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SCIENCE & TECHNOLOGY

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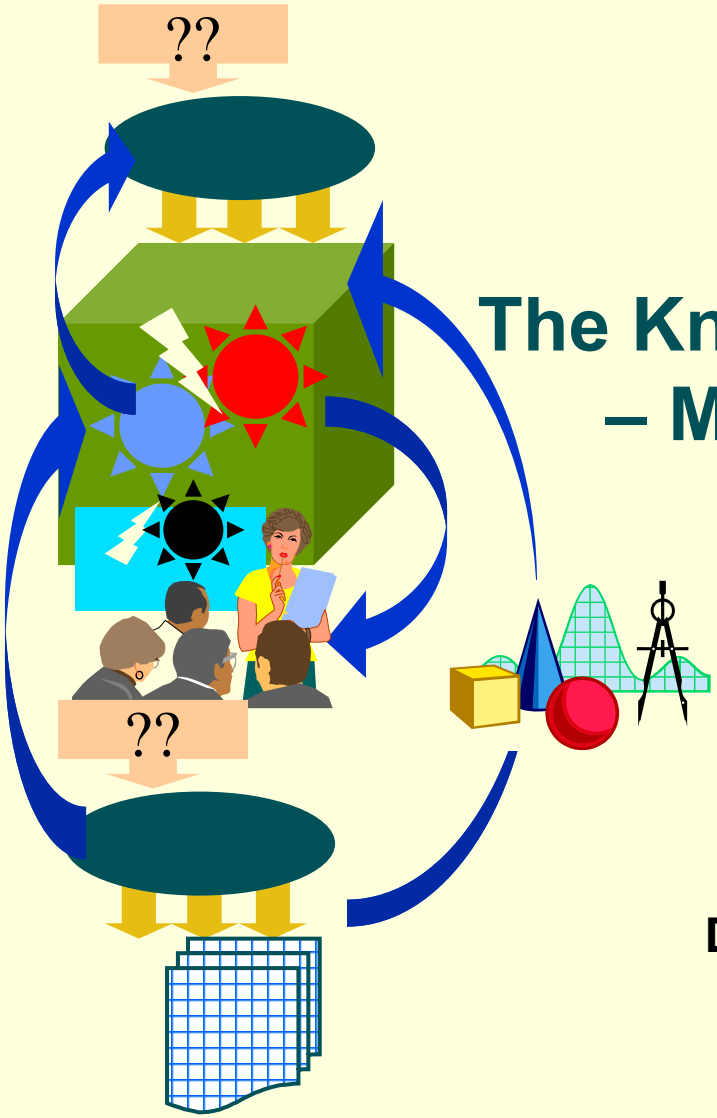

The Knowledge Analysis Framework – Metrics for the Information Age

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Overview

- An Australian perspective on NCW
- The role of experimentation and metrics
- The Knowledge Analysis Framework
- How does KAF differ from the NCW CF?
- Applying the KAF to creating a Net Centric force

An Australian Perspective on NCW

Hypothesis: Networking → mission effectiveness

The NCW Tenets

Robustly networked force

↓

Shared information

↓ + collaboration

↑Info quality, shared SA

↓

enhanced collaboration
+ self-synchronisation
+ command speed
+ sustainability

↓

Mission Effectiveness

Assumes the right information exists

Neither self-evident nor trivial

Neither self-evident nor trivial

Assumes a certain kind of mission effectiveness

Puts force development focus on networking

Hypothesis: advances in IT → force effectiveness

Some questions going begging

What are conditions for validity?

What does it take to successfully drive each step?

What else might networking make possible?

What else might contribute to increased mission effectiveness?

What **is** mission effectiveness?

Does mission effectiveness = force effectiveness?

Opens other aspects for exploration
Challenges assumptions
Puts focus on How?

Generalised Formulation of NCW propositions

Postulate: FE = Across full range of strat scenarios

1. Deter, pre-empt not retaliate
2. Achieve reqd high level outcomes quickly
3. With minimised losses, costs.

1. Networking + smarts + ↑processing power + ↑memory
   ➔ potential for significant Δ(Force Effectiveness)

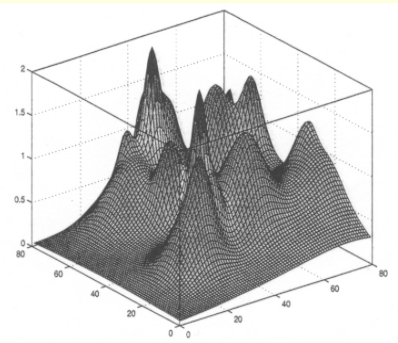
2. Increased connectivity between nodes ← Change topology
   + redefined node roles ← Change organisation
   + redefined node functionality ← Change technology
   + redefined processes ← Change process
   could ➔ very large Δ(FE)

3. Defence SoS are Complex Adaptive Systems
   --- cannot be engineered topdown or piecewise
   --- inter-dependent aspects must be co-evolved

4. FE peaks in a hyperdimensional fitness landscape are:
   - **sparse → hard to find,**
   - **sharp → hard to recognise,**
   - **far apart → hard to climb**

   ⇒ Force transformation needs imagination, innovation, and…**a different approach to experimentation**

System design challenge !!!



System Design Challenges

Able to deter/prevail at min cost & risk over all scenarios, including:

- full spectrum of missions
- max reqd concurrency
- dynamic unpredictable contex+

Dimensions of a Military SoS specified by:

- Organisational - structures, roles, processes
- Technical systems – performance, distribution
- Network – performance, topology
- People – skills, intangibles

System 'genome'

FE peaks in hyper-dim[l] space are:

- **sparse → hard to find,**

the space is astronomically vast, odds are you land in the lowlands …

- **sharp → hard to recognis**

..or on the lower slopes and cant tell…

- **far apart → hard to climb**

because cant know which way is up
- cant extrapolate merit measures from known domains!

What this means is…

- **Zillions of ways to be wrong, v**
  - challenge is to guess where to look (or actively and intelligently search for the peaks)
- **New possibly good concepts are easy to discredit**
  - challenge is how to know you're close to a peak!
- **Potential value of major innova**
  sought via co-evolution of interdepend
  - challenge is to create workable sys design

