TO BE PUBLISHED IN: 2022 IEEE INTERNATIONAL SYMPOSIUM ON SYSTEMS ENGINEERING

The Capability Concept in the Context of Systems of Systems: A Systematic Literature Review

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***Abstract*— Systems of systems (SoS) leverage dynamic configuration of independent systems to achieve a capability neither of the independent constituent systems can achieve on their own. Therefore, SoS engineering goes beyond addressing requirements to addressing capabilities. Due to the independence of the constituent systems, capability is formed by complex interdependence of legacy systems. It is also subject to uncertainty of the evolutionary development of the SoS, making it important to not only see the bigger picture but to plan for the changing capability patterns in the life of an SoS. This study looks at the body of knowledge surrounding definitions, support systems and practices around the concept of capability in the context of SoS. The results show; context dependent nature of the definition of capability, country-specific support systems, ongoing efforts to form more robust frameworks and dominant establishment of this theme in the defense sector.**

Keywords*— *system of systems, capability

I. Introduction

In a networked world, the trend of interconnecting systems to achieve a greater goal is increasing. Eisner envisioned this and created a framework for System of Systems (SoS), (then referred to as S2) to define the new field of SoS engineering [1]. This framework considered: integration engineering, integration management and transition engineering. This and other research efforts have directed interest in the concept of SoS and made it a growing research field. With profound applications in the defense sector, SoS is expanding in other domains including transportation, healthcare, energy and business [2].

Axelsson [3] formulates a refined terminology of SoS sub-structures describing how independent systems that are relevant for an SoS, are transformed into prepared systems, which then become Constituents Systems (CS) once they join the SoS family. SoS achieve their purpose by leveraging the ability to create emergent behavior from the collaborative efforts of CS. This collaboration is achieved by linking of sub-sets of CS to create constellations [3]. It is these constellations that form the basis for SoS capabilities.

The purpose of this paper is to develop an evidence-based insight and broader understanding of the use of capabilities in the context of SoS. This serves to develop a starting point of how different CS can define, use guidelines, and orchestrate their capabilities to form robust constellations which serve the SoS purpose. Lewis et al [4] when looking at the service orientation of SoS, viewed SoS as a repository of capabilities which can be searched for matches, integrated, substituted, adapted, tested, evaluated and deployed [4]. However, the inherent characteristics of CS, particularly their independence which implies that they develop and evolve in their own tasks and schedules, adds complexity in managing and engineering SoS [2]. With such complexity, there are ongoing efforts to establish and standardize SoS concepts. These include developed SoS standards: ISO/IEC/IEEE 21839 and 21841 which address SoS Life Cycle Stages and Taxonomy respectively [5].

This research was funded by KKS, grant no. 2020-0230.

A. Motivation

System of Systems Engineering (SoSE) looks beyond the traditional systems engineering by taking into account socio-technical-economic issues associated with SoS. This means a larger audience and more aspects to: conceptualize, develop, implement, evaluate and negotiate. Capabilities are important because they are tied to the purpose of the system, designed and orchestrated to generate the desired purpose. Therefore, by taking a capability point of view in an SoS, we see the end from the beginning, i.e. we see the outcome from a socio-technical interaction of organizational goals and values led by cost-benefit and selective use of resources.

A tertiary study on SoS architecting [6] studied the use of Systematic Literature Review (SLR) and Systematic Mapping Studies (SMS) in SoS research, and showed more use of SMS studies to connect research areas than consolidation on specific areas through SLR implying it is a growing research area. From this study [6] we see reference to SLR studies on various SoS themes including engineering, architecture, knowledge representation, integration approaches and quality attributes. It is evident that the concept of capability has not been explored. This paper is an SLR that seeks to understand the state-of-the-art use of the concept of capability in the context of SoS.

B. Contribution and Research Questions

The contribution of this paper is to conceptualize the term capabilities, from its definitions and associated elements, categories and characteristics to its use in the SoS research community. This forms a good ground to support further research activities in Model Based Systems Engineering for SoS. This review study addresses three research questions:

RQ1.How is the concept of capability defined in the context of SoS?

RQ2.What guidelines and frameworks exist in capability engineering and how are they related?

