

On the Foundations of Systems Thinking and System Dynamics – Deep Down, What Are We Really Doing?

George P. Richardson
Rockefeller College of Public Affairs and Policy
University at Albany



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University at Albany

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Motivation

- Feedback loops
- Stocks and flows
- BOTGs
- Connection circles
- System archetypes
- Learner-directed learning
- STELLA, Vensim
- Computer simulation
- Nonlinearity, loop dominance
- Etc., etc.
- **What is really deeply important about systems thinking in K-12 education?**
- **...in corporate decision making and policy design?**
- **...in public policy and governance?**



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The Claim:

The deep foundation is the
Endogenous Point of View



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Forrester's Stated Foundations: The four threads (1958)

- Advances in **computing technology**
- Growing experience with **computer simulation**
- Improved understanding of **strategic decision making**
- Developments in the understanding of **the role of feedback** in complex systems
- But it took ten more years before Forrester published the deep foundation of the system dynamics approach



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Forrester's Four-Tiered Hierarchy

Urban Dynamics, Market Growth as Influenced by Capital Investment

- **Closed boundary** around the system
- **Feedback loops** as the basic structural elements within the boundary
- **Level (stock) variables** representing accumulations within the feedback loops
- **Rate (flow) variables** representing activity within the feedback loops
 - Goal, Observed condition, Detection of discrepancy, Action based on discrepancy



Forrester's Four-Tiered Hierarchy

- “**Closed boundary** around the system”!
- The “Closed boundary” signifies Forrester’s *Endogenous Point of View*.
 - It comes *before* feedback loops, stocks and flows, BOTGs, and all the rest of what we do.
 - It has top billing.
 - It is the deep foundation of systems thinking.



An Example



- Exogenous point of view
 - My wife is always mean to me.
 - It's all her fault.
 - If she would be nicer, my life would be better.



- Endogenous point of view
 - Maybe there's something I'm doing ...

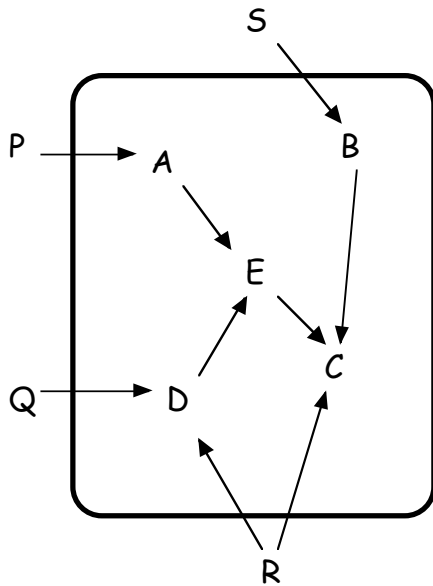


More classic examples

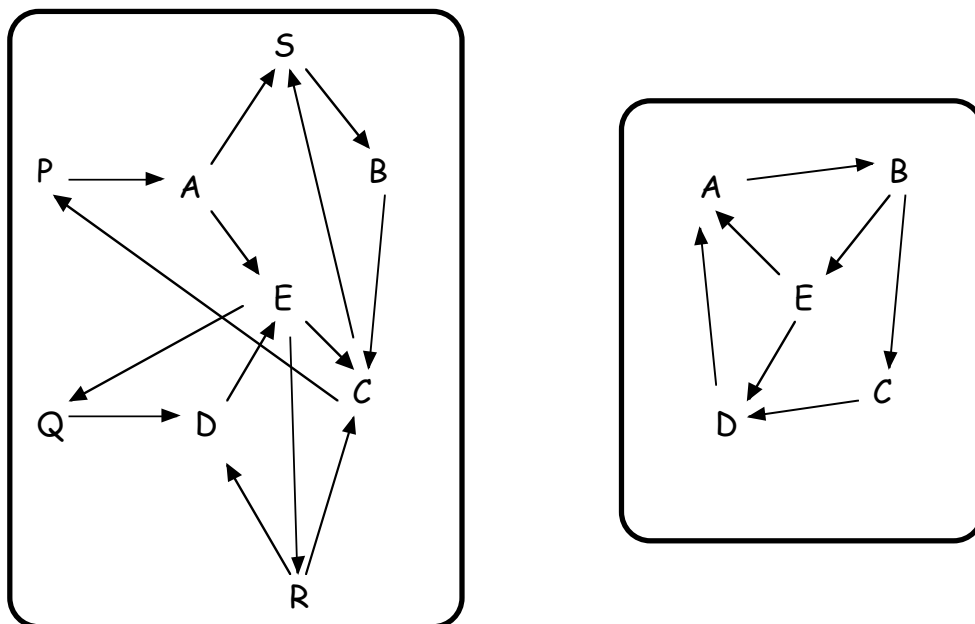
- “The fault, dear Brutus, is not in our stars, but in ourselves ...” [Cassius, in *Julius Caesar*]
- “We have met the enemy and He is Us.” [Pogo]



Feedback Loops are a Consequence of the Endogenous Point of View



Expanding the Boundary to Enable an Endogenous Point of View



Endogeneity and Feedback

“Feedback loops enable the endogenous point of view and give it structure.”