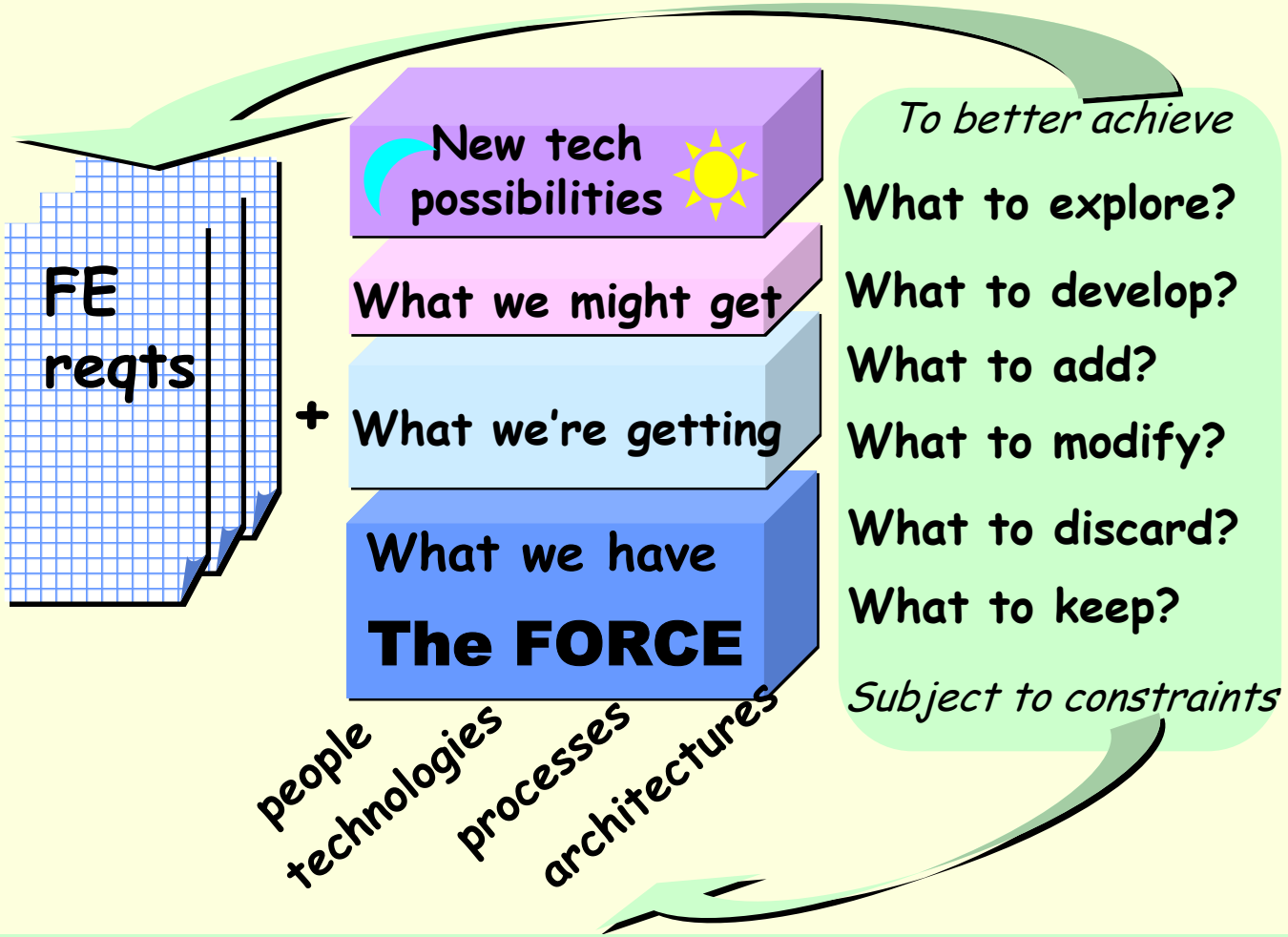
But where do we get our ideas?

Hard… but experimentation can help

Postulate: some local gains in effectiveness from ↑connectivity, ↑sharing and ↑collaboration; but much bigger payoffs from ↑networking/IT if step back from improving things we already do and rethink (re-design) how we create FE.

System Design and the Role of Experimentation

So, to realise potential of networking/IT, pay attention to system design problem!



Role of experiment[n] is to support SoS design process through

- *co-evolution,*
- *problemsolving*
- *idea generation*
- *evaluation*

Role of metrics is to

- *guide design choices*
- *articulate functional and operational reqts*

Be able to substantiate decisions – but only over tiny fraction of design space!

Role of Metrics: Support the Design Process

What is the Design Process?

Since everything is interdependent – how to begin? How to search?

Some reasonable ways:

- **Have something new to try**, and some idea of intended outcome

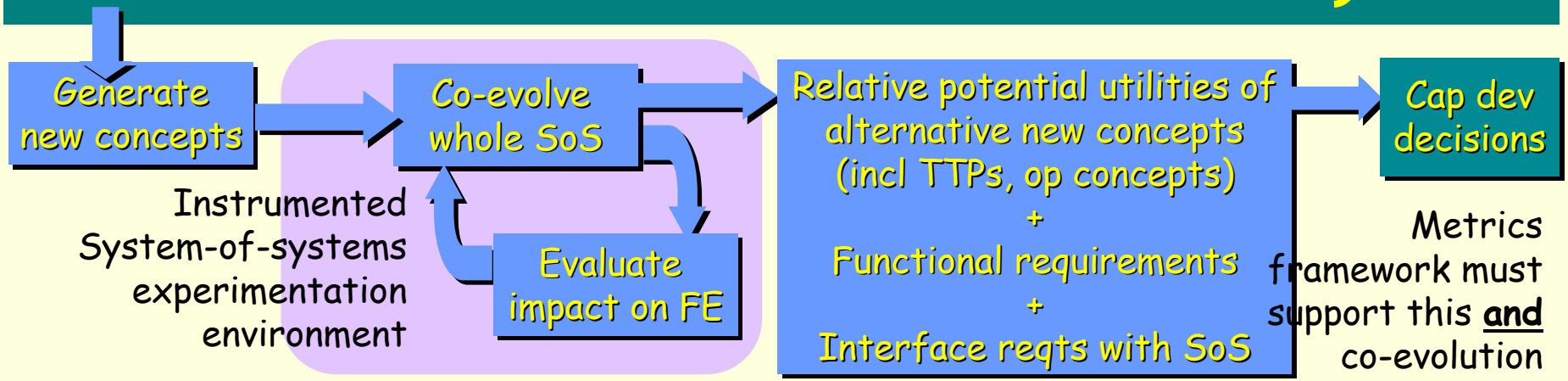
eg a new technology, a new topology, a new process or operational concept …

Use experimentation to explore what else needs to change to produce outcome

- **Have a problem area**

Use experimentation to explore ideas for how to solve it and what is reqd

But still will only explore tiny nbhd



System Design and the Role of Experimentation

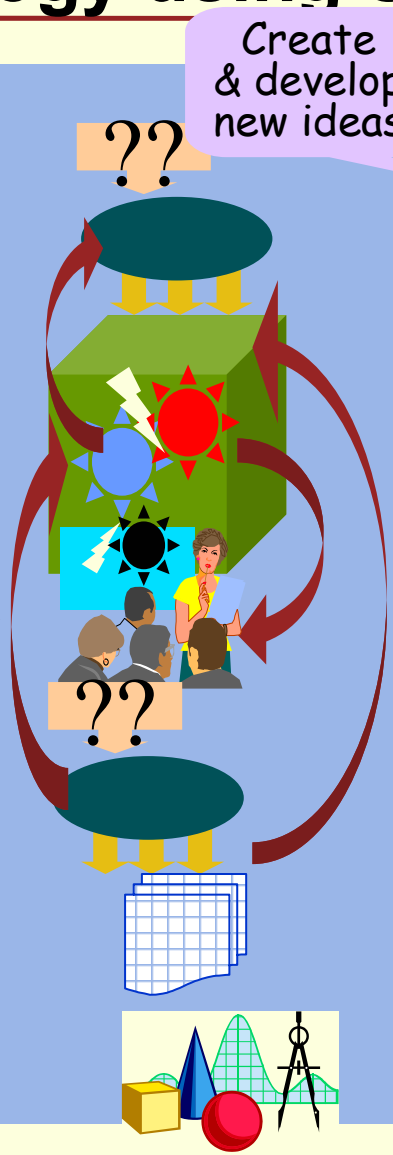
- This is quite different use of experimentation from traditional scientific method.
- Science aims to discover what is by formulating hypotheses and trying to disconfirm them through experimentation
- Here the idea is to create something that doesn't exist yet, and make it work
- **a non-successful outcome** is inconclusive – maybe you're just not smart enough to find how the idea could make a difference!
- **a successful outcome** is suggestive that the idea is worth further exploration
- eventually when a concept is well enough developed you do try to break it to discover its limits and improve it
- and it does need to be 'ruggedized' under full range of scenarios and stresses
- proof-of-concept or demonstration of feasibility in limited scenario is not enough!

