Interoperability Evaluation

in Systems and System-of-Systems

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What is "Interoperability"?

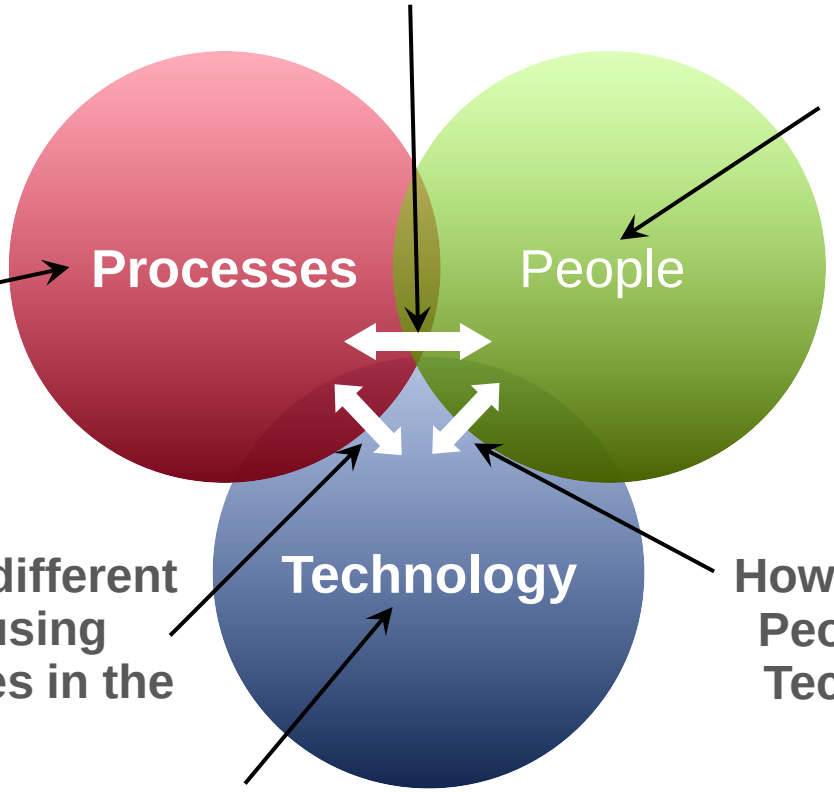
- **First of all, what does "Interoperability" mean?**
  - **Oxford English Dictionary: Noun**
    "Able to operate in conjunction"
- **INCOSE SE Handbook (9.5 Interoperability Analysis)**
  - **"Interoperability depends on the compatibility of elements in a large and complex system … to work as a single entity"**
- **For Systems and System-of-Systems, depends on the RANGE of Compatibility between Components:**
  - **Technologies**
  - **People**
  - **Processes**
- **Classic Military Definition:**
  - **Ability of Joint and Coalition operations to coordinate activities of forces with differing Tactics Techniques & Procedures (TTP) (i.e. People & Processes)**

Source: INCOSE *Systems Engineering Handbook* (INCOSE-TP-2003-002-03.2.2 October 2011)

Interoperability in a System or System-of-Systems (SoS)

How well can different People use different Processes in the System/SoS?

How compatible are the Processes used to operate or support the components in the System/SoS?



How compatible are People (Languages, Training, Attitude, Aptitude, etc.) that operate or support the components in the System/SoS?

How compatible are different Processes when using different Technologies in the System/SoS?

How well can different People use different Technologies in the System/SoS?

How compatible are the Technologies (Communications, Information Systems, Applications, etc.) in the components in the System/SoS?

Interoperability Associations

- **Interoperability is a Key Factor in Resilient Systems**
  - **Resilient System requirements often drive requirements for Interoperability (and vice versa)**
- **Interoperability is a Key Factor in Cyber Security**
  - **Interoperability requirements often drive requirements for Cyber Security (and vice versa)**
- **Interoperability is a Key Factor in Modeling**
  - **Interoperability requirements often drive Model Attributes for Digital Twins**
  - **Models can be used to characterize Interfaces (Technologies, People, & Processes) and thus influence Interoperability requirements**
    - **Especially for Logic Checking of expected Inputs/Outputs (design "holes")**
    - **May be of some use in identifying & characterizing unexpected interfaces, dependencies, and couplings**

Interoperability Constraints

- **A Networked System-of-Systems potentially provides many benefits, but is not "free"– interoperability of the Component Systems is typically constrained by:**
  - **Cost (networks, hardware, software, service fees)**
  - **Implementation schedule**
  - **Performance (especially of older, legacy systems)**
  - **Policy & Law**
  - **Personnel (training, experience, acceptance, etc.)**
- **Systems/SoS may not know or fully understand their interoperability requirements**
  - **Especially for complex System of Systems**
  - **Interoperability requirements may be implicit or implied by particular operational needs**

Source: Network Centric Operations Industry Consortium (NCOIC)
"An Introduction to NCOIC's Interoperability Assessment Tools", Approved for Public Release, Distribution Unlimited

Interoperability of the PEOPLE of a System/SoS

PEOPLE are often different, especially if Global!

- **Different Organizations, and even within an Organization:**
  - **Different Functions**
    - **Commercial: Sales, Finance, Engineering, Operations, etc.**
    - **Military: Administration, Operations, Logistics, Intelligence, etc.**
  - **Different Primary Languages**
    - **Even if everyone agrees to use the same Primary Language**
  - **Different Training & Experience, such as:**
    - **"New-Hires" vs. "Old-Timers"; advantages/disadvantages of each**
  - **Different Aptitude & Capabilities, such as:**
    - **Different Human Factors**
    - **Different Talents & Limitations**
  - **Different Attitudes, such as:**
    - **Willingness to adapt to Change**
    - **Ability to work well alone or in a Team environment**

Interoperability of the PROCESSES of a System/SoS

PROCESSES are often different, especially if Global!

