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Value-added of the A.F. for development of SoS

UTC - 1st international workshop MS2T,
System of Systems in Technology Foundations
5-6 September 2013, Compiègne, France

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Agenda

- **Some of the definitions to share vocabulary**
- **Some ideas and challenges on Systems of Systems development**
- **Environment involving architecture frameworks (AF)**
- **AF added-value for Systems of Systems**
- **Status regarding the AFs**
- **Conclusion: S.W.O.T.**

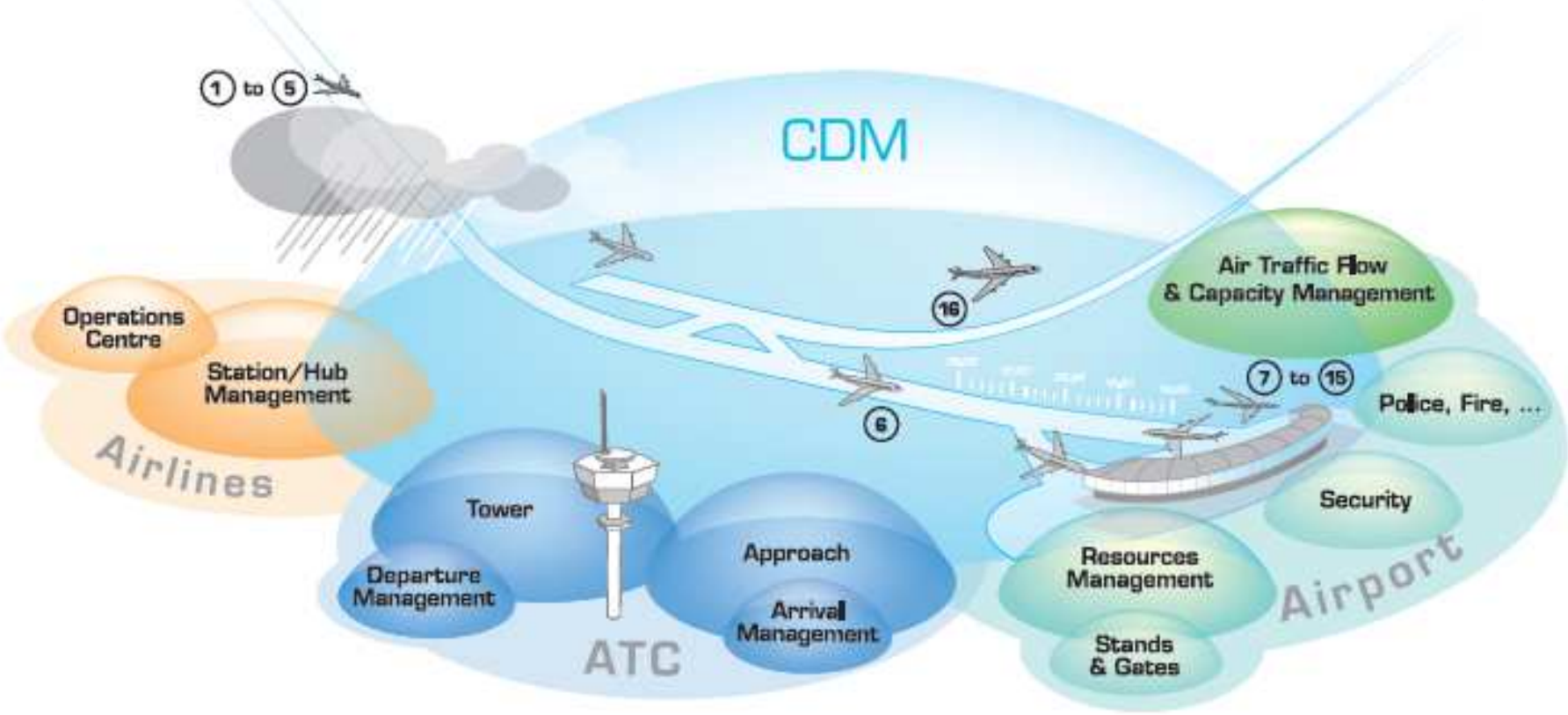
Some definitions (but many others exist)

- A **system** is an integrated set of elements, subsystems, or assemblies that accomplish a defined objective. These elements include products (hardware, software, firmware), processes, people, information, techniques, facilities, services, and other support elements. (INCOSE SE Handbook, v3.2.2, 2011)
- A **capability** is the ability to achieve a desired Effect under specified standards and conditions through combinations of ways and means to perform a set of tasks (CJCSM 3170.01B, May 11, 2005).
- **SoS** is defined as a **set of arrangement of systems** that results when **independent** and useful systems are integrated into a larger system that delivers unique **capabilities** (Defence Acquisition Guide Book ch.4).

SoS definition is towards tangible business/operational objectives and socio-technical issues.

An example with Air Operations

Make several systems working together and get synergy towards common objectives: end-to-end services, traffic, energy, time, etc.



Implementation of SoS is already started [more or less known as such]
Any ICT progress can be transformed rapidly into a benefit.

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Some agreed bases… but far from being formal

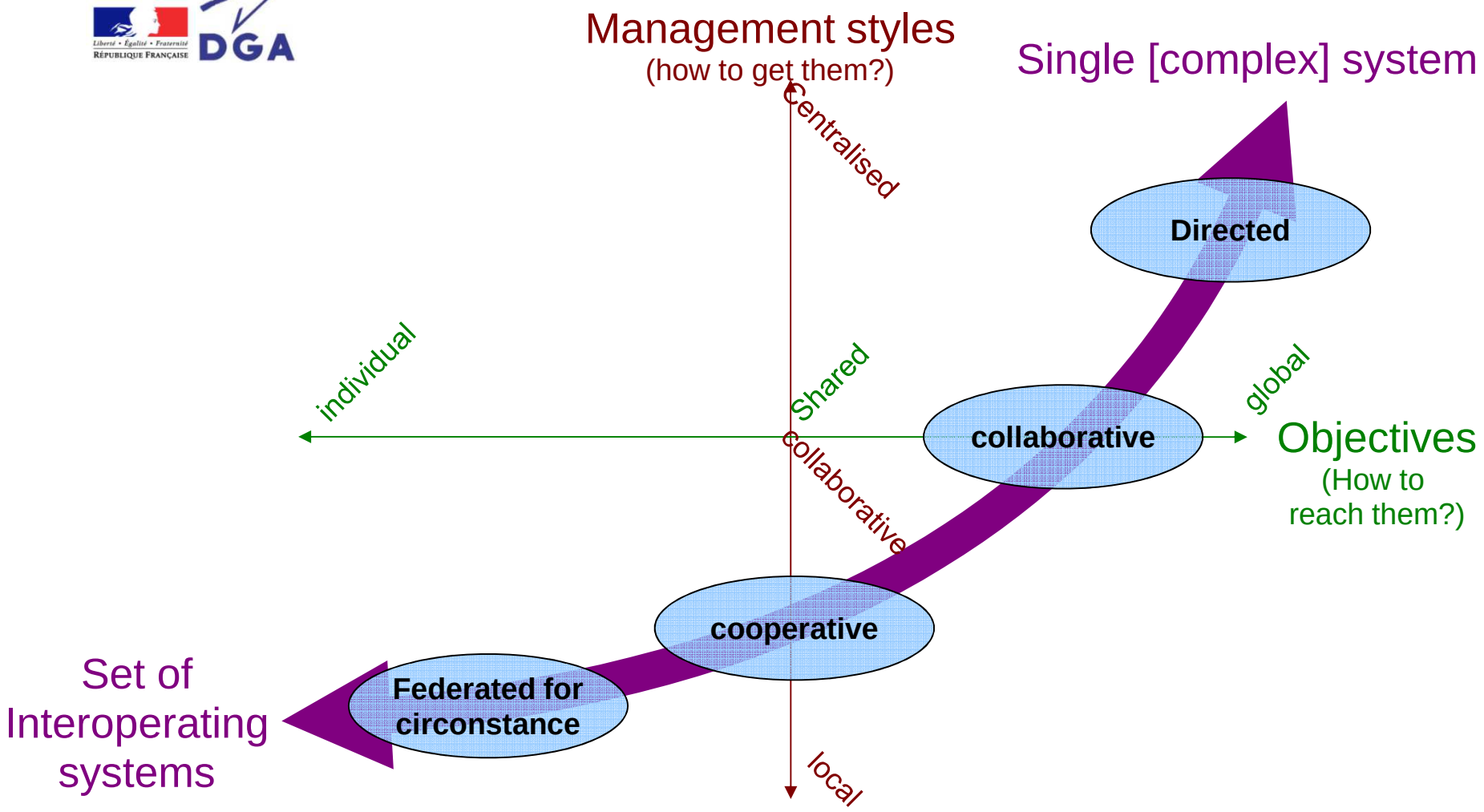
- **MAIER's criteria**
  - Operational independence of the component systems
  - Managerial independence of the component systems
  - Evolutionary development
  - Emergent behavior
  - Geographic distribution *(no shared resource)*

In reality: never totally satisfied

- **John Boardman & Brian Sauser**
  "System of Systems – *the meaning of of*"
  - Autonomy (independence) VS Belonging to SoS
  - Geographical distribution VS Connectivity
  - Diversity & Emergence VS SoS objectives

Compromise have to be got

Classification from French MOD "SoS School"



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Various types of SoS have to be considered

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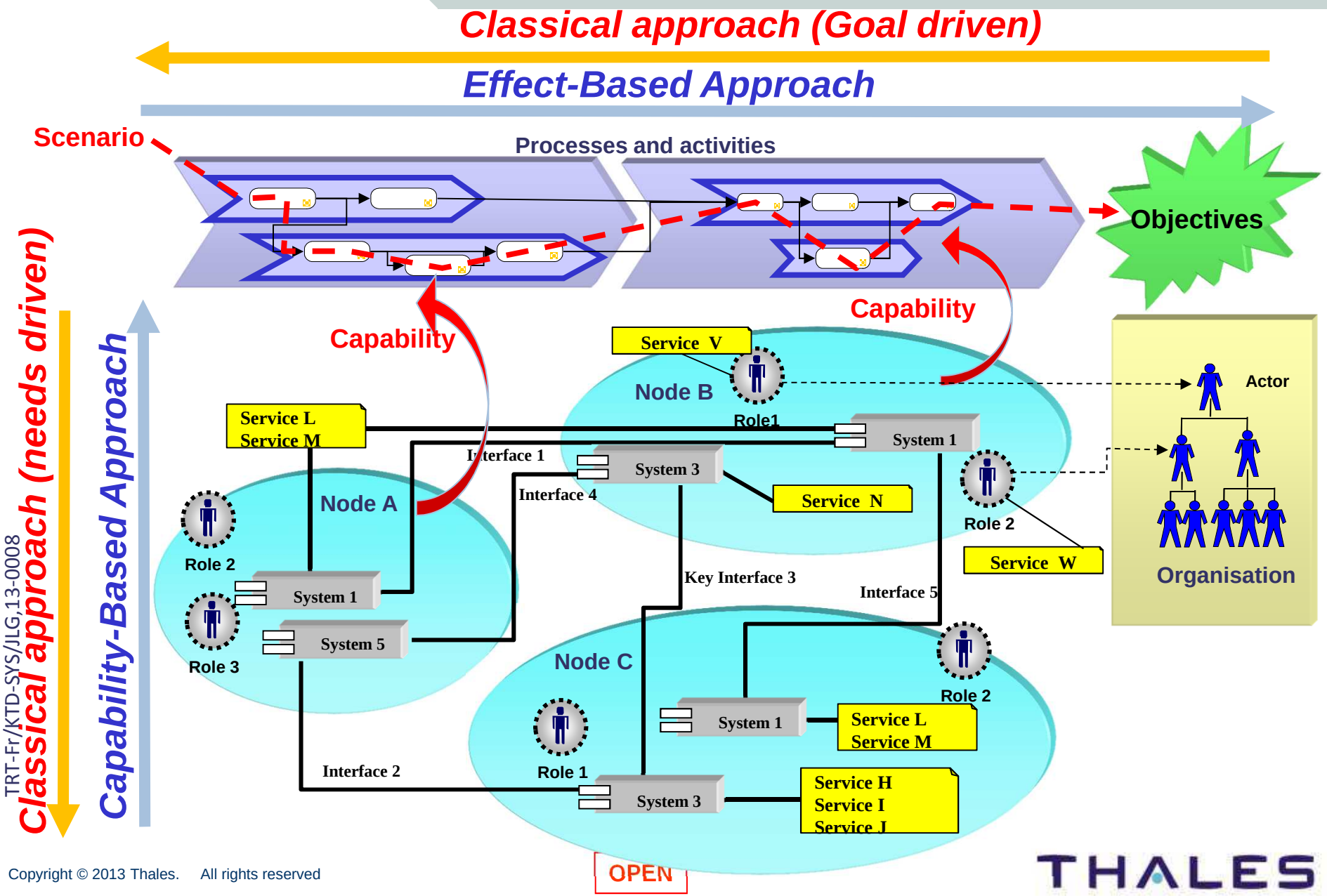
Development Approaches for Systems of Systems



