A systems approach to architect coherent system-of-systems (SoS) capabilities

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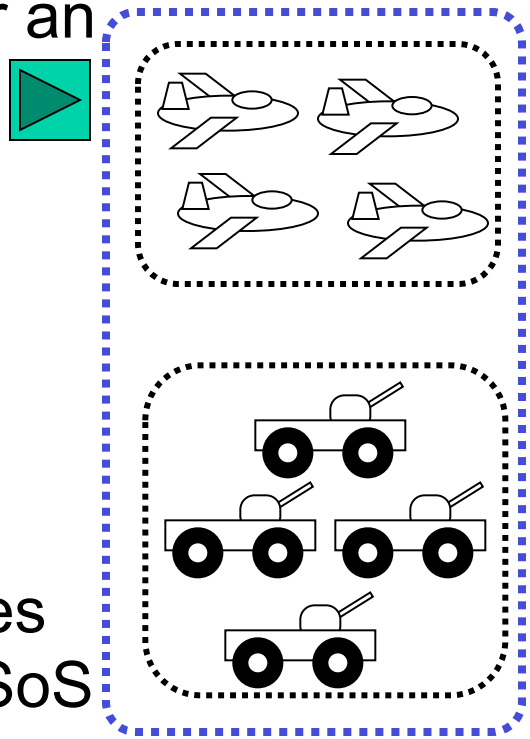
~ A Presentation for INCOSE 2010 ~

Key Ideas & Terminology in Paper

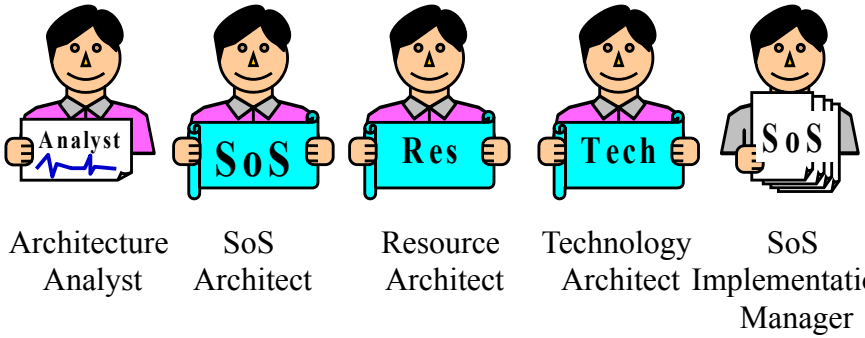
- Architecting integrated mission capabilities for an SoS (**Mission SoS**)
  - context of defence and national security

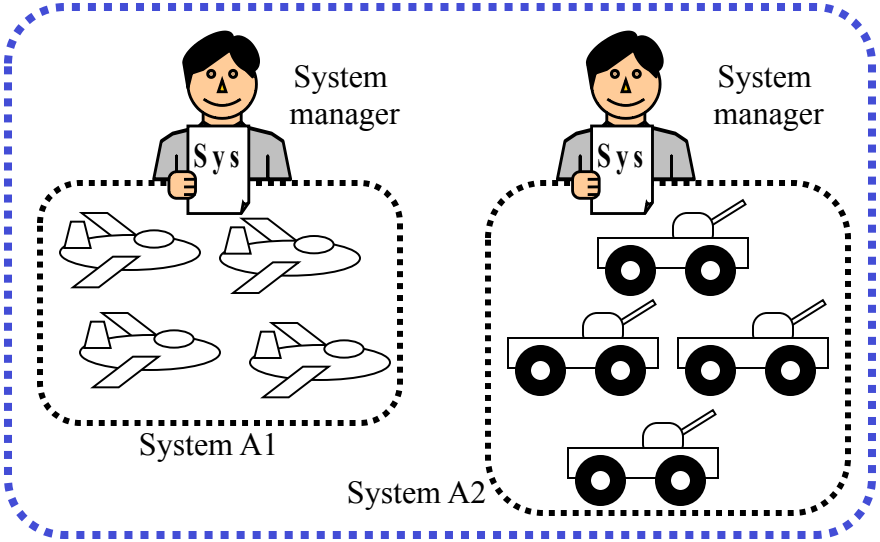


- Impetus to attain “global optimum” in SoS
  - instead of “local optimum”
- Coherent use of limited non-scalable resources (**Enterprise Resources**) by various Mission SoS
- Some level of commonality and synergy in scalable tech solutions (**Enterprise Technology**) across various Mission SoS

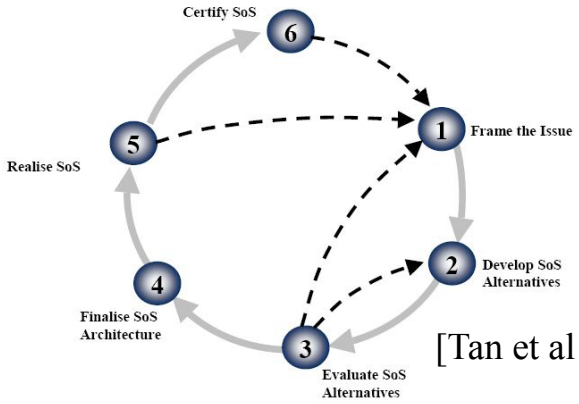
Key Ideas & Terminology in Paper

- Technical organization structure
  - Assumption: "Top-down" leadership approach is applicable
  - Higher level technical authorities that oversee system managers





- Broad process for architecting

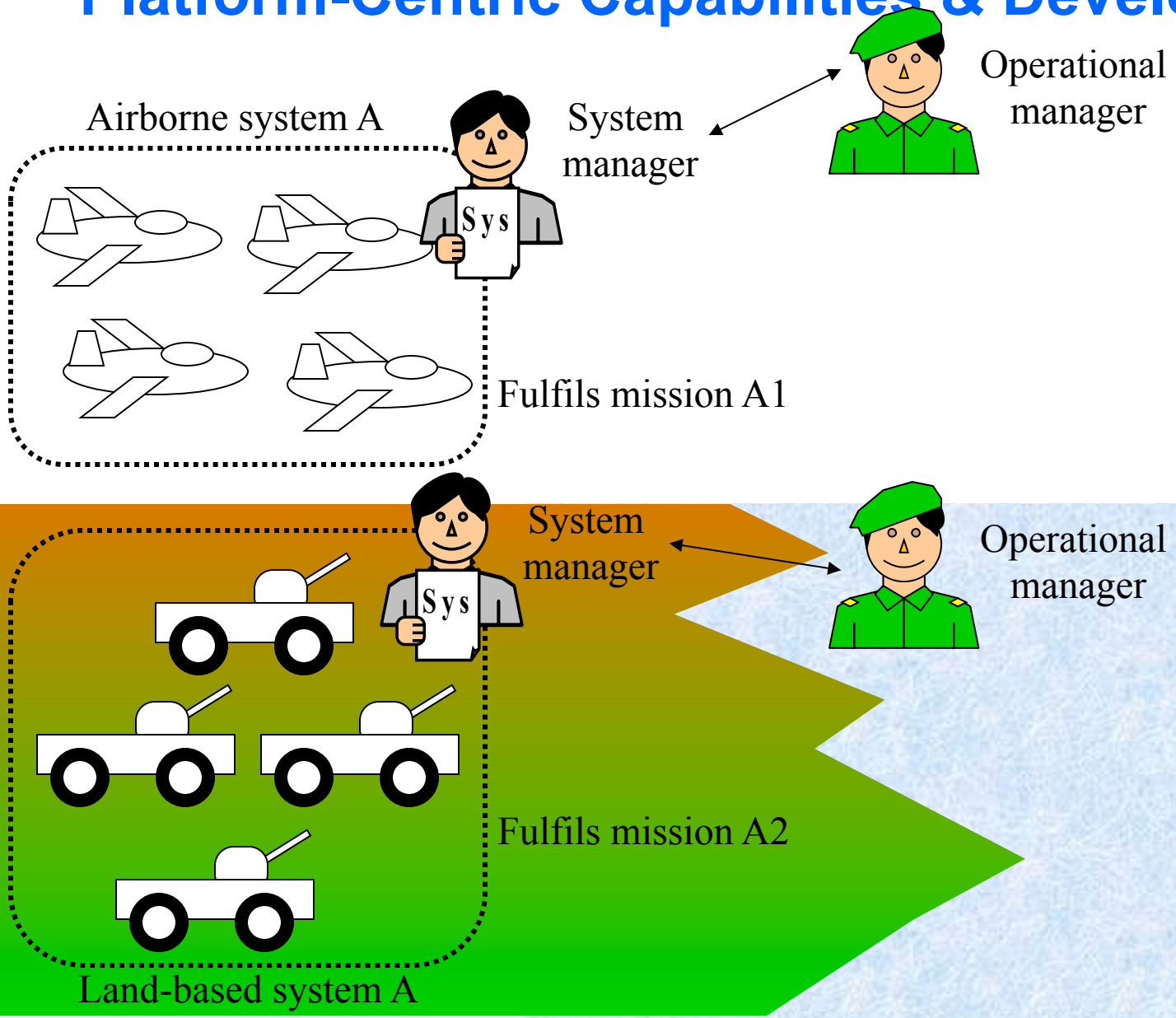


[Tan et al 09]

