Using CommonKADS to model the Air Campaign Planning process

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This document contains models of the Air Campaign Planning process, represented as diagrams and accompanying text. These diagrams are based on knowledge which was acquired between 11 and 15 September 1995 from Doug Holmes of ISX. The purpose of these diagrams is to help members of the ARPI community identify the relevance of their own work to particular parts of the ACP process, and to promote discussion about ARPI projects and about the ACP process itself.

The knowledge which was acquired were determined by the modelling technique which was used. This technique was the CommonKADS approach to knowledge modelling [Wielinga *et al*, 1992] [Breuker & van de Velde, 1994], focusing on an enriched version of the CommonKADS Organizational Model. The diagrams below show the various models which were produced.

This document provides:

- an introduction to Air Campaign Planning;
- an introduction to the modelling technique used;
- diagrams representing models of the Air Campaign Planning process from various perspectives, with accompanying explanations;
- diagrams showing initial work on detailed "task analysis", with accompanying discussion.

1 Introduction to Air Campaign Planning

The knowledge acquisition effort which is described in this document focused on air campaign planning within a Joint Task Force (JTF). A JTF exists for one crisis (which usually implies one theater); however, there may be more than one JTF per theater. The Joint Forces Air Component Commander (JFACC) reports to the Commander in Chief (CINC) of the theater.

The JFACC can be appointed from several locations. If an entire numbered air force is put in the JTF, the the commander of the numbered air force will be the JFACC. If more than one numbered air force is involved, then the commander with the highest rank will be the JFACC. If a portion of a numbered air force is put in the JTF, then the JFACC will come from Central Command (CENTCOM) because the commander of the numbered air force will have to continue to run the troops not assigned to the JTF. If there is no numbered air force stationed in the theater of operations, then the JFACC will come from CENTCOM. To some degree, the CINC will know who he wants to be the JFACC and will appoint that person regardless of who is supposed to be the JFACC.

1.1 Plan Components

A Campaign Plan is a plan for all forces participating in a JTF and typically covers a 6 month period. An air plan, for the Air Force, also covers a 6 month period. The *Air Tasking Order* (ATO), or battle plan, takes 36 hours to produce and covers 24 hours. *Mission plans* are derived from the ATO; a mission plan constitutes the directions for a specific sortie. Pilots then develop an *engagement plan*, which specifies the maneuvers that will be used to execute the mission plan.

1.2 Preparation for planning

Once a crisis occurs, the CINC assesses the situation, selects a Course of Action (COA) and may decide to establish at JTF. Then a *warning order* is given, normally 3 days in advance of the commencement of operations. Operations are initiated by a further order from the CINC, known as the *operations order*. When a crisis occurs and the CINC decides to take some action, the CINC will provide planning guidance to the Joint Forces Commander (JFC). The guidance can take several forms including:

- Situation assessment of friendly and opposing forces
- Resources allocated
- Mission and Military Objectives
- Rules of Engagement
- Policies
- Political Issues
- Potential problems with weather
- Potential problems with crisis in other theaters

All of these types of guidance will change dynamically throughout the planning process as well as the execution of the plan. The guidance is communicated to the component commanders (e.g. the JFACC) through the JFC. The component commanders will in turn communicate the guidance to their planners. Based on the guidance, the planning staff will take between 3 days and 1 week to build a plan that may be executed.

Guidance is given throughout the planning process by every level of command. Although the guidance is considered more of an order than a suggestion, negotiation does take place. If a commanding officer wants to establish objectives or goals that are unreasonable, then participants of the planning process have the responsibility for convincing the commanding officer to take a different approach. For example, the planners may want more time. But, to buy time in a crisis, something diplomatic has to be given up. The commanding officer may not be willing to make a diplomatic sacrifice. In some such situations, the commanding officer will enforce the initial guidance; in other cases, the initial guidance may be relaxed. Rules of Engagement are never negotiable, however.

Initial planning steps include assessing the situation and organizing the planning staff. Assessing the situation involves identifying enemy COGs and air defenses as well as determining a method (strategy), goals and targets. A lot of knowledge about the theater is needed. Typically the planning staff has been studying the theater for years. The types of information they know are whether the enemy has nuclear weapons, the nature of the crisis, and the history of the conflict. The planning staff have, and use, many maps with different perspectives of the theater. These maps give the staff valuable insight into the theater and what is possible.

When the planners cannot find the needed details, they will rely on contacts with people who have the information or can get the information. Typically these are intelligence people on the planning team. Missions may be conducted to find the needed information. Planners are always skeptical of intelligence data; for example, databases are never fully populated ed and are continuously being updated. The planners will use data more current than what is in the target database if the planning staff has access to the data. It's also impossible to prove the accuracy of intelligence data, because INTEL (the intelligence group) must protect their sources; however, duplication of Intel effort between different branches, which is encouraged, may corroborate information or provide additional information.

Usually, the right information gets to the right person eventually. Tracking down information is not always conventional, easy or practical. It often depends on who you know or how much ingenuity is used to get the information. The planners may not get some needed information for 3 days, so they will make assumptions and move to the next step.

1.3 Planning

At this point, the staff is organized according to plan alternatives. During this step, and throughout the planning process, air planners are searching for alternatives, vulnerabilities, consequences and contingencies. The planners may consider alternative situations (the best case, worst case, or most likely case) based on the enemy's predicted course of action; however, the planning team usually consists of 8 people, which is only sufficient to plan for one situation (the most likely case) and look very hard at one other alternative (probably the worst case). There are usually no more people available.

The planning staff hold 4-hourly meetings to discuss progress, obtain a consensus of opinion, and to make sure that there is a smooth transition between phases.

The latter is very important, since it is imperative that friendly forces are not perceived by the enemy as being indecisive. Planning teams normally work 8-hour shifts; in a crisis, the planning team work overlapping 12-hour shifts.

Planning consists of three stages:

- identifying and prioritizing air objectives;
- identifying and prioritizing task objectives;
- identifying and prioritizing targets.

It's important to note that the planning process does not always continue until each stage is fully completed. Often, the planning staff may only be 75% finished with some activities when it is time to move on to the next stage. However, the dynamic environment makes it difficult to complete a stage without the situation changing simultaneously. The time spent on any one task depends on the situation.

The JFACC will not want to be involved in the planning process except for a daily briefing to make sure that guidance has been communicated correctly. The lack of involvement from the JFACC is deliberate, to foster openness and innovation. The air planning team does not communicate with other branches either, in order to enhance creativity. Keeping the number of participants involved in the detailed planning to a minimum reduces the constraints of reconciling too many points of view.

2 Introduction to the modelling technique used

The modelling technique used to model the ACP process was based on the CommonKADS methodology for knowledge modelling. CommonKADS [Wielinga *et al*, 1992] [Breuker & van de Velde, 1994] is a collection of structured methods for building knowledge based systems, analogous to methods such as SSADM for software engineering. It was developed between 1983 and 1994 on two projects funded by the European Community's ESPRIT program. CommonKADS views the development of a knowledge based system as a modelling activity, and so the heart of the method is the construction of a number of models which represent different views on problem solving behavior. A perspective consists of a model or models which only represent one aspect of the organization or behavior: for example, one perspective might model the activities which take place in an organization, while a different perspective may represent the structure of that organization. The recommended set of models is:

- An *organizational* model represents the processes, structure and resources within an organization;

- A *task* model shows the tasks carried out in the course of a particular process;
- An *agent* model represents the capabilities required of the agents who perform a process, and constraints on their performance;
- A *communication* model shows the communication required between agents during a process;
- An *expertise* model is a model of the expertise required to perform a particular task. This model is divided into three components:
  - declarative knowledge about the domain;
  - the inference processes required during problem solving;
  - a hierarchical classification and ordering of the inference processes.
- A *design* model culminates in the design of a knowledge based system to perform all or part of the process under consideration.

2.1 The CommonKADS Organizational Model

The stated aim of modelling the ACP process was to perform a "task analysis" of the ACP process. However, after initial domain familiarization it was felt that there was considerable benefit to be gained from producing an Organizational Model, showing the organization which surrounds ACP, before analysing the activities performed during the ACP process in detail.

The organizational model examines an organization from five major perspectives:

- the **activities**[1] of the organization;
- the **structure** of the organization;
- the **processes** in the organization;
- the **power/authority** in the organization;
- the **resources** in the organization.

Each perspective is represented by a single diagram, or by text. These five perspectives can be combined into cross-products which provide the most useful information. For example, the CommonKADS Organizational Model was used to model

[1] CommonKADS actually calls these "functions" rather than "activities". However, for reasons which are explained in [Uschold *et al*, 1995], I have chosen to use the term "activities" throughout this document.

a Social Security department; a cross-product of activities and structure was produced which highlighted inefficiency, because one of the activities (archiving) was being performed by three different divisions of the department [deHoog *et al*, 1993].

Once the organizational modelling has been completed, the next stage is to construct the *task model*. This involves a more detailed analysis of the activities identified in the process perspective, with an emphasis on deciding which activities could be suitable candidates for computer software support. For this project, the process of performing more detailed analysis of the activities has been initiated using the repertory grid knowledge acquisition technique [Gaines & Shaw, 1993a] [Gaines & Shaw, 1993b]; the results are shown in section 4.

2.2 Enriching the CommonKADS Organizational Model for the ACP domain

The process of domain familiarization also showed that some aspects of the organization surrounding ACP – in particular, power/authority relationships – would benefit from being represented in more detail than the CommonKADS Organizational Model currently permits. It was decided that the multi-perspective approach to organizational modelling would be maintained, but that the perspectives would be altered to permit the representation of rights of access to resources and information, and the representation of who was responsible for performing which activities. The result was that a set of perspectives were developed based on three basic entities: *activities*, *agents* and *resources*.[2] Figure 1 shows the perspectives which were used, and how they were combined.

The **Dictionary** perspectives are simply sets of activities (or agents or resources) which are used as a basis for building the other perspectives. The **Network** perspectives show how entities of the same type relate to one another:

- Activities *precede* each other to produce a *process*;
- Agents *report to* each other and *belong to* departments to produce an *organizational structure*;
- Resources have a particular *status*, and the existence of one or more resources with a certain status may constitute a *state of affairs*. For example, "Air Campaign Plan completed" might be a state of affairs; it would exist if the status of the **Air Tasking Order** was *endorsed*, the status of the **Feasibility Analysis** was *complete*, and the status of the **Master Air Attack Plan** was *endorsed*.

[2] This distinction was derived from the ORDIT project which is intended to support organizational requirements definition [Dobson & Strens, 1994].

The **Cross Product** perspectives show how resources are produced, used, consumed or modified within the process (*Assets perspective*, what rights agents have to resources (*Rights perspective*), and the obligations and responsibilities to perform activities and to create states of affairs (*Responsibilities perspective*).

Further details on each perspective will be given in the next section.

