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Information Age Combat Model

For 9th ICCRTS
Copenhagen, Denmark
September 15th, 2004

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Originally prepared for OSD/Office of Net Assessment

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Information Age Combat Model

Agenda

- Introduction
- Structure of an IACM
  - Basic Structure
  - Types of Cycles
- Dynamics
  - Measuring Networked Effects
  - Autocatalysis in a Combat Model
- Evolution
  - Core Shifts
  - Long Term Statistics

Introduction

- Existing models focus on attrition and can not adequately represent proposed Information Age combat processes.
- Three views of a Distributed Networked System:
  - Structure
    - What are the links, nodes, boundaries and rules for connection?
  - Dynamics
    - Do actual or potential networked effects exist?
  - Evolution
    - What trajectories do the descriptive characteristics take?
      - Do they converge, diverge or cycle?
- These three perspectives are used to create the Information Age Combat Model

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Structure

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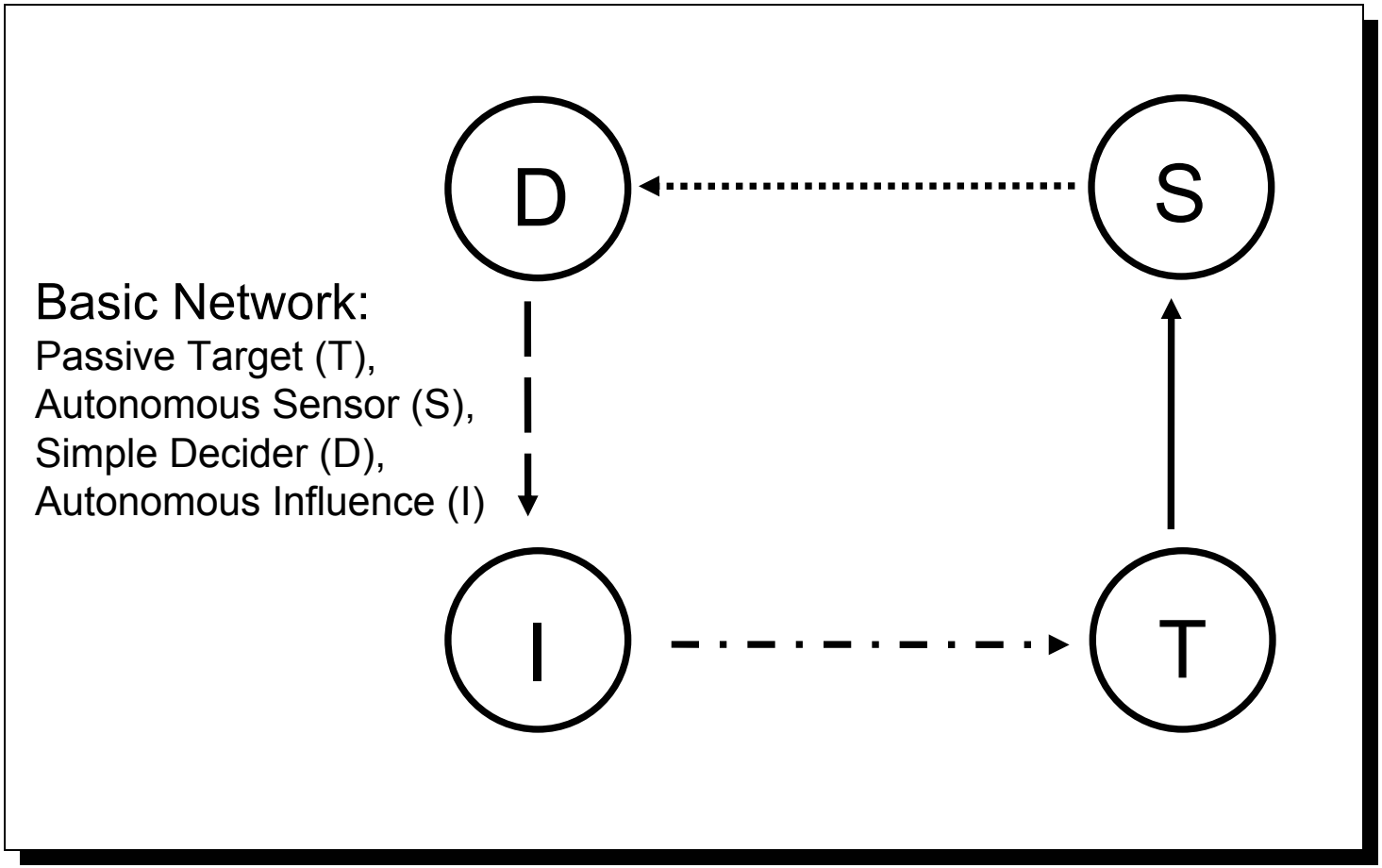
Combat Network



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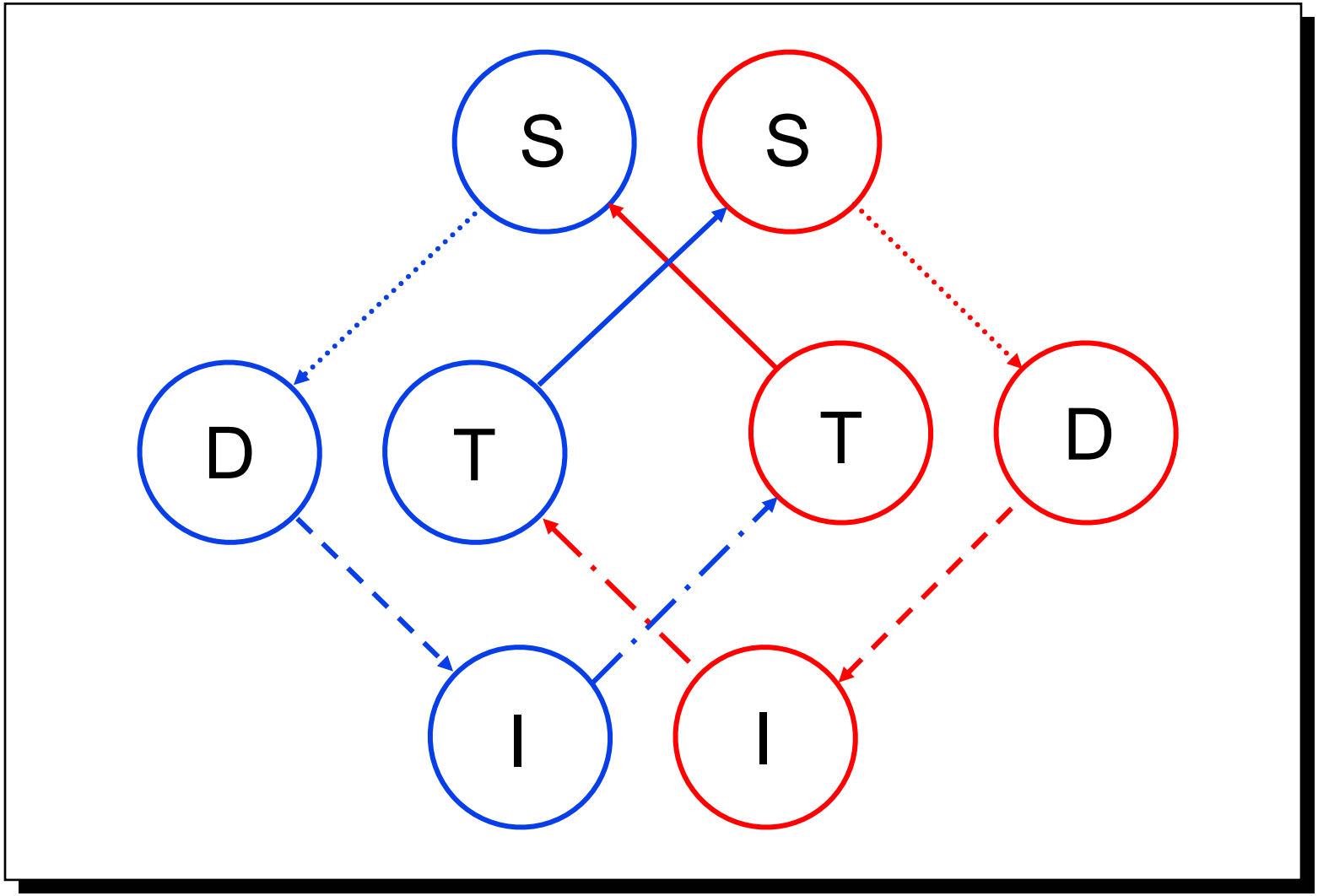
Two-Sided Simple Combat



