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Through-life NEC scenario development

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Through-Life NEC Scenario Development

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Abstract— Scenarios are an important planning tool used by individuals, businesses and governments (especially in the military domain), but many of the currently used approaches focus solely on acute probabilistic timeframes and specific metricated instances of possible future states. Using a mixed method research methodology, we develop a scenario approach in which multiple timeframes are accommodated, by fitting vignettes within each other to represent different time levels. This has the advantage of presenting the end-to-end process of capability development and instantiation. We describe the methodology employed to generate such a scenario as a demonstration aid for a large, multi-disciplinary research programme in systems of systems engineering. The process of scenario generation was an effective integration tool within this programme (that included twelve distributed research groups). The resultant scenario enabled engagement of multiple stakeholders in an integrated demonstration of systems related research outputs. We recommend a new class of scenario (a ‘research scenario’) for incorporation within the standard classifications of scenario types.

Index Terms— Scenario Based Planning, Scenario Development, Multidisciplinary Integration, Research Demonstration, Stakeholder Management.

I. INTRODUCTION

The future is never certain and nothing is ever sure. Designers, technologists, industrialists and military forces have always to deal with uncertainty. But how best to plan for and manage such futures? Scenario-based planning is frequently employed, although there are many ways in which it can be applied [1][2]. Scenarios are used in a multitude of ways and formats, ranging from high level strategic planning to in-depth analysis of human interaction [2][3]. Sophisticated scenarios are used not to predict a specific future, but to envisage possible futures through which people can understand the impact of different interactions upon projected

products and services. Such scenarios test the proposed processes and behaviours by examining adaptation mechanisms for coping with an envisioned environment and understanding the impact of decisions [4].

We describe the development and use of a scenario to underpin a wider demonstration of Systems Engineering research. This is achieved through a scenario that is created from a complex set of Matryoshka-style vignettes (i.e. fitting one inside another, although not in a fractal way like Matryoshka dolls) [5]. The vignettes cover four timeframes, with the detail at each tailored to the major activities they incorporate. The vignettes were linked in such a way that alternative possibilities could be ‘plugged and played’ if necessary.

The demonstration concerned the Systems Engineering needed to support Network Enabled Capability (NEC) and the stakeholders were drawn from UK academia, industry, Government and the military. The challenge was to integrate and showcase individual research contributions from a multidisciplinary team within a system of systems endeavour. This involved accommodation of research that covered diverse themes and disciplines, was relevant to significantly different decision timescales, and was at several levels of maturity. Furthermore, the research contributions came from twelve distributed academic research groups working on a range of systems and technologies in support of NEC. The subject of this paper is confined to the demonstration scenario approach and the reader is referred to <http://nectise.com/publications.html> for details of the individual research contributions and results.

II. RELATED WORK

A. Scenario experimentation

Carroll [6] describes how scenarios can be both concrete and flexible at the same time, by which he means that they provide sufficient data, information

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and context to paint a picture that is wholly believable and real enough to be considered viable for experimentation and analysis. But, at the same time, such scenarios can be easily changed to account for changing circumstances, stakeholder inputs, or varying requirements.

The scenarios literature covers a wide variety of meanings, methods of creation and application [1][2][3][4][6][7][8][11][12][13][14][15][16][17][18][19][20], but it appears that the majority of methods consider a scenario approach to be targeted on a defined, metricated and probabilistic single point in the future. Multiple time frames (concerned with development over long time periods) and possibilities are very rarely catered for. Scenarios are often used in groups as comparators or complements [10] but are rarely interlinked to form a causal time continuum or to examine change over time. Scenarios tend to be symptom-classified, [21][22][23][24], as being for one purpose or another, but not a combination, e.g. short term, but not long term. They are singular, linear instantiations of a set of variables that are highly focused on a particular aspect of the problem situation [12].

