# Systems Engineering: At the Crossroads of Complexity

Kongsberg Systems Engineering Event

June 10, 2011

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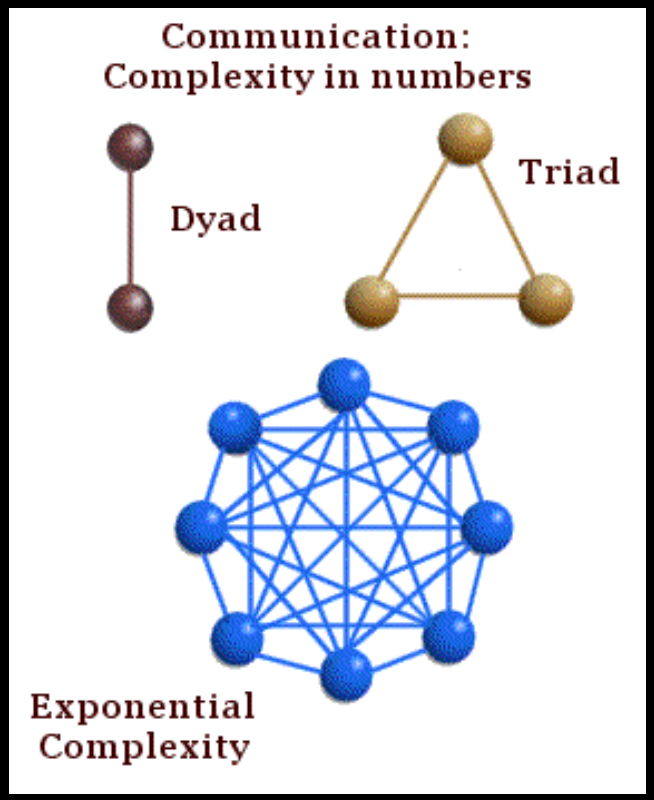
Stevens Institute of Technology

# Objectives




**Provide Context**

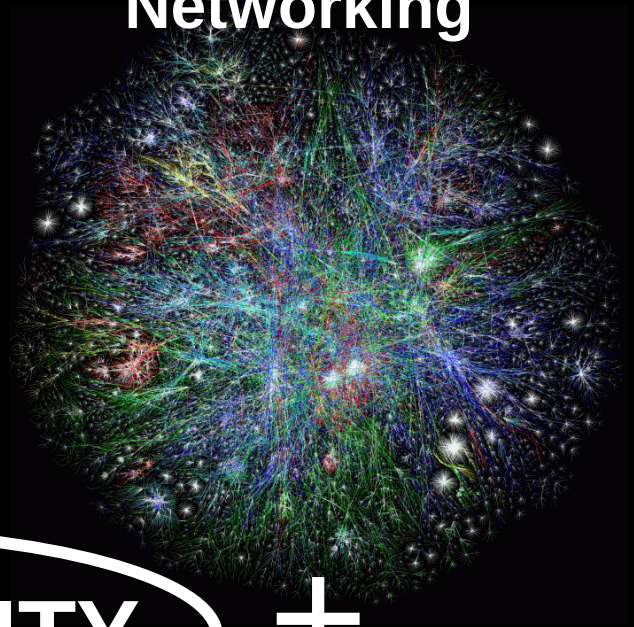
**Provoke Thought**

“I think that the next century (21st) will be the century of complexity”

