DEFENCE CAPABILITY MANAGEMENT: INTRODUCTION INTO SERVICE OF MULTI-ROLE HELICOPTERS

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ABSTRACT

Upgrading Defence capability involves much more than acquiring new hardware such as weapons or aircraft. This paper demonstrates how system dynamics modelling was used to assist in planning and management of the introduction into service of a new generation multi-role helicopter type. It describes the challenges of managing resources; and the complex interrelationships between tasks such as the training of pilots and aircrew, conducting maintenance on the aircraft and the achievement of defined levels of capability to conduct military operations. Whilst the modelling task focused initially on the management of human resources, it soon became obvious that complex dynamic problems are best addressed using a top-down approach, to achieve optimisation at the system level rather than attempting to optimise sub-systems. The modelling approach exploited trusted, functional modules of system dynamics structure rather than *ab initio* model construction. How this aided model construction and verification is described.

INTRODUCTION

Acquiring or updating military systems involves much more than buying the latest equipment or the most capable, that which is designed to the highest specification. In an ongoing series of capability acquisition projects, the Australian Department of Defence is upgrading its fleets of ageing aircraft. The particular case described here involves the upgrading to a new type of multi-role helicopter. Such upgrades create myriad consequences in terms of numbers of personnel needed when and with which specific skill-sets, individual and collective training, provision of facilities, logistics management, and ultimately level of effectiveness achieved in the conduct of operations.

The Australian Department of Defence is committed to acquiring Eurocopter NH 90 helicopters. In Australia these helicopters will be known by the designation Multi-Role Helicopter 90 (or MRH 90). They are being acquired through Phase 2 of the AIR9000 project. The MRH 90is a sophisticated multi-role helicopter capable of operating in amphibious environments, by day and night in most weather conditions. These helicopters will replace the ageing Bell Iroquois fleet, acquired during the 1960s and 1970s. Though the Iroquois helicopter fleet has been upgraded it is nearing the end of its life-of-type. It is unsuited to many of the roles now required, such as operating in support of amphibious operations and carrying much heavier loads and larger numbers of troops, and landing at night in dust or smoke.

The introduction into service of the MRH 90 will demand that pilots, load masters, aircraft handlers and maintenance personnel who currently operate and maintain the Bell Iroquois aircraft be trained to operate the new MRH 90. New organisational structures are being created simultaneously with the transition to the new helicopter type.

There are a number of challenges in planning for, and managing, the successful introduction into service of the MRH 90:

- acquisition of new helicopters;
- training of flying instructors;
- training of pilots;
- training of aircrew, which includes loadmasters, aircraft handlers and weapons technicians;
- preparation for new operational flying roles, including both day and night, all-weather, amphibious and other specialist tasks;
- the need to conduct routine maintenance on the aircraft and do so efficiently;
- the transition to new organisational structures, consistent with the new roles; and
- the achievement of defined levels of operational capability.

This military acquisition and introduction into service project involves interrelated set of complex problems. Each of the sub-systems such as aircraft hardware acquisition, pilot training, loadmaster training, maintainer training and facilities upgrading and management, is complex. Sub-systems are related to each other in the context of both maintaining current capability whilst upgrading to higher levels of capability over a period of transition. For example, the schedule for delivery of operational aircraft drives the sequence and timing of delivery of courses to train pilots and qualified flying instructors, loadmasters and qualified loadmaster instructors. The new aircraft type operates with two pilots and two loadmasters, whereas the older type operates with two pilots and only one loadmaster. The MRH 90 is a sophisticated 'fly-by-wire' aircraft utilizing on-board computer control assistance for the pilots. By comparison the Iroquois is unsophisticated both in its mechanical design and flight controls: they are very different aircraft to fly and maintain.

To facilitate the training, which is delivered initially by the original equipment manufacturer (OEM) under contract, the project management team seeks to maximise the availability of aircraft. However, committing the aircraft to a demanding program of pilot training consumes available flying hours. In turn, this creates increased demands to service the aircraft. Each time an aircraft needs to be serviced it has to be taken off-line and is not available for pilot training. Further, there are two types of scheduled maintenance. Routine minor maintenance is relatively simple and occurs frequently. Deep level maintenance is much more extensive but is needed less frequently. Unscheduled maintenance activities, the need for which are created by accidental damage or unexpected failure also impact on the availability of aircraft. All maintenance activities serve to reduce aircraft availability.

Before the MRH 90 can be flown by the Australian Defence Force (ADF) it must achieve certification. Achievement of certification is critical to the whole project and will impact upon the earliest time that training can be conducted. Similarly, achievement by the OEM contractor of delivery dates for each aircraft will impact upon the timing of training courses.

It was obvious from the earliest stages of the modelling project that to manage conflicting goals, the acquisition project team needed to understand the complex linkages between sub-systems of the AIR9000 project. Once this understanding was developed, opportunities to re-schedule training activities and minimise the impact that maintenance activities might have on availability of the aircraft for training were revealed. The progressive creation of a series of system dynamics models which enabled the analysis of 'what if' scenarios provided these insights. Conventional project management techniques being used by the AIR9000 project team could not provide these insights.

PURPOSE

This paper describes a modelling task undertaken for the Defence Materiel Organisation to examine this set of interrelated problems, to reveal the nature of the complex interrelationships in the AIR9000 project. A set of system dynamics models were created, and sets of risk management strategies were recommended to enable planning and management for introduction into service of the MRH 90 to proceed efficiently. The scope of the task reported in this paper is limited to the first of a set of on-going tasks that of modelling the transition of Army aviation human resources with particular focus on pilot training.