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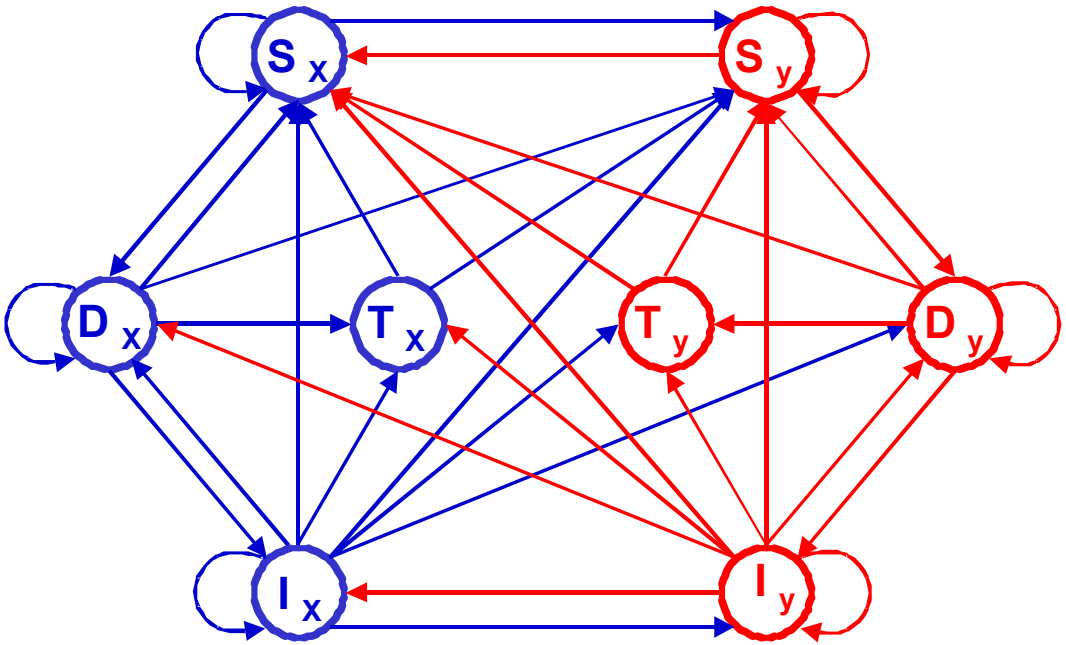
Allowable Connections

Simplest complete combat network



S: Sensor
D: Decision Maker
I: Influencer
T: Target

Adjacency Matrix

Adjacency Matrix for Simplest, Complete Combat Network

	S_x	D_x	I_x	T_x	S_y	D_y	I_y	T_y
S_x	1	1	0	0	1	0	0	0
D_x	1	1	1	1	1	0	0	0
I_x	1	1	1	1	1	1	1	1
T_x	1	0	0	0	1	0	0	0
S_y	1	0	0	0	1	1	0	0
D_y	1	0	0	0	1	1	1	1
I_y	1	1	1	1	1	1	1	1
T_y	1	0	0	0	1	0	0	0

row maps directionally to column = 1, 0 otherwise

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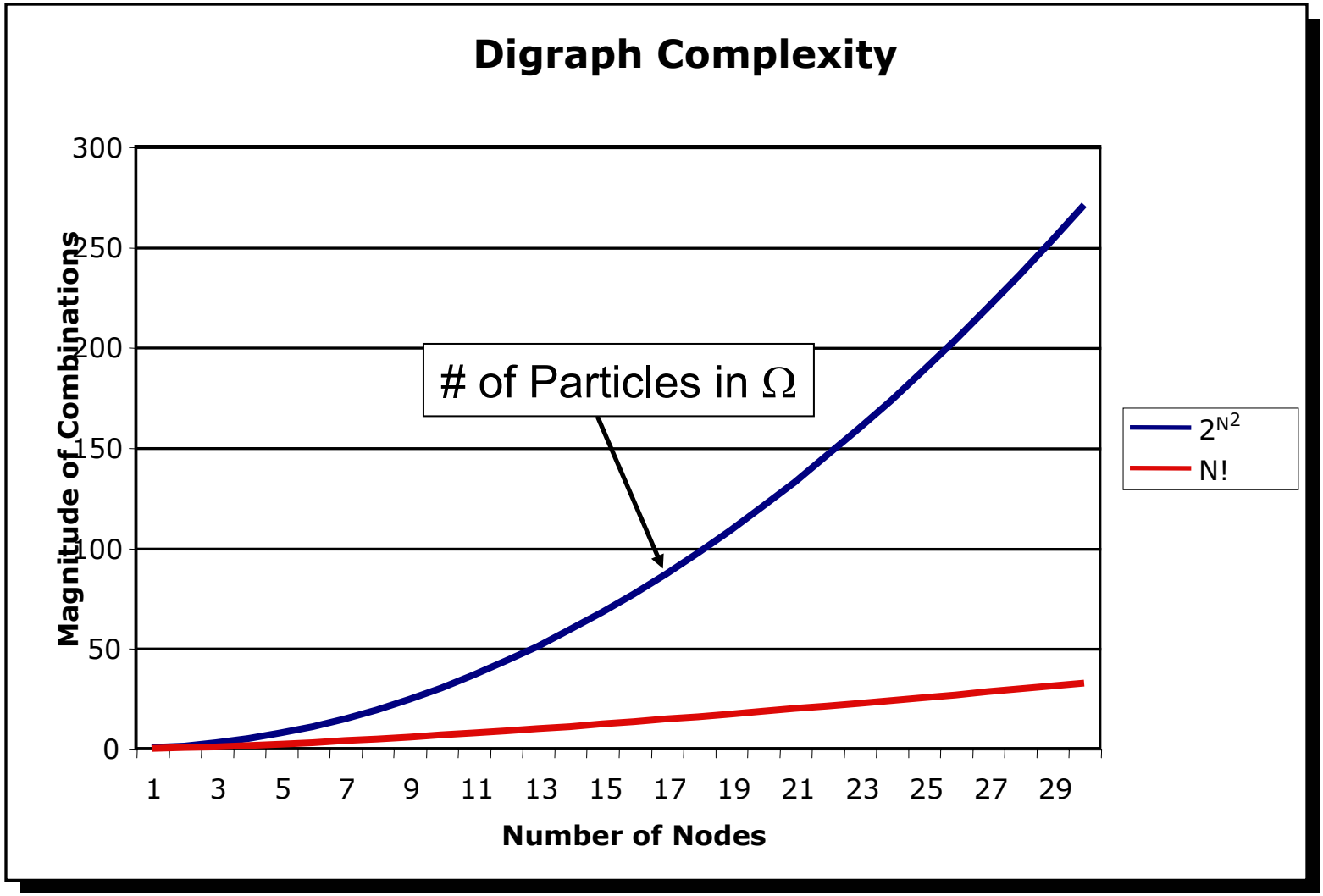
Combat Model Potential Complexity