[Richardson 1991]



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A Few Examples

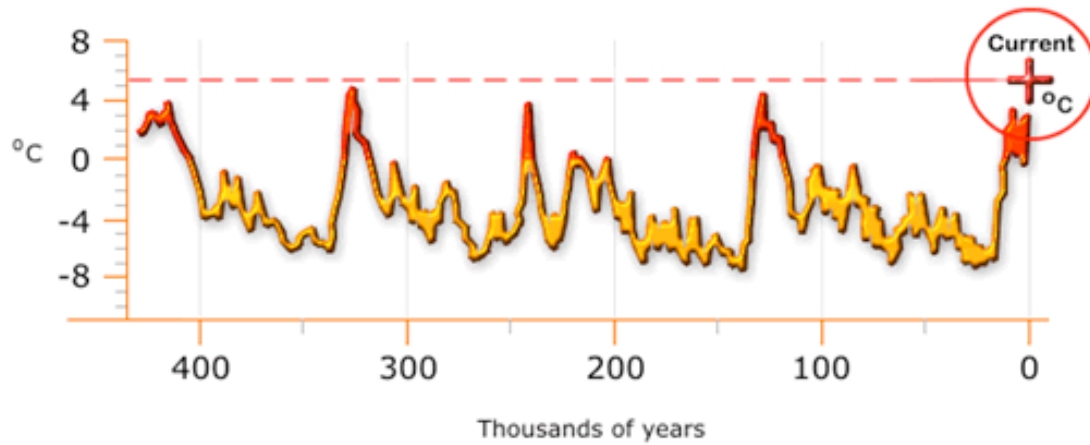
- Global warming debate
- Terrorism
- Flood damage
- Schools



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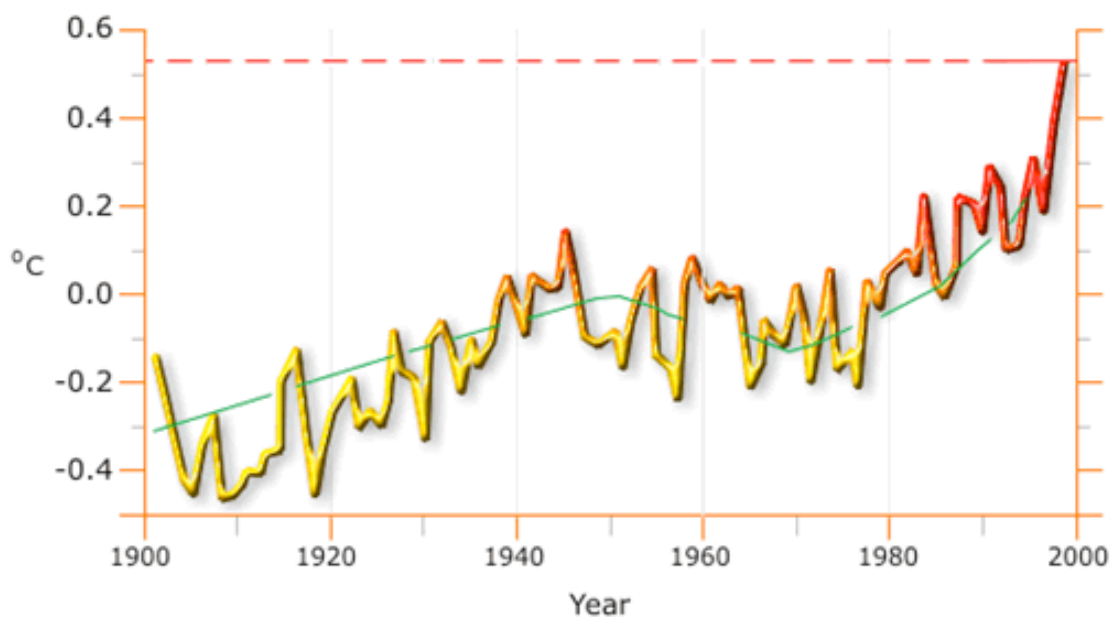
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400,000 Years of Temperature Data

