Assessment of open architectures within defence procurement issue 1: systems of systems approach community forum working group 1 - open systems and architectures.

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Additional Information:

- This is a technical report from the Report of SoSA Community Forum Working Group 1 (Open Systems) compiled by: Prof. Michael Henshaw, Mr. Sean Baker, Mr. Jeff Carter, Dr. Simon Colby, Mr. Robert Cooper, Prof. Charles Dickerson, Mr. Neville Drawbridge, Mr. Carl Evans, Chf. Tech. John Fagg, Dr. Simon Hart, Miss Rachel Haywood-Evans, Mr. Jeremy Hobbs, Sgt. David Huggett, Mr. Andrew Kinder, Mr. Mike Mora, Mr. David Pearce, Mr. Tim Rabbe, Dr. Carys Siemieniuch, Dr. Kirsten Sinclair, Mr. John Spencer, Mr. Steve Tutt [© Crown owned copyright]. You may re-use this document/publication (not including logos) free of charge in any format or medium, under the terms of the Open Government Licence. To view this licence, visit http://www.nationalarchives.gov.uk/doc/open-government-licence or write to the Information Policy Team, The National Archives, Kew, London TW9 4DU, or e-mail: psi@nationalarchives.gsi.gov.uk

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Assessment of Open Architectures within Defence Procurement

Issue 1
Edited by Prof. Michael J de C Henshaw
17th August 2011

Compiled by:
Prof. Michael Henshaw, Mr. Sean Baker, Mr. Jeff Carter, Dr. Simon Colby, Mr. Robert Cooper, Prof. Charles Dickerson, Mr. Neville Drawbridge, Mr. Carl Evans, Chf. Tech. John Fagg, Dr. Simon Hart, Miss Rachel Haywood-Evans, Mr. Jeremy Hobbs, Sgt. David Huggett, Mr. Andrew Kinder, Mr. Mike Morua, Mr. David Pearce, Mr. Tim Rabbets, Dr. Carys Siemieniuch, Dr. Kirsten Sinclair, Mr. John Spencer, Mr. Steve Tutt

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EXECUTIVE SUMMARY

Open Systems and Open Architectures

Flexibility is a crucial requirement for the systems acquired by MoD. Operational flexibility is required to enable agile mission groups to configure and reconfigure available assets to meet rapidly changing operational requirements. Technical flexibility is required to enable more rapid and effective upgrade of systems, especially in terms of technology insertion. Commercial flexibility is required to achieve value and innovation in procurement. Open systems has been espoused in a number of Government papers as an enabler of this required flexibility. 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. An Open (Systems) Architecture applies to a system in which the architecture is published in sufficient detail to enable change and subsequent evolution through the introduction or replacement of modules and/or components from any supplier.

The System of Systems Approach

The Systems of Systems Approach (SoSA) comprises a number of initiatives within UK MoD to achieve more effective interoperability between procured and existing (legacy) defence systems by collaboration throughout the defence supply chain. The SoSA Community Forum (SoSA CF) is an industry-MoD initiative to deliver enhanced capability through achieving commonality, re-use and interoperability of independently procured systems. It reports through the Head of SEIG to a 1 star steering group chaired by the Head of Safety & Engineering at DE&S.

Working Group 1 (Open Systems) Challenges and Approach

Working Group 1 of SoSA CF has examined the challenges associated with increasing the use of open systems and architecture approaches within defence acquisition. It has addressed this through assessing the impact of systems architectural features on benefits that might be sought through openness. The group was established through an open call for participation in the SoSA CF and was formed by senior systems engineers from eight major defence companies and two SMEs, together with Mod, and led by an academic team from Loughborough University. Through a series of two-day workshops the group has established architectural assessment frameworks through which MoD can assess candidate architectures against operational, technical, and commercial agility requirements. The frameworks derived have been exercised on two exemplar programmes: Type 26 Frigate Combat System and the Generic Vehicle Architecture (GVA). All participants were self-funded and, overall, the activity represents approximately £250K of effort by industry and academia.
Principal Outputs

The principal outputs are:

- **Assessment frameworks** - Two similar assessment frameworks that can be combined to provide an analysis framework to compare architecture propositions by relating their features directly to the benefits being sought in systems procurement.

- **Definitions** - A set of much needed definitions associated with systems and architectures that can be incorporated into the SoSA Rulebook and AOF (Acquisition Operating Framework).

- **Case Studies** - Case studies of the application of the assessment frameworks.

- **Desk Officers’ Toolkit Spec.** - An outline specification of a Desk Officers’ Toolkit that will be needed to implement the MoD’s aspirations in terms of open systems approaches in a practical sense.

- **Knowledge** - A compilation of learning and understanding that will greatly enhance the approach to open systems throughout the UK defence domain.

- **Recommendations** - A set of recommendations for implementations and further work.

Key Learning

A very important message from this report is that openness should not be considered to be a requirement in its own right; it is the benefits that openness may, or may not, enable that are the requirements. To realise the benefits sought by UK MoD, a careful and tailored approach is required in programmes to both the systems architecting and (concurrently) the commercial context. A generic, formulaic open systems/ open architectures approach is neither feasible nor desirable.

Benefits are to MoD not Industry

The majority of the benefits of an open systems approach at the contracting interface between MoD and major industrial suppliers are realised by the MoD, rather than industry, within the current procurement environment.

Adopt charter

For the MoD to affordably achieve a more open approach to system, and system of systems, acquisition requires it to establish openness at the enterprise level. Wholehearted implementation of the *Charter for Adopting Open Systems in Defence Acquisition* will increase the likelihood of achieving these aims, but not on by itself.

Modular or open?

Many of the agility benefits sought by MoD may be enabled by a modular approach to systems design, without the need for open architectures. Modularity is a technical construct, whereas openness is predominantly a commercial construct. Openness may provide additional and wider benefits to modularity.

Assess architectures

Systems are neither wholly open nor wholly closed; benefits are enabled by deciding where and how openness should be implemented. To this end assessment across a range of architectural attributes is required. The frameworks derived by this working group provide the basis upon which this can be done. The Type 26 Exemplar team
identified four high-level benefits, namely: Costs (encompassing affordability, value for money, and related system of systems ownership costs); contribution to system of systems capability (i.e. its capability, agility, interoperability, and dependability); Acquisition agility (flexibility, tempo and supportability considerations); Industrial capability (sustainability and exportability opportunities for business). The GVA team related benefits to the four areas of systems architecture, acquisition strategy, DLoD integration, and TLCM strategy.

Limited progress was made on the assessment of enterprise openness, but and approach based on decision making over relevant lifecycles and the clarification and mapping of design authority(/ies) is suggested. The desire to increase the use of open systems in acquisition is partly motivated by the wish to increase competition. It is suggested that appropriate competition models be developed to reduce the risk of unexpected and undesirable long-term outcomes.

The use of open standards does not, of itself, indicate good system design. Advice is required on the appropriate standards for achievement of open systems approaches in acquisition.

Practical implementation of the open systems aspirations requires decision support staff be given appropriate tools through which the merits of open architectures may be fairly compared with other proposed solutions to take proper account of through-life aspects. To this end, a Desk Officers’ Toolkit is recommended with the following content: Architecture Assessment Tool (based on the frameworks created by this working group), Roadmapping tool, cost modelling tool, risk profiling tool, competition model. These should be supported by a maturity scale for benefits assessment, guidelines on the use of open standards, and a compliance matrix.

For progress to be made in the area of open systems (research and implementation) it is essential that a set of definitions of key terms is agreed and published.

**Recommendations to SEIG for further work for SoSA CF in open systems**

**Extend stakeholder coverage**
- The conclusions of this report should be explored with organisations from outside the defence domain and with SMEs.
- The definitions derived by WG1 should be considered by other WGs and the SEIG ontology team for adoption or negotiation to agree common definitions. Outstanding key terms should be defined using the formal process applied herein.

**Use the definitions**
- A further study should be undertaken to develop advice on contracting environments that support openness.

**Look at commercial constructs for open**
- The more detailed assessment measurement identified in section 5.2 should be analysed to support the T26 programme.
## Recommendation to SEIG for exploitation of outputs

**Turn assessment framework into a tool**
- Funded development of the architecture assessment framework is required to provide a tool for MoD to support procurement decisions that best meet the customer needs within the constraints of the SoSA principles.

**Develop Desk Officers’ toolkit**
- A funded activity is required to assemble a desk officer’s toolkit for architecture assessment

**Consider working with OMG**
- Initial exploration of collaboration with OMG on aligned standards work should be carried out by a knowledgeable representative of UK MoD.

## Recommendations to SEIG on the conduct of future working groups

**Re-use WG1 agreement in CF**
- The agreement developed to cover WG1 should be re-used for other SoSA CF working groups that convene on a voluntary (i.e. unfunded) basis.

## Recommendations to DE&S Research Community

**Further research needed for toolkit**
- Research should be supported to develop tools for the desk officer’s toolkit where current tools are insufficient or not developed. This should be preceded by a guiding assessment of current tools.

**Research better communication artefacts for SE**
- Research should be supported to develop the means through which architectural features can be communicated more effectively to non-experts.

## Recommendation to industry and MoD training communities

**Education in architecting is vital**
- High quality educational establishments and providers should be encouraged and supported in the creation of advanced courses in the skills of systems architecting.
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Introduction</td>
<td>9</td>
</tr>
<tr>
<td>1.1 The Systems of Systems Approach (SoSA)</td>
<td>9</td>
</tr>
<tr>
<td>1.2 Open Systems and Architecture</td>
<td>10</td>
</tr>
<tr>
<td>1.3 SoSA CF Working Group 1</td>
<td>11</td>
</tr>
<tr>
<td>2 Requirements and assumptions</td>
<td>13</td>
</tr>
<tr>
<td>2.1 Requirements collection and stakeholders</td>
<td>13</td>
</tr>
<tr>
<td>2.2 A priori Assumptions of the Working Group and Systems Community</td>
<td>14</td>
</tr>
<tr>
<td>3 Definitions</td>
<td>15</td>
</tr>
<tr>
<td>4 Key concepts</td>
<td>18</td>
</tr>
<tr>
<td>4.1 Openness</td>
<td>18</td>
</tr>
<tr>
<td>4.2 Modularity</td>
<td>19</td>
</tr>
<tr>
<td>5 Assessment approach</td>
<td>20</td>
</tr>
<tr>
<td>5.1 Metrics</td>
<td>20</td>
</tr>
<tr>
<td>5.2 Framework A (T26 Exemplar)</td>
<td>21</td>
</tr>
<tr>
<td>5.3 Framework B (GVA Exemplar)</td>
<td>26</td>
</tr>
<tr>
<td>5.4 Follow-on work</td>
<td>29</td>
</tr>
<tr>
<td>5.5 Enterprise Assessment</td>
<td>30</td>
</tr>
<tr>
<td>6 Exemplars</td>
<td>33</td>
</tr>
<tr>
<td>6.1 Type 26</td>
<td>33</td>
</tr>
<tr>
<td>6.2 Generic Vehicle Architecture</td>
<td>33</td>
</tr>
<tr>
<td>7 Discussion of results</td>
<td>35</td>
</tr>
<tr>
<td>7.1 Comparison of Exemplars</td>
<td>35</td>
</tr>
<tr>
<td>7.2 T26 CS Exemplar</td>
<td>36</td>
</tr>
<tr>
<td>7.3 GVA Exemplar</td>
<td>36</td>
</tr>
<tr>
<td>7.4 Standards</td>
<td>36</td>
</tr>
<tr>
<td>7.5 Observations on openness and the contracting environment</td>
<td>37</td>
</tr>
<tr>
<td>7.6 So What?</td>
<td>37</td>
</tr>
<tr>
<td>8 Desk Officers’ Toolkit for Architecture Assessment</td>
<td>38</td>
</tr>
<tr>
<td>9 Supplementary activities</td>
<td>40</td>
</tr>
<tr>
<td>9.1 Tools for Systems Design</td>
<td>40</td>
</tr>
<tr>
<td>9.2 Close Air Combat case study</td>
<td>40</td>
</tr>
<tr>
<td>9.3 Object Management Group (OMG)</td>
<td>40</td>
</tr>
<tr>
<td>10 Good Practice for SoSA Community Forum Working Groups</td>
<td>42</td>
</tr>
<tr>
<td>10.1 Effectiveness</td>
<td>42</td>
</tr>
<tr>
<td>10.2 Contractual</td>
<td>42</td>
</tr>
<tr>
<td>10.3 Working Group links to SEIG</td>
<td>42</td>
</tr>
<tr>
<td>10.4 Participant Benefits</td>
<td>42</td>
</tr>
</tbody>
</table>
Conclusions.................................................................................................44

11.1 Openness and Benefits........................................................................44
11.2 Assessment............................................................................................44
11.3 Definitions.............................................................................................44
11.4 Open Standards .....................................................................................44
11.5 Required further work .........................................................................45
11.6 Implications for DE&S ..........................................................................45
11.7 Implications for Industry ......................................................................45
11.8 Implications for Academia ....................................................................45

Recommendations .......................................................................................46

12.1 Recommendations to SEIG for further work for SoSA CF in open systems ....46
12.2 Recommendation to SEIG for exploitation of outputs..............................46
12.3 Recommendations to SEIG on the conduct of future working groups ..........46
12.4 Recommendations to DE&S Research Community ..................................46
12.5 Recommendation to industry and MoD training communities ..................46

Acknowledgements ..................................................................................48

Works Cited ................................................................................................49

Acronym List ..............................................................................................51

APPENDIX A: THE SoSA PRINCIPLES .........................................................54
APPENDIX B: WORKING GROUP 1 REQUIREMENTS AND ASSUMPTIONS ......56
APPENDIX C: DEFINITIONS .......................................................................63

ANNEXE A: TYPE 26 EXEMPLAR ..............................................................70
ANNEXE B: GVA EXEMPLAR .................................................................79
ANNEXE C: DRAFT SPECIFICATION FOR A DESK OFFICERS TOOLKIT TO SUPPORT ARCHITECTURE ASSESSMENT ..........................................................100
ANNEXE D: UKCeB REPORT ON TOOLS ..................................................103
ANNEXE E: SYNTHESYS REPORT ON CLOSE AIR COMBAT CASE STUDY ....107
WORKING GROUP MEMBERSHIP

The working group was established under the SoSA Community Forum through an open invitation to member organisations of the forum. The requirements for participation were essentially a commitment to co-located work with other group members in the case of larger organisations and defined tasks to be carried out separately for smaller organisations. The focused, co-located activity was necessary to make progress quickly on the questions being addressed. All members of the co-located team contributed to the main body of the work in plenary sessions, but the specific work on exemplars was conducted by sub-groups. Table 1 shows the membership of the group and the activities to which each principally contributed.

<table>
<thead>
<tr>
<th>Organisation</th>
<th>WG Members</th>
<th>Main areas of contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loughborough University</td>
<td>Prof. Michael Henshaw&lt;br&gt;Prof. Charles Dickerson&lt;br&gt;Dr. Carys Siemieniuch</td>
<td>Leader, Integration &amp; management&lt;br&gt;Integration &amp; management&lt;br&gt;Integration &amp; management</td>
</tr>
<tr>
<td>Atkins Limited</td>
<td>Mr. Mike Morua (Principal Systems Engineer)</td>
<td>GVA Exemplar</td>
</tr>
<tr>
<td>BAE Systems Integrated System Technologies Limited</td>
<td>Dr. Simon Colby</td>
<td>Type 26 Exemplar</td>
</tr>
<tr>
<td>General Dynamics UK Limited</td>
<td>Mr. Jeremy Hobbs&lt;br&gt;Mr. Steve Tutt</td>
<td>GVA Exemplar&lt;br&gt;GVA Exemplar</td>
</tr>
<tr>
<td>Lockheed Martin UK Integrated Systems and Solutions Limited</td>
<td>Mr. Robert Cooper&lt;br&gt;Mr. Andrew Kinder</td>
<td>GVA Exemplar&lt;br&gt;GVA Exemplar</td>
</tr>
<tr>
<td>MoD DE&amp;S (LE PPS-SEAD-E&amp;TM2)</td>
<td>Miss Rachel Haywood-Evans&lt;br&gt;Sgt. David Huggett</td>
<td>GVA Exemplar&lt;br&gt;GVA Exemplar</td>
</tr>
<tr>
<td>MoD DE&amp;S (Software Supportability Team)</td>
<td>Mr. Sean Baker&lt;br&gt;Chf. Tech. John Fagg</td>
<td>Type 26 Exemplar&lt;br&gt;Type 26 Exemplar</td>
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<tr>
<td>MoD DE&amp;S SE SEIG-Maritime2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MoD DE&amp;S (Software Supportability Team)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Niteworks®</td>
<td>Mr. Carl Evans</td>
<td>WG Support</td>
</tr>
<tr>
<td>QinetiQ Limited</td>
<td>Mr. Tim Rabbets (Principal Systems Engineer &amp; QinetiQ Fellow)</td>
<td>Type 26 Exemplar</td>
</tr>
<tr>
<td>SELEX Communications Limited</td>
<td>Mr. Neville Drawbridge</td>
<td>Type 26 Exemplar</td>
</tr>
<tr>
<td>SELEX Galileo Limited</td>
<td>Mr. Jeff Carter</td>
<td>GVA Exemplar</td>
</tr>
<tr>
<td>SyntheSys Limited</td>
<td>Dr. Kirsten Sinclair</td>
<td>Supplementary Activity</td>
</tr>
<tr>
<td>Thales UK Limited</td>
<td>Mr. Simon Hart&lt;br&gt;Mr. John Spencer</td>
<td>Type 26 Exemplar&lt;br&gt;Type 26 Exemplar</td>
</tr>
<tr>
<td>UKCeB</td>
<td>Mr. David Pearce</td>
<td>Supplementary Activity</td>
</tr>
</tbody>
</table>

Table 1: Membership of Working Group 1 – Open Systems & Architectures Group
1 INTRODUCTION

This report details an investigation into the assessment of open architectures in defence acquisition through consideration of two exemplar programmes. It has been compiled by senior systems engineers in UK MoD, the defence industry, and academia. The most important message of the report is that openness is not an end in itself and that to realise the benefits of open architectures sought by UK MoD, a careful and tailored approach is required in programmes to both the systems architecting and (concurrently) the commercial context. The main body of the report covers the architectural assessment frameworks that have been developed and recommendations for further work to improve knowledge in this challenging domain and for effective exploitation of the work completed so far. A series of annexes and appendices provide details to support the findings and recommendations.

1.1 The Systems of Systems Approach (SoSA)

The Systems of Systems Approach (SoSA) comprises a number of initiatives within UK MoD to achieve more effective interoperability between procured and existing (legacy) defence systems by collaboration throughout the defence supply chain. It was created to address the problem that ‘too many projects are delivering products that do not work together due to the lack of shared understanding of relationships, requirements and constraints in generating capability’ (1).

The SoSA Community Forum was launched on 7th September 2010 as an industry-MoD initiative, the aim of which is to deliver enhanced capability through achieving commonality, re-use and interoperability of independently procured systems. It is led by the Systems Engineering & Integration Group (SEIG) at Defence Equipment & Support (DE&S). It reports through the Head of SEIG to a 1 star steering group chaired by the Head of Safety & Engineering at DE&S.

The purposes of the Community Forum are to support the development of the SoSA and its products (methods, processes, rules and standards), encourage exploitation of the same through information and knowledge sharing across the community, and to provide collective governance by agreeing the SoSA priority areas and endorsing them in both MoD and industry (2).

Among these endeavours, the Community Forum (referred to hereafter as SoSA CF) is an instrument through which MoD may promote the nine SoSA principles (see Appendix A), the eighth of which specifically espouses the adoption of open standards. All the principles have the potential to be met through the adoption of an open approach (architectural, system, or enterprise).

To make progress in priority areas, the Community Forum launched five working groups, the first of which (WG1) is concerned with Open Systems. It was set up to address the question: How should MoD and Industry specify “open systems” for procurement? Later in the report, we shall find that this was probably not the right question; however, the working group has explored the area of requirements for openness and linked them to anticipated benefits. The analysis has provided an approach that may be fully developed to enable better consideration of open systems architectures in procurement decisions. It has established that it is possible to conduct an assessment of open architectures that links them specifically to a benefits model.

The working group comprised MoD, eight major defence contractors and two SMEs, and was led by Loughborough University Engineering Systems of Systems Group. In terms of commitment from industry and academia, the level of effort contributed to this activity is approximately £250K consisting, as it did, of senior systems engineers from the participating organisations. The activity was conducted on the basis of all organisations funding their own participation. It was covered by a

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1 Small and Medium Sized Enterprise
collaboration agreement, largely based on the Niteworks® associates contract (3), which is considered appropriate for future SoSA CF Working Groups that are conducted on a voluntary basis.

1.2 Open Systems and Architecture

Flexibility is a crucial requirement for the systems acquired by MoD. Operational flexibility is required to enable agile mission groups to configure and reconfigure available assets to meet rapidly changing operational requirements. Technical flexibility is required to enable more rapid and effective upgrade of systems, especially in terms of technology insertion. Commercial flexibility is required to achieve value and innovation in procurement. Open systems has been espoused in a number of Government papers as an enabler of this required flexibility, e.g. (4),(5),(6).

Openness has to do with publication of information so that it is freely available within a community of interest. ‘Freely available’ does not necessarily mean free of charge, but simply that all members of that community of interest have equal access to the information.

It is worth stating, upfront, that openness is not a binary property, i.e. a particular system cannot generally be classified as fully open or completely closed, but will occupy a place on a spectrum of openness. Similarly, there are different ways in which a system can be considered open (e.g. ISTAR, C2, Business, IT, Communications, Logistics, or Mechanical, etc.).

Open, in the context of this work, essentially means that the system specification is published in sufficient detail that a vendor, other than the original provider of the system, has enough information about the specified system to be able to provide systems that may interact with, or even replace, the extant specified system. Open concepts are explored in more detail in sections 3 and 4 of this report, but we note four important and distinct terms here:

- 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.
- An Open (Systems) Architecture applies to a system in which the architecture is published in sufficient detail to enable change and subsequent evolution through the introduction or replacement of modules and/or components from any supplier.
- An Open Enterprise does not restrict access to the commons upon which it is based; it will exhibit openness in its communications and decision making processes and systems.
- An Open Standard is a publically available standard – often for interfaces – such that systems that comply with it should be able to interoperate appropriately.

It is sometimes assumed that open systems are synonymous with the use of, so-called, Commercial Off-The-Shelf (COTS) components. This is not the case; open systems do not inevitably lead to greater use of COTS. Nor does the use of COTS always provide benefit, though it may reduce costs and risks in many contexts. COTS are not necessarily always open themselves, sometimes being designed specifically so as to protect the IP within them. However, many COTS do implement open standards.

Another important distinction to make is the one between open systems and modular systems. Modular systems are those which are made up of components that have common interfaces and so open systems are modular systems first, but open systems also require the interfaces to be specified in an open manner. Modularity extends only as far as sufficiently common interfaces to allow the exchange of modules. Modularity is a technical property of a system, whereas openness is essentially a commercial property.

\(^2\) Niteworks is a trademark registered in the name of the Secretary of State for Defence

\(^3\) Commons are resources that are collectively owned or shared among populations
Agreed definitions for the above terms are provided in section 3; the need to consider them as distinct from each other cannot be overemphasised if the results of this working group are to be properly understood.

It should also be plainly understood that openness should not be considered to be a requirement or benefit in its own right. The requirement is essentially agility; that is to say, that MoD and industry may seek benefits associated with operational, and/or technical, and/or commercial agility and an open approach may support those benefits, but will not deliver them as an inevitable consequence.

Openness is not a requirement in its own right; requirements should focus on the benefits that openness may enable.

1.3 SoSA CF Working Group 1

The origins of this working group activity are in the NDIC SE&OA WG (National Defence Industries Council, Systems Engineering and Open Architectures Working Group) that was established in 2007 by the Research and Development Group (RDG), and which created a draft charter for Adopting Open Systems in Defence Acquisition; the charter is provided as an Annexe to the RDG report (7). The NDIC SE&OA WG provided some important inputs to the work of this WG concerning the benefits of open architectures and OSA Guidance.

Following an initial meeting to engage a core group of participants, held in May 2010, the Working Group was launched in September 2010 with an open invitation to members of the Community Forum. The parameters for the working group were:

The question: How should MoD and Industry specify “open systems” for procurement?

The approach: Establish a framework through which MoD can develop, assess, and manage its agility requirements for a system through life and establish credible and sustainable partitions within a system. Agility should be considered from Technical (Form, Function, Behaviour, Technology), Commercial, Operational and Service perspectives.