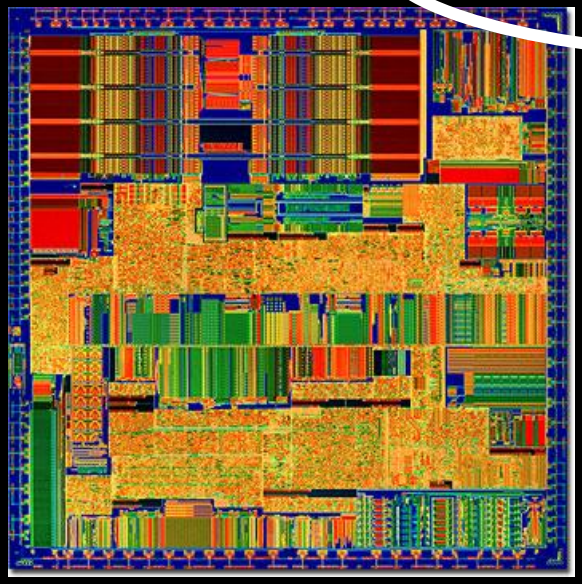
– Stephen Hawking

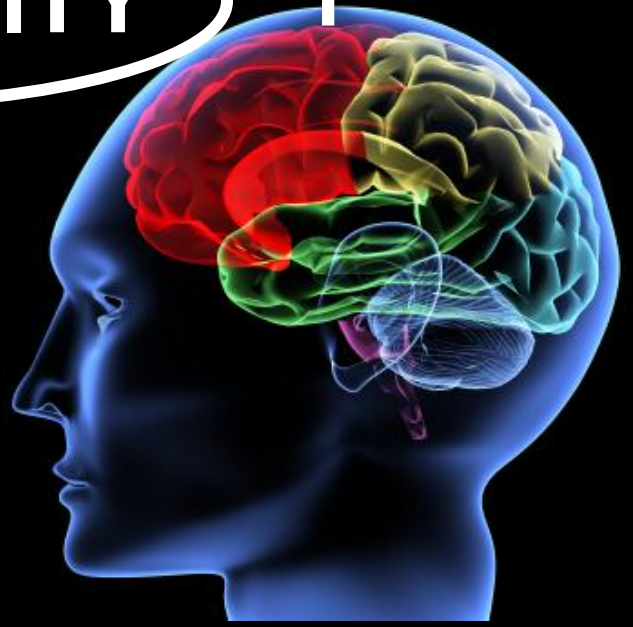
Software

Networking



\+ COMPLEXITY +

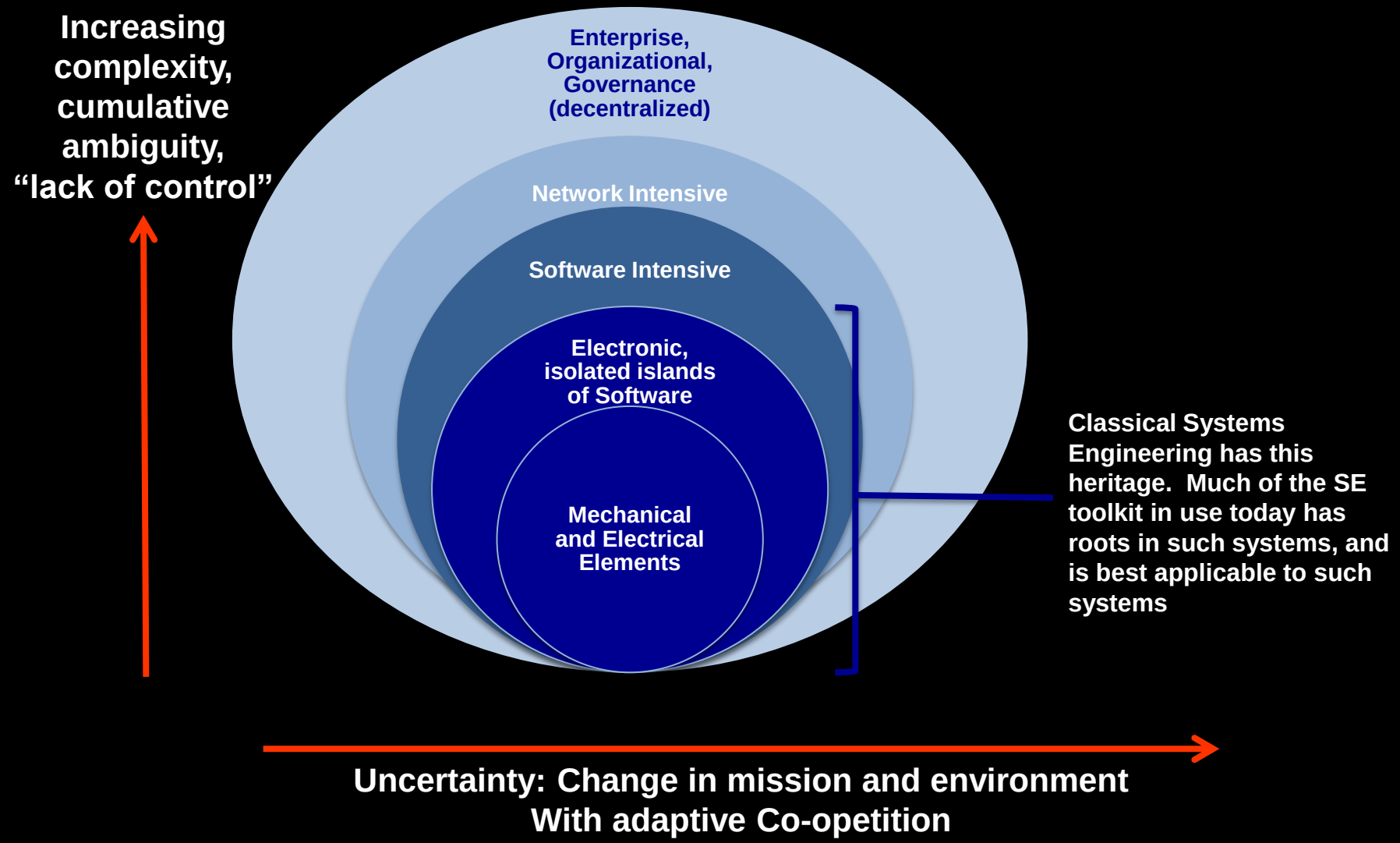




Computation

People

# Complexity and Uncertainty



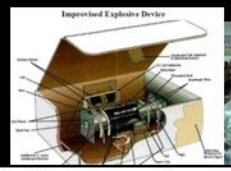
# Evolution & Change

Development takes too long.
Change takes too long.
Replacement takes too long.

The environment is highly uncertain and complex.

System complexity is growing.