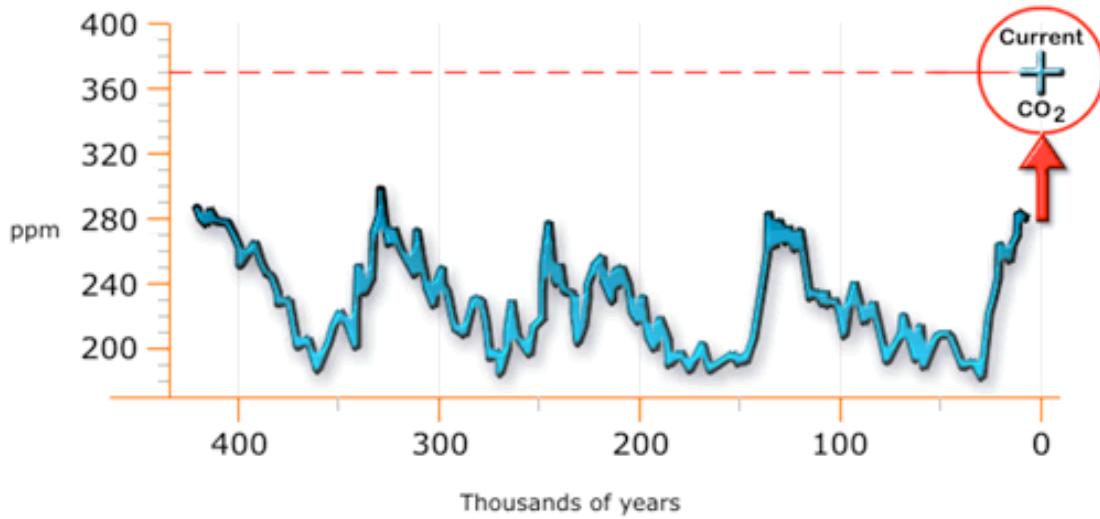


http://www.landcareresearch.co.nz/research/globalchange/climate_change.asp

100 Years of Temperature Data

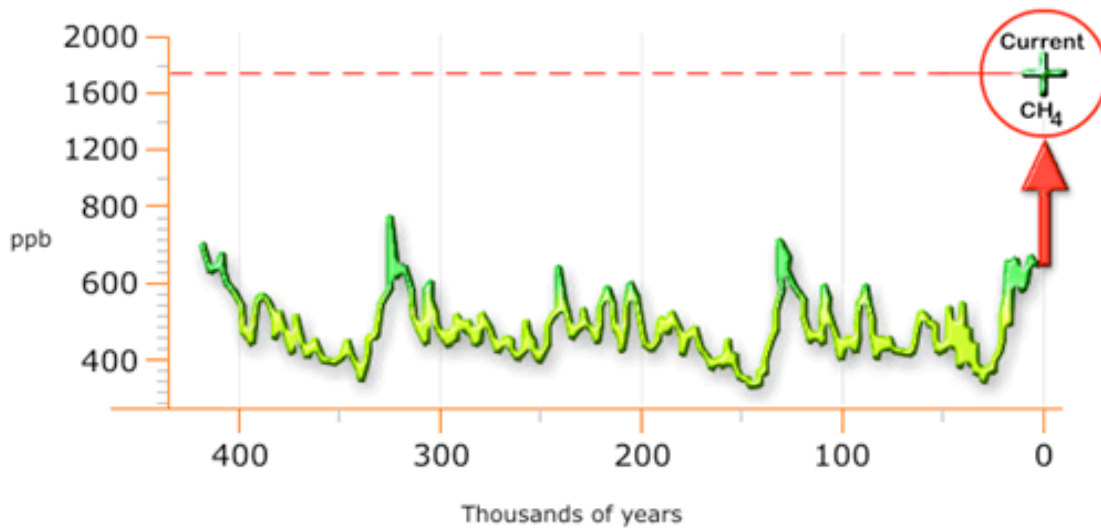


CO2 Concentration



http://www.landcareresearch.co.nz/research/globalchange/climate_change.asp

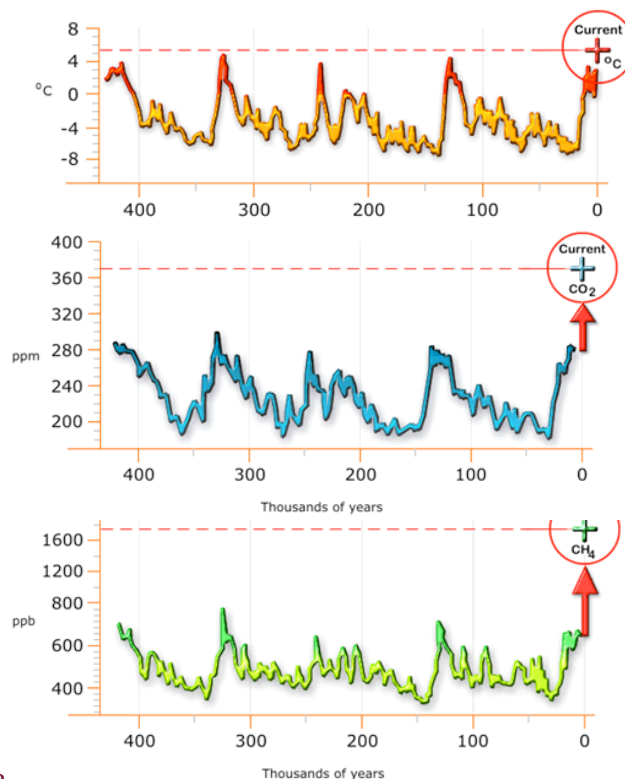
Methane



http://www.landcareresearch.co.nz/research/globalchange/climate_change.asp

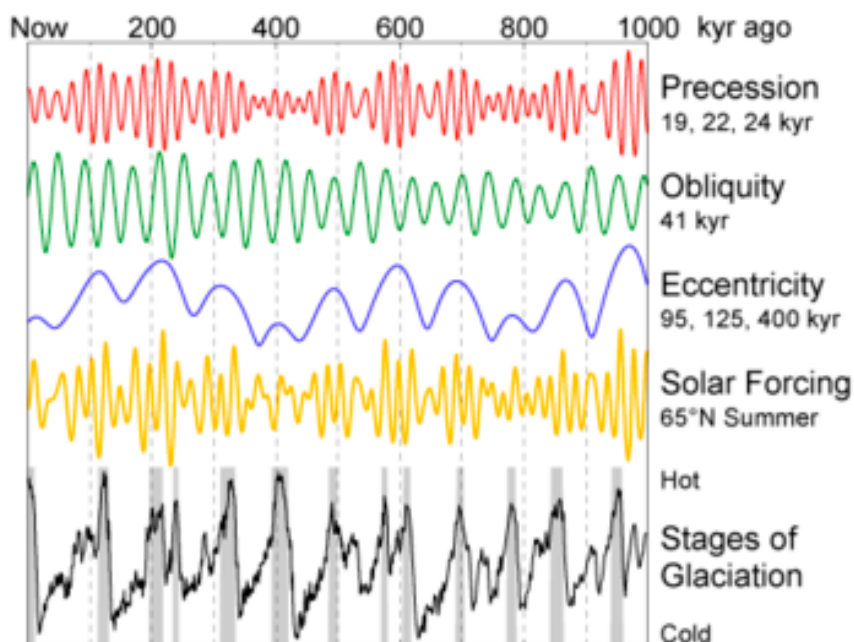
Yes, the peaks line up.

But if it's been going on for 400,000 years, why do we now think humans are to blame?



Milankovitch Cycles (1,000,000 yrs)

There are strong exogenous, structural effects on climate change.



[Source: http://en.wikipedia.org/wiki/Milankovitch_cycles]

The Global Warming Debate

- *Exogenous view:* We are in the warm phase of a 100,000 year cycle caused by exogenous, structural characteristics
 - Policy implication: Adapt to the inevitable
- *Endogenous view:* Human activity is exacerbating the natural cycle
 - Policy implication: Alter human habits to minimize the coming tragedies