The working group was constituted as a tiger team drawn from industry, academia, and MoD to develop, and demonstrate through exemplars (Maritime/Land), a realistic approach to the measurement of openness of an open architecture, such that industry and MoD can evaluate open solutions to capability proposals and make meaningful comparisons with other options. The two exemplars were deliberately chosen to be dissimilar in both domain and complexity.

The core team comprised Engineers from Loughborough University, Atkins Ltd., BAE Systems Ltd., General Dynamics UK Ltd., Lockheed Martin UK Ltd., MoD, QinetiQ Ltd., SELEX Comms. Ltd., SELEX Galileo Ltd., and Thales UK Ltd.; it met for 2 days per week for collocated work. This was principally in the Systems and Integration Laboratory at Loughborough University. Additionally, SyntheSyS Ltd. and UKCeB provided supplementary work undertaken independently of the main collaborative work.

The Working Group was ably supported by Niteworks® in terms of Secretariat.

It should be noted that this represented a substantial investment of time and commitment by all participatory organisations. In all cases, the work was undertaken by senior systems engineers who brought with them a wealth of experience of systems design and delivery. The work schedule is illustrated in Figure 1, and the structuring of the group in Figure 2.

Full details of the activity are included in the Programme Initiation Document (PID), (8).
Figure 1: WG1 Work Schedule

Integration and Management
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Neville Drawbridge (SELEX Comms.)

Supplementary Activities
David Pearce (UKCeB)
Kirsten Sinclair (SyntheSys)

Support Niteworks
Carl Evans

Figure 2: WG1 Participation
2 REQUIREMENTS AND ASSUMPTIONS

2.1 Requirements collection and stakeholders

The requirements to define the working group activities were derived by both MoD and industry participants during the early stages of the WG. The agreed requirements are detailed at Appendix B, with MoD and industry requirements separated for ease of reference. The extent to which the requirements have been addressed is also recorded. It can be seen that the majority of requirements from the MoD perspective were to enable a better understanding of the benefits of adopting an open systems approach, whilst the main requirements from industry were to obtain a clearer understanding of contractual issues relating to the supply of open systems and the impact on sustainability of business.

As anticipated, many of the requirements from the industry perspective were beyond the scope of the study and as such have not been fully addressed by the exemplars. It has been recognised that for the contracting interface between MoD and higher tiers of industry, the majority of benefits from adopting an open system are realised by the MoD rather than by industry, and so it is recommended that further activities be conducted to ensure the requirements from the industry perspective are fully addressed. The benefits to the higher tiers of industry of openness within the supply chain have not been explored in depth.

The majority of the benefits of an open systems approach at the contracting interface between MoD and major industrial suppliers are realised by the MoD, rather than industry, within the current procurement environment.

It is important to note that the stakeholder input to the requirements of the working group did not include significant representation from SMEs (see Figure 3) and was primarily from SEIG on the part of the MoD. The requirements are valid from the perspective of understanding the assessment of openness, but may not fully capture the anticipated implications of procuring open systems. In particular, the risks and benefits to SMEs of open systems are not fully explored.

![Figure 3: Stakeholder input to requirements](image-url)
2.2 A priori Assumptions of the Working Group and Systems Community

Prior to work commencing on the question of how to specify open systems for procurement, it was necessary for the WG to agree a set of assumptions upon which the work would be based. Assumptions originating from the NDIC SE&OA WG and a wider Industry/MoD stakeholder group, which met on 30th November 2010 for the WG kick-off meeting, were used as a starting point for the discussions. Several of the assumptions presented were deemed as no longer valid or the basis for the assumption was not fully understood by WG participants (this was partly due to the unavailability of some participants from the original November meeting).

The set of agreed assumptions was created through a plenary discussion of lists devised within each exemplar group. For ease of reference, the consolidated set of assumptions was divided into four areas of concern:

- The nature of openness/open systems and open systems architecture
- The implementation of open systems and open systems architecture approaches
- The MoD specific concerns with regards implementing open systems and open system architectures
- The context in which the working group would consider open systems and open systems architectures

The assumptions list is provided in Appendix B of this report.

Revisiting the assumptions on completion of the WG activities showed that some of the early assumptions have been disproved, although the majority remain valid. This is partly because the question to be answered changed from assessing openness per se, to assessing the broader ‘goodness’ attributes of an architecture that lead to the realisation of the required benefits. The validity of the assumptions must be considered and taken into account by working groups conducting follow-on work from this report.

The WG outputs must be understood in the context of the assumptions recorded in Appendix B. Follow-on work should also take account of these assumptions.
3 Definitions

A commonly agreed upon set of definitions are needed in the AOF and the SoSA Rulebook for architecture assessment. The definitions in this section are offered to help fill this gap.

A list of 32 terms was derived from the union of a list from a brainstorming exercise within the WG and a list defined by the MOSA project (9). Within the bounds of the time available, each term was analysed individually by reviewing the authority of the sources cited for each term and by a linguistic analysis of the meaning of the term. A comparative analysis was performed on terms having multiple accepted definitions by identifying key words common to the definitions of a term and examining variations in meaning of the key words as well as variations of meaning of different definitions of the same term in a key sentence for that term. The definitions are listed below:

**Agility** is the ability of a system or organization to adapt to rapid, unexpected, or unknown change from its environment.

An **Architectural Stack** is a description of an architecture as a series of successive layers, where each layer comprises specific technologies and/or performs specific functions. Generally hardware is at the lowest layer and business applications are at the highest layer.

**[System]Architecture** is the fundamental conception of a system in its environment embodied in elements, their relationships to each other, and to the environment [and to the system purpose] and the principles guiding system design and evolution.

A **Component** is an operating part of a system consisting of input, process, and output.

A **Computing Platform** is that part of the architectural stack comprising the hardware and the lowest layer and most widely used software infrastructure (including the operating system).

An **Enterprise** is a complex, socio-technical system that comprises interdependent resources of people, information, and technology that must interact with each other and their environment in support of a common mission.

**Enterprise Architecture** is an architecture of an organization that supports strategy, analysis, and planning by stakeholders to determine how an organization can most effectively achieve its current and future objectives.

**[System]Independence** between two systems is a condition in each system has its own governance and each can operate to achieve its stated purpose(s) without interoperating with the other system.

**Infrastructure** is the fundamental structure (hard and/or soft and/or organisational) in the context of the user that facilitates the operation of an enterprise from the perspective of the user.

An **Interface** is a boundary through which two systems interact.

**Interoperability** is the ability of two or more systems not only to interact, but to exchange information, and to provide and accept services in order to operate more effectively than as isolated systems.

A **Layer** is a collection of similar functions that deliver services; it has a position in a hierarchy that defines higher layers that consume services from, and lower layers that provide services to, adjacent layers.

**Legacy** [is an attribute that] refers to any pre-existing entity that must be incorporated into a new requirement set.

**Modularity** is the property that is concerned with the discreteness of individual system parts. It is the art of subdividing a system such that its functional elements are interrelated but

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4 The term *Enterprise* is a polyseme with many related but distinct meanings, including those associated with systems. The definition given herein is applicable in all aspects of this document.
bounded, cohesive and autonomous, with each functional element individually achieving defined objectives through the interaction of its parts.

A Module is procurable elements of the system, and will comprise one or more components. They should be operationally useful, supportable, procurable and commercially saleable. (“Modularity can be contracted for.”)

A Non-Functional Requirement is any requirement other than those categorized as functional and typically is used to qualify functional requirements.

Openness is concerned with system accessibility. An Open Specification is an implementable specification that is published by and freely available within a community of interest. An open specification should be at a level of detail so as to be implementable by independent parties within that community. An Open Standard is standard that is consensus-based amongst a community of interest, and is published by and freely available within that community of interest. 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, to interoperate with other components on local, distributed, and remote systems, to be performance and capability scalable, and to interact with people in a style that facilitates user portability.

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

A Service is a coherent and self-contained combination of related functions accessible through a specified interface that can be performed in support of one or more processes or capabilities.

Service-Oriented Architecture (SOA) is an architectural style that supports service-orientation by exposing functionality from distributed systems as independent services in the form of stateless functions.

Service Orientation is viewpoint based on services and service-based development where interfaces to the services are independent of the implementation of the service.

A Specification is an explicit set of requirements to be satisfied by a material, product, or service.

A Standard is a document established by consensus and approved by a recognised third party body independent of the supply and consumer base that provides for common and repeated use with rules and guidelines for activities to achieve results or characteristics of the results. Standards should be subject to a defined (and involved) standardisation process, and provide a mechanism for proposed evolution. Compliance with the standard is intended to ensure consistent results.

A System is a combination of related elements organized for one or more stated purposes.

A System of Systems is a set or arrangement of systems that result when independent and useful systems are combined into a larger system that delivers unique capabilities.

Refer to Appendix C for a detailed description and analysis of the terms. Seven terms remain that require analysis and agreement: centralised system architecture, complex system, distributed system architecture, federated system architecture, opened system, partition, and segment.

The above definitions should be included in the SoSA Rulebook and the AOF. It is important to recognise that progress cannot be made in the area of architecture assessment or assessment of openness without commonly agreed definitions.
For progress to be made in the area of open systems (research and implementation) it is essential that a set of definitions of key terms is agreed and published.
4 KEY CONCEPTS

4.1 Openness

Openness is concerned with system accessibility. Commercial enterprises may use openness for financial and competitive advantage. Open specifications can be used both to increase access to the commercial market and to improve system, and system of systems, integration of components. Other benefits that can be realised from open approaches to system development and acquisition include speed to market and protection of the buyer from being locked into bespoke solutions from a single vendor. The MoD has been seeking the benefits associated with openness for several years. According to the NDIC SE&OA WG Interim Report issued in September 2008 (10), the stated position of the MoD is that “Across defence, individual systems need to be developed within an architecture that enables straightforward integration of future equipments and flexible reconfiguration”. An open approach to system acquisition should be more concerned with how to reap the benefits of openness than with how to contract for openness per se. That is to say, that the open approach should be tailored to enable the general benefits in the italicised sentence as appropriate to the specific programme or project.

The enablers of technical openness include open standards and open specifications, which draw from consensus amongst a community of interest, and are published by and freely available within that community. An open specification should be at a level of detail sufficient to be implementable by independent parties. Compliance with open standards is intended to ensure consistent results.

But openness relates to more than technical standards and specifications. As the WG activities progressed it became clear that the ‘technical openness’ of a system was not of itself sufficient to achieve all the benefits that might be sought: the enterprise acquiring and developing a system, or system of systems, should also exhibit certain attributes of ‘openness’ particularly in its communication and decision making functions. In order to combine and integrate these requirements, three key questions were identified

- When is OS/OSA the right approach?
- What are the relevant OS/OSA user/systems requirements for the System of Interest?
- How can it be ensured that OS/OSA benefits are both measurable and realisable?

These questions were addressed to a greater or lesser extent in the exemplars studied and the key message emerging from this work was that a generic OS/OSA approach – in the sense of a single formulaic approach - was neither feasible nor desirable. Generic principles, approaches and definitions should be tailored to suit the system under consideration.

A generic formulaic OS/OSA approach is neither feasible nor desirable; OS/OSA should be tailored specifically to the system(s) under consideration

It is also important to understand the business model for an open approach to system acquisition. The incentives for participation in the process of an open approach for both the customer and the vendors must be clearly understood. In the commercial practise of an open acquisition, vendors often collaborate with their major customers and also both collaborate, and compete with each other to influence the open specifications and standards to which their products will be developed.

If the MoD seeks a more open approach to system, and system of systems, acquisition then it must establish openness at the enterprise level and integrate the technical approach with the enterprise approach (see the definition of enterprise in section 3 above). This cannot be achieved with current acquisition processes and behaviours. A genuine shift towards a more open approach will require changes in acquisition policy by the MoD. There are a number of reasons for this, but perhaps the
most significant is based on trust within the enterprise. Industry needs to be sure that if it publishes IP, this will not disadvantage it with respect to future competitions concerning the system in question (e.g. the service support that follows delivery of a system). Clearly this is in direct contradiction with the MoD desire to increase competition.

A genuine shift towards a more open approach (OS/OSA) in acquisition cannot be achieved with the current acquisition processes and behaviours.

Adoption and wholehearted implementation of the NDIC SE&OD WG Charter for Adopting Open Systems in Defence Acquisition (5) would represent a significant step in achieving an acquisition environment in which use of OS/OSA could increase.

Wholehearted implementation of the Charter for Adopting Open Systems in Defence Acquisition will increase the likelihood of OS/OSA within acquisition.

4.2 Modularity

Modularity is a design approach that can be part of an open system specification. It is the property that is concerned with the discreteness of individual system parts, referred to as modules. It is the art of subdividing a system such that its functional elements are interrelated but bounded, cohesive and autonomous, with each functional element individually achieving defined objectives through the interaction of its parts. A Module is a procurable element of the system, and modules will comprise one or more components. The proper specification of modules allows modularity to be contracted for.

This concept is reflected in DEF STAN 23-09 for GVA (11); this states that a modular architecture “is designed in such a way as to allow the replacement or addition of subsystems and upgrades as required without any undesirable emerging properties”. Thus, modular design makes possible the replacement or refresh elements in an open system architecture.

The recent NDIC SE&OA WG work on benefits of open architectures (12) considered that open systems should first be modular systems that bring all the benefits of modularity plus additional benefits in wider areas that lie mostly at the enterprise level, e.g. concerns related to owning and managing systems such as sustainability, flexibility, and agility. These concerns are also linked with business, financial, and commercial issues (and controlling risks).

Modularity is a technical attribute of design that can deliver certain benefits; openness is a commercial attribute that usually includes the benefits of modularity and may add certain other benefits.

Modularity is a technical construct and openness is a commercial construct
5 ASSESSMENT APPROACH

The assessment approaches derived for the exemplars are provided in sections 5.2, 5.3, 5.5 and annexes; in section 5.1 we briefly describe the underlying approach of relating measurements to benefits and hence decisions about choice of architecture.

5.1 Metrics

It is clear from the forgoing discussions that decisions to be made about a systems architecture, and whether it should be an open architecture or not, should be based on the extent to which the architecture and approach enable desired benefits in the operational, technical, or commercial space. The two exemplars considered by the working group were both considered from the perspective of benefits analysis. There are many approaches for relating metrics to benefits, the ones considered here followed the basic form of aggregating base measures to metrics and thence to high level benefits to the stakeholders. This basic form is based on that described by McGarry et. al. (13) expressed generically as follows.

Decisions (e.g. judgements about open systems) have information needs. These are supported by information products (metrics) that are the appropriately combined and analysed measures of the system (Figure 4). A metric is a system of related measures that facilitates the quantification of some particular characteristic.

![Diagram showing the relationship between decisions, information needs, information products, measures, information needs, and measurement plans.](Image)

**Figure 4: Decisions have information needs and should be supported by information products**

<table>
<thead>
<tr>
<th>An Information Need</th>
<th>Required to make decision about the merits of a particular (open) systems approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generates ideas for</td>
<td></td>
</tr>
<tr>
<td>A Measurable Concept</td>
<td>Idea about the entities that should be measured in order to satisfy the information need</td>
</tr>
<tr>
<td>That must be developed into</td>
<td></td>
</tr>
<tr>
<td>A Measurement Construct</td>
<td>Specifies what will be measured and how data will be combined to satisfy the information need</td>
</tr>
<tr>
<td>That is formalised through</td>
<td></td>
</tr>
<tr>
<td>A Measurement Procedure</td>
<td>Defines how data will be collected and organised in order to instantiate the measurement construct</td>
</tr>
<tr>
<td>That is executed through a</td>
<td></td>
</tr>
<tr>
<td>Measurement Plan</td>
<td>Plan for creation of measurement products within a project</td>
</tr>
</tbody>
</table>

**Figure 5: An information need must be developed into a measurement plan**
Assessment for decision making must be based on a measurement plan (Figure 5), which may include measurements that are projections; i.e. estimates based on assumptions within the architecture.

The information products are constructed from the system attributes, which is something that can actually be measured (Figure 6). Inevitably, some attributes will end up being subjectively assessed but, wherever possible, quantification will provide a more rigorous means of assessment of the relationship of architecture to benefits.

This approach has been translated into a framework for the exemplars considered herein that is equivalent to having the information products representing the information needs to determine the extent to which a desired benefit is likely to be achieved; indicators and derived measures representing combinations of measurements that support the products, and base measures being the leaf nodes of the frameworks in terms of the features (or attributes) of the systems architecture.

<table>
<thead>
<tr>
<th>An Information product</th>
<th>specifically addresses an information need (combines an indicator and the associated criteria for a decision)</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑ Supports</td>
<td>An Indicator is an evaluation that provides the basis for analysis or making a decision</td>
</tr>
<tr>
<td>↑ Supports</td>
<td>A Derived Measure is a function of two or more base (or other derived) measures</td>
</tr>
<tr>
<td>↑ Will aggregate to</td>
<td>A Base Measure is a measure of a single attribute by a specified measurement method</td>
</tr>
<tr>
<td>↑ Supports</td>
<td>An Attribute is something that can actually be measured (an entity)</td>
</tr>
</tbody>
</table>

*Figure 6: Measurement Construct*

### 5.2 Framework A (T26 Exemplar)

#### Benefits characterization

The Framework for the Type 26 (T26) Combat System (CS) exemplar used, as its starting point, the preceding generic NDIC SE&OA WG work on 1) benefits and detriments, 2) measures and metrics related to openness (either characteristics of openness or facilitated by openness), and 3) consideration of generic measurement models for assessment (of openness or other characteristics).

Based upon this earlier work the team determined that:

1. Any architecture assessment scheme must be linked to benefits (and detriments) in order to show fundamental utility (i.e. in the problem rather than solution space)
2. The assessment should not be limited to consideration of just openness but should address the range of potential architectural solutions and their characteristics
3. The fully quantitative assessment of candidate architectural options was unlikely to be feasible or plausible and therefore an assessment schema should be aimed at a) promoting the identification and articulation of issues as an aid to architecture selection, and b) record any rationale relating to qualitative assessments made.

In support of the latter position, the experience gained in the use of multi-criteria decision analysis (MCDA) techniques on programmes including the Modular Open Systems Architecture (MOSA) was reviewed. The team supported the view that the difficulties inherent in the overall use of MCDA for
assessment purposes were likely to be repeated, but noted that MCDA may serve usefully in a
subsidiary role where, for example, similar characteristics could be preferentially compared.

The generic benefits schema (recording detriments as negative benefits) was progressed to reflect
complex (e.g. naval CS) architecture issues, reflecting the team’s understanding that:

- A broad range of architecture-influenced benefits should be identified which include
  wins for the supplier industry in addition to the customer (noting that most of the
  benefits of moving towards open systems had more immediate benefits for the
  customer than the system supply chain)
- Benefits and their subordinate characteristics should be tiered hierarchically and, where
  appropriate, either repeated or cross-linked in the hierarchy\(^5\).

This resulted in four high-level benefits being identified, namely:

- Costs – encompassing affordability, value for money, and related system of systems
  ownership costs
- The system’s contribution to system of systems capability – including the system’s
  capability itself, its agility, interoperability and dependability
- Acquisition agility – flexibility, tempo and supportability considerations were detailed
- Industrial capability – the ‘win for business’ decomposed into sustainability and
  exportability considerations.

Lower-level characteristics were taken from the generic NDIC SE&OA WG ‘metrics and measures’
spreadsheet and related to the higher-level benefits. These were then reviewed and, where
necessary, supplemented with further views of such characteristics documented in:

- The MOSA Phase 1 Benefits Model (9)
- Previous research into the structuring of non-functional requirements (14).

Certain lower-level benefits were either renamed (e.g. ‘integratability’ to ‘composability’) or
augmented in the hierarchy (e.g. the addition of ‘fungibility’ improve completeness).

Where appropriate, lower level characteristics have been repeated in the hierarchy and tailored to
be specific to the higher-level benefit. Thus, for example:

- Dependability is a contributor to both system of systems capability and also system’s
  capability
- Commonality is a contributor to both system agility and support chain efficiency, but the
  nature of contribution is different; in the first case it is a consequence of either usability
  or reusability, and in the second, it relates to reduced spares holding, simplified
  waterfront arrangements etc..

The resulting structured benefits hierarchy is shown in Figure 7 below.

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\(^5\) This was undertaken to remove potential horizontal dependencies and to ‘level’ the contributors (allowing
potential future application of MCDA techniques as indicated previously).
Figure 7: Type 26 benefits hierarchy shown in hierarchical mind map format.

Architecture assessment

The leaf level nodes of the benefits hierarchy have been assessed as to whether they are a characteristic of openness or are not facilitated by openness\(^6\).

Given that the Type 26 Exemplar is essentially concerned with whether the architecture is sufficiently open or not, only those leaf nodes which were influenced by openness considerations were analysed further for the present study. Development of a more generally applicable framework will require additional analysis of the other leaf nodes.

The underlying assumption for this assessment is that for Type 26 CS the adoption of a good architecture is important and not specifically the adoption of an open architecture, although openness may well be part of a good solution. Thus it was important for the assessment schema to be able to evaluate a range of architectural attributes rather than only those specific to open systems architectures.

In order to support good decision making on architecture choice, assessment must evaluate a range of architectural attributes, not just those related to openness.

The range of architectural attributes covered was influenced by those identified previously within the MOSA programme\(^7\), and comprises:

- Modularity
- Compliance with open standards
- Component commonality
- Layering
- Segmentation

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\(^6\) Using a ‘smiley face’ as is shown in the figure to denote the characteristic being a factor of openness, and a ‘red flag’ to denote a characteristic not facilitated by openness. Symbology choice was limited by those available within the mind-mapping tool.

\(^7\) The MOSA technical architecture is the Maritime Combat System team’s ‘vision’ architecture.
• Centralisation
• High integrity design
• Use of COTS [products]
• Use of a common underpinning information model.

The relationship (positive, negative, variable, or neutral) of these architectural attributes, as contributors to the leaf nodes of the benefits hierarchy, was recorded by the team in a spreadsheet.

It should be noted that the team recognised that, firstly, this set of architectural attributes may not necessarily be complete and, secondly, that practical complex systems' architectures are likely to exhibit heterogeneity (i.e. different attributes being deployed to differing extents within specific parts of the architecture so as to deliver specific properties such as levels of non-functional requirement (NFR) most cost-effectively).

In addition the team recognised that:

• Certain characteristics, such as ‘the use of COTS’ or (application of) high integrity design, are not strictly architectural but design/implementation considerations, but since they serve as alternatives or supplements to architectural considerations they are included
• Other characteristics, such as centralisation\(^8\) (and related notions of decentralisation and redundancy) are actually composite characteristics and would benefit from further decomposition, analysis, and definition\(^9\).

The leaf nodes in the benefits tree equate essentially to ‘base measures’ (see section 5.1) in the generic measurement model for assessment – see Figure 6.

The base measures for quantifying the leaf nodes of the benefits hierarchy were captured in a spreadsheet, with the measures generally being stated in time or cost terms (and therefore being more amenable to potential compounding as part of the benefits schema). For example the base measures for safety are considered to be the ‘cost and time to certify’.

The benefits hierarchy, architectural attributes and base measures serve as key elements of an overall architecture assessment approach, which is considered next.

**Overall assessment schema**

The team was aware of a number of available architecture assessment techniques and tools. It was not possible to carry out a comprehensive review of such techniques within the available resources to this activity, but a brief, targeted review of two different techniques/tools (in terms of scope, pedigree and features) was undertaken, namely:

• The Software Engineering Institute’s Architecture Tradeoff Analysis Method (ATAM) and its derivative ATO (Architecture Trade Off)-Lite
• The US DoD’s Open Architecture Assessment Tool (OAAT) (15).

The first was selected for consideration because it is broadly representative of a family of well-documented (16) and widely used techniques for evaluating software architectures, with software architectures being recognised as increasingly important contributors to systems architectures. The second was considered because it is a system-level architecture assessment tool and is used by the US DoD for assessing US naval CS architectures (including at the subsystem and equipment levels).

The review of these techniques and tools proved a useful exercise in terms of a) saving time and effort through using off-the-shelf, proven and previously used material, b) benchmarking our

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\(^8\) Of networking, processing, storage, data etc.

\(^9\) For example the distinction between logical and physical centralisation is important with the trend being generally towards increasing the former and decreasing the latter.
understanding of issues, and c) drawing our attention to approaches or features which might prove useful.

Specifically, the review of ATO:

- Raised the issue of scenario-based assessment and its relative pros and cons, such as its relative ease of conduct but concerns about the scenarios’ coverage
- Confirmed how qualities such as availability, interoperability, modifiability, security, sustainability, and testability should be handled (17).

Review of OAAT indicated a tool designed to assist project managers in assessing the ‘openness’ of their programmes. Some of the distinctive features are:

- Its questionnaire-based approach with specific questions designed to tease out specific issues using standardised scoring scales.
- Its separation of technical and programmatic issues.
- Its overall scoring of an architecture assessment under the headings of programmatic and technical ratings with the former, inter alia, including consideration of the adoption of an open systems approach, the resulting open architecture and adoption of an open modular design; the latter considers the extent of adherence to a number of specific design tenets including interoperability, composability and reusability.