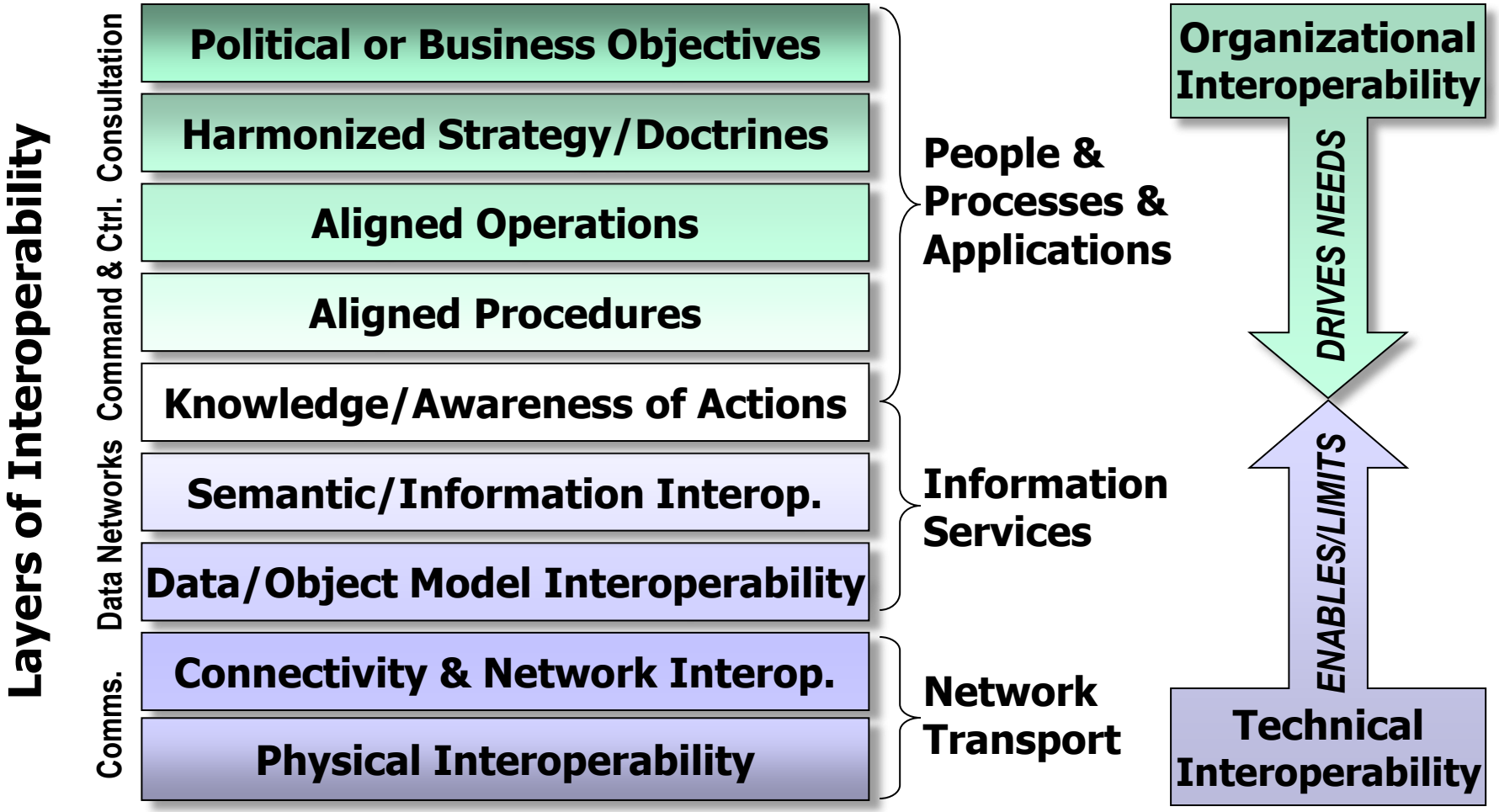
- **Different Organizations, such as:**
  - **Military**
  - **Government Organizations, such as:**
    - **Policy-Makers**
    - **Public Affairs Offices**
    - **Emergency Responders (e.g. Police, Fire, etc.)**
    - **Homeland Security (e.g. FEMA, Coast Guard)**
    - **Judicial/Investigative (e.g. FBI, Inspector General, GAO)**
  - **Non-Governmental Organizations (NGOs), such as:**
    - **International Federation of Red Cross and Red Crescent Societies**
    - **American Red Cross (ARC)**
    - **Médecins Sans Frontières (Doctors Without Borders)**
  - **Corporations (Large, Medium, Small)**
  - **Individuals**

Interoperability of the TECHNOLOGY in a System/SoS

TECHNOLOGY is often different, especially if Global!