RQ3.How is the concept of capability characterized in different communities and contexts?

The remainder of this paper is structured as follows; Section II is on background and related work, Section III explains the methodology, Section IV is on the analysis of the extracted data, Section V discusses the findings, and Section VI is on conclusion and future work.

II. BACKGROUND AND RELATED WORK

The International Organization for Standardization (ISO) [7] defines SoS as a *"Set of systems or system elements that interact to provide a unique capability that none of the constituent systems can accomplish on its own"*. Various researchers have contributed to the evolution of this definition by characterizing what constitute CS. A widely accepted contribution is that of Maier [2] which defines SoS as an assemblage of systems which are managerially and operationally independent, i.e., managed by their respective owners and operating to fulfil their own goals which are separate from those of the SoS. These characteristics increase the complexity of SoS, prompting for more elaborate design rules. Maier [2] further defines design heuristics to govern complex systems: intermediary stability of the constituent systems, policy to selecting supporting SoS components, interfacing, collaboration mechanisms and incentives.

The growing SoS concept is precedented by a shift from system-based to a capability-based approach. Therefore, organizations are leveraging the SoS complexity, opportunities and value propositions to streamline their processes in pursuit of capability as opposed to individual stand-alone systems. The Canadian defense forces [8] through its Capability Definition, Engineering and Management (CapDEM) project developed an engineering construct to theorize and eventually institutionalize Capability Engineering (CE). CapDEM identified CE as composed of a team, process and environment with each element contributing towards supporting investment, requirements, and architectural decisions. Andersson et al. [9] mentions resilience, flexibility and cost-effective solutions as advantages of capability-centric approach as opposed to platform-specific approach. Henshaw et al. [10] outlined the polysemous nature of the word capability by defining seven different views of the word capability with reference to: resource availability and adaptability, innovation and development, investment, service provision, relational issues and interdependencies.

This SLR study takes a step back and improves on the work done in related themes, by looking at the very fundamental word in SoS, "Capability", and synthesizing what it means and how it is used. This is important to support that the big capability talk, is not lost in translation.

III. METHOD

This study employed the Systematic Literature review (SLR) method as described by [11]. The SLR is structured three main activities: planning, data collection, and analysis.

A. Planning

Planning involved establishing the base of the study, defining research questions, tools and work modality. All four authors were involved in all phases of the study. The main author reviewed all papers in all the phases, and at least one of the other authors independently reviewed each of the papers. The review process was supported by using Covidence collaborative review tool.

B. Data Collection

The process involved four phases:

1) Identification of search phrase: This review focused on the Scopus database by Elsevier. Scopus is a rich, well-structured database that supports multidisciplinary literature. Through trials and fine-tuning, the following search phrase was agreed-on as representative of fundamental information in response to the research questions:

```
(TITLE-ABS-KEY(("system of systems")) AND
TITLE-ABS-KEY
("capability" W/3("concept" OR "framework" OR
"analysis" OR "design" OR "engineering" OR
"process" OR "modelling" OR "requirements"
OR "development" OR "method" OR "architecture")
OR "capability driven" OR "capability based"))
```

The search was limited to the title, abstract, and keywords (TITLE-ABS-KEY). It finds the word "system of systems" and its variations and finds the word "capability" in proximity of three words with any of the words from "concept" to "architecture", or searches for "capability driven" or "capability based" keywords. The choice of these words follows a repeated trial and error checking the significance of the words to the term capability.

2) Literature filtering and screening: the filtering and screening processes were based on the following inclusion criteria, the paper; is a peer reviewed journal articles or conference papers (C1), is written in English language (C2), discuses capability in the context of SoS (C3), is a primary study (C4), is the most recent version in-case of duplicate papers (C5) and is available (C6). The filtering and screening processes also involved conflict resolution, where conflicts were resolved by the two respective reviewers. Conflicts in this case refer to any situation where reviewers have different opinions, e.g., when one reviewer selects a paper to be included while the other reviewer either thinks otherwise or is undecided.

