Australian Government
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Defence Science and Technology Group

A Service-based Approach to Force Design, Integration and Analysis

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Force design meets service-based thinking

1. The ADF is a large and complex system-of-systems.

2. None-the-less, a system-of-systems is still just a system (of nodes and links)!

3. ***Force design*** is a large and complex exercise that aims to coherently link and evolve the constituent systems.

4. The challenge is to practically model and manage this large complexity.

5. Our approach is to be **pragmatic and minimalist**:
   1. What are the **minimum set of functions** that describe a system (the nodes)?
   2. What is the **simplest description of the dependencies** of systems (the links)?
   3. What is a **scalable way** to capture the larger systems-of-systems (the size and complexity)?

⇨**A service-based model**

Outline

1. What is a service-based approach?
2. What is the SCMILE (service-based) approach?
3. How are we applying the SCMILE approach to portfolio management?
4. How can SCMILE be applied to force design analysis?
5. Concluding remarks – the benefits

1. What is a service-based approach?

Why services?

- Services have increased in prominence and relevance as a science due to its importance in the economy and is now embedded in systems and software engineering.
- It lends itself to capturing relationships between entities, thereby providing a construct that is flexible and robust in managing extant and emergent interactions and dependencies.
- BUT this begs the question, **"What is a service?"**
  - (Table) service
  - (Tennis) service
  - (Defence) Service
  - service (economy)
  - (Religious) service
  - service (-oriented architecture)
  - (Telecommunications) service
  - …

What is a service-based approach?

- We use a simple working definition:
  - **A service is a value-creating activity involving two entities, where one, *the provider,* generates and supplies a service of benefit to the other, *the consumer***

- Consequently,
  - **A service-based approach is one that models a system (or system-of-systems) as an exchange of services**

Why is a service-based approach useful?

- It focusses on the **consumer needs and the relationship/s that delivers it**
- Nevertheless, it explicitly recognises the **two sides of this relationship** which need to be in alignment: the consumer that wants it and the provider/s that deliver it
- This means there is a **dual "push-pull" surfacing of resources and requirements** arising from the individuals who are involved in the service exchange

Metaphor 1 – the café as a service provider

- Consumers = me and you who want some coffee
- Provider = the café

- At most basic level of service provision, **you and I can each get a cup of coffee** from the café. This is true as far as it goes but **is a limited description** … let's break it down.

- You and I may want **different coffee experiences**
  - I may want a **cup to takeaway** and I will accept anything as long as it is *hot, black, quick and contains caffeine*
  - You may be **more discerning**, and want *organic, fair-trade, dolphin-friendly, double-shot latte espresso using beans that have been through the digestive tract of a monkey and sit in a reclining armchair in air-conditioned comfort while listening to Plácido Domingo*.

- **This description is analogous to a capability dependency** where
  - the **specifications of the service exchange have to precisely suit the consumer,** and the provider needs to be able to deliver it. In addition,
  - **you as a consumer don't care in the ultimate sources and inputs** the provider uses just as long as it can deliver the service you experience.
    - eg A radar provides a sensing service. For different consumers; the radar operator, HQ, weapons officer … ; the requirements of this sensing service may be different and may be sourced through intermediaries

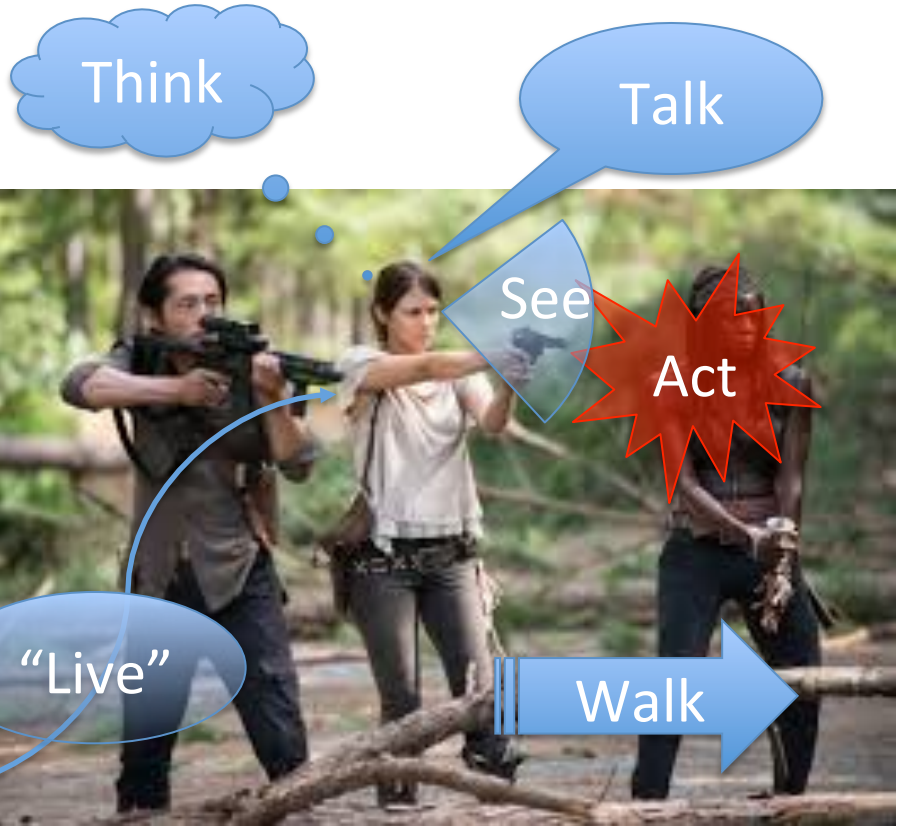
2. What is the SCMILE approach?

