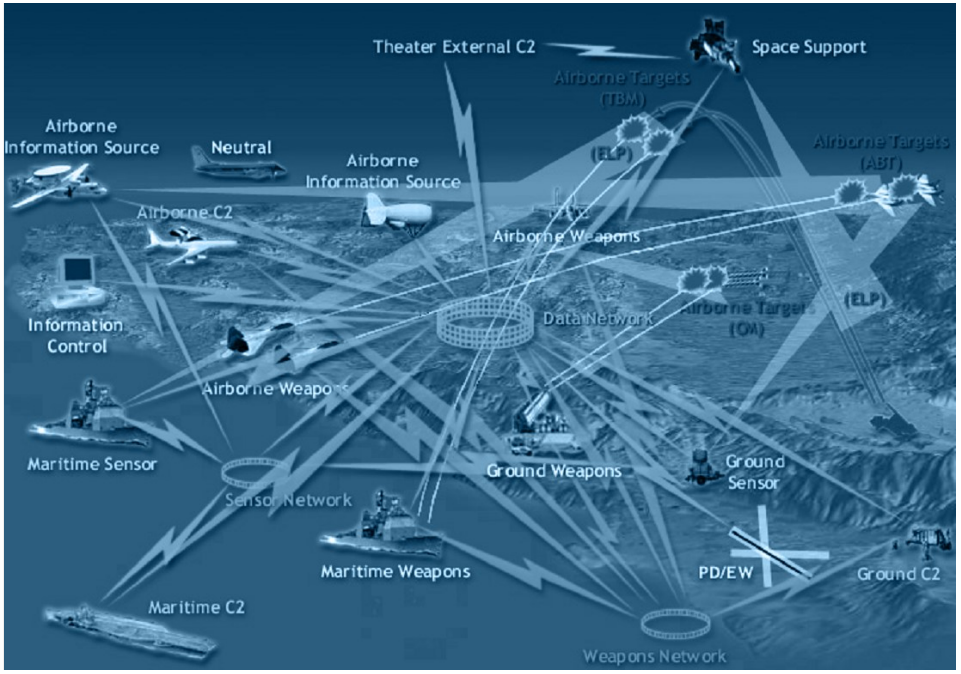
SysEng 6542
Model Based Systems Engineering

Introduction to Systems of Systems

Dr Quoc Do

Materials adopted courtesy of S.Cook and E.Honour

What is a System of Systems?



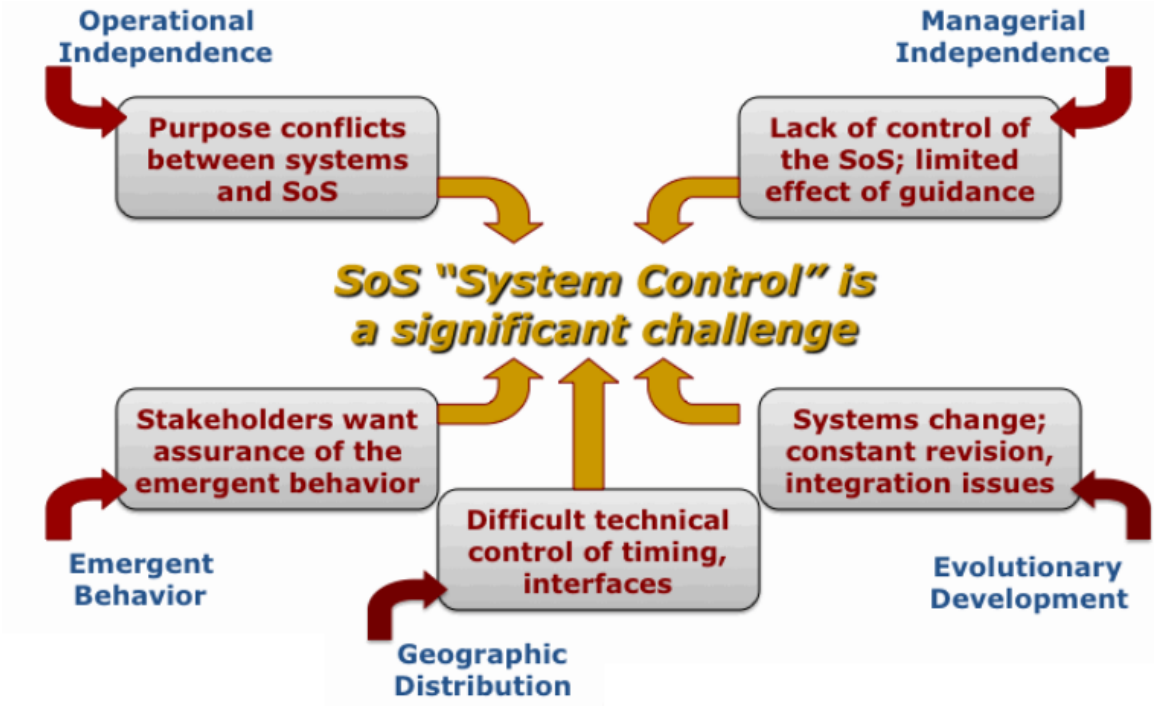
What is a System of Systems?

