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Description and analysis of military planning systems

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Abstract

Future military operations will still rely on increasingly complex joint and multinational operations. Thus, innovative concepts, doctrine and technologies are required to support the emergence of new planning and execution systems, ones that are more flexible, adaptive, interoperable and responsive to a changing and uncertain environment. The ability to conduct joint and multinational operations imposes shared information and systems interoperability requirements, as well as common standards to operate among coalition members. Growing global complexity and the rapid pace of current and future military operations call for a transition from the rigid vertical organizational structure of the past to the more integrated, modular and tailored decision support required by today's demand. The recently proposed Network Centric Operations (NCO) framework offers a unique setting to take on emerging challenges. Even though recent attempts in deliberate planning tools focus on providing "on the fly" precise tailoring and time phasing of force deployment in crisis situations, suitable responses generated by remote military planners and commanders still impose incomplete time-varying information analysis from dynamic and uncertain sources of information. These are subject to a variety of constraints, including bounded computational resources and communication bandwidth, as well as other real-time requirements. The combination of artificial intelligence, operations research, data-mining techniques, and web-based and information technologies, to mention a few, offer a great opportunity to address new planning system design and integration requirements and to better deal with increasingly complex planning problems. In this report, a large number of mission planning and scheduling systems designed to support relevant and specific Air Force and, to a certain extent, Joint and Navy forces needs, is reviewed. The survey addresses various issues associated with mission planning functions and provides a brief description of methods, tools and procedures used to plan and schedule increasingly complex military operations. Emerging techniques used to build advanced mission planning systems are also examined.

Résumé

Les opérations militaires futures demeureront liées à des opérations multinationales et conjointes de plus en plus complexes. Ainsi, de nouveaux concepts, une doctrine et des technologies seront nécessaires à l'émergence de nouveaux systèmes de planification/exécution davantage flexibles, adaptatifs, interopérables et réactifs à un environnement dynamique et incertain. La capacité de mener des opérations conjointes et multinationales implique une information partagée, des exigences systèmes d'interopérabilité, ainsi que des standards d'opération régissant l'interaction entre les membres d'une coalition. La complexité croissante et l'évolution rapide des opérations militaires impliquent la transition d'une structure organisationnelle verticale rigide à une structure intégrée, modulaire et d'aide à la décision adaptée aux exigences d'aujourd'hui. Dans ce contexte, le cadre d'opérations centrées reseau récemment proposé offre une perspective unique pour relever les nouveaux défis. Malgré les récents outils de planification délibérative misant sur l'aspect adaptatif et les étapes de déploiement des forces en situation de crise, la réponse des planificateurs militaires et commandants exige néanmoins une analyse d'information de nature changeante et incomplète provenant de sources d'information dynamiques et incertaines, à contraintes multiples, incluant des ressources de calcul et une capacité de communication limitées, et autres contraintes de temps. L'intelligence artificielle, la recherche opérationnelle et les techniques de fouille de données, ainsi que des technologies web et de l'information peuvent contribuer à définir les exigences de conception et d'intégration de nouveaux systèmes de planification et à mieux aborder les problèmes plus complexes. Ce document constitue principalement une revue des systèmes de planification et d'ordonnancement soutenant les besoins de la Force aérienne, tout en incluant certains systèmes liés aux Forces conjointes et à la Marine. Cette revue souligne différents aspects associés aux fonctions de planification et donne une brève description des méthodes, outils et procédures utilisés pour planifier et ordonnancer des missions pour des opérations militaires de plus en plus complexes. Les techniques émergentes utilisées pour concevoir des systèmes avancés de planification de mission sont aussi examinées.

Executive summary

Planning military operations requires teams to engage in intense collaborative activities. Without a doubt, future military operations will still rely on increasingly complex joint and multinational operations. Thus, innovative concepts, doctrine and technologies are required to support the emergence of new planning and execution systems that are more flexible, adaptive, interoperable and responsive to a changing and uncertain environment. The ability to conduct joint and multinational operations imposes shared information and systems interoperability requirements, as well as common standards, in order to operate among coalition members. The growing complexity and rapid pace of current and future military operations call for a transition from the rigid vertical organizational structure of the past to the more integrated, modular and tailored decision support required by today's demand. In that context, the recently proposed Network Centric Operations (NCO) framework offers a unique setting to take on emerging challenges. Even though recent attempts in deliberate planning tools focus on providing "on the fly" precise tailoring and time-phasing of force deployment in crisis situations, suitable responses, generated by remote military planners and commanders, still impose incomplete time-varying information analysis from dynamic and uncertain sources of information. These are subject to a variety of constraints, including bounded computational resources and communication bandwidth, as well as other real-time requirements. The combination of artificial intelligence, operations research, data-mining techniques, and web-based and information technologies, to mention a few, offers a great opportunity to address new planning system design and integration requirements, and to better deal with increasingly complex planning problems.

In this report, a large number of mission planning and scheduling systems designed to support relevant and specific Air Force and, to a certain extent Joint and Navy Forces, needs is reviewed. The survey addresses various issues associated with mission planning functions and provides a brief description of methods, tools and procedures used to plan increasingly complex military operations. Emerging techniques used to build advanced mission planning systems are also examined.

The study also provides a comprehensive review of the functionalities and capabilities of existing military planning systems, with a final objective to inform the Canadian Forces about the military operations which can be borne or adressed by existing tools.

A.Boukhtouta, F. Boauk, J. Berger, A. Guitouni & A. Bedrouni, 2005. An Assessment of Military Planning Systems. DRDC Valcartier TR 2004-320

Sommaire

Les opérations militaires futures demeureront liées à des opérations multinationales et conjointes de plus en plus complexes. Ainsi, de nouveaux concepts, une doctrine et des technologies seront nécessaires à l'émergence de nouveaux systèmes de planification/exécution davantage flexibles, adaptatifs, interopérables et réactifs à un environnement dynamique et incertain. La capacité de mener des opérations conjointes et multinationales implique une information partagée, des exigences systèmes d'interopérabilité, ainsi que des standards d'opération régissant l'interaction entre les membres d'une coalition. La complexité croissante et l'évolution rapide des opérations militaires impliquent la transition d'une structure organisationnelle verticale rigide à une structure intégrée, modulaire et d'aide à la décision adaptée aux exigences d'aujourd'hui. Dans ce contexte, le cadre d'opérations centrées reseau récemment proposé offre une perspective unique pour relever les nouveaux défis. Malgré les récents outils de planification délibérative misant sur l'aspect adaptatif et les étapes de déploiement des forces en situation de crise, la réponse des planificateurs militaires et commandants exige néanmoins une analyse d'information de nature changeante et incomplète provenant de sources d'information dynamiques et incertaines à contraintes multiples, incluant des ressources de calcul et une capacité de communication limitées, et d'autres contraintes de temps. L'intelligence artificielle, la recherche opérationnelle et les techniques de fouille de données, ainsi que des technologies web et de l'information, peuvent contribuer à définir les exigences de conception et d'intégration de nouveaux systèmes de planification et à mieux aborder les problèmes plus complexes.

Ce document constitue principalement une revue des systèmes de planification et d'ordonnancement supportant les besoins de la Force aérienne, tout en incluant certains systèmes liés aux Forces conjointes et à la Marine. Cette revue souligne différents aspects associés aux fonctions de planification et donne une brève description des méthodes, outils et procédures utilisés pour planifier et ordonnancer des missions pour des opérations militaires de plus en plus complexes. Les techniques émergentes utilisées pour concevoir des systèmes avancés de planification de mission sont aussi examinées. L'ultime objectif de cette étude est de passer en revue les opérations militaires qui pourront être planifiées et traitées par les systèmes et outils existants. Ceci nous aidera sûrement à identifier le système approprié pour planifier une mission militaire ou adapter ce systéme pour la planification de missions militaires plus particulières.

A.Boukhtouta, F. Boauk, J. Berger, A. Guitouni & A. Bedrouni. 2005. An Assessment of Military Planning Systems. DRDC-Valcartier TR 2004-320

Table of contents

List of figures

List of Tables

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1. Introduction

Recent Canadian Forces participation in military operations has provided an opportunity to anticipate many challenges driven by uncertainty and rapidly emerging technologies. The ability to conduct out-of-area operations requires far more than combat capabilities and highly qualified personnel. Past military operations have illustrated the truly effective application of technology developed for Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) devoted to military planning operations. Despite their relative success, however, these operations have shown persistent problems associated with planning and execution. This suggests an urgent need to develop mission planning capabilities with a more integrated view of the battlefield, more accurate and timely force deployment and employment, and an efficient information system infrastructure at multiple levels.

Mission planning and execution capabilities are thus key today, and undoubtedly vital to the future operational effectiveness of modern armed forces. Future military conflicts involving NATO member nations will certainly continue to occur in faraway places, with minimal response time, and often in areas with undeveloped infrastructures. Extending military operations beyond conventional alliance borders will still rely on increasingly complex joint and multinational operations. Thus, innovative concepts, doctrine and technologies are vital to support the emergence of new planning and execution systems that are more flexible, adaptive, interoperable and responsive to a changing and uncertain environment.

The ability to conduct joint and multinational operations across a full range of possible missions commands the need to achieve among NATO allies and coalition members the adoption of shared information and systems interoperability through the use of common advanced standards. To cope with the complexity and rapid pace of future military operations, the planning function will have to transition from the rigid vertical organization of the past, to integrated, modular and specifically tailored decision support and planning packages. Consequently, future planning problems cannot be solved using individual systems, but rather, will require the coordinated efforts of a diverse set of technologies. The recently proposed Network Centric Operations (NCO) framework offers a unique setting to take on these emerging challenges.

The collaborative planning concept has already changed the fundamentals of operational planning for both joint and service operations. However, the absence of a common model of how collaboration should be undertaken by military planners has resulted in the development of a variety of technological approaches that reflect a wider operational disparity. On the other hand, collaborative mission planning is promoted, more than ever before, through the integration of new information systems and databases to dramatically improve operational planning. The resulting systems will allow modern armed forces to achieve an integrated environment in which operators, planners and logisticians, at all levels, will be able to coordinate their activities across organizational boundaries. While providing a more accurate resources estimate to the decision-making process, as Courses of Actions (COAs) are developed and compared, a future networked environment based on collaborative planning will provide a significant reduction of planning time.

Deliberate planning procedures may require considerable time to evaluate a situation and generate an adequate response, whereas a fast-breaking crisis reflecting a dynamic and uncertain situation requires fast and timely decisions. Even though recent attempts in deliberate planning tools focus on providing “on the fly” precise tailoring and time phasing of force deployment in crisis situations, suitable responses generated by remote military planners and commanders still impose incomplete time-varying information analysis from dynamic and uncertain sources of information. These are subject to a variety of constraints, including bounded computational resources and communication bandwidth, as well as other real-time requirements.

Distributed or collaborative planning also have an impact on the resulting complexity of operational planning. The absence of a universal or commonly accepted collaboration model among military planners has resulted in the development of a variety of technological approaches reflecting a wider operational disparity. Collaborative mission planning is therefore largely promoted in new information systems and databases, aimed at providing an integrated environment in which multi-level operators, planners and logisticians are able to coordinate their activities within and across organizational boundaries while reducing the duration of the decision-making process.

This report reviews a large number of missions planning and scheduling systems designed to support the specific needs of the armed forces. The study addresses various issues associated with the mission planning function, and provides a review of the methods, tools and procedures used to plan and schedule increasingly complex military operations. It also examines emerging techniques used to build advanced mission planning systems. The report is organized as follows. Chapter 2 addresses the emergence of military planning systems. Chapter 3 introduces the basic military planning process, describing the planning hierarchy, deliberate and crisis action planning, the Canadian military planning process, and the US doctrinal process. Chapter 4 presents some background information related to basic technologies used for the development of mission planning systems. Typology of the most important systems devoted to joint and air operations planning are then given in Chapter 5. Finally, some concluding remarks are given in Chapter 6.

2. The emergence of military planning systems

The US has been the most prominent nation in its efforts to judiciously incorporate doctrinal, organizational and technological changes into military planning at a pace that far surpasses the other NATO member nations. Through various planning initiatives, the US is developing advanced concepts, carrying out experimentation, assessing results, and implementing new tools that are highly flexible and adaptive enough to cope with a rapidly changing situation. Coupled with major advances in information technology and information systems, the rapid advancement in military planning capabilities has fundamentally altered the character of US military operations planning, and has also dramatically changed the conduct of command, control and deployment of the US Army.

In the 1960s, the US Department of Defense (DoD) launched an initiative to support the standardization of joint operation planning. The initiative was designed to tackle major problems associated with incompatible computer systems, software programs, and planning procedures between Services and Commands. Information transfer between dissimilar computer systems was mechanically difficult, frustrating and time-consuming. Plans submitted by combatant commanders that were not easy to interpret, analyze and review were thus difficult to approve. It was in this context that the US Secretary of Defense instructed the Joint Chiefs of Staff to promote the development of procedures and a standardized automated data processing (ADP) system to support the newly implemented Joint Operation Planning System (JOPS).

Specifically, the JOPS was implemented to support the Chairman of the Joint Chiefs of Staff in his role as the principal military advisor to the US President, Secretary of Defense and National Security Council. This system was oriented toward solving the complex strategic mobility problem associated with force, as well as support deployment and sustainment. Used by the joint planning community to provide a plan of operation in times of peace and crisis, the JOPS supported established procedures for developing, reviewing and executing global and regional operational plans. Over the years, the JOPS procedures were updated to achieve a standardized system for developing and documenting operation plans.

In addition to its inability to monitor the execution of an Operations Order (OP O), the JOPS ADP data output could not be readily accessible for rapid adaptation to crisis action situations. As a result, the Joint Deployment System (JDS) was designed and built to support the ADP in response to increasingly time-constrained crisis action planning. Hence, the JDS was predominantly a crisis planning tool to allow rapid translation of existing operation plans into executable OP Os. In this respect, the JDS allowed the joint planning and execution community to bridge the gap between deliberate and crisis action planning. It provided the ability not only to build, refine and maintain time-phased force and deployment data, but also to monitor deployment movements during execution.

While the JDS brought substantial improvements to the JOPS functions, the performance and effectiveness of the joint operation planning and execution process were hampered by the need to move back and forth between two systems. In May 1981, the US Office of the Secretary of Defense and the Joint Staff formed a committee under the direction of the Joint Staff J-3 Directorate to oversee a review of the joint operation planning and execution process so as to correct deficiencies found in previous command post exercises. As specific initiatives had been identified, the Joint Staff formed the Operation Planning Steering Group to provide direction for developing a new system to replace the JOPS and JDS. As a result, the Joint Operation Planning and Execution System (JOPES) was developed as a unified planning tool that would capture and bring JOPS and JDS functions together into a single user-friendly system. JOPES will be discussed in the last section of the next chapter.

3. Mission planning process and military doctrinal procedures

Usually, the development of planning systems is based on a military doctrinal process, which is used for creating and monitoring military operations. The planning process, as will be discussed later, begins with trigger receipt. After this step, the mission is analyzed and the tasks associated with the plan are identified. Using information from the mission analysis (this step is called orientation in the Canadian Forces Employment Doctrine [1]), the planners develop and analyze the COAs dealing with plans for friendly as well as enemy units. Several possible COAs for accomplishing the mission are developed and then compared with one another on a set of criteria. A set of the best COAs is presented to the commander.

An obvious commitment to a successful planning process is that the commander, the staff, and all people involved in this process, view the planning process as important and are willing to invest the time and effort into that process. This commitment facilitates the preparation and execution of the mission. Monitoring the mission requires a continuous evaluation of the execution of the plan. The commander is alerted when the current situation diverges from the original intent of the plan.

Good mission planning is generally characterized by quick response, decisive action and flexibility to adapt to the exogenous events and changing situations. A COA developed for a mission must consider an *employment* plan for dealing with one or more enemy COAs, and should identify a *deployment* plan for moving forces and their equipment. By performing mission planning, we develop plans for bringing the appropriate combat forces, supporting forces, and their equipment and supplies, to their destinations in time for the successful completion of their mission.

Mission planning usually begins with a high-level political and military goal. After that, the mission planner refines the goal with the use of forces to achieve more specific goals. A mission can be subdivided into a set of operations or tasks, for example a group of identical aircraft acting in concert to perform an operation. In this case, each operation consists of a mission type, number of aircraft, type of aircraft, time and place, and number of "sorties" required to execute the operation. An operation may be expressed, for air mobile operations, as *three C130 cargo planes land on terrain X and rapidly unload soldiers troop S1 and offload equipment E on the day D*. Another operation for airborne operations may be expressed as *two C5 cargo planes to drop soldiers troop S2 and equipment E3 into the combat zone Z on the day D+1*. We can refine the mission planning process in depth by considering very low-level (tactical) mission planning details such as flight path, altitude profile, etc.

In the mission planning process, the planning staff is always confronted with the task of refining goals into subgoals. These refinements provide the different strategies and tactics available. For example, a refinement of the goal *protect country C citizens from hostile attack* might include the subgoal to defend, in a crisis situation,*a friendly country F located on the border of the belligerent country C.* Refinements might include actions such as *patrol the borders of country F* or *legitimate attack of hostile airbase A*. Available options may be constrained by directives or restrictions from political authority, geography, the enemy's capabilities, and availability of aircraft or other resources. Contingency planning is based on the assumption that the ability to accurately forecast exogenous events or resource availability will affect the COAs. In other words, COA refinements reflect the different contingency plans.

3.1 Planning hierarchy

Three levels of planning are considered in Canadian Forces (CF) doctrine, namely, strategic, operational and tactical. Each level of planning corresponds to a level of conflict. The definitions of each level, as addressed in [2], are given as follows.

> "The strategic level of a conflict is that level at which a nation or group of nations determines national or alliance security objectives, and develops and uses national resources to accomplish those objectives. Activities at this level establish strategic military objectives, sequence the objectives, define limits and assess risks for the use of military and other instruments of power, develop strategic plans to achieve the objectives, and provide armed forces and other capabilities in accordance with strategic plans."

> "The operational level of a conflict is the level at which campaigns and major operations are planned, conducted and sustained to accomplish strategic objectives within theatres or areas of operations. Activities at this level link tactics and strategy by establishing operational objectives needed to accomplish the strategic objectives, sequencing events to achieve the operational objectives, and initiating actions and applying resources to bring about and sustain those events."

> "The tactical level of a conflict is the level at which battles and engagements are planned and executed to accomplish military objectives assigned to tactical units. Activities at this level focus on the ordered arrangement and manoeuvre of combat elements in relation to each other and to the enemy to achieve combat objectives established by the operational level commander."

Planning certain air operations, such as air logistics support and aeromedical evacuation for air transport operations, can be addressed at the strategic level as well as at tactical level [2].

3.2 Deliberate and crisis action planning

The planning environment is relative to the operational situation and conditions under which a plan is produced (the time available and the degree of urgency). From an environmental perspective, two categories of planning can be considered: deliberate planning, and crisis action planning or time-sensitive planning, as it is called in the Canadian Force Employment Doctrine (see Figure 1).

The deliberate planning process is not generally subject to immediate timelines or prevailing threats. It develops operation plans for contingencies and for later execution.

The crisis action planning process is needed when the degree of urgency of the crisis demands an accelerated operation planning process. The most significant factor to consider in such planning is time. Consequently, the crisis action planning process is characterized by quick response, decisive action and flexibility to adapt to the contingency situation.

Deliberate and crisis action planning can be interrelated, in the sense that the deliberate planning contributes to crisis action planning. Deliberate plans establish a framework for the transition to crisis response. Deliberate and crisis action planning are structured formal processes. The planning process described below applies to any type of operational or strategic operation. It applies to deliberate and crisis action planning (Figure 1). The deliberate planning process usually refers to the operational level of a mission.

3.3 Canadian military planning process

Strategic and operational levels of planning are structured formal processes. The operation planning process addressed later applies to both. The tactical level, on the other hand, is not a well-known structured process. This level of planning is not addressed in the CF Employment Report [1] which covers the operation planning process. Tactical planning is a very dynamic multi-dimensional process where the decision maker must execute the decision process within the timeframe of the enemy's decision cycle. By doing that, the decision maker forces the enemy to abandon its plans and objectives and drives it into a mode of reactive decision-making.

