Big Data and Artificial Intelligence for Decision Making: Dutch Position Paper

J.A.P. (Antoine) Smallegange
TNO
Anna van Buerenplein 1
2509 JE The Hague
THE NETHERLANDS

antoine.smallegange@tno.nl

Dr. H.J.M. (Harrie) Bastiaansen
TNO
Eemsgolaan 3
9727 DW Groningen
THE NETHERLANDS

harrie.bastiaansen@tno.nl

A.P. (Auke) Venema MS
Ministry of Defence
Kalvermarkt 32
2511 CB Den Haag
THE NETHERLANDS

ap.venema@mindef.nl

Prof. Dr. A.W. (Adelbert) Bronkhorst
TNO
Kampweg 55
3769 DE Soesterberg
THE NETHERLANDS

adelbert.bronkhorst@tno.nl

ABSTRACT

Within the NATO Sience and Technology Board, the Dutch Ministry of Defense is mentor of the theme 'Big data and artificial intelligence for decision making'. This theme is highly relevant to the military and to NATO in particular, because it addresses innovations leading to improved (joint) C4ISR. However, the theme is also complex because it encompasses a wide variety of relevant topics, ranging from architectures to data analytics and to human decision making. In order to provide support for developing the theme, and to bolster its effectiveness, this positioning paper aims to provide guidance for:

- ***Organizing the theme** by describing (five) guiding principles for focusing the work contributing to the theme;*
- ***Managing the theme** by proposing technology roadmapping as structured method for balancing technological and operational requirements.*

In this way we hope to stimulate collaboration and innovation within the NATO research community while at the same time maintaining focus so as to make optimum use of the resources that member nations provide. Specific attention will be given to creating synergy and complementarity with the other STO themes, in particular the theme 'Autonomy from a System Perspective'. Furthermore, efforts should be devoted to the dissemination and demonstration of results, paving the way for further development and utilization of these novel and exciting technologies.

1. INTRODUCTION

At the January 2017 NATO Strategic Sub Group (SSG) Meeting, the SSG launched the concept of a "Thematic Approach", in which themes are defined as multi-disciplinary topics described as a military capability that Nations need to be able to accomplish. As such, themes are cross-panel in nature.

The goals of a theme are (1) to stimulate and inspire novel NATO STO activities bringing the theme forward; (2) to identify research gaps; and (3) to promote alignment of and collaboration within theme-related activities across STO panels. In order to achieve these goals, 'areas of Research and Development (R&D)' are defined, where NATO should increase scientific and technical focus, and where activities can be done in conjunction, leading to improved operational capacities.

The theme ‘Big data and AI for military decision making’ is currently (Q2 2018) making its initial steps in defining and organizing itself. The goal and scope of the theme are being defined and the organization and alignment with the various NATO activities are assessed.While the scope of the theme has already been narrowed down by focusing on the combination of AI, Big data and Decision making, the area of interest is still extensive and diverse. Illustrative for this is the range of topics listed in the Call for Papers for the current IST-160 meeting, which include (1) information analysis; (2) architectures; (3) training and visualization; (4) information warfare; and (5) decision support. Within each of these topics, between 4 and 8 relevant sup-topics have been identified. Whereas it is important to initially review the full, broad spectrum of potentially interesting topics for the theme, a subsequent focus should be on adequate scoping so as to improve the theme’s effectiveness.

2. THE THEME: BIG DATA AND AI FOR MILITARY DECISION MAKING

One of the main tasks of NATO is to facilitate military collaboration between member states. Traditionally, NC3O has focused on interoperability and on ways to support headquarters with C2-systemens to facilitate cooperation. The international trend of hyper connectivity and globalization in combination with the requirement of collaboration at tactical levels, make a shift towards interoperable support of tactical commanders paramount. STO can provide nations and NC3O with insights in new possibilities of emerging technologies to support the commanders.

Furthermore, technology for big data and AI is currently developing at a fast pace, with major potential impact on both the strategic, operational and tactical military decision making processes. As such, the military operational benefits may be huge and diverse. However, the full potential cannot (yet) be overseen and will have to be established over time. Moreover, these new technologies not only have potential benefits, but also short-comings and risks that need to be assessed, and for which possible mitigating countermeasures have to be identified.

