SOCIAL REDUNDANCY IN CROSS-COLLABORATION. AN INSIDE-OUTSIDER'S VIEW ON APACHE OPERATIONS.

Thesis submitted in partial fulfillment of the requirements
for the MSc in Human Factors and System Safety

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Date of submission: 2010-06-25

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Abstract

Today's battle fields are ambiguous and enemy troops may not be recognizable as such. One can only imagine what tragedies might result from this. Apache helicopters however are operated by a crew of two pilots, enabling them to benefit from something that might be called "social redundancy". A case study was therefore conducted with a bounded system as the object of study – a flight of pilots within a European attack unit – in order to find out if and how social redundancy gets exercised in Apache cockpits. From a micro-level task analysis macro-level contextual factors were reflected upon. Research results suggest that social redundancy gets exercised extensively during Apache operations. Research results also suggest that social redundancy is a complex phenomenon, bounded above all by the inherent limitations of complexity in social systems, and that therefore we should not trust on it blindly. Social redundancy was shown to be affected by a broad series and range of contextual factors. Many of these factors – if not all – appeared to be interconnected, making it difficult to trace how factors link together in any fixed – or predictable – manner. Social redundancy, so it seems, is not a fixed attribute that can be switched on and off according to predefined logics. What further seems to have been neglected so far by traditional approaches to social redundancy is that technological innovation has redefined work and job substantially. All this has implications for how to assess crew interaction, even in hindsight as often is done with accident investigations in the aftermath of tragedy.

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Introduction

Ground troops often call in for so-called "air power" to help them out on the battle field. Apache helicopter units often respond to these calls or are specifically requested for to bring "eyes" on target, or to get "steel" delivered. In the first case helicopter crews provide an additional set of eyes on the battle theatre from above, where in the second case they may deliver fire-support as well. Today's battle fields are ambiguous and enemy troops such as Afghan Taliban fighters may not be recognizable as such. In some cases this leads to the locking into a certain course of action of which only hindsight can tell that the outcome was unfortunate:

> Wikileaks today released a video depicting the slaying of more than 12 people – including two Reuters news staff – by two Apache helicopters using 30mm cannon fire. The attack took place on the morning of 12 July 2007 in the Iraqi suburb of New Baghdad. Two children were also wounded. Among the dead were two Reuters news employees, Saeed Chmagh and Namir Noor-Eldeen. Chmagh was a 40-year-old Reuters driver and assistant; Noor-Eldeen was a 22-year-old war photographer. An investigation by the US military concluded that the soldiers acted in accordance with the law of armed conflict and its own rules of engagement. (Thompson, 5-4-2010)

The tendency to continue a certain course of action "in the face of opportunities to revise [this original course]" has in the literature been referred to as "fixation errors" (De Keyser and Woods, 1990) or as "plan continuation" (Orasanu, Martin and Davidson, 2002).

High Reliability Theorists[1] believe that functional duplication or overlap – "*redundancy"* – can contribute greatly to a larger system's reliability as an answer to the inevitable fallibility of individual system components (e.g. Rochlin, La Porte and Roberts, 1987; La Porte and Consolini, 1991, p. 23). In the case of functional duplication "two different units perform the same function" whereas in the case of functional overlap "two units have some functional areas in common" (Rochlin et al., 1987, p. 84). If one system fails the other system will take over, partly or fully, and the more automatically the better. When redundancy is taken to the social realm then *social redundancy* would be – based on the definition for "operational redundancy" as proposed by Rochlin et al. (1987, p. 84) – the presence of people with the ability to take over (cognitive) task execution from others, either partly or fully. The sole ability to step in may however not suffice in socio-technological systems since substituting one actor with another – when facing the situation at stake with similar presumptions and beliefs – might lead to disaster anyhow. *Effective social redundancy* could therefore be defined as to utilize the area of (cognitive) duplication or overlap amongst social actors in such a manner that successful social accomplishment is established. Scholars of Resilience Engineering suggest that "bringing in a fresh perspective" might be an effective – although not ultimate – strategy here (De Keyser and Woods, 1990; Patterson, Cook, Woods and Render, 2004; Patterson, Roth, Woods, Chow and Gomes, 2004). Fresh perspectives after all, so they argue, "generate more hypotheses, cover more contingencies, openly debate rationales for decision making, and reveal hidden assumptions" (Dekker and Lundström, 2007, p. 8).

Social systems might however be regarded as complex systems since they contain any number of "unfamiliar or unintended feedback loops" (Perrow, 1999, p. 82). This complexity sheds another light on the issue at hand here. After all, as Sagan (1993) has argued in his critiquing pamphlet *The Limits of Safety,* the application of redundancy in complex worlds has downsides.

[1] High Reliability Theorists (HRTs) such as Todd La Porte, Gene Rochlin, Karlene Roberts, Karl Weick, and Paula Consolini "have studied a variety of high risk organizations and have reached quite optimistic conclusions about the prospects for safely managing hazardous technologies in modern society" (Sagan, 1993, p. 14)

Sagan for example points out that redundancy in complex systems can "lead to unanticipated common-mode failures"[2] because "redundant systems [in complex systems] often [are] less independent [from one another or from other system components] than their designers believe [they are]" (Sagan, 1993, p. 39). In the case of social systems for instance people "must be able to predict the responses of others to some extent for coordinated action to be possible" (Gersick and Hackman, 1990 p. 68). Another downside of redundancy in complex systems is that "individual component [...] failures will often be less visible, since they have been compensated for by [its] backup devices" (Sagan, 1993, p. 39). In social systems this could be related to a feature that is supposed to attribute to team performance: "supporting other team members" (Flin, O'Conner and Crichton, 2008, pp. 96). A third consequence of redundancy in complex systems that Sagan mentions is that – because redundancy also builds in more capacity – this capacity is sometimes related to the benefit of production goals rather than maintained as a backup for emergency situations (Sagan, 1993, p. 40). It could thus well be that the application of task duplicity or overlap in socio-technological systems – and thus social redundancy –remains ineffective in the sense that fresh perspectives might not emerge or could not be communicated to each other in an effective manner.

Apache attack helicopters are operated by a crew of two pilots, creating thereby opportunities for exercising social redundancy. Crewmembers have been through similar training, are normally members of the same unit, and might even be members of the same flight group within that unit. In the helicopter above all they are held physically tightly together by the shape and size of the helicopter fuselage. On the one hand this enables them to establish a substantial amount of overlap in cognitive functioning – and thus to function as a team. On the other hand however such similarities in backgrounds and working conditions could make it difficult to provide a fresh

[2] Common-mode failures refer to a simultaneous, concurrent or related failure of several critical components due to the "sometimes deliberate, but usually inadvertent condition where critical components share a common feature" (Sagan, 1993, p. 33).

perspective on things. From a systems point of view therefore – in which it is believed that an important piece of people's performance gets shaped by its contextual surroundings (Dekker, 2006, p. 91) – one could ask how these pilots could at all be able to create something that is analogue to a "stereo binocular vision" on things?

On how data became to be data

Research for the purpose of this study has been conducted with a European Air Force Apache unit. Ethnographically inspired qualitative empirical research was used with multiple sources of information in order to triangulate data. The study was divided into six phases; a preliminary research phase, two data gathering phases separated from each other by an intermediate analysis phase, a final analysis, and the writing of the report. Research was conducted from the inside outwards. Micro-level task analysis formed the basis of the study, from which macro-level contextual factors were reflected upon. This research could also be regarded as a case study with a bounded system as the object of study – in this case a flight of pilots within an Apache unit.

