EasyChair Preprint

№ 4161

5th generation fighter aircraft and future command and control: A note on some possible changes

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September 9, 2020

5th generation fighter aircraft and future command and control:

A note on some possible changes

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***Abstract*:** In this paper, we consider some possible consequences for command and control (C2) of the technological characteristics of fifth generation aircraft. Delegation of decision rights may be needed to fully exploit fifth generation fighter aircraft stealth and situation awareness capability. We suggest that when delegating decision rights to the pilot, e.g. target engagement authority, commanders need to weigh the cost and benefits of sharing and not sharing information. The benefits of delegation, and temporarily relinquish information sharing, may come at the cost of less strategic control. Delegation may involve temporarily relinquishing the opportunity to communicate with the pilot. In such a case the mission may be solved better and faster tactically. In making a delegation decision, the commander could therefore benefit from a formal framework, where known factors influencing delegation decisions are systematically examined, and the communication process with the fighter jet pilot is clearly described. This could shorten the decision-making time at the same time as reducing biases from omitting crucial factors in decision-making. Based on such a framework we discuss implications for Air Force and Joint C2.

Keywords: Command and control, Military technology, Fifth generation fighter aircraft, Cybernetics, Delegation, Decision-making, Information sharing, Coordination

I. INTRODUCTION

Command and control (C2) concerns the direction and coordination of forces, or put in another way providing focus and convergence (Brehmer, 2010; Alberts, 2007). One of the key variables influencing C2 is technology (Van Creveld, 1991). As an example, the telegraph made near real-time communication available between a geographically distant commander and his troops, which allowed headquarter control rooms to coordinate military activity in a better way (Lambert, 2005). Delegation, transferring decision-making authority from superiors to subordinates (Leana, 1986), may have been hampered. While such technology improved the speed of information sharing between levels of command, that same technology, in some circumstances, led subordinates to wait for decisions by their superiors (Lambert, 2005). This suggest that technology, as used, does not have straightforward positive consequences for C2. While this technology may have improved coordination, it also hampered the room for delegation. Such questions are also relevant when introducing other types of technology affecting C2. Therefore, the influence of technology on delegation in military hierarchies is still a core topic of research on C2 (Brehmer, 2013).

In this paper, we explore how the commanders delegation of decision-making authority to the fighter aircraft pilot, could be influenced by current 5th generation fighter aircraft technology. Prior conceptual work have in particular highlighted the need and potential for more decentralization and autonomy to the pilot in order to utilize the potential of 5th generation fighter aircraft (Hoeben, 2018). Information sharing and shared situation awareness are seen as fundamental to decentralize decision rights, e.g. target engagement authority, to the pilot (Laird, 2009; Hoeben, 2018; Schaub & Michaelsen, 2018; Kalloniatis, 2018; Frey et al., 2019). This point of view is grounded in recent research on C2, which emphasizes the sharing of information as key to distribute decision rights (see e.g.: Alberts, 2007). In circumstances where information sharing is not possible Granåsen et al. (2018) suggest that one should resort to mission command, i.e. orders to a unit that not specify how they are to be accomplished (US DOD, 2005). Still, the preconditions for delegation is seen as a key issue that need to be discussed further (Hoeben, 2018).

Increased information sharing is undoubtedly a key component of enabling 5th generation fighter aircraft. However, special missions with *silent running*, i.e. restrictions on the communication to and from the aircraft, are missions that are particularly relevant with respect to 5th generation aircraft. A better situation awareness for the pilot, the aircraft as provider of better information, and the need to use stealth to conduct tactically challenging missions, are among the operational potential that could highlight the potential and need for silent running. We thus argue that there is a need to discuss in more detail how commander's decisions to delegate could be made

which considers when information should be shared. On this background, we examine the following research question: What changes do novel 5th generation fighter aircraft entail for C2, specifically delegation of decision rights? In addition to considering delegation, we also discuss some possible implications from our framework with respect to coordination, i.e. integration of activities, between a fifth generation fighter aircraft and other entities in joint missions. We thus cover some ground with respect to what could be called specific functions of C2, *what* the C2 system needs to do (delegation decisions), as well as some more detailed questions pertaining to implementation, *how* this could be done (a delegation framework and coordination) (Brehmer, 2010).

In order to examine delegation decisions, we draw on prior research in cybernetics and research on delegation. The theory of cybernetics suggest that an organization should represent features of the wider system to which it belongs for it to be able to interpret the system correctly and act properly within the arrangements of a wider system e.g. situated control, in other words it should have requisite variety (Ashby, 1970; Weick, Sutcliffe and Obstfeld, 1999). An implication for a delegation framework for a commander is that it should represent the salient features of the endeavors 5th generation aircraft could be used for. To inform what these salient features are, we draw on and extend the research on delegation (Simon, 1947; Sengul, Gimeno & Dial, 2012). A systematic decision of delegation may need to weigh both the need to exchange information on the one hand (to be able to abort a mission because of its perceived negative strategic consequences), and the tactical needs of the pilot with respect to conduct missions without information exchange on the other hand (for example to enable stealth operations). In the following, we ground these suggestions on delegation in background and theory (part 2). We then present a delegation framework (part 3) and finally discuss how the framework could hold implications for coordination of an Air Force in a joint context as well as future research opportunities (part 4).

II. THEORETICAL BACKGROUND

In this section, we first briefly describe *silent running missions*, and then draw on cybernetics and delegation theory to discuss the components of a delegation framework.

Silent running missions

Doctrinally silent running missions are specified as a type of mission, i.e. a military operation assigned by a higher command: “Silent running operations are designed to permit aircraft movement while minimizing the transmission of in-flight data and air/ground communications. These missions are preplanned to operate along a specified track or within a planned corridor to minimize conflict with other military missions or civilian air traffic. A commander will not transmit

to the aircraft unless: 1) An aircraft commander requests information, 2) an emergency dictates or 3) transmissions made at predetermined times and with pre-determined information is mandatory by the mission-operating directive." (U.S Air Force, 2019). Silent missions may be "on-call", so that they can be immediately executed. In that way preplanning may aid the dynamic execution of missions, and "delegating an increasing number of missions (to more and more autonomous systems), capable to adjust to new and unexpected situations within a specific framework." (French Air Force, 2020).

Restrictions on information sharing is not a new aspect of C2, it is at the core of using strategic resources such as submarines and special operation forces, and delegation could be done using *mission type orders* which states a broad intent and tasks, e.g. orders that are being considered for use as part of distributed operations. An example of mission type order is to send a military entity out on patrols without ordering them to report back during the operation. This is key to a silent mission. The military entity may be sent out on patrol (reconnaissance) consisting of multiple missions and several tasks within these missions. Orders will allow the military entity to adapt its way of operating to the encountered situations. This method of control is also known as *mission type command*.

With 5th generation aircraft, the ability to acquire a better situation awareness may surpass what has been technologically possible before. This could speed up the OODA-loop (Brehmer, 2009; Frey et al., 2019), i.e. higher echelons are not part of the decision-making and the pilot do the decisions directly based on his situation awareness. Furthermore, integrating a 5th generation aircraft into a connected collaborative air combat concept at all times may reduce the 5th generation aircraft stealth and ability to remain covert in silent mission mode, especially if it has to transmit into a network (combat cloud). This suggest not a fundamental change away from the use of mission type command, but more considerations of the decision-making and the communication surrounding it.

We suggest that commanders will balance risk versus the required operational effects if assigning the 5th generation aircraft as a node in the combat cloud. However, the dynamic of missions with fifth generation aircraft may require a framework that go beyond mission type orders. In just a short moment of time, the subordinate and superior may need to change holding the authority. A delegation framework may need to include both a systematic way of making decision (for all levels of command), including advanced knowledge of sensor capabilities, plus formalization of the transaction between superior and subordinate. Such a framework could ensure a swift oscillation between centralization and decentralization based on situational characteristics. In order to develop the components of a delegation framework we highlight some key aspects of

how organizations handle uncertainty in their environment drawing on cybernetics theory, and then move on to the more specific discussion of delegation as one way of handling uncertainty.