Example Methodology using SCD

Concept initiation
- *Describe reqt*
- *Capability space*
- *Operational concept*

System design
- *technical, system and operational levels*
- *Draft procedures*
- *Develop metric framework*

Build Sys Concept Demonstrator (SCD)
- *Simulations + humans*
- *Immerse in Synthetic Env for experimentation*
- *Fidelities to support populating metrics*



Refine SCD iteratively

Exploratory expt
Evaluation expt
Refine SCD
Refine metrics

Test them

✱ **Synergistic SoS concept with co-evolved processes, technology, operational and organisational structure.**

✱ **metric framework relates design to effects**

The Knowledge Analysis Framework

The KAF was developed to address these difficult questions:

- How to quantify steps towards →
  - *RMA*
  - *Information Based Warfare*
  - *Knowledge Edge*
  - *NCW*
  - *decision superiority*
  - *< insert next buzzword >*
- How to quantify resulting contribution to overall military effectiveness?
- How to trade off C4ISR against personnel levels, platforms, firepower . . ?
- What are high pay-off areas for C4ISR system development?
- What are the reqd functional performance specs in those developments?
- And how to achieve better capability outcomes faster?

through synergies between systems

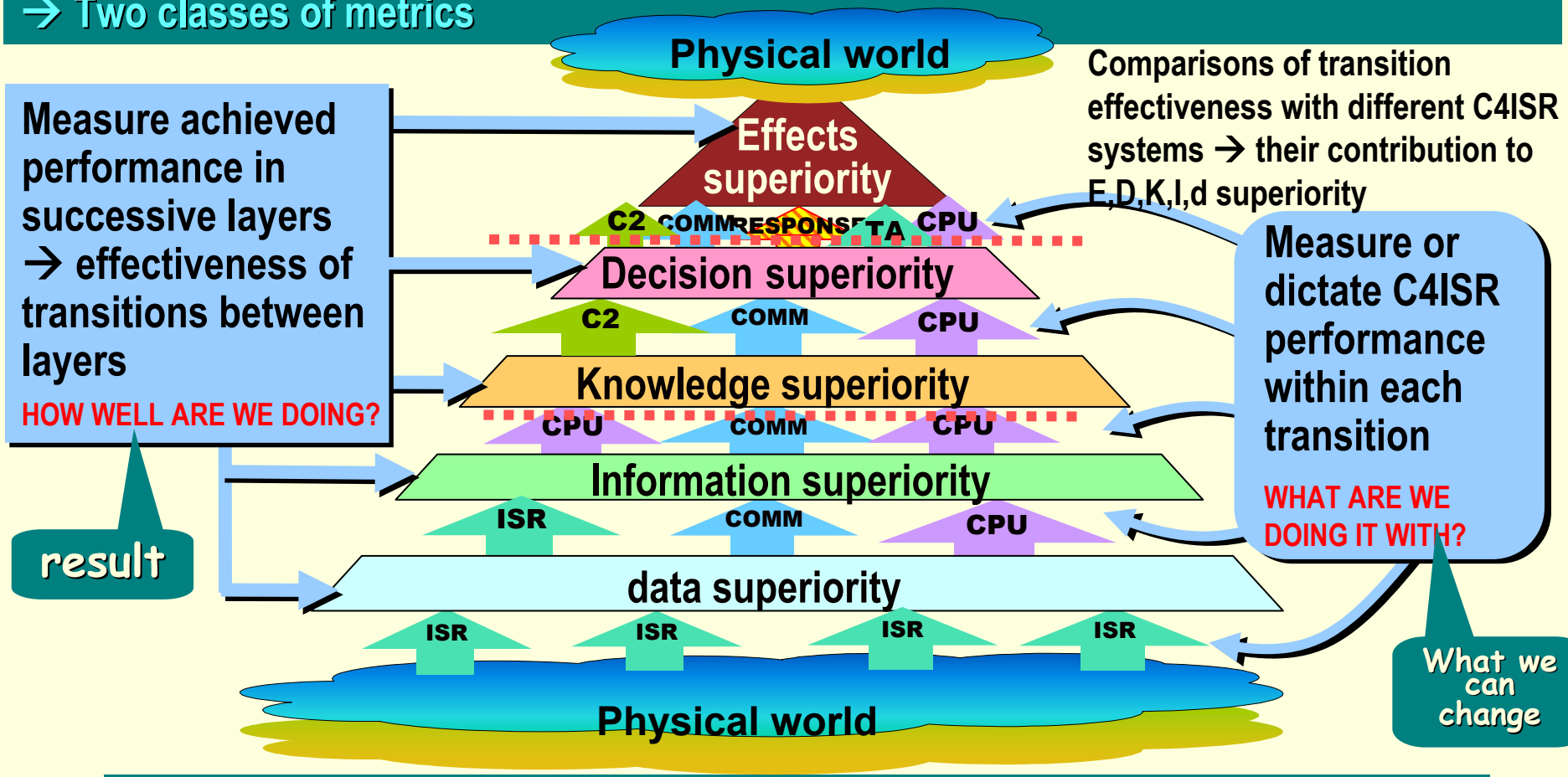
through accelerated IIS

The Knowledge Analysis Framework

C2 CPU COMM ISR RESPONSE

INSIGHT: Role of C4ISR and response systems is to enable transitions between layers

