Technical Report

ACP Process Management: O-Plan IFD-5 Qualifier

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Contents

1 Introduction

The aim of this report is to describe the experiments conducted to ascertain whether O-Plan could be used as a "planning to plan" system to support the agenda management of the NOM control panel of the Air Campaign Planning Planning Tool (ACPT). The current ACPT system does not provide the user with any support in choosing the most appropriate item to work on next from the agenda with the user free to work on any aspect of the air campaign plan they choose. This approach to using ACPT results in a number of serious problems:

1. The user can easily loose track of where they are in problem their solving process and the consequences of changes they have made.
2. The user must identify the most appropriate step to work on next. This is dependent on which steps have already been carried out and the status of the process products in the database of the ACPT.
3. The user must identify the agent (human or software) which is capable of carrying out the step. For example, the SIPE system can be used to refine the prioritised target list whereas EXPECT should be used to critique prioritised target list. In a number of cases more than one agent may be applicable and the user is required to make the choice.
4. In some situations a step in the process may need to be decomposed e.g. "develop Master Air Attack Plan" in order to identify its sub-steps and the agents required to carry them out. In some cases more than one decomposition may be applicable and the user is required to make the choice. In complex cases, one choice may affect other choices.

In order to overcome some of these problems a series of experiments were conducted to show how:

1. O-Plan could take a task description specifying the current entries[1] on the ACPT agenda and the "state" of the process products (e.g. the orders, reports, documents, databases) obtained from an envisaged ACPT process product feature server and return a list of more detailed agenda entries with the target agent(s) identified by O-Plan.
2. O-Plan was able to represent the ACP process level of the ACPT and the constraints between the steps in the process plan. The process plan defines the steps which must be carried out in ACPT to generate an Air Tasking Order (ATO) which specifies the targets to be attacked, their prioritised ordering and the weapons system(s) to be used. The ATO is developed using a series of editors, viewers and support systems e.g. planners, schedulers, simulators, plan critiquers which are used to decompose theatre level objectives e.g. "destroy weapons of mass destruction" into a prioritised list of targets. In addition to identifying the target and weapons systems the ACPT can also be used to identify support requirements including air-to-air refueling, electronic counter measures, etc.

[1] Some entries will have been worked on already while others may be at the most abstract level, e.g. Develop Master Air Attack Plan.

The structure of the report is as follows. Section 2 provides an overview of the ACP domain and the need for support at the process level. Section 3 describes the types of process products in the ACP domain and Section 4 describes the model used to capture information concerning the process products and the current state of the NOM agenda. Section 5 describes the two main experiments carried out to validate the modelling approach and assess O-Plan's capabilities as a "planning to plan" support aid for ACPT. Section 6 provides an overview of the proposed method to allow the NOM agenda controller to automatically generate task specifications for O-Plan. Finally Section 7 provides a summary of the work to date and pointers to future work. Appendix A provides details of the O-Plan Task Formalism domain description of the process planning level of ACP and Appendices B and C contain descriptions of the plans generated in each of the experiments.

2 Overview of the Air Campaign Management Process

The aim is this section is to provide an overview of the process management level of the ACP domain and the modelling approach adopted to represent it. The ACP process is defined by a number of partially ordered steps with each step specifying an activity to be carried out and the objects to which it should be applied. For example, "develop Master Air Attack Plan", prioritise target list, etc,. Research on the related ISAT project has shown that the steps can be modelled using a simple three part grammar whose structure is as follows:

- **Verb**: the activity to be carried out, e.g. analyse, develop, refine, etc;
- **Noun Phrase**: one or more noun phrases which describe the object(s) on which the activity is being carried out, e.g. prioritised target list, tankering special instructions, etc;
- **Qualifiers** one or more qualifiers which constrain the way the activity is carried out e.g. time or resource limits.

Work has already been completed on developing a classification hierarchy of verbs and sub-verbs in the ACP process planning domain and details can be found in [1]. This work compliments the grammar being developed by Andre Valente at USC/ISI [6] which uses the the same verb/noun/qualifier approach to defining the activities at the domain level in the ACP domain. It is interesting to note that both USC/ISI and AIAI reached the same representation design while working on different aspects of the ACP problem.

One of the most important aspects of the grammar is the objects being manipulated which in the case of the ACP process are the documents, reports, orders and letters which are created, modified, used and collated in the development of an air campaign plan. These objects are referred to as Process Products [2] and are central to the modelling approach adopted for the experiments and being proposed for use in future IFDs. Associated with specific classes of process product are features, the value of which can be used as an input condition on the steps of the ACP process. For example, the step to "prioritise the target list" requires a JIPTL to be available and that is should have been recommended by the review board. This can be modelled with two process product features one which states its availability and the second which describes its review status. In addition to using process product features values as input an activity may also create new values or modify existing ones. For example, the step to "refine the prioritised target list" may modify its contents level from CONPLAN to OPLAN and create a new document which contains the special handling instructions. A list of proposed process product features and their associated values is provided in Section 3.

In addition to the three items described above the steps are also constrained by a number of other inputs which include:

- **temporal**: These specify the duration of the step, the delay between the end of steps and the time after the start of conflict the step must start executing.

- **resource**: These specify the resources (human and software) required to carry out the step.
- **authority**: These specify the levels of authority required before a step can be executed.

3 Overview of Process Products

The process products in the ACP process comprise the documents, reports, orders, letter, databases, etc which are used to represent the information present in the ACP planning process. A process product may represent an intermediate result e.g. the draft tanker flows or may be the published document of the planning process e.g. the Air Tasking Order (ATO). Each class of the process products has a number of features, one of which is the content of the ACP plans themselves. Details of the relationship between the process products and the ACP process are given in Figure 1.

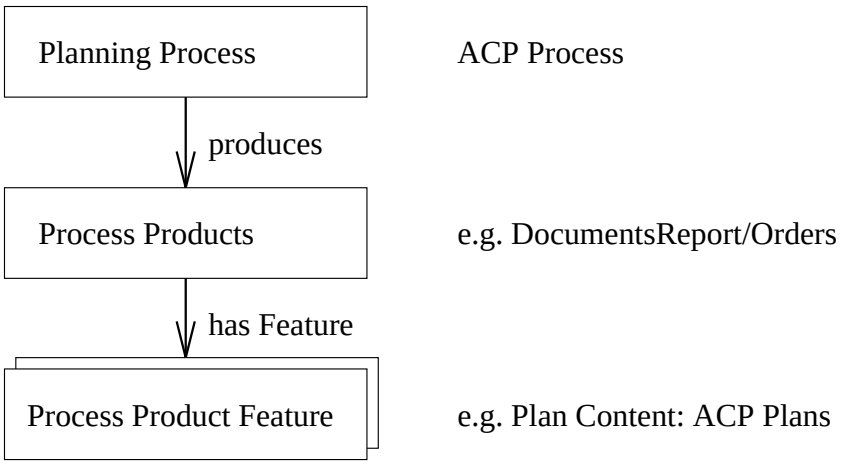

Figure 1: Process Products within the ACP Process

In addition to its contents a process product may have many other attributes which are dependent on its class and use within ACP. The different attributes are important in describing the way in which products are created, modified or used during the planning process. Examples of process product attributes identified in ACP include:

- **Contents**:
  This describes the contents of the process product and would vary for different classes of process products. In some cases the contents will be at the actual string of characters comprising the process product (referred to as primitive process products) but in most cases the contents will be used to describe the structure of the product e.g. summary, chapters, appendices, etc. These are referred to as compound process products and each of its internal components are process products themselves. Examples of the contents include:
  - summary/abstract
  - executive_summary
  - chapter/section/appendices

- **Contents_level**:
  The contents_level defines the different levels at which the contents of a process product can be "measured". The measurement levels will be different for each class of process product and will be defined as needed. Examples of measurement level include:

  – none
  – CONPLAN
  – OPLAN
  – Level(n)

  In a compound process product i.e. one made up of a number of sub-products, there is no contents level. Only "primitive" process products have contents level. In the case of a "level n" tag there needs to be an agreement between the agents involved in the process of what constitutes contents down to a given level. These contents levels can be ordered and the default for most process products would be:

  ```
  none --> CONPLAN  --> OPLAN --> Level(n)
  ```

  When a agent or activity requires a process product which has contents at a certain level the workflow planner should be able to satisfy this by finding the process product at that level or greater. For example, if an activity requires a process product at the CONPLAN level and one exists at the OPLAN level then this would be suitable. In order to compare the contents level of different process products there needs to be a partial ordering on the contents level values defined.

- **Status**:
  This describes the status of the process product as it moves through the planning process. The status values will vary for different process products classes. Examples of status values include:

  – not_available
  – available
  – initial
  – working_version
  – draft
  – approved
  – recommended
  – unreleased
  – released
  – final

  For certain classes of process product it may be possible to define partial orders between different status values. The default for most process products will be:

```
not_available ---> draft ---> final
```

The status values for different classes of process product would have to be agreed between the agents in the process in order to avoid different values arising for the same contents level. For example, it would not be possible for the same contents level of a process product to be referred to as "draft" by one agent and as a "working version" by another.

- **Parts**:
  The parts attributes describes the parts of a process product i.e. the sub-process products of which it is made up. The sub-process products need to be defined as being the parts of their part-product and should identify the number of parts they are expected to contain.