A System is a "System of Systems" if it exhibits significant amounts of:

- Emergent behavior - SoS performs functions not achievable by the independent component systems
- Geographic distribution - geographic extent forces the elements to exchange information in a remote way
- Evolutionary development - functions and purposes are added, removed and modified in an ongoing way
- Operational independence - component systems have purpose even if detached
- Managerial independence - component systems are developed and managed for their own purposes

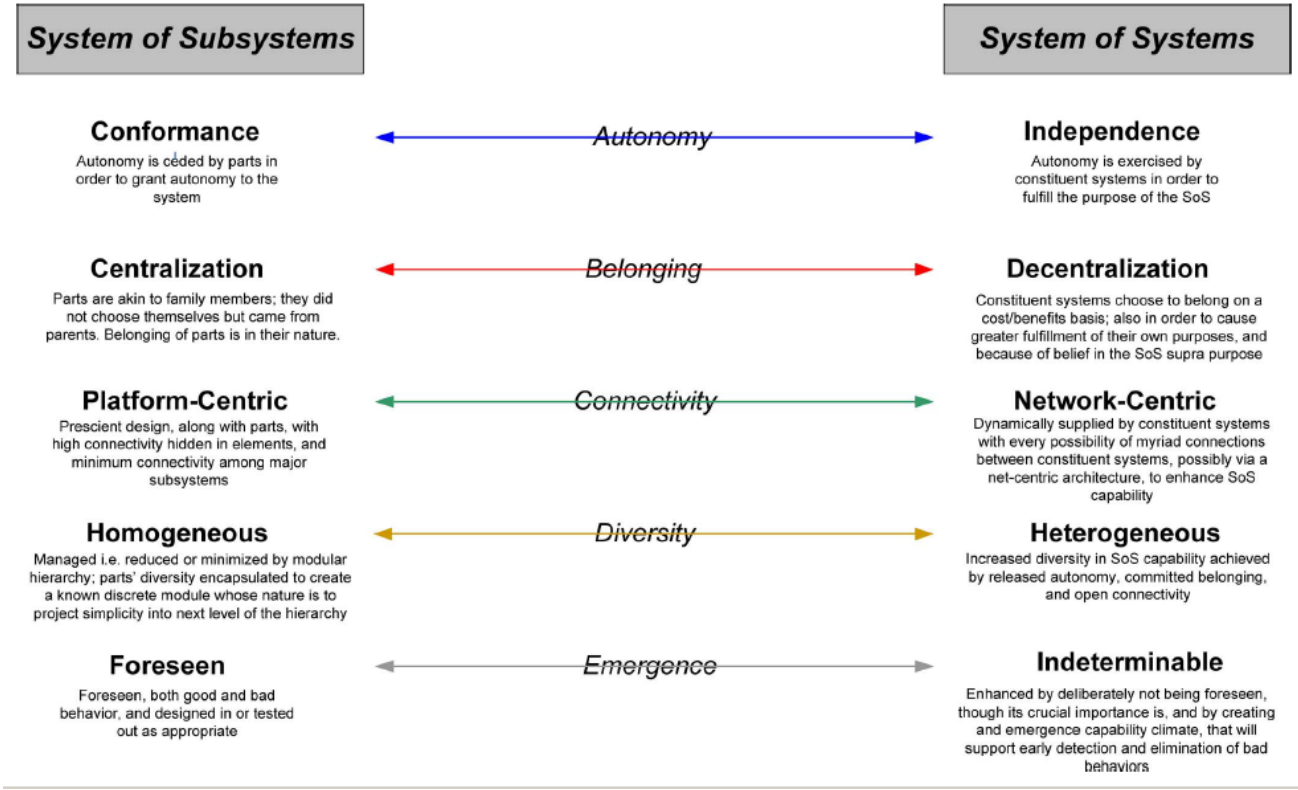
- Mark Maier 1998, "Architecting Principles for SoS," *Systems Engineering* (INCOSE)

What is a System of Systems?



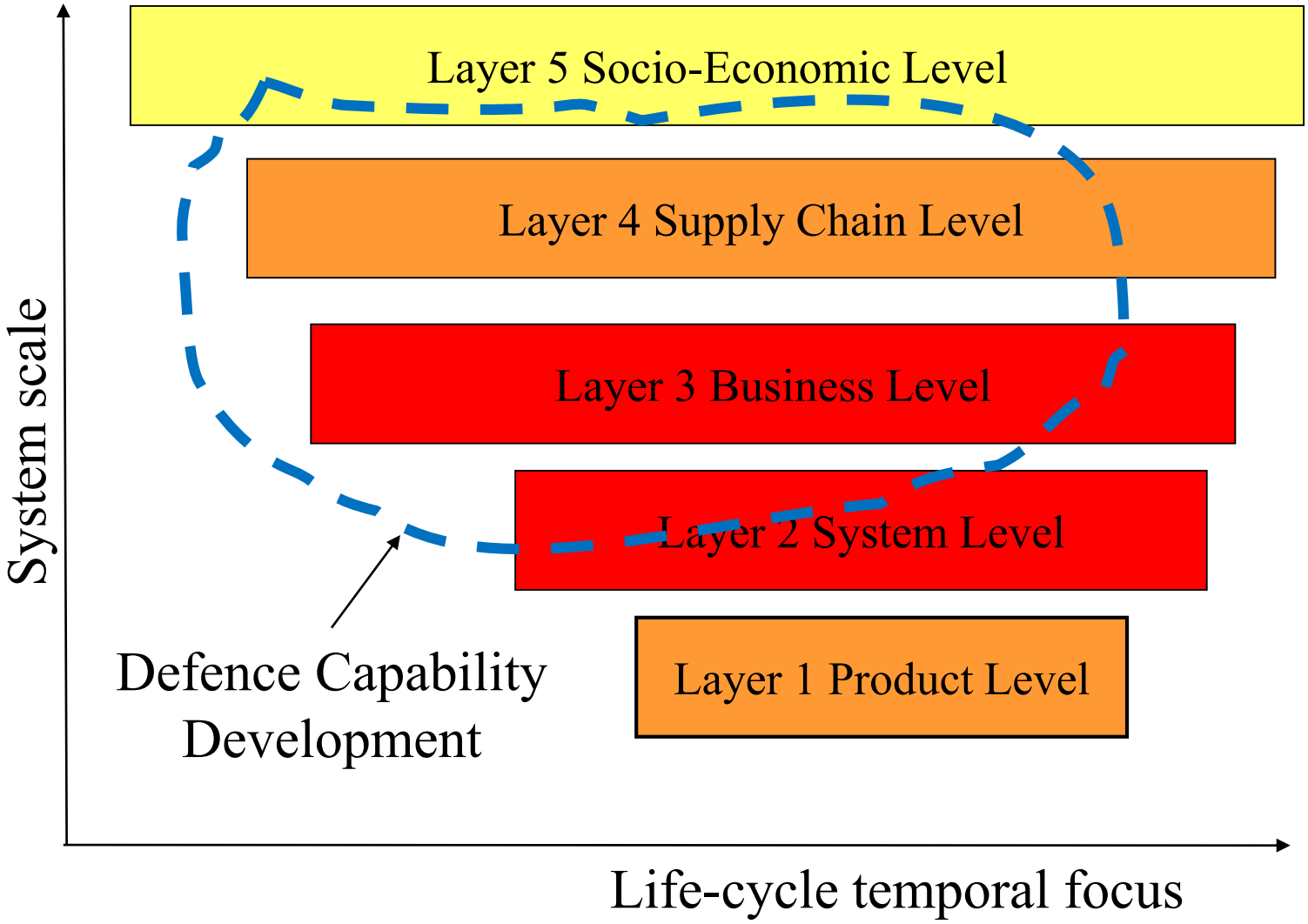
Traditional SE or SoS SE?

