Building Survivable Systems in Engineering and Business Systems

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by

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Presentation Outline

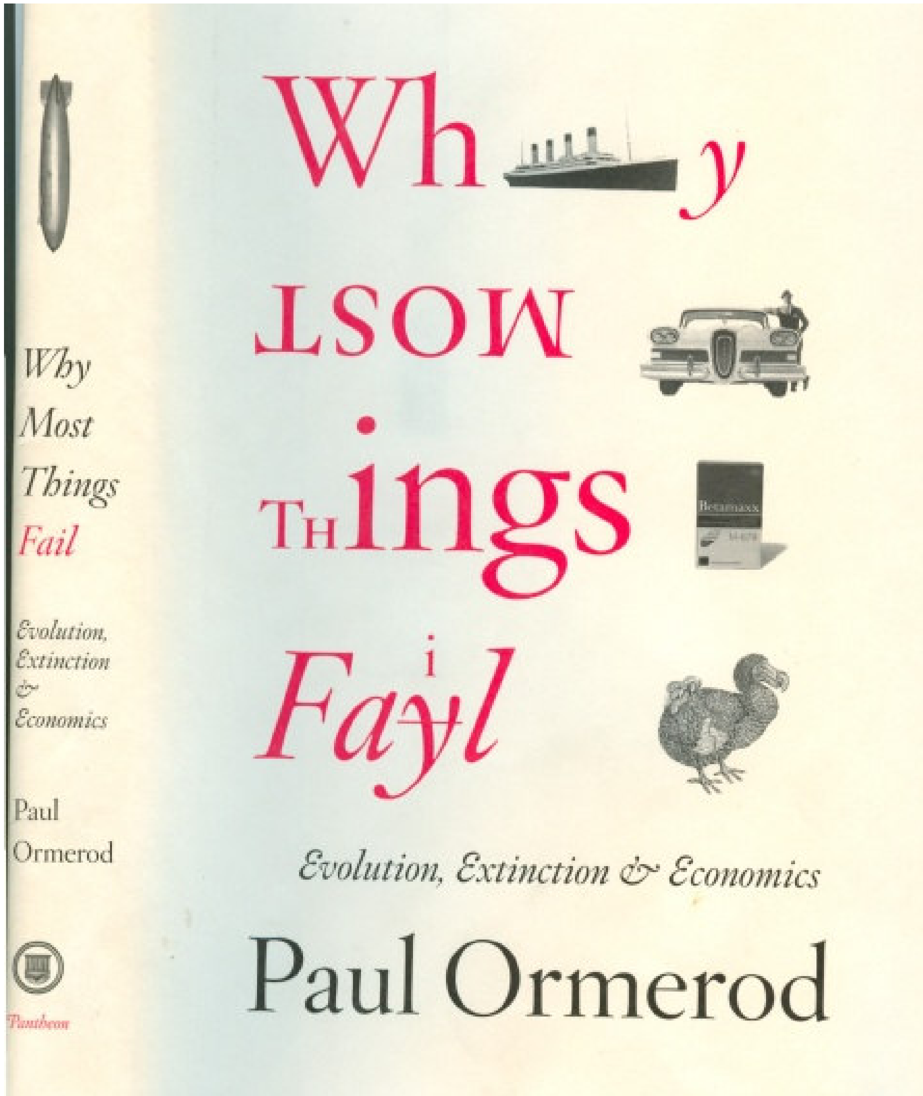
- Introduction: Definitions
- System Survivability Requirements
- Principles and Methods
- Product Modeling using Finite Element Method
- Process Modeling using Simulation Science
- Business Process Modeling & Complex Systems Theory
- Multi-agent Systems and Exception Handling
  Strategy to Ensure System Survivability
- Summary and Conclusion

What is a survivable system?

A system that provides a **contingency** to ensure that the system continues to provide **essential services** even when components' performance falls below **established threshold values**.

