Australian Government
Department of Defence

Introduction to Simulation Guide

Australian Defence Simulation Office

Department of Defence, Canberra

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Serial	Amendment	Date Effected

1 AN OVERVIEW OF SIMULATION

1. All But War Is Simulation – so says the logo of the U.S. Army Program Executive Office For Simulation, Training, and Instrumentation (formerly STRICOM). Perhaps they're biased – but there is no doubt that simulation has a vital part to play in ensuring that our defence forces are well equipped, well trained and well commanded.

1.1 WHAT IS SIMULATION?

2. If you want to do something without using the real equipment or real environment, or suffering the real consequences, then you probably need to use simulation.

3. The general term "simulation" encompasses two main areas:

"Modelling" – creating a representation of something.

"Simulation" – using a tool (such as a computer) to imitate the dynamic characteristics of a real-world system.

A ***model*** is a physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process. Examples of *models* might include a mathematical *model* of sensor response, or digital information flow over a network, or a computer aided design *model* of an armoured vehicle or a helicopter or a human being.
Modelling refers to the process of creating models.

Simulation is the method for implementing a model over time.
For example, if a three-dimensional *model* of an armoured vehicle is instructed to move across a *model* of terrain over time, a *simulation* is created.
Human-in-the-loop simulations are commonly referred to as "*simulators*".

1.1.1 Let's look at some examples:

4. A trainee pilot sits at the cockpit of a Boeing 747 **aircraft simulator**. The cockpit is a *model* – it is not a real aircraft! Inside the computer is a mathematical *model* of the flight dynamics of the B747. On the projected screen in front of the pilot are *models* of other aircraft and airfields, this time implemented as computer graphics. As the pilot "flies" the aircraft, the various models interact so the pilot sees, feels and hears that he is in an aircraft – but it is all *simulation*.

Commercial Aircraft Full Flight Simulator – source CAE

5. A scientist engaged by the Defence Capability group is tasked to check the bandwidth requirements of a new ship’s communications system. On his desktop PC, he has software *models* of the communications systems of each asset – satellites, aircraft and other ships. He has average and maximum transmission rates – but could enough assets want to communicate simultaneously to overload the system? To test this, he *simulates* the actions of the assets during a conflict lasting 15 minutes – and discovers that just prior to engagement, the proposed bandwidth of the ship’s systems will be overloaded.

1.2 WHY USE SIMULATION?

6. The benefits of simulation can be described as any activity involving modelling or simulation that:

a. Enhances capabilities,

b. Saves resources, and

c. Reduces risk.

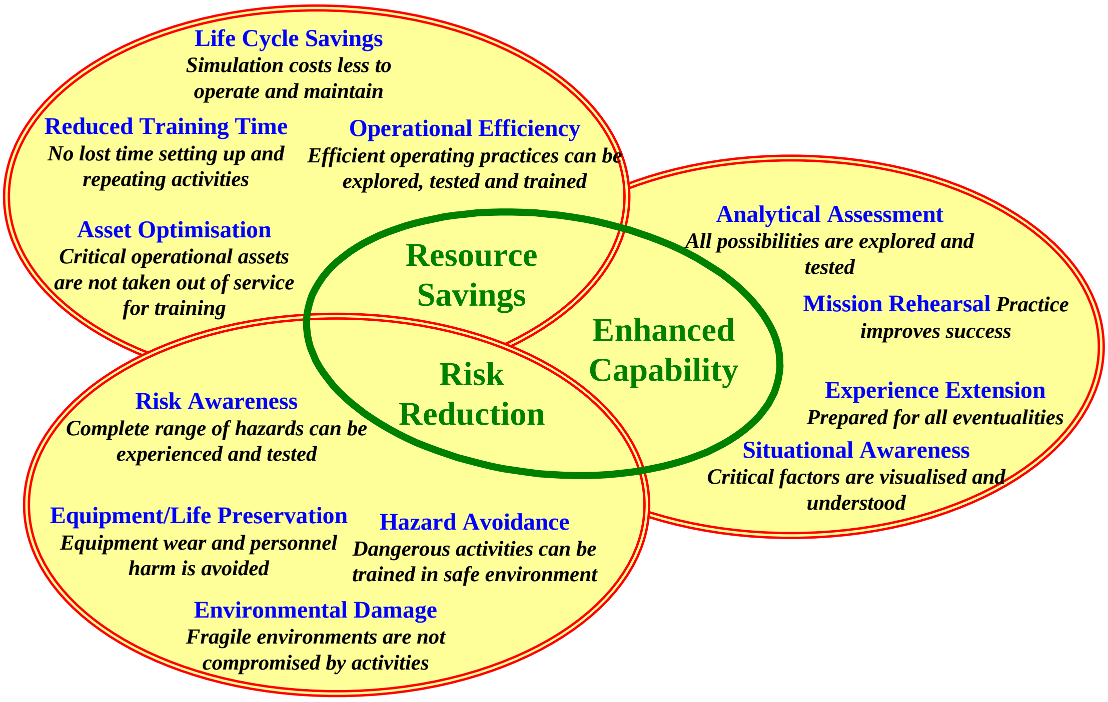


Figure 3- 1: Benefits of Simulation

7. Some examples of these benefits are identified in Figure 3- 1.

Simulation can also provide other benefits such as:

a. Superior instructional utility,

b. Objective student performance analysis and feedback,

c. An ability to capture and replay past lessons learnt,

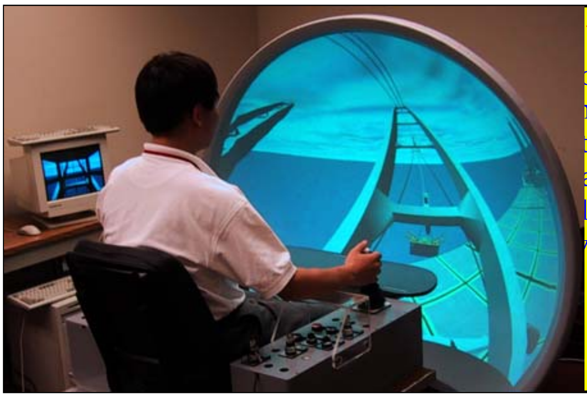
d. Consistent and repeatable competency assessment baseline testing, and

e. Accident investigation and prevention analysis.

1.3 WHAT FORMS DOES SIMULATION TAKE?

1.3.1 A Conceptual View

9. Simulation is often categorised as being *Virtual*, *Live*, or *Constructive*. These are common terms representing different styles of simulation, and are not absolute terms in respect of design or implementation of modelling and simulation. *Live* characterises simulations that make greater use of real people and equipment. *Virtual* characterises simulations that predominantly comprise people in computer representations of the real world equipment. Constructive characterises simulations that individuals generally stimulate (make inputs to) the constructive models but they are not directly involved in determining the outcomes of the simulations. Constructive simulations are used typically in situations, such as combat engagement where participants seek to achieve a specified military objective given pre-established resources and constraints.



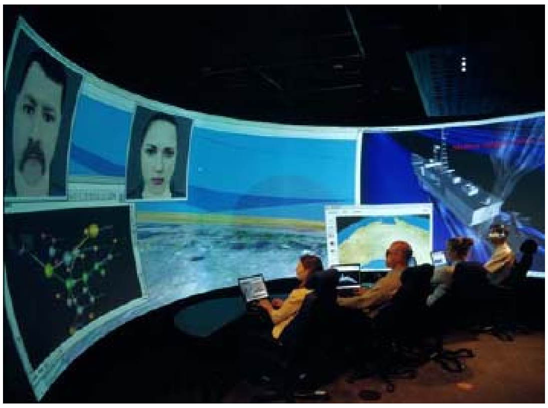
Virtual Simulation

ons inject humans in the loop to exercise motor
ı-making, or communications skills. The human
ual Simulation is not modelled. The simulated
al Simulation would be made up of constructive
les include individual aircraft (or weapon system)
irtual prototypes.

Virtual Crane Simulator – source CSC

1.3.2 Analysis

10. When simulations are used for analysis, the simulation often takes the form of software running on a PC. The output may be a string of numbers, graphs, or data “visualised” in a way so it is immediately apparent to most users. An example of visualisation is the safest path taken for an advancing armoured vehicle – this could be a string of latitude, longitude and elevation coordinates over time, or it could be a dotted line plotted on a plan-view map showing terrain features (such as lakes) and enemy installations.



Future Operations Centre Analysis Laboratory
source Defence Science Technology Organisation

Live Simulation

ations represent military operations using military
periences are achieved using near-combat conditions.
port is enriching this field, enabling real time data
l-time insertion of virtual and constructive
puter controlled targets on live-firing ranges, EW

Live Simulation Exercise – source CSC

Constructive Simulation

stimulate (make inputs to) the constructive models
the outcomes of the simulations. Constructive
as combat engagement simulations for example,
ilitary objective given pre-established resources and
and support models.

Constructive Simulation Control Centre – source CSC

1.3.3 Training

11. For training, forms of simulation include:

a. People in a real environment (such as a forest) with simulated enemies (which might be real people performing specific roles, or replicas of people which appear, then disappear if they've been hit), with a simulated battlefield environment (blank ammunition, and pyrotechnics for effects).

b. Operators in a real environment (such as a ship), using the real equipment, but with a simulator injecting data into the sensors (such as a radar) so that the operators believe there are friendly and enemy forces around them.

Submarine Combat System Trainer – source CSC

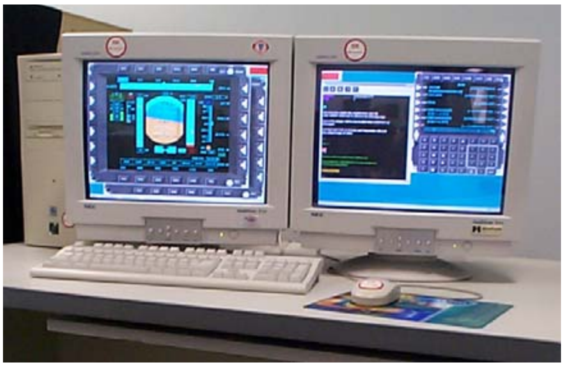
c. Software running in a standard PC which takes a student through an interactive question and answer session – in the office, at sea, or at home.

d. Software running in a PC which displays a picture on the screen which looks like the control screen of the real equipment – the user can interact with the screen's "buttons" and "switches" using a mouse or other pointing device.

e. A replica of real equipment, which looks and behaves like the real equipment, but which is often made from cheaper commercial components.

f. Numbers of simulated replicas, interconnected to simulate radio or data links, so that groups of personnel can be trained as a team or force.

g. One or more training simulators operating with software that simulates friendly or enemy forces – to enable a large scenario with many "players" to be executed with few real personnel.



Integrated Tactical Avionics System Part Task Trainer Source CSC

1.3.4 Simulation Assisted Acquisition

12. Sometimes called Simulation Based Acquisition (SBA), this is an acquisition process in which Defence and Industry are enabled by robust, collaborative use of simulation technology that is integrated across acquisition phases and programs.

13. The process has been embraced by the US, and is included in the UK's "Smart" acquisition process.

14. In the US, SMART (Simulations and Modelling for Acquisition, Requirements, and Training) is a framework to accomplish the vision of using modelling and simulation to reduce the cycle time of providing solutions for Defence's needs in the US, at reduced costs.

15. The SMART concept capitalises on modelling and simulation tools and technologies to deal with system development, operational readiness, and life-cycle cost. This is accomplished through the collaborative efforts of the requirements, training, operations, and acquisition communities.

Armed Reconnaissance Helicopter Synthetic Environment – source Defence Science Technology Organisation

1.4 WHAT CAN YOU USE SIMULATION FOR?

16. The ***Defence Simulation Policy DIG (OPS) 42-1*** has defined nine application areas for simulation:

a. **Training** - covers the routine development of skills at the individual, sub-unit, unit, joint and combined levels.

b. **Mission Rehearsal** - support mission specific training that prepares personnel to employ forces, use systems and apply technologies in generic operations.

c. **Conduct of Operations** - assists the conduct of operations with 'just-in-time' planning information, providing decision support during military operations.

d. **Crisis Management and Planning** - supports deliberate planning for potential/plausible future crisis scenarios; collaborative planning, analytical support, and logistics support.

e. **Force Assessment** - supports decision making in the areas of capability and force structure analysis, including preparedness and resourcing studies from tactical operations, operational and theatre levels through to campaign and strategic levels.

f. **Experimentation** - supports the exploration of concepts and contexts related to future defence capabilities as well as providing analytical support to the force-in-being, including testing of doctrine and tactics, systems evaluation and improvement.

g. **Research and Development** - supports the operational and technical analysis throughout the design and development phases.

h. **Acquisition** - determines and refines user requirements, system designs, prototyping and system testing and evaluation for procurement decisions.

i. **Life Cycle Management** - supports resource planning and allocation for sustaining systems through-life, encompassing logistics and maintenance support from planning to operations.

17. Examples of the use of simulation in these application areas may be found in Appendix A, Appendix B and Appendix C.

F/A-18 Integrated Avionics System Support Facility – source BAESYSTEMS

1.5 HOW DO YOU GET IT?

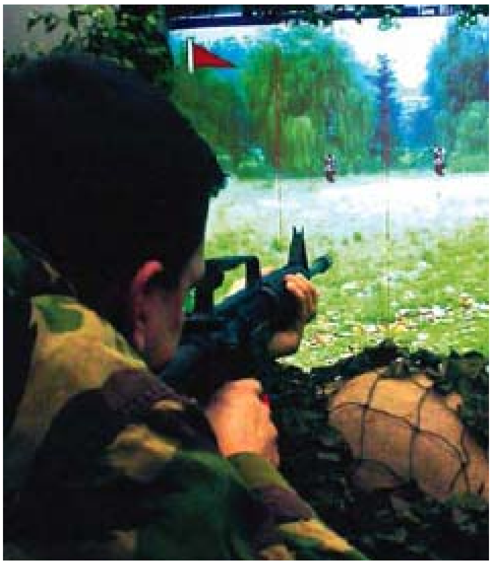
1.5.1 Approval

18. The ***Defence Simulation Policy*** requires that each proposal to develop Simulations needs to be informed by an assessment made against the following criteria:

a. **User requirements** - who wants the Simulation? Why? To do what exactly? In particular, what questions are to be answered with the help of Simulation, or what training needs are to be met?

b. **Representations** - how are people and things with their dynamic behaviours and interactions in various environments going to be represented inside the Simulation?

c. **Data availability and reliability** - how well can these representations be achieved? Does the necessary data exist? Can the appropriate data be found?