Notwithstanding these uncertainties, it is now considered time to act within the NATO Research and Innovation community, so as to be well prepared for upcoming developments. Several advanced civil applications of AI have emerged over the last few years, and adaptation of these innovations is growing rapidly. Examples are autonomous vehicles, personal assistants such as Apple’s Siri, software for “predictive policing” and “cognitive computing” solutions such as IBM Watson [1]. But invariably these applications have restrictions. For example, personal assistants mainly act as voice-activated intermediary between web-based services and the user. Autonomous vehicles only perform optimally in uncluttered, ordered environments. Cognitive computing requires access to sufficiently structured big data and extensive (preparatory) work by experts to train the system and integrate different modules for e.g. reasoning, predictive modeling and machine learning.

For military applications, there are important requirements that may render civilian technologies unsuitable or demand changes in implementations. Systems have to work in a context that is highly unstructured and unpredictable, and with opponents that deliberately try to disrupt or deceive them. Ethical and legal issues will often play a major role. Hence, defense organizations have to make difficult choices because they must, on the one hand, benefit from the rapid civil developments while, on the other hand, choose wisely where to invest to make sure that applications will be fit for military use. Furthermore, the question is whether they are on the right track in enabling the trend/evolution towards big data and AI with their current developments of the data and IT infrastructures.

3. ORGANIZING THE TOPICS IN THE THEME

For organizing the topics to be addressed in the theme, (five) guiding principles are proposed:

- *Use specific military decision making capabilities as drivers.*
- *Focus on functional needs.*
- *Adoption of the OODA-loop perspective.*
- *Focus on topics contributing to targeted joint output activities.*
- *Complementarity to the other themes.*

These guidelines are elaborated in the following paragraphs.

3.1. Use specific military decision making capabilities as drivers

Globalization and hyper connectivity lead to a multitude of influencing factors and actors that contribute to the continuation and maintenance of conflicts and crises. In the international geopolitical arena, power is increasingly exercised by a confluence of (hybrid) instruments and is no longer limited to geographical boundaries [2].