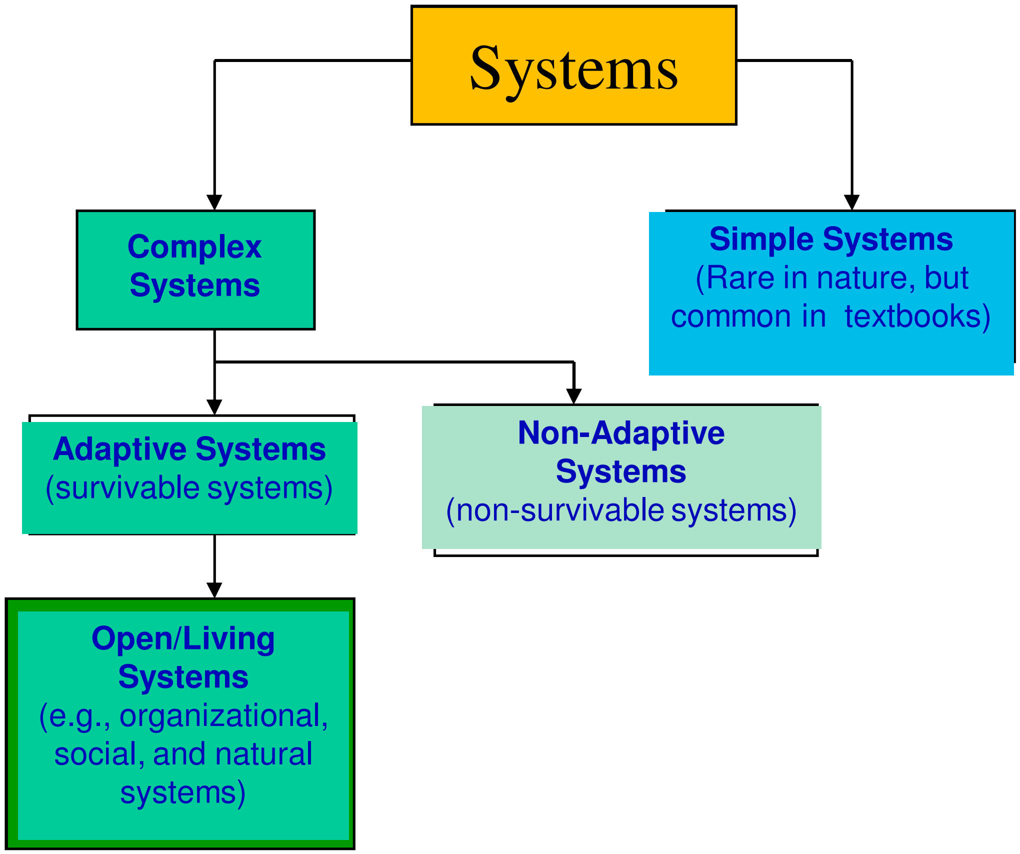
A Premise for System Survivability

To survive, organizations must innovate change drivers within their systems (*i.e., products, processes, and business systems*).



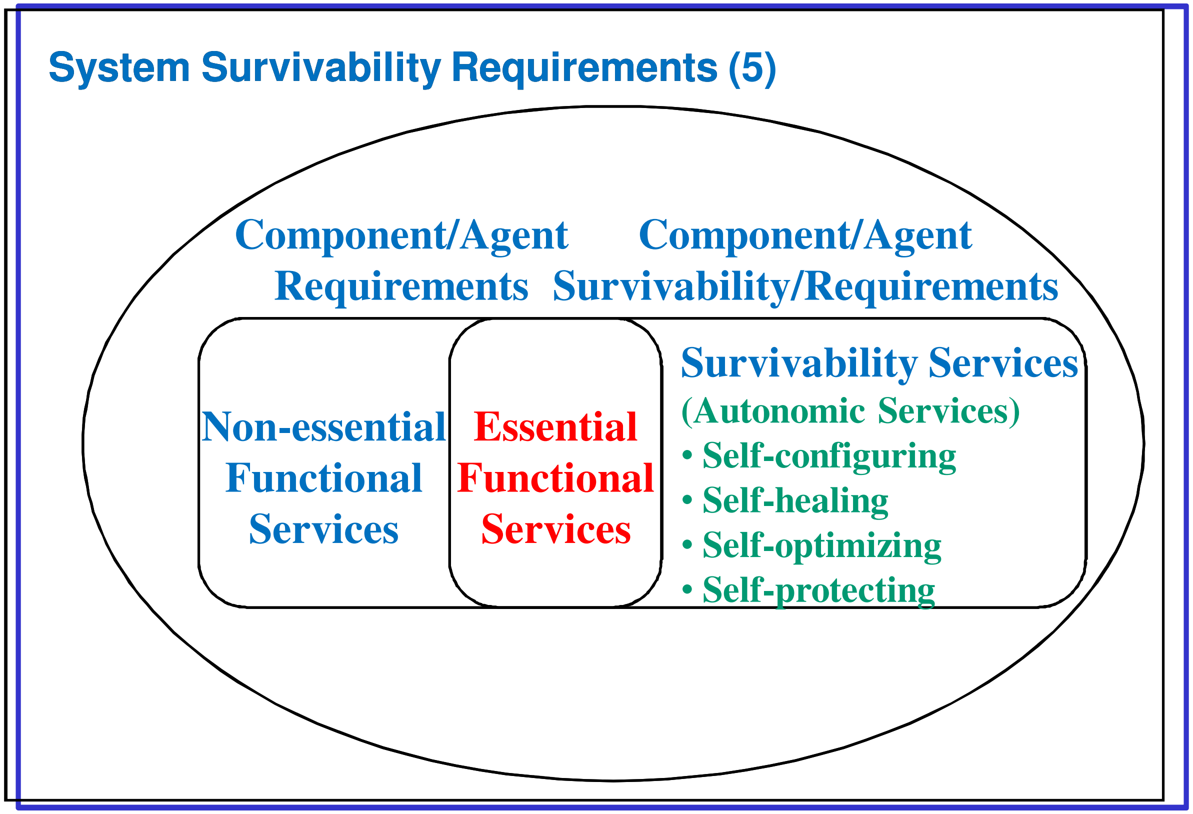
Because they are not designed as complex adaptive systems

Introduction - Taxonomy of Systems



System Survivability Requirements

"He who defends everything, defends nothing". **Sun Tzu, The Art of War.**



Measures of System Survivability

- The emergent behavior of a typical system is determined by interactions of the components of the system

- Survivability of the system depends on successful integration of a set of quality attributes of the components (i.e., *performance, availability, reliability, security, fault tolerance, affordability, and autonomic services*)

Self-Managing (Autonomic) Properties of a Survivable System

1. **Self-configuring**—able to automatically adapt to changes in the environment
2. **Self-healing**—able to detect, diagnose, and react to disruptions
3. **Self-optimizing**—able to automatically optimize resource usage to meet user needs
4. **Self-protecting**—able to anticipate/predict, detect, identify, and protect the system from disruptions.

Metric for a Survivable System

A determination of what constitutes essential services is based on the policies and experience of an organization's decision makers.