(Gorod et al, 2008)



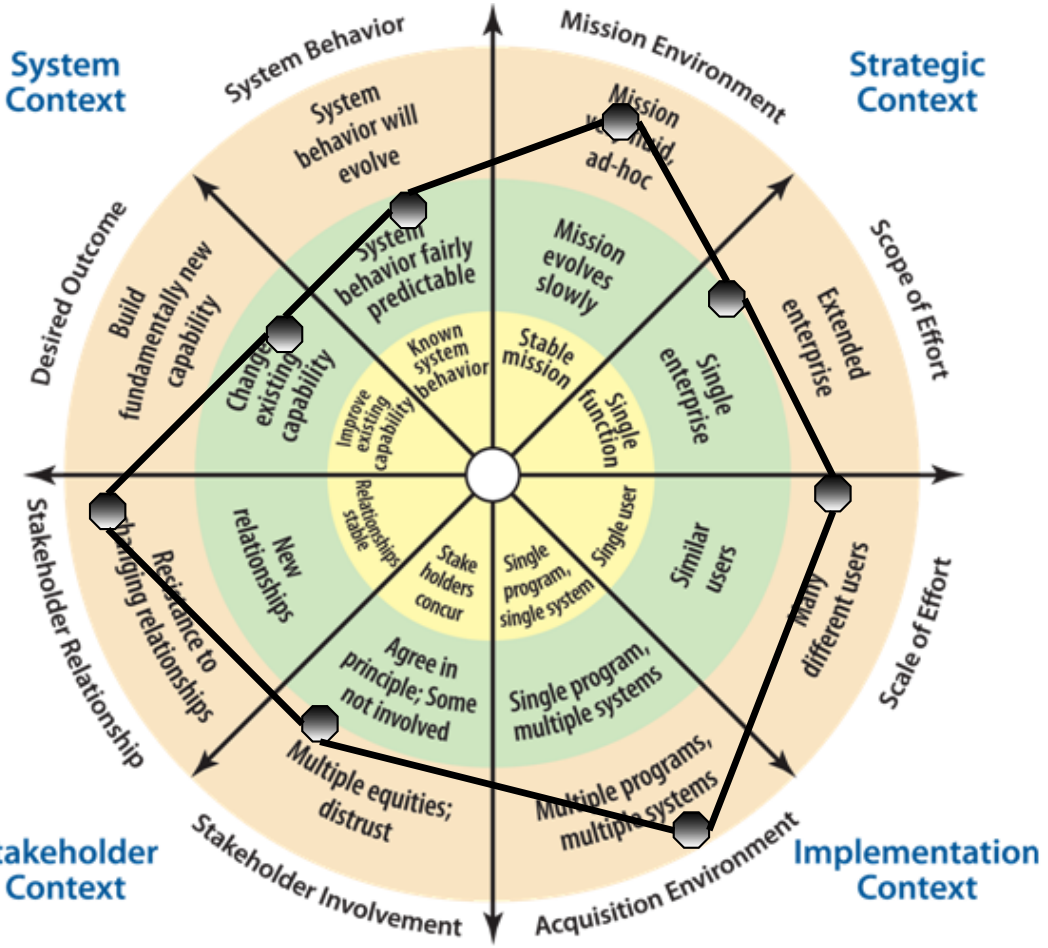
Gorod, A., Sauser, B. and Boardman, J. 2008, "System-of-Systems Engineering Management: A Review of Modern History and a Path Forward", *IEEE Systems Journal*, Vol 2, No. 4, December 2008.