The search phrase resulted in 372 documents. These were filtered directly in the Scopus database by applying inclusion criteria C1 and C2 resulting in 292 papers. These were screened manually based on title and abstract. This process raised 70 conflicts and disqualified 160 papers resulting in 132 papers. Full paper reviews were done on the 132 papers, which raised another 42 conflicts. In the end, 58 papers were disqualified, resulting in 74 papers eligible for data extraction.

3) Data extraction: The data extraction process was guided by an extraction template which addressed the research questions which are mentioned in Section I.

4) Additional resources: In addition to the SLR selected literature and background and related work literature, this study included three additional literature resources which were identified as addressing specific literature needs not covered [10], [12] and [13] which discuss worldviews of capability, SoS V-model, and the use of the Unified Architecture Framework (UAF).

C. Analysis

Analysis involved studying the findings and deducing usable information from the extracted data. The end goal is to find trends, patterns, comparative concepts, usage scenarios and other characteristics to address the research questions

IV. DATA ANALYSIS

This section answers the research questions through an analysis of the extracted data, and a synthesis of the extraction into usable knowledge. It covers publication statistics in

Section A, definitions and constituents of capability in Section B, capability and capability engineering support systems in Section C and Section D is on study characteristics.

A. Study Publication Statistics

This section summarizes the population statistics of the literature, highlighting the publication trends, author affiliations and orientation, and application domains.

1) Publications trend: as seen in Fig. 1. the theme is experiencing some activities. On average, there are approximately 4 publications per year, with a coincidental peaking in 2014.

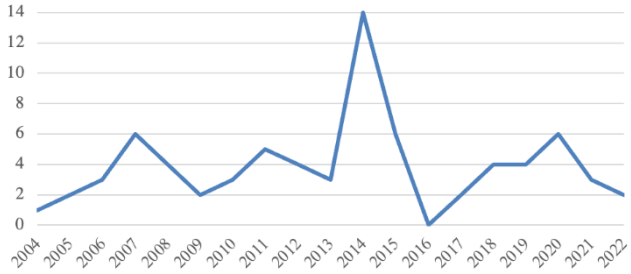

Fig. 1. Publications trend

2) Author affiliation and orientation: Fig. 2. shows regional-wise author affiliation. North America largely dominates the theme followed by Asia. The lined-stacked bars show the dominant contribution of USA (80%) in North America and that of China (93%) in Asia.

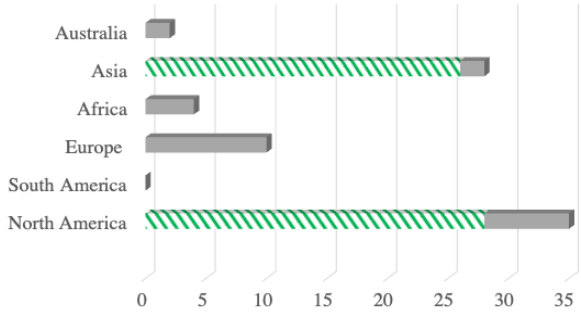

Fig. 2. Author affiliation

The theme is researched largely in academia (62%), there is also significant industrial involvement (22%) as well as academia-industry collaboration (16%).

3) Application domains: Table 1 summarizes domain-wise contribution of the different application areas. The defense domain had 50 publication, representing more than 60% and notably 14 papers (19%) were of unspecified applications. Other smaller subparts are crisis management (disaster relief, wildfire fighting, aircraft emergency, regional area crisis response and tsunami hazard mission), search and rescue and others.

Domain	Publications
Defense	50
Crisis management	5
Search and Rescue	3
Medical first responder	1
IT systems	1
Unspecified	14

TABLE I. APPLICATION DOMAINS

B. Definitions and Constituents of Capability

The first research question sought to understand the concept of capability from its definitions, categories, elements, components it has, as well as its characteristics.

