



Model Driven Aviation Training Family of Systems Architecture

Volume II (Appendices)

By

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EXECUTIVE SUMMARY

The PhD project has evolved from focusing on the technical problem of the integration and interoperability of an assemblage of complex systems and SoS within a flight training system to development of a workflow process using frameworks to aid the decision making process for the selection of optimal flight training blending mixes. The focus of the research involved developing a methodology to satisfy research project proposal requirements agreed upon with the industrial sponsor. This thesis investigates the complexity of a modern flight training systems and the need for understanding that it is supported by a complex Family of Systems (FoS) including Virtual Reality Training Environments such as flight simulators, to live training aircraft with various configurations of avionic controls. One of the key technical problems today is how best to develop and assemble a family of flight training system into an integrated Live / Synthetic mix for aircrew training to optimise organisation and training objectives.

With the increased use of emulation/synthetic data on aircraft for live training, the synthetic boundary is becoming increasingly blurred. Systematic consideration of the most appropriate blend is needed. The methodology used in the research is model driven and the architecture produced is described at a level of abstraction to enable communication to all stakeholders for the means of understanding the structure involved in the system design process. Relational Oriented Systems Engineering and Technology Trade-Off Analysis (ROSETTA) frameworks are described using Model Based Systems Engineering (MBSE) techniques for supporting capability based trade-off decisions for selection of optimal flight training FoS mixes dependent on capability. The research proposes a methodology and associated methods including a high-level systematic closed loop information management structure for blended device/tool aircrew training and a modelling and analysis approach for the FoS aviation training problem to enhance the existing training programmes to provide a more efficient and agile training environment. The mathematical formalisms used provide a method of quantifying subjective opinions and judgements for trade studies to be accomplished on the suitability of technology for each student pilot in relation to training and organisational objectives. The methodology presented is by no means a final solution, but a path for further research to enable a greater understanding of the suitability of training tools / technology used to train individual pilots at various stages throughout the training pipeline lifecycle(s).

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GLOSSARY

ATC	Air Traffic Control	MBSE	Model Based Systems Engineering
BAE	British Aerospace	MDA	Model Driven Architecture
CIM	Computational Independent Model	MEC	Mission Essential Competency
ConOps	Concept of Operations	MFD	Multi-Functional Display
COTS	Commercial off the shelf	MFTS	Military Flight Training System
DEVS	Discrete Event Simulation	MoE	Measures of Effectiveness
DSM	Dependence Structure Matrix	MoP	Measures of Performance
DSS	Decision Support System	NLS	Natural language Sentences
EA	Enterprise Architecture	OMG	Object Management Group
EIC	External Input Coupling	OOTW	Out Of The Window
EOC	External Output Coupling	PIM	Platform Independent Model
FMS	Full Mission Simulators	PSM	Platform Specific Model
FoV	Field of View	QFD	Quality Function Deployment
FoS	Family of Systems	ROSE	Relational Oriented Systems Engineering
FSTD	Flight Simulator Training Device	ROSETTA	Relational Oriented Systems Engineering and Technology trade-off Analysis
FTFoS	Flight Training Family of Systems	RSE	Response Surface Equation
FTS	Flight Training System	RSM	Response Surface Methodology
GBS	Ground Based Systems	SA	Situational Awareness
GBT	Ground Based Technologies	SME	Subject Matter Experts
HITL	Human in the Loop	SoI	Systems Of Interest
HMD	Head Mounted Display	SOP	Standard Operating Procedures
HOTAS	Hands On Throttle-And-Stick	SoS	Systems of Systems
HPM	Human Performance Modelling	SOSE	Systems Of Systems Engineering
HUD	Heads-up Display	TNA	Training Needs Analysis
ISO	International Organisation for Standardization	ToT	Transfer of Training
IT	Information Technology	UI	User Interface
ITAR	International Traffic in Arms Regulations	V&V	Verification and Validation
LVC	Live, Virtual, Constructive	VE	Virtual Environments
M&S	Model and Simulation	VRTE	Virtual Reality Training Environment

APPENDIX A RESEARCH PLANNING

The planning for the research project began with identifying the systems problem moreover why BAE (industrial sponsor) requested investigation into the management of complexity within the flight training system regarding the technology used for to prepare student pilots for readiness. Included in the problem space was to develop a conceptual model of the FTS which would eventually be able to be evolved for the analysis of the appropriate blending mix needed for each respective student pilot. Modelling and simulation (M&S) techniques is seen to be required to advance current evaluation methods, which is over reliant on instructor opinions, to permit other decision makers to become involved and understand how human and technology factors integrate into one seamless assessment method for pilot progression. It was clear from the offset that a workflow process is needed that offers a sequence of activities which both the student pilot and the decision maker have to follow. The key objective of the research is to investigate the suitability of the ROSETTA framework for trade study analysis to help decision maker decide on which system of the FOS to use at each point of the training pipeline.

With time limitations a key problem area for the PhD a number of potential solutions was identified including how to organise the framework in a formal but easy to understand structure that integrates both human and technology factors. At the early stages of planning it became clear that one ROSETTA style framework would be insufficient to analyse the complexity of the FTS, therefore, the potential solution involves a number of disparate domains, which gives a fuller representation of the inclusion of the frameworks into a workflow process. Following the white box solution brainstorm, the main issues are identified including noting the limitations of tools, the time available, and the lack of SME participation (due to the current condition of the economic climate). A number of potential verification procedures are identified for the simulation of the mission scenarios with HITL participation along with how to obtain volunteers to take part in the research. However, with time in short supply and the evolution of the relationships in the ROSETTA framework to go through a number of iterations before any meaningful information and ‘patterns’ can be established, it is deemed the boundary of the research should be limited to the verification of the frameworks and workflow tool, with discussions of why short term evolution of relationships is required before estimations of FoS suitability for student pilots can be established. The Mind Map used for planning is seen in Figure A.

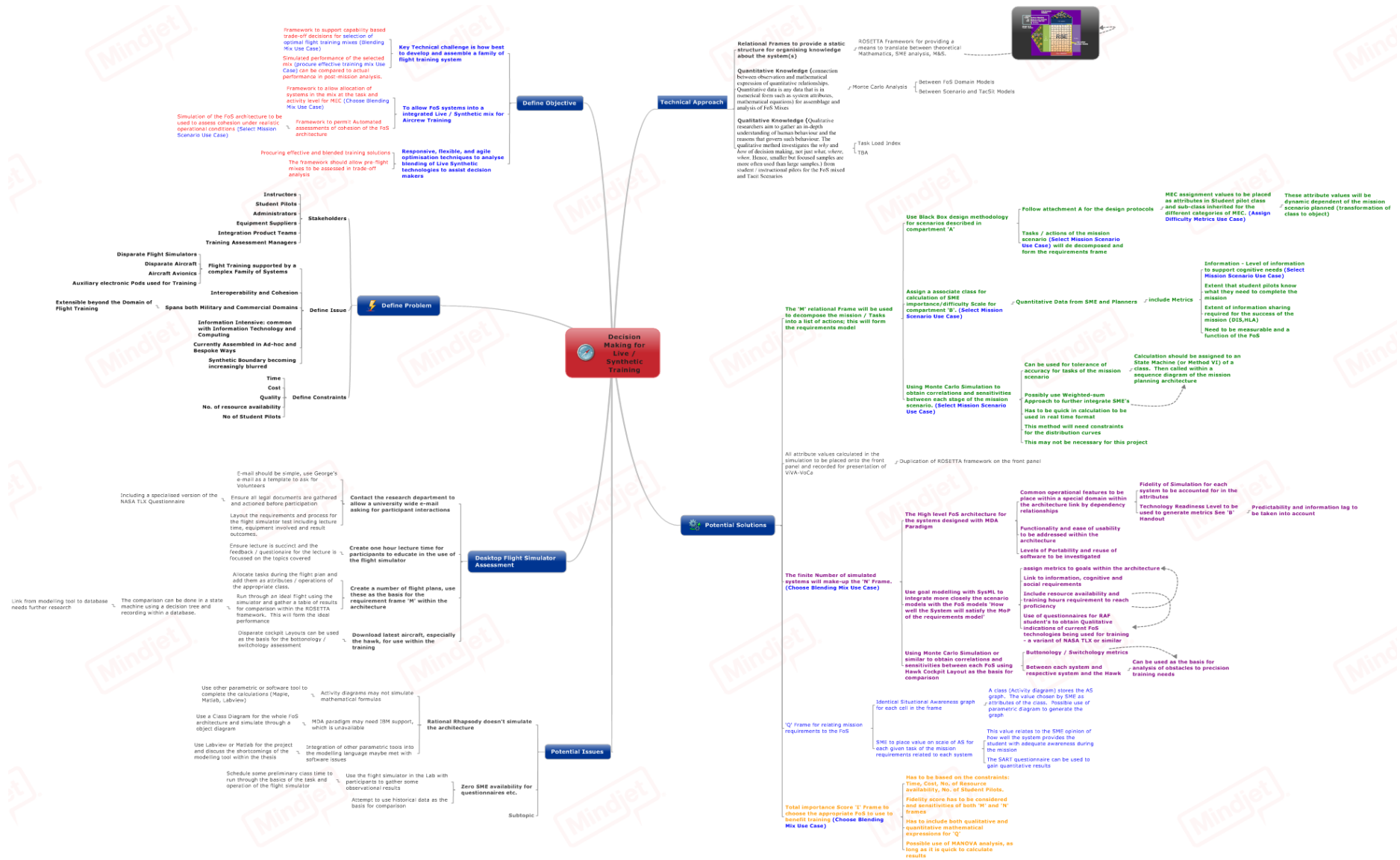


Figure A Planning Mind Map for Research Project

APPENDIX B LVC Capability Descriptions

Table I Live, Virtual and Constructive Capability Description

Training Environment	Description
Virtual Simulation	Real people operating simulated equipment in a virtual environment
Constructive Simulation	Real people employing decisions on the basis of information constructed by a computer system
Live Simulation	Real people operating real equipment with simulated effects in a live environment
Synthetic wrap	Use of live and virtual simulation to provide extended battle-space for training.

APPENDIX C Technology & Human Issues

Table II Mission Scenario Technical and Human Issues

Advanced Technology Systems	Pilot Flight Displays Multi-Functional Displays Traffic Displays Weather Displays Terrain Displays Autopilots
Higher-Order Thinking Skills	Analysis, synthesis, and evaluation Aeronautical Decision Making Situation awareness Pattern Recognition (procedures) and Decision making Automation Competence
Aeronautical knowledge and skills	Planning and execution Procedural knowledge Psychomotor (hand-eye) Skills

APPENDIX D INTERACTION CRITERIA

Table III Human-Machine Interaction Criteria

Types of Criteria	Criteria
Human-Machine Interaction	Duration of the tactile task
	Frequency of the task
	Repetitiveness of the task
	Gestures used
	Task difficulty / accuracy
Human Physical Capability	Working Posture
	Lateralization
	Visual control
	Vibration

APPENDIX E FSTD Qualification

Table IV Qualification Level and Level Requirement for FSTD (amended from JAR-FSTD, 2008)

Military sensors (features)	
Qualification level	General technical requirement
1	Generic sensor performance but with correct switchology
2	Representative sensor performance
3	Specific sensor performance (including the effects of weather)
A	Sensor integrated with other databases ('within' same FSTD)
B	Abnormal and failure modes are included

Level 3 (specific) requirements (cooperative player)	
Feature	Requirement
General	Specific models, exactly corresponding to the training theatre with exact player behaviour
Specific interaction	The interaction with the model is correct
Visual appearance	The visual appearance should enable the recognition of player at realistic ranges and show enough detail
Detectability	The detection range of the representative player deviates less than 20% from the known detection ranges
Dynamic behaviour	Dynamic behaviour which is specific for the cooperative player
Threat and target sensors	Player sensor emissions are detected at realistic ranges
Weather effects	Detection range shall be affected by weather.

APPENDIX F Keyword Analysis

Table V Strategic Goals through Keyword Analysis

Identification	Example keywords
Intentional	In order to, so that, objective, aim, achieve, avoid, ensure, expected to, guarantee, maintain
Prescriptive	Shall, must, should not, has to, may not, will have to
Amelioration	Increase, improve, decrease, enable, support, provide, make, enhance.

APPENDIX G USE CASE REQUIREMENTS

This appendix is an elaboration of Volume I Chapter 6.3, discussing the final use case development process of the DSS system and associated workflow process involving a final recursion back to requirements to enable the model of the DSS to evolve during its lifecycle use. There is a brief description on the operational intent of the use cases with respect to the workflow process, with most of the specific details on the functionality expressed within the figures. For further information on various functions and how they ‘fit-in’ within the global operation of the DSS, please refer to Volume 1, Chapter 7.

A further abstraction of the ‘Perform Pre-Pilot Assessment’ Use Case of Volume I Figure 33 is illustrated in Figure G 1. To ensure a streamline training process for all student pilots, the acceptance criteria has to be reserved for those who are more likely to achieve the readiness levels needed to obtain their wings. Therefore, a screening process is strengthened by using various ‘online’ assessment questionnaires and/or interviews. Of prime importance is to be able to filter out those who are deemed unsuitable for training because their personal traits do not fit the criteria for training. As VRTE technology with varying levels of physical fidelity is used for cost effective training, for safety reasons each prospective participant needs to be assessed for simulator sickness as those who are extremely perceptive to visual and physical distortions may be deemed unsuitable for modern flight training programmes or need preferential training involving considerable less synthetic mixes.

Currently, most training programmes are governed and organised by training contractors who produce standardized lecture material, which is presented by instructors in a typical classroom method. Therefore, it would be useful to gain knowledge of each prospective student pilot preferred learning style to appraise how they would cope with the method of teaching training material and whether interventions might be needed to assist in safeguarding those student pilots who have the skills for pilotage but whose preferred learning style is not preferable with how the information is going to be presented. Finally, for the initial stage of training, knowledge of how the participant copes with stress and pressured situations would be useful when it comes to planning mission scenarios in the early stages of training to ensure minimisation of the ‘startle’ factor and to avoid a reduction of confidence levels. Thus, an assessment can be implemented to gain a ‘feel’ of how participants handle these adverse conditions.

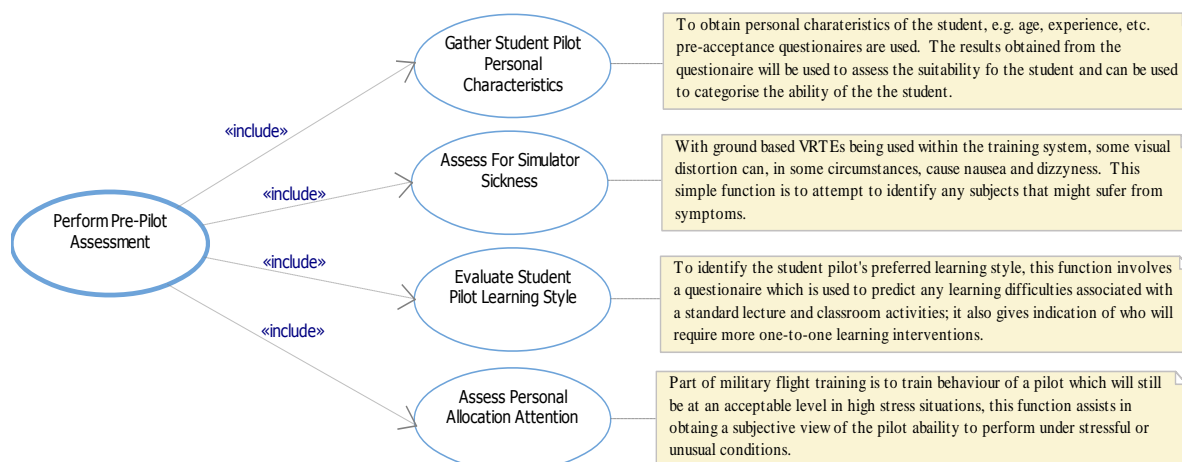


Figure G 1 Further Abstraction of Perform Pre-Pilot Assessment Use Case

The 'select and Evolve Mission Scenarios' Use Case of Volume I Figure 33 is expanded in Figure G 2. Functionality involving the human factor issues, which surrounds performance and mission planning tasks in relation to each student pilot, is considered. The tasks that create the mission scenario are assigned difficulty metrics, which may consider the ability of the student pilot (assignment of metrics up to decision maker discretion). The task include a number of activities (re: Volume I Figure 22) and there may be correlations between tasks that relates to the task importance levels. Consideration of the workload difficulty for the pilot needs to be evaluated; this may include the distinction between disparate training technologies whilst planning the missions. Estimation of performance of the student pilot in successfully completing mission goals and objectives is important for instructors to gain a notion of their own subjective judgment of the student pilot's ability. The basis of this exercise is to assist the instructors in planning follow-on missions for each student and setting of difficulty levels to ensure that student pilots are tested to their ability and the training missions assist those gaining relevant K&S. For assigning difficulty metrics to tasks, more detailed information regarding how each task in the mission scenario is related to another can help assessing how difficult achieving one task is with the knowledge of the next task in the sequence of the mission; the <<refine>> dependency relationship signifies that further information can be sent from another function if needed.