A review of the different scenario generation techniques indicated that two were particularly useful for the scenario challenge faced by the NECTISE¹ research programme; these were The Technical Cooperation Program (TTCP) Guide for Understanding and Implementing Defense Experimentation (GUIDEx) [8] and the Whitworth *et al.* Framework [7]. The GUIDEx approach focuses upon experimentation for defence related matters. Generally, defence experiments are complex and convoluted; GUIDEx aims to ensure scientific rigour is applied to such experiments. The process stages are: problem formulation, experimental analysis, experimental development, analysis and reporting. These themes provide a structure that can be tailored to specific experimental needs. The documentation set defined by GUIDEx proved invaluable in an activity where there were so many stakeholders and it was an essential tool in managing the progressive development of the scenario. In some respects it is similar to a number of eight step scenario development techniques described elsewhere

[17][18][19]. The Whitworth *et al.* [7] framework sets out a basic process for the development of a scenario that essentially provides a check for completeness and consistency between the parts. This structures the information and effectively provides a checklist through which scenario completeness can be assessed

B. Network Enabled Capability

Network Enabled Capability (NEC) is an endeavour to enhance military capability through the networking of existing and future military assets and resources in order to respond to the rapidly changing conflict environment in which the armed forces must operate [25][26][27][28]. NEC is an internationally applicable concept, but this work is focused on the UK approach.

Capability is a key concept defined as the enduring ability to generate a desired operational outcome or effect, and is relative to the threat, physical environment and the contributions of joint or coalition forces [29]. At the highest level, capability is constructed from the seven elements of command, inform, prepare, project, protect, sustain, and operate, as described in the High Level Operational Concept [30]. These are provided through contributions from a set of less abstract, planned capabilities, such as counter airborne threat (as used in our example).

NEC requires interoperability between independent systems that can evolve and operate in a collaborative and dependable manner. NEC makes demands on the overall delivered systems that cannot be fulfilled by traditional design principles that address independent closed-world systems [31][32]. NEC is realised through services that form networks of systems of systems that are dynamic, large-scale and subject to continual change, adaptation and evolution.

III. THE NECTISE RESEARCH PROGRAMME

The impact of NEC on the defense supply chain implies that the principles of Through Life Capability Management (TLCM) [28] must be considered in order to provide NEC-ready systems. The research endeavour and the scenario used to showcase the outputs necessarily considered the systems engineering applicable to both the TLCM and NEC aspects in a linked fashion.

¹ Network Enabled Capability Through Innovative Systems Engineering

In the UK, NEC is considered fundamental to the delivery of military effect. It is a key consideration for future acquisition and management of military capability. The role of industry in supporting those capabilities has developed considerably from being essentially a supplier of equipment to being a partner with Government across the Defence Lines of Development (DLOD) [29][33]. The partnership activities extend from high level capability planning to the delivery of the technologies and training used in military operations. NECTISE contributed systems engineering approaches to industry that are relevant to all of these levels; contributions which should reduce the risk and cost of the various systems that contribute to military capability planning and development, and NEC in particular. The research was founded on the question: *Are you ready for NEC?* (see Fig. 1).



Fig. 1. NEC Organization and Operation Relationship

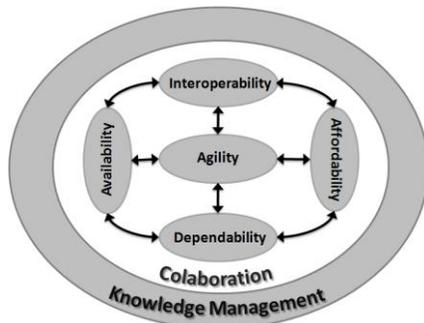


Fig. 2. NEC Readiness Themes

This question is considered from the perspectives of the operation (i.e. military) and the organization (i.e. NEC developer community of industry, civil service, and academia). Through stakeholder enquiry and by consideration of the NEC benefits chain [26], a set of NEC-readiness themes has been derived. Agility is the overall objective, but this is

enabled or constrained by attributes of the other themes (Fig. 2).

