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Adapting C2 to the 21st Century

# Using THE HTA TOOL for Agile Mission Planning

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## ABSTRACT

The software application known as THE HTA TOOL was developed, non-commercially, under the auspices of the Human Factors Integration - Defence Technology Centre (HFI-DTC). This is a UK Ministry of Defence (MoD) initiative. The original driver was a growing demand for the computerisation of Hierarchical Task Analysis (HTA), a well recognised, if 40 year old, methodology. HTA is used predominantly in the training domain, but more recently has been used for air mission planning (for Euro-Fighter). The nature of most missions is changing (e.g. from attrition to effects-based) and while new technology can facilitate changes after the start of an operation, there is a shortage of planning tools to enable agility in the planning process. This paper will argue that THE HTA TOOL can be utilised for mission analysis and rapid modification, and that it has potential as an agile planning tool for ground combat. The paper will discuss the benefits of using a computerised application, look at examples of mission planning and how these can benefit from the numerous features of the tool (which can be freely distributed under the aegis of NATO, the TTCP, and other programs).

# Using THE HTA TOOL for Agile Mission Planning

## Introduction

The nature of Command and Control (C2) is changing at an ever increasing rate. The world order has evolved significantly over the last decade and the military are required to be increasingly agile and adaptable. Adversaries are employing asymmetric approaches to warfare and will likely continue to become more challenging in the future. Similarly, conflicts are fought in a range of environments, including urban and electronic, and enemy tactics have switched from traditional attrition-based to effectual (Gilmour et al 2006). As such, mission planners will need to be aware of an unpredictable and changing adversary, and have a flexible approach to mission design.

Hierarchical Task Analysis (HTA) is a technique which can be used to model any situation with a hierarchical structure, such as the military organisation (chain of command). Until recently there have been no software-based tools to aid the HTA practitioner in the conduct of an analysis. The Human Factors Integration Defence Technology Centre (HFI-DTC) have drawn on their expertise to develop THE HTA TOOL, a software application to facilitate the construction of a computerised HTA. The nature of missions is changing (e.g. from attrition to effects-based), and while new computer technology can enable changes after the start of an operation, there is a shortage of planning tools to assist such agility. Our research has shown that HTA could share similarities with the process used to develop mission plans and, although THE HTA TOOL was primarily developed for training purposes, this paper discusses how it might be utilised as an agile mission planning tool.

## Hierarchical Task Analysis

Hierarchical Task Analysis is a recognised method for describing a task in terms of a hierarchy of operations and plans based on structure chart notation. HTA is generally recognised to have been formalised by Annett and Duncan (1967) although it originates from the beginning of the 20$^{th}$ century. An example HTA is shown in Figure 1.

