32nd Annual INCOSE international symposium
hybrid event
Detroit, MI, USA
June 25 - 30, 2022

The Need for Cyber-Physical Digital Twins for Resiliency Studies

www.incose.org/symp2022

Outline

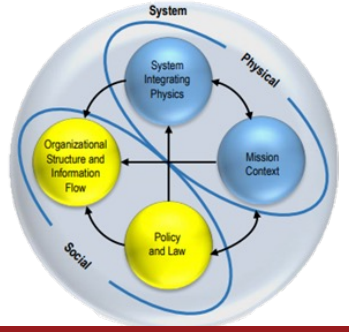
1. Background & Definitions
2. Digital Twins
3. Cyber-Physical Digital Twins
4. ManTech's Approach for delivering Resilience
5. Summary

Background – Demands, Risk, Speed, Change

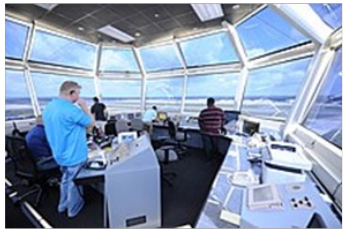
Challenging Needs → **High Risk Engineering in Complexity** → **Success Expectations**

- Resilient Systems
- Intelligent Systems
- Socially Acceptable Systems
- Social Systems
- Scalable Systems
- Sustainable Systems

Speed of Relevance



Air Traffic Management



UAS Traffic Management

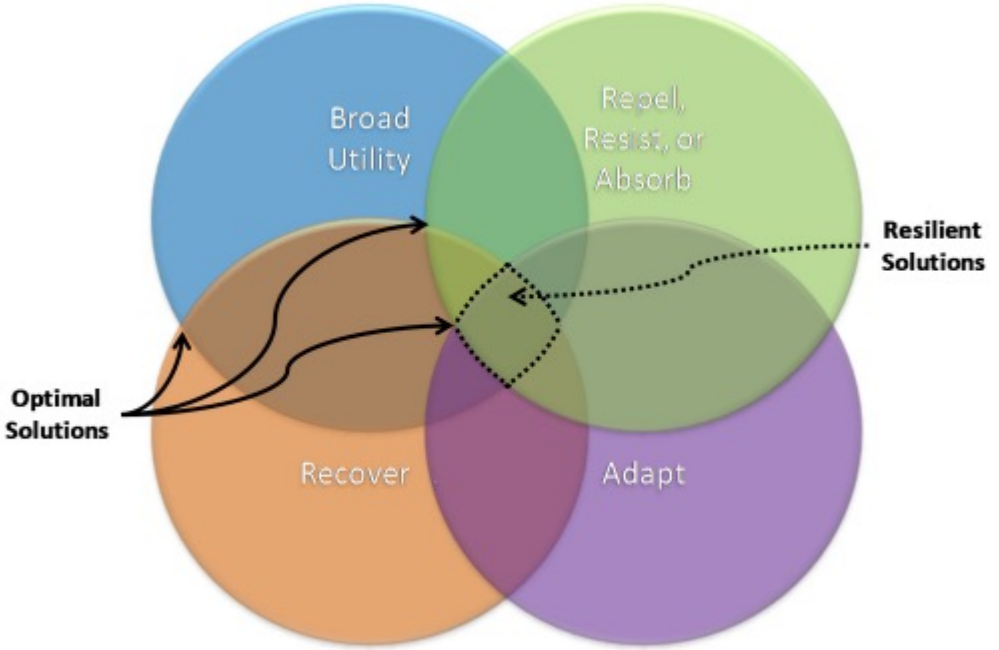
Space Operations

Space Traffic Management

Modern complex problems are multi-faceted that require solutions that include physics and cyber considerations to successfully transition to operations

Definitions

- **Virtual Twin** – an integrated probabilistic simulation of a ***to-be system*** that uses the best models and sensor information to *predict activities/performance* of a physical twin
- **Digital Twin** – an integrated probabilistic simulation of an ***as-built system*** that uses the best models and sensor information to *mirror and predict activities/performance over the life* of a physical twin
- **Physical Twin** – the operational system that is fielded and being operated and/or sustained
- **Resilience** – ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions



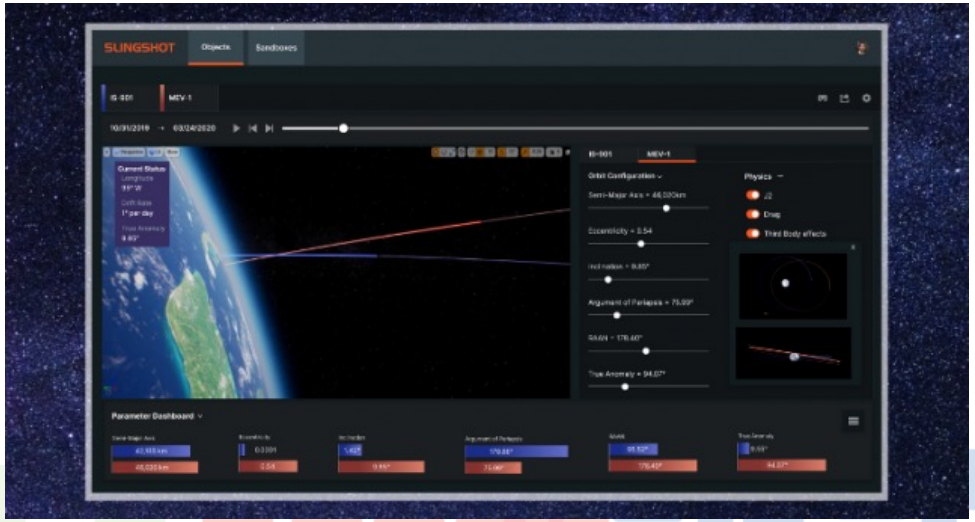
Properties of DoD Systems and Systems of Systems
(Ref: Engineered Resilient Systems: A DoD Perspective, Goerger & Madni)