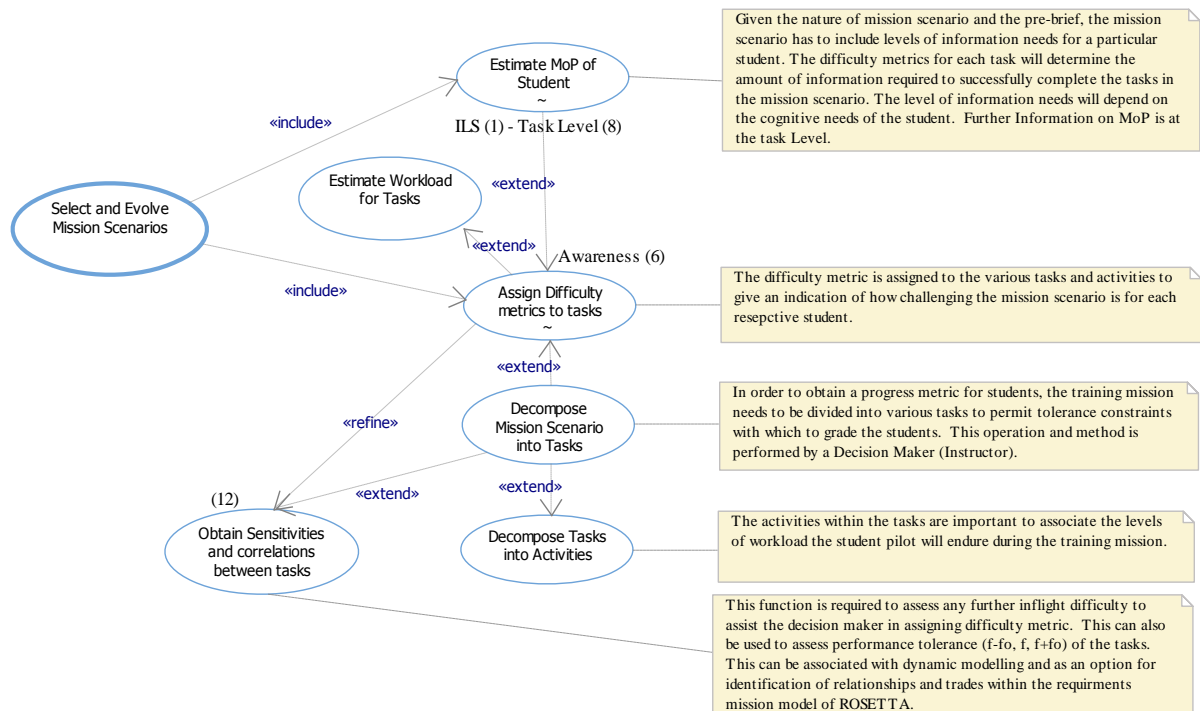


Figure G 2 Further Abstraction of Select and Evolve Mission Scenarios Use Case

The main objective of the DSS is to assist decision makers in the correct choice of blending mix as per the ‘Choose Blending Mix’ Use Case in Volume I Figure 33, which is further abstracted for more detail functionality in Figure G 3. It is perceived that the choice of blending mix occurs pre-flight and in some instances pre-planning of the mission scenario. Of interest are the similarities and differences between systems within the FoS and how these differences, along with the planned mission, affect the attainment of K&S for the student pilot. There are strong dependences to each function and each function requires large amounts of data for analysis to be accomplished and it is within these functions that the ROSETTA framework will be used to organise the data and provide analysis functions. Within the figure are traces to relevant requirements to certify that these functions describe the main functions of the DSS framework and these above others have to be concentrated on within the design process.

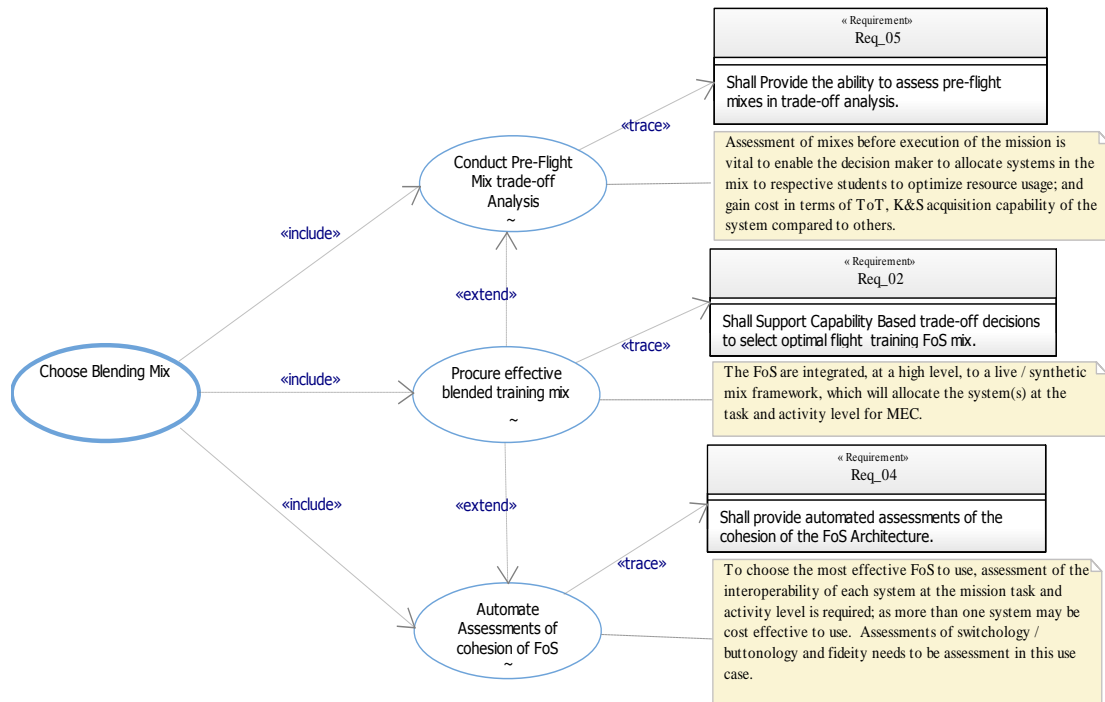


Figure G 3 Further Abstraction of Choose Blending Mix Use Case

Figure G 4 expresses a further abstraction of the 'Estimate MoP of Student' Use Case of Figure G 2. The function includes assessments concerning situation awareness to gain an appreciation of the student pilots understanding of the mission scenario goals and objectives. The information obtained within the parent use case along with its children is used to assist the decision maker in estimating the mission success for each respective student pilot, which intern is used as the basis for evaluating the task load. There includes a main student file, which is part of the student database directory where relevant evaluation metrics are recorded for documentation to give an indication of positive or negative ToT and assist in identifying those who need interventions to help them succeed in training.

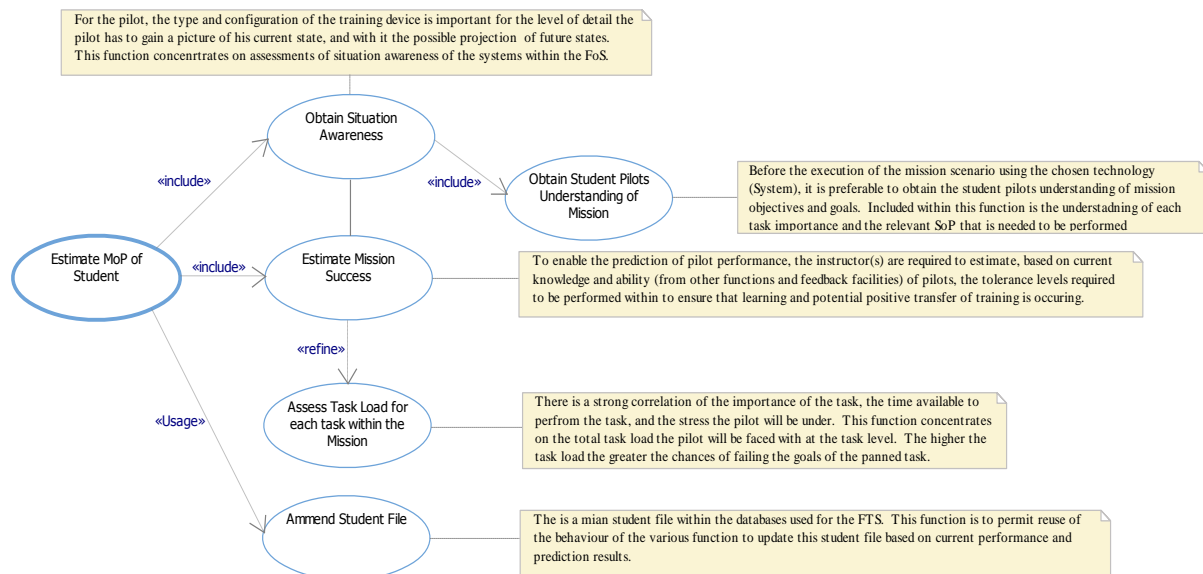


Figure G 4 Further Abstraction of Estimate MoP of Student Use Case

Figure G 5 presents a further abstraction of the ‘Estimate Workload for Tasks’ Use Case in Figure G 2. This function includes information from the mission planning and post-mission assessment phases to assign task importance metrics and grade student pilot workload both for the task and for the differences in available training technology.

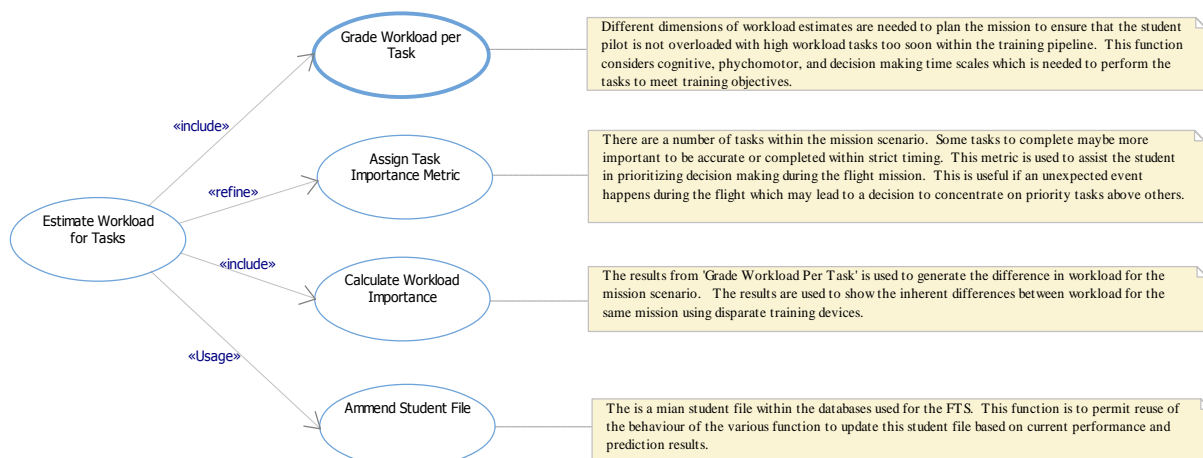


Figure G 5 Further Abstraction of Estimate Workload for Tasks Use Case

Figure G 6 presents a further abstraction of the ‘Assign Difficulty Metrics to Task’ Use Case in Figure G 2. This function includes the task of entering the difficulty metric into the DSS framework and assigning the relevant mission essential competencies (MEC) to the tasks that uses information gathered from the ‘Assign Task Importance Metric’ Use Case to describe the competency that is going to be examined within the mission scenario for assisting evaluation of ToT for the student pilots. Included in the operation is allocation of an MEC grade to signify which competency is of prime importance in the planned mission for the instructors to prioritise when evaluating performance of the tasks. With each executed flight

the student pilot gains experience in K&S; this experience can be used to mitigate some difficulty, for each respected student pilots, of similar tasks in future training missions.

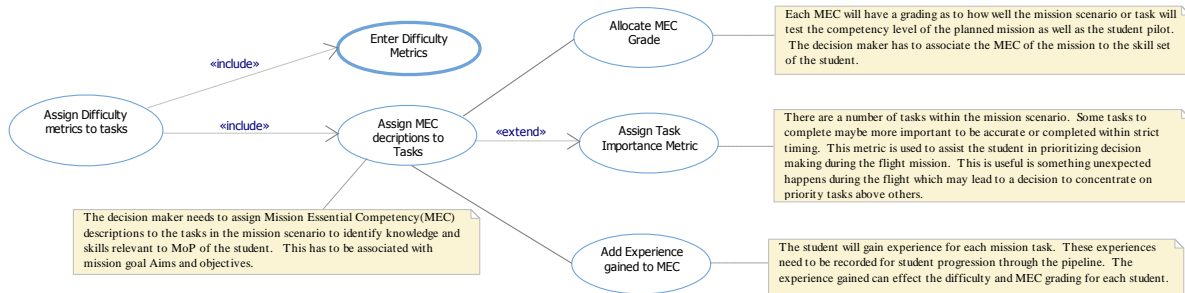


Figure G 6 Further Abstraction of Assign Difficulty Metrics to tasks Use Case

Figure G 6 presents a further abstraction of the ‘Decompose Mission Scenario into tasks’ Use Case in Figure G 2. This function includes the task of planning the training mission using real world longitudinal and latitudinal coordinates along with timelines and aircraft characteristics required to successfully complete mission goals. This information is then used to brief the student pilots of the requirements for the mission scenario. For performance measures, the executed flight is required to be compared to an ‘ideal’ baseline, consequently, the DSS has to incorporate the facility for ‘playback’ of an experience pilots’ flight of the planned mission or a flight that uses mathematical algorithms for simulation, in real time, with which to create metrics with which to grade performance of accuracy and precision.

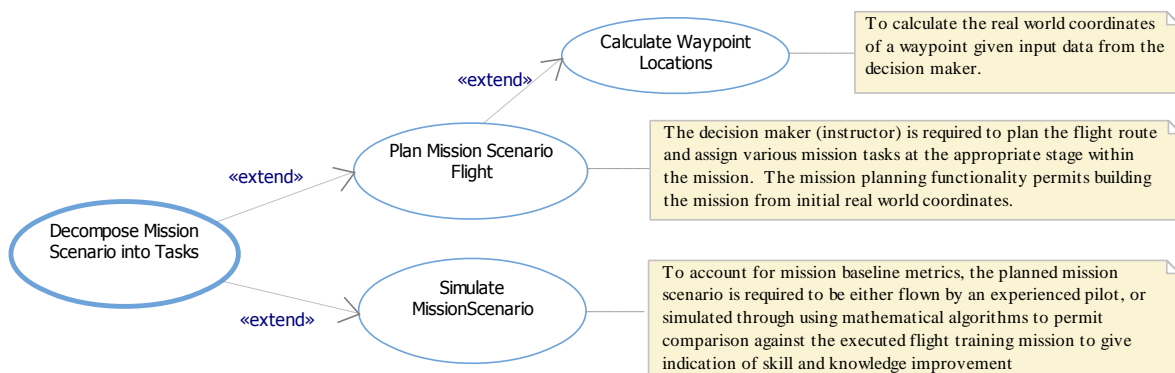


Figure G 7 Further Abstraction of Decompose Mission Scenario into Tasks Use Case

Figure G 8 presents a further abstraction of the ‘Conduct Pre-Flight Mix trade-off Analysis’ Use Case identified in Figure G 3. The figure communicates that within the workflow process there are three ROSETTA frameworks, which uses different data sets to perform analysis on the suitability of the training technology used for training a respective student.