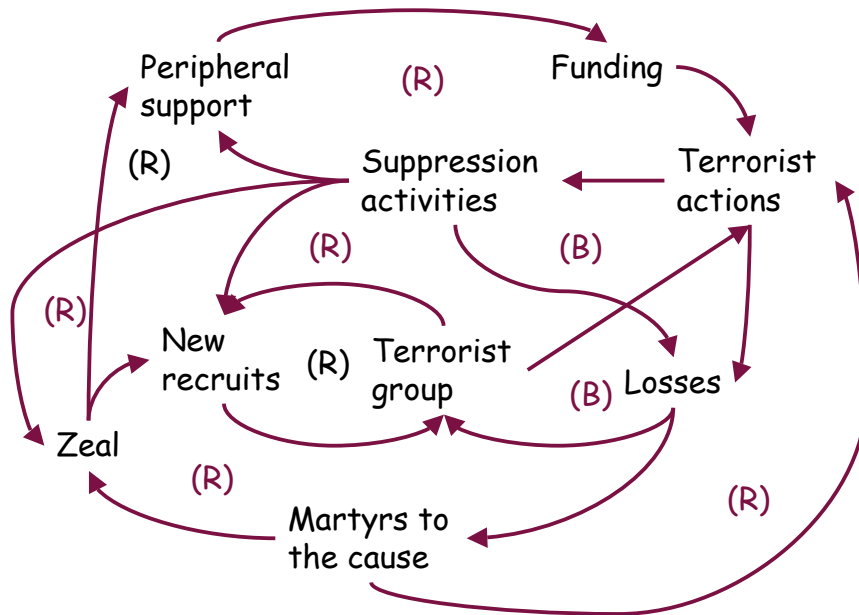
Terrorism

- News of Aden Hashi Ayro's death comes on the heels of a US global survey that concluded **Al Qaeda has been rebuilding its networks from havens in Pakistan, where the number of attacks more than doubled in 2007.**
- Released Wednesday, the State Department's annual terrorism report **attributed 22,685 fatalities to "incidents of terrorism worldwide"** last year, an increase of 8 percent over the previous year, while noting that nearly two-thirds of those lost their lives in Iraq.
- Al Qaeda and like-minded militants remain **"the greatest terrorist threat to the United States and its partners,"** the report said, despite a nearly seven-year war targeting the group.

(Source: Christian Science Monitor, 2 May 2008)



Endogenous View of Structure and Dynamics of Terrorist Cells

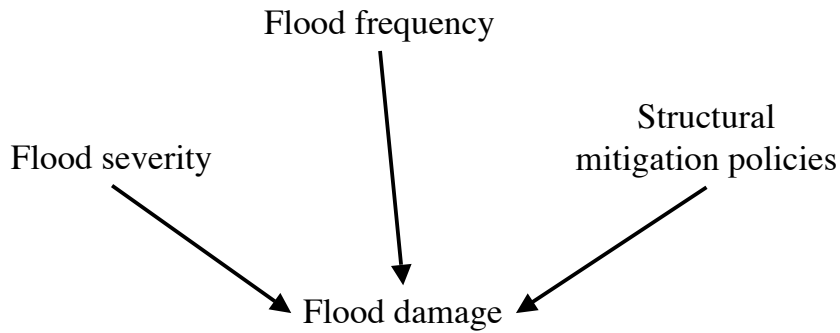


Terrorism

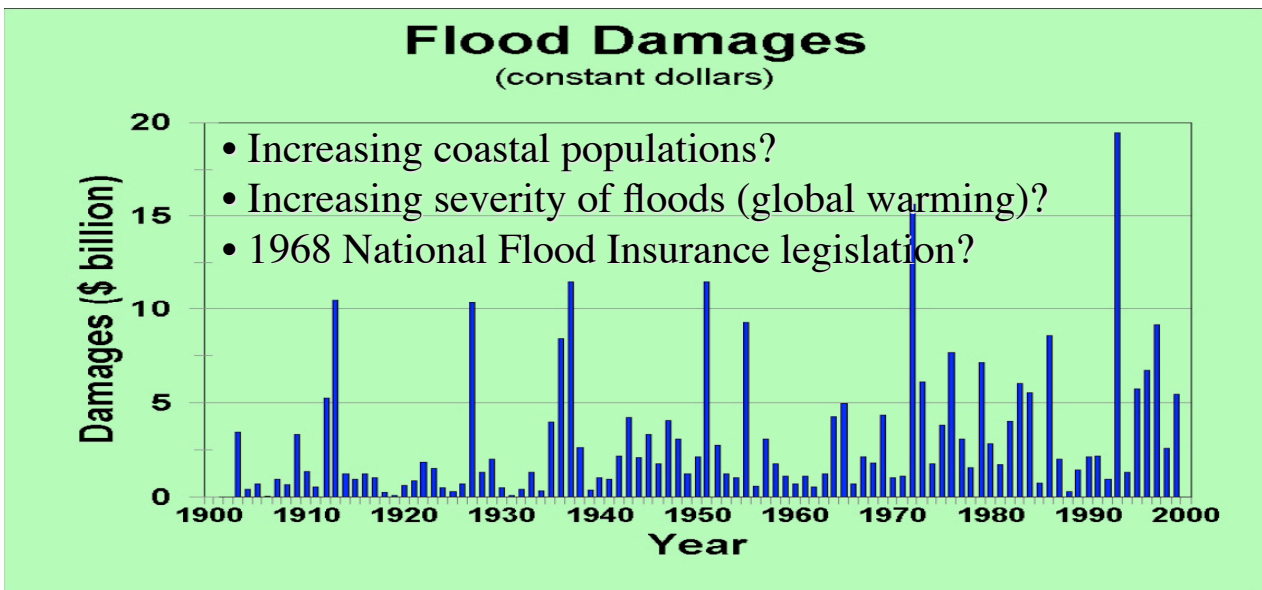
- *Exogenous view*: Violent forces exist that threaten others, and they are growing.
 - Policy implication: Defend to prevent harm; attack to weaken or eliminate the violent forces.
- *Endogenous view*: Violent forces interact with defenses and attacks to create the rising tensions we observe.
 - Policy implication: Defend to prevent harm; minimize behaviors that create nasty reinforcing loops; maximize creation of beneficial reinforcing loops; work toward cross-cultural understandings.