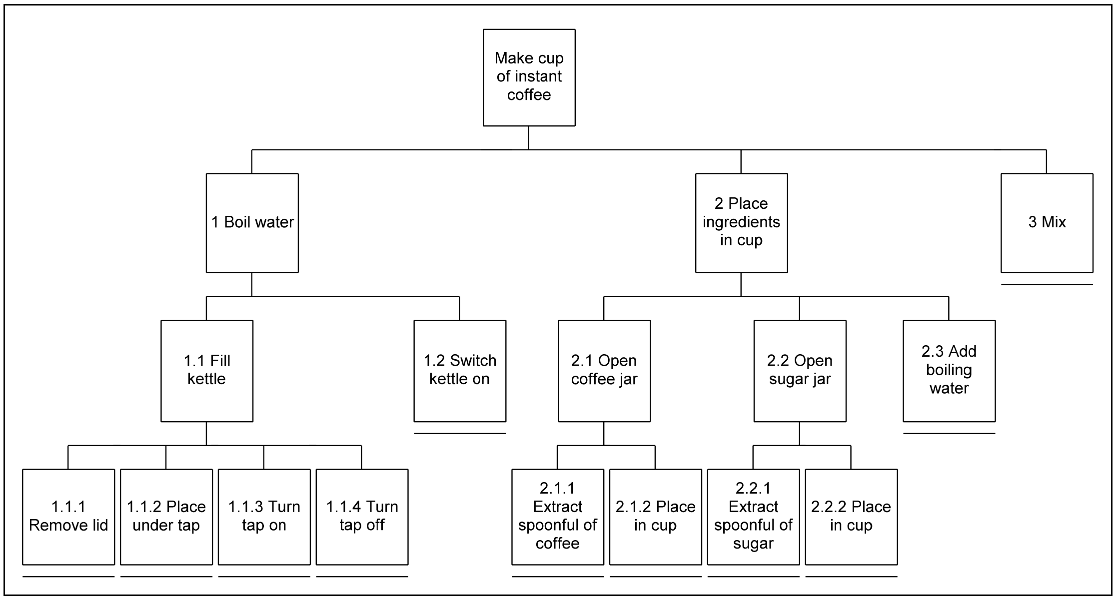


**Figure 1 – Example Hierarchical Task Analysis**

The HTA technique involves recursively breaking down an overall goal, such as “Make cup of instant coffee”, into a sequence of sub-components (“boil water”, “place ingredients in cup”, “mix”), then decomposing those further until it is not possible to break down the cognitive or psychomotor activity any more, or to a point where additional decomposition is not considered useful for the application. This methodology has implementations in a wide range of fields from the simple (as above) to complex and safety critical systems. Indeed, Salmon et al reference a number of domains in which HTA has been applied, including the process control, and power generation industries, emergency services, civil aviation, retail, as well as military applications (Salmon et al 2004).

One of the main advantages of HTA is that it is a simple concept, easy to learn and use. The hierarchical approach allows the analyst to concentrate on specific, more complex or important, aspects of the overall task. Its also a very powerful technique because it can be used in a variety of domains (see above), and form the basis of many other assessments and task analysis methodologies, e.g. DIF (Difficulty, Importance, Frequency) analysis, KSA (Knowledge, Skills and Attitudes) analysis, communication analysis and OPSs (Operational Performance Statements) (Hone and Stanton 2004).

However, there are some drawbacks to “hardcopy” HTA’s: they can become particularly large and unwieldy for any non-trivial situation, and they are difficult to maintain, the process being slow to make alterations and possibly requiring the re-creation of the whole analysis. It is also difficult to ensure an analysis does not contain errors (an HTA is only as good as the analyst who created it) and accounts for unforeseen eventualities, particularly as there is no uniform format to HTA and collaboration between analysts requires all to be present. Hone and Stanton also suggest that there is a need to increase the awareness and usage of HTA within the Armed Forces where it is not currently mandated and utilisation often involves sub-contracting if a major analysis is required (Hone and Stanton 2004).

## THE HTA TOOL

HTAs have traditionally been performed on paper or whiteboard, and later input into a computer as a record of the analysis or for printing, often using any software package of the user's choosing, such as a spreadsheet, without specific consideration for future analysis (Hone and Stanton 2004). Hone and Stanton report Microsoft Excel as the current application of choice for data entry, but this is for representation only, and does not help in the conduct of the analysis. THE HTA TOOL was developed in response to a growing need for the computerisation of the actual HTA process, from initial analysis through to potential modifications. It was developed non-commercially under the auspices of the Human Factors Integration-Defence Technology Centre (HFI-DTC), a Ministry of Defence (MoD) initiative, and is widely (and freely) available through a number of channels.