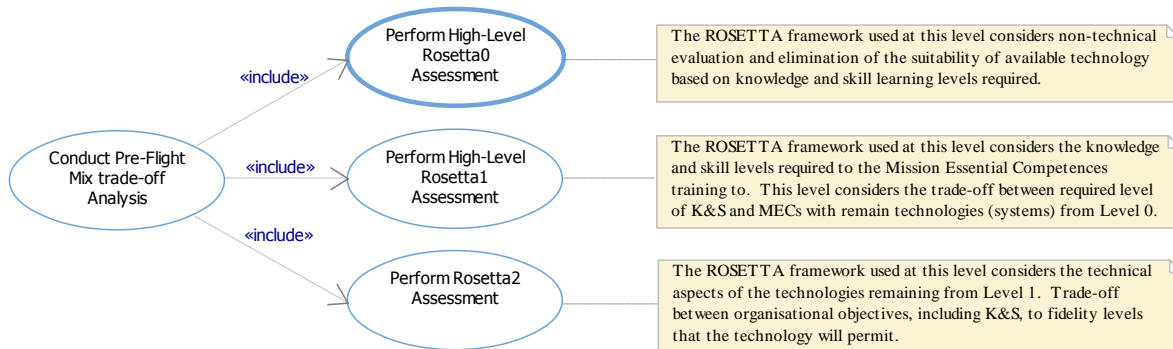


Figure G 8 Further Abstraction of Conduct Pre-flight Trade-off Analysis Use Case

Figure G 9 presents a further abstraction of the ‘Perform High-level ROSETTA 0 Assessment’ Use Case identified in Figure G 8. At the first level of technology elimination, the specific knowledge and skills (K&S) of the mission are required to be known; during mission planning the K&S descriptions are stored within a database, the operations within the ‘Set-up Framework’ Use Case ensures that duplicate K&S are removed to enable the framework to be scaled and structured. Once the framework is produced, the technology is assessed using non-technical knowledge in relation to its suitability in practicing the K&S identified within the framework. Once the suitability is assessed, the framework will provide the facility to simplify the data within it to assist the decision maker in elimination of unsuitable technology from further pre-flight assessments.

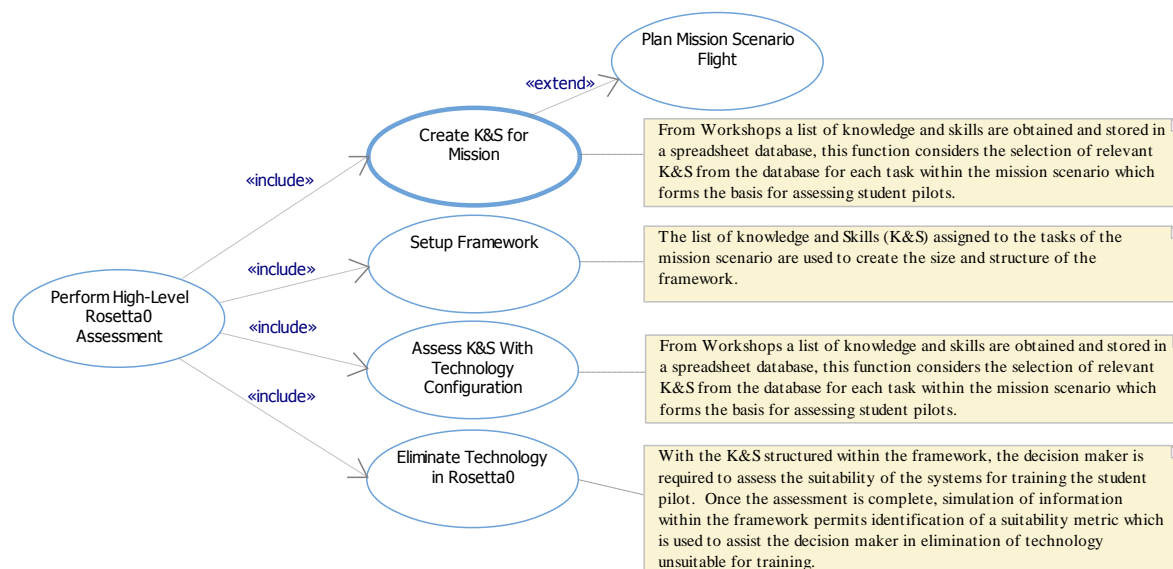


Figure G 9 Further Abstraction of Perform High-Level ROSETTA0 Assessment Use Case

Figure G 10 presents a further abstraction of the ‘Perform High-Level ROSETTA 1 Assessment’ Use Case first identified in Figure G 8. Within this function, relationships between the K&S identified in ROSETTA level 0 and relevant MECs identified in the mission planning phase are investigated. The number of K&S is used to scale the framework

and relevant SMEs are used to produce the response surface equations (RSE), which described the mathematical relationship between framework parameters with which to perform trade studies on.

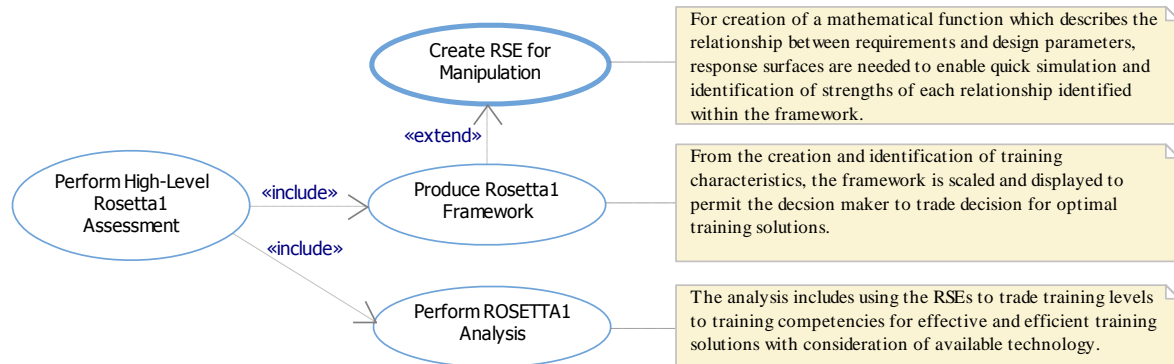


Figure G 10 Further Abstraction of Perform High-Level ROSETTA1 Assessment Use Case

Due to the complexity involved in trade studies the Use Case ‘Produce ROSETTA 1 Framework’ is further decomposed into Figure G 11. Operations for the decision maker include grading the identified MEC and assigning a description to the MEC, if required. Once the RSEs are created or loaded from an existing database, for more accurate trade studies, the number of sample point available need to be increased to permit a more robust analysis using DoE experiments. To enable the data from the multiple RSE to be evaluated together, all of which are arrays that produce the framework, the framework data is structured into a 2-dimensional array that can be loaded into the framework to be presented on a GUI for efficient trade study analysis.

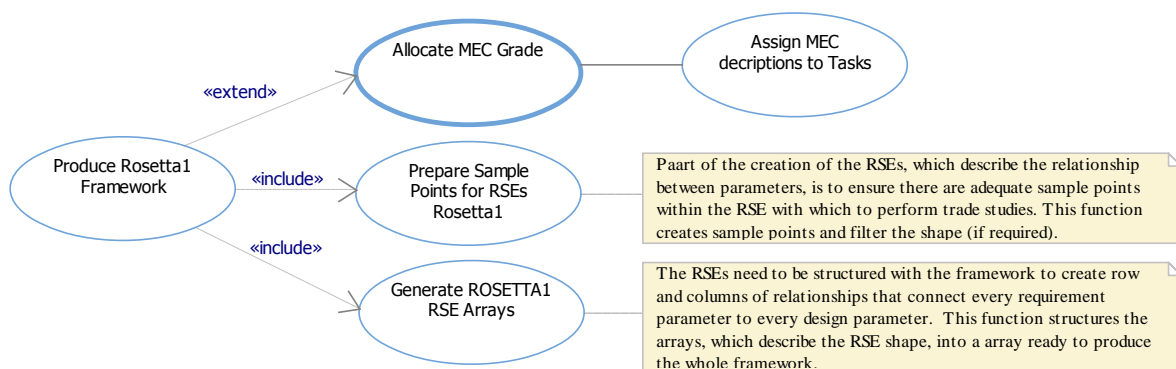


Figure G 11 Further Abstraction of Produce ROSETTA1 Framework Use Case

The ‘Perform ROSETTA 1 Analysis’ Use Case of Figure G 10 is further decomposed into Figure G 12. This function provides the facility for the decision maker to perform the trade study with the added functionality of scaling the slots of the framework to fit all the RSEs onto the GUI. Once the trade study has been complete, the framework will simplify the

analysis and metricise the trade-study to allow the decision maker to perform further technology elimination based on the metrics from the analysis phase.

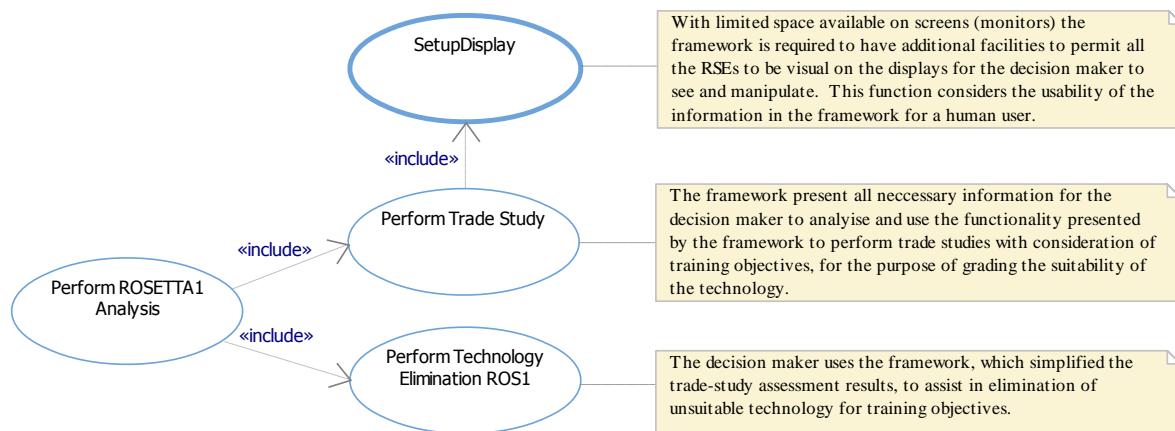


Figure G 12 Further Abstraction of Perform ROSETTA1 Analysis Use Case

Figure G 13 presents a further abstraction of the ‘Procure Effective Blended Training Mix’ Use Case first identified in Volume 1, Figure 40. The operations involved with this function regard the post-mission analyses of student pilot performance. Under consideration is the instructor opinion of success along with student pilot feedback; included within the functionality is the ability to compare actual flight data with a base line scenario.

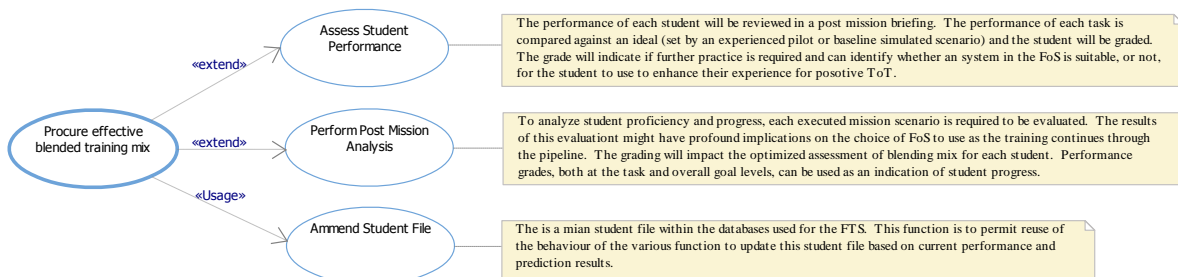


Figure G 13 Further Abstraction of Procure Effective Blended Training Mix Use Case

The ‘Assess Student Performance’ Use Case of Figure G 13 is further decomposed into Figure G 14. This function requires the FoS technology to provide feedback of not only the current location of the aircraft with respect to flight time, but also the data regarding movement of aircraft controls to determine the comfort levels of the student pilot performing SoP manoeuvres whilst completing mission specific tasks. The data gathered from the technology will provide comparison to baseline norms and the accuracy tolerance to mission objectives can then be evaluated with predicted performance levels for each student. This function includes the ability to assess any sharp movements in aircraft controls that might signify that the pilot has suffered from the ‘startle’ affect and thus suggest that a detailed

post-mission brief is required to find out what the student pilot was experiencing in that very moment.

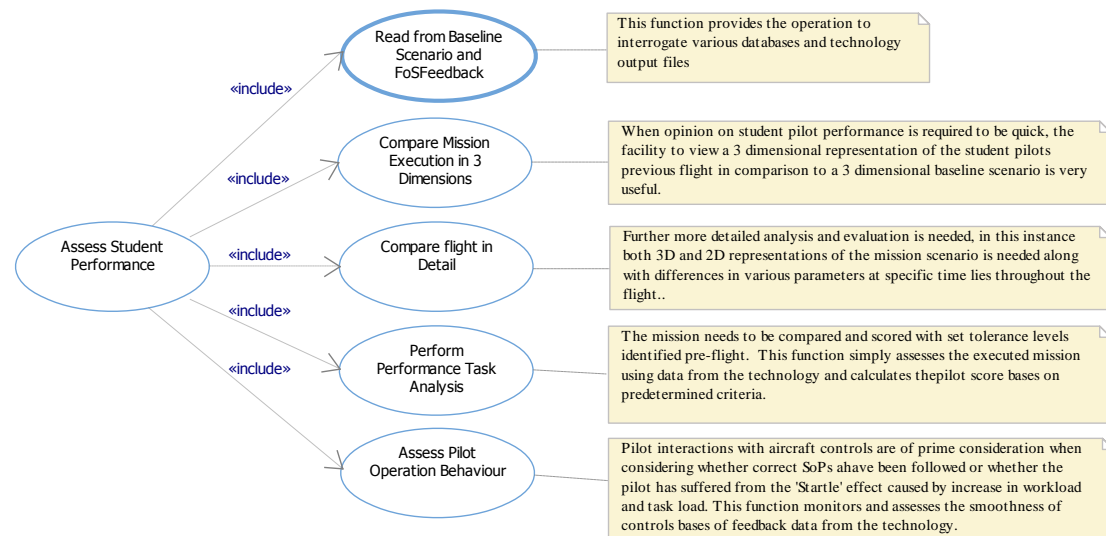


Figure G 14 Further Abstraction of Assess Student Pilot Use Case

The 'Perform Post Mission analysis' Use Case of Figure G 13 is further decomposed into Figure G 15. This function concentrates on both subjective and objective assessments on the suitability on the chosen technology for both executing the mission scenario and for flight training in general. The results obtained could affect how the training technologies are assigned to each student for future training missions and assist in evolving acquisition procedures for future flight training devices. The evaluation also highlights any specific difficulties the student pilot incurs during the execution of the mission scenario in relation to familiarity with control, sizes of displays, and workload. The information gathered is graded and stored within each respective student database file for ToT assessment and for evolution of the RSE shape by SMEs.