- **Type and Information**:
  Each class of process product may be associated with certain generic information. Examples of this information include:

  - type (MIME compliant)
  - agent who created/modified it last
  - creation date
  - modification date
  - author

4 Model Encodings and Structured Examples

This section describes the methods used to model the ACP process management level and the "capabilities" of the technologies being developed in the ARPI. Details are also provided of the Task Formalism (TF) structures used to represent the activities and capabilities.

4.1 Agent Capabilities

One of the aims of the experiments was to show that O-Plan could identify an appropriate agent (human or software) with the capabilities to carry out the activity in the ACP step. For the purposes of the experiment the number of technologies represented was limited to four: O-Plan, SIPE, EXPECT and the user. In a number of cases the capabilities were duplicated i.e. two or more system had the same capability, e.g. O-Plan and SIPE could both "modify" certain process products. The capabilities were represented in O-Plan TF as a series of `always` facts which specify the agents name and the capability it has. For example, {`has_capability EXPECT Review`} states that EXPECT is applicable when the ACP process step states that a review activity is required, e.g. "review prioritised target list". The complete list of agent capabilities is as follows:

```
{has_capability EXPECT Review},

{has_capability O_Plan Modify},
{has_capability O_Plan Develop},

{has_capability SIPE Modify},
{has_capability SIPE Build},

{has_capability User Support},
{has_capability User Approve},
{has_capability User Allocate},
{has_capability User Perform},
{has_capability User Weaponeer},
{has_capability User Coordinate},
{has_capability User Provide},
{has_capability User Deconflict},
{has_capability User Finalise},
{has_capability User Produce},
{has_capability User Release},
{has_capability User Integrate},
{has_capability User Prioritise},
{has_capability User Match},
{has_capability User Consider},
{has_capability User Group},
{has_capability User Calculate},
```

```
{has_capability User Identify};
```

4.2 ACP Agenda Management Support

A second aim of the experiments was to show how O-Plan could accept a task description from the ACP NOM controller which contained a number of agenda entries (some of which are detailed while others are more abstract) and return a number of more detailed agenda entries with their target agents identified.

4.2.1 Agenda Entry Description

The main problem was to create a representation for agenda entries which avoided the NOM controller having to identify which entries needed to be decomposed and those simply needing a target agent to be identified. The representation chosen was as follows:

- **tag**: This is the fixed key word `agenda_issue`[2]
- **source agent**: Specifies the source agent which introduced the agenda entry. The agent is either `user` indicating it was posted by the user in the original task specification, `O_Plan_WFM` indicating it was introduced by the O-Plan system acting as a workflow planner, or a specific ACPT tool, (EXPECT, SIPE, O-Plan).
- **target agent**: Specifies the target agent which has the "capability" to handle the agenda entry. In the case of agenda entries which need to be decomposed further the target agent is `O_Plan_WFM`
- **verb**: Contains the verb to be matched against the agent capability's to identify the appropriate target agent(s).
- **noun phrase**: Contains the process products which the verb acts upon.
- **qualifier phrase**: Contains the qualifiers which constrain the behaviour of the target agent assigned.

An example of an agenda entry introduced by the O-Plan system acting as a workflow planner (as the result of an activity decomposition) is as follows: `{agenda_issue O_Plan_WFM ?dst Perform {weaponeering_assessment} {broad}}`.

4.2.2 Process Product Encodings

Each process product in the ACP domain has associated with it a number of features. The main features identified are: contents, contents_level, status, parts and type_information and these

[2]The O-Plan TF language requires a fixed word in the first position of any pattern stored in the database

features were described in the previous section. Each process product feature has associated with it a specified number of product_feature_values. For example, the product_feature_values of contents_level are: none, CONPLAN, OPLAN and Level(n).

Each process_product_features is described using the following descriptor:

```
{process_product_feature process_product} = product_feature_value
```

For example, to model the development of the "Recommended JIPTL" which has four sections the following descriptors would be used:

```
{parts JIPTL} = (JIPTL-summary JIPTL-section1 JIPTL-section2
                 JIPTL-bib)

{contents_level JIPTL} = undefined
{status JIPTL} = draft

{contents_level JIPTL-summary} = level-3
{status JIPTL-summary} = final

{contents_level JIPTL-section2} = none
{status JIPTL-section2} = not_available

{contents_level JIPTL-section3} = level-2
{status JIPTL-section2} = draft

{contents_level JIPTL-bib} = level-2
{status JIPTL-bib} = draft
```

Once the parts of the JIPTL[3] had been collated and authorised by the JTCB then the JIPTL would then become "available" and its status within the ACP process would be "recommended". This can be modelled using the following descriptors:

```
{contents_level JIPTL} = recommended
{status JIPTL} = available
```

The sub-process products would still exist and could be referred to by the ACP process.

As a process product moves through the ACP process it could be modified by the addition and deletion of parts of its contents which in turn will modify it contents_level feature. For example, the Air Tasking Order (ATO) contains a number of different sections which deal with air tankering, EC planning, targets, etc, and each of these is a separate process product. The contents_level of the ATO changes as more sections are added and existing sections within the ATO are refined. The schema described here allows this modification process to be modelled by changing the values in the appropriate process product feature.

[3] To their appropriate level of detail.

4.3 Workflow Encodings

A series of models of the ACP process have been produced on the ISAT project using the CommonKADS and IDEF-3 modelling methodologies. However, due to the modelling restrictions of these two methodologies, information concerning the actual relationships between the start and finish of activities could not be represented, e.g. tanker operations planning can begin after the SPINS have begun but must not finish before the SPINS are complete. However, the Task Formalism (TF) domain description language developed for the O-Plan system has the ability to capture rich models of activity and encode information which CommonKADS and IDEF-3 cannot. Figure 2 and Figure 3 describe the TF model of the processes of "developing a recommended JIPTL" and "developing a mission plan" respectively. The figures correctly show the relationships between the start and finish of the activities and more truly reflects the way in which the ACP process is carried out.

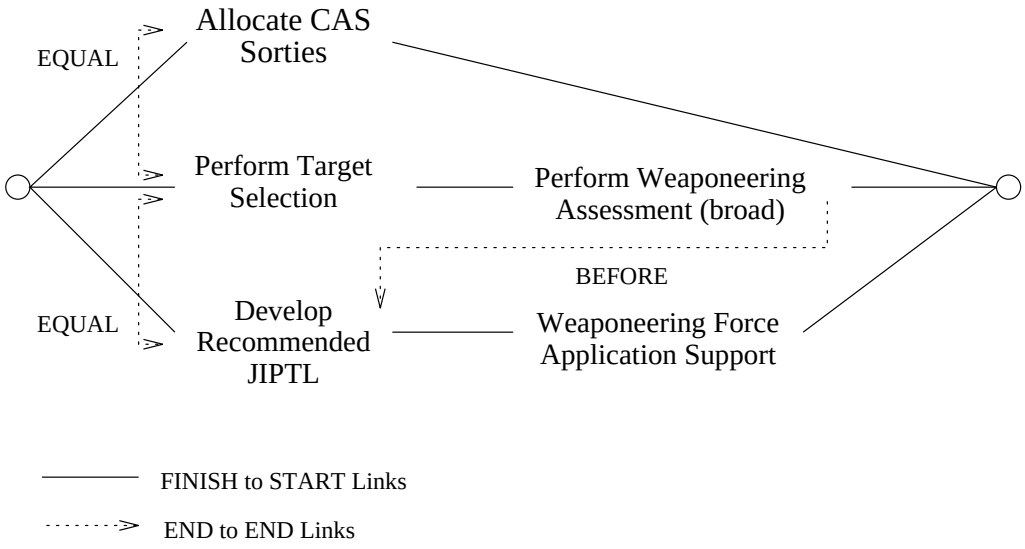

Figure 2: Model of the JIPTL Development Process

Using the models described in Figures 2 and 3 as a base it was possible to identify where process products in the ACP process were being created, modified and destroyed and more importantly where certain process products needed to have specific feature values. The current model of the ACP process uses only two of the process product features, i.e. status and contents_level. As the model is developed further it is hoped to find examples of the other process features and add these to the model. The two process product features and their values are as follows:

- **Status**:
  - available
  - not_available

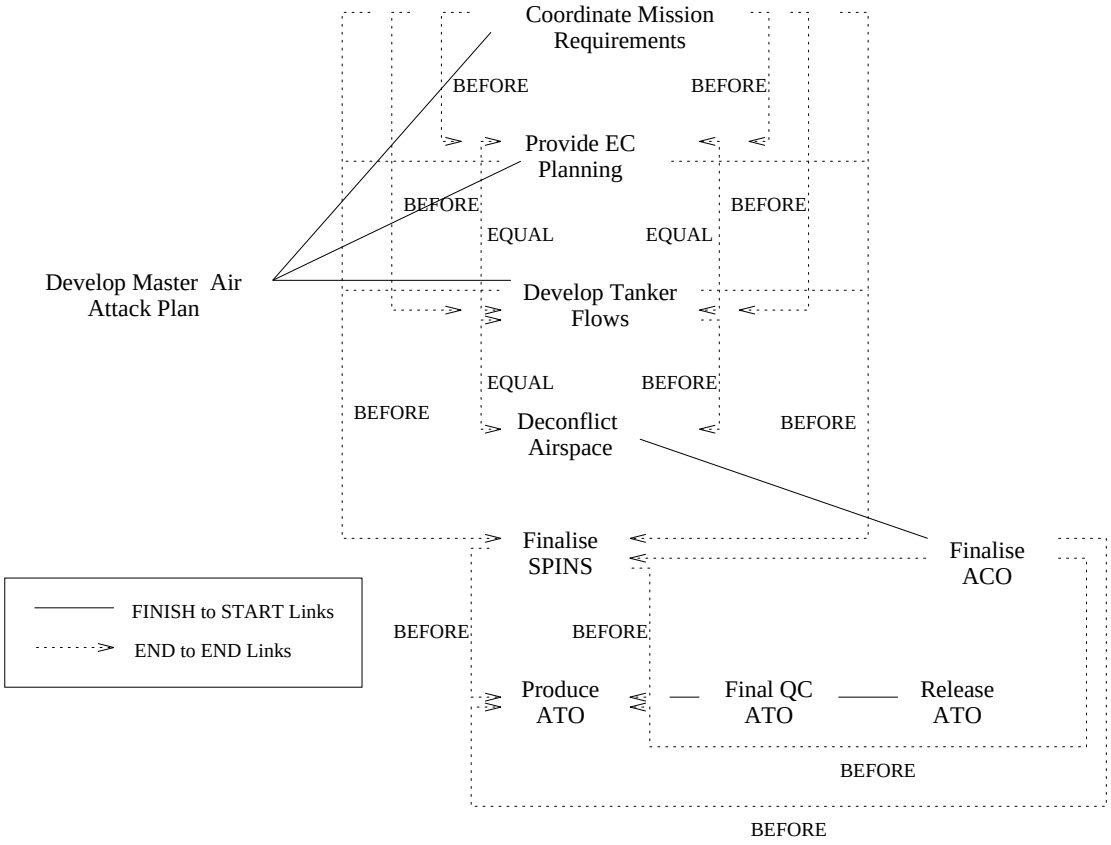

Figure 3: Model of the Mission Planning Development Process

- **Contents_level**:
  - draft
  - rough
  - potential
  - proposed
  - current
  - on_going
  - cut_off
  - recommended
  - approved
  - unreleased
  - released

Using the O-Plan models described earlier is was possible to generate a series of plan schemas for the ACP planning process and the JFACC planning portion is shown here as an example.

```
schema Phase_1_JFACC_Planning;
  vars ?src, ?dst1 = ?{type agent}, ?dst2 = ?{type agent},
       ?dst3 = ?{type agent}, ?dst4 = ?{type agent}, ?dst5 = ?{type agent},
       ?dst6 = ?{type agent};
  expands {agenda_issue ?src ?dst1 Develop {JFACC_plan} {}};
  nodes
    1 action {agenda_issue O_Plan_WFM ?dst2 Support {developing_objectives}{}},
    2 action {agenda_issue O_Plan_WFM ?dst3 Develop {recommended_defense}{}},
    3 action {agenda_issue O_Plan_WFM ?dst4 Develop {recommended_apportionment}{}},
    4 action {agenda_issue O_Plan_WFM ?dst5 Develop {recommended_target}{}}
    5 action {agenda_issue O_Plan_WFM ?dst6 Approve {JFACC_guidance}{}}
end_schema;
```

This shows the 5 activities involved in the JFACC planning process. Each of these activities has input constraints i.e. preconditions on the feature values of certain process products and output constraints i.e. effects which change the product feature values of certain process products. In the case of activity 5 which is the process to approve the JFACC Guidance Letter there needs to be a draft JFACC Guidance Letter available to work on. This is modelled by having two preconditions on the start of that activity:

```
unsupervised {status JFACC_guidance_letter} = available at 5,
unsupervised {contents_level JFACC_guidance_letter} = draft at 5,
```

The outcome of the approval process is an approved JFACC guidance letter which can be modelled by having two effects on the end of the activity:

```
{status JFACC_guidance_letter} = available at 5,
{contents_level JFACC_guidance_letter} = approved at 5;
```

In addition to requiring certain process products be available the process may also require that certain resources be available. In the ACP process the resources are the agents (systems, tools and users) who can be assigned to the process in order to carry it out. In the case of JFACC Guidance Letter approval process a JFACC planning team is required. This can be modelled by ensuring the JFACC planning team are unallocated at the start of the approval process and are not assigned to another process while the approval process is underway. This can be modelled using the following two preconditions:

```
unsupervised {resource JFACC_planner} = unallocated at begin_of 5,
supervised {resource JFACC_planner} = allocated at end_of 5 from
                                      begin_of 5,
```

and the following two effects:

```
{resource JFACC_planner} = allocated at begin_of 5,
{resource JFACC_planner} = unallocated at end_of 5,
```

This example has been simplified for clarity and does not take into account authority and temporal constraints on the process. A full O-Plan description can be found in Appendix A.

5 The Experiments Conducted

The section describes the experiments which were conducted to validate O-Plan as a possible "planning to plan" support tool in IFD-5. In each experiment O-Plan was given a task description which contained:

- a copy of the entries from the agenda of the ACPT together with their associated triggers. Each entry representing a step in the ACP process.
- a list of the process products in the ACPT process product feature server[4] together with their associated process product features and values.

The aim was to refine the agenda entries to an appropriate level and identify agents (human and/or software) with the capabilities to carry out each step. O-Plan would then return the plan (as a list of agenda entries) to the ACPT. The attributes and values of the process products in the process product plan feature server were provided in three different ways:

- `always` **facts**:
  `always` facts are statements which cannot be refuted by the effects of actions in the plan. `always` facts were used to describe the capabilities of the agents (human and/or software) in the ACPT. For example:

```
{has_capability EXPECT Review},
{has_capability O_Plan Modify},
{has_capability SIPE Modify},
{has_capability User Support},
{has_capability User Approve},
```

- `initially` **facts**:
  `initially` facts are statements which are used to define the initial state of the domain and can be altered by the effects of actions in the plan. `initially` facts were used to describe the process products available together with their attributes and values. For example:

```
{status current_status} = available,
{status intelligence_situation} = available,
{status unit_information} = available,
{status SPINS} = available,
{contents_level target_development} = on_going,
{contents_level JIPTL} = recommended,
{contents_level JFACC_guidance_letter} = draft,
{contents_level air_space_management_plan} = current,
```

[4] The process product feature server is the proposed name for the plan feature server in IFD-4.

- Task Effects:
  Task effects are used to augment those stated in the `always` and `initially` lists in order to define the specific problem being addressed by the task. Task effects can be used to over ride those stated in `initially` list. For example, to demonstrate how O-Plan could generate a process plan for a partially solved problem (experiment 2) the task effects were used to define the expected state of the process products feature server at that point in the problem solving process. For example:

```
{status JIPTL} = available,
{status air_space_management_plan} = available,
{status JFACC_guidance_letter} = available,
{contents_level JIPTL} = approved,
{contents_level air_space_management_plan} = current,
{contents_level JFACC_guidance_letter} = approved,
```

Two major experiments were conducted and each is described in a separate subsection.

5.1 Experiment 1: Full ACP Process Management

The aim of the first experiment was to show that O-Plan was capable of generating a process plan for the entire ACP process. The experiment was used to validate the process product approach to modelling the ACP process and to ensure that O-Plan could correctly identify appropriate agents (human and/or software) for each step in the ACP process.

The task specified three high level agenda entries (or steps) which were to develop the plans for the JFACC, JIPTL and Mission Plan respectively. The source agent in each case was specified as the `user` (through the ACPT control panel) and the variables `dst1, dst2` and `dst3` were used for the three destination agents respectively. A partial description of the O-Plan task specification for this problem is as follows:

```
schema Full_Air_Campaign_Planning_Process;
  vars ?dst1 = ?{type agent}, ?dst2 = ?{type agent}, ?dst3 = ?{type agent};
  expands {Full_Air_Campaign_Planning_Process};
  nodes 1 action {agenda_issue user ?dst1 Develop {JFACC_plan}{}},
        2 action {agenda_issue user ?dst2 Develop {JIPTL}{}},
        3 action {agenda_issue user ?dst3 Develop {Mission_plan}{}};

  orderings 1 ---> 2, 2 ---> 3;
end_schema;
```

The experiment required O-Plan to:

- Decompose higher level steps into lower level ones.
- Identify a destination agent (human and/or software) for each step.

- Satisfy each condition on each step specified in the ACP process by ensuring that the appropriate process product and process product feature values were available.
- Ensure that the temporal constraints e.g. "the activity must begin 16 hours after the start of conflict and must taken no more than 3 hours" and resource constraints "this activity requires the intelligence planning cell" are satisfied.

O-Plan was able to carry out this requirements and create a plan for the entire ACP process domain. O-Plan was also able to generate alternative plans where there was an alternative destination agent with the required capabilities. Details of the plan generated are provided in Appendix B.

5.2 Experiment 2: Partial ACP Process Management

The aim of the second experiment was to show how O-Plan could take a partially instantiated ACP process plan in which some activities were partially decomposed while other were still at the highest level. This case is the most likely scenario for the ACP process domain.