These reviews influenced the desired overall architecture assessment schema, reported herein, in terms of a) the relative ease and transparency of employing a questionnaire-base assessment schema, b) assessment scoring often being more meaningfully conducted against a maturity scale rather than somewhat meaningless metrics, such as ‘the percentage of open interfaces employed’, and c) the weakness of an overall assessment rating but potential value in subordinate ratings.

The resulting overall architecture assessment schema is illustrated in Figure 8, below. It shows how an architecture (at figure bottom) can be assessed in terms which progressively relate to overall benefits and architectural maturity levels via architecture attributes and base measures.

Maturity levels in the assessment schema were related to balanced sets of architectural attributes. Five such maturity levels were defined: the status quo of federated CS (equipment based, highway-centric and message-based information passing), the long term endorsed MOSA vision, and three possible coherent intermediate steps on the path of evolution from current architectures to the achievement of the MOSA vision. These maturity levels, in fact, served a key role in enabling the rapid assessment of the proposed T26 CS architecture.

The team recognises that further work is required to:

- Review the quantification of the base measures
- Complete the assessment schema question set
- Detail the contributions of architecture attributes, principally those which are variant in nature and may require further decomposition or elaboration
- Consider how base measures will be quantified using cost and time estimates – cost and time base measures will in general require specialist cost modelling and cost data is generally highly commercially sensitive
- Review how the generic maturity levels will relate to the inevitable spread in architecture assessment questions and answers
- Consider how heterogeneous architectures will be assessed (for example, on a segmented basis and by considering the suitability of the segmentation employed).
- Consider against the requirements to identify intervention points in order to influence the design of the T26 Combat System.
Nevertheless this basic schema is believed by the team to be useful as a basis for assessing complex architectures such as those used in naval CS. It served as the basis for the initial outline assessment of the Type 26 Global Combat Ship (GCS) CS architecture which is described in Section 6.1.

![Architecture assessment schema](image)

**Figure 8: Overall architecture assessment schema**

Architecture assessments similar to the OAAT approach, but constructed as Figure 8 will enable assessment of architectural features against benefits

Complex architectures will, in general, be heterogeneous; these will require further development of the frameworks recommended herein.

### 5.3 Framework B (GVA Exemplar)

#### Background

The pace of the changing threat to military protected patrol vehicles within Afghanistan prompted the MoD to look at the way integration of new protection and mission systems is carried out on existing and future vehicles. The MoD and the Defence Industry have worked together to distil a set of standards in order to gain an open, modular and scalable electronic and electrical architecture across the whole of the land vehicle fleets. This culminated in the Generic Vehicle Architecture (GVA) Defence Standard 23-09 (11), which was released and mandated in August 2010.
Generic Vehicle Architecture is the approach taken by MoD and Industry to ensure that sub-systems on land platforms are properly integrated (electronically, electrically and physically). Defence Standard 23-09 is an output from this approach, and is not an architecture or a design in itself. It does not mandate a specific design, as the design will vary according to the specific requirements of the platform and its role. The GVA approach is based on established engineering principles that emphasise the need to take a whole systems view and the use of open standards for interfaces. The nine basic principles of the GVA Approach and Def Stan 23-09 are that they must:

1. Take account of previous MoD and Industry investment;
2. Be applicable to current and future systems;
3. Use open, modular and scalable architectures and systems;
4. Facilitate technology insertion (upgrade, update, replace, repair, remove and addition);
5. Not needlessly implement in hardware any functionality that can be implemented in software;
6. Take a “whole platform” systems view, through life (including cost);
7. Be done in conjunction with industry and all relevant MoD Stakeholders;
8. Be MoD owned and maintained;
9. Specify the minimum necessary to achieve MoD’s desired benefits avoiding unnecessary constraints in implementation.

GVA sits in the context of the Land Open Systems Architecture (LOSA), a higher level architecture in a brigade context. It is intended to bring together Land domain architectures such as vehicles, dismounted soldiers, static bases, universal fires, tactical communications, and ISTAR. GVA is an essential component of the LOSA and many of the standards that are mandated in GVA are applicable to other areas of LOSA.

In summary, GVA supports a full spectrum of platform functionality, from simple, low cost, low functionality platforms at one end, to highly sophisticated platforms with integrated survivability, surveillance and offensive functionality at the other. It is intended to be sufficient to allow subsystems to interoperate as required but still allow a manufacturer to propose innovative implementation to the MoD. GVA policy is reviewed every 18 months to keep it current and relevant.

The Challenge

The challenge for project teams was to successfully apply the GVA Def Stan, 23-09, so that their procurement will be: a) GVA compliant in a Value for Money (VFM) manner and b) satisfies the constraints of budget, schedule, industry feasibility, user expectations, operational concept of employment and support strategy and through-life upgrade strategy that have been agreed upon by the Head of Capability, the Programme Board, the Operating Centre, the User and the Delivery Team. There are many factors involved and these considerations must be distilled down to the selection of the solution options that when taken together are GVA compliant.

To facilitate this process the GVA Office has developed an implementation matrix, which defines five levels of GVA compliance for each aspect of the GVA standard. This matrix is used to support a Balance of Investment Model developed by the Land Operating Centre to inform Value for Money decisions on common aspects of GVA that could be applied to several vehicle programmes. The objective is to provide Delivery Teams with cost effective, yet discrete options that can improve fleet commonality, interoperability and re-use which are key SoSA (System of Systems Approach) principles.
However, once the constraints of the problem are understood, how could a Delivery Team manage its ability to proceed in a direction that will achieve the desired results once the CADMID process begins and the acquisition moves from Initial Gate to Main Gate to Acceptance and finally to operational use and removal from service? Decisions will need to be made throughout this process to continue to maximise benefits in an environment of competing issues that involve trades over performance, cost, time and risk. Decision makers will need a Benefits Model and a decision dashboard to facilitate effective and informed decision making. The purpose of the Benefits Model and dashboard are to provide the ability to monitor trends, targets and issues that are deemed to be important to the project. Every project will be different and will have different priorities, however the process used to manage these issues could be the same and therefore repeatable, allowing the appropriate level of scrutiny and expertise to manage the process. If several delivery teams are in the process of managing acquisitions for new vehicles or vehicle upgrades, a common process could be scalable and allow several delivery teams to use a common infrastructure to manage their GVA compliance requirements, reducing the overhead cost of managing the entire activity.

**Applicability**

Four basic main scenarios are currently of interest to the Land Operating Centre. These are as follows:

1) Urgent Operational Requirement (UOR) procurement of new vehicles generally as part of a COT/MOTs purchase
2) Equipment Planning (EP) procurement that will consider an enhanced COTS/MOTS design
3) Upgrade of a Legacy vehicle to a more GVA compliant architecture to improve operational flexibility and cost effective upgradeability
4) Transition of a UOR vehicle to Core

Each of these scenarios raises concerns that an open architecture process must address. The objective are: a) to ensure our process allows effective decision making within the time constraints allowed, b) that there is buy-in from the Delivery Teams and the GVA office and c) that it actually provides benefits for the effort expended to manage it.

**The Process**

The team investigated the GVA exemplar with regards to the application of open architectures to achieve GVA compliance.

Through a series of several workshops from February 2011 until May 2011, the team devised a process based on managing three core activities needed for the application of GVA to a particular project. These are:

1) **Determine Applicability** – Apply the GVA requirements and approach to the acquisition problem to be solved. This process involves the selection of the appropriate implementation options that should be considered and further investigated.
2) **Determine the project’s needs** – Determine what the project needs to satisfy technical architecture, acquisition strategy, TLCM strategy and DLoD integration requirements. These can be determined by stating or measuring those needs through the use of a survey. The results will need to be in a form that could be easily applied to the GVA Implementation matrix.
3) **Determine and monitor overall project benefits** – Determine the overall high level project benefits and monitor them throughout the CADMID cycle. The objective is to determine how the GVA requirements, implementation options and project strategies align with the benefits. This is done through the creation of a benefits model. The use of a dashboard to display progress will help to inform decisions on which is the most effective course of action
for the project. This process is designed to keep decision making focused on achieving and maximising benefits as opportunities arise.

The process for applying GVA that this study explored is shown in Figure 9. Figure 10 shows how the process would be managed through the CADMID cycle to inform decisions on DLoD and LOSA integration, Acquisition and TLCM strategy and finally on systems selection and integration. The process is designed to provide traceability between Project requirements as determined through assessments, GVA requirements and implementation options and agreed upon project benefits. Improved traceability amongst these three areas should increase coherency within the Project’s activities and allow decision makers to have a better understanding of the Project’s interdependencies and dynamics. Better understanding of the Project dynamics, allows Project Managers to select options that produce the desired effect based on proven results. “Trial and Error” decision making is therefore replaced by more purposeful and informed approaches based on measured trends with predictable results. In effect the project can improve its agile response to new situations and quickly adapt as the changes and opportunities present themselves.

![Overall Objective - Show Benefits](image)

**Figure 9 Process for Applying GVA**

### 5.4 Follow-on work

The assessment framework described above can be extended as follows:

- Application to the Generic Soldier Architecture (GSA) and Generic Base Architecture (GBA)
- Used to support the development of the LOSA (Land Open Systems Architecture)
- Conduct usability studies with Project Teams

These activities would facilitate improvement of the tool so that it could become a mainstream activity.
Figure 10 Managing the Process through the CADMID Cycle

5.5 Enterprise Assessment

In Section 4.1 it was clearly stated that the MoD must “establish openness at the enterprise level and integrate the technical approach with the enterprise approach” if it wishes to establish a more open approach to Systems Acquisition. However, the question then becomes how to specify, measure, and evaluate the relevant degree of openness required in Enterprise Systems.

There are several models available to assess the structure and performance of organisations: Castka’s High Performance Team Model (18), Tannenbaum’s Team Effectiveness Model (19), and the People Capability Maturity Model (20) among others. However, few if any of these models provide quantitative and qualitative measures of performance and none are truly able to provide a direct multi-point, measurable cause and effect link between the various ‘soft’ attributes10 of an enterprise system and its performance. It is clear, though, that success factors from a human perspective do centre upon the structure of communication (stakeholder management) and decision making processes and systems within the overall Acquisition Enterprise System of Systems (AESoS)

With this in mind, the Working Group decided to focus on decision making within the AESoS (and the federated set of enterprise systems that it contains) exploring barriers and enablers to decision making within this AESoS. The question that was posed was: what is it about the “openness” of an AESoS that enables greater openness to be offered as a solution?

The initial recommendations of the Working Group are to pursue the development of a Framework for measuring openness of decision-making against life cycle phases. An initial Framework is provided at Figure 11, but this is very much at the concept stage.

Assessment of enterprise openness should be based on decision making in the enterprise over relevant lifecycles

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10 The term, soft, is used to imply the social (human and organisational) aspects of a system.
Figure 11: Possible approach to measuring Openness of Decision Making in an AESoS

The idea is that measurable attributes of the decision making system (e.g. interface specification available/not available) could be identified and applied to all enterprise systems making up the overall AESoS and then measured and compared over all the phases of the CADMID, or other Engineering Life Cycle. Some measures would be actual, but others could be projected forward in selected versions of the life cycle (i.e. from the system or capability roadmap). Conflicts in the attributes between enterprise systems participating at any point in the life cycle could be identified and explored further for any potential impact on decision making within the overall AESoS.

Another area considered was that of exploring and categorising the role of Design Authority across the AESoS. Currently this role is diffused across the component Enterprise Systems with little clarity over Design Authority Roles in terms of authority, accountability, interactions, boundaries and responsibilities. The Role Matrix Technique (21), developed at Loughborough University, could be applied here: it is a relatively easy and quick method which enables the analysis, evaluation and distribution of the most appropriate combination of human roles (in this case the Design Authority Role) for a given set of process(es) across the AESoS. Traditionally layers of design authority have been based upon system hierarchy and the handling of inter-element matters at the element aggregation level. The move towards less stovepiped approaches to systems, e.g. modules used in more than one system, architectures applied across multiple systems, product line-based systems etc. require a more sophisticated approach to handling design authority (and issues such as safety etc.).

Enterprise openness will be better understood by clarification and mapping of design authority/ies for the SoS under consideration

One of the motivations that MoD has expressed for openness is the desire to increase competition. The extent to which adoption of OSA increases competition is very context dependent; it depends upon the opportunities for export, the size of market and number of players within it and, in a system of systems environment the impact of OSA within one set of component systems on others
within the overall SoS. It is also very time dependent as an initial increase in competition could reduce the number of players in the longer term so increasing the risk of lock-in to a small number of suppliers in the longer term. On the other hand, OSA could open up the competition to non-defence organisations where volume of the wider market enables reduction in costs and price. It is important to understand the likely market behaviours that OSA would introduce for particular systems; this could be modelled using a systems dynamics approach (see for example ‘The Fifth Discipline’ (22)). Further work to develop an appropriate model for UK Defence procurement is recommended.

Decisions to enforce openness in contracts should be informed by believable competition models of likely outcomes.
6 Exemplars

6.1 Type 26

The three questions answered by the team (see Annexe A for details behind the development of the questions) are:

1. How should a complex architecture such as Type 26 (T26) Combat System (CS) be assessed?
2. Does the T26 CS have an appropriate balance of architectural attributes to deliver the range of required benefits?
3. Is any further work required to assess the appropriateness of T26 CS architecture for its intended purpose?

In endeavouring to answer these questions, key findings made by the T26 CS case study assessment team during the process of completing this exemplar are:

1. No known extant technique was found to be available for assessing the overall suitability of complex systems architectures against their intended or desirable benefits.
2. Progress has been made in devising an approach suitable for assessing complex architectures.
3. The inter-dependency between technical architecture and enterprise (architecture) considerations is fully recognised with proposed technical architectures requiring the identification of coherent and viable enterprise architectures.
4. The T26 CS architecture is an advance on current federated CS architectures and possesses a number of features which will both provide defined benefit, and allow future evolution towards the MOSA vision.
5. It is not possible to assess whether this architectural progress is ‘sufficient’ due to the team’s lack of familiarity with the architecture, limited access to the T26 CS requirements, insufficient knowledge of the MoD’s overall strategy, and uncertainty on specific issues such as whether application layer information modelling is being applied and the extent to which open standards (or open specifications) are being adopted.
6. Improved guidance and advice on architecture assessment and open systems is necessary for acquisition professionals and a Desk Officers’ Toolkit is proposed to assist in this respect.

All these specific findings are elaborated upon in a detailed section at Annexe A. The rationale behind them is also provided in this annexe.

6.2 Generic Vehicle Architecture

The team produced the following products as a result of this work:

1) A description of the process in the form of a PowerPoint presentation and report in Annexe B
2) A description of potential follow-on activities and additional areas of benefit

The work highlighted the current situation found in many projects. These projects must address the needs of many constraints, some of which are opposing, yet maximise the benefits that are delivered. In particular, project managers must have a process in which to shape the constraints and the decision process such that a project’s delivery strategy and direction can be determined and implemented. They also need the means to “command and control” and steer the project to the desired end goals.

The process identified for GVA is scalable and could be used in any of the LOSA generic architectures such as Generic Soldier Architecture (GSA) and Generic Base Architecture (GBA) as well as for LOSA. The process is based on the alignment of requirements, assessments and benefits such that data from these activities can be distilled into meaningful information to inform project decision making.
A framework that aligns requirements to benefits through architectural features can be used to assess the relative merits of one architecture over another.
7 DISCUSSION OF RESULTS

7.1 Comparison of Exemplars

The exemplars were deliberately chosen to provide very different features, and the following differences are noted.

- Appetite for mandation
  - GVA mandates adherence to GVA DEF STAN 23-09, whereas T26 has no mandated standards
- Scale of systems under consideration
  - The exemplars are complex in different ways, but in terms of system design, T26 is complicated and of considerable scale compared to GVA.
- Delivery times, budgets and longevity
- Different drivers for need for openness
  - In the case of GVA, the driver for openness is substantially operational agility (i.e. the ability to reconfigure vehicles in theatre), whereas the motivation for T26 concerns systems reuse and through life cost management
- Different maturity of standardisation documentation
- Exemplar approach:
  - Whereas the GVA exemplar team took a bottom up approach to the derivation of appropriate metrics, T26 took a more top down approach by starting with benefits sought.
- GVA scope of architectural consideration is greater in depth (e.g. Power)
- T26 is a specific vehicle whereas GVA should be applied to many vehicles
- Acquisition approach: land is modification of vehicles obtained from elsewhere, whereas ships are built in nation
- New build supplier base (tier 1) is very different
  - There is one tier 1 supplier in maritime, whereas there are many in land domain
- Likely heterogeneity of architectures (maritime is greater degree)
- GVA leads to greater coherence across the fleet, whereas T26 is not considered from a fleet perspective

Nevertheless, there are a good many similarities that emerged between the exemplars and the approaches taken for assessment, as listed below.

- Understanding the problem domain
  - Both approaches require some element of expert knowledge to be applied
- Both separated out technical and enterprise assessment but in different ways
- Both teams have recognised the importance of architecture
- Both teams applied a benefits model approach
- Both assessments involve some level of subjectivity
  - This is probably inevitable with the current knowledge of architecting
- There is a lot of overlap between the ‘ilities that are considered in the benefits models
- Both exemplars have concerns for real-time performance, security (confidentiality), safety, etc.
- Both try to deal with the re-use question (from acquisition perspective)
- Both try to address the commercial environment – to reduce risk of vendor lock-in from MoD perspective

Of course, the question of whether a particular system (exemplar) is sufficiently open could be addressed equally well for any exemplar, but a detailed examination of the requirements would be required to determine what sufficiently means for the exemplar.
7.2 T26 CS Exemplar
The framework has been applied in sufficient depth to the technical architecture of the T26 CS to give confidence that it would provide useful support to decision makers concerning the discrimination between contending architectures against benefits that are sought. However, the task of assessing the enterprise from the perspective of openness has not been tackled in sufficient depth. From the through life perspective, this is a shortfall in terms of the exemplar. Assessment of openness itself has been carried out in the context of programme progress towards a supposed MOSA ideal. The study lacked the depth to determine whether the progress was sufficient in this respect, however, with access to additional information and an increase in resources, it is believed that this question could have been answered. The study has drawn out the importance of recognising the inter-dependency between technical architecture and enterprise (architecture) considerations. This is very important, because the ability of an architecture to enable identified benefits is intrinsically linked to the commercial arrangements under which the programme is contracted insofar as the benefits are linked to openness. Further work is required to address the challenge of making comparison in the case of heterogeneous architectures, which would require the basis for segmentation to be taken into account.

| The relationship of open architecture to benefits sought can only be determined when both the technical and enterprise architecture, and their inter-dependency, are considered. |

7.3 GVA Exemplar
It had originally been intended to apply the framework derived for GVA to the Mastiff contract, but resources proved insufficient to do more that scrape the surface of this application. With respect to the assessment framework, the GVA exemplar highlighted the need for the programme roadmap to be well understood in order to make a meaningful assessment.

It could be argued that the operational benefits that the GVA approach enables have been realised because of modularity, rather than specifically by openness. This is because the focus of benefits is concerned with reconfigurability (technical) in the operational space.

| In some procurements, the benefits sought could be enabled by modularity, without the need to contract for openness. |

7.4 Standards
The use of standards underpins open architectures; however, the number of standards being used by a programme and/or the number of standardised interfaces does not provide a sound measure of openness or quality of solution. In some environments, there are very few standards available (e.g. T26 CS) and so the measure of how many is meaningless. Similarly, the benefits sought will be realised by the choice of standardised interfaces, not by the number.

There is considerable variation in the usefulness of standards and, depending on the extent to which they are tailor-able, the consistency that one can achieve by applying them. The fact that a standard is open does not inevitably imply that it is a good standard. Indeed, standards have been blamed for decreasing innovation and also for leading to supplier lock-in where, for instance, they do not keep pace with developing technologies. The use of standards is necessary to achieve openness, but support is needed to industry to determine which are most appropriate. Where none exist, an open specification may increase openness in a practical sense and serve as the basis for future codification into an open standard.
7.5 Observations on openness and the contracting environment

The WG devoted a considerable amount of time to the question of benefits of open approaches to stakeholders. In the past there have been many comparisons to the success of open approaches in the commercial (non-defence) environment. These comparisons appear to be misleading; in general the benefits to industry of openness depend on the availability of markets of sufficient size and the suitability of components and systems from a commercial market for defence in terms of robustness and security. Within current defence contracting structures, the group determined that the only potential benefits of open approaches (OS/OSA) to industry are the possibility of increased exportability of products and services, and sustainability. The latter is achievable in the context of a move away from large single procurements towards a more incremental procurement strategy. It should also be noted that these observations refer to contracting between MoD and supplier, not to openness further down the supply chain (e.g. through greater use of COTS by industry).

This study does not have sufficient depth to make recommendations concerning the shape of a commercial environment in which OS/OSA have increased value to industry, but it is clear that the current arrangement is inadequate due to restrictions on export opportunity and the risks associated with divulging design data associated with key commercial discriminators.

7.6 So What?

In terms of the impact of the work carried out in WG1 much depends on the extent to which the outputs can be exploited. The definitions have been agreed among the team and these may be used directly in the AOF and SoSA Rulebook. The frameworks for assessment are similar to each other and could be combined into a tailor-able framework for architecture assessment, with particular emphasis on open architecture features for use by procurement professionals and industry to support the development of more effective architectures. It is worth noting that the frameworks developed herein represent an advance on previous assessment frameworks, which tend to be software focused.

There are a number of tools listed in section 8 which could be developed, from the knowledge generated in this activity, into a usable and comprehensive decision support aid for desk officers.

The ideas presented here about openness and, especially, about the benefits to industry, should inform the forthcoming Government White Paper of defence procurement.
8 **DESK OFFICERS’ TOOLKIT FOR ARCHITECTURE ASSESSMENT**

The WG propose assembly of a Desk Officers Toolkit for assessment of (open) architectures. The purpose will be to enable those responsible for managing technical assessment of bids and determining and agreeing user requirements to be able to relate the features of the bid (principally expressed through the architecture) to the benefits being sought. This will lead to a more holistic assessment of architecture options so that the advantages and disadvantages of open solutions will be more equitably considered against other options. This mitigates the observation, of the NDIC SE&OA WG benefits study (12), that a difficulty with introducing open architecture solutions in defence procurement is that because through life aspects are not sufficiently considered, the solutions are ruled out from the initial set to be considered within the COEIA.

The toolset must be constructed in such a way that it is adopted as a decision support aid, NOT as a decision making tool. Furthermore, it should not answer the question “how open?” which would be a fairly meaningless result. The toolkit should provide the Desk Officer with a straightforward means of relating architectural and other aspects of the solution to the benefits being sought so that trading can be better informed and selection from options carried out with more confidence. The tools do not remove the need for architectural competence, but they do bring clarity to the assessment.

The toolset should contain the following tools:

- **Architecture assessment tool** based on the frameworks reported herein. There are a number of assessment tools available (e.g. SEI’s ATO), but these are for the most part concerned with software architecture and do not address the ‘ilities’ (non-functional requirements) of defence systems sufficiently. A finding of the T26 exemplar is that a system level tool based on a structured set of questions has merit, similar in approach to DoD’s OAAT.

  Operational, technical, and commercial benefits should all be assessable by the framework.

- **Roadmap tool** is essential for a clear understanding of (proposed) evolution of the system. The Roadmap is linked to a Maturity Matrix which serves as a score sheet to indicate how far along the proposed evolutionary path a system has travelled. More importantly it provides the desk officer with a simple means of setting benchmarks for the procurement of new systems or changes.

- **Risk profiling tool** to enable appropriate consideration of risk and change in risk over the lifecycle of the system.

- **Cost modelling tool** appropriate for estimating the life cycle cost profile. It should be noted that, whilst some cost data cannot be shared, the cost model (without its source data) should be openly available to industry so that it can offer the most appropriate open solutions for consideration.

- **Competition model**: because one of the stated reasons for adoption of open approaches is the desire to increase competition, the toolkit should include a model that will indicate the likelihood of, and the extent to which, an open systems approach will increase competition for the type of system under consideration.

  Linked to the competition model should be an indicator of the likely impact on exportability and sustainability for industry.

