OPTIMIZED AIRCRAFT FLEET MANAGEMENT USING APPLIED SYSTEMS THINKING

By

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Synopsis

1. The application of integrated logistics management for a weapon system within the Royal Australian Air Force (RAAF) has highlighted the need to develop decision support tools. Optimization of the management of the RAAF's F-111 aircraft fleet requires understanding of the dynamics of a multivariable system. This fleet system is also constrained by finite economic resources which must also be optimized. To achieve this optimized solution many heuristic business rules must be included in the enterprize model to ensure that output trend data is truely representative of the F-111 fleet system dynamics. Given this cadre of complex rules, relationships, and interactions the application of systems thinking (1) to the F-111 fleet problem was considered appropriate. This paper outlines the application of systems thinking to optimization of F-111 aircraft fleet system.

Background

2. The Vietnam war, 1962 to 1975, saw the involvement of the RAAFs Canberra bomber in executing strategic bombing tasks. By 1968 the RAAF started preparing for the introduction of the F-111 bomber aircraft, as a replacement for the Canberra and to primarily address the needs of No 1 SQN who were, at that stage, operating in Vietnam (2). The Australian Government signed a procurement contract for acquisition of F-111 aircraft on the 24 Oct 1963. The F-111 at that time was plagued with technical problems in the wing carry through box. The aircraft did not enter RAAF service until early 1973. The initial F-111 fleet consisted of twenty four F-111C Strike aircraft. In 1978 through to 1982 a modification program converted four F-111C aircraft to reconnaissance RF-111C aircraft. As an offset to aircraft loss an additional four F-111As were procured in 1982 and converted to F-111Cs in the period 1986 to 1990. Since initial acquisition a total of seven F-111 aircraft have been lost through accidents leaving the F/RF-111C fleet size now at twenty one aircraft.

3. In 1993, as a result of a diminishing cold war threat, adjustment was made to the size of the USAF strategic and tactical strike force resulting in surplus F-111G

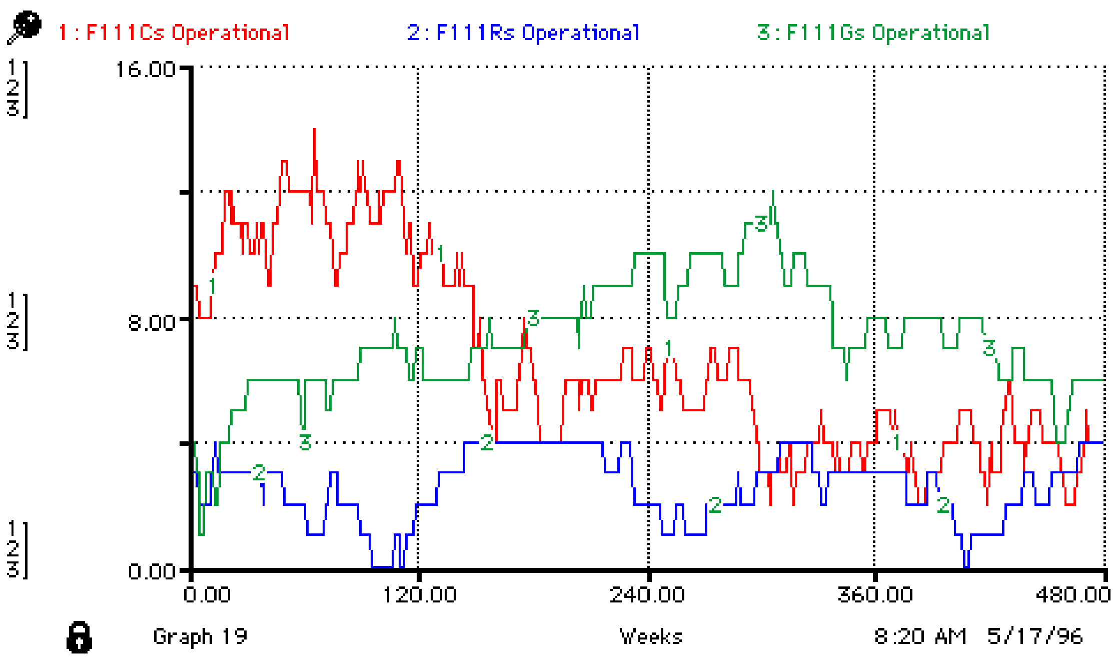
aircraft being offered to the Australian Government. A rapid capital acquisition program was initiated in early 1994 to procure fifteen F-111G aircraft. The selected F-111G aircraft were ferried to RAAF Base Amberley in Queensland by mid 1995. After an induction maintenance program some of the F-111G aircraft were operated by the RAAF under the existing USAF maintenance policy and some were operated under a RAAF maintenance policy. The majority of F-111G aircraft remained in inviolate storage pending induction and maintenance.

