SoSECIE Webinar

Welcome to the
2019 System of Systems Engineering Collaborators Information Exchange (SoSECIE)

We will start at 11AM Eastern Time

Skype Meeting +1 (703) 983-2020, 46013573#

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NDIA System of Systems SE Committee

- **Mission**
  - To provide a forum where government, industry, and academia can share lessons learned, promote best practices, address issues, and advocate systems engineering for Systems of Systems (SoS)
  - To identify successful strategies for applying systems engineering principles to systems engineering of SoS
- **Operating Practices**
  - Face to face and virtual SoS Committee meetings are held in conjunction with NDIA SE Division meetings that occur in February, April, June, and August
  - SoS Track at NDIA 22nd Annual Systems Engineering Conference, Grand Hilton Tampa Downtown, Tampa, FL, October 21-24, 2019
    - Conference Info: http://www.ndia.org/events/2019/10/21/22nd-annual-systems-and-mission-engineering-conference

NDIA SE Division SoS Committee Industry Chairs:
Mr. Rick Poel, Boeing
Ms. Jennie Horne, Raytheon
OSD Liaison:
Dr. Judith Dahmann, MITRE

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- I have muted all participant lines for this introduction and the briefing.
- If you need to contact me during the briefing, send me an e-mail at sosecie@mitre.org.
- Download the presentation so you can follow along on your own
- We will hold all questions until the end:
  - I will start with questions submitted online via the CHAT window in Skype.
  - I will then take questions via telephone; State your name, organization, and question clearly.
- If a question requires more discussion, the speaker(s) contact info is in the brief.

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2019 System of Systems Engineering Collaborators Information Exchange Webinars

Sponsored by MITRE and NDIA SE Division

June 25, 2019
A Tool for Architecting Socio-Technical Problems: SoS Explorer
Dr. Cihan Dagli

July 16, 2019
Modular Online Open SoS Education (MOOSE)
Mr. Kyle Hastings, The MITRE Corporation

July 30, 2019
Graph Theoretic Architectural Analysis: Analysis of Complex Systems and Systems of Systems
Ms. Laura Antul

August 13, 2019
TBD

August 27, 2019
TBD

2019 System of Systems Engineering Collaborators Information Exchange Webinars

Sponsored by MITRE and NDIA SE Division

September 10, 2019
An Analysis of Systems-of-Systems Opportunities and Challenges Related to Mobility
Mr. Jakob Axelsson

September 24, 2019
TBD

October 8, 2019
TBD

October 22, 2019
Modeling System of Systems Configurations
Mr. Jeremy Buisson, Dr. Isabelle Borne and Mr. Franck Petitdemange

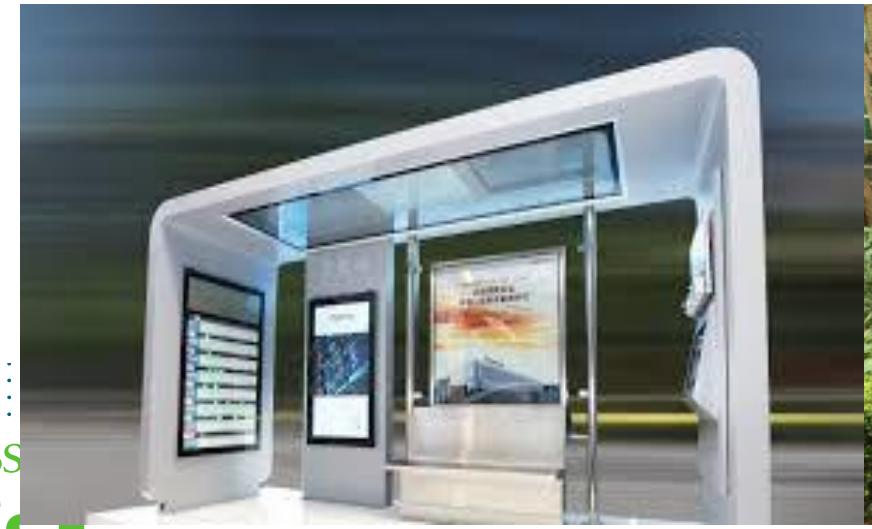
Nov 5, 2019
Irrational System Behavior in a System of Systems
Mr. Douglas L. Van Bossuyt, Mr. Bryan M. O'Halloran and Mr. Ryan M. Arlitt

A Tool for Architecting Socio-Technical Problems: SoS Explorer

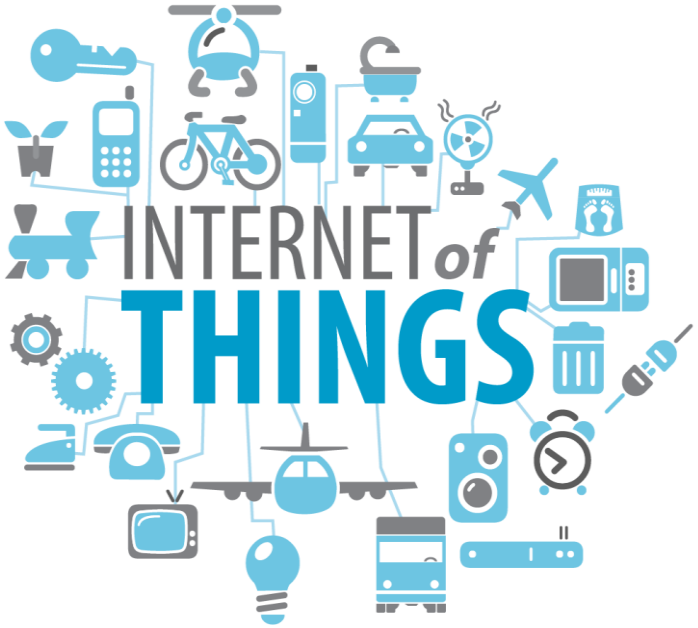
Cihan H. Dagli
Missouri University of Science and Technology

SYSTEM OF SYSTEMS

Changing Human Living Behaviors



SYSTEM OF SYSTEMS



"The network of physical objects that contain embedded technology to communicate and interact with their internal states or the external environment."