Cybernetics theory

Cybernetics is a transdisciplinary approach for exploring regulatory systems - their structures, constraints, and possibilities (Wiener, 1948). Wiener defined cybernetics as "the science of control and communications in the animal and machine." This definition relates cybernetics closely with the theory of automatic control and with physiology, particularly the physiology of the nervous system (Encyclopaedia Britannica). Cybernetics includes the study of feedback, and derived concepts such as communications, command and control (C3). Control can be *reactive*, thus based on feedback. The main requirement for feedback control systems is to achieve a certain desired performance (temporal response and ability to follow a reference) and robustness (stability and ability to suppress interference). In these respects, organizations representing the variety of its environment is better at controlling it (Ashby, 1956). However, feedback may not be readily available to the organization. Control can also be *proactive*, thus based on planning, be it in the form of prediction, calculation or pure chance, resulting in feedforward control. (B. Johansson, 2003) Cybernetic models have thus evolved from a relatively closed system view, where a controlling system can be able to control its surroundings provided it have the requisite variety.

Bjørn Johansson (2003) considers the extension of a cybernetic model to human decision-making. He suggests that whereas a controlling system in the classic cybernetic sense matches the requisite variety of what is called the *target system*; humans do not behave in this systematic way. Control is according to Johansson (2003) defined as the ability to keep a target system/ process in a desired state. The target system generally includes real hardware, software and an operator (e.g. a jet pilot) linked to a C2 system. The target system should of course not be confused with a target system within a joint targeting process. We assume that C2 influences the situation through a mission (Hallberg, et al, 2018;Josefsson, et al. 2019). This article proposes a framework exploring a suitable scope of various missions of 5th generation fighter aircraft. We choose to model the target system as a business process model. Rather, some already known solutions are tried out to problems confronting humans. The uncertainty confronting humans not only relates to information but also the timing of the decision. Due to the complexity and dependence of timely response in military operations, it is common with systems (organizational elements) that provide delayed information. The opposite is also well known, that the feedback is immediate, but that the effects of the actions taken do not become clear until after some time. With respect to this Johansson (2003), citing Berndt Brehmer, suggests that on the one hand it can be dangerous to delegate (possibility of wrong decision), and on the other hand it can be dangerous not to delegate (possibility of using too much

time).

The cybernetic theory indicates that delegating decisions to the fighter pilot thus involve risks and uncertainties. Weick, Sutcliffe and Obstfeld (1999) suggest that for people to act properly in an environment they will benefit from models that have the requisite variety of that system and at the same time are cognizant of the uncertainty of that environment. They suggest that based on a variety of different ways of thinking about the environment and how to carry out tasks organizations may better handle environmental uncertainty. This leads to a slightly looser command and control chain which we call the *mission based approach to Command and Control* (Moffat, 2002; Moffat et al.,2015), but enhances the performance (increased ability to counter threats). The other way around, an external feedback may not be utilized directly by the aircraft rather be provided for a commander which then later makes a decision.

This general cybernetic view of organizations and management suggests that a delegation framework should encompass multiple criteria that takes account both external and internal information, for it to aid the commander in making delegation decisions. These criteria both need to consider the feedback mechanisms necessary as well as the feedforward mechanisms. We now turn to theories of delegation to further specify what breadth of environmental and internal information could be considered when delegating decision rights.

Theory of delegation

Prior organizational research on delegation have primarily focused on how delegation influence the efficiency of the organization. Herbert Simon (1947) suggested that delegation, which he links to decentralization, could be done to save time for the manager both in terms of the time it takes to make decisions as well as the time to communicate about the decisions. Secondly, he suggested that subordinates may hold the best information about the facts, and thirdly Herbert Simon argued that the subordinates may be the best to coordinate their own work and therefore delegation would be appropriate in many situations. Vroom and Jago (1974) highlight a normative model of decision-making building on similar principles as Herbert Simon, where decisions to delegate should fulfill several criteria among them such criteria as “Do subordinates have sufficient info to make a high quality decision?”. Leana (1986 and 1987) as well as Yukl and Fu (1999) tested this normative model empirically, however they added a model of the relationship between superiors and subordinates to explain trust as a precursor to delegation (leader member exchange theory) and they also added models of individual differences (personality) as antecedents of delegation. Some research are critical of the positive effect of decentralization on performance. Lanaj et al. (2013) suggested that delegating decisions had some problematic outcomes in that it could lead to risky behavior and coordination failures.

Some researchers and military work have also focused on the situation as antecedents of delegation decision as well as the importance and strategic implications of delegating (Klein et al., 2006; Aime, 2014; Hoeben, 2017; Sengul et al., 2012; Tørrisplass, 2018). Elaborating the discussion about tactical effectiveness and strategic consequences, there are conflicting views on how complexity of the task affects delegation and decentralization. For some more complex tasks, suggest more decentralization (Dobrajska, 2015) while others suggest that delegation is more appropriate for less complex tasks (Leana, 1986; Norwegian Air Force Doctrine, 2018). With respect to strategic implications research points to the idea of a trade-off between efficiency and strategic effects in the literature on delegation. Delegation may provide efficiency, as suggested by Simon, but it may lead to wrong decisions and to detrimental consequences in a wider strategic perspective.

While most theories primarily concern either effectiveness of delegation or strategic consequences, some research have also focused on increasing subordinates motivation as an underlying reason for delegation (Stea, Foss & Foss, 2015; Gambardella, Khashabi & Panico, 2020) as well as the personality of the commander such as sense of power (Leana, 1986; Hasselhuhn, Wong & Ornisten, 2017).

The literature on delegation is indeed broad however, two topics seem to be less discussed in the literature on delegation. These topics we see as, nevertheless, important for the types of delegation decisions we consider, delegating the right to use deadly force to a fighter pilot with potentially high strategic consequences. The first topic A) is the notion of synchronous communication exchange between supervisor and subordinates and secondly B) the notion of a formal framework for delegating (which is related to the challenges of topic A).

Regarding aspect A: We examine the aspect of whether or not synchronous communication is acceptable to use (given a specific threat). This last factor is new and not, to our knowledge, that much mentioned in the literature on delegation. Although it concerns information and information sharing which is central to theories of delegation, it seems to have been a given in the literature that synchronous communication is always available between the supervisor and the subordinate. For example Simon (1947) and Brehmer (2013) indicate that one reason for delegation is how much time it could take to communicate among supervisors and subordinates assuming that it is possible to communicate two-ways with the subordinate.

Regarding aspect B: The theory largely assumes that supervisors make delegation decisions based on their own perception of their situation, the external situation, and the subordinates, including the information the subordinates may hold and the trust and legitimacy they associate with their subordinates (Yukl & Fu, 1999; Klein et al., 2006; Aime et al., 2014). This process is in

the literature largely seen as at the individual discretion of the commander. However, delegation does also follow formal criteria that can aid the delegation process and make it less prone to biases, as suggested by Aime et al. (2014).

Formalization of delegation framework may hold at least two components: the different criteria for making a delegation decision, and the overview of potential communication between superiors and subordinates. On a general note the notion of having multiple criteria for decision-making borough from other rational frameworks for decision-making such as Banks and Dhami (2014: 35) which suggest that a rational perspective consists of "searching for and selecting the relevant information, weighting it appropriately, and then integrating it". In military operations, it is for example institutionalized through the rules of engagement that soldiers must adhere to, which restricts to only some circumstances the use of force. In addition, effectiveness criteria should be included, which also inform about the need for asynchronous communication. Balancing such requirements could mean that delegation entails less risky behavior and goals are better aligned among the personnel, thus minimizing the risks suggested by (Lanaj et al., 2013) as well as those suggested by Sengul et al. (2012).