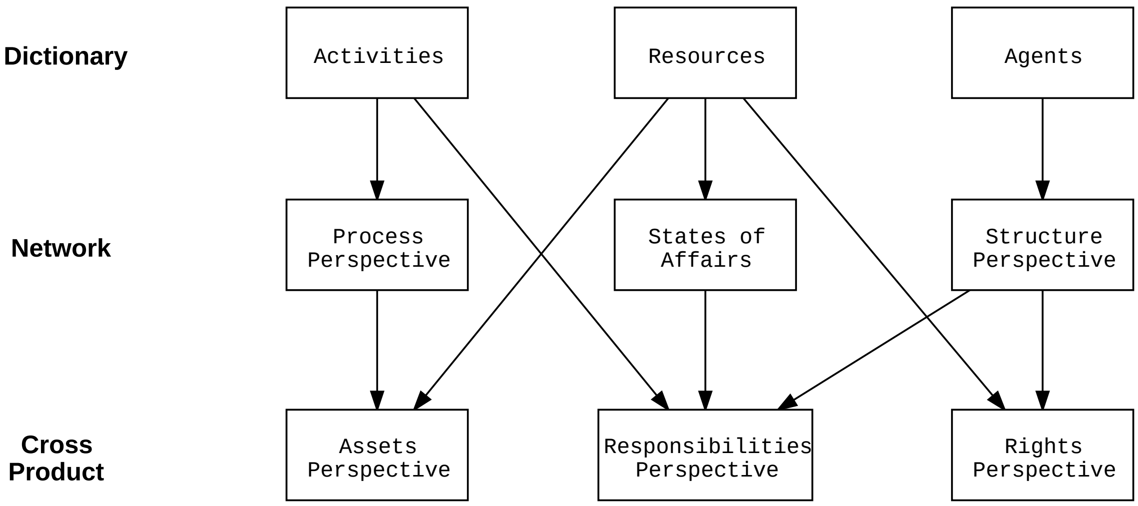

Figure 1: Enriched organizational model: perspectives and cross-products

3 Organizational Model of the ACP process

3.1 Process Perspective

Figures 2 to 8 show the activities involved in ACP, and how these activities link to form processes. The six diagrams are a hierarchical decomposition: Figure 2 is the top level diagram, figures 3, 4 and 8 show decompositions of three top-level activities (**Prepare for ACP planning**, **Produce Air Campaign Plan** and **Execute Air Campaign Plan**), and figures 5-7 show second-level decompositions of activities connected with prioritization within the planning process.

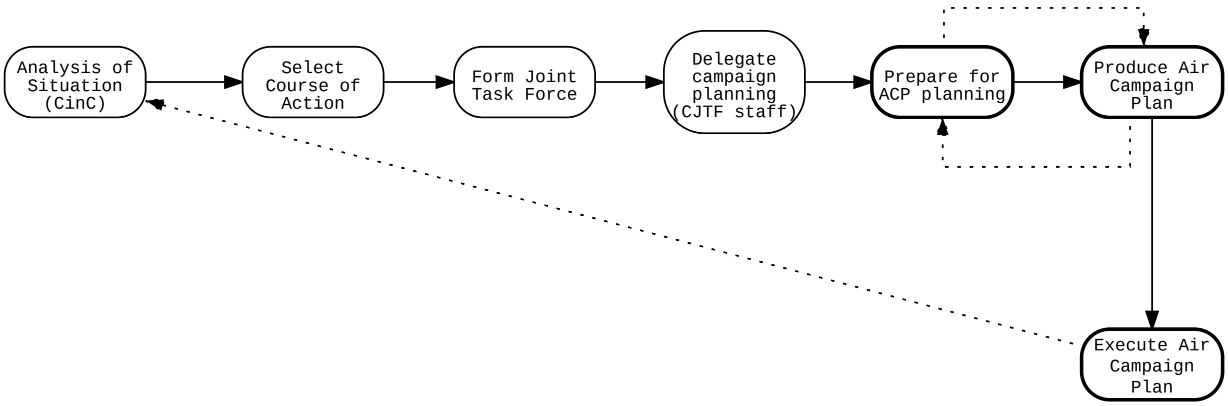

Figure 2: ACP Process Perspective: Top Level

Key:

Solid link	the first activity *precedes* the second
Dashed link	there is an *information flow* from the first activity to the second.

Description of activities:

Analysis of Situation (CinC) : The Commander in Chief analyzes the political and military situation.

Select Course of Action : The CinC selects a course of action for the US military forces to pursue.

Form Joint Task Force : A joint task force is formed.

Delegate campaign planning : The task of campaign planning is delegated to the various Joint Force component commanders (e.g. the JFACC).

Plan Air Campaign : The air campaign is planned. This activity can be viewed in more detail in figure 4.

Execute Air Campaign Plan : The air campaign plan is carried out. This activity can be viewed in more detail in figure 8.

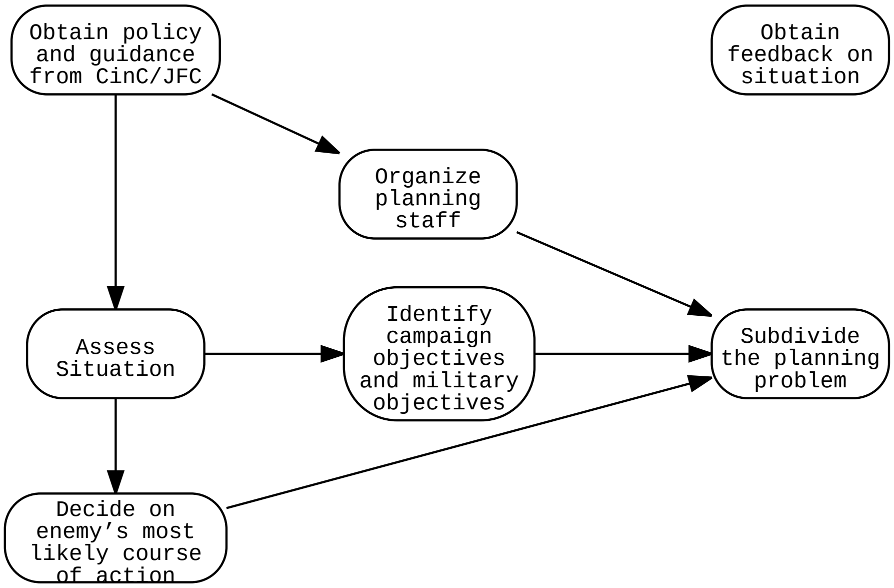

Figure 3: ACP Process Perspective: Prepare for ACP planning

Key:

Solid link	the first activity *precedes* the second
Dashed link	there is an *information flow* from the first activity to the second.

Description of activities:

Obtain policy and guidance from CinC/JFC : The JFACC must receive instructions, and guidance on military and political policy, before he can initiate the planning of an air campaign.

Organize planning staff : The Director of Planning divides his planning staff into small groups to work on different aspects of the plan. Typically, the groups will be pairs, with one member of the Planning unit working with one member of the Intel unit.

Assess situation : Assess the military (and political) situation, using background information and local knowledge.

Identify campaign objectives and military objectives : The JFACC must identify campaign objectives and military objectives from the policy and guidance which he has received from higher echelons. It's actually possible that the JFACC might negotiate these objectives, though it's unlikely until the later stages of planning, when there may be a good case for the negotiation of objectives.

Decide on enemy's most likely course of action : The JFACC must decide on the enemy's most likely course of action. This requires background knowledge as well as a good assessment of the current situation.

Subdivide the planning problem : The production of the ACP is subdivided to allow different planning groups to work on different aspects of the problem. The subdivision will use one or more of the following criteria:

- Phase of the conflict (the most popular way);
- Classes of air objectives (air superiority, interdiction, reconnaissance, etc.);
- Centres of gravity;
- Geographical area.

Assuming that the planning staff breaks the plan down by phase, the way phases are broken down depends on the experience of the staff and the personalities involved. The team will determine how to split people between the phases. The first phase almost always has priority, because phase 1 of a plan is used to gain control of the crisis, stabilize the situation and set up for the next phases. The team will also establish metrics for evaluation of the effectiveness of a phase; the metrics may include cost, logistics, INTELligence reports, and resources.

Obtain feedback on situation : This activity is **not** explicitly carried out as part of the planning process, which explains why it is not linked to any other activity. Doug thinks it should be carried out, though.

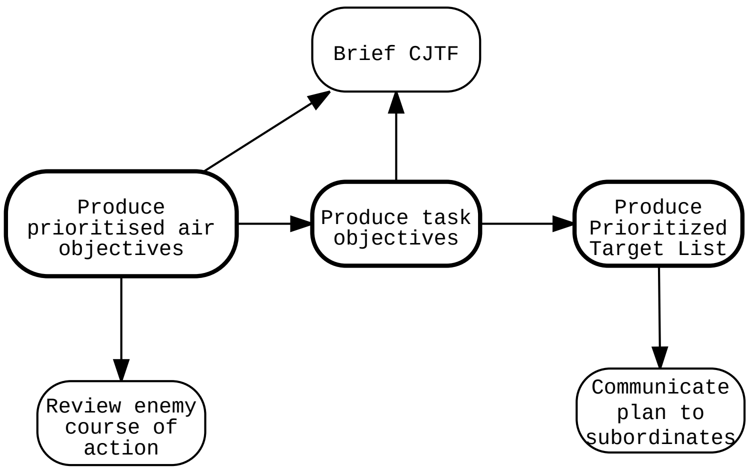

Figure 4: ACP Process Perspective: Plan Air Campaign

Key:		
	Solid link	the first activity *precedes* the second
	Dashed link	there is an *information flow* from the first activity to the second.

Description of activities:

Produce prioritized air objectives : This activity can be viewed in more detail in Figure 5.

Review enemy course of action : This activity is **not** currently carried out explicitly, although Doug thinks it should be.

Produce task objectives : This activity can be viewed in more detail in Figure 6.

Brief CJTF : The JFACC explains the objectives and the current state of the campaign plan. The CJTF is likely to provide feedback, saying that the plan has been prepared incorrectly, or that there are further instructions which the planners need to take into account. These instructions might be "coordinate better with land forces", "the President says don't attack within 50 miles of the enemy capital city", or "deconflict your plan with SOF".

Produce Prioritized Target List : This activity can be viewed in more detail in Figure 7.

Communicate plan to subordinates : This requires the formal plan to be distributed to squadrons. Communicating the plan is not difficult, but there is no way to communicate strategy down the echelons of the Air Force. Pilots are often given the wrong target for any number of reasons, so it is natural for them to question unusual targets; if the pilots had a concept of the strategy they may not question their assignment. An example of this which occurred during Desert Storm was that pilots were ordered to attack transformers of power stations, in order to support the political objective that Iraq should be able to recover quickly after the war, as well as the task objective of disrupting power supplies. However, some pilots observed that the transformers were adjacent to large and vulnerable power stations, assumed that a small mistake had been made in their orders, and attacked the power stations instead.