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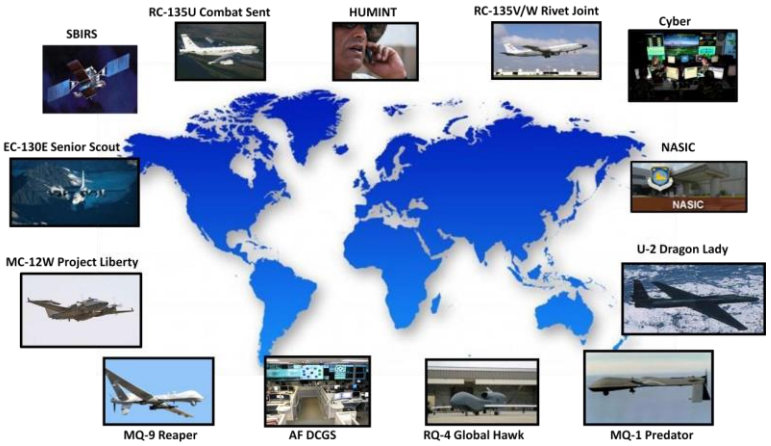
SYSEM OF SYSTEMS

Internet of Things for Defense



Internet of Things for Manufacturing

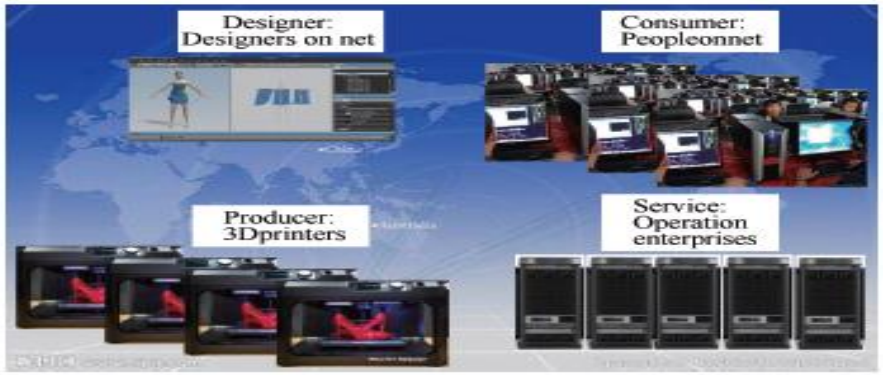


Fig. 4. Social manufacturing array with 3D printing centers.

From Mind to Products: Towards Social Manufacturing and Service Gang Xiong, et.al. IEEE/CAA JOURNAL OF AUTOMATICA SINICA, VOL. 5, NO. 1, JANUARY 2018

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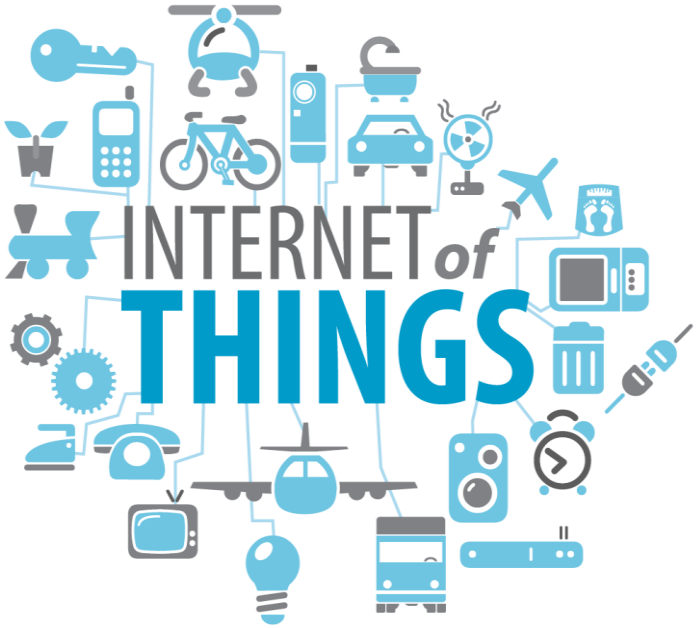
SYSTEM OF SYSTEMS



"This is a complex adaptive systems that can have emergent behavior and requires systems integration and engineering in their design and operation."

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SYSTEM OF SYSTEMS

The integration of technology into society is a socio-technical problem.

The solution to this type of problem results in a system of systems often called a cyber-physical system.

These systems of systems are ubiquitous, ranging from transportation and healthcare to energy and defense.

How well they are architected has a significant impact on sustainability and quality of life.

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SOS ARCHITECTING

At its core, system of systems architecting is finding the set of systems and interfaces that best satisfy a set of given objectives while providing all of the the required capabilities. These objectives are the key performance measures of the architecture.

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SOS CHALLENGES

Defining an optimal system of systems architecture poses significant difficulty as the problem presents:

- A high-dimensional solution space and trade space (difficult to search or visualize),
- Numerous objectives (causes Pareto breakdown and is difficult to optimize),
- Interactions that create emergent behaviors (difficult to predict).

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APPROACH

1. Model each objective as a function of systems and interfaces. The systems are defined by characteristics, capabilities, and feasible interfaces.
2. Model architectural constraints in terms of systems, interfaces, and capabilities.
3. Use a many-objective optimization algorithm to find optimal architectures while maintaining constraints.
4. Provide solutions to the decision-maker in a manner that allows the decision-maker to modify solutions and to explore the trade-space.