Small Arms Trainer – source CAE

d. **Technology** - how can the ideas embodied in the answers to the above be made to work effectively for the user via appropriate technologies?

e. **Confidence building approaches** - how is ‘fitness for purpose’ to be assessed to establish both the overall credibility of Simulation outcomes and the necessary levels of user confidence in them?

f. **Cost/benefit** - how are the returns on investment to be determined and expressed in order to secure both the initial and the continuing resources needed to build, deploy and use the system?

19. Another document, the ***Simulation Proposal Guide***, was designed to assist the Developers of Simulation proposals, and those reviewing and assessing those proposals, to establish clearly how the Simulation will enhance capability, save resources or reduce risk to develop, train for, prepare for and test military options for Government. It provides detailed guidance for assessing simulation proposals against the above criteria.

Members of 5/7 RAR using the Virtual Battlefield System as part of the Virtual Infantry Section Experiment at Army's Headline 03 – source Australian Defence Force Academy

1.5.2 Implementation

20. Following approval, the simulation can be implemented. To do this, you need *data* about the thing you're simulating, a means of *executing* the model, and *presenting* the results to the users. Let's take a simple aircraft flight simulator as an example.

a. Firstly, *data* is required to, for example:

   i. Describe the layout of the cockpit – this would often take the form of detailed engineering drawings, and photos.

   ii. Define the flight dynamics of the aircraft – this may take the form of graphs, or tables, showing the values of various flight parameters (such as speed) under various conditions (eg power, altitude, weight), or values of constants in complex flight equations.

Truck Driving Simulator – source Thales Training & Simulation

b. Secondly, appropriate models have to be created:

   i. The cockpit, mounted on a fixed or moving base, is required to create a sense of being in the aircraft.

   ii. The instruments and controls, with which the pilot interacts, are needed to perform core pilot actions.

   iii. Models that respond to control inputs and provide pilot feedback stimuli are created using software and hardware technologies. These models could provide instrument displays, control force feedback, movement sensations, sounds, and visual representations associated with the various aircraft systems and cockpit view.

c. Finally, the models are executed dynamically as a complete *simulation* to present the pilot with:

   i. Expected cockpit instrument and display presentations and responses.

   ii. An “out-the-window” view of the world around the aircraft for orientation and situational purposes.

   iii. Sounds and vibrations consistent with the activities the pilot is performing.

   iv. Perceived aircraft motion consistent with the aircraft performance response to pilot control inputs.

2 SOME SIMULATION CONCEPTS

21. There are a number of implementation issues, which affect the specification and outcomes of simulations. Some of the more prominent issues are discussed in this section.

2.1 FIDELITY

Fidelity The accuracy of the representation when compared to the real world.

22. A simulation (physical or mathematical) generally involves a fidelity **compromise**, because:

a. Often complete and accurate data is not available (see 2.8.1 below).

b. The behaviour of the system being modelled may not be sufficiently understood or defined to implement a high fidelity simulations.

c. The higher the fidelity, the greater the cost. Depending on the training or analysis requirements, the extra cost for greater fidelity may not deliver adequate benefit to justify the additional cost.

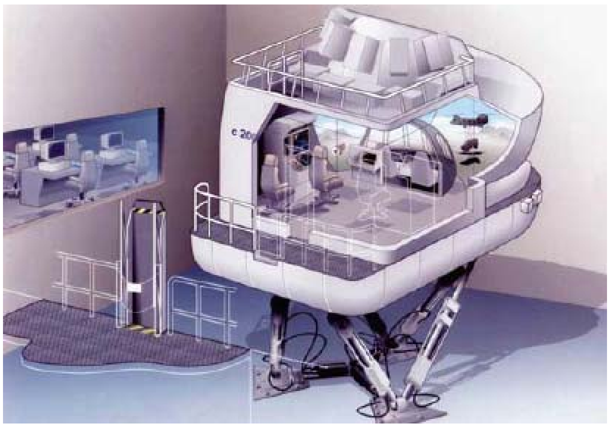
d. Sophisticated mathematical simulations may be too complex to run in real-time.

2.2 RESOLUTION

23. Resolution determines the level of control for the aggregation of models into a “system”. For example:

a. a model may be:
   - i. A Tank, or
   - ii. Tracks, barrel, engine, axles, fuel;

b. Or, a modelled unit may be:
   - i. A Platoon, or
   - ii. Individual soldiers.



Full Flight Simulator Construction
– source Thales Training & Simulation

24. Resolution has implications for cost, usability and inter-operability. For example, force entity models designed for use in theatre level campaign simulations may represent forces at the battalion level. This model resolution is unlikely to be suitable for use in simulations at the tactical level where individual combat unit resolution is of greater interest. Interaction between the two levels is unlikely to yield useful outcomes.

2.3 VERIFICATION, VALIDATION AND ACCREDITATION

25. Verification, Validation and Accreditation (VV&A) assures users of a simulation or model of its fitness for purpose – that the simulation has been correctly designed and implemented to satisfy a specific defined purpose. This is a costly and sometimes overlooked activity.

26. It is particularly important when sharing models or where the output of a simulation will be relied upon for a significant conclusion, decision or action. Before a model is embedded into a simulation, its "correctness" and limitations must be understood. It's important to know the scope or operating conditions / assumptions for the model – as the use of a model which has been designed (and validated) for one purpose may be misleading for a different purpose.

27. **Verification** answers the question: "Was it built right?" For example, if a developer has described and specified the characteristics of a sonar acoustic response model, or an armoured vehicle visual model, or a dismounted section behaviour model, the verification process is conducted to ensure that the resulting model represents that original design input.

28. **Validation** answers the question "Was the right thing built?" For example, if a model has been created to simulate the visual view out of a dismounted soldier's rifle sight for the purposes of small arms training, the validation process would be conducted to determine if the model accurately reflects the visual view of the real world for this purpose.

29. **Accreditation** is the official certification that a simulation is acceptable for use in relation to a **specific purpose**. Therefore, if a simulation was created to train armoured vehicle gunnery, it might be accredited for that purpose - or perhaps for just part of that purpose. For example, it may be accredited only as acceptable for static vehicle gunnery training but not for moving vehicle gunnery training, because the simulation did not have any movement component.

What is "***Verification***", "***Validation***", and "***Accreditation***"?

Verification	The process of determining that a simulation implementation accurately represents the developer's conceptual description and specification.
Validation	The process of determining the degree to which a simulation is an accurate representation of the real-world from the perspective of the intended uses of the simulation.
Accreditation	The official certification that a simulation, or federation of models and simulations is acceptable for use for a specific purpose.

2.4 INTENDED PURPOSE

30. It seems that implementation of simulation involves cost / benefit trade-offs. Issues of resolution, fidelity and design limitations must be understood if simulations are to be of use in achieving some purpose. It is therefore not surprising that simulations are often designed to address specific purposes. Some more common intended purposes follow.

Army Watercraft Bridge Simulator - source CSC

2.4.1 Task specific

31. As the name implies, a *Part-Task Trainer* is designed to train a user how to operate an individual item of equipment, or undertake a specific task. It often involves teaching motor skills, or learning "switchology" so that basic equipment operation becomes almost autonomous.

32. For example, when first learning to drive a manual car, the thought involved in changing gears leaves little brain power for observing road signs and other critical tasks. A gear-box part-task trainer would allow a student to learn how to use the gear lever and clutch, at different vehicle and engine speeds, without distractions or compromising safety. Teenage students may move onto a car stereo system part-task trainer to learn how to operate it without taking their eyes off the road! Having mastered these, the student is ready to progress to more advanced learning tasks, bringing together a set of newly acquired skills in a more holistic situation such as a car simulator, or a car itself.

Intended Purpose Drives Fidelity

If teaching fine-motor skills is important (eg operating a tank commander's hand grip), then the related simulator characteristics (hand-grip size, shape, location of the buttons, weight, resistance, feel, control response etc) need to be very realistic if the learnt control responses are to be successfully transferred to the real world equipment.

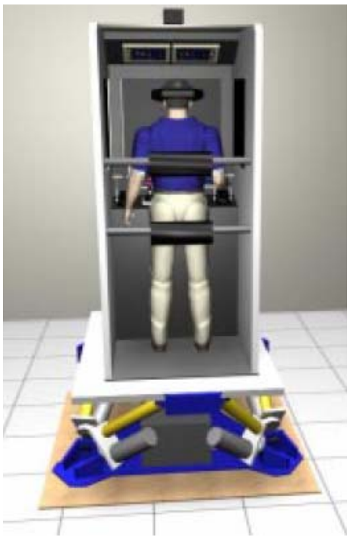
Incorrect responses learnt from simulation-based training can cause significant retraining effort when transitioning to operation of real equipment. This is often referred to as "*negative training*". In safety critical situations, incorrect responses learnt in a simulated environment can cause operating errors that potentially lead to loss of equipment and/or life.

If the learning objective is to understand what function each button and indicator performs, then the size, location and feel of the controls are relatively unimportant – as long as the system response is correct.

2.4.2 Experience

33. Simulators may be designed to coach users to react instinctively through repetitive training and rehearsal. An example is the deployment of smart weapons from a strike aircraft in tactical battlefield conditions at night – which involves low flying and sharp manoeuvres in close proximity to the ground, while at the same time acquiring a target with sensors, releasing and guiding a weapon to its designated target, and dealing with enemy anti-aircraft responses. All this happens in a very short space of time – often less than a minute – thus requiring instinctive actions and responses. A simulator provides the safest means of training such tasks – but to be effective it has to include very realistic models of aircraft flight dynamics, weapon system characteristics, attack sensor displays, and weapons deployment and guidance responses. Notwithstanding, some models do not need to be very detailed or accurate. For example, the out-the-window display is relatively unimportant in this manoeuvre.

34. A simulator is also an efficient way of gaining operating experience and completing prescribed training activities. A simulator can be quickly initialised and reset to the start of the procedure being trained, and active participants can be positioned almost instantaneously, avoiding set-up delays associated with manoeuvring equipment and participants into defined starting conditions. Simulations are also unaffected by circumstances that cannot be controlled in the real world, such as weather conditions, commerce activities and time of day.



Advanced Lighter Simulator
- source CSC

2.4.3 Mission and Team Training

35. Operatives normally work together in a team to achieve a common objective. In some cases, instructors and designated role actors may play the role of a wing-man, air traffic controller, or other participants, to support the mission training of an individual or team.

F-111C Mission Simulator
– source Thales Training & Simulation

36. Mission and team training activities can range in size from a few participants to literally hundreds of active participants. This could consume significant personnel resources, or even not happen at all, if simulation technologies are not exploited. A software module, called an **agent**, may perform the role of mission and team training participants – providing responses to team actions in pre-defined ways. The behaviour characteristics of agents can vary from the simple to semi-intelligent complex behaviours. Some agents are even capable of basic learning strategies.

Agents and Computer Generated Forces

An agent is a module of software written to emulate the reasoning of a human. Most Intelligent Agent technologies have an architecture based on Belief, Desire and Intention (BDI) methodologies.

They experience their environment (that larger system they "live" in) through sensors and can act through effectors; they're reactive, responding in a timely fashion to sensed environmental change; they're proactive, anticipating future goals; and agents can work in teams as humans do, collaborating within their encapsulated system to achieve objectives.

Agents are also often referred to as *Computer Generated Forces (CGF)*, or *Semi – Automated Forces (SAF)*.

Super Seasprite Full Mission Flight Simulator
- source CSC

37. In a team trainer (such as the Airborne Early Warning and Control (AEW&C) Operational Mission Simulator), the crew is located in the one simulator, and may interact with battlespace participants who are either computer generated forces (agents) or other human participants each linked and interacting with the others through a networked environment. Thus crew training may be achieved by linking several simulators together – where they can all participate in battlespace engagements in a common virtual environment.

2.4.4 Knowledge / Analysis

38. As can be seen from many of the examples in Appendix A, modelling and simulation can be used to thoroughly explore an issue to gain knowledge, explore 'what-if' outcomes and validate conclusions. Modelling can also highlight constraints in an operation (eg supply chain), or design (eg between-decks lift speed for an aircraft carrier).

39. In a simulation, the environment can be precisely controlled – enabling the effects of individual variables to be explored and understood.

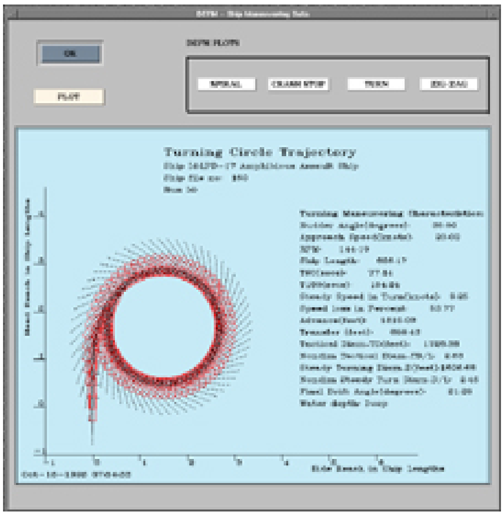
40. A simulation analysis technique which is sometimes used is "Monte Carlo Simulation." This technique derives its name from the casinos in Monte Carlo - a Monte Carlo simulation uses random inputs to a model to define the range of possible outcomes. The technique works particularly well when the process being modelled is characterised by uncertainty, and process outcomes are expressed in a probabilistic manner.

Monte Carlo Simulation

A simulation in which random statistical sampling techniques are employed such that the result determines estimates for unknown values.

Deterministic Simulation

A simulation which, for a given set of inputs, produces an identical set of outputs, each time the simulation is run. The effect of changing a variable can be clearly determined.



Ship Turning Circle Simulation
- Source CSC

2.5 FIDELITY AND RELIANCE ON OUTCOMES

41. Modelling and simulation are generally an approximation of the real world, because of data and cost issues, as mentioned in 2.1 above.

42. As illustrated opposite in Figure 3- 2, the "law of diminishing returns" often operates with respect to fidelity cost and the resulting benefit, or training outcomes. Value judgements must be made on a case-by case-basis. Where training is vital for safety and mission achievement and effective training cannot be gained using actual equipment, the cost of high fidelity simulation is often mandated as necessary and must be paid. Where cost effective alternatives exist, the cost of higher fidelity simulation may not represent a good return on investment.