The SCMILE services

It is important for the services chosen to have definitions that are, as far as is practical, (1) clear, (2) concise, (3) intuitive, (4) distinct and (5) complete as a set.

Service	Short Description
Sensing	The provision of **information** regarding the battlespace and wider operational environment.
Command & Control†	The provision of **sense-making, decision-making and instructions** for agents and **analysis** of the battlespace and wider operational environment.
Engagement	The provision of **effects**, in and on the battlespace and wider operational environment.
Information Mobility	The provision of **information storage and dissemination**, covering infrastructure, activity and processes.
Physical Mobility	The provision of **housing and locomotive ability** (movement, transport and containment).
Logistics, Supply, Sustainment and Support	The provision of activities, physical materials and information that **enable the normal functioning of a system or agent**.

Metaphor 2 – a person as a set of SCMILE functions (and potential services)



A cake baked by Glenn

Maggie from *The Walking Dead**

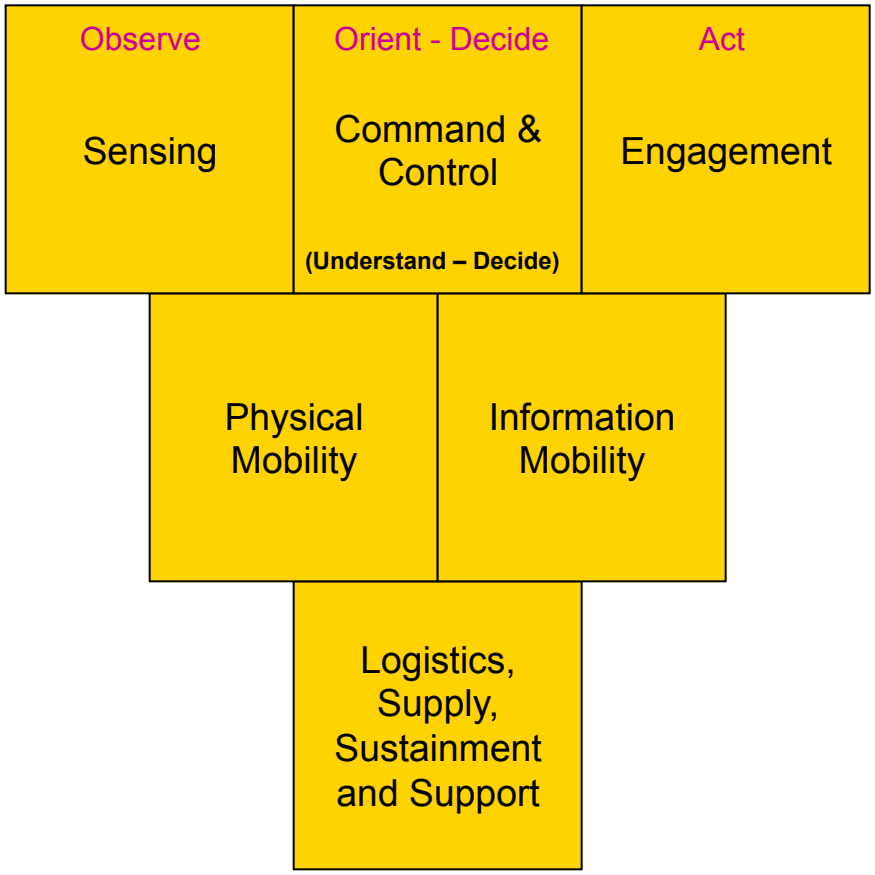
* AMC, FOX Networks

Function	Person
Sensing	See
Command & Control	Think
Engagement	Act
Information Mobility	Talk
Physical Mobility	Walk
Logistics, Supply, Sustainment and Support	"Live"

Why these six? … because they are simple, familiar and "complete"

Together, they are **one of the simplest representations** of the functioning of an entity, be it a person, tank, ship, team or organisation.

- The **top layer** is quite familiar (think OODA loop).
- The **middle layer** are the movement of objects in the Physical and Information domains – these are required for an effective top layer.
- The **bottom layer** captures the "stuff" that needs to have happened that enables an entity to function normally – required for both other layers.



Why these six? – because they map well to previous and current defence taxonomies

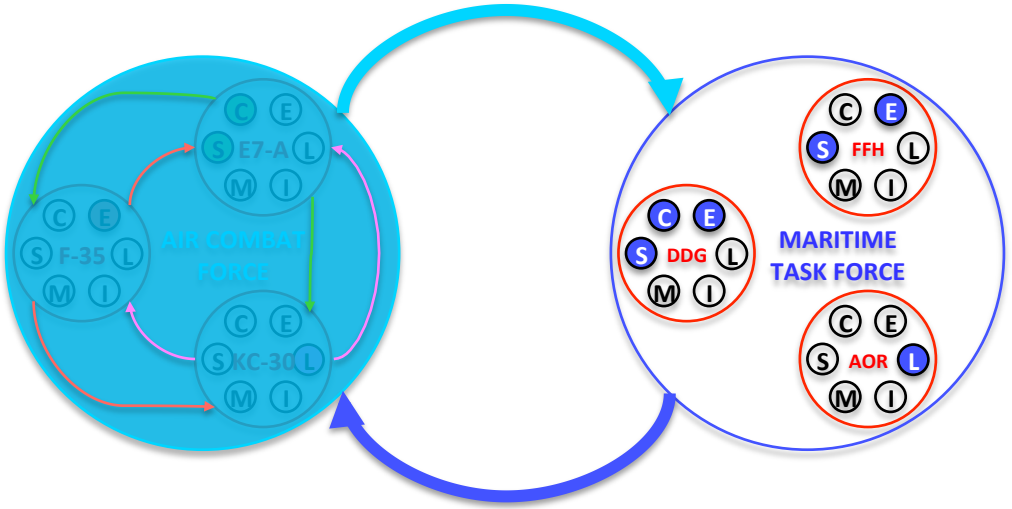
SCMILE Services	Joint Warfighting Functions (2006)	Strategic Level Effects (2008)	Defence Operating and Enabling Functions (2012) Capability Integration Framework (2014)	joint warfighting functions (2016)
Command and Control	command and control	Command, Control and Battlespace Management	Command and Control	command
Sensing	knowledge dominance	Situational Awareness	Battlespace Awareness	situational understanding
Information Mobility		Communications	Communications	
Engagement / Effects	force application	Force Application and Protection	Fire & Effects	force application
	force protection		Force Protection	force protection
Physical Mobility	force deployment	Force Projection	Battlespace Manoeuvre	force projection
Logistics, Supply, Sustainment and Support	force generation and sustainment	Force Sustainment and Support	Logistics	force generation and sustainment
			National Support	