The task description specifies two sub-steps of the development of the JFACC plan (Perform Target Selection and Perform broad Weaponeering Assessment), one form the development of the JIPTL (Develop Recommended JIPTL) and two from the development of the mission plan (Perform Weaponeering Force Support and Develop Master Air Attack Plan (MAAP)). The activities to develop the MAAP and the recommended JIPTL need to be decomposed (and agents found for the sub-activities) whereas the remainder merely need an appropriate agent to be identified. The source agent in each case was specified as `O_Plan_WFM` (as it is assumed that these entries were placed on the ACPT agenda by O-Plan acting as the Workflow planner) and the variables `dst1, dst2, dst3, dst4` and `dst5` were used for the five destination agents respectively. A partial description of the O-Plan task specification for this problem is as follows:

```
schema Partial_Plan_Refinement;
  vars ?dst1 = ?{type agent}, ?dst2 = ?{type agent}, ?dst3 = ?{type agent},
       ?dst4 = ?{type agent}, ?dst5 = ?{type agent};
  expands {Partial_Plan_Refinement};
  nodes
    1 dummy,
    2 dummy,
    3 action {agenda_issue O_Plan_WFM ?dst1 Perform {target_selection}{}},
    4 action {agenda_issue O_Plan_WFM ?dst2 Perform {weaponeering_assessment}{broad}},
    5 action {agenda_issue O_Plan_WFM ?dst3 Develop {recommended_JIPTL} {}},
    6 action {agenda_issue O_Plan_WFM ?dst4 Perform {weaponeering_force_support}{ }},
    7 action {agenda_issue O_Plan_WFM ?dst5 Develop {master_air_attack_plan}{}};

  orderings
     1 ---> 3, 1 ---> 5, 5 ---> 6, 3 ---> 4, 4 ---> 7, 6 ---> 7, 7 ---> 2,
     end_of 4 ---> end_of 5;
```

The experiment required O-Plan to:

- Decompose higher level steps into lower level ones.
- Identify a destination agent (human and/or software) for each step.
- Satisfy each condition on each step specified in the ACP process by ensuring that the appropriate process product and process product feature values were available.
- Ensure that the temporal constraints e.g. "the activity must begin 16 hours after the start of conflict and must taken no more than 3 hours" and resource constraints "this activity requires the intelligence planning cell" are satisfied.

O-Plan was able to carry out these requirements and create a plan for this partial ACP process problem. O-Plan was also able to generate alternative plans where there was an alternative destination agent with the required capabilities. Details of plan generated are provided in Appendix C.

6 ACP Agenda Task Specification

This section describes in outline terms the method to be used by the agenda controller of the NOM of ACPT to construct a task package for use by the O-Plan system acting as a "planning to plan" support aid. The IFD-5 qualifier experiments showed that O-Plan needed access to the current ACPT agenda and the process products (including their attributes and features) in the process product feature server (PPFS). Each of the following subsections described how the information concerning the agenda and the PPFS will be communicated to the O-Plan system.

6.1 ACPT Agenda

Each entry on the ACPT agenda will be converted into a step description as follows:

```
{agenda_issue Source Destination Verb Noun-Phrase Qualifier-Phrase};
```

For example, `{agenda_issue user oplan refine {target-nominations-list}{broadly}}`. Each agenda entry will have one or more triggers which indicates to the NOM agenda controller that the agenda is ready to execute. The triggers can be of the following types:

- **temporal**:
  Temporal triggers can be specified as being either:
  - quantitative e.g. the activity must start 16 hours after the start of conflict and take no more than two hours, two activities must start at the same time. These can be handled by creating `time windows` specification as follows:
    * duration or delay between two activity ends[5]: `duration begin_of 1 to begin_of 2 = 0`
    * duration or delay from a fixed point, e.g. start of conflict: `0 02:00 at begin_of 1`
  - qualitative e.g. the precedence relationships between two activity ends. This can be handled by creating an `orderings` relations as follows:
    * `end_of 3 ---> end_of 4`
    * `3 ---> 4`

    This is likely to be the most common temporal trigger.
- **world state**:
  World state triggers can be specified on the attribute values of the process products in the process products feature server. O-Plan uses a number of different condition types to convey information about the methods and tactics which can be used to satisfy the condition. World state triggers will be handled by creating a condition as follows:

[5]The ends may be the start and finish ends of the same activity or either end of different activities.

  - `achieve {status JTF_guidance} = available at 3`
  - `achieve {contents_level JFACC_guidance_letter} = approved at 4`

- **resource**:
  Resource triggers can be specified on planning groups within the Air Operations Center (AOC). The resources being manipulated are unit, non-sharable ones which are allocated to a task and the deallocated at the end of the task. Resource triggered will be handled by creating a condition as follows:

  - `unsupervised {resource JFACC_planner} = unallocated at begin_of 1`
  - `unsupervised {resource Combat_planning_cell} = unallocated at begin_of 4`

- **authority**:
  Authority triggers can be specified on the start or end of an activity. Authorities are used to specify that a specific level of command authority is required by the activity before it can start of finish. Authority triggers will be handled by creating a condition as follows:

  - `unsupervised {authority NSC} = DEFECON3`

Full details of the TF structures described in this section can be found in [5].

6.2 Process Product Feature Server Status

The contents and their attributes of the Process Products Feature Server (PPFS) will be used to satisfy world state triggers on the agenda entries. The information provided will be of two forms:

- **Agent Capabilities**:
  The agent capabilities will be specified as a series of `always` facts which specify all possible pairs of agents and capabilities, i.e. a separate fact is required for each capability and agent has. It is not expected that this list will change from one task specification to the next.

- **Process Product Information**:
  The process products and their attributes will be specified as a series of effects in the task schema. The NOM agenda controller will be required to create a series of effects each one describing an attribute and its value. Given the potential number of process products and associated attributes this effects list will be quite extensive and will need to be provided each time O-Plan is tasked.

6.3 Planning Requirements

The ACPT NOM agenda controller will need to specify the "amount" of planning which the O-Plan system should carry out. In particular it may wish to specify:

- the level to which planning should be carried out e.g. first level of decomposition.
- the specific agenda entries which should be addressed, e.g. fully decompose the JFACC plan step to level 3.
- that only certain constraint types should be dealt with. e.g. only deal with satisfying temporal constraints.
- a number of different options which should be explored, e.g. assume only limited time and resources within which to generate the plan.

The link between the task assigner and the O-Plan planner agent is the main focus of the O-Plan project during phase III of the ARPI. In addition TIE research is being undertaken with the University of Rochester on how their TRAINS system could be used as a task assigner for the O-Plan system. Preliminary research has already been carried out which shows how O-Plan could support the TRAINS model of problem solving and provide the basis for a mixed initiative planning framework. The results of these investigations can be found in [4]. This work could potentially support some of the featured needed above.

7 Summary and Future Work

This section summarises the work to date and provides pointers to areas of future work.

A model has been produced which encodes the process products, their features and feature values in the current ACP process. The current model uses only a limited set of product features initially identified as being needed for a such a task. Using these models O-Plan was able to generate process plans for the full ACP process and for a partial ACP process. The latter is the most likely use for the O-Plan system in its ACPT NOM control panel agenda support role as a "planning to plan" aid. Preliminary research has been carried out to identify a mechanism to allow the NOM agenda controller to automatically generate task specifications for O-Plan. The task specification will contain a description of the "current" agenda, the agenda entry triggers and the status of the process products on the process products feature server.

The IDEF-3 and CommonKADS models used as the basis of the ISAT ACP models proved to be inadequate (due to restrictions in the expressiveness of the methodologies) in certain areas i.e. temporal modelling and have been recoded in O-Plan's Task Formalism (TF) language to more accurately reflect the way in which the ACP process is carried out [3]. A number of outstanding modelling issues remain and are mainly concerned with the source of the process products and the ways they should be modelled. Details on the outstanding issues are provided in Section 7.1. Future work is now planned to add further process product features to the model and in particular to model compound process products, i.e. those composed of a number of sub-process products. Initial investigations in this areas have begun and a number of pointers have been found to materials which describe the structure and contents of process products such as SPINS, ACOs, ATOs and MISREPs. Details of future work are provided in Section 7.2.

7.1 Outstanding Issues

The current models of the ACP process refer to process products which are either an implicit collection of documents or a single document which never seems to be updated. Examples of this type of process product include:

- Intelligence
- Unit Information
- Current Situation

An activity will have a precondition which states that it needs information on the current status but none of the models define what measures are used to define the current situation and which process products (if any) should be consulted. In addition to obtain information on the current situation may require a "plan" to collate the required process products and review them. Further research is required to understand what is being used here and the most appropriate way of modelling it.

A number of processes make references to resource constraints which constrain their options but no mention is made of where the resource data comes from. An example is the number of "tanker aircraft" limiting the tankering operations. Further research is required to identify the source of the data and the process product which should be associated with it.

The current ACP model appears to assume that certain process products are available from previous iterations of the planning process. This means that there is difficulty in modelling the initial state of the problem. To simplify things a "dummy" process product has been created in the `initially` facts to model this situation. The process products involved are as follows:

```
{status SPINS} = available,
{status JIPTL} = available,
{status EC_planning} = available,
{status Service_target_nominations} = available,
{status Air_space_management_plan} = available,
```

In addition to the process products from previous iterations a number of process products appear "out of fresh air" as preconditions to numerous processes. These have been modelled as `initially` facts at the moment but further research is required to identify the source of the information and how it should be modelled. The complete list of unaccounted for process products is as follows:

```
Initially

     {status current_status} = available,
     {status intelligence_situation} = available,
     {status unit_information} = available,
     {status SPINS} = available,
     {status JFC_guidance} = available,
     {status JFACC_guidance_letter} = available,
     {status operations_feedback} = available,
     {status plans_mission_feedback} = available,
     {status target_development} = available,
     {status target_planning_updates} = available,
     {status JIPTL} = available,
     {status ICM_MOM_supports} = available,
     {status EC_targets} = available,
     {status EC_planning} = available,
     {status JMEM_filter} = available,
     {status Service_target_nominations} = available,
     {status JAG} = available,
     {status air_space_management_plan} = available,
     {status tanker_asset_data} = available,

     {contents_level target_development} = on_going,
```

```
{contents_level JIPTL} = cut_off,
{contents_level JFACC_guidance_letter} = draft,
{contents_level air_space_management_plan} = current,

{resource JFACC_planner} = unallocated,
{resource Combat_planning_cell} = unallocated,
{resource Combat_operations_cell} = unallocated;
```

7.2 Future Work

The future aims of the work are to deepen the process product model and to identify and model compound process products i.e. those composed of sub-process products. To date all process products in the ACP model have been primitive, i.e they contain no sub-process products. A number of activities in the ACP process specify a set of process products as input but it is unclear at to whether the inputs are to be collated into one or more process products or whether they act as constraints on the possible outcomes of the process. The aim is to identify which activities have a collation function and to model the development of the constituent parts.