Survivability = (Level of performance at the new state)/
(Normal level of performance)

Example: Global Network Service Provisioning

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Metric for a Survivable System

Survivability = (level of performance at the new state)/ (Normal level of performance)

Example: Telecom Service Providers and Service Level Agreements

Let $D(S_n, CIR)$ represent the degree to which essential services (i.e., committed information rate (CIR)) has been affected at the new state S_n

NOTE: *The system can be modeled as a chaotic system with a temporal difference equation $S_{n+1} = S_n * R * (1 - S_n)$, where S is a fraction between 0 and 1 and R is the rate of change from one cycle to another. The factor $1 - S_n$ is a resource constraint.*

Metric for a Survivable System: Telecom Example

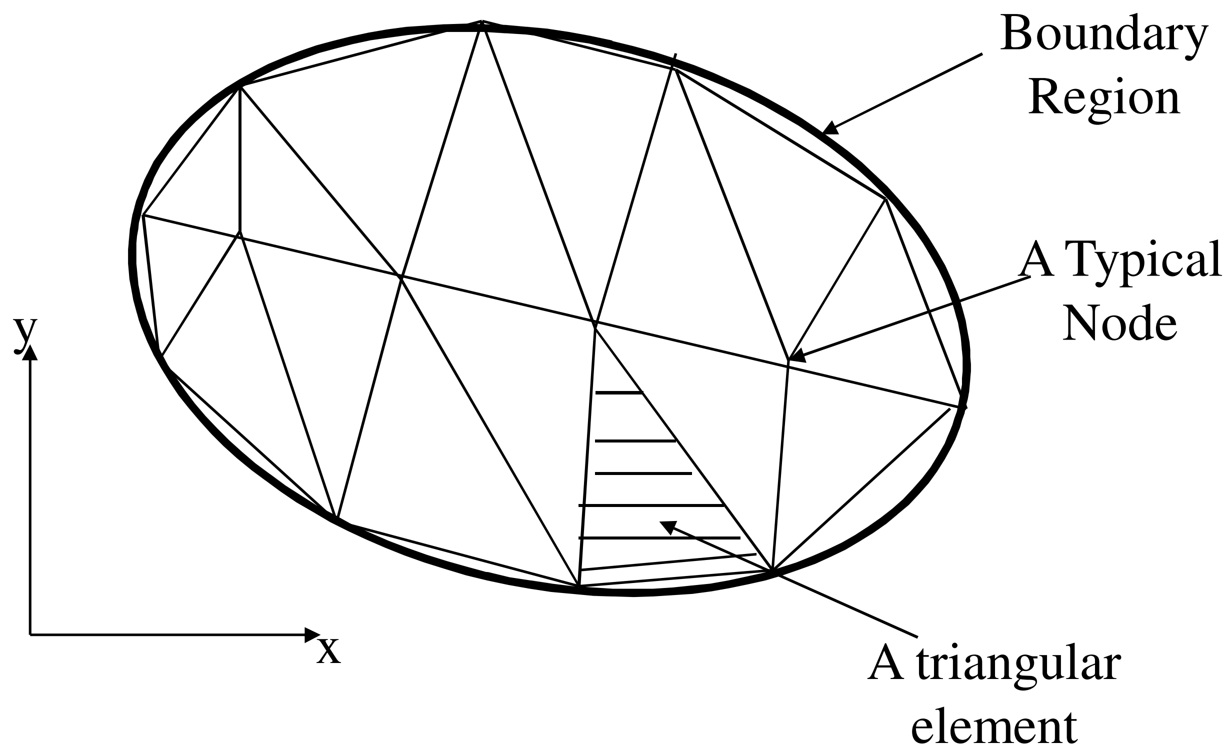
Policy-based *survivability* of the system can be represented as the *product* of the *weighted sum* of customer priorities and the volume of traffic delivered at the new state, S_n:

$$\text{Survivability } (S_n) = \Sigma_{CIR}\, w(\,CIR\,) * D(S_n\,, CIR)$$

$$\text{Survivability } (S_n) = \text{Min}_{CIR}\, (D(CIR, S_n)) : \text{Worst case scenario}$$

Where Min_{CIR} represents the minimum level of traffic (i.e., essential services) that can be provided to meet selected customer level agreements.