It can be seen that the different Defence taxonomies have repeatedly reflected the basic SCMILE Services construct, mostly well aligned with direct mappings of respective elements but differing in minor ways by variously aggregating or disaggregating one or more service.

Why these six? – SCMILE Services are scalable

Any system can be viewed as a collection of the 6 functions e.g. F-35

Potentially, **any of these functions can be provided as a service to other systems.** This exchange of services is performed as part of the operation of a larger system e.g. Air Combat Force, Maritime Task Force.

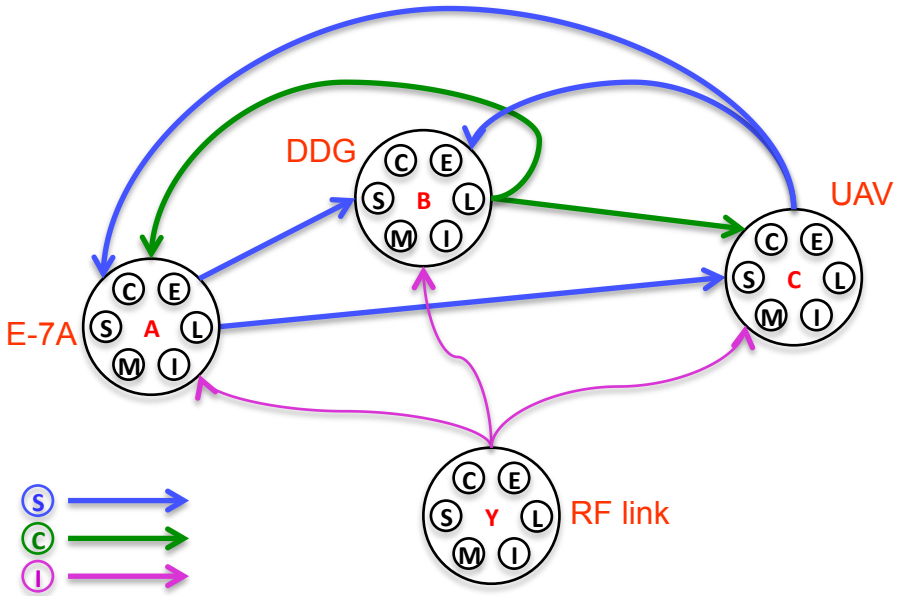


	Command Level		
Service	**Tactical**	**Operational**	**Strategic**
Sensing			
Command & Control			
Engagement			
Physical Mobility			
Information Mobility			
Logistics & Support			

And one can abstract away from the physical systems, and consider how functions and **services at lower levels contribute to services at higher levels** of command.

e.g. while the core of operational-level Wide Area Surveillance (WAS) is undertaken by the sensing at the tactical level (e.g. JORN, P8 radar), it is the combination and orchestration of all tactical-level services that deliver WAS.

Why these six? – It holistically encompasses information exchange (and net-centric concepts)



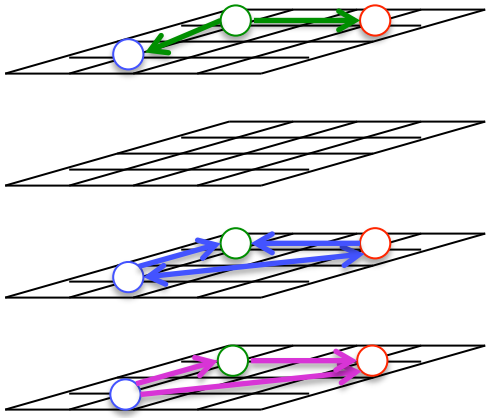
- System A provides a **Sensing service** to B and C
- System B provides a **C2 service** to A and C
- System C provides a **Sensing service** to A and B.

These services are delivered as "packets" of information which needs to be done by system Y (RF Link) which is providing the **Information Mobility service** to the other three systems.

This provides an alternative (but compatible) perspective to the classic NCW grids.

It has the added benefits of collapsing this onto one picture and explicitly identifying the systems required to move the information around.

