# Extend Modelling Of Defence Pilot Training Projects For Boeing Services Australia

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**Abstract.** Since early 2007 the Boeing Australia Limited Systems Analysis Laboratory (SAL) has been engaged with Boeing Services Australia (BSA) to provide modelling and simulation assistance in support of stakeholder engagement for AIR5428 (ADF Pilot Training System) and AIR9000 Phase 7 (Helicopter Aircrew Training System). SAL support has included building models in a discrete event modelling tool called ExtendSim[1] in order to better understand the current pilot training system.

Database-driven models may be readily and rapidly reconfigured to support training system understanding and development, with key metrics captured for later analysis. In addition, 'what if' sensitivity analysis can be conducted to determine time, cost or utilisation impacts of different curricula or resource levels within the system.

The paper will provide details of the ExtendSim modelling work and the support to BSA provided by the SAL.

## 1. INTRODUCTION

Boeing Services Australia (BSA) tasked the Boeing Australia Systems Analysis Laboratory (SAL) with developing an initial baseline model of the ADF Pilot Training System. This was driven by the requirement for Boeing Australia to engage with the Commonwealth in discussions on the strengths and weaknesses of the current system. This would provide a potential future body of work to allow the baseline model to be further developed for subsequent analytical phases where various curricula might be modelled, and required resources identified.

It was important to show where bottlenecks might exist as well as gain other insights from sensitivity analysis of resource levels. For example, the types of questions useful for the customer to have answered are:

- Where are the bottlenecks?
- If we change the resource or scheduling arrangements earlier in the model, what effect might these have on the bottleneck issues?
- What is the duration of flying training, end to end?
- If the instructor pool at the training unit changes, e.g. from (x) to (x+4), does this result in additional throughput? Do changes in instructor numbers (both increases and decreases) change throughput? To what extent? Do these changes raise other issues, such as utilisation levels that are too high or inefficiently low.
- If we change the current numbers of aircraft or students or instructors, what is the effect on graduation rates? e.g. If a training unit plans four annual courses of 30 students each, what effect on throughput might a change to eight courses of 15 students make?
- If throughput needs to be increased, how might this driver affect the earlier blocks of the training scheme, including initial recruiting targets?

This paper will describe the nature of the work undertaken, details of the models, challenges faced, features, limitations, the verification & validation process and sensitivity analysis conducted.

## 2. WORK & DELIVERABLES

There are many blocks of training in the current ADF Pilot Training System, each with its own curriculum, resource requirements and modelling challenges. Challenges will be covered in greater detail in a later section, but suffice to say here that the gaining of data, sufficient to model the system in a robust way, continues to be the greatest challenge. Data made available to industry has been invaluable for the modelling of certain segments of both fixed-wing and rotary-wing training.

Work continues on various blocks of training within the system, and where data remains unavailable, assumptions on course structure, resources and training event flows need to be made. As training blocks are

[1] ExtendSim and Extend are products of Imagine That Inc. Versions used by the author include Extend Version 6 in 2007 and ExtendSim 7 during 2008.

completed and verified, they will become part of the larger system model.

The modelling work detailed for this paper includes the RAAF/RAN Advanced Flying Training at No 2 Flying Training School (2FTS), RAAF Base Pearce WA, and the Army Rotary Wing (RW) Flying Training conducted at Oakey QLD. The Rotary Wing (RW) model will include Helicopter Conversion Course (HCC), Helicopter Tactics Course (HTC), Operational Type Transition (OTT) Course and Regimental Officers Basic Course (ROBC).

## 3. MODELS

Student trainees in both 2FTS and RW ExtendSim models are represented as 'items', while resources such as qualified flying instructors (QFIs), aircraft, certified testing officers (CTO), classrooms, part-task trainers (PTT), cockpit procedural trainers (CPT) etc are represented as variables that constrain the progress of the 'items'.

