5th Gen Mission Planning: Integrated Systems and Algorithms

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ABSTRACT

Mission planning is essential to build the situation awareness needed for successful mission execution. A thorough planning helps to anticipate different situations, which is especially important since the diversity and complexity of the threats increase. Planning processes are team efforts and entail collecting, analysing and integrating relevant information into a comprehensive plan. These processes are under pressure due to the large amounts of information generated by 5th gen platforms, sensors and databases.

This paper describes the creation of an initial helicopter mission planning environment, in which data from different sources is integrated, analysed and visualised. All personnel involved in the planning process can view and interact with all available information. Algorithms process the incoming data delivering potential solutions for specific parts of the plan. Interactive visualisations contribute to an intuitive understanding of the incoming data and algorithm output, while an interactive augmented reality environment facilitates effective collaboration.

Integrated systems and algorithms are an essential part of the intelligent, collaborative mission planning of the future, since they allow handling effectively the large and diverse data streams associated with 5th gen platforms. Combined with intuitive visualisations and a collaboration, this allows crews to build the shared SA needed for flexible and responsive operations.

1.0 INTRODUCTION

1.1 Background

During a military mission, the operators must know which situations can be expected, how to act in these situations, and what the rest of the team will be doing. This knowledge is gathered during the mission planning – a crucial aspect when it comes to mission effectiveness and survivability. Situational awareness on the battlefield is better when the operators know what to expect, and acting effectively on new intel is easier if different contingency plans are prepared.

Many military operations follow a strict scheme in their planning process. While these schemes can vary greatly between nations and parts of the armed forces, most of these processes roughly consist of the following segments: a) gathering information, b) creating a plan, c) preparing the assets and d) rehearsing the mission. The gathering of information could be carried out per topic, for example making one team or person responsible for the information regarding the enemy, a second team for examining one's own assets, a third team for setting up the communication structure and radio frequencies, and a fourth team to determine the landing zone, other points of interest and the distribution of cargo load. Especially in joint operations, this requires a lot of coordination among ground forces, maritime forces and the air force.

1.2 Problem statement

With the rise of 5th gen platforms (like the F-35, AH-64E and MQ-9), more and more data becomes available that can be used as input in the mission planning process. In theory, this data should help to increase the effectiveness of the planning process, resulting in a more robust primary plan and a number of well-explored alternatives, which would facilitate the anticipation of new threats that arise during mission execution.

However, managing large amounts of data is not trivial. Translating this data into useful information with a certain confidence, such that it can be applied within the planning process and comprehended by the persons involved, is even more difficult. In line with this, the NATO Science and Technology Organization [1] predicts that the operational effectivity will be more and more related to an advantage in knowledge and trustworthy information sources, making (big) data processing an urgent asset.

To complicate matters further, the available time to conduct the planning process is limited, which can lead to little room to either develop alternative plans that are as well-explored as the primary plan, or to thoroughly rehearse the mission. When the planning processes and tools remain the same, while more data becomes available, it is not hard to imagine a future bottleneck. Simply discarding a large amount of data is also not an option, since this data could be the essential detail for the mission. On top of that, more qualitative information is preferred to act on the adversary behaviour which is becoming more complex and less predictable.

This need for more data on the one hand, and limited time on the other, causes a mutually conflicting condition which is difficult to break. A reimagined integrated planning process with seamless collaboration between persons involved and systems they use is needed to break this Catch-22 condition.

1.3 Related activities

A vision document on the military decision-making process [2] describes the urge for a robust framework which can tackle multi-dimensional planning issues. They suggest a holistic approach and more iterative processes, both in planning and in operation. The NATO S&T organization [1] underlines this too: they expect a focus on intelligent, interconnected, distributed and digital systems, and emerging disruptive technologies like AI and autonomy.

However, new intelligent systems or disruptive technologies alone will not make the difference. In order to properly support military mission planning, these tools should be incorporated in and in line with the planning process. According to Hrnciar [3], the following tactical variables should be assessed to get a detailed picture of the area of operation: Mission, Enemy, Terrain and Weather, Troops available, Time available, Civil considerations. New technologies should thus be able to deal with these tactical variables.