→ Two classes of metrics

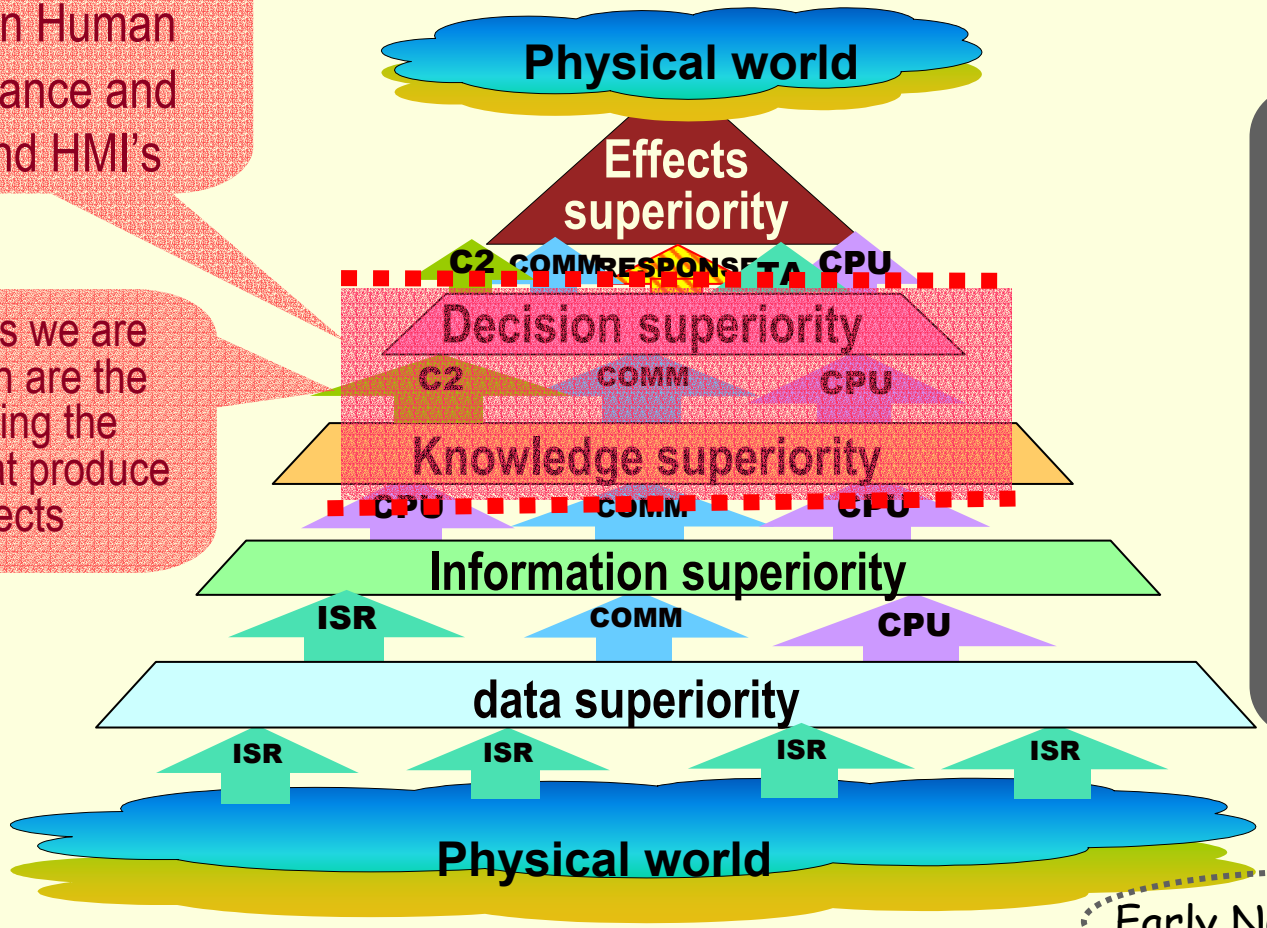


KAF draws explicit relationship between performance metrics of C4ISR systems, intermediate NCW measures, and measures of military effectiveness

The Knowledge Analysis Framework

Cognitive Domain:
Focus on Human Performance and roles and HMI's

The humans we are interested in are the ones making the decisions that produce the effects



Military utility

Exploiting battlespace knowledge

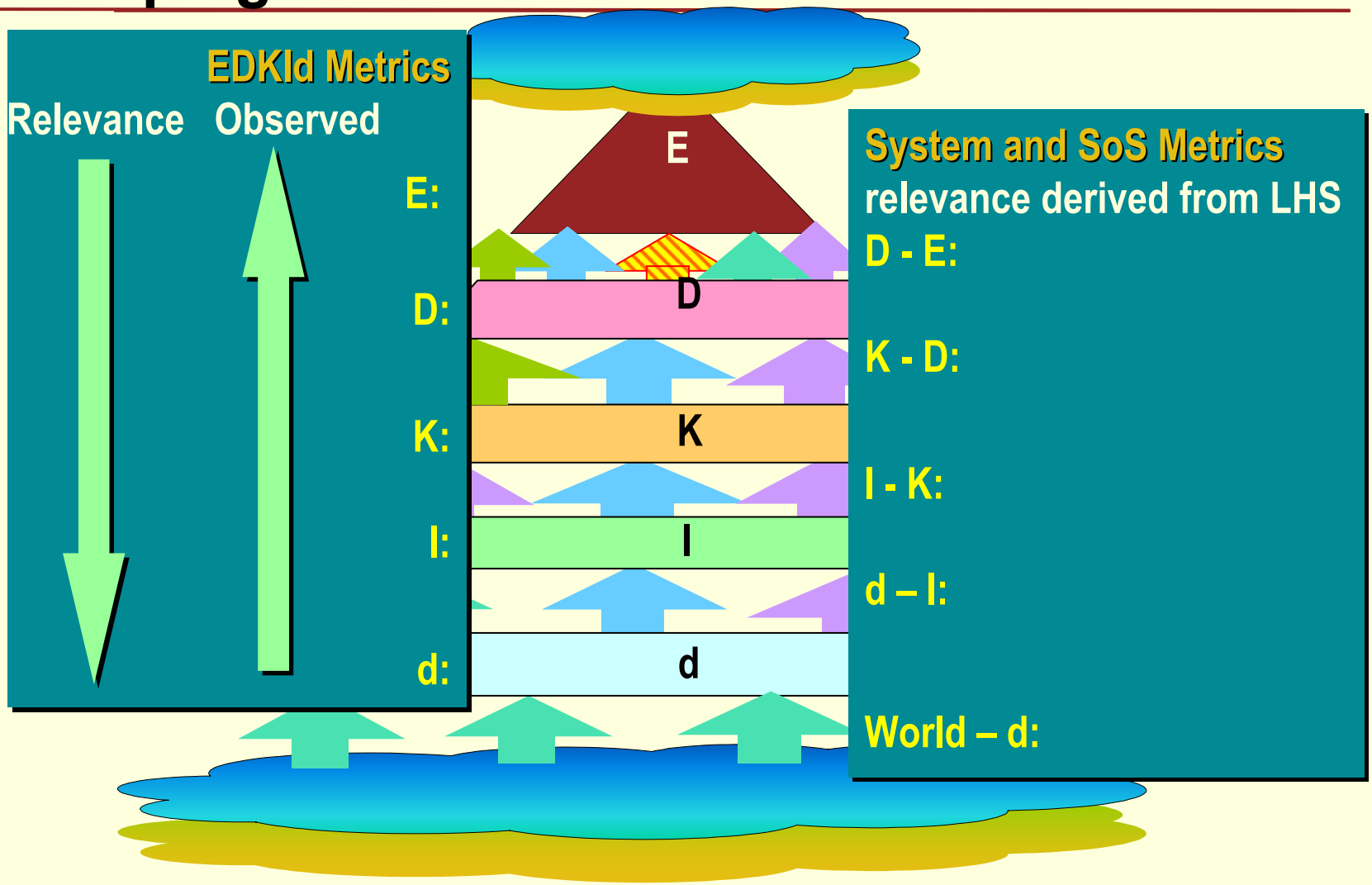
Battlespace knowledge

Battlespace information

Infrastructure performance

Early NCW framework

Developing detailed Metrics



Systems in the Knowledge Analysis Framework

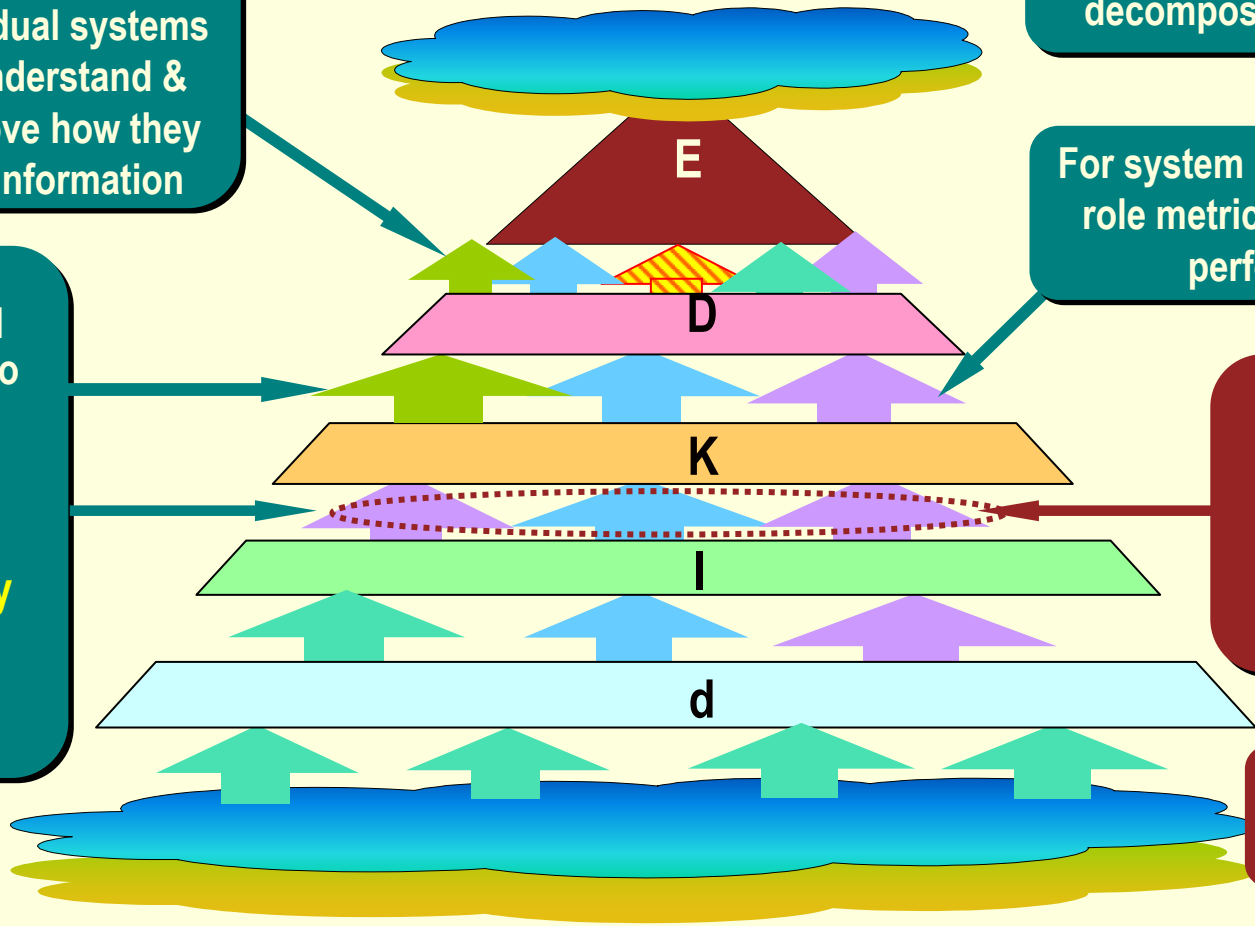
KAF can be applied to individual systems to understand & improve how they use information