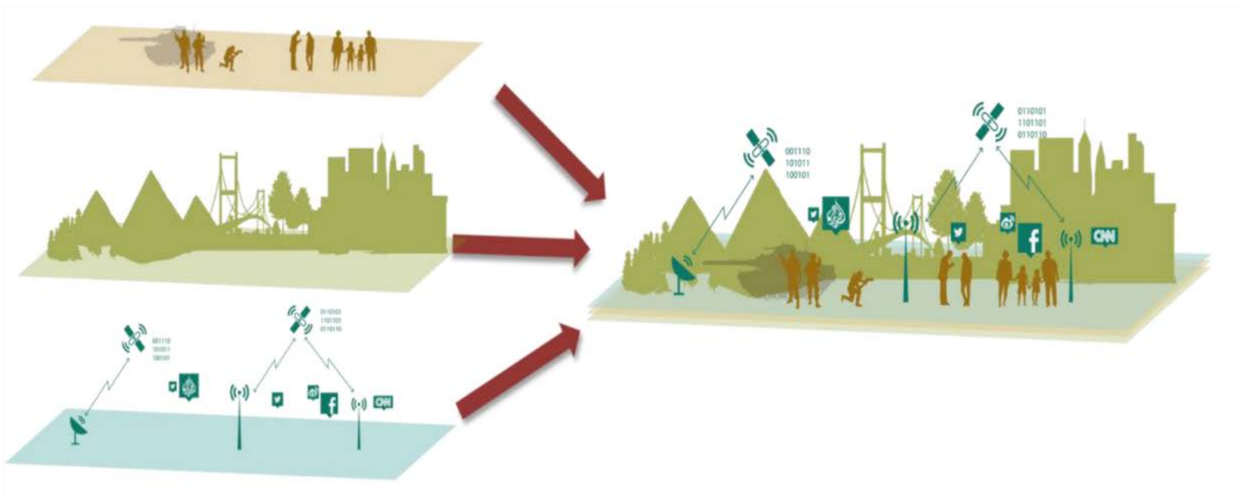

Figure 3-1: Three landscapes form the operating environment

The main purpose of military action is to influence unwanted situations in order to realize political goals. As von Clausewitz already stated, military operations are won in the human mind. Only when the adversary is convinced that opposition is no longer opportune, the conflict can be ended. In the light of the previous, this cannot be limited to the physical landscape alone any longer. Together with the information landscape and the human landscape, it forms a inseparable and interwoven whole, where military operate. Missions take place within the instructed political and legal framework and ethical and social acceptable bandwidth. Opponents or other actors are to be influenced during all stages of decision making or OODA-loop (observe, orient, decide, act) [3] to change their will or behavior. This requires simultaneous effects in all three landscapes.

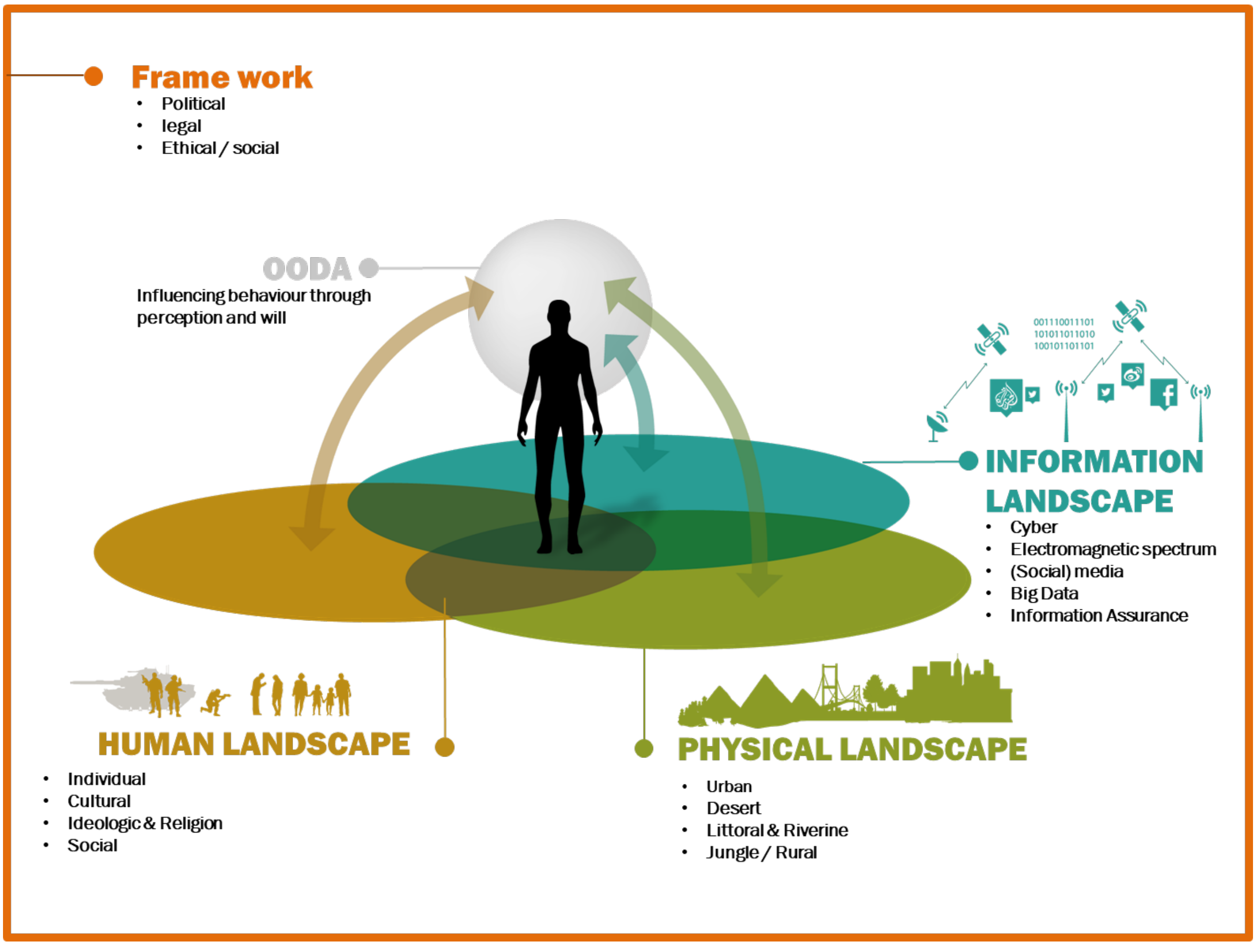

Figure 3-2: Operating in three landscapes [4]