The output of the planning process is a plan or an Operation Order (OP O). A military operation planning process (Figure 1) is generally completed in five steps (for strategic and operational levels):

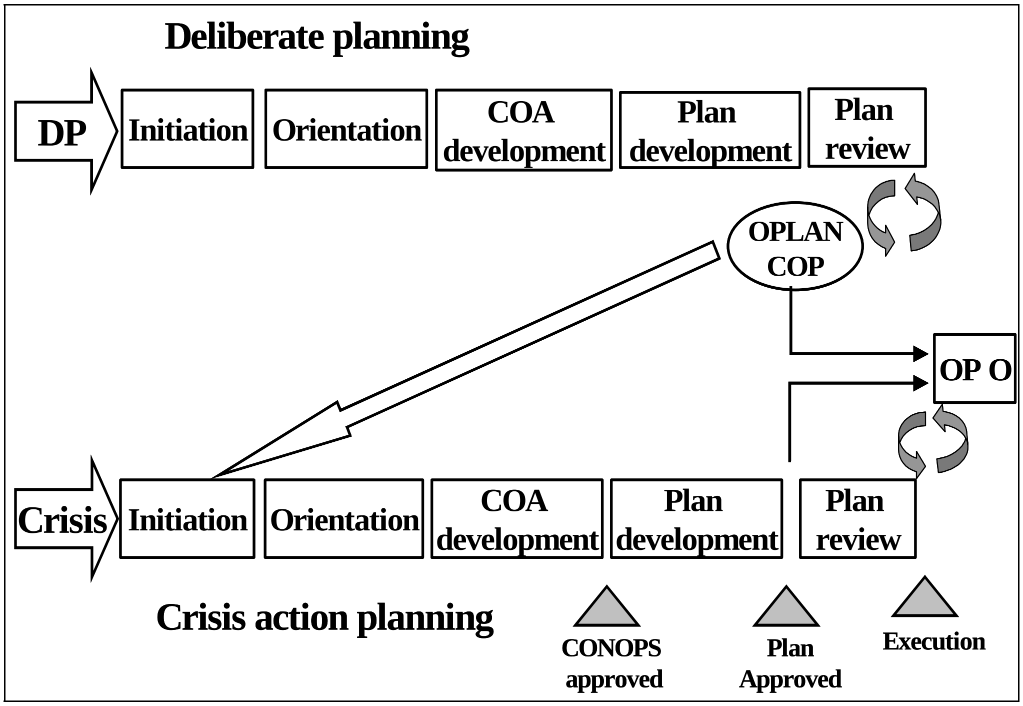

Figure 1. *The Canadian planning process [1].*

Initiation: the initiation step starts with the reception, by the Chief of the Defence Staff (CDS), of a political direction from the Government. Designation and notification of the planning staff and assembly of all relevant material are initiated in this step.

Orientation: at this step a commander orients the staff towards the requirements of the initiated operation, and the mission is developed and analyzed. The mission analysis, which is usually initiated with a brainstorming between the commander and his staff, determines the nature of the problem and confirms the results to be achieved. The commander's planning guidance regarding the tasks required is developed and issued at the end of this step.

COA development: the commander's planning guidance is used as a framework by the planning staff to develop the initial COAs. Factors such as theatre situation, opposing forces, military capabilities, time and space, and assessment of the tasks are analyzed in the COA development. Planners perform a comprehensive range of COAs which focus on achieving the mission. Different COAs are compared to determine the most effective one.

Plan development: in this step considerable expansion or alterations are considered to convert a developed COA into a **Contingency Operations** (COP) plan, in the case of the deliberate planning, and an **Operations Order** (OP O) plan, in the case of crisis action planning.

The COP plans are prepared in the following situations: the contingency has important interest (national security); the nature of contingency requires detailed prior planning for complex issues; and, detailed plans are needed to support a multinational operation.

A COP plan is a complete and detailed operation plan that includes:

- A full description of the concept of the operations;
- Identification of specific forces and specific resources necessary to implement the plan; and
- Estimates of the forces movement in theatre.

The concept of operation (CONOPS) explains how component forces will accomplish the selected courses of action, but is less detailed than the more formal OP O. A COP plan can be converted into an OP O plan, where details of the mission are filled in to include all supporting forces and activities. The OP O plans are presented in the form of a directive issued by a commander to the staff or subordinate commanders to effect the coordinated execution of an operation.

The COP plans which are developed for specific military operations in a non-hostile environment (intratheatre logistics communications and continuity of operations), or to address peacetime operations such as disaster relief, humanitarian assistance or peace operations, are called *Functional Plans* in US force doctrine [3].

Plan review: COP and OP O plans must be reviewed by evaluating their corresponding COAs through exercises, war gaming, or other techniques, such as logistics flow modelling. The choice of the review method depends on the time and availability of resources. COP plans must be reviewed regularly due to the circumstances and the technological changes upon which they were based.
OP O plans must be continually reviewed.

Most of the planning systems presented in this paper do not cover all of the above-mentioned steps of the planning process. The planning process related to US Army doctrine is very similar to the Canadian one. The documentation associated to the JOPES system gives a good description of the US Army planning process.

3.4 Planning joint operations based on US doctrine

As illustrated in Figure 2, planning joint operations in the US could be seen as a complex process that involves multiple actors, including the National Command Authorities (NCA) and the Joint Planning and Execution Community (JPEC). Supported by executive departments and organizations such as the National Security Council (NSC), the NCA provides the ultimate decision on national policy as well as the overall strategic direction of the US Army.

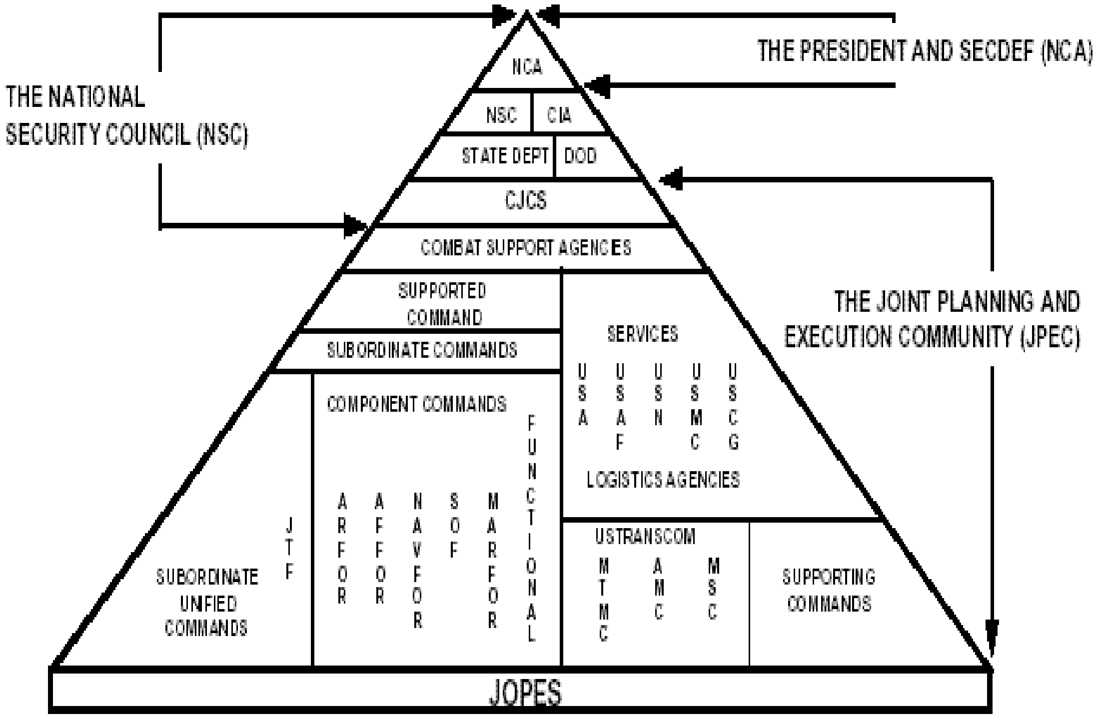

Figure 2. *The Joint Planning and Execution Community (JPEC) [4].*

As the principal forum to consider national security policy issues, the US NSC helps develop national security policy and advises the NCA on national security matters. In this respect, the NSC provides the framework for establishing national security strategy and policy decisions required for presidential implementation. As commander-in-chief of the US Army, the President can either issue orders directly to the military to implement national security strategy or mandate military action through directives.

On the other hand, the headquarters, commands and agencies involved in joint planning for the mobilization, training, preparation, movement, reception, employment, support and sustainment of forces assigned or committed to a theatre of war or theatre of operations are collectively termed the JPEC. Specifically, the JPEC includes:

- **National level.** The Chairman of the Joint Chiefs of Staff, other members of the Joint Chiefs of Staff, the Joint Staff and the Services.

- **Supported command level.** The unified theatre and functional Commander-in-Chiefs (CINCs) and their Service component commands, sub-unified commands, and joint task forces.

- **Supporting organizational level.** Supporting commands, including Service component commands, supporting combatant commands, and Defence combat support agencies.

The supported commands and their subordinates are responsible for developing and executing operation plans and orders. The Services and their logistics agencies provide major support in organizing, equipping, training and maintaining forces for the combatant commands.

Developing and implementing an executable COA in response to directives from the US NCA or the Chairman of the Joint Chiefs of Staff (CJCS) is an integrated process which involves multiple headquarters, commands, Services and Defense agencies. The National Security Strategy (NSS) initiates a process that provides guidance to assist theatre CINCs. The CINC receives more refined guidance through the National Military Strategy (NMS), DoD regional strategy reports ,and various other official documents. Submitted by the CJCS to the President and Secretary of Defense, the NMS is designed to articulate how the US will employ the military elements of power to support the national security objectives formulated in the NSS.

In the US, major national level systems are closely related to the operation planning and execution process. First, the US **National Security Council (NSC) System** is used to prepare and generate National Security Directives (NSDs) that implement national security policy. Formulated through the NSC, these directives provide the basis for both military planning and programming.

The **Joint Strategic Planning System (JSPS)** is another primary formal means by which the CJCS, in consultation with other members of the Joint Staff and the CINCs, carries out his planning and policy responsibilities and discharges his role as advisor to the NCA. In this respect, the JSPS provides the ability to systematically review US national security objectives and the national security environment. The JSPS is implemented to evaluate threats, assess current strategy, and existing or proposed programs and budgets. It is further used to propose the military strategy, forces and programs required to achieve national security objectives in a resource-limited environment.

Based on the Joint Strategy Review (JSR), the JSPS is used to produce the following key documents: the CJCS's Guidance, the NMS, the Joint Planning Document (JPD), the CJCS's Program Assessment (CPA). The NMS guides the CJCS in providing contingency plans and developing the Joint Strategic Capabilities Plan (JSCP). As a product of the JSPS, the JSCP provides strategic guidance, establishes requirements and apportions resources to the CINCs and Service Chiefs to accomplish tasks and missions based on near-term military capabilities.

Whereas most organizations within the US DoD participate in the formulation of the JPD, another important document, the Chairman's Program Recommendation (CPR), is prepared to communicate the CJCS's personal recommendations directly to the Secretary of Defense regarding defense priorities.

As a flexible system interacting with various DoD systems, the JSPS provides support to the **Planning, Programming, and Budgeting Systems (PPBS)**, a third major national-level tool related to the operation planning and execution process. Indeed, the concepts, strategy and plans developed through JSPS must be supported by a programmatic system that identifies, acquires and budgets the capabilities required. As programs are developed and resources allocated, JSPS products and other related documents provide a means to evaluate capabilities and assess program and budget adequacy and, where appropriate, propose changes.

In addition to the NMS-based supporting documentation, the JPD and CPR are prepared to assist the Secretary of Defense in developing the Defense Planning Guidance (DPG). Indeed, the DPG is the principal DoD planning document representing the major link between the JSPS and programming through the PPBS.

As a product of the PPBS, the DPG is intended to reflect the US President's prioritized National Security Objectives from the NSS, and establish policies that provide the Services guidance for planning based on peacetime, crises, and wartime strategies. It includes major planning issues and decisions, strategy and policy, strategic elements, the Secretary's program planning objectives, the Defense Planning Estimate (DPE), the Illustrative Planning Scenarios, and a series of studies. Issued by the Secretary of Defense, the DPG provides Military Departments with programming and fiscal guidance to develop Department Program Objective Memorandums (POMs) for the defence planning period.

The Joint Operation Planning and Execution System (JOPES) is the Chairman's joint planning system which covers the planning spectrum from the NCA to the combat commanders (CINCs) and the joint task force commanders. It is the principal system within the DoD for translating policy decisions into OPLANs, plans in concept format (CONPLANs), functional plans (FUNCPLANs) and OP Os, in support of national security objectives. Designed to interrelate with the three other national systems (NSCS, JSPS and PPBS), JOPES supports and integrates joint operation planning activities at the national, theatre, and supporting command levels.

Designed to translate NCA decisions into combatant commander's joint operations, JOPES includes:

- **Publications and documents** required to guide the development of OPLANs and OP Os.
- **An operation planning process** that provides deliberate plans, OPLANS and OP Os, and
- **An ADP support system** that provides the data processing support required for the development of OPLANs and OP Os.

JOPES-related documents are designed to establish the formats and guidance that govern operation plans development by joint force commanders (see [5] and [6]). These documents include:

- **JOPES Volume I**: "Planning Policies and Procedures;"
- **JOPES Volume II**: "Planning Formats and Guidance;" and
- **CJCSM 3122.02 Volume** "Crisis Action Time-Phased Force and Deployment Data (TPFDD) Development and Deployment Execution."

JOPES Volume I sets forth planning policies and procedures to govern the joint activities and performance of the US Army. It provides military guidance for the exercise of authority by combatant commanders and other joint force commanders. It also prescribes doctrine and selected joint tactics, techniques and procedures for joint operations and training. This publication further provides military guidance for use by the Armed Forces in preparing appropriate plans. It is specifically designed to describe JOPES functions and the environments in which planning for and executing conventional and nuclear joint military operations are conducted.

In this respect, JOPES Volume I provides specific, detailed and standardized procedures and guidance for:

- conducting deliberate planning;
- generating OPLANs, CONPLANs (with and without TPFDD) and FUNPLANs;
- conducting crisis action planning; and
- producing OP Os.

JOPES Volume I also provides specific formats and checklists used for crisis response by commanders and their staffs during crisis action planning.

On the other hand, JOPES Volume II prescribes standard formats and minimum content for operation plans, concept summaries, annexes, appendices, tabs and exhibits. It is functionally oriented to provide directional, procedural and planning guidance keyed to certain plan annexes. Formats for classified subjects and detailed functional area guidance are contained in the classified supplement to JOPES Volume II.

Finally, the CJCSM 3122.02 Volume is established to provide, within the context of JOPES, procedures for the TPFDD and for deployment of forces in support of joint military operations. This manual includes formats for COAs, Plan Identification Number (PID) announcements, Deployment Estimate Requests, Request for TPFDD Sourcing, and TPFDD Validation.

3.4.1 JOPES methodology and procedural principles

JOPES is the integrated joint conventional and nuclear command and control system used to support military operation planning, execution and monitoring activities, including theatre-level nuclear and chemical defence plans. JOPES incorporates policies, procedures, personnel and facilities by interfacing with

ADP systems and reporting systems to provide senior-level decision makers and their staffs with enhanced capability to plan and conduct joint military operations. These policies, procedures and ADP systems provide the mechanisms through which movement requirements are submitted to the US Transportation Command (USTRANSCOM) for joint operations and exercises.

As already stated, JOPES supports the joint planning and execution process used during peacetime operations, exercises, hostilities/military operations other than war, and war. Its procedures provide for various levels of decision making in deliberate and crisis action planning environments. Both deliberate and crisis action planning processes are governed through five operational processes: threat identification and assessment; strategy determination; course of action development; detailed planning; and, implementation.

While ensuring that all participants in all aspects of joint military planning and execution use the same vocabulary, procedures, and joint ADP support, JOPES includes a single set of ADP procedures to facilitate a successful transition from planning and training to the effective execution of military operations. Combined with JOPES administrative policies and procedures (ADP), the procedures govern all aspects of military operation planning and execution, including theatre-level nuclear and chemical plans.

As a capabilities-based planning system, JOPES imposes a planning procedure that consists of comparing force requirements (validated by the Supported Commander) to available support (including combat, combat support and combat service support) and resources apportioned support. In the course of a planning process, supporting commands and agencies, as well as the Services and combined entities, confirm force and resource availability and active source requirements. At the start of the planning process, relevant personnel and logistic data are needed to assess force sustainability and transportation feasibility, requiring coordination and cooperation with the supporting DoD and appropriate foreign agencies.

Indeed, military planners using JOPES employ the forces and resources specified for regional or global planning, as appropriate, in the JSCP, CJCS orders, Service Capabilities documents, Allied and Coalition agreements, and approved operation plans or operation orders. Planners use the apportioned forces and resources detailed in JSCP for regional plans when faced with contingencies without global implications. For contingencies with global implications, the apportioned forces and resources made available to the supported command will be allocated by the Chairman and combined agencies when necessary, in accordance with international agreements and understandings.

On the other hand, JOPES provides specific procedures designed for the supported commander to identify shortfalls between the validated requirement and the provided commander’s sourcing at various steps in the planning process. In this respect, the supported commander then attempts to resolve shortfalls, conducts risk analysis if the shortfalls are not resolved, and redefines the Concept of Operation if the resultant risk is too great.

In support of JOPES' goal of developing and maintaining executable plans, commanders further use appropriate methods at their disposal to keep plans current and accurate, including plan maintenance, conferences and newsgroups. In this respect, completed and approved plans are maintained and updated as required. Commanders and their staffs are thus required to concentrate on keeping existing plans and orders up to date and executable. A new plan is required only when the threat, tasking, forces assigned, resources available, or concept of operations change to the extent that the supported commander and chairman deem it necessary to develop a new plan. The maintenance of the TPFDD falls within a separate and distinct maintenance cycle, which is discussed below.

The most important paradigms and technologies used for military planning systems will also be briefly discussed below.

4. Paradigms used for military planning systems

The technologies used to model a planning process depend on the structure of the problem itself. Special structure can help simplify the approach to be employed.

For a long time, war gaming has been used by the military for planning operations. Germany used war games to plan its invasion of France in 1940. Japan used war games to plan its attack on Pearl Harbor, Hawaii, in 1941 [7]. As outlined in the US Army Staff Organisation and Operations manual [3], the military planning process, which consists in developing COAs, is an *ad hoc* process developed by staff members and the commander after discussing various COAs. War gaming is used to compare COAs in order to perform an operation plan [1]. The effectiveness of the war-gaming approach is subject to the skills of the commander and the individual staff members, however. Usually, a large percentage of the members of a planning staff have no feel for the battlefield. In addition, the effectiveness of an analysis of a COA is subject to the quality of the interaction between the various members of the staff. The strengths and weaknesses of the COAs are analyzed by the same staff that developed them. As a result, the members of the planning staff have personal biases about which plan is best (See [3] and [7]). War gaming, if time permits and resources are available, can be computer assisted using simulation models [1]. The *ad hoc* military planning process based on war gaming is a manual planning method.

The decision theory provides new tools for the planning process. It addresses the problem of how a decision maker could or should choose an action, knowing the state of nature (the state of the world) and its capabilities and preferences. Uncertainty, outside events, knowledge and information are usually modeled within decision-theoretic planning frameworks. The decision-theoretic planning process tends to be extremely complex to solve. The exploitation of the problem structure and abstraction techniques in order to reduce a set of actions is usually used to reduce the complexity of the decision-theoretic planning problem. Decision-theoretic planning models based on an OR paradigm usually use optimization techniques for the development of optimal plans.

Decision-theoretic planning was developed primarily within the artificial intelligence (AI) community. The first problems addressed were based on the decision theory, which is the origin of decision-theoretic name. The Probability and Utility theories, which both belong to the decision theory, provide attractive tools for evaluating a particular COA. Besides the decision theory, other operations research techniques, such as mathematical programming, the graph theory, Petri networks and the game theory, are all tools which have been used to develop mission planning systems.

The challenges now lie in understanding the relative strengths and weaknesses of the different technologies, and how they can be extended and combined to develop better approaches to model the planning process.

AI represents a popular alternate paradigm for building intelligent planning systems. Some planning systems inspired from AI rely on replanning based methods to develop deliberate plans. These systems, which are reactive in nature, generate plans and modify them based on unexpected events.

Replanning approaches have been used in developing many military planners, including:

- DART (Dynamic Analysis and Replanning Tool) [8];
- TARGET (Theatre-Level Analysis, and Graphical Extension Toolbox)[1]; and
- Cypress-SIPE2 [9].

Plan generation algorithms have been developed since the early stages of AI. An overview of techniques adopted for developing them is presented in [10]. Logic-based and hierarchical task network (HTN) approaches have also been proposed in early and current planning systems, and remain popular to this day.