The NCW Grids



Command Grid

Engagement Grid

Sensor Grid

Information Grid

Why these six? – because they also help refine the nature of entities and actions

- The real world can be described as simultaneously existing in three domains:
  - **Physical**: the real world
  - **Informational**: the information about the real world
  - **Cognitive**: the understanding of the real world (based upon the information)

- All entities and actions, and consequently all services, have aspects in all three domains

- e.g. the logistics service of supplying ammunition
  - In the **physical domain, this is the objects and actions** that amount to the service being delivered
  - In the **informational domain, this is the data on this service** (what, when, how, how much, where, …)
  - In the **cognitive domain, this is the knowledge and understanding** (and decision-making) that is generated based upon the information.

This is particularly useful for providing a coherent deconstruction and connection of all *dimensions of information.*

Dimension	General Description	Model Description
Information	The meaning or information content of symbols stored and transmitted around the battlespace.	• Captured as the information content associated with **any of the Services** in the **Information Domain**. • This is stored and transmitted in the Information Infrastructure in the **Physical Domain** but understood in the **Cognitive Domain.**
Information **Infrastructure** / Communication Information Systems	The hardware and systems that physically support, store, manipulate and disseminate information.	• Captured as the **Information Mobility Service** in the **Physical Domain**. • This is instantiated in the physical systems and processes in the **Physical Domain**.
Information **Warfare**	The conduct of operations that manipulate information in order to influence or constrain the decisions and/or actions of others.	• Captured as an **Engagement Service** that is focussed in the **Information Domain**. • This is performed in the **Physical Domain**, to affect artefacts in the **Information Domain**, often for the purposes of producing effects in the **Cognitive Domain**.

3. How are we applying the SCMILE approach to force design management?

A small example of entering service exchange data …

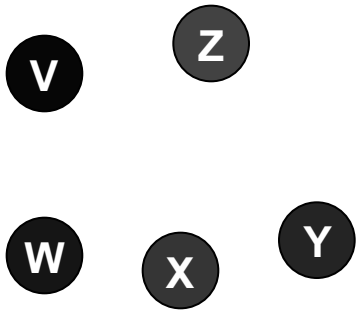
Consider a system consisting of capabilities V, W, X, Y and Z.

In this example, we are only examining the **SENSING** service (this needs to be done for all other five service exchanges).

The SME for capability V considers the capability as
- a PROVIDER and
- a CONSUMER,

of Sensing services to and from the other capabilities.

… i.e. only one row and one column



		CONSUMER				
	S	V	W	X	Y	Z
PROVIDER	V		?	?	?	?
	W	?				
	X	?				
	Y	?				
	Z	?				

		CONSUMER				
	S	V	W	X	Y	Z
PROVIDER	V		?	?	?	?
	W					
	X					
	Y					
	Z					

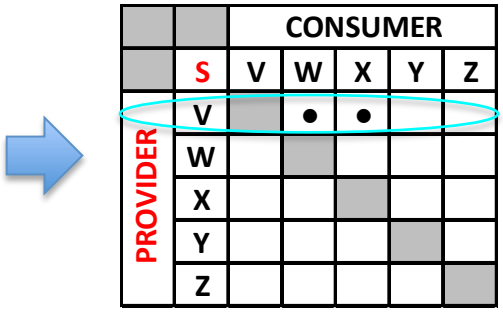
		CONSUMER				
	S	V	W	X	Y	Z
PROVIDER	V					
	W	?				
	X	?				
	Y	?				
	Z	?				

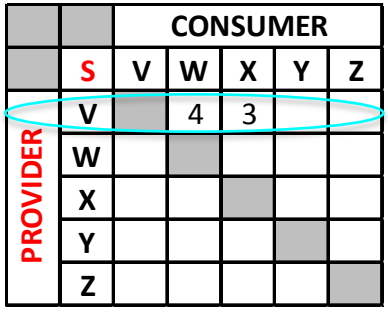
… from the perspective of each capability …

The SME first considers whether they believe a service exchange exists at all …

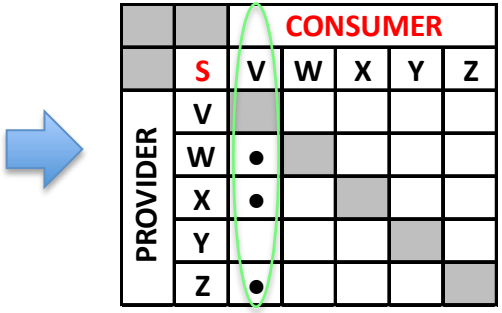
… and if so, what is the level of criticality (i.e. how important) of the service exchange.

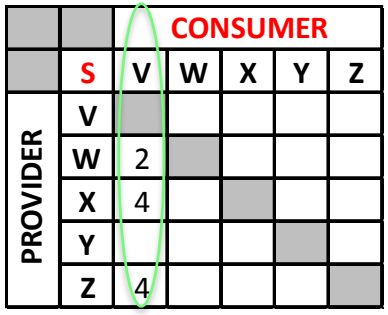
CAPABILITIES AS PROVIDERS ONLY





CAPABILITIES AS CONSUMERS ONLY





… so that service exchange data can be compared

Both agree there is NO service exchange.

PROVIDERS AND CONSUMERS COMPARED

CAPABILITIES AS PROVIDERS ONLY

PROVIDER \ CONSUMER	S	V	W	X	Y	Z
	V		4	3		
	W	4		3		
	X	4	3		4	4
	Y		2			
	Z				2	

CAPABILITIES AS CONSUMERS ONLY

PROVIDER \ CONSUMER	S	V	W	X	Y	Z
	V		4			
	W	2		2		3
	X	4	3		3	4
	Y		3			
	Z	4			2	

Both agree there IS a service exchange and the criticality level.

Provider recognises the service but the Consumer doesn't.