MODELLING METHODOLOGY

The quantitative modelling methodology chosen for this task is the system dynamics modelling approach is based on that described by Sterman (2000: 86) with some modifications. The need to examine the scope of the problem, the stakeholders and their influences using soft systems methodologies and qualitative system dynamics modelling was greatly reduced by preliminary analysis conducted by the project team and much earlier analysis by Defence Capability staff using techniques prescribed by the Defence Architecture Framework (DAF). The DAF is the enterprise architectural framework used by the Australian Department of Defence to define common, technical and systems views of capability systems. The AIR9000 project team had already created a comprehensive set of system and sub-systems views along DAF lines. The context, problem boundaries and cause-and-effect relationships were largely defined before the modelling task commenced. This simplified the task of identifying the requirements for the system dynamics modelling task.

As a consequence it was possible to engage almost directly in developing quantitative system dynamics models, though there was a need to repeatedly refine the dynamic hypotheses upon which the models were to be constructed, and which the models would ultimately be required to test. In particular, the relationship between the existing human resources environment, the desired human resources environment, and AIR9000 Phase 2 program requirements (completion of introduction into service, and entry into the operational sustainment phase) had to be made explicit through critical examination of dynamic hypotheses in consultation with the AIR9000 Project team members. This was an on-going task, the effectiveness of which proved critical to successful delivery of the modelling task.

A particularly challenging task involved identifying those management levers which could be controlled by the AIR9000 team in their day-to-day management. Several management levers were unavailable to the team because of the way the contract for manufacture and delivery of the helicopters had been negotiated. The available (limited) set of management controls had to be identified and then built into the models to be developed. Had this system dynamics study commenced much earlier, during the formative stages of the AIR9000 project, greater flexibility in management of the project would have resulted. The complex interrelationships identified in early stages of the system dynamics study would have been known much earlier and could have been used during early strategy development and might have informed the choice of strategies for negotiating the contract with the aircraft supplier.

MODEL DEVELOPMENT

Problem Articulation

This modelling task set out to investigate the human resource implications of the transitioning into service of Army’s MRH 90, with most of these extant resources residing in the Iroquois helicopter squadrons. Throughout the transition stage, the capability afforded by the current aircraft and those squadrons which operate it could not be diminished. This was a critical requirement.

Training of personnel through the transition period, and aircraft availability had to be managed and coordinated such that this requirement was satisfied at all times. The project end state had to be achieved on time, some time near the end of 2011. In order to achieve successful introduction into service, the AIR9000 project team had defined a number of key sequential activities which basically follow the flow shown in Figure 1.

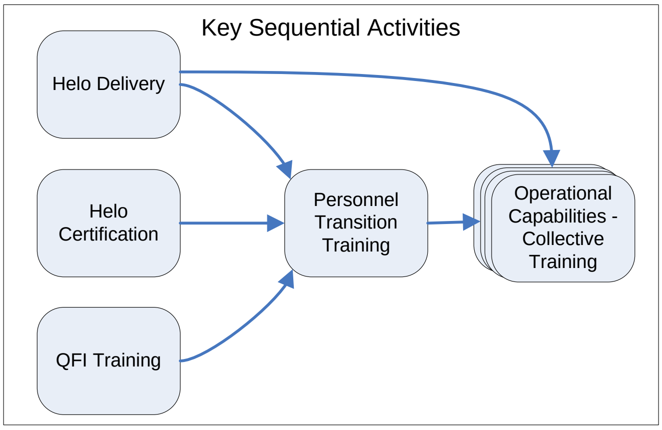

Figure 1. Key Sequence of Activities for Introduction Into Service of MH 90 Helicopters

A number of factors constrained the achievement of each of the activities in Figure 1. The most demanding of these constraints was that pilots, qualified flying instructors, loadmasters, loadmaster instructors were to be available for operational tasking as a first priority and their release for training had a lower priority. Whilst the AIR9000 project team had full support from the Defence executive staff to manage these conflicting priorities, this demanded continual and close liaison with operational units, operational headquarters, manpower managers in the Defence Headquarters and contractor who was responsible for delivering both aircraft and initial training courses. The contractual program proved to be far less flexible than operational constraints: operational alternatives could often be identified but almost no change to the contract schedule or sequence of events could be made without imposition of financial penalties.

Training is divided into preliminary and transition stage training. Preliminary training is to be delivered in Europe. Preliminary training produces MRH 90 qualified flight instructors (QFIs), who will then return to Australia to train the pool of line pilots during the transition training stage. A pre-requisite for this training is that these personnel must be Iroquois QFI. This then produces a management control lever for the AIR9000 project team, in terms of the number of QFIs trained. Availability of MRH 90 QFIs this will dictate the rate at which line pilots progress through the locally conducted pilot training course.

An important customer requirement for this modelling task was to determine how and when to conduct both preliminary and transition training so that the project end state could be achieved on schedule. The delivery dates of helicopters remain fixed throughout the model. Timing of availability of MRH 90 QFIs to conduct training and availability of aircraft need to be critically managed and carefully coordinated. It would not be efficient to train additional QFIs if sufficient helicopters were not available then for them to use to train pilots in the conversion from Iroquois to MRH 90. How this might be achieved could only be determined by simulating a variety of scenarios using the model developed during this study.

CUSTOMER ENGAGEMENT

The customer for this modelling task was the AIR9000 project team within the Defence Materiel Organisation. A number of meetings were held to confirm the structure and scope of the task. This was a necessary step as the model needed to be focused on issues most important to the customer, and over which the customer would have management control. Further this process defined the criteria against which the model would be validated.

Formulation of a Dynamic Hypothesis - Model Boundary Diagram

The sub-system diagram, Figure 2, shows the shows the main boundaries for the modelling activities.