- **Different Levels of Maturity, such as:**
  - **Legacy Systems**
    - **Stand-alone, non-networked Platforms**
  - **Net-Enabled Systems (but not Cloud-enabled), such as:**
    - **"Closed" networks (especially non-Internet Protocol, such as X.25)**
    - **Real-time networks (e.g. Data Distribution Service or DDS)**
    - **Military networks (e.g. Link-11, Link-16)**
  - **Cloud Computing Providers**
    - **Many different proprietary Application Program Interfaces (APIs)**
- **Different Communications Systems, such as:**
  - **Wired vs. Wireless, Protocols, etc.**
- **Different Information Services, such as:**
  - **Operating Systems, Database Management Systems, etc.**

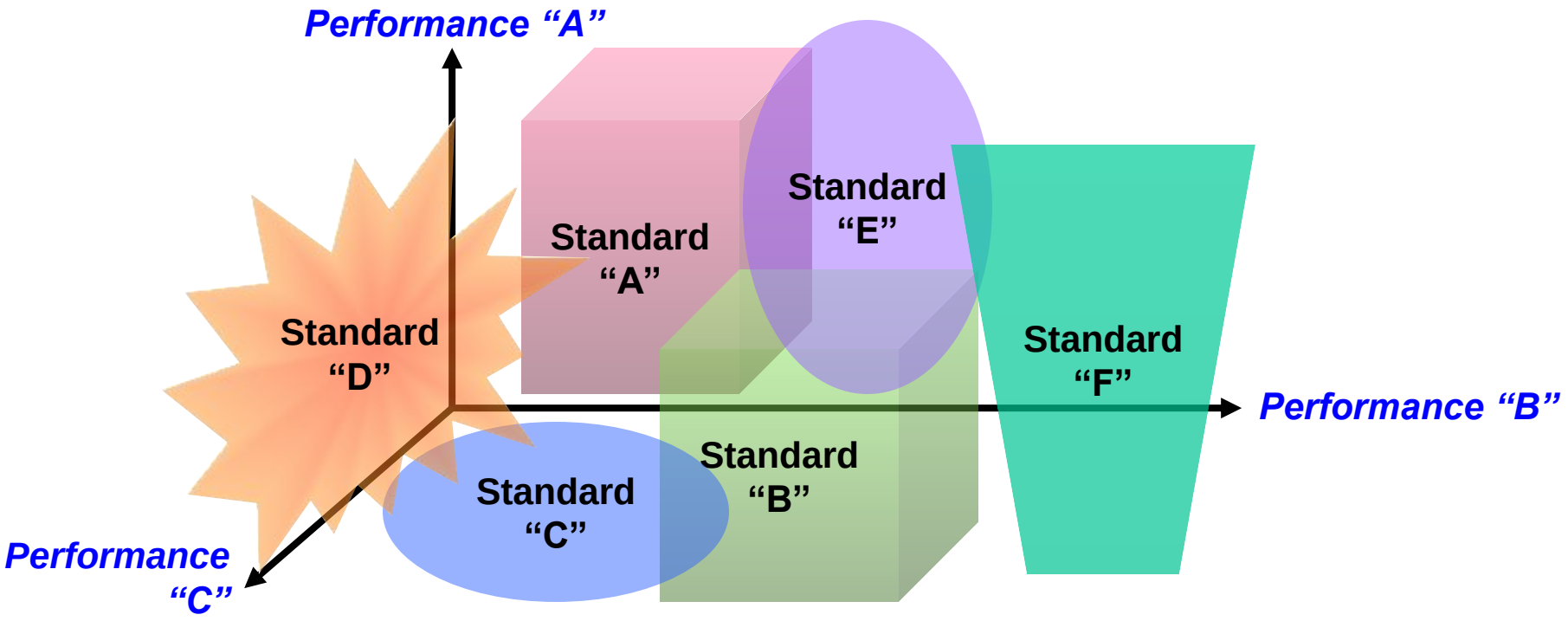
Layers of Interoperability in a System/SoS



Adapted from "Beyond Technical Interoperability - Introducing a Reference Model for Measure of Merit for Coalition Interoperability'. Dr. Andreas Tolk, VMASC, ODU. 8th CCRTS, NDU, June 2003"

Why Can't Everyone Just Use The Same Standards to achieve Technical Interoperability?

- **Often the "BEST" Standard depends on the Mission**
  - **Real-World Condition! Often no "One Size Fits All"**