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Dynamics

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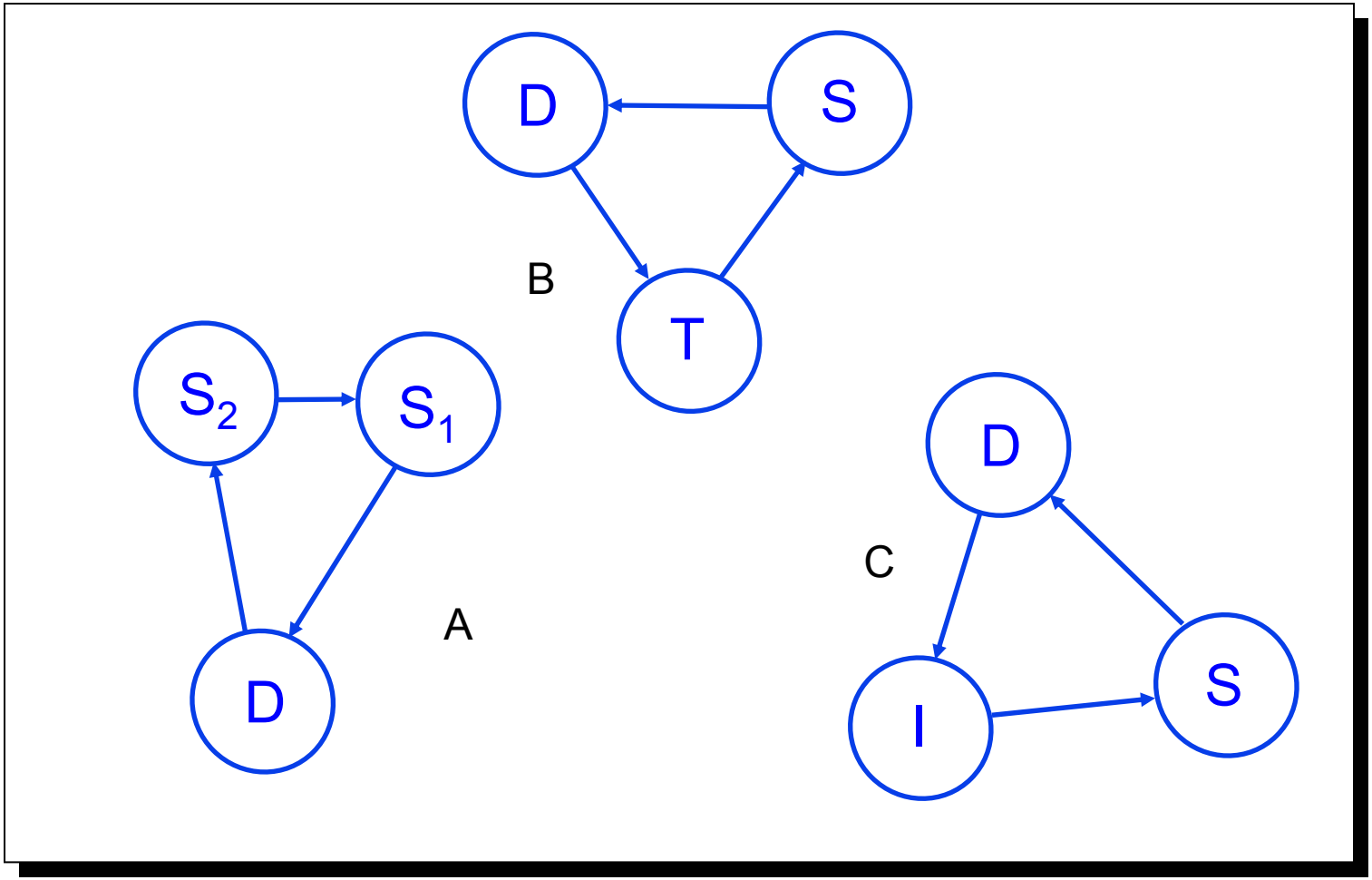
Control Cycles