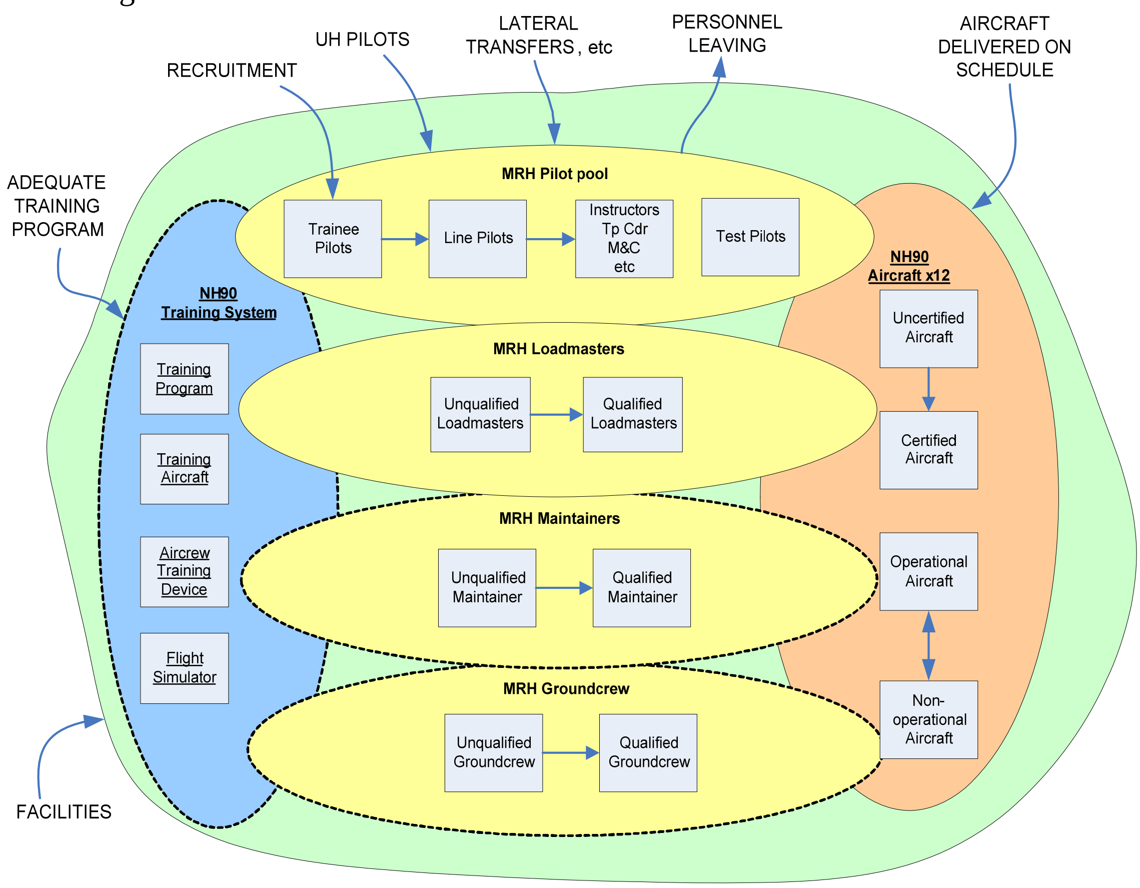

Figure 2. Sub-system Diagram Used to Define the Relationships Between Parts of the Problem to be Modelled

The sectors of the model, identified as being within the model boundary represent those aspects over which the AIR9000 Project team had a mandate to exert their influence.

A MODULAR APPROACH TO MODEL CONSTRUCTION

One of the challenges facing the modelling team was to adopt an approach that would facilitate the construction of the model by members of the team working in geographically separate cities, Canberra and Melbourne.

An approach was needed that allowed collaborative work to occur concurrently and at the same time independently of other work. It also needed to facilitate robust model construction. The modelling team adopted a modular approach to model construction that is advocated by McLucas (2005) and McLucas and Ryan (2005) who argue that system dynamics modellers could do well to learn from disciplines such as systems engineering and software development. Systems engineering techniques were used to define and decompose models down to sectors and components, with the smallest components being identified by McLucas (2005) to as modules. Generic module structure is shown at Figure 3. Each sector and module is defined within the context of the sub-system diagram described at Figure 2 and the systems engineering 'Vee' model described at Figure 4.