To keep the research manageable, task analysis was confined to the navigation task of Apache crews; to how it is that Apache crews bring their helicopters from A to B. Travel over longer distances was considered, as well as repositioning the aircraft within the tactical areas of interest.[3] To focus on navigation was a strategic choice in research design since from this specific task other tasks could be reflected upon as well. Weapons for instance cannot be delivered on time on target without navigating the helicopter to the area of interest in a timely and accurate manner. Also an effective use of sighting equipment for observation or surveillance purposes cannot be performed effectively without continuously maintaining knowledge about the geographical position of the helicopter. As a result data covered many – if not all – aspects of Apache

[3] Since the unit of study is equipped with very sophisticated navigating systems on board, the term navigation refers here not so much to classic air navigation principles, but merely to a more general awareness with the help of any possible means of the current position – geographically or in relation to other elements such as terrain features or enemy or friendly forces – and how to proceed from here to there.

operations. Research results – although limited by sample size – might therefore be regarded to have something to say about cross-collaboration of Apache crews in general.

Preliminary research included data gathering about squadron organization, types of missions and mission execution. Technological aspects were reviewed as well, such as helicopter layout and in-flight data representation in the cockpit. Also individual and crew tasking were studied, general and navigation procedures, and aspects of crew coordination. Relevant documents were looked at, tailored simulator instruction was participated in, a simulator flight in the Longbow Crew Trainer (LCT) was conducted, and start up and shutdown procedures were witnessed from within the helicopter. Several mission (video)tapes have been analyzed during the research which included regular training sorties, weapon deliveries, and one complete in-theatre combat mission. Also a simulator gunnery session in the LCT was witnessed, as well as an actual order assignment, mission preparation, and mission debrief of a full two-ship low level reconnaissance training mission[4] of which the respective tapes were reviewed as well. Task accomplishment as witnessed through observation served to triangulate the data gleaned from participants during interviews.

Two sets of interviews were conducted. The first set covered six out of nine members of the flight of pilots that participated in the research.[5] These interviews mainly were used to gain some understanding about how Apache crews normally conduct their navigation task in cross-collaboration with each other during mission execution. Specific focus was set here upon where and how cognitive overlap – or social redundancy – may be exercised during inter-crew cross-collaborative task accomplishment. Also the ability to bring fresh perspectives to each other

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[4] The respective mission served as a double qualification training mission. In one helicopter the trainee was a FS training to become a section leader (leader of 2 or 3 helicopters). In the other helicopter the trainee was a BS training to become FS. During mission preparation instructors acted as commanding officers. Other instructors acted as in-flight BS co-pilots. When deemed necessary, the instructors changed roles to give feedback as an instructor. The training mission was said to give a reasonable picture of real-time mission execution. The whole process from order assignment till debriefing took about 9 hours, of which 2 hours were actual flight time.

[5] Apache units normally are organized in subunits called flights of pilots. For the research a flight of 9 pilots was invited through their flight commander to participate in the program. Participants included one BS and one BS who became FS during the reserach. Participants further included four FSs of which one was qualified as a maintenance test pilot (MTP), one as a section leader (SL) and flight instructor (FI), and one as a flight leader (FL) and weapon instructor (WI).

during this process was reflected upon. Participants were therefore asked to recall situations in which task intervention or verbal corrections on task accomplishment occurred, as well as situations in which proactive cross-collaborative handling was successfully performed. Cross-collaborative proactive handling refers to actions – as performed by the other crewmember – that are desirable however not yet explicitly asked for. The specific situations as mentioned here were chosen because these represent situations where cognitive overlap – necessary for the application of social redundancy – occurs. After all, as has been noted earlier here, neither intervention, nor corrections, or proactive cross-collaborative handling can occur without the presence of (cognitive) task overlap (Gersick and Hackman, 1990). A preliminary search for macro-level contextual factors that affect the cross-collaboration of crewmembers – and thus the ability for providing social redundancy to each other – was conducted during these first interviews as well.

A second set of interviews was conducted with five Apache key staff members for a more in-depth investigation of these macro-level contextual factors.[6] Focus during these interviews was set on *how* these contextual factors affect social redundancy among Apache crewmembers. Participants were asked to elaborate upon how they considered contextual factors to promote on the one hand a unity of acting and thinking within their unit (in order to be able to establish task duplicity and overlap) while on the other hand diversity in acting and thinking as well (in order to enable the emergence of fresh perspectives). Participants were requested first to bring up contextual factors themselves to reflect upon. Only then a list was given to them to comment on containing contextual factors as they had been derived from the first data set. In this manner analysis of the first data set could be validated. All the interviews took about one hour each, were semi-structured, and were conducted and transcribed in the native language of the Air Force members of study. Relevant passages were translated into English. During both sets of interviews data saturation was regarded to occur after four to five interview sessions.

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[6] 2 flight commanders of other flights of pilots than the one under study, the squadron's Chief of Operations, the squadron's Current Operations Officer, and the Airbase Chief of Operations.

Much of the research was conducted as an honorable guest of the flight of pilots under study. Teaming up with this specific flight potentially narrowed down opportunities for generalizing results. However it also maximized access to research data. It enabled the use of their facilities, the ability to witness their daily activities on a regular basis, and thus to conduct the research "from the inside". The generalizability issue was compensated for by the participation of key staff members in the second data gathering phase, the in-depth investigation of contextual factors. One former Apache flight commander – still currently flying the Apache helicopter – and one current simulator instructor served as expert informants. These subject matter experts have been utilized throughout the process to obtain more detailed information about the roles of the respective Apache pilots – the frontseater (FS) and the backseater (BS) [7], to refine the semi-structured interview setups, to cross-check interview contents, and to validate results and interpretations.

Some of the data sources reviewed – such as the Tactical Standard Operating Procedures document and some of the mission (video)tapes – were classified. Data from these sources served as background information only but has also been used to assess if findings from non-classified data sources should be altered in the light of the information contained in classified material. Intermediate drafts and the final report have been sent to the J2 intelligence section for security reviews with regular intervals.

Data analysis was accomplished in several stages. First, at the end of the initial data gathering phase, the data was edited using global analysis techniques (Flick, 2009) and reviewed thereafter with the aim of gaining knowledge about if and how social redundancy was exercised among Apache pilots during task accomplishment. Then the same set of data was coded and recoded

[7] In the remainder of this document the acronyms FS (front seat) and BS (back seat) are used. No dinstinctions are made between the seat itself and the one that is operating from that particular seat. Dependent on the context FS for instance can refer to the actual front seat but could also refer to the front seat operator. Normally this unit operates with their FSs acting as aircraft commanders. FSs manage the aircraft's sensor and weapon systems that are installed in the front seat. Co-pilot BSs in the meanwhile fly the aircraft from the therefore optimized rear seat.

using open coding (Flick, 2009) with the purpose of identifying common themes – or contextual factors – that affect the occurrence and the character of social redundancy during mission accomplishment. After the second data gathering phase a final – interpretative – analysis was performed on the total data set. The aim here was to gain knowledge on how macro-level contextual factors would balance unity and diversity in acting and thinking of Apache pilots – and thereby on how these factors affect the pilots' micro-level cross-collaborative task execution.

Results included in this paper appeared at least twice in the data set in different data sources (e.g. were brought up by different respondents). Exceptions have been made only when single events were thought to be illustrative for certain important points. In these cases this has been pointed out clearly. In the following section a reflection is given on how social redundancy seems to be exercised by the participants when operating an Apache helicopter. After that an attempt has been made to describe the macro-level contextual factors as derived from the research conducted here, in how these are regarded to affect the application of social redundancy during micro-level task accomplishment. Quotes from participants are printed in italics.