**Renewed focus on the notion of a "system of systems" with heterogeneous elements, asynchronous clock-speeds, decentralized governance, and emergent characteristics.**




IEDs & Software: days to months

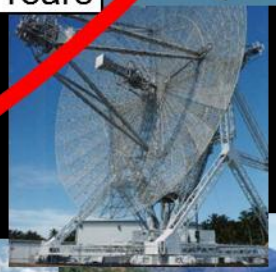


Electronics: 1-5 Years



Mobile Weapons: 5-20+ Years





Infrastructure: 10-25+ Years




Platforms: 20-50+ Years

Rate of Change

*The battle of devices has now become a war of ecosystems, where* ***ecosystems include not only the hardware and software of the device, but developers, applications, ecommerce, advertising, search, social applications, location-based services, unified communications and many other things****.*

*Our competitors aren't taking our market share with devices; they are taking our market share with an entire ecosystem. This means we're going to have to decide how we either build, catalyse or join an ecosystem.*

*- Stephen Elop, CEO Nokia*

**The Challenges are Accelerating!**

**How to adapt classical systems engineering to address complexity, evolution and change?**

# Complicated vs. Complex

Q: How does this system work?

A1: “It’s very technical, you might not understand it.”
(I know some people who might understand it)

A2: “I have some theories on how it might work.”
(I don’t have a clue on how this thing works)

# It’s more than just numbers…

- 25K protein coding genes: humans
- 45K protein coding genes: rice
- 7M lines of code: fighter plane
- 30M lines of code: cell phone
- 100M lines of code: automobile
- 2,000M transistors: PC CPU chip
- $10^{27}$ molecules: gas in room

It’s about structure.

Decomposition will not help

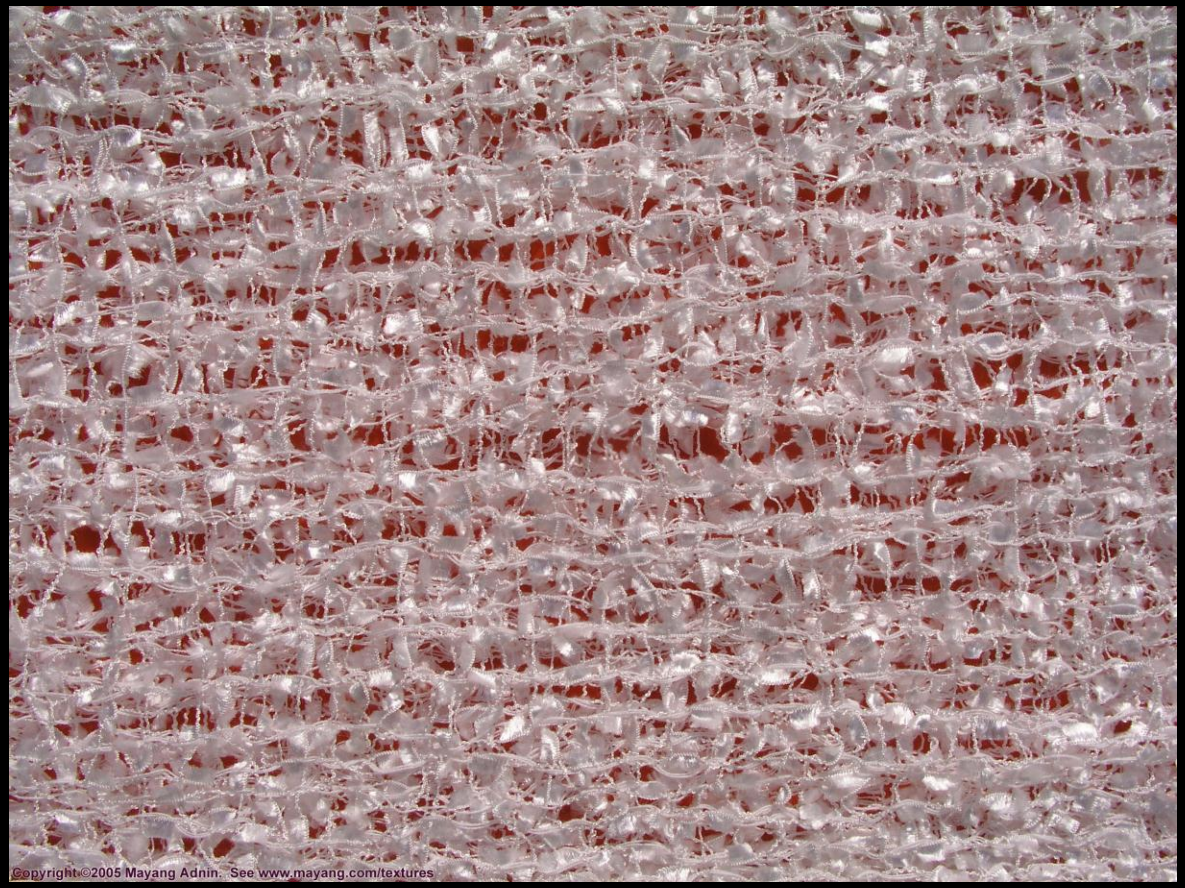
# Complicated

from Latin
com: together
plicare: to fold

The adj meaning
“difficult to unravel”
1656

Source: DeRosa et al, “A Research Agenda for the Engineering of Complex Systems, SysCon 2008.