- **Maturity Scale** associated with main benefits likely to be sought

  Additional support should be included in terms of:

  - **Guidelines on the use of Open Standards**, which would include a list of applicable standards and guidance on their quality (e.g. a OS register)

  - **Compliance Matrix** to provide the desk officer with a check list to ensure that the fullest set of architectural benefits have been considered and properly assessed.
The toolset must be constructed in such a way that it is clearly understood to be a decision support aid and NOT a decision maker. The tools it contains must be loosely coupled such that changes made in the estimate of one set of features are consistently carried through into other estimates. Many of the components of the toolset already exist, or could be developed from currently used tools. These, together with any newly developed tools, must be appropriately integrated with the existing toolsets. Given the stage at which the toolset is likely to be used, it is important that it is constructed from sufficiently simple tools that the cost of using it will not be unnecessarily burdensome. The toolset should be built in such a way that it can be used to suggest or identify desirable architectural features based on the definition of benefits sought.

It is recommended that the Desk Officer Toolkit and Support be developed. This will require the following steps:

- Detailed specification created
- Review current cost tools (esp. those already in use by MoD)
- Create or obtain risk profiling tool
- Create outline Systems Dynamics model of competition
- Generate report on OAAT and how it should be changed to suit UK use
- Publish rationalised benefits model based on the work of this WG

Further details of the specification for the proposed toolset are available in Annexe C

Adoption of open architectures relies on analysis of options by procurement professionals; a Desk Officers’ Toolkit for architecture assessment is required to inform these analyses.
9 SUPPLEMENTARY ACTIVITIES

Three supplementary activities are reported in this section. An analysis by UKCeB of the defence market in the context of use of standards and tools; an application of the metrics derived by the core working group members to a case study in close air combat, by SyntheSys; and a presentation to the Object Management Group of the work carried out in this working group and seeking opportunities to collaborate in the future.

9.1 Tools for Systems Design

Mr. David Pearce, of UKCeB, has considered product lifecycle management and standards. He is concerned that PLM (Product Lifecycle Management) will not be well-served in defence until common (and open) standards are agreed for toolsets used by industry and MoD. He advocates the adoption of an environment which is standards-based and open in order to facilitate a single source of all data for design, manufacture, and supply chain processes across vehicle design and manufacture. His full paper is provided in Annexe D.

9.2 Close Air Combat case study

Dr. Kirsten Sinclair, of SyntheSys Ltd., has used a selection of the metrics derived by the working group within their engineering systems of systems method to evaluate one critical area of acquisition (‘Systems contribution to system-of-systems’) and one lowest level need (‘security’) for a Close Air Support (CAS) case study. Through this process, SyntheSys has been able to indicate a possible way of assessing the impact of openness needs in evolving system-of-systems. Furthermore, although the case study used a small sample of the proposed metrics, SyntheSys believes the process used above indicates the potential usefulness of the defined openness measures. A detailed description of this case study is provided in Annexe E.

9.3 Object Management Group (OMG)

The OMG has been an international, open membership, not-for-profit computer industry consortium since 1989. OMG Task Forces develop enterprise integration standards for a wide range of technologies, including: Real-time, Embedded and Specialized Systems, Analysis & Design, Architecture-Driven Modernization and Middleware, and Systems Engineering.

The Working Group noted that the GVA programme is already implementing the Data Distribution Service (DDS) specification from the OMG. This consideration led to an overview presentation of the WG1 objectives and activities by Prof. Dickerson to the Quarterly Technical Meeting of the OMG, in March 2011, for the purpose of exploring how the MoD and OMG might collaborate on Open Systems specifications.

The presentation was made to the four OMG Working Groups who expressed interest in an enduring dialog with the MoD. The groups were: C4I Domain Task Force (DTF), Middleware and Related Services (MARS) Platform Task Force (PTF), Mathematical Formalism Domain Special Interest Group (DSIG), and the OMG Business Development. They were willing to engage with the MoD to help navigate through the large body of OMG specifications. The objective of the defence contractors involved with the OMG is to develop open specifications for systems that will be built or procured.

Specifications developed in collaboration with the OMG can provide the MoD with a more open approach to system acquisition. Open specifications can be used both to increase access to the commercial market and to improve system, and system of systems, integration. Collaborative work on open specifications could also be useful to other SoSA CF WGs and could become a vehicle to attract other interested parties to participate or seek representation at the Community Forum. Open standards are also a good vehicle for raising the visibility of the work of the SoSA CF with NATO and the US DoD.
The MoD can expand its involvement with the OMG by identifying specific areas of interest useful to the MoD and, wherever possible, aligned with ongoing specification development at the OMG.

The MoD can work with OMG to establish create the specifications that will enable greater openness in UK defence contracting

Exploitation

To establish a relationship between MoD and OMG, then specific areas of interest to the MoD should be identified and alignment sought with ongoing specification development within OMG. A knowledgeable representative from MoD is needed to communicate the MoD objectives in technique terms and to influence the development of the above identified aligned specifications. It is also possible to develop new specifications and, with sufficient MoD interest and initiative, mechanisms exist to fast track these through the OMG process.
10 Good Practice for SoSA Community Forum Working Groups

WG1 has operated differently from other WGs set up in the same first cluster: it has required a high commitment from participants through secondment into a focused, collaborative activity. This has enabled the group to address the challenge in some detail and to rapidly produce exploitable outputs. This section identifies the contributory factors in the group’s success and the pros and cons of this form of engagement within the SoSA CF.

10.1 Effectiveness

The chief enablers of effectiveness, considered to be the depth and relevance of the study in such a short time, are the focused nature of the study and the seniority/experience of the participants. The assignment of MoD staff directly involved with the exemplars to the seconded activity was also a major factor in focusing the delivery of the WG outputs.

A number of industrial participants remarked that the neutrality provided by having an academic lead and host the activity had been beneficial in terms of sharing information and in encouraging industrial participation.

10.2 Contractual

At the SoSA CF launch, it was noted that working groups would be encouraged to work under the Niteworks® contract (3). This is not possible for every organisation, and so an agreement was drafted that drew heavily on the Niteworks® agreement in terms of IPR, but did not have the same conditions regarding selection of participants and liability. It has taken longer to gain agreement than had been anticipated, although in fairness, the task has largely been one of dotting i’s and crossing t’s. The agreement that has been finally concluded is believed to be suitable for future working group activities and may be reused for that purpose.

The agreement drafted for SoSA CF WG1 may be reused for similar activities in the future.

10.3 Working Group links to SEIG

At the working level, the links from the WG to SEIG have been very strong and beneficial in terms of achieving the objectives. Engagement at a more senior level has been insufficient during the course of the work, but this was significantly improved towards the end of the project. Such engagement is vital if outputs are to be exploited effectively by the SEIG.

10.4 Participant Benefits

It is evident that much of the benefit from the SoSA CF OSA WG in undertaking this (and the other) case study and progressing the more general architectural issues has been gained by MoD. This is largely because work which would more usually have been funded has been undertaken on a gratis basis by the contributing organisations. However the intention behind this activity was to also provide benefit to the industrial (including academic) participants so that their involvement could also be justified. It is therefore considered important to elaborate the benefits to both MoD and industry. These are considered to be:

• Demonstration to all participating parties that progress can be made on this challenging topic and that there is at least a possibility that the current uncertainty as to the benefits and detriments of new architectural forms can be resolved
• Achieving advancement of the collective (and individual) understanding and convergence on architectural matters, including architectural forms and attributes, their benefits and detriments, and architecture assessment approaches
• Determining that architectural progress is being made with the T26 CS architecture based upon an initial assessment, but recognition that a) the extent of progress may not be adequate, and b) a more detailed investigation is warranted to confirm or refute this.

Value will only be realised to all parties if effective and timely exploitation of the outputs is achieved.

Value to the MoD, Industry, and Academia of participation in WG1 (and other WGs) will only be realised through timely and effective exploitation of the outputs.
11 CONCLUSIONS

The foregoing study has led to the following conclusions:

11.1 Openness and Benefits

- **Ask the right question**: Openness should not be a requirement in its own right. Requirements should focus on the benefits being sought, which may or may not be enabled by openness.
- **Modularity delivers benefits**: many of the benefits sought are delivered by modular design. Additional benefits may be achieved through open architectures, but modular and open should not be confused with each other. Note that modular is a technical concern, whereas open is, in general, a commercial concern.
- **Industry Benefits**: The only benefits of the open approach to industry at the MoD-industry contracting level may be through increased export opportunity or better sustainability. These benefits are not inevitably realised.
- **Commercial environment to enable OS/OSA**: wholehearted implementation of the charter for adopting open systems in defence acquisition (5), (7) will be a significant step towards an acquisition structure and culture to realise the opportunities of OS/OSA.
- **General applicability of these results**: An important conclusion of the work has been the need to treat the matter of OS/OSA as being particular to each case. A corollary of this is that care must be taken in generalising the outcome of the exemplar studies to other cases. In particular, it is worth noting that OS/OSA may be much more straightforward to achieve for systems that are purely software-based.

11.2 Assessment

- **Assessment for Openness is do-able**: assessment of attributes associated with openness and related to a range of benefits to compare contending solutions is achievable
- **Architecture-based assessment is appropriate**: Architecture is important in delivering benefits. The assessment must be for benefits sought, not openness per se.
- **Recognise coupling between Technical and Enterprise Architecture**: categorisation of benefits should recognise technical and enterprise, or similarly PCTR (Performance, Cost, Time, and Risk).

11.3 Definitions

- **SoSA Rulebook and AOF require well-founded definitions**: The WG1 has derived a set of definitions and concepts that should be included in the SoSA rulebook and that will aid achievement of common understanding. Progress in OS/OSA cannot be made without the agreement and publication of key definitions.

11.4 Open Standards

- **Open and Closed do not exist as absolutes**: Openness is a continuum that ranges from a community of interest (with shared understandings) to Open Standards
- **The use of open standards is not in itself meritorious**: Assessment of use of open standards should take into account: availability, control, and quality. Application of an open standard could undermine certain benefits.
- **The quality of open standards should be assessed**: clear guidance on the quality of open standards does not currently exist.
- **Object Management Group**: engagement with OMG on aligned standards work may benefit the MoD in terms of developing a more open contracting environment.
11.5 Required further work

- **Architectural assessment**: architecting and architectural assessment are immature disciplines.
  - Architecting and architectural assessment techniques from software engineering are insufficient. They do not cover the full range of interest within the ‘ilities.
- **Heterogeneous Architectures**: Heterogeneous architectures are inherently difficult to assess – but these are often necessary architectures.
- **Architectural impact on successful design**: characterisation is required of the technical approaches that contribute to successful design; these should be based on (additional) case studies.
- **Enterprise Openness**: assessment of enterprise openness should be developed, based on the ideas presented in section 5.5, and thence the relationship between technical and commercial architectures and the incentivisation of enterprise openness can be addressed.
- **MoD representatives working on T26 exemplar recommended that a more detailed assessment of T26 architecture be made, including completion of the assessment framework and further discussion with the project to elicit architectural information.**

11.6 Implications for DE&S

- Requirements need clarity of concern: requirements to achieve benefits NOT requirements for openness
- There is a need for desk officers’ toolkit for architecture assessment to enable open considerations to be properly taken into account
  - Hence, investment in creation and/or selection of appropriate assessment tools
  - Note that the cost model (not data) should be open to enable more open offerings from industry
- There is a need for clear policy and control of architecture ownership
- There is a need for a defined list of interface specifications
- Progress is unachievable without agreed and common definitions: update SoSA Rulebook and AOF to incorporate definitions

11.7 Implications for Industry

- Characterise technical approaches that contribute to successful design
- Recognise the role of architecting in the delivery of solutions

11.8 Implications for Academia

- Need to develop additional educational opportunities in the skill of architecting
- Research into architecting and architecture assessment, and improved cost, risk, and enterprise models
- The working group observed that architectural description techniques, such as UML and SySML, were not suitable for communicating effectively with non-specialists and that there is a need for artefacts to enable non-specialists to understand the architectural implications more easily.
12 Recommendations

12.1 Recommendations to SEIG for further work for SoSA CF in open systems

It was noted in section 2.1 that the work drew on requirements from a limited number of organisation types. The conclusions of this report should be explored with organisations from outside the defence domain and with SMEs.

Some terms requiring definition remain outstanding; the remaining key terms should be defined using the formal process applied herein.

The definitions derived by WG1 should be considered by other WGs and the SEIG ontology team for adoption or negotiation to agree common definitions.

The group did not address enterprise assessment or the commercial constructs under which OS/OSA provides benefit to industry; further study should be undertaken to develop advice on contracting environments that support openness.

The T26 exemplar team identified more detailed assessment measurement that is required to support the project in determining sufficiency of openness within the project; the more detailed assessment measurement identified in section 5.2 should be analysed to support the T26 programme.

12.2 Recommendation to SEIG for exploitation of outputs

The frameworks developed for the exemplars should be combined into a single framework and the resulting framework expanded through consideration of other exemplars. Funded development of the architecture assessment framework is required to provide a tool for MoD to support procurement decisions that best meet the customer needs within the constraints of the SoSA principles.

To support procurement professionals in the adoption of OS/OSA within procurements, a funded activity is required to assemble a desk officer’s toolkit for architecture assessment (as described in section 8).

Initial engagement with OMG has suggested that the likelihood of realising MoD aspirations in open systems will be increased through further engagement by MoD experts on aligned standards work. Initial exploration of collaboration with OMG on aligned standards work should be carried out by a knowledgeable representative of UK MoD.

12.3 Recommendations to SEIG on the conduct of future working groups

The agreement developed to cover WG1 should be re-used for other SoSA CF working groups that convene on a voluntary (i.e. unfunded) basis.

12.4 Recommendations to DE&S Research Community

Research should be supported to develop tools for the desk officer’s toolkit where current tools are insufficient or not developed. This should be preceded by a guiding assessment of current tools.

Research should be supported to develop the means through which architectural features can be communicated more effectively to non-experts. (More effective than the techniques currently available such as UML and SySML)

12.5 Recommendation to industry and MoD training communities

Systems Architecting is a key skill required to enable better acquisition decisions and the realisation of the benefits of OSA/OS. Whilst there are many training opportunities in the use of architecting tools, there are few educational opportunities with respect to the more fundamental skills of
architecting. High quality educational establishments and providers should be encouraged and supported in the creation of advanced courses in the skills of systems architecting.
13 ACKNOWLEDGEMENTS

We acknowledge the support of Atkins Limited, BAE Systems Integrated System Technologies Limited, General Dynamics UK Limited, Lockheed Martin UK Integrated Systems and Solutions Limited, Loughborough University, MoD DE&S (LE PPS-SEAD-E&TM2), MoD DE&S (Software Supportability Team), MoD DE&S SE SEIG-Maritime2, Niteworks®, QinetiQ Limited, SELEX Communications Limited, SELEX Galileo Limited, SyntheSys Limited, Thales UK Limited, UKCeB.

We are grateful to Carl Evans for his diligent support to the Working Group.
14 WORKS CITED


12. **Oxenham, David.** *Articulating the Benefits of Open Architectures.* s.l. : Presentation of sub-group the the NDIC WG or SE&OA, 19th Oct. 2009.


15 **ACRONYM LIST**

<table>
<thead>
<tr>
<th>CRONYM</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AESoS</td>
<td>Acquisition Enterprise System of Systems</td>
</tr>
<tr>
<td>AOF</td>
<td>Acquisition Operating Framework</td>
</tr>
<tr>
<td>ASCOD SV</td>
<td>Austrian-Spanish Co-operative Development (military vehicle manufacturer; Madrid, Spain) Scout Variant</td>
</tr>
<tr>
<td>ASD</td>
<td>AeroSpace and Defence Industries Association of Europe</td>
</tr>
<tr>
<td>ATAM</td>
<td>Architecture Trade-off Analysis Method</td>
</tr>
<tr>
<td>ATO</td>
<td>Architecture Trade Off</td>
</tr>
<tr>
<td>A&amp;D</td>
<td>Architecture and Design</td>
</tr>
<tr>
<td>C2</td>
<td>Command &amp; Control</td>
</tr>
<tr>
<td>C4</td>
<td>Command, Control, Communications, and Computers</td>
</tr>
<tr>
<td>CAD</td>
<td>Computer-Aided Design</td>
</tr>
<tr>
<td>CADMID</td>
<td>Concept Assessment Development Manufacturing In-Service Disposal (MoD UK procurement policy)</td>
</tr>
<tr>
<td>CAM</td>
<td>Computer-Aided Manufacturing</td>
</tr>
<tr>
<td>CAS</td>
<td>Commercially Available Software</td>
</tr>
<tr>
<td>CF</td>
<td>Community Forum</td>
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<td>CIM</td>
<td>Common Information Model</td>
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<tr>
<td>CMS</td>
<td>Content Management System</td>
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<tr>
<td>COEIA</td>
<td>Combined Operational Effectiveness Investment Appraisal</td>
</tr>
<tr>
<td>CONEMP</td>
<td>Concept of Employment</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial Of The Shelf</td>
</tr>
<tr>
<td>CS</td>
<td>Combat System(s)</td>
</tr>
<tr>
<td>DDS</td>
<td>Data Distribution Service</td>
</tr>
<tr>
<td>DE&amp;S</td>
<td>Defence Equipment and Support (UK)</td>
</tr>
<tr>
<td>DII</td>
<td>Defence Information Infrastructure</td>
</tr>
<tr>
<td>DIS</td>
<td>Defence Industrial Strategy</td>
</tr>
<tr>
<td>DLoD/DLOD</td>
<td>Defence Lines of Development</td>
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<tr>
<td>DoD</td>
<td>Department of Defense (US)</td>
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<tr>
<td>DSI/G</td>
<td>Domain Special Interest Group</td>
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<tr>
<td>EA</td>
<td>Enterprise Architecture</td>
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<tr>
<td>EP</td>
<td>Equipment Planning</td>
</tr>
<tr>
<td>ESoS</td>
<td>Engineering Systems of Systems (Research Group at Loughborough)</td>
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<tr>
<td>GBA</td>
<td>Ground Based Architecture</td>
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<tr>
<td>GCS</td>
<td>Global Combat Ship</td>
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<tr>
<td>GFX</td>
<td>Government Furnished Equipment</td>
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<tr>
<td>GSA</td>
<td>Generic Soldier Architecture</td>
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<tr>
<td>GVA</td>
<td>Generic Vehicle Architecture</td>
</tr>
<tr>
<td>HMI</td>
<td>Human-Machine Interface</td>
</tr>
<tr>
<td>HUMS</td>
<td>Health and Usage Monitoring System</td>
</tr>
<tr>
<td>ISAF</td>
<td>International Security Assistance Force (UN program)</td>
</tr>
<tr>
<td>IS&amp;LANs</td>
<td>Information Systems and Local Area Networks</td>
</tr>
<tr>
<td>ISTAR</td>
<td>Intelligence, Surveillance, Target Acquisition, and Reconnaissance (warfare)</td>
</tr>
<tr>
<td>ITT</td>
<td>Invitation To Tender</td>
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<tr>
<td>IP</td>
<td>Intellectual Property</td>
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<tr>
<td>IPR</td>
<td>Intellectual Property Rights</td>
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<tr>
<td>LOSA</td>
<td>Land Open Systems Architecture</td>
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<tr>
<td>MARS [US]</td>
<td>Middleware and Related Services</td>
</tr>
<tr>
<td>MCB</td>
<td>MOSA Capability Builds</td>
</tr>
<tr>
<td>MCDA</td>
<td>Multi-Criteria Decision Analysis</td>
</tr>
<tr>
<td>MCS</td>
<td>Monitoring, Control and Surveillance</td>
</tr>
<tr>
<td>MDA</td>
<td>Model Driven Architecture</td>
</tr>
<tr>
<td>MoD</td>
<td>Ministry of Defence (UK)</td>
</tr>
<tr>
<td>MOTS</td>
<td>Military Off-The-Shelf</td>
</tr>
<tr>
<td>MOSA</td>
<td>Modular Open Systems Architecture (UK)</td>
</tr>
</tbody>
</table>
NDIC SE&OA WG  National Defence Industries’ Council Systems Engineering and Open Architectures Working Group

NFR  Non-Functional Requirement

OAAT  Open Architecture Assessment Tool

OC  Operating Centre

OEM  Original Equipment Manufacturer

OMG  Object Management Group

ORBAT  Order of Battle Report

OSA  Open Systems Architecture

OTS  Off-The-Shelf

PCTR  Policy and Compliance Tailoring Report

PDM  Product Data Management

PID  Project Information Document

PIM  Platform Independent Model

PLM  Product Lifecycle Management

PSM  Platform Specific Model

PTF  Platform Task Force

QoS/QOS  Quality of Service(s)

RDG  Research & Development Group (of NDIC)

S2C2  Sustained Surface Combatant Capability (S2C2) Pathfinder studies

SCE  Safety Critical Element

SME  Small and Medium sized Enterprise

SNI  Shared Network Infrastructure

SoSA  Systems of Systems Approach

SRD  System(s) Requirement(s) Document

SSE  System Safety Engineering

STEP  Standard for the Exchange of Product Model Data (ISO 10303)

T26  Type 26 (Frigate)

T&E  Test and Evaluation

TDL  Tactical Data Link

TLCM  Through Life Capability Management

TT  Tiger Team

UOR  Urgent Operational Requirement

URD  User Requirement Document

VSI  Vehicle System Integration

WG  Working Group
APPENDICES AND ANNEXES

APPENDIX A: THE SoSA PRINCIPLES .............................................................................. 54
APPENDIX B: WORKING GROUP 1 REQUIREMENTS AND ASSUMPTIONS ............... 56
APPENDIX C: DEFINITIONS .......................................................................................... 63

ANNEXE A: TYPE 26 EXEMPLAR ............................................................................. 70
ANNEXE B: GVA EXEMPLAR ....................................................................................... 79
ANNEXE C: DRAFT SPECIFICATION FOR A DESK OFFICERS TOOLKIT TO SUPPORT ARCHITECTURE ASSESSMENT .................................................................................................................. 100
ANNEXE D: UKCeB REPORT ON TOOLS ................................................................... 103
ANNEXE E: SYNTHESYS REPORT ON CLOSE AIR COMBAT CASE STUDY ............ 107
APPENDIX A: THE SOSA PRINCIPLES

The SoSA Principles are intended to guide the way in which Defence acquires capability, irrespective of how the individual acquisitions are sponsored and funded (23).

MoD requires that the SoSA Principles be applied by decision makers to guide behaviours throughout the acquisition lifecycle and particularly in the early phases when shaping capability options. The SoSA Principles are:

**P1: Unifying the Defence Enterprise**

The MoD will achieve common business and operational goals and priorities, which will be delivered through a governance framework.

The framework will be used to assign authority and direct dedicated delivery teams.

Delivery teams will be responsible for ensuring collaboration in achieving these goals, in delivery and through life management of coherent solutions and their acceptance into service.

**P2: Driving business and operational effectiveness**

Requirements will include the through-life dimensions of concept, design, development, use and support and disposal (i.e. across the product/service lifecycle), across all Defence Lines of Development (DLoDs). Dimensions to be considered include: Financial, Exportability, Performance, Assurance, Reliability, Security, Safety, Sustainability, End-to-end military integrity, Business continuity, Supportability.

Solutions will be developed to deliver business and operational effectiveness that is informed by experience.

**P3: Minimising diversity**

Solutions will be delivered to achieve operational effectiveness, whilst ensuring that the number of different systems, components, tools, facilities and infrastructure used to generate Defence capability (this spans multiple Force Elements) is minimised across all Defence Lines of Development (DLoDs).

**P4: Designing for reuse**

All Defence Lines of Development (DLoD) will deliver solutions by exploiting those already in existence and ensuring that new solutions and their constituent parts are designed in a way that allows for their reuse across the Defence Enterprise.

**P5: Building with proven solutions**

Where possible, solutions will be Off the Shelf (OTS) based. Only when this is proven to be ineffective, in terms of cost, time or performance, will tailored OTS or bespoke solutions be procured.

**P6: Ensuring commonality of services across the Defence Enterprise**

Common business and operational activities will be supported by the same service irrespective of organisational and operational location, security domain and infrastructure.

**P7: Designing for flexible interoperability**

Solutions will be designed to meet their Interoperability needs. Solutions will be of modular design aligned to business process allowing solutions to be responsive to changes in acquisition and operations.

**P8: Adopting open standards**
Solutions will be designed with open standards in a manner that is not detrimental to security, innovation and operational superiority.

**P9: Information as an asset.**

Solutions will be developed to enable information to be managed and exploited across Defence, maximising accessibility without compromising security.
APPENDIX B: WORKING GROUP 1 REQUIREMENTS AND ASSUMPTIONS

SoSA CF WG1 REQUIREMENTS

The requirements below were generated by the working group members as requirements for the working group activities; they include MoD and industry requirements developed from inputs from the working group members on behalf of their organisations and including requirements identified by DES SE SEIG-DepHd.