4. Overlayed on this complex fleet mix was a capital acquisition mid life upgrade to the F-111C and RF-111C aircraft entitled the Avionics Upgrade Program. This program involved the major modification of twenty one F/RF-111C aircraft using a three bay production line established at RAAF Base Amberley in Queensland. It can be seen that the F-111 fleet system is complex, dynamic and represents a system requiring careful regulation (see Table 1).

F-111C Pre AUP	RF-111C Pre AUP	F-111C Post AUP	RF-111C Post AUP	F-111G RAAF Policy	F-111G USAF Policy	F-111G Storage
15	4	2	0	2	4	9

Table 1. Current F-111 Fleet Architecture

5. The F-111 fleet was a slowly changing system with reducing level of aircraft availability. Initial simulations, as shown at Graph 1, confirmed this behaviour.



Graph 1. Simulation of F-111 Fleet System - Status Quo

Objectives

6. The integrated logistics management goal is to maximize aircraft availability for a given aircraft fleet mix whilst ensuring that the fundermental F-111 strike capability is always present. This activity can be synthesised into a number of processes as follows:

a. Aircraft Availability Planning. Generate sufficient aircraft on line to meet the requirements set by Chief of Air Staff (CAS) in the Capability Preparedness Directive (CPD). This incorporates the generation of the prescribed Rate of Effort (ROE) needed to execute the training and strike exercise program in order to sustain the CPD capability;

b. Maintenance Planning. Project a schedule for deeper maintenance (DM) within the constraints of available facilities, human resources and maintenance policy;

c. Enhancememt Planning. Schedule major and minor modification programs to accomodate acquisition schedule and meet in service target dates;

d. Repairable Item Planning. Estimate demand plan for critical repairable items; and

e. Contingency Planning. Evaluate fleet capacity for short duration contingency operations.

7. The F-111 fleet consists of subfleets, each contributing to the outcome of aircraft on line and aircraft hours available for expenditure. The operational managers of the F-111 fleet must progressively adjust fleet mix namely F-111C, RF-111C and F-111G vis a vis ROE whilst ensuring they do not exceed the prescribed Life Of Type (LOT) for the F-111 fleet currently projected to be the year 2020.

Optimization

8. Optimization of the F-111 fleet, cognizant of the need for a sustainable logistics support solution, is therefore recognized as the primary goal. The model should extract, quantify, implement and evaluate many ‘rules of thumb’ that are dispersed through the staff currently performing fleet management. If this was achieved effectively then the impact of military staff rotation on the overall strategic fleet management process could be reduced. Significant cost benefits should be realized through optimization given that logistics support for the fleet involves a maintenance staff of 1200 people and a logistics budget of over $33m per annum. It was with this potential

benefit in mind that we launched into the development of the model for the F-111 fleet system.

Methodology

9. The existing F-111 fleet system was analysed using classical systems analysis techniques (3). This resulted in a set of upper level data flow diagrams and a data dictionary. Next process re-engineering techniques were applied to refine the context, process and dataflow to develop a framework for a new fleet management function. Using this top level blueprint of the desired outcome an industry search of fleet planning best practise was executed. This yielded little inspiration as most large commercial aircraft fleet operators did not experience the level of fleet complexity contained in the RAAF F-111 fleet system nor did they retain their fleet over long periods of time (1973 to a projected 2020).

10. <u>Simulation.</u> The motivation to generate a simulation of the fleet was triggered on the realization that the F-111 fleet system was characterized as:

a. a multivariable system;

b. highly coupled;

c. ill conditioned; and

c. controllable only over long timeframes.

11. Simulation was well engrained in the RAAF as an engineering and operational training technique. From an engineering standpoint simulation provided insight into controllability of systems at their limiting conditions. As a training tool, simulators were provided so that pilots and navigators could practice control of aircraft and aircraft systems in order to achieve mission experience. Both these applications of simulation assumed that full system characterization was performed in order to faithfully replicate the transfer function of the system. The critical parameters in each simulation case are the closed loop characteristic equation or eigen vectors which mathematically illustrate the embedded dynamics of the system. Once these parameters are established the control of such systems can be implemented. It was recognized that this methodology could be applied to the F-111 fleet system provided we could understand the basic underlying dynamics of the system. By applying a simulation language like ithink™ and

modelling the structure of the F-111 fleet system a more optimized set of closed loop business rules could be derived.