**Figure 1:** Excerpt of model 'canvas' in Extend

The two models will be described in greater detail using the following categories:

- Challenges
- Features, and
- Limitations

Later sections will cover:

- Verification & Validation, and
- Sensitivity Analysis

### 3.1 Challenges

The greatest challenge in relation to modelling training at 2FTS has been the paucity of data. Fortunately the author and other staff at Boeing Australia have first-hand experience of the system, allowing assumptions to be made with reasonable confidence. The types of data and documentation desirable for robust training system modelling include:

- Curriculum, including grouping / sub-grouping requirements, desired time to train, briefing, de-briefing and flight-time durations
- Event flow
- Resource allocation and work constraints (e.g. number of sorties per day, working hours)
- Course numbers and inter-arrival times
- Pass rates
- Testing requirements
- Remedial and retest process, and
- Training days available per year

### 3.2 Features

It was important to model the system with detail sufficient to allow the output and analysis of data to answer key customer questions.

#### 3.2.1 Database

A Boeing Industry database developed in the US as an Excel Add-In and shared with Boeing Australia allows the storage of and access to information such as curricula, event durations, pass rates and shifts. The mean pass rate percentages[2] for 2FTS for RAAF trainees were adjusted via spreadsheet to provide a pass/fail check at each of the seven flight-test events. Distributions for pass rates about the mean were estimated using triangular distributions[3] – however, alternative random distributions for pass rates, if found to be more robust, could be readily incorporated.

Data output to the database may also be exported to Excel for additional manipulation and/or graphical presentation.

Table(5721) : Routing RAAF

| | Step | Event | Event Descriptor (RAAF) | Duration | Walk + Flight Durn | Flight Times | Pass Rate |
|---|---|---|---|---|---|---|---|
| 58 | 58 | Tutorial | TUT5 (Basic IF) | 1.00 | 0.00 | 0.00 | 100.0% |
| 59 | 59 | Flight - Dual | IF14 | 3.15 | 1.90 | 1.40 | 100.0% |
| 60 | 60 | Flight - Test | IF15 (IRT) | 2.95 | 1.70 | 1.20 | [Triangular;0.885;0.985;0.935] |
| 61 | 61 | Mass Brief | MB15 (NF) | 1.00 | 0.00 | 0.00 | 100.0% |
| 62 | 62 | Flight - NF - D | NF1 | 2.75 | 1.50 | 1.00 | 100.0% |
| 63 | 63 | Mass Brief | MB14 (Low Fly) | 1.00 | 0.00 | 0.00 | 100.0% |
| 64 | 64 | Flight - Dual | GF13 | 2.95 | 1.70 | 1.20 | 100.0% |
| 65 | 65 | Flight - NF - D | NF2 | 2.75 | 1.50 | 1.00 | 100.0% |
| 66 | 66 | Flight - NF - S | NF3 | 2.25 | 1.50 | 1.00 | 100.0% |
| 67 | 67 | Flight - Dual | GF14 | 2.95 | 1.70 | 1.20 | 100.0% |
| 68 | 68 | Flight - Solo | GF15 | 2.45 | 1.70 | 1.20 | 100.0% |
| 69 | 69 | Flight - Dual | GF16 | 2.95 | 1.70 | 1.20 | 100.0% |
| 70 | 70 | Flight - Test | GF17 (BHT) | 2.95 | 1.70 | 1.20 | [Triangular;0.885;0.985;0.935] |
| 71 | 71 | Mass Brief | MB21 (Form - two / multi-ship) | 1.00 | 0.00 | 0.00 | 100.0% |
| 72 | 72 | Flight - Form - D | FORM1 | 2.95 | 1.70 | 1.20 | 100.0% |
| 73 | 73 | Flight - Form - D | FORM2 | 2.95 | 1.70 | 1.20 | 100.0% |
| 74 | 74 | Flight - Form - D | FORM3 | 2.95 | 1.70 | 1.20 | 100.0% |
| 75 | 75 | Flight - Form - D | FORM4 | 2.95 | 1.70 | 1.20 | 100.0% |
| 76 | 76 | Tutorial | TUT7 (Formation Solo) | 1.00 | 0.00 | 0.00 | 100.0% |

**Figure 2:** Excerpt of 2FTS curriculum from database

#### 3.2.2 Events on Demand

As trainee 'items' move through the system, they complete events and become suitable for their next event while working through the curriculum one event at a time. Individual event types have been determined based on different grouping, resource needs, or flight test requirement. The trainees complete events on demand subject to time (shift and/or stand-down time),

[2] Source of data was AIR5428 Preliminary Operational Concept Document (POCD), dated August 2007.