Product Engineering with Finite Element Modeling

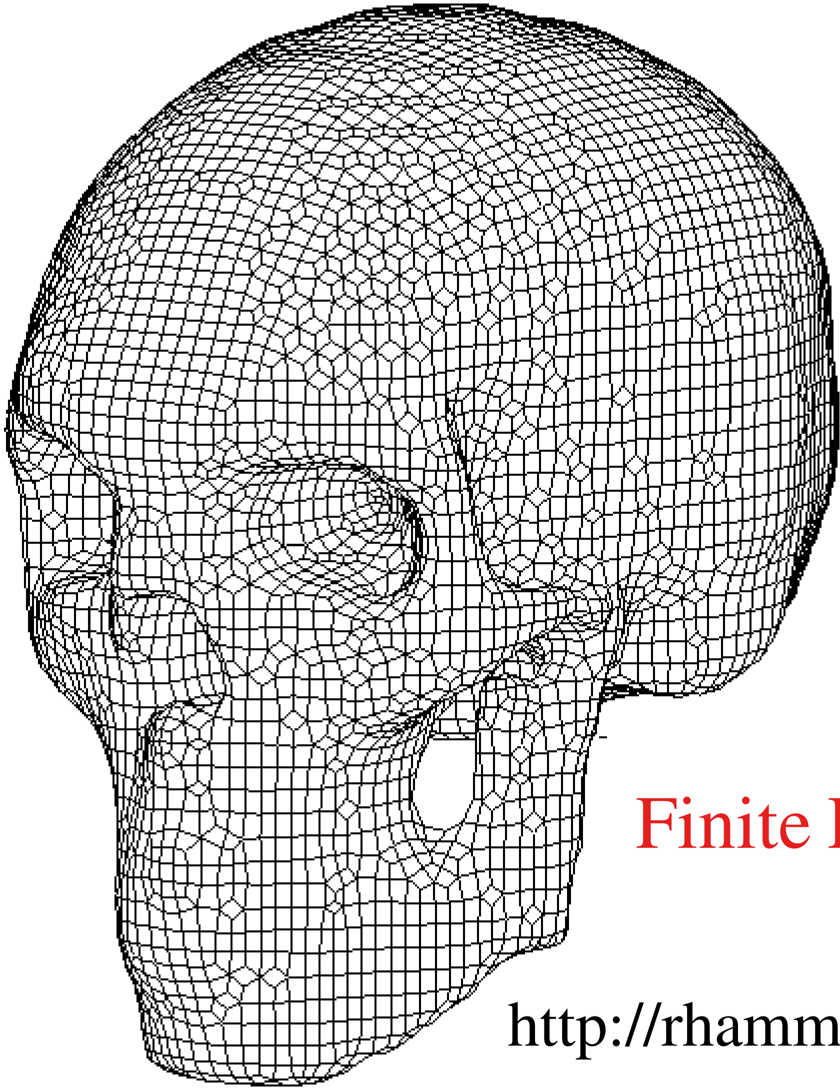


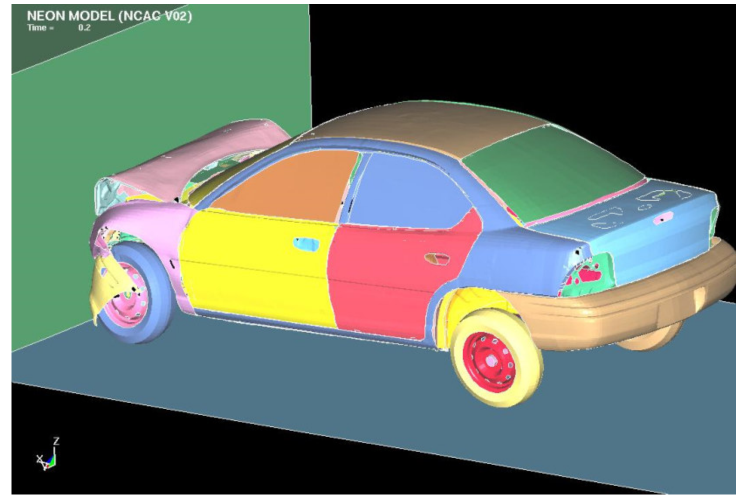
A two-dimensional region of an object represented as a combination of triangular finite elements

Product Engineering with Finite Element Modeling

Six Steps of the FEM Procedure

1. Discretize the structure
2. Select displacement model—a function that approximates the displacement of each element (e.g., a linear polynomial)
3. Derive element stiffness matrix [K] based on nodal displacements {q} and the force vector {Q}: [K] {q} = {Q}
4. Use overall equilibrium relations between the total stiffness matrix [K], the total load vector {R}, and the nodal displacement vector {r}: [K] {r} = {R}
5. Generate solution for the unknown displacements using matrix algebra
6. Compute the element strains and stresses from the nodal displacements using derivatives of the displacements.





Finite Element Modeling: Examples

http://rhamm.com/movies/4frame_neon.wmv

Modeling and Simulation Science for Process Modeling

Caveat: Modeling and simulating a large complex system to make intelligent predictions about the system behavior demand the following prerequisites:

- A strong knowledge of the domain of interest
- Competence in basic mathematics including discrete mathematics/structures
- A sound knowledge of probability and statistics
- Experience with a simulation programming language/package.

Process Modeling using Simulation Science

Simulation science employs both discrete (*state variables change at finite intervals*) and continuous (*state variables change continuously*) system concepts to describe the state of a system in terms entities and their characteristics, processes, events and delays.