In addition, the communication aspect needs to be considered. Research from a military context suggests that the need for secrecy and efficient communication necessitates using codes and simplifications as a part of military terminology (Zohar & Luria, 2003). Such codes clarify the core components of the military system and provide a shared way of communicating orders from a superior to his subordinates. Research on handover-takeover processes, in decentralized networks, suggests that certain design guidelines should be followed for sharing information. Some key words here are verification of information between those communicating. Our view on building situational awareness and communication is that it is a transaction-based process. (Sorensen, & Stanton, 2016; Clark, Stanton, & Revell, 2019). The starting point is that both system components (artifacts) and humans contribute to situational awareness and define the framework for the handover task as a collection of information transactions between components of a socio-technical system, that is, a system where human interaction and technology mutually influence each other. Cultural conditions can strengthen and weaken transaction processes by handover-takeover of situational awareness. The construction and updating of the situation overview at handover-takeover should therefore be facilitated (and should be technically supported) to allow for efficient delegation. In theory, certain Situation Awareness Design Guidelines should be followed (Clark, Stanton, & Revell, 2019). Further, the formatting (that is, the coding, meaning, and context) of the information elements that are communicated and the available media is considered critical in a handover-takeover process. Accordingly, this should be stated and described (Stanton, et al., 2009;

Bowers, Jentsch, Salas, & Braun, 1998)

We suggest that a delegation framework, which is formalized according to the different criteria for decision-making and the handover-takeover mechanisms described above would aid delegation. We see this as important so that the criteria for delegation, and trade-offs among the criteria is available to all decision makers in the military chain of command. We suggest that such a framework would reduce the bias of commanders in emphasizing some but not other criteria (e.g. for example only evaluating the effectiveness criteria and not the strategic consequence criteria). By formalizing the decision-making criteria and the handover-takeover mechanisms, it could also potentially shorten time-critical decisions by structuring decision-making and communication.

III. IMPLICATIONS FOR C2 IN AN AIR FORCE CONTEXT

We now turn to how a framework for delegating could be constructed to enable an optimal use of 5th generation fighter aircraft on the one hand as well as take into consideration other factors such as strategic implications of delegation decisions. We are about to design a Command and Organizational Space for a future Air C2 concept framing a space where we can configure different options for delegation to fighter pilots. As an introduction, we present a connection between mission procedures (in the bottom process schema) and operational effects (at the top two boxes) in Figure 1.

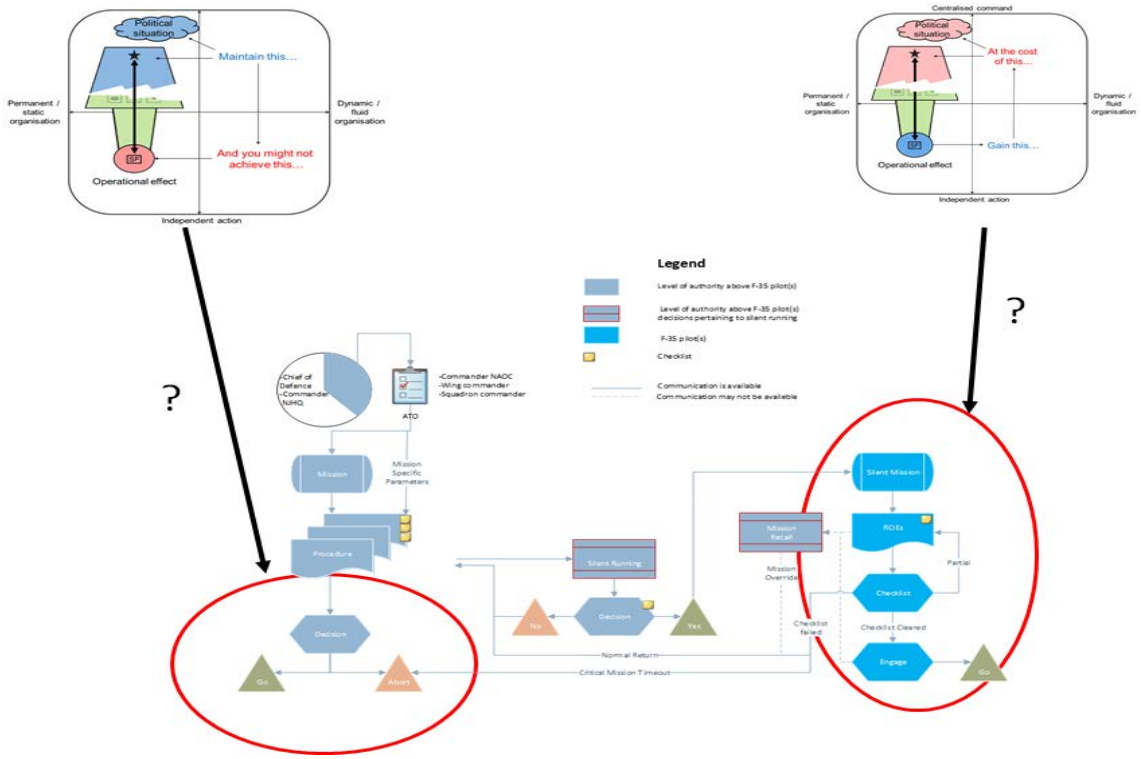

Figure 1. The connection between mission procedures (at the bottom) and operational effects (two boxes at the top).

Figure 1 illustrates the connection between mission procedures (in the bottom process schema) and operational effects considerations (at the top two boxes). Potential operational effects might be blocked by (military or political) choices made concerning the structure of C2 (at the top box on the left side) in Figure 1. Some assets might require (or benefit from) a change in the C2 structure allowing for implicit control (illustrated by the arrow on the right side), rather than explicit control (illustrated by the arrow on the left) in Figure 1. A further complication is whether an asset is capable of information sharing, in both normal and silent running. We will discuss the process schema in more detail but will first discuss the general decisions that a commander may have to make about decision-making authority and organizing.

Framework part 1: initial considerations

This C2 space (Figure 2) represents possible command and organizational concepts that might arise in different circumstances that we derive from Granåsen et al. (2018). In the example (case study), we suggest a way to fill this space.

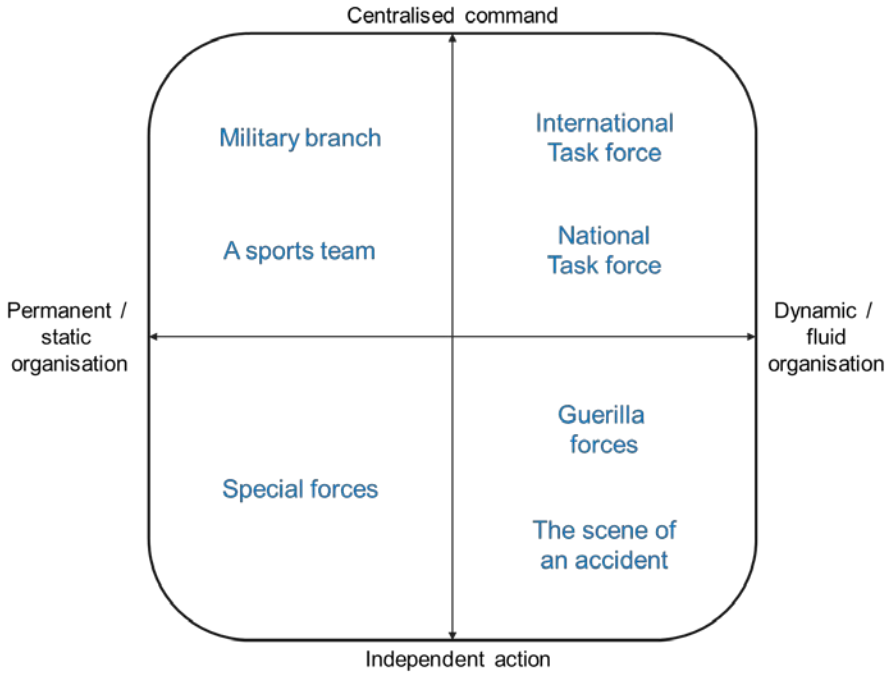

Figure 2. The Command & Organizational Space (with examples)

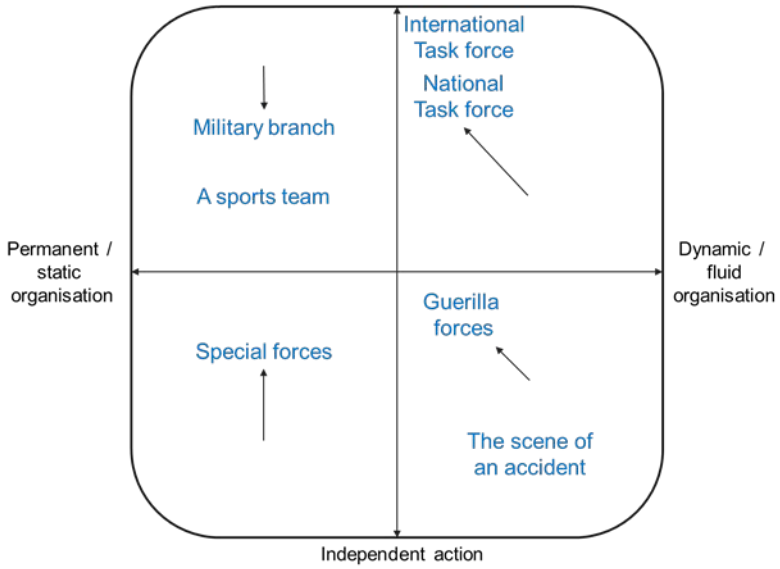

Figure 3. The Command & Organizational Space (with examples).