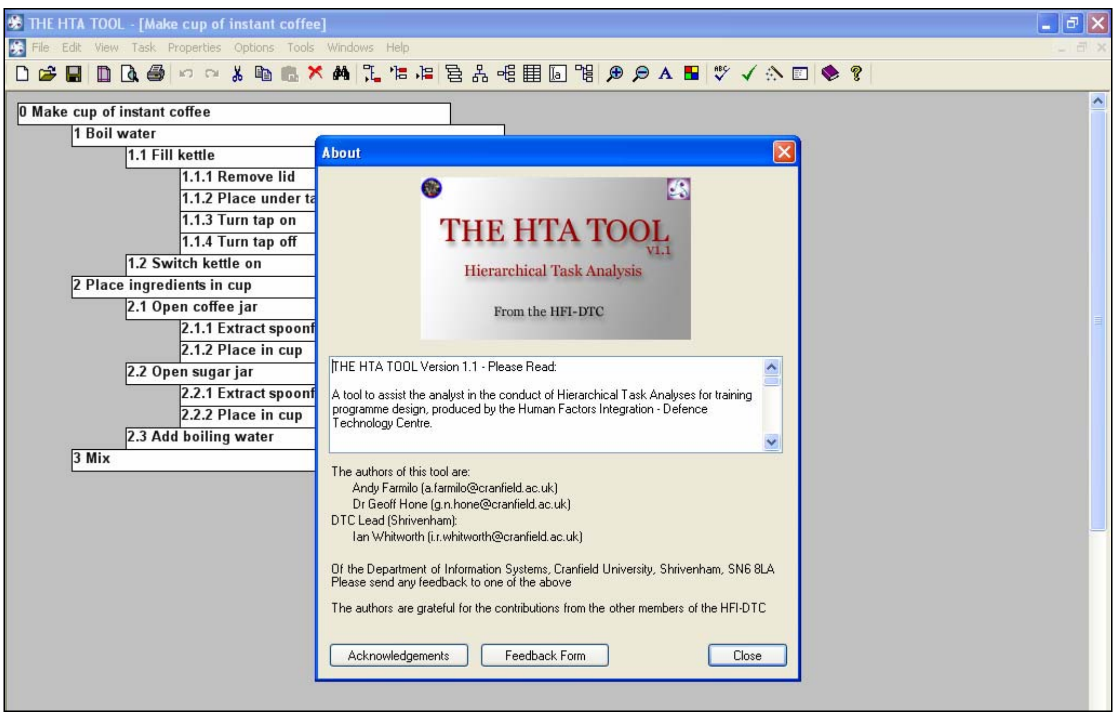


**Figure 2 – Screenshot of THE HTA TOOL**

The original aim of the research was to produce a prototype tool which could support the range of HTA applications, and notably to create a tool to assist a user in analysing and decomposing a task for training purposes. THE HTA TOOL was engineered following the RAD (Rapid Application Development) model at Cranfield University (at the Defence Academy campus), distributed to the MoD for critique in 2005, before being made available for public release, both in the UK, and Internationally. It has been used by a number of multi-national corporations, for many applications beyond its original intentions, and with great success.

There are several advantages to using a computerised version of HTA as opposed to the traditional “hardcopy” method. The most obvious of these is the simplicity in making changes to task names, or more comprehensive adjustments to the entire structure. A software tool also reduces the impact of the previously mentioned disadvantages of HTA: a) the plans facility of the tool allows for a number of ordering styles and for unlimited description (i.e. not restricted by the size of your drawing chart); b) having an electronic version of an analysis facilitates faster modification, greater collaboration between analysts, a standard, clear format for validation and verification, and THE HTA TOOL also has a built-in checker to highlight common mistakes.

**Mission Planning**

Making decisions and plans are key requirements for military commanders requiring a great degree of time and effort at all levels of the hierarchy, to ensure that they are made accurately and on time (Thunholm 2006). Thunholm argues that in recent years there has been a significant shift away from traditional planning methods, which require an unrealistic amount of time to formulate. Lutz adds that there is a demonstrable need for a more agile and fluid command style of leadership in mission planning from the traditionally constrained approach to C2 (Lutz 2005). This does not just mean agility in the sense of having a group of troops who can assume a number of roles, for example, but an ability to move and adapt, quickly, to a changing situation.

Mission planners currently use whiteboards, then document results in spreadsheets and presentations, to support decision making with limited automated tool support (Allen 2006). It is argued that analysis capabilities must be developed for mission planners to leverage emerging mission planning concepts, and to manage complex interdependencies (Gilmour et al 2006). In conjunction with this any new methods must be attractive to the military in order for them to be utilised, because of the time pressures in a real battlespace environment (Thunholm 2006).

Mission plans need to focus on the objectives they are designed to accomplish. Past planning techniques have suffered from failing to connect individual tasks to the end objectives (Bryant 2006, Gilmour et al 2006). HTA is a technique which can accommodate this requirement, as tasks are a direct descendent of the objectives. A commander is assigned an objective which he/she then breaks down into sub-components which are then allocated to sub-commanders, who follow the same process.