Process Modeling using Simulation Science

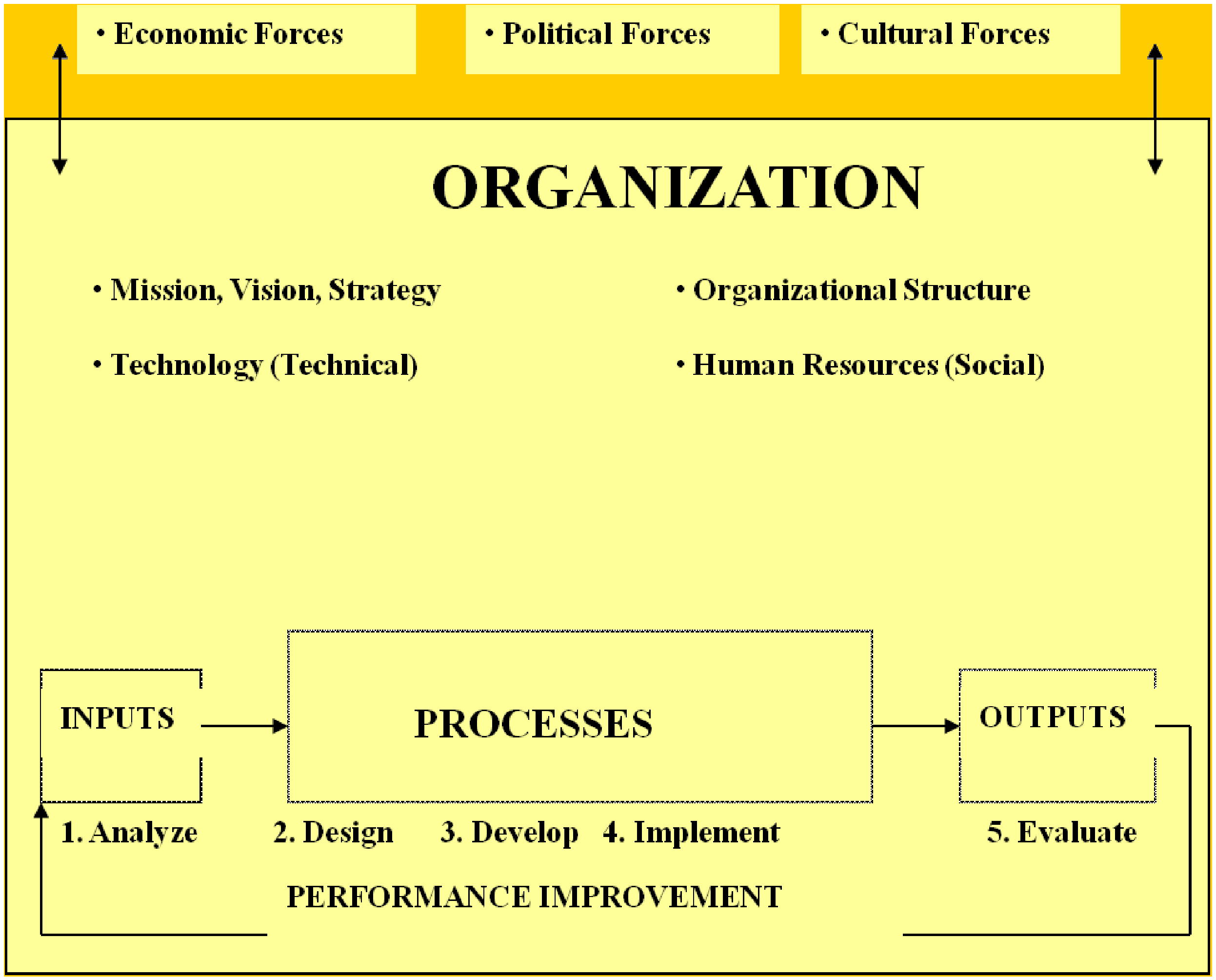
A typical simulation study should follow the scientific problem solving process: observe, hypothesize or predict, test, accept provisionally, and report findings.

Example: modeling the feasibility of the earth-mars Telecom and Information Management System (TIMS) plus antenna visibility determination

Dimensions of Organizational Operational Context

Nature of Environment	Nature of Task	
	Routine	**Non-routine**
Stable/ Predictable	Routine task in a stable environment	Non-routine task in a stable environment
Unpredictable	Routine task in an unpredictable environment	Non-routine task in an unpredictable environment

The Organization as a Socio-technical System



Business Process Modeling and Complex Systems Theory

- Use complex (chaos) theory to explain the complex interactions between the actors within an organization and the implications of the emergent behavior (whole)

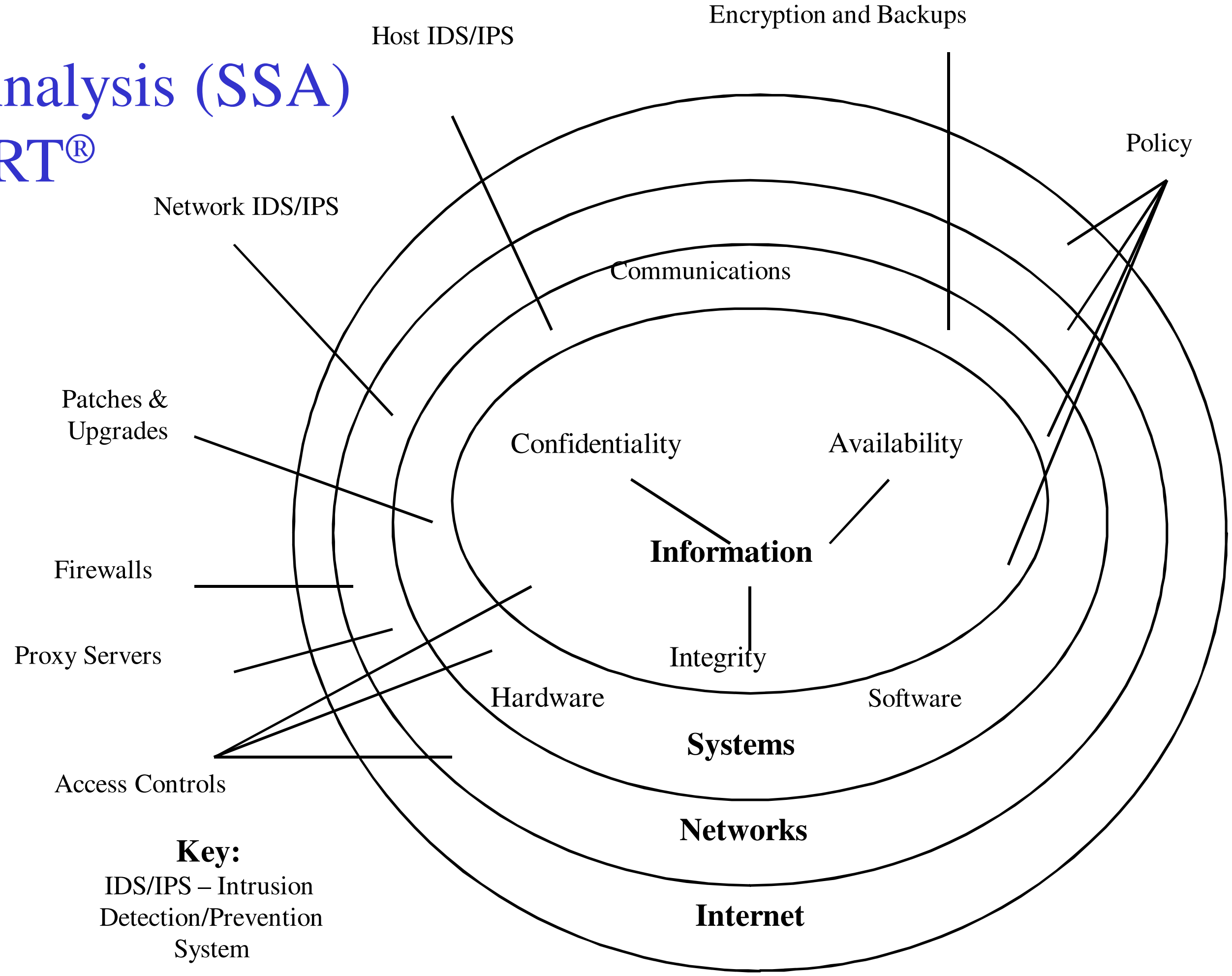
- It is often impossible to predict emergent behavior of a nonlinear system because a very small change may result in new patterns of behavior due to self-reinforcing feedback