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Catalytic Control Cycles

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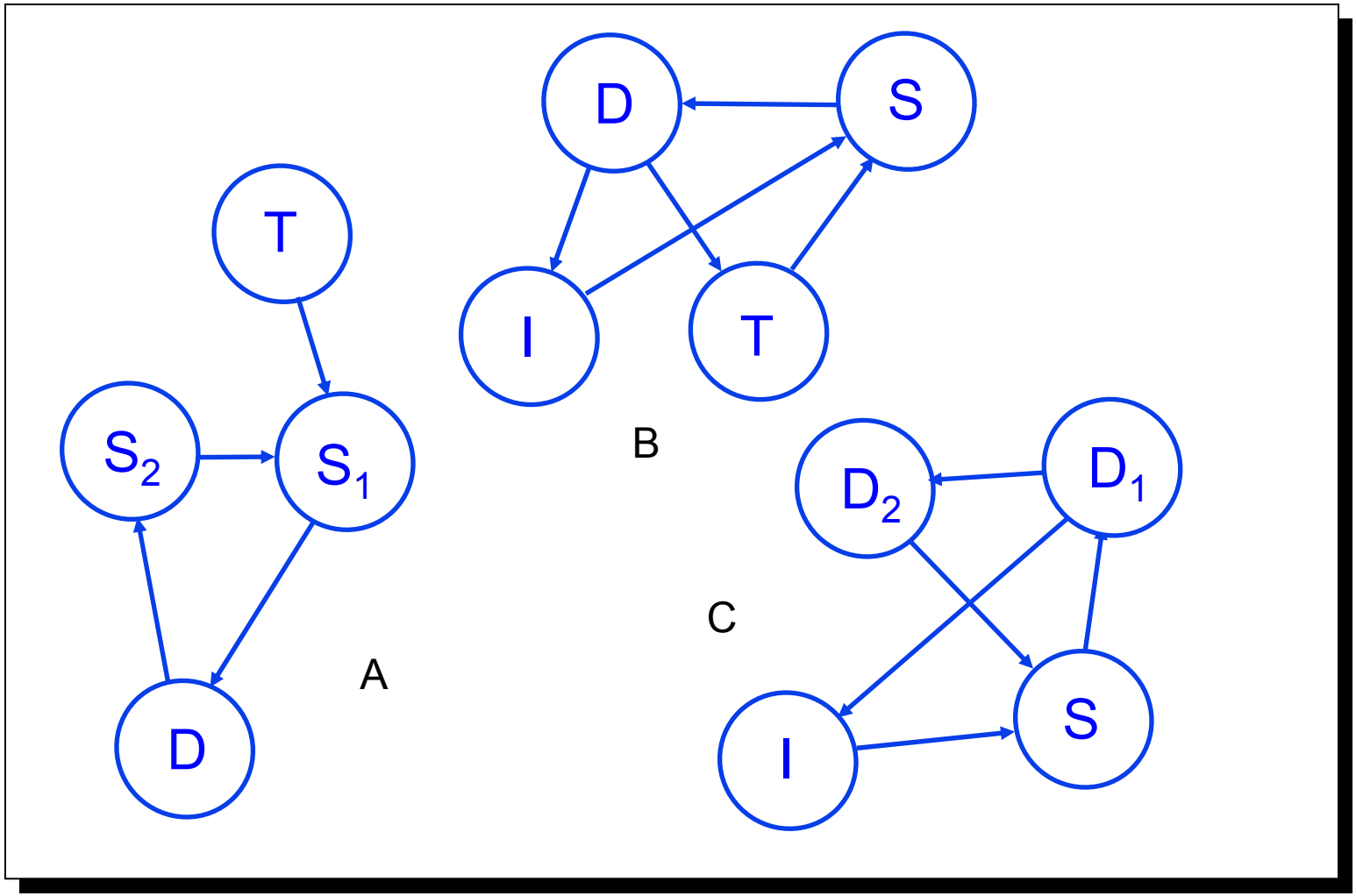

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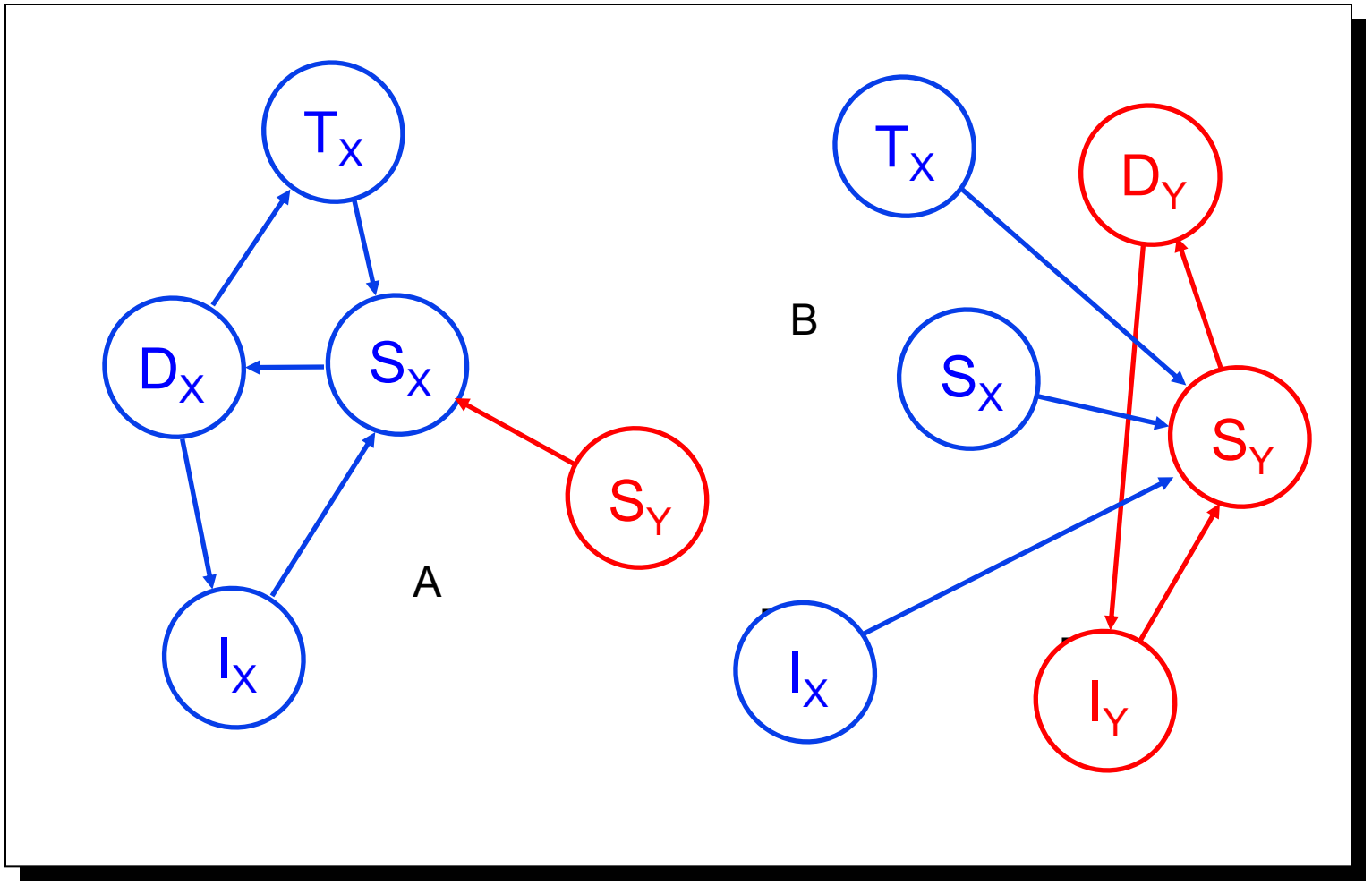
Catalytic Competitive Cycles