Looking at a real world example, Bryant discusses the planning process for a mission involving UAVs:

> *UAV mission planning is a large problem that can be decomposed into small problems to attain tractability… To maintain tractability, we can decompose the planning process into a hierarchical structure in which each level encompasses decreasing numbers of tasks, aircraft, and responsibilities, but increasing detail.*
>
> Bryant, 2006

This shows that the HTA method can be used during military mission planning. The next section discusses how the process can be computerised, and the benefits of doing so.

## Application of the Tool

In the 21$^{st}$ century our lives revolve around technology and computers. Computerised systems have endless power to offer if properly combined with human knowledge and expertise. Software can then help people do their jobs, quicker and more efficiently. THE HTA TOOL is one such software application which has been designed to improve the usability and usefulness of hierarchical task analysis. The tool is in use internationally on a diverse range of projects. For example, a major defence contractor (BAE Systems) is using THE HTA TOOL for air mission planning for the Euro-Fighter.

With any type of mission planner there is a need for flexibility (Sakamoto 2006) and to produce accurate results under time-pressure (Thunholm 2006). A mission planner in the Command and Control system should also account for the uncertainty inherent in the operational execution of the missions. At this point an application like THE HTA TOOL becomes very powerful. It has an easy to use, intuitive interface, and changes can be made on-the-fly and, with the right network, disseminated around the chain of command in seconds.

The tool also facilitates a degree of uncertainty in the initial design phase by the construction of task plans. A plan can be described for any “parent” task in a hierarchy and expresses the order, timing and pre-conditions of “child” operations. There are built-in functions to produce plans automatically, or to highlight where a plan has not been included. Additionally, the plans system allows a considerable amount of customisation, including a simple-to-follow plan builder using common order styles, such as linear and parallel, and provision for an analyst to provide a textual description for particularly complex situations (Figure 3). The plans system also allows selection from the standard text and symbol notation types, as recommended by Shepherd (Shepherd 2001).

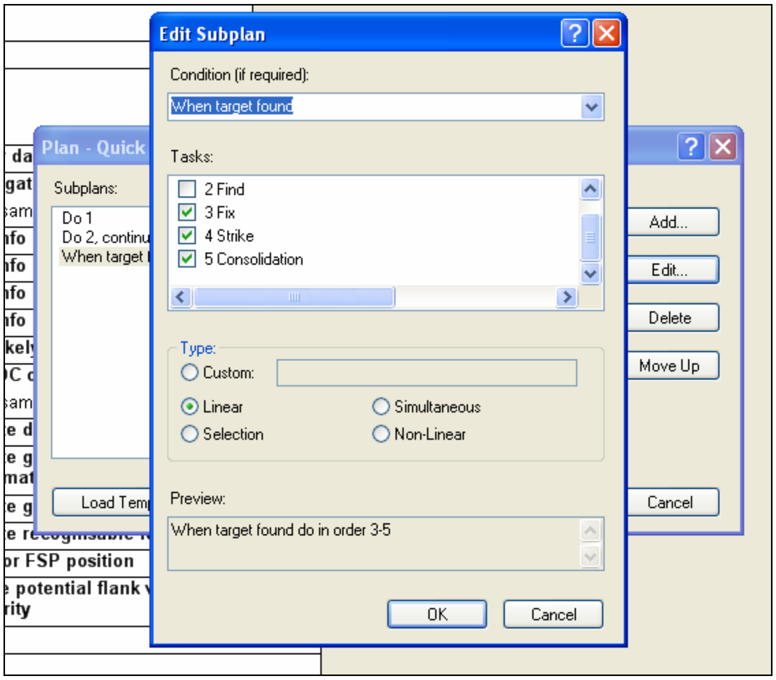


**Figure 3 – THE HTA TOOL Plan Builder**

The nature of missions is changing (e.g. from attrition to effects-based), and while new technology can enable changes after the start of an operation, Stewart points out that there is a shortage of planning tools to assist such agility (Stewart 2006). THE HTA TOOL can support the changing mission challenges from a maintenance perspective (past missions can be easily modified) and in facilitating a decentralised command approach.