The top left quadrant (in Figure 2) is home to organizations like a classic hierarchical organization or sports teams. They have a centralized command structure and are often organized in static organizations. Both might share the same level of centralized command, but in this case, their position in the quadrant is set to indicate the «depth» of the command structure i.e. levels of command and control (how tall, top to bottom).

The top right quadrant is home to dynamic organizations that still operate under a centralized command structure. Examples might be National and International military task forces. The bottom left quadrant might be home to more autonomous yet highly organized organizations, examples of which may be submarines, special forces and the like. These forces might be able to deliver operational effects not available to organizations with a more centralized command structure. This ability is often a result of a "small" operational footprint, e.g. stealth. The bottom right quadrant might contain situations such as the first civilian respondents to an accident, with minimal centralized command, and a fluid set of participants. It might also contain Guerilla forces, though these would undoubtedly be more organized and more centralized in their command structure than a collection of civilian agencies at an accident would.

A «tall» organization, top to bottom, is one that contains more organizational levels than one that is «short». The wider an organization is, left to right, the more diverse elements it contains or the more «agile» the command structure is, making it easier for the structure to adapt to changing participants. The exact positions of these labels (in Figure 2) are debatable, and Figure 3 shows some of the changes you might expect: A single military branch may have a less centralized command structure than a national or international task force. These task forces are probably more organized than the original location let on. Special Forces are probably a little less independent

than shown. Guerilla forces, like task forces, are probably more organized and operate with a more centralized command structure than the original location indicate.

Figure 4, might be an example of an idealized military structure, or single branch of the military, like the army. It would contain a command node at the top, appropriate for the given assignment; nodes performing actions lower down in the organization; and a C2 chain responsible for delivering orders, collecting sensor data and facilitating the OODA loop. The shape of the structure (the green area) is meant to represent the tendency for fewer personnel at the higher levels in the command structure and more personnel at the lower level of the structure.

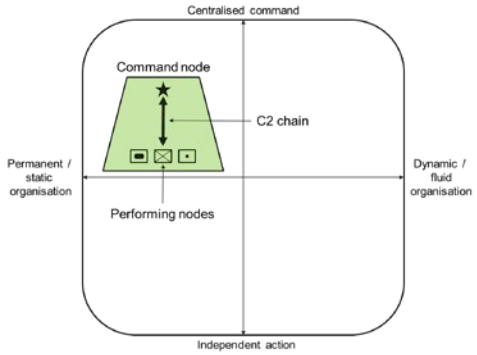

Figure 4. An idealised military structure (the Air Force or the Army).

The structure can be shaped, one example being task force operations. Military Task force operations (Figure 5) are typically joint operations within the armed forces of a nation or with international partners. In practice, the original structure often «cedes» some of its members to the new Task force, and «cedes» Command authority to some higher level in the chain of command, as shown below.

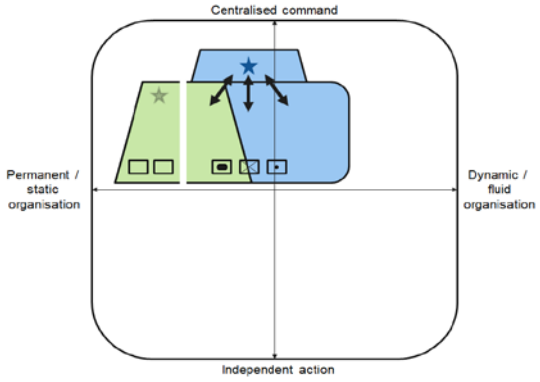

Figure 5. Task Force operations

The original structure is split in two; the commander retains autonomous control over some of the forces; and cedes control over other parts. The new C2 node might use the existing C2 chains

within the old structure (left arrow), or communicate directly to the acquired assets (middle arrow), as well as communicating with the other members of the newly formed Task force (right arrow).

How do you solve the apparent conflict between operational effect and command and control, noted earlier with regards to strategic assets like for example submarines, special forces and fifth generation fighter aircraft? Figure 6 depicts special forces as an example. In this case, we have depicted a strategic asset as an asset with elements capable of independent action (downwards), while still conforming to the organizational nature of the overall structure (left-right). It narrows at the bottom, showing the tendency for such assets to be relatively small in size and footprint. Strategic assets (Figure 6) differ from regular military assets in that they might operate far from communication nodes or in an environment that forces radio silence.

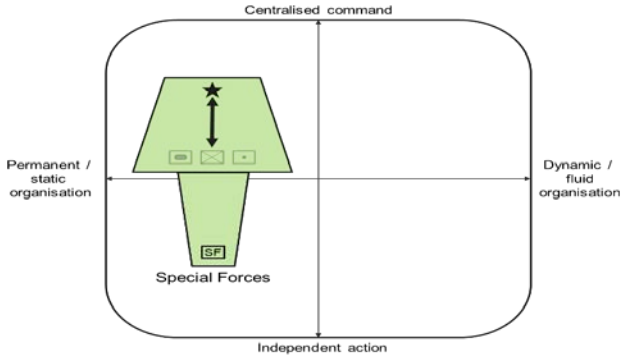

Figure 6. Management of strategic assets.

One potential issue strategic assets face is the elongation of the C2 chain (Figure 7). In other words, C2 either takes too long, or is detrimental to the asset. The elongation of the C2 chain would force the asset to wait for confirmation (in a potentially hostile environment), and thus limit any ability to act quickly in an ever changing tactical landscape. This would represent a potential loss of operational effect.

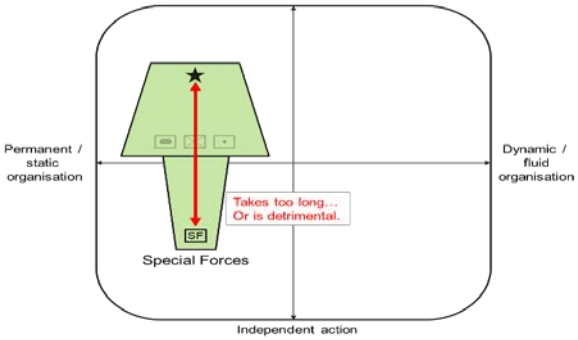

Figure 7. Strategic assets with an elongated C2 chain.

Information flow from the asset may also be reduced due to the tactical situation. Radio silence would mean that the command structure would receive no confirmation of orders, and would therefore be unable to positively identify the status of the strategic asset. How do you solve this apparent conflict between operational effect and command and control?

We have considered three solutions as shown in Figure 8: 1) Direct access (or bypassing the majority of the C2 chain), would allow timely command and control of an asset by an appropriate commander. 2) Compression of levels: when a commander is situated at the nearest C2 node, together with an information-processing cell. 3) Autonomous operations: allowing the asset to act as it sees fit, within standing orders and guidelines.

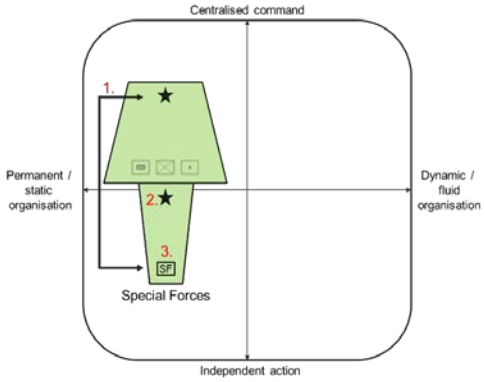

Figure 8. Strategic asset with an elongated C2 chain given alternative solutions.

