The concept of 'system' in a whole-of-society approach

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Abstract. INCOSE has expressed its vision for transdisciplinary approach for systems engineering to address complex societal problems. While the concept of 'system' has been dealt with at length, the purpose of this article is to surface assumptions underlying systems engineering, bringing deeper and new theoretical insights to the concept of 'system'. This is done in the context of previous whole-of-society work and issues of vertical integration. To do this, the article will introduce transdisciplinarity and levels of reality. Heterarchy as alternative to hierarchical control is explored in the context of social systems, leading to identifying participative and representative mode social systems. The definition of systems is presented and the notion of society in the context of whole-of-society is explored. Caution must be applied in universalising any definition of system given the concept of levels of reality.

Introduction

"The profession of design is undergoing a paradigmatic shift away from the design of artifacts as solutions to problems. Instead, we are now starting to see these problems themselves as the symptoms of dysfunctional, larger macro-systems that are themselves shaping the problem space." (Hunt, 2019, p. 119).

The lay of the land for this article is assessed in two areas, although not complete: General Systems Theory (GST) and system-of-systems. von Bertalanffy proposed a GST in the 1960s when the need for the integration of the natural sciences and social sciences was accepted (Von Bertalanffy, 1968). This integration has not yet been achieved. Today it is not clear that this integration will be through GST alone. Firstly, there is the emergence of transdisciplinarity (Nicolescu, 2010) (which will be applied in this article). To deal with complexity, transdisciplinarity has the characteristic of vertically integrating the disciplines that von Bertalanffy sought in his aims for GST but is not a systems theory. Secondly, systems approaches must be supported by narrative approaches to avoid blind spots (Hayles, 1995). von Bertalanffy's definition of system as "sets of elements standing in interaction" may serve as a general definition but it is inadequate for social systems because it fails to consider society, culture and power. This does not mean that the concept of a system should be abandoned. Rather the concept of system should first be differentiated for different sciences before attempting integration of the concept.

In systems engineering, system-of-systems has largely been a phenomenon in the Defence sector that emerged in order to deal with integration of organisational systems (Dahmann, 2014). Maier proposed the term system-of-systems for collaboratively integrated systems and two principal characteristics for applying the term (1998, p. 271):

1. "*Operational Independence of the Components: If the system-of-systems is disassembled into its component systems the component systems must be able to usefully operate independently. That is, the components fulfil customer-operator purposes on their own.*"
2. "*Managerial Independence of the Components: […] The component systems are separately acquired and integrated but maintain a continuing operational existence independent of the system-of-systems.*"

Is the current conceptualisation of systems-of-systems adequate for societal systems? System-of-systems are more complex than purely technical systems (those without any people in them) and systems engineering has been wrestling with system-of-systems (Dahmann, 2014). This article will show that social systems are an anomaly in the "normal" systems engineering paradigm and cannot be addressed from within the paradigm (Kuhn, 1970). A new paradigm is necessary to address such complex problems. The very nature of complex problems limits knowledge about them (Cilliers, 2005). Such problems require whole-of-society and transdisciplinary approaches (Gonçalves, 2017). Complex problems cannot be reduced and various aspects need to be addressed simultaneously (Morin, 2007). Simultaneous interventions are required which address co-occurring problems in the problematique and different scales from the individual, groups, organisations, inter- organisational to world society. Interventions must occur on multiple time-horizons. A further consequence of complexity is that organisations must respond to the dynamics of change in the environment and uncertainty (Hoogervorst, 2009). This requires high levels of integration but in contrast many organisations talk about "silos" and "silo behaviour". Collaboration does not automatically create a harmonised approach and different organisations may still work against each other as "accidental adversaries", a systems thinking archetype (Mella, 2012). Furthermore, if such collaboration can be achieved, tactical and operational level situations may be improved but it cannot address problems which require strategic interventions and deep change. Unfortunately, power can disrupt, stall or undermine any effort in practice. For these reasons it is necessary to reconsider our concept of 'system' in the context of the social.

The concept of 'system' has been dealt with at length more recently (Sillitto, et al., 2017; Dori & Sillitto, 2017; Gonçalves, 2015). Despite this, the topic is not exhausted in relation to complex social systems. The purpose of this article is to surface assumptions underlying systems engineering, bringing deeper and new theoretical insights to the concept of 'system'. This is done in the context of previous whole-of-society work and issues of vertical integration in a modest way. Firstly, the whole-of-society approach is introduced, followed by the vertical integration of whole-of-society, enterprise engineering, systems engineering and technology management. Once this has been done, the four theoretical issues are discussed that advance vertical and horizontal integration and explore the concepts of "society" and "system" in this context.