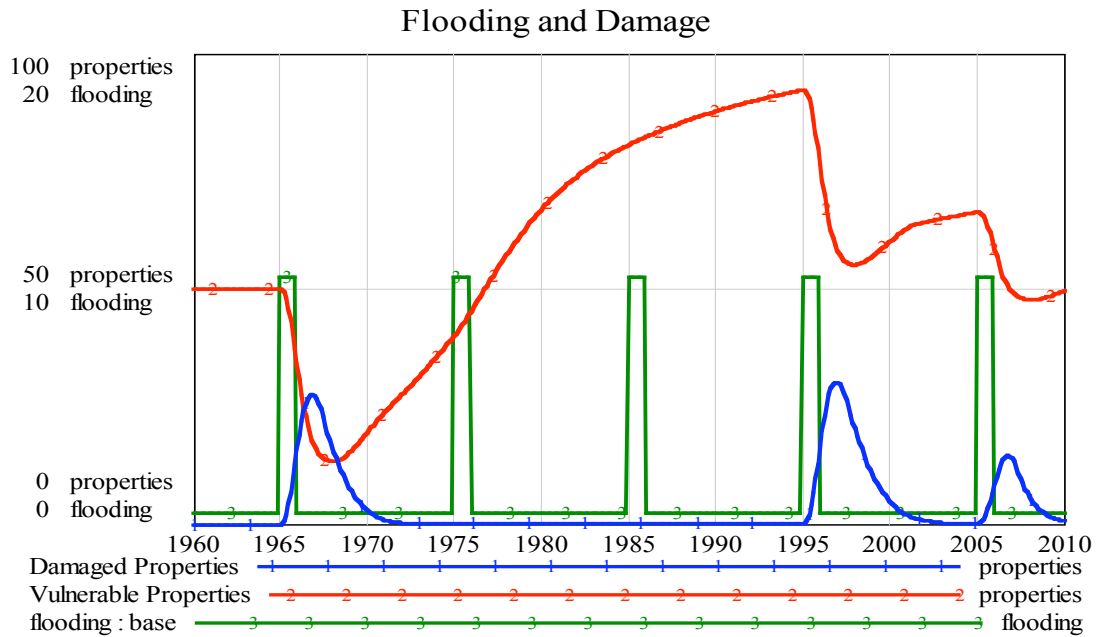
An Exogenous View of Flood Damage



Flood Damages (Deegan 2007, NOAA)

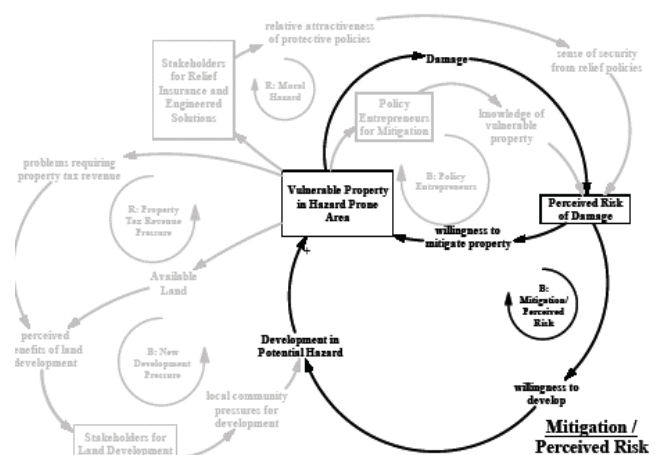
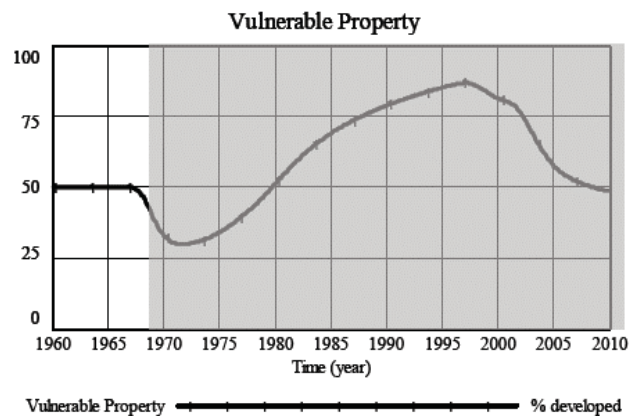


A Model of Floods in which Identical Floods Do Not Cause Identical Damage



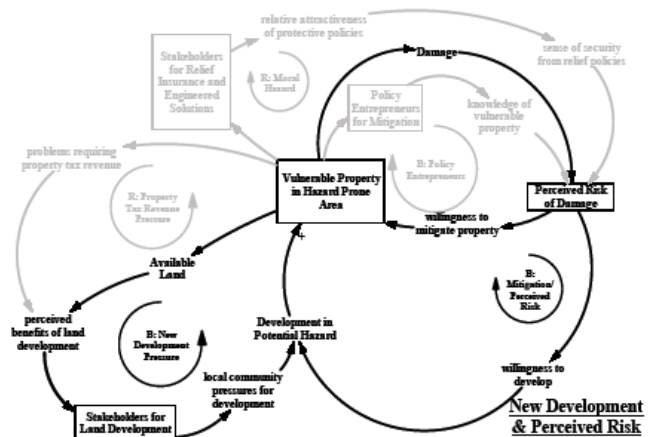
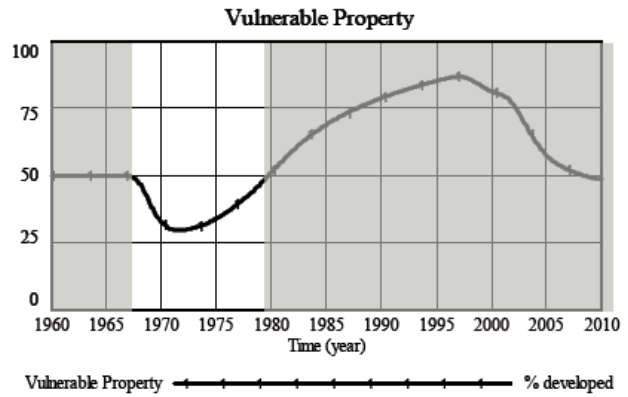
An Endogenous View of Floods