MoD Requirements

<table>
<thead>
<tr>
<th>ID.</th>
<th>Requirement</th>
<th>How Requirement will be met</th>
<th>Requirement status at close of activity (relevant report section in parentheses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC01</td>
<td>When is OS/OSA the right approach?</td>
<td>Use of metrics to discriminate between options – link to benefits and detriments; metrics should quantify the benefits realised from OS.</td>
<td>Done (11.2)</td>
</tr>
<tr>
<td>RC02</td>
<td>Define what OS/OSA user/systems requirements and metrics are.</td>
<td>This is already in the work plan. Relationship of metrics to benefits sought and detriments. SoS requirements must be testable or otherwise addressable (to include the operational level).</td>
<td>Achieved – for case studies; further work required to generalise further. (5)</td>
</tr>
<tr>
<td>RC03</td>
<td>Demonstrate how OS/OSA benefits are realised and realisable.</td>
<td>Use exemplars to illustrate. Apply metrics to benefits and detriments in exemplars.</td>
<td>Achieved for T26 (5.2) Not achieved for GVA</td>
</tr>
<tr>
<td>RC04</td>
<td>Identify OS/OSA benefits to technology refresh.</td>
<td>Technology refresh will be realised as a benefit or detriment related in exemplars. Need to consider through life.</td>
<td>Achieved for exemplars (7.3)</td>
</tr>
<tr>
<td>RC05</td>
<td>Influence Support Solution Envelope (SSE), AOF, SoSA Rule Book, etc.</td>
<td>Recommendations and advice reported in form suitable for inclusion in AOF etc., but can cite other examples for future analysis, e.g. Naval Open Architecture Contract Guide Book for Program Managers dtd 30 June 2010.</td>
<td>Achieved (3, 4, 11)</td>
</tr>
<tr>
<td>RC06</td>
<td>Identify enterprise level changes to MoD attributable to shift to OS/OSA.</td>
<td>Identify enablers and barriers to inform advice as related to the exemplars. Consider OSA as insulation to enterprise changes (like CIM/PIM in MDA). MoD to focus decider role and industry to focus on supplier role (PSM like)? Use exemplars</td>
<td>Not achieved</td>
</tr>
</tbody>
</table>
only to identify enablers and barriers but can cite other examples for future analysis.

| RC07 | Effect of OS/OSA on industry collaboration; e.g. interface specifications, competition, and vendor lock-in. | Use exemplars to analyse effects, e.g. what effects did GVA OSA have on industry collaboration? | Partially achieved (5.5) |

Justification of the SoS Approach:

<table>
<thead>
<tr>
<th>ID.</th>
<th>Requirement</th>
<th>How Requirement will be met</th>
<th>Requirement status at close of activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC08</td>
<td>WG1 outputs need to embody the principles.</td>
<td>Apply principles to exemplars; specifically report on application of principles: map the Principles and the Rule Book into the exemplars and analyse the benefits and detriments. Make recommendations for examples and exemplars for further analysis.</td>
<td>Achieved (7.3)</td>
</tr>
</tbody>
</table>

Identification of potential TLC savings and cost profile management:

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<tr>
<th>ID.</th>
<th>Requirement</th>
<th>How Requirement will be met</th>
<th>Requirement status at close of activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC09</td>
<td>Align with commercial practice to reduce cost by having greater access to the commercial market.</td>
<td>Identify examples (including potential) from exemplars of openness enabling MoD access to commercial markets; not just components but also commercially available skills (e.g. Java vs. Ada).</td>
<td>Not achieved</td>
</tr>
<tr>
<td>RC10</td>
<td>How to explicitly trade-off legacy systems and components vs. open systems?</td>
<td>Report on implications of legacy systems in exemplars with possible mitigation strategies based on an OS/OSA approach used to deal with obsolescence.</td>
<td>Partially achieved (5)</td>
</tr>
</tbody>
</table>

Outline Specification of the Desk Officer Tool Kit / Guidance to implement policy:

<table>
<thead>
<tr>
<th>ID.</th>
<th>Requirement</th>
<th>How Requirement will be met</th>
<th>Requirement status at close of activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC11</td>
<td>User friendly and useable; include an ‘Idiot’s Guide’ to the tool kit.</td>
<td>John Fagg/Dave Huggett to validate outline specification (with colleagues).</td>
<td>Achieved (8, Appendix ???)</td>
</tr>
<tr>
<td>RC12</td>
<td>Relation to cost model (how much savings by when), URD, SRD? E.g. MoD must show cost savings within 1 to 5 years.</td>
<td>Capture the characteristics of cost models in exemplars and propose requirements for cost modelling tool in outline specification.</td>
<td>Achieved for GVA (7.3)</td>
</tr>
<tr>
<td>RC13</td>
<td>Recommendations for further investigation.</td>
<td>Recommendation included in report.</td>
<td>(11.5)</td>
</tr>
</tbody>
</table>

Common approach OS procurement across environments and domains: (post SDSR world)

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<thead>
<tr>
<th>ID.</th>
<th>Requirement</th>
<th>How Requirement will be met</th>
<th>Requirement status at close of activity</th>
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</thead>
<tbody>
<tr>
<td>RC14</td>
<td>Integrate to new Green Paper (new version DIS).</td>
<td>Highlight any differences with the Green Paper.</td>
<td>Achieved (Meeting 16th June 2011)</td>
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</table>
## Industry Requirements

<table>
<thead>
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<th>ID</th>
<th>Requirement</th>
<th>How Requirement will be met</th>
<th>Requirement status at close of activity</th>
</tr>
</thead>
</table>
| IR01   | How might defence OS/OSA contracting and acquisition strategies satisfy sustainable business goals?  
Issues to consider:  
- Competition Space  
  - Specialisation or market domination  
  - Standards generally found in areas of specialisation where many competitors exist  
- Needs for standards for to create a stable competitive environment or to gain a commercial advantage  
- Roles as system/component suppliers or system integrators or both.  
  - Selling IPR  
  - Supply Chain advantages | Compare and contrast the two OS/OSA contracting and acquisition approaches between the two exemplars. | Not achieved |
| IR02   | How does selection of Design Authority and control of the architecture boundaries affect the integrator and the system suppliers?  
- Is Industry able to compete in this market?  
  - Design Authority roles are generally long contracts (10-15 years) and based on through life issues  
  - Where do Design and Architecture Authority lie?  
  - Who is responsible for dealing with or addressing emergent | These questions will be addressed in the exemplars. Other governance models for Design and Architecture Authority will be cited. | Partially achieved (5.5) |
behaviours? Who holds the risk?

- Can MoD policy support competitive business behaviours at the different levels – Sys of Sys integrator, Sys Integrator or component/Sys Supplier?
- This role is generally shared with MoD
- What is the MoD policy on vertical versus horizontal integration?

| IR03 | Is there / can there be a Sys of Sys Integrator role that MoD is willing to compete to industry? This role is generally shared with MoD | This question is beyond the scope of the study but the exemplars can address the question of whether there was a need for an industrial SoS Integrator. | Inconclusive |

| IR04 | Can the adoption of MoD OS/OSA policy allow industry to drive down manufacturing and other development and sustainment costs by commoditising products? | The exemplars may be insufficient to answer this question. Industry might consider suggesting an OS/OSA policy that recognises their commercial interest. Also can cite examples of OS/OSA policy for future study. | Not addressed |

| IR06 | What is the effects MoD OS/OSA policy on competitive discriminators? Market Discriminators Innovation and inventiveness at both the system, architecture and the component levels | The exemplars may be insufficient to answer this question. Industry might consider suggesting an OS/OSA policy that recognises their commercial interest. Also can cite examples of OS/OSA policy for future study. | Partially achieved (5.5) |

**Certification and Acceptance**

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<th>ID.</th>
<th>Requirement</th>
<th>How Requirement will be met</th>
<th>Requirement status at close of activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR07</td>
<td>How to ensure compliance of subsystems and system for open system architectures?</td>
<td>The question of compliance will be addressed through analysis of the GVA exemplar. The answer to this question links back to the MoD metrics question.</td>
<td>(7.3)</td>
</tr>
<tr>
<td>IR08</td>
<td>Is there an information model that is sanctioned and accepted or does one need to be established?</td>
<td>An information model is needed for any OS/OSA approach details of what such a model should look like will use the GVA exemplar as a starting point. The Land Data Model will also be used. Other examples may be cited.</td>
<td>Not addressed</td>
</tr>
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</table>

**IPR and Risk**

<table>
<thead>
<tr>
<th>ID.</th>
<th>Requirement</th>
<th>How Requirement will be met</th>
<th>Requirement status at close of activity</th>
</tr>
</thead>
</table>
| IR09 | How will IPR be respected and managed within the architecture?  
|      | • How will open architecture boundaries be used?  
|      | • What are the drivers and benefits and to whom? | The exemplars should give some insights. Some IP is embedded in the data model. Other examples should be cited, e.g. C-130 data base? | Not achieved |

| IR10 | What is the effect of an OS/OSA approach on how are the Prime contractor / lead contractors and subs selected and managed as part of the acquisition strategy?  
|      | • Within Maritime, there is a prime contractor who can select the lower level integrators  
|      | • Sometime MoD determines who will be the sub-contractors and integrators  
|      | • With these decisions comes risk liability – Which is liable? The Contractor or MoD? | Can be addressed through the exemplars. There are a variety of other models that need to be cited. | Partially achieved (6) |

| IR11 | How is use of GFX mandated by MoD?  
|      | • This is a Re-use issue, but use of GFX could be a cost and risk driver.  
|      | • “Build for but not with” policies. When is this cost effective and when is it too constraining or requires too much effort to clarify. | Both exemplars have experience with GFX which should be examined in light of the OS/OSA approaches and models. (How was GFX done in the exemplars?) | Not addressed |

| IR12 | How does the use of GFX influence the open architecture and the solution options considered?  
|      | How does OS/OSA influence GFX?  
|      | • Use of GFX will be more common in the future as sys from decommissioned ships are used on new ships. | Both exemplars have experience with GFX which should be examined in light of the OS/OSA approaches and models. (How was GFX done in the exemplars?) | Not addressed |
**SoSA CF WG1 Assumptions List**

The objective of the Open Systems WG is to provide advice on how MoD and industry should specify “open systems” for procurement. This objective implies that open systems are regarded as a worthwhile aim affording benefits to one or more stakeholders in defence procurement. As a result of work that preceded the WG within the NDIC SE&OA WG, and elsewhere, there are a number of assumptions that provide a backdrop to the Open Systems WG activities; these are listed below.

**Assumptions concerning the nature of openness/open systems/open systems architectures**

1. Systems have degrees of openness; i.e. no system is ever fully open or fully closed.
2. The degree of openness required is not necessarily the same from one system to the next; i.e. the required openness is variable according to context and system.
3. It may be impossible to explicitly quantify the benefits of Open Systems and/or Open Systems Architecture for certain areas of application, due to lack of comparative data, enterprise impact, etc.
4. Open Systems and Open Systems Architecture are not appropriate to all systems.
5. Open systems concepts may be applied across all domains\(^{11}\) and all industrial sectors.
6. Modularity and openness are not the same, although they may be related to each other.
7. Commercial Off-The-Shelf (COTS) insertion does not necessarily imply that an Open Systems Architecture is being used. To be clear, COTS insertion may be present whether or not OSA is used.

**Assumptions concerning implementation of open systems and open systems architecture approaches**

8. Procured open systems will be compliant with existing standards or agreed baselines regulated by a governing authority (defined in ITTs etc.). Stated simply, this means that an open system can only be created if there is a predefined standard within which it must comply.
9. Standards for openness will evolve over time and will need to be funded (including matters such as backward compatibility and obsolescence, etc.)
10. There will need to be a body to maintain and manage evolving or emerging standards.
11. Open systems will not preclude the incorporation of legacy and bespoke equipment.
12. Open systems will not be allowed to compromise safety and/or security.
13. Second order issues (non-functional), such as security and safety, can be solved for open systems.
14. Road maps will be a key management tool for creating and maintaining openness for a project or programme.
15. Benefits due to Open Systems potentially accrue through both capability insertion and systems maintenance.
16. Open systems approaches will facilitate effective technology refresh on projects.
17. The adoption, and implied need for mandatory use (see assumption 20), of open systems will impact innovation. The impact could be positive or negative, depending on the context.

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\(^{11}\) Domain implies and area of technical or social specialisation
Assumptions concerning the specific implementation of open systems and open systems architectures by UK MoD

18. The MoD and Industry will need to agree a set of principles when using an open systems approach in a competitive procurement (e.g. appropriate weightings of assessment criteria in the tender evaluation, appropriate assessment approach,...)
   - The principles for assessing open systems in a competitive procurement would be informed by the SoSA principles.

19. The MoD and Industry will be able to agree a procurement strategy to acquire Open Systems and/or use Open Systems Architecture across an agreed range of military capability.

20. That Open Systems and/or Open Systems Architecture will be mandated to some level where openness is required.
   - It will only be possible to ensure that Open Systems and/or Open Systems Architecture are considered within procurement when there is some level to which it is mandated (dependent on the MoD level of customisation).

Assumptions concerning the context in which the working group will consider open systems and open systems architectures

21. The open systems question is of interest to both MoD and Industry, although their respective interest may be different.

22. A lack of detailed definition of re-use has led to an assumption that benefits will accrue without being fully justified or explained.

23. Of the issues associated with the adoption of open systems (i.e. commercial, technical, enterprise...), it is generally the enterprise issues that are most difficult to resolve.

24. Assumptions about openness (e.g. benefits, detriments, implementations, etc.) from other commercial and industrial sectors do not necessarily transfer into the defence sector.

25. Openness will bring different strengths and weaknesses to different architectures (to different degrees). This implies that the strengths of weaknesses associated with a particular architecture, of architectural feature, will not necessarily transfer to another domain or sector.

26. Openness is a means to an end; it is not an end in itself. That is to say, openness may be the facilitator of benefits sought by stakeholders; it is neither a benefit nor detriment in its own right.

27. Open Systems and Open Systems Architecture can deliver interoperability with the UK military capability and across multi-national forces capability (e.g. ISAF).
### APPENDIX C: DEFINITIONS

This Annex provides further details on definitions developed by the SoSA CF WG1. Of the 27 definitions provided in Section 3 of this report, 25 are from the merged list of terms and 2 are additional terms to clarify one or more of the 25 terms.

Recall that the following approach was taken to create these definitions. First, a short list of 22 terms was identified at the first session of the Working Group. Then the 24 terms defined by MOSA were merged, which resulted in a list of 32 terms. The merged list was partitioned into three groups for small team analysis. Additional terms were added as needed. Within the bounds of the time available, each term was analysed individually by reviewing the authority of the sources cited for each term and by a linguistic analysis of the meaning of the term. A comparative analysis was performed on terms having multiple accepted definitions by identifying key words common to the definitions of a term and examining variations in meaning of the key words as well as variations of meaning of different definitions of the same term in a key sentence for that term.

After review and analysis, about half of the definitions provided MOSA were used with little or no modification. These are terms that had peer review by MOSA and were also acceptable to the SoSA WG1 team. These account for the definitions of about half of the terms from the merged list. They are listed first in the material below. The remaining 15 terms were defined from other authoritative sources and analysis. Samples of alternative definitions considered and linguistic analysis are included for reference. But the volume and mixed media of the analysis and the limitations of doing this work in an all volunteer environment prohibit documenting the full details of the analysis. If these details are of interest they can be re-visited in future work.

Merged list of terms from MOSA and first session of the Working Group:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agility</td>
<td>Federated system architecture</td>
</tr>
<tr>
<td>Architectural stack</td>
<td>Open system</td>
</tr>
<tr>
<td>Architecture</td>
<td>Open systems architecture</td>
</tr>
<tr>
<td>Centralised system architecture</td>
<td>Opened system</td>
</tr>
<tr>
<td>Complex system</td>
<td>Openness</td>
</tr>
<tr>
<td>Component</td>
<td>Partition</td>
</tr>
<tr>
<td>Computing platform</td>
<td>Segment</td>
</tr>
<tr>
<td>Distributed system architecture</td>
<td>Service</td>
</tr>
<tr>
<td>Enterprise</td>
<td>Service-oriented architecture</td>
</tr>
<tr>
<td>Enterprise architecture</td>
<td>Standard</td>
</tr>
<tr>
<td>Non-functional requirement</td>
<td>System</td>
</tr>
<tr>
<td>Open standard</td>
<td>System of systems</td>
</tr>
</tbody>
</table>

**Definitions used or adapted from MOSA:**

An **Architectural Stack** is a description of an architecture as a series of successive layers, where each layer comprises specific technologies and/or performs specific functions. Generally hardware is at the lowest layer and business applications are at the highest layer.

A **Component** is an operating part of a system consisting of input, process, and output.

A **Computing Platform** is that part of the architectural stack comprising the hardware and the lowest layer and most widely used software infrastructure (including the operating system).
An Interface is a boundary through which two systems interact.

Interoperability is the ability of two or more systems not only to interact, but to exchange information, and to provide and accept services in order to operate more effectively than as isolated systems.

Modularity is the property that is concerned with the discreteness of individual system parts. It is the art of subdividing a system such that its functional elements are interrelated but bounded, cohesive and autonomous, with each functional element individually achieving defined objectives through the interaction of its parts.

A Module is procurable elements of the system, and will comprise one or more components. They should be operationally useful, supportable, procurable and commercially saleable. ("Modularity can be contracted for.")

A Non-Functional Requirement is any requirement other than those categorized as functional and typically is used to qualify functional requirements.

Openness is concerned with system accessibility.

An Open Specification is a specification that is consensus-based amongst a community of interest, and is published by and freely available within that community of interest. An open specification should be at a level of detail so as to be implementable by independent parties.

An Open Standard is standard that is consensus-based amongst a community of interest, and is published by and freely available within that community of interest.

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, to interoperate with other components on local, distributed, and remote systems, to be performance and capability scalable, and to interact with people in a style that facilitates user portability.

A Standard is a document established by consensus and approved by a recognised third party body independent of the supply and consumer base that provides for common and repeated use with rules and guidelines for activities to achieve results or characteristics of the results. Standards should be subject to a defined (and involved) standardisation process, and provide a mechanism for proposed evolution. Compliance with the standard is intended to ensure consistent results.

Sample analysis of the term System:

This analysis of the term system is first of two analyses provided to illustrate the methods used by the Working Group. For many terms it is sufficient to use a purely textual definition of the term. However for key terms which may be critical for specifications, it is important to bring a higher level of precision to the definition. The term system certainly falls into this category.

As noted by Brooks (24), “One needs both a formal definition of a design, for precision, and a prose definition for comprehensibility.” The formalism used for bringing precision to the definition of a term is referred to as logical modelling. This type of modelling results in what is also called a meta model of the term. This may also be regarded as a type of ontology.

The linguistic analysis of the term done in this way seeks first to identify the key words in the sentence that can become the objects in an interpretation of the definition. These words are abstractly referred to as classes. For example, the word element will become an object when interpreted into a more physical description. These typically are the nouns in the definition. The other key words are those that express relationships between the classes. The result is a logical graph of the definition. This type of linguistic analysis reveals whether the proposed definition is logically structured, and hence is an important step in qualifying the definition as being internally sound.
A simple and authoritative definition of the term system already exists from the IEEE and INCOSE:

A system is a combination of interacting elements organized to achieve one or more stated purposes.

Figure 12 below provides a logical diagram of the term system based on both an internal analysis of the sentence and a comparison with another commonly accepted definition of system by Hitchins. From the added detail provided in the logical graph it is seen that there is a gap in the meaning of the key word organized as used in the sentence. What is organized? Is it just the elements of the system or is it also their interactions? Also,

![Figure 12: Logical diagram of the term system](image)

When compared with the Hitchins definition, there was a second question related to the term organized. How is it that the [organised] combination of the elements of the system achieves the stated purpose(s) of the system? Hitchins speaks of properties, capabilities, and behaviours emerging from both the elements of the system and their interactions. The logical graph in the figure attempts to reconcile this issue by introducing organizing principles over the system elements and their interactions that leads to the realisation of system properties, capabilities, and behaviours.

However, given the authoritative source of the IEEE/INCOSE definition, it was considered that perhaps the above concerns would best be addressed by an amplifying discussion of the definition of the term system rather than by changing the details of the definition.

But there was one subtlety of the definition that the Working Group felt did merit a slight modification of the IEEE/INCOSE definition. This relates to the second type of analysis performed on the definitions, i.e. a comparative analysis with the ISO definition of system architecture. The details of the ISO definition are discussed below (along with other authoritative definitions) but these are not important for the change the Working Group has proposed for the definition of the term system.
Specifically, while the ISO definition of system architecture (see below) refers to the elements of the system, it does not refer to their interactions but rather it refers more generally to their relationships. Because interactions can be considered as a special type (or instance of) relationship between the Working Group considered that a minor change to the IEEE/INCOSE definition was merited in order to make the definition of system concordant with the definition of system architecture. Thus,

- A system is a combination of related elements organized to achieve one or more stated purposes.

This was the final definition of the term system that has been proposed by the Working Group.

**Sample analysis of the term System Architecture:**

There are various engineering definitions of this term and the unscoped term ‘architecture’ is reported to have at least 130 definitions around the world. The Working Group focused on three key definitions, one from the electrical engineering community, one from the software engineering community, and one from ISO. These are given below.

From the IEEE Std 610.12-1990:

- [System] Architecture is the organization of the system components, their relations to each other, and to the environment, and the principles guiding its [i.e. the system’s] design and evolution.

From the OMG MDA™ (Miller and Mukerji 2003):

- The architecture of a system is a specification of the parts and connectors of the system and the rules for the interactions of the parts using the connectors.

From working group JTC1/SC7/WG42:

- System Architecture is the fundamental conception of a system in its environment embodied in elements, their relationships to each other and to the environment, and principles guiding system design and evolution.

The key attributes of the historical definitions (i.e. those related to the art and science of designing physical structures) are structure, utility, beauty. See (Pollio ca. 27 BC): a good building should satisfy three principles – Firmitatis, Utilitatis, Venustatis [Durability, Utility, and Beauty].

Figure 13 and Figure 14 depict logical models of the IEEE and OMG MDA™ definitions of system architecture respectively. In the logical model of the OMG MDA™ definition, the architecture of a system is a specification of the parts and connectors of the system and the rules for the interactions of the parts using the connectors. The two logical diagrams can be used to argue that the MDA™ definition is a more narrowly focused interpretation (specialization) of the IEEE definition.

The ISO definition of system architecture is of such a general nature that the IEEE definition (and hence the OMG definition) can be regarded as a more narrowly focused interpretation (specialization) of the ISO definition. However, it is clear that there is a loss of detail in the ISO definition when compared to the IEEE and OMG definitions. And all three definitions lose aspects of the historical principles of the architecture of physical structures.

The Working Group had considerable discussion of whether to include a concept of durability in the final definition to be proposed for the report. Specifically, the group considered adding a new term to the ISO definition, enduring features.
A Model of IEEE Standard 610.12
For [System] Architecture

[System] Architecture is the organization of the system components, their relations to each other, and to the environment, and the principles guiding its [i.e. the system's] design and evolution.

![Logical diagram of the IEEE definition of system architecture](image)

Figure 13: Logical diagram of the IEEE definition of system architecture

A Model of OMG MDA Definition
For [System] Architecture

The Architecture of a system is [the] specification of the parts and connectors of the system and the rules for the interactions of the parts using the connectors.

![Logical Diagram of the OMG MDATM definition of system architecture](image)

Figure 14: Logical Diagram of the OMG MDATM definition of system architecture

Figure 15, Figure 16, and Figure 17 illustrate how the key words of each of the three definitions could be associated if such a modification were made. The inclusion of the term *enduring features* in the ISO definition would serve to better align the three definitions. For example, the concept of *organization* in the IEEE definition (which is also central to the IEEE/INCOSE definition of system) could be regarded as an instance of an enduring feature in the system architecture. Similarly, the concept of *system specification* in the OMG definition could be regarded as an instance of an
enduring feature in the system architecture. However, given the authority and currency of the ISO definition, it was considered that perhaps the above concerns would best be addressed by an amplifying discussion of the definition of the term system rather than by changing the details of the definition.

But there was one gap that was considered to be sufficiently significant to merit at least a parenthetical inclusion in the ISO definition. Specifically, although the ISO definition provides for the relationships of the system to the environment, it makes no reference to system purpose. Therefore, the following definition was proposed for inclusion into the report:

- **[System] Architecture** is the fundamental conception of a system in its environment embodied in elements, their relationships to each other, and to the environment [and to the system purpose] and the principles guiding system design and evolution.

This is the definition from the ISO WG 42 but emphasis added to include system purpose.