In response to some further prompting, Doug supplied more information on two particular circumstances which might affect the planning process:

1. Shortage of munitions. If there is a shortage of munitions for carrying out air operations, this will be taken into account in the planning process, with the most limited munitions being allocated to the most important operations. This allocation may be decided by the JFACC, who issues guidance to the planners that certain munitions are reserved for certain operations, or it may be considered by the planners, based on "their experience".

2. Co-operation with land forces or SOF. There may be occasions where a target which is identified as worthy of attacking by air could be targeted by Army helicopters or SOF forces with equal or greater efficiency. In such cases, there will first be informal liaison between the AOC planners and the appropriate land forces to determine if it's feasible for the land forces to take on the operation; if so, the JFACC will include a request for these forces in his briefing for the CJTF.

   Interaction with land forces gives the relevant land forces rights to view the Master Air Attack plan, for the sake of deconfliction of operations.

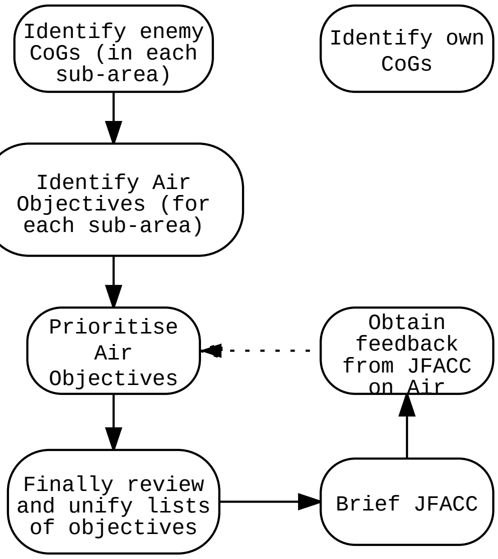

Figure 5: ACP Process Perspective: Produce Prioritized Air Objectives

Key:		
	Solid link	the first activity *precedes* the second
	Dashed link	there is an *information flow* from the first activity to the second.

Description of activities:

Identify enemy Centres of Gravity (in each sub-area) : This activity is carried out by each planning team, each of whom is assigned to a particular sub-area (see **Subdivide planning problem** above). Their task is to analyze the enemy's military forces, infrastructure, and limitations.

This information is continuously updated throughout the planning, because the position of the enemy is constantly changing. The planning staff will find INTELligence documents and books for details. The planners will look at cultural issues, the enemy's intent, how many weapons the enemy has, how the enemy works and how the enemy hides their resources.

The planners then use this analysis to identify key points in enemy territory which, if damaged or destroyed, would seriously disrupt the enemy's military operations. These key points are known as *Centres of Gravity*. For example, the staff will want to know the most likely situation if the enemy troops loose their command and control. Some troops are trained to not think on their own so loss of command and control would result in immediate chaos. In this situation, enemy command and control centres would be considered to be centers of gravity.

Identify air objectives (for each sub-area) : This activity is carried out by each planning team, each of whom is assigned to a particular sub-area (see **Subdivide planning problem** above). Their task is to identify objectives for the air forces to achieve. These objectives should be chosen to provide maximum benefit to the friendly forces (with respect to the identified military objectives)[3] , based on the situation assessment, the expected enemy course of action, and above all on the description of enemy Centres of Gravity.

Planners usually take a breadth-first approach to the identification of air objectives. A good description of different categories of air objectives can be found in [Warden, 1989].

Identify own Centres of Gravity : This is an activity which is not currently performed (and therefore it is not linked to the other activities in the diagram), largely because of time restrictions. However, Doug believes that it should be performed, in order to support strategic planning for defense as well as attack.

Prioritize Air Objectives : This requires decisions about which air objectives are the most important. The key factors in this decision are the Centers of Gravity which are targeted, and the campaign objectives and military objectives. However, a number of factors make this a complex task: the time delay between missions taking place and the enemy's capabilities being affected; the possibility that some missions could achieve more than one air objective; and limitations on the resources available for carrying out certain types of missions.

Finally review and unify lists of objectives : This activity takes place at a meeting where, as the name suggests, the air objectives identified and prioritized by the different planning teams are brought together and unified into a

[3]The official Air Force doctrine on the "mission statement" of the USAF is contained in manual AFM 1-1. However, Doug tells us that most air force officers complete a full career without ever reading that manual.

single prioritized list of air objectives. The reviewing is an important activity, because it is intended to identify any enemy Centres of Gravity or likely enemy activity which is not addressed by any of the identified air objectives.

Brief JFACC and **Obtain feedback from JFACC on Air Objectives**: The JFACC is briefed every day, usually at a set time. On the first day of planning, he will be briefed on the chosen list of air objectives, with justifications for prioritization. He will give feedback on his opinion of the air objectives, especially their relevance to the campaign objectives and military objectives; he may also give specific instructions for modifications, based on his knowledge of operations which the Director of Planning is not aware of.

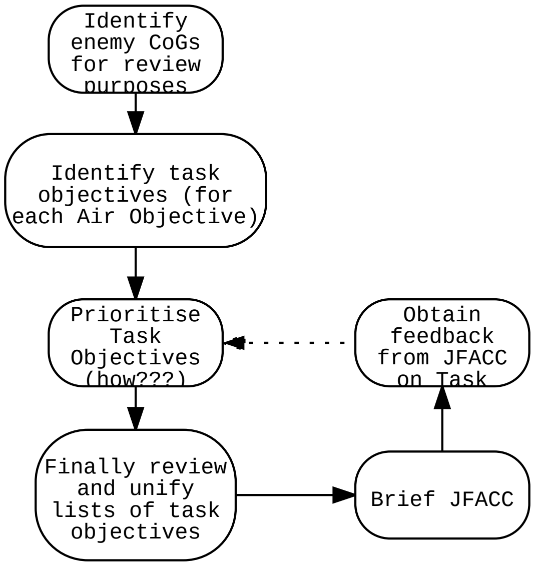

Figure 6: ACP Process Perspective: Produce Prioritized Task Objectives

Key:		
	Solid link	the first activity *precedes* the second
	Dashed link	there is an *information flow* from the first activity to the second.

Description of activities:

One of the main discoveries from this modelling exercise has been that the processes involved in producing prioritized air objectives, producing prioritized task objectives and producing a prioritized target list are very similar. The textvs below should therefore be read in conjunction with the description of activities involved in producing prioritized air objectives.

Identify enemy Centers of Gravity for review purposes : Although the air objectives have already been designed to target enemy Centers of Gravity, it's helpful to review the Centers of Gravity at this stage of planning.

Identify task objectives (for each Air Objective) : Identifying task objectives for the air force to achieve consists of choosing task objectives which provide the maximum fulfilment of the air objectives, based on the air objectives chosen and on identified enemy Centres of Gravity.

For example, if "disrupt command and control" had been specified as an Air Objective, possible task objectives might include:

- attack command posts
- attack lines of communication
- jam radios
- kill men by attaching barracks
- isolate men
- isolate roads
- destroy communication centers

N.B. The term "task objective" is comparatively new; the term "Course of Action" may also be heard, describing the same objectives.

Prioritize task objectives is largely based on the prioritization of corresponding air objectives, although there may be other influences if certain task objectives can fulfil more than one air objective.

Finally review and unify lists of tasks occurs at a meeting, to bring together all the task objectives in a single list and to ensure that all air objectives are addressed by task objectives.

Brief JFACC and **Obtain feedback from JFACC on Task Objectives**: The JFACC's second briefing normally describes both identified task objectives and identified targets, since the identification of task objectives is a relatively quick activity. However, significant feedback may well be produced, enough for the planning staff to require a third day of planning to iteratively refine the lists of objectives and targets to meet the JFACC's requirements.

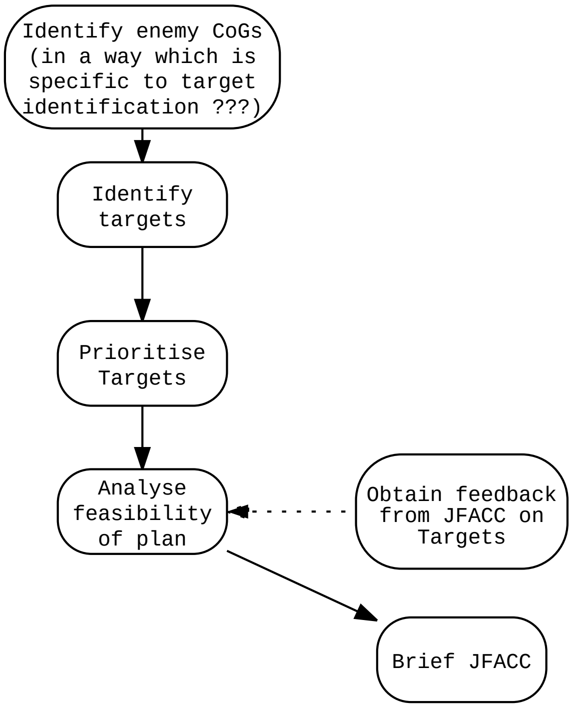

Figure 7: ACP Process Perspective: Produce Prioritized Targets

Key:

Solid link	the first activity *precedes* the second
Dashed link	there is an *information flow* from the first activity to the second.

Description of activities:

One of the main discoveries from this modelling exercise has been that the processes involved in producing prioritized air objectives, producing prioritized task objectives and producing a prioritized target list are very similar. The textvs below should therefore be read in conjunction with the description of activities involved in producing prioritized air objectives.

Identify enemy Centers of Gravity (in a way which is specific to target identification) : Although the air objectives have already been designed to target enemy Centers of Gravity, it's helpful to review the Centers of Gravity at this stage of planning. No information has yet been acquired on any special features of Centers of Gravity which are specific to target identification.

Identify targets : Identifying targets consists of choosing targets which provide the maximum fulfilment of the task objectives, based on the task objectives chosen and on identified enemy Centres of Gravity.

Prioritize targets should largely be based on the prioritization of corresponding task objectives. In practice, the planners spend a lot of time discussing the list of targets and moving certain targets up or down the prioritization; this action effectively incorporates the review and unification of the target list.

Analyze feasibility of plan is a computerized process. The format of the output is not yet known.

Brief JFACC and **Obtain feedback from JFACC on Targets**: see description of **Obtain feedback from JFACC on Task Objectives** above.

Figure 8: ACP Process Perspective: Execute Air Campaign Plan

Key:		
	Solid link	the first activity *precedes* the second
	Dashed link	there is an *information flow* from the first activity to the second.