The themes are also relevant to the agile delivery of systems by the development community. The partnered environment that is needed for such delivery [33] requires changes in the approach to acquisition; these presumed changes (as deduced from [33] and other documents) underlie the demonstration scenario that was generated.

1) Research Streams

The NECTISE programme [34] was a major research investment in systems engineering that involved ten UK universities, each providing one or more discipline-based research activities within an integrated whole. The research was broadly divided into three main parts, each of which contained several work packages:

- Through-life systems management looked at elements of understanding and responding to NEC environments, lifecycle models for evolutionary NEC, the fundamental characteristics of the complex system-of-systems features that drive the NEC challenge and the development of an Integrated Decision Support Environment for capability-based acquisition. This included research into aspects of system dependability such as safety, availability and security.
- Systems architectures, the objective of which was to develop and evaluate a critical set of architectural representations of systems of systems from different perspectives, at different levels of abstraction. This work included a strong element of Service Oriented Architecture development for NEC.
- Management of networked autonomous assets, which integrated health management, prognostics and reconfiguration of autonomous systems within a NEC environment.

IV. METHODOLOGY

The methodology for the whole research program followed the pragmatic approach [35]. All work packages were included in a demonstration to showcase the integrated research outputs. The scenario approach was a means of communicating research to stakeholders and also proved to be an important mechanism for facilitating integration amongst the multidisciplinary research team. The

aim was to engage audiences from the defense community and show the nature of the NECTISE research within a meaningful context that was described and illustrated through the scenario.

The research team as a whole employed research methodologies ranging from positivist techniques concerned with control systems for autonomous systems through to constructivist techniques appropriate for investigating the relationships between organisations in the supply chain. This poses a challenge for demonstration where all research must be included. Only a scenario technique allows the flexibility for all aspects to be included. The research to construct the scenario approach followed a series mixed methods research methodology [35]; i.e. positivist and constructivist approaches used consecutively. The generation of the scenario itself followed a form of the Delphi-Scenario methodology [36], except that the expert opinion was used to validate the description of the complex acquisition environment, rather than to predict possible futures, as is more usually the case. This was conducted within a traditional systems engineering approach of stakeholder identification, requirements solicitation and validation as described in the following sections.

A. Stakeholders

The NECTISE programme had a range of stakeholders from academia, industry, and government (see Fig. 3). The principal ones are: *BAE Systems* (industrial sponsor): divisions engaged across the Land, Sea, Air, and C4ISTAR (Command, Control, Communications, Computers, Information/Intelligence, Surveillance, Targeting, Acquisition and Reconnaissance) domains. The focus of interest varied across these different divisions according to the then current business needs and business models. This provided both a challenge and a motivation to consider the implications of NEC across a range of business interests. These varied from ‘hard’ technical systems research to ‘soft’ systems associated with collaborative processes and whole life costs and safety concerns.

UK Ministry of Defence: the industry sponsor’s customer and ultimate user of the systems developed to which NECTISE approaches and processes might contribute or support.

UK Engineering and Physical Sciences Research Council (public funding sponsor): responsible for funding high quality research in British universities, with strong objectives associated with realising applied research to benefit the UK economy.

Members of the *Research Team*: the scenario had to be sufficiently rich to incorporate all research elements within a common context. An important requirement from these stakeholders was to correctly show the relationship between the various research contributions.

This wide range of stakeholders naturally created multiple points of view that had to be synthesized within the demonstration scenario.

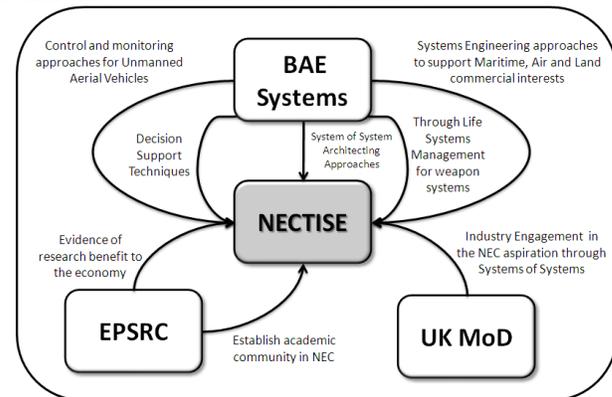


Fig. 3. NECTISE Stakeholder Interactions

B. Requirements

The research programme outputs covered a range of maturity levels and so an important consideration was the presentation of the academic outputs in a form that readily allowed the potential industrial exploitation to be appreciated.