Exercising social redundancy during micro-level task accomplishment

Participants thought social redundancy – applied effectively – a welcome phenomenon: *"It is very difficult to recognize making a mistake when you think you are doing things correct. [ ] One certainly needs help from others to recognize this."* Gaps however did occur. One of the participants for instance recalled an exercise in which a formation of multiple helicopters inadvertently busted a no-fly zone: *"[Rationally] everybody in the planning process could have intervened. Somebody had drawn a line on the map for rough time calculations. However, this line was never intended to be the actual route to be flown."*

On mission (video)tapes and in the LCT it was witnessed – especially when communication and coordination demands raised – that inter-crew communication shifted more than otherwise towards a telegram style staccato communication. Crewmembers remained silent when the other crewmember clearly was occupied, waiting for windows of opportunity to exchange information shortly. Even with communication temporarily blocked tasks often seemed to be executed more or less conform the expectations of the other crewmember, indicating thereby an overlap in cognitive functioning. BSs for example brought the Apache helicopter into a position and on altitudes the FSs wished for in order to spot the enemy. Instead of waiting for directions BSs acted autonomously in these cases and told their FSs what they did, enabling thereby their FSs still to intervene if necessary: *"BS: 200 feet [altitude], FS: Yep, maintain."* Cognitive overlap seemed to be established on a continuous basis, if only it was in a kind of background mode. It seemed as if during flight crewmembers monitored each other's current condition and task load continuously. At the least they seemed to be sensitive for signals that could indicate a decline in cognitive or physical functioning of the other crewmember. Illustrative here was an instance in which a BS challenged his FS about his orientation in an actual hostile area. Just a few minutes before that they had had a short conversation about cumulative fatigue due to the tempo of operations in the days before:

> *FS: "Huh" [combined with some vague sensor movements]*
>
> *BS [instantly]: "You are looking at the south side?" [indicating that he is looking at some information source that tells him exactly that[8]]*
>
> *FS: "Yeah, I just dropped out for a moment. Uhh, yeah, south indeed."*
>
> *BS [after a few seconds]: "What's up?"*
>
> *FS: "Oh, I just had to re-orientate myself"*
>
> *BS: "Ah, ok, roger."*
>
> *FS [ironic]: "Djee, I start orientating myself pretty well at night now."*

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[8] A BS has several ways to determine this. During daylight he might see the helmet of the FS turned in a certain direction. More likely however aircraft systems will be used such as selecting sensor video underlay on one of his cockpit screens in the backseat or by looking at the symbology presented on his Helmet Display Unit (HDU) indicating direction and azimuth of where and what the other crewmember and/or the sensor are looking at.

In another instance a FS called out that *"he missed the bigger picture"* after having been scanning for a longer period through his sensor.[9] The BS immediately pointed out then several visual cues so that the FS could regain his overall orientation and could thus perform his sensor work in a more effective manner again.

Besides these verbal transactions an important amount of communication among crewmembers seems to go "through the aircraft"[10]. One crew for instance was witnessed to reposition their aircraft successfully after receiving a re-task, without the exchange of any verbal information. The FS, responsible for taking the re-task, processed the information silently into the aircraft navigation equipment, directly visible to the BS on his Tactical Situation Display (TSD)[11] to act upon. Apparently the BS had listened in on the FS's tactical radio communication since he never asked for additional guidance but waited instead for the necessary information to appear on his cockpit displays.

Also corrections often seemed to be communicated "through the aircraft". *"The use of symbols on our TSDs makes it very easy for us to communicate corrections"* a participant stated. Interventions in and corrections on the other one's task accomplishment frequently even resulted from monitoring the opposite crewmember's actions via the aircraft's systems. FSs for instance cross-check their TSD regularly in order to see if the helicopter is still heading where it should be and even use the same TSD to pass on corrections to their BSs. Also BSs sometimes glance at what the FS's sensor is looking at, although not primarily for monitoring purposes. There were however other reasons to intervene. Situations were recalled and also witnessed in which FSs directed their BSs

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[9] Apache sensors are capable of scanning the terrain at longer distances. The field of view is however rather restricted so that geographical orientation, or "the bigger picture" can be lost quite easily, especially when the aircraft is maneuvering.

[10] Cross-cockpit communication "through the aircraft" may be conducted via the graphical display of symbols, for instance via cockpit screens, but also through other means such as the Helmet Display Unit (HDU).

[11] A Tactical Situation Display or TSD is available in both cockpits. The TSD presents a bird's eye view of the current geographical location of the helicopter relative to relevant mission essential features, along with information put into the aircraft's navigating equipment.

to bring the helicopter a towards a certain position, only to be notified shortly thereafter that he or she could not comply with the request. FSs often base their directions on what they are looking at with their sensors at a distance while BSs focus more on visual cues in the surrounding environment such as terrain features or enemy presence.

Indications for proactive cross-collaborative handling were derived from cases that were recalled and observed in which BSs set up tactical flight profiles in accordance with the tactical information that was currently available to them. Through listening in on the tactical radios BSs sometimes act on the basis of the information contained in these messages so that FSs do not have to spend time and attention on this. Other indications for proactive cross-collaborative handling could be derived from BSs helping their FSs out in scanning for targets outside. They even identify them first sometimes, to hand them over to their FS in turn. In some cases radio calls directed to FSs are taken by more experienced BSs when FSs temporarily are not able to do so, relaying relevant information to the FS later on. Proactive cross-collaborative handling, so it seems, often serves to reduce a FS's work load, increasing thereby the total crew's operational output.

Micro-level task accomplishment in a macro-level context

How social redundancy gets exercised in an Apache cockpit appears to be highly context dependent. Many contextual factors seem to affect cross-collaborative task accomplishment in Apache helicopters, either directly or in a more indirect manner. Importantly, as one of the participants put it: *"All these items affect one another"*, mirroring thereby the sheer complexity of the socio-technical system of which Apache crewmembers are part of. Not suggesting that strict categorical boundaries can or should be drawn, research results on contextual factors have been organized and described here in eight different categories.

Aircraft system

The most obvious contextual factor that affects crew interactional performance is the aircraft itself. Functions are duplicated in the front and the rear cockpit as much as possible. It is possible for instance to fly the aircraft from both crew stations. It is also possible to listen in and to operate all radios from both stations, as it is possible for both crewmembers to display tactical information on their respective screens. Features and functions however also differ between the two stations. The front cockpit has the sighting equipment for distant observation and carries equipment for managing the weapon systems. The rear cockpit on the other hand is equipped primarily for flying the aircraft.

Apache helicopters have a tandem seat configuration. Although a rearview mirror is installed, opportunities for observing and responding to body language and other physical actions of the opposite crewmember are minimized, especially during night operations. The aircraft is however equipped with high fidelity equipment which makes crew interaction different from how it was done "in the old days". Navigation in these days demanded intense verbal communication and coordination between FS and BS. Today, monitoring each other's task accomplishment as well as inter-crew communication more and more seems to be performed "through the aircraft": *"We just have a lot of digital tools at our disposal [through which] we are able to provide [mission] changes pretty easy using symbols."*[12] Another respondent put it this way: *"Within a nanosecond you know [with a glance on your display during your cross-check] how the navigation is being performed."* A third one: *"Suppose we would have to do this with only our maps available; that would really be a challenge."* The necessity for verbal transactions of information apparently vanished substantially with the introduction of sophisticated navigation and other equipment.

[12] Normally in flight it is only FSs that enter information into the aircraft systems since the BSs are supposed primarily to fly the aicraft.

Task distribution

Task distribution is heavily influenced by the aircraft's configuration. However, other elements must enter here as well since differences can be found among Apache units all over the world. US Forces originally operated – and still mainly operate – the Apache with the BS acting as the aircraft commander (email conversation with an Apache Program Manager from Boeing Global Services and Support). Other Apache units however – such as the one studied here – operate with FSs as aircraft commanders. According to the participants and the email conversation mentioned above here this is because the Apache has evolved over the years from a low level deep attack platform to a highly sophisticated multi-role weapon platform. Such multi-role platforms do not so much gain their successes from maneuvering the helicopter skillfully through difficult terrain – requiring the most experienced pilot to fly the machine from the BS. Rather such platforms demand for the most experienced crewmembers to sit in the FS so as to enable them to combine their broad tactical experience and skills with managing the aircraft's sensors and weaponry installed up front.