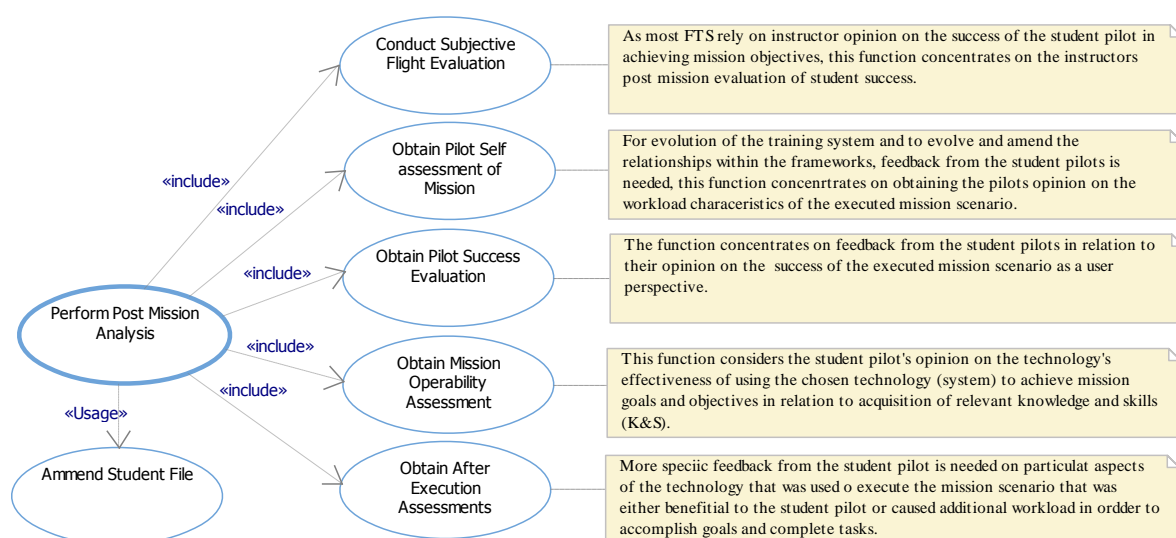


Figure G 15 Further Abstraction of Perform Post Mission Analysis Use Case

Figure G 16 presents a further abstraction of the ‘Automate Assessments of Cohesion of FoS’ Use Case first identified in Volume 1, Figure 40. The operations includes the ability to permit a choice of how detailed the analysis is required to be, however, the assessment of the suitability of technology in this function requires some technical knowledge of the training devices with respect to ‘training’ fidelity value of the system(s). The specific objective of this function is to enable organisational objectives to be included in the choice of training device to use to execute the mission scenario. It is the similarities between the remaining technologies that need careful consideration along with the availability of equipment. The trade study involves using mathematical functions as RSEs to decide which training technology optimises the organisational goals. The technology elimination is incorporated into the ‘Attain Fidelity Value of Systems’ Use Case. The chosen technology description is stored into the main student database file with performance results for subjective assessment of the suitability of technology to the student pilot and mission scenario specifics.

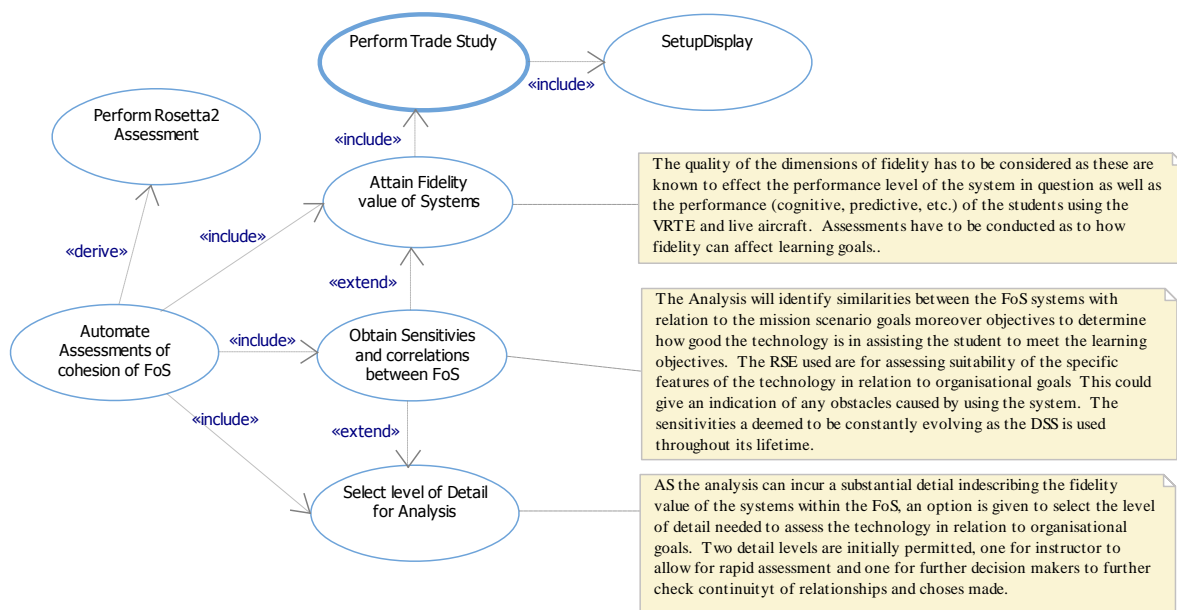


Figure G 16 Further Abstraction of Automate Assessments of Cohesion of FoS Use Case

The ‘Obtain Sensitivies and Correlations between FoS’ Use Case of Figure G 16 is further decomposed into Figure G 17. This function permits the generation of the ROSETTA Level 2 framework which allows, if required, additional sample points to be added to the RSEs to assist in the trade study.

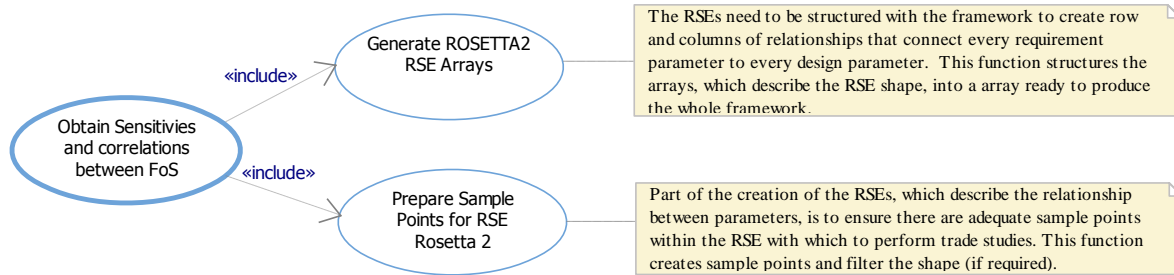


Figure G 17 Further Abstraction of Obtain Sensitivities & Correlations between FoS Use Case

For simplicity, a separate use case diagram is produced which shows the traceability between the NLS and the elicited and derived functions, as illustrated in Figure G 18. A number of use cases are derived and each use case is traced back to the requirement diagram of Volume I Figure 19. This diagram is used to communicate back to stakeholders that the proposed functionality of the DSS will satisfy the requirements and also give an indication to the system designer that all the requirements have been considered through the functional analysis of the requirements statements.

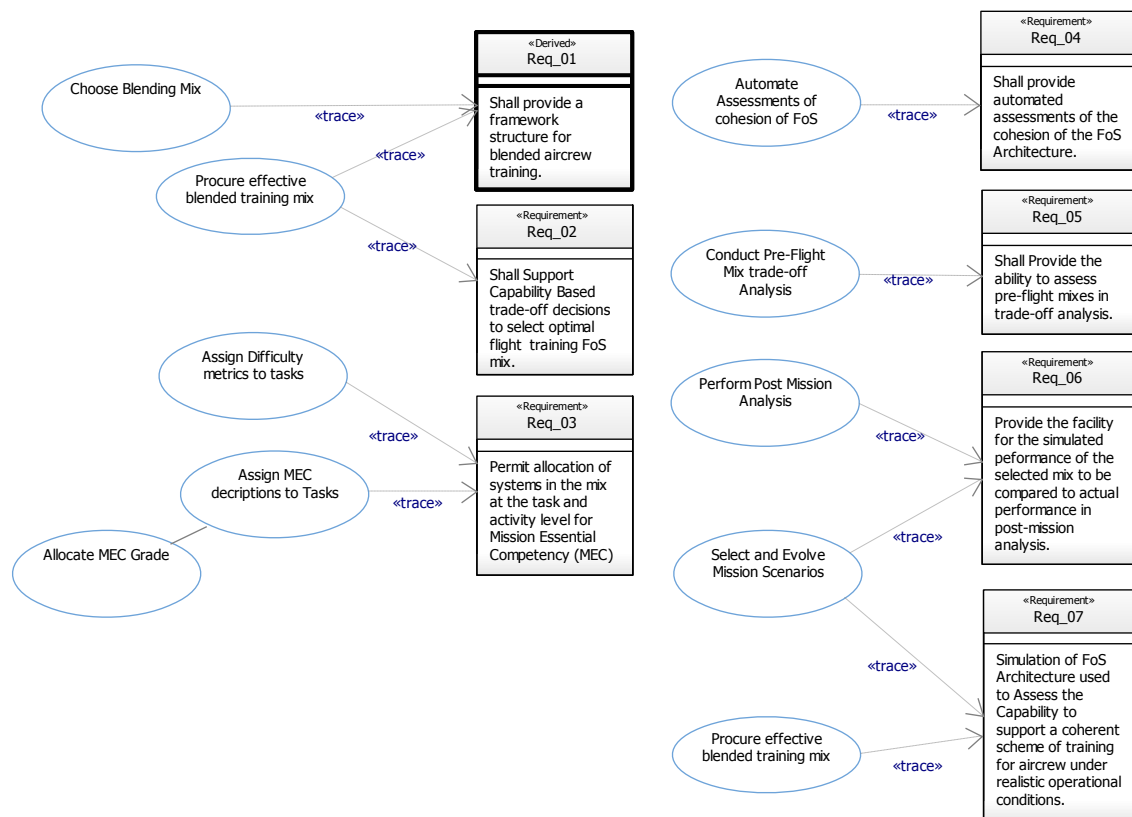


Figure G 18 High-Level Traceability from requirement statements to Functions (Use Cases)

Appendix G1 Subset of Systems Within The FoS Mixes

Within the training enterprise, the training devices are required to be simple enough to provide most student pilots with their initial flying experience and complex enough so the step between them and more sophisticated advanced trainers would not be too vast. For the analysis of appropriate blending mixes needed the number of SoI within the FoS mixes are required to be identified; a simple architecture model illustrating the breakdown of the most common technology available for flight training is illustrated in Figure G 19.

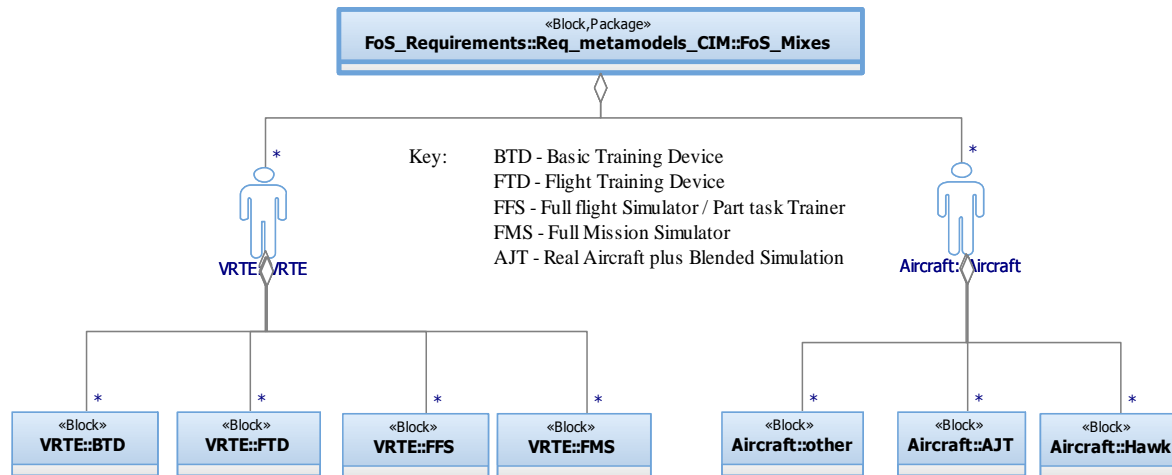


Figure G 19 Training Tool Technology within the FoS Mixes

Separation of VRTE and real aircraft permits further information to be gathered about the specific technology involved in both categories of the FoS and allows for a comparison analysis of similarity of controls, interfaces and layouts to assist in subjective evaluations of suitability of a training technology for accomplishment of training goals. The visit to RAF Valley allowed abstracting the aircraft of interest and the VRTEs of interest into the model. The training contractor uses both the old and new version of the Hawk aircraft for training and within the ground based systems are: desktop PCs, cockpit trainers, distributed FSTDs and dome flight FSTDs with availability of the resource reducing as the technology becomes more complex and expensive to operate. The difference in technology, layouts, environment and feel of the VRTE's between themselves and the live aircraft poses a complex problem when it relates to suitability of the technology/system to practice and evaluate K&S. The added complexity of the blended capability in the new Hawk AJT imposes the question of how is training being managed and documented to allow traceability and comparison analysis between training missions being performed in disparate FoS mixes and how can it be managed in the future.

APPENDIX H MISSION PLANNING MODEL

Baseline scenarios can be used for comparison to benchmark for students' normal performance or a performance set point for a given level of K&S for a particular mission scenario. The facility for the comparison includes analysis to a baseline scenario which obviates discussions based on hypothetical scenarios. It will set standards of performance that is hoped will maximise performance outcomes for the planned training exercise. Finally, it provides a means of establishing the validity of competencies that can be used to evolve a decision support tool to enhance the assessment of performance.

The performance criteria are based on a number of measureable features that can be collected through the training technology, and include:

- Maintenance of velocity
- Maintenance of assigned heading
- Maintenance of altitude
- Smooth control of pitch altitude of the aircraft
- Smooth control of bank angle of the aircraft

All the criteria are subjective to time constraints and require monitoring of aircraft display's and OOTW viewing to ensure flight path is as planned. Using a baseline scenario, the flight plan can be executed using mathematical algorithms to fly the course and this along with performance data for the respective pilot can be used to determine any improvement of performance is needed. There are three sources of data are used for the analysis:

1. Pilot's subjective ratings
2. Instructor subjective ratings and observations
3. The flight simulator (used for execution of the mission) **Note:** mathematical relations within framework(s) are also used to provide an indication pilot's performance using the current configuration.

Only a subset of the data from the FSTD is used for the analysis, attribute values are collected every 0.01s (10ms) for the entire period of the flight for the purposes of robust performance analysis and the flight is divided into stages depicting flight data between each waypoint. Whilst using a subset of data results in loss of variability, it is deemed that abstract data collection for analysis would give a strong indication of pilot performance and reduce the cost of data analysis. The attributes under consideration for the research included:

- Airspeed
- Altitude
- Latitude
- Longitude
- Altitude indicator pitch
- Bank angle
- Heading
- Throttle level position

The stages of flight are used to establish both geographic and assessment criteria boundaries for capturing representative samples of the behaviour of the student pilots across a particular leg of the flight using the training tool. The boundaries ensure the number of data points collected matched the number of samples generated by the baseline scenario simulation, and as a result the summary of the data accurately reflects the performance of pilots and that valid comparisons can be made across individuals.

A number of dimensions of performance can be evaluated on the bases on observed and comparison to the baseline scenario, including:

- The accuracy of maintaining altitude
- The accuracy of maintaining heading (latitude, longitude)
- The accuracy of the control exercised over the aircraft
- Management of situational awareness

Two attributes were considered for the student pilot's ability to maintain physical control of the aircraft, first related to the capacity to maintain a prescribed track and latitude; the second the ability to maintain physical control over the dynamic system by measuring the range of responses exerted by the pilot to stimuli. It is important to realise that performance data in relation to some of the attributes could be assessed against objective criterion (e.g. altitude, control, etc.); there is difficulty to assess features such as SA; nevertheless, indicators include, rubbing eyes, yawning, movement of seat, etc. The identification of these behaviours can be observed and video recordings (if available and required).