- Hazard meets vulnerability



An Endogenous View of Floods

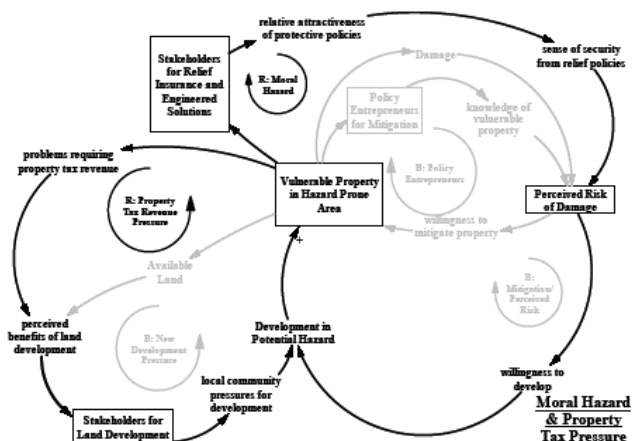
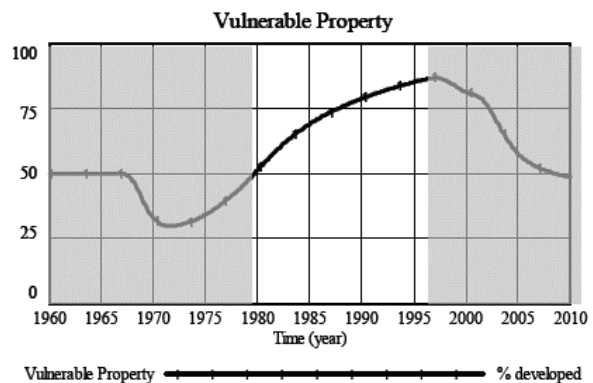
- Hazard meets vulnerability
- Recovery with development pressure



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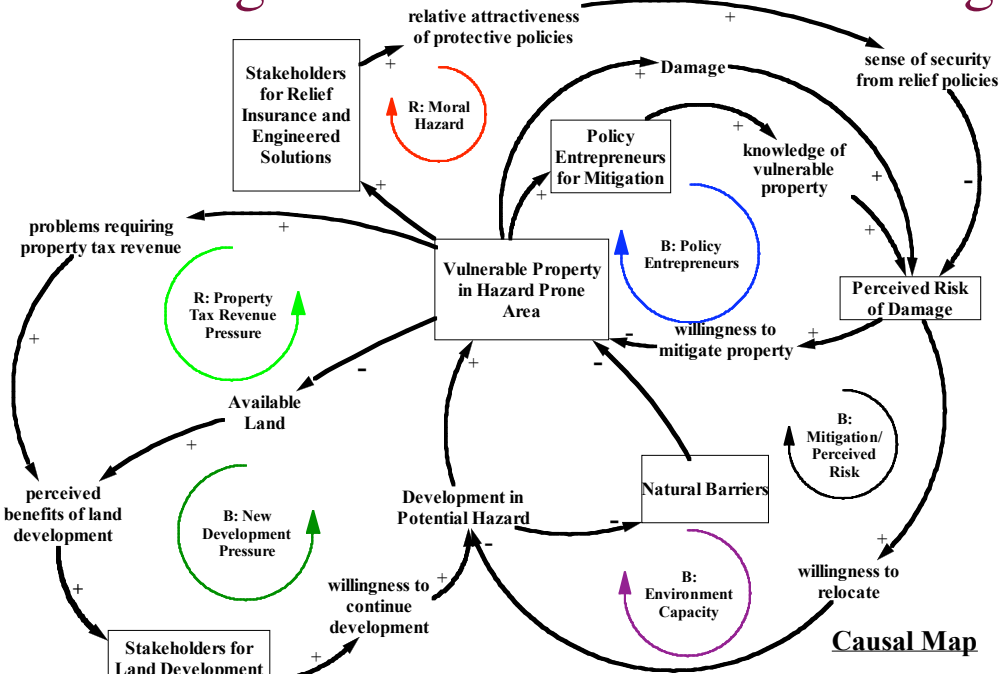
An Endogenous View of Floods

- Hazard meets vulnerability
- Recovery with development pressure
- Moral hazard and property tax pressures



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An Endogenous View of Flood Damage



Flood Damage

- *Exogenous view*: Floods happen sometimes; the greater the flood, the worse the damage.
 - Policy implication: When floods happen to occur, recover and rebuild.
- *Endogenous view*: Damage occurs when hazard meets vulnerability; vulnerability is a result of people policies
 - Policy implication: Recognize human role in damage. Work with stakeholders to minimize vulnerabilities.

Schools

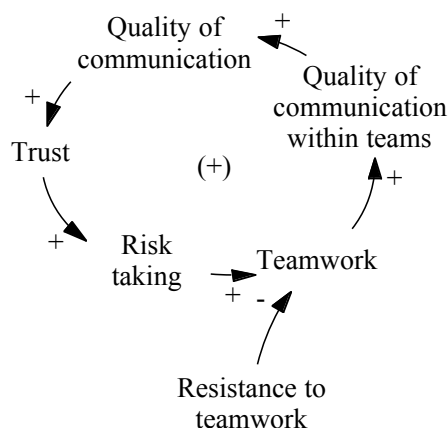
Exogenous view*

“The following proposed amendment will conform the Commissioner’s Regulations with New York State's approved accountability workbook pursuant to the No Child Left Behind Act of 2001 (NCLB), Public Law 107-110, particularly in terms of revising the school and school district accountability plan to incorporate the results from New York’s new grades 3-8 testing program in English language arts and mathematics.”