The scenario needed to satisfy a number of criteria or requirements, viz:

- Include multiple stakeholders’ requirements.
- Be representative of NEC and its implications for the battle space and the UK defence supply chain.
- Be applicable in multiple timeframes.
- Be sufficiently straightforward to be easily understood by non-experts, but at the same time sufficiently rich to be informative to domain and subject matter experts.
- Enable demonstration of integrated research outputs.
- Be representative of all the research activities in the programme.
- Be plausible, in the sense of representing a possible future

The above represent the broad requirements for the demonstration; the requirements from the research programme itself were more detailed. They were provided by the various divisions of the industrial sponsor and ranged from strategic long term business goals, to short term technology focused aspects. The requirements were considered as an initial set of constraints that had to be applied to the scenario creation and writing process. Each set of requirements was fully decomposed, analysed and then used to derive a list of key drivers around which to build the scenario and represent the multiple stakeholders' viewpoints. To connect the business requirements most effectively to the academic research endeavour, the requirements were interpreted as a set of research questions derived through a series of industry-academic workshops [37]. The scenario was created from a subset of the full programme requirements; the subset was derived from a prioritisation by the industrial stakeholders and compatibility with the extant maturity of the research to be presented.

The development and enactment of scenarios is inherently educational in nature. In this case, the demonstrations educated engineers in new systems engineering approaches needed to meet the challenges of NEC. Secondly, the researchers themselves were educated in the integration aspects of the research by the process of scenario development, which is often cited as an excellent learning mechanism [6][9][13][14][21]. The scenario also educated all stakeholders with regard to the possible needs implied by NEC complexity, as well as the art of the possible in terms of systems that might satisfy those needs.

In many areas of interest, increasingly complex research programmes are being initiated in which the integration of different elements is fundamental to the success of the overall research programme. The integrated scenario approach taken here will be a powerful contribution to the integration of such multi-disciplinary research programmes, as it assists experts in understanding the context within which they work and locating their contribution within that wider system.

C. The Matryoshka Approach to Scenario Generation

Early in the programme the activities of capability generation, to which the research would contribute,

were mapped to four time levels. These levels, termed by Mackley *et al.* [38] as Agility Levels, represent the characteristic periods over which decisions and associated actions have influence. Essentially, the time level characterises the duration, rather than the tempo, of the activities. Thus, the highest level (capability planning) takes place on an annual cycle, but the influence of the decision and planning of any particular capability extends over years. The other levels are capability change design (months and years) that includes generation and selection of options, capability change implementation (weeks and months), and military operations (hours and days). These levels are illustrated schematically in Fig. 4. It is important to understand that these levels do not represent a stepwise series, but that the generic activities at each level may occur simultaneously (i.e. long-term planning in level 4 is ongoing). A vignette was created for each level, each fitting inside the next time level up, and the activities mapped against these (see Fig.4). Contributions from the main themes of the programme are also mapped in Fig. 5 and individual work packages were assigned in the same way, enabling researchers to envisage and understand the context into which their own contributions fitted and to interact more effectively with other groups to integrate the various research contributions. Research contributions were made at every level with architectures being a common thread through them all.