As part of the effort to identify compound process products discussions have taken place with David Hess (SAIC) and Tom Fitzgerald (USAF) on the structure and composition of the major process products in the ACP domain. The discussions were able to identify that many of the process products are in the form of structured or formatted messages using the USMTF - message text format and include process products such as ATO ACO, MISREP, JIPTL, etc. There is a series of very detailed manuals which give explanations as to what information goes in which part of the format. However, the USMTF was basically a bad solution to allow a computer to parse the information into something close to computer readable. The aim is to identify a more appropriate structure for the process products and to model them in the current ACP model.

References

[1] Drabble, B. and Lydiard, T.J. Model of the ACP Process Verbs and ACP Tool Capabilities, ISAT Technical Paper ISAT-AIAI/TR/1, August 1996.

[2] Drabble, B. and Tate, A., Air Campaign Planning Workflow Process Products, ISAT Technical Paper ISAT-AIAI/TR/2, August 1996.

[3] Drabble, B. and Lydiard, T.J., Workflow Models of the Air Campaign Planning, ISAT Technical Paper ISAT-AIAI/TR/3, September 1996.

[4] Drabble, B., Tate, A. and Dalton. J., O-Plan Tasking Specification. O-Plan Technical Report ARPA-RL/O-Plan/TR/29 November, 1996.

[5] Tate, A., O-Plan Task Formalism Manual, Materials of the O-Plan release Version 2.3, July 1995.

[6] Valente, A., Swartout, W. and Gil, Y., A Representation and Library for Objectives in Air Campaign Plans, Technical Report, USC – Information Sciences Institute, 1996.

