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Command and Control at the Autonomy and Cognitive Era

For a decision cycle augmented by the symbiosis between human and systems

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Abstract

Introducing massively AI and Big Data technologies in military capabilities and cognitive processes is considered today as a paradigm change, a new revolution in military affairs.

In a fully connected world, where the lines between physical and informational domains are more and more blurred, Artificial Intelligence will make the world far more global than it is today and more intelligent, but harder to manage and anticipate. Artificial Intelligence will also make the world more vulnerable to cyber threats, and that has to be a leading concern in the development of augmented systems.

Thanks to Big Data and AI, future operations hold the promise of real-time information gathering, fusion and sharing on one hand, and on the other hand of an increase or even a substitution of human thought. This is the prospect of a real technological assistance in the management of complex crises that we are likely to face in the long term. In coherence, military decision cycles will need to be largely up-dated to make them more competitive during the compressed activities of future wars.

C2 and Artificial Intelligence

Discussing decision making requires spending a couple of minutes on what is by essence Command and Control. Deeply rooted with technology, C2 is designed and organized to plan, program and lead groups of people and the means available to military commanders to achieve goals set by the political level.

C2 must be considered as the process of implementing a theoretical "machine" in support of **a strategy**, **of which human must remain master**. This machine includes a set of processes, methods and knowledge management techniques that we refer to as the "cognitive triangle" whose success is based on a methodological triad: "information dominance", "cybernetic confidence" and "decision-making superiority".

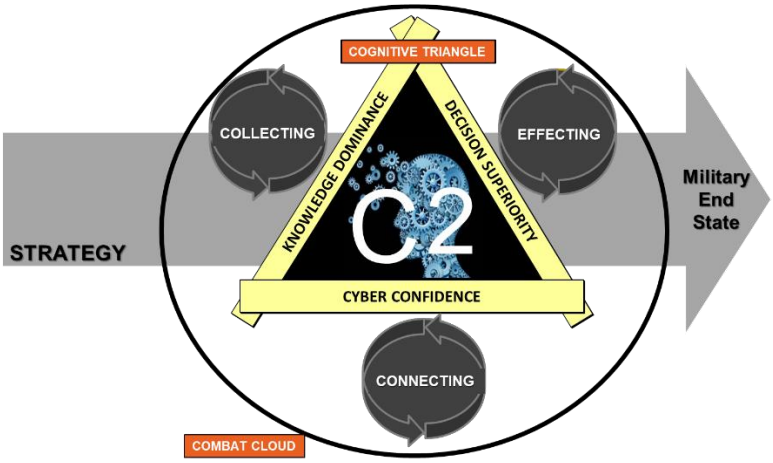

Figure 1 – C2 Representation

Inside that “Cognitive Triangle”, Big Data and AI must bring their full support to help human operators and their commanders who are constrained by levels of efficiency, speed and foresight that today challenge their abilities to face the complexity and exponential influx of information.

Of course, three other processes constituting the “Combat Cloud” (Collecting, Connecting and Effecting) will benefit from these technologies, especially at the effector and sensor edges. We will limit our discussion to the heart of the decision making process (Cognitive triangle) and to the way **human and systems have to pair** to obtain the maximum leverage from autonomous systems.

An opportunity to improve in Strategy development

Strategy making is the first point to address because it is by essence the central process where leaders have to develop and use strong critical and creative thinking skills. And as recent operations demonstrate, strong military capabilities and tactical victories do not necessarily imply a winning strategy.

As the historian Richard Kohn observed, the post-Cold War era has seen the decline of strategy as a central focus for the armed forces, and that has implied a continual string of military problems: namely the first Gulf War's incomplete results, initially successful campaigns in Afghanistan and Iraq which turned into never-ending guerilla wars, without forgetting the dramatic consequences of the Libyan operation.

Many wise observers to whom we subscribe have denounced that the reduction of the Strategy to a linear equation like Ends + Ways + Means = Strategy was misleading. It is simple, fits well on a PowerPoint slide and has spread all over Western headquarters. And strategy became roughly a planning exercise whereby goals and means are aligned. Strategy is by essence always uncertain and this uncertainty exists because the enemy gets a say in strategy-making, a factor excluded from ends, ways and means Strategy.