System Dynamics

12. The application of system dynamics thinking and in particular the ithink™ simulation environment was a natural extension to the philosphy used to understand and control complex systems in the RAAF. The need to apply control to the fleet system from a logistics standpoint required a better understanding of the fleet system dynamics. This concept of industrial systems having system dynamics was first developed by Jay Forrester (4) in 1950 to 1960. This was popularized by articles on Industrial Dynamics and a flurry of books published in the early 1960's. The computer models developed, such as Dynamo, were not very flexible, lacked user friendly operation and were run on main frame computers. The concept of systems thinking was revitalized by Peter Senge (1) in the book 'The Fifth Disciple' . The philosphy projected throughout the book is that only organizations that continue to learn will survive. A key part of that learning process is to understand the dynamics of the systems that are fundermental to your business. The ability to generate, exercise and verify a simulation of the F-111 fleet system on a personal computer presented an opportunity for the RAAF to become a learning organization in its approach to management of the F-111 fleet system.

Development Philosphy

13. Consultant Developers. The review of best practice analysis performed in the earlier phases of the project indicated that most major operators performed fleet management manually or with large, purpose built software systems. It was evident that the RAAF F-111 Fleet System was unique and the business rules were not well understood by any one individual. It was therefore appropriate that the RAAF staff focus on the architecture of the modelling task and leave the model code development to experienced modellers. A program of rapid prototyping was established using a combined team of RAAF domain experts and simulation developers utilizing the ithink™ simulation language environment. This method of development ensured that the model would be frequently validated against known data in order to validate the model parametrics. The incremental development process ensured that the development was in quantifiable steps and within budget constraints. Accordingly the rapid prototyping technique allowed a concept demonstration phase to be completed thus increasing management confidence and early identification of key dynamic parameters.

Model Development - Step by Step

14. Stage 1 - A Strategic Model. A broad requirement specification was developed from the systems analysis performed on the fleet system. The specification did not detail how to solve the problem but rather to specify the outcomes sought. The first stage of development was to generate a strategic model of the F-111 fleet with coarse generalizations and / or assumptions in order to simplify the problem. This model looked at balancing requirements such as:

a. number of aircraft available to contribute to meeting the CPD;

b. number of hours to be flown each year, in essence, Rate of Effort (ROE);

c. total maintenance capacity; and

d. major modification program schedule.

15. The outcome sought from this strategic model was to identify coarse trends such as:

a. aircraft availability versus time;

b. maintenance decomposition;

c. delays within the fleet system; and

d. fleet utilization trends.

16. Stage 1 - Strategic Model. A three day workshop was held (13-15 DEC 94) with the RAAF staff as domain experts to bound the extent of the problem. The prime purpose of the workshop was to expose future development direction for the simulation. The strategic model entitled *Fleetstrat 2020* was developed and assumed a homogenous fleet structure. This tool was targeted for either Microsoft Windows™ or Mac System 7™ PC platforms. A run time only version was generated suitable for distribution to a wider group of RAAF organizations at low cost. This model successfully generated project interest, confidence and support for the approach. The *Fleetstrat 2020* produced results that were coarse but sufficient to rapidly develop a strategic recovery plan for the F-111 fleet. The model, being simplistic, was easily accepted by the RAAF logistics organization and required very little training overhead in order to achieve

positive results. All assumptions were explicitly stated and therefore open to public scrutiny as well as validation. Marketing the product at this stage resulted in full management support for further capital investment in order to refine the model design.

17. Stage 2 - A Micro Model. The next workshop (31 JAN to 2 FEB 95) concentrated on generating a prototype logic model (micro model) for just one F-111 aircraft moving through the various fleet processes. This was a significant improvement to model resolution compared with the simple homogeneous model. The single aircraft had all the required attributes such that the model process logic could steer its passage through the various states of the fleet system. This workshop explored the data input and output requirements needed to initialize such a model. Better definition of the architectural design of such a detailed aircraft specific model was realized. During the period of the workshop the logic for just one aircraft was expanded to support four individual RF-111C aircraft and a homogeneous fleet of F-111Cs and F-111Gs. The workshop concluded with a strategic development plan with realistic milestones for a full model utilizing individual aircraft elements. Following this workshop further development was performed by International System Dynamics (ISD), the model developers, in Sydney. This incorporated greater realism into the basic model including architectural features such as:

a. Storage process for excess aircraft;

b. Priority selection for maintenance servicing bays;

c. Scheduling for major modifications like Avionics Upgrade Program;

d. Model initialization from a database record;

e. Post simulation analysis;

f. Improved user interface;

g. Fleet flog rate output; and

h. Individual aircraft biasing for aircraft operations.