Appendix A: O-Plan Task Formalism Description

This appendix describes the O-Plan Task Formalism (TF) description of the process level of the ACP process and shows how the activities, process products, process product features and their values were modelled and manipulated.

```
;;;
;;; Concept: Terri Lydiard 15th December 1995
;;;
;;; File: ISAT-workflow5.tf
;;;
;;; Purpose: Air Campaign Planning Scenario. Domain to develop a series of
;;;          ideas on workflow management for the ACPT system.
;;;
;;; Created : Brian Drabble 29th February 1996
;;; Modified: Brian Drabble 1-Mar-96:
;;;           - Added Capability Primitives to Model.
;;;
;;;           Brian Drabble 12-Jun-96
;;;           - New IDEF-3 diagrams incorporated.
;;;           - Cabilities for EXPECT and O-Plan added.
;;;           - Process Products and their attributes added.
;;;
;;;           Brian Drabble 27-Nov-96
;;;           - Removed the problem of duplicate right hand side values
;;;             for the contents level of the JIPTL.
;;;           - Created a new process product JIPTL-Cutoff.
;;;           - Added the attribute of approval/recommeded to model.
;;;
;;; The ACPT system provides support to the JFACC planning cell in defining
;;; different levels of objectives and the targets associated with them. The
;;; ACPT system provides partial coverage of the full ACP process. A report
;;; is available which detailed where the coverage is provided.
;;;
;;; Assumptions on Agenda Entries that come from ACPT:
;;;
;;;     1.  The source agent in the agenda_issue structure is always filled
;;;         in.
;;;
;;;     2.  The name of the source agent is the one which placed the entry
;;;         on the agenda. In all cases where O-Plan introduced an entry,
;;;         this will be O_Plan_WFM.
;;;
;;;     3.  The destination agent in the agenda_issue structure will only be
;;;         filled in when there is an agent capable of carrying it out.
;;;
;;;     4.  In those cases where the capability needs to be decomposed the
;;;         destination agent will differ for lower levels. It may or may not
;;;         be filled in (it will be O_Plan_WFM if filled in. NB. There are
```

```
;;;         cases where a decomposition shares the same verb as a primitive
;;;         capability, e.g.,
;;;
;;;         {agenda_issue user       ?? Develop {JFACC_plan}  {}},
;;;
;;;         {agenda_issue O_Plan_WFM ?? Develop {tanker_flow} {}},
;;;
;;;     The first requires further decomposition while the second is a
;;;     primitive.
;;;
;;; Status Notes:
;;;
;;; 1.  The system works on the single task and is capable of
;;;         developing the simple plans quickly. The version of O-Plan
;;;         used for validating and testing was Release Version 2.3.
;;;
;;;     2.  There needs to be a method which captures a task description
;;;         from ACPT and provides it in a form that O-Plan can take
;;;         as a task package.
;;;
;;;     3.  The activities in the plan are described as follows:
;;;         {verb noun_phrase qualifier}
;;;
;;;     4.  The always facts have been used to describe the capabilities of
;;;         the different tools and systems. In future the "Tool Registry"
;;;         of ACPT will need to define this in the task defintion
;;;
;;;     5.  O-Plan needs to have the ability to be tasked to deal with only
;;;         spcified nodes in the task description and to ignore the rest
;;;
;;;     6.  This version uses Plan State Variables (PSVs) instead of the
;;;         ?? match specification. This will create "chains" of PSVs
;;;         which will be reconcilled when the PSV is bound.
;;;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

types process_products = (master_air_attack_plan air_tasking_order
                          JFACC_guidance_letter prioritised_target_list
                          recommended_JIPTL),

      product_attributes = (draft issued circulated available not_available),

      product_perspectives = (risk cost threat_potential quality),

      product_entities = (plan_activities schedule_reservations),

      primitive_pp = (developing_objectives recommended_defense
                      recommended_apportionment recommended_target
                      JFACC_guidance CAS_sorties target_selection
                      weaponeering_assessment weaponeering_force_support
                      mission_requirements ec_planning tanker_flow
```

```
                    Airspace air_tasking_order SPINS target_route
                    targets support_requirements sorties TOT_flow
                    current_status nominated_targets targets
                    prioritised_target_list air_control_order),

      verb_list = (Review Modify Build Support Develop Approve Allocate
                   Perform Weaponeer Coordinate Provide Deconflict
                   Finalise Produce Release Integrate Prioritise Match
                   Consider Identify Group Calculate),

      agent = (O_plan SIPE EXPECT User),
      WF_planner = (O_Plan_WFM);

always  {source_agent} = oplan_WFM,

        {has_capability EXPECT Review},

        {has_capability O_Plan Modify},
        {has_capability O_Plan Develop},

        {has_capability SIPE Modify},
        {has_capability SIPE Build},

        {has_capability User Support},
        {has_capability User Approve},
        {has_capability User Allocate},
        {has_capability User Perform},
        {has_capability User Weaponeer},
        {has_capability User Coordinate},
        {has_capability User Provide},
        {has_capability User Deconflict},
        {has_capability User Finalise},
        {has_capability User Produce},
        {has_capability User Release},
        {has_capability User Integrate},
        {has_capability User Prioritise},
        {has_capability User Match},
        {has_capability User Consider},
        {has_capability User Group},
        {has_capability User Calculate},
        {has_capability User Identify};

Initially

        {status current_status} = available,
        {status intelligence_situation} = available,
        {status unit_information} = available,
        {status SPINS} = available,
        {status JTF_guidance} = available,
        {status JFACC_guidance_letter} = available,
        {status operations_feedback} = available,
```

```
        {status plans_mission_feedback} = available,
        {status target_development} = available,
        {status target_planning_updates} = available,
        {status JIPTL} = available,
        {status JIPTL_cutoff} = available,
        {status ICM_MOM_supports} = available,
        {status EC_targets} = available,
        {status EC_planning} = available,
        {status JMEM_filter} = available,
        {status TNL} = available,
        {status Service_target_nominations} = available,
        {status JAG} = available,
        {status air_space_management_plan} = available,
        {status tanker_asset_data} = available,

        {contents_level target_development} = on_going,
        {contents_level JFACC_guidance_letter} = draft,
        {contents_level air_space_management_plan} = current,
        {approval_status JIPTL} = complete,

        {resource AOC_intelligence_group} = unallocated,
        {resource JFACC_planner} = unallocated,
        {resource Combat_planning_cell} = unallocated,
        {resource Combat_operations_cell} = unallocated;

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;
;;; Top Level Task Description Level

task Full_Air_Campaign_Planning_Process;
  nodes 1 start,
        2 finish,
        3 action {Full_Air_Campaign_Planning_Process};
  orderings 1 ---> 3, 3 ---> 2;
end_task;

task Master_Air_Attack_Plan_Only;
  nodes 1 start,
        2 finish,
        3 action {Master_Air_Attack_Plan};
  orderings 1 ---> 3, 3 ---> 2;
end_task;

task Partial_Air_Campaign_Planning_Process;
  nodes 1 start,
        2 finish,
        3 action {Partial_Plan_Refinement};
  orderings 1 ---> 3, 3 ---> 2;
end_task;
```

```
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;
;;; ACP Domain "Task" Description

schema Full_Air_Campaign_Planning_Process;
  vars ?dst1 = ?{type agent}, ?dst2 = ?{type agent}, ?dst3 = ?{type agent};
  expands {Full_Air_Campaign_Planning_Process};
  nodes 1 action {agenda_issue user ?dst1 Develop {JFACC_plan}{}},
        2 action {agenda_issue user ?dst2 Develop {JIPTL}{}},
        3 action {agenda_issue user ?dst3 Develop {Mission_plan}{}};

  orderings 1 ---> 2, 2 ---> 3;
end_schema;

schema Master_Air_Attack_Plan;
  expands {Master_Air_Attack_Plan};
  nodes 1 action {agenda_issue user O_Plan_WFM Develop {master_air_attack_plan} ??};
end_schema;

schema Partial_Plan_Refinement;
  vars ?dst1 = ?{type agent}, ?dst2 = ?{type agent}, ?dst3 = ?{type agent},
       ?dst4 = ?{type agent}, ?dst5 = ?{type agent};
  expands {Partial_Plan_Refinement};
  nodes
    1 dummy,
    2 dummy,
    3 action {agenda_issue O_Plan_WFM ?dst1 Perform {target_selection}{}},
    4 action {agenda_issue O_Plan_WFM ?dst2 Perform {weaponeering_assessment}{broad}},
    5 action {agenda_issue O_Plan_WFM ?dst3 Develop {recommended_JIPTL} {}},
    6 action {agenda_issue O_Plan_WFM ?dst4 Perform {weaponeering_force_support}{}},
    7 action {agenda_issue O_Plan_WFM ?dst5 Develop {master_air_attack_plan}{}};

  orderings
     1 ---> 3, 1 ---> 5, 5 ---> 6, 3 ---> 4, 4 ---> 7, 6 ---> 7, 7 ---> 2,
     end_of 4 ---> end_of 5;

  conditions
    unsupervised {status JTF_guidance} = available at 3,
    unsupervised {status operations_feedback} = available at 3,
    unsupervised {status target_development} = available at 3,
    unsupervised {contents_level target_development} = on_going at 3,
    unsupervised {status JIPTL} = available at 3,
    unsupervised {status JIPTL_cutoff} = available at 3,
    unsupervised {status ICM_MOM_supports} = available at 3,
    unsupervised {status EC_targets} = available at 3,
    unsupervised {status JFACC_guidance_letter} = available at 4,
    unsupervised {contents_level JFACC_guidance_letter} = approved at 4,
    unsupervised {status JMEM_filter} = available at 4,
    unsupervised {status current_status} = available at 5,
    unsupervised {status Service_target_nominations} = available at 5,
    unsupervised {status JFACC_guidance_letter} = available at 5,
```

```
  unsupervised {contents_level JFACC_guidance_letter} = approved at 5,
  unsupervised {status JAG} = available at 5,
  unsupervised {status JIPTL} = available at 6,
  unsupervised {approval_status JIPTL} = complete at 6,
  unsupervised {status JFACC_guidance_letter} = available at 6,
  unsupervised {contents_level JFACC_guidance_letter} = approved at 6,
  unsupervised {status unit_information} = available at 6,
  unsupervised {status JMEM_filter} = available at 6,

  ;;; conditions of the Master Air Attack Plan
  unsupervised {status JIPTL} = available at 7,
  unsupervised {approval_status JIPTL} = complete at 7,

  unsupervised {status operations_feedback} = available at 7,
  unsupervised {status TNL} = available at 7,
  unsupervised {status current_status} = available at 7,
  unsupervised {status unit_information} = available at 7,
  unsupervised {status SPINS} = available at 7,

  unsupervised {status JIPTL} = available at 7,
  unsupervised {rec_status JIPTL} = complete at 7,

  unsupervised {contents_level air_space_management_plan} = current at 7,
  unsupervised {status air_space_management_plan} = available at 7,