In order to orchestrate operations in these landscapes, military need situational awareness (SA), insight in the possible courses of action (CoA) and their effects in all three landscapes of themselves, their partners and (where possible) their adversaries. Present C2-support systems mainly provide SA in the physical domain and some decision support. The human and information landscapes are not or barely covered and insight om the interaction between the three is not available at all.

Big data and AI can be used to support military decision making in a wide range of circumstances at the strategic, tactical or operational levels, and in support of all military capabilities in all landscapes. In order to restrict the range of applications, we propose to limit them to two capabilities that are operationally relevant and that generally involve complex, time-critical decisions:

- Situational Awareness,
- Command & Control.

These capabilities offer ample opportunities to demonstrate and (critically) test principles, methodologies and tooling that can also be applied to other application areas such as procurement, maintenance or medical support.

3.1.1. Support for Situation Awareness

Since military need to operate in the physical, human and information landscapes, they need SA in all three landscapes. This includes insight in the context of the mission, the interaction between the landscapes, the role of actors in these landscapes and how they influence their environment. For better cooperation with partners, insight in their status, the progress of their actions and consequences of deviations can provide means for coordinated effects. Finally, all of these require a geographical representation and visualization in order to connect to the human interpretation. Of course there are multiple other information flows that can be of individual or situational dependent importance. This means that a future C2-support systems also needs possibilities for personalization. AI can help to provide the military with the information that is tailored to their needs and current (cognitive) capabilities.

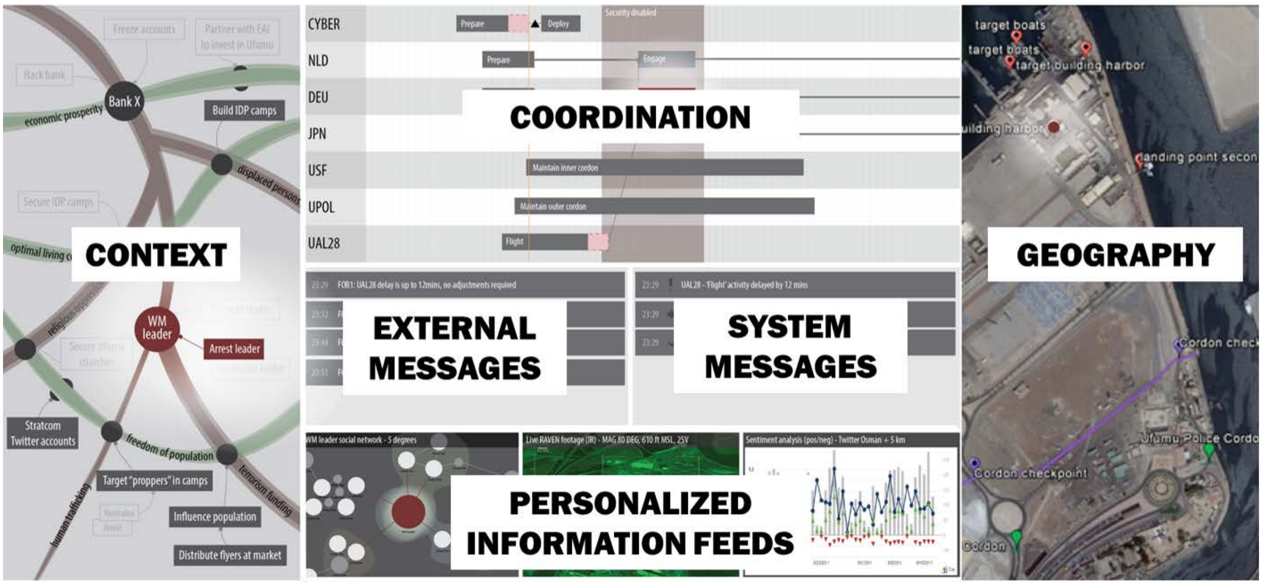

Figure 3-3: Possible representation of future C2-support system

Many means of AI and big data can help to improve or implement the required functions as the other submitted papers for this meeting prove.