How I Will Present the Key Ideas

- A story line
- Simplified fictitious case

Platform-Centric Capabilities & Development



Transition to an Integrated Capability

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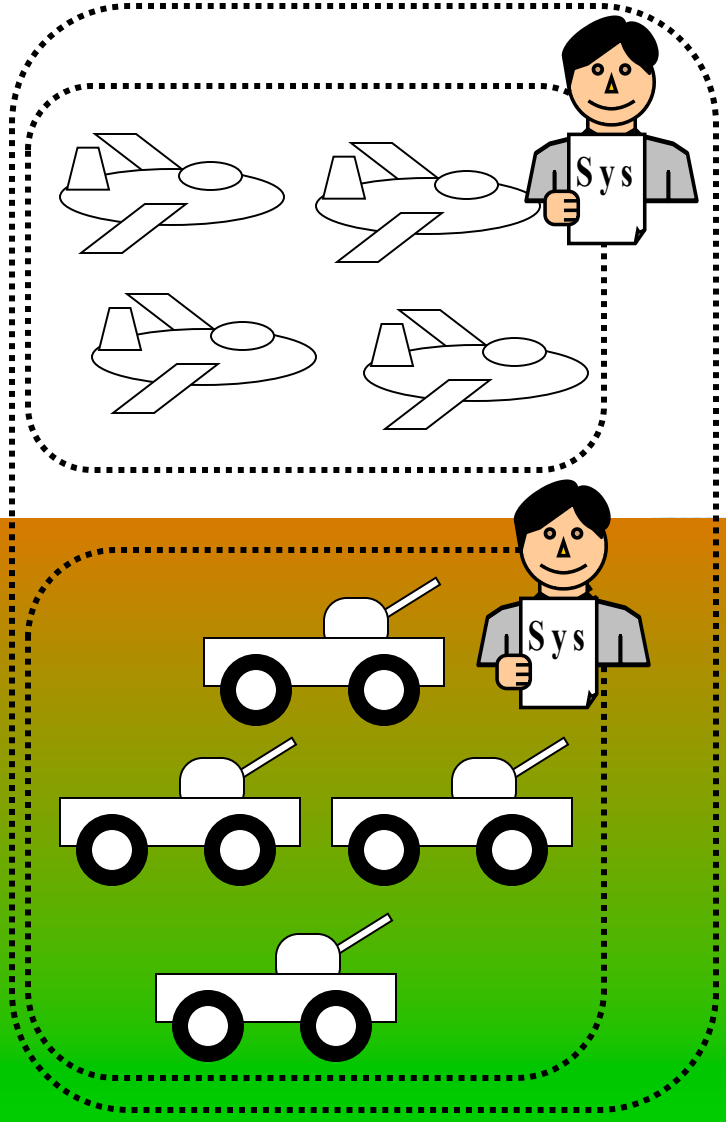
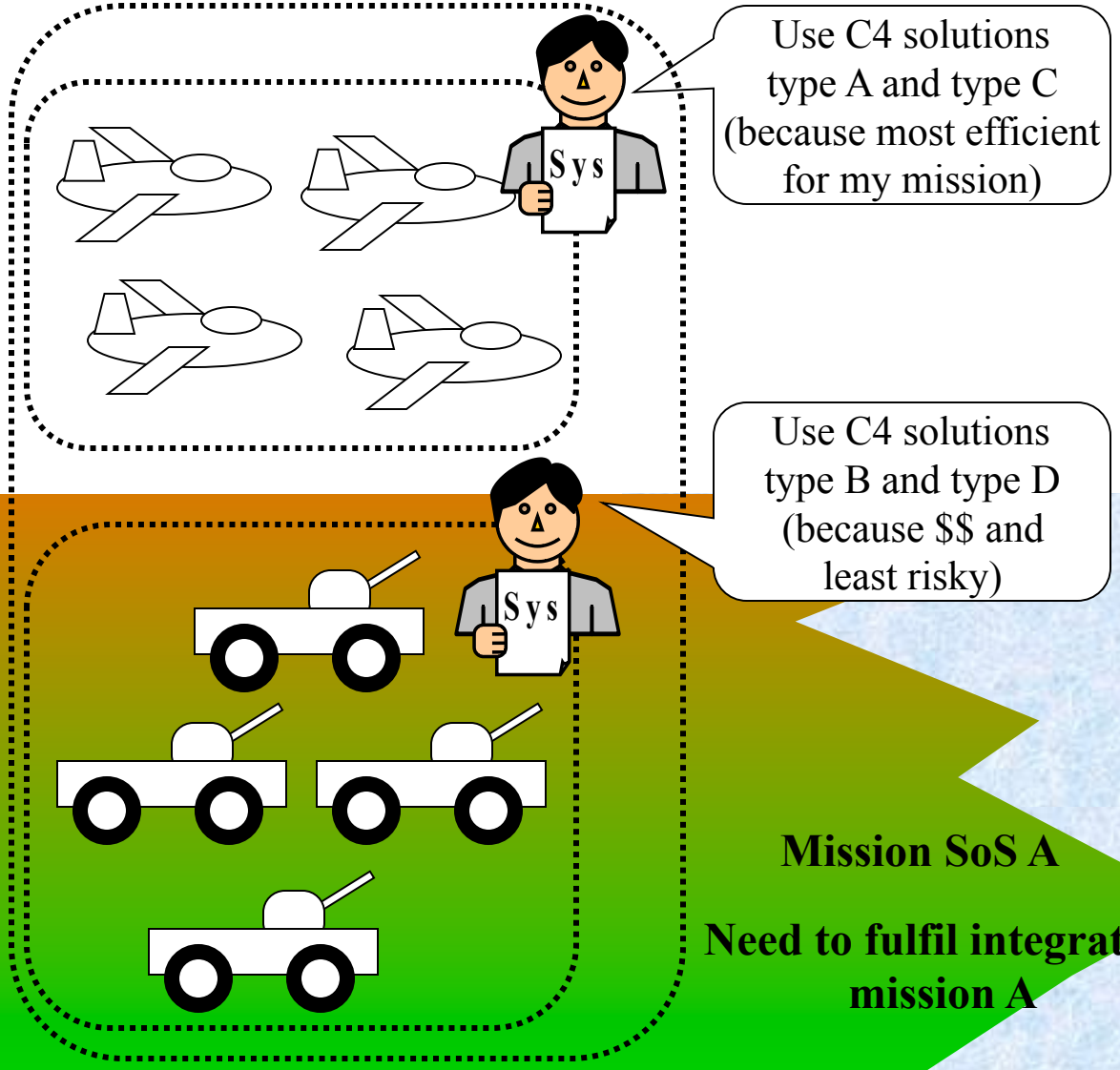