7.1.1 Baseline Scenario Model (General Overview)

To enable simulation of a baseline scenario with which to compare a flight from the student pilot it is important for the model to allow flexibility to associate the model with geodesics in relation to real world coordinates. The model shall permit the instructor to plan a flight or a

tactical mission using the earth coordinate systems involving the identification of latitude and longitude coordinates and allowing the model to calculate the shortest distance on the surface of an ellipsoid (depicting Earth's geometric shape) between two points. The model produced for mission planning considers both direct and inverse solution of the geodesic problem, with the inverse solution behaving as a location tolerance for the direct calculation.

The model requests the instructor to enter the longitude (Λ) and latitude (φ) of a point on the surface of an ellipsoid (the location of the start of the flight: the first waypoint), the starting azimuth ($\text{Direction_}\alpha_1$) and the geodesic distance (DisToWp): signifying the distance required to travel to the next waypoint, and the starting altitude. The direct calculation calculates the finishing point (Λ_2 , φ_2) and the final bearing ($\text{Direction_}\alpha_1$). The inverse calculation uses two points, the starting point and the finishing point, to calculate the geodesic distance (DisToWp_check), and the reverse Azimuth (α_1) with the results saved in a text file. The Vincenty's Formula (Vincenty, 1975) has taken the *de facto* role as the preferred method for the calculation of the geodesic problems, as a result is used for the model.

The model is developed using the SysML tool that is used for both the mission planning system and the baseline scenario simulation. The architecture, illustrated in Figure H 1, describe the system elements that need to be considered when planning a mission scenario for student pilot grading. Important aspects of the tasks in the mission scenario have to be considered for the criteria of grading for the student pilot, it is for this reason why the additional blocks (MissGoal, Task, MEC, Knowledge and Skill) are shown as being integral to the mission planning to allow identification of necessary aptitudes needed to complete the mission scenario through consideration of possible difficulty stressors to the pilot with various systems of the FoS, with a high degree of proficiency.

The 'Flight Plan' block represents the interface from the instructor to the mission planning system. The 'Waypoint' block attributes store the geodesic points (Latitude and longitude) including altitude, the waypoint ID and the velocity required by the aircraft at that point within the flight. The 'FlStat' block represents flight statistics as the simulated flight is being executed; data from other blocks within the architecture relevant to virtual aircraft location or waypoint location is located within this block for interfacing with external databases.

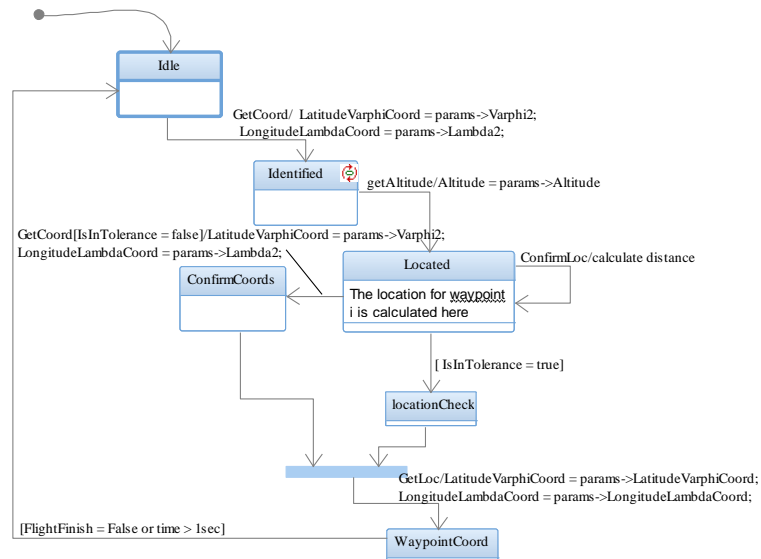


Figure H 2 Waypoint Block State chart

Figure H 3 describes the sequence of events the instructor has to accomplish for basic mission planning tasks i.e. flight path. The tool prompts the instructor to enter the starting real-world coordinates (longitude, latitude); further prompts to enter the distance required to fly, the azimuth angle, the ending altitude and velocity before any other change of state in the aircraft, i.e. the next waypoint is needed to be inputted. If a bank turn is required there will be an additional prompt to enter the degree of the turn the aircraft is required to follow.

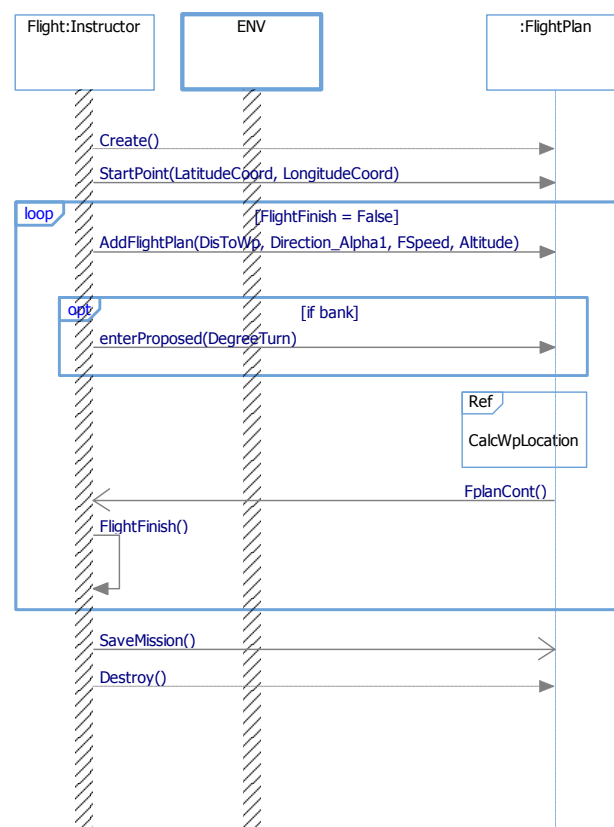


Figure H 3 Behaviour of Plan Mission Scenario Flight Use Case

Once all this data is entered, the tool transfers to a reference sequence diagram to calculate the next real world coordinate of the next waypoint in the sequence of the flight path, as seen in Figure H 4. Once the waypoint has been calculated and confirmed, the instructor will be asked whether this waypoint is the final waypoint for the flight. If it is, the waypoint locations in the flight plan will be saved, if not the program loops to ‘AddFlightPlan’ operation, as seen in Figure H 3.

The ‘CalcWpLocation’ reference sequence diagram is illustrated in Figure H 4, where the function uses all the information entered by the instructor to calculate the new real-world waypoint location (Lambda2 (Longitude), Varphi2(Latitude)), using the direct Vincenty’s formulae for geodetic calculations. Once calculated, the waypoint object requests for the new altitude to add to the locational information. The waypoint object then confirms the location by using the inverse method, which is used to confirm that both calculations are within a certain tolerance (100mm); if not, the direct method is repeated or if within the tolerance the waypoint coordinates are confirmed.

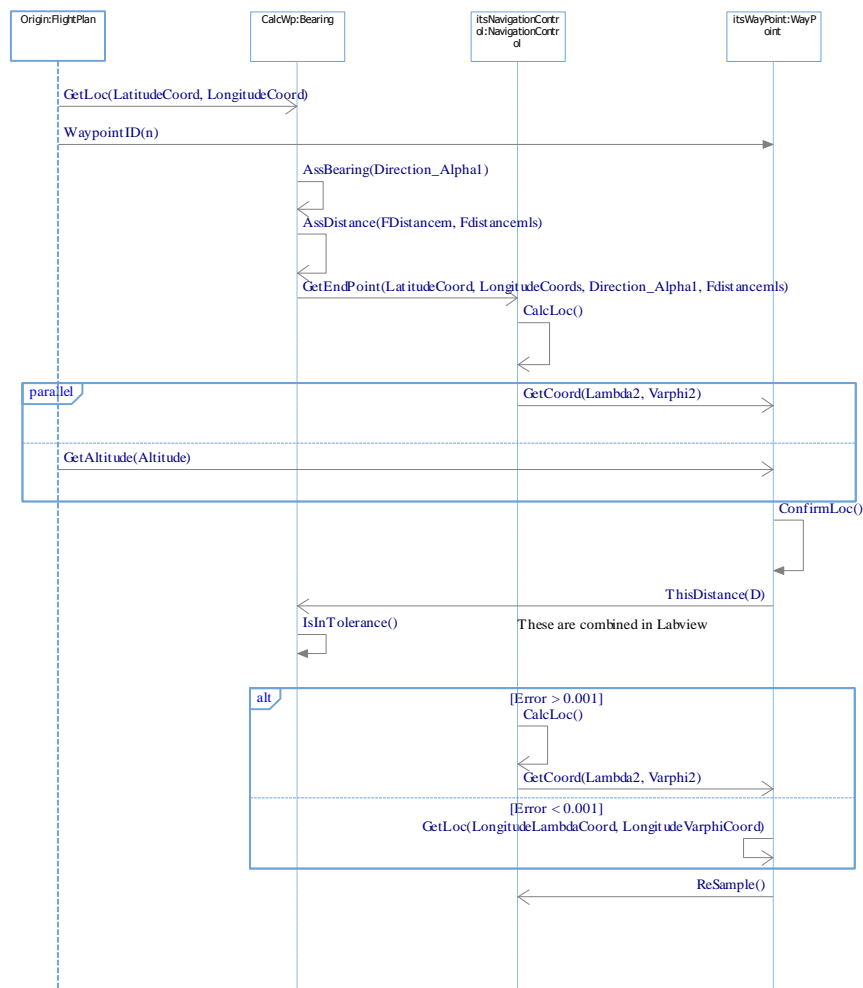


Figure H 4 Behaviour of Calculate Waypoint Locations Use Case

The 'StartPoint' Operation displays instructions to the decision maker to enter the starting latitude and longitude coordinates as seen in Figure H 5, followed by the 'AddFlightPlan' operation that requests more details about the next waypoint; in this case the next waypoint is where a change in state of the aircraft is expected to occur, as seen in Figure H 6. The details are to allow the mission scenario to be planned as a pilot would fly with respect to course corrections; alternatively, generating a text file by choosing points on a world chart and entering finish altitude and finish speed would achieve the same purpose.

Figure H 5 Prompts for Commencement of Mission

Figure H 6 Details for Coordinates to Next Waypoint

To account for standard right or left bank turns, if the planning system detects that a turn is required it will prompt the decision maker to decide the number of degrees the aircraft is required to manoeuvre through the turn i.e. if the coordinate to the next waypoint (Wp_i) is 90° from current bearing, the information is for the number of degrees in the turning circle the aircraft is required to fly to reach Wp_i , within the selected rate turn, to place the aircraft on the correct bearing for the following waypoint (Wp_j), as per Figure H 7.

Figure H 7 Prompt of Information Regarding Degree Turn

Accepting the data for the next waypoint enables the software to execute the state-machines and in turn progress through the events of the sequence diagrams to calculate the real-world coordinates of the next Waypoint in the mission. Once the calculations are complete, information will be displayed to the decision maker about the new waypoint location to which all future waypoints will be calculated from, this information is visually seen in Figure H 8. The inverse calculation ensures that the new waypoint location is in tolerance to the constraints of the calculation, along with the final bearing if a bank turn is required. The figure illustrates the first part of the flight, which is on the runway; hence the altitude is zero or the altitude above sea level of the runway.

INITIAL POINT (start of mission)

Mission Planning Database path

IS_ON

IS_ON check

ISinTolerance

stop

Bearing

LatitudeCoord

39.9771

LongitudeCoord

-77.64178

DisToWp

0.1295896

Enter Bearing (Direction_Alpha1)

328.38909

Navigation Control

Final Bearing

328.388142819208

Varphi2 Latitude

39.9789407792788

Lambda2 Longitude

-77.6432526693807

Waypoint

Altitude

0

Distancecheck km

0.2401553013990014

Distancecheck nm

0.1296734887669062

Figure H 8 Operator Display for Mission Planning System

Each iteration of the algorithm, prompts the decision maker to decide whether the full flight has been planned, as seen in Figure H 9. On the selection of 'No' the loop repeats commencing with the planning system asking for the details described in Figure H 6, alternatively the information regarding waypoint locations will be saved within a text file.

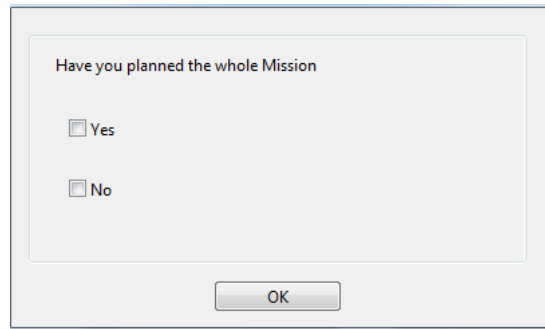


Figure H 9 Query Of Waypoint Assigned Completion

If the bearing to the next waypoint is unchanged, the planning system will prompt the decision maker to select one of three choices regarding the specifics of the aircraft path to the waypoint. These options are: no turn, bank left or bank right, as seen in Figure H 10, upon selection the mission planning system will either consider the route as being straight ahead (with possible altitude change) or will add to the text file either a 1 or 2 to indicate to the simulator either a bank right or bank left respectively, is required. If the bearing is different than previous, the planning system automatically decides which bank is necessary unless the new bearing requires $>360^\circ$ turn, in this case the option will again be available.

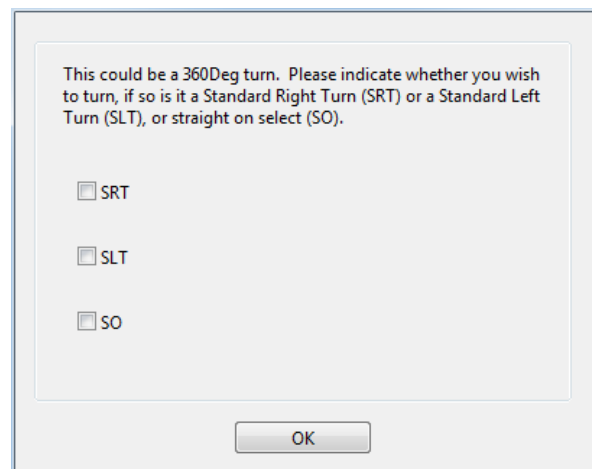


Figure H 10 Selection of Aircraft Path on Identical Bearing Entered

An example of the output text file is seen in Figure H 11, which describes a flight similar to a normal landing pattern. The flight begins on the runway and then climbs to an altitude of 500feet where it begins a standard left hand turn for 180° and climbs to 800feet to the next waypoint. The flight is then required to maintain heading but reduce altitude to 600feet where it begins another standard left hand turn for 180° whilst descending to 250feet and reducing velocity to 105knots. At the waypoint, the flight then requires to maintain current heading whilst descending further to 200feet with final velocity of 100knots.

back on track. The 'AltitudeChange' block concentrates on heading and distance deviations related to a change in altitude.

The 'Turning' block and the 'Position Turn' block concentrates on the complex problem of banking during waypoint journeys; 'Turning' block is responsible for checking that a bank is required and calculates the radius of the turn, circumference, and the total distance to travel in the turn; the 'PositionTurn' block task is to calculate the current bearing and current height (if altitude change is required through banking) through a turn as the virtual aircraft journeys to the real waypoints and communicates this to the 'Turning' block.

The behaviour of the 'Navigation' block, illustrated in Figure H 13, can be described simply as having knowledge *a priori* of the destination waypoints and ensuring that the virtual waypoints calculated along the journey are correctly identified with both the direct and inverse calculations. If there is an error in solutions it merely recalculates the solution before resampling for the next waypoint location.