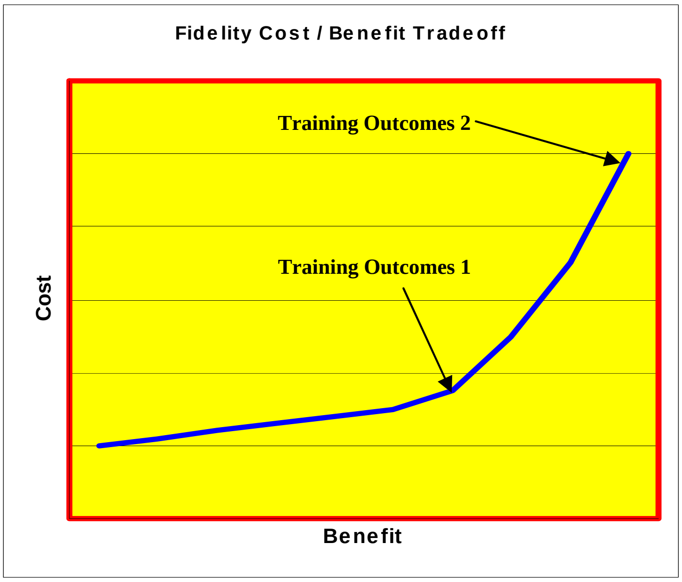


Figure 3- 2: Fidelity – Cost – Benefit Tradeoff

2.5.1 Civil Certification of Flight Simulators

43. Certification of flight simulators is a means by which civil aviation regulators can be confident that pilot training conducted in flight simulation devices achieves proscribed commercial transport pilot competency objectives. The widespread use of flight simulators has been driven by civil aviation operators, where use of simulation avoids removal of aircraft from revenue service for pilot training activities, resulting in significant operational cost savings for airline operators. The high degree of standardisation in operational procedures,

Civil Certification by CASA

In September 2003, CASA (the Civil Aviation Safety Authority) released regulation CASR Part 60, to harmonise various international Synthetic Training Device regulations.

Part 60 prescribes the rules for the design, operation and use of Synthetic Training Devices, covering (in order of complexity):

1. Synthetic Trainers;
2. Flight Training Devices; and
3. Flight Simulators.

Each device type is well defined, and allows airline operators to substitute a set numbers of flying hours with an equivalent number of hours in a suitable certified Synthetic Training Device.

practices and equipment has facilitated wide agreement to an internationally recognised certification standard for commercial multi-engine heavy transport aircraft.

44. Use of civil aviation synthetic training device certifications in a military aviation application merits considerable caution, as the assumptions and objectives underpinning the certification standards are based on commercial transport flying operations, which are considerably different to military flying operations and military pilot training objectives.

2.6 SCALABILITY - ONE, SEVERAL, MANY

45. Simulations may operate in isolation, or be linked together, consistent with Tactical, Operational and Strategic levels.

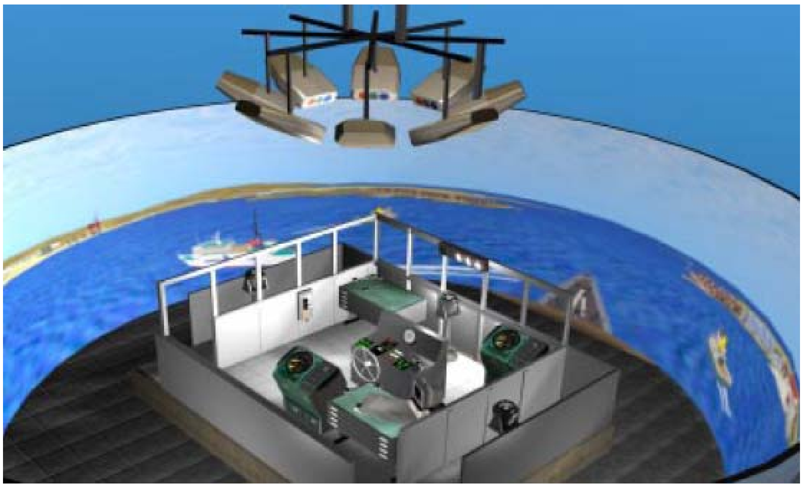
Distributed Interactive Simulation (DIS)

DIS was developed in the US mostly from 1990-96. It consists of a prescriptive protocol of the contents of Protocol Data Units (PDUs).

The advantage of DIS is that because its specification was so detailed, two DIS compliant simulators had a high probability of successfully interoperating with relatively little additional modification. However, this rigidity led to the development of HLA.

It is defined in the IEEE 1278 standard.

46. “Distributed Mission Operations” is the term used when multiple simulators are liked together so that all participants learn from the joint experience. This may range from two simulators to train one helicopter crew (eg the pilot and the battle captain/gunner for Australia’s Tiger helicopter), or a squadron of fighter aircraft simulators, through to a multi-nation, multi-continent, multi-platform mixture of live and virtual simulation.



Full Mission Bridge Simulator
- *Source CSC*

47. A number of issues arise when linking simulators, such as:

a. Having a common synthetic environment (eg area, fidelity, resolution), and

b. The device communications method (such as DIS or HLA).

48. The ***Distributed Simulation Guide*** provides a source of initial information and advice in relation to the development and use of Distributed Simulation in support of the nine applications areas cited in the ***Defence Simulation Policy***. The Guide also directs the reader to where more detailed information and advice can be found.

High Level Architecture (HLA)

The goal of the High Level Architecture is to define a common simulation infrastructure to support interoperability and reuse of defence simulations. It is therefore more than a communications protocol.

In HLA several simulation systems, called "federates", are combined to form a larger simulation, called a "federation". This requires:

a. Specifying the information that will be exchanged in a Federation Object Model (FOM). This is a file that describes the common language of the federation. It provides information about what object classes (eg "car"), attributes (eg "brand, speed") and interactions (eg "honk the horn") that will be exchanged within the federation.

b. A means of exchanging information between the participating systems (federates) using a piece of software called the ***Run-Time Infrastructure (RTI)***, analogous to a telephone exchange, that follows a standardised specification.

The HLA is defined in the IEEE 1516 standard.

2.7 BASIC DEFINITIONS

49. We have already encountered the terms live, virtual, constructive and SMART in connection with classes of simulation (refer back to section 1.1.1). Here are some more terms frequently encountered, some of which can be confusing to those without a deeper understanding of simulation issues:

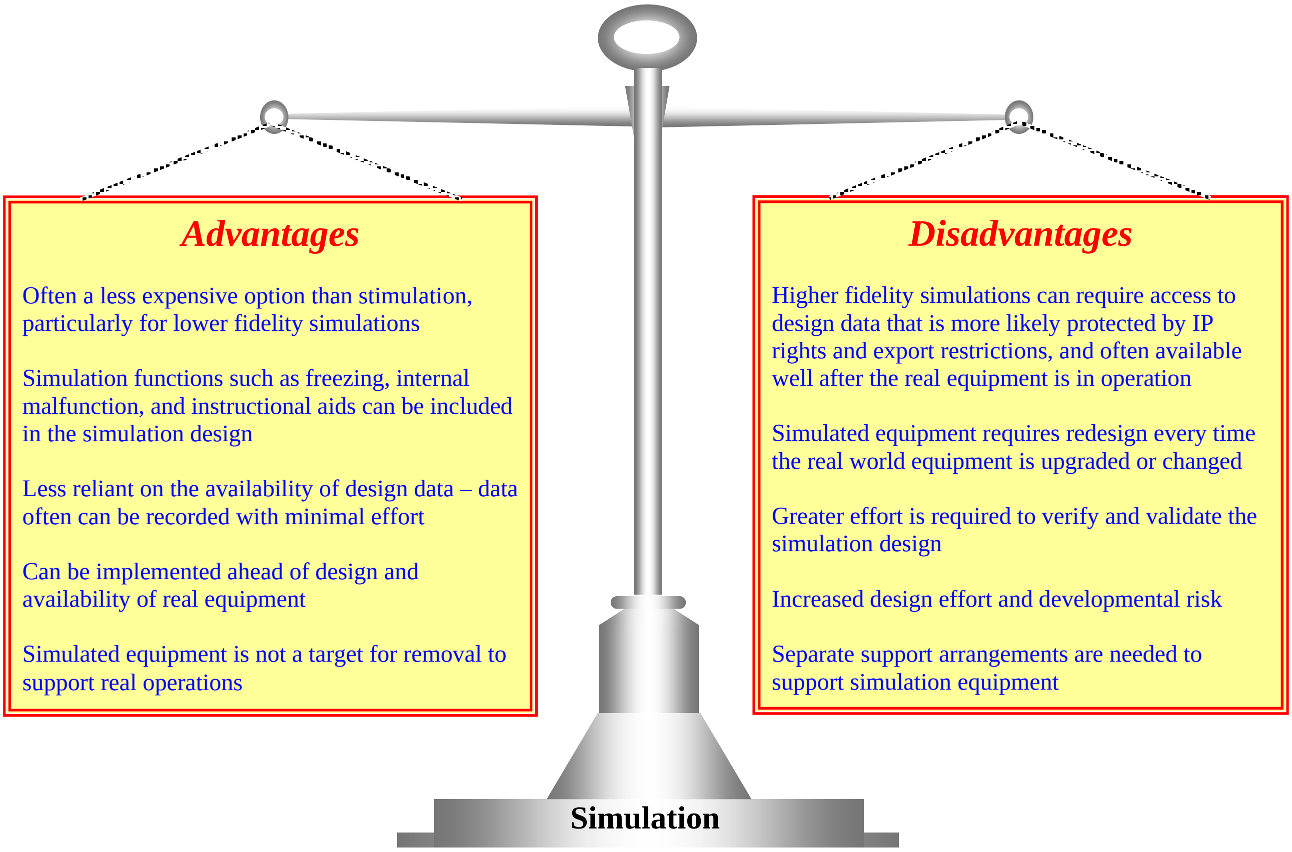
2.7.1 Simulation versus Stimulation

50. When designing a simulation (such as a Flight Simulator), a question that is often pondered by design engineers is: “Should we *simulate*, or *stimulate* the real equipment?” So what is the difference and why does it matter?

Hardware-in-the-Loop Testbed Simulation
- Source CSC

51. The difference is that to *simulate* the real equipment, the designers would create an equipment replica comprising alternative hardware and software models that had the desired appearance, function and performance of the real equipment. Important features, characteristics and behaviours would be preserved, while irrelevant characteristics would be omitted.

52. If the decision was taken to *stimulate* the real equipment, then the designers would acquire the real equipment, design an appropriate input stimuli interface for the equipment and extract systems outputs from the system that are desired for the intended simulation. As long as the input stimuli behave in the same way as expected from real world inputs, then the equipment would behave exactly like the real system because it **is** the real system!



Advantages

Often a less expensive option than stimulation, particularly for lower fidelity simulations

Simulation functions such as freezing, internal malfunction, and instructional aids can be included in the simulation design

Less reliant on the availability of design data – data often can be recorded with minimal effort

Can be implemented ahead of design and availability of real equipment

Simulated equipment is not a target for removal to support real operations

Disadvantages

Higher fidelity simulations can require access to design data that is more likely protected by IP rights and export restrictions, and often available well after the real equipment is in operation

Simulated equipment requires redesign every time the real world equipment is upgraded or changed

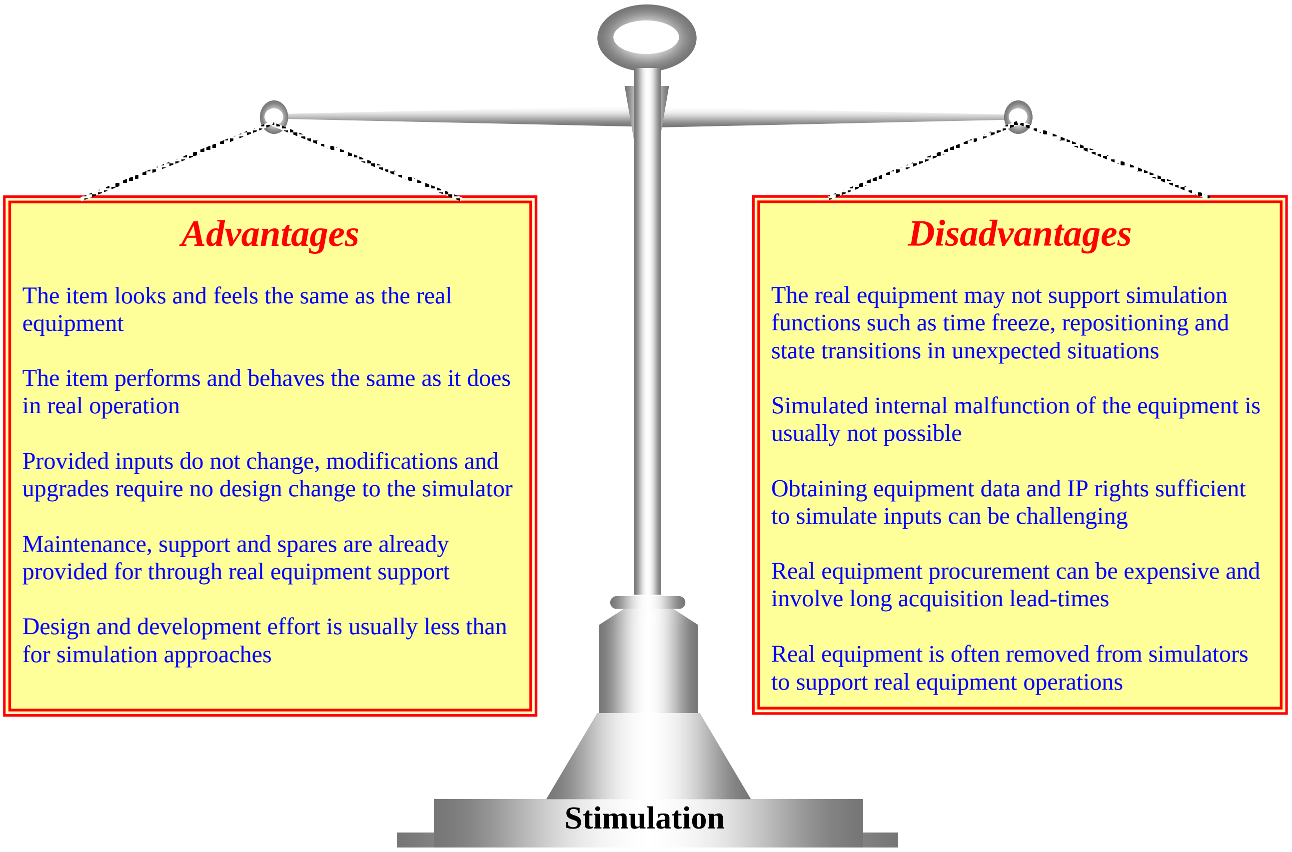
Greater effort is required to verify and validate the simulation design

Increased design effort and developmental risk

Separate support arrangements are needed to support simulation equipment

Figure 3- 3: Simulation Considerations

53. Although this is primarily a decision for those who design simulations, there are wider issues that may impact the acquiring organisation, simulation end users, and those who manage the real equipment. Some of these issues are elaborated in the next two figures.