  unsupervised {status CAS_ATO_sorties} = available at 7,
  unsupervised {status DCA_ATO_inputs} = available at 7,

  supervised {status special_weapons_requirements} = available at 5 from 4,
  supervised {status vunerability_assessment} = available at 5 from 4,
  supervised {status target_list} = available at 4 from 3,
  supervised {contents_level target_list} = potential at 4 from 3,
  supervised {resource AOC_intelligence_group} = allocated at end_of 3 from begin_of 3,
  supervised {status target_list} = available at 5 from 3,
  supervised {contents_level target_list} = potential at 5 from 3,
  supervised {rec_status JIPTL} = complete at 6 from 5;

effects
  {status JTF_guidance} = available at begin_of self,
  {status operations_feedback} = available at begin_of self,
  {status target_development} = available at begin_of self,
  {contents_level target_development} = on_going at begin_of self,
  {status JIPTL} = available at begin_of self,
  {status JIPTL_cutoff} = available at begin_of self,
  {status ICM_MOM_supports} = available at begin_of self,
  {status EC_targets} = available at begin_of self,
  {status JFACC_guidance_letter} = available at begin_of self,
  {contents_level JFACC_guidance_letter} = approved at begin_of self,
  {status JMEM_filter} = available at begin_of self,
  {status current_status} = available at begin_of self,
  {status Service_target_nominations} = available at begin_of self,
  {status JAG} = available at begin_of self,
```

```
    {status JIPTL} = available at begin_of self,
    {approval_status  JIPTL} = complete at begin_of self,

    ;;; conditions of the Master Air Attack Plan
    {status TNL} = available at begin_of self,
    {status current_status} = available at begin_of self,
    {status unit_information} = available at begin_of self,
    {status SPINS} = available at begin_of self,

    {status JIPTL} = available at begin_of self,
    {rec_status JIPTL} = complete at begin_of self,

    {contents_level air_space_management_plan} = current at begin_of self,
    {status air_space_management_plan} = available at begin_of self,
    {status CAS_ATO_sorties} = available at begin_of self,
    {status DCA_ATO_inputs} = available at begin_of self,
    {status JFACC_guidance_letter} = available at begin_of self,
    {contents_level JFACC_guidance_letter} = approved at begin_of self,

    {resource AOC_intelligence_group} = unallocated at begin_of self,
    {status target_list} = available at begin_of self,
    {contents_level target_list} = potential at begin_of self,
    {status special_weapons_requirements} = available at begin_of self,
    {status vunerability_assessment} = available at begin_of self,
    {status JIPTL} = available at begin_of self;

  time_windows
    delay_between begin_of 3 and begin_of 5 = 0;

end_schema;

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;; ;;; Main Activities of the ACP Domain

schema Phase_1_JFACC_Planning;
  vars ?src, ?dst1 = ?{type agent}, ?dst2 = ?{type agent},
       ?dst3 = ?{type agent}, ?dst4 = ?{type agent}, ?dst5 = ?{type agent},
       ?dst6 = ?{type agent};
  expands {agenda_issue ?src ?dst1 Develop {JFACC_plan} {}};
  nodes
    sequential
      1 action {agenda_issue O_Plan_WFM ?dst2 Support {developing_objectives}{}},
      parallel
        2 action {agenda_issue O_Plan_WFM ?dst3 Develop {recommended_defense}{}},
        3 action {agenda_issue O_Plan_WFM ?dst4 Develop {recommended_apportionment}{}},
        4 action {agenda_issue O_Plan_WFM ?dst5 Develop {recommended_target}{}}
      end_parallel,
      5 action {agenda_issue O_Plan_WFM ?dst6 Approve {JFACC_guidance}{}}
    end_sequential;

  conditions
```

```
    unsupervised {resource JFACC_planner} = unallocated at begin_of 1,
    unsupervised {resource Combat_planning_cell} = unallocated at begin_of 4,
    unsupervised {resource Combat_operations_cell} = unallocated at begin_of 4,
    unsupervised {resource JFACC_planner} = unallocated at begin_of 5,

    unsupervised {status current_status} = available at 2,
    unsupervised {status unit_information} = available at 2,
    unsupervised {status JTF_guidance} = available at 2,
    unsupervised {status current_status} = available at 3,
    unsupervised {status JTF_guidance} = available at 3,
    unsupervised {status current_status} = available at 4,
    unsupervised {status JTF_guidance} = available at 4,
    unsupervised {status JFACC_guidance_letter} = available at 5,
    unsupervised {contents_level JFACC_guidance_letter} = draft at 5,

    supervised {resource Combat_operations_cell} = allocated at end_of 4 from begin_of 4,
    supervised {resource Combat_planning_cell} = allocated at end_of 4 from begin_of 4,
    supervised {resource JFC_planner} = allocated at end_of 5 from begin_of 5,
    supervised {resource JFACC_planner} = allocated at end_of 1 from begin_of 1,
    supervised {status op_plan_obj_guidance} = available at 2 from 1,
    supervised {contents_level op_plan_obj_guidance} = recommended at 2 from 1,
    supervised {status op_plan_obj_guide_rec} = available at 3 from 1,
    supervised {contents_level op_plan_obj_guidance} = recommended at 3 from 1,
    supervised {status op_plan_obj_guide_rec} = available at 4 from 1,
    supervised {contents_level op_plan_obj_guidance} = recommended at 4 from 1,
    supervised {status target_selection_criteria} = available at 4 from 1;

  effects
    {resource JFACC_planner} = allocated at begin_of 1,
    {resource JFACC_planner} = unallocated at end_of 1,
    {resource Combat_planning_cell} = allocated at begin_of 4,
    {resource Combat_planning_cell} = unallocated at end_of 4,
    {resource Combat_operations_cell} = allocated at begin_of 4,
    {resource Combat_operations_cell} = unallocated at end_of 4,
    {resource JFC_planner} = allocated at begin_of 5,
    {resource JFC_planner} = unallocated at end_of 5,
    {status op_plan_obj_guidance} = available at 1,
    {contents_level op_plan_obj_guidance} = recommended at 1,
    {status target_selection_criteria} = available at 1,
    {status DCA_ATO_inputs} = available at 2,
    {status defense_posture} = available at 2,
    {contents_level defense_posture} = recommended at 2,
    {status apportioned_sorties} = available at 3,
    {contents_level opportioned_sorties} = recommended at 3,
    {status target_objectives} = available at 4,
    {contents_level target_objectives} = recommended at 4,
    {status JFACC_guidance_letter} = available at 5,
    {contents_level JFACC_guidance_letter} = approved at 5;

end_schema;
```

```
schema Phase_2_JIPTL_Planning;
  vars ?src, ?dst1 = ?{type agent}, ?dst2 = ?{type agent}, ?dst3 = ?{type agent},
       ?dst4 = ?{type agent}, ?dst5 = ?{type agent}, ?dst6 = ?{type agent};
  expands {agenda_issue ?src ?dst1 Develop {JIPTL}{}};
  nodes
    1 action {agenda_issue O_Plan_WFM ?dst2 Allocate {CAS_sorties}{}},
    2 action {agenda_issue O_Plan_WFM ?dst3 Perform {target_selection}{}},
    3 action {agenda_issue O_Plan_WFM ?dst4 Perform {weaponeering_assessment}{broad}},
    4 action {agenda_issue O_Plan_WFM ?dst5 Develop {recommended_JIPTL} {}},
    5 action {agenda_issue O_Plan_WFM ?dst6 Perform {weaponeering_force_support}{}};

  orderings end_of 3 ---> end_of 4,
    2 ---> 3,
            4 ---> 5;
  conditions
    unsupervised {resource AOC_intelligence_group} = unallocated at begin_of 1,
    unsupervised {resource AOC_intelligence_group} = unallocated at begin_of 2,

    unsupervised {status JFACC_guidance_letter} = available at 1,
    unsupervised {contents_level JFACC_guidance_letter} = approved at 1,
    unsupervised {status unit_information} = available at 1,
    unsupervised {status JTF_guidance} = available at 2,
    unsupervised {status operations_feedback} = available at 2,
    unsupervised {status target_development} = available at 2,
    unsupervised {contents_level target_development} = on_going at 2,
    unsupervised {status JIPTL} = available at 2,
    unsupervised {approval_status JIPTL} = complete at 2,
    unsupervised {status ICM_MOM_supports} = available at 2,
    unsupervised {status EC_targets} = available at 2,
    unsupervised {status JFACC_guidance_letter} = available at 3,
    unsupervised {contents_level JFACC_guidance_letter} = approved at 3,
    unsupervised {status JMEM_filter} = available at 3,
    unsupervised {status current_status} = available at 4,
    unsupervised {status Service_target_nominations} = available at 4,
    unsupervised {status JFACC_guidance_letter} = available at 4,
    unsupervised {contents_level JFACC_guidance_letter} = approved at 4,
    unsupervised {status JAG} = available at 4,
    unsupervised {status JIPTL} = available at 5,
    unsupervised {status JFACC_guidance_letter} = available at 5,
    unsupervised {contents_level JFACC_guidance_letter} = approved at 5,
    unsupervised {status unit_information} = available at 5,
    unsupervised {status JMEM_filter} = available at 5,

    supervised {status special_weapons_requirements} = available at end_of 4 from  3,
    supervised {status vunerability_assessment} = available at end_of 4 from 3,
    supervised {status target_list} = available at 3 from 2,
    supervised {contents_level target_list} = potential at 3 from 2,
    supervised {resource AOC_intelligence_group} = allocated at end_of 2 from begin_of 2,
    supervised {resource AOC_intelligence_group} = allocated at end_of 1 from begin_of 1,
    supervised {status target_list} = available at 4 from 2,
    supervised {contents_level target_list} = potential at 4 from 2,
```

```
    supervised {rec_status JIPTL} = complete at 5 from 4;

  effects
    {resource AOC_intelligence_group} = allocated at end_of 1,
    {resource AOC_intelligence_group} = unallocated at end_of 2,
    {status CAS_ATO_sorties} = available at 1,
    {status target_list} = available at 2,
    {contents_level target_list} = potential at 2,
    {status special_weapons_requirements} = available at begin_of 3,
    {status vunerability_assessment} = available at begin_of 3,
    {status JIPTL} = available at 4,
    {rec_status JIPTL} = complete at 4,
    {status TNL} = available at 5;

  time_windows
    delay_between begin_of 1 and begin_of 2 = 0,
    delay_between begin_of 2 and begin_of 4 = 0;
end_schema;

schema Phase_3_Mission_Planning;
  vars ?src, ?dst1 = ?{type agent}, ?dst2 = ?{type agent}, ?dst3 = ?{type agent},
       ?dst4 = ?{type agent}, ?dst5 = ?{type agent}, ?dst6 = ?{type agent},
       ?dst7 = ?{type agent}, ?dst8 = ?{type agent}, ?dst9 = ?{type agent},
       ?dst10 = ?{type agent}, ?dst11 = ?{type agent};
  expands {agenda_issue ?src ?dst1 Develop {Mission_plan}{}};
  nodes
    1 action {agenda_issue O_Plan_WFM ?dst2 Develop {master_air_attack_plan}{}},
    2 action {agenda_issue O_Plan_WFM ?dst3 Coordinate {mission_requirements}{}},
    3 action {agenda_issue O_Plan_WFM ?dst4 Provide {ec_planning}{}},
    4 action {agenda_issue O_Plan_WFM ?dst5 Develop {tanker_flow}{}},
    5 action {agenda_issue O_Plan_WFM ?dst6 Deconflict {Airspace}{}},
    6 action {agenda_issue O_Plan_WFM ?dst7 Finalise {SPINS}{}},
    7 action {agenda_issue O_Plan_WFM ?dst8 Finalise {air_control_order}{}},
    8 action {agenda_issue O_Plan_WFM ?dst9 Produce {air_tasking_order}{}},
    9 action {agenda_issue O_Plan_WFM ?dst10 Finalise {air_tasking_order} {QC1}},
    10 action {agenda_issue O_Plan_WFM ?dst11 Release {air_tasking_order}{}};

  orderings
    1 ---> 2, 1 ---> 3, 1 ---> 4, 5 ---> 7, 8 ---> 9, 9 ---> 10,