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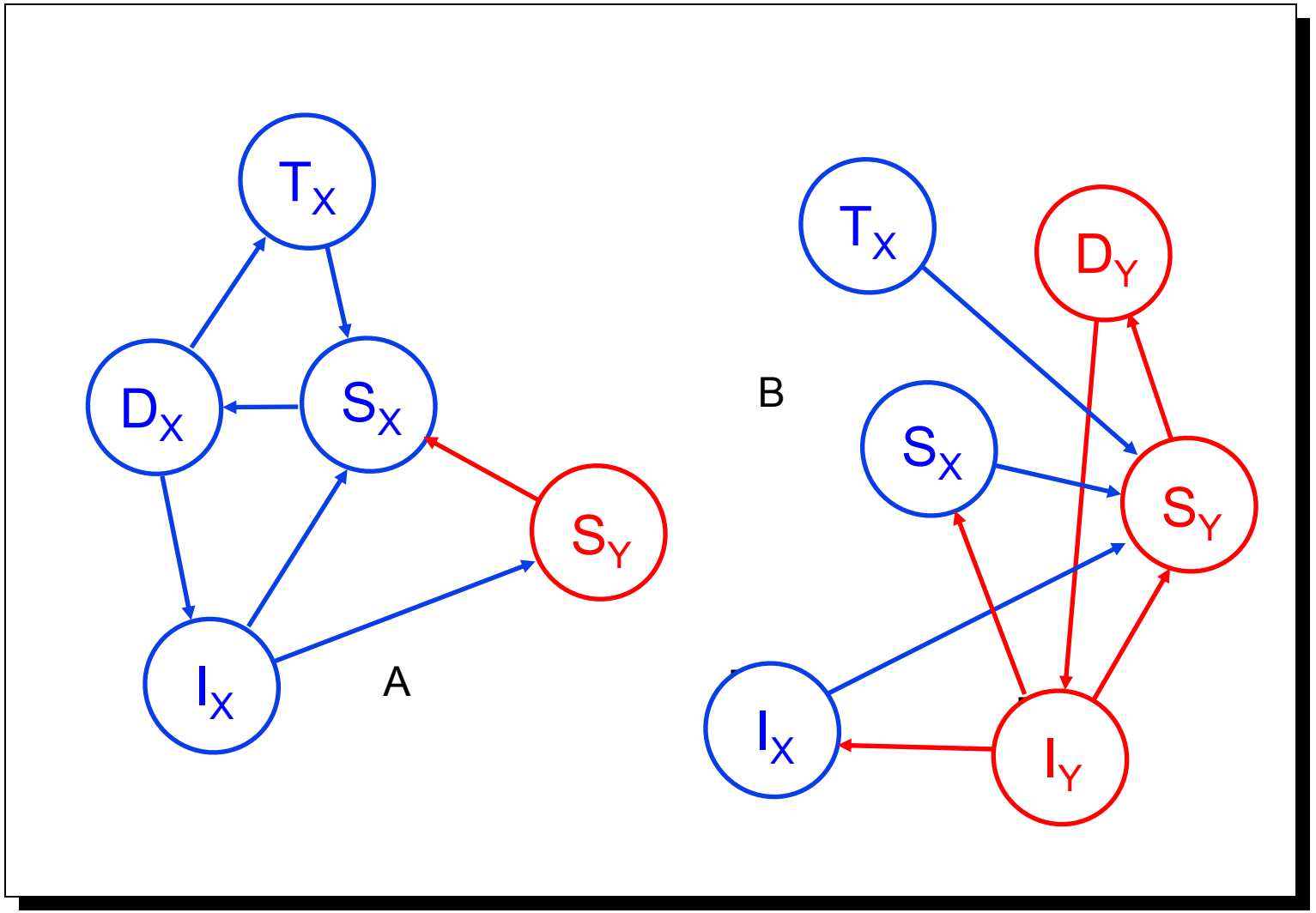
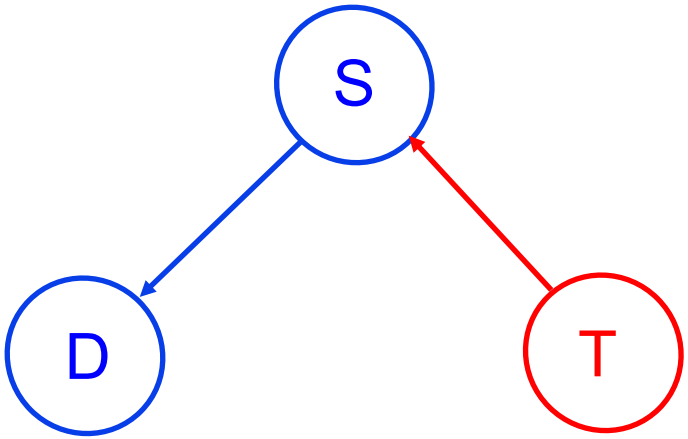
Combat Cycles



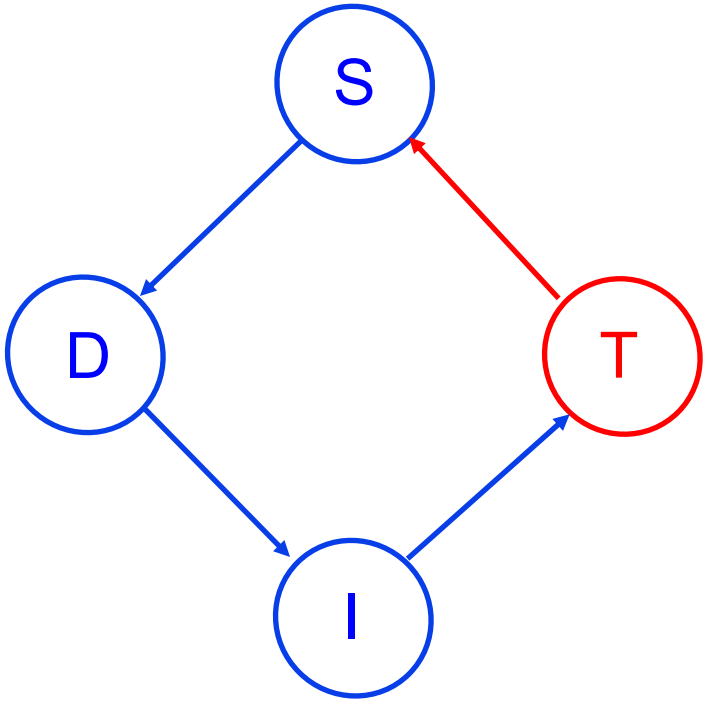
No Cycle



$$\begin{array}{c} \\ T \\ S \\ D \end{array} \begin{array}{c} \begin{array}{ccc} T & S & D \end{array} \\ \begin{pmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} \end{array}$$

$$\lambda_{PFE} = 0$$

Cycle



$$\begin{array}{c} \\ T \\ S \\ D \\ I \end{array} \begin{array}{c} \begin{array}{cccc} T & S & D & I \end{array} \\ \begin{pmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{pmatrix} \end{array}$$