The Problem Situation



Identifying the Class of SE Challenge

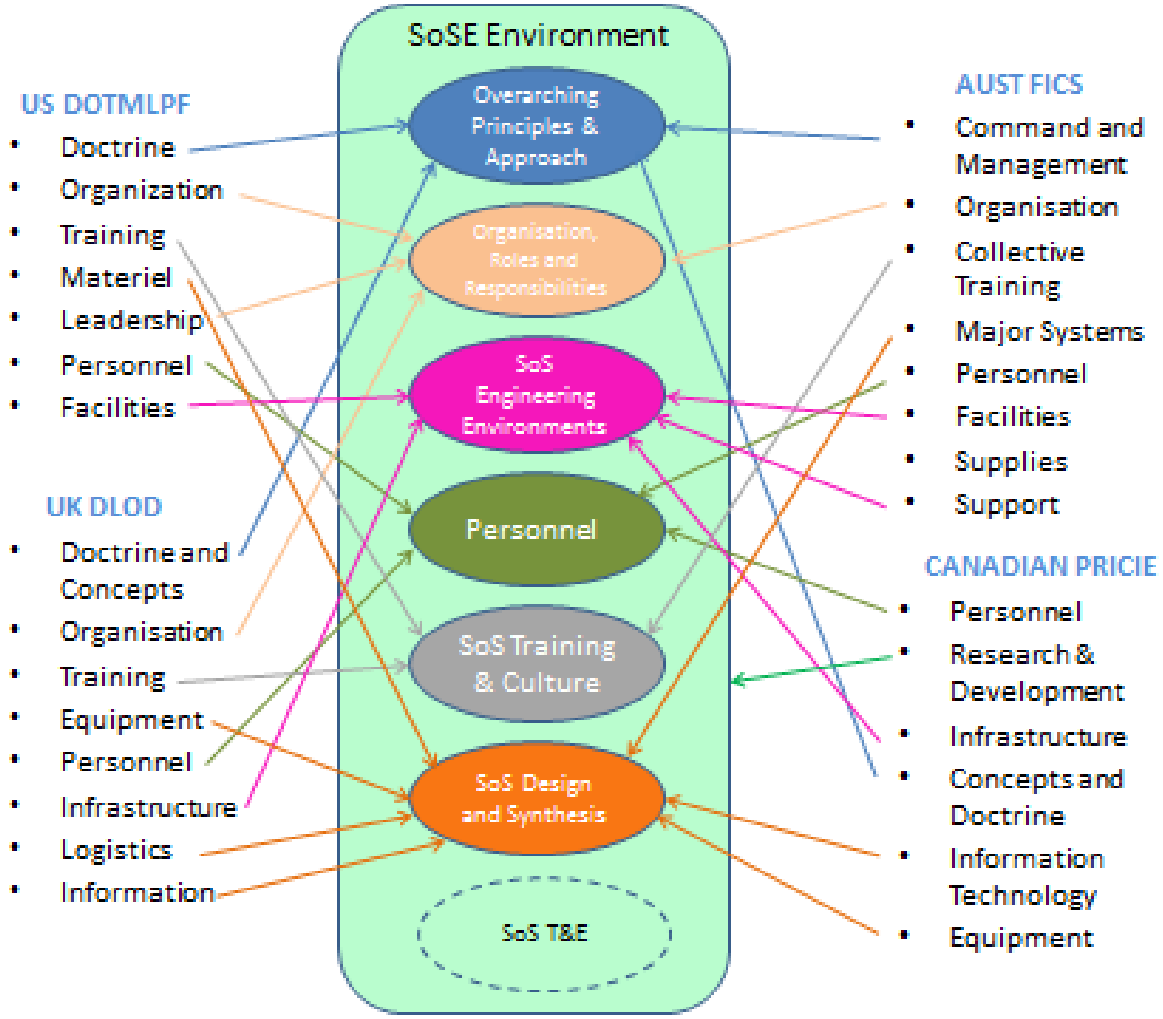
(Mitre 2011, Stevens 2011*)



- **Traditional program domain**
  - *Well-bounded problem*
  - *Predictable behavior*
  - *Stable environment*
- **Transitional domain**
  - *Systems engineering across boundaries*
  - *Influence vs. authority*
- **Messy frontier**
  - *Political engineering (power, control…)*
  - *High risk, potentially high reward*
  - *Foster cooperative behavior*

*Stevens R. 2011, *Engineering Mega-Systems*, ISBN 978-1-4200-7666-0, CRC Press.

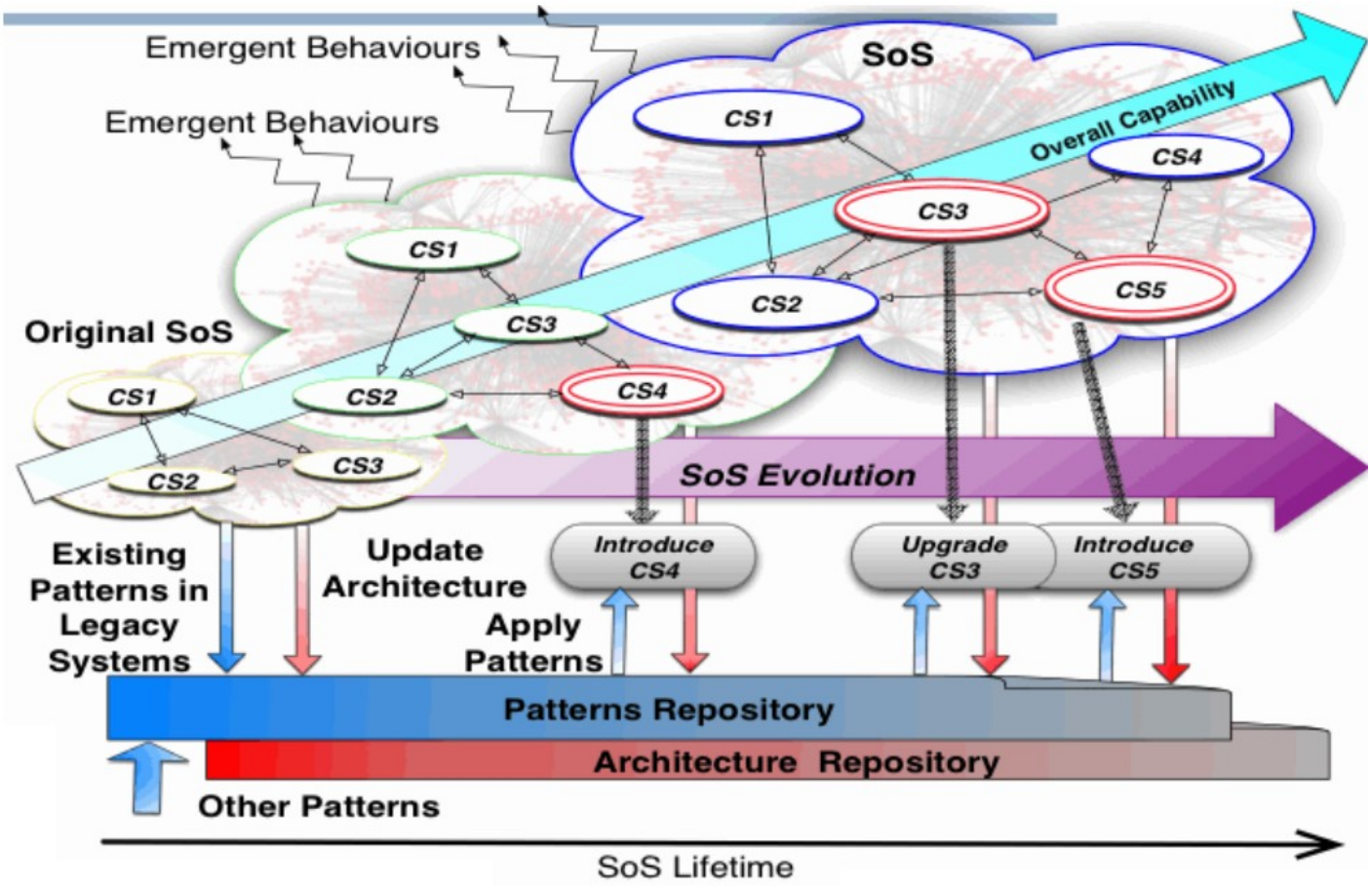
Synthesising what we mean by SoSE Capability from four National Perspectives