    begin_of 2 ---> begin_of 3,
    begin_of 2 ---> begin_of 4,
    begin_of 2 ---> begin_of 6,
    begin_of 3 ---> begin_of 6,
    begin_of 4 ---> begin_of 6,
    begin_of 6 ---> begin_of 8,
    begin_of 7 ---> begin_of 8,
    end_of 2 ---> end_of 3,
    end_of 2 ---> end_of 4,
    end_of 4 ---> end_of 5,
```

```
  end_of 2 ---> end_of 6,
  end_of 3 ---> end_of 6,
  end_of 4 ---> end_of 6,
  end_of 6 ---> end_of 8,
  end_of 7 ---> end_of 6;

conditions
  unsupervised {status JIPTL} = available at 1,
  unsupervised {approval_status JIPTL} = complete at 1,
  unsupervised {status JIPTL} = available at 3,
  unsupervised {approval_status JIPTL} = complete at 3,
  unsupervised {status JIPTL} = available at 3,
  unsupervised {rec_status JIPTL} = complete at 3,
  unsupervised {status operations_feedback} = available at 1,
  unsupervised {status operations_feedback} = available at 5,
  unsupervised {status TNL} = available at 1,
  unsupervised {status current_status} = available at 1,
  unsupervised {status unit_information} = available at 1,
  unsupervised {status unit_information} = available at 2,
  unsupervised {status SPINS} = available at 1,
  unsupervised {status JIPTL} = available at 1,
  unsupervised {rec_status JIPTL} = complete at 1,
  unsupervised {contents_level air_space_management_plan} = current at 1,
  unsupervised {status air_space_management_plan} = available at 1,
  unsupervised {status CAS_ATO_sorties} = available at 1,
  unsupervised {status DCA_ATO_inputs} = available at 1,
  unsupervised {status JFACC_guidance_letter} = available at 1,
  unsupervised {contents_level JFACC_guidance_letter} = approved at 1,
  unsupervised {status JFACC_guidance_letter} = available at 9,
  unsupervised {contents_level JFACC_guidance_letter} = approved at 9,
  unsupervised {status EC_planning} = available at 2,
  unsupervised {status target_planning_updates} = available at 2,
  unsupervised {status plans_mission_feedback} = available at 4,
  unsupervised {status plans_mission_feedback} = available at 5,
  unsupervised {status tanker_asset_data} = available at 4,
  unsupervised {status intelligence_situation} = available at 5,
  unsupervised {status air_space_management_plan} = available at 5,

  supervised {status EC_support_requests} = available at 3 from 2,
  supervised {status refuelling_requests} = available at 4 from 2,
  supervised {status ACM_requirements} = available at 5 from 4,
  supervised {status air_space_management_changes} = available at 7 from 5,
  supervised {status EC_SPINS} = available at 6 from 3,
  supervised {status Tanker_SPINS} = available at 6 from 4,
  supervised {status Target_mission_SPINS} = available at 6 from 2,
  supervised {status Air_Control_Order} = available at 8 from 6,
  supervised {status SPINS} = available at 8 from 6,
  supervised {status Tanker_mission_data} = available at 8 from 4,
  supervised {status Target_mission_data} = available at 8 from 2,
  supervised {status EC_Planning} = available at 8 from 3,
  supervised {status Air_Tasking_Order} = available at 9 from 8,
```

```
    supervised {contents_level Air_Tasking_Order} = unreleased at 9 from 8,
    supervised {contents_level Air_Tasking_Order} = approved at 10 from 9;

  effects
    {status EC_support_requests} = available at 2,
    {status Target_mission_data} = available at 2,
    {status Target_mission_SPINS} = available at 2,
    {status Unit_Heads_UP} = available at 2,
    {status refuelling_requests} = available at 2,
    {status EC_planning} = available at 3,
    {status EC_SPINS} = available at 3,
    {status ACM_requirements} = available at 4,
    {status Tanker_mission_data} = available at 4,
    {status Tanker_SPINS} = available at 4,
    {status air_space_management_changes} = available at 5,
    {status Air_Control_Order} = available at 7,
    {status SPINS} = available at 6,
    {status Air_Control_Order_Summary} = available at 8,
    {status Air_Tasking_Order} = available at 8,
    {contents_level Air_Tasking_Order} = unreleased at 8,
    {status Air_Tasking_Order} = available at 9,
    {contents_level Air_Tasking_Order} = approved at 9,
    {status Air_Tasking_Order} = available at 10,
    {contents_level Air_Tasking_Order} = released at 10;

  time_windows
    delay_between begin_of 3 and begin_of 4 = 0,
    delay_between begin_of 4 and begin_of 5 = 0,
    delay_between end_of 3 and end_of 4 = 0,
    delay_between end_of 7 and end_of 8 = 0;

end_schema;


;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;
;;; Intermediate Level Support Activities

schema Develop_the_recommended_JIPTL;
  vars ?dst1 = ?{type agent}, ?dst2 = ?{type agent}, ?dst3 = ?{type agent};
  expands {agenda_issue O_Plan_WFM ?dst1 Develop {recommended_JIPTL} ??};
  nodes
    sequential
      1 action {agenda_issue O_Plan_WFM ?dst2 Integrate {nominated_targets} {}},
      2 action {agenda_issue O_Plan_WFM ?dst3 Prioritise {integrated_targets} {}}
   end_sequential;
  conditions
    unsupervised {status operations_feedback} = available at 1,
    unsupervised {status EC_targets} = available at 1,
    unsupervised {status Service_target_nominations} = available at 1,
    unsupervised {status JFACC_guidance_letter} = available at 1,
```

```
    unsupervised {contents_level JFACC_guidance_letter} = approved at 1,
    unsupervised {status current_status} = available at 2,
    unsupervised {status intelligence_situation} = available at 2,
    unsupervised {status Service_target_nominations} = available at 2,
    unsupervised {status JFACC_guidance_letter} = available at 2,
    unsupervised {status air_space_management_plan} = available at 2,
    supervised {status JIPTL_list} = available at 2 from 1;

  effects
    {status JIPTL_list} = available at 1;

end_schema;

schema Develop_the_Master_Air_Attack_Plan;
  vars ?dst1 = ?{type agent}, ?dst2 = ?{type agent}, ?dst3 = ?{type agent},
       ?dst4 = ?{type agent}, ?dst5 = ?{type agent}, ?dst6 = ?{type agent},
       ?dst7 = ?{type agent};
  expands {agenda_issue O_Plan_WFM ?dst1 Develop {master_air_attack_plan} ??};
  nodes
    1 action {agenda_issue O_Plan_WFM ?dst2 Consider {target_route}{threat}},
    2 action {agenda_issue O_Plan_WFM ?dst3 Group {targets}{}},
    3 action {agenda_issue O_Plan_WFM ?dst4 Identify {support_requirements}{}},
    4 action {agenda_issue O_Plan_WFM ?dst5 Prioritise {support_requirements}{}},
    5 action {agenda_issue O_Plan_WFM ?dst6 Develop {TOT_flow}{rough}},
    6 action {agenda_issue O_Plan_WFM ?dst7 Calculate {sorties}{}};

  orderings begin_of 1 ---> begin_of 2,
            end_of 1 ---> end_of 2,
            begin_of 1 ---> begin_of 6,
            2 ---> 3,
            2 ---> 4,
            4 ---> 5,
            6 ---> 5;

  conditions
    unsupervised {status JIPTL} = available at 1,
    unsupervised {approval_status JIPTL} = complete at 1,
    unsupervised {status JFACC_guidance_letter} = available at 5,
    unsupervised {contents_level JFACC_guidance_letter} = approved at 5,
    unsupervised {status JIPTL} = available at 2,
    unsupervised {approval_status JIPTL} = complete at 2, ;;; should be approved
    unsupervised {status TNL} = available at 1,
    unsupervised {status TNL} = available at 2,
    unsupervised {status operations_feedback} = available at 2,
    unsupervised {status unit_information} = available at 3,
    unsupervised {status intelligence_situation} = available at 1,
    unsupervised {status CAS_ATO_sorties} = available at 5,

    supervised {status perceived_target_route_threat} = available at end_of 2 from 1,
    supervised {status target_groupings} = available at 3 from 2,
    supervised {status sorties} = available at 5 from 6,
```

```
    supervised {status support_requirements} = available at 5 from 3,
    supervised {status target_groupings} = available at 5 from 2;

  effects
    {status perceived_target_route_threat} = available at 1,
    {status target_groupings} = available at 2,
    {status support_requirements} = available at 3,
    {status sorties} = available at 6,
    {status sortie_target_flow} = available at 5,
    {contents_level sortie_target_flow} = rough at 5;

  time_windows
    delay_between begin_of 1 and begin_of 6 = 0;

end_schema;

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;
;;; Lower Level Support Activities

schema Develop_the_Prioritised_Integrated_Targets;
  vars ?dst1 = ?{type agent}, ?dst2 = ?{type agent}, ?dst3 = ?{type agent},
       ?dst4 = ?{type agent};
  expands {agenda_issue O_Plan_WFM ?dst1 Prioritise {integrated_targets} ??};
  nodes
    sequential
      1 action {agenda_issue O_Plan_WFM ?dst2 Review {current_status}{}},
      2 action {agenda_issue O_Plan_WFM ?dst3 Match {targets} {JFACC_guidance_letter}},
      3 action {agenda_issue O_Plan_WFM ?dst4 Build {prioritised_target_list}{}}
    end_sequential;

  conditions
    unsupervised {status current_status} = available at 1,
    unsupervised {status intelligence_situation} = available at 2,
    unsupervised {status intelligence_situation} = available at 3,
    unsupervised {status JIPTL_list} = available at 2,
    unsupervised {approval_status JIPTL} = complete at 3,
    unsupervised {status JIPTL} = available at 3,
    unsupervised {status TNL} = available at 3,

    supervised {status status_impact} = available at 2 from 1,
    supervised {status target_priorities} = available at 3 from 2,
    supervised {contents_level target_priorities} = proposed at 3 from 2;

  effects
    {status status_impact} = available at 1,
    {status target_priorities} = available at 2,
    {contents_level target_priorities} = proposed at 2;

end_schema;
```

```
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;
;;; Mapping of the Agent Capabilties to the requirement
;;;
;;; This schema identifies the tool with the correct capability to address
;;; the activity needs

schema Find_Capability_and_Construct_Issue;
  vars ?verb,
       ?nouns,
       ?noun = ?{type primitive_pp},
       ?qualifier,
       ?dst,
       ?src = ?{type WF_planner};
  expands {agenda_issue ?src ?dst ?verb ?nouns ?qualifier};
  conditions
     compute {first ?nouns} = ?noun,
     only_use_if {has_capability ?dst ?verb};
end_schema;
```

Appendix B: O-Plan Task Formalism Description

This appendix contains the process plan generated for the full ACP process. The task specified three high level steps which needed to be decomposed and appropriate agents identified. The three steps were:

- develop JFACC plan
- develop JIPTL
- develop Mission Plan

A postscript file of the plan is provided via URL pointer:

`http://www.aiai.ed.ac.uk/~oplan/html/work/bd`

Appendix C: O-Plan Task Formalism Description

This appendix contains the process plan generated for a partial ACP process. The task specified two high level steps and three lower level ones which would have been added to the agenda as the result of decomposing a higher level step. The five steps were:

- Perform Target Selection
- Perform Weaponeering Assessment, broadly
- Develop Recommended JIPTL
- Perform Weaponeering Force Support
- Develop Master Air Attack Plan

Dealing with this type of partially completed ACP process plan is the most likely scenario in JFD-5. The two high level steps needed to be decomposed and appropriate agents identified for all steps in the ACP process plan. The plan generated is as follows:

A postscript file of the plan is provided via URL pointer:

`http://www.aiai.ed.ac.uk/~oplan/html/work/bd`