- To understand complexity, it is imperative to understand its language, such as chaos, fractals, self-organizing systems, complex adaptive system, and nonlinearity.

Defense in Depth Paradigm for Survivable Cyber Security

Survivable Systems Analysis (SSA) Method from SEI CERT®

- System Definition
- Essential Capability Definition
- Compromisable Capability Definition
- Survivability Analysis—Develop System Survivability Road Map



Key:
IDS/IPS – Intrusion Detection/Prevention System

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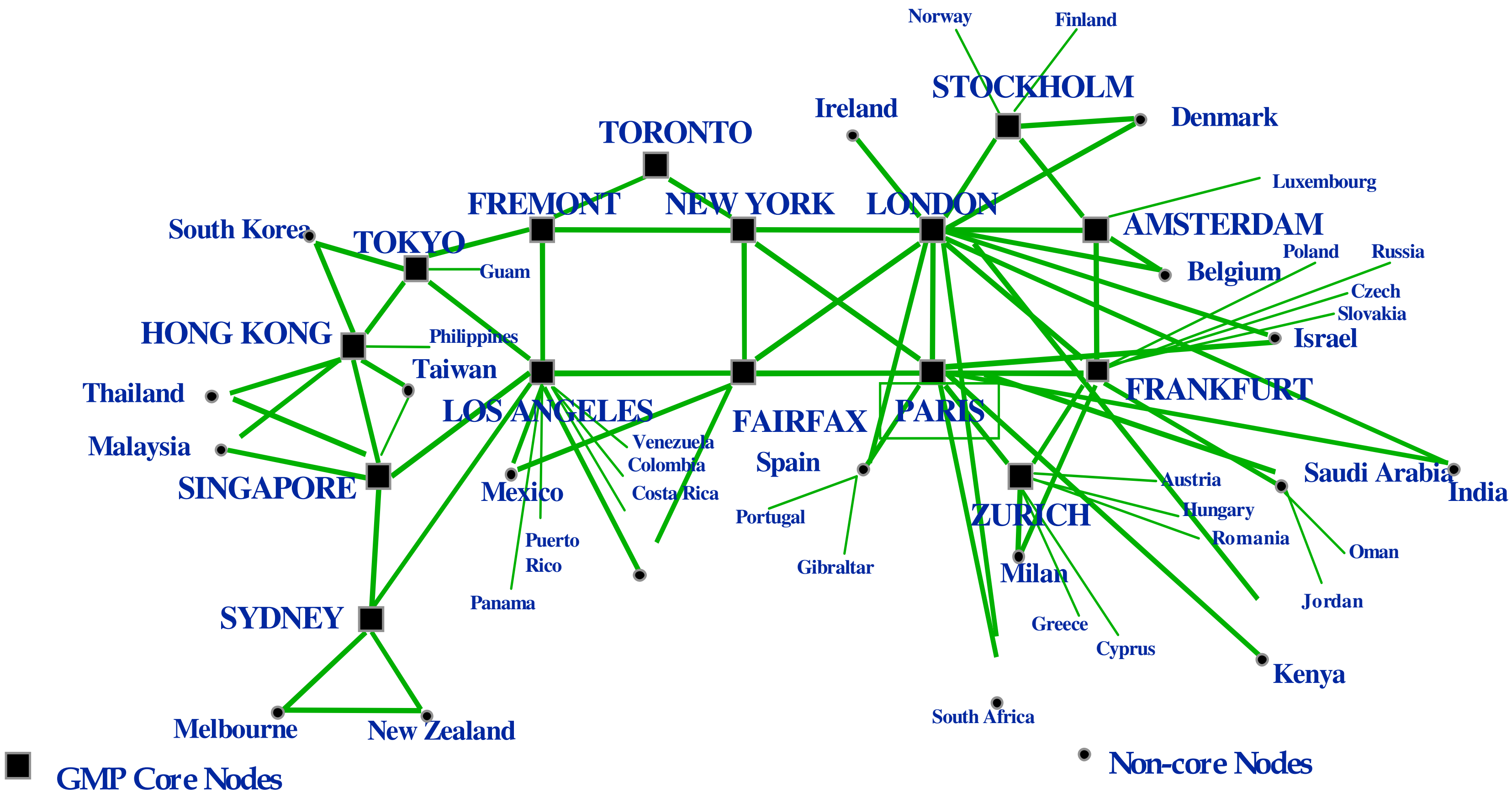
Global Network Management with Exception Handling Strategy for System Survivability