1) Definition of the word capability: With more than 60% of the selected literature in the defense domain, most of the outlined definitions are based in the defense sector. Different points of view define capability to roughly mean the same with different levels of articulation. However, most of these definitions stem from and amplify the Cambridge English dictionary definition [14]: *"the power or ability to do something"*. Table II summarizes various definitions of capability. We have identified four keywords (with their synonyms) from the most popularly used definition, i.e., the United States (US) Department of Defense Architectural Framework (DODAF). These keywords are:

a) *K1: ability/capacity/power*
b) *K2: effects*
c) *K3: standards/ conditions*
d) *K4: tasks/missions/ function, action*

In addition to these keywords, two other words that also stand out, i.e. *measures* which may be thought of as a combination of effects, condition, and action, and *enterprise which* emerges in UAF cited definition. An enterprise mindset thinks of how to generate value through unified, standardized, cross-industry and platform-free approaches [15], something UAF guides through, a way to handle complexity. Reference [16] mentioned that capability must not be thought of as synonymous with system function or purpose. With reference to Table II, there is an outstanding reference to DODAF definition of capability, quoted in different contexts including that of Weapon SoS (WSoS) [17], [18] and Armed SoS (ASoS) [19]

2) Categories and forms of capabilities: SoS are functions of the environment they operate in, they therefore evolve depending on stakeholder needs, technological and environmental changes. From the SoS evolution point of view, two papers [20], [21] distinguish two categories of capabilities:

a) *as-is capability,* the present capability of a system
b) *to-be capability,* the expected future capability of a system

Reference [22] looks at capability from a requirement engineering perspective and as an existing value of the SoS, and mentions two forms of capability: *capability requirement* which shows the expected value of the system and *capability property*, which shows the existing value of an SoS. These forms may be thought of as synonymous to the categories, but it is also possible to envision that the as-is and to-be capabilities of a system are each composed of capability requirements and capability properties.

3) Elements and components of capabilities: In an effort to institutionalize capability engineering and develop the SoS V-model, [8], [12], [23] noted the interconnection between team-process-environment, process-people-materiel and people-process-product, respectively. These give the bigger picture through which capabilities are developed and they are herein referred to as the elements of capabilities. They form the socio-technical aspects of SoS, and are mapped into stakeholders, functionality, and systems respectively [12].

TABLE II. DEFINITIONS OF CAPABILITY

Quoted definitions of capabilities keywords: ***K1**: ability/capacity/power, **K2**: effects* ***K3**: standards/ conditions, **K4**: tasks/missions/ function, action*	**Keywords**				**References**
	K 1	***K 2***	***K 3***	***K 4***	
Capability is the **ability** to achieve a desired **effect** under specified **standards** and **conditions** through combinations of ways and means to perform a set of **tasks**.	■	■	■	■	DODAF V2.0, cited in [9], [17]–[19], [24]–[35]
Capability is a high-level specification of the continuing **ability** to generate a desired **effect** under associated **conditions** and performance **standards** through combinations of material and non-material solutions to perform a set of critical **tasks**	■	■	■	■	[36]
Capability as the **capacity** to deliver, perform, and sustain **functions** to deliver intended **effects**	■	■		■	[37]
Military capability in the context of Network Enabled Capability (NEC) has been described as\the **ability** to achieve a specified `wartime' objective	■	■		■	[38]
An enterprise's **ability** to Achieve a Desired **Effect** realized through a combination of ways and means (e.g., Capability Configurations) along with specified measures.	■	■			UAF cited in [13]
Capability means the **capacity** or **ability** of the South African National Defense Forces (SANDF) to achieve a particular operational **effect**.	■	■			[39]
Defined as the **ability** to achieve a desired **effect** through a combination of ways and means	■	■			[16]
Capability as the **capacity** or **ability** to achieve an operational **effect**. An operational effect may be defined or described regarding the nature of the effect and of how, when, where, and for how long it is produced	■	■			Australian Defense Capability Development Handbook (DCDH), cited in [40]
Capability is an effects-based view of systems and, in the defense context, can be expressed as an explicit requirement (or set of requirements) of the **ability** to fight	■	■			[41]
Defined as the enduring **ability** to generate a desired operational outcome or **effect**, relative to the threat, physical environment, and the contributions of joint or coalition force	■	■			[42]
Capability is the **ability** to achieve a particular military **effect** in a specific context.	■	■			[43]
Capability is the **power** to achieve a desired operational **effect** in a nominated environment, within a specified time, and to sustain that effect for a designated period	■	■			[44]
Capability depicts an **ability** that SoS accomplish a series of **tasks**.	■			■	[22]
Capability is the **ability** to accomplish some **missions**	■			■	[45]
Capability (descriptive sense): The quantitative and qualitative **capacity** of a force to pre-plan a **mission**, generally a function of force structure (the means). Capability (operational sense): Having the **power**, skills, and **ability** to conduct a particular military or civil activity, **mission**, or **task** (the way)	■			■	Canadian Military Doctrine, cited in [35]
Capability is a comprehensive description of performance and effectiveness, reflecting the potential **ability** to design and complete **tasks**	■			■	[46]
Capability as the **effect** of a system of interacting social and technical component		■			[9]
capability is a static property, an abstract summarization of the inherent **ability** to execute a specified course of action	■				[22]
capability as the probability of **mission** success				■	[47]
Capability is the overall potential of the armed forces for combat or other operations					[41]
Capability refers to the needs of the enterprise, that is what the enterprise needs to achieve its strategic objectives					[20]