According to the participants a strong task separation is experienced when operating the Apache. BSs are supposed to fly the helicopter as autonomously as possible so that FSs can concentrate on delivering desired system output: *"As a BS your primary task is to fly the aircraft [and to] take care of the administrative part of flying the aircraft.[13]"* As one of the FSs put it: *"If I have to concentrate on my BS all the time I will never be able to deliver quick reaction support to troops in contact [with the enemy]."* Another one said:

> *"I would have to sacrifice a cockpit display for checking [my BS] to fly at the correct altitudes while I rather want to have video on that display, or weapon information, or anything, except altitude information. When fighting at night at 3000 feet, I expect this guy to fly at 3000 feet…and to get a heads up [from him or her] whenever we do not."*

[13] Such as coordinating with air traffic control

Task separation was mentioned – although frequently indirectly – as one of the main sources that provided a fresh perspective. FSs for instance primarily focus on what they see through their sensors at a distance in the terrain, while BSs have their eyes mainly outside in order to fly the aircraft and to scan the area closer by. Because of the separation in tasks however, crewmembers may also focus on different aspects of the mission itself. FSs for instance normally have a responsibility as aircraft commanders or mission commanders. Therefore they may be focused on higher level or political orders and restraints – on *"the bigger picture"* and the *"desired mission goals"*. BSs on the other hand have to keep the aircraft flying and then to act more on details in the *"here and now"*:

> *"Sometimes you need to cross the forward line of own troops at a certain time. However, when flying the aircraft [as a BS] you have to watch out for other aircraft in the formation [as well] so that you may lack time [and attention] to carefully monitor timings. The FS is much more focused on mission goals and thus with keeping close track on timings [and such]."*

Task separation however has a downside:

> *"Where task separation [ ] gives a solid basis for collaboration in an effective manner, it also puts the door wide open for not acknowledging errors because both crewmembers might just assume that the other one is doing his or her job in a correct manner."*

Counterbalancing strict task separation in Apache operations is inherent task dependency. FSs after all need their BSs to bring them into positions from where they are able to deliver desired system output for successful mission accomplishment. As well they need their BSs to fight gravity all the time – to keep the Apache in the air – since if gravity wins when you are in a helicopter, the whole game is over anyways. The aircraft is designed for BSs to perform these tasks autonomously. However, FSs' and BSs' actions have to be synchronized continuously: *"I will always continue to cross-check my BS['s activities], [if only it was for] maintaining my own situational awareness. [ ] I mean, if I lose my situational awareness during battle, [we] could as well go home."* FSs – as aircraft commanders – are responsible not only for their own actions, but also for their BSs' performance, which makes it logical for FSs to monitor their BSs – more than the other way around. This is even more the case when FSs are scheduled for instance as flight or weapon instructors. Thus, although task separation is heavily experienced, a certain amount of task overlap or duplicity inherently resides at all times in Apache operations.

Mission type

Almost without exception participants, when asked to describe how they performed their navigation task, started to discuss how much cross-collaborative task accomplishment was affected by mission type.[14] Not only differences in planning opportunities were mentioned – nil for instance in the case of a quick reaction combat mission. Also in-flight task accomplishment and crew interaction appeared to depend on many related factors. The *"time of day"* and *"altitudes"* on which the mission were supposed to be performed were mentioned, as well as *"the total number"* and *"the number of different types"* of aircraft involved in the mission[15], the availability and ambiguity of mission essential information provided, and *"the dynamics"* of the mission itself. More regarding this will be taken up in the paragraph on task load below. Mentioned here also was that *"sharpness"* (or vigilance) – and thus the ability to provide fresh perspectives – was perceived to differ with mission type sometimes. One respondent said:

> *"Here we do not perform with the same intensity as we do over there [on a wartime mission]. At least I will not be able to establish that. [ ] Things are so artificial and constrained here. [On the other hand,] I think that if we would perform with that intensity all the time people would eventually drop."*

To determine how exactly all mission type related aspects affect crew interaction would take us however beyond the scope of this research.

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[14] There are many mission types that can be conducted with Apache helicopters. These range from "old school" deep attack missions far behind conventional enemy lines, through convoy security and surveillance or air policing missions, as well as, the deliverance of immediate air support to ground troops from a quick alert status.

[15] Apache operations are normally conducted in formations of two or more (Apache) helicopters, or may be a part of larger campaigns with multiple types of aircraft.

Experience /proficiency of crewmembers

When asked why people might see things that others do not the majority of the respondents instantly referred to the dimension of experience: *"When flying with a young BS, I see things on a map quicker than he does. I will detect things earlier than he does. I know that for sure. That is how it always goes."* Features such as experience, proficiency, and (geographical or task) familiarity, were regarded to mediate in how social redundancy gets exercised and thus in determining the direction of the social redundancy vector – from FS to BS, from BS to FS, or alternating between both these directions. In the majority of the cases experience was believed to direct the vector to point from FS to BS. One of the participants for instance brought up: *"When flying with another FS as his BS, the trick of flying is too easy for me. [I] will have [cognitive] bites remaining then to bring to the FS."* Another participant gave another example: *"If it is a section leader that is sitting in your BS [an intervention or suggestion] will have more traction [than when the intervention or suggestion is coming from a young BS co-pilot.]"* Sometimes however the vector swaps direction and BSs with less experience are able to help out more experienced FSs:

> *"[This FS had been working as a staff officer for years.] One cannot expect him to operate sensors and controls as smoothly [anymore] as for instance somebody who just became section leader or flight leader. [ ] In these cases you are able to help out much more than when flying with a proficient FS."*

Although aviation units normally employ functional leadership, enabling thereby junior ranked people to act as senior crewmembers, in military organizations rank can be confused with experience. When asked directly most participants said that such (perceived) authority issues were absent in this particular unit. Interestingly however, this aspect was referred to indirectly for four times by participants without being asked for, which indicates that authority issues do play a role but that individuals are reluctant to admit it. This on its turn could result from the emphasis and thus the implicit reward normally put on pilots to show assertiveness when experiencing steep authority gradients: *"What we do not want is that pilots do not dare to speak up anymore."* After all, would one admit to be affected by authority issues while assertive behavior is desired instead? One participant showed how this issue came up when he was younger – and less experienced:

> *"When I was [scheduled to fly] with a highly experienced guy I was thinking: "Man, [ ] I really have to show off, because if that guy is blabbing [that] you are a bungler, you will be stigmatized forever." [ ] People will try to make sure they perform well, which will certainly bring stress."*

Respondents put high value on creating a social climate where equity is valued in the social interaction with others, while seniority is also respected. On the one hand *"we encourage very much an open culture. Few people are expelled for speaking outside their authorities."* On the other hand *"these youngsters have to learn what their moments are. [ ] In a planning process there are many opportunities for interaction, but also many moments that work just has to be done."* One of the younger BSs stated about this social process: *"Well, it is a bit annoying of course. However, I can well imagine myself not adopting everything from anybody once I have gained that amount of experience."* It is a delicate balance: *"There is a place and a time for everything. [ ] And one will act more clever here than another."* How exactly this balance can be achieved and maintained is however not yet clear.

Tactical / strategic mindset

Apache pilots are birds of prey. They seem to have acquired a tactical mindset enabling them to calculate with uncertainties, to work through alternatives, and to handle contingencies almost as a second nature. A FS for instance told: *"The egress will be very dependent on mission developments and the tactical information that we receive [during the mission.] So, we just want to have multiple options available."* Although participants – when asked directly – did not see a link between their tactical mindset and their ability to provide social redundancy in a more effective manner, some observations suggest otherwise. In their tactical guidance for instance emphasis is placed on scanning an object from different angles in order to maximize information gathering. A related feature one emphasized within the unit was the ability to engage in *"enemy hat thinking"* so as to better position oneself in order to beat the enemy: *"We very much try to put on the enemy's hat [to try and step in their* *shoes], to try and think what their next step will be, in order to stay ahead."* Obviously, these pilots are trained to search actively for alternative visions up to a level that it might become second nature. Is it not possible then that they would extrapolate those skills to other parts of one's job as well? After all, as was recalled in a scientific analysis of a friendly shootdown over the Iraqi theatre as well, "extended practice produces automatic rather than consciously controlled processes" (Weick, 1985, p. 40 as cited in Snook, 2000).