3.1.2. Support for Command and Control

The possibilities of influencing the three landscapes are much wider than the traditional military means. They include for instance interventions through social media, stratcom, cyber, and through cooperation with financial and utilities providers. All these possible actions have consequences in all the landscapes and contribute in the different ways to the desired effects. For a commander to effectively orchestrate actions in three landscapes, he needs support on possible courses of action, their effects and consequences. AI, simulation and traditional algorithms are techniques that can provide this functionality.

3.2 Focus on functional needs

When AI and Big Data technologies are to be implemented in military applications, they will have to fulfill many requirements. Evidently security and cyber resilience will be crucial, but also scalability, maintainability, portability, cost, and other aspects will be important. It is proposed not to study all such requirements at the same time, but to initially concentrate on the main functionality that is required to support and enable targeted military capabilities. In other words, the focus should first be on assessing and possibly demonstrating the added value that innovations can provide in NATO military theatres.

However, fully ignoring the non-functional aspects may lead to solutions that are not applicable in (military) practice. Therefore, it should at least be checked whether any of them will result in 'shop stoppers'; preferably the non-functional needs should be included by design.

3.3 Adoption of the OODA-loop perspective.

The title of the theme reflects the dual nature of the underlying research fields: on the one hand, advances in Big Data analytics and other AI technology should be incorporated; on the other hand, human factors knowledge should be used to determine which type of decision support is required and how 'meaningful human control' can be enabled. In order to bring the two fields together, we recommend to use the OODA loop (Observe, Orient, Decide, Act) [3] as basic framework for identifying and aligning technologies and topics of interest. The OODA loop represents the life cycle from data acquisition to decision making and also reflects how sophisticated a technology should be in order to provide added value. For example, technology that fuses hybrid sensor data into an integrated picture supports the 'Observe' stage, while technology that is also able to identify and classify objects supports the 'Orient' stage. The characteristics of the 4 stages are:

- *OBSERVE*: Harvesting of (big) data from sensor information forms the base of all further steps. Sensor is here used in its broadest form, hence including social media analysis and other forms of (un)structured data collection. However, for it to become useful this multisensory data need to be verified and fused into a unified view. This also requires a solid infrastructure capable of handling large amounts of data and multiple security levels.
- *ORIENT*: Big data analytics and algorithms for data processing and data presentation are needed to allow for rapid abstraction and reasoning in order to, within limited time, condense the unified view in such a way that the amount of information is small enough to be processed by humans but rich enough to provide the required level of detail. As such, not only the current situation on a Graphical Information System, but also plans (resources, timelines, capabilities, relations and dependencies of activities), and context (point of action, effects) need to be available.
- *DECIDE*: Once condensed, the information needs to presented to the user in such a way that it optimally supports decision making. This includes *how* and, more importantly, *which* information is presented. The holy grail here is to not only reliably present what has happened, but also show probable future CoA's, based on fusion of data, models and expert knowledge. In this way, the AI can advise on consequences of the own CoA's and give insight in the adversaries' most likely CoA's. However, when AI becomes that powerful, and humans start to rely on its advice while making decisions, it becomes paramount that the reliability of the AI can be assessed and validated, and humans can develop proper (calibrated) trust in the AI [5]. One requirement will, for example, be that the AI will be able to explain why it generates certain outcomes.
- *ACT*: As AI gets more advanced or time pressure increases, the human may only be requested to approve a preprogramed action, or decisions will be taken fully autonomously by systems. Requirements for such AI must be stringent, not only because unwanted, erroneous decisions should be prevented, but also because the human will generally be (legally) responsible for the actions taken by the system.