# Complexity

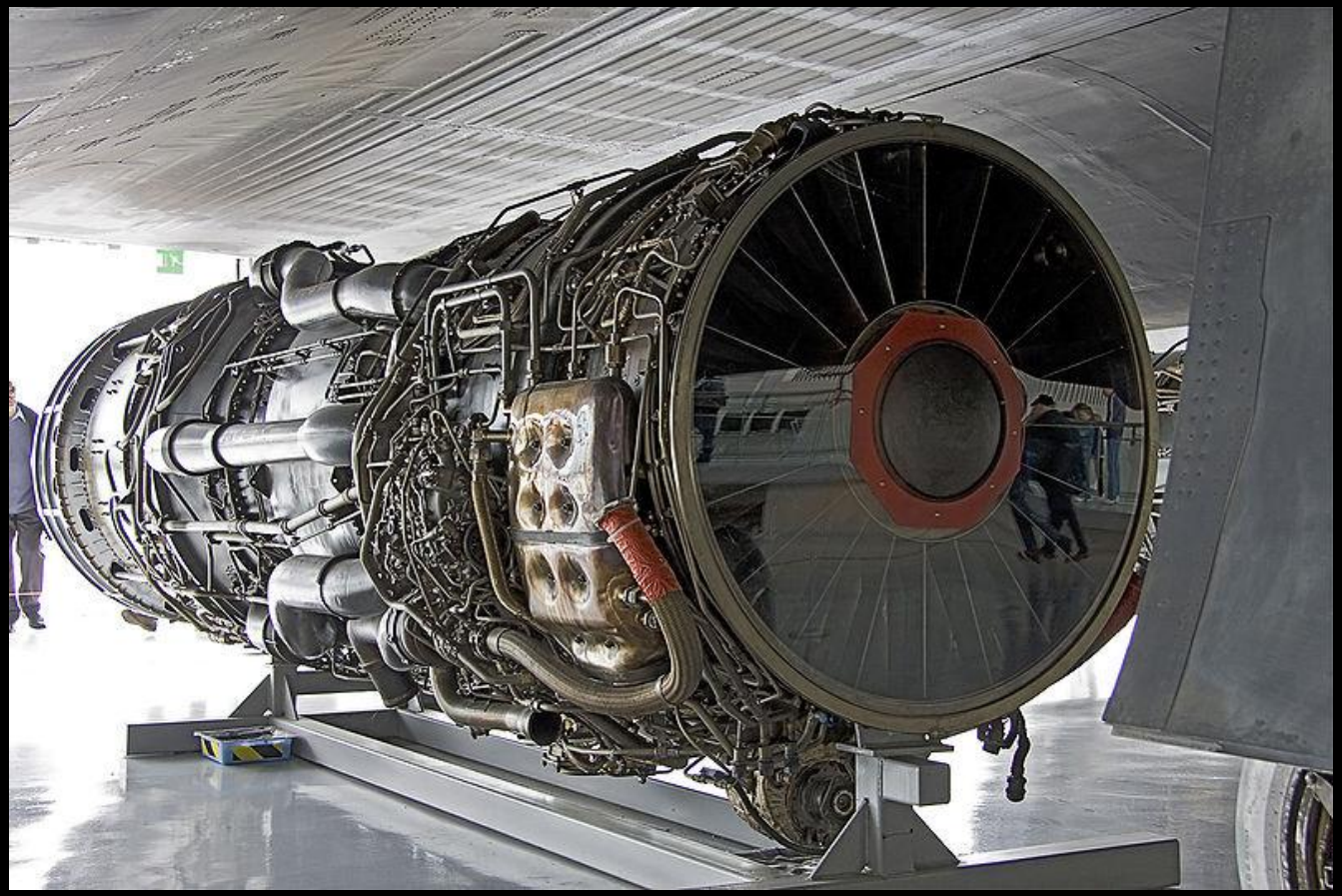



from Latin
com: together
plectere: to weave, braid, twine

The adj meaning "not easily analyzed" first recorded in 1715

Source: DeRosa et al, "A Research Agenda for the Engineering of Complex Systems, SysCon 2008.

# This is complicated!



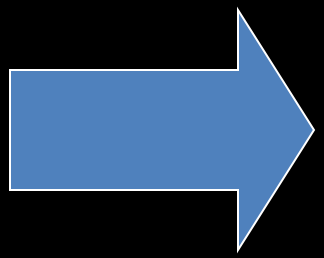
# This is Complex!