A Global Communication Network

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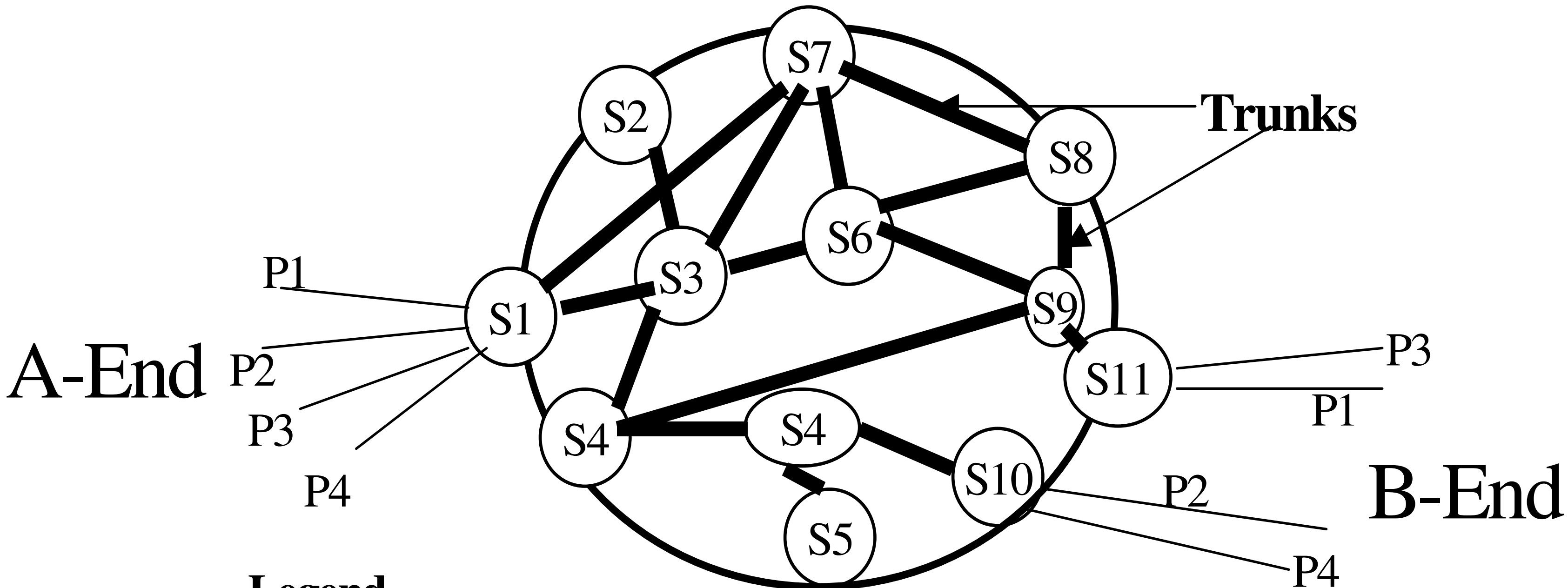
Multi-agent Systems and Exception Handling Strategy for System Survivability



Legend

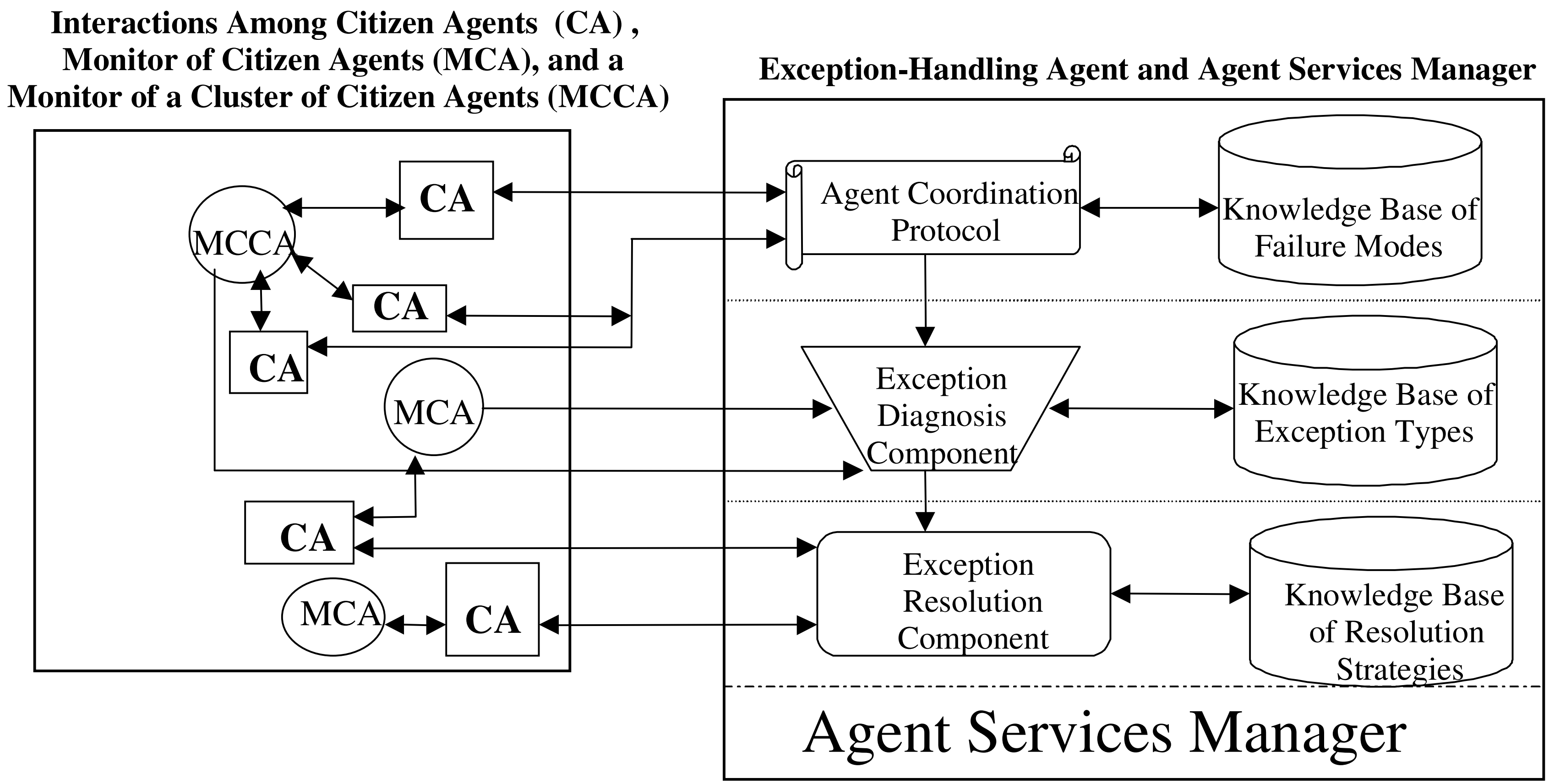
P1-P4: Customer connections traversing the trunks from the A-end to the B-end.