Personal aspects

Despite the homogeneous background of the community, personal characteristics were believed to differ substantially between individuals: *"Even within this group one notices differences between individuals. [ ] Does this mean that there is room for diversity in the cockpit? …well yes, as long as it fits the mission, however these nuances are hard to grab."* Individual differences above all were believed to add to diversity in thinking within the community: *"Although coming from similar backgrounds [ ] everybody takes things up differently, if only in importance."*

The *"golden rule"* is not to allow any discussion to take place in the aircraft – discussions are supposed to be postponed until mission debriefing when on the ground again. Having said this, personality issues and other personal aspects were said to play a role in how alternative visions got communicated during crew interaction: *"Some people [ ] do not talk very easily, or do not say such things such as "well, that is a good idea", definitely not when you are a newcomer."* FSs' characters were emphasized here: *"Some FSs want to keep things under close control and will therefore continuously give directives, even on simple things. When having too many of such people in your flight of pilots, [your] BSs inherently start lacking initiative."* Or, as one of the BSs put it: *"If somebody continuously tells you to do things that you are already doing in one way or another* ["micro-management" as opposed to "end-state management"]*, sub-consciously one starts filtering these comments which could unintentionally result in ignoring very legitimate future remarks."*

BSs' personalities were also noted by respondents. However, one could question if aspects such as *"shyness"*, *"nonchalance"*, and *"tactical mindset"* are simply personality traits. Perhaps these attributes should rather be regarded as personality traits combined with natural ability, experience level, or other factors. To illustrate the complexity at hand here, a BS's performance might even reflect how his FS was trained: *"Flight instructors all have slightly different visions on things. [] Some FSs get trained to put great emphasis on controlling their BS's actions. [] Well, you know how quickly characters can be established on some respects."*

Task load

Task load to affect crew interaction was not only observed on mission tapes, but was also mentioned by the majority of the respondents, either directly or indirectly. Statements were made such as: *"Inexperienced [BSs] will not notice [a FS's mistake] since they are so busy doing their things that no [cognitive] bites are remaining to bring to the FS"* and *"When a FS's task load is increased, he or she loses contact with the aircraft more and more. That space is filled by the other crewmember. [] That area of overlap, it moves around, goes back and forth."* When task load increases, social redundancy obviously gets challenged: *"When a FS gets very busy – for instance because he has not been acting much as a section leader or flight leader lately – [] he gets stressed and starts giving twitchy directions, opening doors thereby for miscommunication."*

Task load was regarded to be affected by many other factors such as *"restrictions in time"*, *"the tactical situation"*, *"enemy presence"* or *"hostilities"*, *"the amount of data and/or radio communication that gets transmitted"*, *"in-flight planning demands"*, and *"demands for coordination"*. Flight related issues such as *"time of day"*, *"terrain"*, *"weather"*, *"altitude"*, and *"formation size"* were considered mainly to influence the BSs' task load. Indirectly however task load could be affected by numerous factors. Coordination demands for instance rise substantially when there is a need to coordinate with multiple forward air controllers on the ground.[16] FSs in different aircraft in the formation are then required to coordinate with their respective controllers on separate frequencies and to relay relevant information to each other. Also the pick order – or *"the position within the formation"* – ultimately effects task load:

> *"When [the FS's role] is to be the Air Mission Commander one can imagine – since he or she has to coordinate that whole package [of aircraft] then – that task load [in this particular aircraft] will be much higher than when [the role of this FS] was just to act as a wingman."*

The higher up the hierarchy of the mission, the more coordination demands are put on this particular FS, and thus on its crew as a whole.

Factors that were considered to lower the task load were higher experience levels of individual crewmembers, and a prolonged familiarization with each other: *"Knowing each other reduces work load"* since *"working together [for longer periods] reduces the amount of words needed for communication [purposes]."* As another respondent put it: *"You know what to expect from the other [crewmember] so to say, or what not to expect..."* Literature however emphasizes that establishing familiarity and trust also have a downside: "the very concrete social relations and structures (or networks) [ ] that play a role in generating trust [ ] also increase opportunities for deceit" (Granovetter as cited in Vaughan, 1999, p. 276). This was recognized by respondents as well: *"In the majority of the cases you are dead on because you know what is expected from you. It is a matter of experience but even then, sometimes you just miss the mark."*

Structure and organization

More indirect effects on social redundancy emerge from the unit's structure and from how the unit is organized. The community studied here seems to be a homogeneous group of people.

[16] Forward air controllers (FAC) are specialists, often embedded within the ground forces, who are qualified to coordinate with air assets and thus to "talk" these on the targets they requested them for.

The group of pilots consists mainly of West-European males from one country[17] with ages mainly between 21 and 40. By selection they have gone through similar levels of education before joining the Air Force. Once in the Air Force they all received the same training program, although staggered over time. These similarities in background, experience, and training help to create cognitive overlap among group members – and the ability to predict another one's responses (Gersick and Hackman, 1990): *"We all have had the same training which makes it easy for us to be teamed up with one another."* Fixed crew pairing was not standard practice within this unit which helps reduce variability between individuals to a certain extent as well: *"Since we do not fly with a fixed crew pairing community members meet one another quite often, creating thereby a kind of common awareness or a common interpretation [of how work is done]."* At the same time however this reduction in variability might open doors for unanticipated "common-mode failures" (Sagan, 1993, p. 39) – or "groupthink" (Janis, 1982) – to enter.

Other structural arrangements – and circumstances – seemed to counter this. Although pilots in this Air Force are hired normally on the basis of a ten-year contract the unit has high turnover rates due to the many missions abroad. Talented pilots are therefore actively coached to take key-functions in the unit so as to enable them to pass on their experience to younger pilots within their contract time: *"We try to get them on track and to stimulate them in a timely fashion."* This strategy provides an opportunity to single out and reward individual and group efforts. People within the unit indeed seem to think that individuals can make a difference:

> *"A flight of pilots with a very assertive flight commander – a pit-bull – who manages to achieve a lot, but who [on the other hand] demands a lot from his personnel as well, differs substantially from flights with people managers as flight commander."*

[17] With the exception of one exchange pilot.

Independent sub-units

The unit studied here appears to be organized in fairly independent operating sub-units or flights of pilots. So, although the unit is under central unit command, individual group members operate relatively autonomously on a daily basis.[18] Interestingly, and agreed upon by participants without exception, each of these flights has a particular character and thus a way of doing things: *"Also an outsider immediately will notice [the differences between flights.] We have very colorful flights, boisterous flights, more serious flight, all kinds of flights actually."* Simulator instructors from outside the unit confirmed this. As has been argued earlier such structural arrangements enable members to predict each other's actions, decisions, and expectations with some degree of confidence: *"[Having operated as a flight] for quite a while now [ ] we know each other very well and know exactly what to expect from one another. Few words suffice."* The division in flights also seemed to improve the unit's quality:

> *"One always tries to do best [by] looking at others how they do things and then [asking themselves:] "How can we do this better?" [ ] I think that if we would have been one group, we would have had much less quality at our disposal."*

Another participant put it this way: *"If we would be doing the same things in the same way [all the time], we would never generate new ideas."*

Operating in a decentralized structure however has downsides as well: *"[With recent prolonged commitments] it has not been possible to switch personnel between flights of pilots too much. Career paths have run inter-flight rather than intra-flight for a while now which raised risks for "group think" severely."* Efforts of the unit's command therefore were sometimes directed to dampen variations between flights through the assignment of new personnel. Where one might think that this could increase the homogeneity of the community as a whole even more – increasing thereby the unit's risk for

[18] A flight of pilots normally consists of ten pilots, including a flight commander and a deputy flight commander. In each flight of pilots at least six pilots are qualified as FSs, one as flight leader, four as section leader, one as flight instructor, and one as weapon instructor. Double qualifications are allowed.

social "common-mode failures" (Sagan, 1993, p. 39) – at least one participant said it had the opposite effect: *"We make sure that bawlers are not put together."*

Planning structure

Chances for social redundancy to be applied effectively in-flight can be increased during the planning phase of missions already. After all, repeating an old maxim in aviation here, "Proper Planning Prevents Poor Performance". For multi-ship missions[19] the unit studied here normally carried out a standardized mission planning process. After receiving mission assignment, mission leaders repeat their interpretation of it back to their unit commander so as to assure that they are *"on the same sheet of music"*. Further mission planning is then conducted in mission planning cells (e.g. intelligence, fire support and navigation) with each cell planning a set part of the mission. In the case of quick reaction (combat) missions most of the items mentioned here may in fact be covered before engaging the standby status.