**Key Words in the OMG and the adapted ISO Definitions of [System] Architecture**

<table>
<thead>
<tr>
<th>Adapted ISO</th>
<th>OMG</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>System</td>
</tr>
<tr>
<td>Enduring features</td>
<td>Specification</td>
</tr>
<tr>
<td>Embodied</td>
<td>Parts</td>
</tr>
<tr>
<td>Elements</td>
<td>Connectors</td>
</tr>
<tr>
<td>Relationships</td>
<td>Interactions</td>
</tr>
<tr>
<td>to each other, and to the environment</td>
<td>of the parts</td>
</tr>
<tr>
<td>Environment</td>
<td>Rules</td>
</tr>
<tr>
<td>System purpose</td>
<td>Design [i.e. of the system]</td>
</tr>
<tr>
<td>Principles</td>
<td>Guiding</td>
</tr>
<tr>
<td>Guiding</td>
<td>Rules</td>
</tr>
<tr>
<td>Design [i.e. of the system]</td>
<td></td>
</tr>
<tr>
<td>Evolution</td>
<td></td>
</tr>
</tbody>
</table>

*Design might be considered as a specification of the system components and their organization.*

Relations are a 2nd order semantic WRT elements.
Parts are a type of relation.
Relationship is an instance of a relation.

**Figure 15:** comparison of the OMG and adapted ISO definitions of **system architecture**
Key Words in the OMG and the adapted ISO Definitions of [System] Architecture

- Adapted ISO
  - System
  - Enduring features*
    - Embodied
  - Elements
  - Relationships
    - to each other, and to the
  - Environment
  - System purpose
  - Principles
    - Guiding
  - Design [i.e. of the system]
  - Evolution

- IEEE
  - System
  - Organization
  - Components*
  - Relations*
    - to each other, and to the
  - Environment
  - System purpose
  - Principles
    - Guiding
  - Design [i.e. of the system]
  - Evolution

Relations are a 2nd order semantic WRT elements.
Components are a type of relation.
Relationship is an instance of a relation.

Figure 16: comparison of the IEEE and adapted ISO definitions of system architecture

Key Word Comparison in the IEEE and OMG Definitions of [System] Architecture

- IEEE
  - System
  - Organization
  - Components
  - Relations
    - to each other, and to the
  - Environment*
  - Principles
    - Guiding
  - Design [i.e. of the system]
  - Evolution*

- OMG
  - System
  - Specification
  - Parts
  - Connectors
  - Interactions
    - of the parts
  - Rules

Design might be considered as a specification of the system components and their organization. And Organization might be considered as a Relational Structure.

*No relationship between terms.

Figure 17: comparison of the IEEE and adapted OMG definitions of system architecture
ANNEXE A: TYPE 26 EXEMPLAR

After the selection of the Type 26 (T26) combat system (CS) as the maritime (and complex system) architectural exemplar, the following set of initial questions was proposed:

- From the NDIC SE&OA WG OSA ‘Tiger Team’ (TT):
  - What are the characteristics of a framework for the assessment of open systems in the context of management of UK MoD agility requirements?
  - What guidance should be provided on appropriate measurement (process and criteria) of openness through which customer and supplier benefits may be assessed?
  - Demonstrate the applicability of the above to the T26 Combat System exemplar.

- These were supplemented by a further requirement identified at the SoSA CF OSA WG kick-off meeting:
  - Identify the requirements for a Desk Officers’ open systems toolkit – It should be noted that this was a commonly agreed output by both MoD and Industry participants

- Perhaps most importantly, the question posed by the Maritime Combat Systems (MCS) team (Cdr Nigel Ferguson) was:
  - Is the T26 Combat System sufficiently Open?

During the team-forming period for the OSA TT/SoSA CF OSA WG there was significant discussion of current and previous architecting studies, benefits modelling, architecture assessment and openness assessment. This led to some common treatment of issues between the case studies (for example on issues such as the definition of terms, measurement processes and criteria, and the provision of acquisition guidance and support). It also led to the refinement of the study requirements and questions based on what was considered to be fundamentally important and what was practically achievable. This did not substantially change the objectives of this case study, but focussed on what are the key questions relating to the adoption of OSA in complex systems such as naval CS.

Thus the questions actually addressed were:

- How should a complex architecture such as T26 CS be assessed?
  - This concerns its delivery of benefits, the consideration of characteristics not limited to Openness, and the form of suitable, practical assessment schema(s). Complex systems architectures are likely to be heterogeneous in architectural form in order to deliver a range of non-functional requirements (NFRs) of differing degrees of severity and functional applicability in the most cost-effective manner.

- Does the T26 CS have an appropriate balance of architectural attributes to deliver the range of required benefits?
  - This is essentially the question of whether the T26 CS is sufficiently open but broadened out into the consideration of a wider range of architectural attributes, architectural heterogeneity & trade-offs.

- Is any further work required to assess the appropriateness of T26 CS architecture for its intended purpose?
  - This concerns the breadth and depth of assessment which has been possible during this short case study, including consideration of the suitability, maturity and completeness of the overall assessment approach and the sufficiency of Type 26 CS architectural information to conduct such an assessment.

Approach adopted

The approach adopted on the (complex) maritime exemplar has essentially been to:
- Participate in and agree upon the definition of terms (as described in Section 3)
- Devise a framework for assessment encompassing a benefits schema, together with linked architecture assessment schema, assessment questionnaire and the assessment of maturity
- Gather source information (T26 assumptions, T26 CS information, and international comparative reference material as concerns architecture assessment techniques and tools etc.)
- Conduct the assessment of the T26 CS architecture against the proposed framework
- Deduce findings, including as concern constraints on the architecture assessment which proved possible within the taut case study timescales.

The main stages of the approach are detailed in the subsections which follow.

**Devising of T26 exemplar architecture assessment framework**

The overall architecture assessment approach devised and applied to elucidate architectural issues and assist in answering the architectural questions applicable to the maritime/T26 case study is described in detail in Section 5.2 and shown schematically in Figure 18 below.

**Figure 18: Overall architecture assessment schema devised for and employed on T26/maritime exemplar.**

The assessment approach adopted essentially combines the following elements:

- The characterisation of benefits delivered (or deliverable) by architecture (together with any detriments of the architecture also)
- The characterisation of architecture (in terms of fundamental attributes) and its assessment linked into benefits characterisation
- Related assessment considerations such as the architecture maturity and evolvability towards any architectural vision or future architectures
- Identification of source information on the architecture under evaluation.

The elements of the approach can be identified in Figure 18 and are described further in Section 5.2.
Type 26 combat system architectural information sought and obtained

Available information on the T26 CS architecture at the outset of the case study was limited largely to a single drawing of the vision architecture. This reflected the fact that CS architecting was essentially an ongoing project activity.

Given the tight timescales and limited effort available for the T26 Exemplar, completion of the architecture assessment schema (as outlined above) and the seeking of architectural information were undertaken substantially in parallel. Thus, in order to provide time for its supply, architectural information was sought from Type 26 project at the time when architectural attributes were being identified (rather than, for example, when more detailed and refined assessment question sets were being devised).

The following architectural information was sought as concerns the T26 CS architecture:

- What is the information model underpinning the architecture? Who owns it?
- Where are open standards employed (e.g. for interfaces) and why have they been selected? If not employed, why not? How has interoperability between open standards been addressed?
- SoSA CF OSA WG needs to define what is meant by ‘open standards’ and discuss with T26 project – note that the definition of terms is addressed further under Section 3.
- Where are common components employed to perform similar functions within the CS? Across surface ships? More widely?
- Where is layering employed and why?
- Where is segmentation employed and for what purpose? If segmentation is not employed how are multiple Qualities of Service (QoS) (e.g. performance, security) delivered?
- Where is high integrity design employed and why (e.g. to deliver demanding QoS)?
- Where is COTS technology envisaged (across CS functionality and throughout the architectural stack)? Will it be used ‘as is’ or modified? Where will COTS not be employed?
- SoSA CF OSA WG needs to define ‘COTS’ and inform T26 project
- Where is modularity envisaged and why? How does it relate to the acquisition of CS functionality? At what level(s) of granularity is modularity envisaged?
- How centralised, replicated, decentralised or otherwise distributed is information processing and why?
- What is the information communication architecture employed? More specifically:
  - What is the connectivity between physical architectural chunks?
  - What information communication paradigm(s)/style(s) is/are employed (e.g. pub-sub etc.)
  - How are different QoS delivered (e.g. latency)?
  - What level(s) of information integrity can be delivered by the information communications architecture?
  - What degree of commonality of information storage is employed?
  - What degree of commonality or centralisation of services is employed?
  - Where, when, and why is operational information persistent?
- The following related enterprise information was also sought:
  - What Enterprise Architecture (EA) does the MoD want or envisage?
  - Information on Design Authorities is required – which organisation responsible for what?

This was a fairly comprehensive question set identifying the key attributes of any potential architecture together with subordinate questions recognising the enduring importance of information communication in naval CS architectures together with the possible changes in this area. The question set also acknowledged the importance of defining terms so that a common understanding of issues could be gained by the information requestors and information suppliers.
(with formal definitions of some of the terms being work in progress when the question set was devised). Assuming (1) this information had been supplied, and (2) the detailed question set had been completed, then a detailed architectural assessment providing clarity of rationale over any findings, would have resulted.

The technical architecture questions were supplemented by questions concerning the corresponding MoD-industrial enterprise architecture. These questions were posed as a consequence of team awareness of the interdependency between technical and enterprise architectures and recognition of the importance of architectural ownership.

In response, the Type 26 project provided the assessment team with an architectural document providing a preliminary description of the Information Systems and Local Area Networks to be fitted to the Type 26 Combat Ship. This document includes:

- Description of the reference design for the equipment
- Information on the associated cost estimates
- Procurement strategy for the equipment.
- The Information Systems and Local Area Networks (IS&LANs) area comprises the following group of systems:
  - Combat Management System CMS) and Tactical Datalinks TDLs)
  - Onboard Training
  - Defence Information Infrastructure (DII)
  - Shared Network Infrastructure (SNI)
  - Shared Computing Environment (SCE)
  - Common Console
  - Visual Surveillance System
  - High Grade Messaging
  - IS&LAN Military Tasking Equipment.

This document provides a description of each of these systems, except for CMS and TDL (which are described in separate documents), with the following information being supplied:

- Purpose
- Requirements
- Procurement Strategy
- Applicable Policies
- Reference Solution
- Integration Approach
- Constraints on Other Systems
- Impact on Other T26 Domains
- Costs
- Risks.

The style of the document is to consider a number of key CS equipments which strongly influence the system architectural form and deliver many of the key enabling functions such as information processing, transfer, storage and display. For several of the CS equipments which are necessarily new development/procurement items (such as SNI, SCE, Shared Network Functions and Common Console), the information provided is architecture-rich in content. However, for certain other equipment the architectural information contained within this document is more limited. Reference is made out to further documentation and models on issues such as cost presumably because of the limited interest in detailed information and its obvious commercial sensitivity. Access to this

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additional information would be required to complete a full T26 CS architectural assessment in accordance with the proposed approach since cost considerations such as value for money are part of the assessment.

Furthermore, the content of the T26 IS&LAN Design Disclosure document reflects the priorities and issues addressed by the T26 project at its time of writing. Thus issues such as Information Modelling which are the subject of more recent discussion by the T26 project are not addressed.

**Architecture assessment as performed**

The architecture assessment as performed on the Type 26 CS was necessarily constrained because:

- The questions which need to be answered concerning the suitability of the T26 CS architecture are beyond the capabilities of any architecture assessment scheme known to be available.
- An architecture assessment approach needed to be devised to address the suitability of complex systems architectures (such as that of the T26 CS). This has been scoped and significant elements completed. However much further work remains (such as clarification as to how architectural heterogeneity should be assessed, detailing of a full set of architecture assessment questions, integration of cost and time estimation for deriving base measures, defining measurement scales for addressing issues such as the sufficiency of architectural ‘openness’, and review of various elements of the approach).
- Information on the T26 CS architecture was sought and supplied in parallel with the devising of the architecture assessment approach. This parallel working was necessary because (1) it was recognised that extant architecture assessment approaches/tools would not address the range of issues which needed to be considered, and (2) it was only when there was some detailing in the proposed architecture assessment approach that the specific information required from the T26 project could be identified.
- The effort and time available for this task was insufficient for conducting a thorough review using the proposed assessment approach.

Therefore the T26 CS architecture assessment has necessarily made use of (1) interim T26 CS architectural information, and (2) a developing architectural assessment approach. Nevertheless the assessment has involved a team of experienced naval CS architects and involved participants from the T23 CS team or with knowledge of its CS architecture. The result is an interim assessment which whilst providing informed insight on the questions of concern would benefit from more complete and up-to-date T26 CS architectural information together with greater completeness of the architecture assessment approach.

In view of the relative incompleteness of the detailed question set for evaluating the contributions of architectural attributes to benefits/contributors, assessment centred on the use of the maturity levels which define coherent sets of architectural ‘maturity’ across the range of identified attributes of any CS architecture. This also allows a more rapid assessment of the overall architecture capability and potential. The consideration of architectural attribute maturity was based on (1) material on the T26 CS architecture available within the SSCSG and similar forums, (2) information progressively obtained and supplied by the assessment team’s DE&S T26 representative, and (3) knowledge of T26 CS architecture available within team members due to relevant related work.

The maturity schema fits within the overall architecture assessment approach as indicated in Figure 18. It indicates coherent sets of architectural maturity (as maturity levels\(^\text{13}\)) across the range of identified architectural attributes. Its usage for T26 CS assessment allowed testing of key parts of

\(^{13}\) These are also termed MOSA Capability Builds (MCBs) based on the concept as proposed by MOSA and documented in (26).
the proposed architecture assessment approach without requiring extensive access to architectural information.

Five such maturity levels are defined:

- The status quo of federated CS (i.e. equipment based, highway-centric and with message-based information passing)
- The long term endorsed MOSA vision technical architecture featuring extensive modularity, openness, layering, common underpinning information model, support for multiple architectural styles/information communication mechanisms, and other advanced architectural devices
- Three possible coherent intermediate steps on the evolution path from current architectures to the achievement of the MOSA vision.

An extract from the maturity schema is contained in Figure 19, below.

**Figure 19: Sample of Maturity Schema showing expected different levels of maturity for two architectural attributes.**

The Type 26 CS architecture as currently envisaged provides an intermediate level of maturity on this scale. This is because certain advanced architectural devices are included in the present T26 vision architecture (e.g. the adoption of state-of-the-art computing platforms and virtualisation) whereas other advanced features (such as the usage of an underpinning information model and movement towards the adoption of open standards) are either the subject of current investigations or their extent of adoption is uncertain.

**Assessment findings**

For the reasons stated above the assessment conducted by the team is an interim view reflecting the status of the T26 architectural description and a maturing architecture assessment approach.

Key findings made by the T26 CS case study assessment team during the process of completing this case study are:

1. No known extant technique was found to be suitable for assessing the overall suitability of complex systems architectures (against their intended or desirable benefits)
2. Progress has been made in devising an approach suitable for assessing complex architectures
3. The inter-dependency between technical architecture and enterprise (architecture) considerations is fully recognised with proposed technical architectures requiring the proposing of coherent and viable enterprise architectures
4. The T26 CS architecture is an advance on current CS architectures and possesses a number of features which will both provide defined benefit and allow future evolution towards the MOSA vision
5. It is not possible to assess whether this architectural progress is ‘sufficient’ due to the team’s lack of familiarity and accessibility to the T26 CS requirements, and uncertainty on specific issues such as whether application layer information modeling is being applied and the extent to which open standards (or open specifications) are being adopted.
6. Improved guidance and advice on architecture assessment and open systems is necessary for acquisition professionals and a ‘Desk Officers’ Toolkit’ is proposed to assist in this respect.

The first of these findings concerns the fact that, based on a rapid trawl through the literature using staff familiar with architecture assessment techniques, the extant techniques are largely software-orientated, feature either a lack in transparency of assessment rationale or may have an unsuitable assessment approach, do not address significant issues such as architectural heterogeneity, or exhibit other such constraints which make them not fully suitable for the purpose.

The second finding concerns the progress made on addressing key assessment issues such as:

- Linking architectural attributes to high level benefits/desired requirements – previously ‘known’ benefits models have failed to adequately separate such issues, not adequately captured dependencies, and/or attempted quantification of dependencies when the basis for such quantification is difficult to justify.
- Offering the potential for including quantified assessment elements within the overall assessment approach – this offers the prospect of progressively shifting from qualitative to quantitative assessment as the understanding of issues improves and architectural information such as metrics and costs become more available and understood.
- Handling issues inherent in complex systems architectures such as a broad range of architectural attributes (which can be used singly or in combination to deliver various desirable architectural characteristics) and architectural heterogeneity (where different parts of the overall architecture are subdivided or tuned to address particularly demanding requirements and other parts of the architecture support less demanding ones)

The team believes that significant progress has been made on this issue and that a viable and useful architectural assessment approach has been devised in overall outline with a number of areas being substantially populated in detail.

Nevertheless, the team also recognises that further work remains to complete such an assessment approach. More specifically, the assessment of a complex system architecture such as that of the T26 CS is hampered by:

- There is no scale for the measurement of an architecture against attributes such as its compliance with open standards. The use of metrics such as the ‘percentage of open interfaces’ employed is fairly meaningless for the situation where (1) what is desirable by way of an open interface/open architecture can only be defined in terms of supporting ‘open standards’, and (2) few such open standards presently exist especially for military-specific functionality (but steps towards their implementation and adoption can nevertheless be made).
- There is no definition of ‘sufficient’ against that openness scale. Sufficiency is a compromise between what is required (in the formal T26 Statement of Requirement), what is desirable (to achieve specified benefits), what is potentially achievable (based on the current state of the ‘possible’) and what is pragmatic (based on affordability, design constraints, timescale and effort constraints etc.). The evaluation of base measures was beyond the scope of assessment feasible at this stage due to a combination of immaturity of the cost (and time) estimation schema and the difficulty in obtaining cost data (due to commercial sensitivities and project infancy).
- There is an issue of architectural maturity (in the sense of maturity levels ‘stepping’ towards some perceived improved state or target architecture) and evolvability which is intrinsic to

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14 This relates to the question posed by the T26 CS team’s Cdr Nigel Fergusson.
15 It is also possible that useful cost data could be obtained from the Sustained Surface Combatant Capability (S2C2) Pathfinder studies.
the assessment of architectural goodness. Within the naval CS arena the MOSA technical architecture has been proposed and endorsed as the long-term vision. The current situation of federated CS (equipment based, highway-centric and message-based information passing) architectures is also well understood. Three possible intermediate steps have been identified enabling transition from current architectures to the achievement of the MOSA vision. However the point along this series of transition steps at which the future T26 CS architecture should be ‘pitched’ to deliver the balance of benefits and practical architectural attributes and constraints remains to be fully determined. This will require the relating of maturity not just to architectural attributes but also the corresponding benefits and contributors.

- The need for practical complex systems architectures to be heterogeneous is recognised and mechanisms for determining the heterogeneity and consequential architectural (and design) features are understood. However the augmentation of the architecture assessment approach to assess architectural heterogeneity (and whether the dissimilar features are deployed appropriately and coherently) has yet to be implemented. This does not detract from the progress made since the assessment approach is suitable for assessing homogenous architectures but just requires a refinement (since a heterogeneous architecture is effectively a coherent set of individually tailored homogeneous architectures).

On the third topic of technical and enterprise architecture inter-dependencies, the assessment team recognises the coupling and dependencies between technical and enterprise architectures and the need for technical architectures to have corresponding and coherent enterprise architectures. Through its previous and parallel experience, participants in the assessment team are aware that, historically, the UK has employed several different enterprise approaches (in terms of MoD-industrial organisations, respective roles and responsibilities, and associated commercial/contractual models) for the development and through life support of different classes of warships and their combat systems.

Having stated the intrinsic inter-dependency between a technical and enterprise architecture, it has always been acknowledged in the SoSA CF OSA WG that the assessment of the associated enterprise is beyond the scope of the T26 exemplar. Enterprise considerations have nevertheless been considered more generically within the WG (and are reported under Section 5.5).

The fourth point attempts to conclude a finding concerning the sufficiency and suitability of the proposed T26 architectural vision. Based upon the comparatively limited T26 CS architectural information available to the team, the parallel development of the assessment approach, and the limited team resource, the team found that the T26 CS architecture (1) is an advance upon current UK CS architectures, and (2) possesses a number of features which will both provide defined benefit (subject to their risk being reduced through ongoing demonstration activity) and allow future evolution towards the MOSA vision. Specifically, the adoption of features including SNI, SCE, Common Console, and virtualisation provide some immediate advantages (for example, increased network capabilities, increased software and hardware independence, and increased computing platform commonality). They also offer the potential for increased adoption of other enabling and ‘future-proofing’ features such as the adoption of open standards\(^\text{16}\).

On the other hand, as is summarized in the fifth point, it is not possible to assess whether this architectural progress is ‘sufficient’ due to:

\(^{16}\) Noting the previously stated issues of open standards availability and the fact that there adoption is likely to be progressive rather than ‘binary’. 
The team’s lack of familiarity and accessibility to the T26 CS requirements set\textsuperscript{17} – the need to access such information and the consequential effort and timescale implications were not factored into this case study

Uncertainty as to whether application layer information modelling is being applied – this is the subject of a current (as of May 2011) T26 CS project investigation

Uncertainty as to the extent to which open standards (or open specifications) are being adopted – this issue is at least partly recognised in the T26 vision architecture (with ‘potential’ open application interfaces being identified) but increased acknowledgement the importance of open standards leading to their formalisation and adoption would be desirable.

During the course of this work the T26 CS assessment team (and the broader SoSA CF OSA WG) recognised the need for (1) improved guidance on systems architecting and open systems architectures, and (2) the assessment of systems architectures and openness as was summarised in the sixth finding. This need is intended to be satisfied by the proposed ‘Desk Officers’ Toolkit’ (which is covered in further detail in Section 7.3). This toolkit would enable acquisition professionals to consider system architectural matters in a more informed manner than is currently the case but would not obviate the need for support from specialist expertise in this challenging and evolving technical area.

Specific recommendations made concerning this Toolkit are:

1. The aim is that it should provide assistance with architectural assessment through the provision of a toolkit with a structured set of questions which are tailorable to the problem in hand and with supporting guidance information also supplied
2. It should enable the \textit{comparison} of architectural options, solutions and bids rather than providing an absolute measure of architectural fitness for purpose, goodness or openness
3. The tool should be presented in a similar manner to OAAT\textsuperscript{18}.

The specification of such a toolset is addressed further in this report at Section 7.3

\textsuperscript{17} User and system requirements.

\textsuperscript{18} The US DoD’s Open Architecture Assessment Tool. OAAT 3.0 download at www.acc.dau.mil
ANNEXE B: GVA EXEMPLAR

Introduction

The following process is based on the presentation that was presented to the Head of SEIG, Steve Hyde on 19 May in Loughborough University. The details in this section were the result of several workshops conducted to address the following questions:

1) How could open architectures be applied to the application of the Generic Vehicle Architecture (GVA) Defence Standard 23-09?

2) How could open architecture features be assessed and applied to deliver benefits to military vehicle programmes?

3) How could a process be devised that allowed a project team to easily match GVA requirements to project needs and then drive the direction of the project to maximise benefits throughout the CADMID cycle?

These questions were raised during a presentation to GVA Team and are listed in Figure 20.

Key Questions

- How can one assess open systems in the context of GVA and the Land Operating Centre’s LOSA architectural vision?

- Key Issues
  - What guidance should be provided?
  - How should compliance be measured?
  - How are benefits realised?

- Can we demonstrate applicability using the Mastiff Upgrade?

- How can results inform technical integration, acquisition and TLCM strategy and DLOD integration decisions?

Figure 20: Key Questions asked by the Project Team

The workshops were conducted to derive processes to address these questions. The intention was to provide a process template that could be applied to a real acquisition problem such as the Mastiff Upgrade project. Time did not allow for application of the process to Mastiff, however, these could be developed at a later time while using the insights from this study to inform Mastiff project decisions.

The approach taken is outlined in Figure 21. This approach ensured that our work was focused on the needs of the GVA office, yet also expanded the scope to include new concepts and insights that were not part of the GVA programme. The team used “ilities” or attributes derived during the combined working group meeting in Loughborough University sponsored by Professor Michael Henshaw. GVA specific workshops were conducted at the Atkins’ office at the HUB in Bristol to address the process, its concept of operations and the spreadsheets needed to align the GVA requirements, project assessments and the project benefits. From this a Benefits Model was constructed.
Figure 21: Approach

Generic Vehicle Architecture (GVA)

GVA is the approach taken by MoD and Industry to ensure that sub-systems on land platforms are properly integrated (electronically, electrically and physically). Defence Standard 23-09 is an output from this approach, and is not an architecture or a design in itself. The nine basic principles of the GVA Approach and Def Stan 23-09 are that they must:

1. Take account of previous MoD and Industry investment;
2. Be applicable to current and future systems;
3. Use open, modular and scalable architectures and systems;
4. Facilitate technology insertion (upgrade, update, replace, repair, remove and addition);
5. Not needlessly implement in hardware any functionality that can be implemented in software;
6. Take a “whole platform” systems view, through life (including cost);
7. Be done in conjunction with industry and all relevant MoD Stakeholders;
8. Be MoD owned and maintained;
9. Specify the minimum necessary to achieve MoD’s desired benefits avoiding unnecessary constraints in implementation.