PROVIDER \ CONSUMER	S	V	W	X	Y	Z
	V		4,4	3,0		
	W	4,2		3,2		0,3
	X	4,4	3,3		4,3	4,4
	Y		2,3			
	Z	0,4			2,2	

Consumer recognises the service but the Provider doesn't.

Both agree there IS a service but NOT on the criticality level.

Confirming and refining the service exchange data

Next steps:

- The inconsistencies are attempted to be resolved by the relevant provider and consumer.
- Where they agree, the two parties attempt to go on to confirm the "Quality-of-Service" (QoS), and any other important information.
- If any disagreement at the product/project level continues, the issue needs to be raised and resolved at the Program level.
- Senior defence decision makers can then review this overall design to assess whether it is as they expect and is both affordable and effective.

		CONSUMER				
	S	V	W	X	Y	Z
PROVIDER	V		4,4	3,0		
	W	4,2		3,2		0,3
	X	4,4	3,3		4,3	4,4
	Y		2,3			
	Z	0,4			2,2	

		CONSUMER				
	S	V	W	X	Y	Z
PROVIDER	V		4	3		
	W	3		2		3
	X	4	3		4	4
	Y		3			
	Z	3			2	

Metaphor 3 – Learning how to herd cats!

- **Managing all of the projects (and products)** in Defence has often been described as a task **akin to "herding cats"**

- But instead of trying to herd the cats, what if we could **get the cats to herd themselves** (at least in part)? But how could we possibly do that?

- **Key insight: some animals do "herd themselves" eg. a flock of birds**

- A **flock of birds** is an example of a **self-organising system** – no particular bird is always in the lead (they often take turns) but the birds still head in the same direction and do not run into each other.
  - So they aren't centrally controlled, and they aren't reading a large set of documentation containing some complicated procedure!
  - So how do they do this?

- Scientists have deduced that each individual bird follows some **simple rules** based upon their **immediate neighbours** (i.e. they don't have to directly know what the rest of the whole flock is doing!)
  - Separation – Don't get too close to your neighbours,
  - Cohesion – … but don't get too far apart from them either,
  - Alignment – … and move in the same direction as them!

- **Our approach "mimics" this by first focusing on aligning expectations of "nearest neighbours"** (those provider-consumer relationships).

How is the SCMILE approach being applied?

- In the new First Principles Review (FPR) has recommended a "**3P+P" approach** (Portfolio-Program-Project-Product).

- There are **40 Programs** in the new **Integrated Investment Program (IIP)**. We have performed some proof-of-concept trials and have very recently been given formal go-ahead to apply this approach in **five pilot programs**.
  - Integrated Air & Missile Defence (IAMD)
  - Maritime Communications
  - Amphibious Capability
  - Land Intelligence, Surveillance and Reconnaissance
  - Joint Electronic Warfare

- IAMD is a good case study as it owns **3 critical Projects** but (we assess) has **connections to around 100 individual Project phases and Products** (around 50 distinct systems or sub-systems) in more than **20 Programs**.

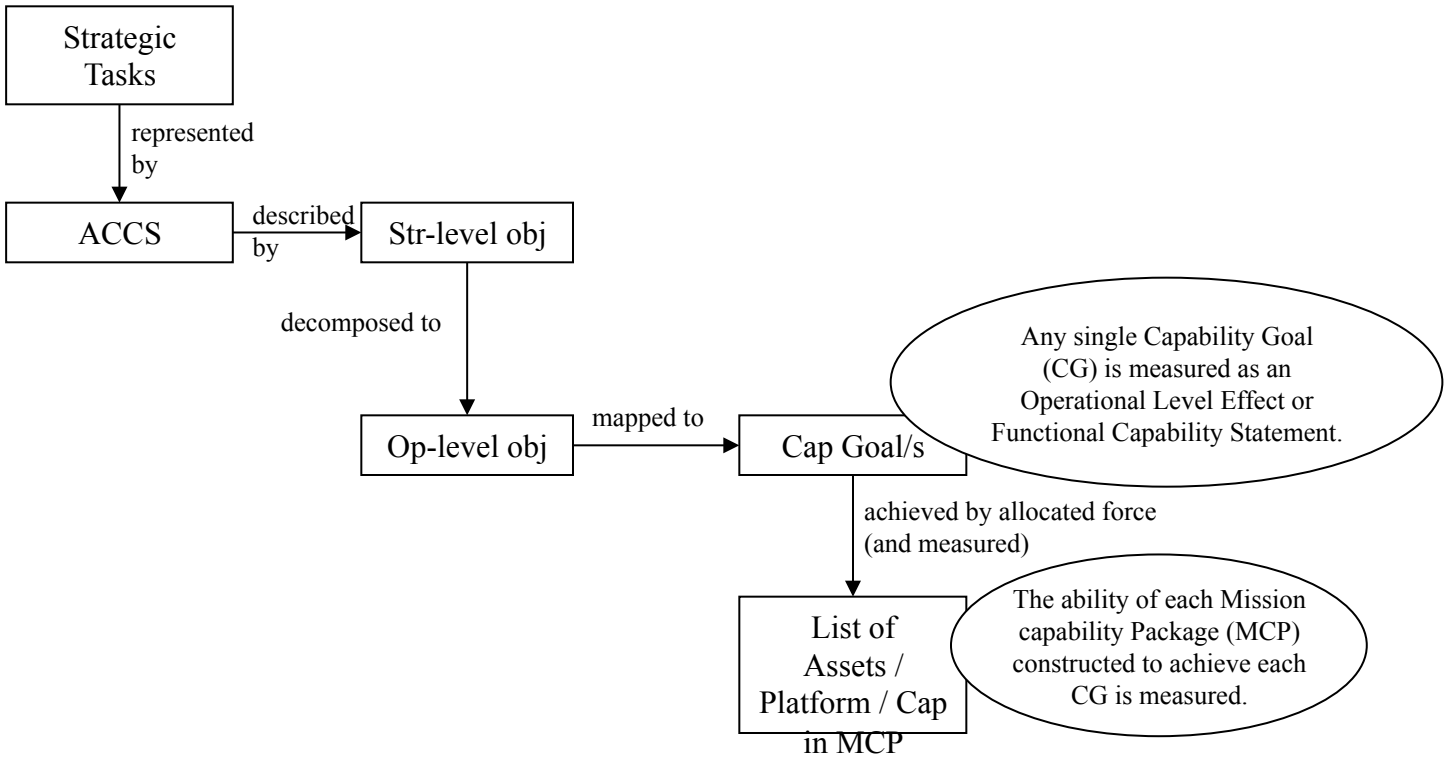
4. How can SCMILE be applied to force design analysis?