S1-S11: Switches connecting the trunks that hold the PVCs.

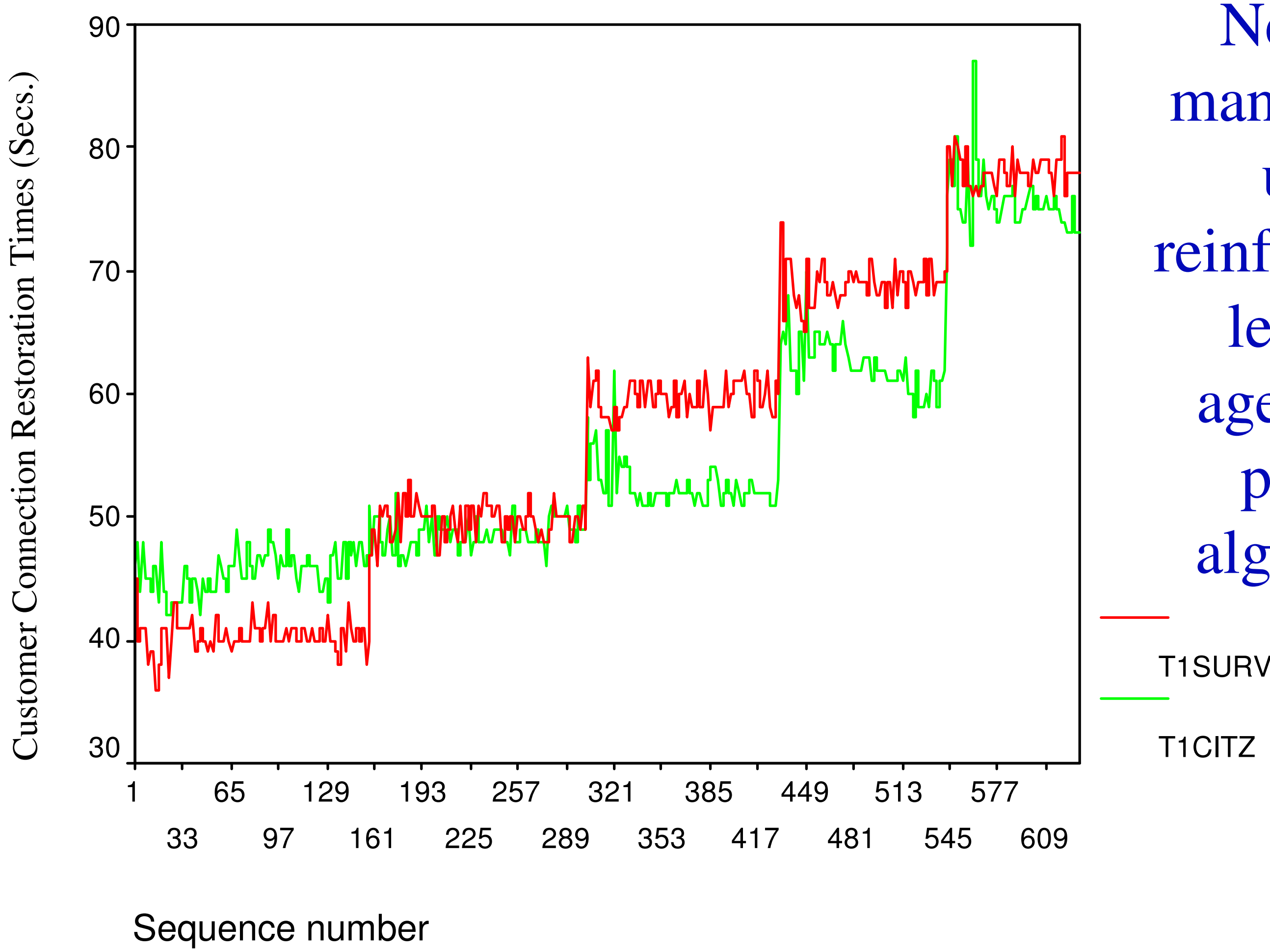
A-end: One end of the globe. B-end: The other end of the globe.

A Conceptual Model of a Global Communication Network Topology

Multi-agent Systems and Exception Handling Strategy for System Survivability



Restoration Times by two Classes of Agents for A Sample of 632 Customer Connections



Network management using reinforcement learning agents and polling algorithms

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Summary and Conclusion

One Minute Video on Building Survivable Systems

See the accompanying file to open.

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Questions?

Thanks for listening!

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