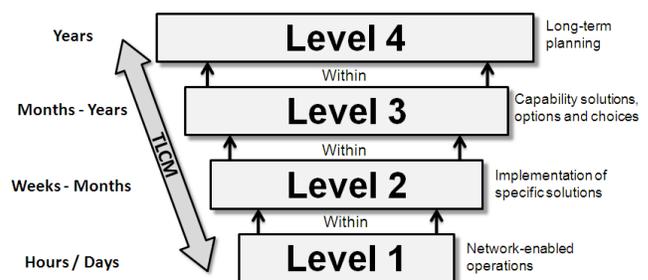


Fig. 4. Multiple Timeframes for Capability Management

D. Scenario Development

Using a combination of the GUIDEx [8] and Whitworth *et al.* [7] approaches, the scenario architecture was developed with the project and business requirements (Fig. 6). The initial scenario structure and key themes were generated at a two-day workshop involving about fifty stakeholders. The requirements came from both the industrial

sponsor and the academic research teams. Industrial requirements naturally focused on the business needs driving the research and the academic requirements defined what needed to be showcased. The requirements were formulated and refined subsequently by academic and industrial team members, whilst the industrial team replayed the emerging scenario within their business areas to identify exploitation routes and to enhance the richness of the scenario.

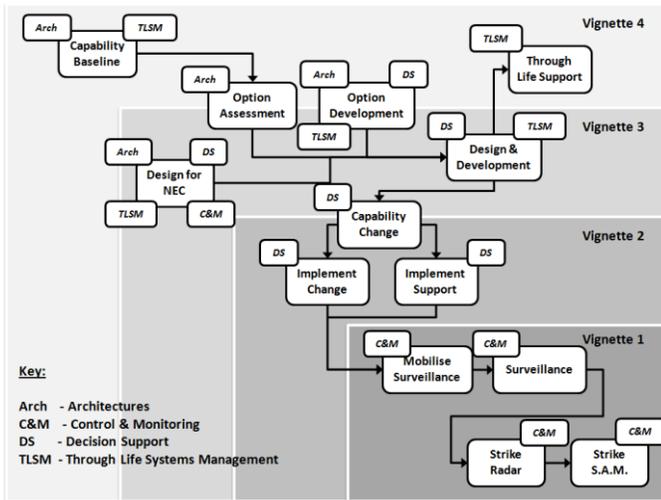


Fig. 5. Scenario conceptual map

An important ‘reality check’ was provided by military and civil service members of the UK MoD. The scenario was developed iteratively, through monthly meetings of the full (academic and industry) team. These meetings advanced the detail of the scenario, served as a negotiating forum through which requirements were harmonised, and enabled integration of research outputs. Thus, the scenario generation process informed the research continuously to achieve an integrated multi-disciplinary set of outputs.

Validation of the complete scenario relied on expert opinion which, here, involved a representative of the UK MoD responsible for NEC advice and support. This ensured inclusion of the then current understanding and thinking about NEC within the UK MoD and the projected future trends.

A cornerstone of the NECTISE demonstration development process has been the use of design reviews. These are typically used to assess the maturity of equipment and systems within defence and aerospace companies; applied in the research context, this brought rigour and traceability to the scenario development process forcing those

responsible to question every aspect and show it was representative of each of the stakeholders’ needs.