Advantages

The item looks and feels the same as the real equipment

The item performs and behaves the same as it does in real operation

Provided inputs do not change, modifications and upgrades require no design change to the simulator

Maintenance, support and spares are already provided for through real equipment support

Design and development effort is usually less than for simulation approaches

Disadvantages

The real equipment may not support simulation functions such as time freeze, repositioning and state transitions in unexpected situations

Simulated internal malfunction of the equipment is usually not possible

Obtaining equipment data and IP rights sufficient to simulate inputs can be challenging

Real equipment procurement can be expensive and involve long acquisition lead-times

Real equipment is often removed from simulators to support real equipment operations

Figure 3- 4: Stimulation Considerations

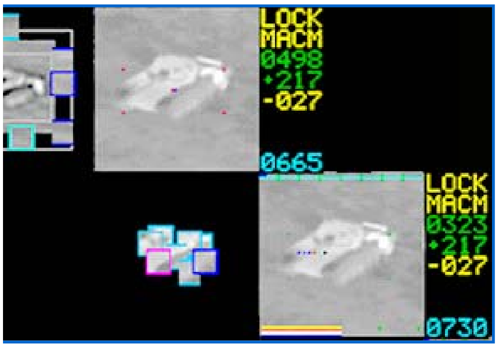
54. The decision to simulate or stimulate should normally be left to designers to ponder in the light of the requirements placed upon the designer by the acquirer. Simulation may be a cheaper proposition during initial acquisition, but more expensive over the life of the simulator if the real equipment undergoes frequent modifications and upgrades.

55. One final word for thought – whatever approach is decided, assistance from the acquirer is likely to be needed for success - either to secure economic order quantities and/or acceptable lead times for real equipment, or assist in the identification and collection of data to support design efforts.

Stimulation Stimulation is the use of simulations to provide an external stimulus to a system or subsystem. An example is the use of a simulation representing the radar return from a target to drive (stimulate) the radar of a missile system within a hardware/software-in-the-loop simulation.

2.7.2 Emulation

56. In the above discussion on simulation versus stimulation of equipment, the two approaches were represented as mutually exclusive. Sometimes, however, a hybrid approach involving both stimulation and simulation represents an effective implementation approach. This approach is often referred to as "emulation".



High Fidelity Thermal Evaluation Simulation
- Source CSC

Emulation A simulation methodology in which the same inputs are accepted and the same outputs are produced as a given system.

57. A common example of an emulation approach is where the actual real equipment software is hosted on a completely different hardware processor that emulates the software environment normally provided by the real equipment. In this approach the use of the real system software ensures the function and performance of the real system is captured. The substitution of expensive specialised hardware with commercially available common hardware is undertaken to realise equipment cost savings, address design data availability issues, and avoid equipment supply lead times. In this example, software upgrades can be implemented with minimal design effort, but hardware modifications would require more design effort.

58. An advantage of an emulation approach is that the need to develop hardware input stimuli can be eliminated, with those inputs being inserted at the point where they are converted to software inputs in the real equipment. This removes the need for stimulation hardware interfaces.

2.7.3 Synthetic Environment

ASLAV Synthetic Environment
– source Thales Training & Simulation

59. A synthetic environment is the linkage of models, simulations, people (real or simulated), and equipment (real or simulated) into a common representation of the world. When a number of simulations or simulators are linked through networking, whereby a series of models are interacting in the same virtual battlespace, a synthetic environment has been created. Similarly, if a digital model of a large weapons platform, such as a ship, has been created allowing a number of different models of user interfaces to interact together in the virtual ship environment, a synthetic environment has

been created.

2.8 SOME COMMON PROBLEMS IN DEFINING AND IMPLEMENTING SIMULATION

2.8.1 Data

60. Perhaps the most significant problem with defining and implement simulation is the availability of data that describes the real world system characteristics. As the simulation is attempting to replicate the real world (to the extent required for the simulation purpose), then data that describes the real world is indispensable to the task. Data issues often encountered are:

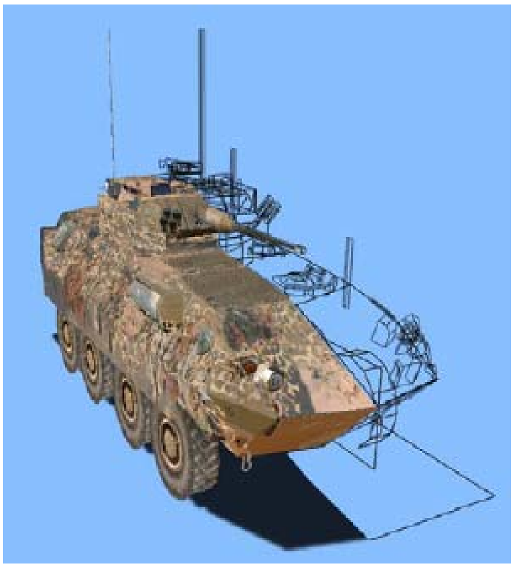
a. **Level of Detail** – the information required to simulate a system is often more detailed than the Original Equipment Manufacturer (OEM) publishes or releases. Sometimes information at the required level of detail is not available (especially for older systems), either because it was never collected, compiled and retained during the equipment development effort by the OEM, or the OEM is unwilling to release the data as it comprises sensitive Intellectual Property for the OEM.

b. **Standards** – data from various suppliers may conform to some defined standard – which the simulation designer needs to be aware of and able to handle. An example is geographic data – where the data structure may assume the world to be flat, perfectly spherical, or an approximated oblate spheroid (as it actually is).

c. **Consistency** – if two simulation designers each have data about an area which is ostensibly the same, but in fact is inconsistent (eg of different resolutions), then problems can arise when the two simulators try to interoperate. An example is terrain data, where one aircraft simulator flies just over the top of a mountain peak, but another simulator using different inconsistent data perceives the aircraft as flying through the mountain peak.

d. **Currency** – as equipment undergoes changes during its lifecycle, the related data used by the simulator supplier for model design is often not updated – making it difficult to keep the simulator consistent with the real equipment.

e. **Classification** – some data is classified (particularly weapons sensors data, and electronic warfare systems), which can complicate acquisition of the data and who can access the data. As models developed using the data often embed classified performance and functions, simulation models can assume an unwanted security classification, resulting in operational and support



Model of an Australian Light Armoured Vehicle – source Thales Training & Simulation implications for the simulator.

f. **Validation** – the validity of equipment design data (ie how accurate is it) is often undeclared or unknown. If a simulator is built using data of unknown validity, then the validity of the simulation may not be able to be established. Ideally, data should be certified as valid by an appropriate body that can attest to the validity of the data. Data validity is often an issue where data is compiled from computer models and other predictive techniques. This is often the case for data describing system performance beyond the established operating limits of the equipment - particularly so for aircraft and nuclear reactors.

2.8.2 Latency

61. Latency or transport delay is a design issue related to the length of time it takes simulation systems to react from the time of operator input until the system starts to present a response to that input. Just how much latency affects a simulation depends on the speed of real-time processing of the models and how sensitive control feedback is to the activity being performed.

62. Tasks that are characterised by dynamic fast moving displays and fine motor skills based on displayed conditions are typically known as “high gain closed loop” control tasks. Accurately tracking a fast moving target on a screen with a cursor is an example of this type of control activity. These tasks are most susceptible to latency delays, and sometimes experience unwanted effects due to latency. Tasks that do not require close attention to displayed information or demonstrate low rates of change are known as “low gain” control tasks. Such tasks are rarely affected by latency.

63. The effects of latency on simulations can vary considerably. Mild effects could be a perception that the simulation is different from the real equipment, but not sufficiently to prevent the simulation from achieving its objectives. Latency can also make closed loop or “feedback” control tasks more difficult to perform. In very high gain situations, it could be impossible to complete the task.

2.8.3 Sensory Disorientation

64. Variations in human sensory stimulation can lead to disorientation, which manifests itself as vertigo or motion sickness. The brain subconsciously correlates various sensory perceptions, including aural, visual, vestibular (inner ear), proprioceptive (skeletal and organ movement) and haptic sensations. When these sensory inputs lack consistency, the brain becomes confused, and body responses such as vertigo are induced. Some circumstances induce a rapid onset of vertigo that prevents activities from being completed successfully. The most common circumstance causing vertigo is inconsistency between visual and motion perceptions. Caution and expert analysis is required where motion simulations are used, or where body motion is simulated visually. Both fixed base and moving simulations are

Spatial Disorientation Simulator
- Source ETC Aircrew Training Systems

affected to some degree by this problem.

65. Where there is potential to induce disorientation, it is important to prevent people who have used such simulations from performing other activities immediately following use of the simulation where their state of disorientation could impair their performance and lead to accident, injury or death. The time required to recover from disorientation effects will vary depending on the severity of disorientation induced and the criticality of special awareness for ensuing activities. Activities such as flying, driving and operating hazardous equipment should be prohibited immediately following a simulation use session. Expert advice should be sought on the time required for recovery.

Simulation Induced Disorientation

Simulation induced disorientation occurs in all simulations where inconsistent or incomplete sensory inputs are perceived by the brain.

Critical activities such as flying, driving and operating hazardous equipment should not be performed immediately after using a simulation with disorientation characteristics until adequate time has passed to recover from any disorientation effects.

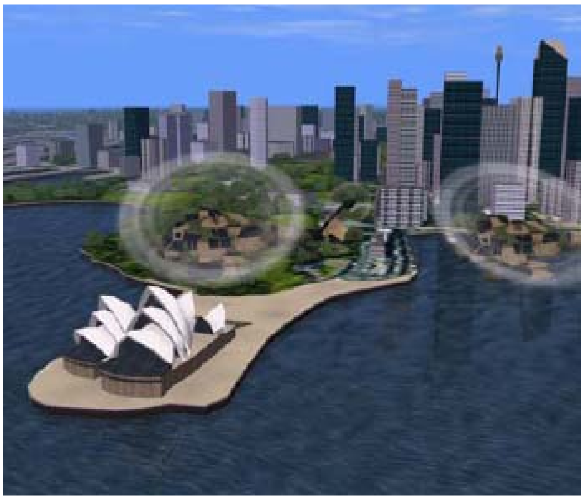
2.8.4 Desired outcomes

66. Writing the specification for a simulation is a difficult task. As previously mentioned, practicality dictates that the simulation will be a compromise or approximation of the real world – so the specification has to clearly define what should, and need not, be simulated. A methodology that derives modelling requirements from the intended use or purpose for a simulation is needed.

67. For a training simulator, a good place to start is to perform a Training Needs Analysis (TNA). This views the simulator as just one resource to be used in the total training regime – other resources could include the classroom, computer based training software, multi-media demonstrations, and the real equipment or operational environment. Linking the resources together in a defined learning strategy creates a complete training system.

68. The **Training Needs Analysis** defines all training tasks that need to be addressed by a training system, catalogues those training tasks best accomplished using simulation, and identifies the characteristics and fidelity required from a simulation in order to successfully accomplish specific training tasks.

69. For example, are circuit breakers important in an aircraft cockpit simulation? Will a photograph, fixed onto the cockpit structure at the right position suffice for the intended purpose of the aircraft cockpit



ARH Synthetic Environment - Source CAE simulation? Does the pilot need to be able to operate the breakers to practice a procedure, and if he does, what consequences of operating the breaker need to be simulated to successfully accomplish the intended training procedure?

70. These are vital questions that help define what the simulation supplier must model, and the fidelity required for the simulation to achieve its intended aims. The same questions are vital for the ultimate simulation users to decide whether the simulation provided is suitable for its intended purpose, and whether to authorise the use of the simulator for that purpose.

2.8.5 Unintended outcomes

71. A potentially serious simulation issue is avoidance of unintended outcomes. In training applications, this is often referred to as "negative training" and occurs when the simulation model designs exhibit characteristics and behaviours that vary from the real system being simulated. Unintended outcomes are more likely when the nature of the model approximations have significance that leads to incorrect conclusions and learnt behaviours, and these become the root cause of incorrect use and application of the real equipment.

Instrument Procedure Trainer
- Source CAE

72. There is no rule of thumb for deciding how much model variation will lead to unintended outcomes. The smallest of variations between a simulation model and the real world can cause unintended outcomes, and large modelling variations may have no adverse effects whatsoever. The factors are human perception and cognitive response processes.

73. Some have attempted to avoid unintended outcomes by specifying higher than necessary levels of model fidelity. This approach incurs significant additional cost, provides little guarantee of avoidance, and does not eliminate the need to evaluate the simulation for unintended outcomes.

74. Identifying unintended outcomes is, by its very nature, difficult to accomplish in design phases when creating simulation models. Thus it is advisable to evaluate the simulation when used for its intended purposes to determine whether unintended outcomes or negative training is occurring. This is normally a focus of VV&A activities, but something that should be undertaken in situations where no VV&A activity is performed.

75. The remedy for unintended outcomes is to either modify the design of the simulation models, or alternatively avoid using the simulation for those practices where adverse unintended outcomes have been identified.

2.8.6 Acceptance

76. Acceptance of a simulator by users is often a thorny issue, both from a procurement contract perspective, and gaining user confidence and support for the simulation. The two perspectives more often than not became tangled together. Acceptance of simulation is rarely a problem if the intended purposes are defined, if the desired outcomes are well known and understood, the requirements clearly specified to best practice, and all necessary data is all available and validated.

77. Seems simple – but often ends up becoming an issue! Acceptance for many simulators has been a lengthy and difficult experience. Savvy buyers, users and designers will try to avoid subjective acceptance criteria. Some common techniques used to overcome acceptance issues are:

SH-2G(A) Full Mission Flight Simulator - Source CSC

a. Design and test to agreed “**design criteria**” – a collaborative approach between designer and expert user that catalogues all relevant sources of data, examines and agrees which data items are the best reference for design and test, identifies gaps in design and test data, and agrees inventions and assumptions to address identified data gaps. Models are then tested against the agreed design criteria. This approach is very effective in situations where there are numerous inconsistent sources of data, where there is an absence of suitable data to complete some design and test activities, and where there is significant input required from users on display and control presentations. The approach also inherently gains user participation and ‘buy-in’ to the simulation.

a. Provide for “tuning” under subjective guidance by an acknowledged expert user – often referred to as a “**golden arm**” in flight simulator applications. This approach is based on adjusting performance characteristics of a simulation model based on the subjective opinion of a single acknowledged expert during a single period of model “tuning”. The approach has limited scope as the range of tuning possible is confined by the underlying design assumptions embedded in the model, and the expert often quickly “learns” the performance of the simulation model, diminishing his ability to discern differences from the real system. The approach does engage the user community to a limited extent and it does avoid differences of opinion between uses, but to keep things in perspective, it should be acknowledged that the approach does exclude most of the user community, and relies on an appeal to authority – which can be fallacious, particularly where the identified expert user is not universally respected.

b. Identify one item of the equipment being modelled as the single **reference baseline**. This approach selects the one instance of the equipment being simulated that is to be used as the reference source for model acceptance. Selection of the single reference item of equipment is problematic, as there could be significant variation within the equipment inventory, and it is difficult to determine whether the function and performance of the selected reference item is representative of the equipment inventory. It can also difficult to determine whether published equipment design data is consistent with the referenced item, and potentially commits the reference item to exhaustive testing in order to extract sufficient data to design and test the simulation model. This approach excludes participation and buy-in from the simulation user community, and risks creation of a simulation that is not representative of the range of the equipment inventory.