Mission SoS A

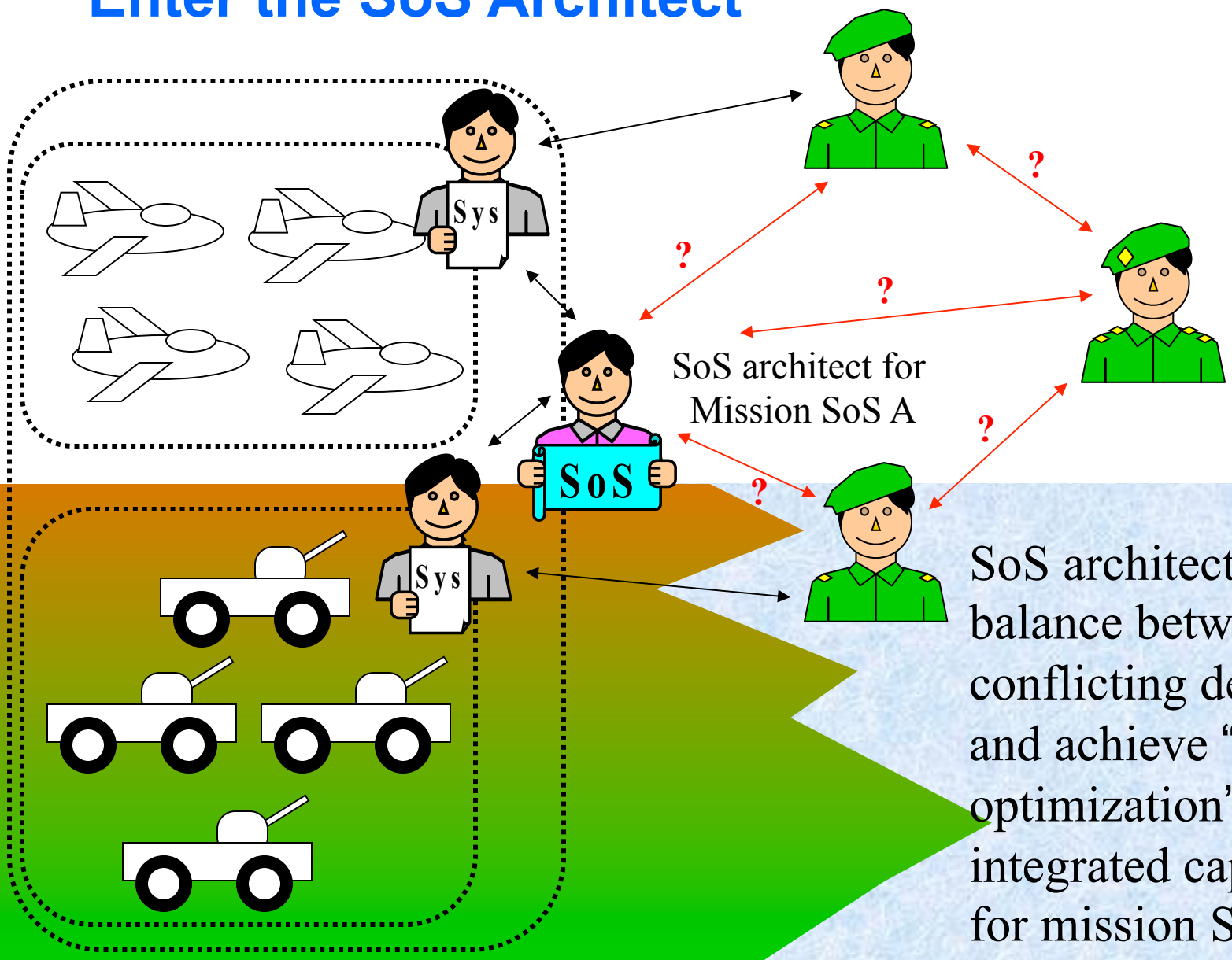
Needs to fulfil integrated mission A

Need to Enhance Technical Organization Structure for the Development of an SoS



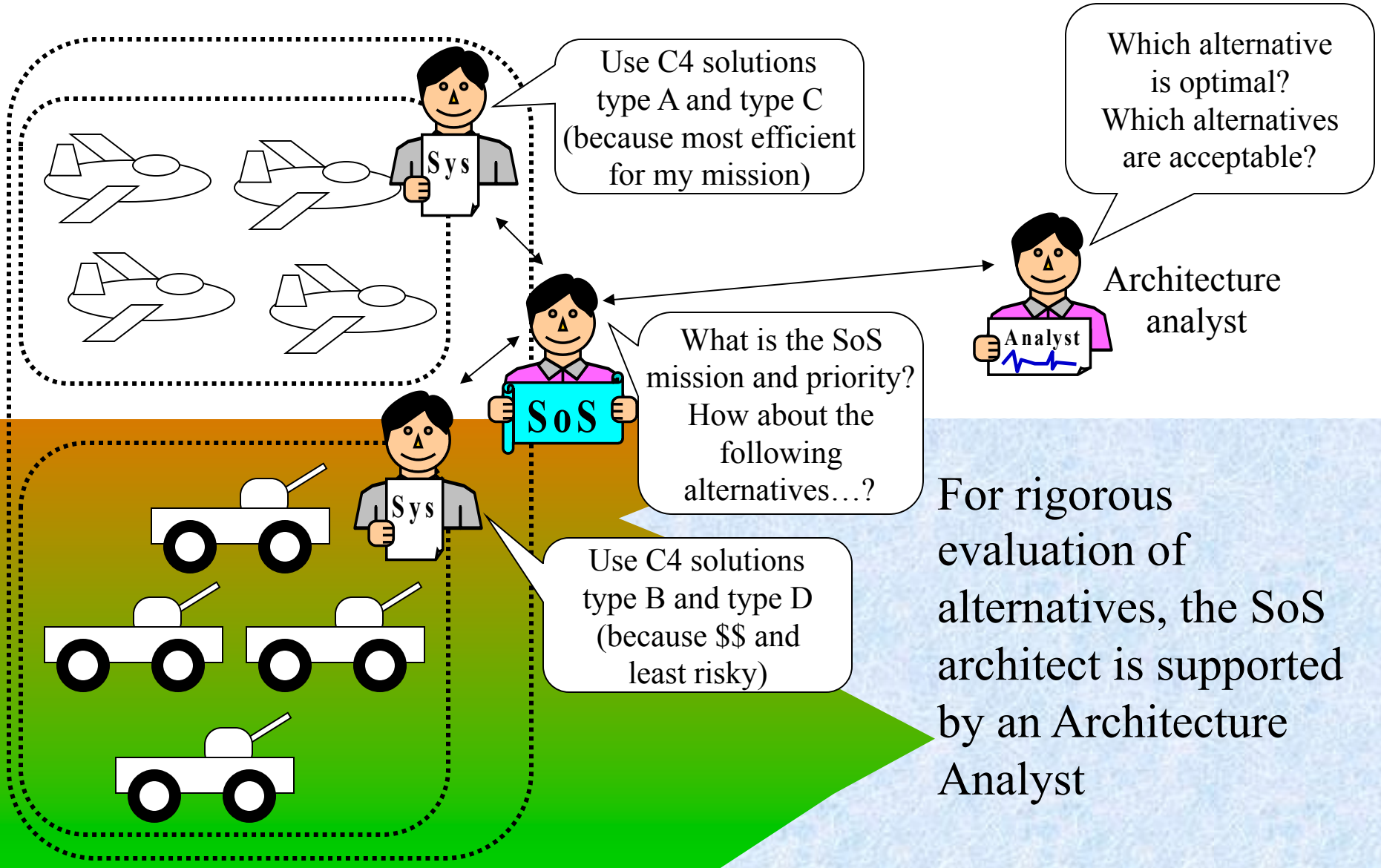
Example: To achieve C4 interoperability to fulfil integrated mission A, issues of "local optimization" may need to be addressed

Enter the SoS Architect



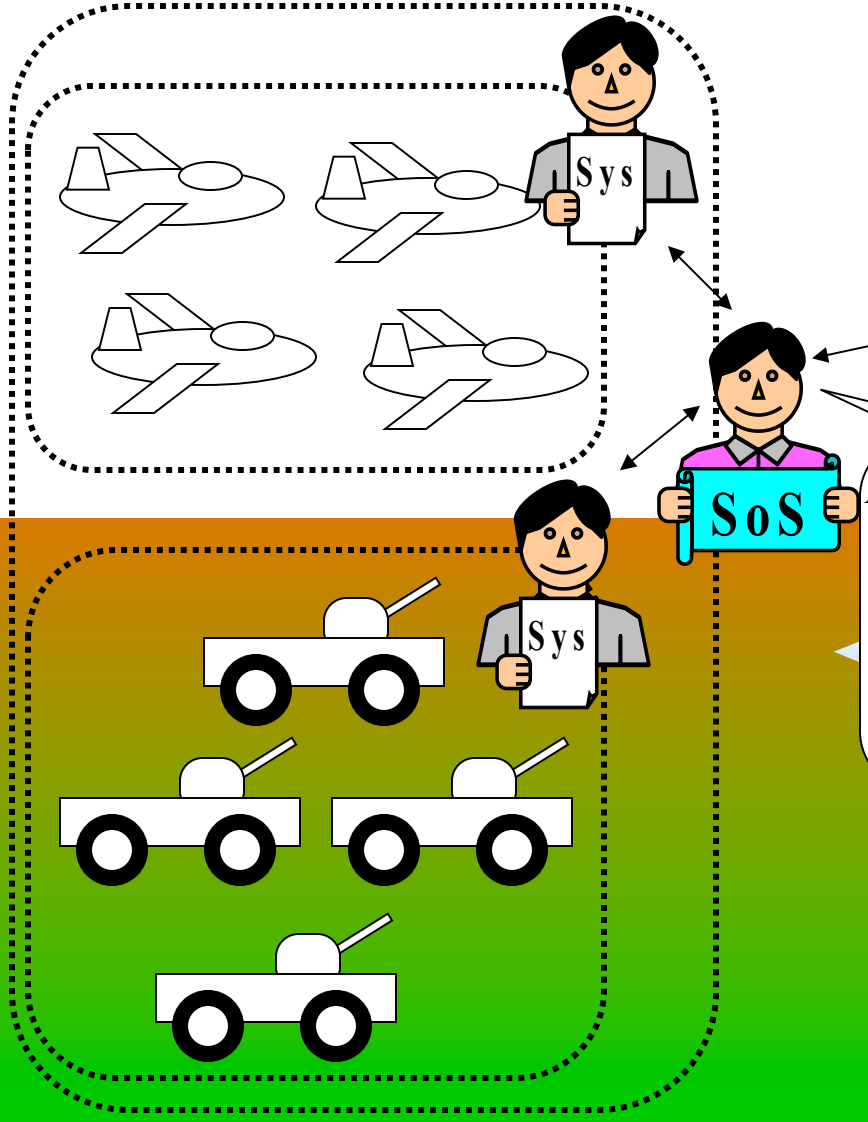
SoS architect to strike balance between conflicting demands and achieve “global optimization” to realise integrated capability for mission SoS

Enter the Architecture Analyst



For rigorous evaluation of alternatives, the SoS architect is supported by an Architecture Analyst

The SoS Architect Finalizes the SoS Architecture

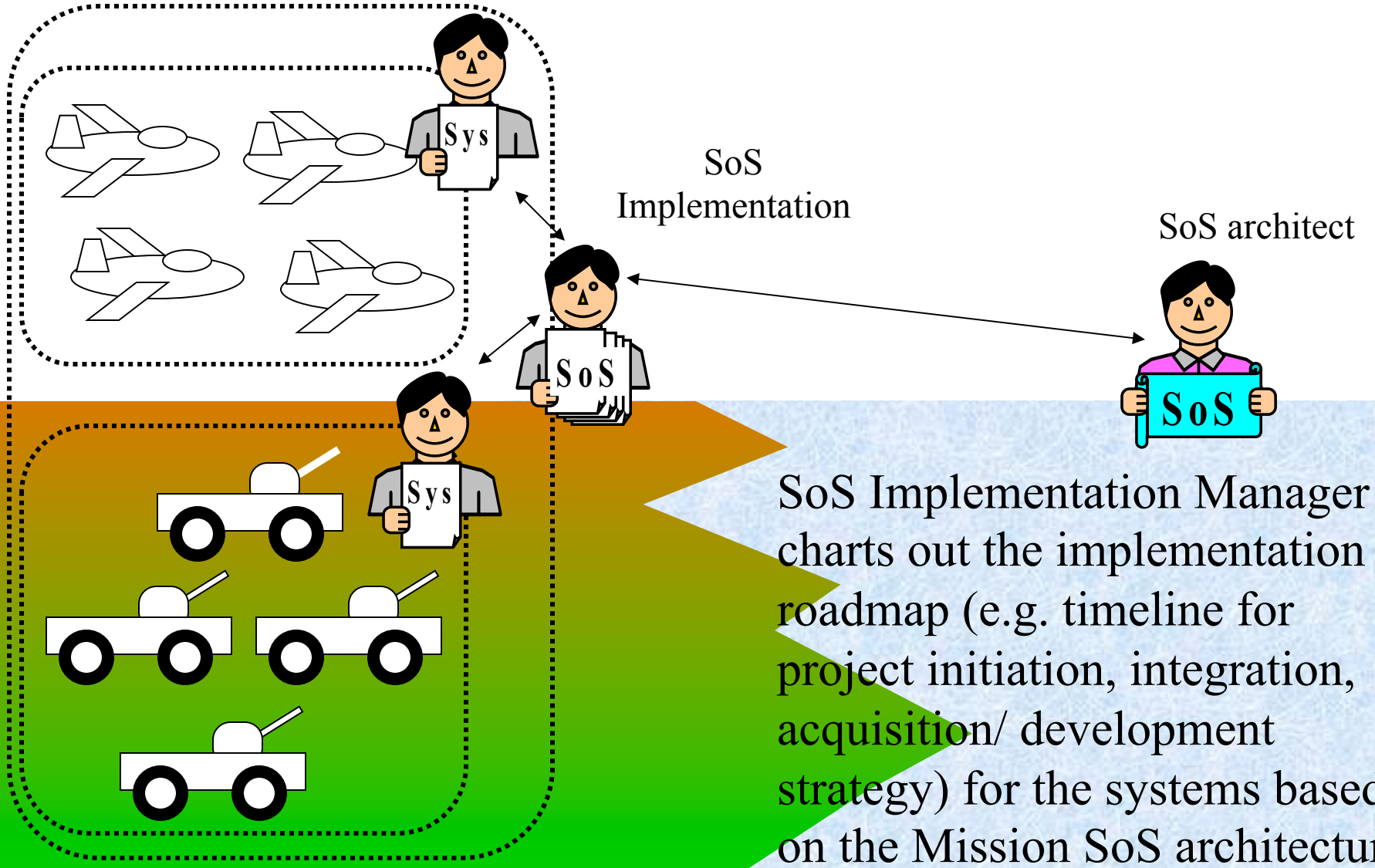


In terms of
- mission performance
- intrinsic resilience of architecture (flexibility, robustness…)
the comparison of the alternatives is as follow…

After careful analysis, the SoS architecture will be…
This means that the viable technical options for you are...