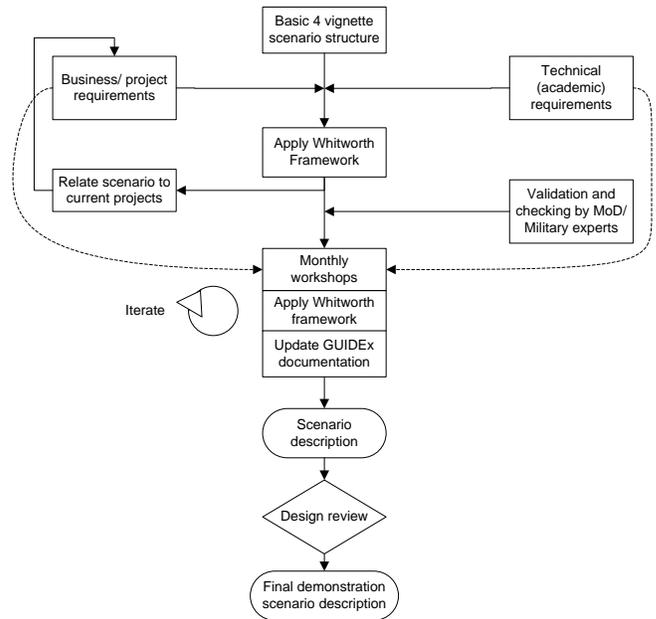


Fig. 6. Scenario Generation Process for NEC Demonstration

V. RESULTS

A. The NEC Scenario

The scenario derived to demonstrate the Systems Engineering for NEC research outputs postulated a political context in which a foreign state threatens international airspace with a surface-to-air missile (SAM) weapon system. The storyline is as follows: “With the current political and military stance of Country ‘A’, a coalition decision has been made that such threats are unacceptable and action must be taken to stop the intimidation of international civil air activity. A Type 45 destroyer and a supporting Royal Fleet Auxiliary ship have already been deployed to the area and are situated in international waters not far offshore Country ‘A’. A small group of Special Forces has already been inserted to reconnoitre an airfield that is believed to possess a SAM site which is the closest to international airspace. The goal is to neutralise the SAM site to reduce the threat issued against civil air activity.”

The scenario is composed of four synthesized vignettes. The main question concerns the integrated development of military capability from inception and planning at the governmental level,

development and assessment within industry, through to use by the military in the battle space. It looks at an incremental increase in surveillance system capability for monitoring no-fly zones. The scenario progresses through the four vignettes that represent different levels of capability planning and development, different timeframes in terms of the range of influence of decisions, and different groups of stakeholders (see Fig. 7).



Fig. 7. NEC Scenario and Vignettes

- Vignette 4 represents capability planning. At this level, the decisions are taken by the MoD with industry having a supporting role. Systems engineering approaches are studied by which industry can support the MoD's capability planning framework. Capability planning is a continuous process in which decision times for individual capabilities can be of the order of years.
- Vignette 3 is the capability development stage where decisions are made about capability change including the development of options, selection, and change plans. This is applicable to industry and the MoD. Typically the timeframe for this is from years to months.
- Vignette 2 looks at the deployment of new, changed, or updated capability. Again, this is applicable to both industry and the MoD. The timeframe for this vignette is measured in months to weeks.
- Vignette 1 is concerned with a military operation that is NEC-relevant. This concerns the military, but shows how technologies and systems approaches provide agility benefits at this level; this is also applicable to industry and MoD. The timeframe here is hours and minutes.

It is important that the vignettes at each level are consistent with each other. This was achieved through the tailored GUIDEx process and in part through the development of architecture artefacts. This latter is suggested as the principal means by which consistency may be assured with this approach.

B. Demonstration Events

The culmination of the NECTISE research programme was a series of demonstration events, which were effectively a NEC-systems engineering road show, held at four different venues around the United Kingdom and finishing at the Royal Academy of Engineering in London. The total attendance at these events was 125 people ranging from senior levels within the UK MoD (military and civil service) and industry to managers, junior officers, and team leaders at technology integration levels within defence companies and the military.

The demonstrations comprised a morning plenary session and afternoon breakout sessions. The plenary session was an integrated presentation of all research outputs set within the scenario; the story showed a realistic and logical flow of lifecycle stages within the defence industrial sector applied to a potential future state. From this the individual work packages were related to the scenario to demonstrate applicability to real world issues and value to businesses and the defence sector.

The syndicate sessions for individual work packages allowed attendees to visit a range of presentations, workshops and live demonstrations, in which they could delve into the detail of the research and discuss aspects with the academic researchers. Attendees could explore and use developed software for through life decision support, see live demonstrations of unmanned autonomous robots performing an operational mission and visit topical workshops about architectures, human factors, safety and through life capability management. Links between research packages were identifiable both through the scenario and the NEC-readiness themes.