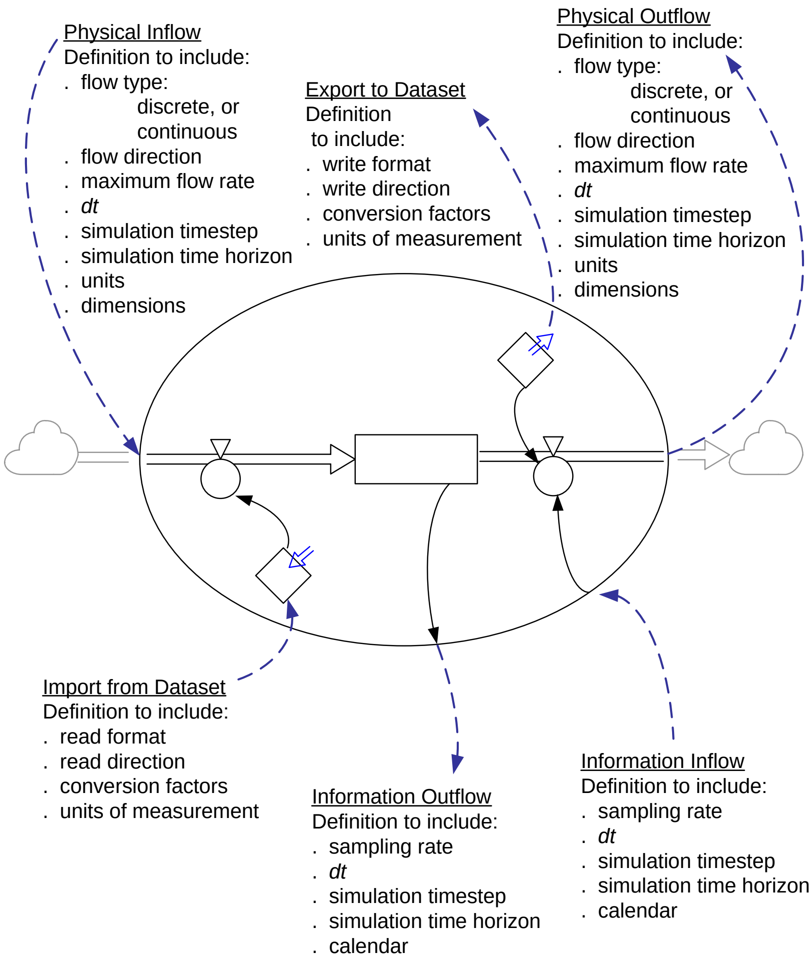

Figure 3. Generic Module Structure

The systems engineering approach, depicted diagrammatically in Figure 4 (Faulconbridge and Ryan, 2003, McLucas and Ryan, 2005) proved to have significant advantages for this modelling task. It allowed for clear decomposition and definition of the modelling products, the defining of functionality of each sector and module, integration of the modules, sectors and model, progressive verification and final validation.

Many of modules used in this modelling study can be reused (McLucas, 2005). An example is described in Appendix 1. In this modelling task the modular model development approach enabled the team to divide the modelling work into a number of clearly defined modules. These were constructed and independently verified before being integrated into sectors and the complete model.

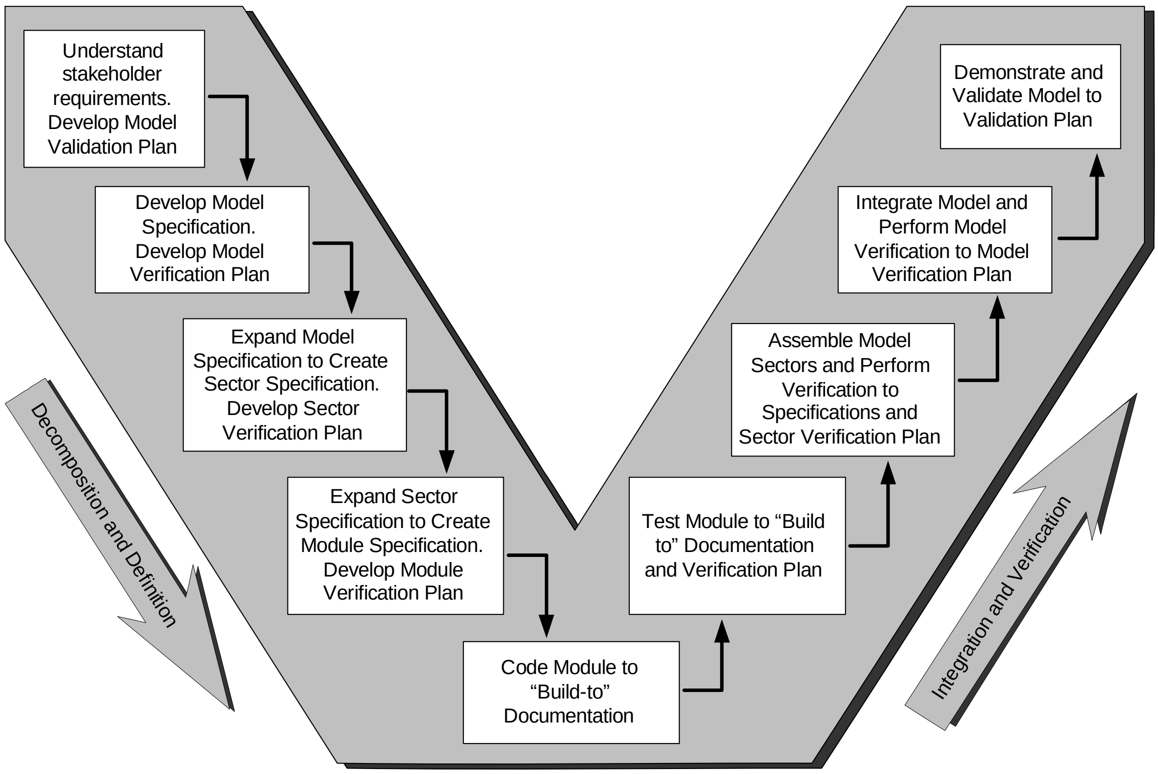

Figure 4. The Basic Systems Engineering 'Vee' Model Applied to System Dynamics Model Building.

Implementation Of A Modular Approach To Model Construction

Initial meetings of the modelling team focused on the division of the projects into two sectors within the main model, these being:

- Training of personnel (pilots, load masters, ground crew and tech crew) being transitioned from the Bell Iroquois to the MRH90 platform.
- The availability of helicopters for training, this being the major resource required for training and one which could have a significant impact on the rate of training.

Next, the team agreed on common units of measure, dimensions, measures of time and timesteps, and how each sector would interface with the other. From these discussions, a template was produced in Powersim Studio 2005 which was distributed to members of the modelling team. This became the template for producing modules.

The template ensured consistency of units, dimensions, timesteps and ensured maximum compatibility between the modules produced by different members of the modelling team. Figure 5 illustrates the modules created for this model and the linkages between the different modules.