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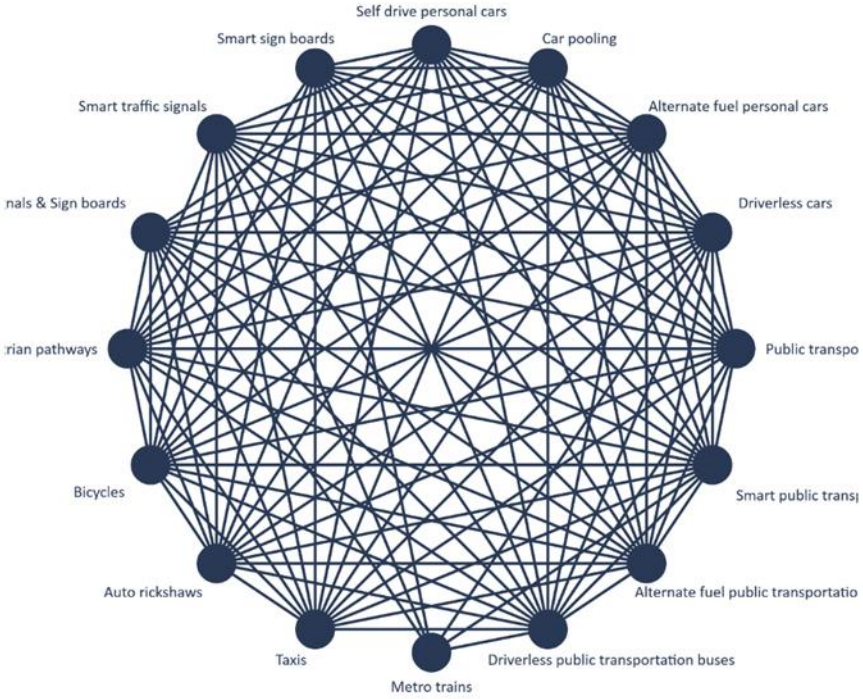
META ARCHITECTURE

Meta-architecture generated for the identified 16 systems and their interfaces are shown below.



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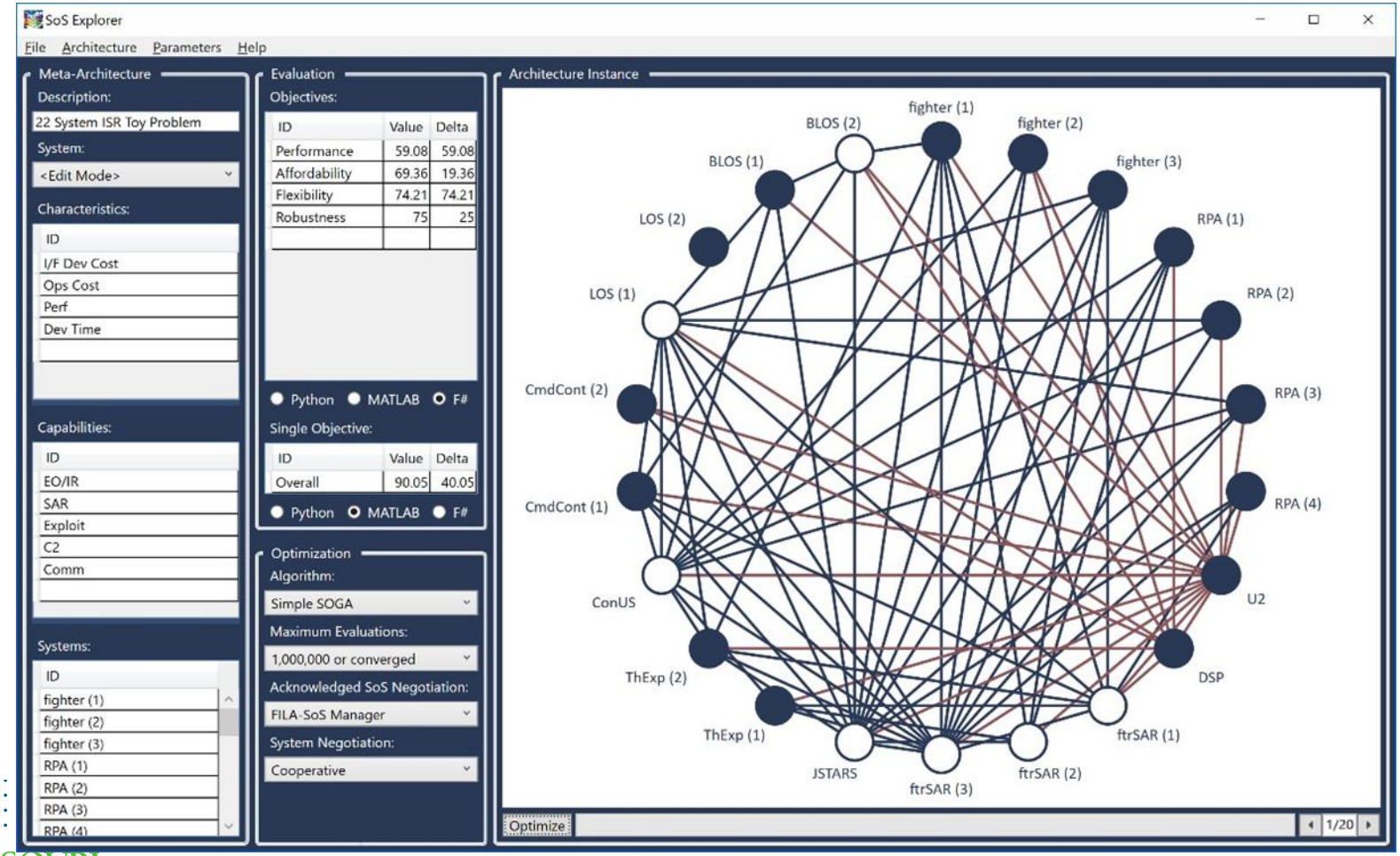
SoS EXPLORER



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SoS EXPLORER

SoS Explorer is a tool developed by the Engineering Management and Systems Engineering department at Missouri University of Science and Technology.

This tool incorporates the given approach, allowing modeling of objectives and constraints in three languages: MATLAB, Python, and F#.

It utilizes evolutionary algorithms and supports both single- and many-objective optimization.

It also provides an interactive GUI and real-time evaluation of solutions and deltas between solutions.

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ARCHITECTING

- Improving System-of-Systems means improving System-of-Systems architectures.
- System-of-Systems architectures must make trade-offs between many competing objectives, for example:
  - Affordability
  - Reliability
  - Sustainability
  - Flexibility
  - Performance
- Choosing a best architecture is a multi-Objective optimization problem.

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OBSTACLES

- Multi-objective optimization problems are difficult for a number of reasons:
- Finding optimal solutions requires careful modeling and advanced optimization methods.
- The number of optimal solutions is usually too large to be comprehended.
- Creating a final architecture from a subset of optimal solutions can easily become arbitrary and sub-optimal.