Source: Network Centric Operations Industry Consortium (NCOIC)
"NCOIC Interoperability Framework (NIF) and NCOIC Patterns Overview", Approved for Public Release, Distribution Unlimited
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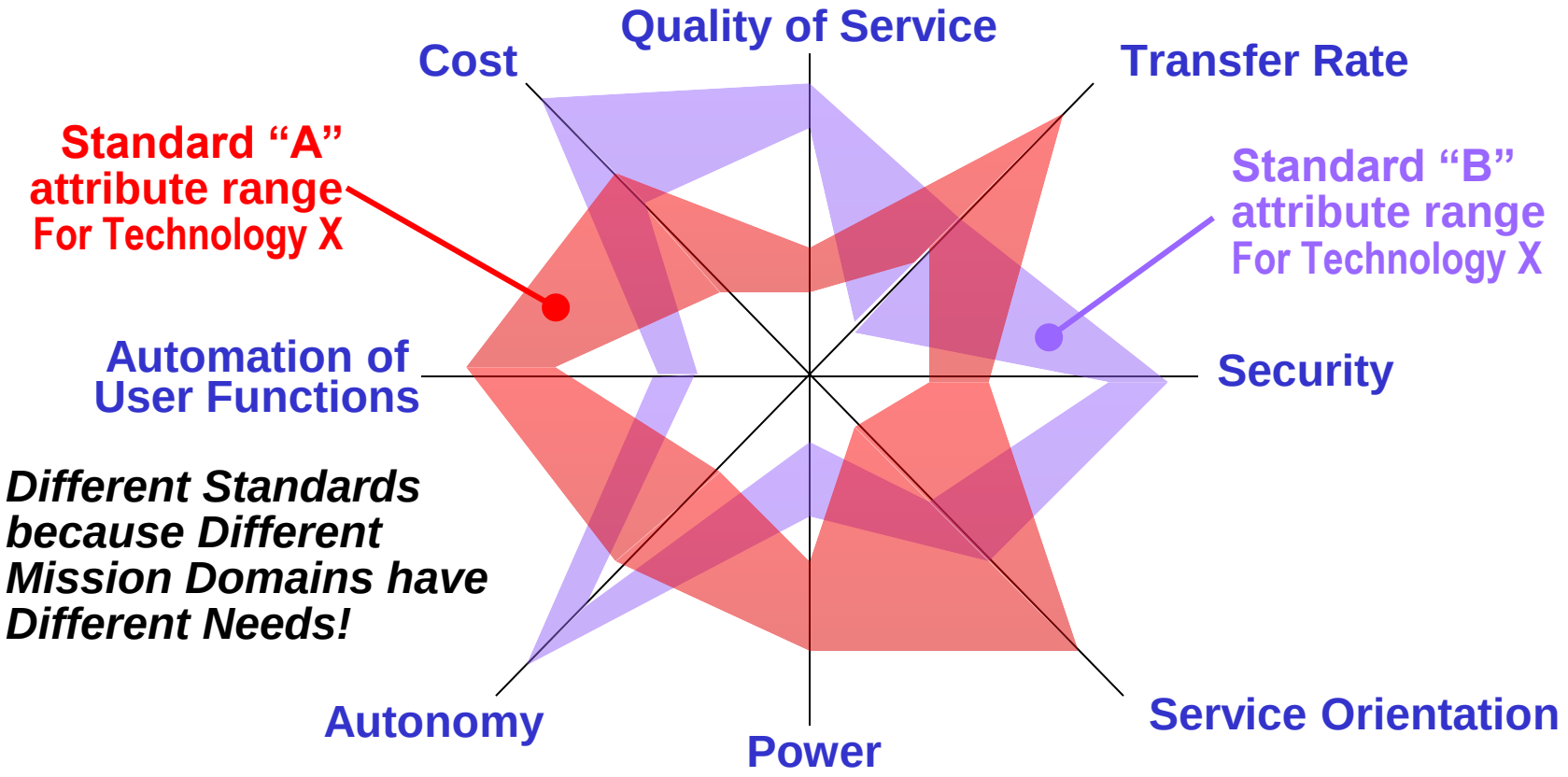
Why Can't Everyone Just Use The Same Standards to achieve Technical Interoperability?

- **Usually no <u>one</u> Standard can be general enough to meet all needs of all intended uses**



Different Standards because Different Mission Domains have Different Needs!

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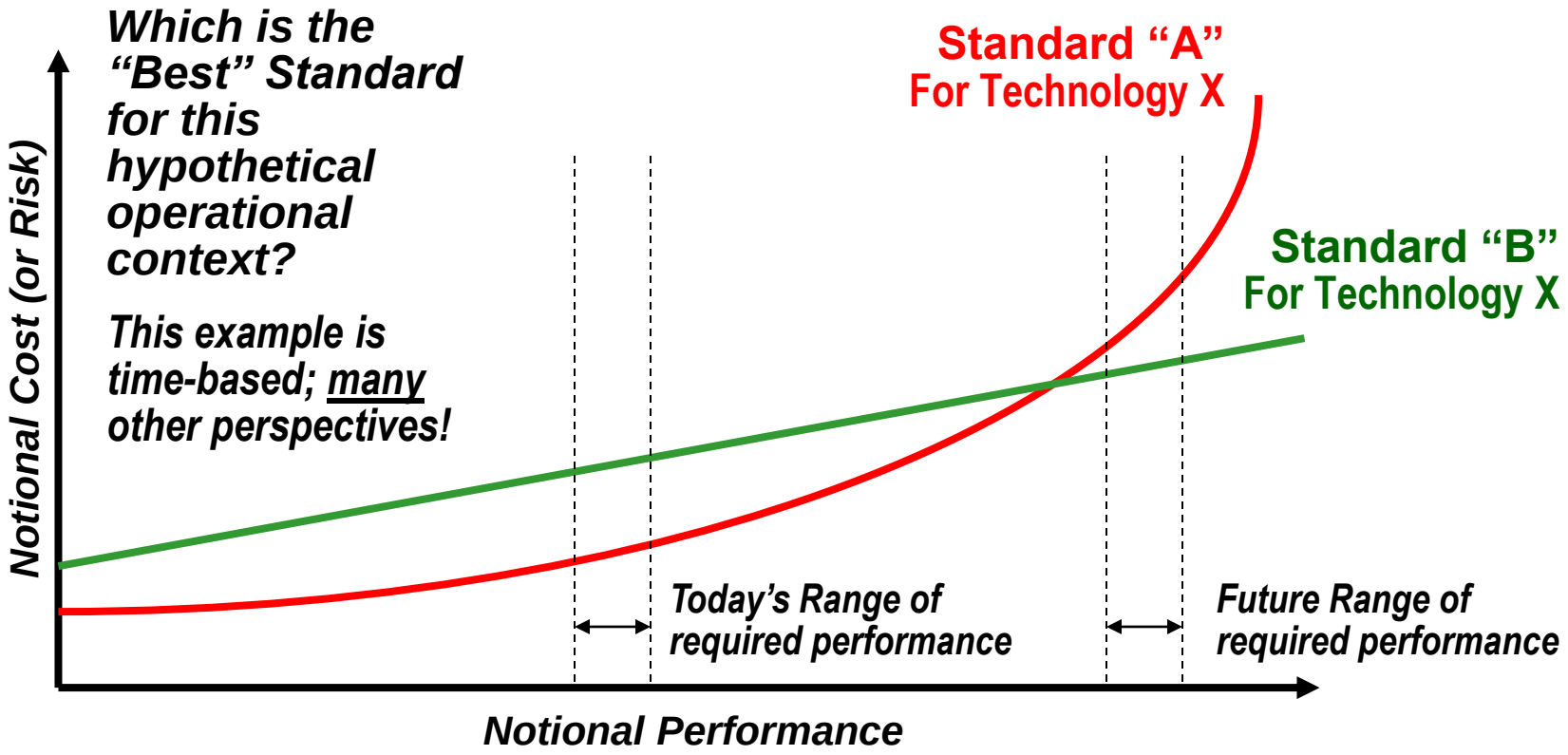
Why Can't Everyone Just Use The Same Standards to achieve Technical Interoperability?