The tool boasts a number of advantages over traditional non-computerised methods. Initial analysis creation is simplified by the use of an Analysis Wizard which prompts the user for increasing levels of decomposition, one step at a time, as well as allowing quick selection of plans and an ability to load previously created sub-goal templates: custom-made sections of re-usable analysis. These could, for example, cover standard military tasks, the Mission Essential Task List (METL) comes to mind.

Any changes to the analysis result in an automatic update to the numbering system (in particular, and where appropriate, to the plans). The tool is designed to recognised graphical user interface (GUI) standards and has a familiar Microsoft Windows look and feel, including shortcut keys and menus, and toolbar buttons. This enables a user to learn the tool's basic functions in a few hours. The analysis tree is easily modifiable, with the ability to insert, cut, copy and paste tasks at any level (with undo and redo options).

Hone and Stanton highlight that different analysts find different representations of an analysis more useful to them (Hone and Stanton 2004). As such, THE HTA TOOL supports all of the main visual representations of the decomposition, including indented list (as Figure 1), vertical and horizontal hierarchies, and tabular list. Using the latter an analysis can be extended using custom or recommended techniques including DIF analysis. It is also possible to attach other information to tasks such as images, particularly useful for identification or clarification. When an agreed stopping point has been reached the analysis can be printed, with appropriate classification, or exported to a number of formats including XML (Extensible Markup Language), Vector Graphics metafile or Microsoft Excel.

> *A good planner should develop plans that provide an efficient allocation of resources and take advantage of the system's true potential while still providing ample "robustness." If plans are robust, they are more likely to be executable and for a longer period of time.*
> Sakamoto, 2006

It is argued that all of the above features of the tool unite to create a package which would enhance the planner's potential for creating, analysing, maintaining and re-using plans which are as robust as possible. In addition, THE HTA TOOL is freely available to all MoD organisations, and is biased towards usage by the Armed Forces (e.g. DIF analysis template, classifications included on print-outs).

**Proof of Concept**

Figure 4 shows a screenshot of THE HTA TOOL in use as a mission planner for an Armoured Battlegroup executing a Quick Attack. This example shows the differing degrees of complexity of plan and at different levels of the decomposition. It also highlights the fact that some parts of an analysis are potentially re-usable and, using the tool, can be integrated directly into another analysis or mission plan.

The tool enables on-the-fly changes to the analysis including task ordering and plans. For example, it has been agreed to feint an attack on an enemy, if that feint then turns into a breakthrough then hasty re-planning is required. The components and resources involved in the operation may not change, but the order, and in particular timing, will. It will be necessary to move support troops, re-orient guns on new targets etc. Similarly, one could have the situation shown in Figure 5. Two infantry companies, A and B, are in contact with the enemy, who has been expected to weaken at the point attacked by company B. A third company, C, is in reserve and is planned to support B in order to defend the new position once taken. However, should company A make the breakthrough, a fast re-plan would be necessary to re-direct company C to the alternative position. This change in the course of action also has a knock-on effect on logistics, such as the re-location of ammunitions, and new plans would include this as a step (as well as notifying logistics support that this is required).

It may be argued that the original mission plans should include contingencies to deal with each of the potential situations (i.e. if A make the breakthrough, or B, or both concurrently, or neither). But, as argued by Gilmour et al, it would be virtually impossible to account for all possibilities and equally you would end up with too much detail, and commanders do not want to have to factor in all possible actions themselves (Gilmour et al 2006). A better solution is to be agile when re-planning should the tactical situation change unexpectedly.