GVA sits in the context of the Land Open Systems Architecture (LOSA), a higher level architecture in a brigade context. It is intended to bring together Land domain architectures such as vehicles, dismounted soldiers, static bases, universal fires, tactical communications, and Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR).

In summary GVA supports a full spectrum of platform functionality, from simple, low cost, low functionality platforms at one end, to highly sophisticated platforms with integrated survivability, surveillance and offensive functionality at the other. It is intended to be sufficient to allow subsystems to interoperate as required but still allow a manufacturer to propose innovative implementation to the MoD.
GVA highlights are shown in Figure 22. GVA provides the Land Equipment Operating Centre a framework and requirements process to address issues of operational agility and flexibility, limited vehicle capacity growth, lack of modularity, increased crew work load and stovepiped information handling that is found on legacy and UOR vehicles. GVA mandates that new vehicle procurements and legacy/UOR upgrades apply the GVA approach so that MoD could reap the benefits of open vehicle architectures across the land vehicle fleet. GVA policy will be reviewed at least every 18 months in order to keep it relevant to operational needs technology lifecycles.

Figure 22: GVA Highlights

Land Open System Architecture (LOSA)

GVA is just one of three Land Open System Architectures (LOSA). GVA and the LOSA architectures are shown in Figure 23. The 3 LOSA architectures are GVA, GSA (Generic Soldier Architecture) and GBA (Generic Base Architecture). Each architecture pertains to a platform type within LOSA. The three platform types are described in terms of physical, power and electronic/information infrastructure on which platform specific functionality for human interface, logistics, lethality, ISTAR, C4 and mobility can be added. LOSA provides an architecture in which common features for GVA, GSA and GBA can be addressed in order to enable better interoperability and coherency between the three platform types within the operational context of the Multi-Role Brigade. The British Land Forces consists of all three types of platforms and its doctrine is dependent on all three working in a coherent fashion to support combat, counterinsurgency and stabilisation operations.

More work is needed to mature the LOSA concept and how it will be used. However, at a minimum it should provide coherency amongst GVA, GSA and GBA and identify requirements for common solutions and interfaces across platform.

Figure 24 illustrates how the Land Equipment Operating Centre (OC) might use the LOSA architectures to define equipment architecture within the Multi-Role Brigades. LOSA could provide the architectural context in which to centrally address C4, ISTAR and Logistics interfaces with systems that are outside the Land Equipment OC remit.

Essentially, the LOSA sub-architectures, GVA, GSA and GBA, provide an architectural framework for Delivery Teams in order to improve coherency and reduce duplication of effort in these platform groups. For instance, GVA allows synergy and commonality amongst combat tracked, wheeled and support vehicles so that they can share common crew station “look and feel”, logistics and system
health ministering systems, common middleware product and data model, common power and computing solutions and common lethality and sensor options. GSA allows soldiers to receive integrated solutions of lethality, C4, ISTAR, protection and support options that are reduced in weight, can be easily reconfigured and provides operational agility. GBA allows all bases to follow a common modular architecture that can be easily and quickly assembled, can be powered from an integrated and efficient power management system and can easily integrate vehicle and soldier needs. The GVA Def Stan was published in 2010. GBA is due to be published in 2011 and GSA in 2012. These documents are reviewed at least every 18 months.

Figure 23: GVA and LOSA

Land Operating Centre

Key Points – 1) Multi-Role Brigade and LOSA are directly linked. 2) Land OC supports at least 5 Programme boards and 4 HoCs (Heads of Capability). 3) LOSA and SOSA Domains are at same level

LOSAs provides Force Element and organisational coherence. Directly supports SOSA Principle 1

Figure 24: The Land Equipment Operating Centre and LOSA
The Architecture within GVA

The architectural scope for GVA is described in the GVA Def Stan(11). This is shown in Figure 25.

**Figure 25: Scope of GVA on the Vehicle Architecture**

GVA primarily addresses physical, information exchange and power infrastructure and key functional areas such as crew stations and HUMS. GVA compliance is a key user requirement. The GVA Def Stan helps Delivery Teams to identify system and interface requirements.

The SoSA Open Architecture Working Group GVA Exemplar Team (referred to hereafter as the Team) created a more detailed version of the diagram based on the GVA implementation matrix provided by the GVA Office. This diagram in Figure 26 highlights the 3 core infrastructures: 1) physical, 2) electronic and 3) power and 4) the modular functional elements that use common interfaces.

**Figure 26: GVA Diagram constructed by the GVA Exemplar Team**

In this format, the GVA architecture that is most pertinent to the needs of the project can be easily identified and cross referenced to a section of the GVA Def Stan and Implementation Matrix. The
diagram also addresses the information environment as a layered model consisting of applications, data, network and backbone layers. These layers can also be described in terms of modularity, common standards, and abstractions to decouple the dependencies between layers in order to improve upgradeability and modularity. As a result, a Delivery Team can address all of the architectural features which may be important for a new buy or it can focus on particular features such as power or electronic infrastructure upgrades or additional functionality. Decision can then be based on infrastructure enhancements or increased functionality that could be applied to existing platforms or “off the shelf” ones. The GVA architecture can also be applied to existing vehicle so that architectural changes can be expressed in terms applicable to GVA. Likewise, the GVA architecture can be adjusted to reflect architectures common to commercial and military vehicle market.

Figure 27 shows a simplified view of the Team’s diagram so that the important features can be highlighted. The diagram shows the 3 core infrastructure and the centre functional elements that are connected to the vehicle through physical, data and power interfaces. The ideal situation is to have the functional elements connect in a “plug and play” manner. It would also be beneficial if the core infrastructures can be upgraded as separate entities, yet mindful of the overall vehicle constraints of size, weight, power, and data quality of service (QoS).

![Figure 27: Simplified view of the GVA Architecture](image)

**The Process**

The process for applying GVA that this study and the Team explored is shown in Figure 28 (reproduced in Annexe from Figure 9). The process is designed to provide traceability between project needs as determined through assessments, GVA requirements and implementation options and agreed upon project benefits. Improved traceability amongst these three areas should increase coherency within the Project’s activities and allow decision makers to have a better understanding of the project’s interdependencies and dynamics. Better understanding of the project dynamics, allows Project Managers to select options that produce the desired effect based on proven results. “Trial and Error” decision making is therefore replaced by more purposeful and informed approaches based on measured trends with predictable results. In effect the project can improve its agile response to new situations and quickly adapt as situations and opportunities present themselves.
GVA Requirements and Implementation Matrix

The GVA requirement is sub-divided into sections that pertain to areas highlighted in the GVA architectural diagram. The Implementation Matrix, previously known as the Maturity Matrix, allows solution for these sections to be categorized into 5 levels, levels 0 to 4. Level 0 does not satisfy that particular section’s GVA requirement but is allowed because it captures the current state of a non-GVA compliant vehicle in that area. This might be allowed if it provides the most cost effective solution that meets the vehicle’s user requirements. An example of the 5 levels is show in Figure 29 which highlights the GVA section on middleware. Level 0 indicates that no middleware and data model are used. In each higher level, the degree of middleware and data model usage increases.

Since these levels exist for every section of the GVA requirement, there could be many combinations that are acceptable. In order to establish more commonality amongst the various land vehicle types,
the GVA office is establishing three GVA compliance profiles based on these levels. These profiles are High, Medium and Low. The selection of sections and their corresponding compliance levels will be determined by the GVA office and provided to the Delivery Teams as a starting point for determining the appropriate GVA requirement for their project.

**Project Assessments and Metrics**

During the workshops, the Team defined “ilities” or attributes for four key areas that are associated with the procurement of new systems and capability. These four key areas are:

1) System Architecture
2) Acquisition Strategy
3) DLoD (Defence Lines of Development) Integration
4) TLCM Strategy

Together these areas cover the scope of most projects. By assigning attributes and metrics to describe their features, a project can be assessed on how it needs to be focused on these areas. Not all projects have the same goals, objectives and needs and may need more of one attributes than another. The assessment process allows these issues to be addressed. This assessment also allows a project to manage competing and opposing demands which require early de-confliction.

The assessments are performed by answering a series of questions in each of the 4 areas. The questions were captured in a Excel spreadsheet which generates a score. The score is determined on a 5-1 scale using Green for a score of 5-4, Amber for a score of 3-2 and a Red for a score of 1.

The Systems Architecture section uses 15 questions which are based on the VSI metrics and include the attributes of Reconfigurability, Enhaceability, Integration, Logistics Support, Scalability and Openess. Reconfigurability addresses operational flexibility by providing features that are interchangeable and adaptable such that they can be reconfigured in an operational environment. Enhaceability addresses upgradability by providing features that manage capacity, allow modularity and use enablers to enhance the upgrade process. Integration addresses data and information sharing by providing features that allow better external and internal information exchange and allow for better human and automated control. Scalability addresses growth needs by providing features that allow for horizontal and vertical growth where modules can be added in parallel or in layers. Openess addresses MoD ownerships needs for core aspects of the architecture by providing open standards, accesible documentation to suppliers and usable interface control documents. As such, these attributes determine the technical and system architecture and provide features that enable system integration, the design and implementation of upgrades and the ability to adapt to the needs of the soldiers who will use it.

The Acquisition Strategy section uses 31 questions to assess the degree and priority in which these issues need to be considered. It includes the attributes of affordability, programmatic, flexibility, exportability, re-use and commonality, efficiency and accountability. These attributes are grouped into three areas. Affordability and programmatic capture MoD needs since they address MoD resouce allocation and scheduling requirements. Flexibity and exportability capture industry needs since they address industry’s requirements to find new markets for their products and to have flexible supply chains as technology changes and system enter into obsolescence. Re-use and commonality, efficiency and accountability capture both MoD and industry needs since they influence cost saving, eliminate dublication and establish legal liability and responsibility requirements. An acquisition strategy will generally be devised such that all of these areas are considered and that a balance is achieved amongst competing demands.

The DLoD Integration section uses 64 questions to assess the degree and priority in which these issues need to be considered. It includes the attributes of readiness, doctrine and order of battle (ORBAT), support, information, training and interoperability. These attributes are grouped into four
areas. Readiness, doctrine & ORBAT and support capture operational issues since they influence how a military organisation conduct combat and operations in a sustainable manner. Readiness consists of availability as an attribute which is further described in terms of reliability, maintainability and testability. Support consists of logistics as an attribute which is further described in terms of sustainability and supportability. Information has security as an attribute since information must be protected yet accessible to the user. People has training as an attribute which is further described in terms of usability. Finally, interoperability has integration of legacy and backward compatibility as attributes since interoperability with legacy equipment and the degree of backward compatibility to make this practical are key drivers.

The TLCM Strategy section uses 42 questions to assess the degree and priority in which these issues need to be considered. It includes the attributes of upgrades, disposability, configuration control, standards management and supply chain management. These attributes are grouped into five areas. Evolution/upgradeability capture upgrade issues since they directly influence how upgrades are managed. Evolution/upgradeability is further described by scalability, re-usability, portability and licensing attributes. Disposibility capture disposal and recycling issues and compliance with Green policies. Configuration control captures configuration issues which are further described by configuration management, configuration identification and qualification and safety attributes. Standards management captures standards issues which are further described by MoD owned and industry owned attributes. Finally, supply chain management captures supply chain issues which are further described in terms of MoD controlled and industry controlled attributes.

Figure 30 highlights metrics based on the attributes identified in the previous paragraphs as well as how the process is conducted. The objective is to use these assessments to determine important needs from each of the four project areas such that they are readily identified and presented in a manner that can be tracked and managed. The assessment is conducted with the use of questions scored on the basis of need. This process allows the project team to assess the need, assign a priority and enable better GVA implementation option selection.

**Figure 30: Assessment Metrics and Process**

**Dependencies between Assessments and the GVA Requirements**

In order for the assessments to be applied meaningfully in the project’s decision making process, they must be linked to the GVA architecture and the associated implementation options. This dependency establishes a relationship between a project need and a GVA implementation option.
that will satisfy it. The objective is to determine how the project’s needs impact the GVA requirement and influence the selection of implementation options. Likewise, if one starts by first selecting GVA implementation options, then it can be determined which project needs are required and the degree that they must be satisfied.

Figure 31, Figure 32, Figure 33 and Figure 34 show how the attributes to the System Architecture, Acquisition Strategy, DLoD Integration and TLCM Strategy impact the GVA architecture, respectively. Using the GVA Implementation matrix, it can be determined which implementation option best satisfies the need. These diagrams provide a visualisation in which to understand the cause and effect of needs and implementations. Once this is understood, then the selection of the most appropriate implementation options can be achieved.

![Diagram of Sys Architecture and GVA Interdependencies]

**Figure 31: Dependency of System Architecture Attributes to the GVA Architecture**

With regards to the Systems Architecture, reconfigurability impacts all interfaces, infrastructures and functional areas. This attributes allows these areas to be modified due to operational need. Enhanceability mainly impacts the infrastructure areas. Upgrades to these areas impact the size, weight, power, and information qualify of service capacities. Integration impacts mainly the information environment which consists of the electronic infrastructure and functional elements that include the crew stations. Logistic support impacts the information environment with regards to logistic information and the HUMS functional element. Scalability and openness impact all elements of the GVA architecture.

The Acquisition Strategy impacts all areas of the architecture. This also means that each section of the GVA architecture can been seen as a separate entity that can be purchased and managed as separate from the selection of the vehicle supplier. Careful consideration of these attributes allows the Delivery Team to make important decisions on re-use, areas of fleet commonality and value for money volume purchases.
With regards to DLoD Integration, information impacts the electronic infrastructure, training and Doctrine/ORBAT impact the crew station and functional elements and interoperability impacts all interfaces, the electronic infrastructure and C4 functional areas. Readiness and support impact all areas.

With regards to the TLCM Strategy area, the standards management section impacts all infrastructure and interface areas and the remaining attributes impact all areas. Since a TLCM strategy can be applied to all components of the architecture, the overall TLCM strategy will have implications on the best value for money means to manage the fleet of vehicles for the long term. The TLCM strategy will also determine, based on the need, how the resources should be balanced amongst the GVA architectural areas.
Once a relationship between the GVA requirements and the project’s needs have been established, it is then necessary to align this with overall project benefits. Whereas the previous items established requirements, the project’s benefits establish overall priority and a common measure of “goodness” that extends beyond the boundaries of the project. In this case, the SoSA Principles were used to describe the project’s benefits. The SoSA Principles are:

1) Unifying the business
2) Driving business and operational effectiveness
3) Minimising diversity
4) Designing for Re-use
5) Building with proven solutions
6) Ensuring commonality of services across the Defence Enterprise
7) Designing for flexible interoperability
8) Adopting open standards
9) Treating information and data as an asset

The SoSA Principles are defined in MoD’s Acquisition Operating Framework and define high level guidance that should be generally followed in order to receive benefits in term of performance, cost, time and risk.

In the following nine figures, the 4 Project Areas and elements of the GVA architecture have been linked to each SoSA Principle so that their dependencies can be identified, tracked and managed. The objective is to track the accumulation of benefits based on actions planned and taken so that future decision making could be informed by these trends.

Figure: 35 shows the benefits mapping for SoSA Principle 1. The attributes of this Principle are described in the dark grey box. To the left of this box are the project areas and the GVA architecture elements that pertain to the Principle attributes listed. Principle 1 addresses the use of governance
frameworks, enterprise architectures, common vision and sustainable TLCM and product delivery strategies.

**SOSA Principle 1**

![Figure: 35 SoSA Principle 1 Benefits Mapping](image)

Figure 35 shows the benefits mapping for SoSA Principle 1. Principle 1 addresses unifying the business through governance frameworks, enterprise architectures, common vision & objectives, capability management, and solution delivery and TLMP.

**SOSA Principle 2**

![Figure: 36 SoSA Principle 2 Benefits Mapping](image)

Figure 36 shows the benefits mapping for SoSA Principle 2. Principle 2 addresses the description of activities in terms of business and operational effectiveness. Business effectiveness is discussed in terms of dimensions such as affordability, exportability, etc. Operational effectiveness is discussed in terms of mission threads, scenarios, CONEMP and the application of lesson learnt.

**SOSA Principle 3**

![Figure: 37 SoSA Principle 3 Benefits Mapping](image)

Figure 37 shows the benefits mapping for SoSA Principle 3. Principle 3 addresses minimising differences and the reduction of duplication amongst the system solutions. This is done through establishing a value for money statement and strategy, taking more of an operational perspective when deciding the degree of duplication and minimisation that should be allowed and implementing practices that better manage the supply chain.
Principles 4 through 9 address various design and architecture process policies. Figure 38 shows the benefits mapping for SoSA Principle 4. Principle 4 addresses Re-use as a policy and the design process that manages and controls it.

Principle 5 addresses using Off the Shelf items as a policy and the design process manages and controls it.
**Figure 39: SoSA Principle 5 Benefits Mapping**

Figure 40 shows the benefits mapping for SoSA Principle 6. Principle 6 addresses the use of Common Services as a policy and the design process that manages and controls it.

**Figure 40: SoSA Principle 6 Benefits Mapping**

Figure 41 shows the benefits mapping for SoSA Principle 7. Principle 7 addresses the use of use of flexible interoperability as a policy and the modular design process manages and controls it.
Figure 41: SoSA Principle 7 Benefits Mapping

Figure 42 shows the benefits mapping for SoSA Principle 8. Principle 8 addresses the use of open standards as a policy and the design process that manages and controls it.

Figure 42: SoSA Principle 8 Benefits Mapping

Figure 43 shows the benefits mapping for SoSA Principle 9. Principle 9 addresses the use of information as a policy and the design process that manages and controls it.

By linking the SoSA Principles to the 4 Project areas and the GVA architectural elements, benefits can be captured in terms of agreed upon SoSA benefits. These benefits can be captured in terms of performance, cost, time and risk indicators. Therefore, the SoSA Principles can be used in a benefits model that allows a Delivery Team to choose options that steer the project toward the accumulation of more SoSA benefits. The benefits models results can be monitored through the use of
dashboards that can use the performance, cost, time and risk indicators to interpret trends and inform decisions.

![SOSA Principle 9](image)

**Figure 43: SoSA Principle 9 Benefits Mapping**

**Operational Concept**

The operational concept for the use of assessments, GVA requirements and benefit model is shown in Figure 10. It shows how the process would be managed through the CADMID cycle to inform decisions on DLoD and LOSA integration, Acquisition and TLCM strategy and finally on systems selection and integration.

![Operational Concept](image)

**Figure 44: Managing the Process through the CADMID Cycle**

The process is based on considering system architecture, acquisition strategy, TLCM strategy and DLoD Integration up front through either through an assessment process or through stakeholder
engagement and detailed project planning. Once it is determined that enough information exists to begin the process, further analysis can be conducted on project needs, GVA requirements and benefits to determine if trade studies are needed and if additional options should be examined. Trade studies and option analysis can first begin at a high level with DLoD Integration and LOSA/Multi-Role Brigade considerations. The focus should be on vehicle roles, doctrinal and operational CONEMP considerations so that it can be clear on how the vehicles will be used and in which operational context. These considerations will also inform activities on the right side of the “V” by providing operational scenarios and mission threads needed to demonstrate that the vehicle meets the acceptance criteria.

Based on the operational and DLoD Integration needs, acquisition and TLCM strategies can then be addressed to procure and maintain the vehicle throughout their expected lifecycle which is informed by the intended use. However, acquisition and TLCM strategy might actually be part of a higher level architectural policy mandated by the Land Equipment OC in terms LOSA or the Integrated Equipment Support Model. In any case, the acquisition and TLCM strategy serve as constraints on which solutions and their support schemes are allowed. Acquisition and TLCM considerations are also linked to activities on the right side of the “V” and help to inform the nature of system and integration tests, demonstrations and the review acceptance documents.

Finally, technical considerations will need to be addressed based on the constraints and context provided by the DLoD integration, acquisition strategy and TLCM strategy considerations. The technical considerations will focus on the range of solution options allowed and the considerations needed to select the most appropriate solution and award the contract to that supplier. Technical considerations are also linked to activities to the right side of the “V” in order to inform systems verification and validation, testing and integration.

This operational concept also addresses the use of metrics to assist with the management and decision making required to manage and control the process. Figure 45 shows this process and linkages and dependencies required. The diagram shows the assessment metrics and their linkage to the GVA implementation levels. Therefore as the project’s needs change, the impact on the GVA implementation levels can be observed. Likewise, as project changes implementation options, the impact on project needs can be observed. The final linkage is through the benefits model. The model links benefits based on SoSA, GVA and project Principles to the implementation options chosen and the project needs assessments.

Figure 45: Use of Metrics and Dashboards to Manage the Process
Follow-on Activities

The processes outlined here serve as the basic infrastructure in which to support decision making in vehicle projects that will use GVA. Since this study focused on a core process in which architectural attributes, also known as “ilities”, are compared and assessed, many other activities can be supported and enabled through this process. Figure 46 highlights the activities enabled by our process.

In particular, this process can improve the Invitation to tender (ITT) process by providing structured questions and methods to address key issues identified in the project’s needs assessments. ITT questions can then be more process orientated and touch areas such as exportability and upgradeability along with other commercial and support issues. By clearly articulating these issues up front, they can be managed and dealt with as part of the benefits process where they can be managed for successful delivery.

Project milestone reviews can be better managed with regards to documentation maturity, identification of key issues and decisions points and the clear understanding of interdependencies so that cause and effect relationships can be established. This allows decision makers to focus on performance, cost, time and risk indicators to help them identify trends and the actions important to the project so that they can alter the project’s course in a purposeful manner.

Finally, the process allows decisions and option analysis to be performed. In this case, the use of the benefits models could identify options which provide the best value for money benefits, yet stay within the allowable option constraints and project’s needs.

Figure 46: Activities enables by the our Process

This process could be applied to actual system procurement. There are at least four basic scenarios that are of interest to the Land Equipment OC. These are as follows:

1) Urgent Operational Requirement (UOR) procurement of new vehicles generally as part of a COT/MOTs purchase
2) Equipment Planning (EP) procurement that will consider an enhanced COTS/MOTS design
3) Upgrade of a Legacy vehicle to a more GVA compliant architecture to improve operational flexibility and cost effective upgradeability
4) Transition of a UOR vehicle to Core
Each of these scenarios raises concerns that an open architecture process must address. The objective is to ensure that the process followed allows for: 1) effective decision making within the time constraints allowed, 2) buy-in from the Delivery Teams and GVA office and 3) that it actually provides benefits for the effort expended to manage it.

For Mastiff 3, Figure 47 illustrates the considerations that could be made and integrated into our process. This example highlights the project needs of a UOR vehicle and the considerations that must be made to transition it into core. The goal is to produce Mastiffs that are configured and tailored to the needs of the British land forces.

![Mastiff 3 Upgrade](image)

**Summary and Conclusions**

The Team produced the following products as a result of this work:

1) A description of the process in the form of a PowerPoint presentation and report

2) A description of potential follow-on activities and additional areas of benefit

Projects must address the needs of many constraints, some of which are opposing, yet maximise the benefits that are delivered. In particular, project managers must have a process in which to shape the constraints and decision process such that a project delivery strategy and direction can be determined and navigated to a desired end goal. Therefore, they need the means to “command and control” and steer the project.

The process the Team identified for GVA is scalable could be used in any of the LOSA generic architectures such as Generic Soldier Architecture (GSA) and Generic Base Architecture (GBA) as well as for LOSA. This process is based on the alignment of requirements, assessments and benefits such that data can be distilled into meaningful information to inform project decision making.

However there are limitations which are addressed in Figure 48. These limitations require intelligent and purposeful application of the process to solve the problem at hand. The assessments should be meaningful and conducted to capture the true state of conditions. Benefits could be captured via the SoSA Principles and put into PCTR terms that can inform the project’s decision making process. However, in order for this process to be useful, it must be updated and used on a regular basis. Its use must become the main manner of doing business. Through use will come improvements.
Limitations

- Requires assessments to be performed by an informed assessor
- Requires SOSA Principles to be applied above the project level to gain most of the benefits
- Requires cost and programmatic data to be generated and managed in order to provide meaningful PCTR indicators
- Requires regular updates and use to gain full benefit
- Needs to be better than doing it the “old” way

Figure 48: Limitations

Follow-on work is anticipated, especially for areas above the project level. GVA could provide more benefit to MoD and Land Equipment OC when it is actively used as a driver for common solutions. Figure 49 highlights follow-on work and activities. In this context, LOSA has the potential to both represent the operational system architecture for the Multi-role Brigade as well as to satisfy architecture needed to support an Integrated Equipment Support infrastructure. Understanding these two diverse yet needed objectives will shape LOSA and how it is managed. Open architectures will provide the mechanism for managing all of the key attributes as discussed in this paper.