A whole-of-society approach

This section is an overview of a whole-of-society approach developed in the area of border management and wildlife crime (Gonçalves, 2014). A whole-of-society approach is of interest in complex problems that require more sustainable, proactive approaches that lie outside the mandate of any single department or agency, private organisations, and individual members of the public. One of the important characteristics of complex problems is the large number of stakeholders with different values, worldviews and interests (Gonçalves, 2017). Each organisation or department sees the problem(s) through the *lens of their mandate*. Different

aspects of the problem are interconnected, but stakeholders address only those parts of the problem within their mandate, addressing the problem in parts, thus creating new problems. Furthermore, for any problem the public is either directly involved or has some interest in the problem along with non-governmental organisations (NGOs), private sector and communities.

Stakeholder engagement fundamentally underpins the approach and is important for the co-development and assimilation of strategies and technologies by stakeholders involved in the intervention. The process consists of creating a shared understanding of the current situation, foresight, and developing cross-organisational interventions and the implementation of the interventions (establishing capabilities within an enterprise) (Figure 1).

The interventions, which are the strategic tasks required to address a complex problem or to reach a desired future, are first identified. Interventions are a practical way of managing large numbers of stakeholders. An intervention can be a project, for example. From these interventions, tasks and the required capabilities are identified and allocated to the departments, NGOs, and private sector based on fit in terms of mandate, cost, and subject to legal and other constraints. A capability, the "ability to do something", refers to appropriately selected and trained people, processes, information and supporting technical systems, with the right behaviours (which are driven by rewards and recognition, culture, leadership and management) required to perform a task. Capacity is the number of people and equipment quantities required for the capability. Thus, the level of capability is about having each of the elements outlined and the required maturity.

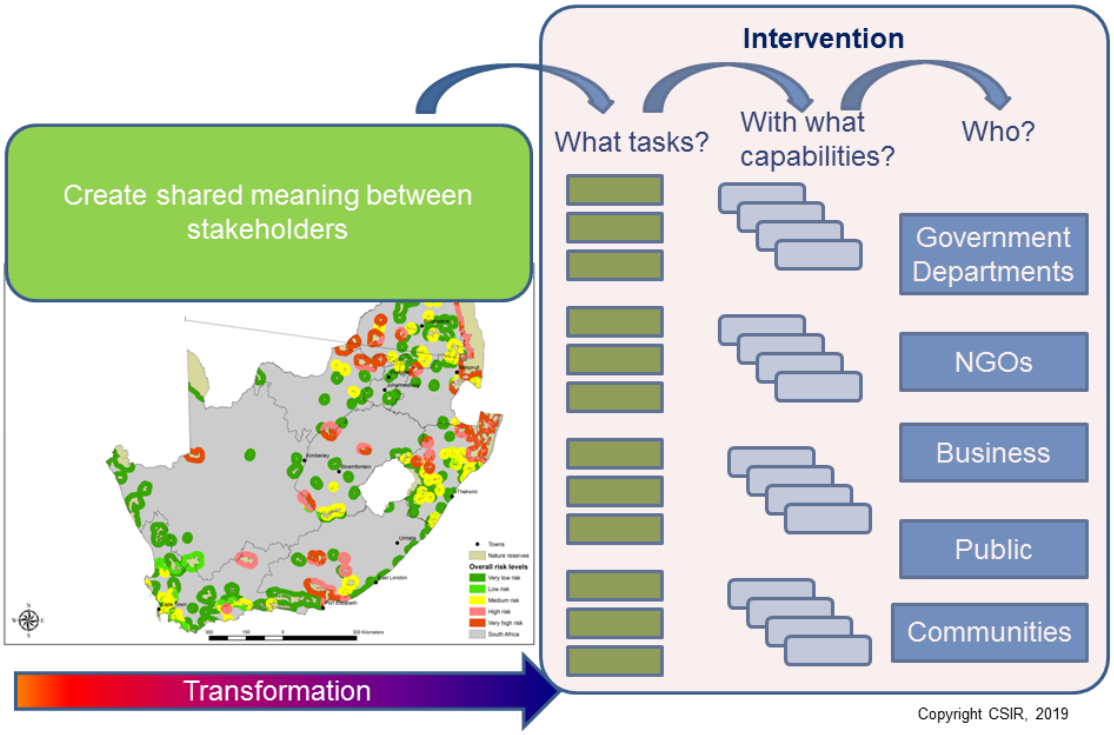

Figure 1. The whole-of-society approach (Gonçalves, 2017)

The set of tasks, capabilities and the particular allocation to departments is referred to as an intervention (or in systems engineering language, an "operating concept"). The fundamental principle is that interventions are developed outside organisational mandates. There are always alternative interventions, and at least one alternative should be developed to arrive at a good

intervention. The intervention builds on the shared understanding of the situation to co-develop a shared approach to addressing the problem. An intervention may also include defining new capabilities required in an organization. To close the gap between the required capabilities and current capabilities requires organisation level governance (Hoogervorst, 2009) or dynamic problem solving which requires cyclical feedback (Andrews, et al., 2013). Governance ensures sustainability and relevance of the capabilities in the broader context – it is not only about compliance. In the context of human security, organizations other than just law enforcement are required such as social development, NGOs and the private sector. The key to a whole-of-society approach is that by working across organizations the constraint of individual department mandates is removed in addressing the problem. In complex problems there isn't a "problem owner": problems belong to everyone and to no one. A question often asked in practice is: "Who is in charge?" and "Who will fund?". There is no single person or organisation in charge of the set of stakeholders required for an intervention. With government departments, their legal mandate defines their responsibilities. Power must be shared - a topic that will be revisited in the section on *Hierarchy and heterarchy*.