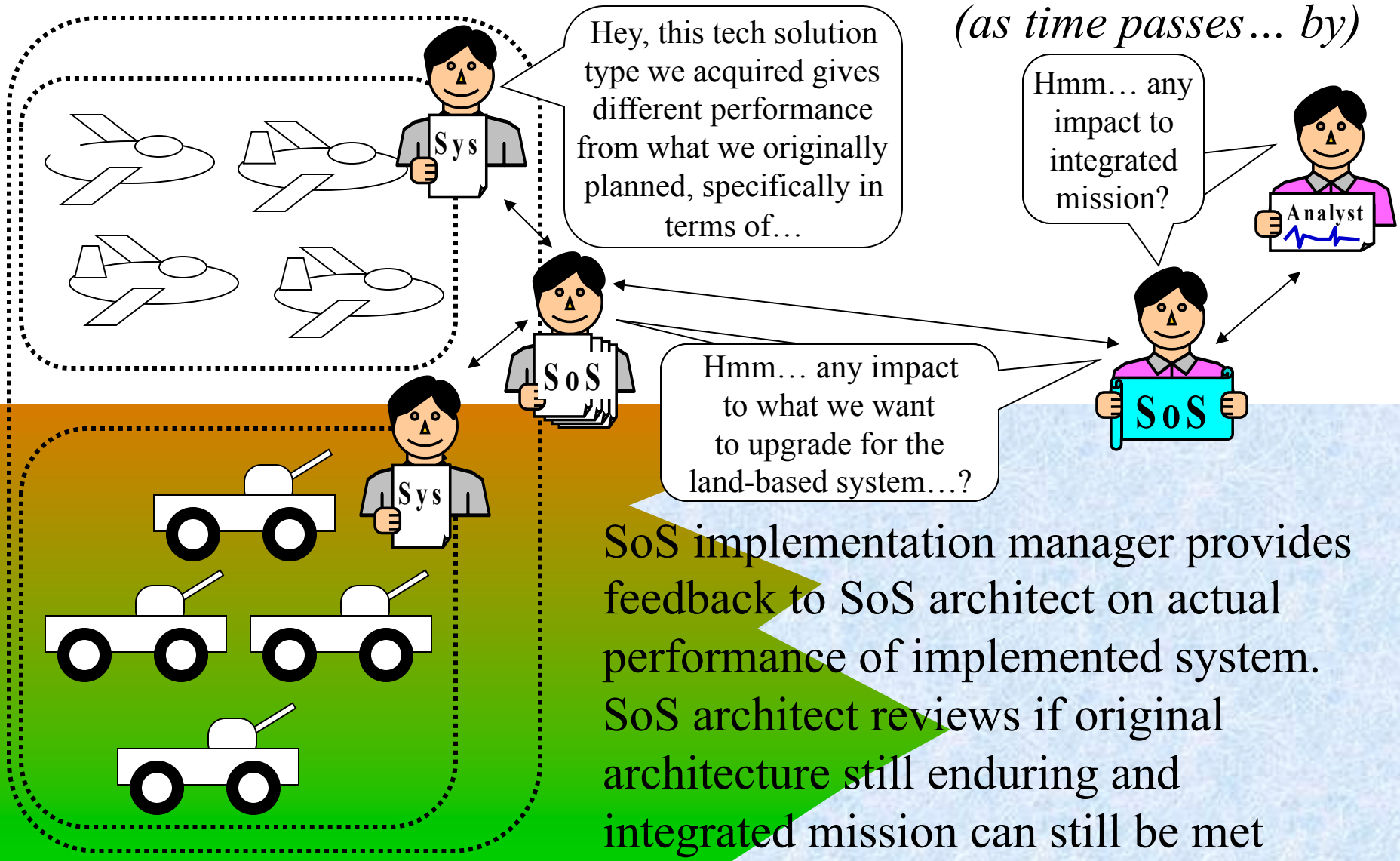
SoS architect reviews the analysis findings and finalizes the mission SoS architecture

Enter the SoS Implementation Manager



SoS Implementation Manager charts out the implementation roadmap (e.g. timeline for project initiation, integration, acquisition/ development strategy) for the systems based on the Mission SoS architecture

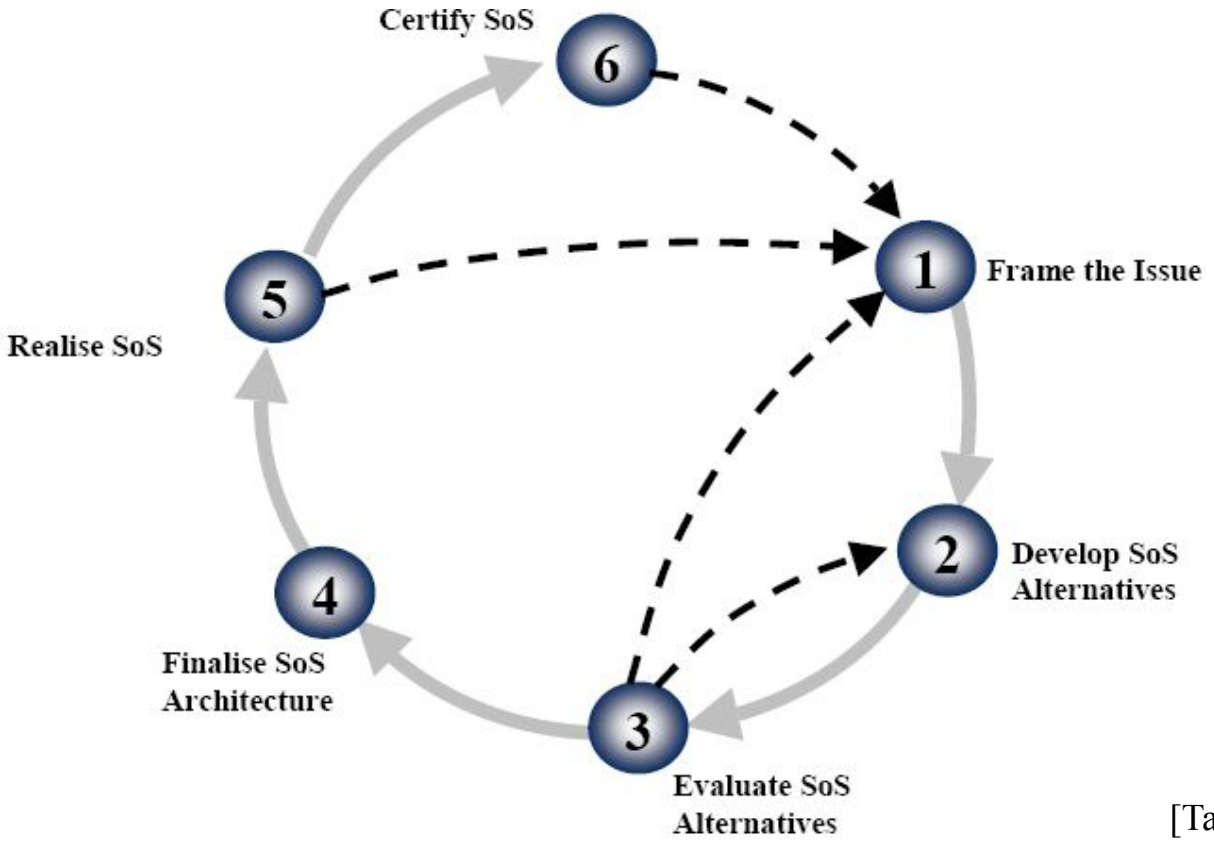
Feedback from the SoS Implementation



SoS implementation manager provides feedback to SoS architect on actual performance of implemented system. SoS architect reviews if original architecture still enduring and integrated mission can still be met

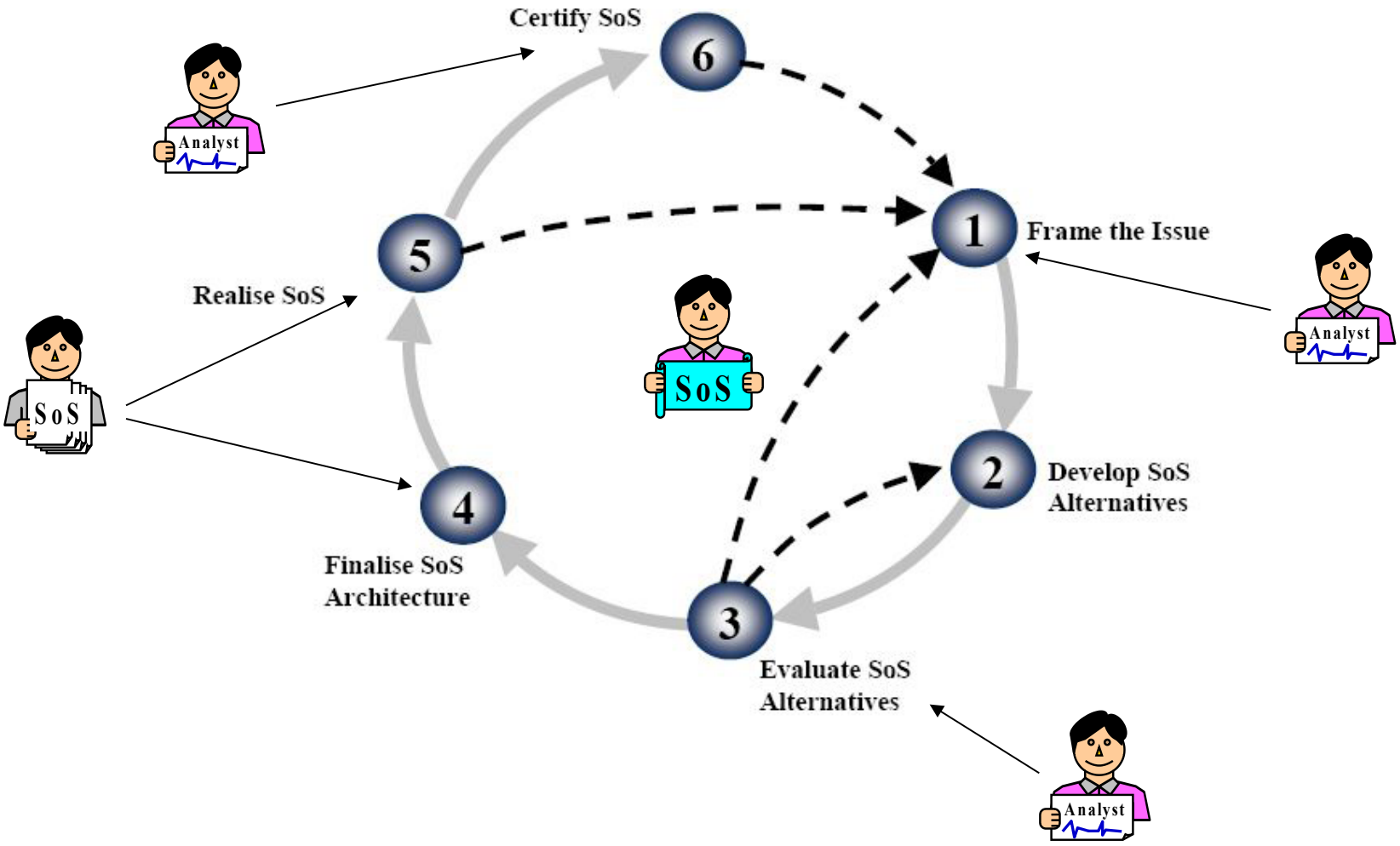
Architecting Process for SoS Architect to Develop Integrated Capabilities