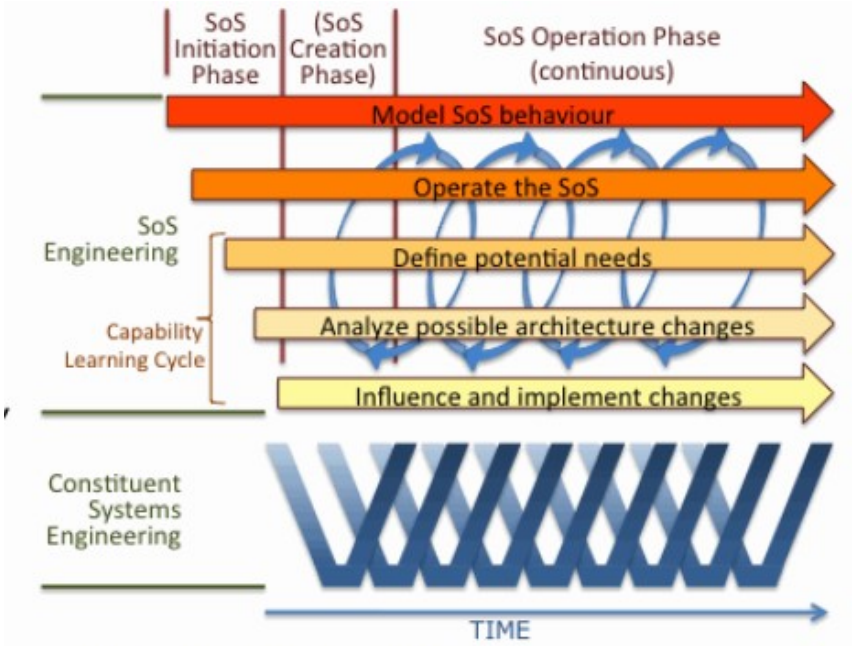
DANSE Methodology for Systems of Systems

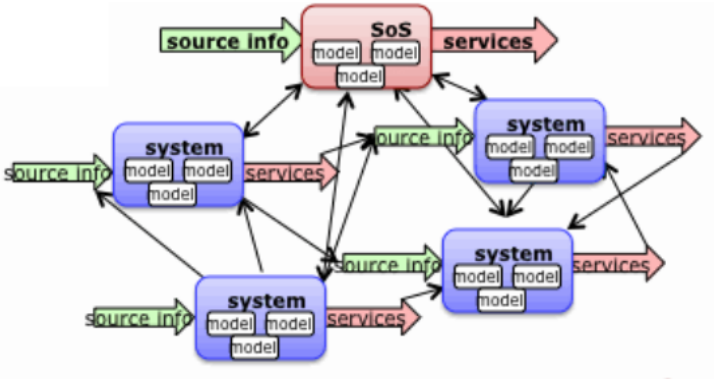
Designing for adaptability and evolution in system of systems engineering