3.4 Focus on topics contributing to joint output activities

Joint output activities resulting in (field) demonstrators, e.g. during NATO exercises would represent a very valuable result of the theme because these can involve, stimulate and mobilize the operational community. Furthermore, developing demonstrators up to higher Technology Readiness Levels facilitates transfer of knowledge to industry. It seems therefore wise to focus in particular on topics that are instrumental in realizing such activities.

3.5 Complementarity to the other themes

To prevent overlap and strive for complementarity and consistency, scoping should be aimed at complementing and extending upon the work within other themes, in particular the theme ‘Autonomy from a System Perspective’. Within this theme, the Specialist Meeting SCI-296 was held in 2017, which resulted in recommendations and a list of proposed NATO activities [6].

It will be important to delineate and distinguish topics that will be of interest to both themes. Table 4-1 represents a first effort towards generating an overview of topics relevant for the present theme, organized along the stages of the OODA loop, which also identifies topics related to the Autonomy theme. Evidently, this overview needs to be updated based on the output of the current IST-160 meeting and on further progress made within the themes.

Table 3-1: Topics and within the themes structured using the OODA loop.

The OODA perspective for structuring the topics and activities within themes	
OBSERVE (O)	**Link / overlap with Autonomy Theme**
- *Internet of Things* - *Data Collection Architectures* - *Social Media Analysis* - *Data Fusion* - *Interoperability*	- *Autonomy for Intelligence*
ORIENT (O)	**Link / overlap with Autonomy Theme**
- *Analytics and Statistical modeling* - *Anomaly and False data detection* - *Knowledge Abstraction*	- *Machine Leaning*
DECIDE (D)	**Link / overlap with Autonomy Theme**
- *Decision Support Mthods* - *Augmented/Virtual Reality* - *Modelling & Simulation for Decision Support* - *Predictive Analytics*	- *Training, Trust and V&V* - *Human-Machine Interfacing*
ACT (A)	**Link / overlap with Autonomy Theme**
- *Moral Decisions*	- *Autonomous Decision Making* - *Human-Machine Teaming* - *Modeling and Simulation of Autonomy* - *Legal, Ethics, Policy*

4. MANAGING THE THEME

Research and Development should be a balance between top-down and bottom-up approaches. Especially in Information Technology, where developments go much faster than the operational embedding. AI and Big Data are therefore both enabling and driving the possibilities for decision making. As an enabler, it follows the operational requirements and provides the commander with better means to conduct his operation. As a driver is provides the commander (new) means to conduct his operation differently. It opens ways to new possibilities and new doctrines. In either way close cooperation with the operational users (military) is essential to connect to the operations and actually improve military capabilities.

Our view is that the theme is best organized along a technology roadmap that focusses on future military capabilities (such as mentioned in 3.2). A technology roadmap is a flexible methodology to support planning, by matching short- and long-term goals with specific R&D solutions. It creates shared understanding of capability needs and the R&D & innovations required to satisfy those needs. It provides a common framework to plan and coordinate activities. However, it is not intended as an elaborate, rigid planning tool but as a concise, flexible means to stimulate and facilitate collaboration and convergence.