Description of activities:

Weaponize Target List : determine what weapons will be needed to damage or destroy particular targets, and therefore decide which types of aircraft should carry out the mission. This is done by calculating the Desired Mean Point of Impact (DMPI) and required munitions for each target. The DMPI specifies the best weapons for a target, the exact angle the target should be hit and the exact location that the target should be hit. This activity is carried out by the Ops group at the Air Operations Center.

Schedule Target List : determine when each target should be attacked. This will depend on both the priority of the target and the availability of suitable aircraft. This is also carried out by the AOC Ops group, using a system known as CTEMS. The result of this is the Air Tasking Order, which is the document which is passed to the Wings.

In the course of refining the air campaign plan, the Ops group sometimes find and report anomalies in the plan.

Produce Mission Plan : The Wings (and/or???) the squadron leaders are responsible for planning how their mission(s) should be accomplished at the required time(s).

Fly mission : Once the aircraft are airborne, responsibility for the mission passes to the flight leaders. If changes to the ATO occur at this stage (e.g. a sudden change in weather), the Ops group at the Air Operations Center will communicate directly with the flight leader.

Report results : Once the mission is completed, the fliers are required to report their results to help in gauging the success of a mission.

3.2 Structure Perspective

Figures 9 and 10 show two different aspects of the organizational structure surrounding the ACP process. Figure 9 shows the structure of the US Air Forces, from AFOR (Air Force Command) downwards; it also shows that AFOR "belongs to" the JFACC. Figure 10 shows the structure of the Joint Forces Command, including the staff who produce the Air Campaign Plan and report to the JFACC, and the upper echelons from whom the JFACC receives his instructions.

Doug Holmes highlighted a difficulty with modelling the structure of a Joint Forces Command; sometimes the CinC chooses to adjust the structure according to his own preferences. To be more precise, the CinC may alter the lines of authority or reporting requirements, in order to improve his own liaison with selected groups or individuals. For more detail on these alterations, see section 3.5.

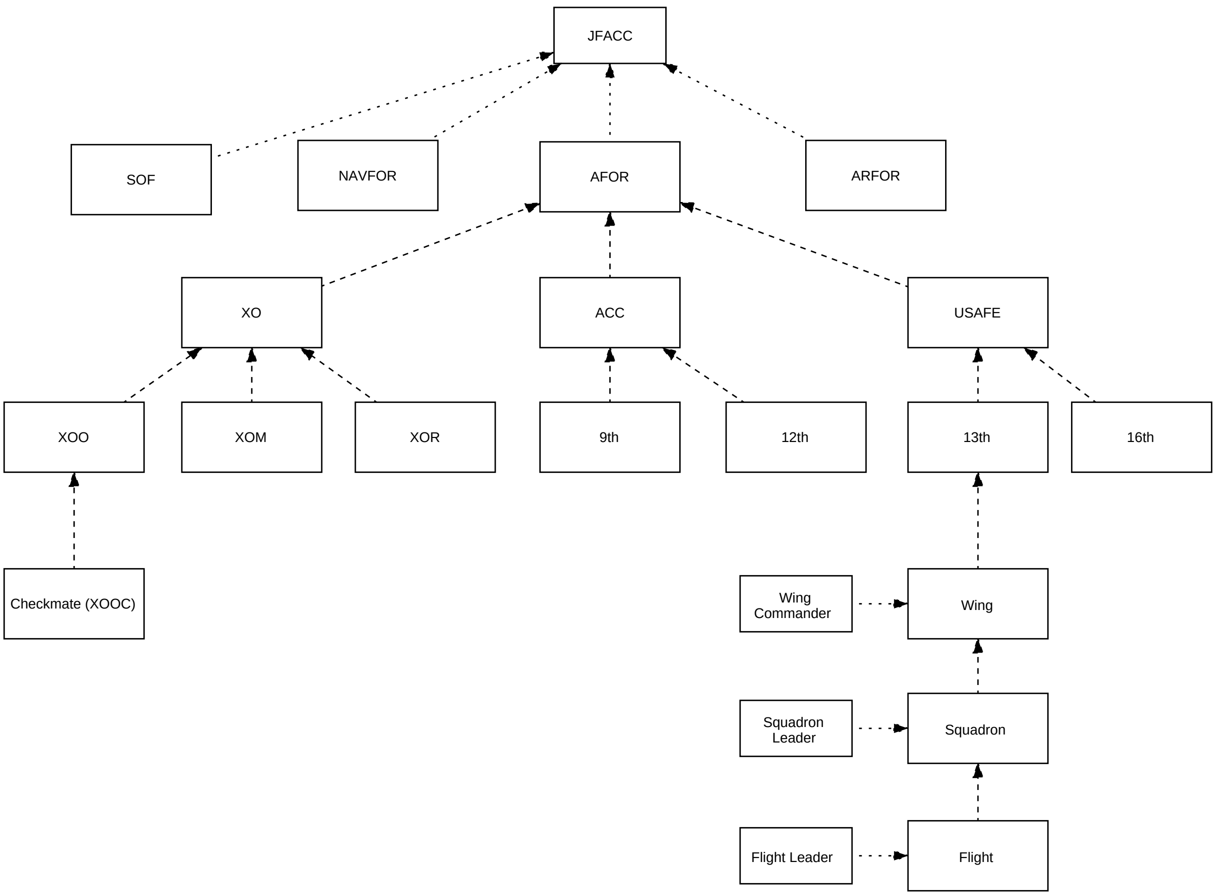

Figure 9: Structure of the US Air Forces

Key:		
	Solid link	the first agent *reports to* the second
	Dashed link	the agent *belongs to* the department

N.B. This diagram is *not* complete, and not currently intended to be; Doug's main purpose in producing it was to show where Checkmate fitted into the structure. The numbered Air Forces are shown for illustration purposes only, and may not correspond to real numbered Air Forces.

Partial description:

Wings give missions to squadrons. There will be 3-4 **squadrons** in a wing, with 17-24 aircraft each. The personnel in a squadron will be divided into **flights**; there will be 3-4 flights, typically of 12 pilots each.

N.B. Once a mission is in progress, the term *flight* is used to apply to a subgroup of aircraft within the mission forces. A "mission flight" typically consists of 4 planes, which may be drawn from one or more "squadron flights". The Navy avoid this confusion by using the term *section* for a "mission flight".

Checkmate is a group of expert air planners at the Air Force Headquarters in the Pentagon, who may play a role in a JTF by augmenting the JFACC planning group or by working separately from the JFACC planning group. Checkmate was originally a war gaming center for evaluation of plans with a focus on high level strategy; for example, Checkmate modeled WWIII in Europe so that logistics, purchasing and training could be planned in the event that crisis occured. However, the senior Air Force officers often use Checkmate to supplement their planning staff. As a result, Checkmate personnel have real world planning experience even though it is not in the group's original charter.

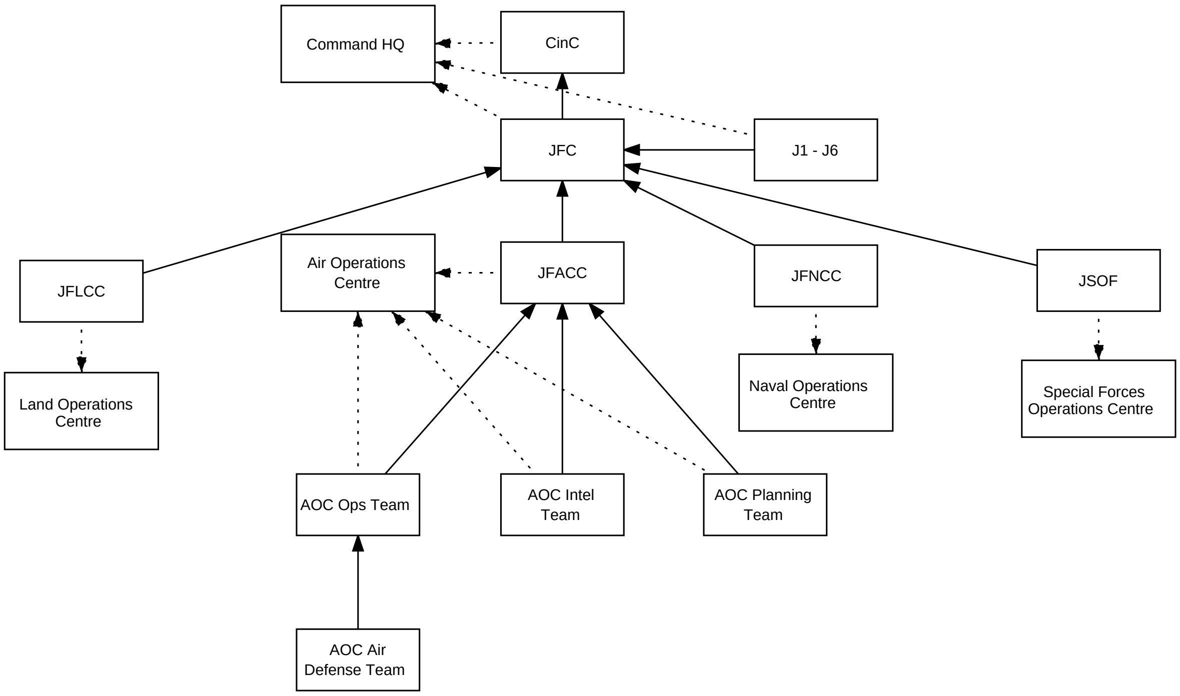

Figure 10: Structure of a typical Joint Task Force

Key:

Solid link	the first agent *reports to* the second
Dashed link	the agent *belongs to* the department

In addition to the information shown in this diagram, Doug explained the operational sequence within the Air Operations Center when an ACP has to be produced. The INTEL group, who gather information constantly, are assigned to work with the Planning group (typically in pairs) on various sub-parts of the planning problem. Redundancy (two pairs working on the same problem) is very rare. The parts of the plan are unified by the head of the Planning group (Director of Planning), who briefs the JFACC at various stages of the planning cycle. The completed plan is then passed to the Ops group, who perform the activities shown in Figure 8.

3.3 States of Affairs

A State of Affairs indicates that one or more resources have reached a certain status which is important to the ACP process. Since most of the resources used by ACP planning are passive resources (e.g. documents), most of the important states of affairs will correspond to the completion of certain documents.

No states of affairs have yet been fully identified; however, the diagram of the Responsibilities perspective 3.6 below illustrates some possible states of affairs which might emerge as being important.

3.4 Assets Perspective

The Assets perspective takes the activities identified in the Process perspective, but replaces the precedence links with information regarding the resources which are produced, consumed, used or modified by the various activities. A diamond-shaped node in the diagram represents a *passive resource* (a document or file); ellipses represent *computer resources* (e.g. databases); rectangles represent a *human resource*; and rounded rectangles represent activities.

The diagrams in Figures 11 to 16 use the same hierarchical decomposition as the Process perspective; thus Figure 11 displays the activities shown in Figure 4, Figure 12 displays the activities shown in Figure 5, and so on.