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REMOVING OBSTACLES

- System-of-Systems architecting could be improved by
  - Structuring the modeling effort
  - Optimization methods yielding targeted solution sets
  - Visualization of architectures
  - Interactive architectures allowing “what-if” experimentation

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SoS EXPLORER

- SoS Explorer is our solution to the previously identified architecting difficulties. It provides Structure for the modeling effort
- A novel optimization method called “MOEA-DM” tailored to the needs of SoS architects:
  - Many-objective optimization
  - Use of clustering to cultivate a limited set of solutions of interest
- Visualization of architectures
- Interactive “what-if” experimentation

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OVERALL APPROACH

- The SoS architecture is comprised of systems and their interfaces.
- Systems are modeled using the following attributes:
  - Characteristics: Real-valued attributes such as cost and MTBF.
  - Capabilities: Boolean attributes that a system either has or doesn't have such as a VHF radio or ground-mapping radar.
  - Interfaces: Boolean attributes describing whether a system can support an interface with another system.
- The models output key performance metrics that are used as the objectives in the provided optimization algorithms.

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MODELING

- The models take as input the system attributes and calculate the values of the KPMs.
- The models are used for two purposes: to display the KPMs for the displayed architecture and for the optimization algorithms.
- Models may be written in any of the following languages:
  - Python,
  - MATLAB,
  - F#

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LANGUAGE SELECTION

- The languages can be selected based on the priority of the modeler:
  - Python provides portability and can be run without anything installed other than SoS Explorer.
  - MATLAB provides a rich set of tools but requires MATLAB to be installed.
  - F# is a compiled Microsoft .NET language and is around 100 times faster than MATLAB and Python. However, it requires the F# SDK (free from Microsoft) to be installed.

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CODE GENERATION

- SoS Explorer can auto-gen source for each KPM in any supported language. The code is a fully functioning template for creating a model:
  - All systems and attributes are fully mapped
  - Sample calculations illustrating scalable methods of using the attributes and given architecture to find a KPM.

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OPTIMIZATION

- SoS Explorer supports
  - Single objective optimization
    - User specifies a function (Python, MATLAB, or F#) to map the objectives to a single overall objective
    - Employs the SOGA genetic algorithm
  - Multiple objective optimization
    - Supports the NSGA-III many objective algorithm
    - Supports the MOEA-DM many objective algorithm

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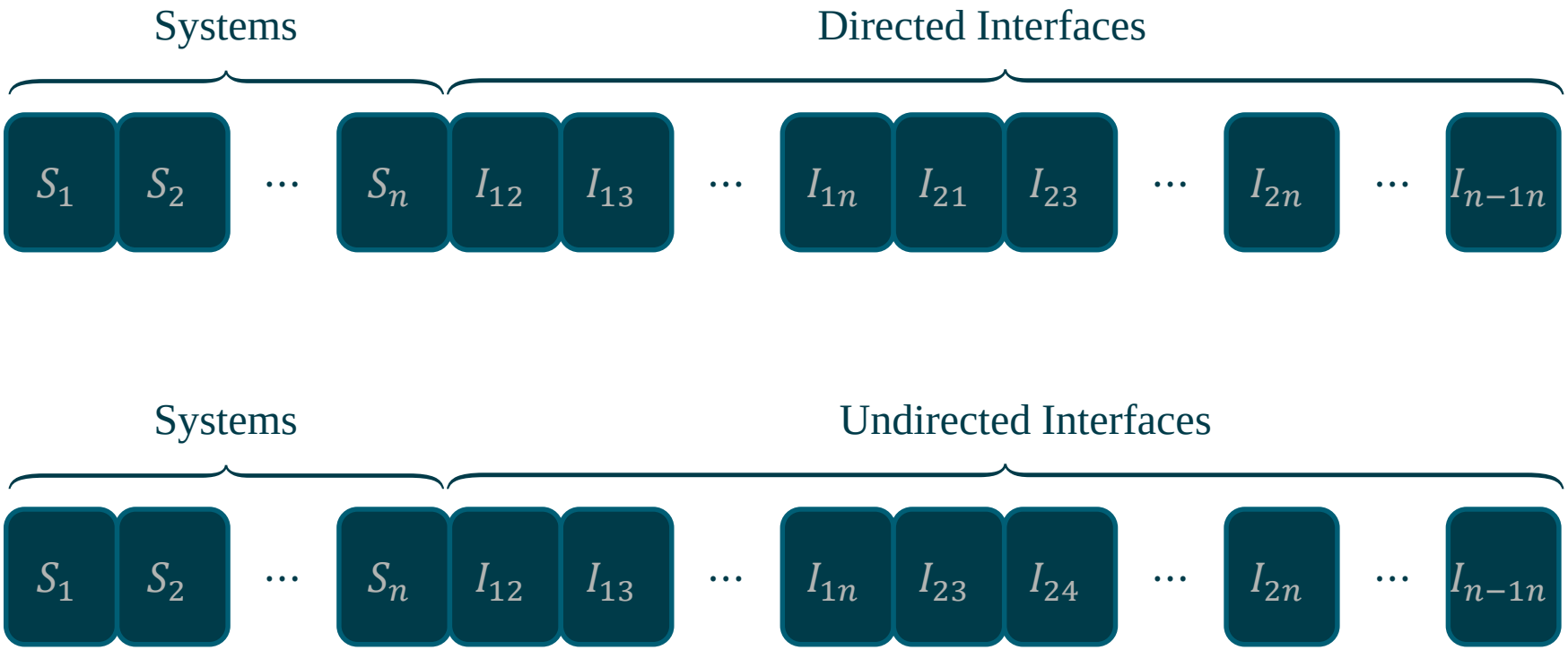
CHROMOSOME



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Cybersecurity as a Centralized Directed System of Systems Example

Lirim Ashiku, SysEng PhD Student

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Is this Strong Business Cybersecurity?

Normal Download

I just copy it

BYOD to work

Backed access for trouble shooting

It people will take care of it.

Can not remember it?.

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What is Cybersecurity?

> Measures and actions taken to prevent unauthorized access to, manipulations of, or destruction of systems, networks and programs.

Why do we care?

- Identity theft
- Extortion
- Loss of important data
- Financial loss
- Business loss
- Transportation issues
- Digital manufacturing
- Power plants, etc

Focus on banking security

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Why Banks?