- **What is the appropriate Standard for a particular usage over the Total Life-Cycle?**



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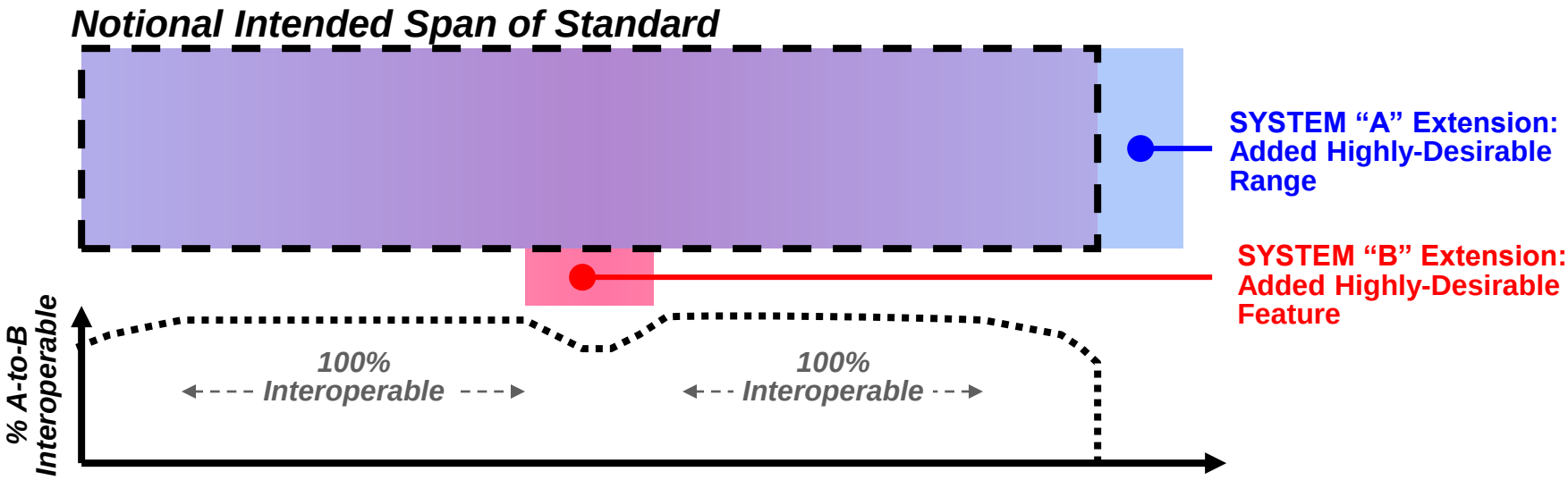
Why Can't Everyone Just Use The Same Standards to achieve Technical Interoperability?

- **In a SoS, cannot force systems to not use highly-desirable features when operating independently**
  - **A "Bad" Standard, or "Bad" System Implementations?**
    - **Real-World Condition!**



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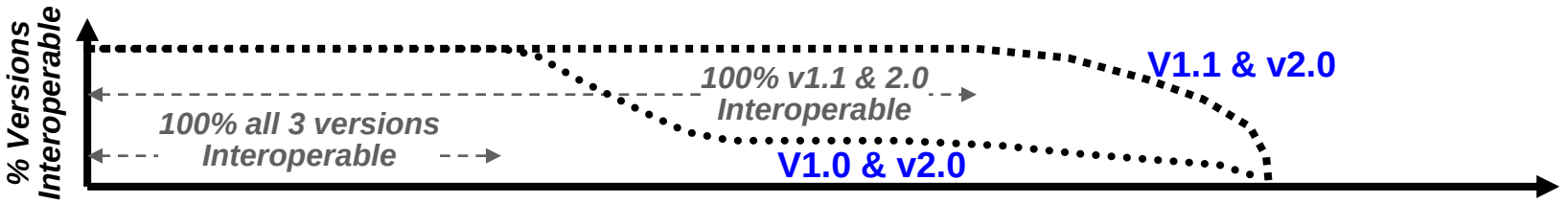
Why Can't Everyone Just Use The Same Standards to achieve Technical Interoperability?

- **Are all Systems in a SoS using the Same Version of a Standard?**
  - **Real-World Condition!**
  - **In a SoS, cannot force Legacy systems to update to newest standard**

ORIGINAL Standard v1.0

UPDATED Standard v1.1

NEW Standard v2.0: "Backward Compatible"