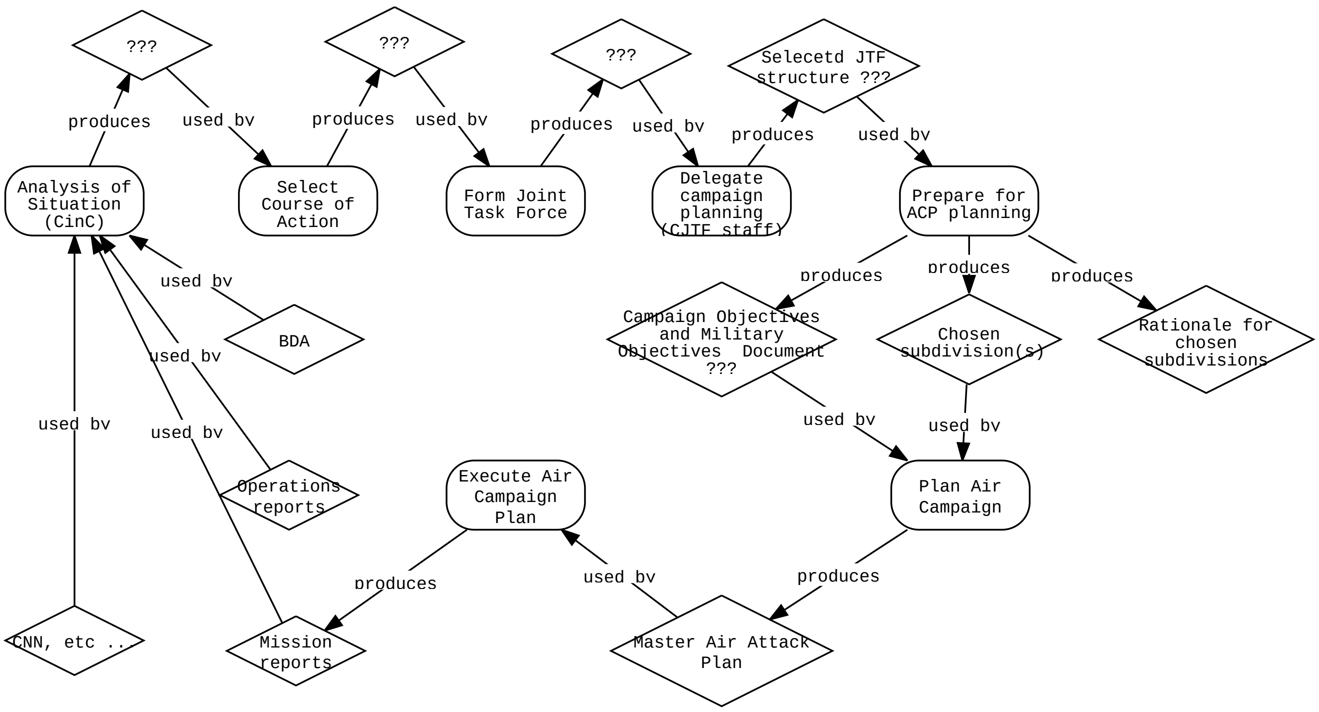

Figure 11: ACP Assets Perspective: Top Level

Key:	Labelled link	the activity *produces/consumes/uses/modifies* the resource
	Diamond	Passive resource
	Ellipse	Computer Resource
	Rounded rectangle	Activity

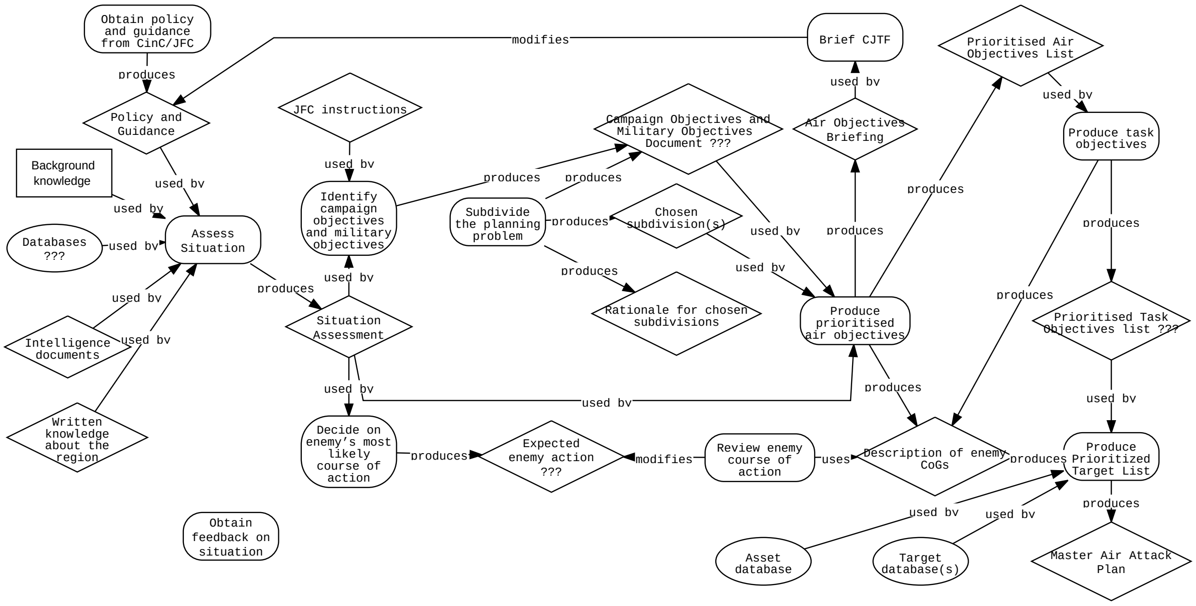

Figure 12: ACP Assets Perspective: Plan Air Campaign

	Labelled link	the activity *produces/consumes/uses/modifies* the resource
	Diamond	Passive resource
Key:	Ellipse	Computer Resource
	Rounded rectangle	Activity
	Blue Rectangle	Human resource

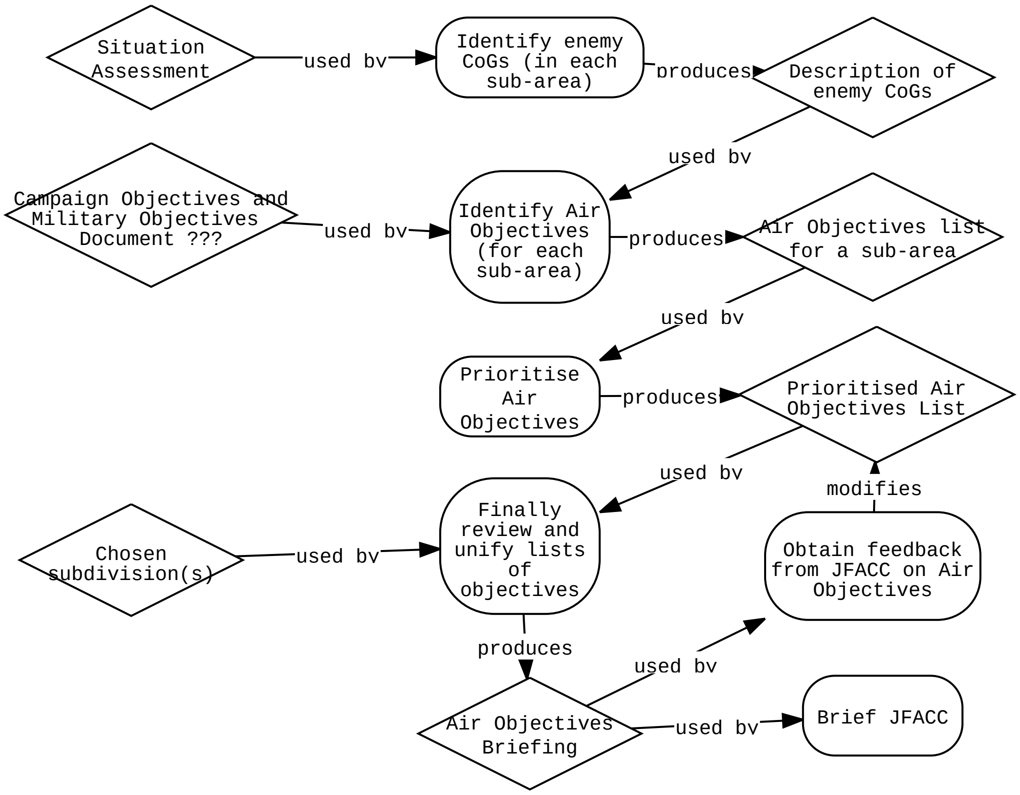

Figure 13: ACP Assets Perspective: Prioritize Air Objectives

Key:

Labelled link	the activity *produces/consumes/uses/modifies* the resource
Diamond	Passive resource
Ellipse	Computer Resource
Rounded rectangle	Activity

Partial description:

Air Objectives Briefing contains:

- An interpretation of the situation assessment;
- A list of identified enemy Centres of Gravity, with justification for that list;
- A list of air objectives, with justification for each. The justification typically takes one of three forms: "it's obvious", "conventional wisdom says to do this", or a specific justification;
- A rationale for the prioritization of air objectives.

In practical terms, the prioritization of air objectives correlates closely with the sequencing (temporal ordering) or air objectives.

Situation Assessment is usually comparatively short in its written form; perhaps a paragraph in a document, or the first 2 slides in a briefing. The format varies between different operational theaters; in some cases, this assessment will be incorporated into the formal air campaign plan.

Campaign Objectives and Military Objectives do not usually appear ina document these days; instead, they appear in the Objectives Viewer of ACPT (the Air Campaign Planning Tool). However, a slot for these objectives appears in formal campaign planning templates, so if ACPT did not exist, a document describing these objectives would be produced.

Most likely enemy action : This is typically represented in note form, although it would be advantageous if it were made more formal.

Rationale for subdivision : This does **not** currently exist, although it should.

Description of enemy Centers of Gravity : These are defined within ACPT. ACPT makes use of 2 input forms:

1. The hierarchy of Centers of Gravity which is outlined in [Worden 94]
2. The ACPT Rationale editor, where statements of the following form are made:

   (The plan includes an) *air objective* FOR *centre of gravity* BECAUSE OF *documents* (cut-and-pasted)

Sometimes the ACPT Rationale Editor is not used, since it is considered to be implicit in the ACPT Objectives Editor.

Prioritized Air Objectives List : Not all formal ACPs include this list, although Doug said that if he were a JFACC, he'd want this list on a daily basis.

Chosen subdivisions exist in ACPT.