18. Stage 3 - Micro to Macro Model Expansion. The next workshop (28 MAR -30 MAR 95) reviewed the performance of the Micro Model against actual data sets. This assessment provided the validation and confidence that the final Macro Model would

reflect the true fleet dynamics. The next phase of development was to expand the simple four aircraft RF-111C model structure to cover the remaining F-111 aircraft types. The model run time was expanded to 480 weeks, representing a ten year model run at 48 weeks per year. Integration of the model code onto a new PowerMac 9500 platform was critical at this stage as the rate of development and model size was limited by the performance of the existing development platform. Coding of the model aircraft states, queue initialization, development of a target ROE profile were all addressed at this stage. A generic maintenance capability and aircraft type specific modification line were modelled in order to explore various management control options. The last phase of this workshop refined the specification for the final design of the macro model and established the test conditions that would be applied to perform verification. This was reviewed by ISD during 20 to 21 APR 95 allowing model development to continue without the domain expertise being present. Final model expansion took place in Sydney on 22 APR 95 and 19 MAY 95 resulting in a simulation of all 34 aircraft within the fleet system.

19. Stage 4 - Database Development. As an adjunct to the model development process a separate contract was established with Fallon Project Management for the development of Claris FilemakerPro™ databases to support initialization of the Macro Model and for storage / interrogation of model output data. The interface with the model was invoked via the Macintosh System 7™ publish and subscribe functionality. Initialization data capture was achieved using a number of pages within FilemakerPro™ with data manipulation in Microsoft Excel™. This post collection manipulation, using Excel™ macro's, was proven to lack sufficient robustness and eventually all data manipulation was assigned back to the Filemaker Pro™ application. This illustrated to the development group that it cannot be assumed that application software packages are stable on a Mac System 7™ environment when ported from a Microsoft Windows™ environment. This was the case for Microsoft Excel™ on a MAC System 7™ platform using publish and subscribe functionality.

20. Stage 5 - Integration alias *The Big Bang*. After considerable manipulation of the model by ISD the integration phase was attempted in a workshop at Amberley on 22 to 26 May 1995. The model had evolved enormously from *FleetStrat2020* and was working at the limits of the ithink™ simulation environment. Integration of the database, spreadsheet, model and analysis software required considerable ‘sticthing together’ before a truely integrated simulation tool existed. This phase of the project was underestimated, inspite of a generous allowance of time, primarily due to the complex interaction between each subsystem component. Progressive interface layer testing was performed to ensure each data exchange was valid. Augmentation of the F-

111G logic was performed and output graphical displays defined. The model size continued to grow larger until some undocumented hard limits were found in the ithink™ software. These were recorded and despatched for resolution to the parent company, High Performance Systems, in the USA. A new native language version of ithink™ was loaded in order to improve the operation of the Macro Model, which had now grown to be 5.6 Megabytes in size. Integration with the database application was established through publish and subscribe functionality. ISD then spent time improving the finess of the model before building the first protype version for delivery on 17 AUG 95.

21. Stage 6 - Verification and Validation. The RAAF staff at Amberley then tested the simulation system using actual historical fleet data. Test cases were not extreme but were focused on revealing any underlying errors in interpretation or functionality. All system trouble or change requests were logged in order to track and verify change processing. Reasonable confidence was established in the underlying model and a presentation on the simulation tool was made to senior RAAF management at Amberley on 17 August 1995. An ongoing endorsement was provided which lead to a workshop on 21 to 23 August 1995. This targeted resolution of residual errors and made essential changes to the model whilst also updating the database interface. Again the specification of the resulting system was reviewed and a future direction established. Since August 1995 smaller incremental changes have been made to the Simulation tool to remove bugs and incorporate esssential embellishments. The simultation product baseline was drawn in JAN 96 with the product being named *Fleet Doctor*.

***Fleet Doctor* - Overview**

22. The simulation system entitled *Fleet Doctor* utilized a number of commercial applications stitched together to provide the required functionality. The schematic at Figure 1 illustrates these inter-relationships.