[3] The triangular distribution for pass rates represented (minimum pass rate, maximum pass rate, most likely pass rate).

availability of resources, grouping or sub-grouping requirements, pass/fail check and remedial/retest check. A pass/fail check is conducted seven times corresponding to the seven flight test events at 2FTS. Trainees cease moving as individuals through the system when grouping is required for events such as:

- Mass briefs
- Tutorials
- Part-task trainers
- Formation flights (Dual, Solo and Mutual formation flights are different event types)
- Mutual flights (student waits for a fellow course student)

The trainees will group for as long as is required and then revert to individual 'items'.

#### 3.2.3 Inputs at run-time

The user is able to change database information at run-time if required, plus make adjustments to resource levels for QFIs, aircraft, etc. A simple way of changing input data at run-time makes the set-up straightforward for sensitivity analysis.

#### 3.2.4 Outputs

Outputs to Excel of model runs for the 2FTS system currently total 16 courses of data for up to 27 students across the curriculum of 145 events, resulting in greater than 60,000 events in run times of approximately 10 minutes. Selected data is analysed as appropriate to attempt to gain 'steady state' output for the system, e.g. for a system with 16 courses of 27 starting students, data from courses 3-14 inclusive are analysed with reasonable results.

The data is further manipulated in Excel into graphs, an excerpt of which is shown below. The charts can display, for each course and across all courses, the minimum time to train (fastest student), maximum time to train (slowest student) and average time to train for Basic, Advanced and Applied phases. Note that at 2FTS, all passed students graduate together, therefore the end date for each 'time-to-train' metric is the date of individual Wings tests.

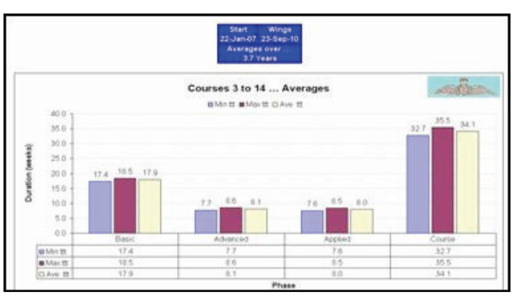


**Figure 3:** Excerpt of Excel output for 2FTS

Outputs to the database include tables like the HCC excerpt at Figure 5, showing each student's progress on an individual line, time spent on course, date of last test passed and date of suspension if applicable. Note that time spent on course is equivalent to 'time-to-train' as discussed previously for a trainee who passes the course.

### 3.3 Limitations

There are some functions for which the models were not designed, and other real-world system constraints that may not be 'show-stoppers' if not modelled in detail. Some limitations of the pilot training system models will be discussed under the following headings:

- Flights per day
- Predictive pass rates
- Flight program production, and
- Throughput

#### 3.3.1 Flights per day

The model does not restrict instructors or students to a certain number of flights, or flight hours in any set amount of time. The real system does place certain flight and hours restrictions on aircrew, but these have not been modelled. Based on the verification and validation procedure that produced certain key metrics close in accuracy to the curriculum figures, the duration and flow of events appears to constrain the students to a reasonable maximum of two flying events per day. In addition, QFIs are not represented as 'items' in the model, so individual instructor activity and utilisation cannot be tracked.

#### 3.3.2 Predictive pass rates

The model does not predict pass rates based on the current curriculum, or based on any different potential curriculum. Pass rates are not outputs, but are inputs to the model that impact on students. However, if training methodology behind a revised curriculum has been shown to produce certain improved pass rates in other military pilot training systems, then adjusted pass rates may be readily incorporated into the database for that revised course of training.