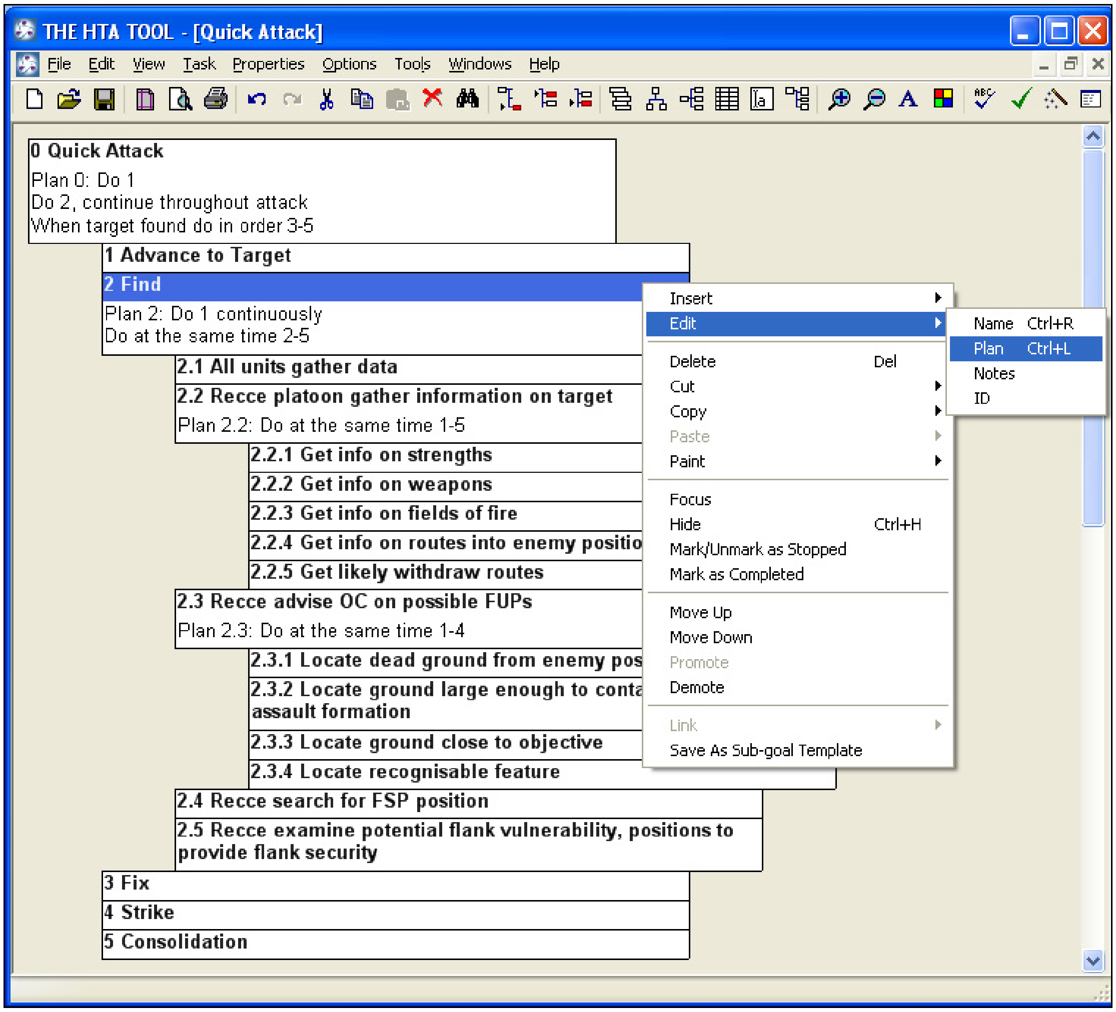


**Figure 4 – Screenshot of Quick Attack analysis [BDFL]**

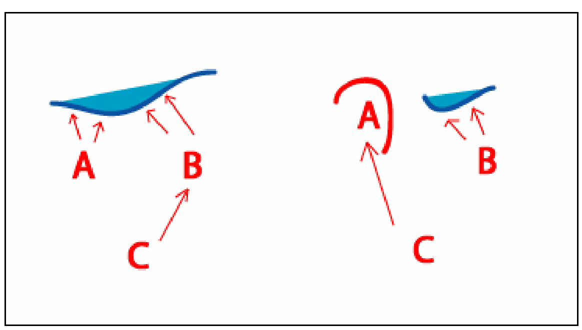


**Figure 5 – Demonstration of change to company C position if company A gains position before B**

Another example application of the tool is in the co-ordination of air, sea and ground units in an attack and reducing the possibility of deconfliction. As highlighted by Aitken et al the increase of weapon ranges and joint use of a variety of weapon systems within the battlespace has led to issues of co-ordination which must be avoided with a faster planning mechanism, probably using IT solutions (Aitken et al 2001). In a literal operation a ground assault may move swiftly. If they gain position faster than anticipated in the original plans then these must be altered to prevent artillery from firing on them (or other support units such as helicopters) and to change the position of logistics support. Using HTA one part of the mission can be re-planned, without the need to go into detail or revise the entire plan. Using THE HTA TOOL, this can be achieved in real-time, during an operation, and the result disseminated to commanders in seconds. Timings could also be encorporated into the plan, particularly with the suggestions in the next section.