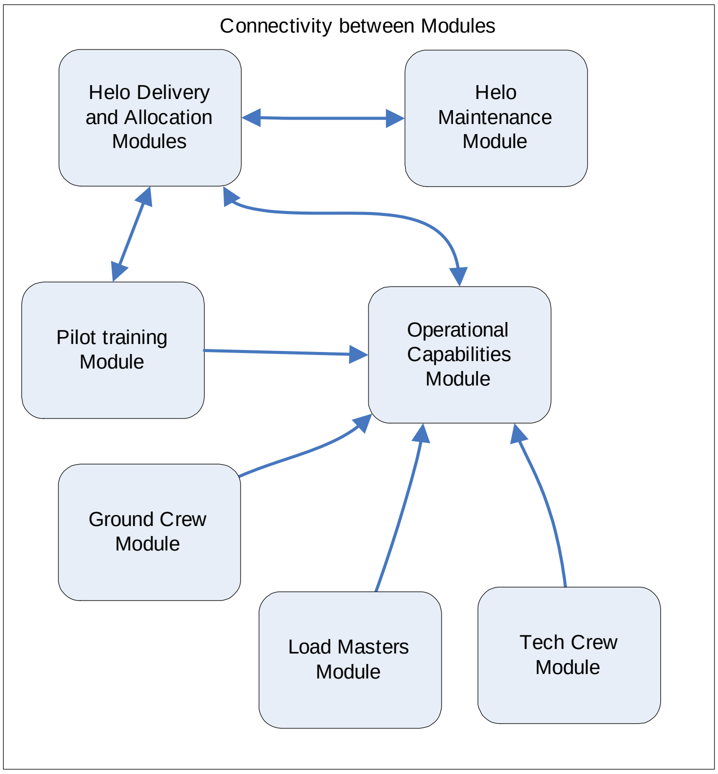

Figure 5. Connectivity Between Modules.

ANALYSIS

The ultimate goal of the AIR9000 project is to achieve the project end state at the scheduled time – which is sometime towards the middle of 2011. There are a number of sequential tasks which must be balanced in order to achieve this scheduled end state. One of the aims of this modelling task is to understand the best configuration of each task. The main task requiring configuration is the pilot transition, as this will ultimately effect the dates for achievement of the operational capabilities (OC), which in turn effects the date of the project end state.

In this model, the collective training requirements to achieve an operational capability are assumed fixed at six months for each of the operational capability levels 1 through 4 (OC1-4), with a defined number of flying hours represented as a Rate of Effort (ROE). For collective training towards an OC to begin, all the resources need to be in place.

Resources are helicopters and personnel. For OC1 and OC2, a Troop (3 helicopters) has to be operational. For OC3 and OC4, a squadron needs to be operational (9 helicopters). Therefore the sooner the resources are in place, the sooner an OC can be started and achieved. Part of this analysis will determine what the critical resources are, i.e. those which delay the commencement of an OC.

The key parameters for the throughput of line pilots on the pilot training course are the number of QFIs and training helicopters available. A number of simulations were run to analyse the AIR9000 problem situation. The model allows for many parameters to be adjusted, including the number of QFIs, the ratio of QFIs to trainee pilots, the required number of flying hours to complete training, the length of classroom training and the number of flying hours per helicopter per day. In consultation with the AIR9000 project team, the modelling team chose three scenarios to test and report upon. These were:

- Simulation one – two QFIs available
- Simulation two – three QFIs available
- Simulation three – two QFIs available and starting pilot training six months earlier.

For all simulations, helicopter delivery dates were fixed according to the latest project delivery schedule.

Simulation one – two QFIs available.

Figure 6 and 7 depict the transition of line pilots successfully completing the MRH 90 pilot training course. Note that the required pool of pilots does not complete training until the beginning of 2010.

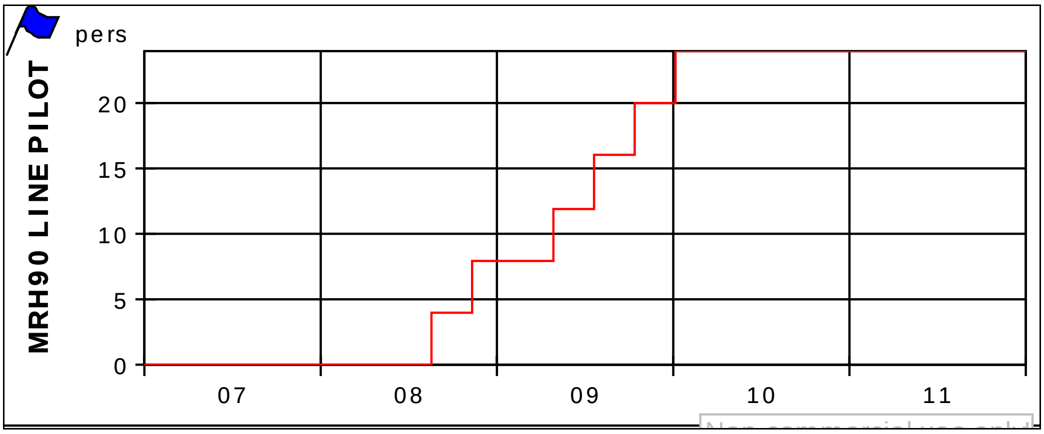

Figure 6. Simulation one - Trained MRH90 Line Pilots

This simulation revealed a number of interesting results. Note the length of time it takes to complete OC3 and OC4, shown in Figure 8, even though the length of collective training time is set at 6 months. This variation (7.7 and 8.9 months) is due to multiple times helicopters go into their deep level maintenance cycle simultaneously. This can be observed at Figure 7. where maximum availability does not continue to grow beyond the beginning of 2010, and there are numerous occasions where availability levels drop.

