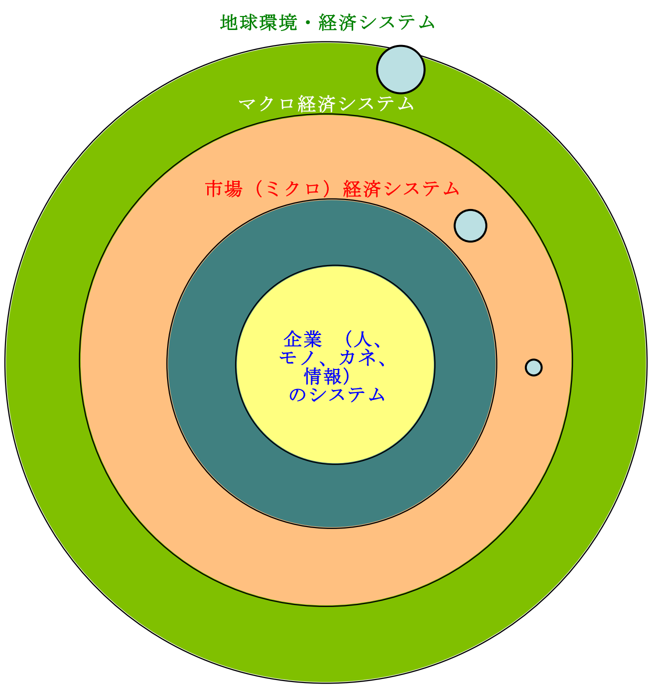


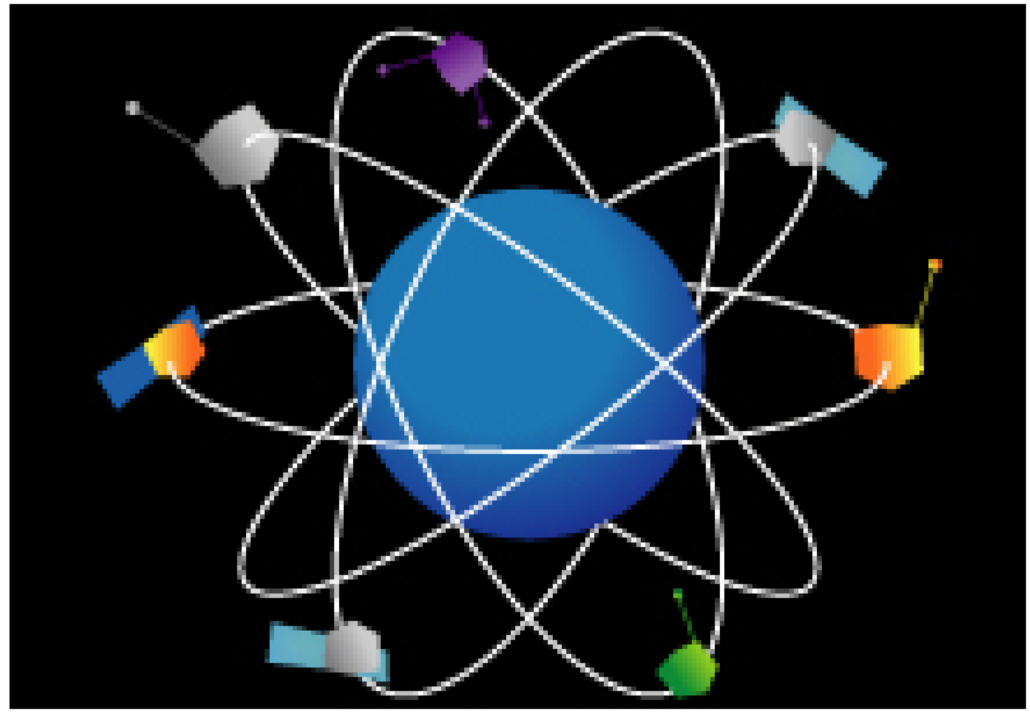
Which System to Think and Manage？



Which System to Think and Manage?

Nano-Satellite
Sub-system





Problem-Solving on Earth
Using S D
with Feedback Info from Space