The process should not be seen as a linear recipe. Learning is an important part of responding to complexity in a whole-of-society approach and iteration is required to arrive at an intervention. As Parsons points out "…improving policy-making is…about learning, rather than command and control." (Parsons, 2002). Jumping to a solution too early will usually lead to a failed intervention. Because of the number of stakeholders and the range of interests, it is usually necessary to separate the interventions practically, but alignment needs to be maintained. This means that for each intervention, there may be partially overlapping (in the sense that the same actor may be involved in more than one intervention, for example) versions of the whole-of-society model in Figure 1. Without dealing with worldviews, the same kind of thinking and hence policy recommendations emerge again and again. Culture eats strategy for breakfast[1] and without change to organisational ways of doing, there will also be no change in behaviour. Actors with power may want to keep the status quo. Moving from the current situation to a new future through an intervention requires transformation of thinking and culture (depicted by an arrow in Figure 1). These aspects are dealt with through participative, facilitated approaches. From a complexity perspective, a method must rest on a transdisciplinary approach (Gonçalves, 2014).

The next section shows how the whole-of-society approach introduced here fits into a vertically integrated approach for dealing with complexity. Theoretical nature of this integration is discussed in the section Theoretical issues underpinning vertical integration.

Vertical and horizontal integration

This section summarises but also updates earlier work on vertical and horizontal integration shown in Figure 2 (Gonçalves, 2017). Wildlife crime specific content used for illustration is indicated on the left-hand side and the integrating discipline on the right-hand side. A methodology appropriate to a particular problem and level is constructed by drawing from the particular integrating discipline. There are four vertical levels in this model (Figure 2).

[1] A phrase originated by Peter Drucker.