The most referred-to concepts of capability is that of the US DOTMLPF-P followed by UK TEPIDOIL, Australian FICS and Canada PRICIE. These concepts, as summarized in Table III, define capabilities to include closely connected elements which link material and non-material aspects that build and sustain capabilities.

These frameworks show different levels of articulation but overall, they all combine people-process-materials. With elaborated explanations from [48], [49], we combined the components into twelve attributes as seen in Table III.
The following were noted with regard to these components:

- DOTMLPF: is more oriented in the defense point of view, and it does not exclusively name some components which are discussed by the other models.
- TEPIDOIL and PRICIE: include an information component, which from TEPIDOIL point of view focuses on understanding capabilities and processes from the context of required data, how this data is synthesized into information and developed into knowledge.
- FICS: gives a more relaxed outlook by including the support and industry resilience components which address support system for processes involved and consideration of the industry ability to support these processes, respectively.

TABLE III. COMPONENTS OF CAPABILITIES

Attributes	DOTMLPF-P	TEPIDOIL	FICS	PRICIE
The way	**D**octrine	**D**octrine, Concept	Doctrine, Management	**C**oncepts, Doctrine
The how	**O**rganization	**O**rganization	Organization	Organization
Prepare	**T**raining	**T**raining	Training	Training
Systems	**M**ateriel	**E**quipment	Systems	**E**quipment
Leadership	**L**eadership, Education			**R**esearch & development
The who	**P**ersonnel	**P**ersonnel	Personnel	**P**ersonnel
Establishments	**F**acilities	**I**nfrastructure	Facilities	**I**nfrastructure
Policy	**P**olicy			
Information		**I**nformation		**I**nformation management
Support			Support	
Logistics		**L**ogistics	Supply chain	
Industry			Industry	

4) Characteristics of capabilities: The literature discuss a lot of capability related issues,, from which the following characteristics were extracted:

- Composition: a capability may have its own serial and/ or parallel sub-capabilities [50]
- Nature: capability may be a description and/or a process, addressing the what and/or the how, respectively [35].
- Boundaries: capability boundaries are defined by measurable and intended effect, allowing for flexibility for organizations to design multiple ways to deliver the desired effect [37].
- Measures: [46] groups complex SoS capability measures into three categories: performance, topological and evolution measures which address the effectiveness, communication and robustness-susceptibility, respectively.
- Directional view of capabilities: [35] showed that capabilities can be horizontal or vertical, by looking at the concept of capability-based planning in enterprise architecture, where processes in-line with the organization structure as well as processes that cut across the structure all work towards creating capabilities.
- Evolution: by virtue of the evolution of SoS, CS may leave the SoS family which implies SoS experience receding capabilities, as discussed by [51]. Furthermore [16] discusses the challenge of capability replacement which is associated with architectural challenges and complexities.
- Engineering: capabilities are engineered through an iterative, tailored, incremental process that is agile to change and supported with a feedback mechanism, making capability engineering domain insensitive [52].

C. Capability Support Systems

The second research question focused on support systems surrounding capability and their relationship. These include guidelines and frameworks, standardized methodologies, models, tools and techniques. The literature mentions the use of specific frameworks and guidelines, as summarized in Table IV.