A different AI-based method, namely constraint programming [11], has also been the subject of investigation in planning systems. Most derived methods focus primarily on generating "feasible" COA solutions, and then achieve cost minimization. This approach seems suitable when the problem is fairly constrained and solution feasibility is preferred to optimality. However, basic constraint programming methods are not formulated to handle problems dealing with uncertainties.

Multi-agent systems and automated planning technology have also been widely used in a variety of mission planning systems. Other IT technologies, such as data mining (for extracting hidden predictive information from databases), knowledge management, online analytical processing (a way of presenting relational data to users), and business intelligence tools, have also been widely exploited in developing military planning systems.

The research community offers benefits from adequate commercial off-the-shelf (COTS) components in developing planning systems. Implementing COTS hardware and software into defence planning and scheduling systems would obviously result in significant cost and time savings. However, a carefully controlled approach to pre-packaged COTS software selection and integration within a larger system requires the need to develop guidelines, verification methods, and assessment and acceptance criteria.

[1] DART and TARGET were developed by BBN Technologies for the US Department of Defense.

5. Planning System Taxonomy

The systems surveyed in this study have been split into four categories. The first addresses the deployment and battle operations systems. The second reviews systems dedicated to one of the most important areas of military activity -- the airlift and transportation operations. The third deals mainly with tactical isssues related to flight and route planning. The last addresses other specific military operations which do not fit into the other categories.

5.1 Deployment and battle operations systems

Deployment and battle operations systems address the relocation of forces and materiel to desired areas of operations or/and the movement within areas of operations. Deployment usually includes all activities from the origin or home station through to destination.

5.1.1 Fox Genetic Algorithm (FOX-GA)

The Decision Support Systems Laboratory at the University of Minnesota and the Illinois Genetic Algorithms Laboratory at the University of Illinois collaborated to develop the FOX Genetic Algorithm (FOX-GA) [12] under the auspices of the US Army Research Laboratory (ARL).

This system provides an intelligent decision support tool for assisting US Army planners and military intelligence to rapidly generate and assess large numbers of battlefield COAs. Indeed, since the battlefield environment is uncertain, dynamic and full of risks, standard procedures are limited in addressing and exploring sufficient numbers of COAs, and less replanning happens than is desired. FOX-GA was designed to provide the capability to automate and thus speed up the military planning and replanning process during execution, i.e. the course of the battle, to give users flexibility and control over planning objectives and options.

The approach used by FOX-GA is based on Genetic Algorithm (GA) technology [12], and allows the decision support system to rapidly generate a large number of potential COAs through crossover and mutation. FOX-GA then uses a war gamer based on coarse-grained representations to allow efficient assessments and rapidly evaluate the “fitness” of the generated COAs. The system can evaluate up to 3,000 friendly COAs per minute, while manually the process requires 10-15 minutes to war game one friendly COA against one enemy COA.

Since standard GAs have the tendency to generate a group of very similar or identical “best” solutions, a scheme called “fixed” niching strategy is used to ensure diversity in the solutions. In other words, newly generated COAs will in fact be different from the existing ones, providing users with a more satisfactory range of choices. Planners, according to their own judgment, re-evaluate the best few COAs provided, and select a small group for further development.

Currently, FOX-GA provides the ability to develop offensive COAs for common grounded force, including mechanized infantry and armoured units. However, due to its architecture, this tactical system can be generalized to support the generation of defensive and enemy COAs. It can also be easily adapted to other scenarios.

5.1.2 Contingency Theatre Automated Planning System (CTAPS)

The Contingency Theatre Automated Planning System (CTAPS) [13-14] is a theatre-level battle management system developed to respond to the specific needs of the US Air Force (USAF). It was established to meet requirements for a rapidly responsive Command, Control, Communications, Computers and Intelligence (C4I) system.

CTAPS is a command and control system that was designed to provide the ability to manage complex air/land battle operations. As a complex system, it was developed to help monitor a given situation and make an appropriate diagnosis. CTAPS is therefore able to generate, select and execute an operations plan.

The CTAPS development project has adopted a philosophy based on the use of a common core computer system. This approach has been implemented to provide mechanisms for the integration of mission-oriented software applications. In fact, the CTAPS core module is not designed to provide mission-oriented functions. Other mission systems are created, tailored and integrated into the core to provide mix applications. In this respect, the CTAPS core module can continually adapt emerging standards and technologies to meet the evolving needs of integrated applications.

The CTAPS core module is an open system with a reusable software environment, which has been critical to the evolution of the DoD-wide Theatre Battle Management Core Software (TBMCS). The TBMCS system is the future replacement for the CTAPS applications and communication interfaces that allow ground commanders to nominate, track and verify targets in the Air Tasking Order.

The CTAPS open module is an open architecture that includes and provides the following fundamental components:

- Host, network, database and security configuration software.
- A configurable support environment for functional user duty positions incorporating discretionary access profiles, a top-level human-machine interface (HMI) and communication utilities.

- US Message Text Format (USMTF) message parsing and preparation to be used to send and receive messages.

Focused on developing, disseminating and executing tasking orders, CTAPS mission applications include intelligence management, targeting and “weaponeering,”and air battle planning, dissemination and execution software. These applications include:

- The Advanced Planning System (APS);
- The Airspace Deconfliction System (ADS);
- The Computer Assisted Force Management System (CAFMS);
- The Force Level Execution (FLEX);
- The Joint Munitions Effectiveness Manual (JMEM);
- The Rapid Application of Air Power (RAAP);
- The 5D Imagery Server; and
- The Theatre Integrated Situation Display (TISD)/JTIDS- Modular Air Operation Center (MAOC) Integration (JMI).

5.1.3 Joint Assistant for Development and Execution (JADE)

The Joint Assistant for Development and Execution (JADE) [15] is being developed through new techniques to suit increasing needs for rapid deployment planning in crisis situations. This effort is conducted within the ARPA-Rome Planning Initiative to design and produce a system that can be incorporated in the Global Command and Control System (GCCS).

Although the JOPES is currently used in GCCS, military planners intend to move beyond JOPES-like tools to overcome the shortcomings associated with the speed at which TPFDD is generated. JADE is therefore being developed to respond to the need to use a system that can provide the required information in support of time-sensitive planning.

Like today’s planning and decision support systems, the transition of JADE to a fully operational system requires the need to integrate various data systems, seek user input and buy-in, port to new computing environments, assure compliance with the Defence Information Infrastructure Common Operating Environment, and finally, test in exercise scenarios. Based on AI technology, JADE implements case-based and generative planning methods to provide the ability to handle large scaled and complex plans. The system is designed to enable the rapid retrieval and reuse of previous plan elements. Using map-oriented drag and drop interface, JADE will offer the opportunity to drag force modes used in previous plans from the plan library and drop them into a geographic destination.

JADE architecture (Figure 3) integrates major software modules, such as the Force Module Analysis and Management Tool (ForMAT), “Prodigy”and

"PARKA." The resulting system is designed to enable a user to modify force compositions, describe force capabilities and tailor the evolving force deployment plan to changing mission requirements. JADE uses mission guidance and task force information provided by the Adaptive Course of Action (ACOA) tools to build a deployment plan.

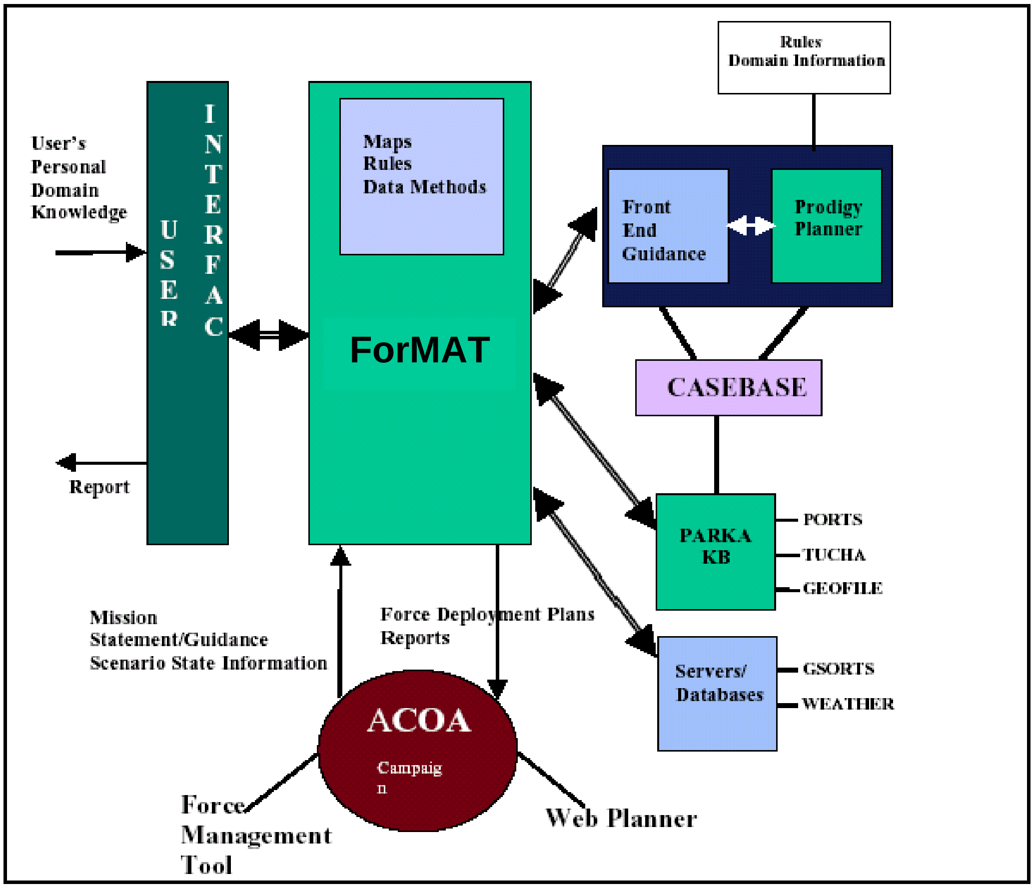

Figure 3. *JADE Architecture [15]*

5.1.4 Dynamic Analysis and Re-planning Tool (DART)

The Dynamic Analysis and Re-planning Tool (DART) [8] is a user-interactive information system that assists military planners to develop and analyze war plans for deploying large numbers of troops and equipment. Each deployment plan is defined by the TPFDD**, which** describes the movement requirements for troops and equipment.

DART is part of a set of automated data processing tools plus a database management system designed to provide the ability to rapidly create, view and edit TPFDDs and analyze the transportation feasibility of a plan.

It allows planners to modify TPFDDs, and set up and run strategic transportation models in a matter of minutes. In other words, DART provides the ability to consider more alternatives and produce a potentially feasible course of action in less time.

The Integrated Feasibility Demonstration (IFD-1) was launched in March 1990 as part of the ARPA-Rome Planning Initiative to create DART, a system designed to support the US Transportation Command (USTRANSCOM). Spurred by the needs of Operation Desert Shield, the development phase was increased in August 1990. After eight weeks of intense effort conducted on site at USTRANSCOM, a sufficiently mature system was ready and moved to the US European Command (USEUCOM). DART was then used to help plan the movement of troops and equipment from Europe to Saudi Arabia between November 1990 and January 1991.

Although the DART prototype showed satisfactory results at USEUCOM, it remained a fragile system. From January to July 1991 (Phase 2), a list of problems was compiled and the user interface was improved and unified to enhance the system. October 1991 marked the start of the deployment phase (Phase 3) of DART. The system was fielded to 13 sites, where it was used and evaluated by military planners on a daily basis.

In April 1992, Phase 4 was initiated to transition DART into the World Wide Military Command and Control (WWMCC) ADP Modernization system through the Technology Insertion Project (TIP). This offered the opportunity to add several enhancements to the system. Finally, in July 1992, DART was successfully completed and transitioned to the Defence Information System Agency (DISA) as an operational system.

5.1.5 Anticipatory Planning Support System (APSS)

The Anticipatory Planning Support System (APSS) [16-19] has been developed by the Department of Computer Science at Texas A&M University to provide a sophisticated automated decision support system for the planning and execution of military operations. Based on a new approach proposed by a retired US Army General, the APSS prototype was built to mix planning and execution, and to provide the capability to anticipate events rather than react to them.

New techniques from several areas such as AI, planning, inference mechanisms, evolutionary algorithms and software agents have been modified and applied to tackle military planning in such complex environments.

In the traditional planning process, only one COA is chosen for use during execution. This new approach allows the ability to develop and maintain as many possible friendly actions against as many enemy actions as possible.

The plan is described in Figure 4 as a tree with nodes and branches representing actual or predicted states (option points in the plan) and the transition between those states. Using inference mechanisms for determining branches, the goal is to develop as many branches as possible in the initial planning process and to modify and update the plan during execution.

As the operation progresses, invalid future branches will be pruned and new ones developed and predicted using simulations well before their execution state. In other words, APSS combines execution monitoring and planning by comparing anticipated and planned states to predict deficiency and allow replanning.

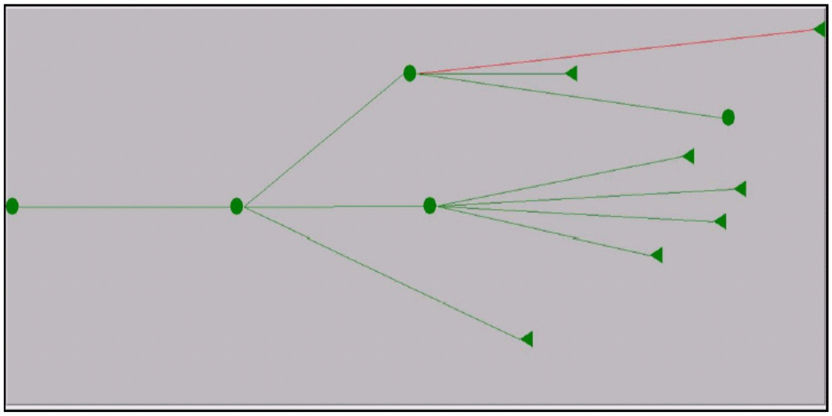

Figure 4. *APSS plan description [16]*

As depicted below in Figure 5, the overall architecture of the APSS prototype system includes the following major components:

1. **World View** and **World Integrator:** Information on the actual state of the operation is monitored by the World Integrator and passed to the World View module after processing. The World View receives this information through a series of Application Programming Interfaces (APIs) and converts it so that Execution Monitors can easily interpret it.

2. **Execution Monitors:** Using forward simulation from the actual state, Execution Monitors generate an anticipated state at the node of interest. It also determines the significance of differences between the anticipated state and the planned state at a particular node and, if replanning is necessary, a recommendation is sent to the *Planning Executive*.

3. **Planning Executive:** Using the inputs from the *Execution Monitors*, the Planning Executive controls the overall operation of the APSS system. While monitoring the use of system resources, the Planning Executive determines the priority of planning. According to the differences between the plan and the actual operation, the Planning Executive can

control the activities of the *Planners* and *Execution Monitors* by anticipating future branches to the plan.

4. **Plan Description:** Based on inputs from the *Planners*, *Execution Monitors* and *Planning Executive*, the Plan Description is built to represent and manage the plan tree. Possible alternatives to the operation progress can also be shown. The plan can be manually modified by a human planner using the Graphical User Interface (GUI).

5. **Planners:** After receiving a state (either planned, anticipated or actual) with a mission objective from the *Planning Executive*, Planners develop new branches and determine their viability. A *Branch Generator* is invoked by using a genetic algorithm and inference mechanisms. A discrete simulation is then used to generate a new-planned state at the end of the developed branch. The planner then invokes a *Branch Evaluator* to examine and assess the Branch, using simulation and inference mechanisms.

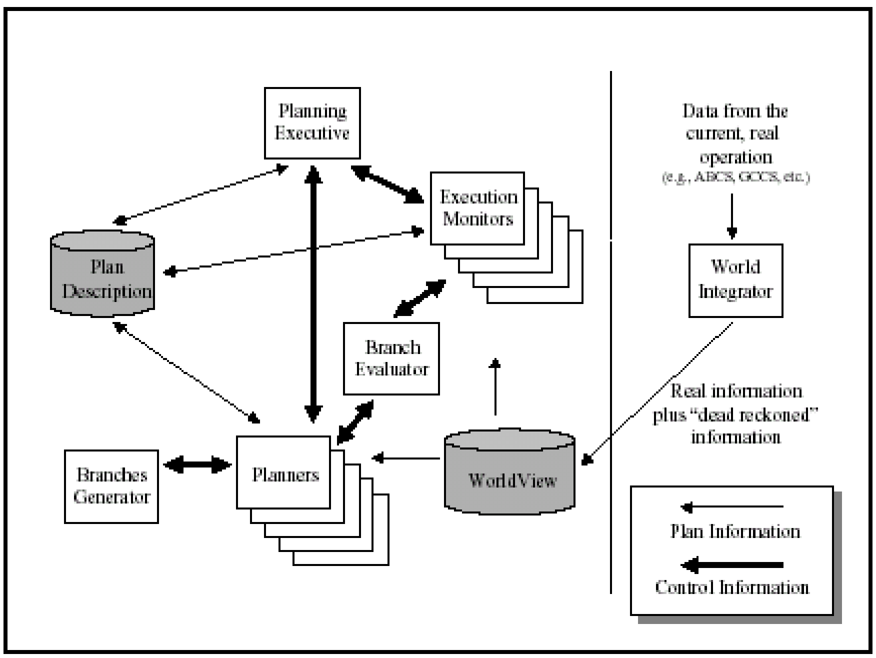

Figure 5. *Architecture of APSS [17-19].*

5.1.6 Time-Phased Force Deployment Data Editor (TPEDIT)

Developed by Ascent Technology [20] during Operation Desert Shields, the Time-Phased Force Deployment Data Editor (TPEDIT) is a temporal constraint-based tool, which was designed to help military planners plan troop deployment. It provides the capability to enter, manipulate, and analyze force and movement requirements.

Operationally employed by the US Atlantic Command, TPEDIT provides the ability to graphically represent Time-Phased Force Deployment Data, using the Gantt chart. Taking into account successful scenarios stored in an ORACLE database, TPEDIT allows planners to modify their content, as well as the ability to build new content.

5.1.7 Collaborative Operational Planning System (COPlanS)

The Collaborative Operational Planning System (COPlanS) [21] is a workflow-based prototype developed at DRDC Valcartier, which supports the Canadian Force Operations Planning Process. Although it is mainly intended to support the Operational Air Force, it can be applied to more complex environments, such as joint operations.

The COPlanS mediates group decision-making in the creation and selection of a common COA, providing an integrated flexible suite of planning, multi-criteria decision-aid and analysis tools. It is a mixed-initiative decision-support environment, which involves multiple users exploiting web-based tools, as well as some capabilities to integrate selected group decision-making commercial off-the-shelf technology software. It also includes a variety of computerized tools and graphical user interfaces to facilitate visualization and cognitive tasks (planning, simulation and information retrieval). Workload and decisions in dynamic situations remain entirely devoted to humans, however. The system prototype has been tested during multiple international military exercises and is currently subject to military trials.

COPlanS provides the ability to plan an operation in a net-centric environment with integrated collaborative tools. The system offers functions to design and manage multiple concurrent distributed battle rhythms at different planning levels. The system helps to synchronize workflow, document processes, and replay the decision-making path. Planning tools allow sketching COAs on maps to perform time and space synchronization, manage capabilities and ORBAT (Order of Battle), and perform logistics analyses. The decision-aid tools rationalize the process, improve the COAs evaluation and comparison, and quickly produce documents to support Commander's decisions. COPlanS also has interoperability capabilities with C2IS, COP21 [2]Portal, CPIGS, and other systems.