Over the past decades, several research groups have worked on developments to support the mission planning. Boukhtouta and colleagues [4] reviewed a number of mission planning systems and discovered that most of these support the planning of optional Courses Of Action (COAs), planning regarding transportation or route planning. They too conclude that a more adaptive planning and interoperability is required for future warfare. One of these tools [5] covered the whole mission planning cycle from order income to mission debriefing. This prototype was an integrated planning environment, which assembled all the available data to present it to the user in a combined manner. On top of that, the system gave recommendations to the user on certain parts of the planning, like route suggestion. Two tests showed that the mission planning cycle was faster with, than planning a mission without this tool. However, their prototype was not yet ready for military use. One of the suggestions they made in their discussion, was visualizing the mission plan in Augmented Reality to facilitate collaboration [5].

2.0 TOWARDS AN INTEGRATED PLANNING ENVIRONMENT

2.1 The project

The Dutch Ministry of Defence funded the ‘IMPACT’ project (Intelligent Mission Planning with Augmented Collaborative Technology) to develop technology that can support the future mission planning process for helicopter missions and can break the Catch-22 mentioned above. IMPACT was performed by the Royal Netherlands Aerospace Centre (NLR), with Infinity Labs serving as a subcontractor.

IMPACT aims to break the Catch-22 mentioned above by developing a mission planning tool which integrates all available data, gives suggestions on specific parts of the mission plan, and facilitates collaboration between the users. The system relieves the operators from data gathering and processing that data into information, possibly resulting in a faster mission planning cycle. The operators could use that freed up time to rethink and construct additional contingency plans, or to more thoroughly rehearse the mission before take-off. The glue which facilitates this human-machine teaming are the Human-Machine Interfaces, consisting of a screen-based application and a collaborative Augmented Reality (AR) application. These HMIs ensure a shared mental model between all persons involved in the mission planning.

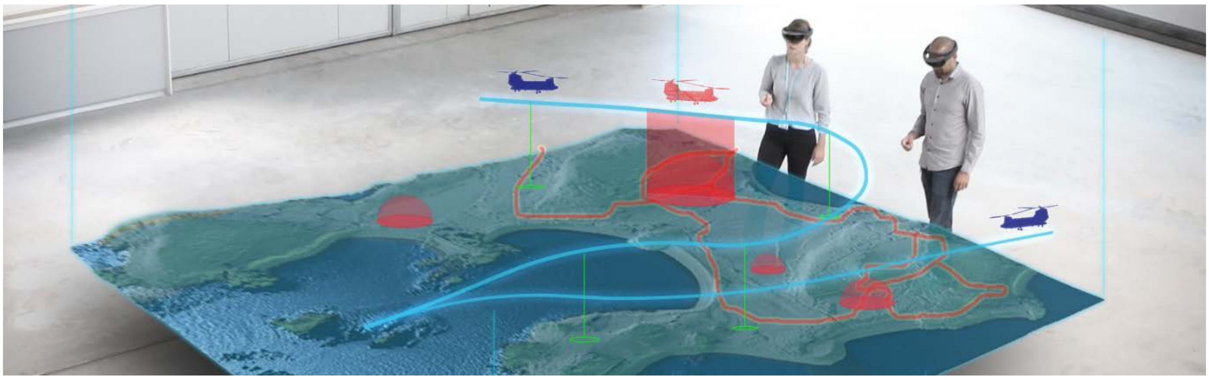

Figure 1: IMPACT – Intelligent Mission Planning with Augmented Collaborative Technology.

2.2 An integrated system

In order to align all the available data and intermediate results, the newly created IMPACT-system integrates all the available information and stores it in one central location. This reduces the amount of work regarding information sharing and briefings, since all team members have access to the same information. Above that, having the information stored in one location makes it possible to directly connect different intermediate results and information, to calculate the effects of one partial plan on another and to detect possible bottlenecks at an early stage.

The IMPACT system consists of three layers (see Figure 2):

- HMI applications layer
- Transport layer
- Supporting services layer

Currently, the HMI application layer contains the two different applications named before: the screen-based application and the collaborative AR application. Both are accessible for all users to interact with the system.

The transport layer allows different services and applications to exchange messages. The transport medium used to facilitate this information exchange is the open source message broker RabbitMQ. This transport medium ensures that the communication is secured, correct and timely.

The supporting services layer enables the HMIs to connect with the “underwater” analytical applications. This is achieved by using individual services, which operate as a translator between the IMPACT system and specific other components, like the MySQL database or the military planning software which is currently used by the RNLAF. The central database facilitates simultaneous use of the IMPACT system – both by different operators as well as by different programs within the system – because the database has the most recent version of the available data and mission plan at all times. The MySQL database is used to store and retrieve raw data, categorized information and (intermediate) results. The geographical data is stored in another database, because of the storage capacity needed for these large files.