$$\lambda_{PFE} = 1$$

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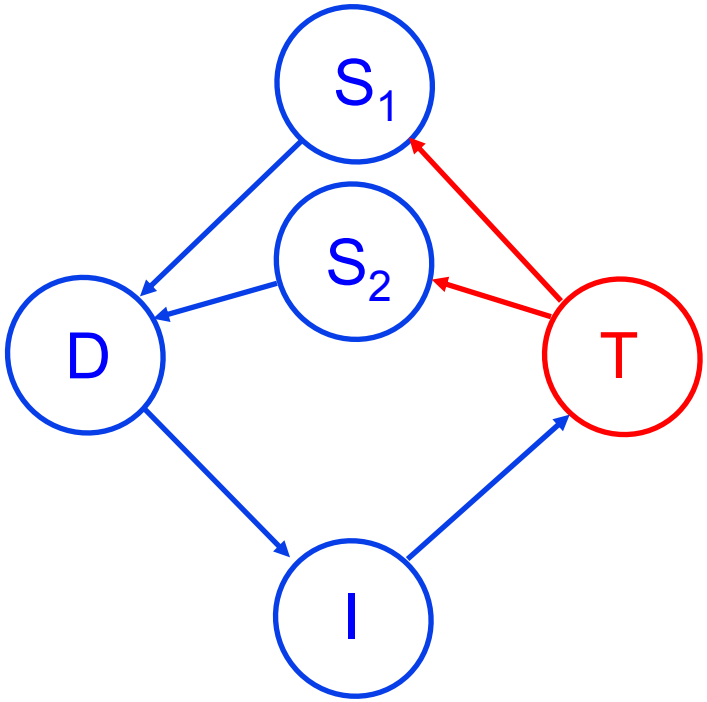
Information Age Combat Model

Autocatalytic Set



	T	S_1	S_2	D	I
T	0	0	0	0	1
S_1	1	0	0	0	0
S_2	1	0	0	0	0
D	0	1	1	0	0
I	0	0	0	1	0

$\lambda_{PFE} = 1.19$

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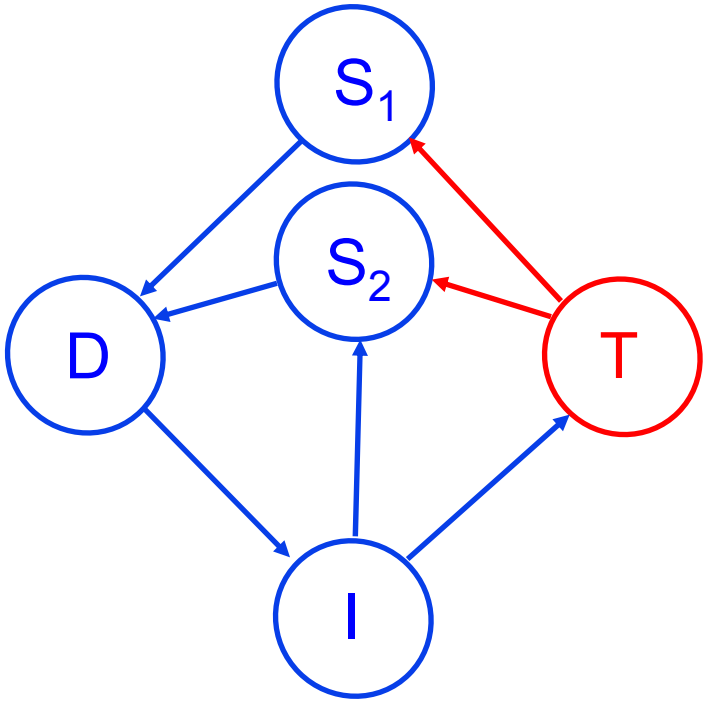
Autocatalytic Set



	T	S_1	S_2	D	I
T	0	0	0	0	1
S_1	1	0	0	0	0
S_2	1	0	0	0	1
D	0	1	1	0	0
I	0	0	0	1	0

$\lambda_{PFE} = 1.35$

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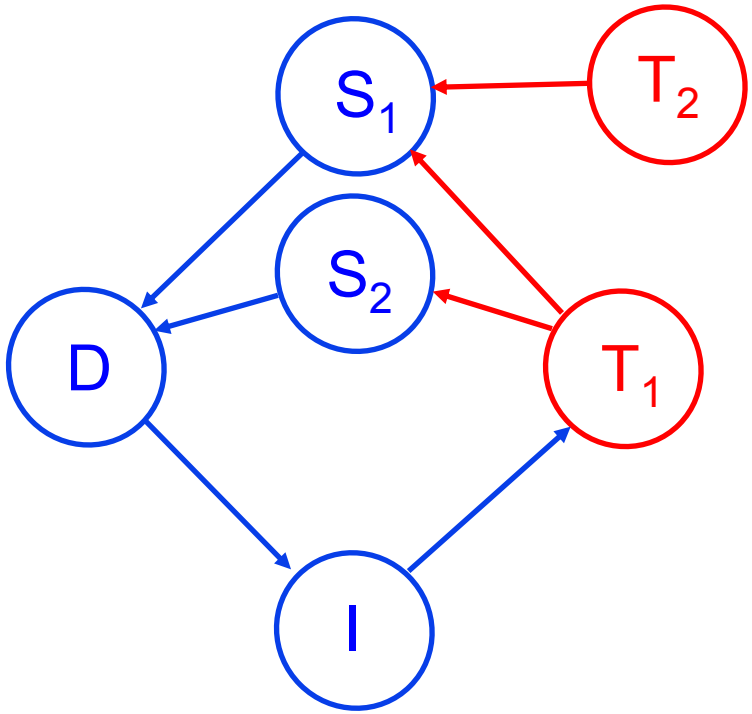
Autocatalytic Set