# Where is SE?

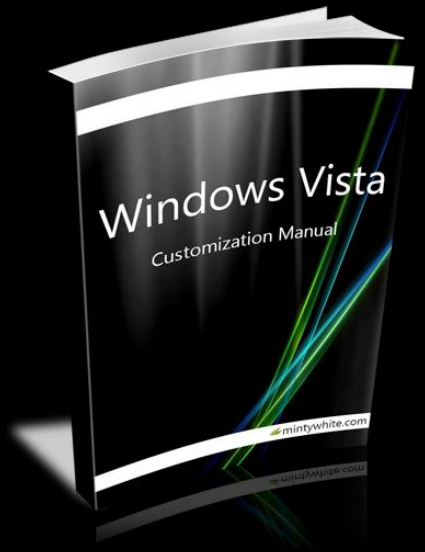

High
Complexity
Low
Low
Complication
High
Dow Jones Industrial Average ($INDU) INDX
© StockCharts.com
1-May-1997 Op 7009.00 Hi 7041.90 Lo 6891.40 Cl 6976.50 Vol 49.7M Chg -32.50 (-0.46%)
DJIA 6976.50 (Daily)
7158
842 points
6316
Volume 49,712,000
EMA(60) 57,756,448
24 Mar 10 17 24 Apr 7 14 21 28 May

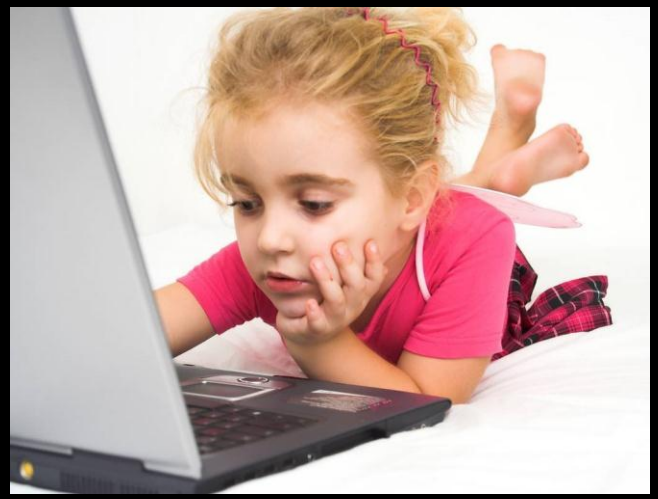
# Embracing Complexity

**How a systems works deterministically**



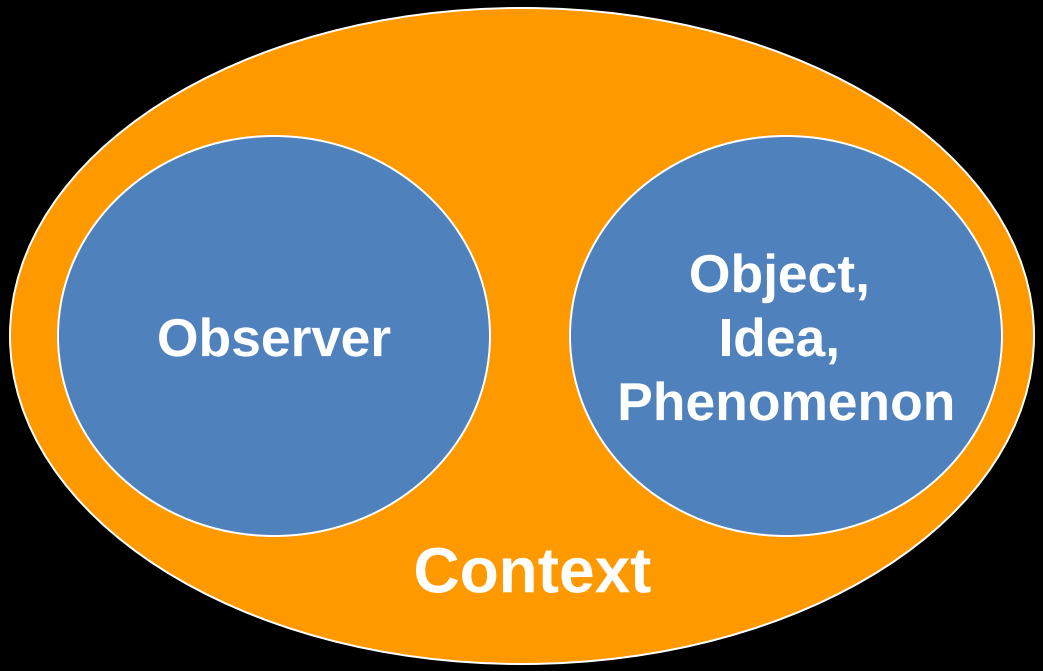
**How a systems behaves stochastically**



