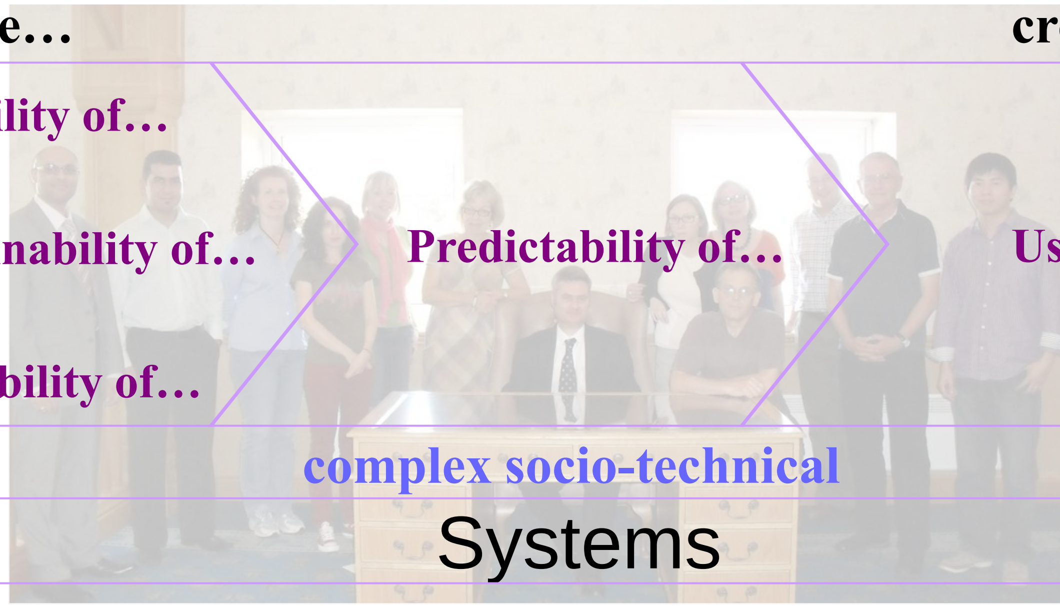
Behaving nicely in a Systems of Systems Society

Professor Michael Henshaw
Loughborough University

Engineering Systems of Systems (ESoS) Group



The group researches the…

To improve the…

To enable the creation of…

Interoperability of…

Sustainability of…

Reconfigurability of…

Predictability of…

Usable…

complex socio-technical

Systems

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Dr. Ella-Mae Hubbard

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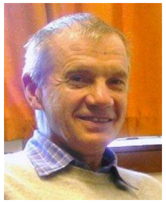


Dr. Murray Sinclair

Storyboard

- **Assumptions**
- **SoS challenges and examples of behaviours**
- **Causes of SoS problems, accidental and deliberate causes of failure**
- **IT/OT integration**
- **Open architectures (in defence procurement)**
- **Conclusions**

SOME BASIC ASSUMPTIONS

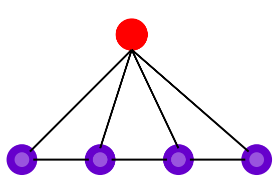
System of Systems Characteristics

- **Maier Criteria**
  - Operational Independence of the Components
  - Managerial Independence of the Components
  - Emergence
  - Evolutionary
  - Geographic distribution

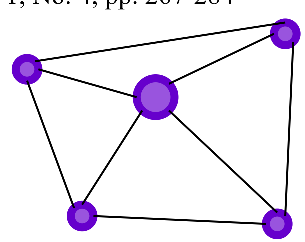
Maier, M.W. (1998), Architecting Principles for Systems-of-Systems, Systems Engineering, Vol. 1, No. 4, pp. 267-284

- **DeLaurentis adds**
  - Inter-disciplinary Study
  - Heterogeneity of Systems
  - Networks of Systems

DeLaurentis D. (2007) System of Systems Definition and Vocabulary, School of Aeronautics and Astronautics, Purdue University, West Lafayette, IN.



Directed



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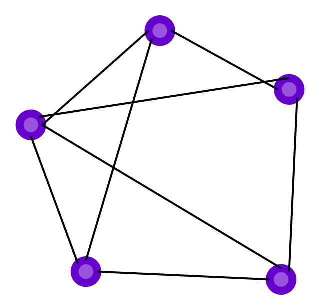
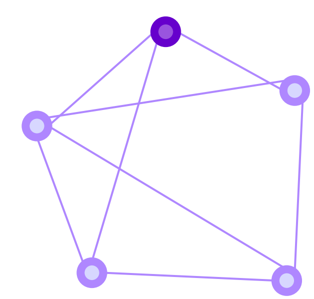


Collaborative



Virtual

Based on Dahmann, J., Baldwin, K.J. and Rebovich, G. (2009), Systems of Systems and Net-Centric Enterprise Systems, 7th ann. Conf. on Sys. Eng. Res., Loughborough, April 2009.