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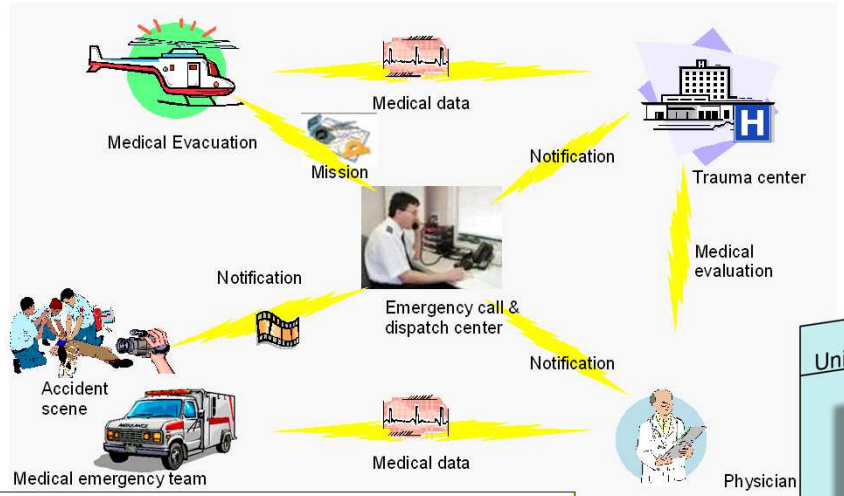
Challenges identifies for SoS development

SoS Challenges
1. System loose/smart coupling and dynamic (re)configuration
2. Flexible paradigms for interaction (mix of services, artefacts, events and streams)
3. Behaviour (Scheduling & emergence + non-functional properties)
4. Multi-level life cycles management
5. Engineering process to meet both bottom-up; top-down; dynamic system insertion/removal; legacy alignment
6. Run-time Management, Integrated logistic support and training on SoS or system built dynamically
7. Modelling and simulation to estimate feasibility, forecast behaviour and provide a reference for management

Presented during E.C. Workshops on SoS: Sept' 2011 and July 2012

Some examples worked in the French chapter of INCOSE

Association Française d'Ingénierie Système



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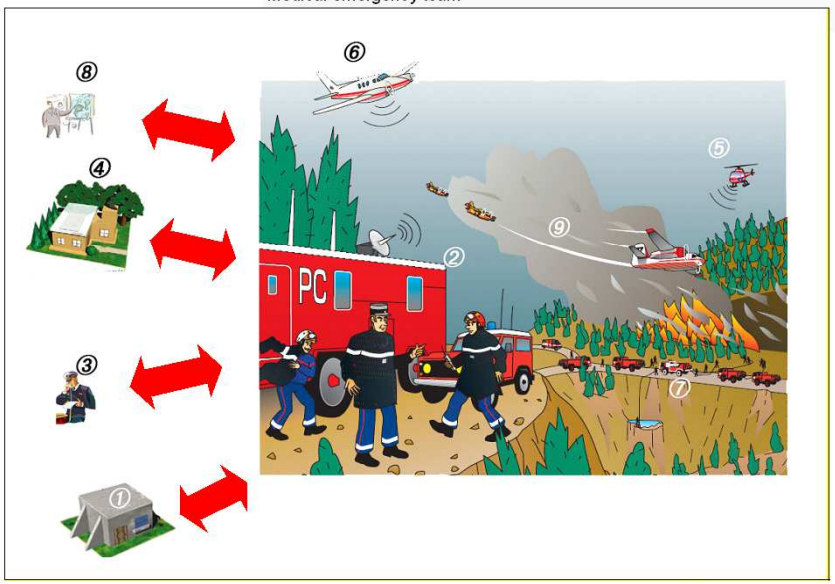

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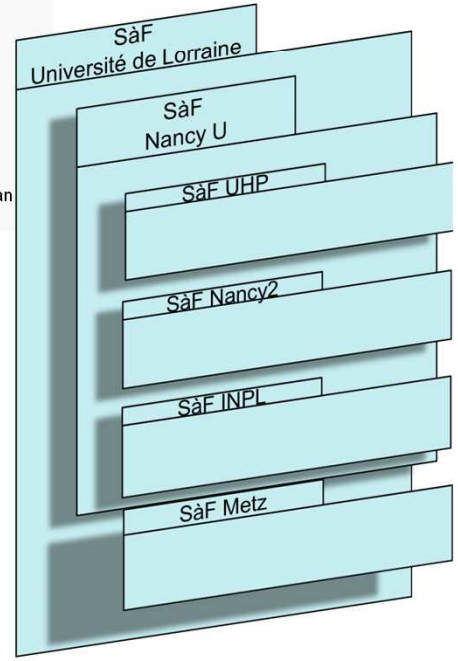
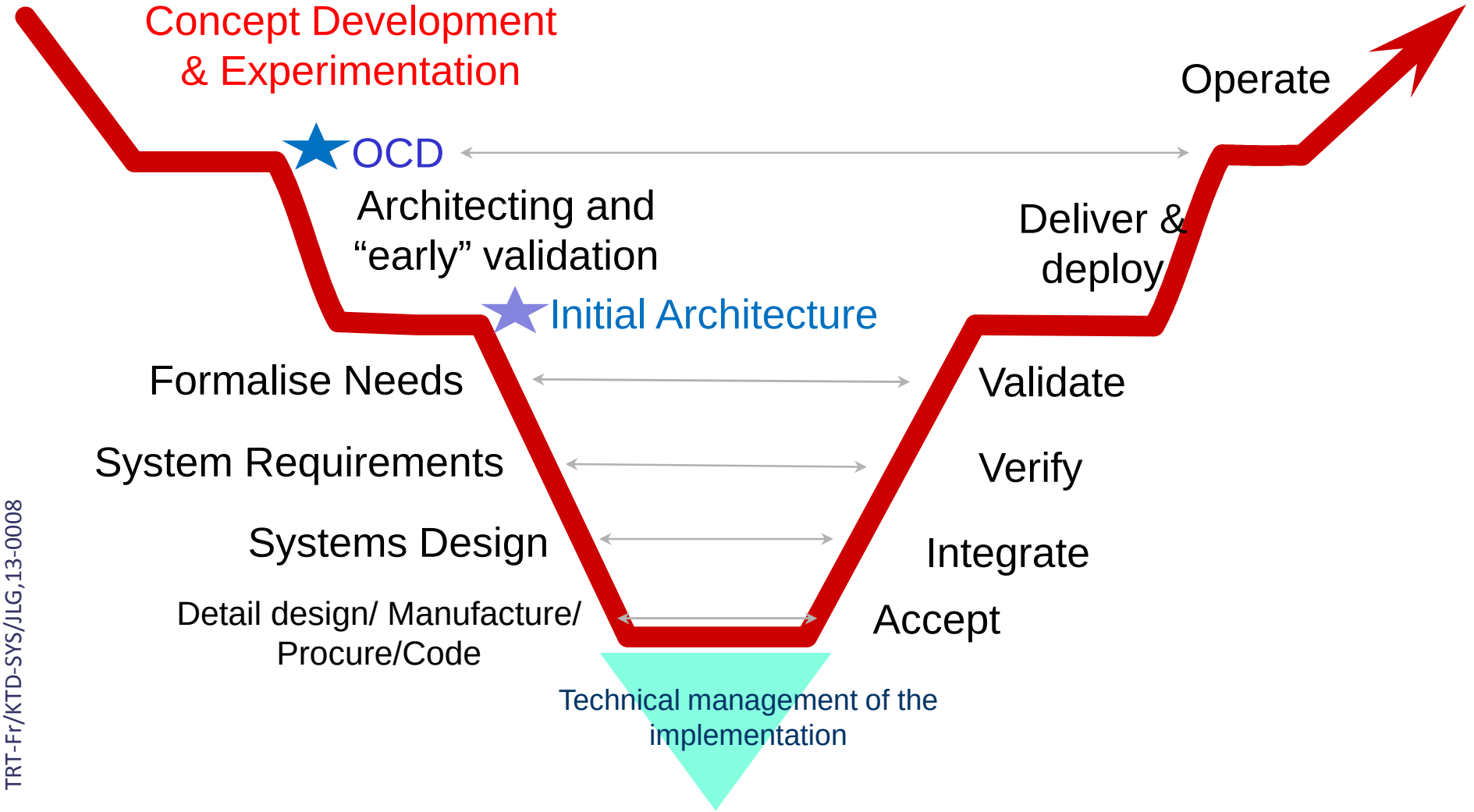


1) Autran et al, 2007
2) Autran et al, 2008
3) Auzelle, 2009

Workflow (theoretical V-model)



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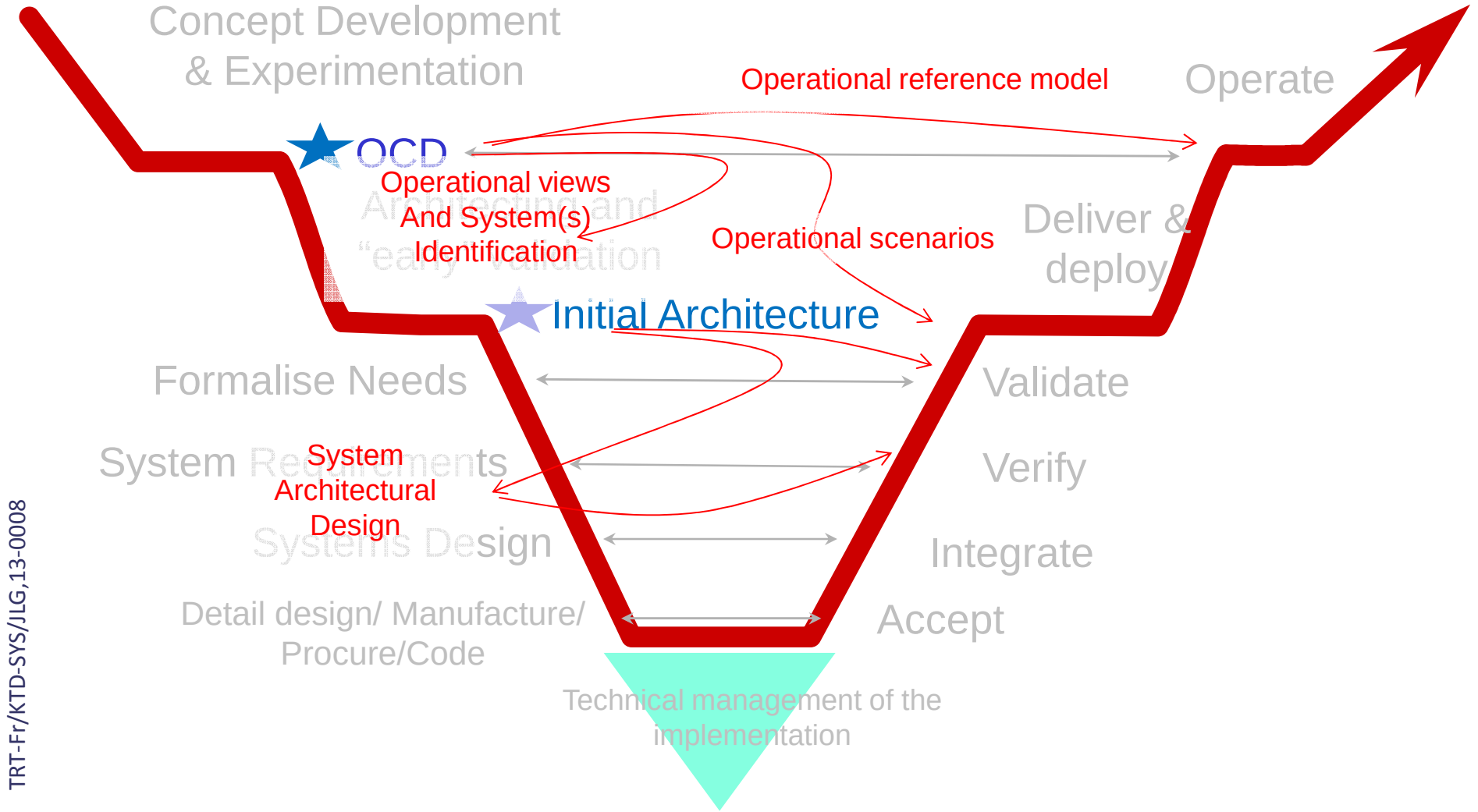
Workflow (CD&E and Architecting contribution)