- According to research, most critical domain prone to cyber-attacks
  - JPMorgan Chase (83 million accounts)
  - Heartland Payment Systems (134 million accounts)
  - Global Payments, Inc. (1.5 million accounts)
  - Citigroup (360K accounts)
- Why?
  - Bank is where the money is
  - Data for millions of users
  - Profit through extortion, theft, fraud

Daily encounter

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Cyberattack Categories

Category	*Short Description*
Malware	*Malicious software infecting systems to steal information*
Social Engineering	*Psychological manipulation that enables access to information*
Password Attacks	*Password cracking tools and techniques to gain access to a network/account*
Denial of Service	*Attempt to disrupt network resources by flooding*
Man in the Middle	*Secretly hijack a session to alter information to end parties while mimicking legitimate communication*
Drive by Downloads	*Automatic downloads of malicious code matching weaknesses of outdated system flaws*
Sniffers	*Software tool that monitors data flow over network in real time*
Malicious Insiders	*Insider threat of a disgruntled employee to retaliate against an employer*
Trap Doors	*Secret entry point into application or OS for debugging and testing purposes bypassing security controls*
Negligent Employee	*Inadvertent compromise providing opportunity for hackers to leverage access to network*

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Defense Mechanisms

Category	*Short Description*
Anti-Malware	*Software protection against malicious code*
IDPS (6)	*Network security threat detection and prevention technology*
Contingency Planning	*Alternatives for disaster recovery and business continuity*
Penetration Testing	*Deliberate software attack to exploit own system vulnerabilities*
UE Behavior Analysis	*Detection of anomalous behaviors deviating from normal conduct*
Security Awareness	*Educating and training personnel on cybersecurity*
Security Policy	*Organizational rules and procedures*
Firewalls (5)	*Network security device monitoring incoming and outgoing traffic*
Cryptography	*Use of protocols to conceal and handle information content*
Multi-Level Security	*Security schemes that enforce multiple level of security clearance*
Whitelisting	*Software applications provided at particular privilege*
User Account Control	*Ability to run and control applications base on security clearance*
Auto-Backup	*Recovery of data and operations against data loss incidents*
Software Patching	*Updates including critical patches to security holes*
User Education	*Creating a cybersecurity culture*

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System Capabilities

24 Systems

10 Capabilities

If System advances capability → 1
Otherwise → 0

SoS Classes

- Virtual
- Collaborative
- Acknowledged
- Directed

Systems	*Capabilities*									
	Malware	Social Engineering	Password Attack	DDoS	MiTM	Driveby downoads	Sniffers	Malicious Insiders	Trap Doors	Negligent Employee
Anti-Malware	1	0	1	0	1	0	1	0	0	0
IDPS-host	1	0	0	1	1	0	1	0	1	0
IDPS-network	0	0	0	1	1	0	1	0	0	0
IDPS-signature	0	0	0	1	1	0	1	0	0	0
IDPS-behavior	0	0	0	1	1	0	1	0	0	0
IDPS-rule	0	0	0	1	1	0	1	0	0	0
IDPS-anomaly	0	0	0	1	1	0	1	0	0	0
Cont. Planning	0	1	1	0	0	0	0	1	1	1
Pen. Testing	0	1	1	0	0	1	1	1	0	0
UEBA	0	1	1	0	0	0	0	1	1	1
SAT	0	1	0	1	0	0	0	1	1	1
Policy	0	1	0	1	0	0	0	1	1	1
FW-packet	0	0	1	0	1	1	0	0	0	0
FW-circuit	0	0	1	0	1	1	0	0	0	0
FW-stateful	0	0	1	0	1	1	1	0	0	0
FW-proxy	0	0	1	0	1	1	1	0	0	0
FW-nextG	0	0	1	0	1	1	1	0	0	0
Cryptography	0	0	1	0	1	0	0	1	1	1
MLS	0	0	1	0	1	0	0	1	1	1
Whitelisting	0	0	1	0	0	1	0	1	1	1
UAC	0	1	1	0	0	0	0	1	1	1
Auto-Backup	0	0	0	0	0	1	0	1	1	0
Patching	0	0	0	0	1	0	0	0	1	0
User Education	0	1	0	0	1	1	0	1	1	1

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Key Performance Parameters

Confidentiality	• Assessess the ability to protect cyber space from unauthorized acces
Integrity	• Assesses the ability of preserving the consistency, accuracy and trustworthiness of cyber space
Availabiilty	• Assesses the ability of allowing authorized users to access cyber space
Resilience	• Assesses the ability to continually deliver the intended use despite incident occurence
Affordability	• Calculates the lowest LCC of implementing a given system, inversely related to cost

Measured in terms of

- **Protect** – *the ability to defend cyber space from attacks*
- **Detect** – *performance of detecting an attack*
- **Respond** – *performance of responding to an attack*
- **Recover** – *estimated time to full recovery*
- **IF Dev Cost** – *interface development cost*
- **Oper-Cost** – *operational costs*