C. Feedback

A questionnaire was provided to all attendees that addressed two aspects of the demonstration. Firstly, it served as an evaluation of the research relevance to stakeholders. The attendees included both

customers and suppliers in the defence supply chain and so the relevance criteria were important for planning purposes, with a particular emphasis on exploitability of the projected research outputs. Secondly the questionnaire sought to determine the usefulness of this type of scenario approach to the understanding of the NEC context.

To assess the relevance of individual work packages, attendees were asked to score them as -1 for not relevant, 0 for do not know, +1 for relevant and +4 for very relevant. The totals for sixty-two responses are shown in Fig. 8; this shows broadly that all work packages were regarded as relevant to some stakeholders, but the priority area for development across all stakeholders (air, land, maritime, C4ISR) is development of systems architecture techniques (Fig. 9.). The highest priority was development of novel architectures for dynamic integration.

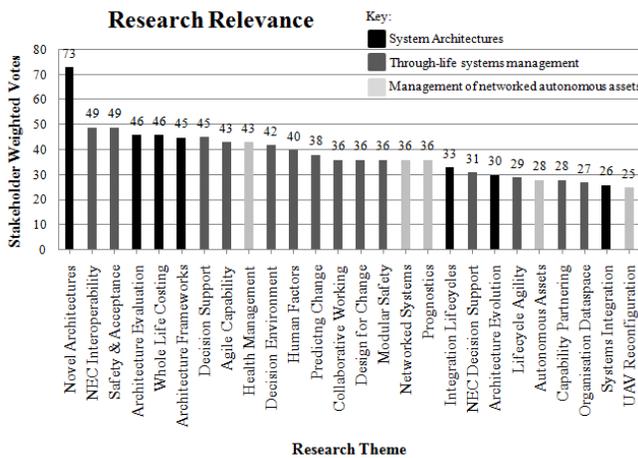


Fig. 8. NECTISE Research Theme Relevance

Assessment of the usefulness of the scenario technique was not based on scores against a scale, but rather on participating stakeholder comments considering the achievement of the demonstration to enable them to:

- A. Gain an appreciation of the overall TLCM process and the contributions of NECTISE research to achieving effective Through Life Management (TLM) of lifed products and/or services provided by industry in support of that.
- B. Gain an appreciation of the impact of NEC on the management of capability projects and the manner in which the research outputs will support these projects.

The feedback indicated that these aims were largely met and that the industrial participants, in particular, gained a better understanding of the NEC context and the manner in which research outputs could be used to support development of NEC-ready systems.

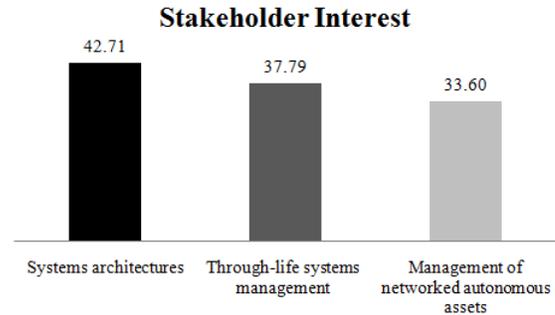


Fig. 9. Stakeholder Work package Interest

VI. DISCUSSION

The NECTISE Scenario puts forward a number of different timescales within a construct that is unique in approach. The literature shows that scenarios are generally heavily focused upon instantiations / symptoms relative to a single timeframe. The scenario generation technique reported here produces a wider ranging and more integrated scenario. The scenario sets out contextual, transactional and organizational levels of detail. It can be related to the scenario classifications of Dammers [22], Steinmüller [23] and the typology of van Notton *et al.* [24]. It incorporates the timescales of macro, meso and micro, which is unique in that it addresses short-term goals, but also considers much longer term objectives too. Additionally environmental and policy aspects are incorporated into the longer time frame planning section of the scenario, enabling it to synthesize changes in focus and direction dependent upon the government and customer needs. The classifications and typologies that exist allow different scenarios to be assessed and differentiated. The NECTISE scenario differs in some respects from these classifications because it contains and aims to integrate most of the constructs within those classifications, i.e. it is a structured, consistent combination of different classes of scenario. Not only does it offer global levels of information and perspective but also utilizes industrial and technological aspects to create a storyline across different timeframes. It could be modified to allow competitive situations to be

assessed so as to show trade-offs and decision points.