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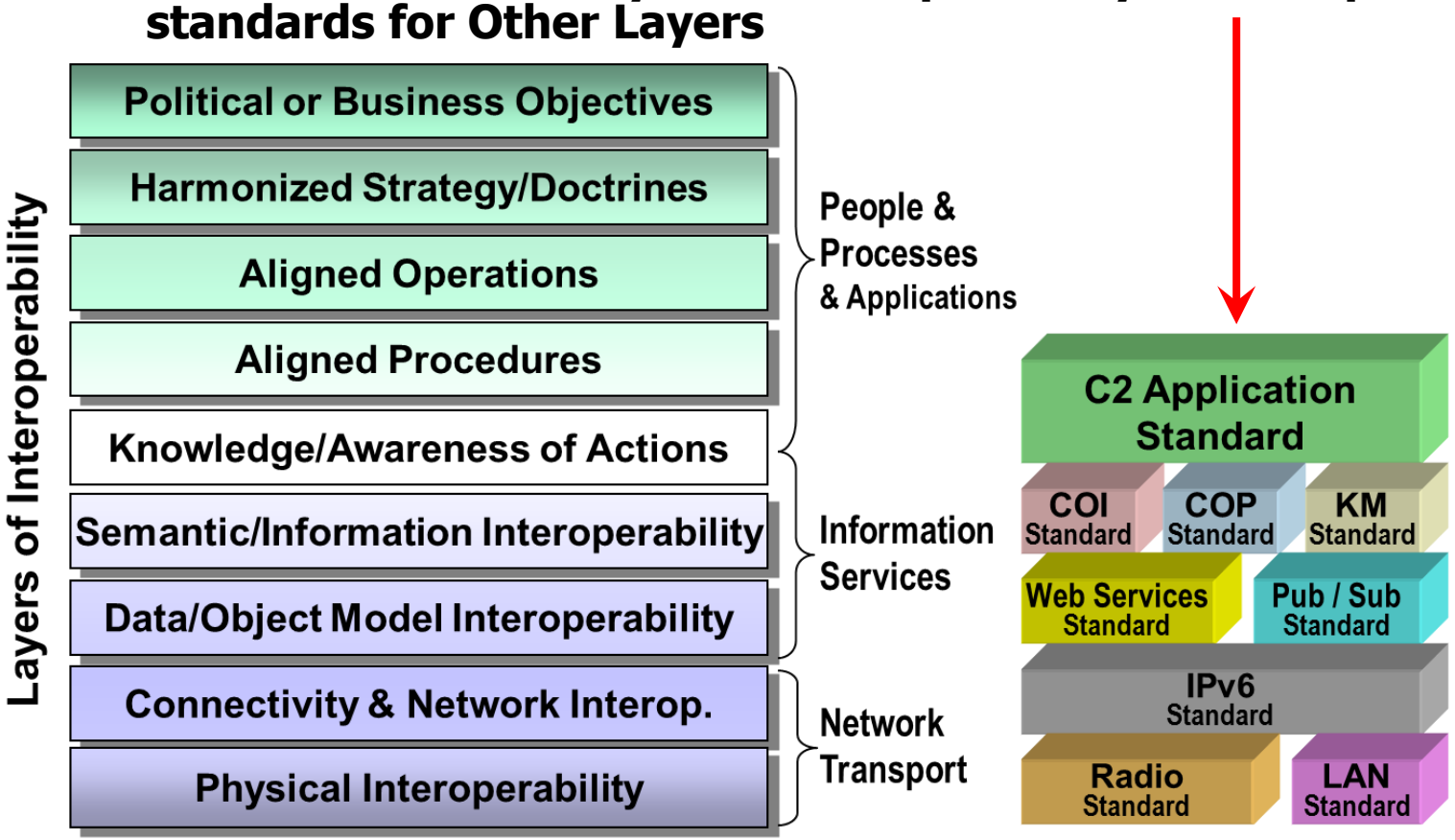
Why Can't Everyone Just Use The Same Standards to achieve Technical Interoperability?

- **Standards are Interdependent!**
  - **Standards for one Layer of Interoperability often dependent on standards for Other Layers**



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Assessing Interoperability

- **Many Different Interoperability Attribute & Measurement Tools, for example:**
  - **Network Centric Operations Industry Consortium (NCOIC) SCOPE®**
    - **SCOPE® = Systems, Capabilities, Operations, Programs, & Enterprises Assessment Methodology**

Source: Network Centric Operations Industry Consortium (NCOIC)
"An Introduction to NCOIC's Interoperability Assessment Tools", Approved for Public Release, Distribution Unlimited