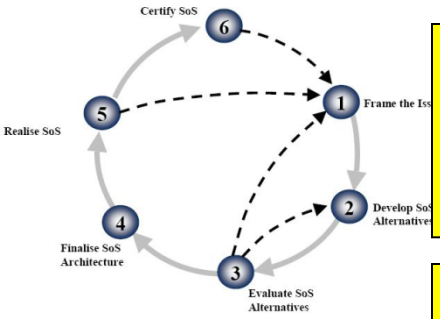
- we briefly illustrated phases 1 to 5 in our story



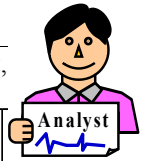
[Tan et al 09]

Interactions between SoS Architect, Architecture Analyst and SoS Implementation Manager

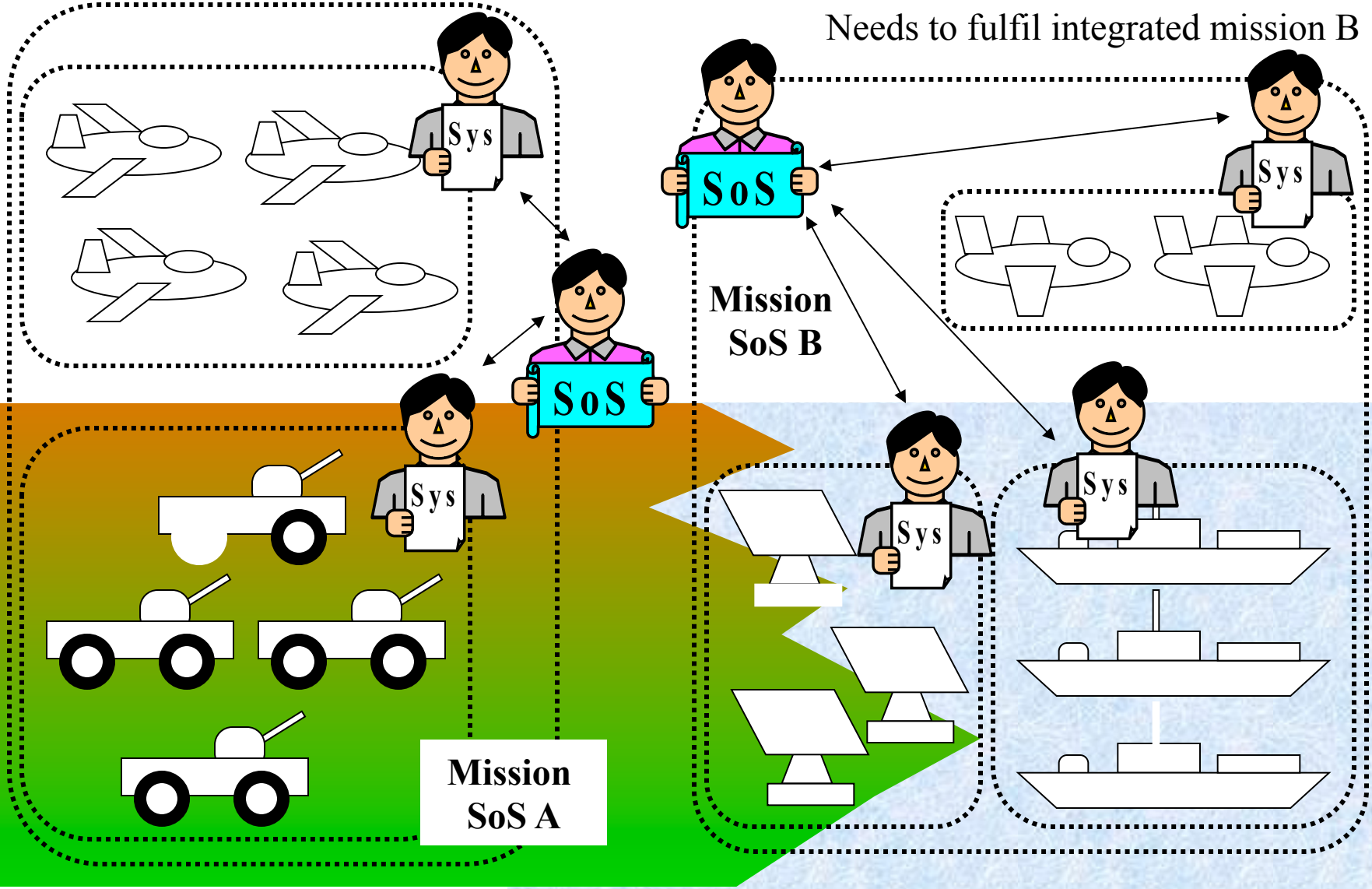




	Activities to architect an SoS	Technical lead for SoS A
1	Establish the operational environment, threats and mission objective for this SoS	Not applicable (military stakeholders only)
	Establish the existing capability gap of this SoS	SoS Architect (SoS A), supported by Architecture Analyst
2	Develop SoS alternatives (across required time frames) via redefining	Overall – SoS Architect (SoS A)
	SoS boundaries (and roles of platforms)	SoS Architect (SoS A)
	Connectivity requirements for platforms	SoS Architect (SoS A)
3	Evaluate SoS alternatives	Architecture Analyst, SoS Architect (SoS A)
4	Finalize SoS architecture based on acceptable SoS alternatives	Overall – SoS Architect (SoS A),
	Establish SoS implementation road map based on	Overall – SoS Implementation Manager (SoS A)
	SoS architecture and SoS capability spirals	SoS Architect (SoS A)
	Acquisition or development strategy for constituent systems	SoS Implementation Manager (SoS A) and
5	Decision points for constituent systems (e.g. project initiation date, integration date)	SoS Implementation Manager (SoS A)



But Mission SoS A does not exist in isolation…



But Mission SoS A does not exist in isolation…

- It takes various SoS and systems fulfil a broad range of missions for defence and national security
  - SoS A, SoS B, SoS C….
  - “Isolated” systems M, N, …

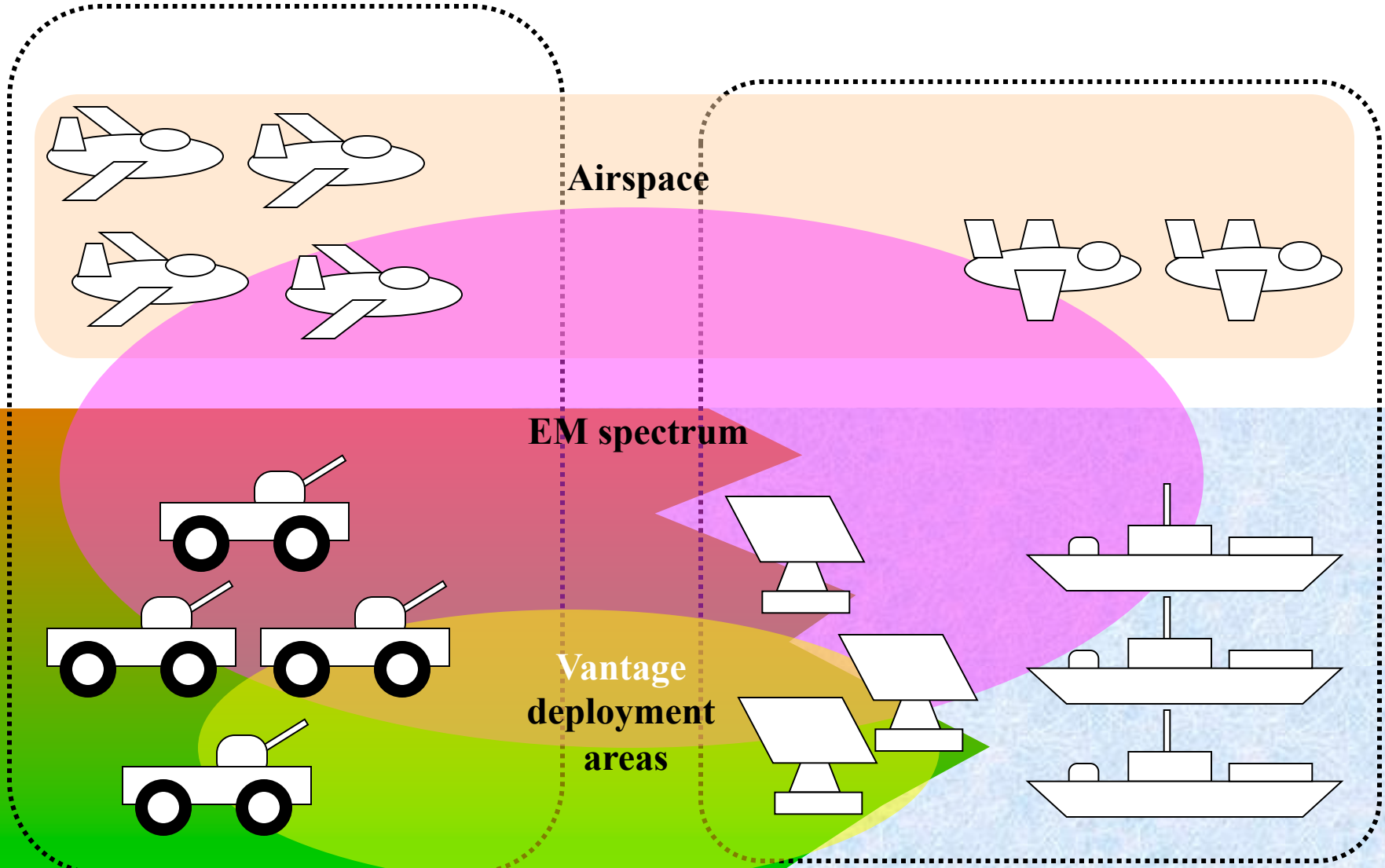
- What are some potential challenges for each Mission SoS to fulfil its integrated mission?