The NECTISE scenario was created to be able to demonstrate research. As such it was consciously conceived not to be wholly solvable, but to show how academic research can contribute to the real problems faced by Government and industry. Generally, scenarios exist to be executable so as to obtain results and outcomes by following a prescribed plausible storyline. The authors posit that an additional type of scenario can be added to the Steinmüller [23] classification of scenarios, that of a research scenario. The scenario adds validity and context to the research, which is beneficial both in terms of influencing the research and grounding it in facts and reality and also bringing together stakeholders to interact with and integrate multidisciplinary research.

The scenario that has been created is intended to be used as a plug and play tool. Each of the vignettes can be changed according to the context that needs to be articulated and the information intended to be used. The lower level vignettes can be changed to fit within the same overall context, to introduce different applications.

VII. LIMITATIONS

Scenarios are used in many different ways and there are some general inherent weaknesses associated with their lack of formality and completeness. These risks are reduced in limited scope scenario applications, such as use cases for software design, where complexity is deliberately restricted. In general, though, scenario methods are not associated in rigorous investigative procedures but are used, instead, as a means of enabling greater understanding among stakeholders of humans and systems interactions, whether this be for training, investment decisions, or a range of other applications. The application considered herein is highly complex; it concerns the incorporation of individual systems within a Systems of Systems and the implications of such incorporations over the appropriate lifecycles associated with a particular capability. The purpose of this Matryoshka-style scenario technique is to enable stakeholders to visualize the operation of newly developed systems, not to predict specific behaviours and, as such, this implies the following specific limitations. The

focus on interoperability enables identification, but not definition, of interoperability requirements; other techniques are required to rigorously specify these requirements. The assumptions about lifecycle model may fail to properly account for alternative, or multiple, lifecycles. Whilst the plug and play nature of the vignettes should mitigate this risk, nevertheless, wrong assumptions about lifecycle model may lead to sub-optimal decisions. Sufficient completeness is an important indicator of quality but, because there is no measure of sufficient completeness, this introduces a risk of oversimplification. This has been addressed through a process, rather than analysis, by the use of the Whitworth et al. [7] and GUIDeX approaches [8]. These approaches both rely to a large extent on expert judgement. The main limitation of this Matryoshka-style scenario technique is, then, that it provides a means through which an appreciation of Systems of Systems evolution may be gained, but it cannot be used to make specific predictions.

VIII. CONCLUSION

This paper describes an approach to the development and use of a multi-dimensional scenario for demonstrating multi-disciplinary research.

The approach utilised a recognised method for defence experimentation and scenario generation (GUIDeX) [8]. The scenario that was generated contained Matryoshka-type vignettes, which is a new approach to scenario building and development that can be applied in a flexible manner to a range of industry problems. These vignettes allow for different levels of detail to be described and put into context, enabling multiple timeframes and their respective aspects to be integrated, compared and assessed.

The authors propose a new classification of scenario type, that of research scenario. The success of the scenario was to allow academic research to be demonstrated and synthesized against a realistic and contextually rich scenario to enable domain experts to understand how such research applies to defence industry problems and where it can be exploited. A significant benefit of the approach related to the improved integration that was possible for the multi-disciplinary research team; this should prove beneficial in other large research

programmes, but it is important that the scenario development takes place early enough for the integration benefits to be realised in the research. No cost-benefit analysis has been undertaken, but the authors speculate that investment in this type of scenario generation will be rewarded by the improved programme integration that it enables. The method used was necessary for multidisciplinary Systems of Systems research. It has proved to be a highly effective way of integrating and empowering a diverse and wide ranging research team and bring about successful collaborative working.

ACKNOWLEDGMENT

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