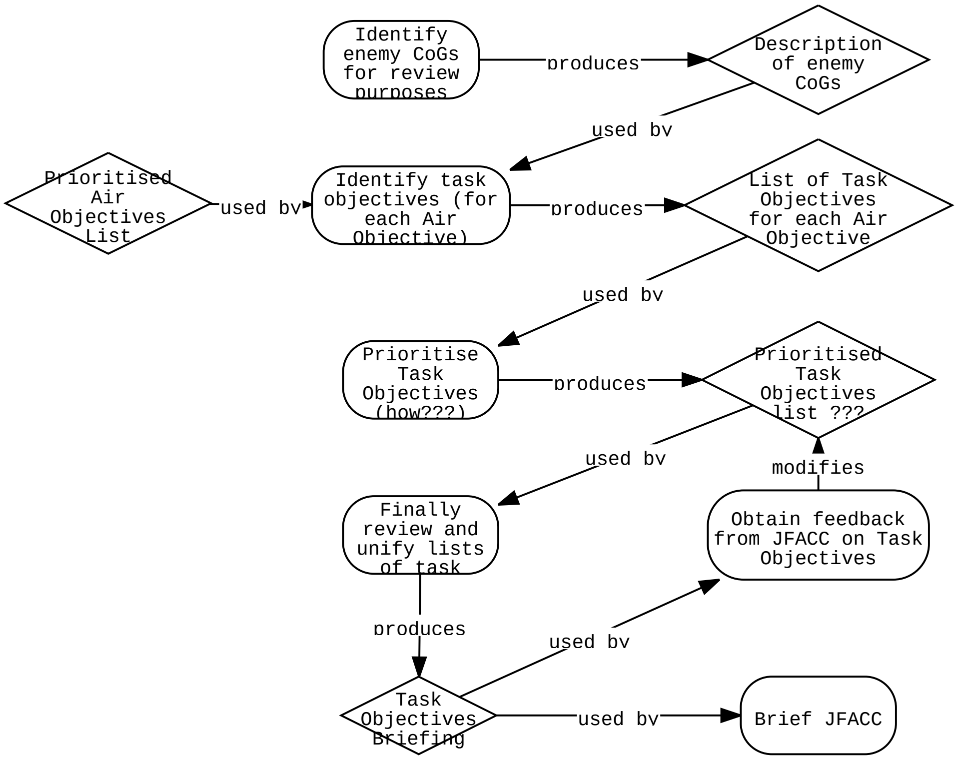

Figure 14: ACP Assets Perspective: Prioritize Task Objectives

Key:

Labelled link	the activity *produces/consumes/uses/modifies* the resource
Diamond	Passive resource
Ellipse	Computer Resource
Rounded rectangle	Activity

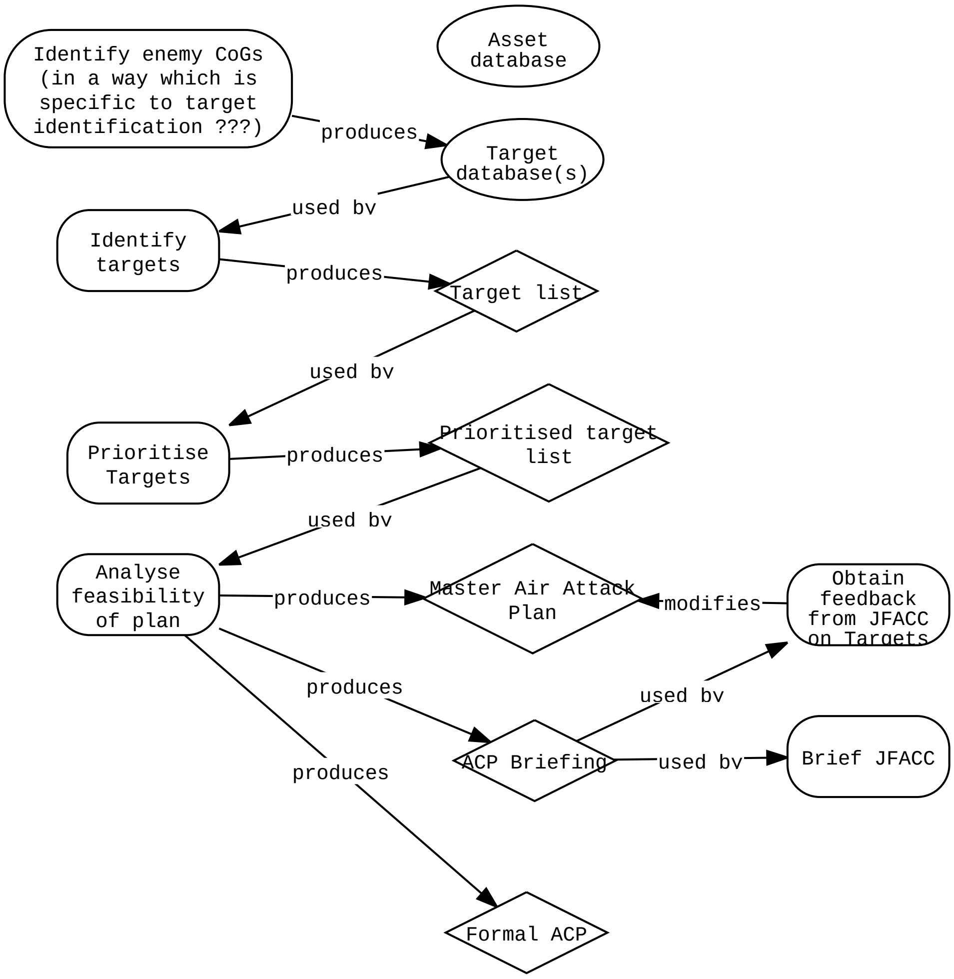

Figure 15: ACP Assets Perspective: Prioritize Targets

Key:

Labelled link	the activity *produces/consumes/uses/modifies* the resource
Diamond	Passive resource
Ellipse	Computer Resource
Rounded rectangle	Activity

The **Asset database** is not linked to anything because it is not currently used within the process.

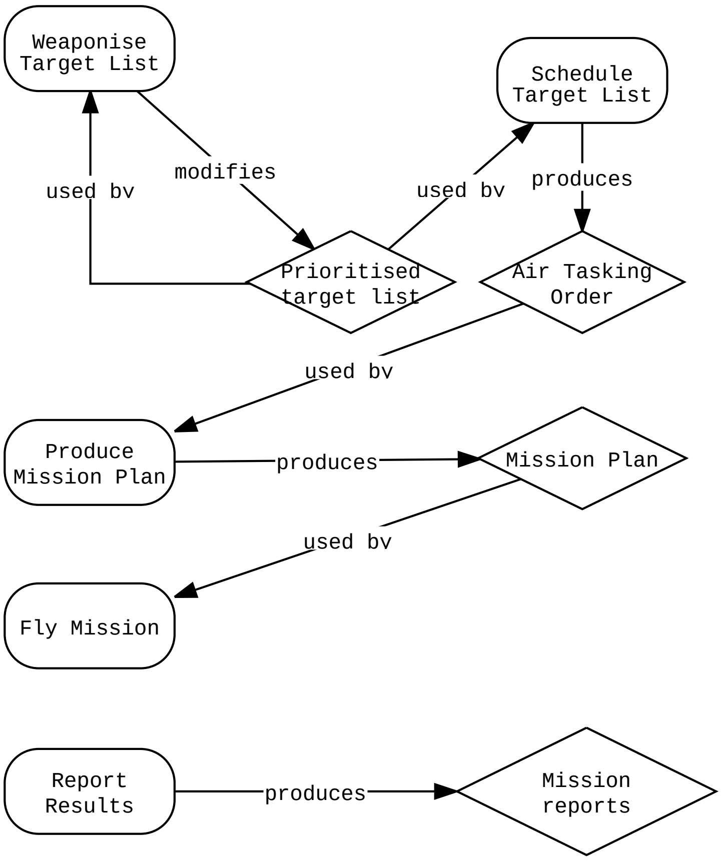

Figure 16: ACP Assets Perspective: Execute Air Campaign Plan

Key:	Labelled link	the activity *produces/consumes/uses/modifies* the resource
	Diamond	Passive resource
	Ellipse	Computer Resource
	Rounded rectangle	Activity

3.5 Rights Perspective

Very little knowledge has been acquired for the Rights perspective. However, this perspective is considered to be important because it represents the authority of various individuals or groups to view or to alter certain resources. By representing this authority, it becomes possible to frame discussions about the consequences of changing these rights.

An example of the consequences of changing rights can be drawn from Desert Storm [Thaler & Shlapak, 1995]. General Schwarzkopf, the CinC, not only briefed all Joint Force Commanders at meetings, he also sometimes gave out guidance or instructions to an individual Joint Force Commander by telephone or in private meetings. One such instruction, given to the JFACC, was that Iraqi units believed to be below 50% of full combat strength should no longer be targeted for air strikes. This instruction was not communicated to the land commanders, who were left to wonder why the Air Force had ceased to support them; indeed, many did not find out about this instruction until after the war! It can be seen that the CinC decided to withdraw (or neglected to provide) the JFLCC's rights to view the instructions and guidance which the CinC was providing to the JFACC, and that the result was considerable scope for confusion and irritation. Of course, there may be advantages (e.g. in security) in General Schwarzkopf's approach; but it is important to have a framework for weighing the pros and cons of a particular decision.

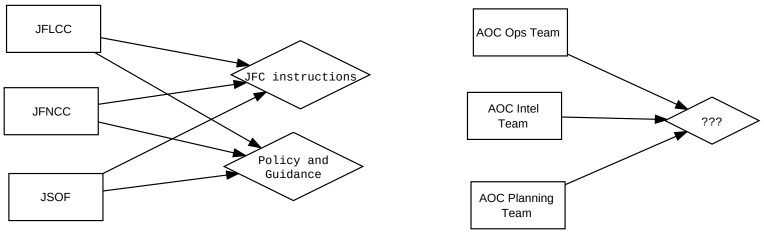

Figure 17: Rights Perspective

Key:	Solid link	the agent has a *right* to the resource

3.6 Responsibilities Perspective

The Responsibilities perspective shows which agents are responsible to which other agents for a state of affairs, and what obligations agents have as a result of their responsibilities. There is very little information available for the Responsibilities perspective at present; the diagram in Figure 18 illustrates the format which a diagram of the Responsibilities perspective would take.