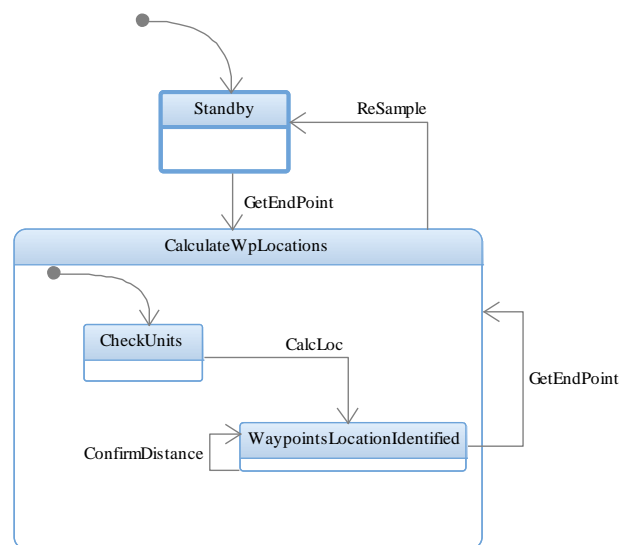


Figure H 13 Navigation Block State chart

The 'Bearing' block, illustrated in Figure H 14, has two separate operations for either mission planning or simulation mode. In mission planning the interest is in the calculation of the real waypoint of interest within the flight. The geodesic points (Latitude, Longitude) the azimuth bearing to reach the next waypoint and ensuring the distance between the waypoint is within tolerance. Within the simulation mode (FlightMode), the task is to calculate the virtual waypoint positions, the bearing, current virtual aircraft speed, and travel distance at each virtual waypoint, which designates the simulation operation.

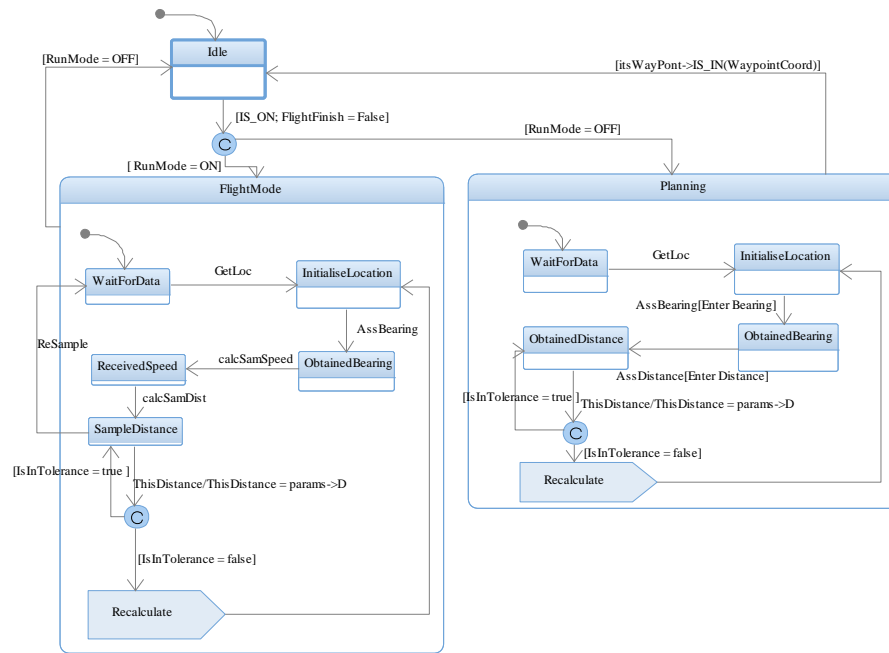


Figure H 14 Bearing Block State chart

The 'Altitude' block, illustrated in Figure H 15, merely checks whether there is any altitude change between waypoints, and calculates the new height required at the sampled time through the journey; once the height is reached the block rechecks if any height change is required.

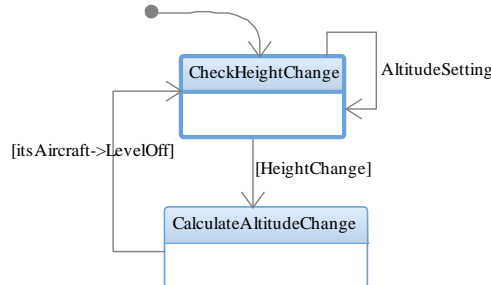


Figure H 15 Height Change Block State chart

The 'Turning' block, described in Figure H 16, assesses for any bank changes needed through the journey then checks the current heading (bearing) of the virtual aircraft; once the heading matches the calculated, the block returns to assessing for bank changes. The behaviour of this block is tightly coupled to the behaviour of the 'PositionTurn' block.

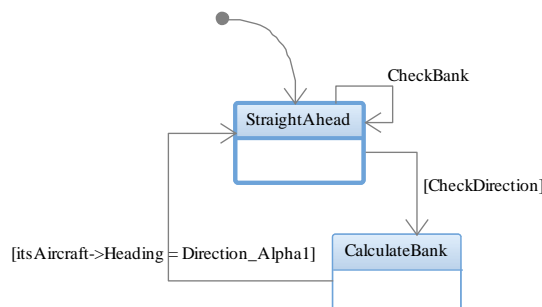


Figure H 16 Turning Block State chart

The identical guard condition is used for the ‘Turning’ block, described by Figure H 17, causes a transition within the ‘PositionTurn’ block that calculates any new heading (bearing) that the virtual aircraft has to fly in order to remain on course for the real waypoints. Once the virtual aircraft has reached the virtual waypoint, the block returns to the first state ready to proceed checking the heading for the next point in the journey.

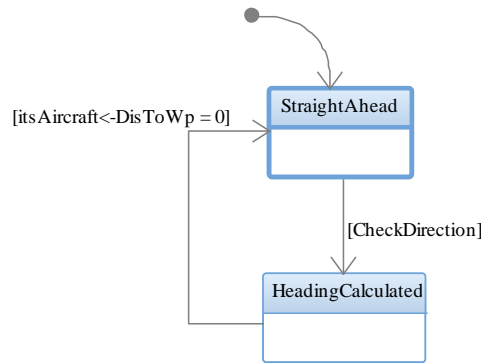


Figure H 17 PositionTurn Block State chart

The ‘FlStat’ block, illustrated in Figure H 18, gathers mission planning data from the database and the sampled simulation data for position of the virtual aircraft and calculates the distance to the next waypoint and distance from the waypoint. The block also places a time stamp of the sampled data for export to a text file.

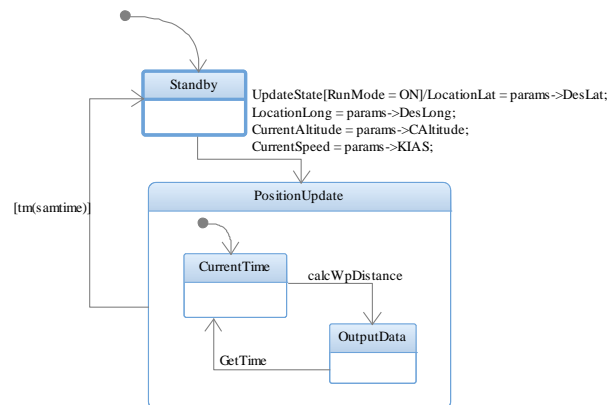


Figure H 18 FlStat Block State chart

The behaviour of the virtual aircraft requires information about the destination waypoint(s) before the ‘Aircraft’ block transfers to the ‘Flight’ state. Once in this state, there are four possible parallel behaviours of the aircraft each with their own unique sub-states. One of the behaviours concentrates on the velocity of the aircraft, the states that the aircraft can be in are: Acceleration, Deceleration or Cruise; another concentrates on the pitch of the aircraft, this has three possible states: Climb, LevelFlight or Descend; the next considers the roll of the aircraft and can be in one of three states: BankLeft, Straight or BankRight. The final parallel behaviour evaluates the current position of the aircraft compared to the final destination i.e.

the next waypoint in the sequence. Depending on this calculation the aircraft object will change state(s) in any of the other three parallel behaviours to compensate for course deviation by checking guard conditions on the transitions, to ensure the virtual aircraft stays on-course to the waypoint.

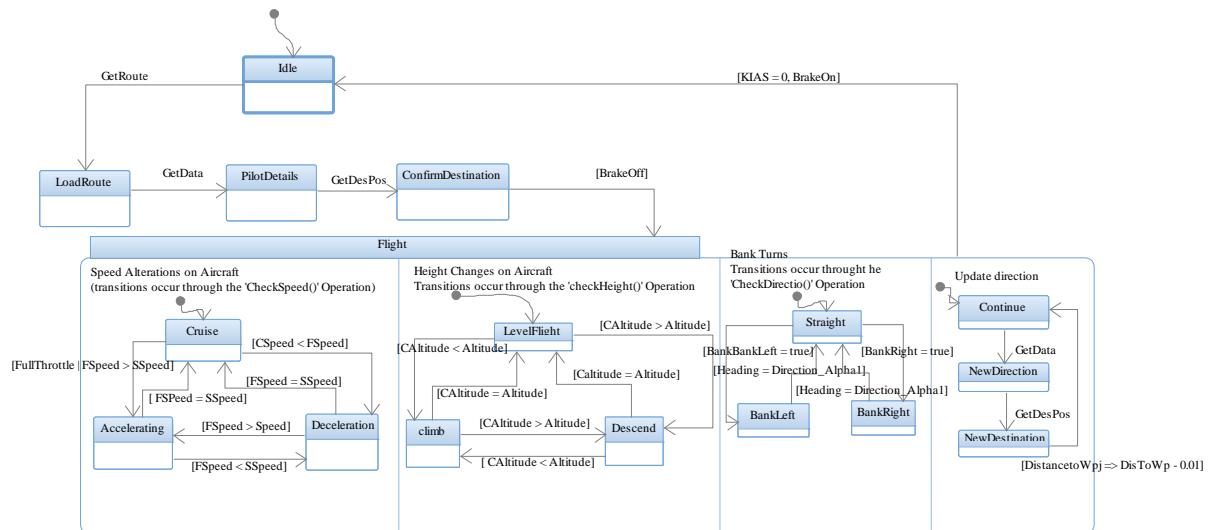


Figure H 19 Aircraft Block State chart

The behaviour of the simulation can be summarised in Figure H 20, the 'Bearing' block has to be switched into run mode, which essentially improves efficiency of waypoint calculations as each calculation becomes a new virtual waypoint through the journey. Once the first virtual waypoint has been calculated, the aircraft is switched to flight mode state through the 'BrakeOff' operation. Certain checks are actioned to assert if there is any height change or bank turns required; the 'Flstat' block is then updated with new information and current location of the virtual aircraft. The behaviour then transfers to a loop that calculates new virtual waypoint coordinates throughout the journey to the next planned waypoint from the mission planning database. Once the waypoint has been reached within a certain distance and altitude tolerance, an option to transfer to a tactical mission, e.g. find, fix, track target, engage, is checked. The behaviour then checks whether this final act is the last stage of the planned mission. If not, the next planned waypoint location is gathered from the 'FlightPlan' block and the sequence repeats; if the current location matches the last waypoint position of the flight plan the flight details are saved to the 'SimulationFiles' database within the Simulation_Run directory.

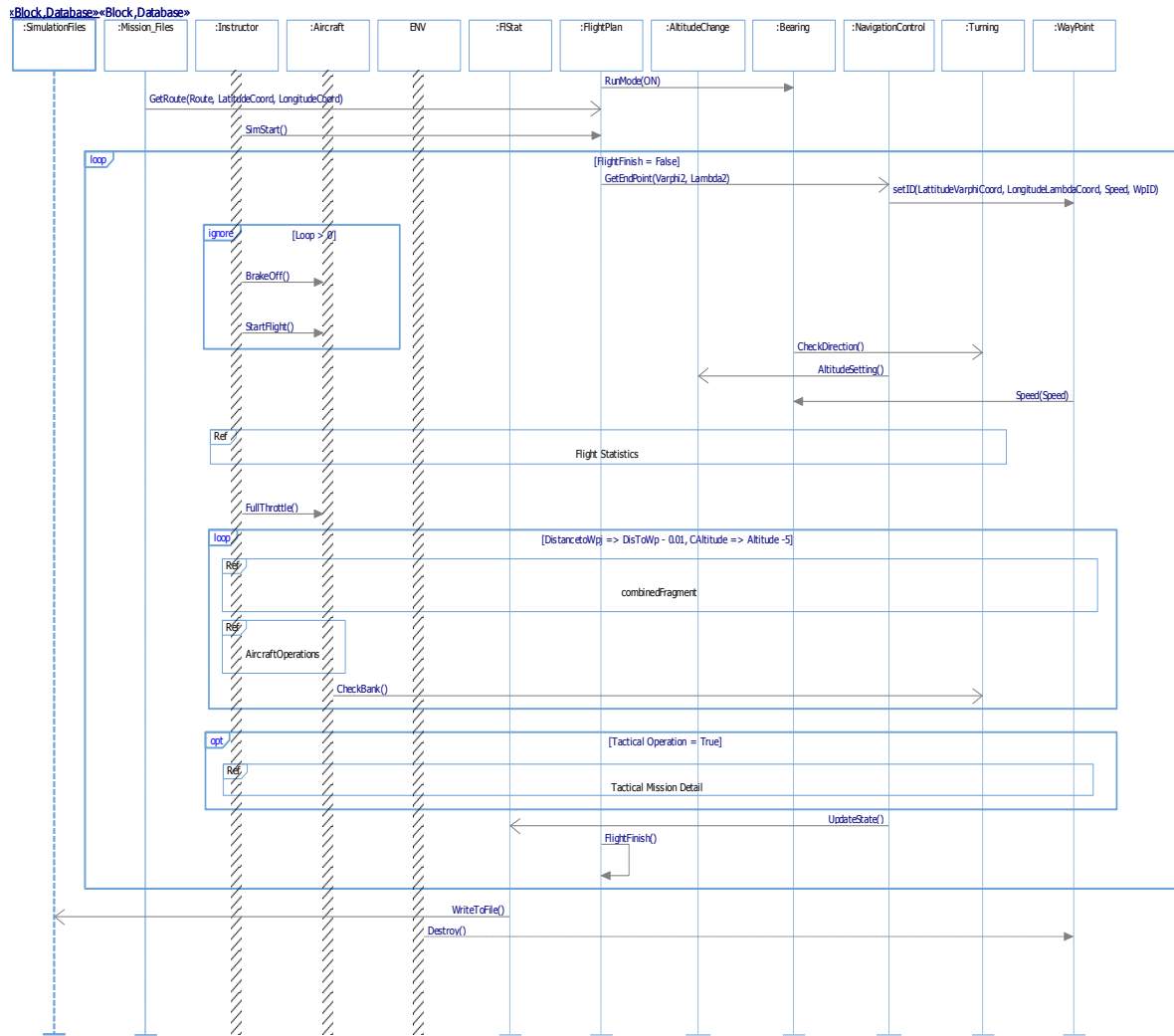


Figure H 20 Behaviour of Simulate Mission Scenario Use Case

The Flight Statistics reference sequence diagram is visualised in Figure H 21. The current speed, in knots, is updates to both the 'AltitudeChange' block and the 'TurningBlock' block, followed by an update in attribute values of the 'FStat' block including renewing the current flight time from the operating system. The 'FStat' block then calculates the travel distance between the last update in attribute values; followed by an update in bank information. For calculation of virtual waypoints throughout the journey, the number of samples made has to match the output data rate of the associated FSTD or VRTE. In this case a sample rate of 10ms matches the desktop simulator: the sample rate can be made as an instructor selected rate, however, the speed of the baseline simulation is highly dependent on the computer hardware constraints for speed.