#### 3.3.3 Flight program production

The model was not intended to produce a flying program, but might be used as a tool to assist with course programming. The use of filters on output data in Excel can provide an easy gross-error check on event flow for students.

#### 3.3.4 Throughput

It would be handy if a model could be set to a throughput end-state, then run 'backwards' to show the conditions required at system start to produce the throughput. For example, rather than 24 fast-jet pilots required by the system (of which 2FTS is a part), decision makers may need to know the impact of increasing this number to 36. Clearly, increasing the throughput in an Australian context with known pass and wastage rates implies increased starting numbers at operational conversion units and at each preceding training step, i.e. 76 Squadron, 79 Squadron, 2FTS, Basic Flight Training, Flight Screening Program and as *ab initio* recruits at the Pilot Selection Agency. Since ExtendSim works logically and chronologically left to right, ExtendSim is not the tool to assist directly with this issue.

However, a simple spreadsheet of the system (excerpt in figure below) is able to provide a guide to potential starting numbers based on a given and desired throughput[4]. ExtendSim is then able to use this info as inputs for further analysis of metrics within the training system.

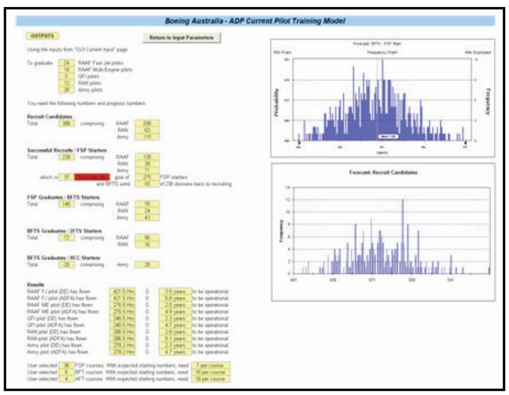


**Figure 4:** Excerpt of supporting Excel model

## 4. VERIFICATION & VALIDATION

The SAL sought advice from many sources to assist with verification and validation (V&V) including former QFIs, various Commonwealth stakeholders, in-house SME's and first-hand knowledge of the 2FTS system.

### 4.1 Single Course – 2FTS

The 2FTS curriculum states that for a system of 14 aircraft and 14 QFIs, the planned time to train (without a 'friction factor') for 27 students = 27.2 weeks.[5]

Using these same inputs, the 2FTS model produced an average time to train of 28.7 weeks (mean of 10 runs), a result within about 5.5% of the curriculum figure, and a reasonable starting point to investigate steady-state conditions.

### 4.2 Steady State – 2FTS

Annex C of the curriculum gives Total Pragmatic Course duration of 34.8 weeks, defined as the likely number of weeks the course will take with all factors applied. The model was re-run with baseline parameter inputs of 16 courses of 27 students[6], 12 weeks between courses, 24 x QFI, 5 x CTO, 2 x testing officers (FIHT & Wings)[7], 24 x aircraft, 31 x briefing rooms, 3 x CPT, 2 x PTT and 4 x classrooms.

The 2FTS model produced an average time to train of 33.9 weeks (mean of 12 runs), a result within about 2.6% of the curriculum figure of 34.8 weeks.

Note that the model does not currently cater specifically for the curriculum friction factor of 28%, but based on V&V conducted and feedback received to date during briefings to Commonwealth personnel, Boeing Australia considers the model sufficiently valid to provide a solid platform for continuing work on the pilot training continuum.

### 4.3 Rotary Wing Courses At Oakey

At the time of writing, V&V had been conducted for the Helicopter Conversion Course only, and current intention is to provide a detailed update on the remaining three RW courses in the presentation that accompanies this paper at SimTecT 2008. According to the curriculum, the approximate total duration of the HCC is 50 training days[8] or 10 weeks (along with 55.7 hours of flying training).