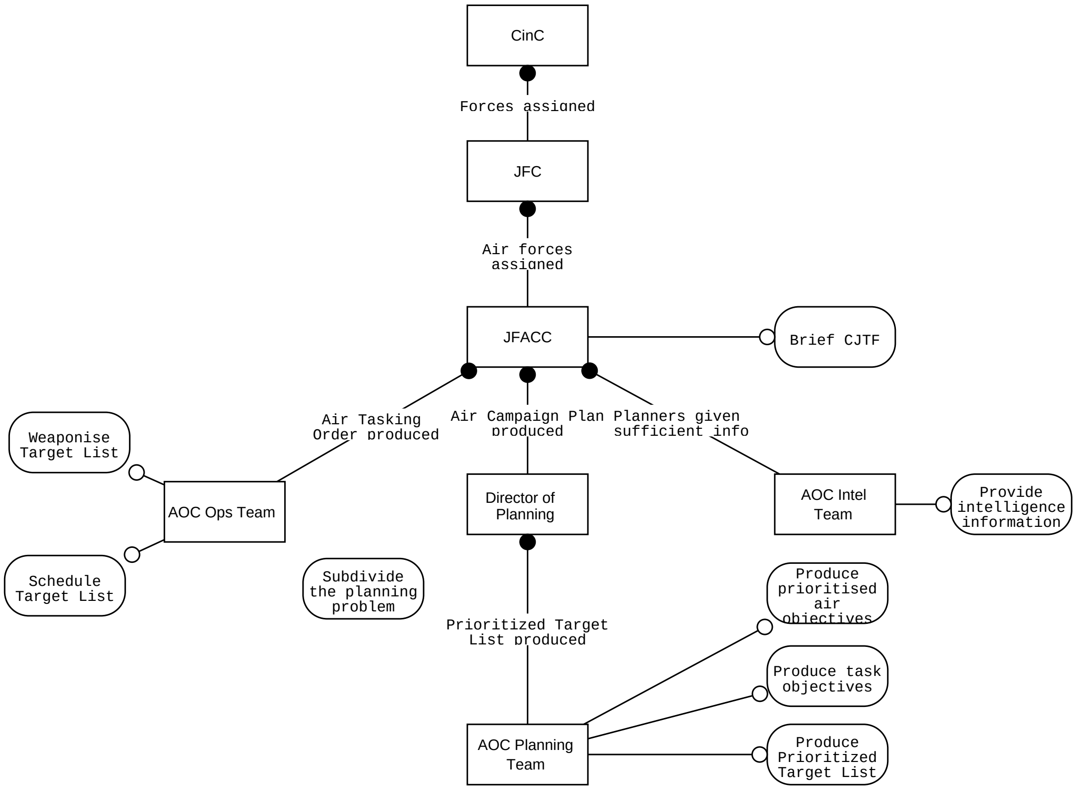

Figure 18: Responsibilities Perspective

Key:		
	Link with black circle	the first agent is **responsible** to the second for a state of affairs (which is indicated by the label on the link)
	Link with white circle	the agent is **obliged** to perform the activity

4 Initial Task Analysis

4.1 Repertory Grids

Figures 19 and 20 take a different perspective on the activities. A grid is drawn with each activity forming a separate column in the grid. The rows are labelled with attributes against which each activity can be classified on a 1-5 scale; these classifications were obtained from Doug Holmes using the "repertory grid" knowledge elicitation technique. For example, the grid in Figure 13 shows that, in Doug's opinion, identifying campaign objectives and military objectives takes very little time (1 = Short), but requires considerable experience (4 = Fairly Much). The activities displayed in Figure 4 appear as columns in Figure 19, and the activities displayed in Figures 5-7 appear as columns in Figure 20. The purpose of completing this grid is to differentiate the activities on dimensions which are important to the ACP process.

The first four attributes in these grids were derived from previous experience of using this technique to obtain knowledge about activities. The final two attributes (**Analytic vs Synthetic** and **Evaluation required**) were suggested by Doug, after prompting using a triadic elicitation technique (choosing three domain items at random and asking the expert to specify a dimension on which one of the three items differs from the other two). There is much useful information to be gained from this technique, both by statistical analysis of the scores provided (see below) and also from the 'asides' which the expert mentions as he is completing the grid (see below).

The repertory grid is also a good way of objectively identifying differences in opinion between different experts. It is hoped that this technique will be used with other experts in the ACP process in the course of this project.

	Plan Air Campaign	Obtain policy and guidance from CinC/JFC	Organize planning staff	Assess Situation	Identify campaign objectives and military objectives	Subdivide the planning problem	Decide on enemys most likely course of action	Review enemy course of action	Communicate plan to subordinates	Brief CJTF	Produce prioritized air objectives	Produce prioritized task objectives	Produce prioritized target list
1 = Little 5 = Much	Experience required	2	3	4	4	4	3	4	3	4	5	4	3
1 = Trivial 5 = Very serious	Seriousness of mistake	2	3	4	3	3	4	4	3	4	5	4	3
1 = Rare 5 = Frequent	Likelihood of mistake	2	2	3	3	1	3	2	1	3	3	3	3
1 = Short 5 = Long	Time required	1	2	4	1	2	1	2	2	3	4	4	4
1 = Analytic 5 = Synthetic	Analytic vs Synthetic	1	4	2	1	1	2	1	4	4	3	3	3
1 = Little 5 = Much	Evaluation required	1	4	3	1	4	2	2	1	4	5	5	5

Figure 19: Repertory Grid: Attributes of Air Campaign Planning

	Prioritizing air objectives, tasks, targets	Identify enemy CoGs (in each sub-area)	Identify Air Objectives (for each sub-area)	Prioritize Air Objectives	Finally review and unify lists of air objectives	Brief JFACC on air objectives	Identify enemy CoGs (for each air objective	Identify Task Objectives	Prioritize Task Objectives	Finally review and unify lists of Task Objectives	Brief JFACC on Task Objectives	Identify enemy CoGs (in a way which is specific	Identify targets	Prioritize targets	Analyze feasibility of plan	Brief JFACC on Air Campaign Plan	Review targets
1 = Little 5 = Much	Experience required	5	4	4	5	5	3	3	3	5	4	3	3	3	5	5	5
1 = Trivial 5 = Very serious	Seriousness of mistake	4	4	3	4	4	3	3	3	4	3	3	2	3	4	4	2
1 = Rare 5 = Frequent	Likelihood of mistake	3	3	2	2	3	2	2	2	2	2	2	1	3	2	2	3
1 = Short 5 = Long	Time required	5	3	2	1	4	3	2	2	2	3	3	4	4	2	4	3
1 = Analytic 5 = Synthetic	Analytic vs Synthetic	2	4	1	4	3	2	4	1	4	3	2	4	1	1	4	4
1 = Little 5 = Much	Evaluation required	2	3	5	4	1	2	3	5	4	1	2	1	5	5	2	3

Figure 20: Repertory Grid: Attributes of Tasks involved in Prioritization

Recording the "aside" comments which Doug made while completing the grid produces much useful information about the activities involved in air campaign planning. Doug made some general comments about the criteria which he used in filling in the numbers in the grid; these are listed below, followed by the information which was gathered on individual activities.

4.1.1 Criteria for filling in the grids

The criteria are listed for each row in the grids:

Experience required : The criterion which Doug was using here was the rank of the officer who normally carried out the activity; 3 indicated an activity which was normally assigned to a major, 4 an activity normally assigned to a lieutenant-colonel, and 5 an activity which normally required a colonel to perform it.

Seriousness of mistake : Doug's criterion here was the length of time for which a mistake could go uncorrected in the planning process. For example, an incorrect decision on the enemy's most likely course of action could go uncorrected until the end of the war (thus meriting a high score), while a mistake in obtaining policy and guidance from CinC/JFC will always be corrected at the first briefing.

Likelihood of mistake : No comments made.

Time required : Doug stated that he was considering activities within a 3-day time frame (the length of an average planning cycle), so a small number indicated an activity taking a few minutes, whereas a large number indicated an activity taking hours or even a whole day.

Analytic vs Synthetic : No comments made.

Evaluation required : No comments made.

4.1.2 Further information on ACP activities

Obtain policy and guidance from CinC/JFC : The instructions from the CinC are not often misunderstood; if they are, the JFACC's understanding is corrected (often painfully!) at the next briefing of the CJTF. The activity doesn't usually take very long, because the JFACC will probably have already spent time considering the situation, and the policy and guidance which is obtained is likely to confirm a previously formulated hypothesis. Understanding the policy and guidance doesn't require much evaluation; it's an order, so there is no option to decide whether to follow it or not.

Organize planning staff : A mistake here causes inefficiency, but it quickly becomes apparent when deadlines approach. However, mistakes are rare; Directors of Planning become fairly skilled at this job.

Assess situation : This is one of the most complex activities in the ACP process. It requires a high ranking officer to perform it, and considerable evaluation is required, both in the weighing of information, and in the weighing the costs and benefits of obtaining or using further information. It's not a completely analytic activity, because it's usually performed by formulating and testing hypotheses. Doug thought that the likelihood of a mistake was about average, although he admitted that he didn't have much evidence for this.

Identify campaign objectives and military objectives : This is also a complex activity; the main reasons for this are that there are many nuances in the language used which need to be understood, and the reader also requires a lot of previously acquired contextual information to understand the objectives fully. If the objectives are not understood properly (which happens sometimes), this is corrected (often painfully) at the first briefing of the CJTF.

Subdivide the planning problem : A mistake here causes inefficiency, but few other problems.

Decide on enemy's most likely course of action : The emphasis here is on making a decision which is "good enough". The assessment of the enemy's likely course of action could probably be made more accurate, but the marginal improvement is usually judged to be not worth the extra time required; this activity is therefore relatively swift. Despite the seriousness of mistakes on this activity, mistakes do happen; the beginning of Desert Storm is a good example, when few planners correctly predicted Saddam Hussein's dig-in-and-wait strategy. Fortunately, this strategy was less damaging than the one which had been predicted.

Review enemy course of action : Since this activity is not currently carried out explicitly, Doug made his own estimates of the characteristics of this task, using the scores for **Decide on enemy's most likely course of action** as a guide.

Communicate plan to subordinates : This activity is more complex than the name might suggest, because it includes both a completeness check and a "sanity check" on the completed plan. Once the checks have been done, mistakes in communication are very rare, since the plan is formatted as an Air Tasking Order and a Master Air Attack Plan.

Brief CJTF : This is a complex activity, perhaps surprisingly so. Doug hinted at the underlying complexity when he stated that this activity required a lot of evaluation "because there's a lot of tradeoffs in what you say and what you do".

Produce prioritized air objectives, task objectives and targets : Producing and prioritizing air objectives is a more difficult activity than doing the same for task objectives; prioritizing targets is the easiest task of the three, though the difference is not great. There isn't much experience available concerning mistakes in these activities.

4.1.3 Further information on prioritization activities

Identify enemy Centres of Gravity (in each sub-area) : This activity takes a long time – maybe as much as half a day.

Identify air objectives (for each sub-area) : This is a relatively quick activity, once Centers of Gravity have been identified. However, it does require some evaluation, because it requires some "internal allocation of resources". Doug stated that this was a synthetic activity, but he also pointed out that the identification of air objectives is really a selection from a pre-existing set of objectives; in that case, it's probably a more analytic activity (deciding which objectives are applicable in this situation) than a synthetic activity.