Generic Force Structure Analysis Process

A generic Force Structure Analysis process often **cascades down from strategic tasks** to operational objectives.

This is ultimately represented by some **capability goals, against which a "Mission-Capability Package" (MCP) is assigned** by the SME operational planners.

This is often articulated as **a set of assets** or capabilities.



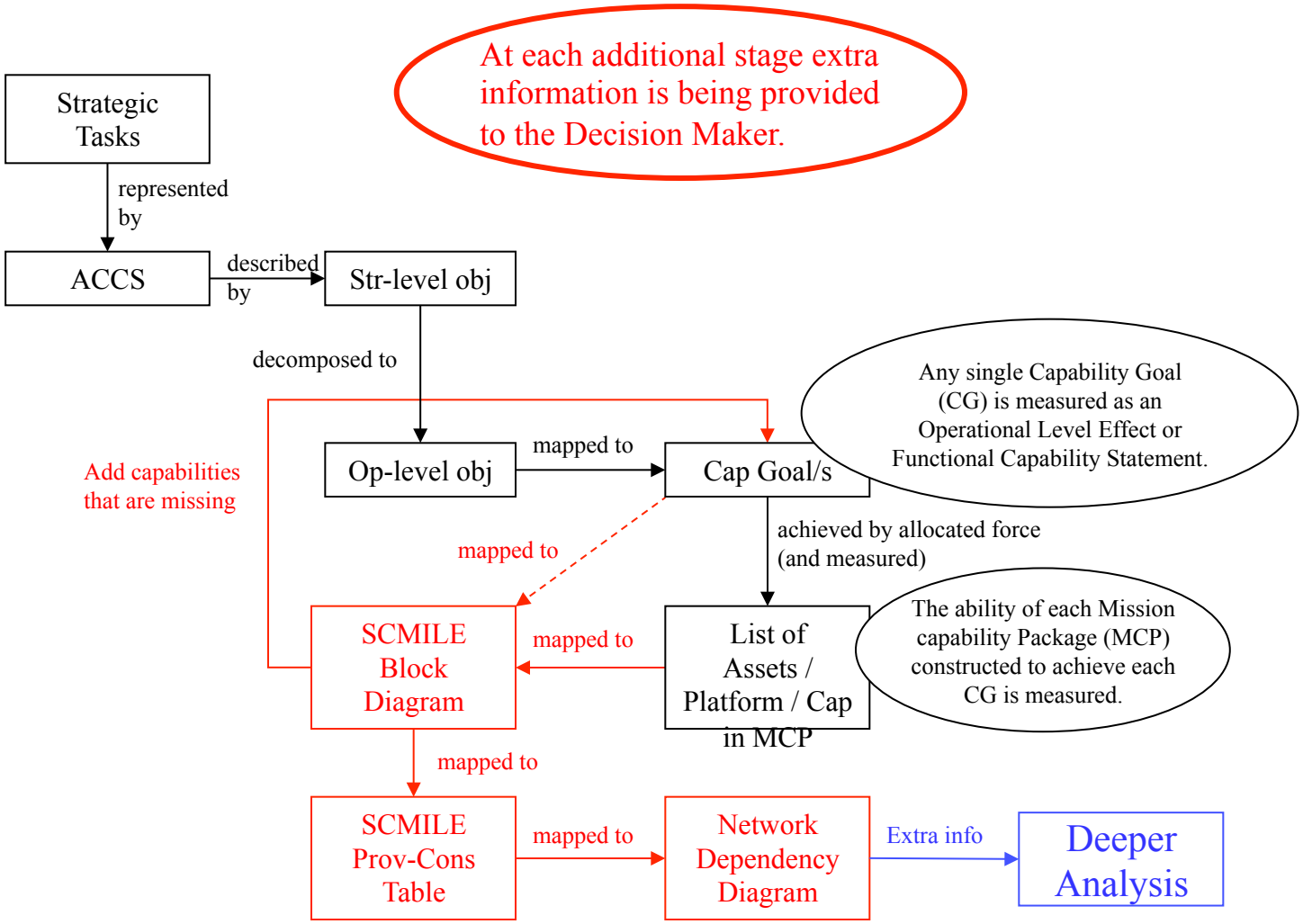
SCMILE Analysis Process

The **SCMILE framework provides a systematic method for analysing** the "Mission Capability Package" (MCP).

The **SCMILE Block Diagram** provides an initial functional analysis of the MCP, which can identify gaps.

The **Provider-Consumer Table** explicitly explores dependencies.