	T_1	T_2	S_1	S_2	D	I
T_1	0	0	0	0	0	1
T_2	0	0	0	0	0	0
S_1	1	1	0	0	0	0
S_2	1	0	0	0	0	0
D	0	0	1	1	0	0
I	0	0	0	0	1	0

$\lambda_{PFE} = 1.19$

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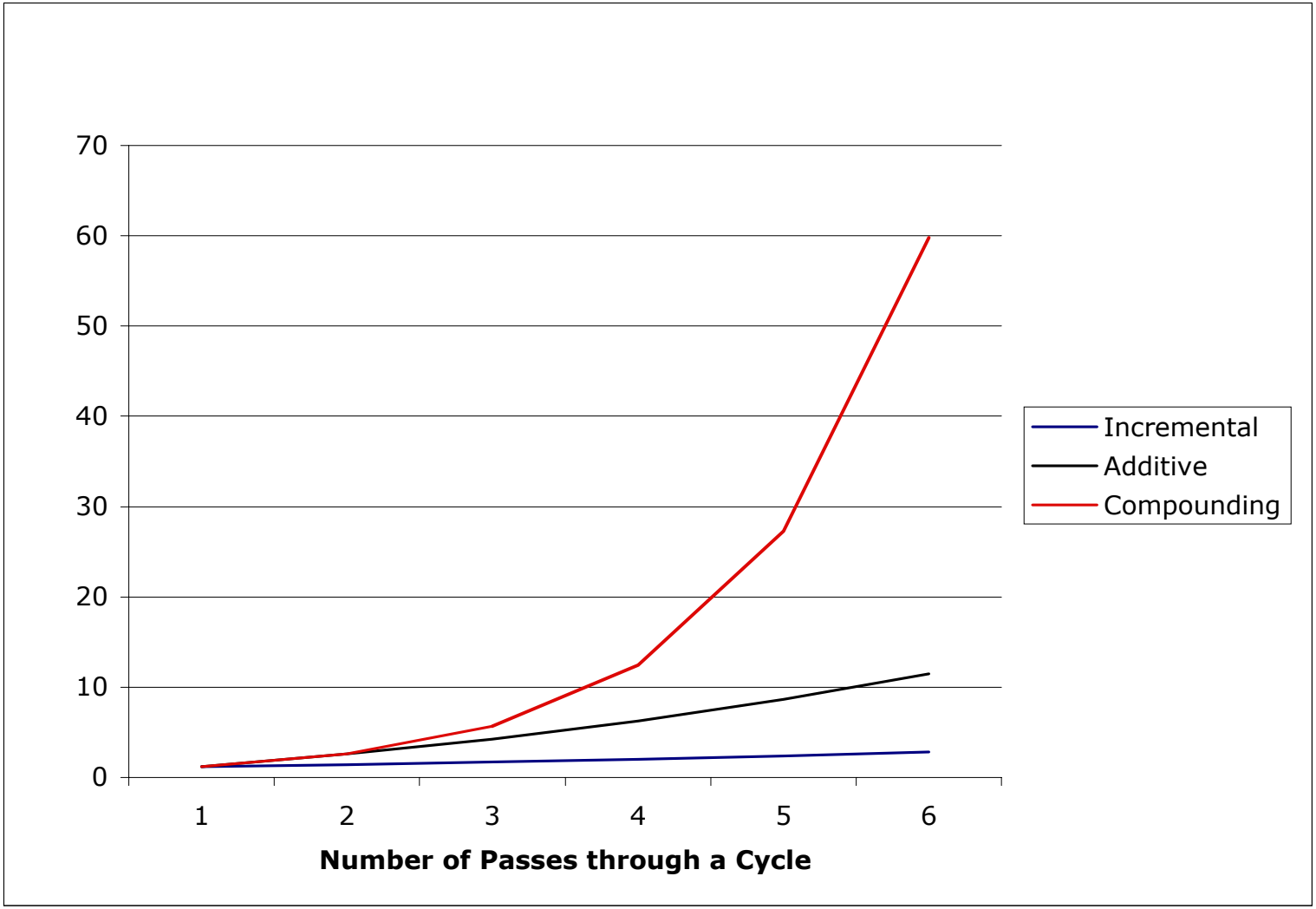
Networked Effects



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Evolution

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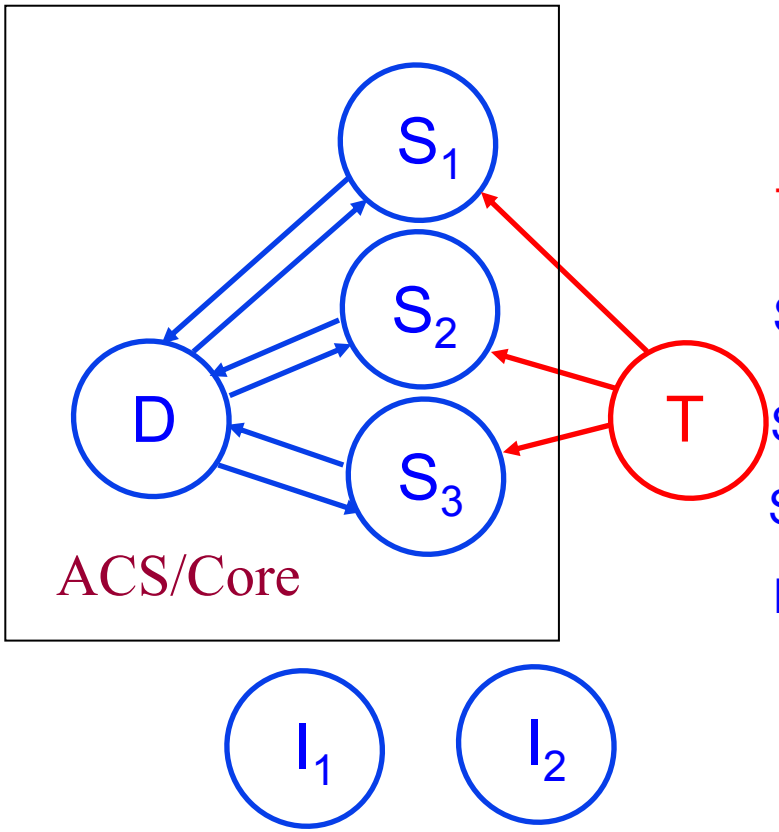
Core Shift

Time Step 1



	T	S_1	S_2	S_3	D	I_1	I_2
T	0	0	0	0	0	0	0
S_1	1	0	0	0	1	0	0
S_2	1	0	0	0	1	0	0
S_3	1	0	0	0	1	0	0
D	0	1	1	1	0	0	0
I_1	0	0	0	0	0	0	0
I_2	0	0	0	0	0	0	0

$\lambda_{PFE} = 1.73$

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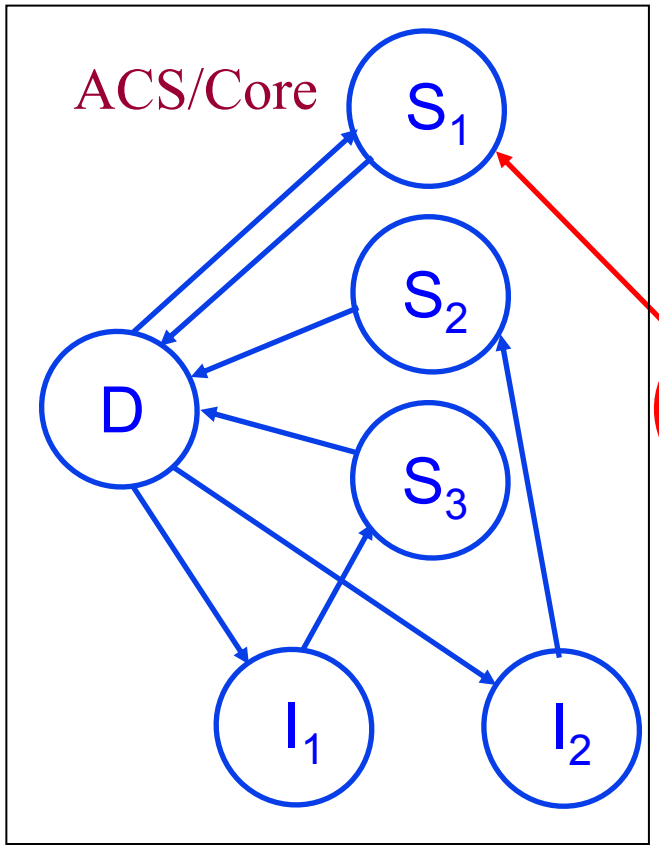
Core Shift