The modular set-up makes the IMACT system relatively flexible for future use, by providing the possibility to change or add components in each of the three layers.

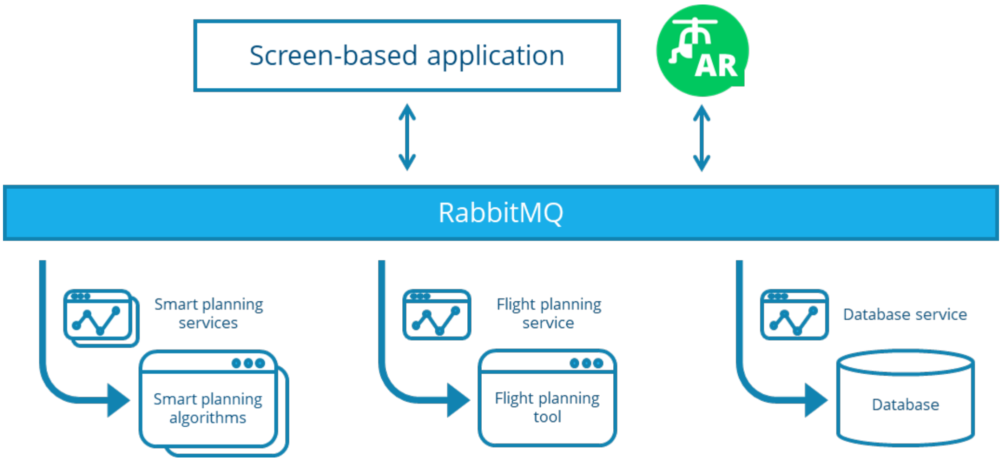

Figure 2: IMPACT architecture from a functional perspective.

2.3 Integrated information in the screen-based application

The integrated data and up-to-date information will, however, only have significant impact when the user can access and use it. Therefore, a dedicated screen-based application was created (see Figure 3). All users, including commanders and liaisons at physically different locations, have access to all aspects of this application to create a shared overview and improve collaboration.

The application includes different components, which can be categorized into a) general overviews, and b) "smart planning tools". The user can navigate to all these components through the collapsible navigation menu on the left, which will redirect to a new page within the application.

The general overview pages include a) a digital collection of orders, briefing materials and other documents, b) the opportunity to create a digital sketch of the mission on the map, c) the status of the mission planning, and d) a chat function. The smart planning pages navigate to the planning tools discussed in the next section.

Each user receives notifications which are of interest for them specifically. A personal message will trigger a notification, as well as new information which influences the planning component that is being worked on. When, for example, a new threat is identified, the landing zone planner should be aware of the additional location on which landing is not possible.