Recently, strategists began thinking about strategy differently, saying that what was missing in this equation was context and consequences. Context and consequences capture the dynamic process of strategy and more importantly address better causality.

Social sciences can play an important role in assisting military planners and decision-makers who are trying to understand complex human social behaviors and systems. But current social science approaches are not sufficient facing the complexity of today's world. Big data and AI based systems may discover connections and critical correlations human cannot observe and may predict evolutions. Many research programs, mainly in the US, have recently been launched in this context. We can briefly describe some of them.

Causal Exploration of complex environments seeks to develop a modeling platform to help military planners understand and address the underlying causal factors that lead to complex conflict situations. Hybrid Forecasting Systems is a project meant to combine machine learning and human forecasting to predict socio-economic and geopolitical events. The Ground Truth program aims to improve knowledge of social science modeling's capabilities and limitations.
PAINT, COMPAS, RAID are other very interesting research programs aiming to understand crisis dynamics, lifting the fog obscuring adversaries' intentions or reading the mind of the enemy, as stated in their respective definitions.

Understanding and sense-making are really the first and mandatory steps where Big Data and AI have to bring major benefits. Context and consequences are the corner stone of complex operations.

Big Data & AI: The Big Picture – big impacts.

When exploring the future role of autonomy, at rest or in motion, in war time, people often want to focus on the rather obvious issues of whether an armed machine should decide or how much autonomy should be given to keep the human in the loop. But it is a far more complex world that we are facing. We choose to address 3 major consequences and benefits of massively incorporating AI in our C2 processes.

First, in recent years, information technologies have already increased interpenetration between the discrete levels of war. For example, the combination of networked connections and unmanned systems has pushed a trend towards centralization of command and somehow towards micromanagement. In the words of Michael Evans, an Australian Defense College fellow, who wrote an interesting paper named "The rise of the tactical Generals", "higher commanders can be empowered as omniscient "electronic Napoleons" directing battle from computer screens so decreasing the need for either an operational level" and even to some extent for a component level.

Furthermore, by advances in cognitive technologies thanks to Big Data and AI, a digital battlespace makes it possible for a central strategic headquarters to employ multidimensional tactical means that can compress the

entire theater of operations into one continuous strike. In this context, fundamental changes may occur in the role of commanders at war. This is a major point of vigilance, and to work on. How to effectively lead from afar and, for leaders, how to figure out when to intervene.

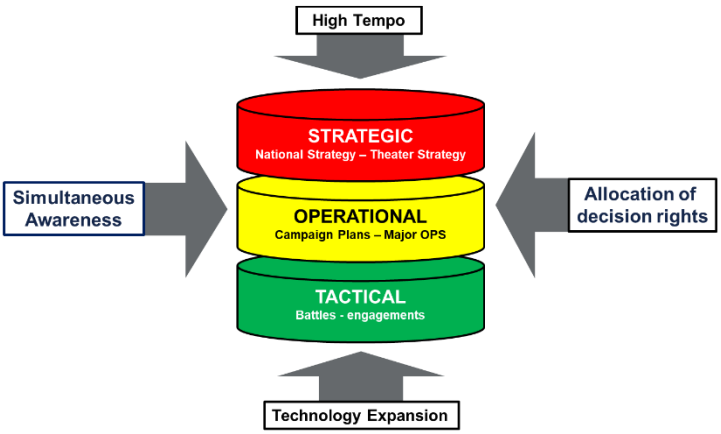

Figure 2 – The compression of various levels of war

Secondly, C2 Doctrine has theorized three nested event horizons that share the planning of the tasks to be performed and the analysis of the results and effects obtained. This articulation is often describe by three simple questions: “what is” – “what if” and “what’s next". Each event horizon spins at different rates concerning the key aspects of the decision cycle: namely planning, execution, and assessment.