The ExtendSim model included public holidays and was run with baseline inputs of five aircraft, six QFIs and one ground instructor[9], producing an average time on course of 10.2 weeks or 51 training days (mean of 12 runs), a result within two percent of the curriculum planned course duration. There is reasonable confidence that HCC has been modelled accurately enough to proceed with the remaining RW training courses.

Table(5747) : FlyHours-HCC-Stud

| | Stud No | Course No | Start Date | Step | Training Event (HCC) | Time on Course (weeks) | Test (Passed) Date | Suspension Date | Flying Hours |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | | 0 | | 0.0 | | | 0.0 |
| 2 | 1 | 1 | 22/01/2007 7:30 AM | 86 | Critique | 10.3 | 23/03/2007 8:30 PM | | 55.7 |
| 3 | 2 | 1 | 22/01/2007 7:30 AM | 86 | Critique | 10.3 | 27/03/2007 8:30 PM | | 55.7 |
| 4 | 3 | 1 | 22/01/2007 7:30 AM | 60 | Primary Handling Assessment | 5.3 | | 28/02/2007 1:30 PM | 26.5 |
| 5 | 4 | 1 | 22/01/2007 7:30 AM | 86 | Critique | 10.3 | 26/03/2007 8:30 PM | | 55.7 |
| 6 | 5 | 1 | 22/01/2007 7:30 AM | 86 | Critique | 10.3 | 26/03/2007 10:18 PM | | 55.7 |
| 7 | 6 | 1 | 22/01/2007 7:30 AM | 86 | Critique | 10.3 | 27/03/2007 8:30 PM | | 60.2 |
| 8 | 7 | 1 | 22/01/2007 7:30 AM | 86 | Critique | 10.3 | 26/03/2007 8:30 PM | | 55.7 |
| 9 | 8 | 1 | 22/01/2007 7:30 AM | 86 | Critique | 10.3 | 26/03/2007 8:30 PM | | 55.7 |

**Figure 5:** Excerpt of HCC output to database

## 5. SENSITIVITY ANALYSIS

The 2FTS model was assessed as valid enough to answer further questions about system bottlenecks, and the effects on training times and utilisation rates of changing resource pool sizes.

[4] A model of the system has been built in Excel to support the Extend models.

[5] RAAFPLTADV Course 110888, AL2, Annex C to Section 2, 2C-1

[6] As previously stated, the purpose of running 16 courses was to obtain 'steady-state' conditions from 3-14 inclusive.

[7] No 2FTS currently has two QFIs, the Commanding Officer and Chief Flying Instructor, who are able to fly with and assess trainees during their Final Instrument Handling Test (FIHT) and 'Wings' flights.

[8] Australian Army 2005, Helicopter Conversion Course, AL6, Preface. The training duration of 50 days does not include public holidays.

[9] Boeing Australia SME advice.

The baseline option (Option 1) used input and resource parameters as per *Steady State – 2FTS* section above. Resource levels were then changed to note the impact on certain metrics, in particular the average time to train.

A total of seven options were tested with 12 runs per option. The table below shows input parameters for each option and average time to train in weeks and as a percentage of the model's steady-state baseline of 33.9 weeks.

**Table 1:** 2FTS Sensitivity Analysis

| Option | QFI | Aircraft | CTO | TO | PTT | CPT | Ave.ttt | 33.9 wks |
|---|---|---|---|---|---|---|---|---|
| 1 | 24 | 24 | 5 | 2 | 2 | 3 | 33.9 wks | 100.0% |
| 2 | 24 | 24 | 5 | 3 | 2 | 3 | 32.0 wks | 94.5% |
| 3 | 24 | 24 | 5 | 4 | 2 | 3 | 31.2 wks | 91.9% |
| 4 | 24 | 24 | 5 | 5 | 2 | 3 | 31.1 wks | 91.6% |
| 5 | 24 | 24 | 5 | 4 | 3 | 3 | 31.2 wks | 92.1% |
| 6 | 24 | 24 | 5 | 4 | 2 | 4 | 31.2 wks | 92.2% |
| 7 | 24 | 28 | 5 | 4 | 2 | 3 | 30.0 wks | 88.5% |

The table shows that various options trialled changes to numbers of testing officers (TO for FIHT and Wings), PTT, CPT and aircraft available, while QFI numbers were kept constant.