COPlanS provides the following modules:

[2] Common Operation Picture

a. **Workflow management module:**

i. *Workflow Designer:* Access a predefined list of activities; create or modify an activity; drag and drop an activity and logic components; link components in the desire flow logic; load/save workflow template; create multi-level workflow (sub-workflow);

ii. *Control Centre:* Instantiate a workflow template; assign users/role to the activities; assign workflow leader; start workflow; manage a workflow in progress (e.g. reassign user, modify logic, and skip activity); cancel workflow in progress; email notification to assigned users;

iii. *Activity Centre:* Display assigned activities to user; display detail information on a specific activity; start activity with the associate tool; skip the activity; forward activity to another user; manage multiple mission/context;

iv. *Consultation Centre:* Display a graph view of the workflow evolution; display the users/team work status for each activity of the workflow; display and access/open, in read mode only, the documents produced or associate with the workflow; access multiple missions/contexts.

v. *Document Repository:* Display documents produced or associated with a particular workflow or activity; display detailed information of a particular document; access/open documents; add/remove documents to the repository; manage concurrent access to documents

b. **OPP (Operations Planning Process) Modules:**

i. *Initiation:* Gather the tools needed to do mission analysis; obtain Higher Headquarters order or plan; obtain maps of the area of operations; obtain SOPs from own and higher headquarters; determine the time available from mission receipt to mission execution; determine the time needed to plan, prepare and execute mission for own and subordinate units; determine staff estimates already available to assist planning; obtain Commander's initial guidance; obtain warning order; initial intelligence preparation of the battlefield (IPB) products; restated mission of commander's intent and commander's guidance; initial time allocation; initial reconnaissance to begin; authorized movement; issue warning order to subordinate and supporting units.

ii. *Mission Analysis:* Conduct initial IPB; determine specified, implied and essential tasks; review available assets; determine constraints; identify critical facts and assumptions; conduct risk assessments; determine initial commander's critical information requirements (CCIR); determine initial reconnaissance annex; identify planning requirements; write restated mission; automatically produce a mission analysis briefing; approve the restated mission; develop the initial commander's intent; issue commander's guidance; issue a warning order; review facts and assumptions.

iii. *COA Development:* Gant planning; hierarchical task decomposition; ORBAT browser that displays all available information on ORBAT resources; assign resources to task using the ORBAT; search for past COA similar to current mission/context; develop new COA based on an existing one; automatically produce a COA development briefing; visualize the different phases of the COA on a GIS; collaborate on map planning; map and Gant planning synchronization; generate COA SOR.

iv. *COA Analysis:* Manual structured analysis of COAs (war gaming); compute and display criteria aggregation; display an overview of all proposed COAs.

v. *COAs Comparison:* Trade-off analysis of the decision criteria; graphically fine-tune criteria importance; what-if analysis: graphically modify the criteria values and compare the difference with the initial values; compute and graphically display the sensitivity of criteria values modification; compute and display the COA ranking in a global evaluation or for a particular criteria; produce decision brief.

vi. *Decision:* document the commander’s decision; document after action reports; ability to link with a lessons-learned database.

vii. *Plan Development:* parsers the COA into mission requests; generates warning orders; generates the OPLAN; sends the ABP[3] to TBMCS[4]/TAP[5]; logistic check.

viii. *OPP Profiler:* case-based reasoning tool to propose/update checklists/templates and SOPs based on the mission initial/updated parameters/tasks.

ix. *Cost Calculator:* Querying tool to extract accurate manning, elements and cost figures, from the TO&E/dimensions and cost data for material, personal, elements and shipping.

x. *Readiness estimator:* Readiness estimation is a complex issue. However, through the ability to access updated database about the real resources and capabilities, it is possible to check this availability at any given points in time. It is intended to introduce a criterion that will evaluate qualitatively the readiness based on information fusion of multiple readiness indicators.

xi. *Risk Manager:* The risk manager should support the new risk analysis methodology proposed in the new CF OPP manual (described in Figure 1, see also [27]).

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[3] Air Battle Plan
[4] Theater Battle Management Core System
[5] Tactical Air Planning

c. Collaboration module:

i. *Chat:* A collaborative session is available for each context (context can be defined as a mission, workflow or activity); private chat; invite a user to join a session, save/retrieve tagged chat sessions; display users status currently in a session; join/leave a session; instant messaging.

ii. *Geo-referenced white boarding:* Whiteboard tool available by session; whiteboard drawing tools; use a map as whiteboard background; insert text and military pictograms in the blackboard; save/retrieve a picture of a whiteboard snapshot.

iii. *On Map Collaborative Planning Tools:* COPlanS uses the LuciMap of Luciad GIS tools. LuciMap is compliant with Open GIS Standards. It offers full-integrated functions to support COPlanS requirements and supports Military Symbols. J2 IM would evaluate Luciad Tools. The team is confident that the COPlanS GIS Tool is compliant with the different CF C2IS Geomatic Requirements.

iv. *Virtual presence awareness:* Display other users status.

d. Administration Module:

i. *COPlanS Console:* Allow the user to login into COPlanS with a specific role and access the application; start and access the available module of COPlanS; start COPlanS from the COP21 Portal.

ii. *System Management:* Create/modify a user; create/modify a team; assign/remove a user to/from a team; assign/remove permission to a user/team; assign/remove a role to/from a user/team.

COPlanS architecture: The COPlanS is based on distributed application architecture. It is a Client-Server system architecture with different layers, which is developed using the WEB-Technology concept. Different Client configurations are engineered, such as Web, Light and Full clients.

COPlanS data structure: The data and meta-data models are generated using Sylverun. Three databases are managed by COPlanS: an Oracle 9i database, an application database, and a Luciad GIS database. A data business layer manages all the databases which makes COPlanS independent of the dataset management systems.

5.2 Airlift Resource Allocation and Transportation Systems

Transportation is an important branch in military activities, as it supports and makes possible most other miltary activities, including logistics, deployment, and air-to-air refueling. Civil as well as military transportation operations are one of today’s most important activities. This is measured not only by their share of the gross national product (GNP), but also by the increasing influence that the transportation and distribution of goods have on the performance of virtually all other sectors.

5.2.1 Joint Operations Planning and Execution System (JOPES)

The Joint Operations Planning and Execution System (JOPES) [4-6 and 22-25] has been designed to support joint planning, execution and monitoring activities from the National Command Authorities (NCA)[6] level throughout the Joint Planning and Execution Community (JPEC)[7]. This all-level, joint conventional command and control system is the principal system within DoD that provides the ability to translate NCA's policy decisions into combatant commander's joint operations.

The system was developed to replace and integrate the planning capabilities of the deliberate Joint Operations Planning System (JOPS) and crisis-action Joint Deployment System (JDS), and is a comprehensive integrated system of personnel, policies, procedures, training and reporting structure supported by automated systems and applications for planning and execution. The Global Command and Control System (GCCS)[8] currently provides Automatic Data Processing (ADP) support for the JOPES.

Designed to support the mobilization, deployment, employment, re-deployment and sustainment associated with joint activities, the JOPES system is used for deliberate planning during peacetime conditions to develop OPLANs and CONPLANS, with or without TPFDDs, and Functional Plans. In crisis situation, JOPES is used for Crisis Action Planning to support a time-sensitive development of Campaign Plans, as well as Op Os for execution. Used to develop and manage TPFDDs in the Operation Desert Shield for the first time in real world operational deployment, the JOPES applications are grouped by functions as follows:

- **Requirements:** Requirements Development and Analysis (RDA) for TPFDDs edition and analysis and COA transportation feasibility, Force Module Editor (FMEDIT), and GCCS Status of Resources and Training System (GSORTS) for units status and location.
- **Transportation and Scheduling**: Joint Flow and Analysis System for Transportation (JFAST) for transportation feasibility of an OPLAN or COA, Scheduling and Movement (S&M), and Transportation Component Command External System Interface (ESI) links JOPES and TCC scheduling systems.

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[6] The NCA, which includes the US President and the Secretary of Defense, sets the national policy and strategic direction of the US Army.

[7] The Joint Planning and Execution Community (JPEC) includes the Chairman of the Joint Chiefs of Staff (CJCS), down to the combatant commanders (CINCs) and the joint task force commanders.

[8] Developed to replace the World Wide Military Command and Control System (WWMCCS), the GCCS, a Command, Control, Communication, Computer, and Intelligence (C4I) system, is an integrated architecture of telecommunications, software, and computer equipment.

- **Sustainment Modeling:** Joint Engineer Planning and Execution System (JEPES) for civil engineering planning, Force Augmentation Planning and Execution System (FAPES) for mobilization planning, Individual Manpower Requirements and Availability System (IMRAS) for manpower and personnel planning, Logistics Sustainment Analysis and Feasibility Estimator (LOGSAFE) for logistics planning, and Medical Planning and Execution System (MEPES) for gross medical feasibility and supportability assessments of OPLANs.
- **Reports and Retrievals:** Ad-Hoc Query (AHQ), Reports.
- **System Resources:** System Services (SS) for database management, Reference File Administration (RFA) for reference table update and maintenance, and JOPES Information Trace (JSIT) Commands.
- **Communication:** Internet News, Internet Chatter, and Secret Internet Protocol Router Network, SIPRNET Web (SWEB).

Operating in a classified, shared data environment on the SIPRNET, the JOPES allows US Military Departments and Commands to link with Joint War Planners through the following automated systems (Figures 6 and 7):

- The Deliberate Crisis Action Planning and Execution System (DCAPES)[9] is the new interface between Air Force planners and JOPES.

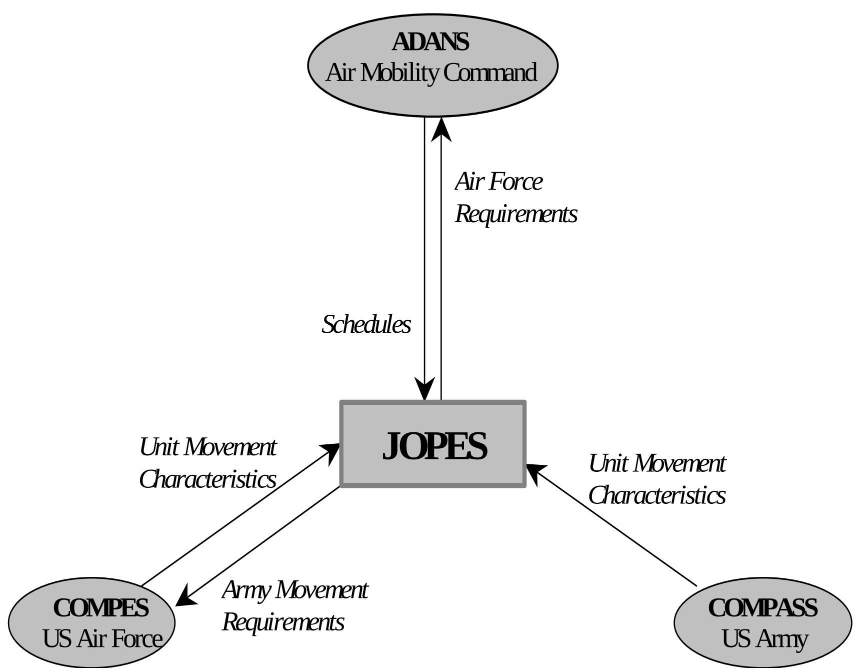

Figure 6. *ADANS interfacing with JOPES.*

[9] The Deliberate Crisis Action Planning and Execution System (DCAPES) replaced the Contingency Operations and Mobility Planning and Execution System (COMPES) in March 2002.

The Computerized Movement Planning and Status System-Army (COMPASS-A), a logistical system that supports deployments, re-deployments, mobilization planning and the execution of any military operation, provides accurate and timely strategic transportation data to JOPES.

- The US Marine Corps (USMC) uses the Marine Air Ground Task Force (MAGTF II) system between the USMC family of automated information systems and JOPES.
- The Air Mobility Command (AMC) is linked to JOPES through the Consolidated Air Mobility Planning System (CAMPS)[10].

5.2.2 The System for Operations Crisis Action Planning (SOCAP)

The System for Operations Crisis Action Planning (SOCAP) [26-28] was developed by SRI International to provide decision support for planning a course of action in response to a crisis. In this context, SOCAP was built to integrate mature AI planning systems in order to provide military planners with advanced capabilities required to produce more flexible and accurate joint military courses of action.

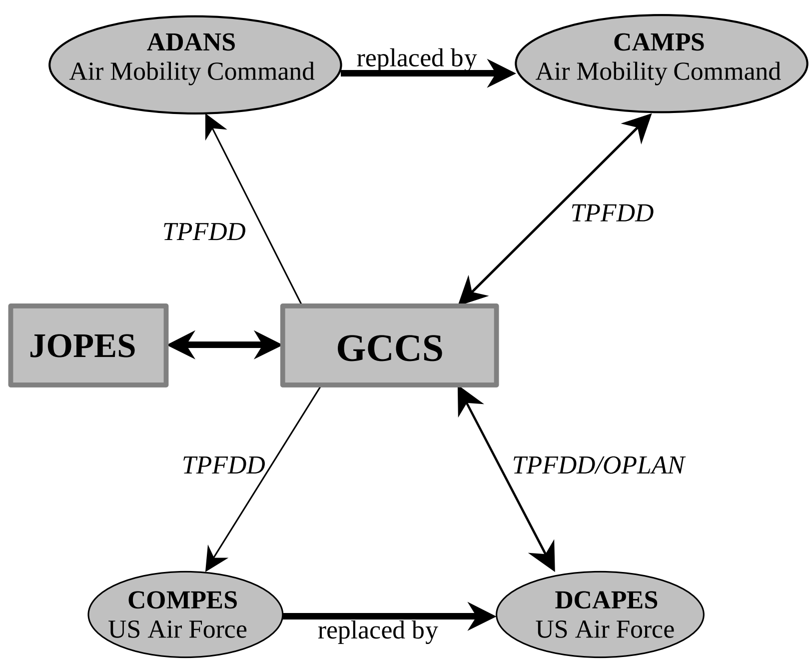

Figure 7. DCAPES and CAMPS interfacing with GCCS and JOPES.

[10] The Consolidated Air Mobility Planning System (CAMPS) replaced the Air Mobility Command (AMC) Deployment Analysis System (ADANS) in February 2002.

SOCAP was developed as part of a project conducted through consultation with US Central Command (CENTCOM) military planners to elicit and implement their knowledge and requirements of a complex planning process. The project led to a new and highly sophisticated planning and execution system based on the integration of several high performance AI technologies. The integration procedure was designed to extend SOCAP's core reasoning engine, a generative AI-based System for Interactive Planning and Execution SIPE-2, so as to provide the ability to incorporate various independently developed AI tools. The approach aimed to tackle the limitations of an original version of the system developed as an application of SIPE-2 designed to plan military operations. The resulting overall system was tested in early 1992, both at CENTCOM and at the Pentagon, to demonstrate its ability to generate robust and feasible plans with realistic allocation of resources and to allow feedback from scheduling operations. As a result of user feedback, the core module SIPE-2 was extended to allow specification of the order in which goals are pursued.

SOCAP was later integrated with other modules to produce the Air Campaign Planning Tool (ACPT). This system was designed to capture and codify the experience of air campaign planners in Desert Storm so as to enable them develop a workable operational plan -- which would have consumed months of manual effort -- in just 36 hours.

The development of SOCAP taught the designers valuable lessons associated with the task of inserting independently developed technologies. SOCAP also showed that state-of-the art AI technology could address operational scenarios well. Finally, it outlined the need to pay sufficient attention to existing user processes.

Within the ARPA-Rome Planning Initiative, the Integrated Feasibility Demonstrations (IFDs) were developed for various joint commands of the US Army. Built around specific types of military planning situations, IFD-2 was conducted in January 1991 to uncover the strengths and weaknesses of SOCAP. It focused on strategic and transportation planning for a typical small-scale, primarily defensive, military operation to demonstrate advancements in generative planning. IFD-2 thus provided the opportunity to outline the operability and applicability of AI planning technology to the military domain requirements being addressed, and helped to identify specific technology gaps in SOCAP. As a result, SOCAP was extended to incorporate other tools to enhance its capabilities.

As an overall system based on the integration of various independently developed AI subsystems, SOCAP architecture, shown in Figure 8, incorporates advanced generative planning, temporal case-based reasoning, scheduling techniques, and capacity analysis to generate military operations plans. Through the integration of various mature AI based subsystems, SOCAP was designed to provide the following capabilities:

- To help planners select the correct operations to form a set of plans;

- To maintain dependencies and check consistency among the operations in a plan;
- To set up input for different feasibility estimators; and
- To support changes to the plan.

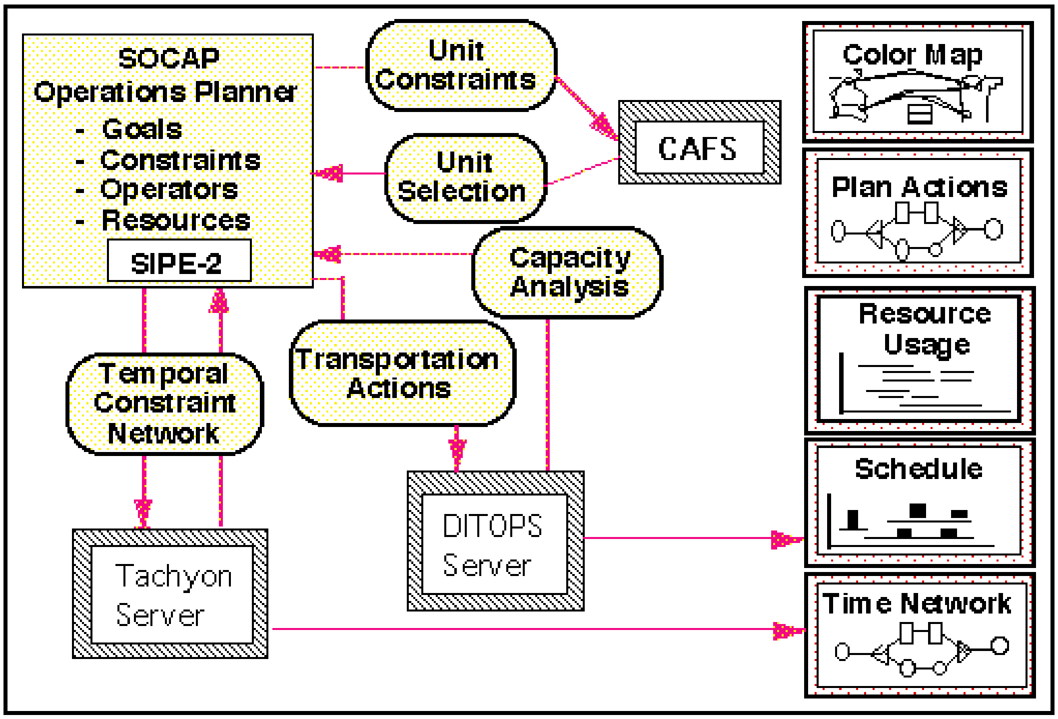

Figure 8. *SOCAP Architecture [27].*

At the heart of SOCAP is SIPE-2, a hierarchical, domain-independent, non-linear planning subsystem with powerful formalism for representing domains and generating partially ordered plans. As a result, SIPE-2 provides the core-reasoning engine for plan generation. The architecture and interactive abilities specific to SIPE-2 offered the opportunity to integrate additional technologies into SOCAP as a way to satisfy military requirements.

At the beginning, SOCAP was unable to reason about the utilization of resources or place temporal constraints between actions in the plans. This shortcoming was associated to the limited temporal reasoning capability of SIPE-2. In this respect, SOCAP's ability to represent and reason about time was extended through an additional layer placed on top of SIPE-2 so as to keep track of the temporal constraints within a plan. The added module is Tachyon, a general-purpose constraint-based subsystem developed by GE's R&D Centre to provide temporal reasoning. The interface to Tachyon is a general tool designed to allow the incorporation of a different temporal reasoning subsystem.

A user of SOCAP initially had to rely on personal preferences to select a unit form a list that meets the constraints of the operator. As a result of this, users wanted to be able to modify the list. The need to select and tailor a force was seen as a request that would be dealt with through the introduction of case-based reasoning mechanisms. A Case-based Force Selection (CAFS) was therefore incorporated to enhance the capabilities of SOCAP. Developed by the GE Research and Development Centre, CAFS was modified to handle SOCAP objects and operators. Instead of presenting a list of units to the user, SIPE-2 was modified to call the CAFS module for major force selection.

The need to get feedback from external plan feasibility evaluation tools in order to produce better and more transportation-feasible plans was demonstrated within IFD-2. To overcome SOCAP's simplified model of resource management, a constraint-based scheduler called Distributed Transportation Scheduling in OPIS (DITOPS) was thus integrated to assess the feasibility of the partial plan, taking into account the transportation-resource capacity requirements. DITOPS was initially developed by Carnegie Mellon University as a tool for generating, analyzing and revising crisis-action logistics schedules. Indeed, the IFD-2 version of SOCAP was modified to call DITOPS at various stages of the search through the space of possible plans.

As shown in Figure 9, the input to the system includes a description of the mission, threat assessments, terrain analysis, apportioned forces, transport capabilities, planning goals, key assumptions, and operational constraints. Based on this data, SOCAP is set to generate and address plans with known military employment and deployment actions. The system then generates a plan representation that can be displayed or excerpted in different ways to suit different purposes: a network and map display, time-phased actions for transportation analysis, or natural language.