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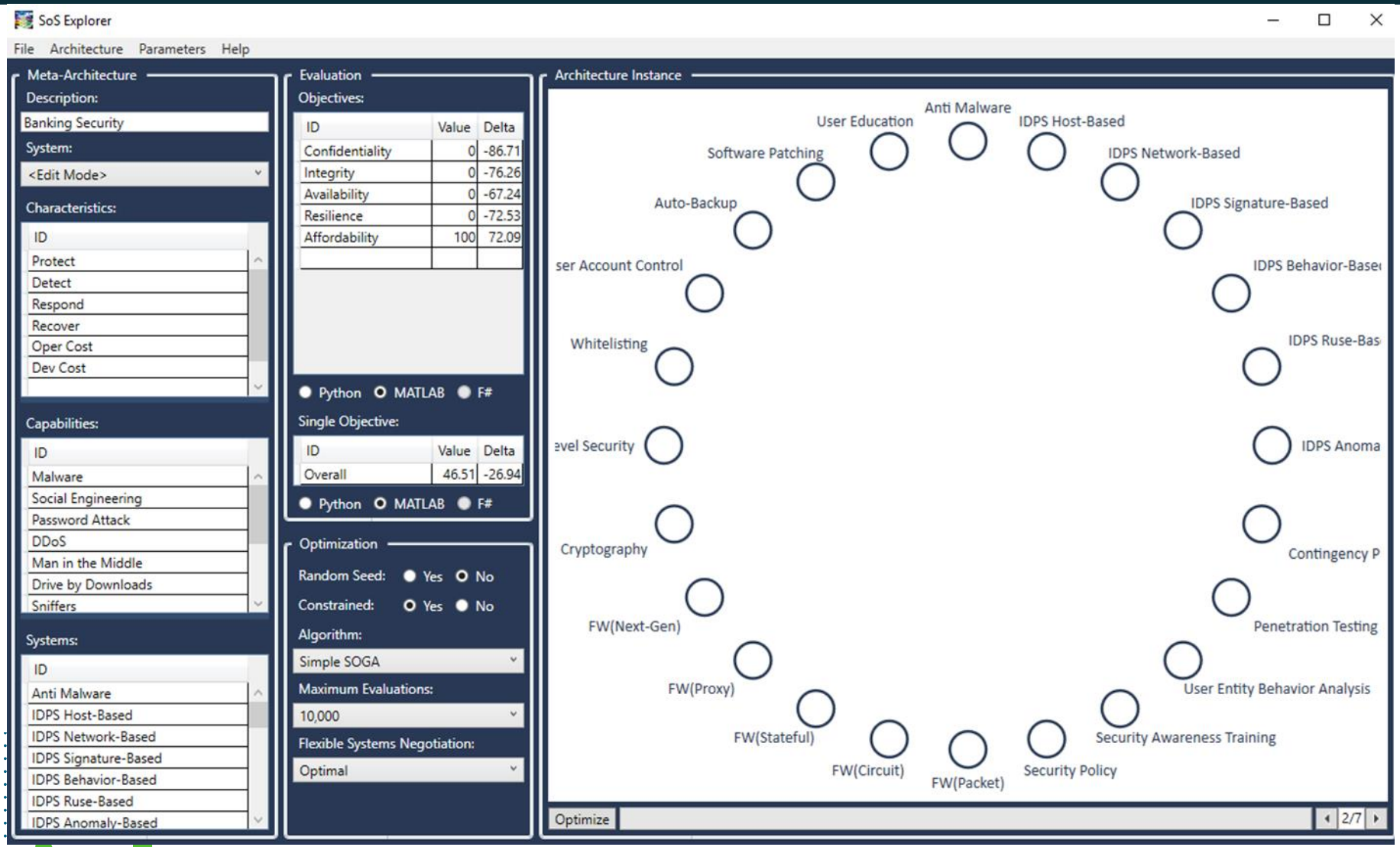
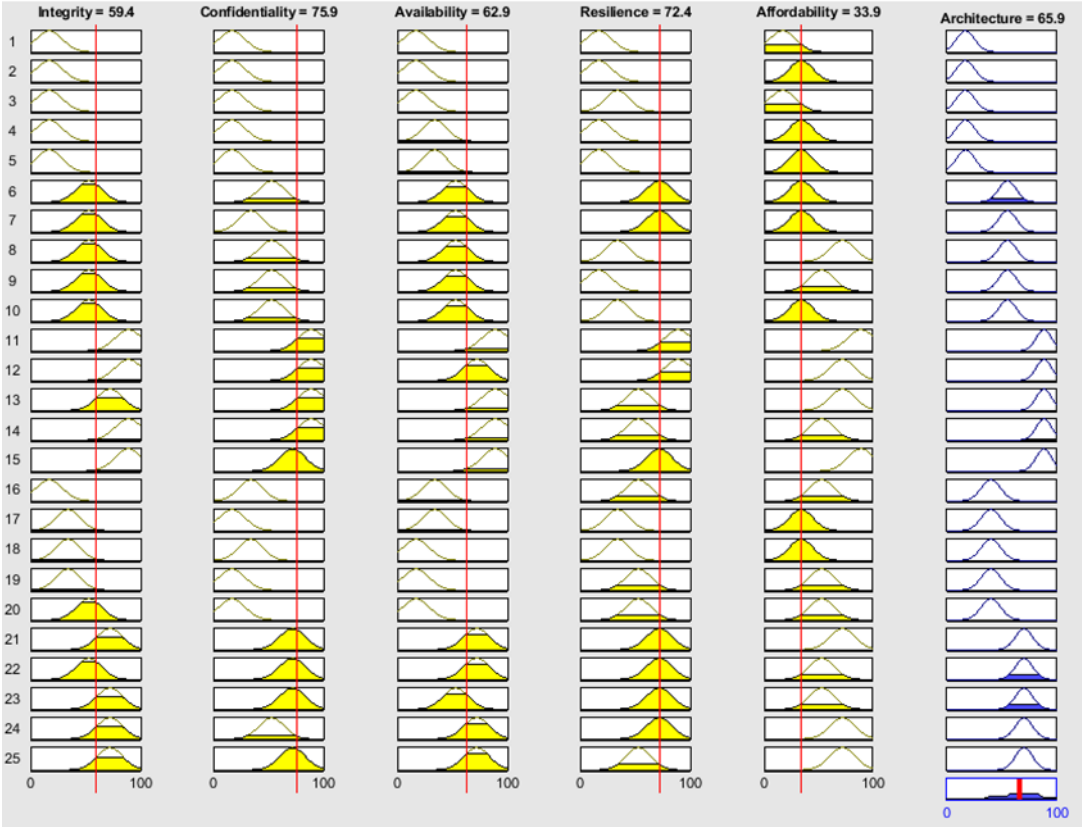
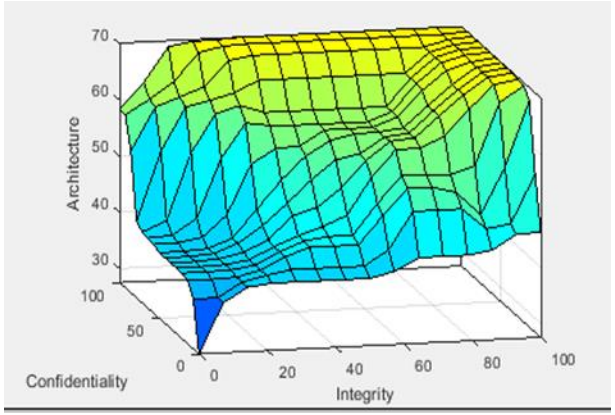
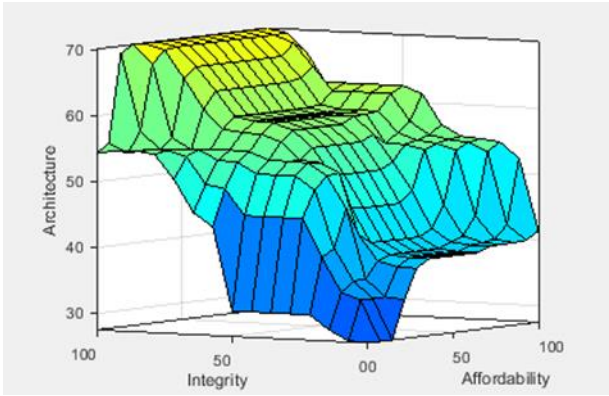
SoS EXPLORER