Armed Reconnaissance Helicopter Simulators
- Source Thales Training and Simulation

Appendix A. Examples of simulation in use

A.1. DEFENCE APPLICATIONS

A.1. Modelling and simulation has broad applications – both in the defence, and non-defence contexts. Here are just a small number of defence-related examples, grouped into the ***Defence Simulation Policy*** Application areas described previously in section 1.4:

A.1.1. Training

- A Mine Warfare and Clearance Diving Gaming capability for the Royal Australian Navy (RAN).
- Training courses, delivered over the internet, embodying simulation to improve knowledge transfer.
- Personnel weapons training simulation systems to train in weapons handling, and target identification.
- A live simulation environment which will be used to train and evaluate combat team leaders and their combined arms teams in a realistic battlefield environment. The system will simulate direct and indirect fire weapon effects and other area effects, in the live domain.
- An Advanced Ground Based Air Defence Simulator used to train target recognition, acquisition and missile deployment.
- A Black Hawk Full Flight and Mission Simulator enhances both aircraft handling skills, and operational competence.
- The Airborne Early Warning and Control platform has both an Operational Flight Trainer (for training pilots) and an Operational Mission Simulator (for testing the sensor system operators)

Advanced Ground Based Air Defence Simulator Concept
- Source Thales Training and Simulation

- Part-task trainers at HMAS WATSON develop skills in radar, sonar and missile systems. Team capabilities are developed in ship operations room simulators.
- Training simulators located in Australia, manned by real ship's crews, were networked with similar simulators in the US, including an operational US Navy ship, for a Coalition Readiness Management System (CReaMS) training exercise.

A.1.2. Mission Rehearsal

- Simulating a landmine route clearance task.

- Using a desktop flight simulator to review, optimise and rehearse a mission route profile from initial entry to egress from the target area.

A.1.3. Conduct of Operations

- Agent technology (refer to section 2.4.3), which simulates human behaviour to an extent, is being considered for use in the Joint Strike Fighter cockpit to assist the pilot in making optimum decisions during conflict.
- Using a real-time virtualisation of the battlespace to gain situational awareness and test battlefield strategies.

A.1.4. Crisis Management and Planning

- On 17 June 2004, Australian Defence Force troops stormed a Sydney office building as part of a mock counter-terrorism exercise. The training was coordinated with Sydney's emergency and security services.

A.1.5. Force Assessment

- A modelling and simulation capability is used to analyse the impacts of networking on a force; that is, for exploring the concepts of Network Centric Warfare (NCW). The study of NCW is primarily focused on understanding the effect that exchange of information within a group of coordinating forces has on their effectiveness, especially the dynamic interactions from command and control to communication and decision-making.

A.1.6. Experimentation

- DSTO has undertaken a research approach to explore optimum helicopter defensive tactics against a generic man portable surface to air missile. The cognitive model is based on the OODA (Observe, Orient, Decide and Act) loop.
- Using simulation to study how people alter their decision-making and interactions with other military personnel when they are influenced by various moderating factors, such as heat, tiredness, consumption of stimulants like caffeine, as well as battlefield experience and cultural factors.

Constructive Simulation Adaptable Pilot Station
- Source CSC

- The Future Operations Centre Analysis Laboratory (FOCAL) provides a large collaborative semi-immersive Virtual Reality display environment to explore new paradigms for situation awareness and command and control in military operations centres.

- The Virtual Battlefield System was used to examine alternate section structures - 8-member, 9-member, and 12- member – for optimum performance under various scenarios.

A.1.7. Research and Development

- Modelling of the positioning of land based radar system to maximise the instantaneous probability of detection, taking into account overlapping coverage regions.
- Using modelling to study the robustness of communications network topologies.
- A night-vision laboratory at DSTO simulates the effects of flying helicopter formations at night, to study the effects of infrared lighting.
- The Integrated Avionics Systems Support Facility (IASSF) provides a simulated environment to test F/A-18 avionics, avionics software and system behaviour on the ground without the initial need for real F/A-18 flight testing.

A.1.8. Acquisition

- A simulation environment that allows for rapid integration and usage of new models of physical systems and human operators was used to evaluate competitor Airborne Early Warning and Control (AEW&C) aircraft in specified mission scenarios.
- Operations Research was used to analyse air-to-air combat related to the possible acquisition of a major new air capability.
- The environment was extended in an exercise that involved an assembled AEW&C crew viewing an air picture presented on a screen in real-time, and controlling many aspects of the platform through a graphical user interface. These include the movements and sensor usage of the aircraft. Enemy and allied forces were inserted and controlled, to provide a total air picture of the scenario.

Royal Navy Lynx Full Mission Simulator – source CAE

A.1.9. Life Cycle Management

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- Simulation tools for the ADF’s replacement patrol boat project included reliability modelling, logistic support system design and simulation, use of optimisation techniques to simulate annual and life cycle operational plans and life cycle cost modelling to identify cost drivers, refine design and fine tune the integrated support system solution.

A.2. NON-DEFENCE APPLICATIONS

A.2. Simulators are used in non-defence areas too – such as:

a. Aviation – for example evacuation training

b. Medical – surgical and anaesthesia training simulators

c. Transport – post-accident analysis, and work-force team training

d. Manufacturing – rapid prototyping and testing, optimisation of equipment and assembly lines

e. Business - simulation tools to support organisational change and development.

RAN COLLINS Class Combat System Trainer
- Source CSC

Appendix B. Simulation Enhancing Defence Personnel Skills and Effectiveness

B.1. Modelling and simulation is a valuable tool in developing staff operative skills, facilitating operational excellence, improving staff effectiveness, and preparing staff to accomplish tasks beyond their ability to imagine. Expert and innovative application of simulation has great potential for optimising the activities of Defence organisations that contribute to Defence outputs.

B.2. In these Appendices, we look at two "journeys" – one of a person (Appendix B), and the other of a platform (Appendix C) – to illustrate the potential value of simulation application within Defence.

B.3. Let's follow the career of a new recruit – we'll call her Simone. She has just left school (where she was Dux), and has applied to join the ADF with ambition of being the best pilot in RAAF. Simone is confident she is made of the "right stuff" to be the best, but knows that to achieve her ambition she must "go where others before her have not gone".

B.1. DOES SIMONE HAVE THE RIGHT STUFF?

B.4. Even before gaining selection for entry into the ADF as a pilot, Simone was being assessed for pilot aptitude using simulation. At the recruiting office, she had to sit in this pilot screening device and keep a moving dot on the screen within a small circle in the centre of the screen. She had to do this operating a combination of a hand lever and foot pedals that influenced the motion of the dot across the screen. It was a little more difficult than she imagined, and she had to coordinate hand and foot movements. The simulation device monitored and analysed her performance and presented Defence psychology staff with information on her aptitude to be a pilot. She scored well and the simulation gave recruiting staff high confidence they were making the right decision to select Simone for pilot training. The simulation model had been continuously refined over many years and had become a reliable indicator of pilot aptitude. Her score indicated a high probability that she would pass flying training – an important consideration since pilot training is very expensive to complete. This simulation is delivering real cost savings for Defence.

B.2. LEARNING THE BASICS

B.5. Simone starts her journey by learning the basics of what it means to be in uniform in the ADF - saluting, marching, field deployment skills and basic arms training. During her first field exercises she experienced her first simulation – a mock attack where instructors, students and other "players" stepped through a *live* simulation of an ambush engagement. Simone thought she was well prepared for the simulation and knew all that she was expected to do, but she was surprised at how unexpected events in the simulation disrupted her understanding and decision-making thoughts. She performed OK, but not as well as she thought she would, and she now knew some things she need to work on to be better. She also learnt that knowledge alone would not be enough to achieve her ambitions, and that she would need to practice her skills to develop the experience needed to achieve her career ambitions.

B.3. SPECIALIST ROLE TRAINING

B.6. Having completed basic service induction training, Simone now starts her flying training. Her initial training is all classroom based, learning flight theory and aircraft operating procedures and practices. However, it is not long before Simone encounters new simulators, which help her understand what she has been taught in classroom lessons.

B.3.1. Desktop Part-Task Trainer

B.7. Simone has just been taught basic operation of aircraft flight instruments, how they work, what they mean, and how they should be read and interpreted. She has now been programmed to continue her training using a part-task trainer – another simulator that allows Simone to reinforce her knowledge of the instruments and practice scanning and interpretation skills. Simone notices that the instruments look just like some of the instruments she has seen in pictures of aircraft cockpits and the instruments that were used to teach how each type of instrument worked.

B.8. The simulator is just a standard desktop PC with simulation software loaded. Using a mouse, Simone finds she can operate all of the knobs and controls on the instruments, and that interactive help is available simply by moving the mouse pointer over the part of the instrument that she is unsure of. Simone finds she can also change the instrument look to one of many predefined types, and that she can select different flight profiles that demonstrate various instrument responses and test her interpretation of what the instruments display. She takes the simulation software home on a CD, and loads it into her own computer. She continues testing herself until she is satisfied she knows her stuff.

Instrument Procedures Trainer - Source CAE

B.3.2. Procedural Part-Task Trainer

B.9. Having mastered instrument presentations and interpretation Simone moves on to practice instrument scanning techniques that she was taught during classes. She knows that developing a good subconscious scan technique will give her the edge she needs to deal with unexpected emergency drills that her instructors will use to test her progress. Simone remembers back to her first simulation out in the field, how it revealed her weaknesses, and gave her direction on where she needed to practice.

B.10. Determined to learn from that experience, Simone moves onto a different part-task trainer. This one is still a desktop PC, but it has several monitors attached that display aircraft instrument and control panels. It also displays a simple cartoon image of a runway drawn on a flat textured representation of the ground. Not as good looking as in some computer games, but nonetheless easy to picture as a runway. There is also a control stick handgrip and throttle grip with lots of buttons beside the monitors – they look just like the real trainer aircraft. Simone quickly loads the instrument panel that replicates the aircraft she will first fly next week. It looks like the real aircraft and she quickly starts practicing her initial checklist actions and her engine start procedures. The part-task trainer monitors all of her cockpit actions that require control actions and reports to Simone some that she missed and others that she did out of sequence. Simone quickly learns where she needs to improve and sets about achieving flawless execution.

B.11. This part-task trainer includes sound simulation, and Simone quickly learns to use background sounds to reinforce her actions and identify when something is amiss. Because she has practiced and rehearsed her procedures thoroughly, she is confident she will perform well and will not be distracted by unexpected events. She also knows that she will be able to maximise her limited time in the aircraft by not having to concentrate on things she has already mastered using the part-task trainers.

B.12. Simone is surprised when she takes her first flight, not by the experience of her first flight, but that her instructor did not drill her on completing procedures and instead coached her on techniques to improve some of her weaknesses. He seemed to know just where she needed help. Simone soon discovered that the instructor reviewed her progress on the part-task trainers through the network, and extracted the analysis of her performance that highlighted areas where Simone needed some coaching. Simone was just now starting to understand that the simulators were more than just a training tool for students to practice on.

B.3.3. Basic Flight Training Device

B.13. Having got over the thrill of her first flight, it was now down to the hard work of developing Simone's piloting motor skills. Simone was quick to pick up manoeuvring skills – something that was accurately predicted by her initial simulation screening test. She also found the basic flight training devices used by the flying school to be helpful. They were not the high fidelity flight simulators used by civil airlines that she had read about. They were surprisingly basic – a crude cockpit representation mounted on a motion base with a look ahead and up display projection system mounted in front of the cockpit on the platform. The basic cockpit flight instruments were all presented on a single flat screen display – not the real instruments, but the right size and in the right place. There were no radios and none of the ancillary systems she was used to seeing in the real aircraft, but it did have an aircraft seat harness to strap into.

B.14. Simone's instructor explained that this flight training device was designed to allow Simone to rehearse and practice flight manoeuvres before she attempted the manoeuvres in the real aircraft. He went on to explain that this would avoid wasting valuable flight time on learning manoeuvring and allow him to refine her manoeuvre skills in the limited flight time that they could use. He also joked that it would save him the unnecessary anxiety that instructors once experienced in the first 10 or so hours of flying with a new student. Simone was also warned that she would need to rehearse her manoeuvres at least eight hours before her real aircraft flights, as there was a rule prohibiting flying in the real aircraft within eight hours of using the basic flight training device.

B.15. Now being savvy to the benefits of simulation, Simone set about rehearsing her second real flight in the basic flight training device. After confidently strapping in, she initialised the simulated aircraft ready for take-off. She was sure that she would be able to handle the take-off without too much drama – after all, it was fairly straight-forward and seemed easy on the first flight when the instructor performed thought the take-off. Simone thus decided not to use the demonstration mode where a pre-recorded take-off manoeuvre could be experienced before attempting the manoeuvre herself. Simone released the brakes and advanced the throttles. She experienced the feeling of acceleration - being pushed back in her seat and was momentarily reassured by that feeling. However, she did not expect the sideways lurch she felt and was not ready for the large swing of the aircraft direction. She struggled to keep the aircraft going straight down the runway. Speed built up rapidly and Simone, still unsettled by the challenge of steering the aircraft straight jerked back on the control column. The aircraft continued to veer off the runway and as her wheels left the ground her wing dipped and caught the ground. The cockpit was thrown violently forward and Simone felt herself restrained by the seat harness. Everything stopped – Simone had misjudged the yaw effect of applying full power and lost control on take-off.