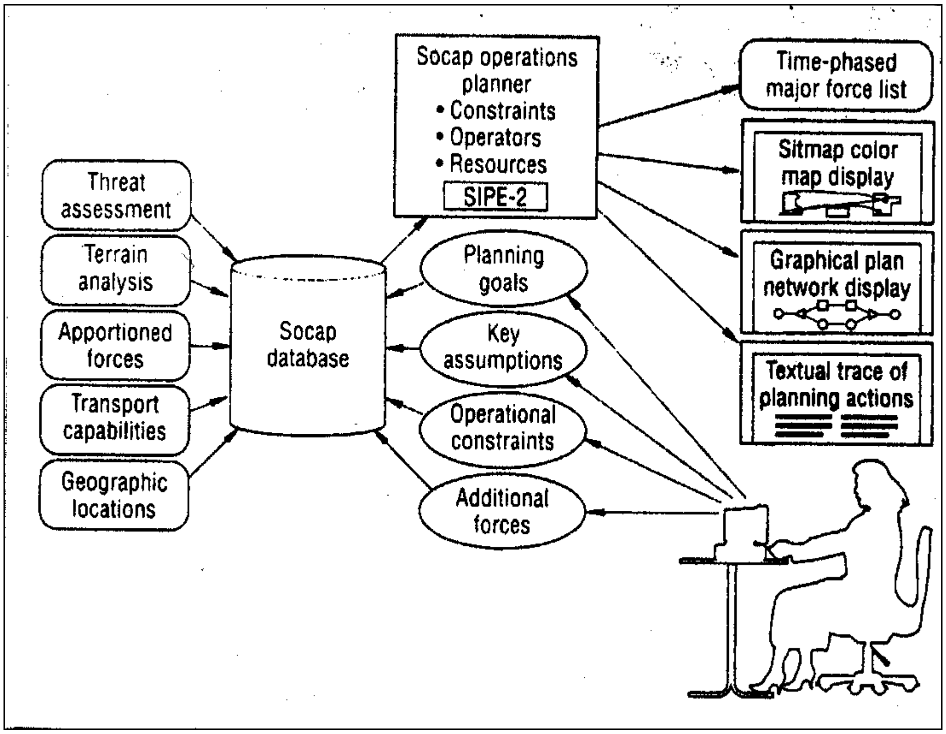

Figure 9. *SOCAP Functional Representation [8].*

5.2.3 Airlift Deployment Analysis System (ADANS)

The Airlift Deployment Analysis System (ADANS) [29] is designed to provide the Air Mobility Command[11] (AMC) with integrated automated airlift and air refuelling planning, and a scheduling and analysis system to support peacetime, crisis, contingency and wartime operations. Developed by Oak Ridge National Laboratory, this system is currently maintained by Logicon Inc. as a part of the effort to merge its functionality and capabilities with those of the Combined Mating and Ranging Planning System (CMARPS) to create the Combined (Consolidated) Air Mobility Planning System (CAMPS).

One of the major goals of this system is to integrate the existing slower scheduling systems into a faster single system that would have a common user interface and a centralized database. The first component of ADANS was operational in early 1990, and replaced the Advanced (or Aviation) Mission Planning System (AMPS). Later, it was successfully used to plan and schedule airlift missions for Operations Desert Shields and Desert Storm to support the Persian Gulf War, for refugee relief and for disaster response.

[11] The Air Mobility Command (AMC) is the successor of the Military Airlift Command (MAC) which was a major command of the US Air Force and a component of the US Transportation Command (USTRANSCOM).

As shown in Figure 6, ADANS represents the Air Mobility Command to support the JOPES. Integrated into the Global Command and Control System (GCCS) (Fig. 7), ADANS provides the mission planner with a set of decision support tools for matching movement requirements with airlift resources in order to create a schedule for an airlift operation. In other words, ADANS provides the ability to:

- Enter and evaluate cargo and passenger movement requests such as the use of commercial or military aircraft.
- Allocate airlift resources, including aircraft availability and characteristics, crews, airfield resources and airlift network configuration.
- Create schedules for routine *channel missions* (regular routes to deliver mail, food, etc.), *quick response missions* (movement of critical items on extremely short notice), *civilian aircraft missions*, and *time-phased airlift flow missions* (movement of multiple military units from one or more on-load airfields to one or more off-load airfields).
- Analyze schedules using tools that allow mission planners to quickly and easily evaluate any individual mission details. In addition to textual displays, movement requirement deliveries, resources commitments and aircraft activities can further be analyzed using graphical displays such as the rainbow chart.
- Distribute the schedule to AMC's worldwide command and control systems in order to follow and manage each aircraft throughout its mission.

When the data available is imprecise and an early high-level analysis is required, the mission planner has the ability to use the ADANS's "Quick Course-of-Action Evaluation Toolkit" (QCOA) to create a "plan set." The results can be used to complete the detailed scheduling process, as the requirements and aircraft allocation become known.

5.2.4 Consolidated Air Mobility Planning System (CAMPS)

CAMPS was developed by Logicon Inc, a Northrop Grumman Corporation company, and other companies and research establishments such as BBN Technologies, Kestrel Institute and Carnegie Mellon University [30-34]. The system is designed to support the rapid deployment of the Air Mobility Command (AMC). Responsible for scheduling, executing, and monitoring airlift operations to carry out the global deployment of US forces, AMC uses CAMPS for planning and scheduling airlift missions.

The CAMPS mission planner (MP) provides the ability to rapidly build AMC's portion of the Time Phased Force Deployment Data (TPFDD) that supports the projection of combat forces required to enable the command to deploy combat-ready forces.

Indeed, the CAMPS-MP is designed to work against an organization-wide database to provide unified planning and control of AMC operations. Integrated into the Global Command and Control System (GCCS) (Fig. 7), the CAMPS-MP provides the mission planner with an integrated view for planning and scheduling air mobility resources to support peacetime, contingency, humanitarian and wartime operations.

The CAMPS-MP provides advanced user capabilities for operational planning and allocation management. It has a graphical user interface for specifying input parameters, and a variety of views of the schedules produced, including maps, tables and charts. Based on a set of requirements, the task faced by a user of the CAMPS-MP is to specify a set of suitable aircraft resources and ports to be made available for refuelling (or locations for aerial refuelling), and to ensure that the schedule produced moves all of the requirements by their due dates.

5.2.5 Contingency Operations/Mobility and Execution System (COMPES)

The Contingency Operations/Mobility Planning and Execution System (COMPES) represents the US Air Force (USAF) planning system used to support the JOPES. Interfacing with JOPES (Figs. 6 and 10), COMPES provides USAF planners access to near real time logistics, manpower and personnel data, including the entire Air Force – Active, Guard, and Reserve. While JOPES provides the TPFDD (Fig. 7), COMPES translates and tailors the operations plan for Air Force tasking. In this respect, COMPES supports deliberate planning by translating joint tasking into detailed unit tasking and then defines and tasks the manpower and equipment required.

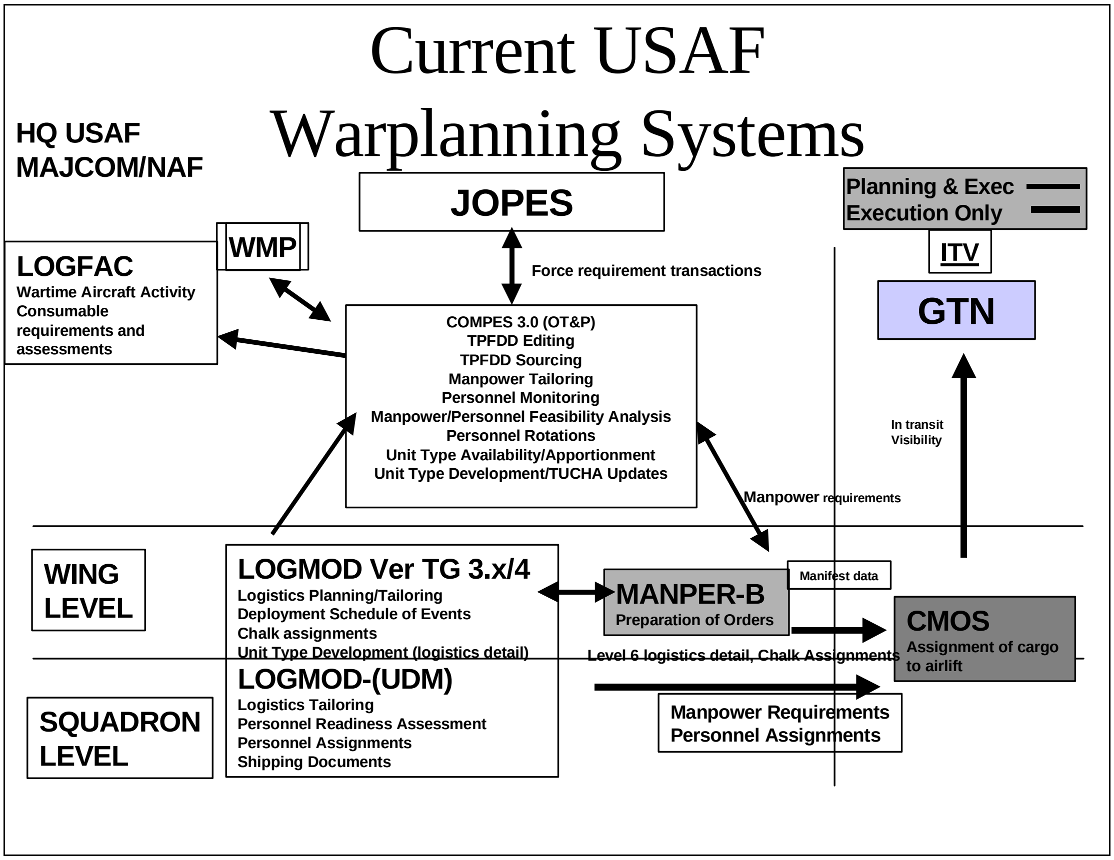

***Figure 10.** COMPES interfacing with JOPES [4].*

COMPES is used to support planning functions not only within the Global Command and Control System (GCCS) operating environment/architecture at Headquarters United States Air Force (HQ USAF), Major Command (MAJCOM), and Numbered Air Force (NAF), but also at the base/unit. Within the GCCS operating environment/architecture, COMPES operates at the secret level to allow, as mentioned above, the USAF to support service and joint deliberate/crisis action planning and execution operations. At base/unit level, COMPES operates in the unclassified and classified modes to allow planners to receive deployment-planning tasks that support service and joint operations. As a result, it is used to provide the tools required to support deployment operations by assisting with the preparation of personnel orders, cargo manifests/documentation and tracking capabilities.

The COMPES system includes the following modules:

- Operational Tasking and Priorities (OT&P), and
- Logistics (LOGMOD).

OT&P is designed to coordinate the information flow between JOPES, Manpower and Personnel MANPER, and LOGMOD during the Operations Plan (OPLAN) tailoring process. On the other hand, LOGMOD is a computer program designed to manage the database containing logistics equipment and supplies for Air Force Unit Type Codes (UTCs).

5.2.6 Deliberate Crisis Action Planning and Execution Segment (DCAPES)

The Deliberate Crisis Action Planning and Execution Segment (DCAPES) [35] is an application of the GCCS designed to achieve the Chairman's, Joint Chiefs of Staff (CJCS) goal: develop a TPFDD within 72 hours. Operating in a classified, shared data environment on the SECRET Internet Protocol Router Network (SIPRNET), the DCAPES system is used to link Air Force Planners with Joint War Planners through the GCCS Joint Operations Planning and Execution System (JOPES) (Fig. 7).

Planned by the Air Force to replace the Contingency Operations and Mobility Planning and Execution System (COMPES), the DCAPES system provides data and data manipulation capability to Air Force planners and commanders to:

- perform rapid OPLAN development, and
- conduct feasibility and capability analyses.

The objective behind the DCAPES system lies in the need to integrate the Air Force "stand-alone" war planning systems into a single, logical database so as to bring the Air Force one step closer towards supporting the Integrated Command and Control System (IC2S) vision. Designed to support deployment, re-deployment, sustainment, mobilization and reconstitution, the DCAPES operating as a single system eliminates duplication of efforts and re-work, and improves the response time, while enhancing overall data integrity and accuracy.

DCAPES supports all levels of command, across the operational continuum using modern integrated tools, shared infrastructure, and common data consistent with the Air Force C2 Vision. While supporting collaborative planning, DCAPES offers the ability to track individuals and equipment from home station through deployment. Designed to be standard compliant, DCAPES is capable of coexisting with other established data systems.

5.2.7 Knowledge-Based Adaptive Resource Management Agent (KARMA)

The Knowledge-based Adaptive Resource Management Agent (KARMA) [36] is a prototype-automated mission planning system developed at DRDC - Valcartier. KARMA is conceived to alleviate concerns associated with a number of tactical mission planning tools operating in highly dynamic and uncertain environments. Substantial development efforts are focused on implementing advanced planning and scheduling technology concepts to automate the sequence generation process while responding in a timely fashion to a dynamic and unpredictable environment. Besides the ability to combine plan construction and execution, KARMA provides other features that allow plan repair to support continuous updating of a current plan in light of the changing operating conditions.

Motivated by the need to address requirements associated with real-time tactical mission planning subjected to various constraints in complex and uncertain environments, KARMA is designed to provide an open tool framework based on the blackboard paradigm. As a practical approach, a parallel agent-based blackboard-style architecture is implemented to allow the handling of complex tasks, multiple interactions among concurrently executing agents, communicating agents with heterogeneous sources of information, and resource-bounded reasoning issues. New features have also been added to the basic blackboard framework to offer more flexibility and adaptiveness as a way to enhance abilities and performance of the knowledge-based KARMA mission-planning tool.

As shown below, the overall architecture of the KARMA prototype system (Fig. 11) includes, among other features, the following components:

1. ***Blackboard Data Storage***. Based on an object-oriented database management scheme, the Blackboard Data Storage represents the common working memory used to support information flow and transactions. Other concepts associated with distributed systems and blackboard locking and data consistency reinforcement have also been considered, engineered and implemented to address concurrency control issues such as locking protocols and mechanisms, and effects of class inheritance, object encapsulation and delegation on locking protocols. The Blackboard Data Storage contains information that can be divided into various parts of knowledge grouped into structured knowledge bases. Formulated via a basic query language, information can be performed on searchable object characteristics through complex requests. Concurrency that can be disabled to allow conventional locking is automatically ensured through an autonomous locking strategy designed so that transactions acquire and release locks via operations on shared-memory. Moreover, concurrency reading and exclusive writing transactions are synchronously controlled by a locking mechanism encapsulated in a specialized object called monitor that preserves data integrity.

2. ***Knowledge Sources.*** KARMA is a parallel blackboard-based adaptive intelligent system used to accomplish specialized tasks through an expertise embodied within knowledge sources, which are executed concurrently. This execution corresponds to the activation of the action part aimed at changing the state of the blackboard (object creation, modification, deletion, goal posting, etc.) At first, the knowledge sources were implemented as procedural processing methods. Current research efforts, however, are focused on the development and implementation of anytime knowledge sources to address resource-bounded reasoning.

3. ***Control Unit.*** Embedded as a separate control thread, the control unit acts as a mediating component between competing knowledge sources to support the serial execution of various actions, namely knowledge source triggering, goal management, agenda management, knowledge source scheduling and execution. The control actions are achieved through specialized components involving all functions required to perform successfully and supervise/manage adequately.

As already stated, the blackboard control cycle involves a triggering process, goal management, agenda management, scheduling phase, and interpreting mechanism. The triggering action consists in extracting relevant objects from the event/goal input and performing condition verification. A knowledge source triggers exclusively on events or goals, depending on whether triggering condition input is associated to a blackboard event or goal.
A knowledge source is instantiated when a set of triggering conditions is satisfied. In this context, the data structure of a knowledge source instantiation conveys all relevant information. When a triggering action is completed, proper bookkeeping is achieved, thus leading to the second phase of the control cycle, which is goal management.

Following the triggering phase, the goal manager offers the ability to ensure goal achievement as new facts are compared with the blackboard. Hence, the goal manager is conceived to track/manage the evolution of a goal from generation to selection, and then, to goal achievement or failure. As it interacts with other control components, the goal manager provides the ability to process and move goals from one state to another.

Once a new generated knowledge source instantiation (KSI) is stored on the agenda into a triggered state, the agenda checks the obviation conditions for all KSIs, except those already deactivated. In this context, KSIs are disregarded, and moved into an obviated state when the obviation conditions are satisfied. Since this process is time-consuming and susceptible to creating a potential bottleneck for the control unit, various approaches are considered, ranging from process "parallelization" to making knowledge source obviation conditions event-selective. On the other hand, triggered KSIs that do not satisfy obviation conditions are moved into an "executable state" to be considered for further activation. That agenda is constantly updated through the agenda manager.

The next step of the control cycle consists primarily in selecting actions or scheduling KSIs. While ensuring that domain and computational resource constraints are met, the scheduler establishes which knowledge source(s) is to be executed based on control knowledge. To support adaptive resource planning and control, the classical scheduling scheme is extended and refined through the integration of meta-reasoning in the KSI selection process.

This approach is designed to introduce intelligent behaviour and resource-bounded reasoning capabilities into the control loop. Future work intends to explore a promising avenue regarding utility driven control derived from a particular form of planning-based control. The latter involves anytime computation in which a meta-level controller component performs deliberation scheduling and run-time monitoring of the next action(s) to be selected.

While reasoning about the interleaving of plan execution so as to guarantee response time, the meta-level can also achieve execution monitoring involving feedback to correct the system’s inability to accurately predict the effects of the control action on the behaviour of a controlled process.

In charge of scheduling, resuming, and interrupting the execution of a selected knowledge source, the interpreter can also interact with other control components so as to maintain the required blackboard data structures consistency at the appropriate time. The implementation of the interpreter involves the use of a Task Scheduler object in charge of timely scheduling tasks (knowledge sources). Using a separate thread, the Task Scheduler can monitor task(s) to be activated and manage the task queue. With its associated components, the interpreter can capture specialized object and methods so as to ensure task scheduling and execution/interruption and also provide the ability to modify information on a task queue as required or desired.

Finally, a blackboard agent can communicate with other agents, external feeds or a database through a communication manager. In achieving agent-to-agent communication task, the communication manager provides services using low-level functions embedded in communication libraries to support agent interaction at the transport level.

The communication manager is designed to manage synchronous and asynchronous communication through IPC and KQML links. Using the IPC link, the blackboard system can connect to an IPC server and maintain an online feed through an active channel. In addition, the communication manager also provides a higher-level message exchange between agents through KQML language specifications.

On the other hand, the communication manager involves a suitable interface component to translate data to be sent or received from the environment. Within the communication manager, the transaction manager is designed to properly ensure KQML message encoding and decoding and to perform transactions. Prior to the transit of messages via the transaction manager for further processing, agent-to-database communication is achieved through a specialized environment data or database server. The KARMA system in its current design employs a specialized data server with an ORACLE relational database to mediate transactions with the blackboard via the communication manager.

