Dependability of Computing Systems: Memories and Future
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Challenges and Perspective in Dependability for Information Society

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June 29, 1996

Thanks to Jean-Claude,

1. Concepts and Taxonomy of “Dependability”
   - Built up the base of research and policy-making for dependability

2. Dependability in the presence of “changes”
   - Gives another key concept for information societies that change
   - Challenges the community to cope with “complex” systems

Jean-Claude has made paramount contributions to the community !

For the above 2), however,

I would prefer to say “Dependability with Resilience” rather than “From Dependability to Resilience” which is misleading, i.e. sounds like “departure from dependability”

Changes

- Technologies change
- Market changes
- Societies change

The update today may no longer remain up-to-date tomorrow

The optimum today may no longer remain optimal tomorrow

In spite of these, dependability must be perpetual !

This requires us to explore a new frontier of science

40 years ago…

- Our flag-ship symposium, FTCS, launched in Pasadena, California, chaired by Al Avižienis
- Since then, many things have changed, while some others haven't
- *What should be taken as a dependability threat in future may be different from what used to be in the past*

What have changed

- Number of Transistors on a VLSI Chip:
  - 2300 “Intel4004”(1971) => 2.3 Billion “Intel Nehalem-EX” (2009)
- Performance:
  - 5MFlops “CDC7600” (1969) => 1.75 PFlops “CRAY-XT5” (2009)
- Internet:
  - ARPANET started with 4 IMPs at UCLA, SRI, UCSB and U.Utah (1969) => One billion people on line in the world (2009)

What haven’t changed

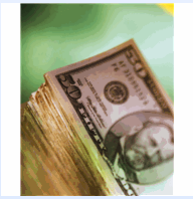
- Human nature and capability
- Cosmic rays that impinge on Earth’s atmosphere
- The life of materials
- Disciplines of sciences

Gaps between what change and what don’t can be the major sources of threats to the dependability for information societies !

And, the gaps are increasing !

Information Society

Social Systems


economy


law

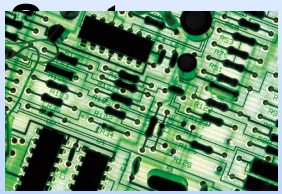

welfare


enterprises

Services / Information

Infrastructures

Information



Dependability

Threats

- Open systems : Systems can interact unintentionally with unknown systems
- Black-box components: Systems can include components whose mechanism and internal behavior are unknown
- System complexity: Systems are increasing in complexity and interdependency with huge scaling gaps between hierarchical layers
- VLSI miniaturization: Nanometer devices can be highly sensitive to process variation and environmental interferences
- System deterioration: Systems can deteriorate due to aging and environmental changes

Threats --- continued

- Data explosion: The amount of data produced and distributed everyday on the network grows explosively.
- Human behavior: Psychological behavior of human beings is uncertain and error-prone
- Service diversity: Services provided by networked systems are unpredictably diversified
- User diversity: A variety of people, even malicious or naïve users, can equally have access to networked systems.
- Ambiguous responsibility: It is somewhat ambiguous who should be responsible for what happens in globally networked systems