B.16. Simone now understood why the flight training device had a seat harness. She also appreciated that while her pride had taken a crash, there was no other damage. No one had been hurt, there was no wrecked aircraft and her instructor did not suffer any unnecessary anxiety. Her instructor, who had been observing the whole incident from the instructors console, chuckled and asked Simone if she would like to replay the sequence to analyse where she went wrong, or whether she would like to review the demonstration to learn what control inputs she should have been applying. Humbled, but wiser, Simone elected to review the demonstrations first, and then replay her effort to understand where she went wrong.

Electric Motion Base
- Source Moog Australia

B.17. Simone quickly learned not to judge a simulator by its looks. It may have seemed a crude device, but it accurately modelled the aircraft flight controls, engine throttle and aircraft performance. By Simone’s reckoning, the cost of the device had just been repaid 10 times over.

B.3.4. Flight Rehearsal

B.18. Determined to be the best, Simone continued to use the flight training devices to improve her emerging pilot skills. She was also keen to allay her instructor’s anxieties. Simone found that rehearsing flights in a simulator allowed her to spend more time perfecting, rather than learning, her skills in the real aircraft. Her aircraft flights were not consumed in getting the manoeuvre basics right, and her instructor was always well prepared to assist Simone overcome her weaknesses and difficulties. By observing Simone’s performance in the basic flight training device and applying the expert analysis tools embedded in the simulators, Simone’s instructor was able to apply specific coaching to address her weaknesses.

B.19. It was no surprise to the Flying School instructional review staff that Simone had excelled. Simone was very confident in the air, advanced quicker than her peers and consistently achieved superior assessments. It was no coincidence that Simone also logged the greatest amount of time in the flight training devices, particularly before her progress tests and assessment flights.

What is Field of View?

Field of view (FOV) refers to the extent to which imagery is presented horizontally and vertically on a display. The FOV determines the extent to which an operator seated in the normal viewing position is presented with visual imagery. For example, a small 48 x 36 degree FOV may only allow an operator to view objects directly in front as one might through a small window. A larger 180 x 40 degree FOV would allow an operator to view a wider range of objects to the left and right, but still with a limited view up or down.

The FOV of a display is measured in terms of degrees measured from the viewing eye point. The FOV reference point is normally directly in front of the operator at eye level, and is referenced as 0 degrees.

B.4. OPERATIONAL CONVERSION TRAINING

B.20. Simone graduated at the top of her flight school course, and was assigned to the Fighter Conversion Unit, where she would learn fighter jet handling and air combat tactics. Simone was on the way to achieving her ambition of being the best. She recognised that the next phase would be even more difficult than what she had been through, but was confident that her ability to make the most of simulation would help her excel in this new phase of her career.

B.4.1. More Part-Task Trainers

B.21. Simone knows that the first step she must take is to learn how to fly the lead-in fighter training aircraft. She recalls her initial pilot training and remembers how useful the part-task trainers were for learning the aircraft systems, cockpit layout and flight procedures. She is pleased to learn that the fighter conversion unit has the same comprehensive suite of training simulators, and very soon is flying the lead-in fighter jet with confidence and growing skill. It is now time for Simone to take her flying skills to the next level – that of a novice fighter pilot.

B.4.2. Distributed Mission Trainers

B.22. Simone is ready to start learning basic fighter manoeuvres. She is hardly surprised to learn that a new type of simulation will be used – one that allows multiple participants. This simulator comprised a lead-in fighter cockpit fixed to the floor beneath a large dome upon which imagery of the sky and ground were projected in a complete hemisphere Field of View around the cockpit. She noticed that there were several of these simulators in the facility and that the training program scheduled them in pairs. Simone soon realised that these simulators were linked, so that the pilot in each cockpit could fly in formation with the other. Simone was soon practicing manoeuvring as a wing-man to her lead in the other simulator. She found this a little difficult at first, over compensating her control of the simulated aircraft and finding herself swinging wildly around the position she was meant to be relative to the other aircraft. She practiced manoeuvring as a wing-man until she could keep station with precision and smooth control. Practising her skills in the simulator paid off yet again, as she was able to quickly master the skill in the real aircraft, and some of the flight could be used to demonstrate more advanced formation manoeuvres.

What types of Visual Display system are there?

Helmet-Mounted Displays obscure the trainee's normal vision, so that they only see what is projected. This can be wide-angle, stereoscopic images, to give depth perception and total visual immersion. A *head tracker* allows the position of the head to be measured, so that the displayed image can be adjusted so that the viewer sees what he expects as he looks "around" an environment.

Less expensive than a *dome* display, Helmet-Mounted Displays have issues with comfort, resolution, and latency, and need special provisions so the user can see the actual cockpit instruments.

Other systems involve some form of projection (front or rear), onto a screen (curved, or series of flat screens), or via mirrors.

Multiple projectors operating on the one screen will need some form of *edge blending* to avoid obvious boundaries.

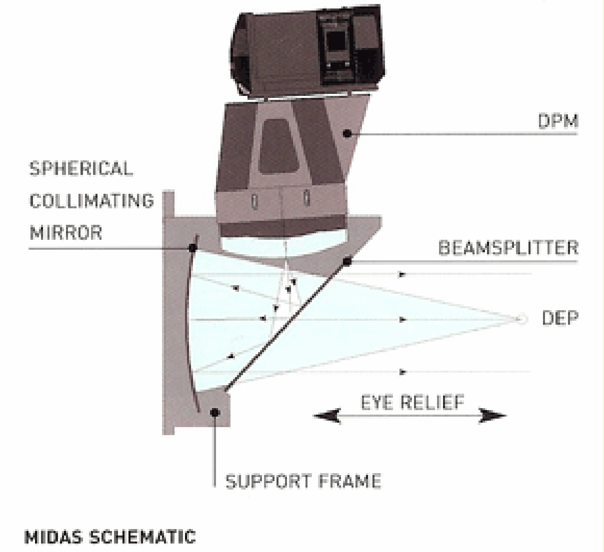
Selection and design of the Visual Display system is a complex and critical task.

B.23. As Simone progressed, she found the number of aircraft in formation increased and the manoeuvres became more complex. To her surprise more simulators were networked together, so that she could now practice with her colleague in multi-aircraft formations. Simone and her fellow students found the demonstration mode of the simulators particularly useful in this phase of training, as they could sit in the cockpit of the simulators and repeatedly watch the manoeuvres being performed by the computer simulation model. The simulation model allowed the manoeuvres to be slowed down at crucial times when aircraft passed at close proximity, and each aircraft had its own colour trail left in the air behind it, showing where it had been in relation to the other aircraft. Simone found that she and her colleagues could view the flight paths from any viewpoint they wished, above, below, in front, behind or to the side of the formation. She found this to be particularly useful in gaining her spatial orientation prior to attempting the manoeuvre herself. Simone also liked the way she could switch between each aircraft to see what it looked like from the other aircraft.

B.24. Simone also found that she could practice in the simulator by herself – using computer generated forces manoeuvring according to programmed rules and behaviours to provide the other participants in the formation. She found the simulated participants to be equal to the task at this stage of her training. Having completed intense practice on formation manoeuvres in the simulators, Simone found the training she had completed in the simulators allowed her to easily visualise where she needed to be when flying the real aircraft. As a consequence there were no mishaps when they attempted the same manoeuvres in the real aircraft and they were able to achieve considerably more in the limited flight time they had available for training.

B.25. Simone soon found herself able to take the aircraft to the limit with confidence and authority, and she quickly developed aggressive flying skills that enabled her to excel against her peers. She was cruising on her path to be the best – but was she? One day, after concluding a particularly demanding flight, Simone was approached by the squadron engineering officer. He informed Simone that the way in which she was manoeuvring the aircraft was causing unnecessary fatigue damage to the aircraft. The engineering officer took the data recorder from the aircraft she had just flown and loaded it into a different type of simulator – one that allowed Simone to view the forces she was placing on the aircraft and the flight dynamics profile of the aircraft. The engineering officer replayed control movements that Simone had just performed just a few hours before. The simulator presented the stress profile on critical aircraft components, and then demonstrated alternative control inputs that would have achieved the same flight profile but with significantly less stress on the aircraft. Simone was stunned just how much airframe stress could be reduced, and realised that this simulation could help her better manage the energy profile of the aircraft. She realised this could be the edge she might need to beat an adversary. Simone was soon using this simulator to study the efficiency of her aircraft energy-manoeuvre management.

Collimated Visual Display



- Source SEOS

Collimated – Collimated displays theoretically are focussed at infinity. Hence it is a virtual image. The advantage of collimated displays is the image has correct perspective from a wide range of horizontal viewpoints. In practice they provide an image eye relief of about 20 metres. The disadvantage is a very limited vertical FOV.

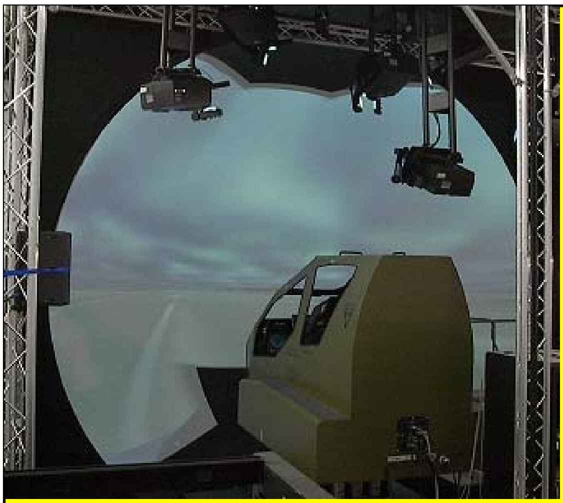
By their very nature, collimated displays are curved.

B.4.3. Weapon and Sensor Trainers

B.26. Simone was developing into a competent fighter pilot and was now ready to enter weapons and sensors phases of her training. In this phase Simone learns how to efficiently operate the aircraft sensors and weapons to accomplish specific engagement objectives. Simone starts with radar training. This starts with desktop simulators of the radar controls and displays. This desktop simulator allows Simone to quickly familiarise herself with the detection performance and mode characteristics of typical air-to-air and air-to-ground radars. The simulation quickly guides her on how to use the radar to maximise the probability of detection and achieve a quick lock and track of a target. Simone starts with simple single target tasks, and rapidly moves on to multiple target scenarios requiring advanced interpretation skills and fine control of the radar. Simone also learns how to interpret ground mapping radar returns and artefacts. What surprises Simone is the simulated radar images are indistinguishable from the real radar images she sees later on in the aircraft.

B.27. The next step is for Simone to integrate her radar operation skills with her fighter combat tactics. Simone is introduced to a new simulator for this task – it is a cockpit with basic operating flight instrument replicas, an accurate simulation of the radar displays and controls, representative flight manoeuvre performance and a single flat panel display in front of the cockpit displaying a basic sky-earth image with the head-up display superimposed on the image. It is crude in some respects, but it provides the basic aircraft orientation and control, an accurate radar picture and weapon inputs needed to reach a weapon release against an enemy target. It allows Simone to practice the integration of her flight manoeuvres, sensor control and weapon delivery to achieve an effective weapon launch solution. This simulation allows Simone to bring together flight manoeuvres and sensor control to achieve an effective enemy target engagement. Simone is now learning the skills she will need to master to become a good fighter pilot. In the modern fighter game, the advantage rests with the pilot who can achieve the quickest and most effective target acquisition and weapon solution.

B.28. Simone continues practicing sensor and weapon engagement using the variety of simulators available to her to complete fighter conversion. She soon learns that most of her weapons training will be accomplished using simulation. Only a limited supply of live weapons are available for use during peacetime, and environmental concerns restrict opportunities for live weapon releases. Simone rehearses some weapon delivery profiles in the real aircraft, and finds that she can practice these manoeuvres and procedures in a simulator. In fact, Simone prefers to practice these manoeuvres in the simulator as she does not have to modify her delivery profiles to satisfy noise abatement measures that are in force at the nearby weapons range, and she does not need to use modified procedures to simulate live weapons carriage and release in the aircraft.



SEOS PRODAS Display System - Source SEOS

Non-collimated Visual Display

Non-collimated displays are real images projected on a display surface. The advantage of non-collimated displays is an almost unlimited FOV. The disadvantage is the image perspective is only correct when viewed from a single eyepoint. In practice non-collimated displays provide an image eye relief equivalent to the distance from the eye to the projection surface.

Non-collimated displays can be almost any geometry desired as long as the image can be corrected for viewing on that geometry and no shadow zones are created.

B.29. Having mastered sensor and weapons in the aircraft, Simone moves onto self-defence tactics. She finds this easy to accomplish in the real aircraft when the threat is another fighter aircraft, but Simone is worried that there are few realistic opportunities in the real aircraft to train against SAM (Surface to Air Missile) and other projectile threats. She knows that experience in dealing with enemy threats is the difference between battle-ready pilots and those who are simply skilled at delivering weapons against enemy targets. It is relatively easy if no one is firing at you, but can you do it when the enemy has you aimed up and is firing at you? Simone is nearing the end of her conversion and she wonders if she will measure up to this benchmark. She knows this is one of the most vital skills she must gain, and that there are few opportunities to gain these skills outside of combat.

B.30. Simone has used an EW (Electronic Warfare) simulation pod on her aircraft that injects threats into the aircraft EW system, and finds this simulation system of some use, but she is disturbed that she cannot see the threat effects using this system. She finds it difficult to manoeuvre against something she cannot see out of her cockpit, but ought to see. She recalls viewing cockpit imagery in the Gulf War where the sky before the F-117 aircraft was literally filled with tracer projectiles, and missiles were seen to be streaking across in front of the aircraft. Simone wondered what it would be like to fly in an environment like that and whether she could pick out the important threats from the ones that could do her no harm.

The CARDS simulator at Renault using SEOS' Head Mounted Display - Source SEOS

Helmet Mounted Display

Helmet mounted displays use small beam splitters mounted in front of each eye to project images from small display tubes. By using a head tracking device, the image can be stabilised to respond to hand movements, providing continuous uninterrupted viewing of an environment

Because of their small size, image resolution is low, and the presence of beam splitters, tubes and umbilical cables can detract from the simulation.

Latency between head movement and image response can also cause significant discomfort.