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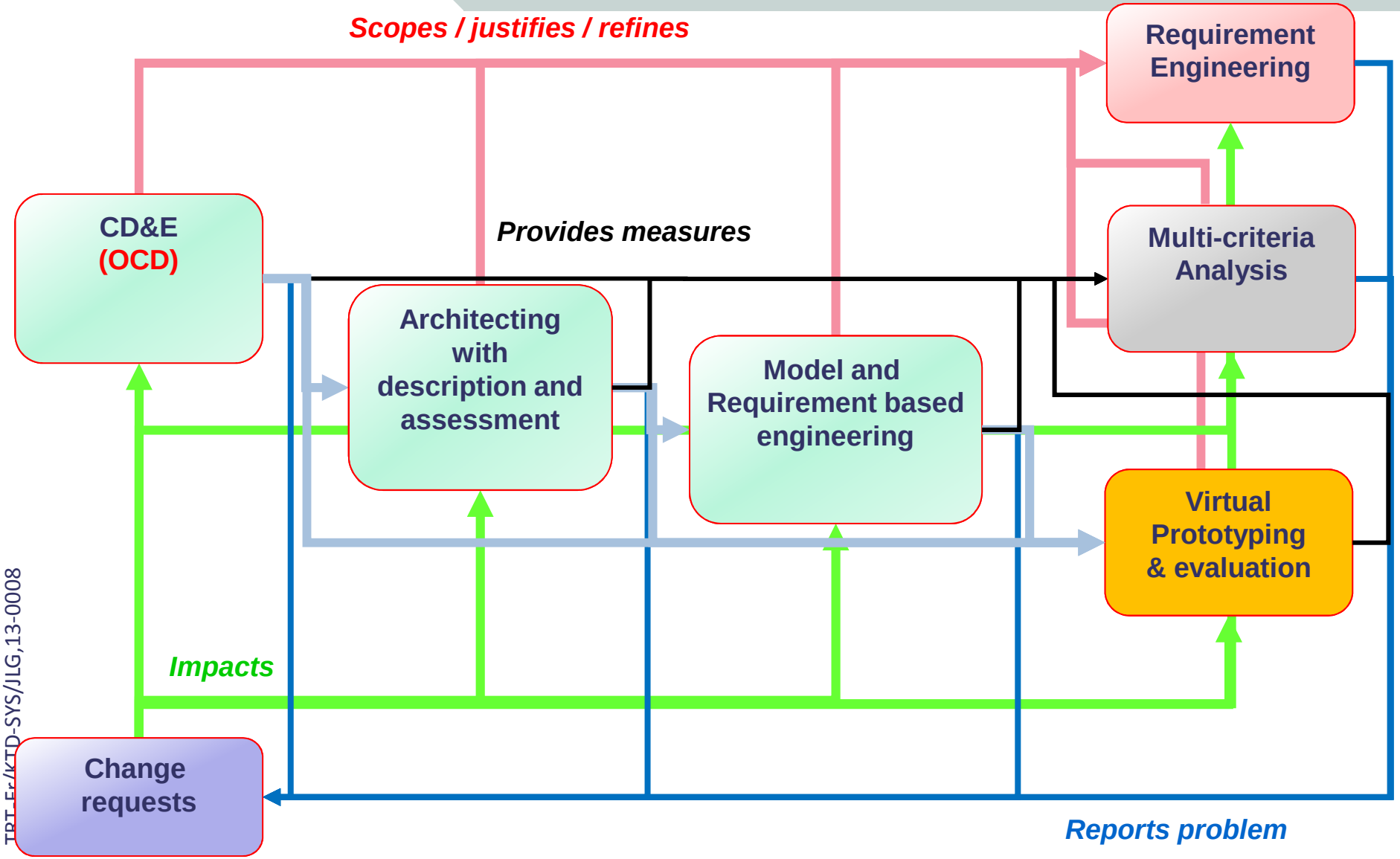
Typical workflow



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Operational Concept Development and Experimentation

Scenarios

Concept of operation

Concept of employment

Concept of use

Context

Stakes,
Mission,
Objectives,
Constraints,
Life-cycle

System Behaviour

System structure

Capabilities, activities
Actors, roles, responsibilities
Measure of Effectiveness

Acquisition, Deployment, Installation, Exploitation and Maintenance

User interactions
"non-functional" aspects of usage: performance, reliability, availability, maintainability, security, safety, trainability, etc.

States and modes
Functions, Capabilities
Services
Measure of Performance

Operators
Constituents and interfaces seen externally

"Out of the box" description

For each system visible from the operations: operational, training, logistic, etc.

From current to target situation

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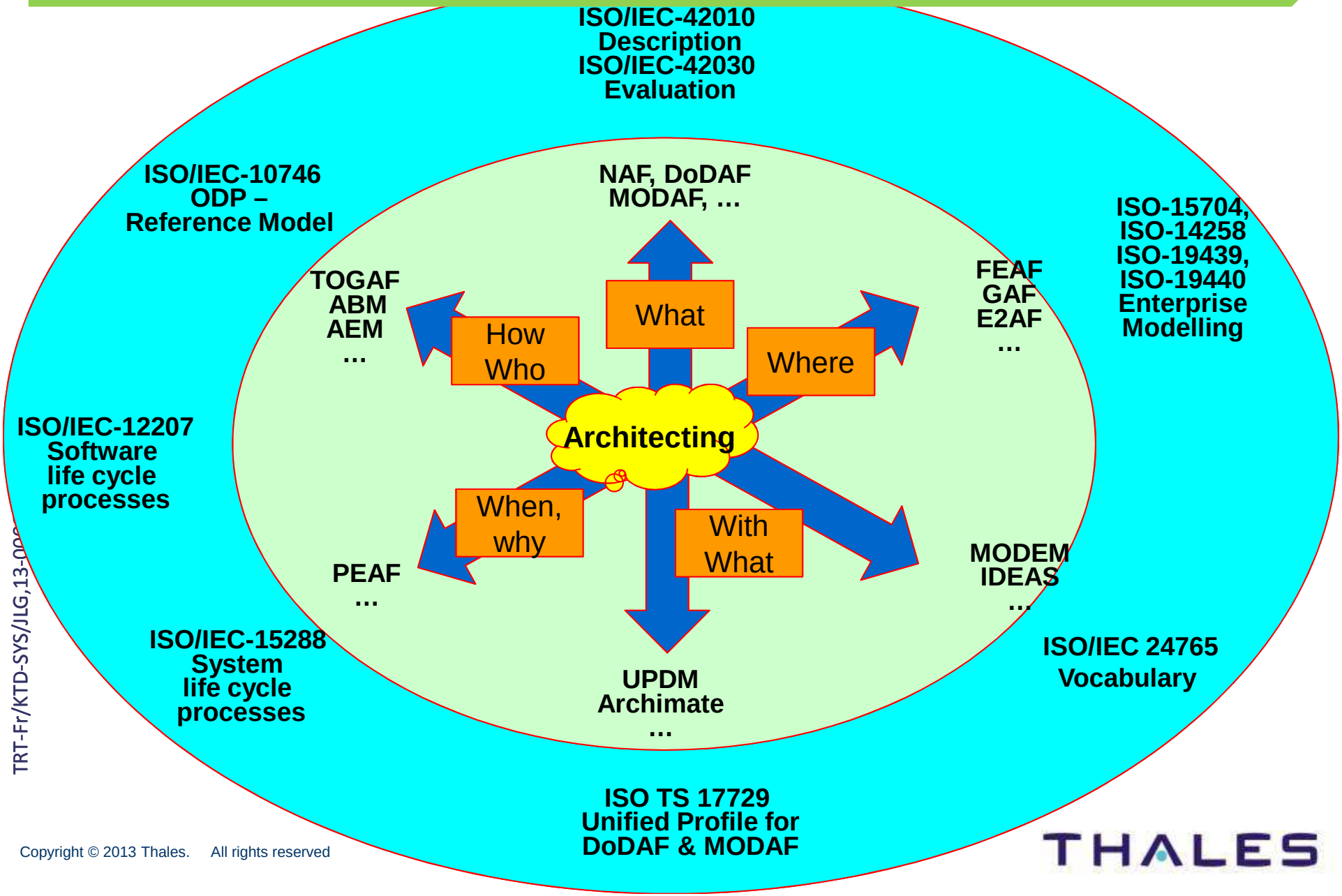
A lot of A.F. and standards for various concerns

Need to select and combine some of them in an architecting environment



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The main Architecture Frameworks: documents on the Web

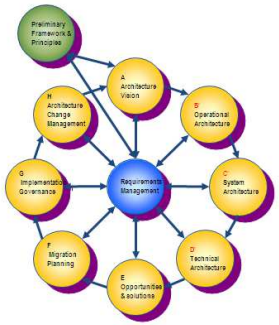
- ArchiMate, Open Group, http://www.opengroup.org/subjectareas/enterprise/archimate
- DoDAF, US Department of Defense, https://dars1.army.mil
- DNDAF, Canadian Department of National Defence ,http://www.img-ggi.forces.gc.ca/pub/af-ca/indexeng.asp
- E2AF, IFEAD, http://www.enterprise-architecture.info
- EAEA, Eurocontrol, http://www.eurocontrol.int/oca/gallery/content/public/docs/OATA-MCS-22-01 EAEA Framework v1.31.pdf
- FEAF, US Federal Enterprise, http://www.feapmo.gov
- MODAF, UK Ministry of Defence, http://www.modaf.com
- NAF (NATO AF), NATO, http://www.nhqc3s.nato.int/ARCHITECTURE
- RM-ODP, ISO, http://www.rm-odp.net/
- PEAF, PragmaticEA, http://www.pragmaticea.com/
- TOGAF, Open Group, http://www.opengroup.org/architecture/togaf
- TRAK, UK-Ministry of Transport, http://trak.sourceforge.net/
- UPDM, Object Management Group, http://www.omg.org/spec/UPDM/1.0/PDF
- Zachman, Zachman, http://www.zifa.com/framework.html

Architecting environment

Architecture Cycle

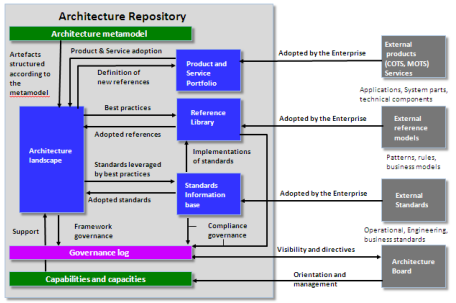
- ✓ Architecture Definition
- ✓ Architecture assessment
- ✓ Key requirement management
- ✓ Implementation governance

As example, TOGAF Architecture development method



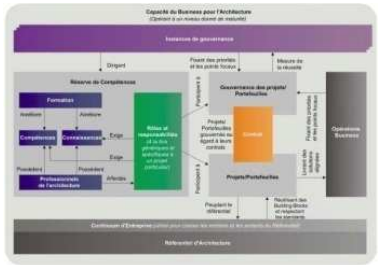
Architecture Content

- ✓ Norms and standards
- ✓ Best practices and patterns
- ✓ Product portfolio



Architecture Capability

- ✓ Skills & competencies
- ✓ Architecting Governance
- ✓ Formalisms &Tools
- ✓ Organisation & means (People and funding)



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Adapted from Open Group and Arismore sources