Threats in Information Society

Social Systems

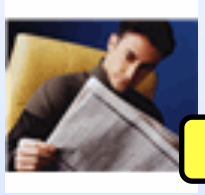

economy


law


welfare


enterprises

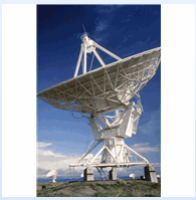
Services / Information



ambiguous responsibility

Service/user diversity

Infrastructures



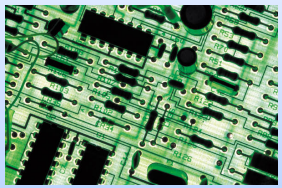
uncertain human behavior

data explosion

Information Systems

system deterioration

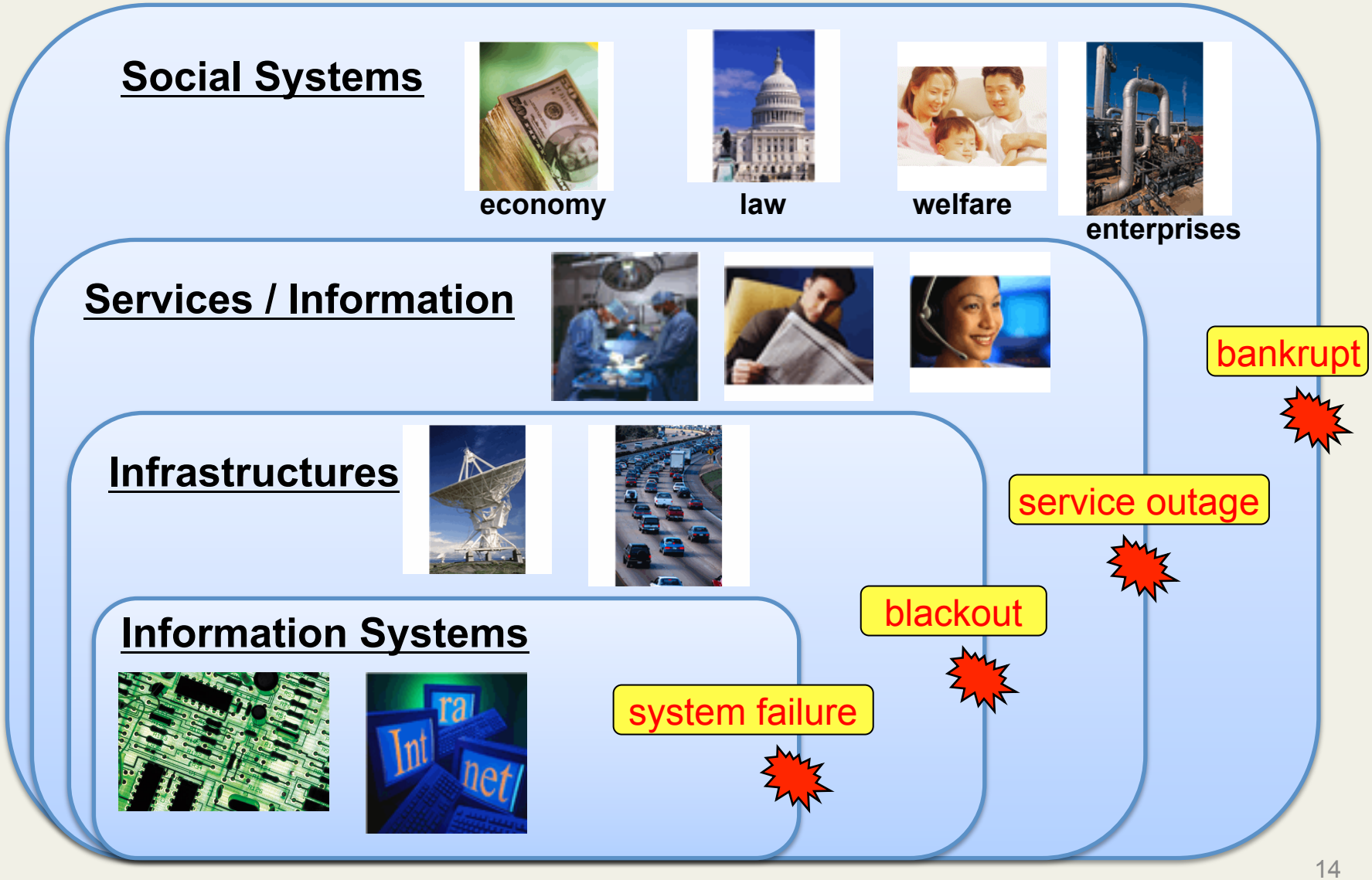
system complexity



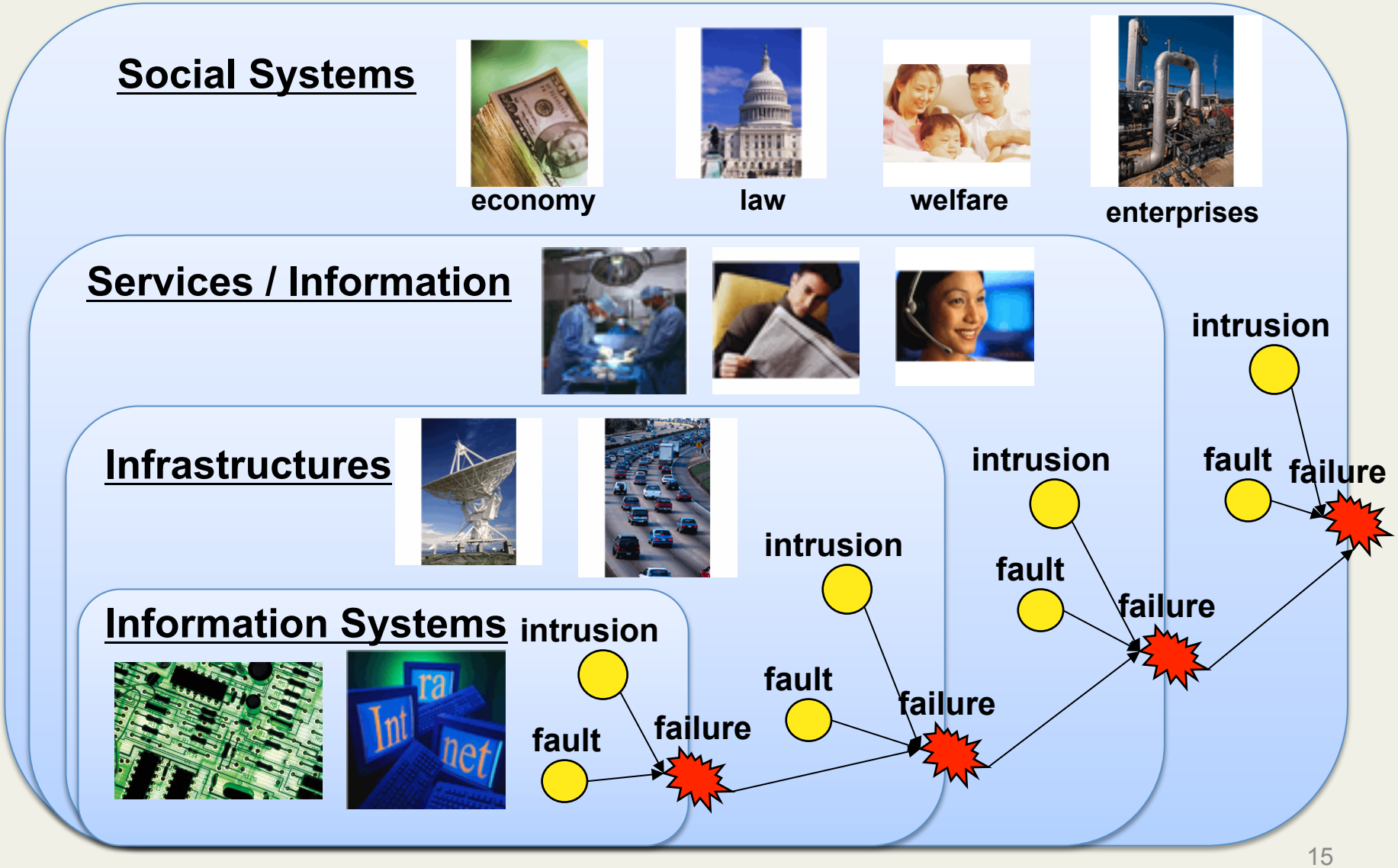
black box / open system

VLSI miniaturization

Failures


Social Systems
economy
law
welfare
enterprises
Services / Information
Infrastructures
Information Systems
bankrupt
service outage
blackout
system failure