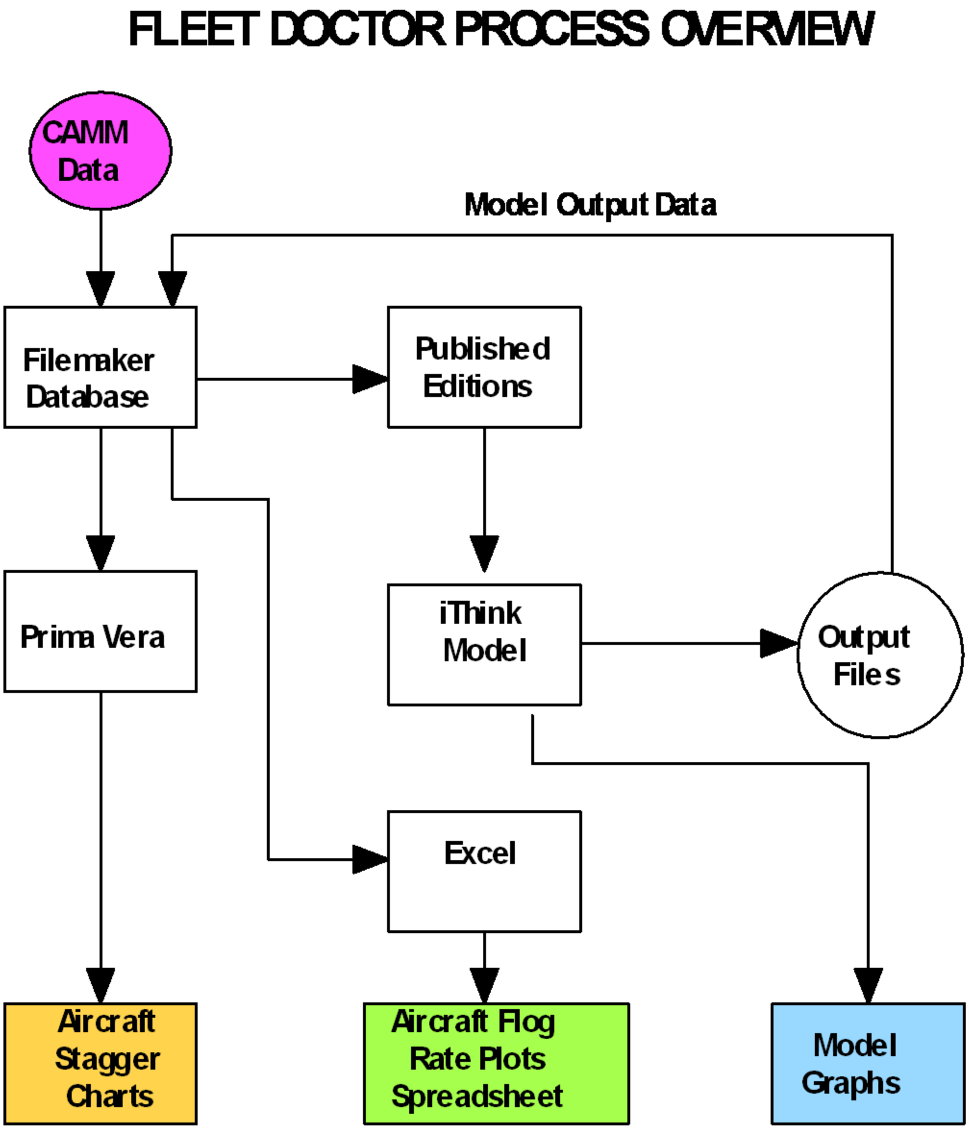


Figure 1. Schematic of Fleet Doctor Simulation

23. Model Parameters. Table 2 summarizes the model inputs and the model control variables within the ithink™ simulation. The usage of the simulation commences with the establishment of a data date which is used to extract fleet status primarily from the Computer Aided Maintenance Management (CAMM) system. This data, together with other environmental data, is uploaded and verified within the Filemaker Pro™ database.

Once established as a valid data set Filemaker Pro™ scripts manipulate the source data and publish initialization data for time step t=-1 (week -1). The model subscribes to the published data and when run is initiated, the data is uploaded at time step t=0 into the respective model elements setting the initial conditions. Prior to runtime the ithink™ model parameters are set as outlined in Table 2. The model then iterates with each time step representing 1 week of actual fleet operation time.

Model Inputs	**RunTime Inputs**	**Model Operations**	**Model Outputs**
Hrs to R3	ROE by subfleet	Set CPD & Flog Rt.	**Graphs**
Hrs to R4	CPD by fleet	Set Weightings	Aircraft on Line
Hrs to R5	A/C weightings	Set Max Hrs per A/C	A/C waiting maint.
Hrs to S33	Service Times TMS	Set Maint Capac.	A/C in maint.
Hrs since last R3/4	Service Bay Capac.	Set Service Times	Hrs Achieved
Weeks to S1	Mod Program Seq.	Set Future Mods	ROE miss margin
Weeks to S2	USAF Service	Run	Queues at bays
Total Airframe Hrs			Service by Type
USAF Stop Hrs			Total Hrs by Type
Flags -AUP Status			**Tables**
Init of Maint Bays			Hrs flown by A/C
Fleet Requirement			A/C TailNo in/out
Total on line Ramp			
Total on line USAF			
Total Ramp Maint			
Total Storage			
Total F-111G -Shed			