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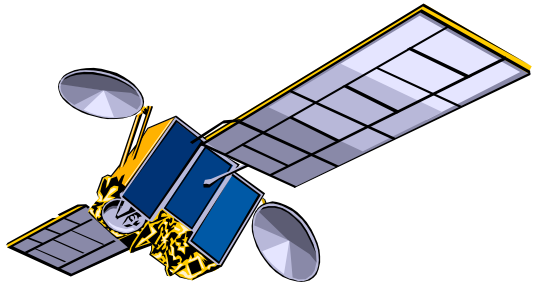
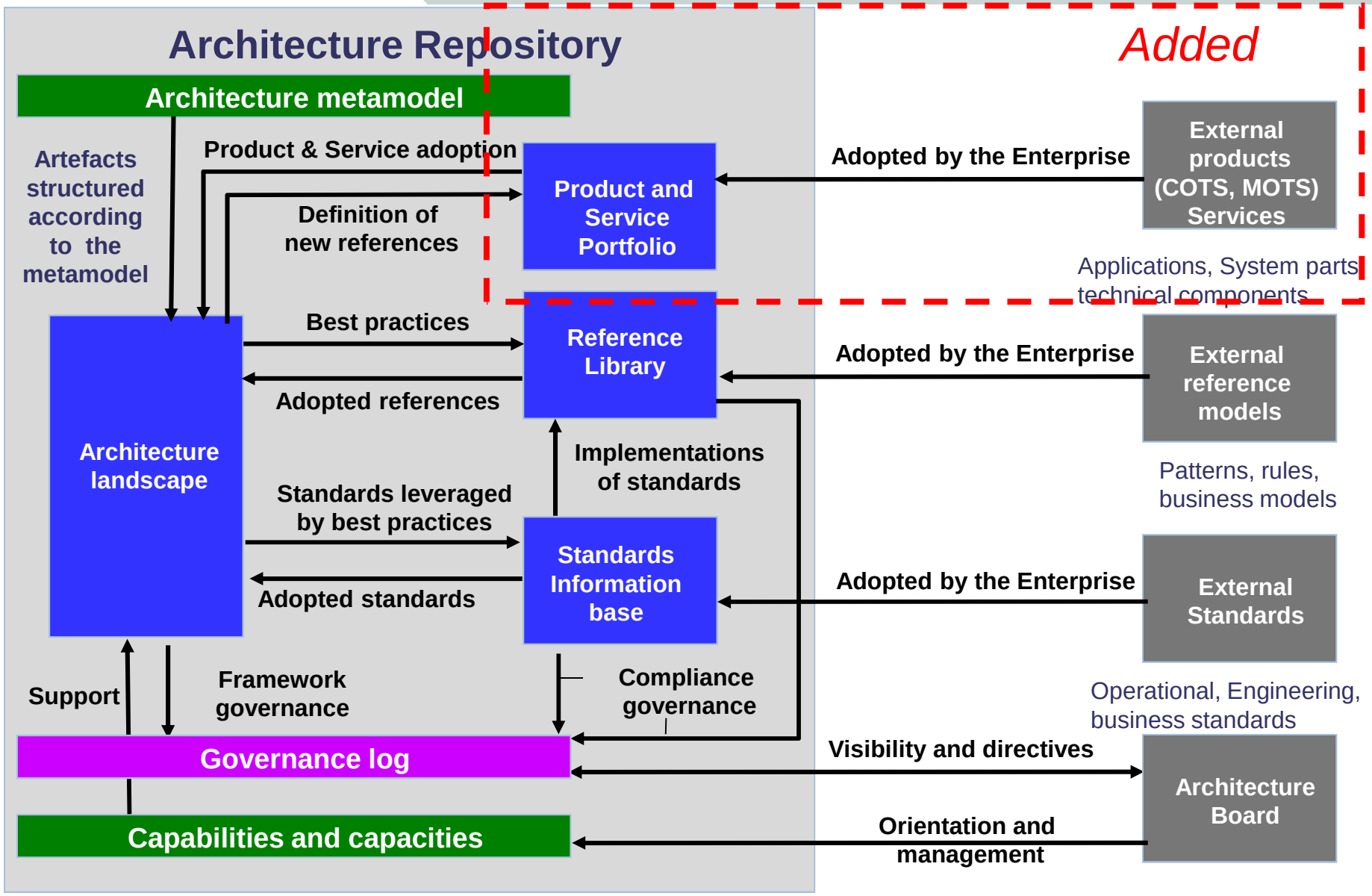
Skills and engineering capabilities management: balance between generic and domain-specific needs



Architecting landscape: Adaptated from TOGAF



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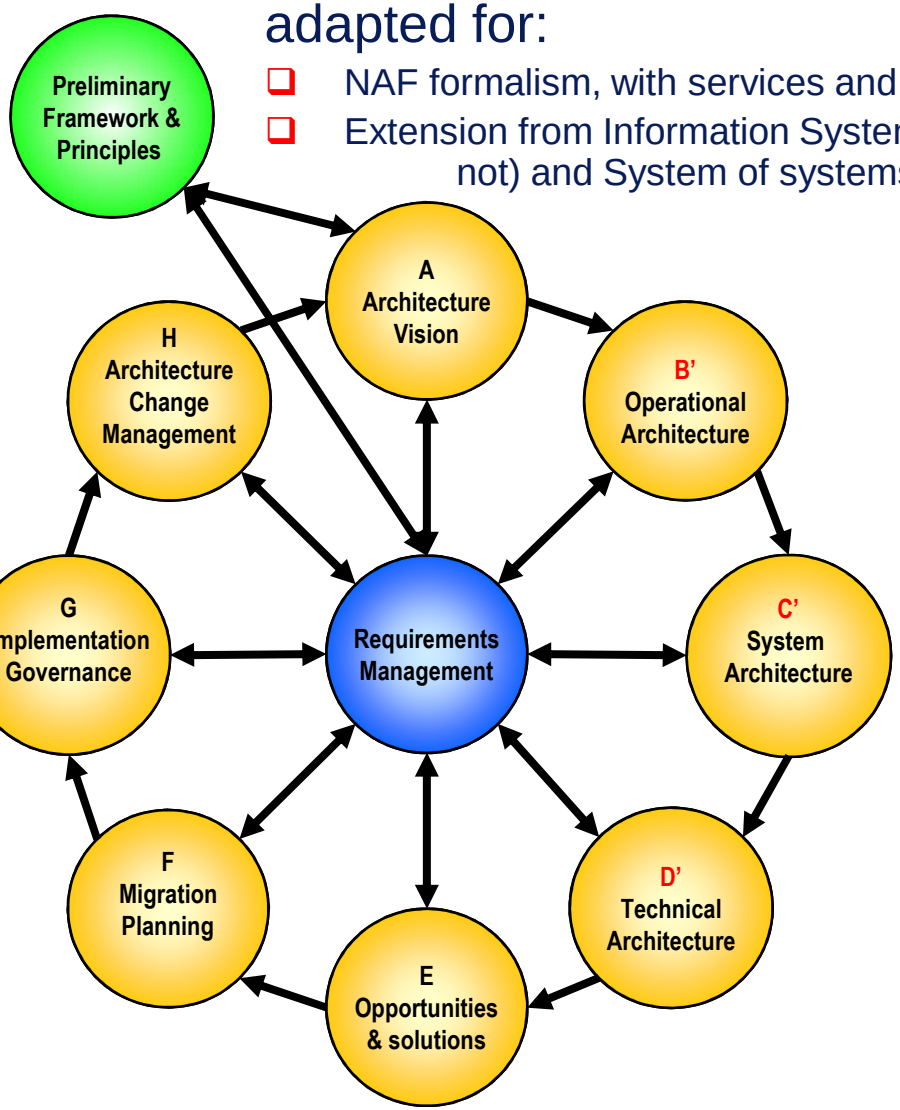
Example of method: Architecting process based on TOGAF

Choice of the TOGAF Architecture Development Method adapted for:

- NAF formalism, with services and capabilities
- Extension from Information System to complete system (complex or not) and System of systems



- Preliminary works: for the stakeholders and the enterprise
- A: strategy and business roadmap
- B': Operations and usage
- C': how system works?
- D': how it is made?
- E: Trade-offs
- F: Evolution roadmap
- G: Link with SE
- H: Evolution

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A set of views: e.g. NATO AF

Documents the strategic picture of how military capability is evolving in order to support capability management and equipment planning

NATO CAPABILITY VIEW

Provides summary information for the architecture that enables it to be indexed searched and queried

NATO ALL VIEW

Documents Human Concepts, Constraints, Functions, Roles, Human Networks, Training, and Metrics

HUMAN FACTORS

Extension

Documents the operational processes, relationships and context to support operational analyses and requirements development

NATO OPERATIONAL VIEW

Documents programme dependencies, timelines and status to inform programme management and procurement synchronization

NATO PROGRAM VIEW

NATO SYSTEM VIEW

NATO TECHNICAL VIEW

NATO SERVICES VIEW

Documents system functionality and interconnectivity to support system analysis and through life management

Documents policy, standards, guidance and constraints to specify and assure quality expectations

Documents Services functionality, constraints and interoperability

NATO-AF V3: Views (1/3)

View Type	Subviews	Subview Name	
All View	NAV-1	Overview and Summary Information	DODAF
All View	★ NAV-2	Integrated Dictionary	DODAF
All View	NAV-3	Metadata	New
Capability	NCV-1	Capability Vision and Strategy	MODAF
Capability	★ NCV-2	Capability Taxonomy	MODAF
Capability	NCV-3	Capability Phasing	MODAF
Capability	NCV-4	Capability Clusters	MODAF
Capability	NCV-5	Capability to Systems Deployment Mapping	MODAF
Capability	NCV-6	Capability Function to Operational Activity (Military Functions) Mapping	New
Capability	NCV-7	Capability to Services Mapping	New
Operational	NOV-1	High-Level Operational Concept Description	DODAF
Operational	★ NOV-2	Operational Node Connectivity Specification	DODAF
Operational	★ NOV-3	Operational Information Exchange Matrix	DODAF
Operational	NOV-4	Organizational Relationship Chart	DODAF
Operational	★ NOV-5	Operational Activity Model	DODAF
Operational	NOV-6a	Operational Rule Model	DODAF
Operational	NOV-6b	Operational State Transition Description	DODAF
Operational	★ NOV-6c	Operational Event-Trace Description	DODAF
Operational	★ NOV-7	Information Model	New

★ NAF Essential View

NATO-AF V3: Views (2/3)

View Type	Subviews	Subview Name	
Systems	★ NSV-1	Systems Interface Description	DODAF
	NSV-2a	System Port Specification	MODAF
	NSV-2b	System To System Port Connectivity	MODAF
	NSV-2c	System Connectivity Clusters	MODAF
	NSV-3	Systems-Systems Matrix	DODAF
	★ NSV-4	Systems Functionality Description	DODAF
	NSV-5	Operational Activity to Systems Function Traceability Matrix	DODAF
	★ NSV-6	Systems Data Exchange Matrix	DODAF
	NSV-7	Systems Quality Requirements Description	New
	NSV-8	Systems Evolution Description	DODAF
	NSV-9	Systems Technology Forecast	DODAF
	NSV-10a	Systems Rules Model	DODAF
	NSV-10b	Systems State Transition Description	DODAF
	★ NSV-10c	Systems Event-Trace Description	DODAF
	★ NSV-11a	Logical Data Model	DODAF
	NSV-11b	Physical Data Model	DODAF
	NSV-12	Service Provision	New

★ NAF Essential View

NATO-AF V3: Views (3/3)

View Type	Subviews	Subview Name	
Service Oriented	★ NSOV-1	Services Taxonomy	New
	★ NSOV-2	Service Definition	New
	NSOV-3	Services to Operational Activities Mapping	New
	NSOV-4	Services Orchestration	New
	NSOV-5	Service Behaviour	New
Technical	★ NTV-1	Technical Standards Profile	DODAF
	NTV-2	Technical Standards Forecast	DODAF
	NTV-3	Standard Configurations	New
Programme	NPV-1	Programme Portfolio Relationships	New
	NPV-2	Programme to Capability Mapping	New