B.4.4. Mission Rehearsal

B.31. To Simone's relief, she learns that there is a mission simulator where she can develop her skills in self-defence and weapon delivery. This simulator is like the distributed mission simulator she started her conversion in, except it has a complete simulation of all the aircraft sensors and weapons, and contains a comprehensive set of simulated enemy entities that can engage her aircraft as an enemy might in real combat. In her first exercise in this simulator, she sets off to deliver some laser guided bombs on some heavily defended air defence targets. Simone is confident that she can easily pin-point and deliver her weapons on the targets and sets off confidently on her simulated mission. She has previously completed numerous simulations of similar weapon delivery profiles flawlessly. Shortly before her initial run at the first target, Simone is startled by an unexpected missile launch warning on her threat display. She quickly deploys flares and manoeuvres to defeat the missile, but has now missed her initial point from which she had planned her run to the target. She quickly readjusts and sets about rejoining her planned track. She encounters expected radar contacts and anti-aircraft fire to the side of her flight path, and sees lines of tracer arcing toward her aircraft. She checks to ensure her electronic countermeasures set is operating and continues knowing that the countermeasures are effective against the threat and that her aircraft will be outside the engagement envelope of the AAA (Anti-Aircraft Artillery) battery before they can lock her on their radar. Simone has not quite made it back to her planned track and decides to attack the first target from a slightly different approach than planned, as this would be a straight-forward weapon delivery from her current position. She successfully completes her targeting and releases her weapon, encountering more anti-aircraft fire and another SAM missile launch. Although anticipated, she finds the missile threat distracted her from her weapon delivery profile. The weapon guides successfully to its target, but her weapon release parameters were marginal. She now swings her aircraft round to intercept the attack path for the second target. She accomplishes this easily, but finds that she cannot sight the target as thick smoke from the attack on the first target now obscures the next target. Alerted by the first attack, she encounters heavy enemy air defences. Simone is startled by the density of projectiles and missiles in the air before her and rapidly loses her situational awareness. She concentrates on intercepting her planned exit flight path and takes some hits. Her aircraft, now damaged, speeds away from the undamaged second target. Simone, now focussed on just escaping the engagement, is slow to fully assess the damage indicated by the aircraft warning systems. She completes many of the actions she needs to, but was too late in shutting off fuel flow to one of the aircraft's damaged tanks. Safely away from the targets and enemy threats, Simone realises she does not have sufficient fuel to reach her recovery base. She flies on, but mentally acknowledges that she will ultimately have to eject from the aircraft.

Full Mission Engine Room Simulator
- Source CSC

B.32. Simone stops the simulation and carefully weighs up what went wrong. She soon realises that she was not mentally prepared for the enemy threat environment. She knew enough about each type of threat, but found that unexpected threats distracted her in ways that she did not anticipate. She also learned that when she became 'saturated' with too much information, she narrowed her attention to returning to her original exit path, shutting out events which proved to be critical to returning safely from the mission. Although she failed to complete her planned mission and return her aircraft to home base, Simone was buoyed by the experience she had gained, experience that could not be gained other than through mission simulation or war. She was also interested to learn how she reacted when faced with task saturation. She recalled one of her instructors saying ‘whatever happens, just continue to fly the aircraft’, and she had done that. But she now also knows that she needs to control her response to such situations and to work on picking out the critical actions she needs to perform. Simone also pondered the smoke on the second target, and realised that she had not considered the effect of prevailing winds in her attack plans. Simone could forgive herself for encountering unexpected enemy fire, but vowed to be never embarrassed by a simple oversight like wind ever again. She was pleased that this lesson was gained in the confines of a simulator, and did not come with a real price tag.

B.5. OPERATIONAL LINE PILOT

B.33. Simone is now an operational fighter pilot. Like all pilots, she likes to get up in the air as much as possible. But Simone is also driven by her desire to be the best to continue using simulation. She mainly uses the mission simulator now – primarily to rehearse every mission she plans in the real aircraft. Simone uses the simulator to test the efficiency and effectiveness of her mission plans, and to mentally prepare herself for unexpected outcomes in each mission. Simone has found that rehearsing her missions in a simulator enables her to better deal with the unexpected.

B.5.1. Real and Simulated Become Blurred

B.34. Simone’s operational line duties as a fighter pilot involve continuous training activities. Some days Simone flies in real aircraft with and against other real aircraft. On other occasions she trains entirely using simulations. What surprised Simone was that it was becoming increasingly difficult to know whether the participants she interacted with were in real aircraft or simulations.

B.35. One night, Simone was flying a real aircraft – performing combat air patrol duties under the direction of an Air Defence Officer in an Airborne Early Warning and Control (AEW&C) aircraft. Simone received a vector from controllers to intercept a formation of four in-bound aircraft. Simone’s aircraft received datalink target information from an AEW&C aircraft – but she had not detected the AEW&C aircraft in the area and did not know if it was real or not. Simone steered onto an intercept course and observed the four aircraft approaching on her tactical display. One aircraft was real, the other three were simulations generated by the AEW&C simulator and attached as formation wingmen of the approaching real aircraft. On the ground, an AEW&C crew was busy in their mission simulator, receiving live and simulated radar tracks from real ground radars (which detected Simone’s and the approaching aircraft) and the Operations Centre. A complex air picture was forming, and for most participants, they could not distinguish between the real entities and the simulated entities. Simone was directed to attack the lead aircraft (which was the one real aircraft). She quickly locked the aircraft up on her radar and simulated an air-to-air missile release. The three wingmen (simulated aircraft) quickly turned and flew away with Simone’s attack. Simone broke off the engagement and returned to base.

What is an Image Generator?

The displays shown on the Visual Display System are produced by one or more image generators. These are PCs or specialised computers which can rapidly draw *polygons* and *textures*. These computers need to be rated to smoothly display an image of the correct resolution (detail). If the image generator and display system update too slowly (typically less than 30 times per second), then distracting flicker may result.

The images to be displayed come from the *visual database*. This is generally a combination of drawn and photographed objects. Generating visual databases can be expensive, and image generator-specific, and standards such as *SEDRIS* (Synthetic Environment Data Representation Interchange Standard) aim to improve re-use.

B.36. The following day Simone was programmed to fly in a Distributed Mission Trainer. The scenario included simulated aggressor strike aircraft, simulated combat patrol aircraft, a real AEW&C aircraft and real Operations Centre staff. Simone was once again on combat air patrol, and received intercept vectors from the AEW&C aircraft to attack inbound aircraft. This time the AEW&C aircraft was real, but Simone had no indications of which aircraft were real and which were simulated. She successfully completed her intercept as directed, and chatted a little with the AEW&C crew over her simulated radio (it was networked into the radio communication system) before completing her session and leaving the scenario. Simone reflected that it was getting harder to say who was real and who was not.

B.5.2. Mission Experience

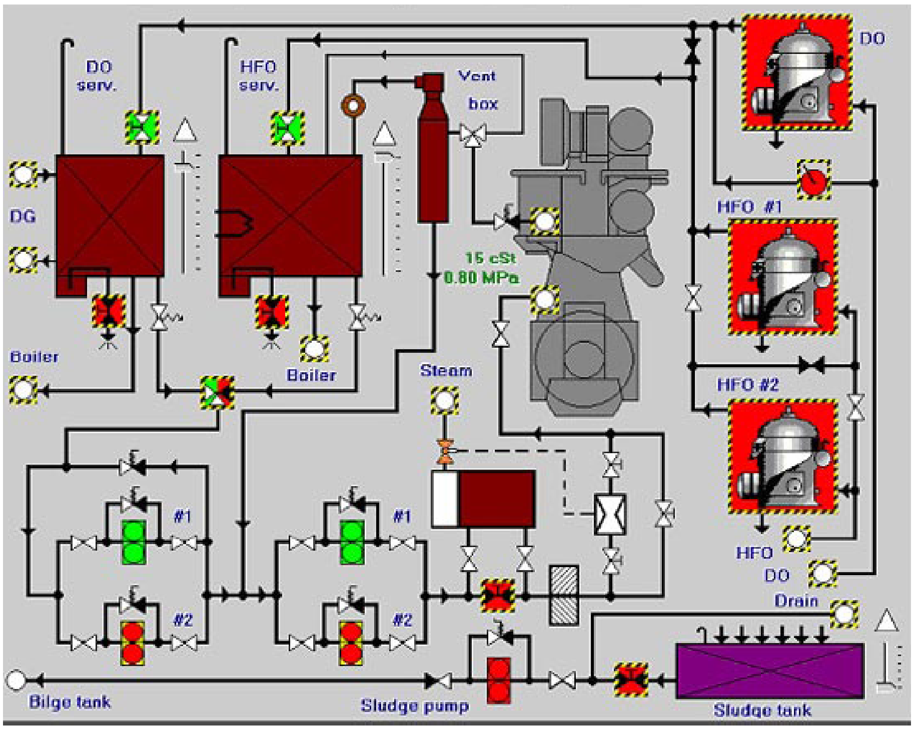
B.37. Simone later completed active service in the second Gulf War, and used simulation to prepare herself for the intensity of enemy air defences. She was astounded by how many shells were being put in the air over Baghdad, but was not the slightest bit worried. Through her simulation sessions, she was able to satisfy herself that the planned tactics, countermeasures and profiles were effective against the enemy air defences that she would encounter. Simone noted after her first mission that it had happened just like she had expected, although a little easier than what she had experienced beforehand in the simulator. Mission accomplished.

B.5.3. Using Simulation for Instruction

B.38. Returning from duty in the Gulf, Simone is selected to undergo fighter combat instructor training. Only the best are selected for this training, and upon successful completion become the instructors for future fighter pilots.

B.39. The fighter combat instructor training is hard, and involves considerable work in the mission simulators and distributed mission trainers. Besides honing her fighter combat skills, Simone also learns the other side of the simulators that she used when training to become a fighter pilot. Simone is introduced to a new world of instructional features and functions, ranging from presentation of simple training aids, and after action review, through to use of performance analysis software to identify weaknesses and coaching strategies.

B.40. Simone also learns that the success of the simulations rests very much on creating gaming scenarios that follow a learning strategy for each particular phase of training, how to correctly devise and implement gaming scenarios, and how to test the simulations to confirm the desired learning objectives will be achieved by students. She soon finds that the instructional features of the various simulators her students will use help her plan each instructional phase and activity, and provide her with the ability to see the performance of her students in real-time, as they are completing tasks. This allows Simone to address her student's problems immediately while the situation remains fresh in the mind of the student. Simone excels as a fighter combat instructor, due in part to her expert use of simulation for instructional purposes.



Desktop Mechanical Auxiliary System Simulation
- Source CSC

Appendix C. Simulation in the Capability Development Lifecycle

C.1. After many fruitful years of flying, Simone, whom we met in Appendix B, moves on to her next career phase, where she will take on command roles. While performing command tasks, Simone discovers a new range of modelling and simulation applications that help her excel in her command role.

C.1. OPERATIONAL LOGISTICS MODELLING

Life Cycle Management

C.2. Simone's first command role calls upon her abilities to understand the various operational elements that must be drawn together to successfully deploy a fighter squadron. She knows she can rely on her engineering colleagues to work out just how many spare parts and personnel need to be deployed to the forward base. The logistics staff officer told her that they were using a supply chain model that accurately predicted support requirements and staffing based on inputs of expected rates of effort and location of the forward base. Feeling confident that arrangements for maintenance and supply support were being well served by models, Simone turned her thoughts to considering requirements for fuel, liquid oxygen, and the types of weapons and munitions the deployment would require for the types of targets they were engaging.

C.2. WEAPON EFFECTS MODELLING

Research and Development

C.3. Simone initially selected munitions that were sure to get the job done, but quickly found out that sufficient stocks were not available to support her requests. The explosives engineer suggested to Simone that there were other munitions she could use that would achieve the same objectives. Simone was unsure of the destructive performance of these weapons, and decided to consult with Defence scientists who specialise in these problems. The scientists told Simone they would run some numbers through their warhead models and advise on delivery techniques and warhead sizes she would need to successfully attack the identified targets. The results impressed Simone, providing her with numerous delivery options with detailed descriptions of damage effects for each delivery technique and warhead size. Simone took the weapon model simulations away and replanned the munition requirements for the deployment. She would need to use greater quantities of some munitions than originally wanted, but these were cheaper and in greater supply.

Experimentation

C.3. SUPPLY CHAIN MODELLING

C.4. Simone discovered other models that helped her plan the boil-off rate of liquid oxygen, and fuel requirements for the anticipated missions. She worked out schedules for resupply of these vital supplies and forwarded the complete munitions, fuel and oxygen requirements through to the logistics staff.

C.5. Later that afternoon, the logistics staff contacted Simone to advise her that the schedule for supply of mission consumables could not be met, as each commodity had to be transported separately from the others for safety reasons, and there were not sufficient air and land based movement assets available to keep up supply at the rate Simone had planned. The greater quantity of munitions had been a factor, but this could not be avoided. Simone had some serious re-thinking to do – should she advise the Air Commander that a lower rate of effort than desired could be sustained, or was there another way to solve the problem? Simone was feeling less and less comfortable, as each time she tried adjusting one aspect, other constraints emerged. She needed a much wider view of the operational supply chain.

Crisis Management and Planning

C.6. Simone contacted a colleague at the Warfare Centre and asked for his advice. He advised that a gaming scenario could be quickly constructed to model the supply chain and explore methods of overcoming supply choke points. Simone headed out to the warfare centre and was soon working with Warfare Centre staff constructing models of all elements and defining the rules for their behaviour. Later that evening the supply chain entity models were completed and the gaming scenario was ready to run. The gaming scenario helped Simone identify critical supply chain elements and devise approaches to overcome supply chain choke points. Through a combination of caches and alternative transport methods, Simone and her colleague were able to work out a new mission consumable supply schedule that would sustain the rate of effort that was planned. Simone was grateful that modelling and simulation highlighted the supply chain problems before plans were finalised, and that gaming models were available to devise sustainable approaches. Simone submitted her completed deployment plans confident that they would accomplish the desired objectives. She was happy to observe her plans worked flawlessly later that month, and the deployment was a complete success.

C.4. SIMULATION OF COMMAND POST EXERCISES

Conduct of Operations

C.7. Impressed with the utility offered by the Warfare College simulation, Simone hoped to return to further explore the potential uses of the wargaming simulation. She did not have to wait long, as she was soon engaged to participate in a command post exercise, where command and control activities of headquarters staff were being tested. The exercise was being conducted using their normal operational command systems – only the outputs of these systems were being diverted into a wargaming simulation. Simone soon discovered that the exercise was being run at faster than real-time – so there were no delays waiting for sorties and engagements to commence and unfold. The simulated exercise proceeded at good pace, and at the end of the week, Simone had identified a number of areas where improved planning and execution were needed from the headquarters team.

C.8. Simone went away and analysed the exercise results and experimented with some alternative approaches to better understand the causes of the problems that were experienced, and which contributing factors were more significant. She ran various gaming scenarios using the semi-automated forces that were available in the wargaming simulation. After many runs through various aspects of the exercise, Simone had identified a number of areas where significant improvements could be achieved. The explanation and dynamics causing the problems were complex and were not easily explained. Realising that senior staff have busy schedules and do not have the time to sit through long explanations, Simone arranged demonstrations that highlighted the underlying causes of the problems experienced, and her proposed approaches that addressed the problems. These were short sequences that could be run at normal and faster than real-time. She had carefully selected her scenarios to highlight the causes, and was able to pause and replay scenarios to make her points. Senior commanders were impressed with the presentation and endorsed her improvement proposals for immediate implementation. Simone was gaining a new appreciation of the power of simulation, now realising that it had the potential to optimise Defence operations at all levels of activity.