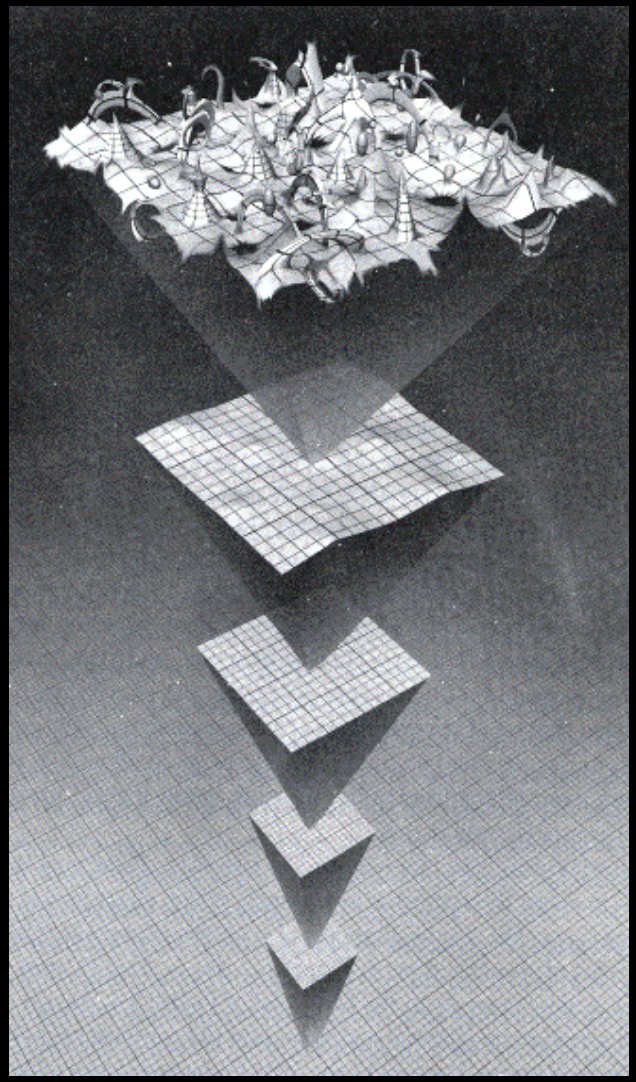



# What is Complexity?

"the degree of difficulty in accurately predicting behavior over time"



# Taxonomy of Complexity



**Prediction Quality:**
- Precision
- Time scale
- Context

**Prediction Difficulty:**
- Relationships
- Current state
- Computation

# Complexity Reduction

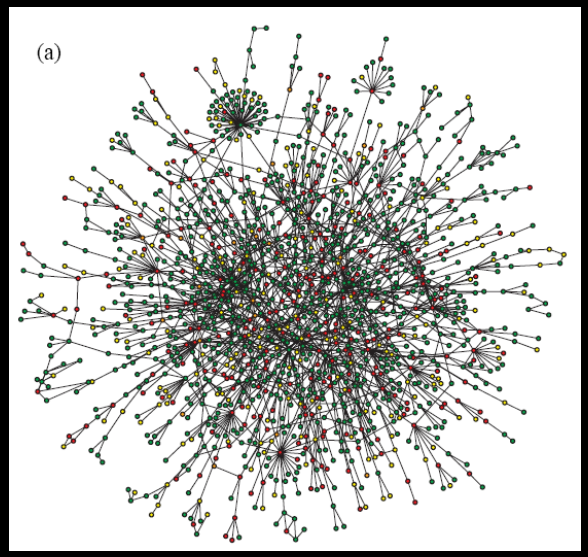
- Abstraction
- Transformation
- Reduction
- Homogenization

# Abstraction

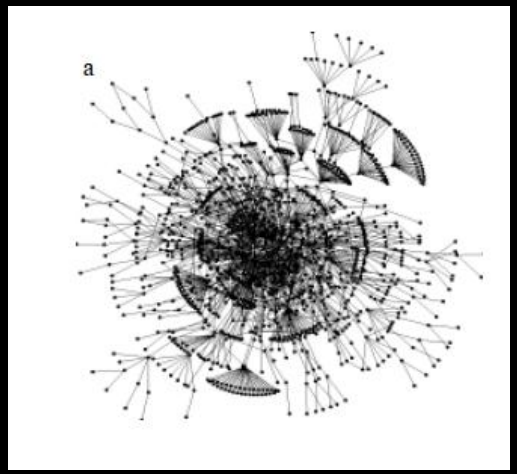
| |
|---|
| Applications – Software Engineering |
| Binary Code – Computer Science |
| Architecture – Computer Science |
| Logic – Computer Science |
| Circuits – Electrical Eng |
| Device Models – Electrical Eng |
| Device Properties – Device Physics |
| Material Properties - Material Science |