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★ NAF Essential View

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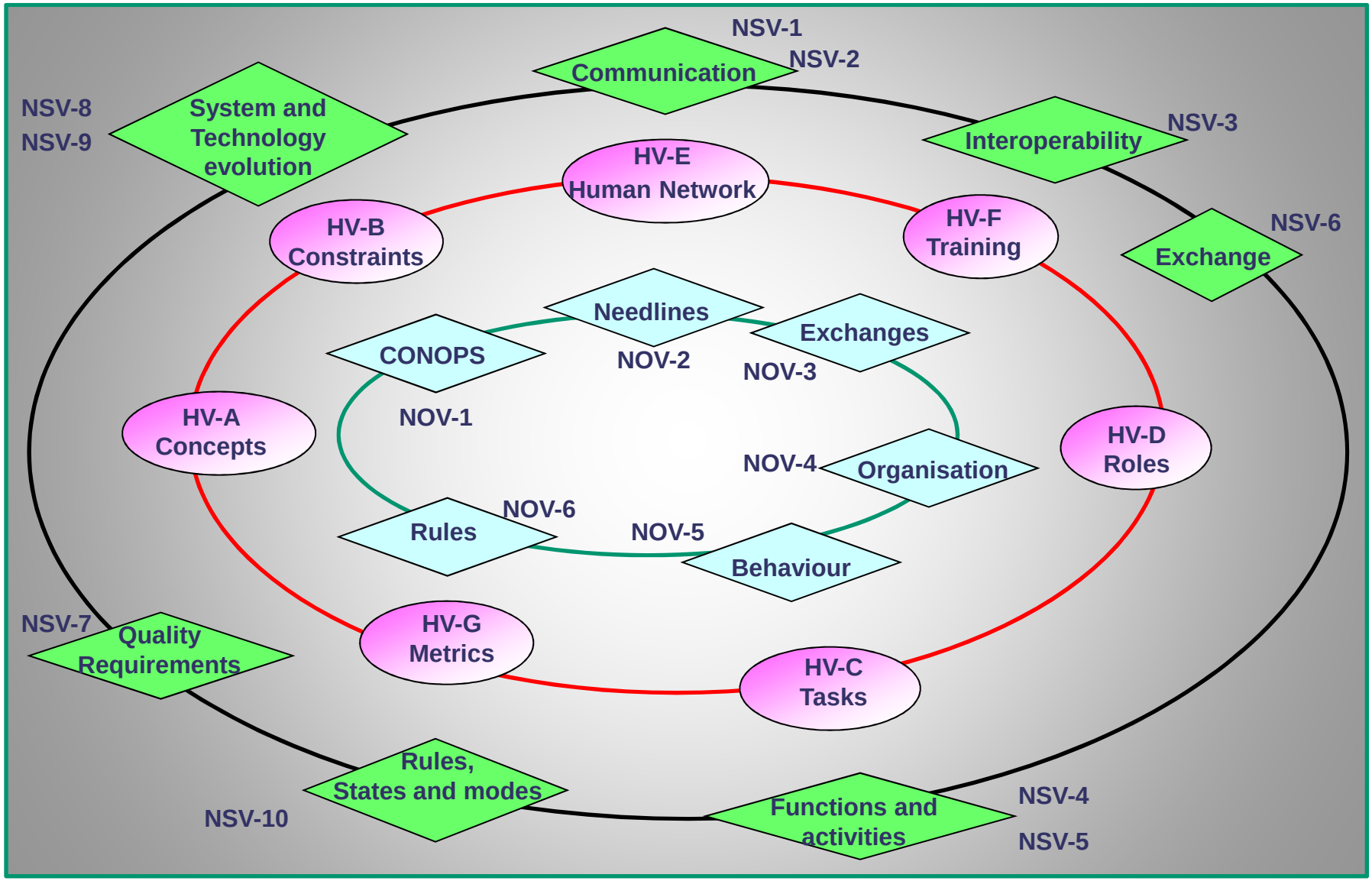
Human views: Adapted from UK-MOD and NATO studies



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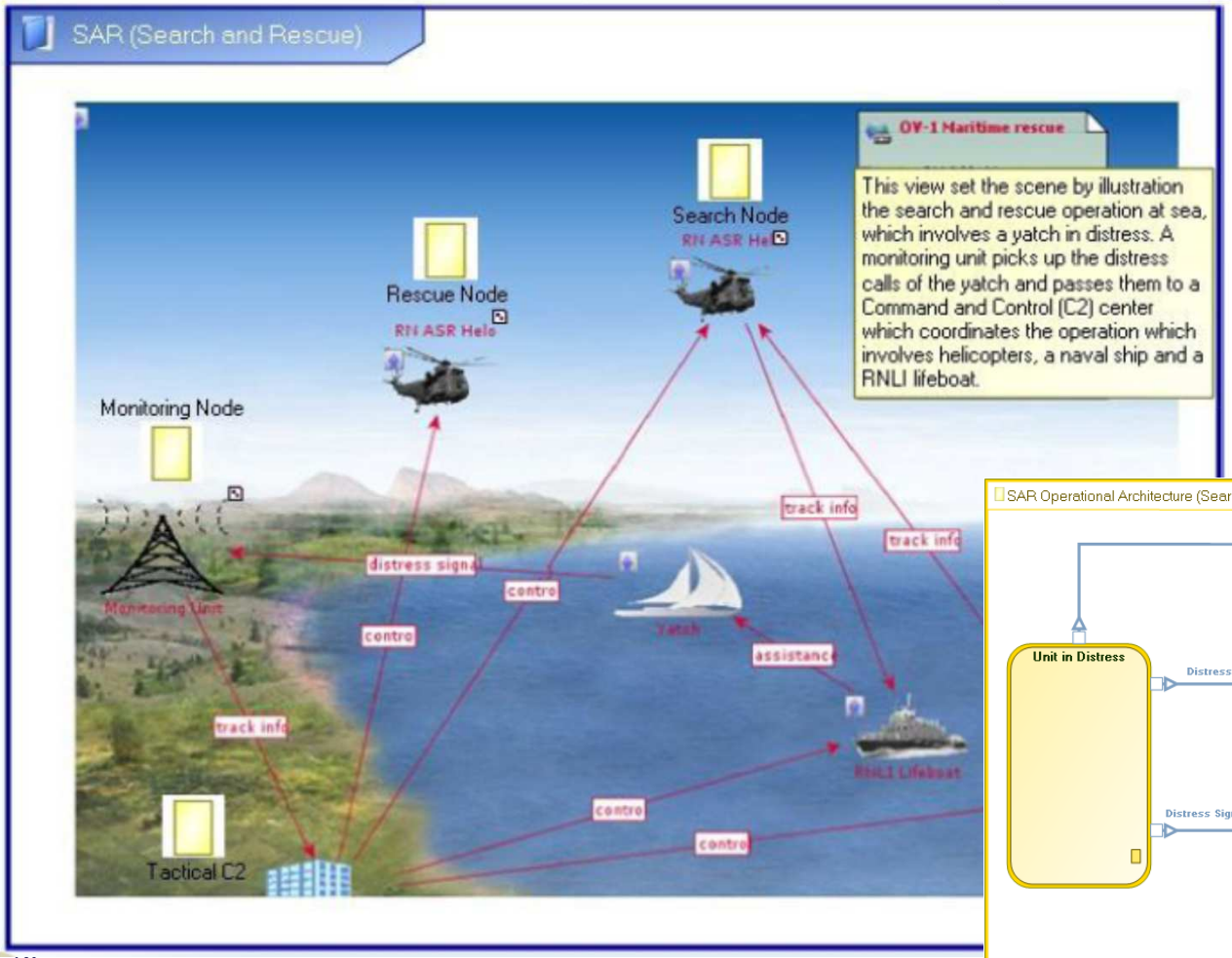
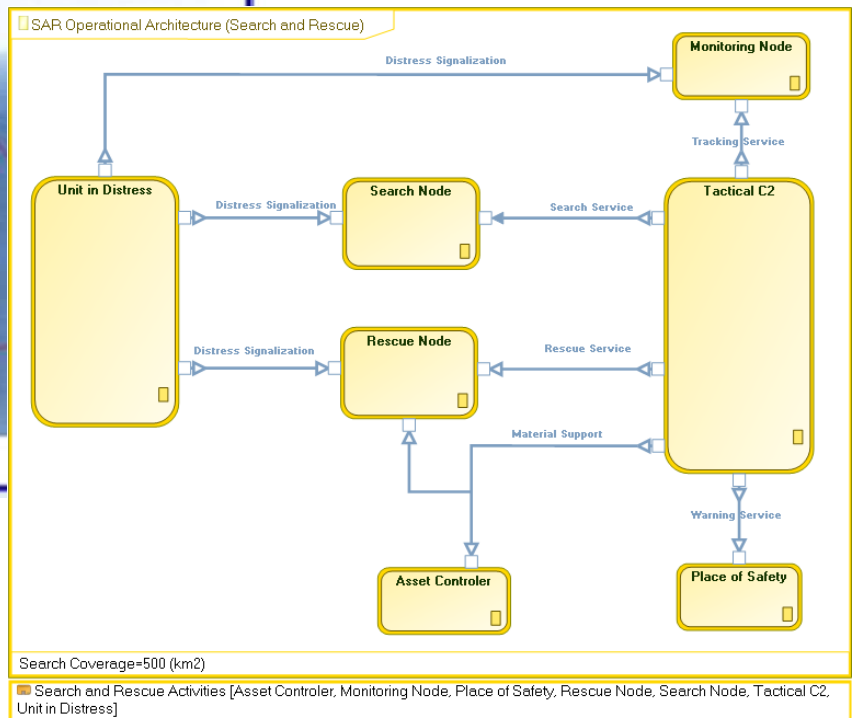
Useful for SoS: High-Level Operational Concepts





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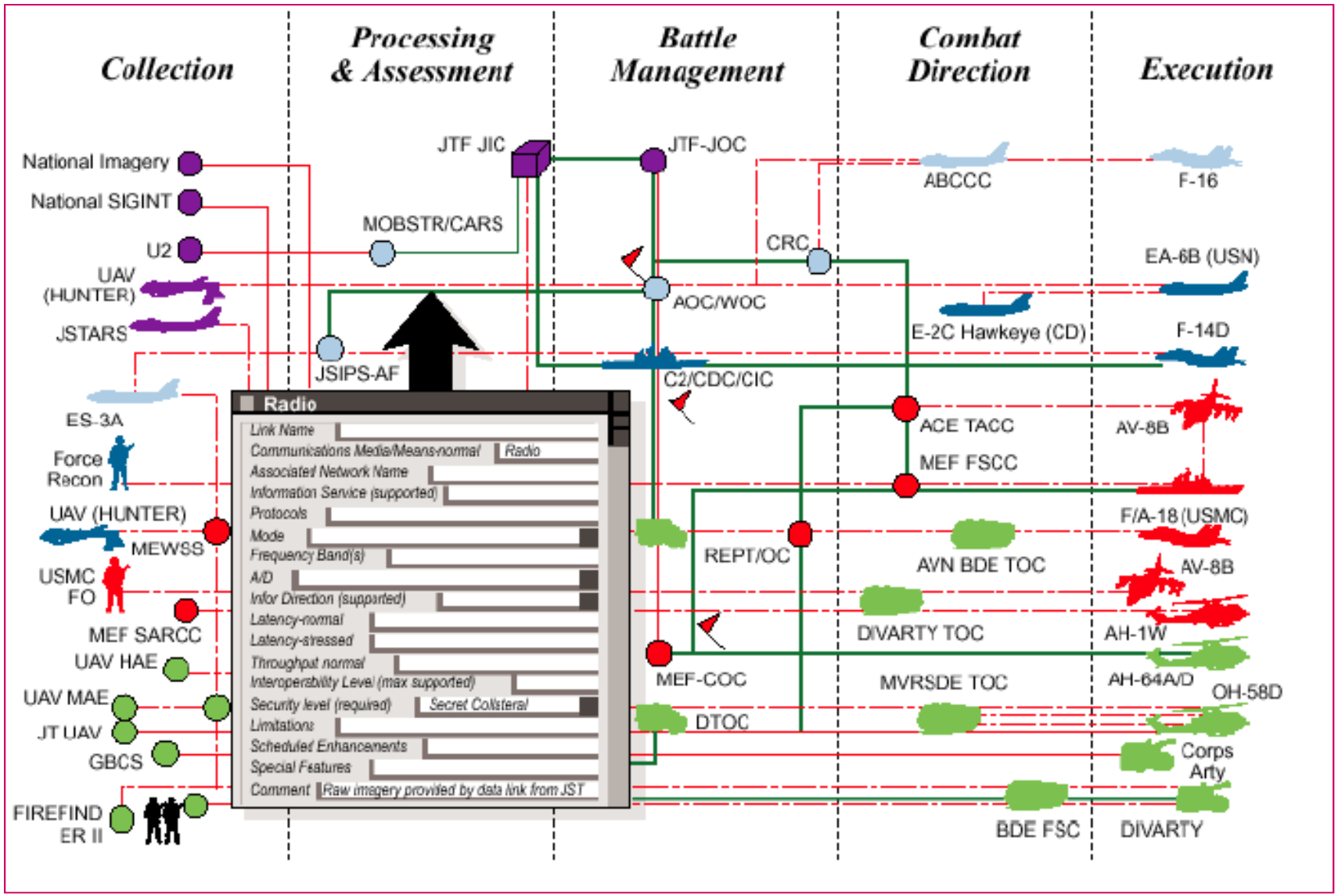
Useful for SoS: Operational Node Connectivity