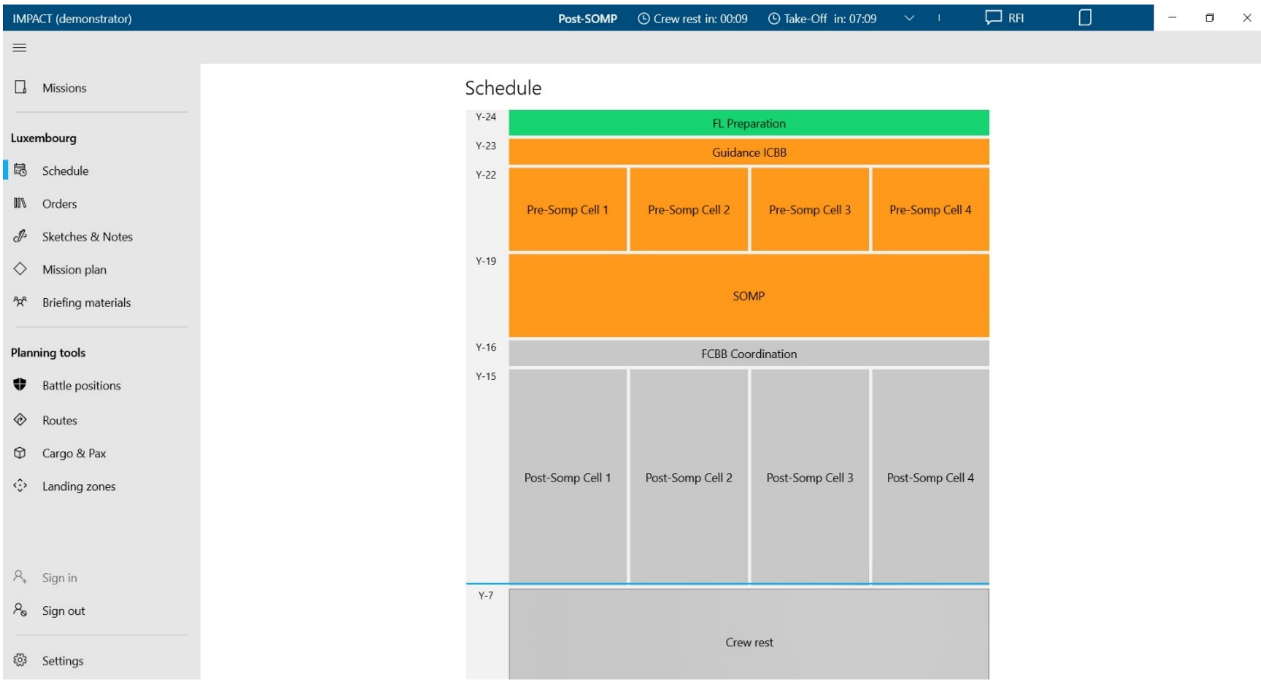

Figure 3: Screenshot of the screen-based IMPACT application.

2.4 Collaboration in the AR application

While the screen-based application can be used to construct new plans for specific planning components, the mission plan is also visualized in 3D. The Augmented Reality environment stimulates collaboration and supports the users in having a shared situational awareness of the mission. This makes it easier to discuss and rearrange the mission plan, ultimately resulting in an improved mission plan.

The 3D visualization is being built up gradually, during the information gathering phase of the planning. Whenever new information is available – e.g. a threat or convenient landing zones – these become apparent in 3D. The mission commander and the planners can look at the current mission plan(s) by Augmented Reality. This technology makes it possible to see the plan in 3D, interact with the plan in a natural manner, while still interacting with each other. When a colleague indicates a bottle neck in the plan and points to a certain location, everyone with AR glasses on can see which part of the plan is pointed at.

The same 3D visual can be seen in Virtual Reality for mission commanders or liaisons who are physically at another location. This can also be used for rehearsal purposes, from a helicopter eye point of view.

3.0 SMART PLANNING TOOLS

3.1 Rationale

The smart planning tools were created to support the planners by processing the raw data into information that can be used in the planning process and/or by suggesting solutions for specific aspects of the mission plan. These tools were included in IMPACT to provide an integrated planning environment and will be discussed in the following section. Since the integrated collaborative environment of IMPACT aims to be greater than the sum of the individual tool, first stand-alone tools and algorithms developed by others will be highlighted that indicate the possible added benefit when combining this with the custom tools developed for IMPACT.

Several other research groups have developed complementary smart planning tools for military mission planning that can be included in IMPACT to potentially further extend its functionality. Two papers presented at IITSEC 2019 describe the development of a decision support tool which visualizes the effects of different Courses Of Action (COA). The user has to come up with a COA, after which the system calculates the expected effects for resource consumption, enemy engagements and cargo load [6]. The system by McDowell and Lee [7] accounts for *the fog of war*. Since the location of the enemy can be unsure, the underlying algorithm calculates the effects of a COA for different enemy locations. By visualizing the line of sight from these possible locations, it helps the user with creating an operational picture.

Other planning tools suggest COAs themselves. Several research groups have worked on route planning for Unmanned Aerial Vehicles (UAV) or drones [8,9] or on the amount of engagement during an air-to-ground battle [10-12]. These battle planners aim for a maximum (defensive) efficiency, either by calculating how many missiles should be launched [10], or which location would be the ideal battle position [11-12].

3.2 Route planner

Planning an adequate mission route is a basic component in any mission planning and should therefore be present in any integrated mission planning environment. Nevertheless, it is complex and depends on a multitude of variable like the weather, the enemy's location and hit range, the height of the terrain, obstacles, expected battle positions and landing zones. These variables are being examined during the information gathering phase of the planning process, and can be conflicting, leading to bottlenecks in the route plan. Finding the most optimal route for the mission based on all these variables and tactical considerations can be quite challenging.

To simplify and speed up this process, NLR's custom route planning algorithm was extended and integrated in IMPACT. The underlying algorithm generates an optimized initial (three dimensional) route from point A to point B, while considering the distance of travel, expected threats, the height of the terrain and the chance of being detected by enemy radar and/or hit by their countermeasures. The user can indicate how these variables should be weighed against each other in order to optimise the route for the current mission. The algorithm is integrated such that it is able to consider new or revised information at any time during the planning phase. The route planner renews its optimisation status whenever new information comes in, for example regarding threats and/or possible landing zones that are identified by other planners.