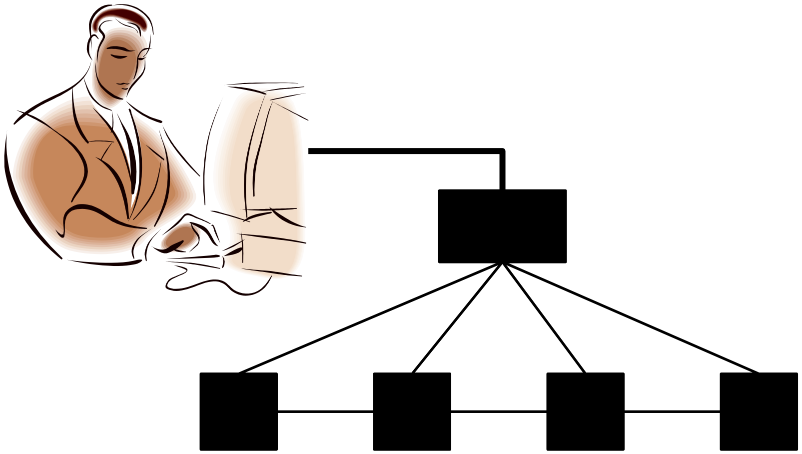
SOME EXAMPLES

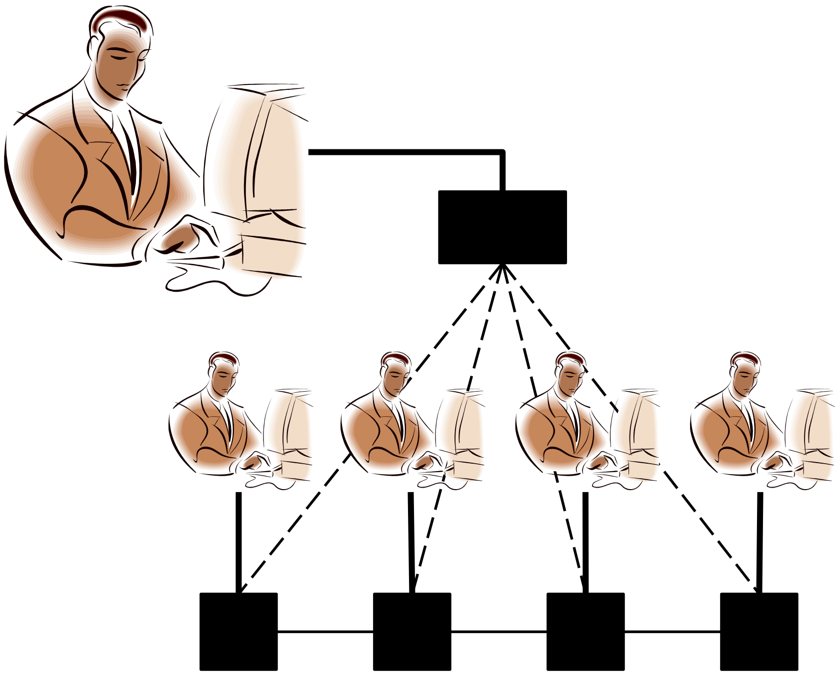
National Programme for IT in the NHS (NPfIT)

- **Purpose**
  - Share information about patients across health providers more effectively
  - Transform healthcare – quality of service
  - Improve efficiency
- **Cost**
  - ~£12 Bn at time of cancellation
- **Challenges**
  - Procure new IT systems
  - Integrate with existing IT systems
  - Configure to meet local circumstances
  - Train staff
  - Four local service providers responsible
  - But work needed by local NHS organisations – Strategic Health Authorities, NHS Trusts and other providers working for the NHS, such as General Practitioners (GPs) and Pharmacists.

What type of SoS were they managing?

Directed





Acknowledged (/collaborative)

Reported in T-AREA-SoS State of the Art Report (WP2, D2.1), Barot, et. Al., 2012

Hurricane Katrina

- **Response**
  - Mixed military and civilian
    - Each own systems
    - Each has different C2
  - Requires command agility – dependent on peer-to-peer interactions (esp. horizontal)
  - National Response Plan defines governance and authorities
  - But
    - National guard did not know mission in advance
      - Lacked situational awareness
    - No coherence between C2s

Based on James Moffat, THE RESPONSE TO HURRICANE KATRINA: A CASE STUDY OF CHANGING C2MATURITY, NATO RTO SAS-065 working group, 2008

C2 Levels for Katrina Response

Collaborative C2

- Collaborative process and shared plan
- Significant and broad interaction between participating entities
- Additional information distributed across collaborative functions

Co-ordinated C2

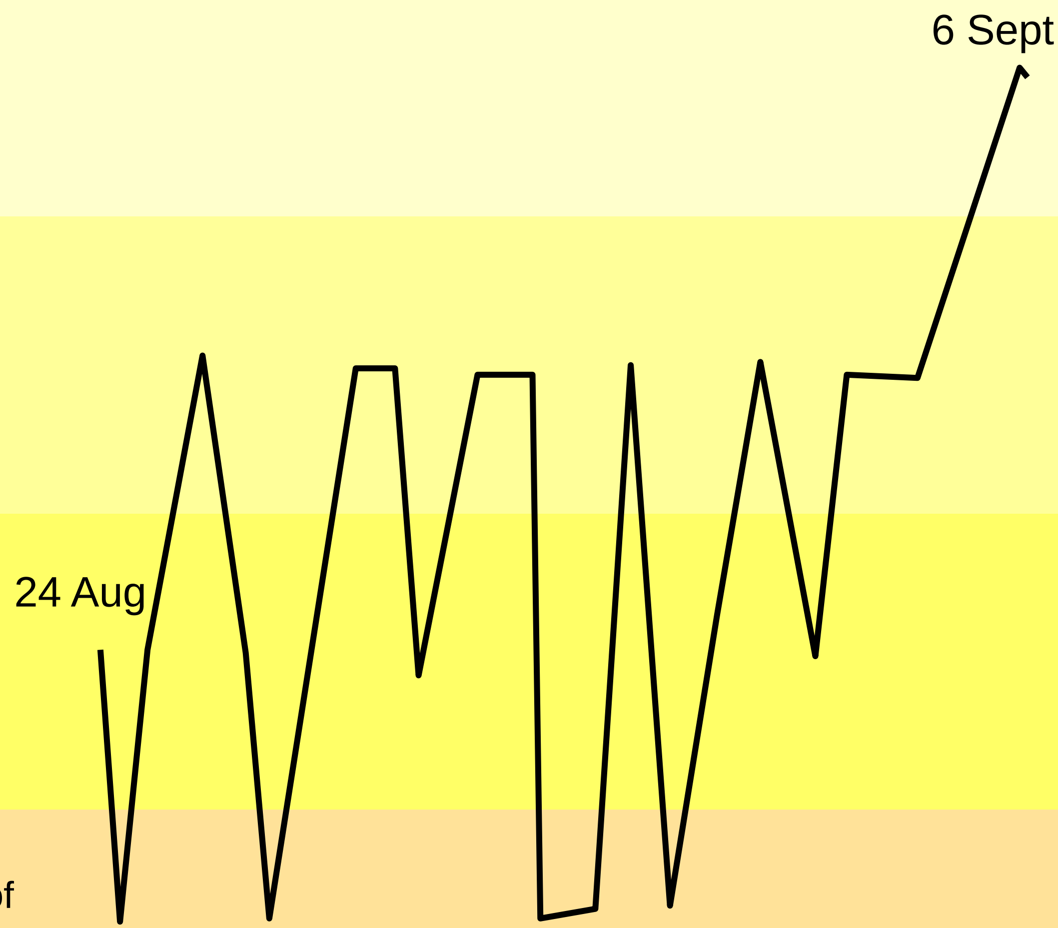
- Co-ordinated process and linked plans
- Limited interaction between participating entities
- Additional information about co-ordinated functions