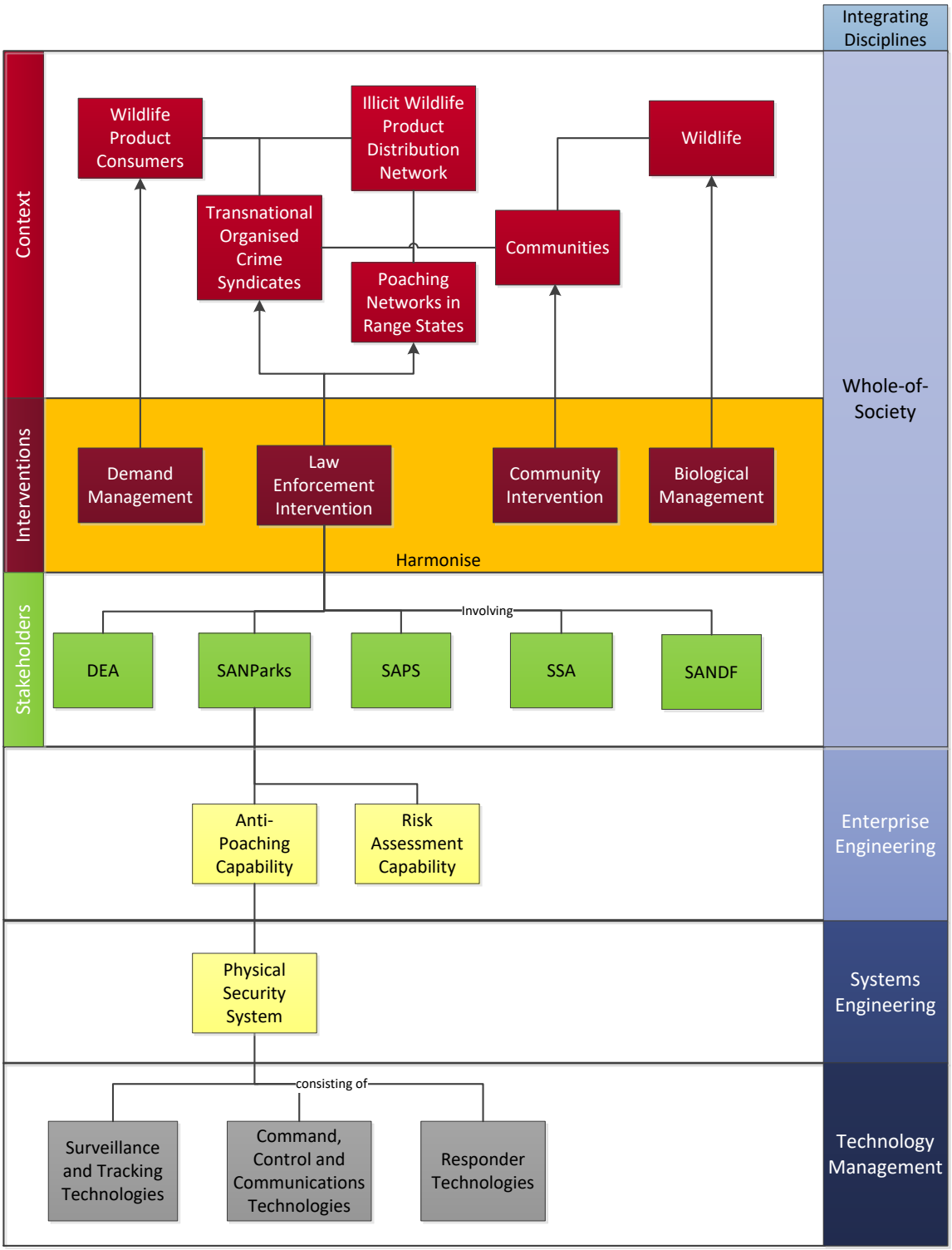

Figure 2. Vertically and horizontally integrated approach to addressing wildlife crime (illustrative model – not complete; updated from (Gonçalves, 2017)[2])

[2] Range state is a term used in zoogeography and conservation biology to refer to any nation that exercises jurisdiction over any part of a range which a particular species, taxon or biotope inhabits, or crosses or overflies at any time on its normal migration route. (Source: https://en.wikipedia.org/wiki/Range_state)

The **first integrating level** or whole-of-society level contains the context, the interventions and the stakeholders. The **context level** includes the end-users of wildlife products in South-east Asia, the illicit product distribution network, the syndicates involved in transnational organised crime, poaching networks in southern Africa, wildlife parks, and communities around parks. The context level is important in terms of understanding the problem and spans the international, regional and national levels. The **stakeholder level** includes the government departments and other organisations involved in **interventions**. Different interventions will involve different combinations of stakeholders. Including stakeholders in the development of interventions increases the chance that these interventions are successful. Community interventions that address basic needs are proactive approaches. Horizontal integration at this level is concerned with understanding and integrating across different interventions, and between organisations involved in the interventions.

The **second level** provides the capabilities for the intervention within a particular organisation such as the anti-poaching capability developed for the Kruger National Park. Various capabilities will be required for a law enforcement intervention in a number of different organisations. The **third level** provides the technical systems required for the capability. The Physical Security System for Kruger National Park comprised sensors, communications, and software for integrating the various types of information and presenting it geospatially. The **fourth level** includes the technologies for a particular capability, such as command, control and communications, surveillance technologies and responder technologies.

One level should not be assumed to be more important than another and activities occur on all levels simultaneously. Each of these levels requires horizontal integration, such as harmonising interventions at the whole-of-society level. There is a temptation to dismiss methodology in the face of complexity and to be "practical" – this simply results in "muddling through" (Lindblom, 1979). To avoid this, not only have integrating disciplines become more important, *but also the relationship between these integrating disciplines*.

The four *integrating methodologies or disciplines* (right-hand side of Figure 2) span the various levels of the systems hierarchy. The **whole-of-society** approach was introduced in the previous section. An enterprise is an intentionally created entity of human endeavour with a certain purpose. The **enterprise engineering** level is concerned with implementing capabilities against strategic requirements. There are a number of developments leading to improved means for achieving integration of enterprises (Hoogervorst, 2009). This includes ICT, organisational design (leadership, rewards and recognition, and culture) and governance. This is important since the behaviour that the enterprise exhibits depends not only on the technical systems, but also on management and leadership practices and organizational culture (Hoogervorst, 2009). Hoogervorst's central concern is designing an organismic system. This is an adaptive enterprise in a *complex* environment where behaviour is shaped by principles that keep it stable as opposed to rules and regulations which are brittle under uncertainty and complexity.

The **systems engineering** is concerned with the development of operating concepts, requirements analysis, architecting, implementation, verification and validation of technical systems and capabilities. These are the types of practices described in the INCOSE Systems Engineering Handbook (Walden, et al., 2015). While systems engineering may have ambitions to solve problems at other levels, it is not there currently (Sillitto, et al., 2018).

A technology is "a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome" (Rogers, 1995). **Technology**

management is about developing, acquiring and maturing new technologies which form part of a system, which may be at the whole-of-society, enterprise or technical systems levels. Thus a climate-change resistant crop is a technology, as is the practice of boiling water to reduce disease.