There is a problem with all three approaches, namely a loss of centralized control, to one degree or another. **Direct access** might not be possible due to a lack of communications or outright radio silence. **Compression of levels** may still not provide a quick enough OODA loop, which could lead to a loss of operational effect, in addition to the above issue (i.e. communication not being possible). **Autonomy** allows for the successful completion of the mission (operational effect) at the cost of a loss of direct control and a missing opportunity to coordinate. In addition, it is likely that the women and men in the field do not have a good understanding of the political situation, with all the ramifications that this brings. The consequence is a forced choice: Operational effect, or confirmable command and control (Figure 9 or Figure 10). The autonomy option is appealing, but there might be situations where the political landscape is evolving minute by minute and the strategic implications of tactical actions change. In contrast: there might be situations where the political consequences of an action are already settled. Is it then acceptable to take the risks associated with autonomous operations?

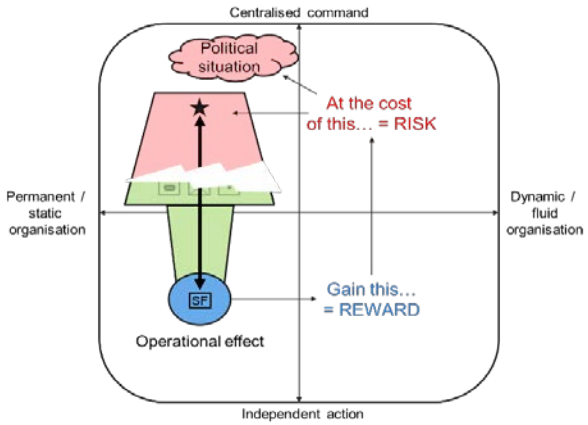

Figure 9. Challenges when delegating authority to a strategic asset.

Figure 9 illustrates the challenge associated with autonomy. Figure 11 illustrates the opposite regarding control. If you want to maintain control over the actions of your assets, while being mindful of the political situation, then you must be content to forgo a potential operational effect at your disposal.

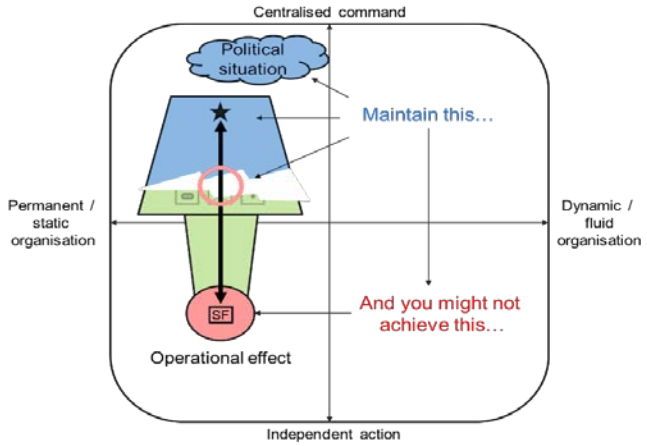

Figure 10. Challenges when <u>not</u> delegating authority to a strategic asset, maintaining an elongated C2 chain.

The trade-off might not be clear-cut. In some circumstances taking initiative at the tactical edge, have positive strategic implications.

Framework part 2: formalized mechanisms for delegation from strategic to subtactical asset

At each level of command, we thus suggest that the decision to delegate should be informed by several criteria, of which the tactical effectiveness and strategic implications are two of the most important ones. Given a predefined type of mission, some of them may be decided upon by default. However, due to potential dynamics of a situation, all criteria should be updated and evaluated and then a delegation decision can be made as close as possible to the final tactical actions. At each of

the decision points decision criteria pertaining to those reviewed from the delegation literature is assessed as well as those we have added. Generally, as described in more detail above, these criteria typically include: (1) Effectiveness criteria (2) Situational dependent demands (3) Accomplishment of objectives (4) The trust among subordinate and superior

Regarding (1): Whether to delegate based on effectiveness should be carefully considered taking into the commanders perception of time pressure: Do the decision maker not have the time to communicate with subordinates when final decision should be made? Are there too many decisions to be taken potentially overburden a commander? If these questions are answered with a yes, delegation may be a way to reduce time pressure and overload for the commander. In addition to the stress perceived by the commander, effectiveness may also concern the use of the capabilities of the fighter aircraft. Questions to consider are: Do the subordinate have better situation awareness than the superior? Is it necessary to do a silent mission to accomplish the mission? In the type of mission, is it important for the fighter aircraft to be free to coordinate with other entities? Answering yes to these questions may call for delegating decision rights. Regarding (2): Situational dependent demands concerns who have the best available resources to execute the particular mission, given the situation. A question to consider: Is there a dynamic and changing situation? If the answer is yes, delegation may be called for so that the entity with the best resources are free to use these resources. Regarding (3): Accomplishment of strategic goals are central criteria for delegation of authority and a crucial question to answer: Do delegating decisions make the risk higher for escalation? If the answer is yes, delegation may not be favored as a careful consideration by the commander need to be done before the final decision. Regarding (4): The trust among subordinate and superior needs to be taken into to the equation as well and built over time, but is not made part of the formal framework.

We now turn to how delegation decisions can be further accomplished in a process of delegation, describing the decision points that can be used, spanning from tight control to fully delegated decision rights. We start with a generic example of mission procedure for situation when there are direct communication between commander and subordinate (Figure 11).

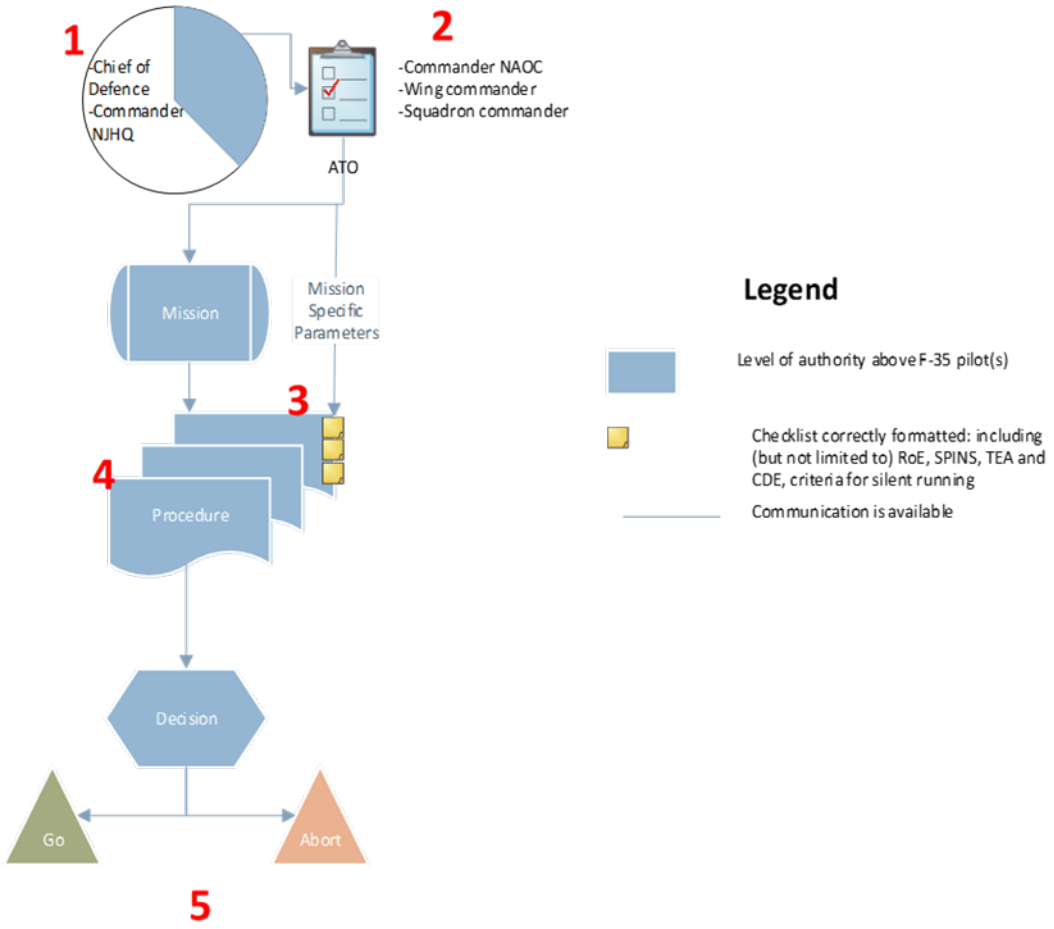

Figure 11. Example of mission procedure when direct communication is selected.

The column flowchart on the left of Figure 11 is a simplified illustration of typical C2 with direct communication. On the right of Figure 11, we have indicated the Legend of graphics in use.