Potential Challenges

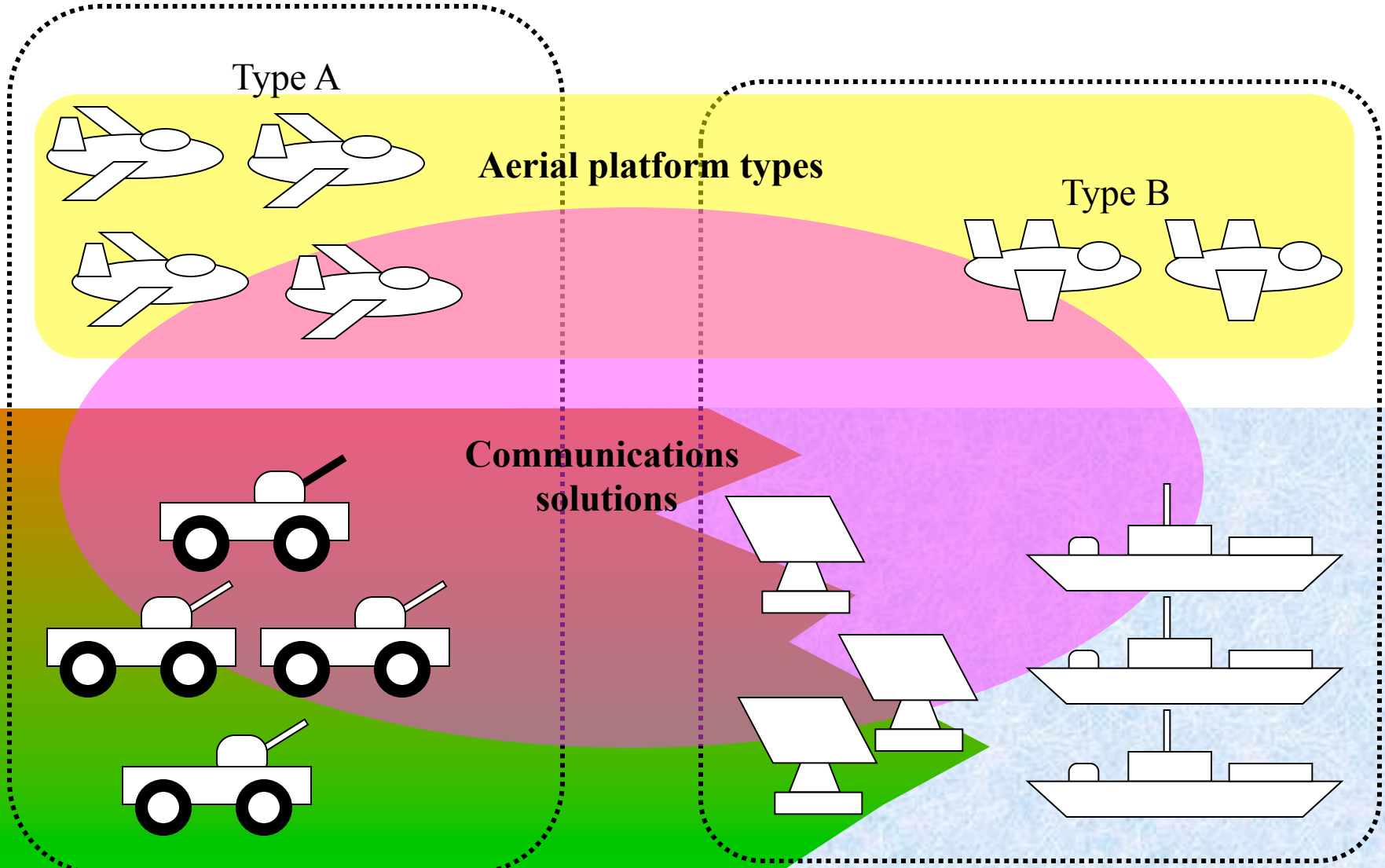
- Competition for **Enterprise Resources**
  - finite, non-scalable resources shared across various Mission SoS
  - e.g. EM spectrum (if emphasis is on networked capabilities)
  - e.g. vantage deployment sites, airspace etc
  - will all Mission SoS be able to share these resources and meet their respective integrated mission requirements?

- An non-optimal myriad of **Enterprise Technology**
  - scalable technological solutions used across various Mission SoS
  - e.g. C4 solutions (if emphasis is on networked capabilities)
  - e.g. aerial platform types
  - can certain technology requirements be streamlined at the enterprise level (across various Mission SoS) so that sustainable (e.g. human resource, cost) capabilities can be achieved?