IMPACT's route planning tool is essentially based on the A* optimisation algorithm [13], but implemented for helicopter missions specifically. This implementation included an extension with military aspects, such as radar detection considering the vehicle's radar cross-section, and the likelihood of being hit by countermeasures considering their simulated dynamic behaviour. The algorithm is connected to the existing planning software using the service-based architecture, making it possible to use the calculations from the existing planning software in IMPACT, for example regarding fuel use and expected time of arrival.

3.3 Landing zone planner

Finding suitable landing zones for one or multiple helicopters depends on several variables, e.g. the weather and wind, the location and range of the enemy, the height of the trees and buildings and the slope of the terrain. Collecting this information and deciding which area is the most optimal place to land takes a lot of time – especially when this comes down to a manual search on the map.

The landing zone planner aids this process by combining geographical information (which is currently derived from an OpenStreetMap dataset) with mission parameters (e.g. the location of possible threats) and user preferences (e.g. the maximum slope of the terrain). This results in a few selected areas, which are presented to the user as marked areas on the map. The final decision remains in the user's hands, who can take tactical considerations into account.

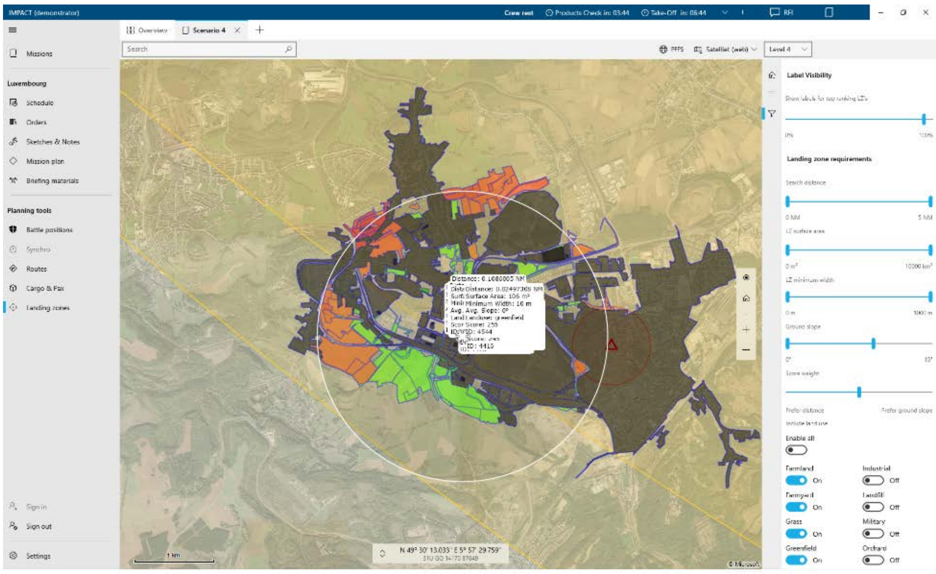

Figure 4: Screenshot of the Landing Zone planner.

3.4 Cargo load planner

An important aspect of mission planning in joint operations is the distribution of the passengers and cargo load. The task of the loadmasters is to find an optimal distribution given the number of available aircraft (storage space and aircraft capabilities) on the one hand, and the number of cargo items (size, weight and priority) on the other hand. Since the loading plan affects the fuel consumption, the maximum flying height and the center-of-gravity of the aircraft, this is a very demanding and precise task which requires a lot of calculating.

To ease and speed up this process, a load planner tool was designed which works by a two-step approach. First, it determines the optimal distribution of the load over the different available aircraft. Then, it determines the optimal location for each item within the aircraft. Both steps use a genetic algorithm to identify the best fit. The user can identify a prioritization to specific items.

4.0 OUTLOOK

We set out on a path to reimagine the mission planning process to allow seamless collaboration between persons involved and systems they use. This must eventually break the Catch-22 mentioned in the introduction: operational requirements necessitate the use of more data, while time for planning is already limited. The integrated approach towards planning as sketched in this paper will eventually lead to a planning process with a higher data throughput (collection, analysis and comprehension) and result in more robust mission plans. New data that becomes available during the planning period can be used to optimise the plan, transforming the current linear approach into a more continuous process where the plan is created and refined in an iterative fashion.