All members are supposed to participate in the planning process. Crewmembers scheduled to fly together normally get allocated to different planning cells: *"In particular with more complex missions crewmembers of one crew are allocated to different planning cells so as to assure an overlap of knowledge between crews."* Inter-crew this adds to the ability to provide social redundancy since the allocation to different planning cells enables crewmembers to bridge each other's knowledge gaps during mission accomplishment later on. Normally BSs are assigned to the planning cell in which mission products such as route charts, tactical maps, and communication cards are created. In this way they become familiar with many of the technicalities of the respective mission so that during mission accomplishment less guidance might be needed from their respective FS: *"BSs are supposed to review [specifically the tactical part of] the route; to look for and memorize features so that they can keep track there autonomously if needed for whatever reason [such as with enemy engagements]."*

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[19] Missions conducted with more than one helicopter.

Indicative for functional overlap during planning are the several coordination and briefing events that are incorporated in the mission planning process. Either few key players are allowed to participate in these, or the group as a whole: *"With smaller groups one might enable everybody to participate. [However] with larger formations you really don't want them all to join sometimes."* Mission products get checked on these instances by multiple people but may be altered later in the process due to for instance updates on enemy positions. If time is available (sub-)commanders are supposed to backbench with their assigned crew and to utilize them for option generation regarding the mission. From the observations conducted planning however normally tends to be too time-constrained to permit much of this. In such a time-constrained arena choices have to be made in order to create opportunities for reflection at crucial moments in the planning process: *"The scheme of maneuver planning (SOMP) and the mission briefing are the items [in the planning process] saved the least upon."*

Eventually all pieces produced in the different planning cells are put together in a mission briefing. A selection of staff is supposed to present here their respective parts of the mission. Junior crewmembers are to brief here as well and are thus encouraged early in their careers to show assertiveness – a necessary trait for communicating fresh perspectives: *"New BSs immediately get responsibilities assigned for certain parts of the mission planning process, but also for parts of the briefing. We take these people along as full-fledged crewmembers instantly."*

Exchange of information and experience

One aspect of work in (military) aviation that differs substantially from many other industries – although tides slowly seem to be changing in for instance the medical world (WHO, 2009, p. 4) – is the relatively structured manner in which work starts and ends. Before every mission at the least a briefing gets conducted in which crew attempt to reach a shared understanding – or cognitive overlap – of mission intent and of how this is planned to be accomplished. These briefings might even end with check-questions so as to find out if the information received equals the information sent. Check-questioning is however not applied after each briefing: *"Usually one notices really fast [from subtleties] if [the other crewmember] gets it or not."* Conducting check-questions every briefing might even turn it into a meaningless exercise, jeopardizing thereby its function:

> *"You have to perform this properly. How to assess how and when it is proper to do this? I don't know. From whom I learned when to do it and when not? I also don't know. But I have had very ineffective check-questions fired at me[, that I know]."*

At the end of each mission a mandatory debriefing is conducted. Here the mission is walked through once more mentally so as to find out whether things in hindsight could or should have been done differently and whether things had been unclear for one another or maybe even for both crewmembers. Several participants thought debriefing more important than conducting the pre-mission briefing: *"In general we think debriefing is more important than briefing. [ ] We brief each other thoroughly, we fly what we have briefed, but then we mainly [spend time to] debrief each other. It just makes you stronger."* Through debriefings not only cognitive overlap is established for future flights, but also individuals' toolboxes get enriched through the exchange of knowledge and experience as catalyzed by the discussion of mission events. Tools such as mission tapes seemed to make debriefings even more valuable creating educational opportunities: *"Tapes [eliminate] rubbish. One is able to see what has happened, one can hear the audio. Tapes just make debriefings more engaged and also less susceptible for personal interferences."*

Also at higher unit levels debriefings are conducted. After missions abroad flight commanders brief the unit's key staff members on how they accomplished these missions. They also debrief the unit as a whole on lessons learned such as new combat tactics. On a more daily basis flight commanders are expected to bring relevant items from their (informal) flight meetings to regularly scheduled staff meetings. Based on all this information, standards for instance can be evaluated and renewed. Also new training scenarios can be built and rebuilt again to enable crews to learn how to identify potential trouble indicators.

The value of learning seems self-evident. However, social climates can change over time as a flight member stated: *"In the old days criticism was avoided. Today we criticize each other on aspects ready for improvement, but also on what went well."* Perceptions of how the social climate historically had functioned appeared however to differ as another member of the community stated: "*Since I was allowed to speak up as a youngster [ ] I think it normal for my youngest pilot to speak up [to me] as well.*" These differences might be relative since members of the flight studied here in general deemed critical thinking to be more evident within their sub-unit:

> *"Contrary to the other flights this one has been more or less together in this configuration for the past five or six years. [ ] We have had fights and struggles. However we have long past that stage. We are fully aligned now and dear to critique each other."*

This particular perception could however also reflect the fourth stage of the so-called "group developmental stages" as proposed by Tuckman (1965 as cited in Hackman, 1990) in which groups are supposed to progress through subsequent stages of "forming, storming, norming, and performing".

How exactly a "correct" social climate was achieved and maintained – a climate in which constructive criticism is provided and received in an unproblematic manner – remained unclear. Illustrative here was the following answer to questions about this: *"I don't know, I think…well…I think…If only I knew…"* Participants could however explain how they themselves as individuals contributed to this climate. One of the key staff members for instance said:

> *"I only can tell how I think that we do not jeopardize this [climate]: by giving the example. [ ] I do think that that is the essence. When I would be out of reach I would immediately set the tone here and cannot then demand other people to be accessible."*

A flight member stated the following: *"[Regardless if one has conducted some] stupidity [or] something everybody can learn from things remain open for discussion [and reflection] because we do not make a fool of each other."* It seems plausible that a social climate that stimulates collective learning emerges from a number of formal and informal structures characterizing the unit combined with stressing again and again the value that openness and reflection have for long-term mission accomplishment.