which links with MoP level of traditional MORS system decomposition approach

For system playing enabling role metric just describes performance

For systems being targeted metrics have to include all aspects, i.e.

systems =
technology
+ processes
+ people
+ context



Also need to describe the SoS formed by the systems in the transition layer

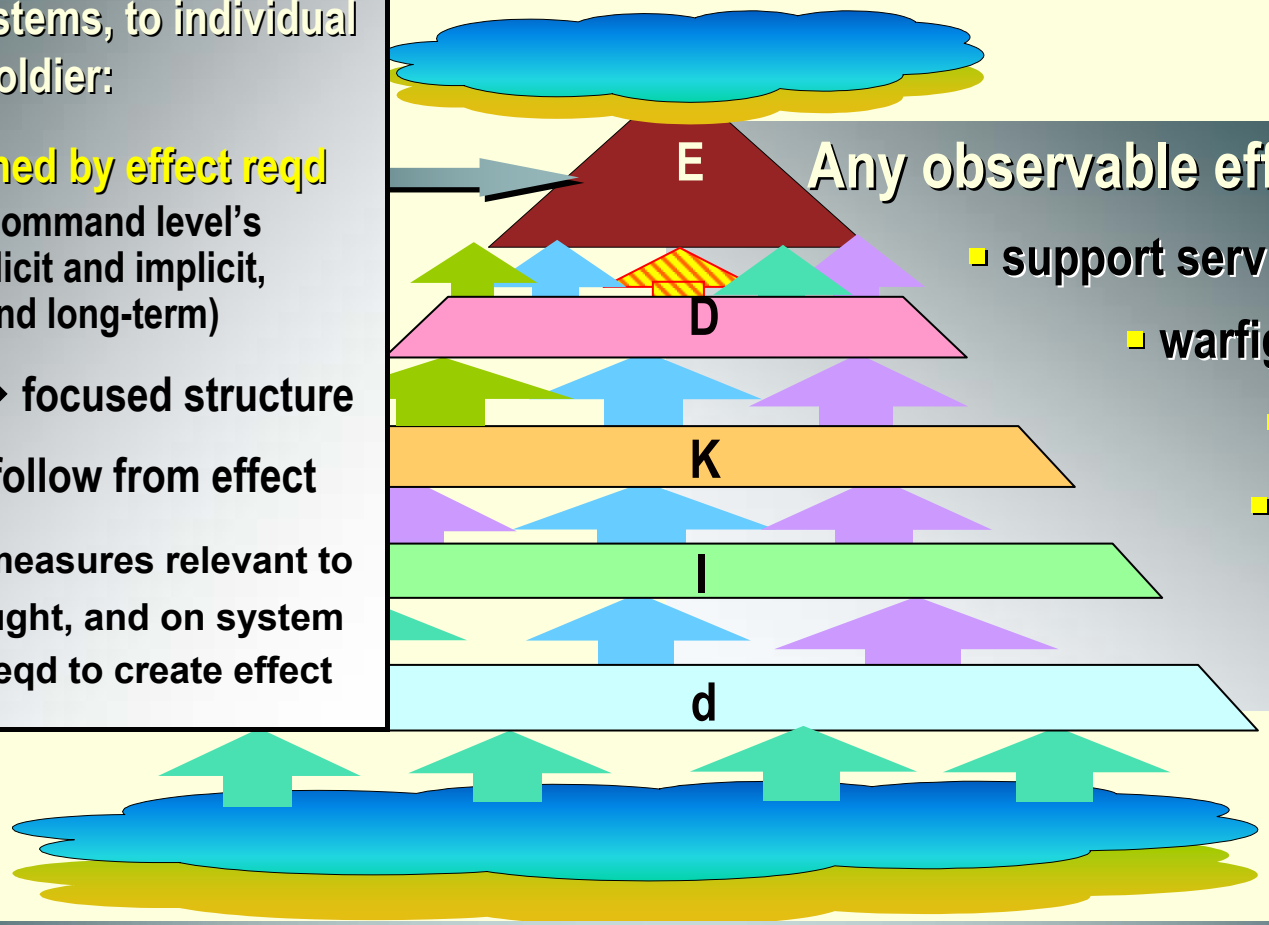
Interoperability requirements

Knowledge Analysis Framework - scalability

The KAF is scalable from whole-of-force, to systems, to individual soldier:

Scale is defined by effect reqd
(= higher command level's intent, explicit and implicit, short- and long-term)

- Start at top → focused structure
- levels below follow from effect
- i.e. identifies measures relevant to effect being sought, and on system performances reqd to create effect