Hierarchical recursion

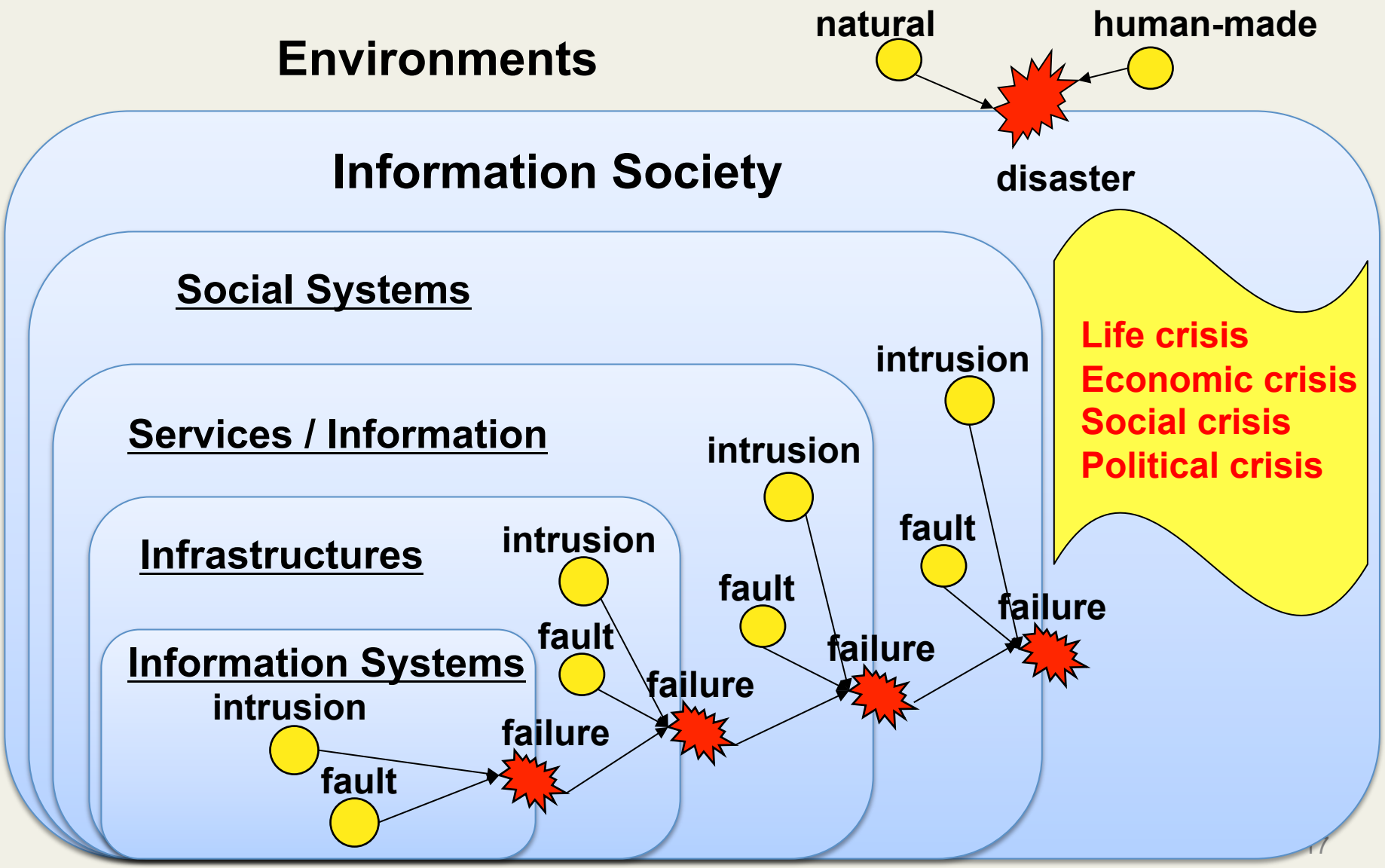


What we need

At each of the four layers, i.e. information systems, infrastructures, services and social systems,