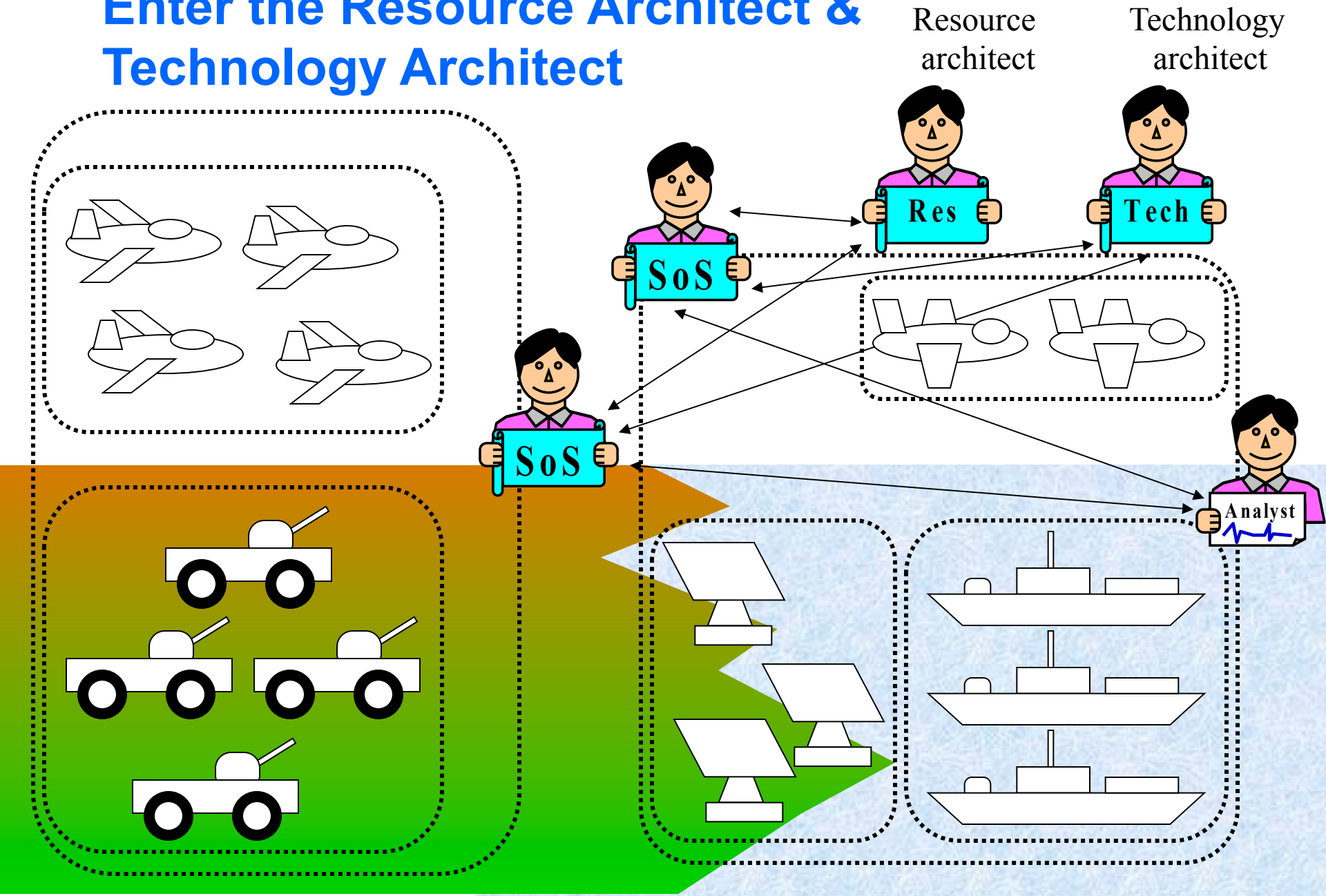
Competition for Enterprise Resources



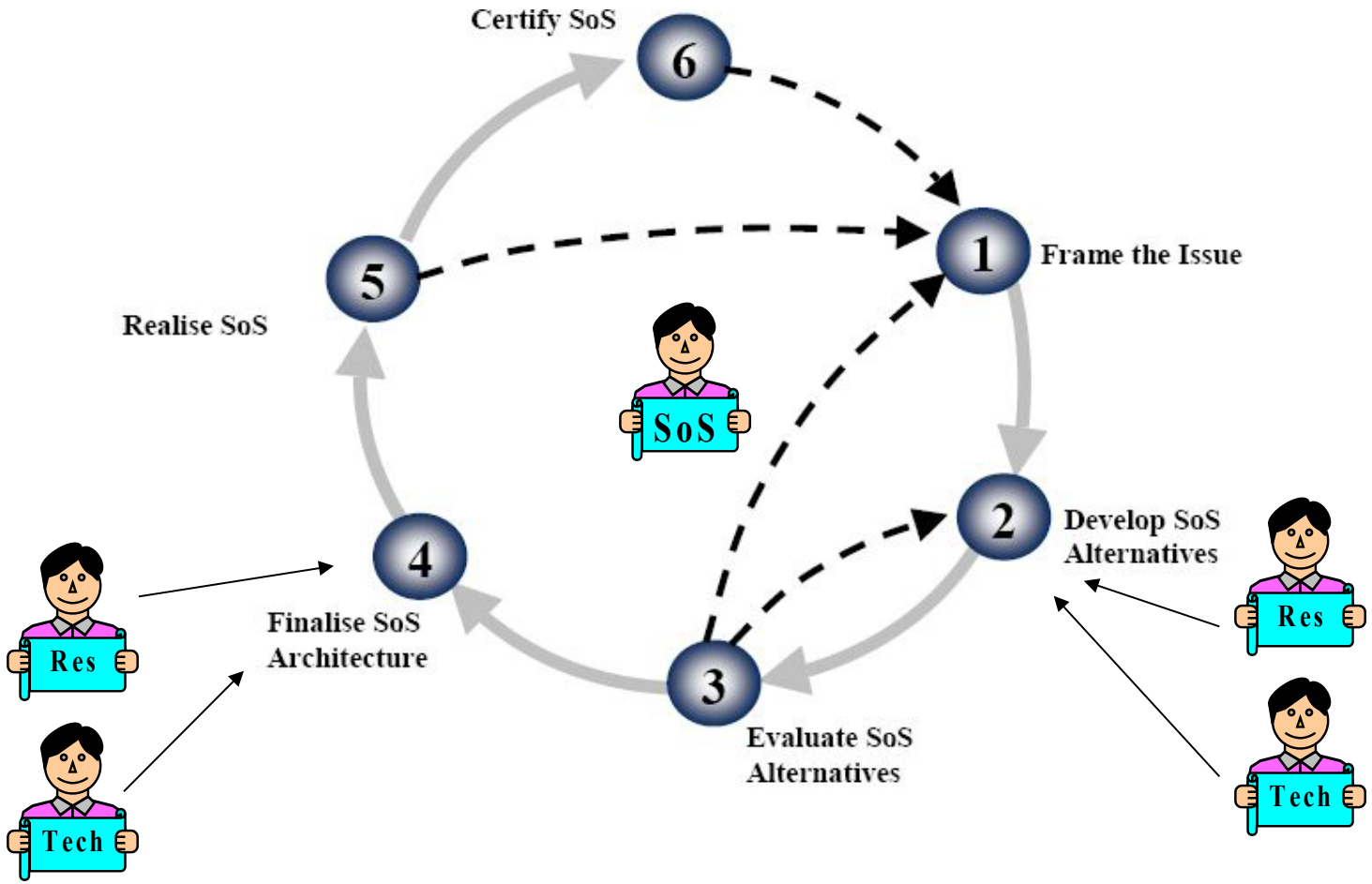
A Myriad of Systems & Technical Solutions

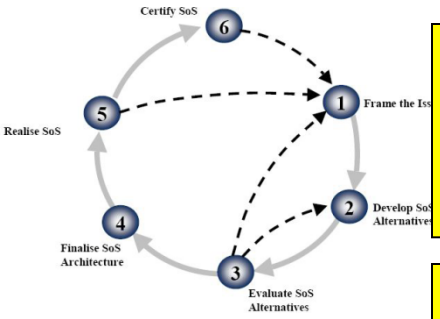


Enter the Resource Architect & Technology Architect



Interactions between Architects in the Process (SoS Architect's Perspective)