The above are examples to illustrate how THE HTA TOOL could be used as an agile mission planning tool. The next step is to put the theory to the test in a real (or at least simulated) mission environment. Successful trials would enable any specific formatting or other requirements to be discovered and a mission plan template to be developed for exercise training.

## Further Development Routes

There are a number of ways in which THE HTA TOOL's support of mission planning could be improved or extended. As suggested above, there is the potential for creating a unique template specifically for the process or, if necessary, creating a customised version of the tool. Furthermore, there may be advantages in developing a version of the software for hand-held computers such as PDAs, to provide changing, real-time mission plans to commanders in the battlefield.

The current version facilitates the allocation of timings to each task, and these can utilise the allocated plans to calculate an overall expected time to complete. Figure 5 provides an example of this technique. Here, tasks A, B and C are carried out in parallel (see the plan for task 1), so the time required for task 1 is the largest of its sub-tasks, which is 6 hours. Whereas, tasks D, E and F are to be sequential so to find the total time required for task 2 you must sum the times for all its sub-tasks, which is 12 hours. As tasks 1 and 2 are also due to occur in sequence the total time required for the Overall Activity is 6 + 12 = 18 hours.

| Super-ordinate | Task | Time to Complete (hrs) | Total Time Required (hrs) |
|---|---|---|---|
| 0 | **Overall Activity**<br>Plan 0: Do in order 1-2 | | 18 |
| 1 | **Tasks done in parallel**<br>Plan 1: Do at the same time 1-3 | | 6 |
| 1.1 | **Task A** | 5 | 5 |
| 1.2 | **Task B** | 6 | 6 |
| 1.3 | **Task C** | 3 | 3 |

| | | | |
|---|---|---|---|
| 2 | **Tasks done in sequence**<br>Plan 2: Do in order 1-3 | | 12 |
| 2.1 | **Task D** | 4 | 4 |
| 2.2 | **Task E** | 1 | 1 |
| 2.3 | **Task F** | 7 | 7 |

**Figure 5 – Example of Timings**

This method can provide a quick way of estimating how long it will take to complete a military operation, for example. But it is not easy to see where the timings have originated, or visualise how the operation is organised.

One of the alternative diagrammatic views in THE HTA TOOL would help with the latter. But from our extensive collection of feedback a common suggestion for improvement to the tool has been to develop a flow charting view, which utilises the plans system to display tasks as they would occur in chronological order. Examples of this concept are shown in Figures 6 and 7.