Prioritize Air Objectives : This is done at a meeting which typically lasts half an hour at most; it's not a difficult activity to perform.

Finally review and unify lists of objectives : There's a lot of implicit internal weighting within this task; but mistakes (i.e. missing out important air objectives) are rare, because every planner's work is available and easily verifiable.

Brief JFACC : Doug gave this activity a medium score for *Likelihood of mistakes*, because "when a general briefs a general, the former is right about half the time".

Identify enemy Centers of Gravity for review purposes : No further information.

Identify task objectives (for each Air Objective) : No further information.

Prioritize task objectives : This has a slightly higher likelihood of mistakes than the prioritization of air objectives, simply because there are more task objectives than air objectives.

Finally review and unify lists of tasks : This has a slightly higher likelihood of mistakes than the prioritization of air objectives, simply because there are more task objectives than air objectives.

Brief JFACC : The likelihood of a mistake is quite small in these briefings, since anyone who is going to brief a general tends to spend a lot of time making sure that the briefing is correct.

Identify enemy Centers of Gravity (in a way which is specific to target identification) : Despite the increased time required to consider Centers of Gravity in relation to thousands of possible targets, the likelihood of a mistake here is small – 1.5 might be a better score than 2.

Identify targets : No further information.

Prioritize targets : The likelihood of a mistake here is high because there are so many identified targets.

Analyze feasibility of plan is a computerized process, which reduces the likelihood of a mistake to a score of around 2.5.

Brief JFACC on Air Campaign Plan : This requires some evaluation in deciding what to stress in the final briefing.

4.2 Statistical analysis of repertory grids

Once the grid has been completed, it's possible to perform statistical clustering on the value supplied, to see if there is any implicit categorization of the activities reflected in the scores provided for each activity. Figures 21 and 22 show the results of performing statistical cluster analysis on the scores in the two grids shown in Figure 19 and 20. This gives some idea of the (subjective) similarity of activities on the attributes identified in the grid. The result of cluster analysis is a "taxonomic" hierarchy, in which the "classes" are actually nodes identifying the percentage of similarity between activities, or groups of activities. For example, in Figure 22, the identification of enemy Centres of Gravity is carried out 3 times (when prioritizing Air Objectives, Task Objectives and Targets); the latter two are scored identically (100% similarity) whereas the prioritization of Air Objectives only merits 79% similarity with these two.

It is often instructive to ask the expert why certain activities are considered similar or different. In the example above, Doug suggested that this phenomenon was due to the fact that it's harder to identify Centres of Gravity at the first attempt; once the task has been done once, at a high level, it is less difficult at lower levels of detail. In another example, Doug was asked why "Identify Targets" was so different from the other activities (se Figure 22). By looking at the scores in the grid, it can be seen that "Identify Targets" is the only activity which requires a lot of time but does not require much evaluation or experience. This observation led the knowledge engineer to suggest that "Identify Targets" might be a suitable activity for automation using conventional (i.e. not knowledge-based) computing; Doug replied that such a task was already being undertaken.

It can also be helpful to ask the expert to rationalise the statistical hierarchies; to reduce the number of "class" nodes, and to label them with a meaningful class name rather than a percentage of similarity. This has not yet been carried out; however, Figure 23 shows the type of hierarchy which might be generated if the hierarchy shown in Figure 21 was rationalized, based on some of Doug's comments on Figure 22.

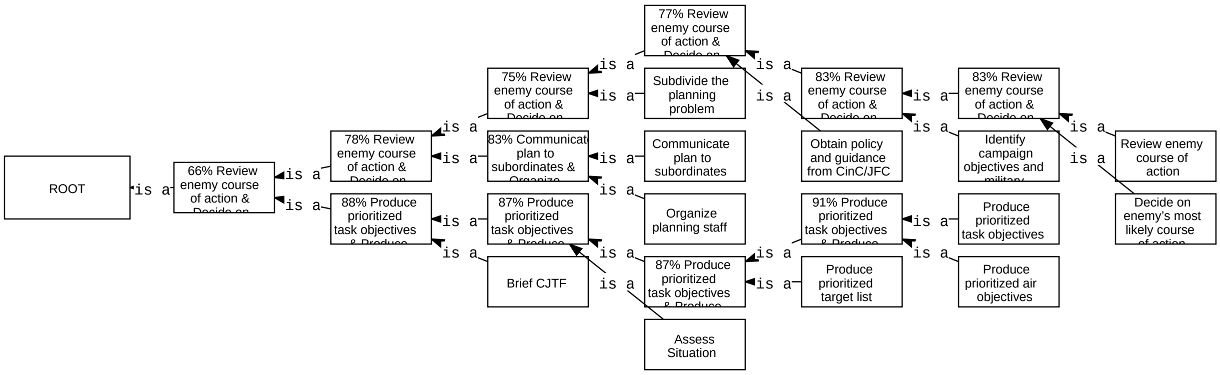

Figure 21: Cluster Analysis: Similarity of Air Campaign Planning Tasks

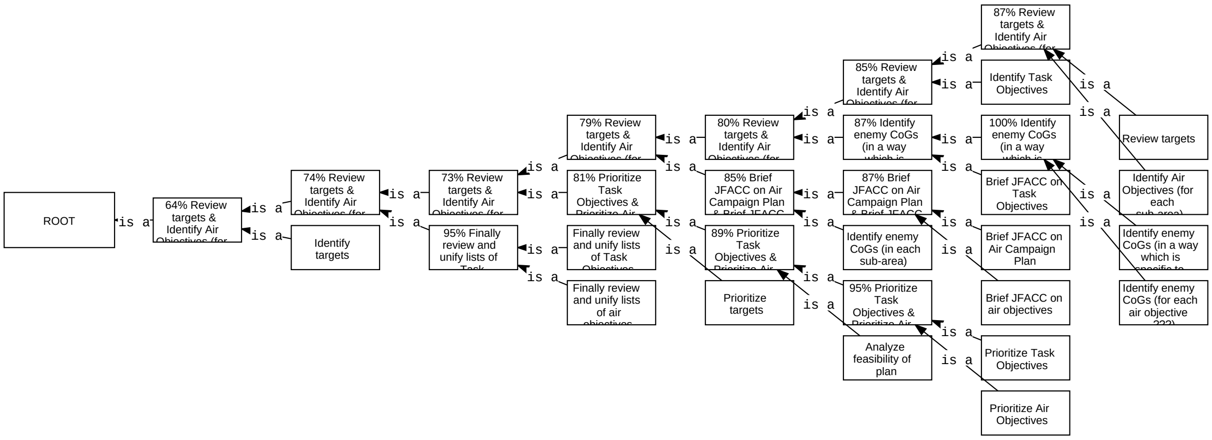

Figure 22: Cluster Analysis: Similarity of Tasks involved in Prioritization

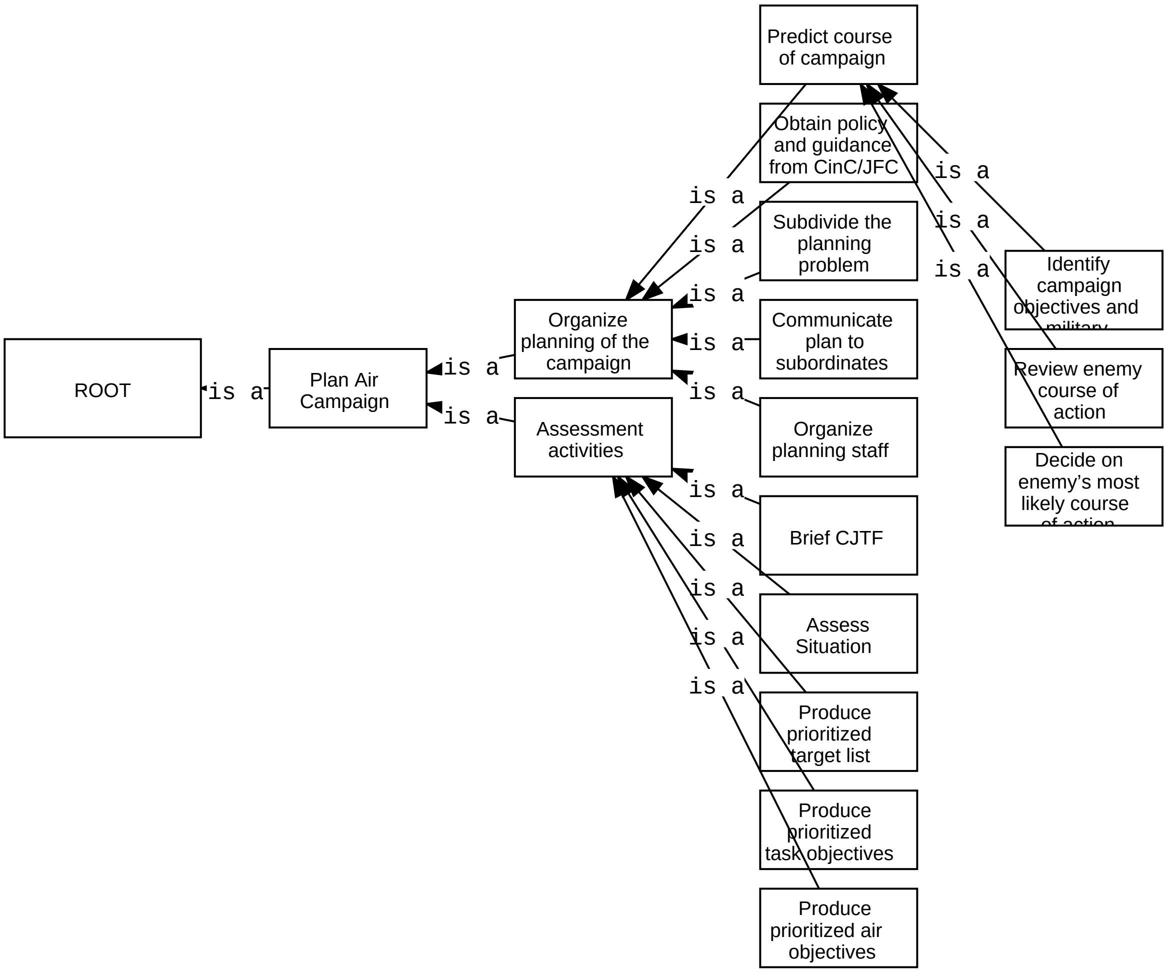

Figure 23: Rationalized Cluster Analysis: (Hypothetical) Hierarchy of Air Campaign Planning Tasks

The comments which led to this rationalization included:

> **Assess situation** and **Brief CJTF** are aspects of the same process
>
> Producing prioritized objectives and targets is heavile dependent on the situation assessment
>
> The **identification of campaign objectives and military objectives** is driven by **Decide enemy's most likely course of action**, *Review enemy course of action* and **Obtain policy and guidance from CinC/JFC**

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