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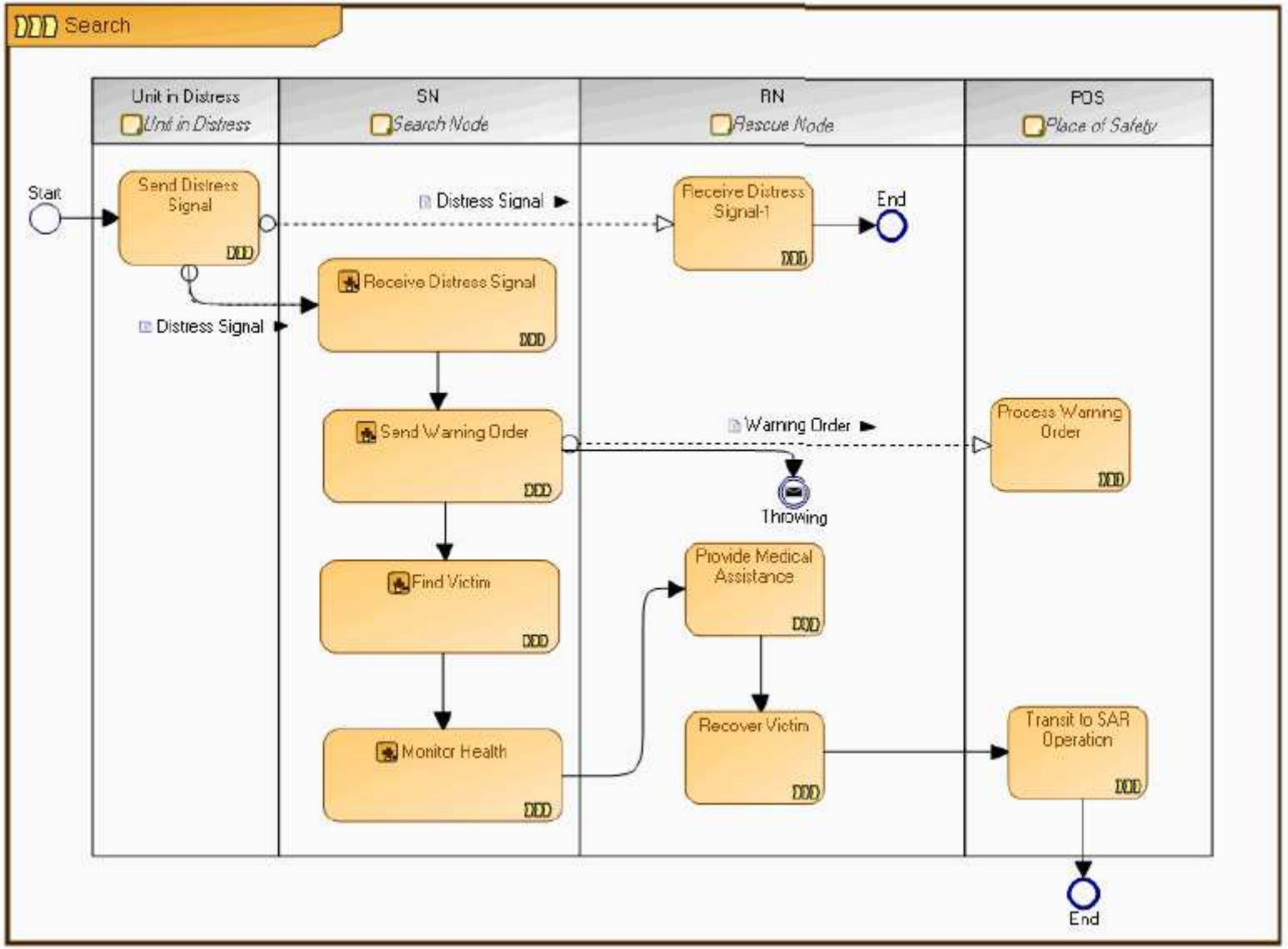
Useful for SoS: Operational Activity Model



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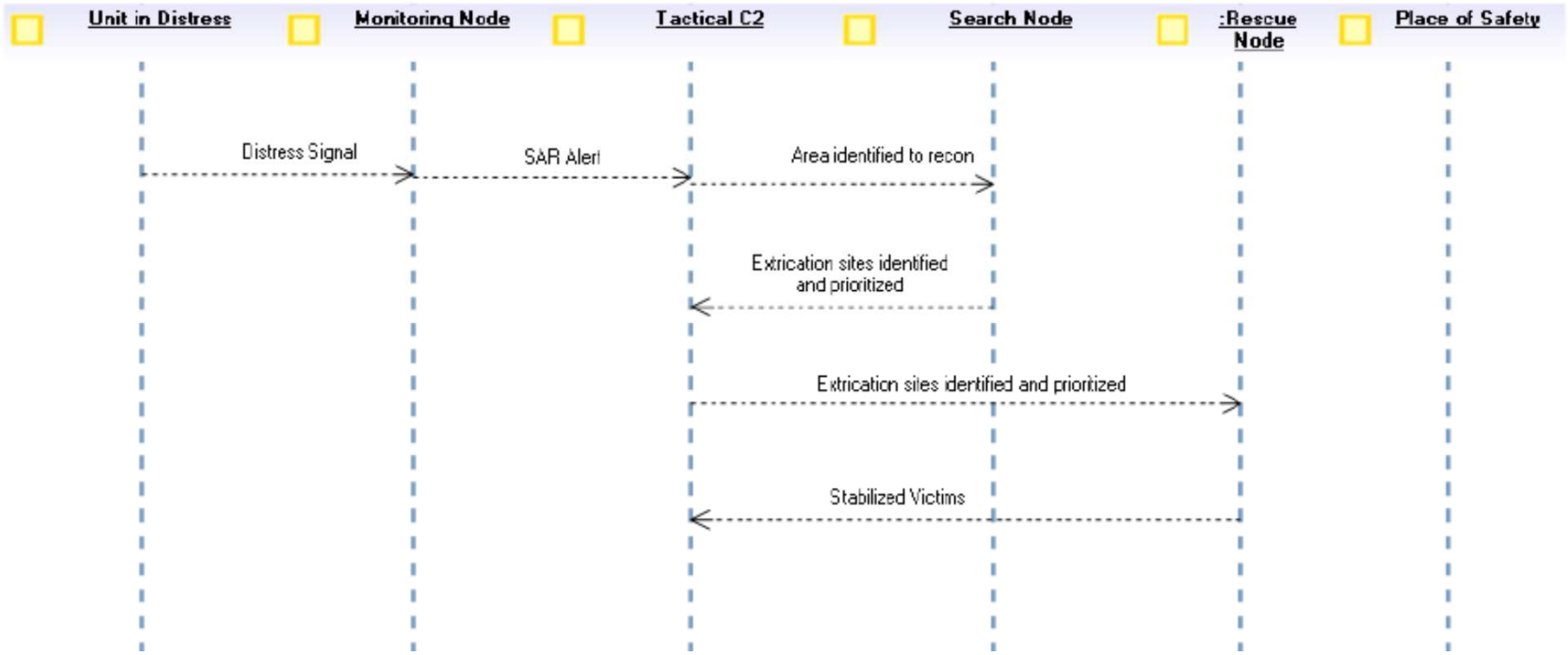
Useful for SoS: Systems interaction



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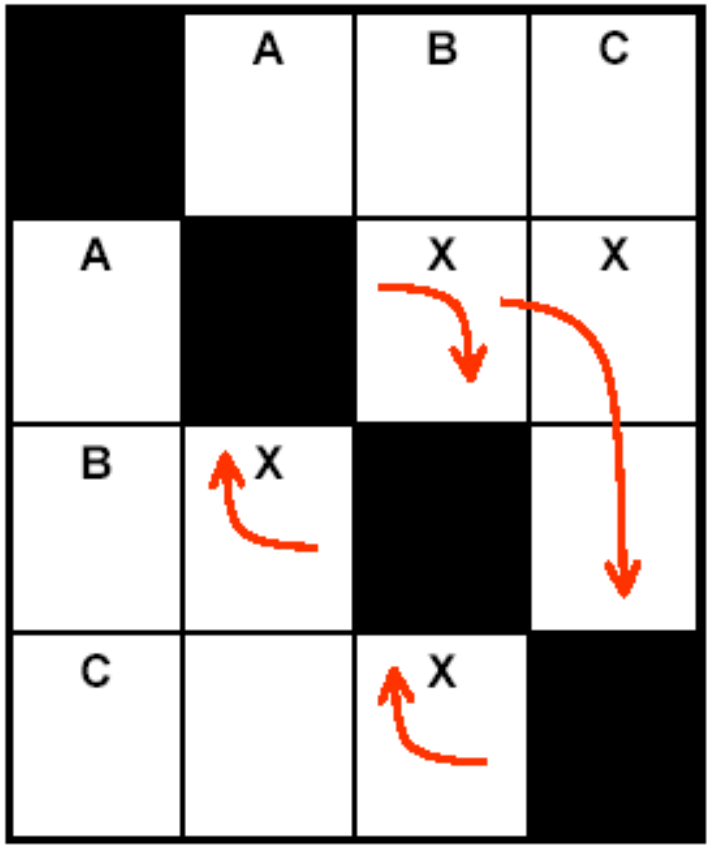
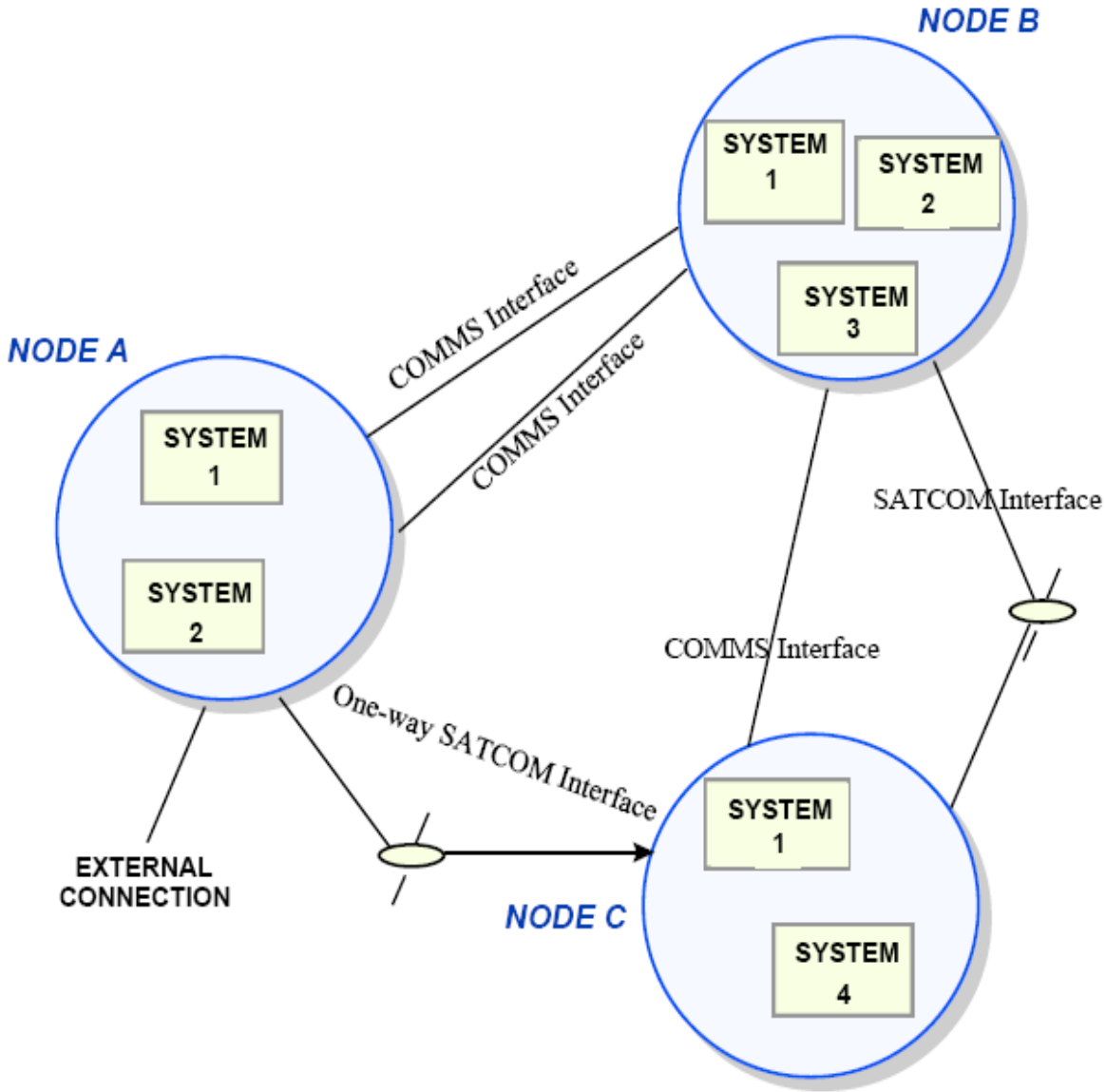
Useful for SoS: Systems to Systems Matrix