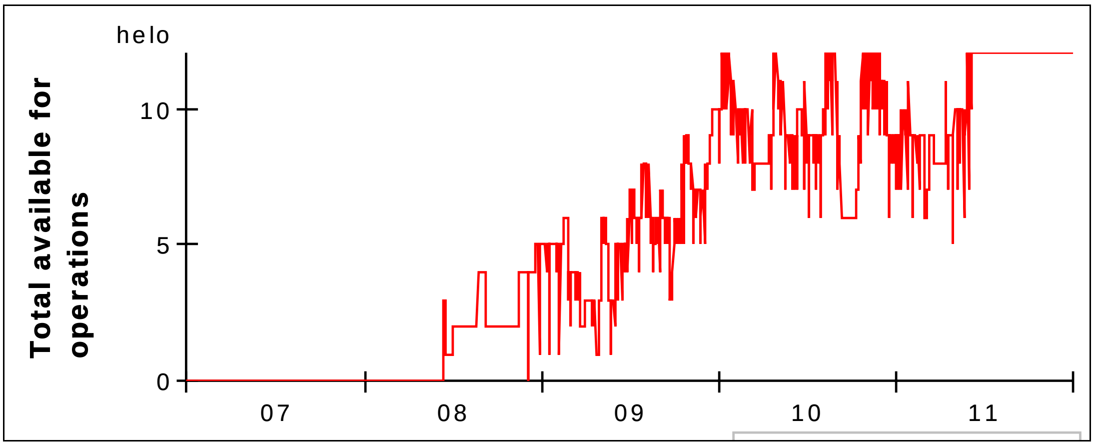

Figure 7. Simulation one - Helicopters available on Operations

OC Achieved Dates

OC1 start/finish	15/11/2008	11/06/2009	6.80 mo
OC2 start/finish	12/06/2009	11/12/2009	5.90 mo
OC3 start/finish	8/01/2010	3/09/2010	7.70 mo
OC4 start/finish	5/09/2010	5/06/2011	8.90 mo

Figure 8. Simulation one - OC1-OC4 Achieved Dates and Length of Time to Complete

There is a weakness in the model developed for this study as it does not have a mechanism for varying helicopter usage to stagger allocating of tasks to avoid simultaneous entry into the deep level maintenance cycle. A better (and more realistic) simulation would have been achieved had the maintenance of helicopters been switched off and a general assumption made on the number of available helicopters at any one time – unfortunately there was not enough time during the study to simulate this .

In this simulation, it appears the critical resource for the beginning of OC3 is available helicopters - OC3 requires a squadron of helicopters. As soon as the pilot training course is completed all helicopters are immediately allocated to the operational troops. Note the one month delay between the completion of OC2 and the beginning of OC3.

Simulation 2 – three QFIs available

This simulation, Figures 9 and 10, is identical to the previous one, except three QFIs have been made available to train the pool of Line Pilots requiring transition.

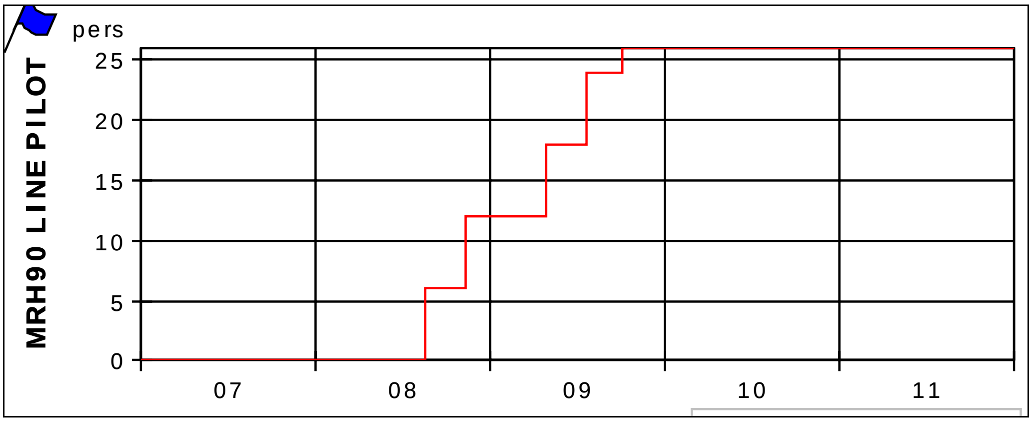

Figure 9. Simulation two - Trained MRH90 Line Pilots

Note that all pilots have undergone the pilot training course by September 2009, compared to end 2009 in simulation one. The aim of this analysis is to see how this will affect the OC achieved dates, which are shown below.

OC1 start/finish	15/11/2008	23/06/2009	7.20 mo
OC2 start/finish	24/06/2009	23/12/2009	5.90 mo
OC3 start/finish	24/12/2009	5/10/2010	9.20 mo
OC4 start/finish	6/10/2010	5/06/2011	7.90 mo

Figure 10. Simulation two - OC1-OC4 Achieved Dates and Length of Time to Complete

Note here that collective training for OC1 takes an extra two weeks – this is due to more of the initially limited helicopters being used for the pilot training course (three QFIs means that three helicopters are allocated).

In this simulation, the end date of OC4 is identical to that of simulation 1, which may indicate that available helicopters is the limiting factor to achieving OC1-OC4. More analysis is required to confirm this however, as the omission of the staggered deep level maintenance cycles may be the cause.

Simulation three – Two QFIs available, certification achieved early, pilot training course early.

With this simulation, all scheduled pilot training courses were run six months earlier to determine if expedited training would lead to achieving OC1-OC4 earlier. In order to enable the early pilot training course, certification was set as being achieved a year earlier. This was necessary as the model will not allow a pilot training course to undertake the flying component until certification is achieved. Setting certification back effectively simulates sending pilots to Europe for training prior to certification.