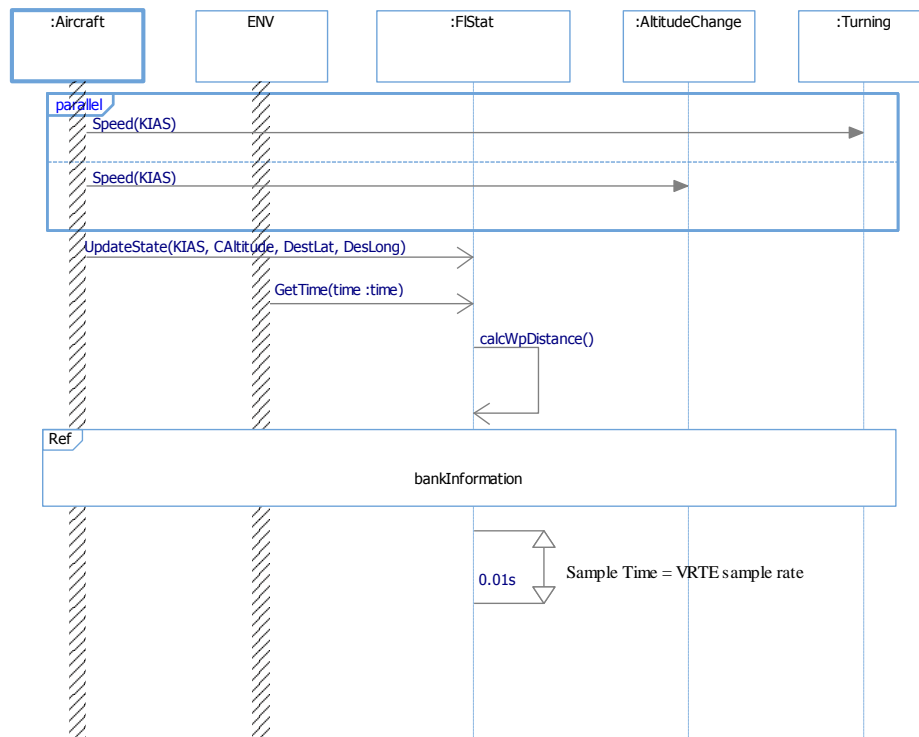


Figure H 21 Behaviour of Flight Statistics Reference Sequence Diagram

For a bank turn, the calculations required is to find the centre of the turning circle and the circumference of the turn to calculate the distance the aircraft will travel through the turn and is described in Figure H 22. Given a new bearing to the planning waypoint, for smooth flight more matched to real world flight, preliminary headings for virtual waypoints are required to be calculated. The 'Turning' block is to make a decision on whether a turn is required, information is then exchanged with the 'PositionTurn' block that then calculates the new bearing and distance to travel, exchanges these values to the 'Bearing' block who then decides the new state(s) of the virtual aircraft.

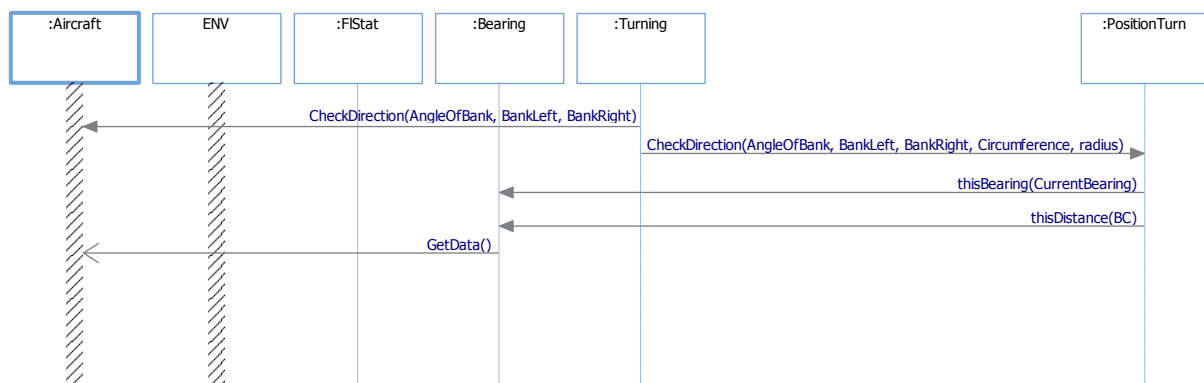


Figure H 22 Behaviour of Bank Information Reference Sequence Diagram

The combined fragment reference sequence diagram, illustrated in Figure H 23, includes the Flight Statistics and the SampleWpLocation reference sequence diagram, which are responsible for calculation of the current location and attribute values of the ‘Aircraft’ block.

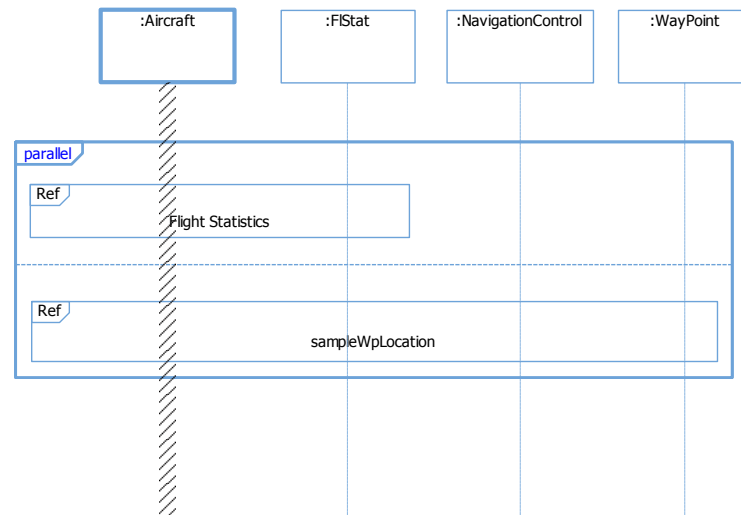


Figure H 23 Behaviour of Combined Fragment Reference Sequence Diagram

For the baseline simulation the current simulated speed, bearing and distance for each 10ms sample is required to be calculated along with the next coordinate of virtual waypoints; the main part of the simulation that satisfies this task is described in Figure H 24. The ‘Bearing’ block first receives information from the ‘Aircraft’ block with regards to current velocity and whether there is a bank turn. The block then calculates the new bearing (Heading), the current aircraft speed (samspeed), and the current travel distance (samdist); all of which identifies the attributes for the current sample point waypoint. This information is exchanged with the ‘NavigationControl’ block, which calculates the virtual waypoint coordinate that then creates a new virtual waypoint using the ‘Waypoint’ block. The function then uses the direct Vincenty’s calculation to check the calculation, which is confirmed. The behaviour of the blocks is then set ready for the next time the reference sequence diagram is called.

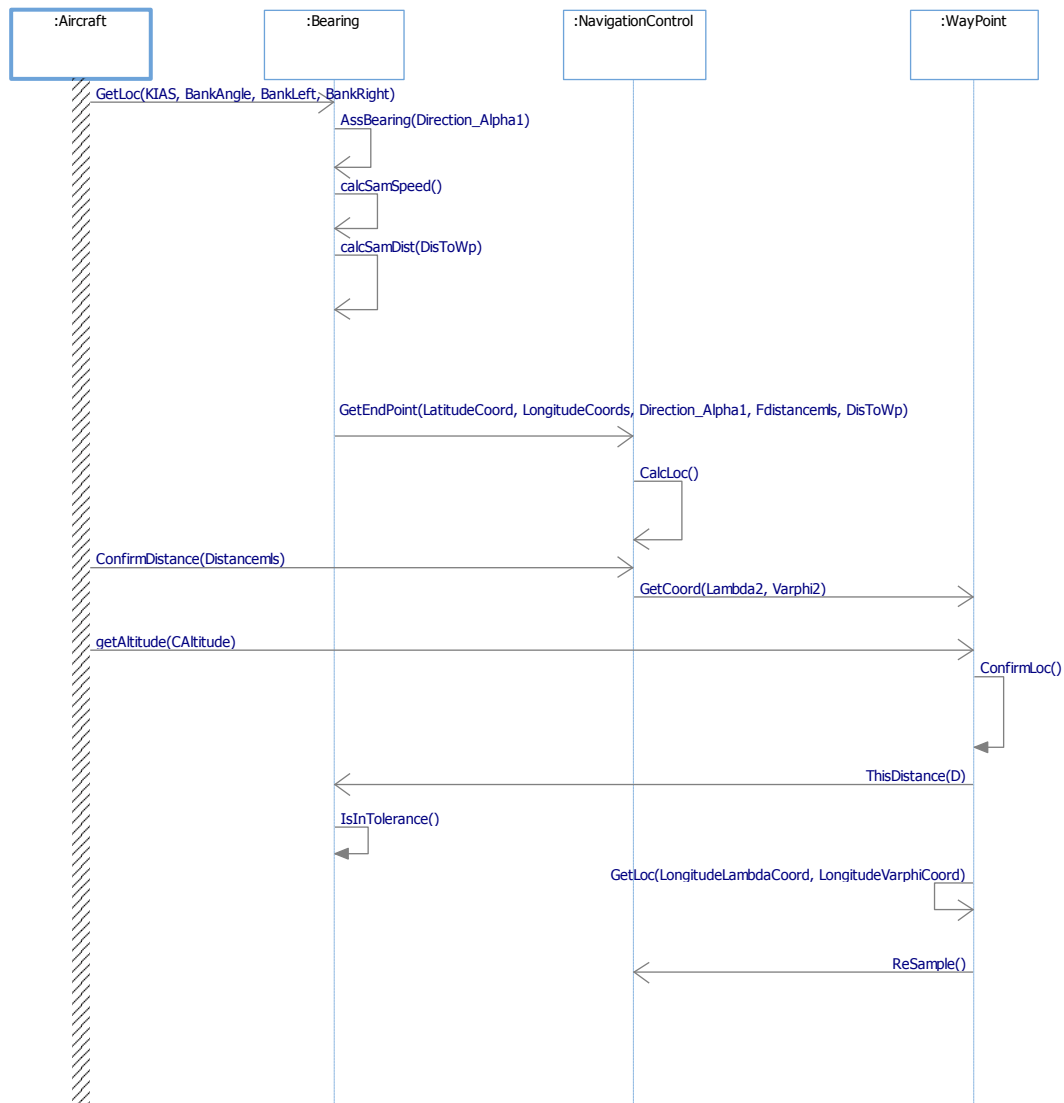


Figure H 24 Behaviour of SampleWpLocation reference Sequence Diagram

The behavioural diagram for the aircraft is seen in Figure H 25. This simple sequence diagram updates the aircraft attributes to match those calculated in Figure H 24, once updated the baseline simulation transitions to the next virtual waypoint in the sequence and associates a linear line between both points.

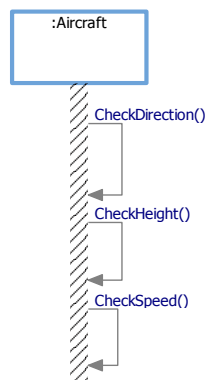


Figure H 25 Behaviour of Aircraft Operations Reference Sequence Diagram

When simulation of the mission planning data is required, the decision maker is first asked to select the missions that they wish to simulate to obtain the baseline scenario data with which to compare the student pilots executed mission with. The options are seen in Figure H 26, which relate to basic flight paths used for private pilot training flights that have been fully verified to function with the flight simulator designed specifically for the research project; furthermore, additional flights have been verified using a variety of waypoint locations and distances for the calculations. Upon selection of the mission scenario, the simulator will gather the text file generated from the mission planning system and will execute the necessary algorithms to obtain real time data of an ideal flight.

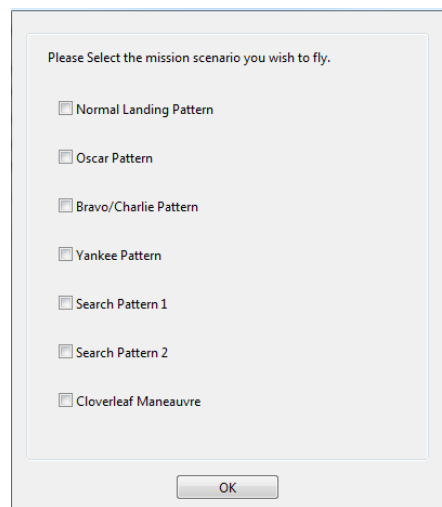


Figure H 26 Mission Scenario Selection List

To monitor progress of the flight, the simulator displays the UI as seen in Figure H 27, which gives the decision maker substantial information regarding the current position of the aircraft at each sample time point. To initialise the simulator, the IS_ON function is 'primed', which permits the simulator to load the data into the 'Mission Planning Data' table shown on the bottom right of the figure. The simulator begins the flight path at the start coordinates indicated on the two columns of the first row and uses the information contained within columns 4-9 of the first row with which to base the tolerances of a successful flight. The 3-D graph at the right hand side displays a real-time plot of the aircraft location as the algorithms calculate new locations every 10ms. The data in the grey box consists of an altitude indicator and a compass indicator to display in real time any altitude change and the magnetic bearing of the virtual aircraft during a bank turn; there are also discrete values to the right of the graphics to ensure the simulator has not 'crashed'. This information presents to the decision maker/observer the current calculated speed of the virtual aircraft based on the acceleration algorithms used in the simulation, along with the current latitude and longitude coordinates of

the aircraft; directly under the coordinates is an estimate of the time to reach the next waypoint, the global simulation time, the distances to and from waypoint and the current bearing, which will consistently alter during a bank turn.

The current mission, illustrated in Figure H 27 is the Normal Landing Pattern described on Figure H 11. The plot of the virtual aircraft can be rotated to allow for multiple views during the execution of the simulation to see any state changes in aircraft control. The simulation can also be used in conjunction with the student pilot executing the mission scenarios, especially in the early stages of training, to give key changes of state indications to the pilot on the current bearing, velocity and altitude of the aircraft to ensure the waypoints are reached in the required time schedule. The pitch and roll values along with the compass heading during live executions can give an inexperienced student pilot the information needed to maintain the course of the aircraft or be used in quick glances to double check aircraft current state.

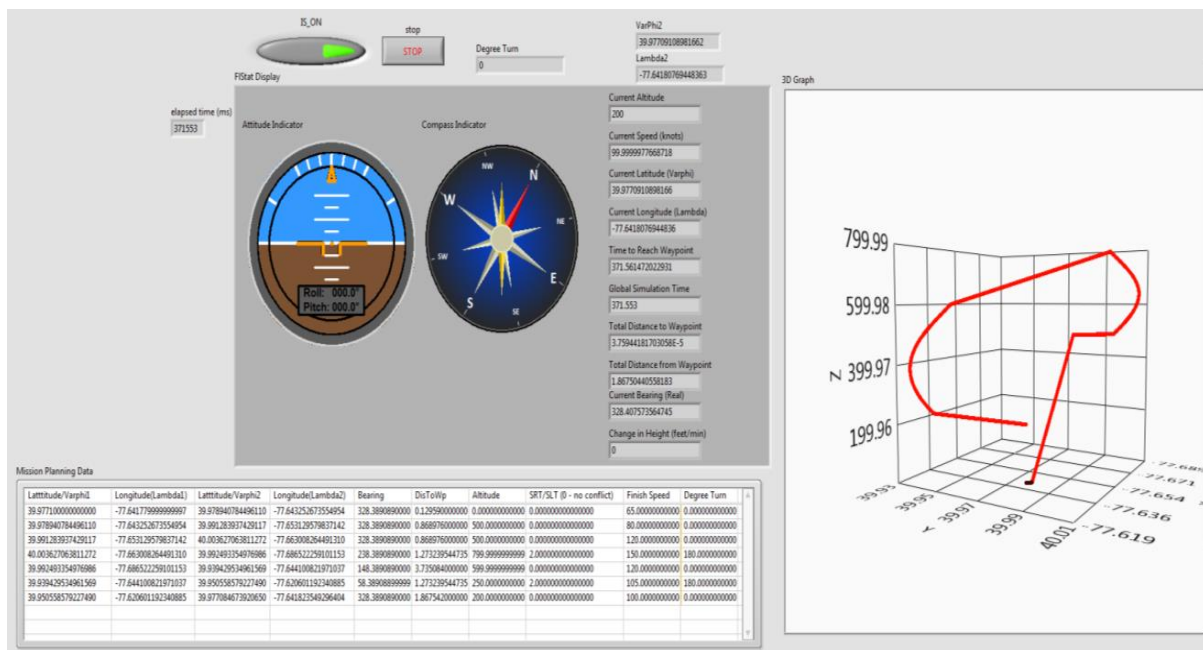


Figure H 27 Simulator User Interface

On completion of the simulation, i.e. the final waypoint in the table (last row columns 3 and 4) has been reached, the instructor will be asked to save the simulation data to a file, a subset of which is seen in Figure H 28. The first column signifies the task number (Task Number -1); the second and third columns the current latitude and longitude coordinates of the virtual aircraft; the fourth column is the current altitude in feet; the fifth column is the simulation time in seconds, which will be used to coordinate with the student pilot executed mission scenario output file from the chosen technology; the sixth column is the total distance

travelled in nautical miles including the bank turns; the seventh is the virtual aircrafts current bearing/heading.