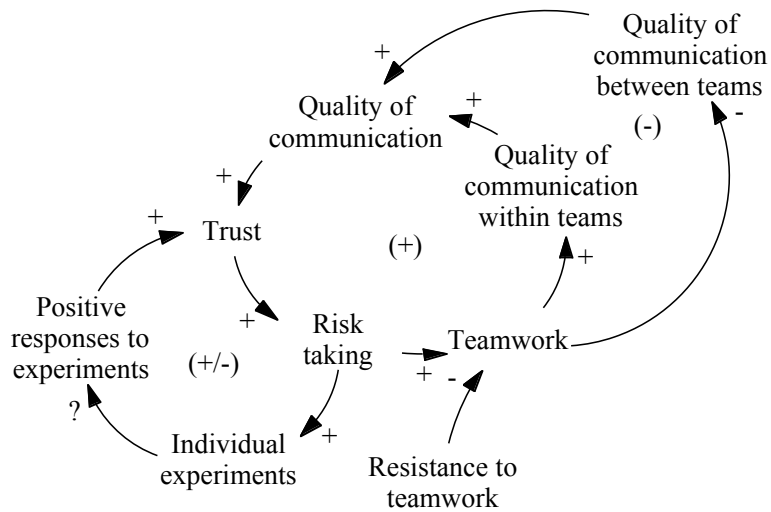
*NYS Information and Reporting Services, Statement on Accountability
<<http://www.emsc.nysed.gov/irts/accountability/home.shtml>>



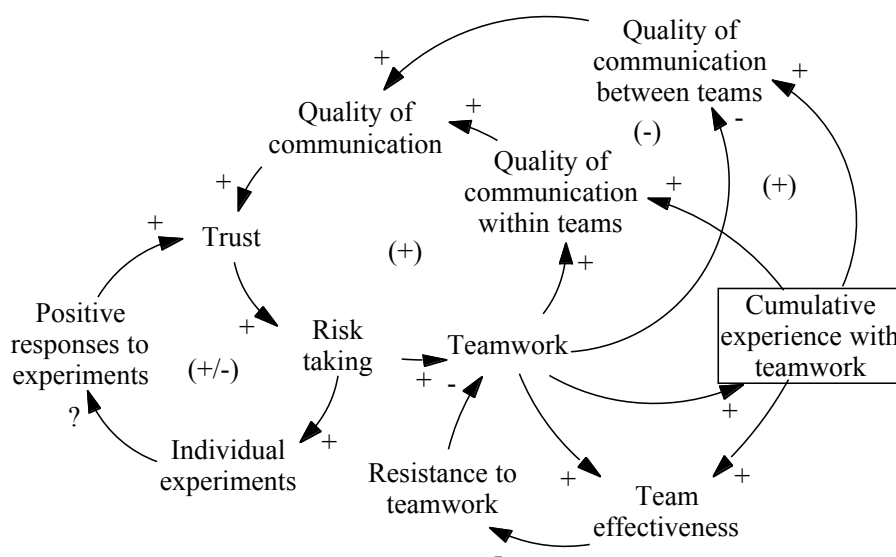
Endogenous View Example: Insights about building teamwork in a public school



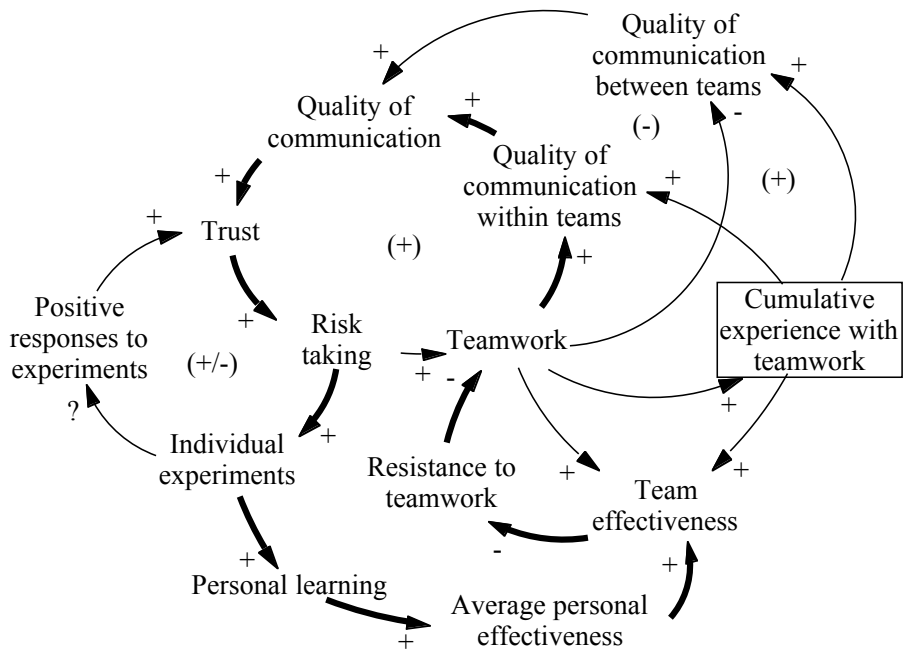
Isolation of teams and punishing risk-taking inhibit the growth of trust