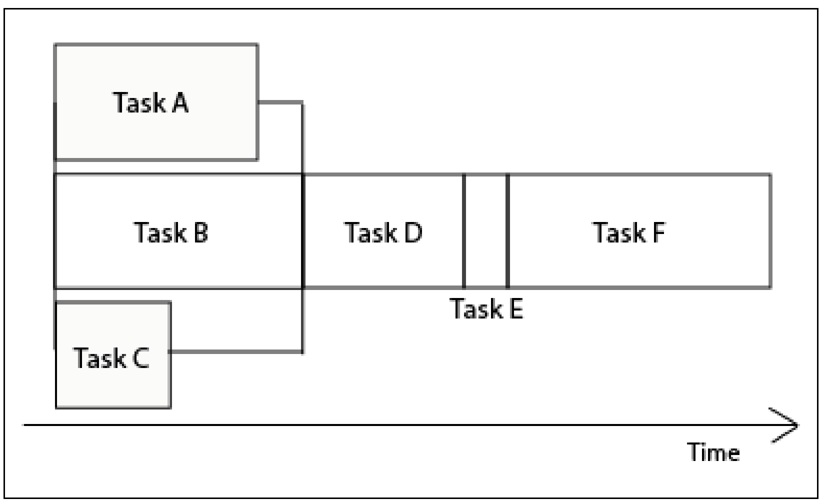


**Figure 6 – Example Timeline-based Flow Chart**

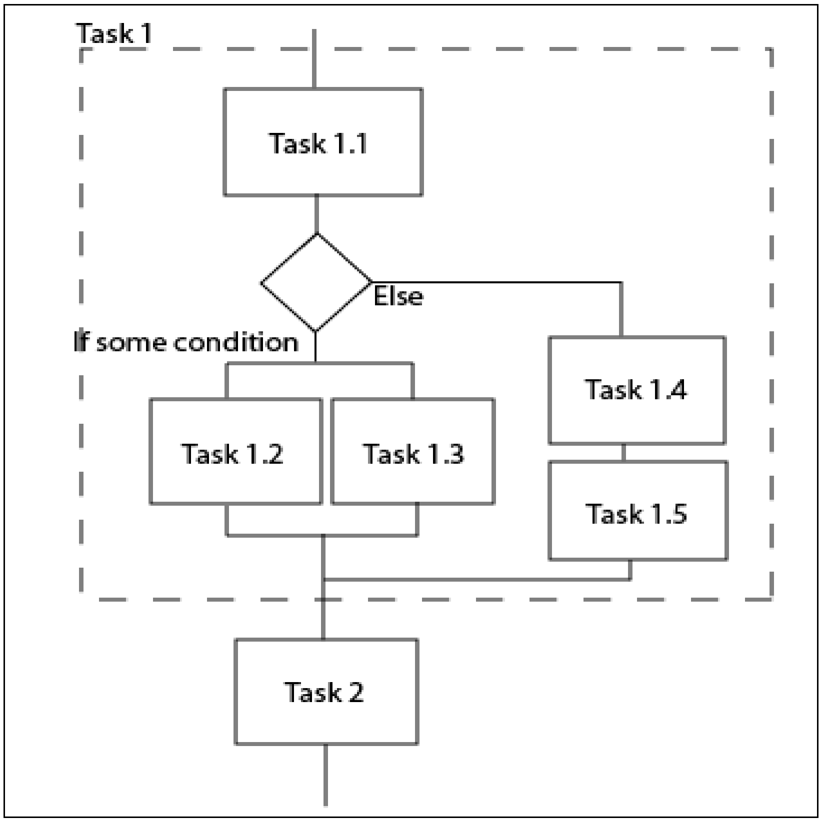


**Figure 7 – Traditional Flow Chart style with Hierarchy**

A further development for the mission planning domain would be the ability to assess COAs (Courses Of Action) programmatically before taking the decision on how to update the plan. In order to maintain agility this would also need to be usable in real-time during a conflict situation. Such a system has been proposed by Gilmour et al who have been developing a Scenario Generation tool (SGen) and results have so far been positive (Gilmour et al 2006). It is believed that such a tool could be an ideal support to THE HTA TOOL for agile mission planning.

Similarly, if plans can be modified and disseminated in real-time then there becomes a need for human planning and decision-making to be completed in as timely manner as possible. In this case, traditional methods may slow the process sufficiently that the advantage of utilising a computerised tool is lost. It is therefore suggested for discussion that THE HTA TOOL could be used in conjunction with a planning model such as PUT (Planning Under Time-pressure) as advocated by Thunholm whereby decision-making has been shown to be significantly faster (Thunholm 2006).

## Conclusion

It has been shown that mission planning can be regarded as a process which is broken down hierarchically into subsequent sub-components and can therefore be modelled using HTA. From initial investigation, and responses from current users of THE HTA TOOL, it is also known that the software can be (has been) used for mission planning, particularly for input and display. But it also has the advantages of being easy to maintain or modify an analysis with automatic updates including task plans. These are characteristics that could make it suitable for implementation in an agile, time-critical environment. However, it is noted that extensive trials need to be undertaken in real or simulated mission planning scenarios to assess how easy the tool is to use in such a situation. It would be very beneficial to find a military partner who can co-operate in the development and testing of the tool.

It is our belief that in order to support mission planning THE HTA TOOL may require development using a different approach. This would include developing purpose-specific extension templates or perhaps the evolution of an exclusive version of the tool. Other modifications which would be beneficial include either a flow chart or time-line based view of an analysis, and a closer integration between tasks and plans. There may also be potential for collaboration with other planning tools and methods.

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