Figure 2 is an attempt to communicate a variety of complex ideas but has several limitations. Firstly, individual level appears to be missing because technical systems become part of enterprises. Incorporating the individual is well established in systems engineering as human factors design and enterprise engineering and management literature. Secondly, the boundaries between integrating disciplines are fluid rather than clear, hard lines suggested by the diagram. For example, based on the definition of technology above, technology management is relevant to technical and social levels. The boundary between systems engineering and enterprise engineering is fuzzy. Thirdly, research can be conducted at any of the four levels. Fourth, the downward expansion of the systems hierarchy is truncated as soon as "know how" is achieved, which can be through an existing capability, system or technology. The important issue is that the approach be problem focused as opposed to discipline focused or organisation centric and vertically integrated with enterprise engineering, and technical systems. Finally, the astute reader will have observed a different order of tasks, capabilities and stakeholders in Figure 1 and Figure 2. This is not an inconsistency, but the result of different views.

The article now shifts to introducing the theoretical issues underpinning vertical integration and the new contributions relating to the concept of system in a whole-of-society approach.

Theoretical issues underpinning vertical integration

Systems engineers may be quite familiar with the concepts of system and hierarchy. In this section assumptions underlying these concepts will be explored and the implications for integration. The discussion of integration is anchored in the concepts of transdisciplinarity and levels of reality. The concept of the scale, hierarchy and heterarchy are introduced, building up to the new concepts of participative and representative mode systems. This is followed by a definition of social systems and society.

Transdisciplinarity and levels of reality

The concept of transdisciplinarity is used to provide a theoretical basis for vertical integration (as contemplated in Figure 2) required for addressing complexity. Transdisciplinarity draws on existing disciplines at various levels or scales and seeks to generate knowledge between disciplines and to move beyond disciplines. Nicolescu's levels of reality are levels that are described by a set of laws, theories or principles (Nicolescu, 2000). Examples of different levels of reality are:

- quantum physics is different to classical physics and thus correspond to two different levels of reality in the study of natural systems that are objective.
- the subject, referring to the thinking and feeling mind or the conscious mind.
- social systems, with a geographical and historical context as examples.
- biological systems are another example of a different level of reality.

It is fundamentally important to note that *no level of reality is privileged in terms of understanding reality*. In a transdisciplinary approach all perspectives and levels of reality are required, although the importance of each will be problem dependant. Nicolescu (2010) formulates transdisciplinarity in terms of three axioms (shown diagrammatically in Figure 3):

- **The ontological (existence) axiom**: There are different levels of reality of the object and, correspondingly, different levels of reality of the subject.
- **The logical axiom**: The passage from one level of reality to another is ensured by the logic of the included middle (to be defined shortly).
- **The complexity axiom**: The structure of the totality of levels of reality is a complex structure: every level is what it is because *all the levels exist at the same time*.

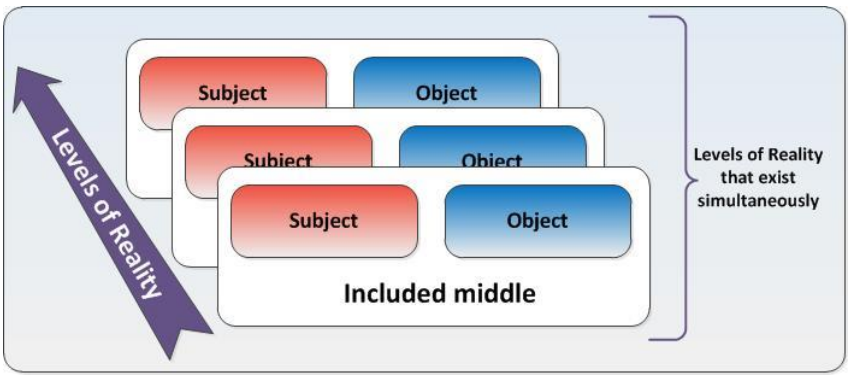

Figure 3. Model of transdisciplinarity (Nicolescu, 2010)

Different ways of knowing, each having a particular paradigm, must be integrated ranging from natural sciences, social sciences and humanities. Integrating these ways of knowing requires working at a meta-paradigmatic level. Integration *across and between* the levels of reality is required for an approach to deal with complexity. Thus, there is not only subject and object but also an *included middle which describes the knowledge and interactions between different levels of reality and the subjective and objective. It is the included middle which addresses the spaces between disciplines identified by Morin as the source of complexity* (Morin, 2007). Furthermore, all levels of reality exist at the same time and thus must be addressed simultaneously.

There are several dividing lines for the integrating disciplines required at various systems levels, or what Nicolescu (2010) refers to as levels of reality: i) purely technical systems; ii) individual human systems; iii) organisations; and iv) society. It is important to note that within each of these levels there may be several systems levels.

Hierarchy and heterarchy

In order to understand what is meant by whole-of-society, it necessary to understand scale and society (which will be revisited in more detail in *The definition of social systems in society*) and different ways of organising social systems. An individual can participate in a group, constituted of at least two individuals, through communication. This may be a loose association or more formal organisation. In a group the individual has a particular identity and role. The critical observation is that an individual is a member of multiple groups, with partial or full participation. *Individuals constitute the group and groups constitute the individual.* With full participation individual members and the group are formed through communication. Partial participation is illustrated by unidirectional communication and mass media as a specific example. Here the intent might be described as influence.