Standardization

Very refreshing in a more and more regulated world – which (military) aviation is becoming today (e.g. BBC News, 2009; EMAAG, 2010) – was how the unit handled issues of standardization. While acknowledging benefits of standardization, the unit seemed to make deliberate choices on what to standardize on and what not. Technical procedures such as how to perform flight maneuvers and how to prepare maps – typically BSs' tasks – are laid down in detail in manuals and orders. Tactical procedures on the other hand provide the reader with a series of possible alternatives and considerations to calculate with, rather than with a set of prescribed actions. After all, tactical decisions – a FS's responsibility normally – depend on interpretation and estimates of how the enemy will act that day: *"There is no right and wrong here, [except for in hindsight of course]."* Grey areas exist. Cockpit setup for instance might be regarded a technical aspect of how to operate an Apache helicopter. Other considerations however seemed to enter here: *"We teach people how to [perform cockpit management] however we have no fixed standards for how to setup cockpit displays."* Historical decisions on standardization were said to have been *"trade-offs"* every time between "*forcing people in certain roles"* and *"leaving them the necessary freedom of choice"*: *"We work towards a consciousness [of options] rather than towards [strict and sole] adherence to regulation and rules."*

Task distribution was informed by a more or less hidden and dynamic structure. Obviously cockpit layout has a forcing function here: *"Cockpit layout is such that specific tasks are best performed from a certain crew station"* Also the absence of fixed crew pairings – as mentioned under structure and organization – contributed to standardization. Further checklists slightly differ between front and rear seats. Tasks may however shift with FS and BS experience levels for instance. Despite this, and although a standard was not prescribed in detail, participants did experience a strict although dynamic standard: *"It is not written down but everybody knows [these conventions]."*

Deviations are discussed explicitly: *"When conducting things in a non-standard way I always say so during crew briefing, or I will say out loud for instance "I am flying faster or slower or higher now because of this or that"."* Interestingly, by pointing out these deviations explicitly, implicitly it is thereby the reverse – the standard – that gets emphasized. With growing inter-crew familiarization however one can imagine that these deviations are not something that is explicitly discussed or directly commented on anymore.

Within boundaries of procedures one might utilize certain techniques in order to establish desired end states:

> *"Multiple reasons exist for rounds to hit or to miss a target. [If multiple solutions are available] but one is – for whatever reason – extremely proficient in the worst option available, one should consider to use that option anyways at that time, as long as wished-for results can be achieved that way."*

Contextual dynamics also can encourage adaptations. These might however be so inferior small that collective blindness can occur and thereby their cumulative impact – or "drift" (Dekker, 2005, 2006 p. 194) – missed: *"[Under current circumstances] we have come to the point where we frequently alter between [high and low] profiles which brought some new aspects that we were not explicitly aware of."* After all, with current contracts the unit's pilot community is refreshed less than every ten years: *"[Seven years ago] the low flying era ended which means that the majority of the community comes from the [high flying era instead]." "In the tactical realm"*, so was argued by one of the participants, *"we are inherently much more vigilant for risks. I think therefore",* he continued, *"that it is especially with ordinary and simple tasks [such as basic flying and navigating] that we might miss important features of risk."* From the unit's historical record this statement seems accurate since in the past six years the unit has lost two helicopters while conducting basic flight manoeuvres. However, one should beware of a "hindsight bias" at work here (Fischhoff, 1982; Dekker, 2004, 2006). After all, does this statement reflect an undisputable truth supported by facts? Or should it be regarded as a biased historical "after-the-facts" explanation? Or could it even serve a more pragmatic goal: to allow operators to cope with and anticipate the future? After all, "the linearization and simplification that happens in the hindsight bias [ ] allows us to export and [to] project our and others' experiences onto future situations[, highlighting] for us where we could fix things (or where we *think* we could fix things), so that the bad thing does not happen again" (Dekker, 2004, p. 7-9, emphasis added).

Training structure

A final element considered to affect social redundancy is the training structure of the unit. Initial flight training, recurrent non-technical skills training, and regular flight checks are conducted by independent training units in order to establish and monitor standardization of operations – and thus a certain unity in acting and thinking. On the other hand these independent training units also were supposed to prevent the unit as a whole from drifting – unaware maybe of a possible state of united blindness – towards any "boundary of functional acceptable [performance]" (Rasmussen, 1997).

All pilots enter the unit as BSs, to become FSs only after gaining a certain amount of experience and successful completion of the FS training program. Even when qualified as FSs, pilots remain scheduled to fly as BSs once a while. This means that every FS has a thorough understanding of what BSs' tasks are and how these should be performed: *"They know what it is about, their own [task] but also the [task] of the other [crewmember]."* This enhances FSs to monitor a BS's activities since it maximizes opportunities for cognitive overlap between FS and BS. At the same time however it enables FSs also to experience other FSs at work, cultivating thereby a common or corporate understanding – a standard – regarding how to operate the Apache from the FS.

Training scenarios are often relatively simple, *"leaving room for talking and thus for controlling a BS's actions closely.* However, *"during some missions one will not have the time to talk to their BS. Therefore we normally train worst case scenario with that respect"* (as in that a BS has to hold up his or her own pants). Members of the flight of pilots studied here often exercised the same procedure time and time again, using *"the power of repetition"* to their benefits, while constantly approaching the target from different angles. Here we see again a balancing between unity – as in fine-tuning the crew's standard of a certain procedure – and diversity – as in remaining sensitive for the need for adaptations due to the dynamics of the surrounding environment.

Context put into context

Research results suggest that, while relatively high degrees of task separation are experienced, crewmembers in Apache helicopters exercise social redundancy extensively. Where some features – such as a difference in focus among crewmembers – were regarded important for establishing fresh perspectives on things, other features were seen to determine how such alternative perspectives might be utilized in the interaction with each other. In the dynamics of Apache operations the area of cognitive overlap – necessary for social redundancy to have a chance of being effective – seems not only to move back and forth between crewmembers with changing circumstances, but also to be sized up and down accordingly. Also the *social redundancy vector* – an abstract representation for the current amount and direction of social redundancy proposed here – seems to alternate frequently between FS and BS, may even point in both directions simultaneously, and is regarded to vary in degree as well. Young BSs for instance need close monitoring of their activities, making social redundancy to occur from FSs to BSs especially. With more experienced BSs, or when conducting mission types that require intensive coordination and in-flight planning on the part of the FS, social redundancy may instead come from the BS, while for the FS monitoring the BS's end state performance probably will suffice. As soon as obstacles to a BS's task accomplishment are perceived however, the social redundancy vector might instantly reverse. Short (telegram style) or longer directions from FSs may then be expected with the intention in the majority of the cases to enable their BS to regain autonomous task accomplishment so that FSs can return to their own tasks again.

Apache helicopters obviously evolved into high fidelity socio-technological weapon systems over the years by integrating crew and machine more and more. Inter-crew interaction – as well as intra-crew interaction – severely differs from how this was done "in the old days". When discussing navigation issues some operators for instance said: *"We do not navigate at all anymore with this aircraft."* Although this in itself is contra-factual – a helicopter by itself is not going anywhere unless an operator somewhere in the process has given it a certain input – it shows that people may not see or feel themselves as doing certain tasks anymore, although in fact they are still the ones that operate the system. They almost seem to rule themselves out of these tasks. If that is correct, it can say much about how technological innovation has redefined work and job. Crew coordination nowadays seems to be conducted "through the aircraft" in many instances using graphical symbols, various displays, and sensor information – tightly coupling thereby people, tasks, system, and environment. Interestingly, this is not something that traditional approaches to social redundancy have much reflected upon. It seems as if there is a tendency to assume prior that this works and is effective, rather than to trace how this works out in concrete examples. The result is a rather distorted, naïve acceptance of redundancy. It seems as if the cart analytically is put before the horse, while theory building might be beneficial for operators here.

As has been argued before here social systems are complex systems since its components "interact in more than linear, sequential ways, and therefore may interact in unexpected ways" (Perrow, 1999, p. 83). This research confirms these findings and also suggests that social redundancy itself is a complex phenomenon. The application of social redundancy in Apache operations at the micro-level was found to be influenced by a broad series and range of macro-level contextual factors. Many of these contextual factors – if not all – appeared to be interconnected as well. Task load for instance was shown to follow largely from other factors such as mission type, environmental conditions, and skills, while skills at the same time were affected for instance by the unit's training structure, personal aspects, and recent task exposure. Also a BS's performance appeared not only to emerge from natural ability and experience. It also depended on the FS's performance, and indirectly therefore even on how this particular FS had been socialized within the unit. Obviously, for social redundancy to have a chance of being applied effectively once in the air, one has to start working on it well before taking off. More importantly however, this research seems to suggest that difficulty exists in tracing how factors link together in any fixed – or predictable – manner. Patterns may be discerned but will be probability patterns at best (Laszlo, 1996; p. 84).