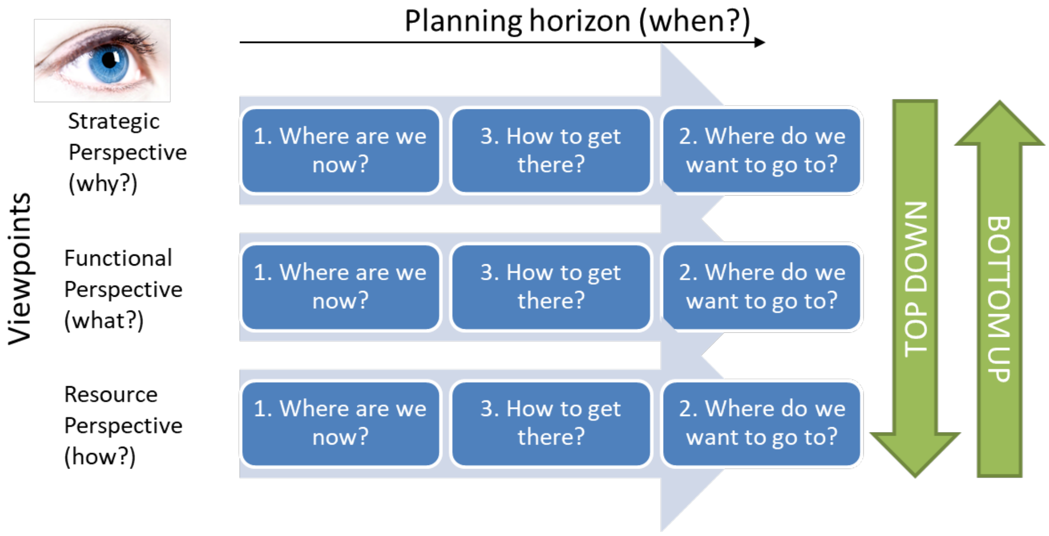

Figure 4-1: Technical road mapping

For the development of a roadmap the following process can be followed, divided into 3 phases: the definition, construction and embedding phase.

In the definition phase, the core team (with guidance of the process facilitator) determines some matters that are needed before construction of a roadmap can start. This includes in any case:

- Purpose of the roadmap (what will it be used for),
- Strategic goal(s) (what will it strive for, what is the point on the horizon),
- Subject and scope of the roadmap,
- The timeline and perspectives to be used,
- The appearance (e.g. picture, document, Gant-chart, … or combination),
- Who will be involved (core team, roadmap team, stakeholders),
- What planning is foreseen (e.g. meetings to discuss the roadmap will be planned, when will workshops be held, etc).

The construction phase is an iterative process of gathering & structuring, sharing, integrating and securing knowledge. Usually it takes a combination of workshops, interviews, surveys and/or desk research to collect all necessary knowledge/items, with some time in between.

After the roadmap is finished, embedding is very important. This starts with disseminating the roadmap so it will actually be used to plan future work (PLAN), which is subsequently actually performed (DO). Frequently it should be checked whether the roadmap is still fitting its purpose (CHECK) and if needed the roadmap should be updated and then again disseminated (ACT).

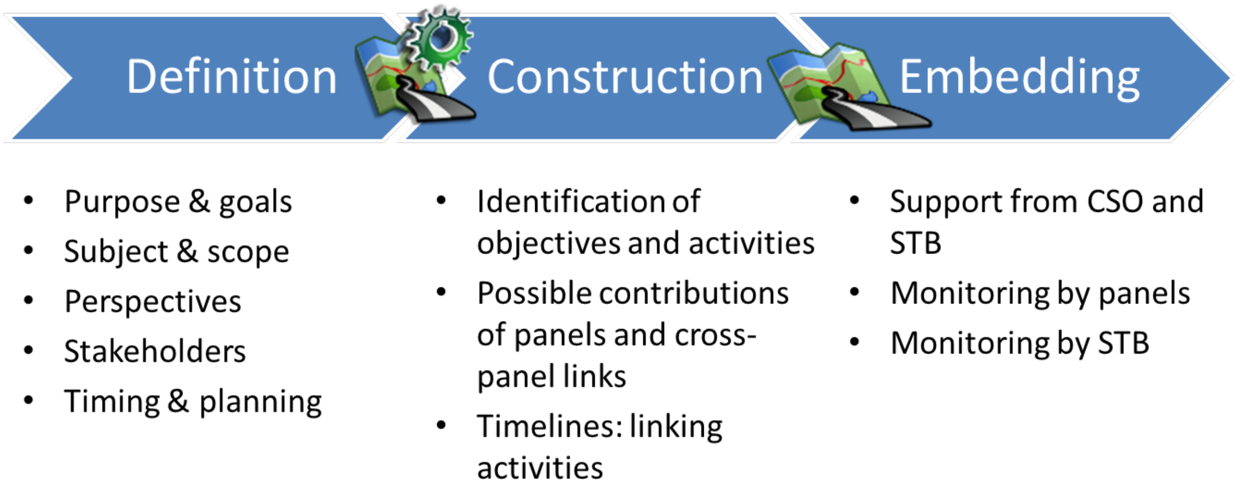

Figure 4-2: Constructing a Technical roadmap

5. CONSIDERATIONS ON THE ENABLING DATA INFRASTRUCTURE

The above mentioned functionality may require a different way of implementing the enabling big data infrastructure, enabled by various emerging trends and technologies including data centric infrastructures, containerisation and (micro-)service development:

- The availability of a data centric military infrastructure

Over the last decades, the application centric architecture has been the major focal point of the IT industry, in which the applications were the primary structural element, supported by middleware solutions to enable interconnectivity. With the growing omni-presence of ICT, the number and intensity of interactivity between organizations and the resulting complexity of operations, it is becoming clearer that a data centric approach might provide a better way forward. This is driven by the observation that the data in the application is the really valuable asset, not the applications. Therefore, leading organizations are currently focusing on a data centric approach. In the military domain, developments as described in the Fraunhofer Shared Information Space [7] pave the way to a similar data centric approach.

- The use of containerized deployment approach

Containerized service deployment technology allows processing functions, applications and services to be frequently and rapidly deployable, allowing computer code to be shipped and deployed nearly instantaneously when needed on a specific location and/or computing platform.

- Applying a (micro-)service architecture approach

A microservice architecture enforces loosely coupled components in the design of a software application [7]. It can be seen as counterpart of monolith applications, where you typically have a single, big code base. In a microservice architecture, each microservice implements a set of narrowly, related functions. The advantages of a microservice architecture are that individual services can (more) easily be extended, updated or replaced and that separate development teams can work on the microservices simultaneously. Moreover, testing and deploying the software becomes easier.

Several secondary potential benefits with military relevance are foreseen by deploying the enabling data centric and containerised (micro-)service deployment approach:

- User applications can be simpler and smaller in size. Optimizing the use of (micro-_services, makes the overall application landscape more flexible.
- The combination of a data-centric approach with micro-services enables applications to be more easily made suitable for various military operational contexts, e.g. for in-vehicle usage or for the dismounted soldier. It enables the ease of development, deployment and maintainability of the system and simplifies the design leading to a high degree of reliability and performance.
- By focussing on the protection of data instead of applications and infrastructure the overall defense information infrastructure is expected to be more cyber resilient.

Hence, in order to really profit from big data possibilities, C2-applications need to become data centric, this means that data and information are not incorporated in the application. Applications are a means to access and manipulate information and return it for use by other applications. A data centric architecture also makes data centric security possible and improves interoperability. These considerations are further elaborated in “Enabling a Big Data and AI Infrastructure with a Data Centric and Microservice Approach: Challenges and Developments”, by Schenk, v.d. Geest, a.o.. [8]

6. CONCLUSIONS AND RECOMMENDATIONS

While it is recognized that the theme ‘Big data and AI for military decision making’ should be explored in its full breadth and that the IST-160 Specialist Meeting seems ideally suited to do just that, the wide range of possibly relevant topics brings with it risks of lack of focus and dilution of efforts. Furthermore, there are clear connections between the topics of interest to this theme and to the theme ‘Autonomy from a System Perspective’.

Our recommendation to the SSG is to provide guidance in order to stimulate convergence of subsequent work within the theme and within follow-on activities. We suggest five principles on which such guidance could be based:

- *Use specific military decision making capabilities as drivers.*
- *Focus on functional needs.*
- *Adoption of the OODA-loop perspective.*
- *Focus on topics contributing to targeted joint output activities.*
- *Complementarity to the other themes.*

In order to fully benefit from the possibilities of AI and big data, we advise to start a migration to an enabling big data infrastructure, enabled by various emerging trends and technologies including data centric infrastructures, containerisation and (micro-)service development.

Finally, we suggest to apply the technical road mapping process as described to allow for full benefit of the potential of organizing R&D in themes. This requires special attention to disseminating the roadmap so it will actually be used to plan future work (PLAN), which is subsequently actually performed (DO). Frequently it should be checked whether the roadmap is still fitting its purpose (CHECK) and if needed the roadmap should be updated and then again disseminated (ACT).

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