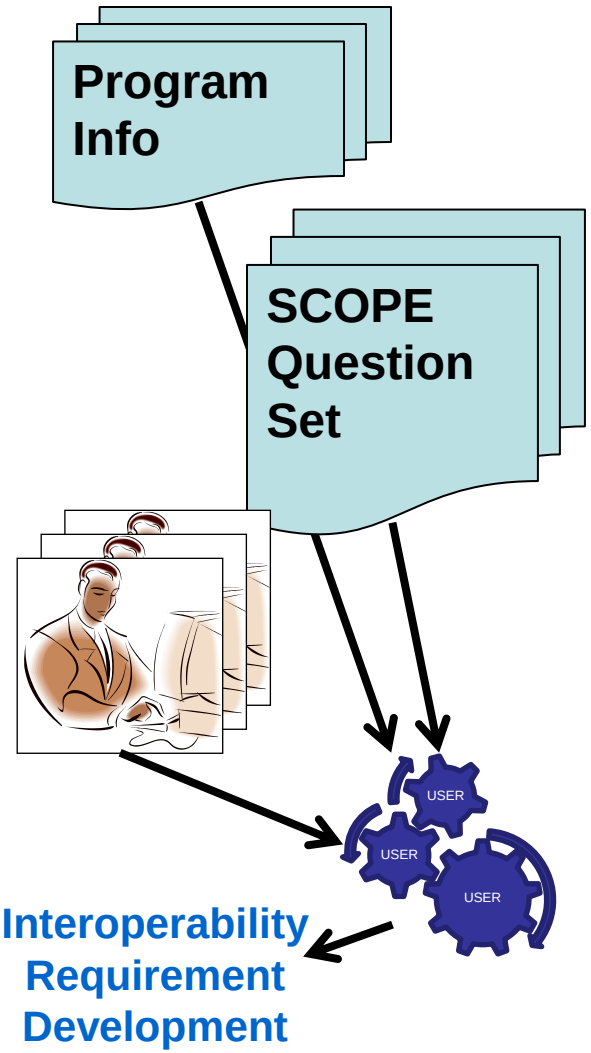
Assessing Interoperability via SCOPE

- **A comprehensive understanding of interoperability requirements and ability to understand interoperability capability of proposed system will reduce program risk**
  - **Obtain useful requirements up-front, reduce discovery of errors in implementation**
- **SCOPE Helps to Understand those Risks!**
  - **Goal: Validated Needs for Interoperability in a System/SoS**
  - **Not a Computer Model: Structured Analysis using Subject Matter Experts**
    - **Not "One Size Fits All": Tailored to meet stakeholder needs**
    - **Not a set of prescriptive requirements**
  - **SCOPE helps obtain consensus across multiple viewpoints**
    - **With focus on integration/interoperability**
    - **In a specific range of environments, and within constraints**
    - **Can expose essential differences that can't be negotiated away**

Source: Network Centric Operations Industry Consortium (NCOIC)
"An Introduction to NCOIC's Interoperability Assessment Tools", Approved for Public Release, Distribution Unlimited

Assessing Interoperability via SCOPE

- **SCOPE Applies a Detailed, Multi-element Definition of Attributes of Interoperable Systems and Enterprises**
  - **Includes All Core Attributes**
  - **Not Just Technology, But Also People, Process, & Technology Interactions**
  - **Participation Of Users and Designers is Essential**
  - **Uncovers Unknown, Unanticipated, or Under-Appreciated Needs for Interoperability**
    - **Characterizes Conflicts and Constraints**
    - **Tailorable to Program Needs**
  - **Provides Validated Needs for subsequent development of Interoperability Requirements**
    - **SCOPE does NOT output "Shall" Statements**



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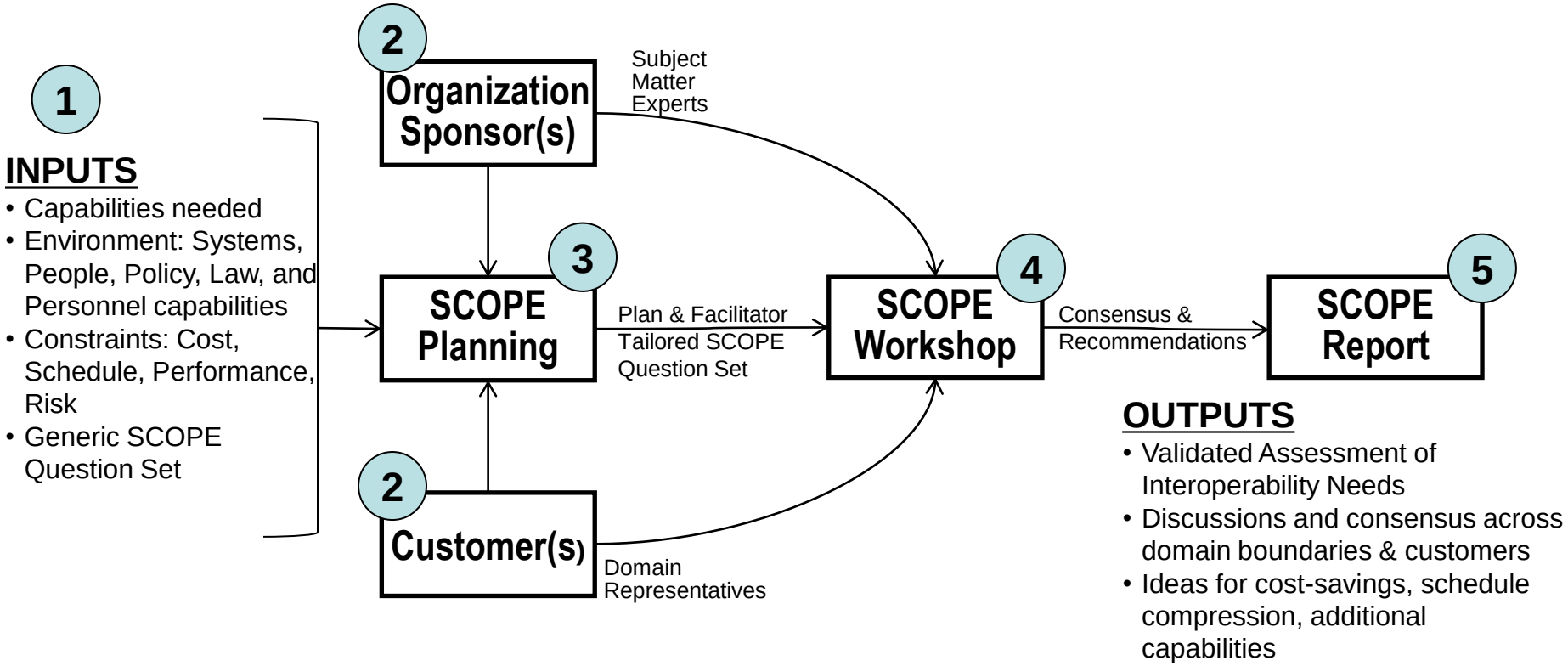
SCOPE Workshop Approach for Assessment



1. **Collect Needed Information and Documentation**
2. **Identify the Participants**
3. **Plan the Workshop : Select and Tailor the Question Set**
4. **Conduct the Workshop (4 hours ~ 4 days)**
5. **Document the Results**

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SCOPE Question Set Characteristics