DANSE Methodology - SOS Evolution



DANSE Methodology - SOS Lifecycle Overview





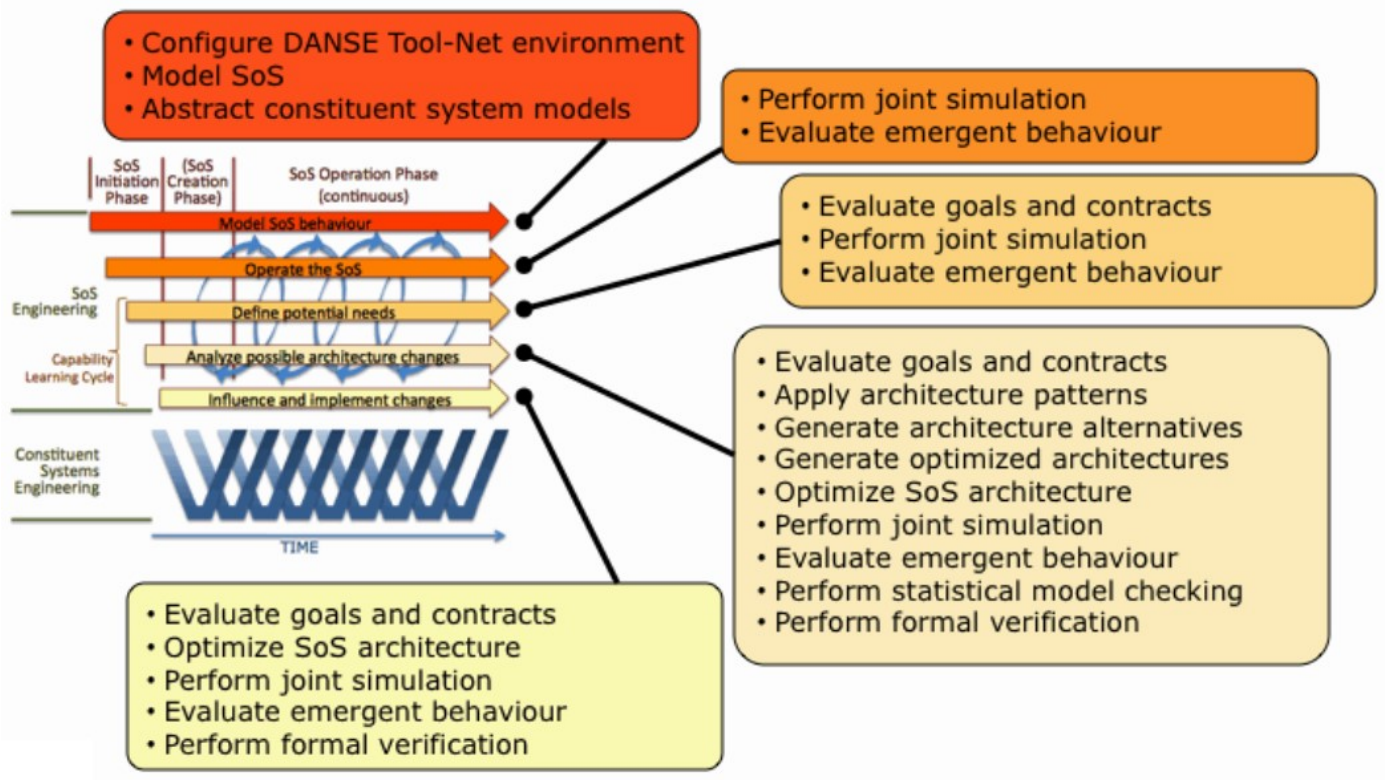
DANSE Methodology

Nbr	Solution Method	What it Does
1	Model SoS	Create UPDM SoS model, particularly focused on the SoS behaviour
2	Abstract CS model	Make a pre-existing (or new) constituent system model available for joint use with the SoS model
3	Apply architecture patterns	Build or enhance the SoS model by the use of a repository of useful patterns, proven by prior use
4	Generate architecture alternatives	Create multiple architecture alternatives for analysis, by the use of graph grammar constructs
5	Generate optimized architectures	Create and evaluate multiple architecture alternatives using concise modelling, with selection of an optimum