Scales of social systems could be: society; enterprise; group; and individual. Regional, international or planetary scales and the ecological are important but would expand the scope of the article without being required for the arguments that follow and are not considered any

further. It should also be noted that a region or a sector may constitute a category rather than a system. The difference between a category and system is that a category may have a *common* characteristic but not a *unifying* characteristic.

While hierarchy is useful in systems engineering for the engineering of technical systems, in social systems this is not the only option, especially when dealing with complexity. A hierarchy is composed of "elements which on the basis of certain factors are subordinate to others and may be ranked" (Crumley, 1995). A bureaucracy is an example of an enterprise organised as a hierarchy (Mintzberg, 1989). This is a common organisational form employed by states using control through direct supervision, standardisation and regulation, although there are exceptions that will be dealt with later in this section. This is in sharp contrast to agile, networked (peer-to-peer) criminal organisations (Williams & Godson, 2002). This does not mean that hierarchy should be abandoned, although Crumley surfaces a number of assumptions in relation to hierarchy (1995):

1. Scale and control hierarchies are often confused;
2. Hierarchy is a pervasive reductionist metaphor that defines order, which needs to be challenged in the context of complex social problems.
3. The interactive elements of a complex social system are permanently ranked in relation to one another. This may well be the case in a technical system.

In terms of adaptability and interactivity, human self-organising systems are the most complex and an alternative to hierarchy is heterarchy. Heterarchy is the "relation of elements to one another when they are unranked or where they possess the potential for being ranked in a number of different ways" (Crumley, 1995). Heterarchies are networks of elements in which each element shares the same "horizontal" position of power and authority, each playing a theoretically equal role. The characteristics of hierarchy and heterarchy structures are listed in Table 1 for comparison.

Table 1: Characteristics of authority structures: Hierarchy and heterarchy (Crumley, 2005)

	Advantages	**Disadvantages**	**Trade-offs**
Hierarchy	1. Clear decision-making chain - Respond well to fast-developing crises. 2. Rules and responsibilities known to all: Political interactions few and formalized; Political maintenance of the system is low. 3. Powerful means of security: Defend the organization; Suppress internal dissent.	1. Slow movement of information to the top: Especially true of subversive activity; Formal and elaborate internal security. 2. Expedient decisions not necessarily popular: High popular dissatisfaction; Considerable investment in coercion. 3. High security costs.	1. Value rule-based authority. 2. Social distinctions elaborated. 3. Power defined as control. 4. Value exclusivity and the *status quo.* 5. Heavy cost for security.
Heterarchy	1. Good quality information. 2. Fair decisions reflect popular consensus. 3. Variety of solutions to problems presented. 4. Contributions of disparate segments valued: Women, ethnic groups, etc.; Better integrated group; Proud and energized workforce.	1. Consensus is slow. 2. Dialogue requires constant maintenance. 3. Cacophonous voices and choices.	1. Value spontaneity. 2. Achieved status builds individuality. 3. Define power as inclusive or counterpoised. 4. Value flexibility and group involvement. 5. Greater response choice/Slower response time. 6. Long-range planning more difficult.

Participative and representative systems

Participation and representation are ways of being in a social system, shown in Figure 4. In this discussion of participation and representation, the concern is not democracy as an ideology or a governance approach but a way of being in a social system. In the extreme this represents two modes of being in a social system: the first is primarily participative and the second is primarily representative, although there are always both elements. For a soccer team, each player represents himself while the fielded team experiences full participation with the opposing team (those on the bench participate conditionally). It can be argued that the team carries the hopes of a country but this is an argument at a different level and not the point of this example. In the context of multiple groups, it is an individual(s) from a group that represents the group. The president of a country representing his/her country in bilateral negotiations participates as president but represents all the people of his country – the representative mode.

Similarly, the organisational stakeholder does not participate as a whole – it sends representatives. The key insight is that the whole-of-society intervention indicated on Figure 1 and several interventions indicated Figure 2 are developed by a social system in representative mode. One of the challenges with representative mode systems is that the individuals that are sent have power or status. This hampers working in groups and tasks that require coordination, making it less likely to reach agreement on a negotiation task (Hildreth & Anderson, 2016). Power leads individuals to jockey for status in the group, to be less focused on the task and share information less effectively. Returning to the earlier question of who is in charge of interventions, and the concepts of hierarchy and heterarchy. Stakeholders in a representative mode system bring the assumption of hierarchical control, when there are benefits to be had from a heterarchical mode, as outlined in Table 1.