Facing today’s fugitive and weak signature targets, this conventional decision-making is becoming less relevant in a time constrained environment against an opponent who doesn’t employ the same process. Cognitive computing and analytics here should augment both planning and assessment processes which are time and staff consuming. C2 operators will be able to benefit as quickly as possible from the critical information needed to conduct the overall strategy, from a better understanding of opposing tactics and intentions, and from a more sophisticated vision of the effects and consequences of their decisions.

In the same spirit, huge progress in communicating decisions will accelerate these cycles because they will be able to convey the underlying commander’s intent and context using sophisticated representations, a very powerful manner to communicate a leader‘s decision. This will save manpower and make the commanders more available to envisage the “What’s after” which should benefit to the entire strategy and accomplishments.

The third aspect of these technological evolutions is to fit perfectly to the needs of future wars. Two global non-exclusive trends are easily identified once it is understood that predicting the future of the conflicts is a challenge. The first one, is the management of complex, mostly hybrid and globalized crises that we face today and are likely to face in the long term. The second will be influenced by technological breakthroughs and geopolitical instability, and may lead to the return of state-on-state conflict.

In this context, Western advantages may not be persistent as rival states develop anti-access weapons and tactics in all global commons. Not a single domain is preserved: from anti-satellite to hypervelocity missile, from very long range and resilient Ground to Air systems to modern maneuvering TBMs, and of course from cyber-attacks to smart attacks in the Electromagnetic Spectrum.

This observation has motivated the development of the concept of Multi-domain Battle or Multi-domain C2. Although this approach of warfare is still evolving, it can be roughly described as a combination of capabilities employed simultaneously to create multiple effects within a domain or in multiple domains in order to provide multi-dilemmas to a powerful adversary.

We can easily understand that this will only happen through the collection of data by a global network of sensors, platforms and weapons, everything being highly **synchronized by a modernized C2 where the key decision-contributing processes are strongly augmented.** Only a massive use of Big Data and AI will enable what is today a promising theory.

Key Principles of incorporating BD & AI in the military decision cycle.

After this big picture, it is worth to go down and deeper into decision-making mechanics to understand how AI and Big Data can transform the way we conduct our operations.
It is essential to have, assuming the risk of certain artificiality, a simplified vision and understanding of the overall C2 processes. The activity that takes place within the cognitive triangle can be represented according to two simultaneous and interlaced macro-processes.

One is the declination of the general strategy into tasks according to the three event horizons. It represents the so-called "reflected" time or not "real time" (S2T). For instance, this is typically the core business of an Air Component Command HQ.

The other symbolizes more the so-called short loop that tends, in front of the fugacity and the weak signature of the targets, to merge all available information, to consider and compare the possible solutions, and finally to decide on the appropriate action in the shortest possible time (D2D). This is typically the essential function of a current operations center or an airborne C2.

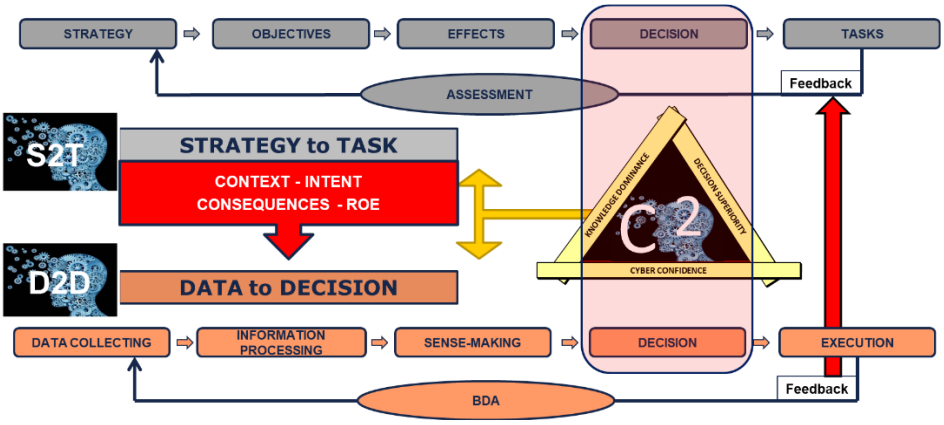

Figure 3 – Two intertwined macro-processes

These two macro-processes are naturally linked with the preeminence of the first (S2T) on the second (D2D). It is indeed essential that each decision, especially if it is a strike, is part of the overall strategy, is coherent with the intent of the moment chosen by the commander and fits well in the context, fully understanding the consequences of this action.