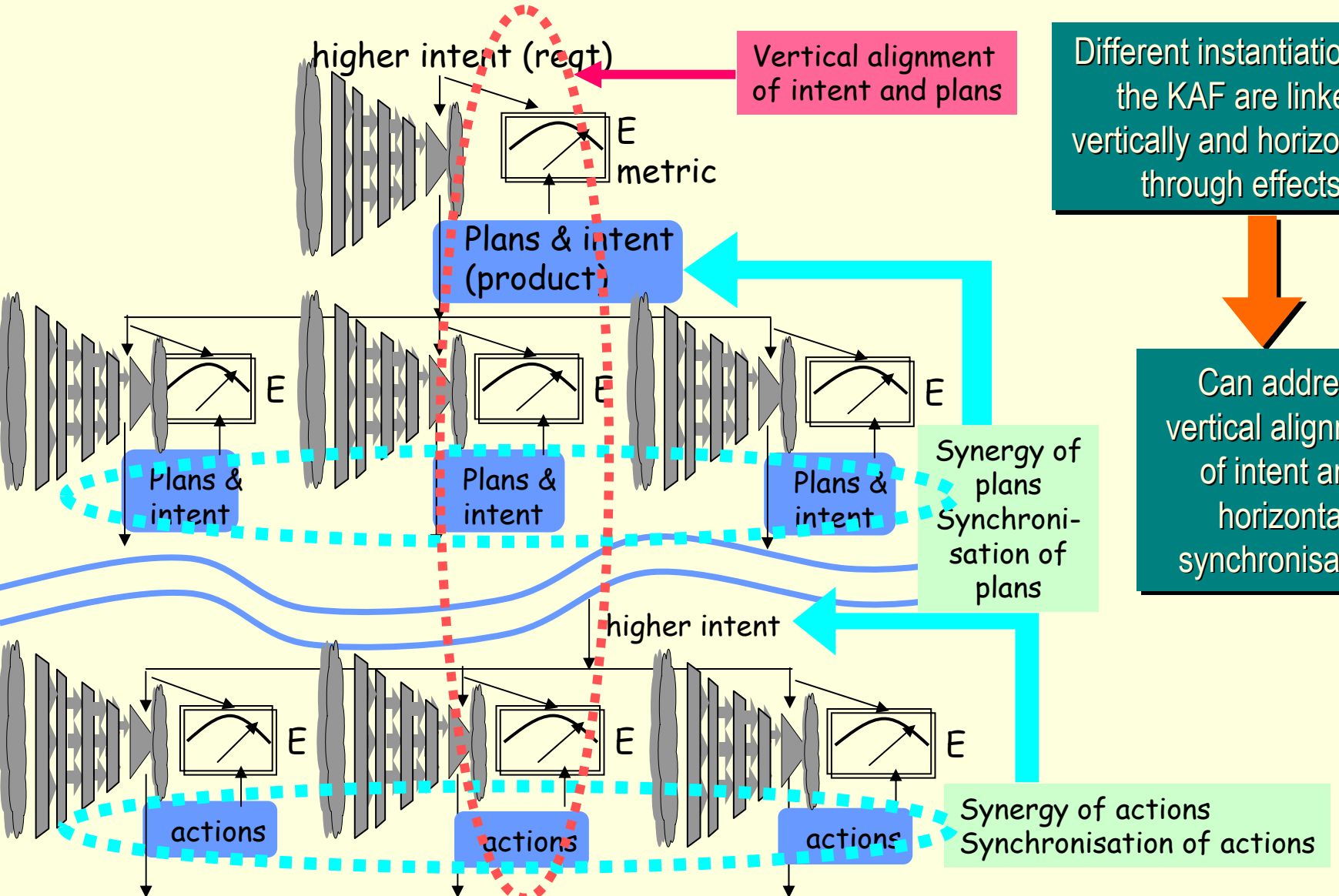


Any observable effect is OK:

- support service provided
- warfighting effect
- deterrence
- information
- plans
- ?

At unit level: effects required will change with time – invoking different systems, people, processes

Knowledge Analysis Framework - scalability



Vertical alignment of intent and plans

Synergy of plans Synchroni-sation of plans

Synergy of actions
Synchronisation of actions

Different instantiations of the KAF are linked vertically and horizontally through effects

Can address vertical alignment of intent and horizontal synchronisation

How do we use the KAF?

1. in diagnostic mode (where is the 'flow' being blocked? Where do we need to apply some effort to free it up to enable the intended effectiveness to result?),
2. in system development mode (what is the utility of this system concept compared to that one? Is it better to do things this way or that? etc)
3. in problem-solving mode (by clearly communicating where the 'problem' is and providing immediate feedback to the people trying to solve it as to what works and what doesn't) and
4. in capability analysis mode (what are the consequences of reducing/increasing this system's performance? What are the bounds of the capability envelope?)

All of these support the creative design or synthesis of the system.

For a real problem KAF helps to tell a story

- baseline expt
  - ***EDKId metrics identify a problem:***
    "crews' relevant knowledge is excellent, but decision making is not good enough"
  - ***→ Improvement is needed in K-D transition:***
    "in DSS, or in crew training, or in improved decision processes, or in command structure,.."
- intervention:
  - ***Develop system metrics to describe baseline***
  - ***Propose modified system metrics that may solve problem***
    "redefine C2 roles in this team, develop a new team process, provide new DS tool, ..."
  - ***Implement a simulated prototype of the modified systems for experimentation***
  - ***Undergo co-evolution until robust. Train users in new systems and processes***
  - ***Evaluate EDKId metrics with baseline system replaced by modified system***
- intermediate outcome:
  - ***"when A is replaced by A' the quality of decisions improves by Δ as measured by the D metrics, and there is a resulting improvement of Δ' in the effectiveness as measured by E metrics".***
- iterate:
  - ***Until both Δ and Δ' are deemed sufficient.***
  - ***If Δ is now good but and Δ' remains insufficient there may be another problem in D-E transition and the whole process must be repeated there.***

Using the KAF to support System Development

Effects required
= E metrics for KAF applied to system
= system outcome metrics for KAF applied to bigger SoS

Start thinking about how sys supports human roles – develop info flows → I,d metrics

Start thinking about how it will be used – develop TTPs → D,K metrics for human roles

Start thinking about sys components and interfaces – develop system metrics for SCD

Start thinking about interactions with SoS and context – develop fidelities reqd for experimentation environment to ensure E metrics observable

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Refine SCD iteratively
Exploratory expt
Evaluation expt
Refine SCD
Refine metrics

Produces
Synergistic system concept with co-evolved processes, technology, ory
metric hierarchy relates design to effects

Basis for dev of training needs and human perf measures

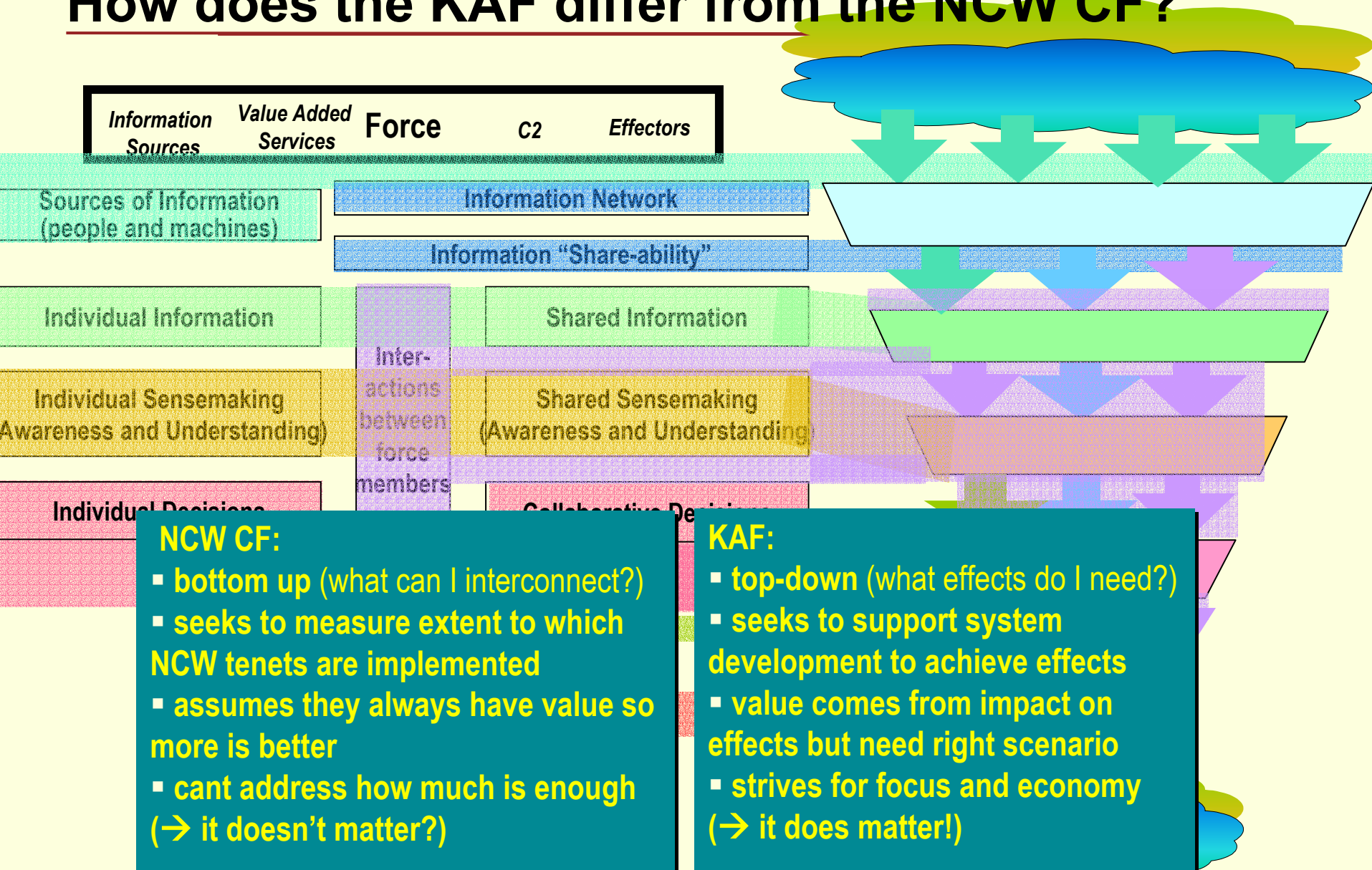
Basis for dev of all FIC aspects – total system approach