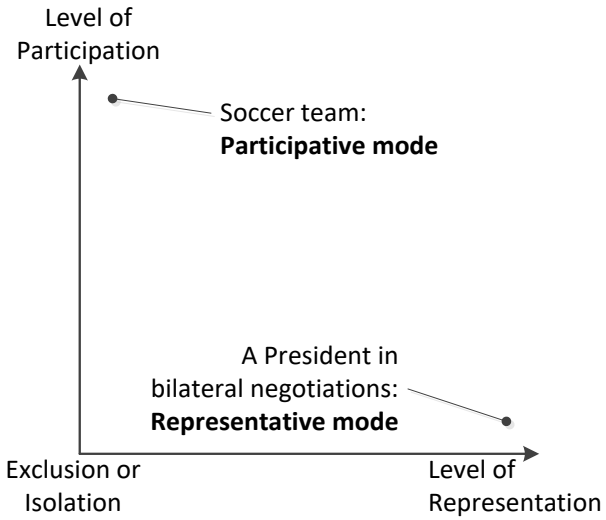

Figure 4. Participation and representation in a social system

The definition of social systems in society

"If you don't know how your mind reacts, if your mind is not aware of its own activities, you will never find out what society is . . . because your mind is part of society; it is society. . . . It is not distinct from your culture, from your religion, from your various class divisions, from the ambitions and conflicts of the many. All this is society, and you are part of it. There is no "you" separate from society." (Krishnamurti, 1989, pp. 83-84)

This section will consider a number of issues with the definition of social systems in society. The purpose of this section is not to come up with a new definition of a system, but rather to raise some issues regarding the definition across multiple systems levels. It is not uncommon for some systems engineers to say that "everything is a system". An element of a technical system is an element in a hierarchical, "part of" sense. The observer is never part of the technical system and always stands outside the system (external reference). With social systems, the observer can observe from outside or from inside the system. If the observer is inside the social system, then the *observer is not independent* and *the observer can see the system-boundary distinction*, i.e. social systems are self-referential (Luhmann, 2006). Thus there has been an evolution from closed systems to open systems to self-referential systems. Social systems are dynamic and reorganisation is possible – an individual can be a member of many systems at the same time or simply with a group that may not constitute a system. Luhmann's social systems theory has four important consequences (Luhmann, 2006):

- The system is the difference between system and environment;
- A social system can be reproduced through a single type of operation, in this case *communication*;
- Every social system observes internally (i.e. from within the system) its own system/environment distinction; there is a re-entry or self-reference of the system/environment distinction into the system; and
- Every social theory is part of the social domain and as such part of what it describes.

Do police and criminals constitute a system through their interactions? Is interaction enough? Applying Luhmann, criminals exist because their particular values and norms are different from the environment. It is this difference that distinguishes the environment from the group of criminals. This does not mean that the group of all criminals forms a system. This is a limitation of Luhmann but is resolved with a qualifier or additional requirement (Makarovic, 2001). A group of criminals may form a system because they have a common purpose, such as in the case of organised crime. The police form a counter-balance. The police and the criminals do not form a system, but from the perspective of society, the police have a regulating function. Some social systems may work across purposes and so constitute each other.

Various groups will come together only when the problem cannot be solved within individual groups, i.e. a purpose outside that of any of the member organisations. But this does not mean such organisations have reached consensus on common purpose. Consensus is merely a stage that can be arrived at in a conversation, but "is a horizon never reached" declares Lyotard (1984, p. 61). His view was that "consensus is a component of the system, which manipulates it in order to maintain and improve its performance." (Lyotard, 1984, p. 60). Complete consensus is not always possible because it requires that all contradictions be resolved but stakeholders have a range of values and interests. Getting stakeholders around a table to discuss common purpose can be challenging. The first task is to obtain "consensus for seeking a consensus", or what Dimitrov and Russell call *second order consensus*, which rests on three major components: willingness to change; mutual trust; and willingness to share power (heterarchy) (1994).

In social systems, *society is the environment* (Schwanitz, 1995). The human beings are the 'environment'. Luhmann in defining society as *world society* adopts a novel, radical position that recognises globalisation (Makarovic, 2001). This moves away from a society being defined around a particular political system or nation state since states are not functionally differentiated. Furthermore, complex problems transcend national borders in a globalised world. For example, wildlife crime has a transnational organised crime component and jurisdictional boundaries are more of an impediment for law enforcement than for criminals.

This allows whole-of-society principles to be applied at national, regional and international scales.

Applying a definition of technical systems to social systems is not appropriate. The argument has been made that there are different levels of reality, i.e. they have different explanatory theories and principles. Integration is not the obliteration of these differences – it is an understanding of differences. Difference can be based not only on functional considerations but also on other considerations such as values and ethics (aspects of the subjective). In the context of defining the system boundary in a social problem, ethics is critical but not always central (Gonçalves, 2019). In systems thinking a boundary is drawn between the "system" and its "outside". What is the basis for bounding a complex problem? On the basis of the problem or the actors? But it is the actors who decide the problem. What is inside the system is based on framing, interest, influence, or what can be controlled. But systems boundaries are value laden, especially in social systems (Midgley, 1992). For example in a business, who is allowed to participate in strategy development and who is not? The boundary around the business is what Midgely refers to as the primary boundary. But what about customers - are they really outside the boundary? What about those who are unemployed? The business logic of optimizing system performance and efficiency leads to socio-economic contradictions: lower production costs which implies less work, but to reduce the social burden of an idle population, more workers should be utilized (Lyotard, 1984). The primary boundary hides, marginalizes and protects the status quo in a tacit or unconscious way (Midgley, 1992). Moving from the primary boundary to a more inclusive secondary boundary (the expansionism referred to earlier) is an ethical and value laden decision (Midgley, 1992). Critical approaches seek to surface assumptions about the status quo, emancipate the marginalized and expand cognitive autonomy (Jackson, 2003; Krippendorff, 1993).