One such a problematic relationship is that both task separation *and* task dependency seem to attribute to social redundancy, making it difficult for an optimal value for task distribution to arrive with. "Redundant safety systems, *if* truly independent, can enhance system reliability in theory" Sagan argues (1993, p. 39). Task separation for instance enables individual crewmembers to develop alternative viewpoints. In order to utilize these alternative perspectives in an effective manner however, social actors, as Katzenbach and Smith (2006, p. 60) have stated as well, are required to be "interdependent" and to "trust" each other up to a certain extent in order to get work established as a team. This opens doors for "common-mode failures" (Sagan, 1993, p. 39). Social redundancy apparently is bounded – and this is not often acknowledged – by the limitations of complexity in social systems. Other scholars have recognized this as well. Redundancy "depends on an assumption of random failure of [individual] components for its effectiveness [while] many, if not most, causes of accidents in interactively complex and tightly coupled systems do not involve random component failure" (Marais, Dulac and Leveson, 2004, p. 10). Even when social redundancy has been installed and functions seemingly well we should therefore not trust on it blindly. The paradox of social redundancy after all seems to be that it will show its dark side one day or the other – often in ways that we least expect or are prepared for.

Social redundancy, so it seems, is not a fixed attribute that can be switched on and off according to predefined logics. Manoeuvring, especially at higher order macro-contextual systems levels, seems to require a continuous and conscious balancing and rebalancing of contextual factors concerned – and thus of multiple goals and benefits. An optimal mix of unity and diversity in a unit's acting and thinking for instance seems to be totally circumstantial and only dynamically stable at macro levels. Above all, contextual factors appear to work in two seemingly contradictory directions sometimes. The exchange of experience in debriefings for example not only seems to encourage unity of behaviour and thinking. It can enhance diversity as well in the sense that it can broaden one's toolbox, enabling one thereby to generate more and more creative future hypotheses. In contrast with its technical anti-pole, social redundancy apparently is not an undisputable and necessary good whose features are either universal or constant at all times. Perhaps acknowledging that multiple goals and benefits have to be balanced simultaneously – taking time and process into account thereby as well – can lead to a more realistic representation of how to maneuver best in environments like the one described here.

A practical implication

Accident investigations often include statements about the quality of crew interaction. This research however has made clear that, because of the inherent complexity, it can be very difficult to make accurate assessments of (inter-)crew interaction, even in hindsight. As results have shown, the BS's task is to fly the helicopter according to strict standardized technical procedures. FSs on the other hand are responsible for making tactical decisions based on interpretations of tactical guidance material which makes right and wrong here far more difficult to assess. Within this context it is understandable and also acceptable for operators to expect corrections and interventions to be directed from FS to BS rather than the other way around. In the aftermath of an accident however – with investigators often "cherry-picking"[20] (Dekker, 2006, p. 33) from the "evidence" presented to them – investigators might interpret these findings as evidence for less than optimal crew interaction due to authority issues. After all, literature on Crew Resource

[20] Cherry-picking is the "[arbitrary] grouping and labeling of behavior fragments that, in hindsight, appear to represent a common condition" (Dekker, 2006, p.33).

Management (CRM) notes the unfortunate role that status differences between senior and junior team members can play (Flin et al., 2008; Kern, 2006; Foushee and Helmreich, 1988; e.g. Tenerife, 1977). Such unqualified statements, especially when lacking any contextual analysis, should however be approached with skepticism and should rather often be seen as "leaps of faith" (Dekker, 2006, p. 121). Any assessment of crew interaction – including expert judgments – can only have value when related to an implicitly or explicitly chosen – and thus negotiable – standard. Any assessment made should therefore take into account as many contextual factors as possible, as well as their inherent and multiple goal conflicts.

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ANNEX A – INTERVIEW SET-UP FIRST ROUND

Introduction

- Short introduction of the research topic
- Short introduction about procedural issues of the interview (tapes, notes, de-identification of data, etc.)

The purpose of this interview is to focus on the navigation task of a single helicopter crew. During the interview I will ask you to recall situations. It might be that you recall situations in which you were preparing or flying as a section, a flight, or in another formation form. However, please remember that this interview is directed towards that what took place inter-crew (within your one crew) rather than intra-crew (between helicopters).

Questions by the interviewee?

Questions

A – General

- Please tell me something about yourself (name, age, rank, position within the squadron, position within the flight, experience (total and on type), etc.)
- Explain how you and your copilot/pilot in command as a crew prepare and execute to bring your helicopter from A to B for the purpose of conducting a mission.

B – Recalling situations

- Please recall and describe one or several situations from your own experience in which the non-navigating pilot corrected the navigating pilot with regard to the navigating task, intervened in the navigating task, or made a suggestion to change direction or to go to another location because it would suit the mission better.

- Please recall and describe one or several situations from your own experience in which the navigating pilot decided to navigate the helicopter in a better position to enable the non-navigating pilot to conduct his tasks more easily.

C – For every recalled situation:

a. What was it in this particular situation that made you decide to correct, intervene, suggest or act the way you did?
b. Why was it that in this particular situation you were able to interpret the situation from a different perspective or to notice other cues than your colleague?
c. What made it possible or even enhanced it for you to bring in a fresh perspective in the cross-collaboration with your colleague in that particular situation? (both interactional or cross-collaboration aspects, as well as contextual factors)
d. What would have complicated it for you to bring in a fresh perspective in the cross-collaboration with your colleague in that particular situation?

Would you like to add anything to this interview?

ANNEX B – INTERVIEW SET-UP SECOND ROUND

Introduction

- Short introduction of the research topic
- Short introduction about procedural issues of the interview (tapes, notes, de-identification of data, etc.)
- Questions by the interviewee?

Before we start could you please tell me something about yourself? (name, age, rank, position within the squadron, position within the flight, experience (total and on type), etc.)

Human functioning is subject to contextual factors such as group composition and environmental factors. We all know that when people are working together in identical work areas and under equal circumstances, they will show similarities in behavior after a certain amount of time.

Translating this to your community, I see a community of mainly Dutch white male people between 21 and 40 years old, having had similar or equal education, being members of one Helicopter Command Group, members of one squadron, and following nearly similar training schedules. This contextual similarity could result in similar thinking strategies or in similarity in problem solving techniques. This on its turn could result in collective blindness for certain hazards or risks, or in the collective application of rigid problem solving techniques despite ineffectiveness for certain situations.

During the first data gathering period however (with interviews, observation of daily activities, and the review of mission tapes and LCT sorties) it seemed to me as if your unit is fairly effective in creating a learning organization with regard to operating the Apache. At the one hand people seem to be adapted to each other while on the other hand diversity in action and thinking seems to be aimed for in an attempt to prevent people to go along with faulty actions or decisions of others. This could mean that:

- there is less contextual similarity than appears at a first glance, or
- the contextual similarity has less similar impacts on respective individuals than the literature would suggest

Question

What is it according to you that brings:

a) the ability to be able to predict each other's actions and decisions up to a certain amount on the one hand, while on the other hand,
b) keeping a sufficient amount of diversity in acting and thinking so that people will not go along blindly with faulty actions or decisions of others?

During the first research phase I have collected already a certain amount of possibilities that I would like to discuss with you. First however, I would like to start with giving you the opportunity to mention some factors. I suggest that we concentrate on listing the factors first, after which we can discuss each factor separately. In this discussion I would like to ask you to elaborate about:

- how this factor affects unity of acting and thinking
- how this factor affects diversity of acting and thinking
- how this factor (by itself or in combination with others) balances:
    - on the one hand unity in acting and thinking of people
    - on the other hand diversity in acting and thinking of people

Of course it is possible to bring in other factors at any time during the interview.

Would you like to add anything to this interview?