- **MS Excel Spreadsheet**
  - **No custom/proprietary software required for use**
- **Question Set Tailored from a Comprehensive but Generic Set of Interoperability Dimensions**
  - **Typically, only a few of the 600+ Generic Dimensions useful**
  - **Serves to guide Sponsoring Organization to fully explore all aspects of Interoperability**
  - **Typically, most pertinent Dimensions are Domain Dependent and must be identified by Sponsoring Organization**
    - **SCOPE provides samples for a few representative domains**
- **Explanatory Comments on many Dimension Name, Question, and Value Description cells-- also Tailorable!**
  - **Helps Sponsoring Organization to understand context of dimensions, questions, and value descriptions**

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Sample SCOPE Questions
(Domain Dependent Questions from Haiti Earthquake Response Scenario)

Dimension Name: A-- Fault Tolerance to Temporary Outage

- **Question: If shared Public Cloud access & use of Hybrid Cloud temporarily disrupted (locally by an aftershock, or remotely by Cloud provider issues), how will participants cope with disruption?**
- **Values & Description *(group can add/delete/modify values)***
  - **0: Fall-back to manual methods (accept impacts to timeliness, synchronization of information, accuracy, etc.)**
  - **1: Fall-back to local processing and locally-stored data, some reach-back to national systems via SATCOM, share data between remote nations via Internet (e-mail, IM/SMS, social media, etc.)**
  - **2: Fall-back to local processing and locally-stored data, some reach-back to national systems via SATCOM, share data locally via a single Command-Control center (note trust issues, cost of backup datacomm channels)**
  - **3: Use alternate Cloud service suppliers for Hybrid Cloud (note cost impact)**
- **Response: (TBD by Subject Matter Experts & Stakeholders)**

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Sample SCOPE Questions
(Domain Dependent Questions from Haiti Earthquake Response Scenario)

Dimension Name: B-- Compliance with laws & regulations

- **Question: How to deal with participants that have conflicting laws/regulations regarding disclosure of Personally-Identifiable Information (e.g. Medical Records)?**
- **Values & Description *(group can add/delete/modify values)***
  - **0: Use manual methods of PII screening and transmission as per legal constraints**
  - **1: Use more automated methods of screening/transmission under local control by national systems**
  - **2: Use automated methods of screening/transmission via remote national systems(assume allowed by national laws/regs, likely some timeliness impact)**
  - **3: Use fully automated methods of screening/transmission via a trusted third-party broker (note trust implications: assume allowed by national laws/regs, likely some national monitoring to ensure continued trust)**
- **Response: (TBD by Subject Matter Experts and Stakeholders)**

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Sample SCOPE Questions
(Domain Dependent Questions from Haiti Earthquake Response Scenario)

Dimension Name: C-- Identity and Access Management

- **Question: How to determine authorization and access credentials of diverse participants (hastily-assembled, dynamic entry/exit)?**
- **Values & Description *(group can add/delete/modify values)***
  - **0: Only allow access and use of Public Cloud for pre-screened participants (requires both pre-agreed national credentials and common credentials)**
  - **1: Only allow limited access and use of Public Cloud (limited to national data) for nationally-accepted participants, manual screening of common credentials for access to authorized, broader capability (note trust issues regarding "who" does such screening)**
  - **2: Provide for automated, dynamic assignment of common credentials via an automated screening process (confirmation from national systems regarding national credentials)**
- **Response: (TBD by Subject Matter Experts and Stakeholders)**

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Sample SCOPE Questions
(Domain Dependent Questions from Haiti Earthquake Response Scenario)

Dimension Name: D-- Data Protection: Data Isolation

- **Question: How to protect shared national data such that access by another nation can be revoked if needed?**
- **Values & Description *(group can add/delete/modify values)***
  - **0: "Shared Data" is actually stored in each national system's databases and transmitted to selected other nation(s) (note implications regarding bandwidth and data synchronization to form a Common Relevant Operating Picture)**
  - **1: "Shared Data" is actually stored in each national system's databases and dynamically made available to selected other nation(s) via a central information broker (note implications regarding bandwidth and data synchronization)**
  - **2: "Shared Data" is stored on a cloud-based common database with national ability to withdraw "their information" and fall back to Value 0 or 1 conditions**
  - **3: "Shared Data" is stored on a cloud-based common database with national control of access to "their information" (note trust issues and potential legal/policy implications regarding access auditing)**
- **Response: (TBD by Subject Matter Experts and Stakeholders)**

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SCOPE Assessment Workshop Value

- **Discussion amongst Workshop Participants is Key!**
  - **Consensus is not necessary, but recorded if achieved**
  - **Differences of expert opinion are valuable & recorded!**
    - **Two (or more) groups of expert opinion**
    - **Individual dissenting opinion ("Parking Lot")**
  - **Opportunity to record information for follow-up**
    - **Capture need for specific expertise not at hand**
    - **Identification of potential design drivers or issues**

- **Interaction of Participants is often the Key Benefit of a SCOPE Assessment!**
  - **Especially for interaction between traditionally "stovepiped" organizational elements**

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Summary: Interoperability in a System/SoS

- **Dependent on a Range of Technologies, People, and their Processes**
  - **Difficult to assess in Networked Systems for an Enterprise**
    - **Especially difficult for System-of-Systems**
  - **Helps to anticipate "undocumented" interoperability needs**
- **Interoperability Requirements are typically constrained by:**
  - **Cost (networks, hardware, software, service fees)**
  - **Implementation schedule**
  - **Performance (especially of older, legacy systems)**
  - **Policy & Law**
  - **Personnel (training, experience, acceptance, etc.)**
- **Systems/SoS may not know or fully understand their interoperability requirements**
- **Interoperability in Systems/SoS may be assessed**
  - **Absolutely critical to obtain Stakeholder involvement regarding their needs, constraints, and assumptions**
  - **Such assessments may for the basis for Interoperability Requirements, Trades, and Models**