One way of viewing a system is as being comprised of individuals, or integration of part into whole. With system as difference from the environment, Luhmann does not rely on integration as a precondition for a social systems reproduction, but the idea of reproduction based on a specific self-referential operation, namely, communication. However, system as difference still has a unity, just without the part-whole focus. The unity of the system is constituted from within the system – it cannot come from the environment. One aspect of unity can be common purpose, a topic discussed in the previous section. The abstract nature of Luhmann's definition is its strength.

Conclusions and implications

"Not every consensus is a sign of truth; but it is presumed that the truth of a statement necessarily draws a consensus." (Lyotard, 1984, p. 24)

Since the genesis of systems engineering in the defence sector, it has undergone many changes and advances, especially in the last 20 years. The new challenge INCOSE has set for itself is to adopt transdisciplinary approaches (Sillitto, et al., 2018). In order to do this, INCOSE will need to become aware of its worldviews, values and paradigms and language (Gonçalves, 2019). New examples highlighted in this article include: hierarchy as "part of" relationship; hierarchy as control; beyond life-cycle phases, systems are largely assumed to be static. This works for technical systems, but for social systems these are not valid or incomplete.

If complexity occurs because all levels of reality occur at the same time, then complex systems must be designed at various levels of reality at the same time. Simultaneous design of strategy,

organisation and technical systems requires a transdisciplinary approach and maps that support cognition. Some have advised against designing multiple systems levels simultaneously and called for an "onion model", starting from the top down and "freezing" higher levels before proceeding to lower levels, for solutions to converge (Long & Scott, 2011). This advice may be sound in the context of technical systems which occur only at one level of reality. For technical systems, control and order may be desirable. But control and order are not always compatible with self-organisation. Some chaos leads to creative, emergent solutions (Shaw, 2003).

The key contribution of this article is that social systems operate in a blend of participative and representative modes. An example of a system in a representative mode is the UN Security Council, (in South Africa, the Security Cluster which comprises of representatives from various government departments). In a whole-of-society intervention spanning multiple organisations, a system in representative mode is formed, while the existing organisations continue in a participative mode. As such an intervention system goes through an exploration and framing of the issues, where *the stakeholders may vary* until the system stabilises to some extent (although it does not become static). The *environment of a system in representative mode is the systems represented*. Whole-of-society problems require balance and counter-balance and addressing cross-organisational problems. Integration does not mean that we abandon difference, but rather keep these differences in tension. Multiple interventions can each cascade to capabilities, technical systems and technologies that are not obvious considering technologies in a single organisation. A whole-of-society approach is not just the application of "systems thinking" at a higher level in the systems hierarchy, without consideration for the levels of reality.

The four levels (Figure 2) do not constitute a systems hierarchy in the traditional sense, but a social scale hierarchy coupled with technology. Society has multiple scale levels which do not necessarily form a control hierarchy. Systems engineering and a whole-of-society approach integrate different levels of reality. The enterprise engineering level consists of at least two levels of reality since it is where technical systems meet within the context of an organisation. The technology level may include different levels of reality from these depending on the definition of technology and the specific context. Many other levels of reality may also be included such as the natural environment and psychic systems.

This article has also shown that social systems: i) can be hierarchical and heterarchical; ii) are not in a part-whole, but in difference from the environment; iii) reproduce through communication; and iv) occur in a dynamic participation and representation space. Thus system exists as unity *and* as difference. Social systems are "formed out of" society more than they "consist of" individuals whereas for technical systems it is the "consists of" relationship that is dominant. With social systems the observer cannot be independent and outside of the system as might be possible with technical systems (Gonçalves, 2019). Caution must be applied in universalising any particular definition of system given the concept of levels of reality. The problem is not the definition of a system, but the worldviews and underlying assumptions of practitioners.

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Biography

Duarte Gonçalves is currently employed by the CSIR as a Principal Engineer where he currently leads the on-going development and application of a whole-of-society approach to security in the areas of disaster management, infrastructure security and wildlife crime. He has contributed to national strategies in wildlife crime and the development of whole-of-government and whole-of-society approaches nationally. In this capacity, he works with a variety of government departments, social scientists, engineers and other experts and has developed experience using transdisciplinary research methods in security for "dealing" with complexity. He has facilitated stakeholder workshops for developing futures and interventions.

Duarte Gonçalves is a registered professional engineer with a PhD in Engineering Development and Management.