- **The SV-3 illustrates the system connectivity**
  - Trivial for small systems
    - Most useful when architecture is very large
  - Does not typically indicate directionality of link
  - Diagram is read "clockwise"
    - A talks to B & C
    - B talks to A
    - C talks to B
- **Similar to N-Squared Diagram**



Useful for SoS: System Interface Description



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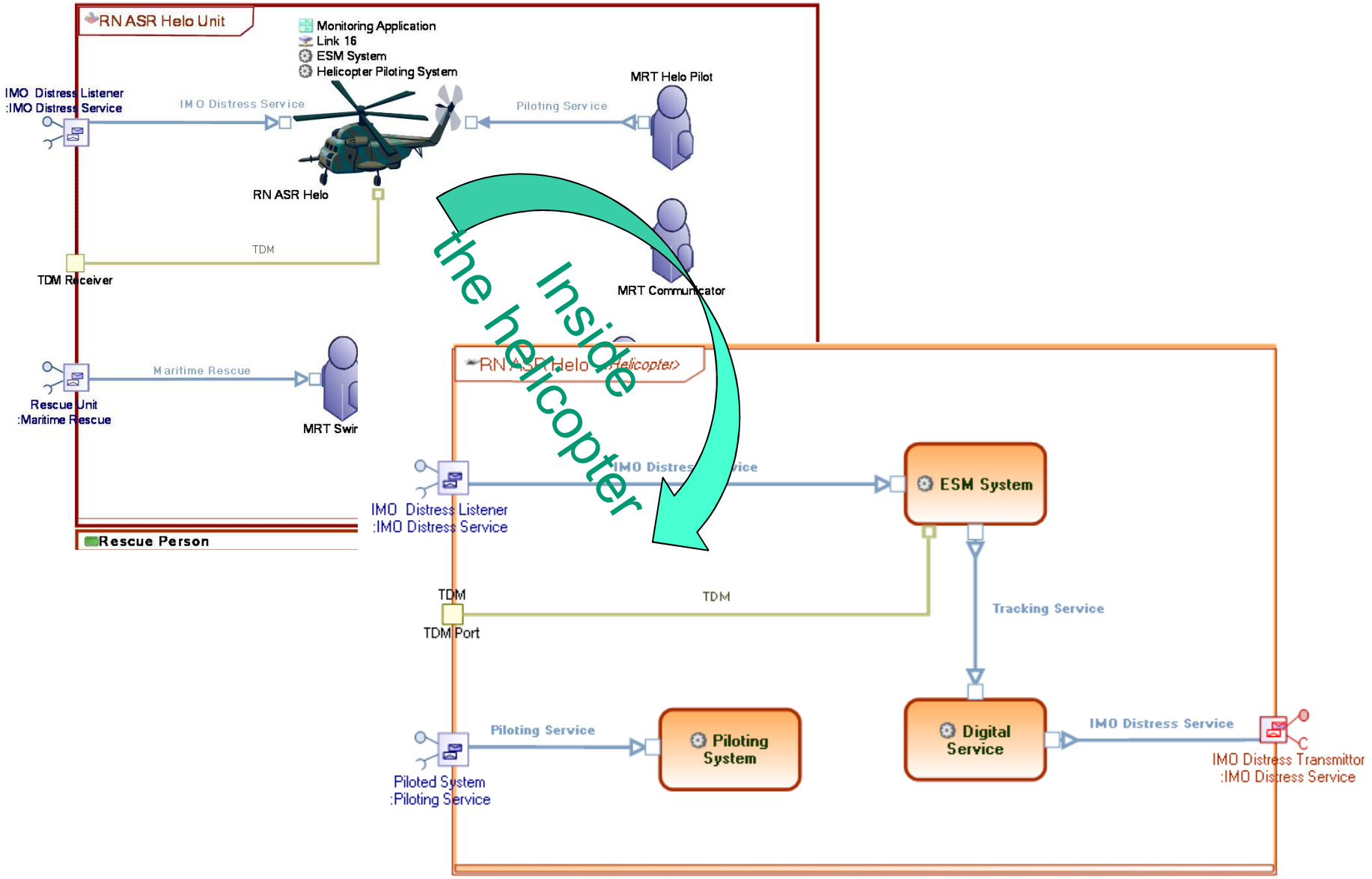
Useful for SoS: multi-level modelling



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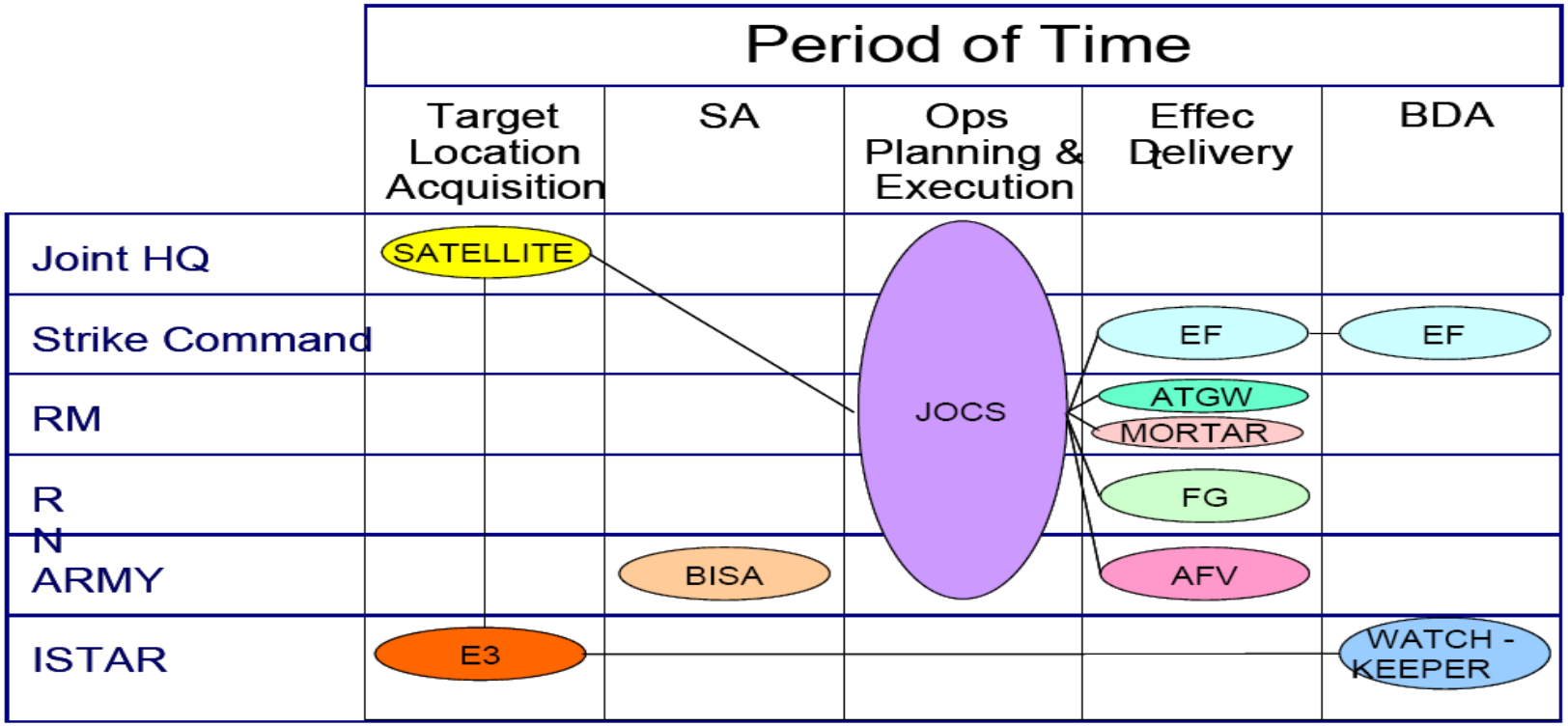
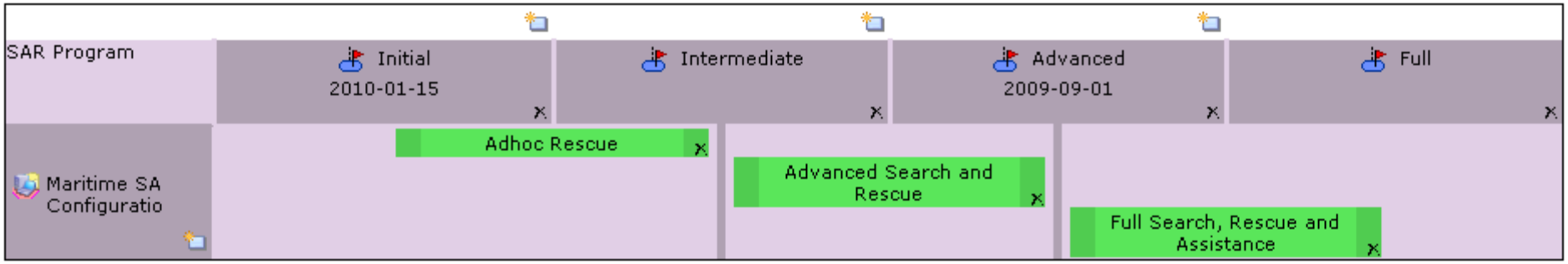
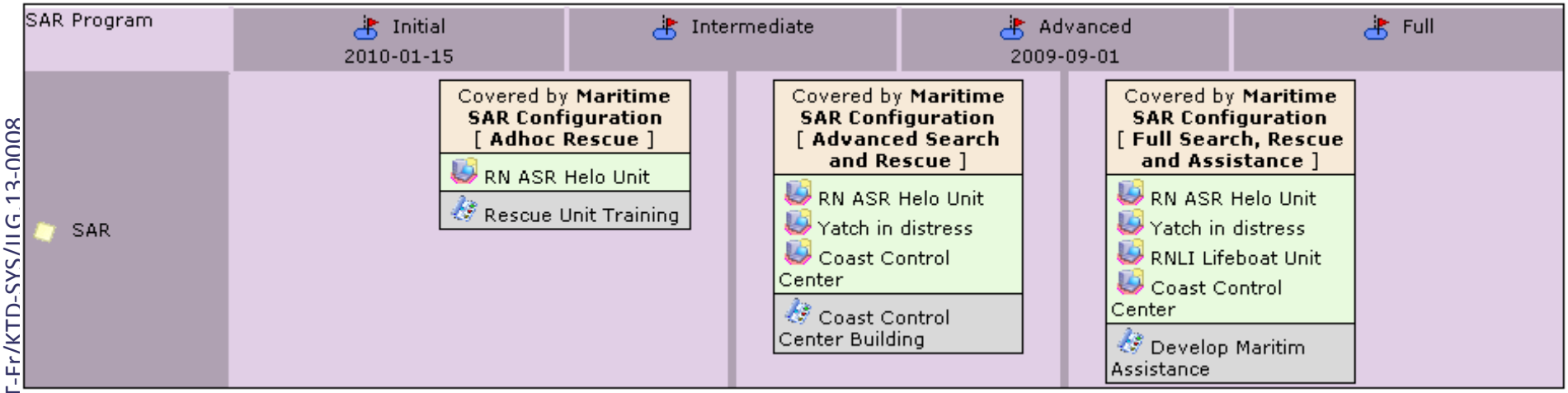
Useful for SoS: Capability to Organisational Deployment Mapping