- ***Resilient system architecture*** *for persistent dependability in the presence of changes in environment, societies and technologies*
- ***Consistent system design, implementation and maintenance*** *through the entire systems hierarchy*
- ***Quantitative evaluation*** *for dependability to be made visible and mapped to economic values*

Extreme events



Difficult problems

1. Effect estimation and action planning for global environmental changes
2. Forecast, protection and recovery strategy for natural disasters
3. Prevention and recovery strategy for epidemic diseases
4. Understanding life processes and prevention of incurable diseases
5. Understanding mental phenomena and healing of mental disorder
6. Global security for energy, food and water
7. Sustainability and risk management of critical infrastructure
8. Understanding economic phenomena and prevention of financial crisis
9. Dependability and security in networked systems, services and information
10. Design and synthesis of new functional materials

Research Gaps

- Extreme events in modern societies include
  - System failures (internally caused)
    - social systems, services, critical infrastructures, information systems
  - Disasters (externally caused)
    - natural disasters, human-made disasters

- Most difficult problems encountered in modern societies are attributed to "complex systems"
  - *Can the traditional "complexity science" solve these difficult problems ?*

Issues of complex systems

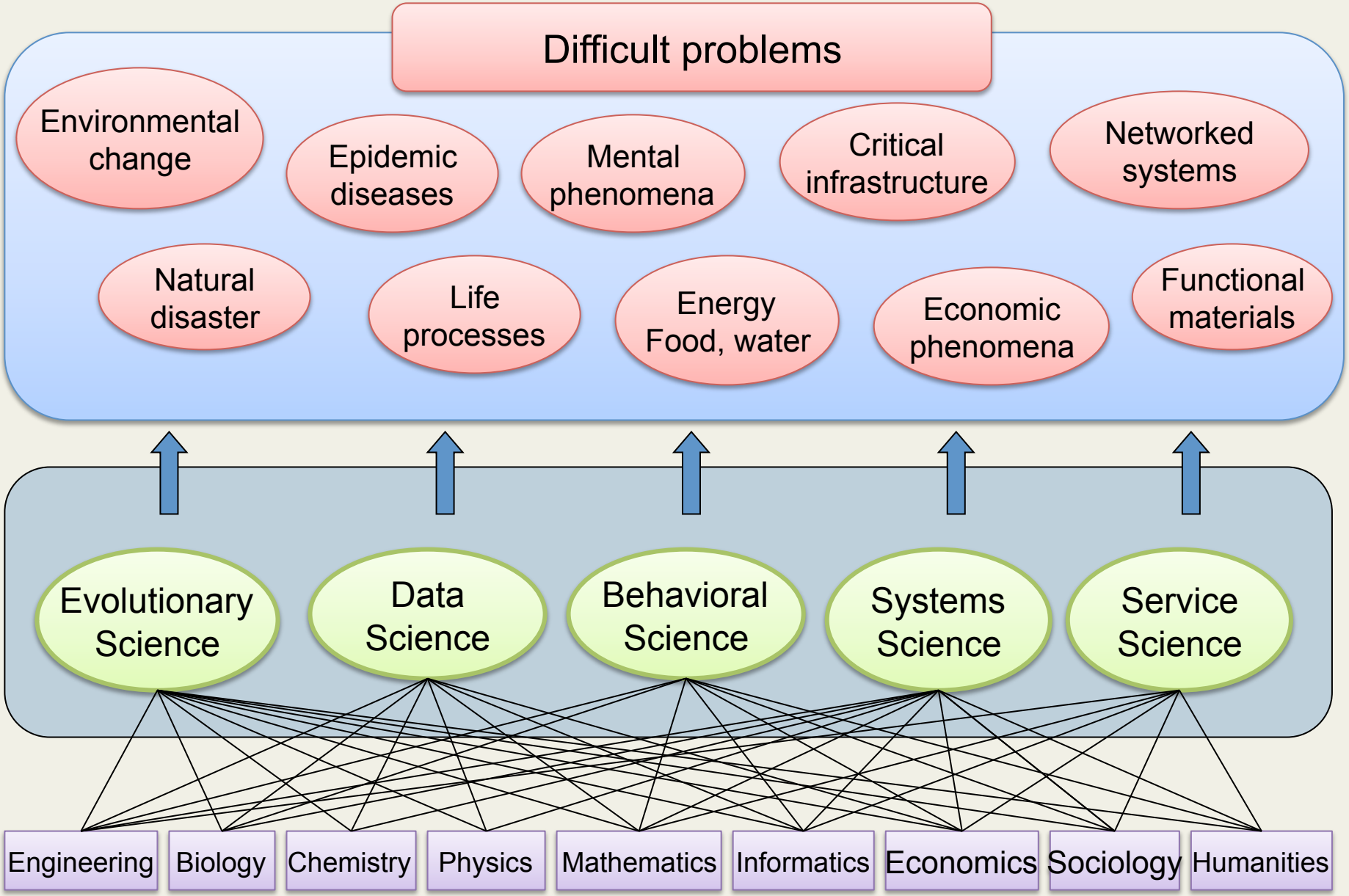
- Scientific points of view
  - Can the systems (including interdependency) be modeled ?
  - Can all the necessary parameters be measured ?
  - Can the modeling be verified ?
  - Can the model be computed for analyses and simulations ?
  - Can the results be evaluated ?