1. A governing authority allocates resources for desired missions.
2. A selected mission is given to an asset.
3. The mission is planned, with its given mission parameters.
4. Finally, a call is made by the tactical controller, based on procedures, The mission begins and follows outlined mission procedures, or the mission is given a no-go.
5. During a mission, a call is made by the tactical controller, based on procedures, whether to give the mission an abort, or go for a new mission.

In the bluegrey boxes, the pilot is still controlled by a level above the fighter aircraft. The communication is continuous two-ways indicated by the lines. Checklists are indicated by the yellow boxes. The checklists typically contain the rules of engagement and different caveats for the mission and criteria for proceeding with a mission.

Below we propose different trajectories of delegated decision-making i.e. non-direct control of the asset. In the procedure block, (dotted lines) there may be room to expand to include

non-direct control of the asset. One such way could be the inclusion of pre-planned silent running, where the asset is given control of the final call for go/no-go (Figure 12). It is here that the changes to 5th generation C2 come into play.

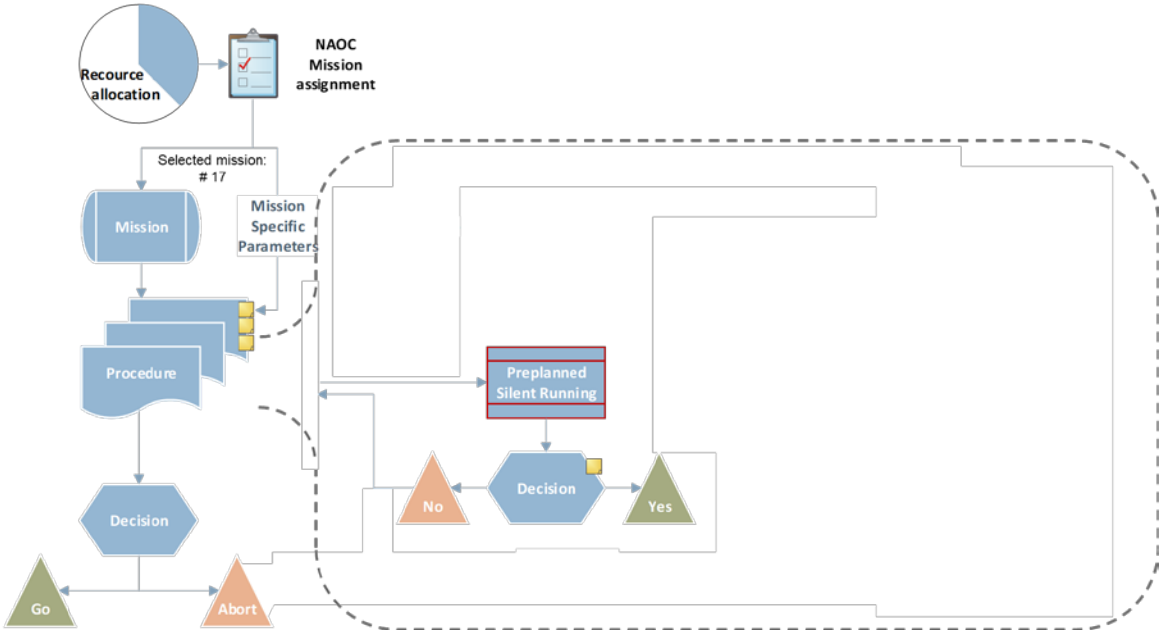

Figure 12. Example of mission procedure: initiating silent mission

In this example, it is still the tactical controller that makes the decision to approve silent running for the asset, based on approved rules. If the asset is cleared for silent running, the asset now «owns» the decision tree and initiates silent running (Figure 13 and Figure 14). This is communicated to the aircraft. The color change from gray to blue indicates the nodes that the asset controls for itself. Strategic or tactical controllers already generate the rules of engagement and other criteria, so one could say that the command structure does still have a level of control over the asset, albeit an implicit control, rather than explicit and ongoing. If the asset clears the required checklist to engage, then the mission is carried out.

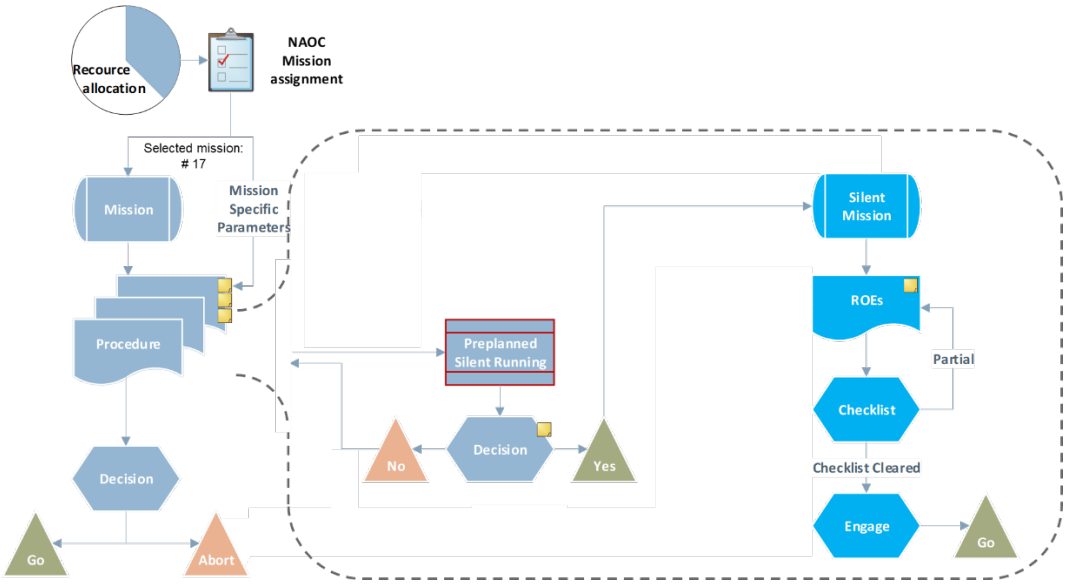

Figure 13. Silent mission: asset controlled decision.

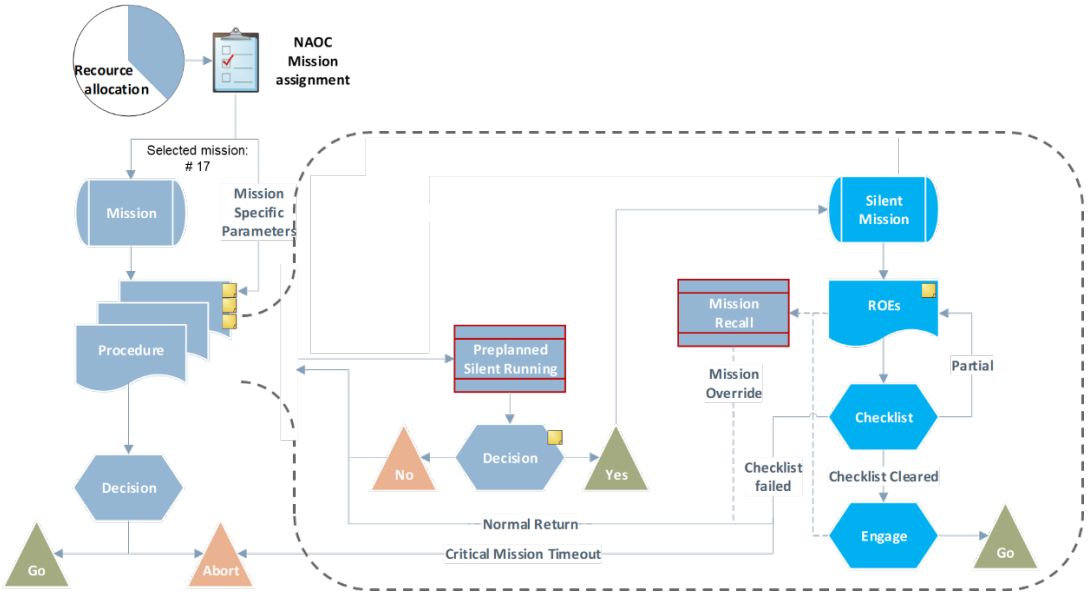

Figure 14. Silent mission: abort procedures.