The **Network Dependency Diagram** permits network analysis of the system.



Exemplar Mission Capability Package

Mission / Operational Effect

Strategic Strike. Be prepared to neutralise/deter key enemy strategic capability.

A set of assets might be ascribed by a stakeholder to form the basis of the Mission Capability Package (MCP) required to complete the mission in a particular scenario.

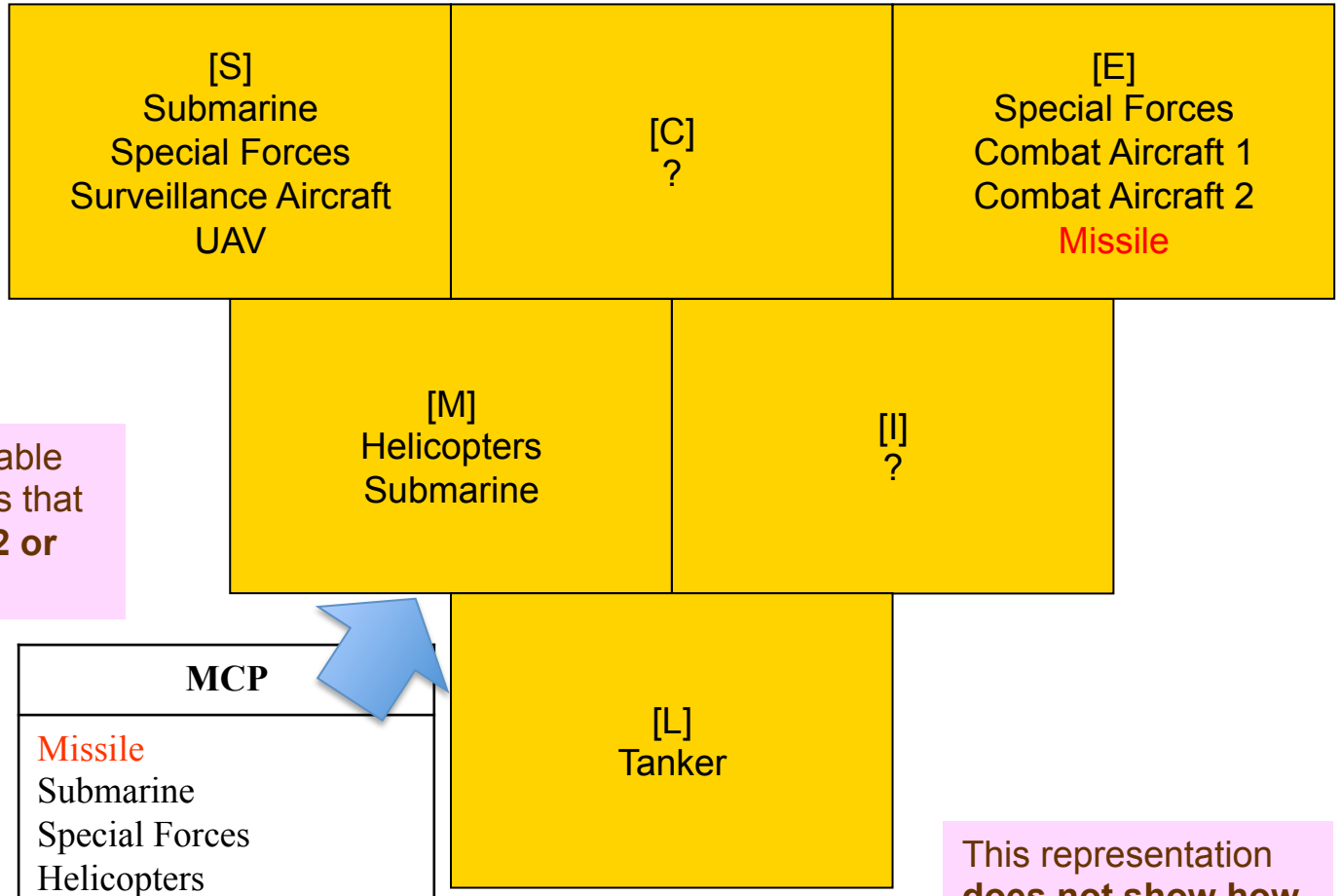
This represents perhaps the simplest “analysis” possible.

MCP
Missile
Submarine
Special Forces
Helicopters
Combat Aircraft 1
Combat Aircraft 2
Surveillance Aircraft
Tanker
UAV

At this stage, it consists only of a list of assets / capabilities and doesn’t show how the MCP operates.

SCMILE Block Diagram

The simple list can be extended by ascribing the **primary functional roles** played by each of the assets in the mission (represented here in the SCMILE block diagram).



In this toy example, it is notable that there are no capabilities that has a primary function of **C2 or Information Mobility**.

This representation **does not show how the capabilities are linked**.