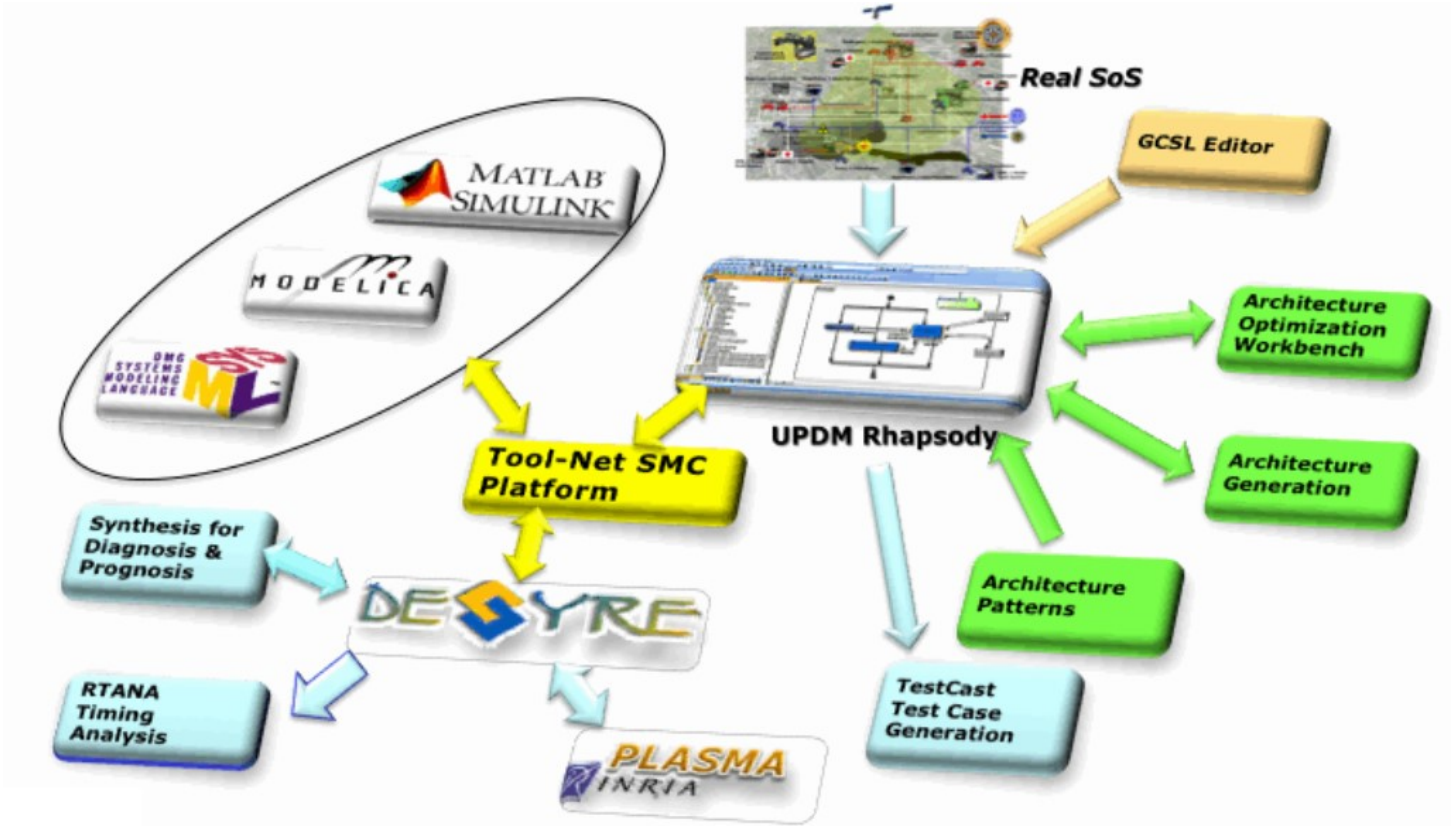
DANSE Methodology

Nbr	Solution Method	What it Does
6	Perform joint simulation	Time-based execution of a joint simulation using SoS and CS models
7	Perform statistical model checking	Identification of simulated performance levels against parameters/goals
8	Evaluate emergent behaviour	Confirmation/discovery of desired or unknown SoS emergent behaviours
9	Evaluate goals and contracts	Definition of SoS/CS goals/contracts, with automated checking during simulation
10	Perform formal verification *(TBD)*	Knowledge of time-based compliance against formal requirements *(TBD)*
11	Configure DANSE Tool-Net environment	Installation of necessary tools, ontologies, rules, and clients to perform DANSE modelling