Basis for dev of requirements on other systems needed to enable effectiveness or that can be enhanced by this system
i.e. addresses SoS aspects incl interoperability

Design metric overlay for experiments to address design choices or illuminate problems

Refined metrics characterise required system functionality (→ supports acq, T&E, IIS) and resulting effectiveness – supports 'so what?' questions when reqts change

How does the KAF differ from the NCW CF?



NCW CF:

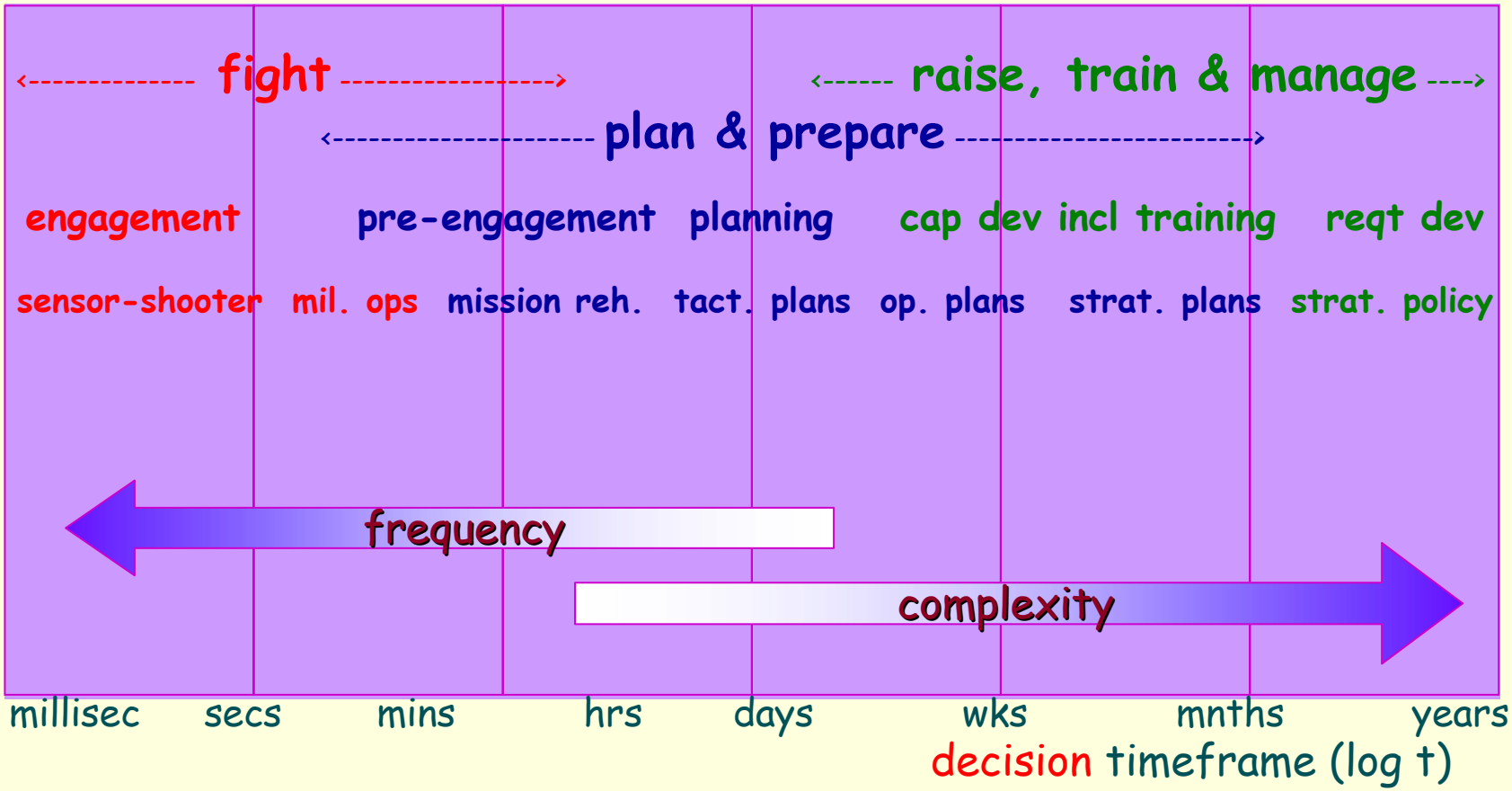
- **bottom up** (what can I interconnect?)
- **seeks to measure extent to which NCW tenets are implemented**
- **assumes they always have value so more is better**
- **cant address how much is enough (→ it doesn't matter?)**

KAF:

- **top-down** (what effects do I need?)
- **seeks to support system development to achieve effects**
- **value comes from impact on effects but need right scenario**
- **strives for focus and economy (→ it does matter!)**

Applying the KAF to create a Net-Centric Force

IT & Networking can support the entire Defence Decision Space



What are Good Decisions?

- Produce desired end-state

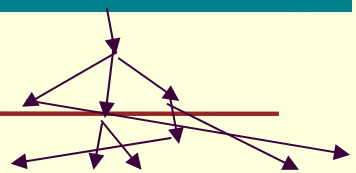
accepted
enacted
'right'
timely

- Minimise cost

casualties
$ now / $ later
$ never

- Minimise risk

'wrong' outcome
cost / schedule
-ve 'side-effects'



Decision trees

events
assumptions
weights

Changing environment

	right reason	wrong reason
right outcome	✓✓	✓??
wrong outcome	X??	XX

observables / hiddens / non-events

Complications

How can we improve decisions? They should

Metrics of input and process quality

Metrics of decision quality

Metrics of impact (effectiveness)

be based on . . .	be. . .	in order to. . .
right data	fast (enough)	ensure outcomes
right assumptions	adaptive	minimise costs
right predictions	communicable	
right values	trusted	manage risks
right process	executable	
right structure	viewed	adapt to change

I Metrics

D Metrics

E Metrics

K Metrics

D-E sys Metrics

K-D sys metrics

accepted
enacted
'right'
timely

casualties
$ now / $ later
$ never

'wrong' outcome
cost / schedule
-ve 'side-effects'

events
assumptions
weights

HYPOTHESIS: get these right - and these will improve

Networking + IT to solve the information problem

(USA: "what information problem?")