Table 2. Model Parameter List

24. <u>Model Operation.</u> The model simulates fleet activity within the business rules optimizing to achieve fleet flying hours in proportion to the target weighting. Airframe hours to next servicing are decremented according to aircraft operation mapped to usage profile. When a servicing is triggered by a zero hours clock the aircraft ceases to be in the pool of operational aircraft and is routed to a maintenance process queue. The airframe hours clocks and next service type are reset as each aircraft enters a specific maintenance process. Aircraft are queued by sub fleet type so that servicing priorities within a sub fleet type can be implemented. When a maintenance bay is next available the next aircraft in the queue is assigned into that maintenance bay and placed onto a

conveyor structure appropriately timed for service duration. When the service is completed the tail number is detected on exit from the conveyor logic block. The time based lifing events are zeroed at this point in order to avoid lost life in maintenance process. The aircraft is then returned into the operational pool of aircraft and again assigned slices of ROE based on usage profiles. Aircraft assigned for modification programs leave the operational pool and go to a modification area for the prescribed period of modification incorporation. While in modification calendar based lifing events continue to decrement. Statistics on each aircraft are aggregated to produce a fleet health summary.

Key Construction Methodology

25. The model developed for *Fleet Doctor* now has 20,000 elements in the model structure. This requires a high throughput capacity computer to effectively process 10 years of steps in a short actual time period. The MAC Power PC platform using ithink™ V3.0.6b++ is used for the *Fleet Doctor* model principally to capitalize on the publish and subscribe functionality not available on Microsoft Windows™ systems. Careful control over naming conventions was required in order to ensure that duplication did not occur when additional structure was added. One of the key concepts behind the development methodology was the adaptation of engineering simulation techniques to the F-111 fleet system. The key features were the development of an attribute tracking algorithm for tail numbers such that identity was not lost whilst on conveyors. Extensive application of *proof of concept* technicques were used in each stage of the development cycle. Concept demonstration and prototyping were primarily performed in the workshops with model builders and domain experts working together in an environment decoupled from regular business distractions. In order to avoid non productive rework on the model extensive debugging was performed on prototype structure before replication to support 34 aircraft.

26. Construction of each section of the model elicited more knowledge about the actual fleet system operation. Some sectors of the model such as the AUP modification and USAF maintenance lines did not have any defined maintenance policy so assumptions and rules were developed in sync with model development. Downloading of CAMM and other environmental data to a spreadsheet representation allowed easy recognition of inconsistencies within the initialization dataset.

27. The resulting model solution was developed in two discrete parts and spliced together with a 17hr cut and paste operation on a MAC Power PC 6100/66. This process highlighted the undocumented limitations within the ithink™ application which

were quickly resolved by a new release of the ithink™ application from the USA. Thus *Fleet Doctor* represents the biggest ithink™ model ever built. The model structure represents six A0 sheets at 40% reduction in order to fully document the product. It has approximately 450 publish and subscribes for data upload into the model. Initialization at t=-1 was mechanized to allow an initial phase at t=0 to set up the initial condition thus avoiding purturbations in results. Aircraft awaiting maintenance sit in their own sectors with clocks expired and join the queue in the time step t=-1 to t=0. This overcomes the problem of having to initialize a queue element with more than one aircraft.

28. The model is now resident on a MAC Power PC 9500/132/48/2Gbyte which is the newest MAC PPC in Australia. This gives a run time of 3 minutes for 10 years of fleet operation. Development of *Fleet Doctor* including the Strategic Model called *Strat2020* took 12 months. The model has been designed to offer extensibility within fleet processes with allowance for future unscheduled process events. Implicit in any fleet simulation like *Fleet Doctor* is the realization that the logistics support for the plan, namely repairable items (RIs) and breakdown spares, are key ingredients which were not modelled.