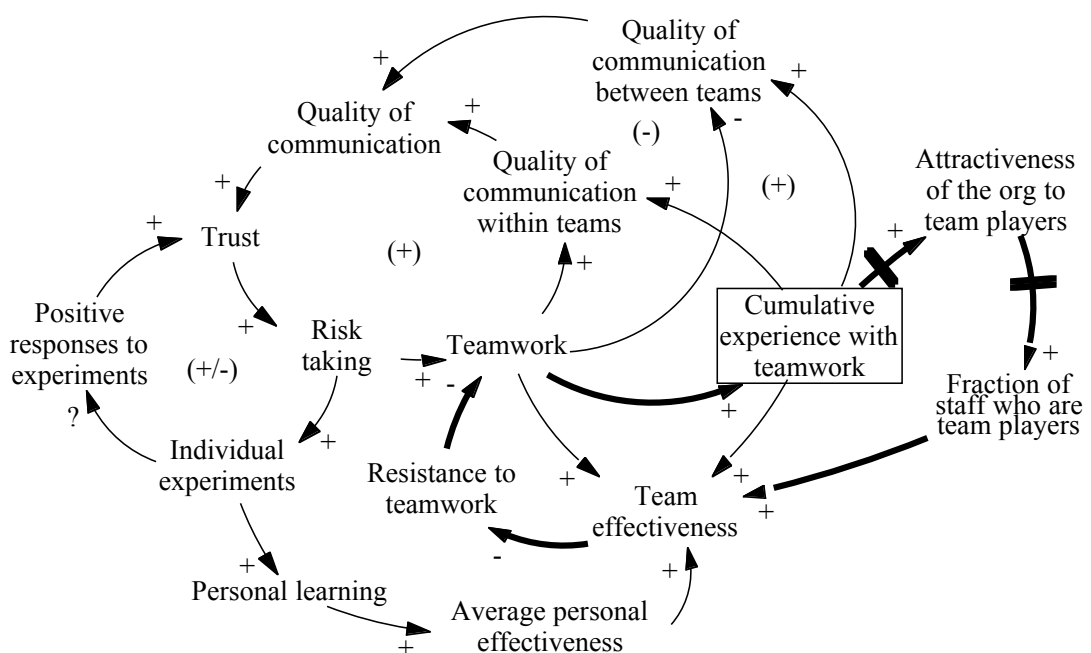
But longterm experience with teamwork can build communication



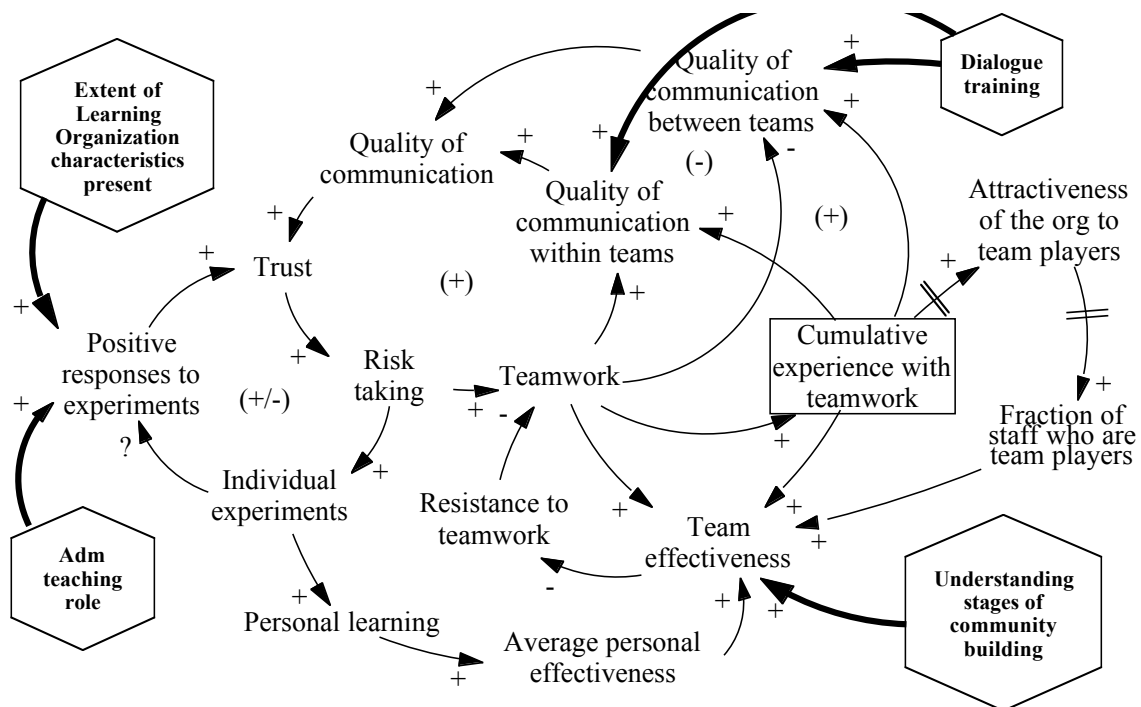
Risk taking can enhance effectiveness, which can build trust



A team-player culture is self-reinforcing: an opportunity or a trap



Likely leverage points



Schools (you know more than I)

- *Exogenous view*: We're at the mercy of external forces.
 - Policy implication: Duck and cover as best you can.
- *Endogenous view*: External forces create the scenarios within which we are empowered to create.
 - Policy implication: Much of what happens in classrooms is the result of interacting forces internal to the school; maximize their beneficial directions and effects no matter what the constraints.

Governing

- The great insight of servomechanisms engineering: *The act of trying to govern / manage / control generates system dynamics of its own.*
- “A closed-loop control system is thus an error-sensitive system and, being such, it acquires certain peculiarities and idiosyncrasies which, in large measure, are the reasons for this book” (Gordon Brown, 1948).



A search for terms

- “Exogenous / Endogenous”
 - Works for me!
- “External / Internal” or “Outward / Inward”
 - Simpler, but omit “generated”
- “Outy / Inny”
 - For navel gazers
- “Caused by Others / Caused by Us” [They-Them / We-Us]
 - “Caused by You / Caused by Me / Caused by Us”
- “Blaming / Understanding”
 - Probably too accusatory, but often accurate



The “X/N” Matrix

Predominant Mode of Analysis	Endogenous	Striving for understanding and leverage, but failing ☹️☹️	Achieving understanding and leverage 😊😊😊
	Exogenous	Accepting fate, Predicting, Preparing ☹️☹️	Confused, Misguided, Misguiding ☹️☹️☹️
		Exogenous	Endogenous
True (Predominant) State of Affairs			

The Foundation of the Systems Approach

- *Definition:*
“Systems thinking is the mental effort to uncover endogenous sources of system behavior.”
- *Outrageous Hypothesis:*
What we mean by the word “**understanding**” is really **the knowledge of endogenous forces** at work.

The Foundation of System Dynamics

- What do systems thinkers and system dynamicists do?
- We use systems thinking, management insights and computer simulation to

*Hypothesize, test, and refine **endogenous** explanations of system change*