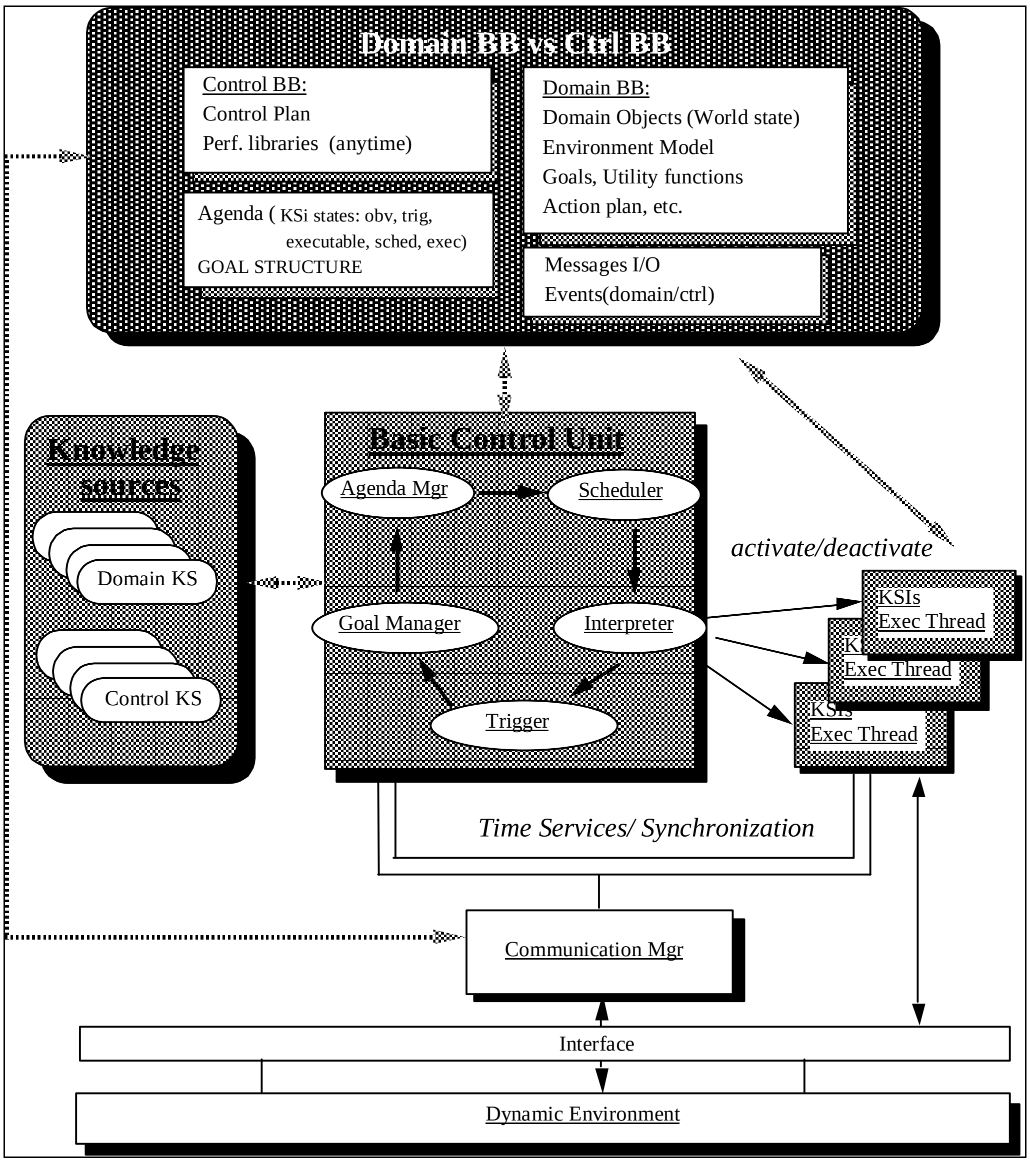

Figure 11. *KARMA Architecture [36].*

5.2.8 Decision Scheduling System (DSS)

Optimal resource management has been recognized as a critical issue to be addressed by the Canadian Air Force military community. In 1998, a joint venture involving university, private industry and DND was created to address simultaneous aircraft and crew scheduling (resource management) within the context of air operations management. The Decision Scheduling System (DSS) [37] for Simultaneous Aircraft and Crew Scheduling is a project for which the Defence R&D Canada-Valcartier is involved.

The project was aimed at developing a methodology and an operational and marketable implementation for the integrated scheduling of airframes and crews, as well as the selection of itineraries. Research focused on the development of an open-loop decision support system using innovative and promising algorithms and decomposition methods from Operations Research. The mathematical programming methodology was based upon a multi-commodity non-linear network static model using column generation as a problem-solving technique.

Targeted military application domains focused on air operations including operational Air Mobility and Tactical Aviation. Even though most modeling and solution implementation efforts were unexpectedly spent toward the Air Mobility domain, some minimal work has been reported on the mission-scheduling problem associated with Tactical Aviation. The problem involves the scheduling of tactical and training missions while simultaneously constructing aircrew schedules for tactical units or squadrons operating under the Army Aviation Fleet.

The line-tasking problem consists in selecting airlift requests and constructing strategic airlift missions to be achieved over a specific time horizon, and generating a periodic (monthly, yearly) airlift program. It can be described as follows: given a set of prioritized requests with time windows, construct a set of valid missions assembled in task lines in order to maximize the number of supported requests while minimizing operational cost subject to a variety of resources (aircraft attributes such as type and fleet size associated to each squadron) and mission constraints (e.g. maximum number simultaneous missions allowed at squadrons).

The operational cost is defined as the sum of travel times associated with scheduled missions. A mission characterizes a plan describing an itinerary for a specific aircraft, including its base and type, the sequence of supported airlift requests (legs) with temporal characteristics as well as related ground tasks (briefings, stops, etc.). A mission is assumed to start and end at the aircraft affiliated base. The generation of scheduled missions assumes the availability of static accurate information reflected through prior knowledge about the number of lines of tasking for each wing as well as the number of serviceable transport aircraft and types over the targeted time horizon. Crew training missions are also naturally interleaved to the monthly airlift program, imposing additional constraints while constructing the plan. More details on the line tasking problem description and its formulation (problem modeling) may be found in [37].

DSS relies on a natural and straightforward process. Based on a profile specification, the user can collect valid data inputs and specify directives to generate a scenario in which missions can be manipulated, and then submitted to the optimizer to provide a solution. The results can then be archived, retrieved or easily visualized. The DSS prototype includes six components, namely, the user manager, the input manager, the mission manager, the scenario manager, the optimizer and the output manager. Figure 12 shows these components and their relationships in the functional model. These components are briefly described next.

The user manager defines the user (planner) profile establishing privileges and preferences managing interactions with databases and connections to local and remote systems.

The input manager supports user interactions in specifying input information to be further submitted to the optimization component. Data inputs are generated and validated through specialized dialog and editing capabilities embedded in suitable interfaces. Accordingly, the user is provided with the flexibility to create or modify sets of inputs, either from scratch or based upon current and past scenarios imported from selected databases. Inputs include information such as airfields, bases, resource attributes and characteristics (aircraft types, number, availability, affiliation, permissible freight combinations, etc.)

User directives to instruct the optimization engine in mission generation are introduced with system dialogs through the mission manager. As such, the user defines the missions considered as input data for the optimization engine. The operator can either create a new set of missions from scratch, or modify an existing one. The mission manager supports user definition of airlift requests (sequence of legs, time windows, travel time, etc.) and related constraints, as well as explicit missions to be imposed by the user if needed. Solutions from previous optimization runs can also be displayed, edited and modified by the user before reactivating the optimization process.

The scenario manager provides the basic tools to piece together scenario elements and then organize or file the resulting scenarios created by the user on external data storage. This component allows the user to create, duplicate, access, destroy or store scenarios. A scenario is then submitted to the optimization engine.

Through a user-system dialog capability, the optimizer manager provides the user with the commands to activate and control the optimization engine for a specific scenario while monitoring its working status. The DSS automatically monitors the evolution of the running optimization process every three seconds and updates its status display. The optimization engine uses a column generation technique to solve the problem. Once a solution is found for a targeted scenario, the results are timely displayed for user consumption and then stored for future use and analysis. The user can easily retrieve stored scenarios and then initiate new executions or carry out further analysis. Should the situation change or assumptions no longer hold, the optimization process could be promptly interrupted or terminated.

The output manager provides the user with capabilities to visualize the computed solution based on different perspectives and formats. In addition, the output manager supports the edition of the solution enabling the user to shape the mission plans by accepting, modifying or rejecting partial results. As a result, a set of missions is finally presented to the user under the form of task lines. Optimization results are automatically appended and stored with their related scenario file.

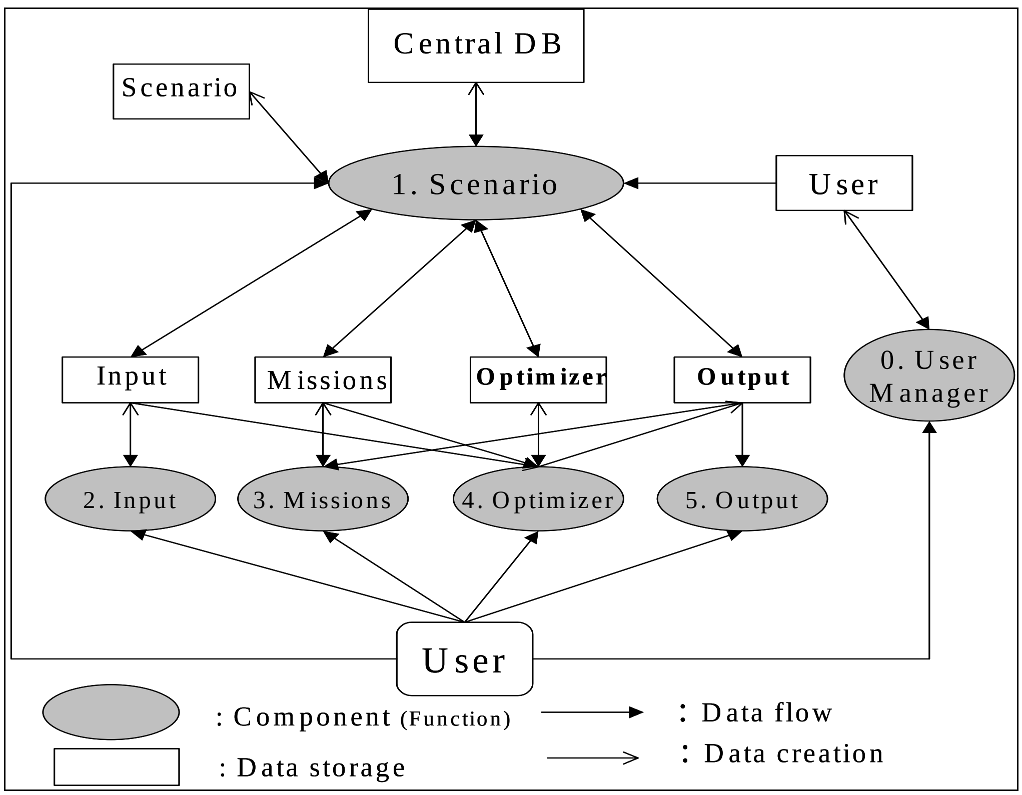

Figure 12. *DSS functional model [37].*

5.3 Flight Planning or Route Planning Systems

The flight planning or route planning systems are computer-based mission planning systems for tactical operations. These systems have been designed to:

- maximize the mission success as well as crew and aircraft survivability by performing optimal routes calculations;
- optimize the use of air assets;
- compute mission data such as weapon and fuel requirements, air refuelling schedules and transfer data to onboard computers; and
- provide support for mission rehearsal and aircrews.

5.3.1 In-Flight Planner (IFP)

The In-Flight Planner (IFP) [38] is a real-time, computer-aided mission replanning system designed to greatly increase flight safety and hence the survivability and effectiveness of an aircraft through continued reduction of exposure to threat. It is also designed to reduce pilot workload associated with the complex and time-consuming task of replanning a mission while operating the aircraft and weapon system.

The Real-Time IFP development project was launched as part of a major R&D program called the Mission Reconfigurable Cockpit (MRC). Beginning in 1992 with the award of a R&D contract to General Dynamics, Fort Worth Division, the MRC program was structured to lead to the development and implementation of novel technology that comply with cockpit requirements and advanced design concepts for future multi-role fighter planes. Within the MRC program, the Air Force Technical Planning Integrated Product Team (TPIPT) and Fighter Configuration Plans (FICOP) outlined the need for the development of an in-flight mission planning capability.

The availability of an on-board replanning capability is indeed critical as new events can significantly change the course of a mission and force the pilot to replan the mission based on the latest information. Initially, data output from ground-based mission planning systems, such as the Air Force Mission Support System (AFMSS) or the Navy's Theatre Automated Mission Planning System (TAMPS) is transferred to an aircraft platform through a Data Transfer Unit (DTU).

The relevant information transferred to the aircraft is related to the mission objectives, known threats and environmental data, target positions, aircraft and weapon systems parameters, as well as rules of engagement. As the system is initialized and the aircraft is airborne, the Real-Time IFP can then monitor various parameters associated with the environment, aircraft conditions, and pilot commands. As new information acquired is not likely to disturb the mission execution, the COAs obtained from the ground-based system are conducted as initially planned.

Given the uncertainty of the threat environment, it is unlikely that the mission plan would be executed as generated by the ground-based planning system. Indeed, significant events related to new threats, navigation errors, and pilot commands can occur and consequently affect the initial plan. The response would be either to abort the initial mission plan or accept a higher level of risk. The Real-Time IFP is designed to provide the ability to generate a new plan through a series of must-fly steer points, provided by the DTU or pilot via the Pilot Vehicle Interface (PVI). When a new plan is proposed, the pilot is allowed to accept or reject it. The initial plan can be maintained only if the new plan is rejected.

Unlike the ground-based planning environment, the cockpit of a single-seat fighter cannot obviously accommodate a large screen display and input devices. As a result, the Real-Time IFP can only operate with an appropriate screen display and reduced pilot input. In this context, the in-flight planning system is designed to operate almost autonomously, and with less input from the pilot.

Another requirement imposed on the Real-Time IFP lies in the need to plan extremely quickly. Whereas a ground-based planning system takes time to model dozens of different planning criteria at high resolution and high fidelity, an in-flight planner operating in real-time is required to take far less time to conduct a real-time planning operation. In this respect, the IFP models the environment with less fidelity. Though similar in nature, a mission plan generated by an in-flight planner is slightly different from that obtained from a ground-based planning system.

The Real-Time IFP has been written in Ada. Throughout the development of this IFP system, the software development standards and styles of the Software Productivity Consortium (SPC) were implemented. These standards offered the opportunity not only to enhance the IFP portability but also to greatly increase its integration possibilities and simplify its evaluation. Furthermore, various measures have been taken and implemented so as to make this system well structured and modular. In addition, an intermediate interface was built between the IFP and the MRC simulation. The idea lies in the need to isolate the real-time planning system from the external system (i.e., the MRC simulation). This arrangement has been designed and implemented since the MRC simulation uses a shared memory scheme to communicate with other subsystems and modules written in C and FORTRAN. However, the MRC simulation could not use the SPC guidelines to build a functional interface to ensure subsystem communication. In this way, the Real-Time IFP can be easily integrated into another system without the need to change its internal structure. This can be accomplished through a modification of the intermediate interface.

Indeed, the Real-Time IFP system integrates different software packages. The most important modules or subsystems include the terrain database, threat line-of-sight maps, a map data reduction technique, an auto-router, a SAR planner, and a system executive designed to control the entire system.

Based on a 100-m. resolution, the terrain database is a standard DTED level 1 provided by the Defence Mapping Agency (DMA). Indeed, the resolution can be reduced to 500 or 800 meters in order to save memory or improve the system's execution speed. The most fundamental element of the Real-Time IFP is the line-of-sight map generated in order to position an identified threat and allows the route planner to avoid it. The line-of-sight maps generated (one for each threat) are then merged into a single Composite Line-of-Sight Map (CLOSM) so as to depict the required altitude of the aircraft before entering the line of sight of an identified threat. Indeed, the CLOSM can be very large and overwhelming. As a result, the IFP uses a data reduction technique called quad tree compression in order to achieve real-time performance. Unlike the image compression designed to reduce storage space, the data reduction technique is a method of segmenting the route planning space into a quickly usable form. On the other hand, the route planner includes two important components:

- The route-planning graph or network representing nodes and links. While the nodes are used to describe the discrete positions, or states, in space, the links represent the methods or path used to get from one node to another.
- The route-planning algorithm is designed to execute on the information associated to the nodes and links.

Using the radar, the SAR planner is employed to perform a pop to find mobile or uncertain targets prior to any attack phase. The purpose is to find a good location to perform a SAR pop manoeuvre without exposing the aircraft to any known threat. Finally, the system executive is designed to manage the IFP system to ensure that all internal databases are updated. It is also used to monitor the external environment and parameters and conditions associated with the aircraft system. In case new threats, navigational or timing errors are identified, the system executive provides the ability to execute and run the appropriate planners. As a result, the system assembles the generated components of a plan into a single mission plan.

Indeed, the Real-Time IFP system has been evaluated and shown to be effective in reducing dramatically the pilot's workload related to replanning a mission. In doing so, the system demonstrated its ability to greatly increase the survivability of the aircraft.

5.3.2 Joint Mission Planning System (JMPS)

Logicon Inc. developed the Joint Mission Planning System (JMPS) to provide unit-level mission planning capabilities to support all phases of USAF flight operations. Indeed, the JMPS [39-40] project is still going through the development phase scheduled to proceed with a series of five Beta releases. Each Beta release is designed to include added functionality until a full functional basic mission planning system is delivered in 2002.

The development and implementation of the basic mission planning capability will be followed by the integration of the Navy Tactical Automated Mission Planning System (TAMPS) and the Air Force Mission Support System (AFMSS) into JMPS.

Although it was designed for the US Air Force, Navy, Marine Corps, and Special Operations Command, JMPS will evolve to support fixed and rotary wing aircraft, weapons, and sensors, including precision guided munitions, cruise missiles, and unmanned aerial vehicles. Indeed, command and control enhancements are introduced in the development of this system through the incorporation of improvements in information and systems integration technologies to provide collaborative inter-Service mission planning capabilities.

Initially built on the functionality of the existing Portable Flight Planning Software (PFPS), JMPS is designed to provide required mission data for the aircrew. In addition, it offers the ability to generate and transfer data to aircraft and weapon systems through Data Transfer Devices (DTDs). Figure 13 shows the architecture of the JMPS system.

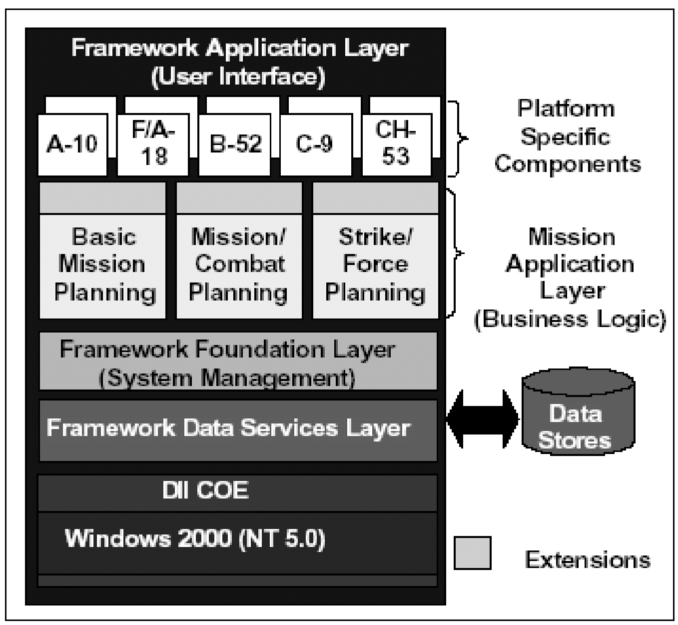

Figure 13. *JMPS System Architecture [40].*

5.3.3 Portable Flight Planning System (N-PFPS)

The Naval (or Navy) – Portable Flight Planning System, or Software, (N-PFPS**)** [41] is a basic Navy-Marine Corps flight planning system. As an automated computer-based system, N-PFPS provides the ability to perform route planning (time, distance fuel and aircraft performance) taking into account the aircraft's configuration (weight, drag, speed, etc.) as well as the environmental factors (altitude, wind, pressure, humidity, etc.).

Although N-PFPS does not support weapons, it provides the capability to rapidly generate plans from starting point to end point, end point to starting point or route portions. This system also allows aircraft navigation data loading, such as the Global Positioning System (GPS) and the Digital Aeronautics Flight Information File (DAFIF). In addition, flight data can be transferred to the aircraft computer by using a Data Transfer Device (DTD). The transferred data are then used to initialize the database to be operated by the onboard aircraft computers.

Based on a modular architecture, N-PFPS includes software modules called Flight Planning Modules (FPMs), which allow the planner to prepare missions that are exactly tailored to each supported aircraft. Moreover, without changing the whole system, N-PFPS offers the opportunity to develop new flight planning modules in order to include and support new aircraft. Finally, N-PFPS functionality has been replaced by the Joint Mission Planning System (JMPS) in 2002.

5.3.4 Tactical Automated Mission Planning System (TAMPS)

The Tactical Automated Mission Planning System (TAMPS) [42-44] is a US Navy/Marine Corps unit-level aircraft mission planning system. As a computer-based support system, TAMPS is designed to provide the ability to load aircraft software with route-of-flight data files, including waypoints and sequential steering files, air-to-air radar presets, navigation aid channels and identification files. In addition, TAMPS offers the opportunity to load independent overlays for aircraft software and bulk files for missile software. As a result, it enables the use of a variety of weapons while decreasing weapon system pre-flight preparation time.

In this respect, TAMPS is a mission support system that can rapidly process large quantities of digitized terrain, threat and environmental data, aircraft and weapon system parameters, and imagery. Data output from the system can be transferred to aircraft platforms using Data Storage Units (DSUs), Memory Units (Mus), Mission Data Loaders (MDLs) and Tactical Tape Cartridges (TTCs).

Based on a modular architecture supporting common planning requirements of various weapon systems, TAMPS includes core modules that allow the integration of independently developed Mission Planning Modules (MPMs) and Mission Planning Functions (MPFs). In other words, the TAMPS architecture offers the opportunity to add and update specific modules without the need to modify the whole system or change the core module.