The Power of Abstraction
For VLSI - 1980

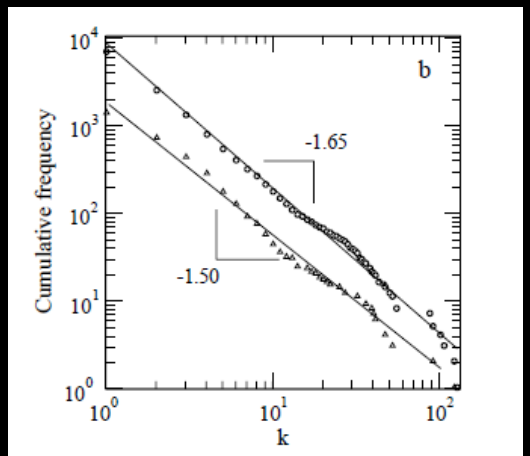
# Transformation

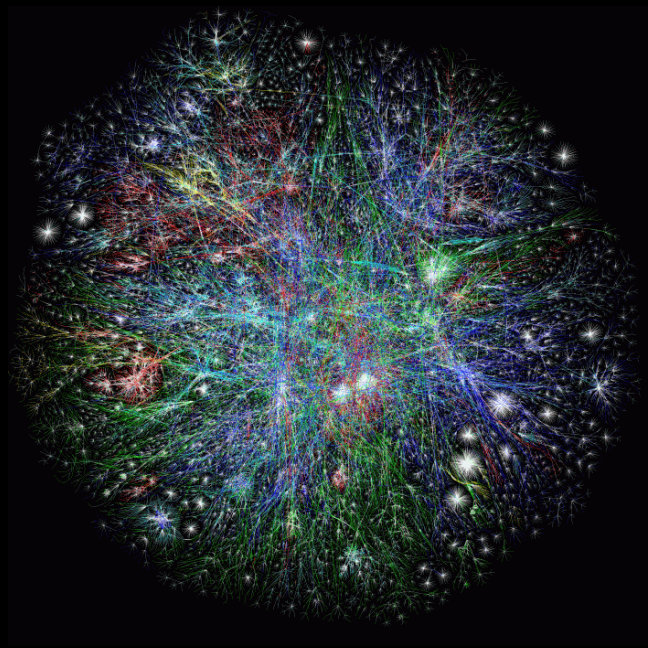



**Protein Interactions In Yeast**




**Java Code Network**



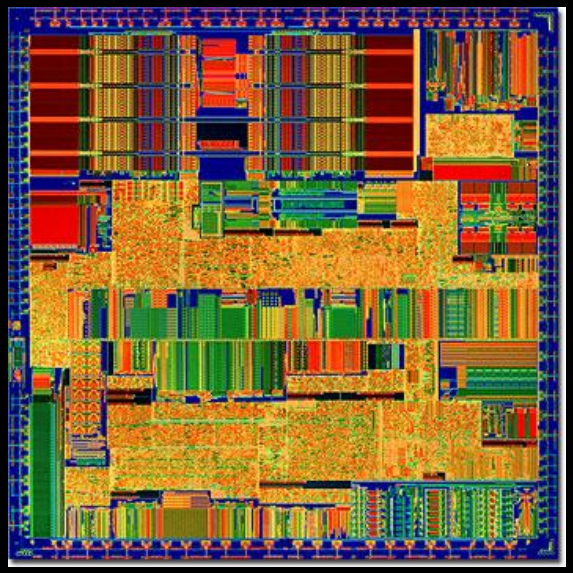



**Internet**

# Reduction

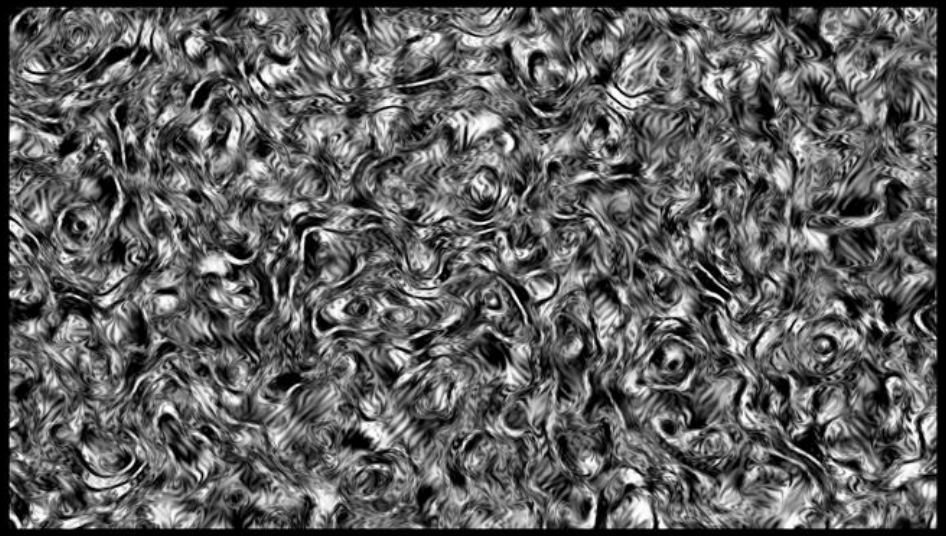
## Elements


## Context



0degC < T < 125degC
2.1V < V < 2.4V
2.0GHz < f < 2.3GHz

# Homogenization



Gas Molecules

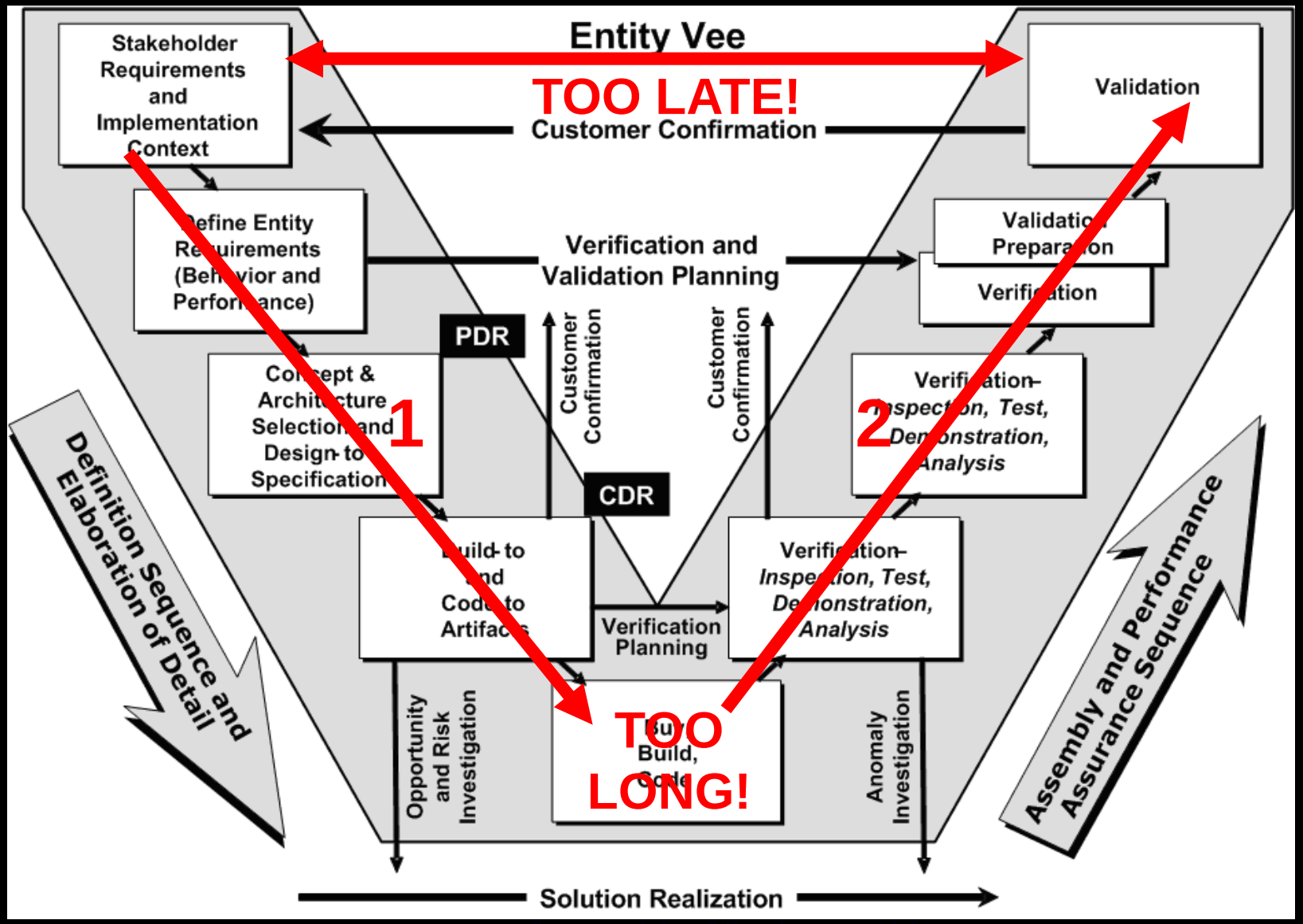