De-conflicted C2

- Establish constraints on decision rights
- Very limited interaction between participating entities
- Additional information about constraints and joins

Conflicted C2

- No allocation of decision rights, or pattern of interaction between participating entities
- Organic information only



From NATO NEC C2 Maturity Model, CCRP, 2010

Based on James Moffat, THE RESPONSE TO HURRICANE KATRINA: A CASE STUDY OF CHANGING C2MATURITY, NATO RTO SAS-065 working group, 2008

Fire at Aisin Factory 1997

- **Aisin Seiki Company's Factory No. 1**
  - Only supplier of brake fluid proportioning ("P") valves to Toyota
  - Delivered just in time: 4 hour inventories
  - Toyota relied on delivery for 14,000 cars per day
- **Sat. 1st Feb. 1997**
  - Fire destroys plant
  - Estimated 2 weeks to achieve some production, 6 months to get back to normal rate

- **Wall Street Journal, 8 May 1997, Page A-1, by Valerie Reitman**

Recovery

- **Full production returned in five days**
  - 36 suppliers + >150 subcontractors manufacturing P-valves
  - Voluntary – no contracts negotiated in advance
  - Blueprints shared by Aisin
- **Without rapid reaction**
  - Supply chain businesses impacted
  - National finances impacted
- **Long term outcomes**
  - Business sustained
  - Reduction in parts variation

Comparison of examples with Maier Characteristics

Maier characteristic	NPfIT	Katrina	Aisin & Toyota
Managerial and/or operational independence	Different systems procured Pressure to build systems to support local goals	Civilian / military authorities	Toyota supply chain
Emergence	Additional (induced) complexity	Failure to search areas or search particular areas several times	Collaborative behaviour by suppliers
Evolutionary	Legacy systems mixed with new	Short-term changes in C2 approach	Initial towards single supplier, then changed toward collaborative
Geographic distribution	Distribution occurs at many layers	White house, new Orleans, national guard	N/a

WHAT MOTIVATES SOS BEHAVIOURS

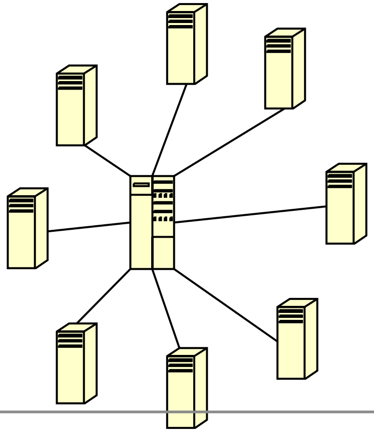
Managing and Engineering

- Members of the *SoS owners' club* have partial knowledge and influence
  - Need to engineer for compliance (interoperability)
    - Standards
  - Manage own system (part) through control
  - Manage other parts of SoS through influence, protective measures, collaboration, … (not at all)
- **If systems thinking tells us that we should make our systems behave in certain ways to maximise benefit, why don't we do it?**
  - ***From the single-system community's perspective, its part of the SoS capability represents additional obligations, constraints and complexities. Rarely is participation in an (sic) SoS seen as a net gain from the viewpoint of single-system stakeholders.***
    - George Rebovich, Jr., 2009