Digital Twin Examples

USAF F-16 digital twin for sustainment, modernization

Virtual Singapore

Digital Twins for Space Situational Awareness

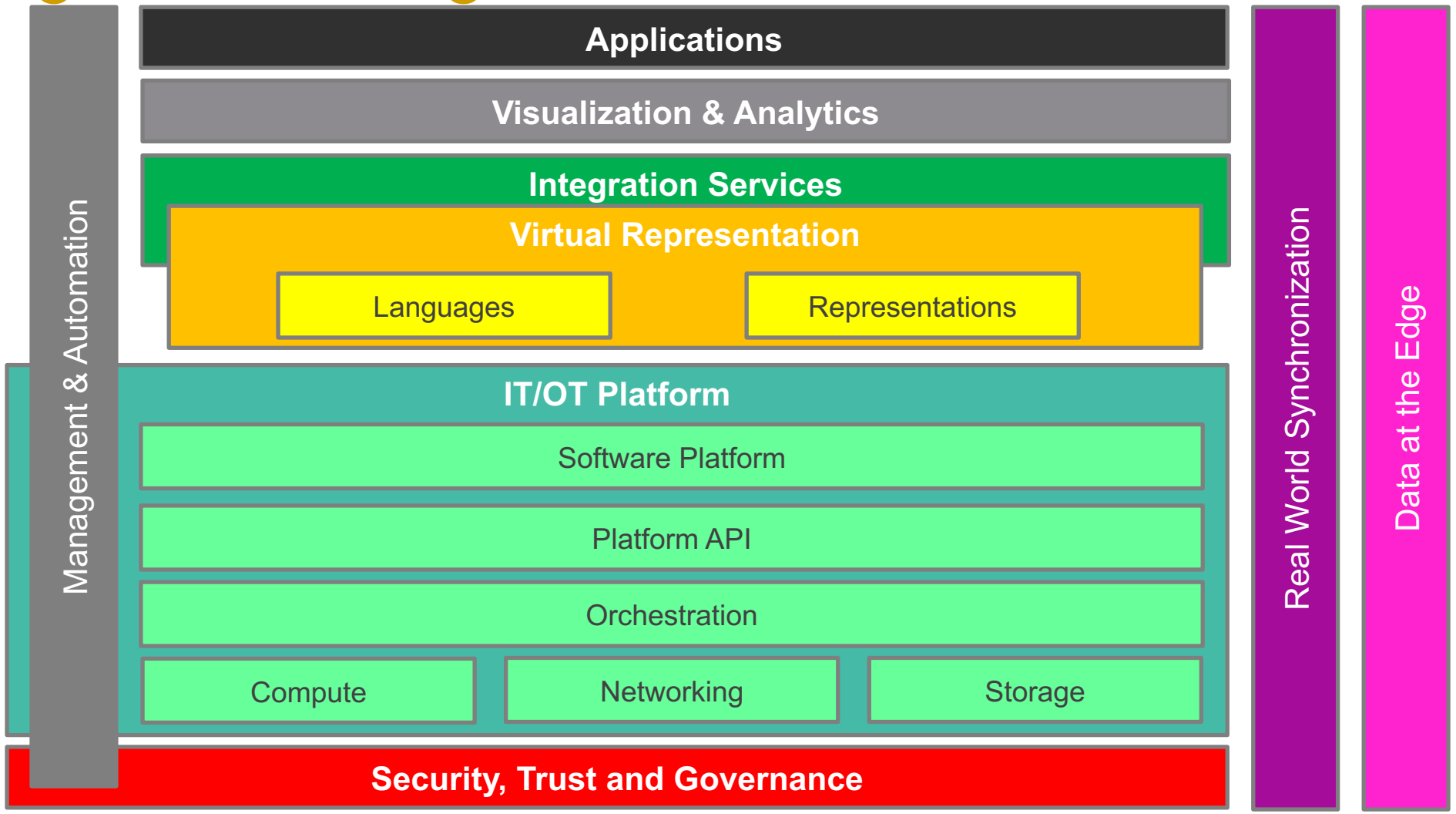


Why combine cyber & physical domains?

- With the proliferation of IoT devices, modern technology systems have numerous interfaces – each of which can be vulnerable to cyber-aware adversaries
- Examples include:
  - Providing latest intel to the warfighter's goggles, headset, or handset
  - Supporting HD video and voice communications in spectrum dense or contested environments
  - Delivering real-time sensors and indications & warning (I&W) data to stay abreast of operating conditions of an assembly line or airborne platform

The combination of cyber and physical models in a common virtual environment would enable a robust, holistic approach for digital twins and their utility