1

2

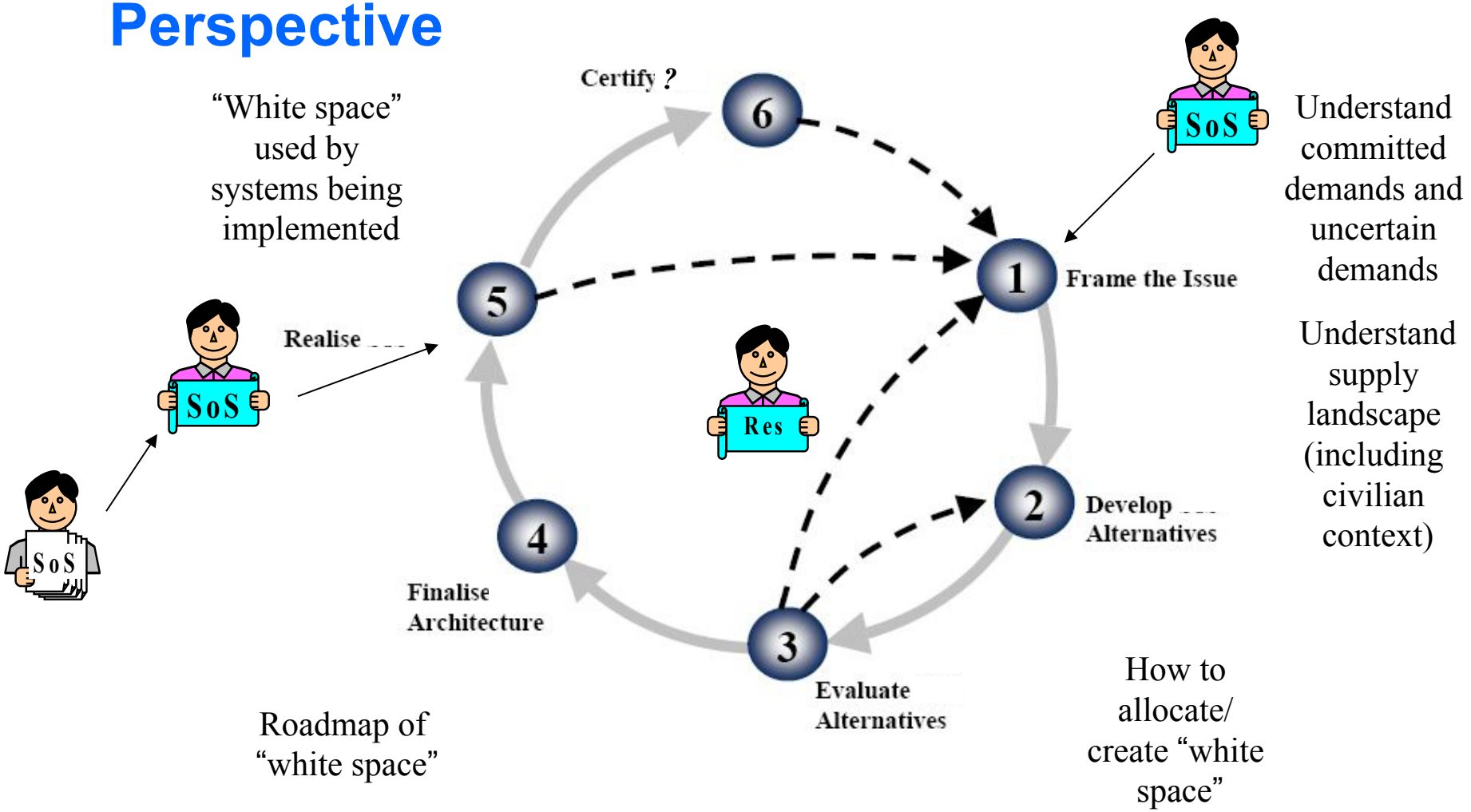
3

4

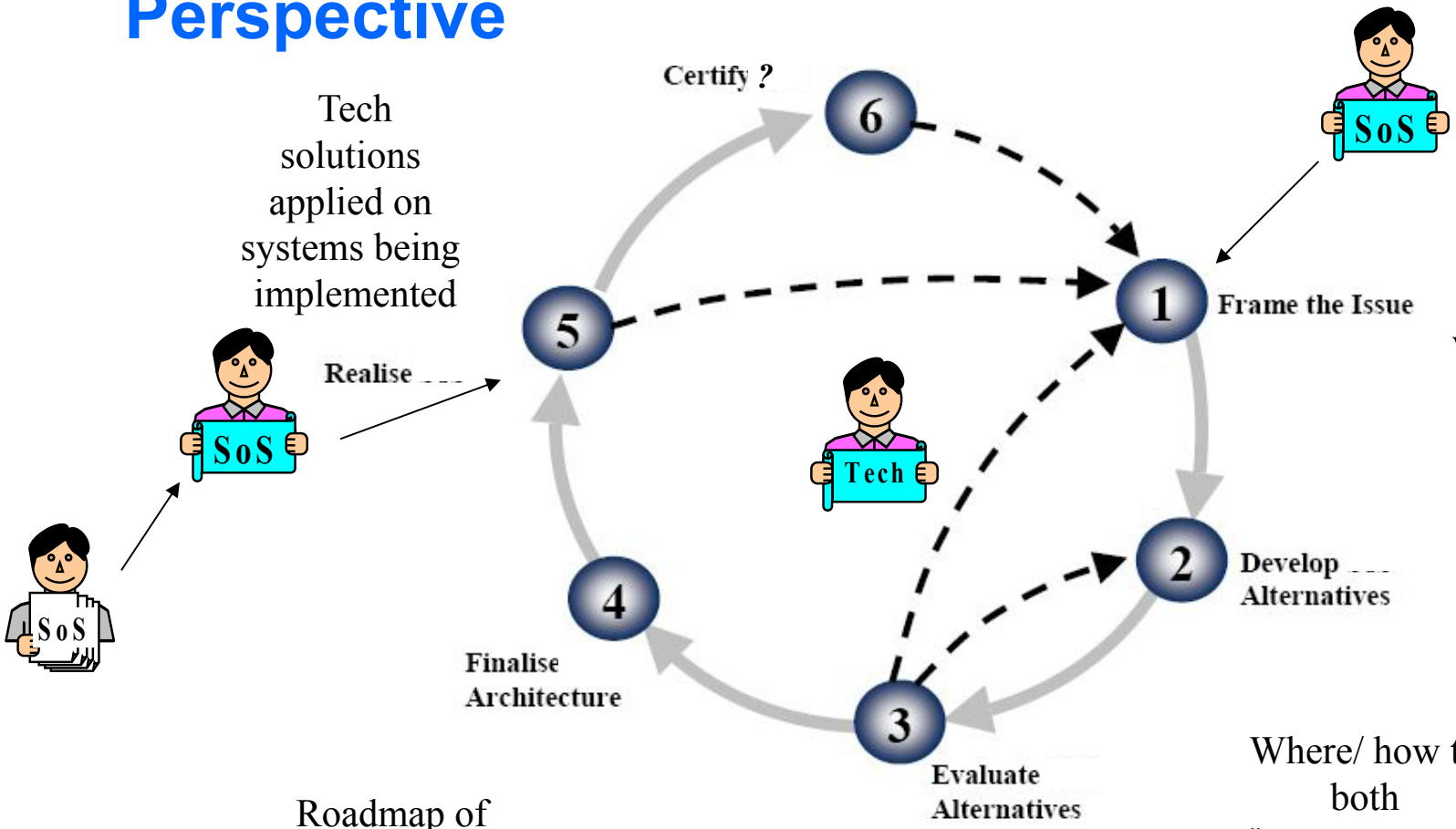
5

Activities to architect an SoS	Technical lead for SoS A	Technical lead for SoS B
Establish the operational environment, threats and mission objective for this SoS	Not applicable (military stakeholders only)	Not applicable (military stakeholders only)
Establish the existing capability gap of this SoS	SoS Architect (SoS A), supported by Architecture Analyst	SoS Architect (SoS B),
Develop SoS alternatives (across required time frames) via redefining	Overall – SoS Architect (SoS A)	Overall – SoS Architect (SoS B)
SoS boundaries (and roles of platforms)	SoS Architect (SoS A)	SoS Architect (SoS B)
Connectivity requirements for platforms	SoS Architect (SoS A)	SoS Architect (SoS B)
Application of specific Enterprise Technology	Various Technology Architects	
Utilization of specific Enterprise Resources	Various Resource Architects	
Evaluate SoS alternatives	Architecture Analyst, in consultation with SoS Architect (SoS A)	SoS Architect (SoS B)
Finalize SoS architecture based on acceptable SoS alternatives	Overall – SoS Architect (SoS A), in consultation with Resource Architects, Technology Architects	Overall – SoS Architect (SoS B),
Establish SoS implementation road map based on	Overall – SoS Implementation Manager (SoS A)	Overall – SoS Implementation Manager (SoS B)
SoS architecture and SoS capability spirals	SoS Architect (SoS A)	SoS Architect (SoS B)
Acquisition or development strategy for constituent systems	SoS Implementation Manager (SoS A) and Various Technology Architects	SoS Implementation Manager (SoS B) and Various Technology Architects
Decision points for constituent systems (e.g. project initiation date, integration date)	SoS Implementation Manager (SoS A)	SoS Implementation Manager (SoS B)

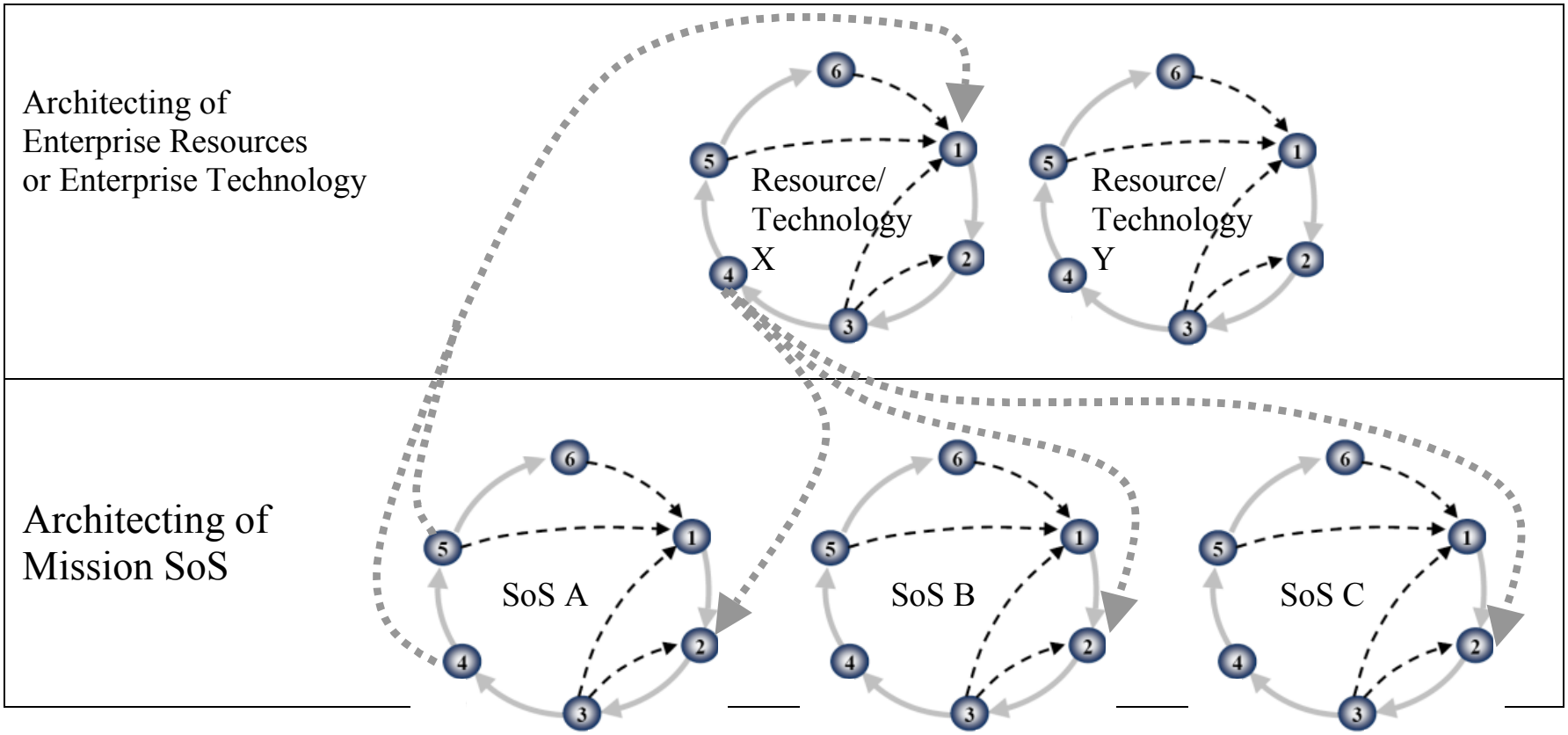
Process from the Resource Architect's Perspective



Process from the Technology Architect's Perspective



Interactions between Architects in the Process (Macro Perspective)



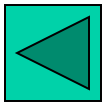
Summary

- Impetus to attain “global optimum” for Mission SoS
- Organizational structure
  - Assume “top-down” leadership viable to oversee system managers
  - SoS Architect, Resource Architect, Technology Architect, SoS Implementation Manager
  - Architecture Analyst
- Broad process for architecting
- Interaction between architects when architecting Mission SoS, Enterprise Resources and Enterprise Technology

Thank you!

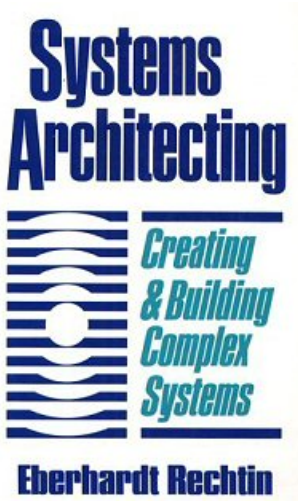
What is Systems Architecting?

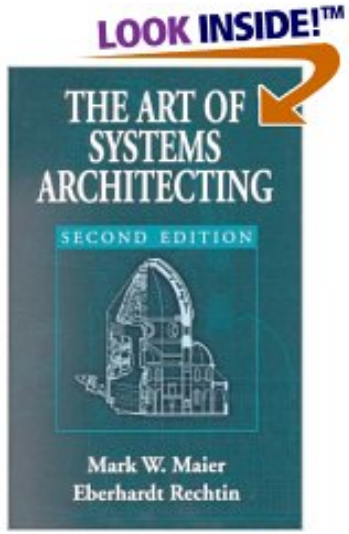
- Building the big picture…
- Achieving operational capability greater than sum of what individual systems provide ...
- Satisfying stakeholders ...



Systems Architecting...

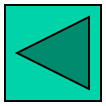
- The Art that complements its science
  - Dealing with immeasurable
  - Reducing past experience and wisdom to practice
  - Involves collaborations with people and organisations
  - Conceptualisation with domain experts using modelling & simulation





Roles of the Systems Architect

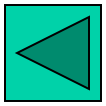
- To lead SoS architecture development
- To strategize the synthesis and integration of capabilities
- To master plan and provide technical governance
- To develop systems architecting tools



Value of Systems Architecting in Defence

- Coherently realise a network-centric SoS capability
- Within an SoS, reduce weaknesses of each system and enhance "jointness" and overall effectiveness
- Creation of positive emergent capabilities

Value of SoS (X1, …, Xn) >> X1 + … + Xn !!!



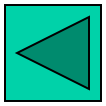
System-of-Systems (SoS)

"System-of-systems" (SoS) are defined as an interoperating collection of component systems that produce results unachievable by the individual systems alone.

INCOSE Systems Engineering Handbook v3

Examples of System-of-Systems

- Military Context
  - Maritime Security
  - National Air Defence
- Civilian Context
  - Land Transport
  - Civil Aviation



SoS Key Challenges

- Balancing stakeholders' needs and requirements
- Interoperability and integration amidst change
- Complexity challenges