The largest gain resulted in Option 2 with one additional TO, reducing average time to train by 1.9 weeks or 5.5% from baseline. Option 3 included a fourth TO that reduced average training time by a further 0.8 weeks or 2.6%. Option 4 added a fifth TO but improvement was an insignificant 0.1 weeks. Changing the numbers of PTT or CPT (Options 5 and 6) provided no additional improvement in training times. Option 7, the final option tested, increased the pool of available aircraft from 24 to 28. This change reduced training time by a further 1.2 weeks compared with Option 3. It is reasonable to conclude from this example sensitivity analysis that the numbers of TO's and aircraft appear to be significant constraints on students progressing through 2FTS.

In summary, two extra TO's provide an enormous training improvement of 2.7 weeks or 8.1%, and four extra aircraft improve baseline training duration by a further 1.2 weeks or 3.4%. Combined, the improvement is 3.9 weeks or 11.5%. The table results are also presented in the figure below, with Options on the horizontal axis and training duration in weeks on the vertical axis.

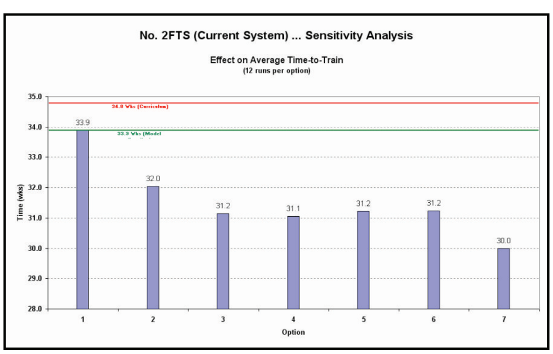


**Figure 6:** 2FTS Baseline model – Sensitivity Analysis

Changing the current system to make such improvements is not simple in reality. However, analysis such as that provided in the example above may allow decision makers to consider all available information before deciding on either changes to the current system or a desirable construct of a future system.

## 6. CONCLUSION

The SAL has provided modelling and simulation assistance to BSA in support of stakeholder engagement for pilot training projects AIR5428 and AIR9000. Work continues on components of both fixed wing and rotary wing training systems.

The discrete event modelling tool ExtendSim has been used to build pilot training system simulations in order to better understand the current system. Important metrics have been time-to-train for students and the level of utilisation of various resources that place constraints on the trainees as they move through the system.

The models were described in terms of challenges faced, features, limitations, verification & validation and sensitivity analysis. Challenges included trying to understand the system without ready access to data. Features include extensive use of a Boeing Industry database for the reading and writing of run-time data, plus trainees complete events on demand subject to time, resources, grouping requirements, pass/fail checks and remedial/retest checks. Changes can be readily made to most input parameters at run-time, while for output, the database has been used to store data for later analysis, while MS Excel has been used to both store and display results.

Limitations include inability to restrict the number of flights flown per day (by QFIs or students), inability to produce predictive pass rates, lack of flight program production and inability to work from right to left from desired output/throughout back to planned or intended input. The limitations are not 'show-stoppers', and verification and validation have shown how closely the models represent the real system's planned student time to train.

Verification and validation revealed an average time to train for 2FTS steady-state within 2.4% of curriculum, while the HCC prototype model was within 2% of curriculum.

Sensitivity analysis can be easily conducted to determine the effects of changing variables, and short run-times of around 10 minutes allow for reasonably rapid collection of data across multiple runs.

## REFERENCES


1. *RAAF Advanced Pilots Course*, RAAFPLTADV Course 110888, Revision April 2007, AL2.

2. Australian Army 2005, Helicopter Conversion Course, AL6