Possible Follow-On Work

- If successful, apply to GSA and GBA architectures
- Use to develop LOSA
- Conduct usability studies with Project Teams
- Use and improve the tool!

Figure 49: Follow-on Work
ANNEXE C: DRAFT SPECIFICATION FOR A DESK OFFICERS TOOLKIT TO SUPPORT ARCHITECTURE ASSESSMENT

Introduction
The SoSA CF WG1 has shown that the benefits sought through adoption of open architectures can only be realised if appropriate consideration is given to where (in the system) openness is required to enable those benefits and that tailoring is required to achieve them. Furthermore, to avoid these benefits being traded out of a solution, or indeed not making it into the solution space, the evaluation of architectures must fully recognise the link between the architecture features and those benefits and the needs of industry must be taken into account when tailoring the openness in order that openness will be affordable across the enterprise.

Openness is a key part of the SoSA principles and so it should be considered as policy; but to enable policy to be implemented effectively, the whole of the acquisition decision making components must be enabled. That is to say, the people charged with implementing the policy in real systems must be adequately equipped. To this end, a practical tool kit is required to assist desk officers in assessing the merits of various architectural offerings and ensuring that the benefits of openness are fairly considered. In this appendix, we provide the high level requirements for such a tool kit.

This appendix does not set out to argue the case for a Desk Officer’s Toolkit, but presents an outline specification on the assumption that it is agreed that this is a necessary development to support the greater use of open architecture within Defence Procurement.

Specification

Overarching requirement

A set of easy to use, coupled tools is required to support acquisition decision making through the comparison of systems architectures relative to the benefits they enable.

The toolset must be implemented as a decision support aid, not as a decision making system.

Benefits

The benefits sought will fall into the following (non-exclusive) categories (Table 2):

<table>
<thead>
<tr>
<th>Acquisition Agility</th>
<th>Flexibility, Tempo</th>
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<tbody>
<tr>
<td></td>
<td>Supportability</td>
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<tr>
<td></td>
<td>Cost of Ownership</td>
</tr>
<tr>
<td></td>
<td>Scope for amortising costs over SoS Changes</td>
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<tr>
<td></td>
<td>Industrial capability – Exportability, Sustainability</td>
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<td></td>
<td>Reuse of previous investment</td>
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<td></td>
<td>Software instead of hardware implementation</td>
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<tr>
<td>Operational Agility</td>
<td>Modular, reconfigurable</td>
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<tr>
<td>Technical Agility</td>
<td>Adherence to SoSA Principles</td>
</tr>
<tr>
<td></td>
<td>Technology insertion</td>
</tr>
</tbody>
</table>

Table 2: Benefit Categories for Architecture Assessment

Approach

The assessment shall be based primarily on architecture analysis

The assessment shall address both functional and non-functional requirements

The assessment shall be based on benefits realised over time using an appropriate system roadmap

The roadmap shall account for systems of systems evolution
The assessment shall include one or more cost models that are available to suppliers
The assessment shall be able to use measured and estimated data and...

The results of the assessment shall clearly indicate the level of confidence in the derived metrics

**Development**

The tools in the toolset should be based – wherever possible – on existing tools
The assessment framework should be integrated into the current Desk Officer toolsets.

**Use**

The Desk Officer’s toolset for architectural assessment shall be designed for use during the initial assessment of systems solutions to capability requirements

Initial assessment comprises new build, upgrade, technology insertion, and decommissioning

Assessment shall be achievable within 1-3 weeks depending on project size

The Desk Officers’ Toolkit for Architectural Assessment shall be useable in reverse: i.e. identification of benefits sought should enable the Desk Officers’ Toolkit for Architectural Assessment to indicate likely characteristics of systems solutions to maximise those benefits

The Desk Officers’ Toolkit for Architectural Assessment shall allow the Desk Officer to conduct sensitivity analysis

**Components and Structure**

Figure 50 shows the basic structure of the proposed toolkit; the principal inputs concern:

- Benefits sought – i.e. top level requirements of the system
- Candidate architectures – i.e. solutions offered to the customer
- Commercial constraints – specific legal and previous contract constraints on the commercial model
- Competition factors – information about the market place

Additionally, information on costs, risks, legacy systems, etc. will be required but this can be regarded as database although, in reality, much of it will need to be assembled from various sources and some of it may only be estimated. The benefits sought should be expressed in terms of timeline and information from other programmes and sources will be needed to determine the appropriate roadmap.
The outputs will provide the decision makers with an estimate of the extent to which benefits sought (i.e. requirements) are met and over what time period. This will be matched against a cost profile and an indication of the likely risks over that same time period. All information presented to the decision maker should be coded in such a way that the level of confidence in the information is immediately apparent.

**Figure 50: Components and Structure of the Desk Officers Toolkit**

The outputs will provide the decision makers with an estimate of the extent to which benefits sought (i.e. requirements) are met and over what time period. This will be matched against a cost profile and an indication of the likely risks over that same time period. All information presented to the decision maker should be coded in such a way that the level of confidence in the information is immediately apparent.
ANNEXE D: UKCeB REPORT ON TOOLS

“Defence manufacturers procure toolsets, as well as developing their own, to design and manufacture military capability. If we are to advocate open architectures and open systems, doesn’t it necessitate a view on what the leading providers of toolsets to the Defence Industry are doing on the topic of ‘openness’, and its likely impact on answering the question posed to WG1?”

- A paper to inform the System of Systems Approach Community Forum Working Group 1, Open Systems and Architectures.

David Pearce, UKCeB Task Force Business Consultant

The UK Council for e-Business (UKCeB) is an independent, mutually co-operative, not-for-profit organisation funded by its members with ca. 600 members representing over 80 organisations that see itself as the catalyst within Team Defence. UKCeB is at the forefront of e-business in Defence, energising advances in e-business across policy, delivery and implementation. UKCeB represents industry with eight 2* MoD groups, and is involved in 30 Working Groups and a range of joint MoD/Industry projects and has been closely involved in 40 MoD/Industry events in the past year facilitating workshops; joint Mod/Industry Communities of Interest and good practice visits. UKCeB also arranges tutorials on specialist e-business topics for our membership, as well as supporting fundamental research. www.ukceb.org

In December 2010, Zachs Investment Research produced an analysis on the US Defence market, the findings of which could be equally ascribed to this side of the Atlantic. The analysis broadly concluded that US core defence spending was expected to follow a downwards trend as the wars in Iraq and Afghanistan are expected to wind down in the coming years and that the big Defence contractors, in order to counter defence budget cuts, would most likely target mergers and acquisitions to bolster their operations. Secondly, Zachs felt that as a response to the asymmetric terrorist threats, the Defence equipment capability emphasis would appear to be shifting to high-tech intelligence equipment, replacing demand for conventional big guns and heavy armour. As a result of this growing trend, major Defence contractors have, in response, resorted to bolt-on acquisitions to plug holes in their product offerings and are also entering into strategic alliances and partnerships with competitors to improve their prospects to close major contracts.

Running this analysis alongside the statement at the head of this paper that ‘Defence manufacturers procure toolsets, as well as developing their own, to design and manufacture military capability’, aren’t there parallels in the demands to run effective business models amongst the Defence Contractors, as there are within the toolset technology providers - if we are to advocate open architectures and open systems to satisfy the demands of the Customer – for example, the various Departments of Defence, and in particular in the UK, the MoD?

Here’s one example. There are about 3TB of data and 1 million parts in a ship. The F35 aircraft consists of 1.5TB of CATIA V4 data in 200,000 unique drawings. In all, almost 40TB of data were migrated in 2007 (creating a $5.5 billion market for about 150 service providers worldwide). And much of this data must move forward with the business. If we accept Zachs premise and compound this situation with contract and commercial driven alliances with a proliferation of new technologies, acquisition acquired technologies, applications, and an explosion of product data then the dynamics of Defence capability acquisition are likely to get more convoluted over time, and the drive towards open architectures and open systems to assist in the process of data homogeny becomes very appealing – or does it?
Let’s consider software in the generation of a Defence capability: it has a long lifecycle in an environment of absolute complexity of application, and of extremely high cost of change. A significant portion of the capability product lifecycle is to support people in the way they run product development, exchange information, and make decisions; simply put, it’s all about data, and about the lifecycle management of that data.

The following example is provided courtesy of John Martin, BAE Systems Submarine Solutions, and is taken from his Paper: Data Modelling, Its Use and Contribution to Ship Design, Manufacture and Build presented to ICCAS in 2009. In his Paper, John argues that the warship design process develops data that is high in volume and complex in content for very small build quantities, often only one, in order to create a feasible concept; the design intent and a physical solution for the design. Together with manufacturing information, installation, build and test data – this has to be in sufficient detail to enable the vessel to be maintained and operable for a 25-30 year life.

Modern technologies enable this data to be captured, stored and managed electronically and selectively extracted to enable use throughout the product life cycle. The high data volume, categorisation and relationship of design, manufacture, build, test, and in-service support information is such that it is captured, stored and used in a variety of independent systems with interfaces developed for copying or converting data between systems.

The above refers to perhaps one shipyard: for the new carriers, project organisation involves a central functional design office and four major shipyards, each responsible for the detail design, integration, build, outfit, installation and testing of specified ‘mega-blocks’ of the ship and many supporting companies provide design, support, and fabrication services or ‘supply and fit’ contracts. This could therefore qualify as one of Zachs ‘strategic alliances and partnerships’

In an ideal world, what John would be looking for would be a product life-cycle management regime that would guarantee integrity of data with controlled access throughout the organisation(s), coupled with version and variation control all under a collaborative project management structure. In this would be, for example, workflow and change management and version control capabilities and controlled visibility of product data supporting a single Bill of Materials. This would ultimately lead to improved collaboration across departments, and faster and more reliable product development and sustainment through-life.

The technology toolsets that would typically be available would be specialised systems such as CAD/CAM/CAE, planning, materials management and finance applications used to manage ship design/build data. During design the data content evolves as more detail is obtained, with input from several functions. Typically IT systems are modified and/or developed to suit the culture and processes of a particular shipyard and involve intensive systems training and considerable dependence on the user’s product knowledge and an understanding of company functional processes, practices and culture. From the early days of CAD, we have now evolved into a world of Product Life-cycle Management (PLM) - a comprehensive information system that coordinates all aspects of a product from initial concept to its eventual retirement, in other words, the digital backbone. On the road to all embracing ‘PLM solutions’, Product Data Management (PDM) - an information system used to manage the data for a product as it passes from engineering to manufacturing – and individual applications such as, for example, analytics, document management, simulation and digital mock-up capabilities have all been swept up to create PLM – defined by the Ford Motor Company as “the management of information, processes, people and applications used from the inception of a product through the end of its life. The objective is to bring these disciplines together to create an environment that enables the creation, maintenance, access and retirement of product data, and extends across traditional boundaries - product development, manufacturing, and service, across brands and across continents and cultures”

In our world of Defence, toolsets for the design, manufacture and sustainability of Defence capability, PLM is all pervading with maybe four or so $bn companies providing the bulk of the PLM
software tools in use worldwide today. So how are they measuring up to the challenge of being open, and to allow other vendors products to be incorporated into their offerings to provide the end-user with a best of breed, user defined, toolset? In 2011, the CAD industry operates with about 52 CAD standards. The absolute leader is STEP (32% usage for CAD data exchange). Other formats used for the same purposes are CATIA V5, 21%; SolidWorks 15%, and NX with 6%. The notable standards are STEP. Remember also that they have their own Standards and Formats. Open standards are not well developed in the engineering and manufacturing space: CAD / PLM vendors are not on the leading edge of open standard development - why should they be when the traditional emphasis is on proprietary data and strong, feature rich competition? There is also IP protection to consider, as well as a business model oriented on locking customers on the particular software with strong emphasis of recurrent revenues coming from upgrades, renewals and future releases. The scope for some form of openness and standardisation covers a relatively small part of the "PLM space" with so many areas still neglected and where Vendors see little or no commercial advantage in aligning with them. In the main they profess that they have ‘an open architecture, or a ‘robust integration platform’, ‘unified user interface model and an ‘open business model’; ‘open data model’; ‘open architecture’ and ‘open applications’

My view is that the lifecycle of PLM software systems is very complicated - as complicated as the A&D product lifecycle they are managing and to change existing systems in a Defence company can be a very costly, and far reaching. However, to re-use existing systems can be a technical challenging whereas common toolsets will enhance interoperability and reduce training and support costs. Common toolsets will enhance interoperability and reduce training and support costs; common CAD/PLM system across the enterprise enables manufacturers to more readily reuse existing IP embedded in their 3D models. Notwithstanding the Zachs analysis alluded to earlier, a collaborative (for example, strategic alliances and partnerships) community may change in membership during the lifecycle of the acquisition contract, as indeed the toolset providers and will need to interact with others during the lifecycle for different projects & durations putting further pressure on the need for some form of open or standards strategy. With respect to PLM and Standards today, the picture of Standards is over complicated, and at best, confusing. A whole industry has built up around swapping CAD files, Standards, best practice, et al. In many situations people equate ‘openness’ with ‘standards’- and there are many scars.

The AeroSpace and Defence Industries Association of Europe – ASD represents the Aeronautics, Space, Defence and Security Industries of Europe in all matters of common interest with the objective of promoting and supporting the competitive development of these sectors. ASD pursues joint industry actions which have to be dealt with on a European level or which concern issues of an agreed transnational nature, through generating common industry positions, and has created a PLM Interoperability Work Group to look at the use of international open PLM as a way to reduce the number and varieties of interfaces and conversion levels between tools, and to improve the integrity and quality of engineering data exchanged across the applications, and to ensure the long term data management and archiving for long-life products. But perhaps we should be considering ‘Standards’ as a Framework to assist in the process of communicating per se between different stakeholders in a Defence enterprise. This would seem eminently more productive than just the ability to convert CAD file from one format to another. The focus of a PLM Framework would be to embrace Standards at the point of need to ensure information exchange, again at the point of need.

Trends emerging at from the Automotive OEM community is that they are realising that the traditional heterogeneous and fragmented PLM environment, even when comprised of excellent tools, is unable to provide the level of visibility, manageability, and fidelity of decision-making required and are taking steps to migrate to a design and manufacturing environment capable of supporting a global platform strategy. They maintain that this environment must be standard-based and open in order to facilitate a single source of all data for design, manufacturing and supply chain processes across vehicle design and manufacturing. Can it be much longer before the Defence
 Contractors reach the same conclusion, and opt for a toolset Vendor that can demonstrate similar merits and not let the efforts to standardise take precedence over the business needs?

To support open standard is expensive – from whichever side of the debate. A witticism currently doing the rounds is that Standards are like toothbrushes: everybody needs them, but nobody wants to use someone else’s.
ANNESE E: SYNTHESYS REPORT ON CLOSE AIR COMBAT CASE STUDY

DR. KIRSTEN SINCLAIR

Evaluation of Open Systems Metrics derived by Working Group 1

Executive Summary

A range of metrics were suggested by members of the System-of-Systems Approach Working Group 1 in response to MoD and industry requirements related to open systems. To help assess the usefulness of these metrics, SyntheSys has undertaken a small work package (approximately three days of effort) as part of the working group’s activities. We have interpreted these metrics in the context of our own system-of-systems (SoS) engineering method to provide feedback on the results to the working group.

Problem: Usefulness of suggested openness measures

Four core areas critical to the acquisition of defence systems-of-systems were listed in [1]. These are: acquisition agility, industrial capability, systems contribution to system-of-systems, and costs. A hierarchy of needs (and related sub-needs) normally considered for each area were then identified. An example of one area and its hierarchy of needs is:

CRITICAL AREA OF ACQUISITION

1. Systems contribution to SoS

NEEDS OF AREA

1.1 Systems capability

1.1.1 Dependability

1.1.1.1 Safety (lowest level need)

1.1.1.2 Security (lowest level need)

1.1.1.3 Availability

1.1.1.3.1 Maintainability (lowest level need)

1.1.1.3.2 Reliability (lowest level need)

1.1.2 Performance (lowest level need)

1.2 Agility

For each lowest level need in the hierarchy, metrics that could be used to imply a level of ‘openness’ associated with the need were suggested. For example, for the ‘Safety’ need (1.1.1.1 above), base measures ‘Cost to certify’ and ‘Time to certify’ were suggested [1]. Reductions in the cost and time to certify safety of a system-of-systems could be a positive result of adhering to ‘openness’ needs in the acquisition of a system-of-systems.

Ten further needs (attributes) directly related to openness were also identified [1]. These were: modularity, compliance with open standards, component commonality, layering, segmentation, centralisation, high integrity design, use of custom-off-the-shelf (COTS), and common underpinning information model. In [1], these were used to indicate their likely effect (positive, positive or negative, and no effect) on each of the lowest level needs. For example, for the safety need (1.1.1.1 above), the following openness needs were believed to have a positive effect: modularity, component commonality, segmentation, high integrity design, and common underpinning information model. Segmentation and use of COTS were believed to have both positive and negative
effects on safety while compliance with open standards and layering were thought to have no effect on safety.

The problem is to evaluate how useful these suggested metrics are in the context of system-of-systems engineering.

**Approach: How has SyntheSys evaluated the metrics?**

SyntheSys has developed its system-of-systems engineering method in partnership with the University of Durham. Using its method, it has tried to evaluate one critical area of acquisition (‘Systems contribution to system-of-systems’) and one lowest level need (‘security’) for a Close Air Support (CAS) case study.

The UML graphical modelling language was used to build a blueprint ‘as-is’ model of the proposed close air support system-of-systems. Two viewpoints were used: a Strategic Level and a Solution Level. The strategic level covers the ‘top-down’ engineering perspective, the solution level the ‘bottom-up’ perspective. The strategic level aims to capture (some of) the vision, goals, objectives, strategy, capabilities, guidance and measurements related to close air support. The solution level aims to capture (some of) the assets combined in real-life to perform close air support. This level can also be used to capture real-life performance measurements related to components of an asset, each asset, or combination of assets.

As the evaluation is UML-based, models can be used to show relationships between model elements. Relationships can be traced between model elements to highlight gaps. Performance measurements related to model elements can be reported on and used to derive aggregate measurements. Fig. G1 shows our interpretation of capturing what we currently know (the ‘as-is’) for the close air support system-of-systems in relation to openness:

![Diagram](image)

**Figure 51: Close air support strategic level**

Figure 51 relates the desired end results for close air support (vision, goals, objectives) to how the organisation plans to get there (strategy, capabilities). Guidance (policy) is intended to support the achievement of end results and inform how to go about getting there (i.e. the aim of capabilities); performance measures are for the purposes of measuring goals and objectives. For critical
acquisition area ‘Systems contribution to SoS’ (and one of its lowest level needs, ‘security’), associated metrics and openness characteristics were modelled as follows:

- ‘Systems contribution to SoS’: acquisition policy model element.
- ‘Security’: sub-policy model element.
- ‘Security metrics’: measure type model element.
- ‘Openness characteristics’: policy and measure type model elements.

In Figure 51, security certification metrics ‘Time to certify’ and ‘Cost to certify’ were used to measure the goal ‘To provide secure CAS systems when needed’. Recording and base-lining actual values of these metrics can be used to establish if objective ‘By end of 2011, 10% reduction in certification time and cost’ is achieved.

Figure 52 shows what we know for close air support (the ‘as-is’) in relation to openness at the solution (bottom-up) level. This level captures the real-life assets combined to meet the ‘Conduct CAS’ capability and actual values for the metrics related to security and openness. It can be seen that in our small case study, the ‘Conduct CAS SoS’ system-of-systems is comprised of three autonomous systems, ‘ASCOD SV’, ‘UK Air Support Centre’, and ‘Boeing AH-64 Apache Helicopter’. The ‘Conduct CAS SoS’ system-of-systems is the real-life implementation of ‘Conduct CAS’ capability in the strategic level.

The ‘Conduct CAS SoS’ should have been acquired according to acquisition policy as indicated by the strategic level. Each of the autonomous systems comprising this system-of-systems and component systems comprising each autonomous system should have also been acquired according to the acquisition policy and its derived sub-policies (including the openness sub-policy).

To evaluate our interpretation of the problem, example values for metrics were populated in the model of real-life assets. The process followed was: lowest-level component systems comprising an autonomous system were measured first, then autonomous systems comprising the system-of-systems, and finally the system-of-systems was measured.

In our case study, component system (‘Synth CAS UI’ system software) was measured first. Security metric values ‘Time to certify’ of 2 days and ‘Cost to certify’ of 700 GBP were created and related to this component system model element (Figure 52). It was assumed that these values would be based on independent testing carried out to meet component system security policy requirements and may involve consideration of internal software components as well as behaviour of the end product.

Openness metric values were derived for our case study from the working group’s openness needs and populated with example values (these metrics were derived by SyntheSys for the case study and would benefit from further analysis). The same logic for adding security metrics was applied to adding openness metrics, i.e. consideration may be given to internal software components in order to derive values for openness metrics.

Next, security and openness metrics were populated for the autonomous system (‘Boeing AH-64 Apache Helicopter’). Security metric values ‘Time to certify’ of 30 days and ‘Cost to certify’ of 25600 GBP were created and related to this model element (Figure 52). It was assumed that these values would be dependent on the security certification status of each component system within the autonomous system and the certification of the autonomous system as a whole. Component systems may have to have additional security checks performed on them (outside of their own individual security requirements) before they can be integrated into the autonomous system.

Openness metrics were then considered for the autonomous system as a whole. Again, it was assumed that these values would be based on the component systems forming the autonomous system. The example values are shown in the ‘Boeing Open’ actual measure model element (Fig.2).

The final part of the metrics population process was to create security and openness metrics for the system-of-systems as a whole, i.e. populate and relate the two actual measures to the ‘Conduct CAS
SoS’ system assembly model element. Again, the security certification metrics relate to the ‘Conduct CAS SoS’ system-of-systems and were influenced by the certification metrics of its autonomous systems and their component systems security certification as well as the certification requirements for the system-of-systems. The openness metrics also relate to the system-of-systems as a whole and were derived from the autonomous systems comprising the system-of-systems.

Figure 52: Close air support solution level
Results

The process we followed to evaluate the metrics used a combination of top-down and bottom-up engineering. Top-down engineering was used to relate the needs and measurements identified by the working group with the strategic needs of close air support. The strategic level was used to try and position needs and measurements at the right level of abstraction so that their scope of influence could be completely and correctly implemented at the solution level. These strategic needs were then related to the real-life assets used to execute close air support. The measures identified as being potentially suitable to indicate openness at the strategic level were populated for these real-life assets using bottom-up engineering.

The strategic level relates acquisition policy to capability and desired end results. The model indicates that the acquisition policy and its sub-policies should influence all capabilities. The effects of applying this policy and its sub-policies will be measured by metrics associated with policies at different levels of abstraction. At the solution level, this was modelled by applying the metrics associated with security and openness at different levels of system abstraction, starting with the lowest component system and working up to the parent system-of-systems level. Metrics at the higher level of abstraction were assumed to be influenced by lower level metrics.

At the highest level of abstraction, i.e. the system-of-systems level, the associated (actual) security and openness metrics were related back to the strategic level (desired) objective ‘By the end of 2011, 10% reduction in security certification time and cost’. Base-lining these current values means that if and when any changes relating to openness are made to the real-life assets used to conduct close air support capability in the future (‘to-be’), re-populating the same metrics should enable an organisation to compare the most recent metrics with those base-lined. In this way, the organisation can see if measures of openness do impact on and help reduce security certification time and cost.

Summary

Our case study tried to interpret the needs and metrics identified by the working group and evaluate their use in the engineering of system-of-systems (and potential inclusion in MoD’s System-of-Systems Approach guidance). By applying our system-of-systems engineering method to this short exercise, SyntheSys has been able to indicate a possible way of assessing the impact of openness needs in evolving system-of-systems.

Further work would be required to establish, verify and validate more detailed process and metrics for each of the four acquisition areas and openness needs in ‘as-is’ and ‘to-be’ blueprint models, and to consider the relationship between acquisition area needs and their recorded metrics more fully against recorded metrics for openness. Further work would also help to highlight gaps within and between strategic and solution levels for ‘as-is’ MoD systems-of-systems.

Although the case study used a small sample of the proposed metrics, SyntheSys believes the process used above indicates the potential usefulness of the defined openness measures.

References

[1] SoSA T26 Exempl Measures v2(MJDH).xlsx