IT/OT INTEGRATION

IT-OT environments

IT systems

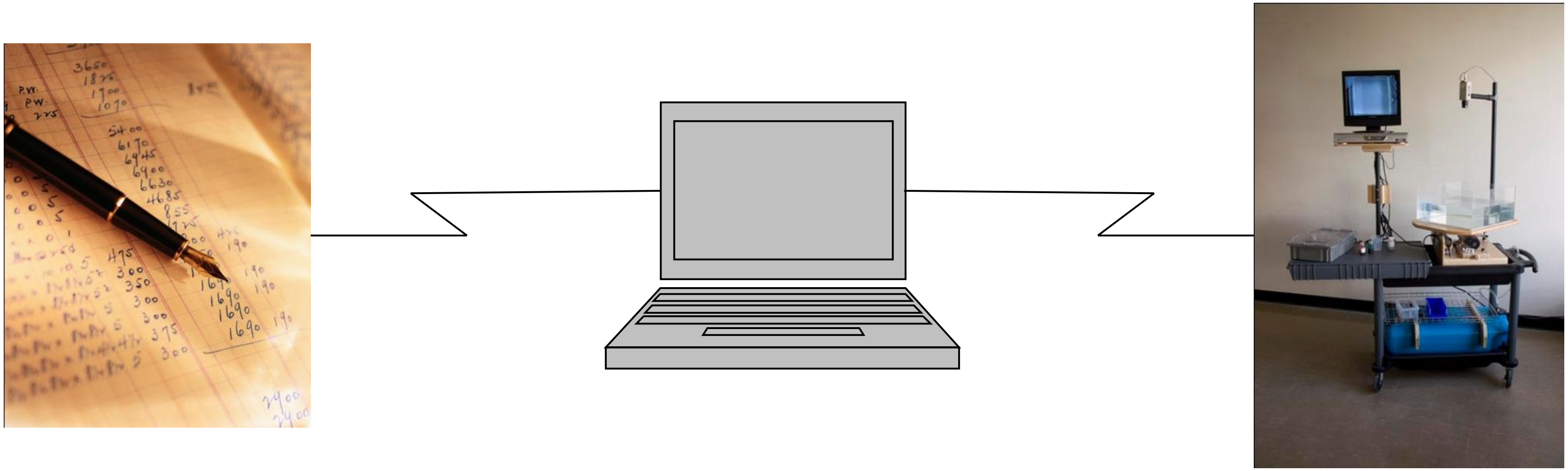


OT Systems

Speed	Human	“Real world” physical processes
Architecture	Centralised data centre (hub and spoke)	Decentralised
Data flow	Transactional, non real-time	Event-driven: sensors, alarms, commands, time critical
Platforms	Powerful servers	Tiny embedded or mobile systems through powerful servers
Characterised as	Lacking performance and scalability	Limited integration capabilities

Slide based on a presentation from rti (http://www.rti.com/)

OT systems are becoming more IT-like



Software used for industrial control systems is similar to that used for business processes

Why integrate IT and OT ?

- **Economics**
  - Long distance network control of physical assets
  - Improve situational awareness of business systems using real-time operational data, and hence…
  - Holistic management of systems Automatic/rapid upgrade
  - Better asset management – where and how used
  - Real-time analytics
    - Predictive maintenance
    - Improve agility by linking real time applications to business processes (supply-demand matching)

- **It just happened!**
  - We are connecting everything
  - There are now about 12Bn devices connected online (cyberspace)

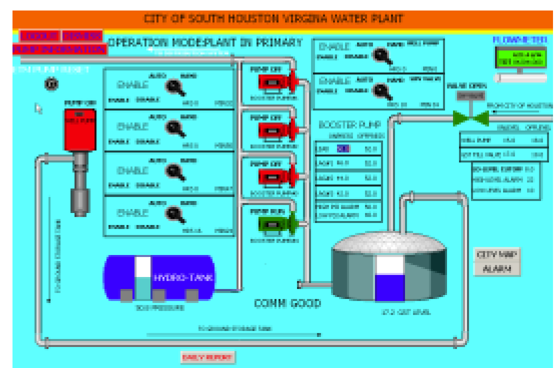
Problems

- **OT systems are “stripped down” and lack security**
  - Designed for *security through obscurity*
- **Wireless devices may provide unrealised connectivity**
- **Systems without adequate security connected to the local network**
  - Security may be disabled by default
- **Firewall perimeter not understood**
- **Partial interoperability may lead to unexpected behaviour**

Bad stuff 1 – a latter day Captain Blood

- **SCADA* vulnerability**
  - P0rf hacked into a South Houston water utility to show that it can easily be done
- **Posted screenshot**
  - "I'm not going to expose the details of the box," pr0f wrote in his Pastebin post. "No damage was done to any of the machines; I don't really like mindless vandalism. It's stupid and silly.
  - "On the other hand, so is connecting interfaces to your SCADA machinery to the Internet," he added. "I wouldn't even call this a hack, either, just to say. This required almost no skill and could be reproduced by a two-year-old with a basic knowledge of Simatic,"

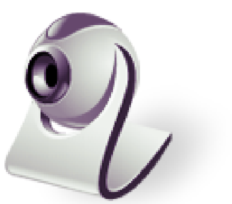
*Supervisory Control And Data Acquisition



http://news.cnet.com/8301-27080_3-57327968-245/hacker-says-he-broke-into-texas-water-plant-others/

Bad Stuff 2 - SHODAN

- **Sentient Hyper-Optimized Data Access Network**
  - Created by John Matherley from 2003
- **Maps and captures specifications of online devices**
  - Desktops, network printers, web servers
  - Webcams, Routers, Power Plants, iPhones. Wind Turbines, VoIP Phones, etc.






http://www.washingtonpost.com/investigations/cyber-search-engine-exposes-vulnerabilities/2012/06/03/gJQAIK9KCV_story.html

Non-malicious problems

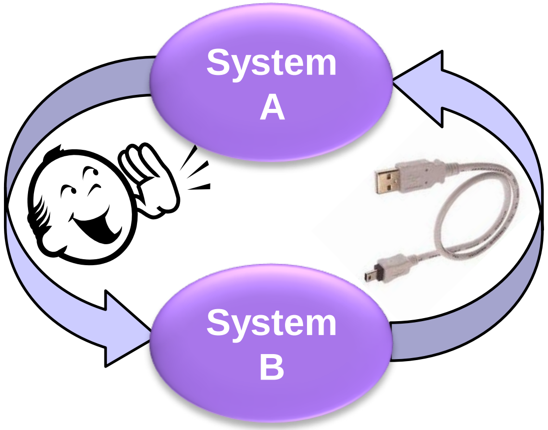
- **Security by design**
  - John McManus *on IT Security*
  - In security, beauty appears in simplicity and graceful design, a product of treating security as a critical goal early in the system design lifecycle.
  - Security is an integral attribute of the system, designed, built, and tested.
- **IT – OT integration**
  - OT is legacy
  - No overall design
  - Undefined lifecycle – made of many lifecycles
  - Complicated, complex, unknown
  - Security is not a goal