Fleet Doctor Application

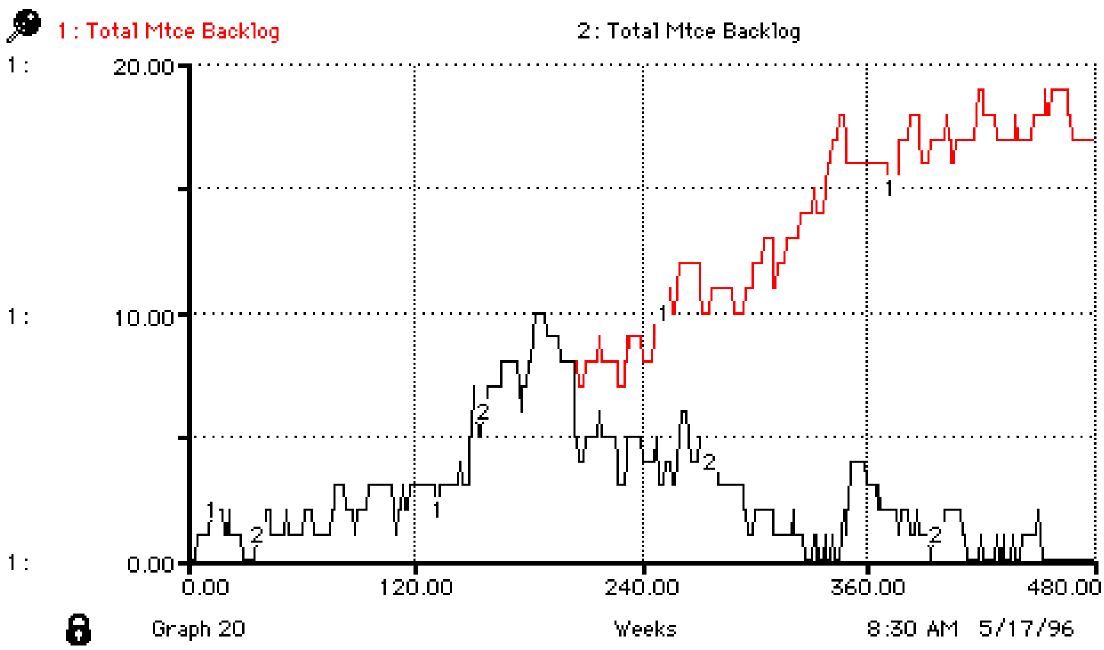
29. <u>Logistics Restructuring.</u> The decision by the US government to phase out the F-111 aircraft within the USAF has refocused attention on the F-111 weapon system in Australia. A project team was formed at Amberley to study the F-111 Life of Type (LOT) support arrangements cognizant of the phase out of US support for F-111 by 1998. Both the Strategic Model, *Strat2020* and the *Fleet Doctor* have been used to evaluate logistics support options by the F-111 Support Study Team.

30. <u>Fleet Planning.</u> A prime purpose of the *Fleet Doctor* system was to schedule the fleet maintenance activities into the future. The model is operated by a service / civilian group who are not computer experts. An extensive effort was put into generating a user friendly interface to minimize the level of in-service training required. A level of understanding of the system architecture was generated through involving this group in system testing and verification. The documentation of the system and the operational procedures were developed by this group ensuring that clear, simple procedural guidance was developed. Unfortunately little involvement from the operations staff of the F-111 aircraft at Amberley has meant that the developed model has had a predominate logistics focus.

31. <u>Future Usage of Model</u> The model supports contigency planning which is now being factored into future capability directives issued by the RAAF. The model is also

being used to quantify logistics costs. The model will provide an ability to better manage adjustments made to F-111 exercise schedules whilst maintaining training and standing capability requirements. A marketing plan has been developed to promote the techniques employed and capabilities offered by this style of technology. This paper is a component to that strategy ensuring wider dissemination of the concepts employed. More optimum management of RAAF material division modification programs for the F-111 should be achievable by utilizing the *what-if* functionality within the simulation. Development of operational roles and induction rates for F-111G aircraft should be able to be developed using this tool. Better business rules for the storage of aircraft can be established together with appropriate maintenance policy. Most importantly the mismatch between required ROE and maintenance capacity will be highlighted and resolved in order to avoid a sub optimal fleet mix situation developing.

32. Case Example - Fleet Recovery Plan Development. The *Fleet Doctor* has already been used to generate a strategic plan of fleet recovery. By performing forward estimates of maintenance requirements combined with the major modification programs a significant deficit of projected operational hours was identified vis a vis a growing maintenance backlog as seen in graph 2 curve 1. By adjustment of various parameters within the model as detailed overleaf both short term and long term solutions to the problem were developed in less than a month (refer Graph 2 curve 2 and Graph 3).



Graph 2. Projected Maintenance Backlog

Key Corrective Actions are:

a. Short Term. Provide extensions to servicing intervals for some specific aircraft in order to better condition the fleet maintenance aircraft stagger. Augment existing maintenance resources. Generate a contigency R3 maintenance process performed using operating level resources rather than Depot resources;

b. Long Term. Long term solutions are multi tiered and concurrent as follows:

(1) Accelerate G induction;

(i) Perform two deeper maintenance F-111G R5 maintenance at USAF facility; and

(ii) Induct two more F-111Gs to fly out USAF residual life.