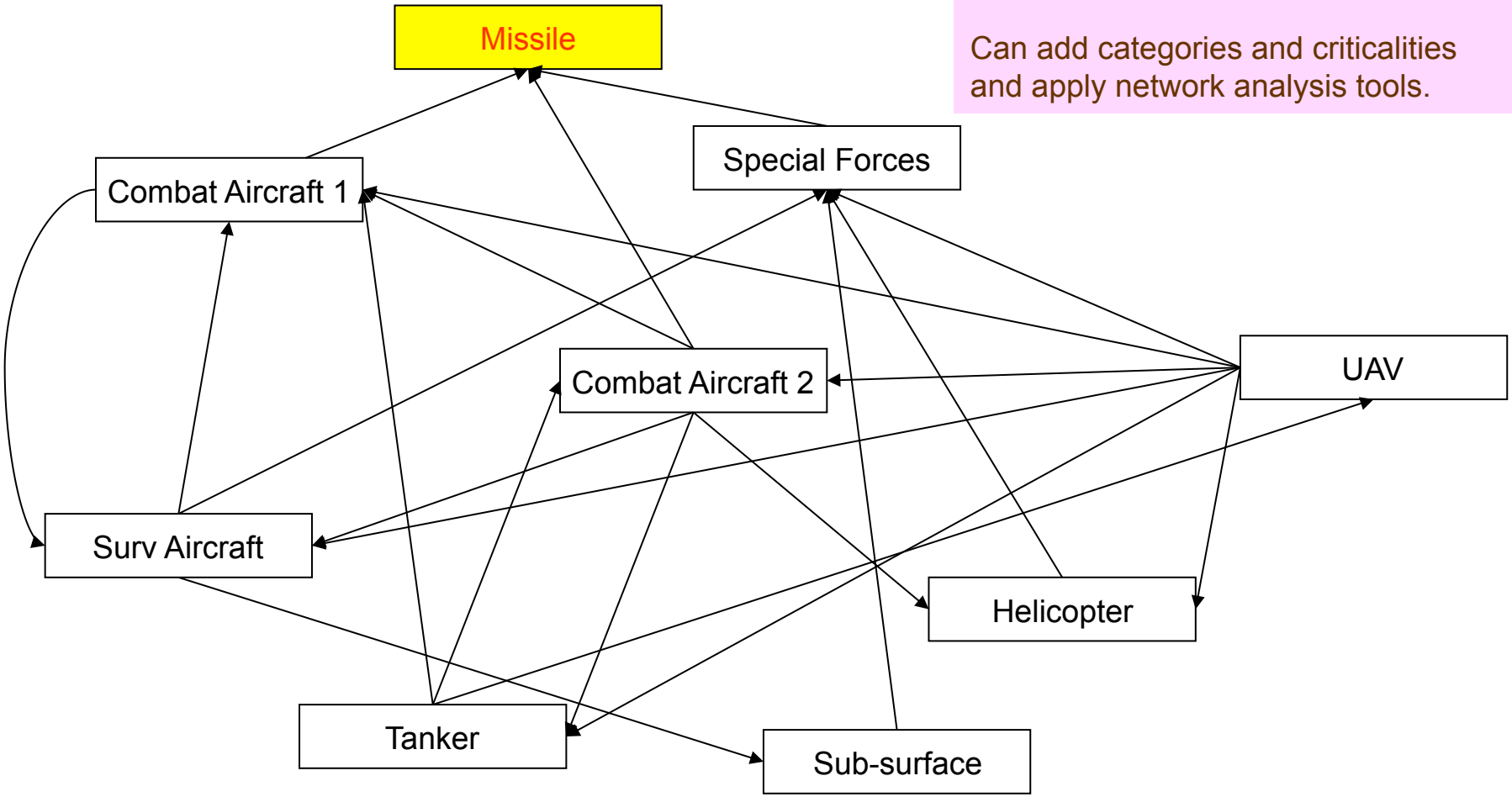
SCMILE Services *Provider-Consumer Table*

		SYSTEMS AS CONSUMERS								
		Submarine	Special Forces	Helicopters	Combat Aircraft 2	Tanker	Surveillance Aircraft	Combat Aircraft 1	UAV	Missile
SYSTEMS AS PROVIDERS	Submarine		M							
	Special Forces									S
	Helicopters		M							
	Combat Aircraft 2			E		E	E	E		SCM
	Tanker				L			L	L	
	Surveillance Aircraft	E	S					S		
	Combat Aircraft 1						E			SCM
	UAV		S	S	S	S	S	S		
	Missile									

System *Network Dependency Diagram*

The Provider-Consumer table can be represented by a network diagram.

Can add categories and criticalities and apply network analysis tools.



Other related (and potential) work

- Architectures
  - Constructing explicit connection with **standard architectures** approaches/frameworks
  - Constructing explicit connection with **ADF C4ISR designs and architectures**

- Force Modelling
  - Constructing a consistent **force structure ontology** of nodes and links.
  - Applying it to whole-of-force capability **analysis and experimentation**.
  - *Expanding its application into hybrid warfare and non-military operations.*

- Management
  - Incorporating *cost, schedule, risk* and **value**.
  - *Connecting strategic tasking explicitly to system design and project management*.

- *Simulation*
  - *Applying the framework in Agent-Based Distillations (ABD).*
  - *Mapping out and modeling mission threads, kill-chains and operational cycles and connecting to Discrete Event Simulations (DES).*

5. Concluding remarks

Positive attributes of the SCMILE Service-based approach (in a nutshell)

- It is **simple and efficient**
  - Minimalist framework and set of concepts
  - Data entered once only or when it changes
  - Designed to resolve issues at the lowest possible level of decision-maker
- It is **scalable and universal**
  - Applicable to different sizes, scales and levels
  - Applicable to any type of military design (industrial-age or information-age) and system types more broadly
- It is **"comprehensive" and extensible**
  - Provides high-level and "complete" overview of dependencies in the whole-of-force design which provides first-order information for analysis, understanding and management
  - Provides a foundation which can be deepened with requisite level of detail if required
  - Provides a data framework for conducting coherent analysis from design to operations

Beneficial applications (in a nutshell)

- A **pragmatic approach** to dealing with aspects of the complexity of force design and integration activities

- A **coherent foundation** for doing more detailed analysis and modelling

Questions?

Acknowledgements

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