McManus, J. 2009, Security by Design, ch 10 in Beautiful Security, ed. Oram and Viega, pub. O'Reilly

OPEN ARCHITECTURES (IN DEFENCE PROCUREMENT)

Open System – A Definition

- **An *Open System* is one that implements sufficient**
  - open specifications or standards for
    - interfaces,
    - services,
    - and supporting formats,
  - to enable properly engineered components to
    - Be ported with minimal changes across a wide range of systems from one or more suppliers,
    - interoperate with other components on local, distributed, and remote systems,
    - be performance and capability scalable, and
    - interact with people in a style that facilitates user portability.



Henshaw, et. al., 2011, Assessment of Open Architectures within Defence Procurement, Report of SoSA Community Forum WG1, pg. 16.

Open Systems Architecture – A Definition

- **An *Open System Architecture***
  - is an open specification of the architecture of a system or system of systems
    - for the purpose of acquiring specified capabilities.
  - should allow for easy improvement and update of system capabilities by adding or changing components.
    - As a general feature of good design [for a system or system of systems],

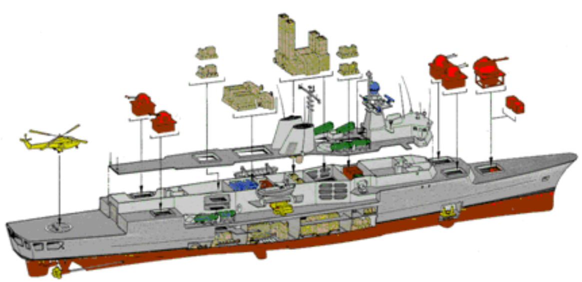
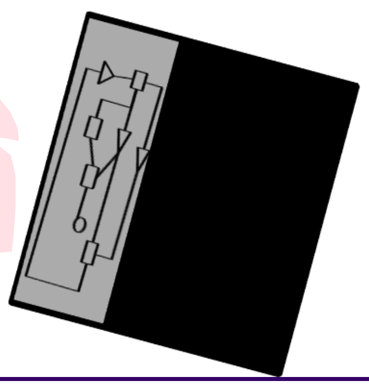


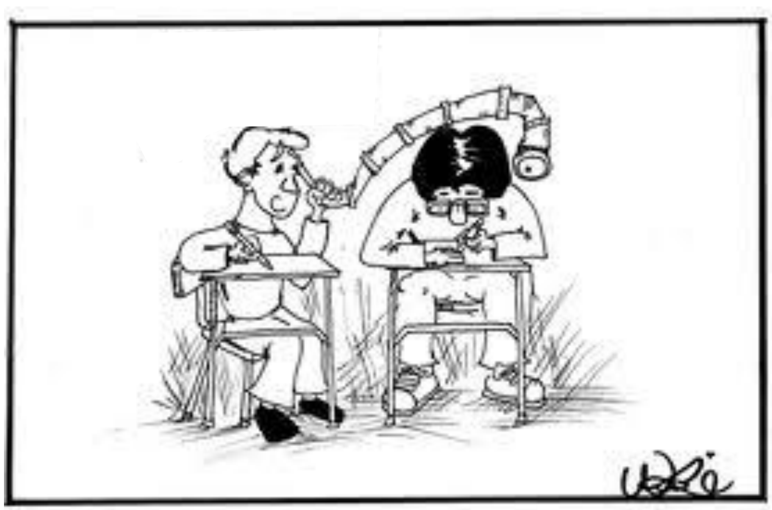
Image from http://aocinc.net/

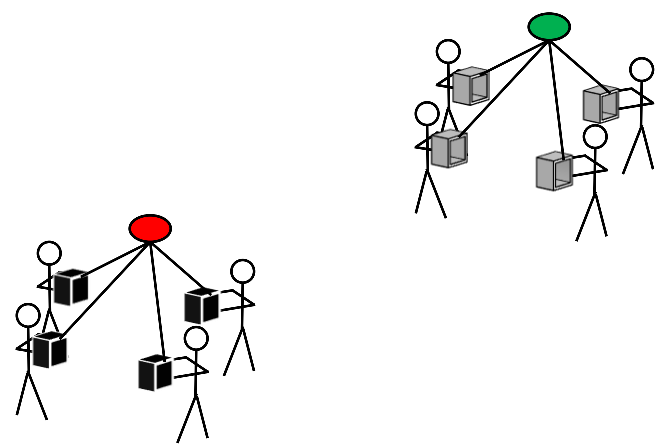


Open System Challenges

- **From the single-systems community's perspective, its part of the SoS capability represents additional obligations, constraints and complexities. Rarely is participation in an *(sic)* SoS seen as a net gain from the viewpoint of single-system stakeholders.**

Rebovich, G, 2009, Enterprise system of systems, in Jamshidi: Systems of systems engineering principles and applications, CRC Press, ch. 6, pg. 169





What are the benefits sought by MoD?