5.3.5 Air Force Mission Support System (AFMSS)

The Air Force Mission Support System (AFMSS) [45-48] includes the following subsystems:

- Portable Flight Planning Software (PFPS) (PC-based),
- Family of Mission Planning System (MPS) (UNIX-based)

The Portable Flight Planning Software (PFPS), a PC system of AFMSS, was first designed independently of AFMSS by Air Force personnel and is currently government-owned and developed with annual revisions by the 46th Test Squadron Mission Planning Flight (TS/OGET).

The two systems, PFPS and AFMSS, can exchange flight plans (routes) and point libraries. By using tools, PFPS is capable of supporting all missions (such as simple day-to-day training proficiency flights, peacetime operational/exercise sorties, or conventional or nuclear conflict) and all aircraft. PFPS also provides supporting planning for air-to-air, air-to-ground, air refuelling, electronic combat, reconnaissance, special operations, conventional gravity weapon releases from high, mid or low altitudes using a wide variety of release procedures, to airlift and rescue missions.

The major system components are:

- Combat Flight Planning Software (CFPS);
- FalconView (a government-owned mapping package);
- Combat Weapon Delivery Software (CWDS);
- Combat Airdrop Planning Software (CAPS); and
- Cartridge Loader (selected aircraft).

5.3.6 Mission Support System - Computer Aided Mission Planning at Air Base Level (MSS/CAMPAL)

The Mission Support System/Computer Aided Mission Planning at Air Base Level (CAMPAL) [49], also known as MSS/C, is an automated tactical mission planning system designed to support the Royal Netherlands Air Force (RNLAF) flight operations. As a computer-based system, MSS/C provides the ability to perform route planning for each supported aircraft (up to four), as well as to give the opportunity to aircraft pilots to familiarize themselves with the battle theatre.

Using electronic maps including Intel overlays, MSS/C gives air mission planners the capability to perform planning for the following missions: (i) offensive missions to/and from the destination area, (ii) manoeuvring (e.g. attack and combat air patrol), and (iii) ferry missions (the route from home to the destination base). The MSS/C system also allows calculations for level flights, climbs and descents. Additional features and functions of

MSS/C lie in the possibility to perform in-flight refuelling; aircraft performance package (aircraft's capabilities and fuel requirements); and finally, the generation of flight plans and Combat Mission Folder (CMF) in either peace, war or tension times. The transfer of data output (such as coordinates, fuel loads, the flight plan and overview map) from the planning system to the aircraft is performed via a Data Transfer Cartridge (DTC).

Using external command and control systems and/or database resident in MSS/C, the system can retrieve data information for the actual scenario. This information is divided into three main types: geographical and weather data, friendly, and enemy (intelligence data on enemy defence systems) assets, including aircraft and weapon system parameters. MSS/C has been improved in order to be faster and to run on state-of-the art Commercial Off-the-Shelf (COTS) hardware. The enhanced system has been named MSS/Pandora.

5.3.7 SAIC Mission Planning System (SAIC/MPS)

The SAIC Mission Planning System (SAIC//MPS) [50] provides the ability to conduct air mission planning, analysis, replanning, and rehearsal. As a tactical planning system designed for the air force, navy, marine and army, the SAIC//MPS is designed to give air mission planners more effective and automated capabilities in developing mission plans for fighters, bombers, transport aircraft and helicopters.

Using digital maps, imagery and elevation data, the system provides the ability to perform route planning (time, distance fuel and aircraft performance) and calculate other key flight parameters regarding weapons configurations, threat analysis, and weapons load effects on weight and balance. In addition, flight performance of each supported aircraft (up to 32 in each mission) can be changed for cruise, climbs and descents. Another feature provided by the SAIC//MPS lies in the ability to perform optional route segments such as refuelling or orbiting. On the other hand, a user is finally allowed to assess the feasibility of a planned route through mission pre-fly over 3D terrain. In the end, data output from the planning system is then transferred to the aircraft using data transfer cartridges.

Used in Command and Control, the SAIC//MPS is a portable system that can be integrated with the SAIC Air Combat Evaluation System, a companion product for post-flight analysis. It is also designed to incorporate RADSIM, a SAIC's precision radar simulation capability, so as to provide a total and effective mission planning package. Using C++ object oriented Libraries, the SAIC//MPS system can be configured on either a PC (desktop or laptop) or a UNIX workstation, depending on the customers' needs.

5.3.8 CINNA

The mission planning system CINNA [51] provides the ability to conduct air mission planning from tasking to debriefing. As a tactical ground-based planning system designed for the French[12] air force, this system is designed to give air mission planners and aircrews more effective and automated capabilities in developing route planning, stand off weapon mission preparation, target analysis, data base management and mission rehearsal.

In this respect, CINNA 4 can rapidly process large quantities of the following data type: Digital Terrain Elevation Data (DTED), Satellite Photography (Photo), Intelligence Data (Intel), Operational Data (Ops), and Radar Imagery (Radar). Therefore, the system provides the ability not only to compute in real time fuel flow, heading, distance, etc., but also to calculate other key flight parameters such as weapons delivery.

In the end, using variable speed simulation as well as dynamic events, a user is allowed to assess the feasibility of a planned route through mission pre-fly over 3D (bird's-eye) terrain and 2D simulation/deconfliction.

5.4 Other Specific Military Planning Systems

This category addresses some specific military planning systems that do not fit into the other categories.

5.4.1 The Rochester Interactive Planners System (TRIPS)

The Department of Computer Science at the University of Rochester in the United States has developed the Rochester Interactive Planner System (TRIPS) [52-53]. This system integrates speech recognition, natural language understanding, discourse processing, planning and plan recognition and other features. It is designed to provide the human user with an interactive, intelligent problem-solving assistant in a transportation/logistics domain.

TRIPS represents an integrated AI system based on previous experience gained in developing the TRAINS system. However, TRIPS functions in a more complicated logistics domain compared to TRAINS, a simple route-planning domain. In addition, TRIPS supports the construction of much more complex plans than TRAINS could produce or understand, and embodies a more complex model of collaborative problem solving.

The TRIPS system can be regarded as an assistant to a human manager where the two can collaborate to construct plans in crisis situations. As shown in Figure 14, TRIPS includes various modules that communicate by exchanging messages through a central message-passing Input Manager. TRIPS is based on an infrastructure designed to allow any program that can read standard input and write standard output to exchange messages.

[12] Developed by Matra Systèmes & Information (a subsidiary of EADS, European Aeronautic Defence and Space Company).

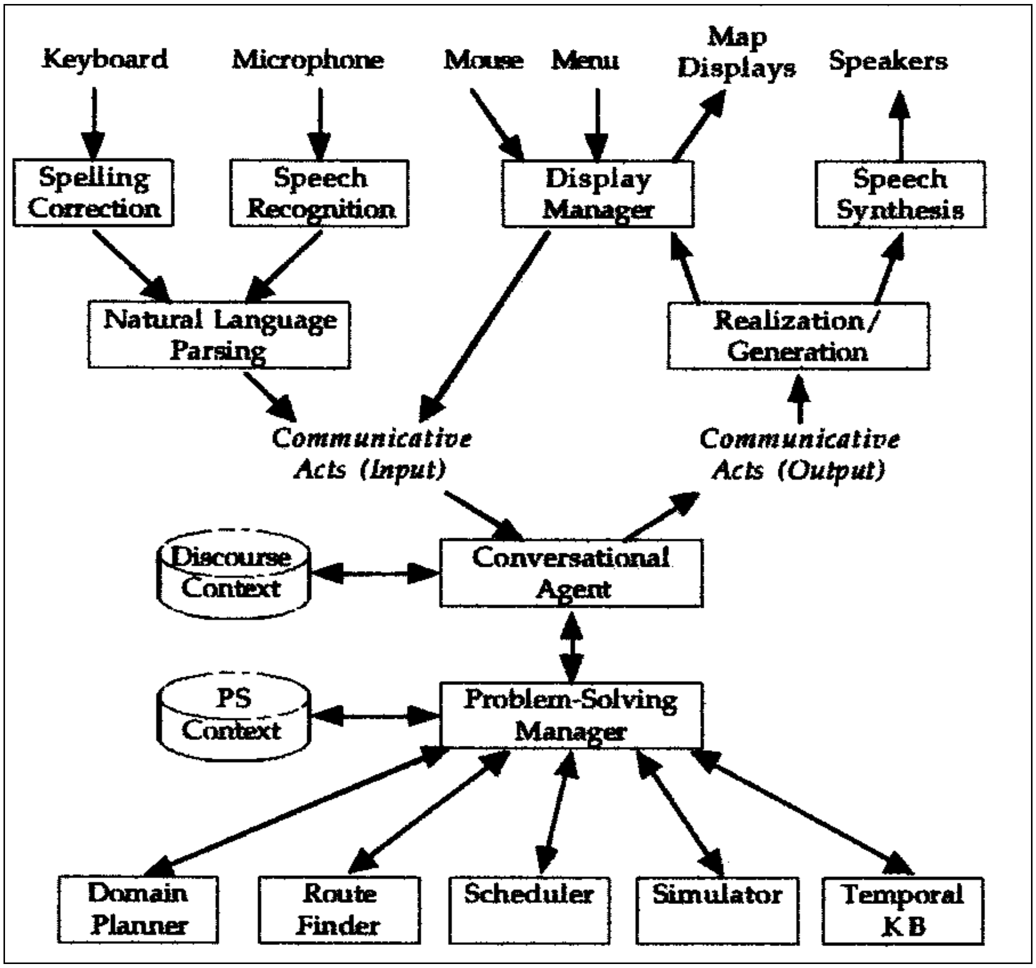

Figure 14. *TRIPS Architecture [52].*

5.4.2 Joint Maritime Crisis Action Planning (JMCAP)

The Joint Maritime Crisis Action Planning (JMCAP) [54] System was developed as a combined effort of the US Navy Space and Naval Warfare Systems Center (SPAWAR), formerly known as the Naval Research and Development (NraD). Sponsored by the Office of Naval Research (ONR), the JMCAP prototype was built as part of a project designed to ensure the transfer of technology and applications developed by SRI International and other supported research institutions into operational navy systems. The idea was to conduct user-centered, participatory design of end-to-end systems, supported by commercial technologies and advanced research prototypes, which were already shown to be feasible for military planning and execution problems.

Based on available information, the present description can only briefly report the applied research undertaken within the Advanced Concept Technology Demonstration (ACTD) that led to the development of systems and concepts called Extending the Littoral Battlespace (ELB). At the time, these systems and concepts were considered likely to provide the basis for a JMCAP prototype. The problem was to provide the ability to semi-automatically generate crisis response options in the presence of multiple, competing objectives and constraints, within a distributed computing environment, that included multiple agents collaboratively solving the overall planning problem.

The operational concept for littoral warfare in ELB is based on a required virtual command centre, the Enhanced Combat Operations Centre (ECOC), divided into tightly coupled cells. Within this operational centre, human planners in the Planning and Shaping Cell can plan operations involving force and fire employment and naval support for ground forces. Obviously, distributed tactical planning occurs in this cell through the collaborative efforts of onshore, afloat, mobile, and in-transition units. In this near-real-time situation, collaboration among units is required to jointly deconflict shared plans or to recognize opportunities for coordination. In supporting ELB-type operations, problems arise from the move towards shorter planning timelines, and the greater authority and autonomy invested in the small teams, combined with the need for greater cooperation and coordination. Obviously, in a tactical situation, time is just not available to conduct an extensive, face-to-face plan de-confliction and negotiation session.

In the ELB operational context of plan conflict detection and repair, lengthy collaborative sessions, where the participants argue over the allocation of resources or negotiate the assignment of weapons, are just not feasible. In this context, the ELB ACTD requires the coordination of activities during such operations as forcible entry and restraining operations, such as that designed to prevent the spread of hostilities. The coordination of the Naval and Marine units is critical under the guidance of a unified commander. Past experience has shown that managing several lesser regional operations can lead to unnoticed inconsistencies. Temporal conflicts may also arise, as some operations must be completed prior to others.

SRI International addressed these specific problems through the development and the transition of a technology designed to provide useful capabilities to support better coordination of planning activities. The plan de-confliction system is thus seen as a facility for instant collaboration that is driven by and focused on an automated analysis of the plan highlighting conflicts and/or opportunities. This analysis is called plan overlap detection, a concept that is broadened beyond de-confliction.

The plan overlap may be handled by creating a merged plan that contains each plan appropriately modified in order to create a consistent plan. It can also be handled by negotiating changes in each plan to achieve consistency.

In this respect, the efforts undertaken within this project were focused on the development of a technology for distributed, collaborative, continuous planning in a maritime campaign domain. The problem consists in developing advanced knowledge-based technologies required to provide, as mentioned above, the ability to generate crisis response options in the presence of multiple, competing objectives and constraints. The whole planning process is designed to be conducted within a distributed computing environment that includes multiple agents collaboratively solving the overall planning problem.

Conducting rapid and effective planning in this environment requires the ability to provide support for automated and interactive plan generation so as to enable human planners to negotiate resource, temporal, and operational constraints among the distributed planning agents. It also requires the ability to reuse previous plans, planning doctrine, and plan templates so as to quickly develop integrated responses to new situations; and to replan in case planning conflicts arise or situations change.

Based on these requirements, the technical challenges associated with the JMCAP project lie in the need to:

- identify a common plan representation that allows distributed plan authoring, plan generation, and execution monitoring components to share knowledge about the evolving plan;
- develop techniques for distributing the planning problem, managing the distributed planning and plan de-confliction process, and merging the resulting component plan;
- develop and apply a hybrid approach to plan generation that integrates AI generative planning and case-based reasoning methods; and
- provide support for re-planning as a result of conflicts that may arise during planning or execution failures.

In this respect, the applied research undertaken within the JMCAP project led to the development of a hybrid-planning tool that integrates Case-Based Reasoning (CBR) methods into a generative planning system. This hybrid planning research was conducted to respond to maritime crisis action planning requirements for quick continuous distributed planning. SRI International, on the other hand, developed Distributed SIPE (DSIPE), a distributed planning system that provides decision support to human planners in a collaborative planning environment.

Hence, the applied research conducted within the JMCAP project has focused on the development of hybrid/case-based planning methods and a technology designed to manage a distributed, collaborative planning and execution process.

The distributed planning technology developed by SRI International incorporates techniques that provide the ability to:

- represent and reason about constraints in a distributed planning environment;
- represent and propagate temporal constraints;
- synchronize and maintain multiple views of a distributed plan structure;
- reason about relevance of planning constraints;
- merge plans; and
- interface to a plan execution monitoring system.

Integrated with the JMCAP planner, the Joint Force Level Execution (JFLEX), an execution monitoring system by SPAWAR, can graphically display plan objectives, tasks, and preconditions in a timeline format on three separate levels of a screen. The display of the connections between objectives and their supporting tasks, or between tasks and their associated preconditions can be conducted through menu commands. Through JFLEX, a variety of human planners can monitor the execution of a plan. Based on scheduled completion times, users can check whether tasks have been completed and important conditions have been met. As a result, a new execution record can be edited by modifying the state of various tasks and conditions.

When the JMCAP project was conducted, it was thought that a Java-based system called Enhanced Common Operational Picture (ECOP) may be incorporated to offer useful features for map-based displays. Developed by DTAI Incorporate, the ECOP software can operate from any java-capable browser, run on a variety of platforms, and provide one integrated display for many data sources. Indeed, ECOP provides an advanced geographical map display that includes real-time updates of positional data from a variety of sources, as well as overlays, zooming, and other standard map operations.

Still within this project, SPAWAR has also examined the possibility of integrating a reactive planning system into the loop between JFLEX and the JMCAP planner. This approach is designed to provide a quick response to plan repair capability for limited situations. In this respect, SPAWAR has proposed the use of an enhanced version of the University of Michigan’s Procedural Reasoning System (UM-PRS). It was planned to connect this system to JFLEX through the Common Object Request Broker Architecture (CORBA). As a result, JFLEX would have access to the reactive planning to deal with rapid plan repair issues.

5.4.3 Joint Strategic Planning System (JSPS)

The Joint Strategic Planning System (JSPS) [55] represents the primary formal means by which the Chairman of the Joint Chiefs of Staff (CJCS), in consultation with the other members of the Joint Staff and Unified Commanders in Chiefs (CINCs), carries out planning and policy responsibilities detailed in Title 10 of the US Code. As the primary military advisor to the National Command Authorities (NCA), the CJCS can provide through the JSPS system:

- assistance to the US President and Secretary of Defense on matters regarding the strategic direction of the Army;
- military strategy and strategic plans and assessments in support of strategic national objectives;
- advice to the Secretary of Defense on the US Army's capability deficiencies and strengths in conducting national security objectives; and
- recommendations on defence programs and budget proposals.

In addition, the JSPS system can also provide the ability to monitor the strategic environment and identify changes in conditions or trends that may justify changes in the strategic direction of US Army. The Joint Strategic Planning System is designed to help the CJCS prepare and review strategic and contingency plans and to advise both the US President and the Secretary of Defense on programs and budgets.

The JSPS is also used to assist the CJCS in his task of providing advice to the President and Secretary of Defense on matters related to provision of net assessment on the capabilities of the US Army. Integrated into JOPES, the Joint Strategic Planning System provides extended flexibility in interacting with other DoD systems, such as the Planning, Programming, and Budgeting System (PPBS).

5.4.4 Open Planning Architecture (O-Plan)

The Open Planning Architecture (O-Plan) resulted from a project conducted at the Artificial Intelligence Applications Institute (AIAI) [56] of the University of Edinburgh around computer-based generative planning. The plan grew out of research work into AI planning conducted in the late 70s and 80s. The O-Plan inherited features from NOAH, NonLin, Deviser, Molgen and OPM. Its architecture or framework was designed and built to incorporate all these borrowed features into a single system.

O-Plan1 represents the initial project conducted to build a knowledge-based system capable of generating plans. The idea stemmed from the need to develop a system to experiment with and integrate novel ideas and concepts, and the system was tailored to suit particular applications. In this respect, time and resources constraints were handled to restrict search while still working within an activity-based plan representation.

Launched in 1989, O-Plan2 was designed to offer a generic domain independent computational architecture suitable for command, planning and execution applications. The O-Plan2 research provided the opportunity to gain a complete vision of a modular and flexible planning and control system incorporating artificial intelligence methods.

In O-Plan2, the task assignment process consists in enabling a user to specify a task, which can be performed through some suitable interface. On the other hand, the execution system seeks to carry out the detailed tasks specified by the planner while working with a more detailed model of the execution environment. Indeed, the system is designed to operate both as a planner and a simple execution agent.

The O-Plan2 agent oriented architecture (Fig. 15) consists of the following components:

- **Domain Information** – this component contains the information required to describe an application and the tasks to the agent;
- **Plan State** – the identified tasks associated with the emerging plan to carry out;
- **Knowledge Sources** – the processing capabilities of the agent;
- **Support Modules** – functions designed to support the processing capabilities of the agent and its components; and
- **Controller** – controls the order in which processing is carried out.

Similarly to SIPE-2, the O-Plan technology has been used to support various military projects undertaken within the ARPA-Rome Planning Initiative. The approach was designed to incorporate O-Plan as a subsystem to assist military users in generating plans and reviewing qualitatively different solutions. O-Plan can be used to perform concurrently different task assignments, planning and execution monitoring. Indeed, multiple users can interface to this planning system via Open Planning Process Panels that are configurable interfaces through any World Wide Web browser.