Should he or she only clear part of the checklist, he or she could wait in the operational area to perhaps gain sufficient updated intelligence and thus clear the checklist.

In terms of mission abort, the C2 chain has no direct control. The C2 chain can invoke a mission recall, but the downside of silent running is that the asset cannot always confirm the recall if it is requested. Dotted lines indicate the uncertain communication (i.e. a two- or one-way

continuous communication may not be available).

In addition, the asset may not be able receive a recall if it is outside communication range, illustrated by the dotted lines. Together with the checklist, the mission recall node gives rise to three potential ways for the mission to be aborted. (1) A mission recall received by the asset, which returns the asset to standard control, once it is outside the silent mission area, where it may be used for other missions. (2) A checklist failure (for example a mission timeout, or lack of sufficient intel), which returns the asset to standard control once it is outside the silent mission area. Again, it may be used for other missions. (3) A critical mission timeout, forcing the asset to completely abort, perhaps due to the tactical situation. Here it is defined as being forced to return without being available for other missions.

One last element that might influence the handover-takeover of control is the dynamic nature of a potential threat, and the context.

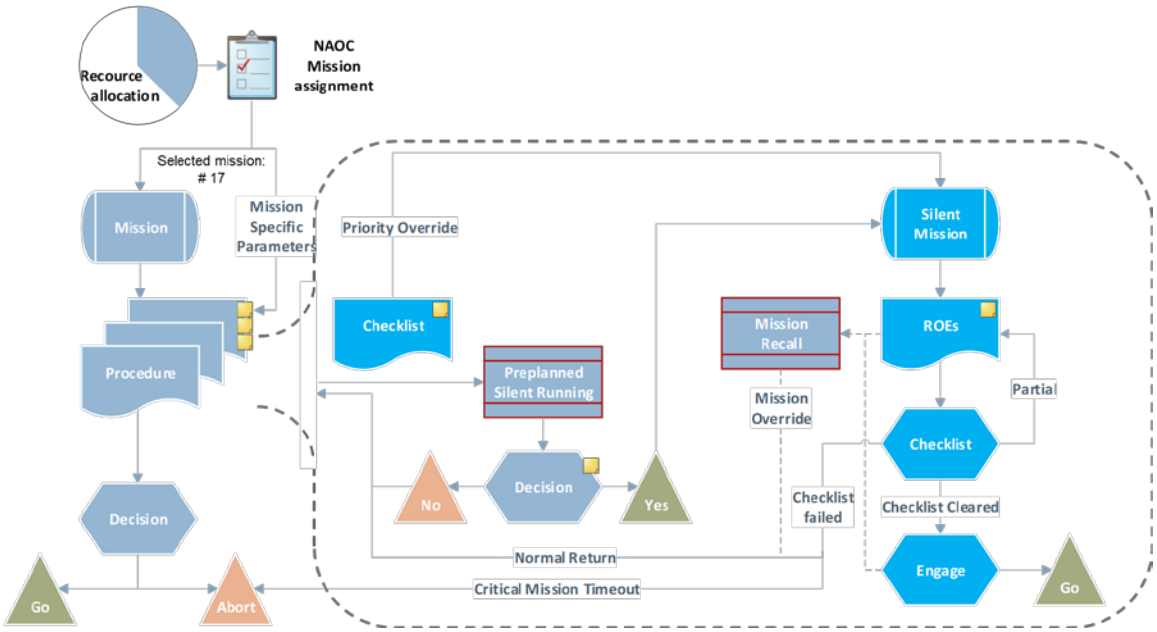

Figure 15. Silent mission: forced asset takeover.

In certain situations, the asset may assert a takeover and enter silent running. This is named priority override in the schema depicted in Figure 15 above. The strategic and tactical controllers would approve the checklist that would have to be cleared, so again there is an implicit level of control. There might also be additional restrictions here, such as the overall strategic and political status or other factors. There may be other considerations that are mission specific, like the transitions between regular and silent running. Different ways of configuring the process could be done for different missions, depicted in Figure 16. This as a generic example of possible procedures that might fit 5th generation aAir Force C2.

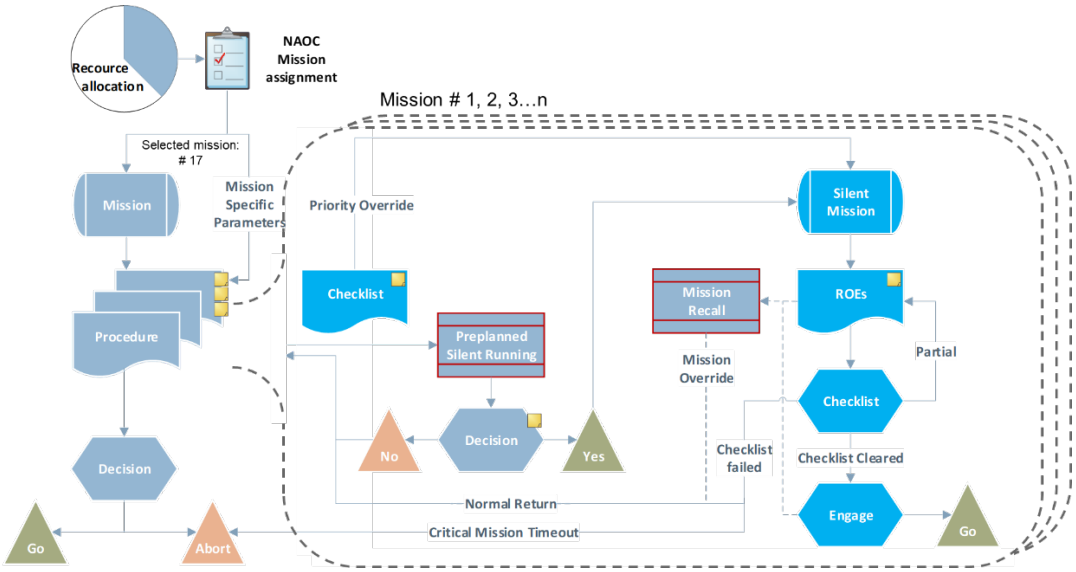

Figure 16. Silent mission: different mission parameters for different missions and operational settings.

IV. DISCUSSION

The delegation framework we propose may hold some implications for Air Force C2 and Joint C2. Prior conceptual work has emphasized both decentralization as well as information sharing as key evolutions (Alberts, 2007; Hoeben, 2018). Our concept also subscribes to this idea, however we add a twist: central to exploiting 5th generation aircraft could also be to understand when it is useful not to share information. This could imply that when directing 5th generation aircraft, commanders may be confronted with a higher degree of uncertainty than what it has been used to in a network centric concept of C2.

We suggest that these changes extend beyond the Air Force, since many of the missions 5th generation aircraft are thought to execute are joint and strategic. Thus the commanders at a joint and a strategic level, may need to use the framework for making decisions that help them take into account the tradeoffs we foresee when delegating. If the missions are strategic or joint, then there is a dependence among the component commands and a joint headquarter or the strategic headquarter. If, based on the framework, decisions are delegated from the strategic level directly to the aircraft there should also be a requirement to make such potential decisions part of preplanned options, so that the joint and component level know what assets they can use and not use and are part of the decision-making process.

Implications for coordination

We now move to the coordination aspect of C2 and starting with the interdependencies vertically from the aircraft to superior levels. We suggest that the interdependencies among

participants varies based on the degree of delegation. If there is extensive delegation, then there is a sequential dependence, input from one entity is needed for the work by another entity (Thompson, 1967): the commander handing over the decision authority to the pilot and the pilot reporting after making the final decision. However if there is no delegation there may be a more reciprocal interdependence, the entities (at different levels) need input from each other to carry out their work (Thompson, 1967). The commander holds the authority and the aircraft pilot must provide information to the commander before the commander makes the final decisions. Then when providing information there may be intensive interdependence, i.e. real-time reciprocal interdependence (Rico et al., 2018), depending on the information needs of the commander. This suggests that different coordination mechanisms may be needed: both tacit coordination mechanisms (i.e. a common ground between the pilot and the commander as to how to act in specific situations) as well as ongoing communication coordination mechanisms (Srikanth & Puranam, 2011). Tacit coordination mechanisms should be important for sequential interdependence, while ongoing communication should be important for reciprocal and intensive interdependence.