Time Step 2

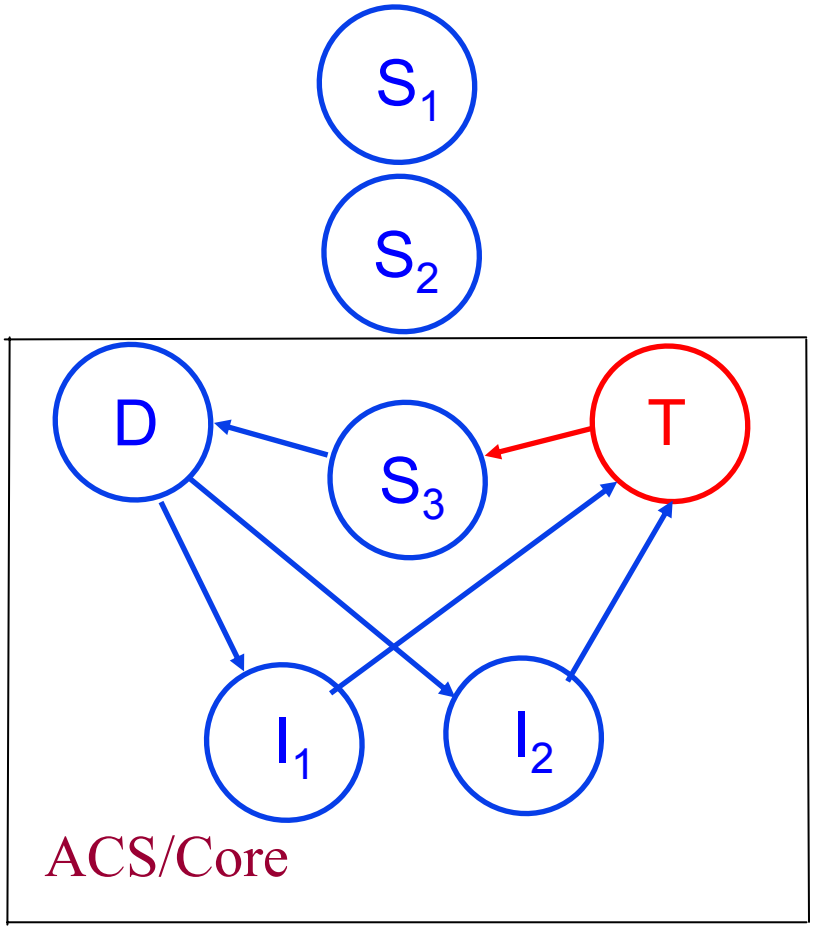


	T	S_1	S_2	S_3	D	I_1	I_2
T	0	0	0	0	0	0	0
S_1	1	0	0	0	1	0	0
S_2	0	0	0	0	0	0	1
S_3	0	0	0	0	0	1	0
D	0	1	1	1	0	0	0
I_1	0	0	0	0	1	0	0
I_2	0	0	0	0	1	0	0

$\lambda_{PFE} = 1.52$

Core Shift

Time Step 3



	T	S_1	S_2	S_3	D	I_1	I_2
T	0	0	0	0	0	1	1
S_1	0	0	0	0	0	0	0
S_2	0	0	0	0	0	0	0
S_3	1	0	0	0	0	0	0
D	0	0	0	1	0	0	0
I_1	0	0	0	0	1	0	0
I_2	0	0	0	0	1	0	0

$\lambda_{PFE} = 1.19$

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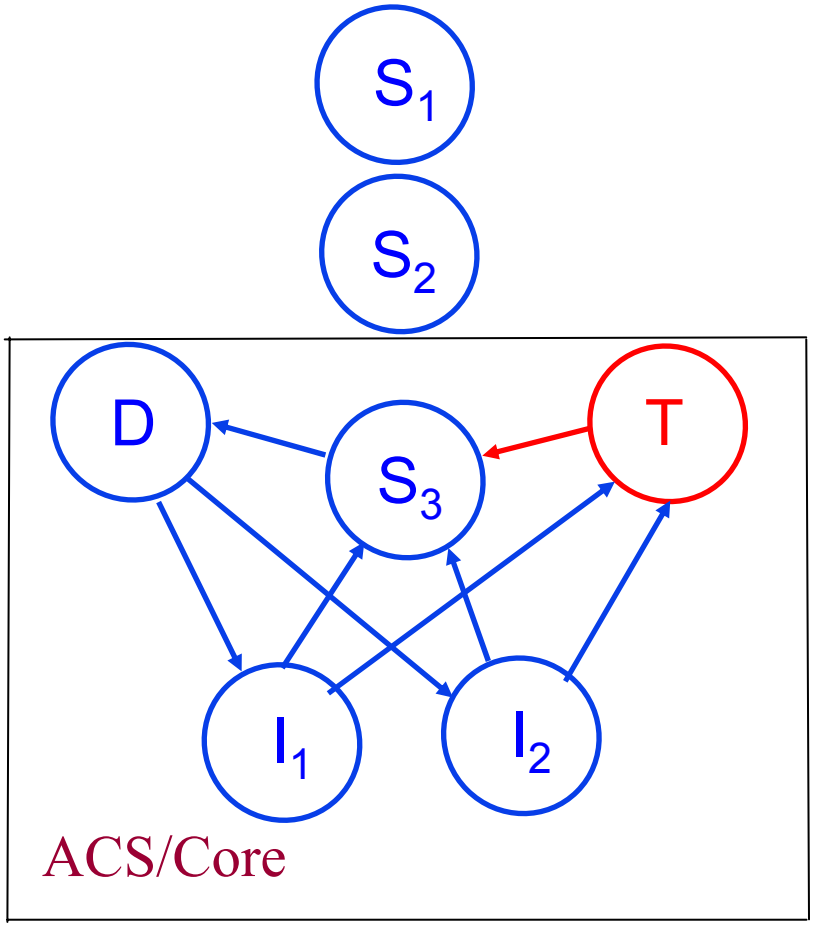
Core Shift

Time Step 4



	T	S_1	S_2	S_3	D	I_1	I_2
T	0	0	0	0	0	1	1
S_1	0	0	0	0	0	0	0
S_2	0	0	0	0	0	0	0
S_3	1	0	0	0	0	1	1
D	0	0	0	1	0	0	0
I_1	0	0	0	0	1	0	0
I_2	0	0	0	0	1	0	0

$\lambda_{PFE} = 1.50$

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Thumb Rules

Analysis and Experimentation

Property	Range	Effect
Number of nodes, n	n > ~100	Network effects unlikely to occur with n < 50
Number of links, l	l < ~2n	l << 2n, too brittle l >> 2n, too much overhead
Degree distribution	Skewed	Adaptivity, modularity
Largest hub	< 100 links	Hub appears, recedes by reconnection 5% of links
Average path length	log(n)	Short distances even for large networks (e.g., 10^4 nodes → Average path length = ~4)
Clustering	Skewed	Hierarchy, organization
Between-ness	Skewed	Cascade control
Path horizon	log(n)	Self-synchronization
Susceptibility/ Robustness	Low (random removal) High (focused removal)	Hubs should be kept obscure until needed, damage abatement/repair schemes
Neutrality	High	Increased network effects, decreased susceptibility, tipping points

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Complex Systems Research

Process Innovation & Analysis

Strategic Investment Advice

Future Concept Generation

Corporate/Government War Games & Events

Questions?