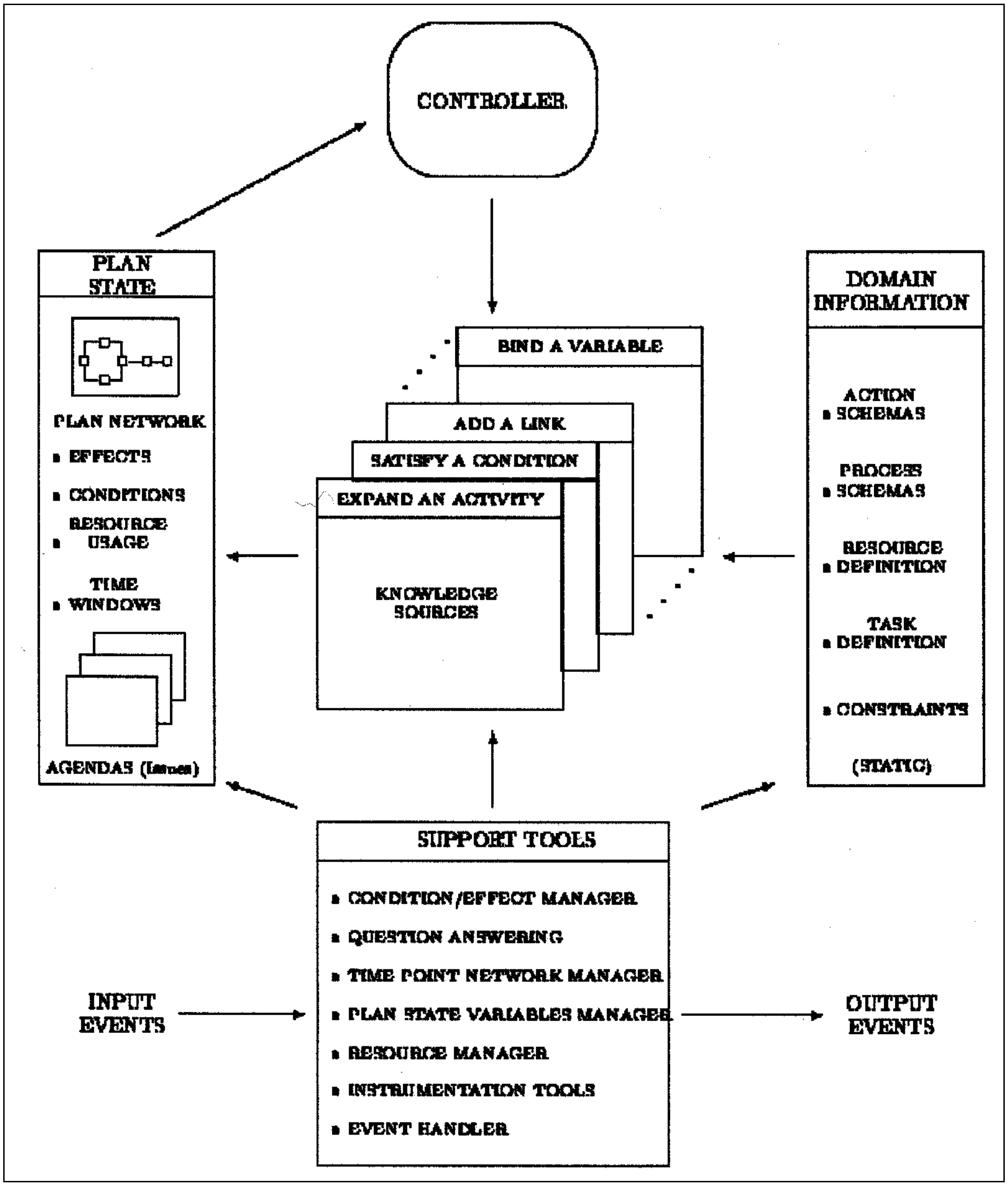

Figure 15. *O-Plan2 Architecture [56].*

5.4.5 Joint Standoff Weapon – Mission Planning Module (JSOW-MPM)

The prototype Joint Standoff Weapon (JSOW) Mission Planning Module (MPM) [57] was developed under a contract with the Naval Air Systems Command (NAVAIR) to improve JSOW mission planning by using real-time Meteorological and Oceanographic (METOC) data. The developer collaborated with JSOW mission planners and METOC personnel in order to provide the mission planner with a tactical display and tool for environmental data management.

This mission-planning module provides the ability to edit the missile's route (route information) and modify preferences. Moreover, using Metplan (the Meteorological and Oceanographic data management server), JSOW MPM allows the capability to edit data management preferences as well as view METOC products. Finally, the mapping functionality of Falcon View is used to provide the user with up-to-date charts, drawing routes and objects.

6. Conclusion

The development of planning systems is usually based on a military doctrinal process, which is a structured formal process that mainly addresses:

- different levels of planning: strategic, operational and tactical
- planning environment: deliberate planning vs. crisis action planning

The Canadian military planning process describing the doctrinal elements driving the development of planning systems was first presented in this report.

In preparing this report, a large number of mission planning and scheduling systems addressing specific military needs were surveyed. The review covered various issues associated with mission planning function, methods, tools and procedures used to plan and schedule complex military operations. Emerging techniques involved in the design of advanced mission planning systems were also examined. Key paradigms and technologies characterizing such mission planning systems were then depicted. Finally, typology was proposed to classify the most important joint and air operation planning systems.

Despite a wide variety of systems and prototypes currently available and relevant to military operations, new challenges are emerging in the progressive trend towards network centric operations. This dictates requirements to achieve adaptive planning on a continual basis, interweaving plan construction and execution in distributed environments. In addition to plan generation and execution monitoring tasks, distributed continual planning includes critical issues associated with shared plan representation, adaptive coordination and interoperability. Developing, selecting and incorporating suitable technological innovations to provide integrated and interoperable systems and tools can enhance military capability to accomplish multi-level operational planning and execution.

The tables presented hereafter give the most important characteristics of the addressed systems.

Table 1. *Deployment and battle systems.*

	System	**Op**erational or **P**rototype	**A**rtifical **I**ntelligence, **O**peration **R**esearch or **O**ther	Fully **A**utomated or **S**emi-Automatic	Air **F**orce, **A**rmy, **N**avy, **M**arine **C**orps, **S**pecial **F**orces, **J**oint, (CF, **FRA, NLD, US** or **I**nternational)	Operations Type: **A**ir, **J**oint, **L**and, **M**aritime or **N**avy	Operational Level	Strategic Level	Tactical Level	Deliberate Planning	Crisis Action Planning	**C**ommercial, **G**overnement or ...	**Additional Informations :** **T**ransportation, **L**ogistics, **M**obilization, **D**eployment, **B**attle, **E**mployment, **S**ustainment, **R**edeployment
1	**FOX - Genetic Algorithm (FOX-GA)**	**P**	**AI**	**A**	**USArmy**	**L**	✓		✓		✓	**G**	**B**
2	**Contingency Theater Automated Planning System (CTAPS)**	**Op**	**AI**	**S**	**USAF**	**A, L**	✓		✓		✓	**G**	**T, D, B**
3	**Joint Assistant for Deployement and Execution (JADE)**	**P**	**AI**	**S**	**USArmy**	**J**	✓				✓	**G**	**D, B**
4	**Dynamic Analysis and Re-planning Tool (DART)**	**Op**	**AI**	**S**	**J**	**J**		✓		✓	✓	**G**	**T, D, B**
5	**Anticipated Planning Support System (APSS)**	**P**	**AI OR**	**A**	**USArmy**	**L**			✓		✓	**G**	**B**
6	**Time-Phased Force Deployment Data Editor (TPEDIT)**	**Op**	**AI OR**	**S**		**J**			✓		✓	**G**	**T, D**
7	**Collaborative Operational Planning System (COPlans)**	**P**	**AI OR**		**Can Air Force**	**A J**	✓			✓		**G**	**L, B**

Table 3. *Flight and route planning systems.*

	System	Operational or Prototype	Artifical Intelligence, Operation Research or Other	Technical Documentation	Fully Automated or Semi-Automatic	Air Force, Army, Navy, Marine Corps, Special Forces, Joint, (CF, FRA, NLD, US or International)	Operations Type: Air, Joint, Land, Maritime or Navy	Operational Level	Strategic Level	Tactical Level	Deliberate Planning	Crisis Action Planning	Commercial, Governement or ...	Additional Informations : Transportation, Logistics, Mobilization, Deployment, Battle, Employment, Sustainment, Redeployment
1	**Real-Time In-Flight Planner (IFP)**	**P**		✓	**A**	**USAF**	**A**			✓		✓	**G**	**B, SAR***
2	**Joint Mission Planning System (JMPS)**	**Op**		–	**A**	**USAF USN USMC**	**A**			✓	✓	✓	**G**	**B**
3	**Navy-Portable Flight Planning Software (N-PFPS)**	**Op**		–	**A**	**USN USMC**	**A**			✓			**G**	
4	**Tactical Automated (or Aircraft) Mission Planning System (TAMPS)**	**Op**		–	**A**	**USN USMC**	**A**			✓			**G**	
5	**Air Force Mission Support System / Mission Planning System (AFMSS)**	**Op**		–	**A**	**AF (US, I), USSF**	**A**			✓	✓	✓	**G**	**D**
6	**Mission Support System Campal (MSS/C)**	**Op**		–	**A**	**RNLAF (NLD)**	**A**			✓	✓	✓		**B**
7	**SAIC Mission Planning System (SAIC//MPS)**	**Op**		–	**A**	**J (USA or I)**	**A**			✓			**C**	**T, L**
8	**MATRA Mission Planning System (CINNA 4)**	**Op**		–	**A**	**AF (FRA)**	**A**			✓				**B**

* SAR (Search and Rescue)

Table 2. *Airlift and transportation systems.*

	System	Operational or Prototype	Artifical Intelligence, Operation Research or Other	Fully Automated or Semi-Automatic	Air Force, Army, Navy, Marine Corps, Special Forces, Joint, (CF, FRA, NLD, US or International)	Operations Type: Air, Joint, Land, Maritime or Navy	Operational Level	Strategic Level	Tactical Level	Deliberate Planning	Crisis Action Planning	Commercial, Governement or ...	Additional Informations : Transportation, Logistics, Mobilization, Deployment, Battle, Employment, Sustainment, Redeployment
1	**Joint Operation Planning and Execution System (JOPES)**	**Op**	**AI OR**	**S**	**J**	**J**	✓	✓	✓	✓	✓	**G**	**T, L, M, D, E, S, R**
2	**System for Operation Crisis Action Planning (or SIPE-II Operational Crisis Action Planner) (SOCAP)**	**P**	**AI**	**S**	**J**	**J**		✓	✓		✓	**G**	**T**
3	**Airlift Deployment Analysis System (ADANS)**	**Op**	**OR**	**A**	**(AMC)**	**A**	✓	✓		✓	✓	**G**	**T**
4	**Consolidated (Combined) Air Mobility Planning System (CAMPS)**	**Op**	**AI**	**S**	**(AMC)**	**A**	✓	✓		✓	✓	**G**	**T, D**
5	**Contingency Operations Mobility Planning and Execution System (COMPES)**	**Op**		**A**	**(USAF)**	**A**	✓		✓	✓	✓	**G**	**L, M**
6	**Deliberate Crisis Action Planning and Execution System (DCAPES)**	**Op**			**(USAF)**	**A**	✓		✓	✓	✓	**G**	**L, M, D, E, S, R**
7	**Knowledge-based Adaptive Resource Management Agent (KARMA)**	**P**	**AI**	**A**	**Can Air Force**	**A**	✓		✓			**G**	**T**
8	**Decision Scheduling System (DSS)**	**Op**	**OR**		**Can Air Force**	**A**	✓	✓	✓			**G**	**T**

Table 4. *Other specific military planning systems.*

	System	Prototype or Operational (P / Op)	Artificial Intelligence, Operation Research or Other (AI / OR)	Technical Documentation	Semi-automated or Fully Automatic (S / A)	Marine (M), Navy (N), Army (A), Air Force (AF), Joint (J), Canadian Forces (CF), Special Forces, Corps (SC), International (FRA, NLD, US)	Ops Type: Navy (N), Maritime or Marine (M), Land (L), Joint (J), Air (A)	Operational Level	Strategic Level	Tactical Level	Deliberate Planning	Crisis Action Planning	Government or … Commercial (G / C)	**Additional Informations:** **T**ransportation, **L**ogistics, **M**obilization, **D**eployment, **B**attle, **E**mployment, **S**ustainment, **R**edeployment
1	**The Rochester Interactive Planning System (TRIPS)**	**P**	**AI**	✓	**S**		**J**					✓		**T, L**
2	**Joint Maritime Crisis Action Planning (JMCAP)**	**P**	**AI**	✓	**S**	**USN USMC**	**M**			✓		✓		**B**
3	**Joint Strategic Planning System (JSPS)**	**Op**				**J**	**J**		✓		✓	✓	**G**	**S, Asset manag.**
4	**Open Planning Architecture (O-PLAN 2)**	**Op**	**AI**	✓	**S**		**A**	✓	✓	✓		✓	**G**	
5	**Joint Stand Off Weapon Mission Planning Module (JSOW MPM)**	**P**		**–**	**A**	**N**	**A**			✓			**G**	**Missile's route**

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List of symbols/abbreviations/acronyms/initialisms

AAMPS	Automated Aircraft Mission Planning System
AAMPS	Army Aviation Mission Planning System
ACOA	Adaptive Course of Action
ACOM	Atlantic Command
ACPT	Air Campaign Planning Tool
ACTD	Advanced Concept Technology Demonstration (ACTD)
ADANS	Airlist Deployment Analysis System
ADP	Automated Data Processing
ADRG	Arc Digital Raster Graphics
ADRI	Arc Digital Raster Imagery
ADS	Airspace Deconfliction System
AFCCIS	Air Force Command and Control Information System
AFMSS/MPS	Air Force Mission Support System/Mission Planning System
AFMSS/PFPS	Air Force Mission Support System/Portable Flight Planning System
AI	Artificial Intelligence
AIAI	Artificial Intelligence Applications Institute
AIRPLAN	Military Air Operations Planning
AJP	Advanced Joint Planning
ALD	Available to Load Date
AMC	Air Mobility Comman

AMPS	Aviation (or Advanced) Mission Planning System
AMPS	Army Mission Planning System
AOC	Air Operation Centre
API	Application Programming Interface
APPS	Ammunition Prepositioning Planning System
APSS	Anticipatory Planning Support System
APS	Advanced Planning System
ARL	Army Research Laboratory
ARPA	Advanced Research Projects Agency
C2	Command and Control
C2IS	Command Control Intelligence System
C4I	Command Control Communications and Intelligence
CAD	Canadian Air Division
CAFMS	Computer Assisted Force Management System
CAFS	Case-based Force Selection
CAMS	Computer-Aided Mission Planning System
CAMPS	Consolidated Air Mobility Planning System
CAN	Canada
CAP	Crisis Action Plan/Planning
CAPE	Crisis Action Planning and Execution
CAPS	Combat Airdrop Planning Software
CCIR	Commander's Critical Information Requirements
CF	Canadian Forces

CINC	Commander-in-Chief
CJCS	Chairman of the Joint Chiefs of Staff
CJCSM	Chairman of the Joint Chiefs of Staff Manual
CJTF	Commander Joint Task Forces
CMARPS	Combined Mating Ranging Planning System
COA (or CoA)	Course of Action
CORBA	Common Object Request Broker Architecture
COG	Centres of Gravity
COMPASS	Common Operational Modeling, Planning, and Simulation Strategy
COMPES	Contingency Operations Mobility Planning and Execution System
CONPLAN	Concept of Operations Plan
COO	Concept of Operation
COP	Contingency Operation
COTS	Commercial Off-The-Shelf
CPA	CJCS's Program Assessment
CPR	Chairman's Program Recommandation
CSC	CINC's Strategic Concept
CTAPS	Contingency Theatre Automated Planning System
CWDS	Combat Weapon Delivery Software
COPlanS	Collaborative Operational Planning System
DAFIF	Digital Aeronautics Flight Information File
DARPA	Defense Advanced Research Projects Agency

DART	Dynamic Analysis and Replanning Tool
DCAPES	Deliberate Crisis Action Planning and Execution System
DISA	Defense Information System Agency
DITOPS	Distributed Transportation Scheduling in OPIS
DND	Department of National Defence
DoD	Department of Defense
DPE	Defense Planning Estimate
DPG	Defense Planning Guidance
DSIPE	Distributed SIPE
DSS	Decision Scheduling System
DSU	Data Storage Unit
DTC	Data Transfer Cartridge
DTD	Data Transfer Device
DTED	Digital Terrain Elevation Data
DTRA	Defense Threat Reduction Agency
DTU	Data Transfer Unit

EAD	Earliest Arrival Date
EBB	Electronic Battle Box
ECOC	Enhanced Combat Operations Center
ECOP	Enhanced Common Operational Picture
ELB	Extending the Littoral Battle space
EMPRS	Enroute Mission Planning and Rehearsal System
EPW	Enemy Prisoner of War

EUCOM	European Command
FAPES	Force Augmentation Planning and Execution System
FICOP	Fighter Configuration Plans
FLEX	Force Level Execution
FMEDIT	Force Module Editor
FMP	Force Module Packages
ForMAT	Force Module Analysis and Management Tool
FOX-GA	FOX - Genetic Algorithm
FPM	Flight Planning Modules
FRA	France
FRN	Force Requirement Number
FUNCPLAN	Functional Plan
GA	Genetic Algorithm
GCSS	Global Combat Support System
GCCS	Global Command and Control System
GNP	Gross National Product
GPS	Global Positioning System
GSA	General Services Administration
GSORTS	GCCS Status of Resources and Training System
GUI	Graphical User Interface
HMI	Human-Machine Interface

IAF-MSS	Italian Air Force - Mission Support System
IC2S	Integrated Command and Control System
IFD	Integrated Feasibility Demonstration
IFP	Real-Time In-Flight Planner
IO	Information Operations
IPB	Intelligence Preparation of the Battlefield
ITAS	In-Theatre Airlift Scheduler
ITEM	Integrated Theatre Engagement Model

J	Joint
JADE	Joint Assistant for Deployment and Execution
JDS	Joint Deployment System
JEPES	Joint Engineer Planning & Execution System
JFACC	Joint Force Air Component Commander
JFAST	Joint Flow and Analysis System for Transportation
JFCOM	Joint Forces Command
JFLEX	Joint Force Level Execution
JMCAP	Joint Maritime Crisis Action Planning System
JMEM	Joint Munitions Effectiveness Manual
JMI	JTISD - Modular Air Operation Center (MAOC) Integration
JMPS	Joint Mission Planning System
JNOCC	JOPES Network Operations Control Center
JOPES	Joint Operation Planning and Execution System

JOPS	Joint Operational Planning System
JPD	Joint Planning Document
JSCP	Joint Strategic Capabilities Plan
JSPS	Joint Strategic Planning System
JSR	Joint Strategy Review
JTB	Joint Transportation Board
JTL	Joint Theatre Logistics
JTF	Joint Task Forces
KARMA	Knowledge-Based Adaptive Resource Management Agent
KIDS	Kestrel Institute Interactive Development System
KSI	Knowledge Source Instantiation
MAC	Military Airlift Command
MAJCOM	Major Air Command
MAOC	Modular Air Operation Center
MEPES	Medical Planning and Execution System
MP	Mission Planner
MPRS	Mission Planning and Rehearsal System
MPS	Mission Planning System
MRC	Mission Reconfigurable Cockpit
NAVAIR	Naval Air Systems Command
NCA	US National Command Authorities

N-PFPS	Navy-Portable Flight Planning System
NEO	Noncombatant Evacuation Operation
NLD	Netherlands
NMS	National Military Strategy
NSC	National Security Council
NSD	National Security Directives
NSS	National Security Strategy
OOTW	Operations Other Than War
OPLAN	Operation Plan
O-PLAN	Open Planning Architecture
OPORD (or OpO)	Operation Order
OPP	Operations Planning Process
OR	Operation Research
ORBAT	Order of Battle
PID	Plan Identification Number
POM	Program Objective Memorundums
PPBS	Planning, Programming, Budgeting Systems
QCOA	Quick Course-of-Action Evaluation Toolkit
RAAP	Rapid Application of Air Power
ROE	Rules of Engagement

RNLAF	Royal Netherlands Air Force
SAAM	Special Assignment Airlift Mission
SAIC	Science Applications International Corporation
SAIC//MPS	SAIC//Mission Planning System
SAR	Search and Rescue
SIPE	System for Interactive Planning and Execution
SIPRNET	SECRET Internet Protocol Router Network
SOCAP	System for Operations Crisis Action Planning
SOFPARS	Special Operations Forces Planning And Rehearsal System
SOR	Statement of Requirement
TALPS	T-AVB Automated Load Planning System
TAMPS	Tactical Automated (Aviation) Mission Planning System
TARGET	Theatre-level Analysis, and Graphical Extension Toolbox
TBMCS	Theatre Battle Management Core System
TIP	Technology Insertion Project
TISD	Theatre Integrated Situation Display
TOPFAS	Tool for Operational Planning, Force Activation and Simulation
TPEDIT	Time-Phased Force Deployment Data Editor
TPFDD	Time-Phased Force and Deployment Data
TPIPT	Technical Planning Integrated Product Team
TRANSCOM	Transportation Command
TRIPS	The Rochester Interactive Planner System

USAF	US Air Force
USEUCOM	US European Command
USMC	US Marine Corps
USMTF	US Message Text Format
USN	US Navy
USSOF	US Special Operations Forces
USSTRATCOM	US Strategic Command
USTRANSCOM	US Transportation Command
UM-PRS	University of Michigan’s Procedural Reasoning System
VIPERS	Virtual Integrated Planning and Execution Resource System
WASP	Wing And Squadron Prototype
WWMCC	World Wide Military Command and Control

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