The relationship between the supporting systems is summarized as follows:

- JCIDS is more of a directing factor of the DODAF from product-based framework of DODAF v1.0/ 1.5 to data- centric DODAF v2.0 [30] . The advent of JCIDS facilitated the shift in focus of military acquisition from platform-based to mission-capabilities based [20], [53] therefore shaping the concept of capabilities through integrated architectures. As popular frameworks, MODAF and DODAF were unified into UPDM, which was later renamed UAF. UAF also supports Canadian and NATO Architectural Frameworks as well as extends from defense perspectives to supporting other civil technical and organizational processes [13].

TABLE IV. SUPPORT SYSTEMS

Frameworks
Department of Defense Architectural Framework (DODAF) [9], [16]–[19], [24]–[36], [44], [53]–[62]
Ministry of Defense Architectural Framework (MODAF) [27], [35], [43], [56], [57], [63]
Unified Profile for DODAF and MODAF (UPDM) [57], [56]
Unified Architecture Framework (UAF) [13]
Joint Capabilities Integration and Development System (JCIDS) [58] [64] [31] [28] [36] [20], [65]
Joint Test and Evaluation Methodology (JTEM) [31]
Network Enabled Capability (NEC) [38] [43]
NATO's Measures of Merit (MoM) [42] [43]
Joint Staff National C4ISR Imperatives (NCI) [60] [27]
Military Operational Research Society's (MORS) hierarchy of Merits [60]
Models, Methodologies and Processes
Australian Schedule Compliance Risk Assessment Methodology (SCRAM) [66]
JCIDS 4-step methodology to define capability gaps [20]
Canadian Capability Engineering Process CEP [52]
Capability Meta Model (CMM) of DODAF 2.0 [59]
JTEM's Capability Evaluation Metamodel (CEM) [31]
US Military Capability Test Methodology (CTM) [58]
Guidelines
Capability Requirements Document, System Integration Requirements Document, Defense Strategic Guidance, Defense Capability Framework, Military Tasks, Joint and Service Doctrine and perational Concepts papers [41]
US DOD Systems Engineering Guide for SoS [66]
JSC Capability-Based Assessment (CBA) User's Guide, The Air Force Materiel Command (AFMC) Development Planning (DP) Guide and the AF Early Systems Engineering Guide [67]
Defense Acquisition Guidebook [56]
Australian Defense Capability Development Handbook (DCDH) [40]

- The frameworks mostly discussed in literature are the country-specific frameworks DODAF and MODAF which have evolved through joint action teams, and they provide guidance in: defining methodologies [20], [31], [58] and ontology [63], architectures [58], support the understanding, mapping and evolution of enterprise architecture capabilities to components [56]. They also serve as references in the development and establishment of other frameworks and measures, e.g. SoS MoE view from DODAF [35], NEC readiness themes view and NETC(L) specification from MODAF [43].

D. Study Characteristics

This section addresses the third research question, by looking at how the concept of capability and capability engineering and practices around these concepts are used in different communities and contexts.

1) Application areas in dominant countries: Section IV. A. shows the dominant contribution of USA and China in this theme. Their respective concentration areas are summarized in Table V.

TABLE V. USA AND CHINA MAIN APPLICATION AREAS

USA	
Defense – Air	44%
Crisis response	25%
Surveillance	12.5%
SAR	12.5%
Defense – Naval	6%

CHINA	
WSoS	53%
Combat	21%
Other	16%
SAR	5%
Defence – Air	5%

USA defense-air sub-group covers areas including air power, air defense, aircraft and weapons, and aerospace, whereas crisis response sub-group includes wildfire, disaster relief and aid delivery in hostile environment scenarios. China shows a concentration in Weapon SoS (WSoS), which is a more integrated way of looking at combination of weapon systems with their associated elements, while the other smaller sub-group include complex IT systems, weapons portfolio and engineering construction.

2) Industrial involvement: Industrial involvement in research activity keeps the theme in line with recent developments. Within the 22% industry-only papers, 50% of the researchers are affiliated with USA, 19% with Canada and 19% with UK and the rest with others. The industry focus in USA is approximately equally distributed between domain-specific themes (air force, air power, disaster relief, surveillance) and unspecific papers. The 16% industry-academia collaboration focus is dispersed and there is no clear pattern that suggest dominant themes in such collaborations.