- **Commercial agility**
  - Increased competition
  - Widen supplier base
- **Technical agility**
  - More rapid upgrade of systems
- **Operational agility**
  - More rapid configuration/reconfiguration of systems by mission groups

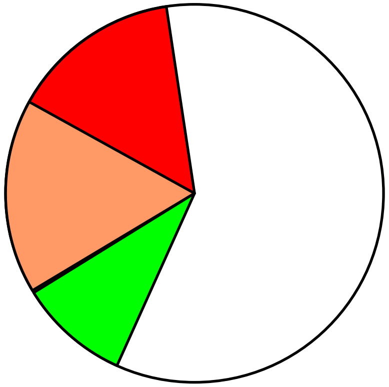
- **It's all about agility !**

Potential OSA Benefit – Operational (Partnerships)

- **Maier Characteristics of SoS**
  - Operational independence of component systems
  - Managerial independence of component systems
  - Emergent behaviours
  - Evolutionary development of SoS
  - Geographic distribution of component systems
    - Maier, M.W. (1998), Architecting Principles for Systems-of-Systems, Systems Engineering, Vol. 1, No. 4, pp. 267-284

Individual owners/operators optimise performance of their own systems

At the expense of performance of the SoS (?)

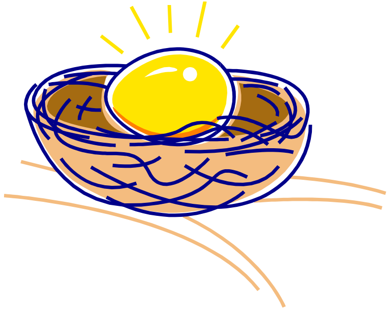


OSA enables system owners/ operators (and developers) to understand likely combined behaviours and performance

Improved situational awareness of SoS participants

OS/OSA enables Improved Partnership Behaviours?

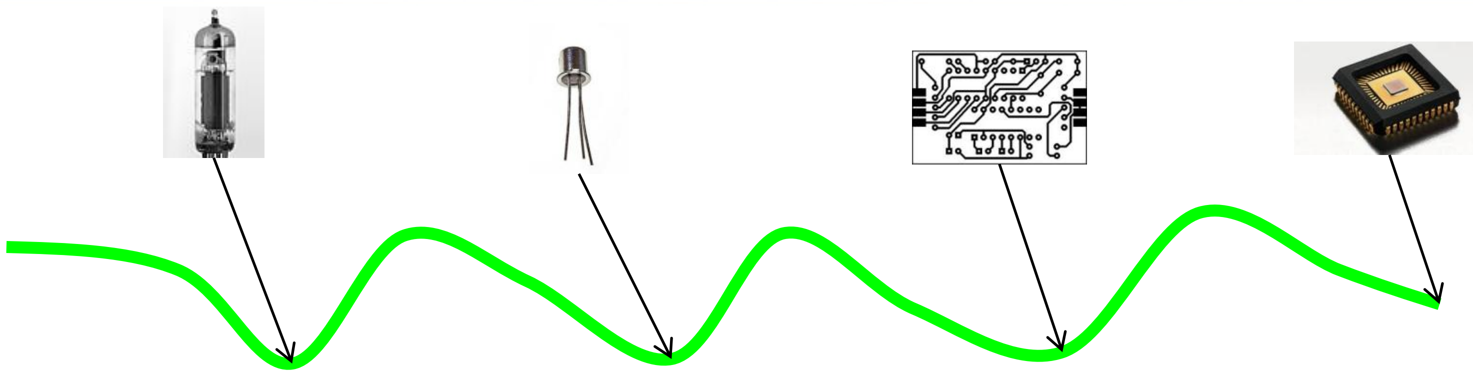
?



Potential Through-Life Costs Benefit

- **Open architecture <u>may</u> increase use of COTS and MOTS**
- **Greater variety of available components/systems reduce costs and risk of obsolescence**
- **Re-use facilitated**

Potential Technical benefit – Technology Insertion



- **Reduced costs of technology insertion**
  - Simpler integration
- **More straightforward qualification of new technologies**
- **Incremental development of capability**

- **BUT may constrain innovation**

"This really is an innovative approach, but I'm afraid we can't consider it. It's never been done before."

Operation agility through plug and play

- **GVA project is largely concerned with this benefit**
- **Reconfiguration in theatre, to cope with**
  - Rapid Changes in Threat Scenario
  - Increasing Changes in Capability Required
  - Increasing Platform Axle Weight
  - Decreasing Platform Availability
  - Decreasing Platform Capacity
  - Increasing Power Requirement
  - Increasing Crew Workload

To whom is “open” valuable?