With respect to coordination among the aircraft and other Air Force and entities from other services, a framework may aid in defining when there are specific types of interdependencies among entities, and based on this what kind of coordination mechanisms could help manage these interdependencies. As already suggested by Simon (1947) one of the central motivations for delegating authority is to make operators free to coordinate horizontally with other operators. However, delegation when accompanied by silent running may constrain how coordination with other entities can be done. Ongoing communication may not be possible, and the only coordination mechanism available is planned tacit coordination. This could potentially restrict the only type of interdependencies among an aircraft and other entities to a pooled type of interdependence, i.e. the aircraft and other entities contribute to a joint task but they do not communicate. Or they communicate in a sequential way and the fighter aircraft exchange information with other entities only before and after entering into silent running. If a mission should entail more extensive reciprocal and intensive interdependencies, such as in larger joint operations, this requirement may again feedback to the delegation decision. For example, the aircraft may be delegated decision rights but in order to communicate horizontally with other entities silent running may not be done at all times. Not doing a silent running mission may again have consequences for what types of missions the 5th generation aircraft is able to conduct.

Requirements for concurrency and handling of multiple parallel missions for the 5th generation aircraft (Figure 16), with other air, land and maritime entities, will require system

support to safeguard the condition of each mission. Particularly related to several concurrent missions and where 5th generation aircraft collaborates with other units, such handling will be required (French Air Force, 2020).

Delegation and decentralization may lead to each entity setting plans for themselves and thus increases the risk of coordination failures according to Lanaj et al. (2015). Delegation may thus put an extra burden on coordination for these reasons. However, a framework of the type we suggest in Figure 16 extended with the modeling of status, may help such coordination by helping to set clear rules for what type of plans can be made by the individual entity. This could help create common ground among the entities.

Summarized, a formal delegation framework may be well suited as an input to formal coordination mechanisms (tacit coordination) where needed, as well as identifying needs for informal coordination mechanisms (ongoing communication). In order to help coordination modeling of status could be essential.

Directions for future research

A future aspect to consider is how to reduce the costs of coordination (Rico et al., 2018). As an example, we can look at reciprocal interdependence that is a consequence of a decision not to delegate (e.g. in situations the operations are joint and decision rights are not delegated below the joint commander). In this situation, there could be a requirement to simultaneously coordinate among entities tactically but at the same time keep the joint commander informed and possibly change the mission on the fly based on the commander's directions. While this may be desired, it could put a heavy toll on the operators in terms of continuously communicating with other entities horizontally and vertically. In such situations, a further specification of who should coordinate may have to be done to reduce the cost for the operators (Davison, et al., 2012). In order to delegate in ever more contested environments, what would be the impact on future military operations if we expanded the framework presented in the paper (process schema, and design space for future Air C2 concept) and applying the concept of delegation mechanisms on other asset class, say cyber, where cyber operations are in "silent" mode. Would the same logic apply?

One argument is the objective of multi-domain operations as a better unified battlespace for integration of effects from the tactical level in order to optimize joint maneuver and to cope through with engagements in ever more contested environments. Therefore, multi-domain operations must allow taking advantage of tactical time-sensitive opportunities. Special attention should be paid to future digital transformation i.e. connectivity and effects produced by silent missions in other domains supporting future air operations. As net enabled weapons affect air operations, a decomposed task as framework is not enough to solve situations. We suggest that there may be

emerging tasks going on. We will need status and states on new, on-going and emerging tasks. In multi-domain collaborative entities we will be depending upon subordinate tasks also may delegate or need statuses and state information to accomplish their work. David Landén's work on complex task delegation is an example of logic and mechanism of synchronization that may handle the coordination requirements according to the objectives to be reached. Additionally according to French Air Force: *concept of connected collaborative air combat*, the Multi Domain Command and Control must gradually become agnostic of sensors and platforms, beyond environment, and support safe actions. (French Air Force, 2020). The proposed framework may support delegation on other asset class if extended by proper mechanisms and mindset. "As a preparation for a future near-peer fight, it is crucial to have an active mindset on avoiding unnecessary transmissions that could feed adversarial sensors with information that can guide their actions. This might require a paradigm shift, where we are migrating from an abundance of active systems to being minimalists in pursuit of stealth (Jan Kallberg, 2019)." (David Landén, 2011; A. Josefsson et al., 2019; French Air Force, 2020)

So-called small-world networks could be one possible solution to some of the challenges of costs and coordination, by defining parts of a network of entities as having more reciprocal interdependencies than other parts of the network (Stanton, Walker & Sorenson, 2012). As suggested state modelling is another way to support delegation and developing procedures for coordination of manned and autonomous entities in a future 5th generation airforce (Frey, 2019). These considerations could be decided upon using heuristics and further refine the delegation framework and state modeling we suggest.

Future research should examine empirically whether or not the framework actually increase mission effectiveness. This could be done in several ways ranging from live field studies to experimental studies. The timeliness and accuracy of decisions could be measured using already developed techniques for example those used in prior C2 experiments (Alberts, 2007), number of enemy attacked and own objects not attacked are classical measures of effectiveness (Lanaj et al., 2013). Testing the performance difference between experimental groups that use and do not use the delegation framework are one way of testing the principal value of the framework. However much could also be gained from examining live data. We believe that communication and data link analyses are promising alternatives assessing command and control effectiveness (Valaker et al, forthcoming). Successful communication is important for command and control performance, and measuring changes in communication patterns can indicate information overload or time stress. More generally, different types of communication analysis are relevant to measure the impact to prove value of a change case. The strategic implications of delegation actions need to be examined

using for example red-teaming techniques where an expert group judges the potential strategic outcome of a delegating decision rights.

A further complication with respect to new capabilities and its implications for C2 is whether an asset is capable of information sharing, in both normal and silent running. Which leads to some more detailed questions that a 5th generation C2 should be capable of handling:

- When do fighter pilots have superior situational awareness, and how can the different levels of command know this is the case or predict the likelihood of this?
- Is superior situation awareness at a local level an argument in favor of «implicit control / silent running»?
- How can tactical effects best be translate into strategic effects?
- How do we approach the competing aspects of operational effect and control in C2?
- How should the different criteria be weighed when making a decision to delegate or not?

The delegation framework that we have developed is likely not suitable under all circumstances. Modifications may be needed given that more stakeholders than fighter aircraft are involved in missions. In particular how decision-making authority should be granted to other entities than the fighter aircraft pilot need to be considered. It may be that the mission environment shifts abruptly after decision authority is already delegated. This calls for an awareness among all entities of the uncertainties involved in using the process schema. How the framework can be updated and modified as one learns about the changes both in organization and environment, is thus in need of further discussion. Another aspect to consider is military leadership. Wong et al. (2003) described research on military leadership as multifaceted, and more work are needed to develop rigorous and valid measure of leadership. Yukl's tri-dimensional leadership model identifies three major categories, adding change dimension to the classical models (task and relation-oriented leadership) (Martinsen, Fosse, Johannesen & Venemyr, 2020). Future research on mechanisms of delegation supported by Yukls's concepts of leadership and the impact on delegation of authority may be an idea to follow and investigate to mitigate the cost for the operators

Considering some possible consequences for command and control in a broader sense, an important conclusion in terms of leadership is that two aspects occur in today's and perhaps also tomorrow's command and control systems: (1) the hierarchical organization and (2) the design of the future command and control functions and structures must be built so they can rely on feedback. Both of these aspects are related to costs paid in time. The development of command and control can be understood as striving in various ways to reduce these inevitable costs. The most radical gain in time could probably be made if one could deduce alternatives to the hierarchical

organization and the feedback-dependent control function, but many believe that such alternatives are not in sight. (Brehmer, 2013, p.158). However further develop a delegation framework through training, and exercise could reduce the costs of hierarchy: Future-training requirements is needed, and learning the "when, what, and who" of delegating authority.

Conclusion

In this paper, we discussed consequences for command and control of the fifth generation aircraft. We suggested that when delegating decision rights, e.g. target engagement authority, to the pilot, commanders need to weigh the cost and benefits of sharing and not sharing information. When relinquishing the opportunity to share information the potential consequence might be at the cost of less strategic control, although it may be beneficial in terms of solving the mission tactically (and vice versa). We suggest a formal framework, where additional known factors influencing delegation decisions are systematically examined. Further refinements through experimentation are needed to verify whether these C2 tools actually helps accomplishing the missions foreseen.

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