- Engineering/policy points of view
  - Can value metrics agreeable to international societies be defined ?
  - Can the value metrics be measured and quantitatively evaluated ?
  - Can systems adaptable to changes be designed, implemented and maintained both technologically and economically ?

Emerging and Converging Disciplines

- In order to solve difficult problems encountered in the modern society, what disciplines are required to emerge or converge ?

- How research and education systems must be reformed to promote the emerging and converging disciplines?


Difficult problems
Environmental change
Epidemic diseases
Mental phenomena
Critical infrastructure
Networked systems
Natural disaster
Life processes
Energy Food, water
Economic phenomena
Functional materials
Evolutionary Science
Data Science
Behavioral Science
Systems Science
Service Science
Engineering
Biology
Chemistry
Physics
Mathematics
Informatics
Economics
Sociology
Humanities

Converging Disciplines

- **Data Science** : *Understanding management of a huge amount of data*
- **Behavioral Science** : *Understanding psychological behavior of human beings*
- **Evolutionary Science** : *Understanding change and evolutionary processes of nature, human and society*
- **Systems Science** : *Understanding complexity of systems with interdependencies and uncertainties*
- **Services Science** : *Understanding quantitative evaluation for quality of services from users' point of view*

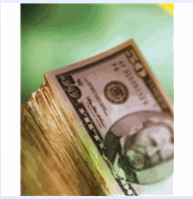
Proposals

(with international co-operation)

- *Promote new "complexity sciences" as an ensemble of the five converging disciplines for dependability*
- *Create new incentive systems to foster research communities for the converging disciplines*
- *Formulate grand challenges for "dependability of information societies"*
- *Construct test beds and data sets for evaluating "dependability of information societies"*

Changing Information Society

Social Systems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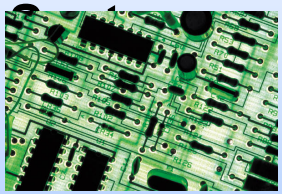

Perpetual Dependability

Thank you,

and

Congratulations !

Jean-Claude