The helicopter delivery dates for this simulation are the same as for the other two simulations. See Figure 11.

Compared to Simulation one, Simulation three achieves all required pilot training courses six months earlier.

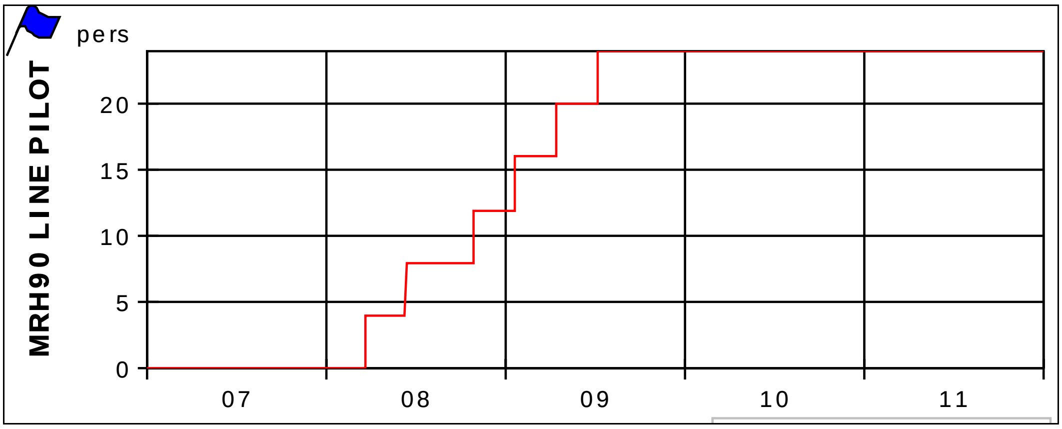

Figure 11. Simulation three - Trained MRH90 Line Pilots

Figures 12 shows helicopters allocated to operations (i.e. collective OC training). Note here that there is still an apparent problem with all helicopters going into deep level maintenance simultaneously during 2010 as shown in the figure below, Figure 12.

Helicopters in Deep Level Maintenance.

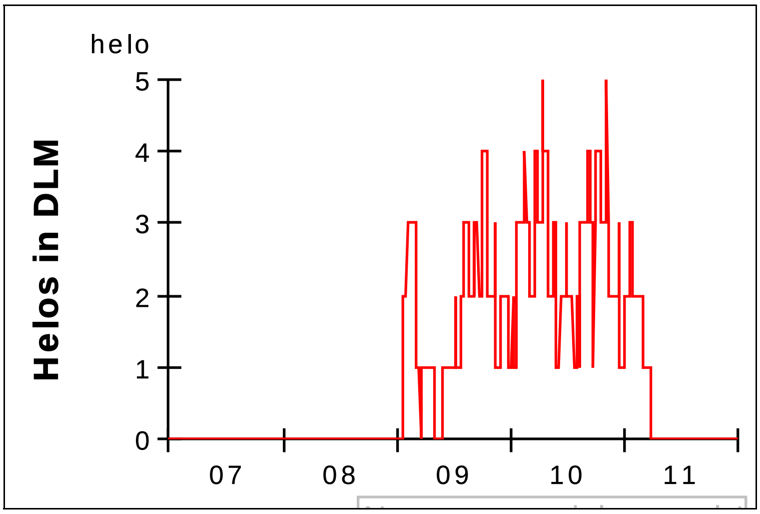

Figure 12. Helicopters in Deep Level Maintenance

OC1 start/finish	19/06/2008	3/05/2009	10.30 mo
OC2 start/finish	4/05/2009	3/11/2009	5.90 mo
OC3 start/finish	4/11/2009	2/07/2010	7.80 mo
OC4 start/finish	3/07/2010	26/02/2011	7.70 mo

Figure 13. Simulation three - OC1-OC4 Achieved Dates and Length of Time to Complete

Figure 13 shows the achieved OC dates. Note that the Operational Capabilities are achieved some five months earlier than the two prior simulations. OC1 takes a considerable length of time due to the limited number of available helicopters from mid 08 – start 09.

KEY FINDINGS

The main finding to arise from this model is that the availability of operational helicopters is critical to achieving successful introduction into service. Staggering the allocation of helicopters to flying tasks and thereby ensuring the deep level maintenance does not occur simultaneously for several aircraft is critical to scheduling of the introduction into service program.

CONCLUSION

The aim of this project was to create a systems dynamics model that could be used to assist in the planning, management and risk minimisation for the introduction into service of the Multi-Role Helicopter, by providing a management flight simulator that would allow the AIR9000 project team to experiment with the decision levers they have available to them and simulate the outcomes.

Planning and managing the introduction into service of new military hardware, such as the MRH90, requires careful management of a number of interrelated systems of resources. System dynamics proved to be the ideal tool for modelling this problem.

This project has completed a number of the preliminary steps towards this goal, with more work yet to be done.

This task has succeeded in the creation of a management flight simulator for the planning, management and risk minimisation of transitional stage training for pilots and crew transferring from the Bell Iroquois to the MRH90.

Testing and simulations of various scenarios run on the model have shown that helicopter availability has a significant impact on that rate at which pilots can be trained. This model allows the AIR9000 project team to assess this impact.

As a first iteration, this model creates a solid basis for further work and refinement. The model demonstrates how a system dynamics modelling approach can provide a valuable tool for managing and planning the transitional training for personnel required to operate and crew new military hardware.

Risk free experimentation permitted by the model enhances learning about the complex and dynamic relationships that exists between trainees, trainers, equipment maintenance and availability and the impact and influence they exert on each other.