To our perspective, **it is essential to develop an augmented S2T process where the human remains first and in full control, and in the search for a greater autonomy for the D2D process** provided that it can be totally enslaved to the first one. We evoke here the importance of distinguishing clearly between the various forms of AI: namely augmented AI, substitutive AI, and hybrid AI.

Plan & Design, Direct, Monitor and Assess are the four fundamental bases of the C2 machine and constitute the decision cycle which leads to the adequate action, at the conjunction of the strategy and the informational context. This representation translate clearly what is effectively done in an operational headquarters, especially if you want to understand how the battle rhythm and its associated Working Groups and Boards are constructing the decision. This is clearly a commander-centric process. Each of these phases involves decisions for the Commander or his delegates. Cognitive tools, soundly organized, will increase the decision-making capacity and support the necessary compression of the decision cycle.

But it remains critical to allow the human being to remain the ultimate-decision maker regarding operations end states. This leads to implement three fundamental stands.

First, it is essential that Artificial Intelligence does not invade in an uncoordinated way every elementary C2 function or process. Indeed, AI is pervasive by nature and could have applicability everywhere. C2 can be broken down into a dozen important processes. From sensor systems to the heart of effectors and the management of

networks and tactical data links, the AI can invade each of its elementary building blocks. A learning AI, able to generate its own codes, can lead to a loss of control of the direction desired by the human, especially in the perspective of an increasing autonomy of platforms and part of the effectors.

Secondly, from my perspective, any C2 augmentation project has to be articulated sequentially and organized around the planning function.

The basis of every military action lies in the planning process and the Operational Design synthesizes it. It is an excellent tool for representation and command, continually revised and improved. It allows a commander to develop a shared awareness of the situation, to distribute his strategic intent and to anticipate the evolution of the critical path towards the desired end state. The construct of the "Operational Design" should be an essential choice to affirm the primary role of the human in selecting the ends and the strategy that allows reaching them.

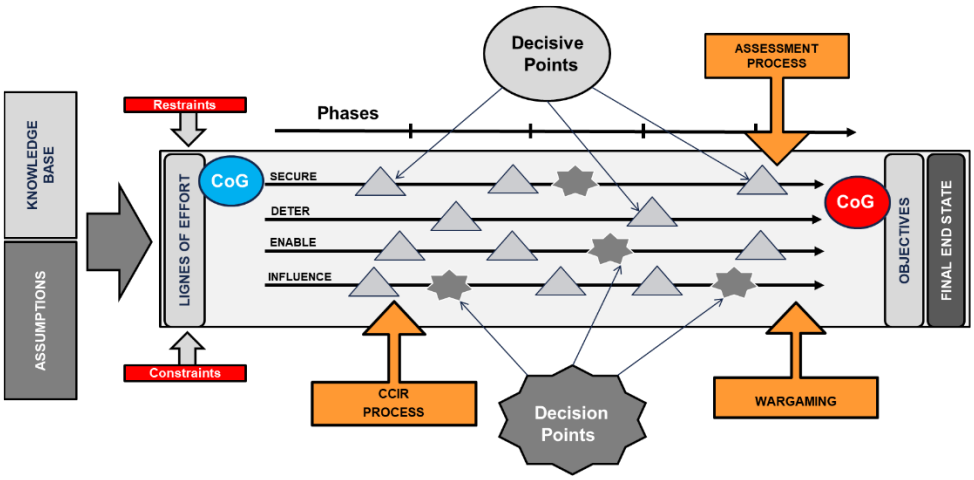

Figure 4 – The operational Design and Key processes

Three important processes arduously executed at the desired level, demanding a large and experienced human resource, would greatly benefit from being augmented by technology:

- Wargaming, which allows choosing the best options by confronting them with the strategies and tactics of the opponent. It is one of the heaviest and time-consuming processes.
- Assessment, which is often imperfectly conducted as it requires the collection and analysis of an ever greater volume of data, mostly unstructured and subjective, will have to be widely assisted by Big Data and Analytics.
- The Commander's Critical Information Requirement process, a central process that allows the commander to mark his critical path with information necessary for the taking of his major decisions.