Fuzzy Rules and Trade Surfaces







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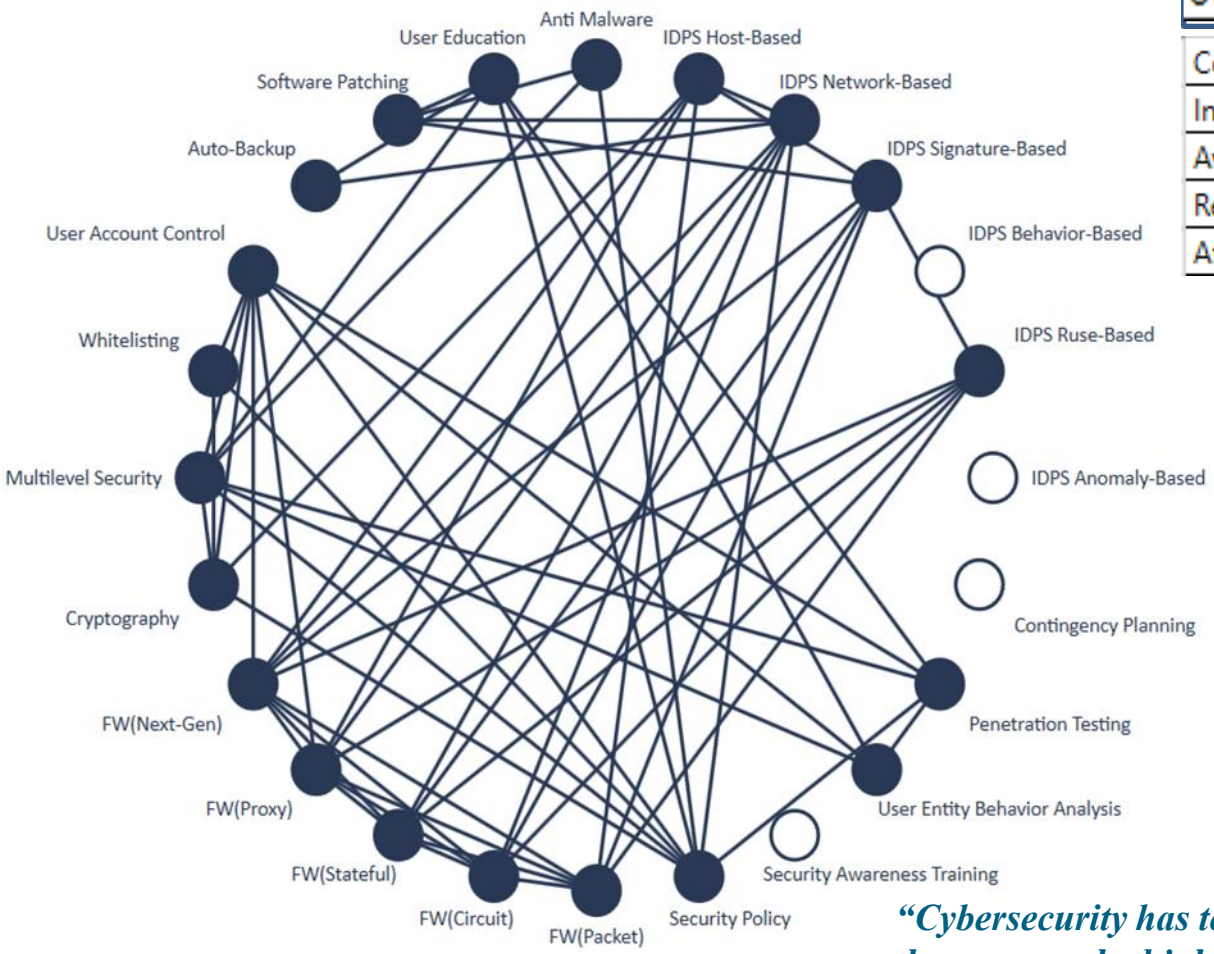
Selected Meta Architecture



Overall	74.32
Confidentialit	82.72
Integrity	75.39
Availability	68.52
Resilience	72.76
Affordability	34.58

Major Contributions:

- **MLS**
- **Software Patching**
- **Anti-Malware**
- **User Education**

"Cybersecurity has to be something that's ingrained into the way people think about new business opportunities and capabilities. It can't be just something that the technology guys are going to fix."

- Joe Nocera, US Financial Services Cybersecurity Leader

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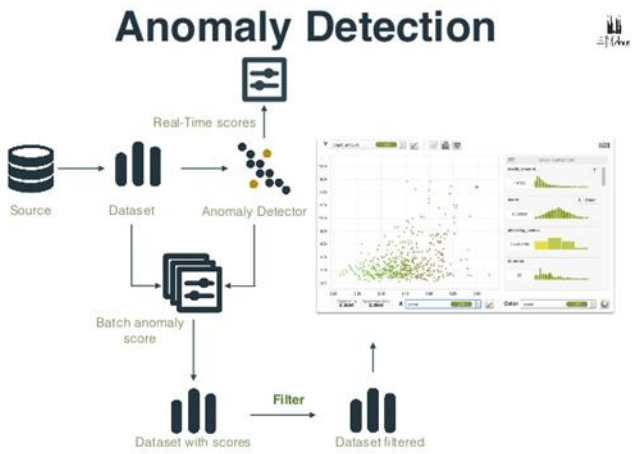
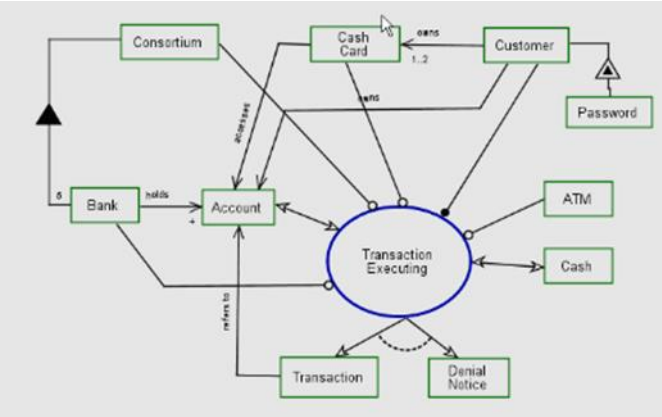
NEXT STEPS