Useful for SoS: Programmatic view and capability phasing





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AF support to solve the challenge on SoS

SoS Challenges	Some A.F. views
1. System loose/smart coupling and dynamic (re)configuration	Systems connectivity, needlines & exchanges
2. Flexible paradigms for interaction (mix of services, artefacts, events and streams)	Service and capability description
3. Behaviour (Scheduling & emergence + non-functional properties)	Process models and functional views
4. Multi-level life cycles management	Capability phasing and program views
5. Engineering process to meet both bottom-up; top-down; dynamic system insertion/removal; legacy alignment	Multi-level modelling
6. Run-time management, Integrated logistic support and training on SoS or system built dynamically	Usage of AF views in MBSE
7. Modelling and simulation to estimate feasibility, forecast behaviour and provide a reference for management	Usage of AF views in MBSE

But strong weaknesses exist within the A.F. and associated tooling

- Formalism is not aligned within the different Architecture Frameworks
  - Lack of interoperability
- Few Architecting methods
- Poor concepts for evaluation
- Some concerns poorly or not addressed
  - Human Factors
  - Safety
  - Security
  - Performance
  - Multi-physics
- Poor compliance of the tools to AF formalisms
- Lack of standards to cover Architecting and transition to Systems Engineering

Conclusion on AF usage to sustain SoS development

	Positive	Negative
Internal factors	**Strengths** • Thought for multi-project/system acquisition, orientation and governance (SoS) • Well advanced for development of information systems and net-enabled operations	**Weaknesses** • Some important views missing: human view, safety, security, performance & multi-physics. • Few methods • Formalisms not stabilised • Poor tooling
External factors	**Opportunities** • Governmental agencies and large programmes are requiring usage of A.F. • Ministries, national and international agencies are motivated to issue of standards	**Threats** • Resistance to change • Return on investment not enough explained / proven • Lack of scientific basis and researches on A.F. including modelling and simulation

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Another typology

DoD introduced a four-valued typology:

- Virtual : Virtual SoS lack a central management authority and a centrally agreed upon purpose for the system-of-systems (ex: Global Information Grid)
- Collaborative: In collaborative SoS the component systems interact more or less voluntarily to fulfil agreed upon central purposes. (ex: the Internet)
- Acknowledged: Acknowledged SoS have recognized objectives, a designated manager, and resources for the SoS; however, the constituent systems retain their independent ownership, objectives, funding, and development and sustainment approaches.
- Directed: the integrated system-of-systems is built and centrally managed to fulfil specific purposes. The component systems maintain an ability to operate independently, but their normal operational mode is subordinated to the central managed purpose.

SoS Engineering Key Concepts

	Traditional Systems Engineering	System-of-Systems Engineering
Purpose	Development of single system to meet stakeholder requirements and defined performance	Evolving new system-of-systems capability by leveraging synergies of legacy systems
System Architecture	System architecture established early in lifecycle and remains relatively stable	Dynamic reconfiguration of architecture as needs change; use of service oriented architecture approach as enabler
System Interoperability	Defines and implements specific interface requirements to integrate components in system	Component systems can operate independently of SoS in a useful manner Protocols and standards essential to enable interoperable systems
System "ilities"	Reliability, Maintainability, Availability are typical ilities	Added "ilities" such as Flexibility, Adaptability, Composeability
Acquisition and Management	Centralized acquisition and management of the system	Component systems separately acquired and continue to be managed as independent systems
Anticipation of Needs	Concept phase activity to determine system needs	Intense concept phase analysis followed by continuous anticipation, aided by ongoing experimentation

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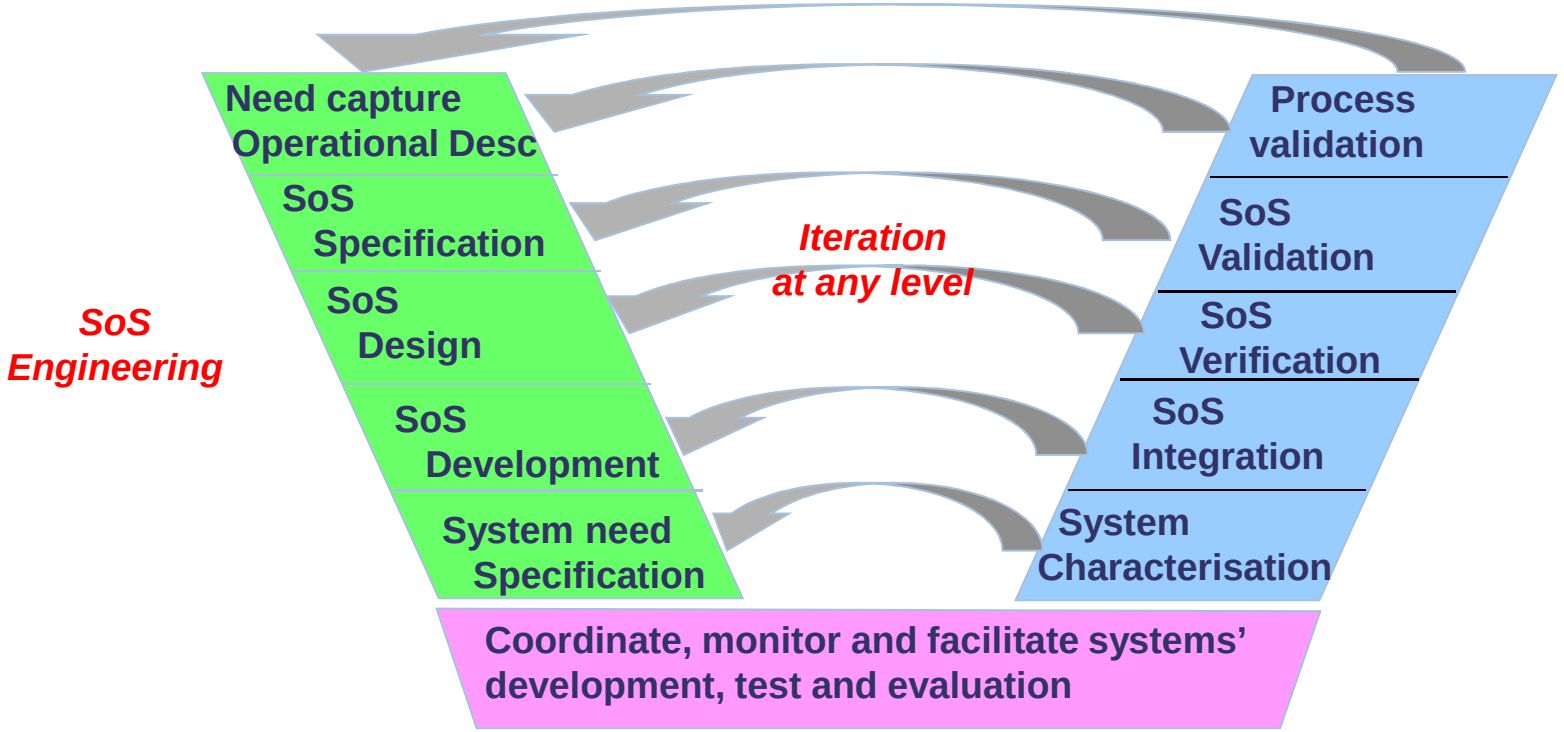
Saunders, T. *et al,* "United States Air Force Scientific Advisory Board Report on System-of-Systems Engineering for Air Force Capability Development," SAB-TR-05-04, July 2005

SE for SoS: basic steps are classic



SoS Engineering

Constituent Systems Engineering

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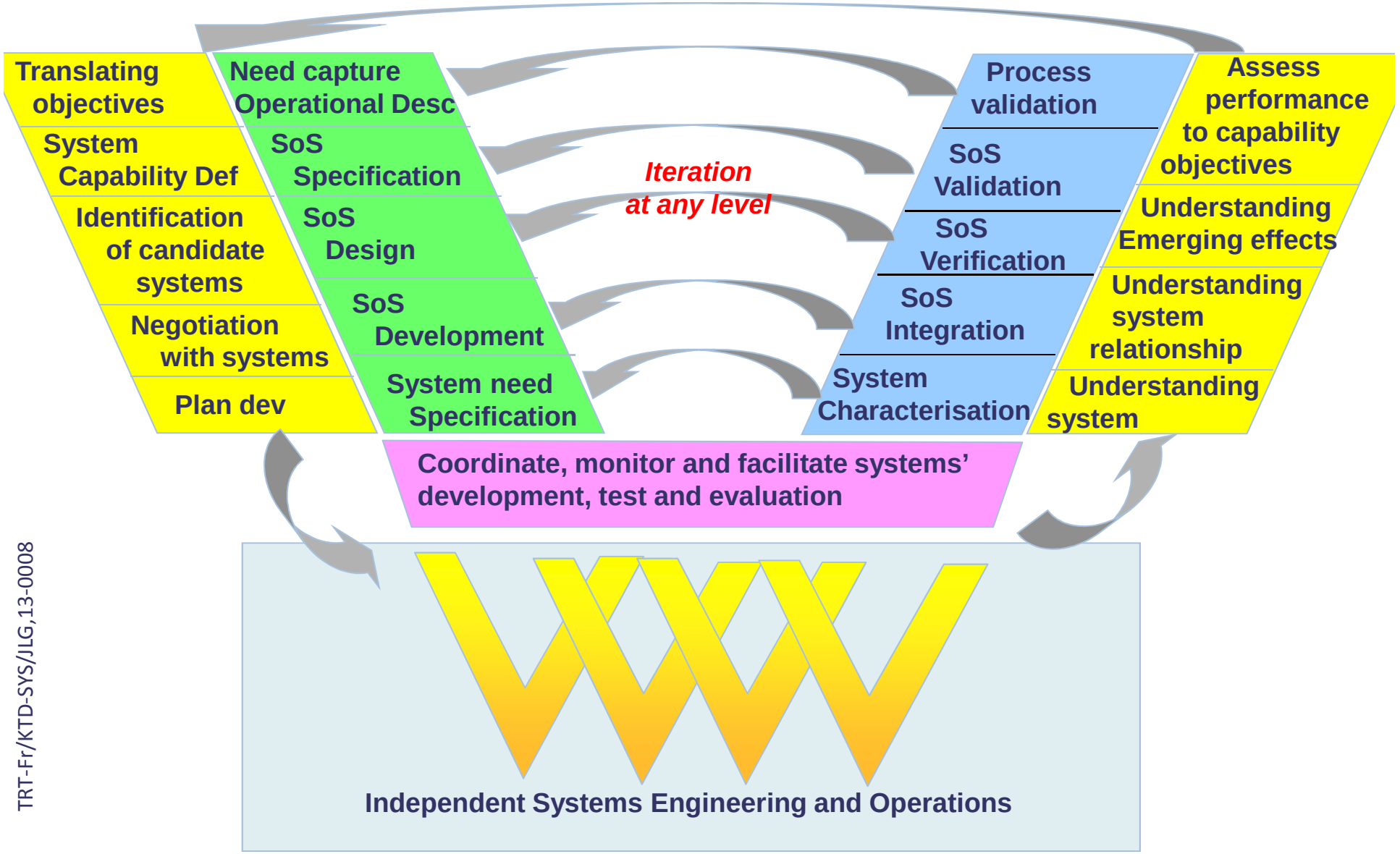
SE for SoS: but new activities are required



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