C.5. CAPABILITY DEVELOPMENT LIFE-CYCLE

C.9. Simone's analytical and planning abilities have been reported and recognised widely. There is some contention on how to provide air defence for the Navy fleet, and Simone is recommended as a role specialist to assist Capability Division determine options for Naval fleet air cover. Simone joins the project team and starts working with the team on capability options. The Project Capability Manager is aware of Simone's simulation prowess, and tasks her to commission an experimentation capability in which options can be fully explored and tested.

C.5.1. Operations Modelling

Force Assessment

C.10. Simone ponders her initial task, and quickly realises that the scale of this experimentation environment is too large to attempt with real assets. There are too many options ranging from land based aircraft, Unmanned Aerial Vehicles (UAVs), to ship based air defence systems. Simone also knows she will need to draw in other related systems, such as the Jindalee Operational Radar Network (JORN), High Frequency (HF) communications and various naval platforms that are to be protected from air attack. Network information flow will also be crucial to ensure the capability can be scaled to meet operational needs and cooperate with our allies. She knows she will need to rely on simulation, but is concerned at how she will establish the validity of the experimentation environment – after all the cost of the project will amount to a multi-billion dollar investment. Simone knows that the experimentation environment must stand critical scrutiny if the project is to progress without controversy.

Experimentation

C.11. Simone completes some preliminary planning in the context of her allocated budget. She quickly ascertains that she does not have the time or budget to create an experimentation environment from scratch – she will need to exploit existing assets where she can. She consults with some Defence scientists that she had worked with before, and learns of some simulation assets within the Defence Science and Technology organisation that seem to have some potential. Simulation experts from industry are also engaged. It is soon agreed that the Defence Science and Technology Organisation's Virtual Ship and Virtual Air Environment simulations can be networked, along with some simulation demonstration laboratories owned by industry. The framework of an experimentation environment starts to come together.

C.12. A few months later Simone has the experimentation environment working in a basic form, and in collaboration with Defence scientists, she initiates some basic proof of concept experiments using semi-automated forces to demonstrate the viability of the experimentation environment. The experiments go reasonably well, but it is clear that human-in-the-loop participation is needed to fulfil some of the more complex behaviours.

The semi-automated forces are performing to expectations, but the limitations of their behaviour models prevent more advanced concepts from being explored. Conscious of time and budget constraints, Simone considers her options for inserting real role players into the experimental framework. After talking with some simulation experts, Simone moves to link in some of the operational flight trainers she used during her fighter training, as well as ship operations room trainers located in the Maritime Warfare Training Centre. These simulators can provide an adequate representation of the simulated environment for real fighter pilots and the operations rooms of ships, allowing their participation in the experiment. She discovers this can be accomplished relatively easily because the simulators have been designed to support a standard simulation interface architecture known as HLA (High Level Architecture). This utility has opened up the experimentation environment to include participation by real war-fighters from their home bases. This adds considerable flexibility to the framework and allows for a greater variety of specialist participants.

C.13. The experiments are growing in complexity, and the timetable for narrowing the project options to a preferred approach is nearing. Whereas earlier use of the experimentation framework was largely conducted in an informal manner, the experiments were now being examined closely, and Defence decision makers were starting to seek greater assurances that the framework conclusions were valid. Simone had noted that some experiments reached unexpected outcomes. Some of these were easily excluded as anomalous when underlying assumptions were reviewed, but not all unexpected results could be accounted for in this way. Simone recalled some advice she had received from a simulation specialist – that the accuracy of the simulation model representations of the real world must be consistent with the intended purposes of the model. She researched further and quickly discovered that this process was known as VV&A (Verification, Validation and Accreditation). Simone checked the VV&A history of the individual simulation components and discovered that several had never been subjected to VV&A, and that two of the simulations were being used in a manner that was beyond the scope of previously conducted VV&A activities for those simulations. It was clear that the conclusions reached using the experimentation framework would not stand scrutiny.

C.14. Realising there was much riding on the conclusions reached through the use of the experimental framework, Simone commissioned a VV&A process for the experimentation framework. Many of the simulators were certified for their intended use in the experimentation framework, but there were some notable exceptions where VV&A processes revealed critical modelling deficiencies for the intended use of the simulations. Simone arranged for modification of one of the deficient simulations, and replaced another with a higher fidelity simulation model that had been previously certified for use in a similar application. The experimental framework was independently certified as suitable for its intended purpose, and key experiments were now repeated. To her surprise, Simone noted that many previously recorded outcomes were now significantly different, and the previously favoured option of using land based aircraft was proving to be less effective than a ship based air defence system. Although against her own professional judgement and Service loyalty, Simone was glad she had conducted an independent VV&A process on the experimentation framework as it saved her from the embarrassment of recommending a demonstrably inferior option and shielded her from possible accusations of Service bias.

C.15. The Capability Manager was pleased with the results achieved by Simone, not because of the preferred approach that was ultimately recommended, but because the experimentation framework had established beyond reasonable doubt the most effective means for providing air defence to the Navy fleet. The findings of the capability experiments commissioned by Simone were widely accepted as valid, and the capability proposal for new Air Warfare Destroyers passed through Cabinet smoothly. Simulation had provided the evidence needed to correctly identify the best approach and establish this beyond reasonable doubt.

C.5.2. Design Support Modelling

Acquisition

C.16. Although a fighter aircraft solution was not to be pursued, Simone was retained on the project due to her demonstrated ability to leverage simulation capabilities. During design of the ship hull and deck structure, doubt emerged as to whether the proposed ship structure would cause unstable airflow over the proposed rear flight deck. The Project Manager called upon Simone to use her knowledge of simulation to smoke out if there was a problem. Simone engaged some aeronautical engineers and simulation specialists from a well respected tertiary institute. They quickly developed a simulation of the ship structure and tested the airflows across the proposed rear deck under various ship speeds and wind directions. The simulations provided graphical images of air mass movement over the flight deck. Colour coding was used to highlight adverse air mass movements. The simulation model illustrated several instances of severe airflow over the flight deck that would pose a flight hazard to hovering helicopters. The proposed positioning and design of the ship loading crane was also revealed to be a significant contributor to the problem.

Research and Development

C.17. Several different approaches were tested to improve the air flow. Some were based on adding vortex generators to parts of the ship to deflect adverse airflows, while others modified the shape of the ship structure. Aerofoils were also tested in an attempt to deflect adverse air currents, with moderate success. Changing the ship deck structure was preferred, but Simone was concerned that this would compromise the radar stealth characteristics of the ship. Simone arranged for radar models to be applied to the proposed structure, which confirmed her fears. The crane was also exposed as a significant radar reflector. Ultimately the airflow and radar simulation models indicated that the use of vortex generators, together with an aerodynamic stealth shell around the ship crane when stowed, as the most acceptable compromise. Simone was pleased that this design problem had been resolved before there had been any commitment to bend and cut metal. She pondered what might have been the cost and schedule implications had she not used simulation to resolve the matter before construction started.

Acquisition

C.18. Some time later, during conversations with her Project Office colleagues, Simone became aware of numerous instances of design conflicts, where cable runs were being put through compartment spaces intended by others in the design team for equipment installation and stowage. There were even instances where cable runs would prevent the easy servicing and removal of other installed components. This situation was not good, but the design engineers were finding it hard to visualise the space requirements of different systems and components. Simone recalled once seeing a demonstration sequence from a university professor during a simulation technology conference. The demonstration was highlighting the same problem that now faced the ship design teams, and Simone immediately recognised the potential of this simulation technology to reduce the project cost and schedule risk posed by the problem. Simone contacted the professor and before long had been able to convert the ship CAD (Computer-Aided Design) drawings into a three dimensional model. Simone arranged for a head mounted display for each design team. The head mounted display allowed design team members to walk through the ship and view the compartment designs as they would appear in real life. Design engineers very quickly found the simulation to be very useful, and it ultimately reduced the incidence of design conflicts and rework. By linking the three dimensional model directly to the current authorised baseline drawings, the design teams grew confident in their design decisions.

Acquisition

C.19. Simone saw further benefits could be gained from this simulation by including examination of component removal and servicing into the simulation. Tactile gloves were procured, and now the design teams could see and use their hands to operate switches, knobs and fasteners in the virtual environment as viewed through the head mounted display. With some further investment, Simone was able to include the ability to remove and replace items of equipment, which proved invaluable in identifying obstructions and difficult access arrangements. Soon the design teams were using this simulation to make it easier to perform maintenance activities. Simone was beginning to wonder if there would be anything left for this ship's crew to complain about.

C.5.3. Financial Modelling

Acquisition

C.20. Simone's activities in exploiting simulation had led to a significant decline in design rework and construction efficiency. Many of the project risk allowances were not being used, and activity schedules were being achieved ahead of planned durations. Simulation was having a positive effect on all project activities and it now seemed likely that the project budget could be reduced, allowing diversion of money to other Defence procurement priorities. Having seen the benefits of simulation that Simone had brought to other areas of the project, the PM (Project Manager) commissioned a new detailed financial model of the project to reliably predict the final cost and schedule outcomes. Simone was pleased to see others take up simulation as a tool, and casually coached the PM that a Monte Carlo simulation would be appropriate to account for the variability in possible activity outcomes. The PM agrees and sets about defining an appropriate Monte Carlo simulation using vendor products designed for this purpose. The PM is surprised at how easy it is to set up the simulation, and soon completes a sample of 1000 runs. The PM notices that the schedule is being driven by two parallel activities, and establishes that the first ship is likely to be commissioned into service 9 months ahead of schedule with a 95% confidence rating. The PM feeds the output of this schedule model into a cost model, and finds that the cost of the first ship is likely to be $300m less than currently estimated. This news at first receives widespread scepticism within the Department and Defence industry media, however the PM is satisfied with the thoroughness of the cost and schedule modelling tools he has developed for the project, and sticks to his guns. He ultimately proves to be in the right ball-park.

C.5.4. Personnel Modelling

Life Cycle Management

C.21. The improvements realised in maintainability has caused a rethink of the skills and size of the ship's crew. Simone suggests that simulation be used to explore crew utilisation factors for different rates of effort and failure modes. The simulation model is created and reveals that fewer crew are required than first anticipated. The simulation also reveals that crew with specific skills are critical to the sustainability of the ship systems, and that crew savings can be achieved through some multi-skilling activities. The simulation model is used to study crew optimisation opportunities, as the simulation model outputs resource savings over the entire life-cycle of the ship. The revised crew structure is provided to Navy personnel managers, who in turn analyse specific crew requirements with simulations to determine the recruiting and training profile that is needed to assemble the ship crew in time for its revised commissioning. The simulation reveals that time is short and that recruiting action is urgently needed.

C.5.5. Medical Simulation

Training

C.22. Simone leaves the project to take some well-earned leave, starting with some skiing. Simone finds she is not as young and agile as she once was, and she tears the ligaments in her knee. She is upset that the injury will take considerable time to heal, and that her knee will bear the scars of the surgery needed for reconstruction. However, she is pleasantly surprised to learn that advances in medical surgery technology will allow the reconstruction to be completed using key-hole techniques, and that she should be back on her feet within six weeks with only very small scars showing on her knee. During surgery preparation Simone learns that the advances made in this type of surgery were largely possible due to the advances in simulation technology that allowed the surgeon to gain expert skills in the use of laparoscopic equipment. The surgeon added that the techniques he was going to use were quite difficult to master, and said that he doubts he could have gained the necessary skill had he not been able to practice with laparoscopic simulations. Simone understood exactly what the surgeon was saying, and was not surprised to find that the surgeon had accomplished her ligament repairs with minimal damage to her knee.

C.6. OPERATIONS TESTING AND TRAINING ON A LARGER SCALE

C.23. Simone left the Air Warfare Destroyer (AWD) Project to take command of the Air Surveillance Force Element Group. Although now back in an Air Force role, Simone was soon to be re-acquainted with the AWD project. The first AWD was soon to be commissioned, and the Navy was now working up procedures and processes to integrate the AWD into the air defence network. Simone knew this would be a difficult undertaking as technology now enabled huge amounts of data and information to be shared across many combat elements. Correlation of air targets detected by multiple independent sensors and fusion of this data to provide a consistent and accurate air picture continued to present a challenge. Coordination procedures and practices between the AWD and the Air Force air defence Operations Centres would be a crucial link in establishing an integrated air defence network, as would coordination of information flow from surveillance Unmanned Aerial Vehicles (UAVs) and the Airborne Early Warning and Control (AEW&C) aircraft. Simone knew that simulation provided the only viable means to experiment and refine the fabric of this new integrated air defence environment.

Experimentation

Mission Rehearsal

Force Assessment

Acquisition

C.24. Simone resurrected the experimental framework she had helped create when the AWD project was first started. She realised the focus of the simulation would be different, and would be more information-centric than the previous experimentation framework had anticipated. She remember her experience with the semi-automated forces simulation that was used by the Warfare College, and reasoned that this could be used to create simulation federates where specific aspects of the AWD and air defence network could be partitioned and managed in a simulation environment. Simone also remembered the need to ensure the simulation concept forming in her mind was suitable for its intended purpose, and recalled that simulations designed for HLA compliance could be interfaced more easily than those without this interface architecture. Simone had soon created a new experimentation framework architecture based on the use of simulation, and realised that this framework could become enduring if the AWD included embedded simulation features that allowed the AWD to be stimulated by an HLA enabled simulation framework. Simone envisaged this framework as providing the means to work up and exercise AWD crews without the need to commit real assets to the task. She also realised the framework could be used to validate and test the AWD design, and conduct operational evaluations of its effectiveness. It also dawned that this simulation framework could be used to exercise the whole air defence network, ensuring that all air defence elements were able to competently perform when called upon in armed conflict.

C.7. IS SIMULATION BETTER THAN REALITY?

C.25. Simone reflected that she was now using simulation as she had been during her early days in fighter pilot and command roles – the only difference was the scale of the simulated operation. It seemed that there were now more simulated elements to her profession than real elements. She did not know if she had achieved her early ambition of being the best, but she was sure that her use of simulation made her better than those who did not exploit simulation as well as she had.

C.26. Simone also reflected that she had progressed to a stage in her career where simulation was as close as she would get to real combat action…