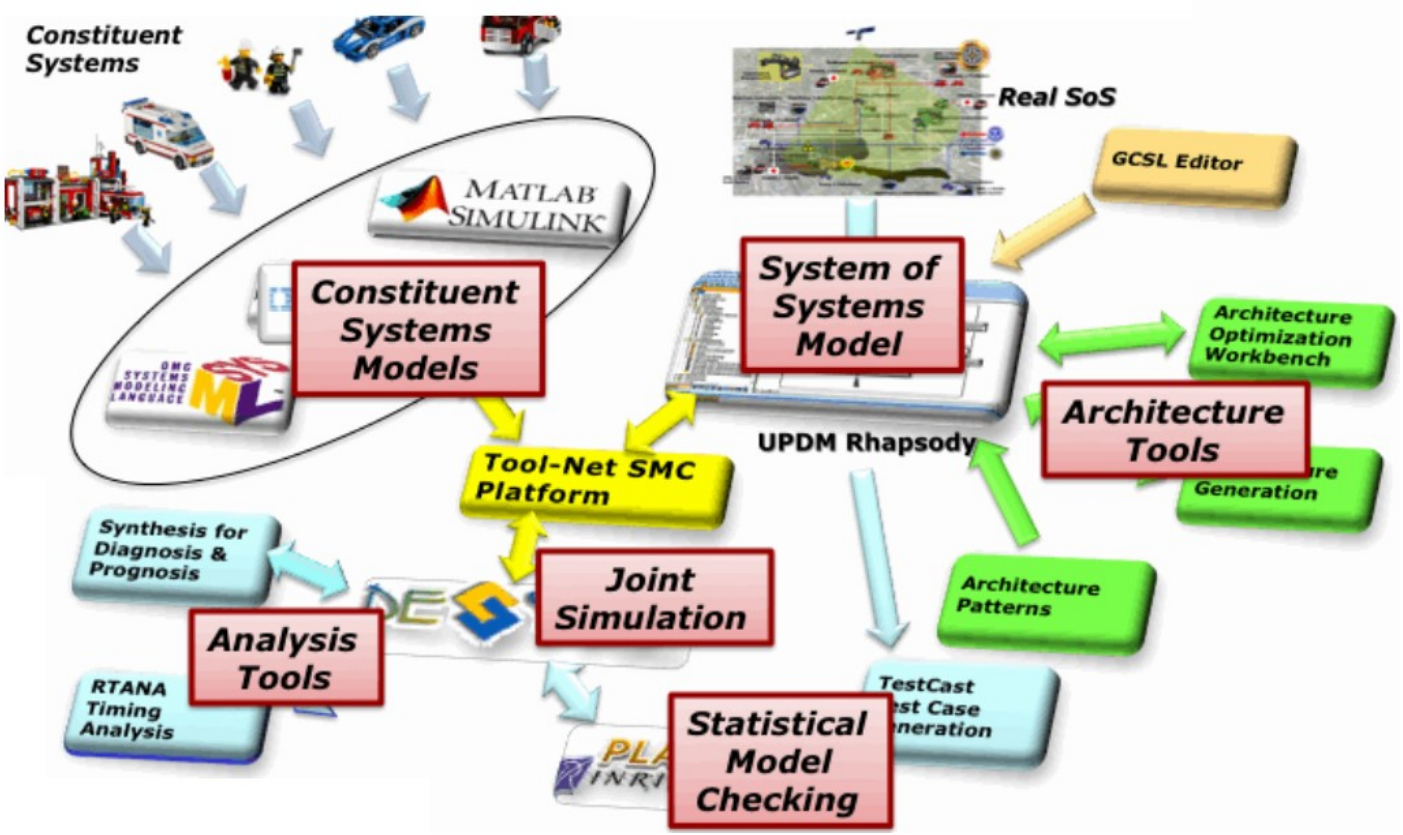
DANSE Methodology



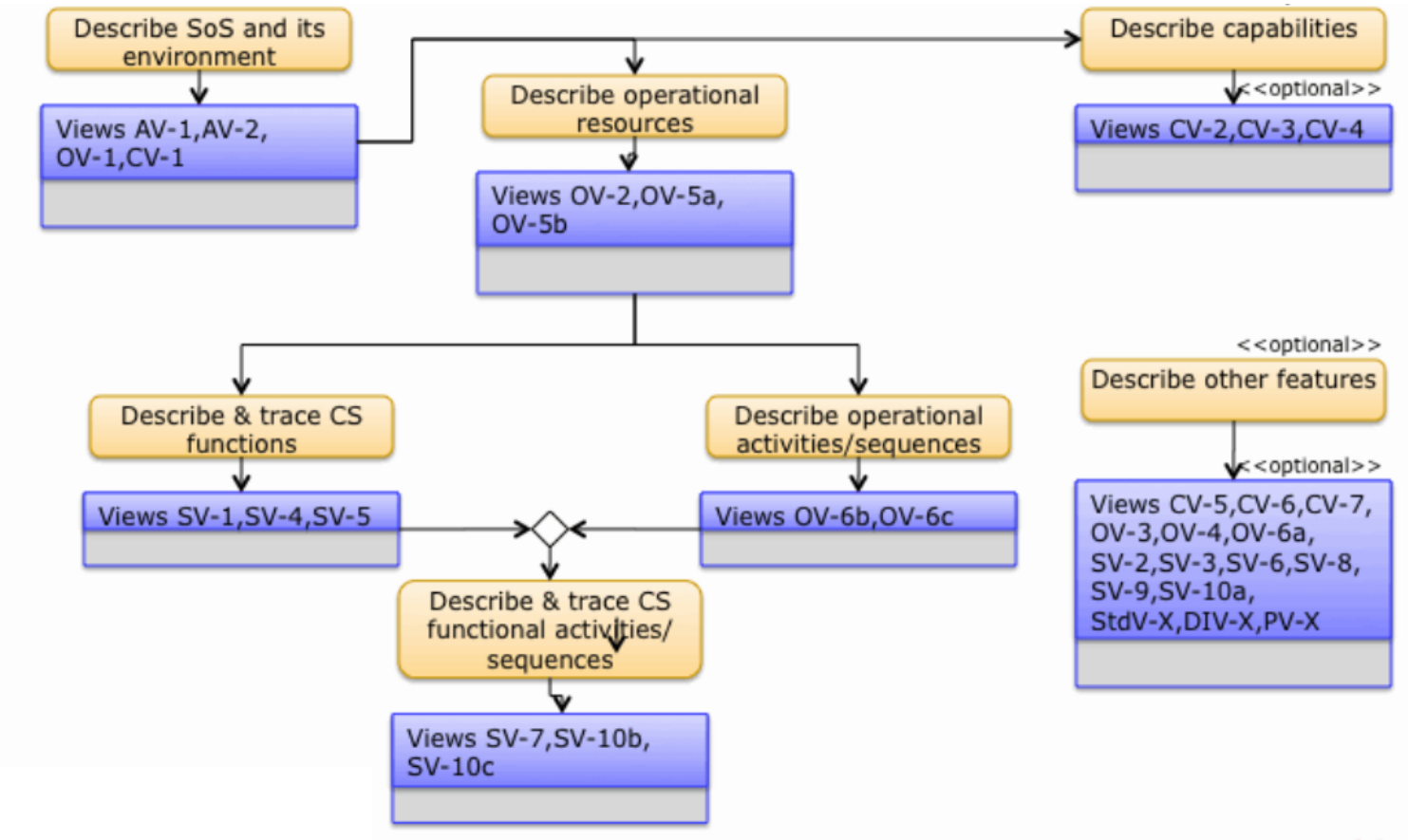
DANSE Tools


Real SoS
GCSL Editor
MATLAB SIMULINK
MODELICA
OMG SYSTEMS MODELING LANGUAGE SysML
Architecture Optimization Workbench
UPDM Rhapsody
Tool-Net SMC Platform
Architecture Generation
Synthesis for Diagnosis & Prognosis
DESYRE
Architecture Patterns
RTANA Timing Analysis
TestCast Test Case Generation
PLASMA INRIA

DANSE Tools


Constituent Systems
MATLAB SIMULINK
Constituent Systems Models
Real SoS
GCSL Editor
System of Systems Model
Architecture Optimization Workbench
Architecture Tools
UPDM Rhapsody
Tool-Net SMC Platform
Synthesis for Diagnosis & Prognosis
Joint Simulation
Analysis Tools
RTANA Timing Analysis
Statistical Model Checking
Architecture Patterns
TestCast

DANSE - UPDM


Describe SoS and its environment
Views AV-1,AV-2, OV-1,CV-1
Describe operational resources
Views OV-2,OV-5a, OV-5b
Describe capabilities
<<optional>>
Views CV-2,CV-3,CV-4
Describe & trace CS functions
Views SV-1,SV-4,SV-5
Describe operational activities/sequences
Views OV-6b,OV-6c
Describe & trace CS functional activities/ sequences
Views SV-7,SV-10b, SV-10c
<<optional>>
Describe other features
<<optional>>
Views CV-5,CV-6,CV-7, OV-3,OV-4,OV-6a, SV-2,SV-3,SV-6,SV-8, SV-9,SV-10a, StdV-X,DIV-X,PV-X

Program Completed

Missouri University of Science & Technology