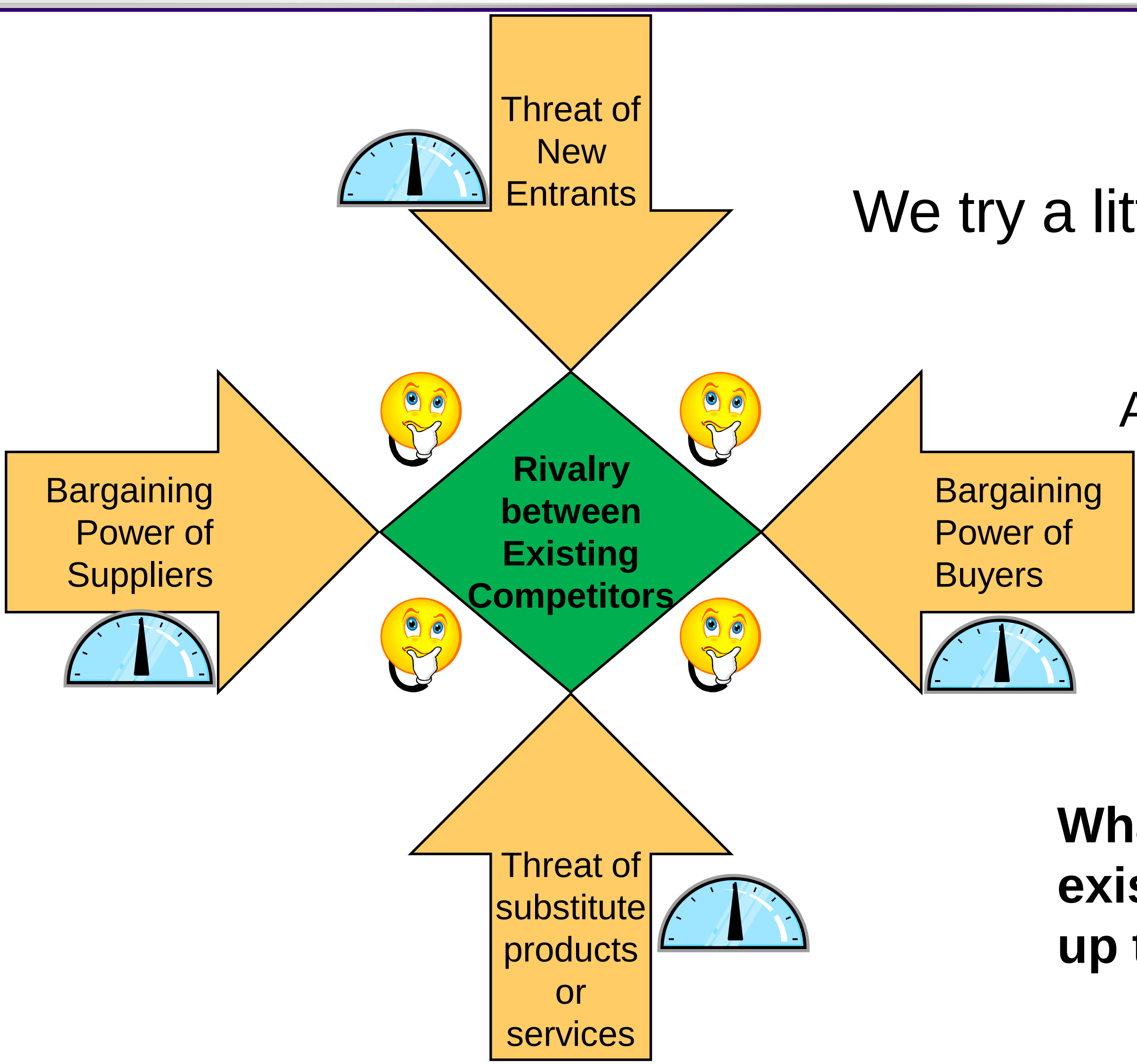
Military?

MoD?

Tier 1 suppliers?

Tier 2 + suppliers?