Executable Models to test scenarios



Time Dependent Performance

System:

IDPS Host-Based

Characteristics:

ID	Value
Protect	2
Detect	9.9
Respond	8
Recover	6.1
Oper Cost	100
Dev Cost	0.9

Capabilities:

ID	Has	Time	Cost
Malware	☑		
Social Engineering	☐		
Password Attack	☐		
DDoS	☑		
Man in the Middle	☑		
Drive by Downloads	☐		
Sniffers	☑		

Interfaces:

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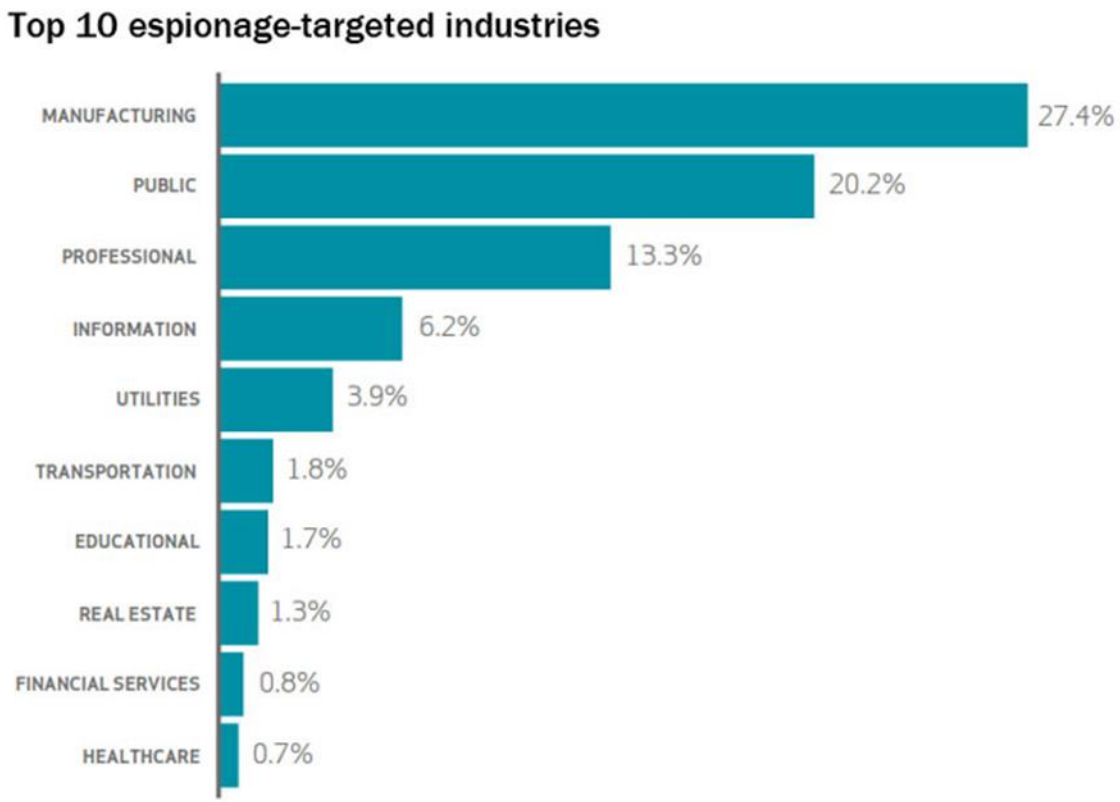
DIGITAL MANUFACTURING CYBERSECURITY



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Network Intrusion Detection using Deep Learning

IDS

- Host-Based (HIDS)
- Network-Based (NIDS)
  - Anomaly-Based
    - Machine Learning Method
  - Behavior-Based
  - Signature-Based
  - Rule-Based

Detection Mechanism

- Statistical Method
- Data Mining Method
- Machine Learning Method

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SOS EXPLORER

SoS Explorer is Missouri S&T's solution
http://emse.mst.edu/sos-explorer/

A novel optimization method called "MOEA-DM" tailored to the needs of cyber physical systems

Many-objective optimization

Use of clustering to cultivate a limited set of solutions of interest

Visualization of architectures
Interactive "what-if" experimentation

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PUBLICATIONS

Abhijit Gosavi, Siddhartha Agarwal, Cihan H. Dagli: Predicting Response of Risk-Seeking Systems During Project Negotiations in a System of Systems. IEEE Systems Journal 11(3): 1557-1566 (2017)

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Gene Lesinski, Steven M Corns, Cihan H Dagli ” A fuzzy genetic algorithm approach to generate and assess meta-architectures for non-line of site fires battlefield capability” Evolutionary Computation (CEC), 2016 IEEE Congress on 24-29 July 2016. DOI: 10.1109/CEC.2016.7744085

Rahul Alaguvelu, David M Curry, Cihan H Dagli ” Fuzzy — Genetic algorithm approach to generate an optimal meta-architecture for a smart, safe & efficient city transportation system of systems “System of Systems Engineering Conference (SoSE), 2016 11th IEEE, June 12-16, 2016. DOI: 10.1109/SYSOSE.2016.7542935

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George Muller, Cihan Dagli “Simulation for a coevolved system-of-systems meta-architecture” System of Systems Engineering Conference (SoSE), 2016 11th IEEE, June 12-16, 2016. DOI: 10.1109/SYSOSE.2016.7542931

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QUESTIONS

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