This model also demonstrates how a model can be built using re-usable and expandable (multi-dimensional array) modules. These models are based around a particular function, such as the pilot training or aircraft maintenance, and as such can be easily adapted for other purposes. The MRH 90 helicopter modules could be easily adapted to become generic human resource management and maintenance modules for other acquisition projects such as those which will deliver some of the largest acquisitions in Australia's history, such as Air Warfare Destroyer and Joint Strike Fighter projects. Development of the modules is continuing.

Appendix:

1. Description of Sample Module – Multiple Channel Variable Length Waiting Lines - Array

References:

Faulconbridge, R., and Ryan, M., 2003, 'Managing Complex Technical Problems: A Systems Engineering Approach', Artech House, Boston, MA.

Sterman, J.D., 2000, Business Dynamics: Systems Thinking for a Complex World. Irwin/McGraw-Hill

McLucas, A.C., 2005, System dynamics applications: a modular approach to modelling complex world behaviour, Argos Press, Canberra.

McLucas, A.C. and Ryan, M.J., 2005, 'Combining Generic Structures and Systems Engineering to Manage Complexity in System Dynamics Modelling' in: Proceedings of International System Dynamics Conference, System Dynamics Society, Boston, MA.

DESCRIPTION OF SAMPLE MODULE – MULTIPLE CHANNEL VARIABLE LENGTH WAITING LINES – ARRAY

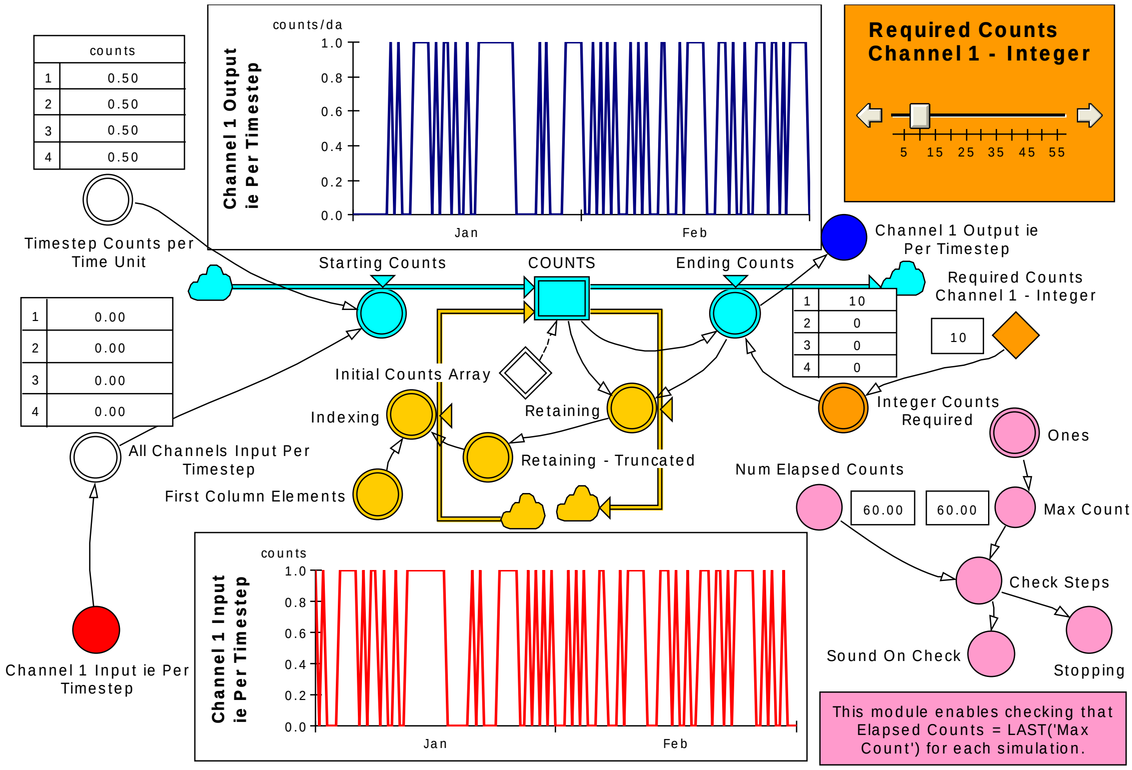

Figure A.1. Sample Module Description

This module uses an multi-dimensional array structure to control the progress of customers through a number of parallel waiting lines. The length of the waiting lines can be varied as required as can the number of waiting lines. The inputs and outputs for one selected waiting line (channel 1) for a selected number of counts is depicted in Figure A-1.

The number of parallel lines is defined by the array dimension 'ID No'. In effect, this is the number of rows in the array. The number of steps through which data is manipulated, with one step being taken per timestep, is defined by the array dimension 'Max Count'. This is the number of columns in the array.

In this example, the array dimension 'ID No' has been set to 1..4. The array has 4 rows. The 'Max Count' dimension is 1..60, that is it has 60 columns. In this example, this corresponds to 60 days of simulated time because the simulation timestep has been set to 1 day.

The array can be set to almost any size. The module will work equally well for an array of 3x5, 12x100, or 50x60. The number of 'columns' used in any given simulation can be adjusted at the beginning of a simulation without re-setting the Global Range. For example, we might wish to retain the number of parallel paths, that is retain 'ID No' as 12, but only use 50 columns of the available 100 in the array (effectively counting to 50 rather than 100). This is achieved by setting 'Integer Counts Required', with one value to be set for each of the array elements (corresponding to the length of delay in each of channel).

The module has been designed to demonstrate how an array structure can be used as the basis for building models for delivery of services in any parallel queue servicing situation, where the there is a need to count the time to complete service activities. In combination with versions of the same module a model could be constructed to investigate the utilization of service-delivery resources.

A complete listing of modules is at: http://www.systemdynamicsapplications.com/