However, planning is only one element of the mission cycle (see Figure 5). A similar integrated approach as for planning can be applied to mission execution, where the result of the planning process is the starting point for a continuous, cyclic optimisation of the plan based on new data that becomes available during the mission. That could involve local optimisation of the primary plan, switching to an alternate plan or the creation of a new global plan. It can even be envisioned that the distinction between the planning and execution phase will blur, and inflight replanning will become possible or perhaps even necessary to be able to respond dynamically to emerging threats and opportunities during the mission. Naturally, the constraints will be different, for example changing the weapon loadout may be difficult after take-off, but balancing the robustness of a mission plan against time available for planning is done today. New technology, such as the IMPACT system, may stretch the time available before take-off, and systems like the Virtual Cockpit [14] could be used for mission rehearsal.

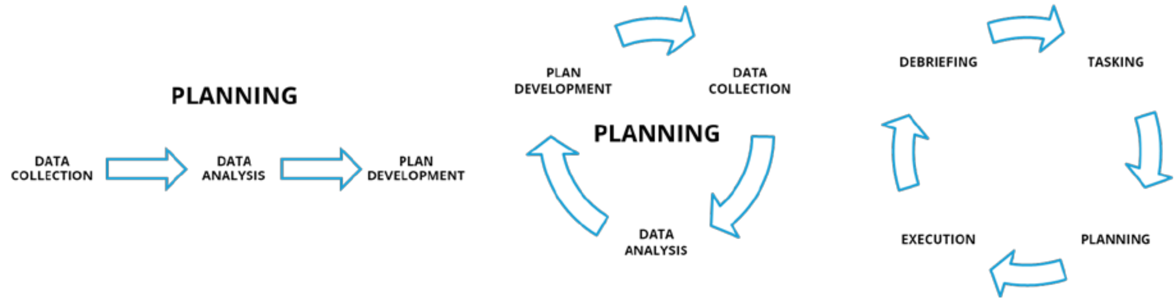

Figure 5: From a mostly linear process (left) towards a cyclic planning process (middle) that is fully integrated into the mission cycle (right)

A key requirement for the future will be an information loop that covers the complete mission cycle. Mission plans and underlying information should be available before and in flight. Executing the mission generates data – including the response of the opponent – that should be effortlessly available to allow deriving new information for use during the mission as well as during debriefing. Debriefing should not only provide insight to the participating crews, but should also be an input to tasking. Tasking should always consider the latest information, either obtained through executing missions or otherwise. The tasking with underlying information flows into the on-ground planning phase and so forth.

Such a mission cycle will be much more dynamic in nature, not only during mission execution. Technology should support in collection and analysis of data or even in development of the plan. Although this may at first sight be an attractive prospect, since it allows to always have an up-to-date plan at the start and during a mission, a key challenge that arises is to keep the process and the plan comprehensible for the crews involved in performing the mission. The ability of tools supporting these dynamic mission cycles to clarify conclusions and recommendations, will be key to end user acceptation and eventually to the tools' success.

5.0 CONCLUDING REMARKS

More and more data is becoming available that can be used as input during the mission planning process. However, more data does not automatically result in a better mission plan. Time is already very constraint during planning and more data implies more effort for processing, translation into information and ultimately comprehension by the persons involved. This mutual conflicting condition, referred to as the Catch-22 condition, is difficult to break, but the integrated planning environment developed in the IMPACT project aims to achieve this by supporting a seamless collaboration in between the persons involved and the systems they use.

The IMPACT system consists of an HMI application layer, a transport layer and a supporting services layer. The application layer includes both a traditional screen-based interface and an AR environment, and provides the means to interact with the information. The HMIs thereby support the team in their collaboration effort, while iteratively constructing the mission plan. The combination of data integration and algorithms generating plan suggestion, provides the potential for more iterative planning, possibly leading to an early detection of bottlenecks and a stretch in available time for mission planning and rehearsal. By continuously updating new information, the system can support the user better compared to using the smart planning tools only: the whole is more than the sum of its parts.

However, the mission cycle includes more elements than mission planning. To anticipate on future missions, the information loop should cover the complete mission cycle, making it more dynamic in nature. An important challenge is to keep the crews in the loop: the process and plan as suggested by the system should be comprehensible for the crews involved. It is therefore essential to validate such concepts and accompanying human-machine interfaces using a Concept Development & Experimentation (CD&E) approach that strongly involves end users.

APPENDIX A. REFERENCE SECTION

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