Porter's Five Forces that Shape Industry Competition

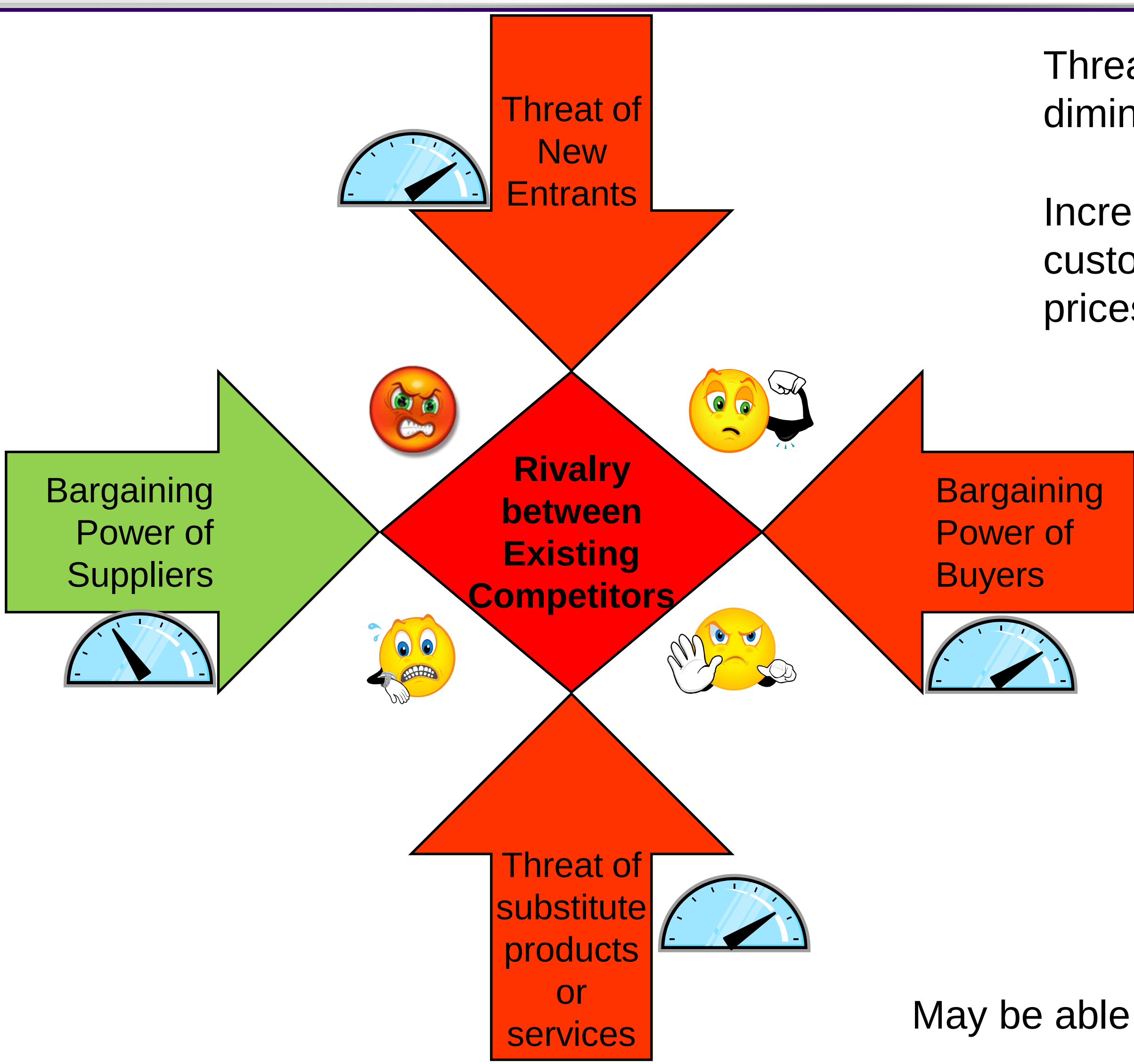


We try a little thought experiment

Open systems Architectures lies in the gift of existing competitors

What would happen if the existing suppliers opened up their architecture?

Porter's Five Forces that Shape Industry Competition



Threat of new entrants in an already diminishing market

Increased competition means that customer can increase pressure on prices

Loss of uniqueness of product/system offering

Also, increases the risk to the customer of counterfeit products

May be able to drive down supplier costs

Draft 'Charter for Adopting Open Systems in Defence Acquisition

- **Published as draft in 2008**
- **Concerns <u>behaviours</u> of MoD and Suppliers**
  - Suppliers will (for e.g.)
    - commit to develop the behaviours, relationships and competencies to enable the full exploitation and benefits of an open systems approach in acquisition, etc.

  MoD will
    - Recognise the primacy of commercial and contractual incentives in responding to its requirements
    - Be responsible for the top level architecting, design and integration task for military capability
    - Accord appropriate weight to adoption of modular and open system needs

OS/OSA can be achieved only through openness at all levels

Open
Sharing
Trusting

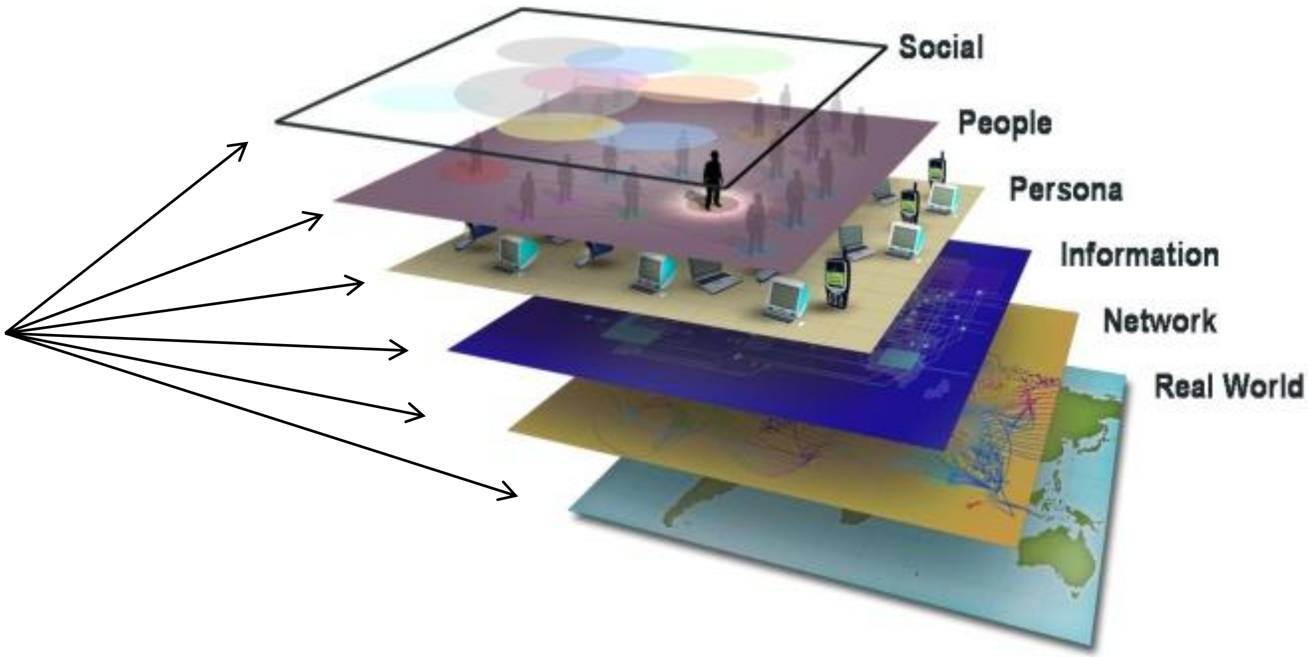


Diagram borrowed from MNE07

Some conclusions from OSA work

- **There is clear value to UK MoD and the war fighter in the adoption of open systems and open architectures**
- **This requires commercial models that will support industry more effectively (by reducing the commercial risks of adopting OS/OSA)**
- **It is about behaviours – particularly commercial behaviours**
  - In these times of austerity partnership is vital
  - Competition based only on lowest bidder will undermine the OS/OSA aspiration

SOME RESEARCH THEMES FOR SOS

Encouraging SoS behaviours

- **Need to develop business models to support SoS behaviours**
  - Need to incentivise shared goals over individual goals
  - Reduce risks of sharing useful information
  - Couple enterprise models to the technical models
- **Situational awareness in SoS**
  - Information sharing
  - Decision support systems
  - Consider human aspects of design for participating systems in SoS context

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