**PV = nRT**

Q: At what temperature does pure water in isolation @ 1atm become a solid?

A: -42degC, -108degC if cooled sufficiently quickly

As simple as possible, but no simpler!

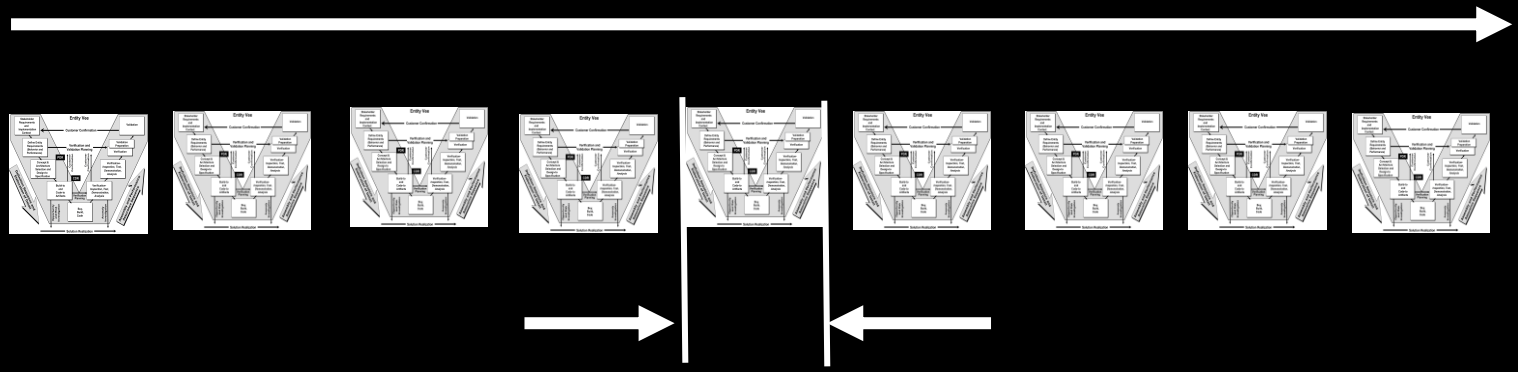
# Traditional SE




wpedia.goo.ne.jp/enwiki/Dual_Vee_Model

# The Disappearance of the Vee

## Continuous Coherent Development



Leveraging Computation, Visualization,
Communication & Information Technologies

# Validate and Verify, early and often!

**Subtle**

**Not So Subtle**


SE


Thank You!