(2) Introduce extra R5 capacity service bay for up to two years;

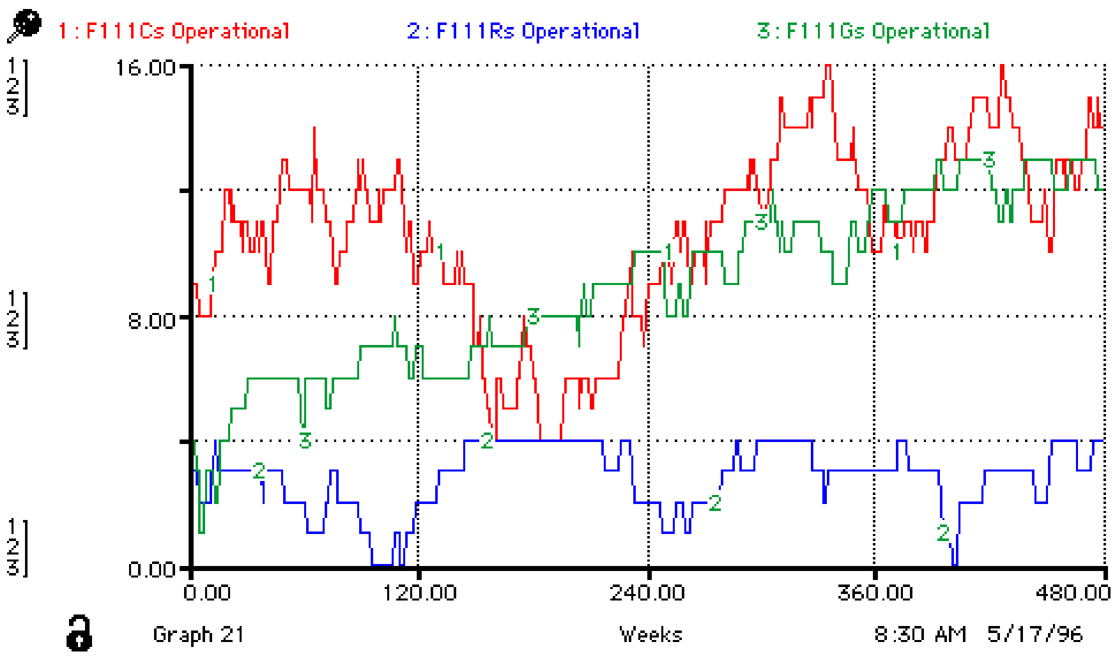
(i) Establish Two lines at one shift basis (one possibly commercial);

(ii) Perform better resource levelling; and

(iii) Instigate a culture of maintaining input / output dates.

(3) Reduce R3 duration time to 11 weeks; and

(4) Generate an engineering study aimed at extending S1 life (calendar based).



Graph 3. Projected fleet availability post recovery plan imlementation on Week 200.

Future Enhancements

33. The current baselined *Fleet Doctor* represents a product that is achieving the objectives of the RAAF fleet management staff at Amberley. Continuous product improvement is desireable to remove some of the rough edges generated through the process of rapid prototyping. These improvements include:

a. Automatic generation of a suite of bar charts from PrimaVera™;

b. Improved input of ROE profile, referred to as Flog Rates;

c. Automatic sequencing for modification programs;

d. Enhancements to enable future acquistion programmes to be merged with the existing fleet dynamics;

e. Inproved model navigation using hotspots rather than scroll bars (*ithink*™*Ver 4*);

f. Message log produced during the run to provide traceability of automated model decisions;

g. Simplification of model structure by using matrix representation (*ithink*™*Ver 4)*;

h. Improved performance in the post processing of model output data;

i. Linkage to aircraft subsystem (RI) models such as Engines, Pavetack and Wings; and

j. Adaption of simulation tool for use by aircrew to promote a joint shared fleet management culture.

Conclusion

34. The transformation of the F-111 fleet system into model representation has occurred over a twelve month period using an incremental development methodology. With domain experts and systems thinking philosophy it is possible to simulate, with adequate resolution, the operation of a complex dynamic system. The cross pollination of ideas from systems thinking and engineering simulation has developed a tool which will provide insight into the health of the F-111 aircraft fleet in Australia. This paper has described the application of systems thinking and in particular the product called ithink™. Both the thought process and the simulation product have been stretched to

new limits of performance. We hope that by reporting on this development similiar applications can be conceived and implemented by learning organizations.

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