For the rest of us…

- **limited ISR assets** (numbers, FOV, coverage, resolution, endurance)
- **huge areas and coastline, lots of clutter, low signatures**
- **limited comms, fragile comms**
- **limited capacity networks and processors**
- **vulnerability to deception with sporadic ISR** (esp if forced COP)

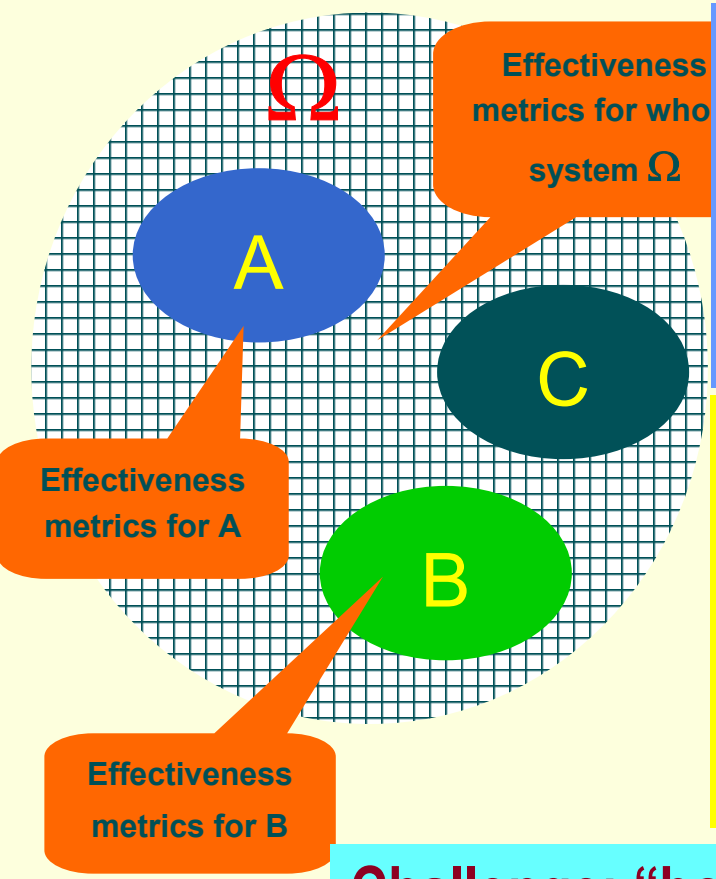
We need to

- **task our assets to ensure maximum utility**
- **understand value of CCIRs / information**
- **understand cost of CCIRs**
- **deconflict, prioritise, cross-cue, fuse, raise alerts…**
- **Build learning into the C4ISR System-of-systems**

i.e. actively manage collection in realtime to ensure we have right info

Networking the Force as a basis for interoperability

- Systems A,B,C have existing processes; and they are part of Ω, a bigger SoS;
- A,B, C may already interact (to a degree)
- What is the case for making them interoperable or integrating them further?



Incremental improvement:

- A's processes could be more effective with (more/faster) aid from B, C
- → reqt for specific interactions (hence 'cost') and produces observable Δ in A's effectiveness, and hence in Ω's
- → reqts for technical and semantic interoperability and some HMI aspects

Revolutionary improvement:

- Ω's intended effects could be much more effectively produced if A, B, C engaged in a new cooperative process
- → generate /synthesise /evolve NEW integrated processes
- →determines reqd interactions (→cost)

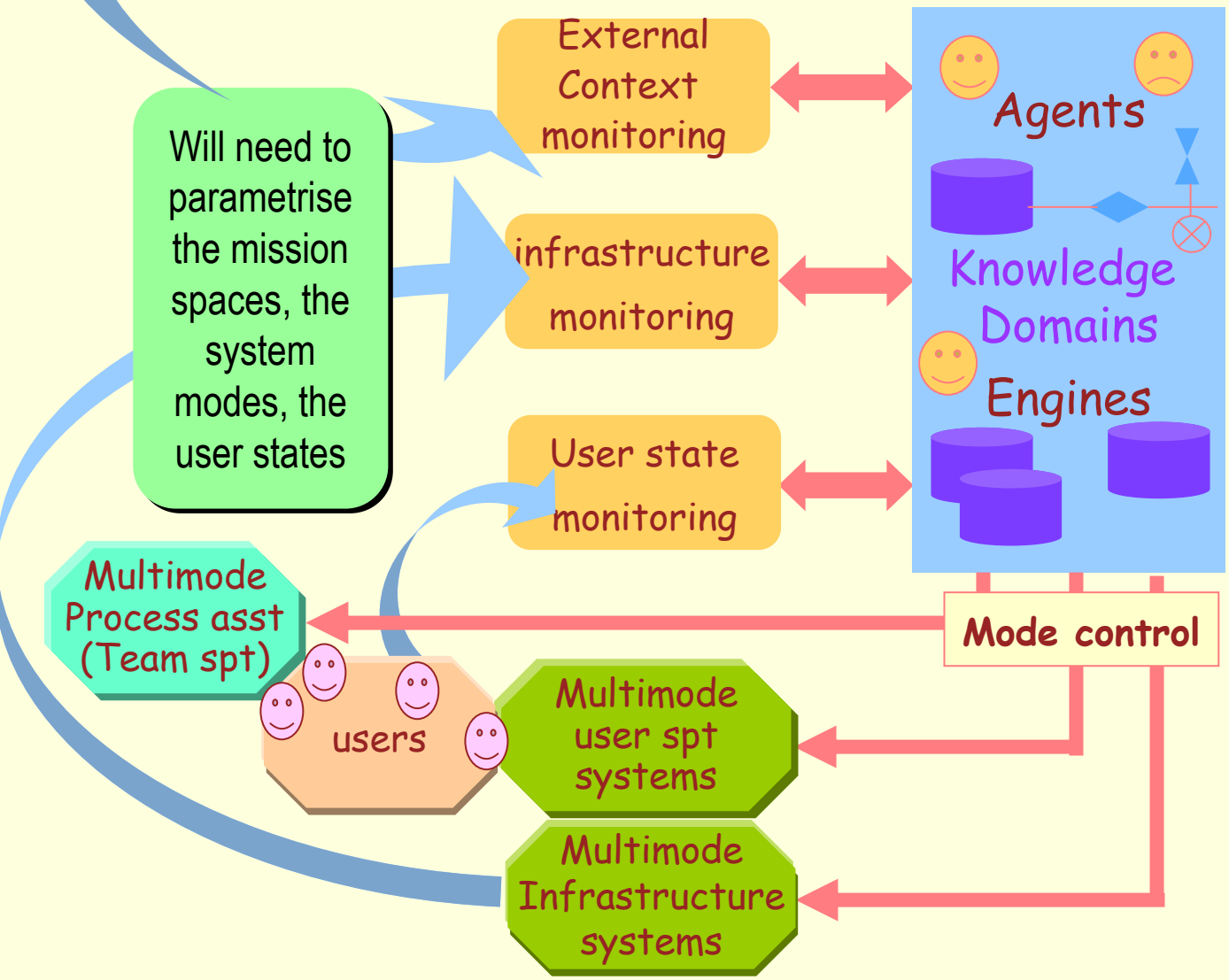
→ observable Δ in Ω's effectiveness

Challenge: "born Joint" at the tactical level

Interoperability

- **Physical** – can systems share consumables?
- **Technical** – can A send data to B?
- **Semantic** – can B understand what A sent?
- **HMI** – does system help user in B to exploit A?
- **Process integration** – do systems know what to send?
- **Enterprise** – can systems adapt behaviours to 'optimise' in changing context?

Networked Force + IT → evolve Adaptive Systems



VISION:

Responsive and Adaptive force at all scales

- individual dec spt
- team processes
- unit & formation structures & proc
- infrastructure
- …
- scenario-indep C2 architectures
- portfolio level

Questions?