Digital Twin Logical Platform Architecture



* Adaptation of Digital Twin Consortium Logical Digital Twin System

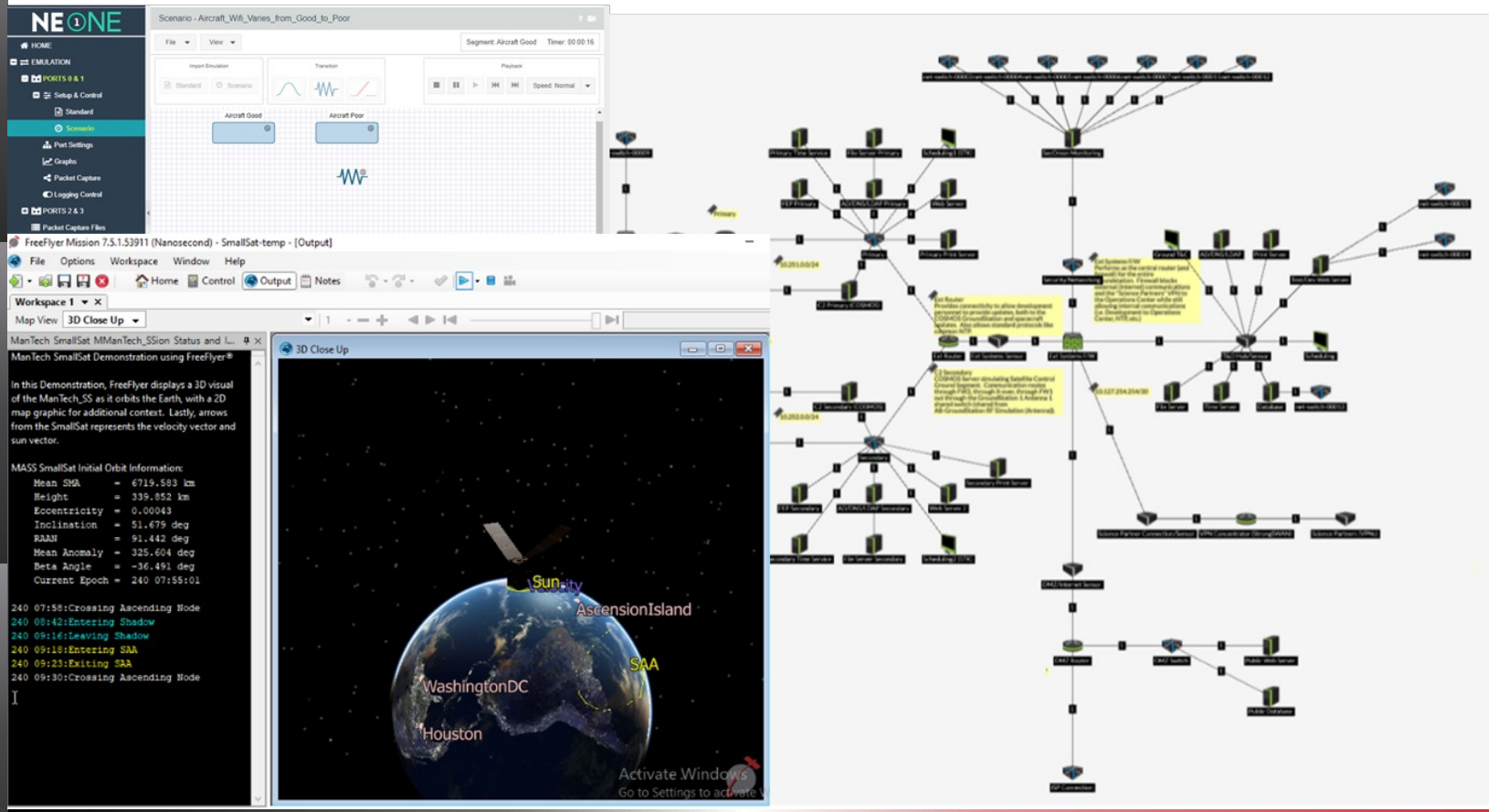
Cyber Physical Digital Twin Use Cases

System Digital Twin

Mission Integration Testbed

Cyber Test Range

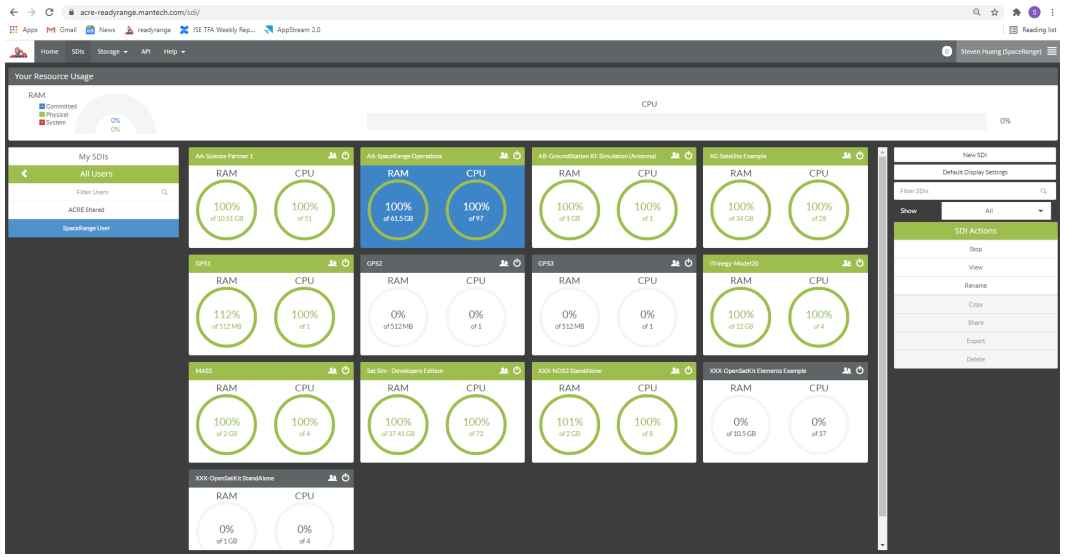
Multi-Domain Analysis and CONOPS Development



Physics-Based Modeling — **Software Defined Infrastructure**

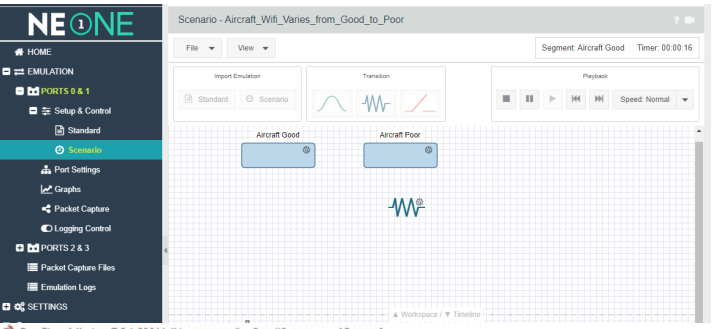
ManTech's Approach for a Cyber-Physical Digital Twin (1/2)