Finally, many researchers' works have demonstrated that autonomous systems get their best efficiency when closely paired with humans. The primary reason is that, still for quite some time, human creativity and judgment will remain indispensable. Thus, it appears that the most useful model is a hybrid system, capable of solving problems where an isolated man or the system is less effective or even ineffective.

In this context, the concept of Human-Autonomy Teaming (HAT) has been proposed to provide automation transparency and Human-Autonomy interactions. As an interesting study from NASA Ames Research Center stated: "Understanding and effectively designing for HAT may be the key to finally realizing the promise of automation". A HAT agent is software-based entity that intercedes between Automation and the human operator. It should regroup at least 4 important aspects of the human / autonomy interactions which are the focus of ongoing researches: Working agreements, Rules, Transparency and Context.

The role of well-designed HAT agents is crucial in mastering the technology, especially regarding **working agreements and transparency.**

Our project: "Drawing a decision cycle augmented by the symbiosis between human and systems to better approach complexity"

Overall our project is to move the C2 from the age of mechanized processes to that of man-machine symbiosis. In their definition of C2 agility and global performance, Alberts D.S. and Hayes R.E. have characterized it by the distribution of knowledge, by the allocation of decision rights and by the ability of units to interact with each other. This can now be taken for granted thanks to the development and capacity of networks and data links, although today we witness some step back characterized by a lack of delegation or micromanagement by higher headquarters.

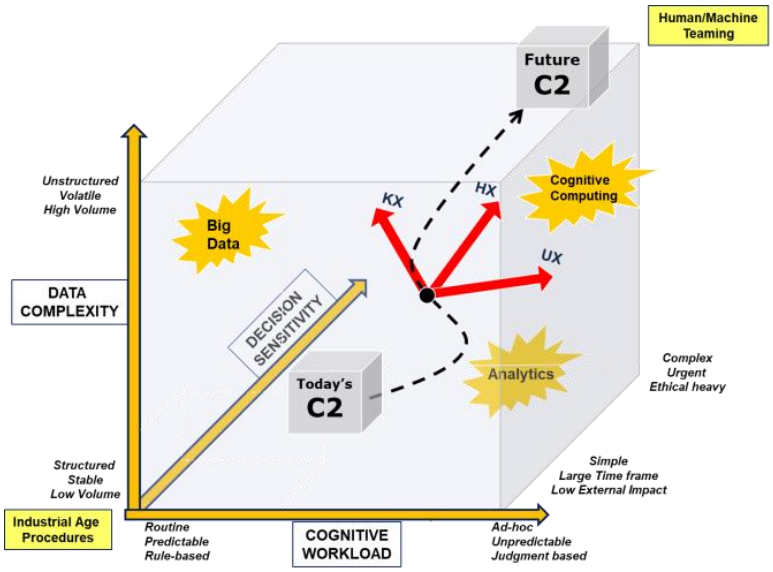

Figure 5 – From Industrial age to Human/Machine teaming

From our perspective, future C2's performance will be measured by its ability to process massive and complex data, by the cognitive workload it can produce and its ability to generate complex decisions, under strong time constraints, while assuming complete knowledge of their consequences. (Figure 5).

It is within this trihedron that the C2 must evolve thanks to the contribution of new technologies and to the application at each stage of its evolution of the virtuous methods of human increase

In the current C2, each Human/Technology segment or specialized technology group sees the complexity of the data and their processing increasing beyond their capabilities. It is in this sense that the increase of the human is necessary and must be organized by mobilizing complementary methods.

Three broad areas of increased performance of individuals or groups can be briefly described, using digital technologies. Each of these domains is concerned with cognitive computing, in particular by introducing into each of them a set of data provided by Artificial Intelligence.