3) Most discussed themes: Overall, the literature is dispersed from general discussions with specific capability areas of focus (45%) to capability-specific areas (55%). The most dominant capability-specific topics include capability requirements (8.1%), capability evaluation (5.4%), capability engineering, generation, architecture, and NEC (each at 4.1%) and capability development, gap, modelling, and measures/ metrics (each at 2.7%) and smaller topics.

*4) Research area maturity:*Reference [68] characterizes maturity of a research theme to include: well documented, accessible, differentiated literature, agreed research constructs, robust across paradigms and contexts, impactful and diffused in the research community. To only narrowly address a few of these characteristics, this review found that, the included literature is predominantly case study based, reasonably differentiated for the defense sector, however, the very low number of citations (51% of the literature is cited by between 1 to 9 other studies, while 35% is not cited at all) suggests that this research theme is largely fragmented. Moreover, only one author had four papers as a first author and four other authors each had two papers each as first authors, hinting that the field is still growing, with researchers establishing their prominence. These factors, although not complete and conclusive, largely suggest low maturity of the research area.

V. DISCUSSION

This section discusses the findings in the context of the study and method used.

A. Definitions and support system

The popularity of the DODAF definition of capability and DODAF as a support system, may be attributed to its early establishment and the country's dominance in the defense sector where SoS is highly invested. With the four identified keywords, capability is taking more of a process point of view, that is more directed towards accomplishing a task which may as well be an objective. However, the literature shows a lot of emphasis on linking capability to the purpose of the SoS and this goes beyond the objectives. The big question then is if these are the only keywords we would like to define capability by, and if we even think these words are relevant enough because of the contextual nature of capabilities.

We would argue that capability is only a starting point, but much of the implementation is dependent on the system and the mission. It is one thing to be able to define a capability, but another thing to implement it. If we shift our focus from looking at theoretical definitions of capability to practical implementation, we see that understanding both the compositional and de-compositional nature of a specific capability guides in defining capabilities of practical systems because capabilities are part of everyday processes of the respective systems.

B. Literature homogeneity

Through the literature we have come to an understanding that capability in the context of SoS has precedence in the defense sector. However, this does not mean that the concept of capability is not applicable in other domains. The overall idea of capability is based on realizing the business benefits, i.e., incorporating business principles in engineering activities. Therefore, although the defense sector is herein seen as the dominant domain, it is only dominant because it is in the context of SoS. However, the concept of capability is also discussed in the business context.

C. Validity

The extent to which the results of this SLR can be trusted is accounted for by the step-by-step processes followed. Although we used Scopus database which is rich in multidisciplinary resources, we included three additional papers which addressed issues not covered. The defense domain is sensitive and its vocabularies are not always clear-cut defined, this poses risk of limited disclosure to documentation and misinterpretation. The validity of this SLR could be further improved by including other databases or apply snowballing process in search for more resources.

VI. CONCLUSION AND FUTURE WORK

This paper is aimed at understanding the concept of capability as used in the SoS research community. It is noted that most of the input is from the defense domain and the complexity of defense systems serves as a good ground in understanding the concept of capability. The end goal is to be able to harmonize SoS operations through optimized ontological approaches that address critical capability challenges and optimize resources. From the defined components of capabilities, it is possible to harmonize these components in line with what UAF offers, therefore extending from the defense point of view into a more generalized outlook, something we may address in the progression of this

research work. Moreover, there is need for more research on the use of the generic UAF framework.

To practically define capabilities in very complex SoS we may need specific methods to trace processes and their use of resources. This makes going back to methods such as Checkland's [69] soft systems methodology important. Iteratively using such methods to recognize and describe the problem, decide on root definitions, creating and comparing conceptual models, and dealing with changes [69], will largely support proper understanding of capabilities used and offered. When we couple such methodologies with the guide of generic architecture models such as UAF, we can better understand our systems vis-à-vis the organization and their respective capabilities and handle the complexity thereof.

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