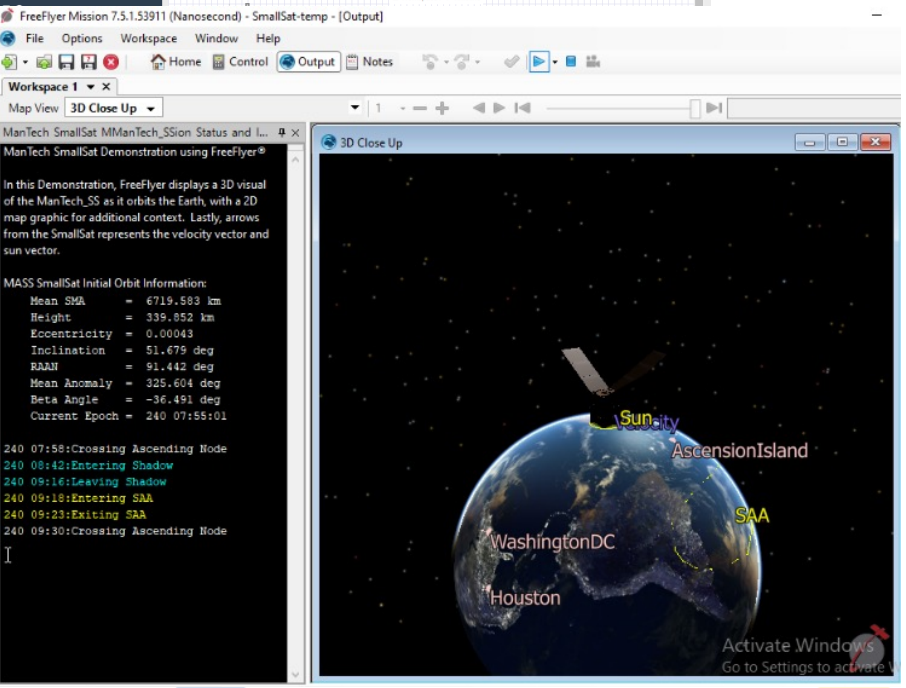
- Leverage our Cyber Test Range expertise to deliver an environment to virtualize realistic cyber operations
  - IT architectures
  - Communication Terminals
  - Terrestrial networks and wireless RF links
  - Multi Domain Systems
    - Mission payload
    - Communication payload



- Software defined infrastructure (SDI) enables efficient management and exquisite control of the environment

ManTech's Approach for a Cyber-Physical Digital Twin (2/2)





- Incorporate physics-based COTS, GOTS tools to create dynamic, operationally representative scenarios
  - FreeFlyer (a.i.solutions)
  - NE-ONE (iTrinegy)
  - Systems Toolkit (Ansys)
  - Matlab (Mathworks)
- A hardware-in-the-loop (HITL) framework is being developed to enable 2-way communication for
  - Early interface risk reduction of prototype hardware
  - Early operator training to make use of new capabilities
- Secure data connections of digital twins allow
  - Physical systems to inform their digital twins of actual performance
  - Assurance that physical systems have not degraded or changed unknowingly (e.g. malware)

Benefits of a Cyber-Physical Digital Twinning Platform

- To Analyze System Architectures, a platform provides
  - Flexibility to mix and match multi-domain segment capabilities to assess and evaluate best-of-breed solutions for the Enterprise
- To Integrate & Test System Architectures, a platform manages
  - Hosting, integrating, and testing hardware and software intended for the system in a cost-effective manner
  - Assessing deployment strategies, duration of installs/patches, to minimize operations down-time and improve user expectations
- To Assess System Architecture Cyber Risks, a platform delivers
  - Dynamic scanning and assessment of cyber risk for every virtualized platform
  - Environment for operators to train and improve cyber threat awareness and checklists

Cyber-Physical Digital Twinning Platform should be host-agnostic to support investigations using on-prem, in-cloud, or hybrid IT architectures

Summary

- The demand for robust and reliable systems has never been higher
  - Need to continue development of standards for interoperability and interconnectivity
  - Need more awareness on system of system attack vectors
- The benefit of combining cyber physical simulation and analysis capabilities is increasing
  - Should serve as a cornerstone (authoritative source of truth)
  - Collaborative connections with SysML-based architectures and Multi-Disciplinary Analysis and Optimization (MDAO) tools will help to deliver and sustain an authoritative source of truth throughout a program's life cycle
- The value of digital twins cannot be under-estimated
  - Significant investment is required for digital twin development
  - Digital Twins should be used across organizational boundaries
  - Access and distribution of operational data (real-time or near-real-time) will strengthen the ROI

32nd Annual INCOSE international symposium

hybrid event

Detroit, MI, USA

June 25 - 30, 2022

www.incose.org/symp2022