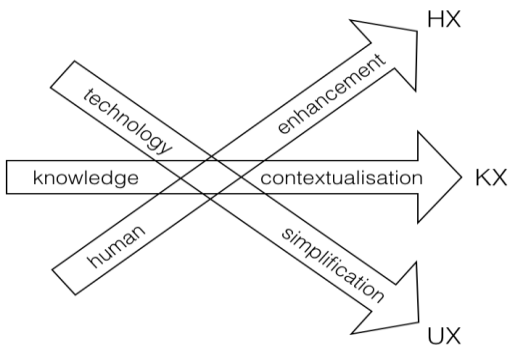

Figure 6 - The augmentation trident

The progress of the interfaces (comfort, performance, security, error control ...) present today a challenge in the field of "fluid interfaces" or "transparency of interfaces" for "increased cognition". This domain, whose purpose is to simplify the use of technologies, is usually referred to by the acronym "UX" (User eXperience) to refer to the "user experience".

A second component consists in improving the quality of information, its processing and sharing. This is an AI applied to knowledge management. Defined as "KX" (Knowledge eXchange), this domain refers to everything

related to the increase and performance of "knowledge sharing".

Finally, it is necessary to examine how AI directly increases the performance of humans collaborating with the systems, which opens the way to hybridity “HX” (Hybridity eXpension).

The CCIR Process selected for Augmentation as a first step

In the framework of the NATO STO Research Task Group IST 157, under the theme “*Human Considerations for Artificial Intelligence in C2”*, we are developing an experiment we have named “ANTICIPE”. ANTICIPE stands for Augmented Near real Time Instrument for Critical Information Process Experiment.

To design and prototype this autonomous tool, the **Engineering School for Cognitive Sciences of Bordeaux (ENSC)** has teamed up with **Thales Raytheon Systems** and **IBM France**. Our final objective is to conduct this experiment in the framework of an important NATO exercise at the end of 2019.

CCIRs encompass information linked to decision points, or making it possible to verify assumptions or protecting our own centers of gravity. At times, many events can occur simultaneously and quickly overwhelm the decision cycle for many operators. In such situations an **Augmented CCIR Process** may provide a useful performance level to ensure a timely and coherent response.

The CCIR process is a key and central process. It is an anticipation tool; it directs collection, analysis and dissemination of key information supporting main decisions. It focusses the staff on key elements and reduces complexity. That’s many good reasons for selecting this process for augmentation.

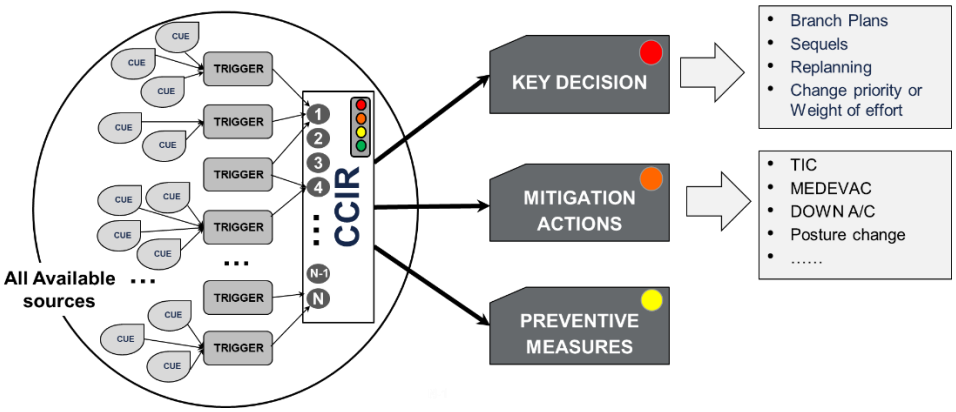

Figure 7 – The CCIR Space and Decision links

Key features, choices and challenges we are facing in the development of this experimentation.

We are right now focusing our works on the Critical Information Tracker Module and on the definition of the HAT Agent. Our Critical Information Tracker will be based on an **IBM Watson Explorer solution**.
The Decision-Making Cognitive Assistant part will be, at this stage, simulated by an IF-THEN-ELSE model based on doctrine and planning products.

About the challenges, they are still many. We can evoke: the diverse interfaces to plug the system to the sources of information from the C4I system, the definition of the semantic model, the selection and testing of annotation tools, rules and working agreements mechanics...

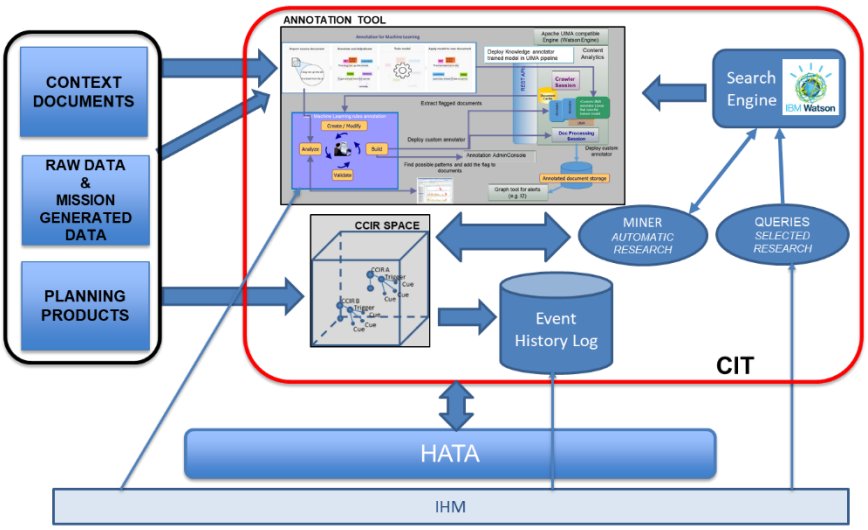

Figure 8 – Augmented CCIR process Tool

We are progressing rapidly, thanks to our superb industrial partners, towards our objectives.

Conclusion and future research

Managing the convergence of people, information and technology constituted as a sociotechnical system is the global challenge of an augmented C2 system. Overall the project is to move C2 from the industrial age to one of man-machine symbiosis. To reach that end-state, the whole C2 concept, from our political masters to the single fighting element, should be considered.
Facing today's complex environment and information deluge, it may be argued that we have recently focused too much on processes and staff work and not enough on the ability to deliver the right strategy. Thanks to these new augmented tools and processes, we can expect a more accurate coherence between the everyday actions and more sound strategy in an ever-faster tempo.

Big Data & Artificial Intelligence help us moving from a process-based C2 to a more context and consequence-based C2. This will improve the integration of command functions and allow us to move towards a more fluid, more agile and better distributed C2.

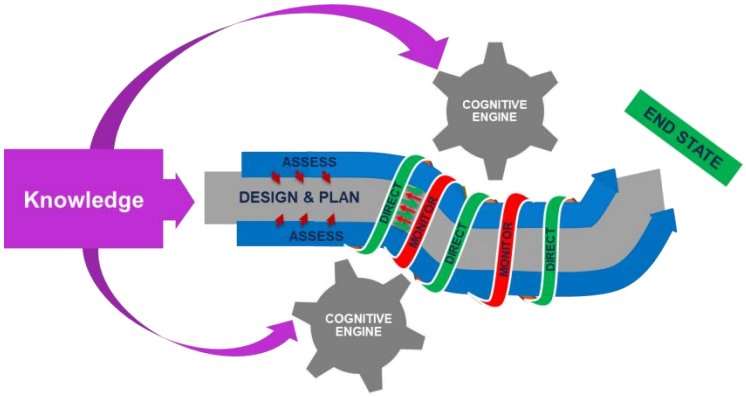

Figure 9 – The augmented decision making process

In summary, considering that the envisaged tools develop the expected gains and autonomy, the impact of these evolutions on the decision cycle should be major. Thus what is translated today by a closed cycle, run according to several tempos, could be transformed into a more linear and continuous global process, as represented in diagram n ° 9.

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