Task Number -1	Latitude Coordinates	Longitude Coordinate	Current Altitude	Simulation Time	Distance Travelled	Current Bearing
0.0000000000000000	39.9771000000000000	-77.6417799999999999	0.0000000000000000	0.0000000000000000	0.0000000000000000	328.389089000000012
0.0000000000000000	39.977100000893365	-77.641780000704685	0.0000000000000000	0.0100000000000000	0.000000062891250	328.389089000000012
0.0000000000000000	39.977100003573426	-77.641780002848733	0.0000000000000000	0.0200000000000000	0.000000188673751	328.389089000000012
0.0000000000000000	39.977100008040203	-77.641780006422152	0.0000000000000000	0.0300000000000000	0.000000314456252	328.389089000000012
0.0000000000000000	39.977100014293690	-77.641780011424927	0.0000000000000000	0.0400000000000000	0.000000440238753	328.389089000000012
0.0000000000000000	39.977100022333886	-77.641780017857073	0.0000000000000000	0.0500000000000000	0.000000566021254	328.389089000000012
0.0000000000000000	39.977100032160791	-77.641780025718603	0.0000000000000000	0.0600000000000000	0.000000691803755	328.389089000000012
0.0000000000000000	39.977100043774406	-77.641780035009475	0.0000000000000000	0.0700000000000000	0.000000817586256	328.389089000000012
0.0000000000000000	39.977100057174738	-77.641780045729732	0.0000000000000000	0.0800000000000000	0.000000943368757	328.389089000000012
0.0000000000000000	39.977100072361779	-77.641780057879345	0.0000000000000000	0.0900000000000000	0.000001069151258	328.389089000000012
0.0000000000000000	39.977100089335522	-77.641780071458328	0.0000000000000000	0.1000000000000000	0.000001194933759	328.389089000000012
0.0000000000000000	39.977100108095975	-77.641780086466682	0.0000000000000000	0.1100000000000000	0.000001320716260	328.389089000000012
0.0000000000000000	39.977100128643137	-77.641780102904406	0.0000000000000000	0.1200000000000000	0.000001446498761	328.389089000000012
0.0000000000000000	39.977100150977002	-77.641780120771486	0.0000000000000000	0.1300000000000000	0.00000157281262	328.389089000000012
0.0000000000000000	39.977100175097576	-77.641780140067937	0.0000000000000000	0.1400000000000000	0.000001698063763	328.389089000000012
0.0000000000000000	39.977100201004866	-77.641780160793758	0.0000000000000000	0.1500000000000000	0.000001823846264	328.389089000000012
0.0000000000000000	39.977100228698859	-77.641780182948935	0.0000000000000000	0.1600000000000000	0.000001949628765	328.389089000000012
0.0000000000000000	39.977100258179576	-77.641780206533482	0.0000000000000000	0.1700000000000000	0.000002075411266	328.389089000000012
0.0000000000000000	39.977100289446994	-77.641780231547401	0.0000000000000000	0.1800000000000000	0.000002201193767	328.389089000000012
0.0000000000000000	39.977100322501116	-77.641780257990689	0.0000000000000000	0.1900000000000000	0.000002326976268	328.389089000000012
0.0000000000000000	39.977100357341946	-77.641780285863334	0.0000000000000000	0.2000000000000000	0.000002452758769	328.389089000000012
0.0000000000000000	39.977100393969501	-77.641780315165363	0.0000000000000000	0.2100000000000000	0.000002578541270	328.389089000000012
0.0000000000000000	39.977100432383757	-77.641780345896748	0.0000000000000000	0.2200000000000000	0.000002704323771	328.389089000000012
1.0000000000000000	39.986546591964291	-77.649337820979326	308.087617062924039	42.0940000000000001	0.000206294852812	328.389089000000012
1.0000000000000000	39.986549522463179	-77.649340165703279	308.20632254210568	42.1039999999999999	0.000206304423399	328.389089000000012
1.0000000000000000	39.986552453098000	-77.649342510536016	308.325033526316247	42.1140000000000004	0.000206313993986	328.389089000000012
1.0000000000000000	39.986555383868776	-77.649344855477665	308.443750018240734	42.1240000000000002	0.000206323564573	328.389089000000012
1.0000000000000000	39.986558314775493	-77.649347200528211	308.562472016984202	42.1340000000000000	0.000206333135160	328.389089000000012
1.0000000000000000	39.986561245818166	-77.649349545687556	308.681199522546649	42.1439999999999998	0.000206342705747	328.389089000000012
1.0000000000000000	39.986564176996779	-77.649351890955813	308.799932534928132	42.1540000000000003	0.000206352276334	328.389089000000012
1.0000000000000000	39.986567108311341	-77.649354236332968	308.918671054128481	42.1640000000000001	0.000206361846921	328.389089000000012
1.0000000000000000	39.986570039761851	-77.649356581819020	309.037415080147752	42.1739999999999999	0.000206371417508	328.389089000000012
1.0000000000000000	39.986572971348302	-77.649358927413885	309.156164612986060	42.1839999999999997	0.000206380988095	328.389089000000012
1.0000000000000000	39.986575903070701	-77.649361273117634	309.274919652643348	42.1940000000000003	0.000206390558682	328.389089000000012
1.0000000000000000	39.986578834929048	-77.649363618930295	309.393680199119615	42.2040000000000001	0.000206400129270	328.389089000000012
1.0000000000000000	39.986581766923337	-77.649365964851754	309.512446252414804	42.2139999999999999	0.000206409699856	328.389089000000012
1.0000000000000000	39.9865846699053580	-77.649368310882124	309.631217812529087	42.2240000000000004	0.000206419270444	328.389089000000012
1.0000000000000000	39.986587631319765	-77.649370657021379	309.749994879462178	42.2340000000000002	0.000206428841031	328.389089000000012
1.0000000000000000	39.986590563721890	-77.649373003269559	309.86877453214250	42.2440000000000000	0.000206438411617	328.389089000000012
1.0000000000000000	39.986593496259964	-77.649375349626624	309.987565533785300	42.2539999999999998	0.000206447982205	328.389089000000012
1.0000000000000000	39.986596428933979	-77.649377696092486	310.106359121175558	42.2640000000000003	0.000206457552792	328.389089000000012
1.0000000000000000	39.986599361743949	-77.649380042667261	310.225158215384510	42.2740000000000001	0.000206467123379	328.389089000000012
1.0000000000000000	39.986602294689867	-77.649382389350933	310.343962816412443	42.2839999999999999	0.000206476693966	328.389089000000012
1.0000000000000000	39.986605227771726	-77.649384736143418	310.462772924259468	42.2940000000000004	0.000206486264553	328.389089000000012
1.0000000000000000	39.986608160989533	-77.649387083044786	310.581588538925302	42.3040000000000002	0.000206495835140	328.389089000000012
1.0000000000000000	39.986611094343289	-77.649389430055066	310.700409660410173	42.3140000000000000	0.000206505405727	328.389089000000012
1.0000000000000000	39.986614027832985	-77.649391777174145	310.819236288714080	42.3239999999999998	0.000206514976314	328.389089000000012

Figure H 28 Subset of Output Data from Simulation of Standard Landing Pattern Example

Mission Scenario ref <input type="text"/>		Task No. in Mission <input type="text"/>		Task Difficulty <input type="text"/>					
Task Objectives <input type="text"/>		Task Importance <input type="text"/>		Task Load <input type="text"/>					
		Supporting Competencies <input type="text"/>		importance <input type="text"/>					
Assigned MECs <input type="text"/>		Start <input type="text"/>	Stop <input type="text"/>	Purpose <input type="text"/>	MEC importance <input type="text"/>				
				Task tolerances task time: <input type="text"/> relative position: <input type="text"/>					
				Task Goal Grade: <input type="text"/> optimal strategy <input type="text"/>					
List of activities or actions <input type="text"/>		Number of strategies available <input type="text"/>		Cockpit Operations Required <input type="text"/>					
Waypoint assignment <input type="text"/>		Between Waypoints <input type="text"/>		Time required <input type="text"/>					
Distance from Wpt <input type="text"/>				Time available <input type="text"/>					
Cues for activities <input type="text"/>		Satience <input type="text"/>	Info. Value <input type="text"/>						
				Assigned Altitude (feet) <input type="text"/>					
				Altitude deviation (<200ft) <input type="text"/>					
				Climb rate (if required) <input type="text"/>					
				Descent rate (if required) <input type="text"/>					
				Assigned airspeed (kts) <input type="text"/>					
				Airspeed Deviation <input type="text"/>					
				Attention Weight <input type="text"/>					
				S.A. level <input type="text"/>					
				probability of error <input type="text"/>					
				Aircraft Assignment Heading <input type="text"/>					
				Heading Deviation (+/- %) <input type="text"/>					
				Bank angle deg (if required) <input type="text"/>					
				pitch angle <input type="text"/>					
				S importance <input type="text"/>					
				K importance <input type="text"/>					
Family of Systems configurations (domain package subject to change)									
	Basic Training Device (BTD)	Desktop Trainer with Helas (DTH-24)	DT with cockpit Chair (DTCC-24)	DTCC multiscreen-3-24 (DTCC-MS3-24)	DTCC multiscreen-6-52 (DTCC-MS6-52)	Flight Training Device (FTD341)	Full Mission Simulator (FMS)	Live Aircraft (LA)	LA with Embedded Sensor Simulator (LA-ESS)
Workload scale									
	Cognitive								
	Visual								
	Auditory								
	Kinesthetic								
	Psychomotor								

Figure H 29 Optional Paper Based Planning Sheet for Mission Scenario

APPENDIX I PRE-PILOT ASSESSMENTS

The pre-pilot assessment stages consists of gathering personal characteristics of prospective student pilots along with a simple medical questionnaire followed by an holistic assessment of pilot current learning and stress coping ability. The pre-pilot functional behaviour can be seen in Figure I 1. Each sub-stage, represented by reference sequence diagrams, involves interaction with a decision maker, whilst the ILS sub-stage has detailed information that needs to be displayed to the decision maker in a separate UI. The information gathered is used to update a main student database file to give the decision maker a quick reference to the results obtained.

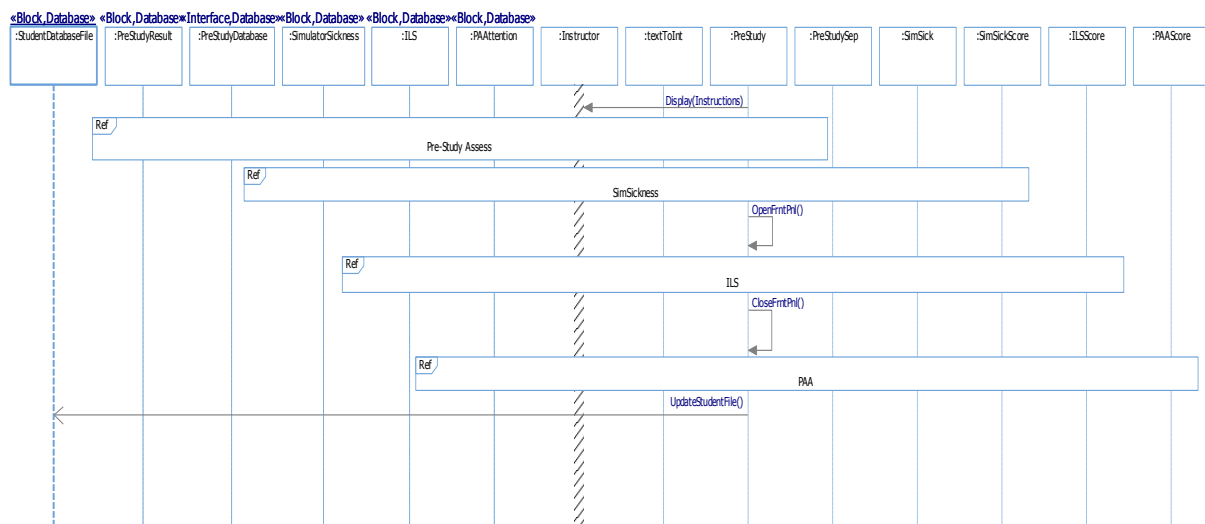


Figure I 1 Behaviour of Perform Pre-Pilot Assessment Use Case

The Pre-study assess sub-stage, seen in Figure I 2, involves interrogating a main textual database where all prospective student details from the characteristics questionnaire is retained from the online sources, an example is seen in Assessment Form 1. The decision maker searches for a particular student pilots name from this database. The 'PreStudy' block retrieves the number of questions and the answers and separates them into two 1D text arrays. The questionnaires contain both qualitative and quantitative data, from Likert scale questions; as a result the quantitative data is converted by the 'textToInt' block to integer values for mathematical manipulation, whilst the qualitative descriptive results are used for further assessment on the student if required based on assessment outcome. The quantitative results are then used by the 'PreStudySep' block to gather an overall score of student suitability including details of gender, age range, and previous experience in real world flying as well any previous simulator experience. For detailed description of GUI, refer to Volume I, Chapter 7.2.2.

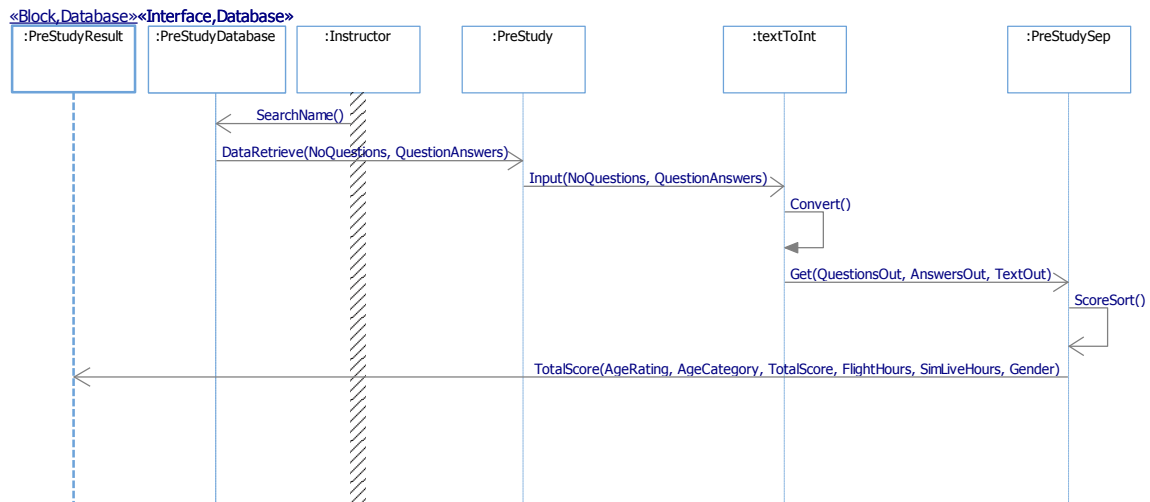


Figure I 2 Behaviour of Gather Student Pilot Personal Characteristics Use Case

The simulator sickness sub-stage, seen in Figure I 3, includes a simple assessment of prospective student pilot's reaction to using VRTE technology for training. The functionality asks for the decision maker to search for a name from the simulator sickness questionnaire, see Assessment Form 2 for details, and then converts the answers to Boolean values. These Boolean values are used to give a quick indication, via the computer display, of any potential issues with the probable disorientation effects of VRTE for each student. If the assessment identifies any problems by illumination of a virtual LED on the issues array provided by the 'SimSickScore' block, the qualitative answers given are used for clarification of the potential problem. For detailed description of GUI, refer to Volume I, Chapter 7.2.2.1,

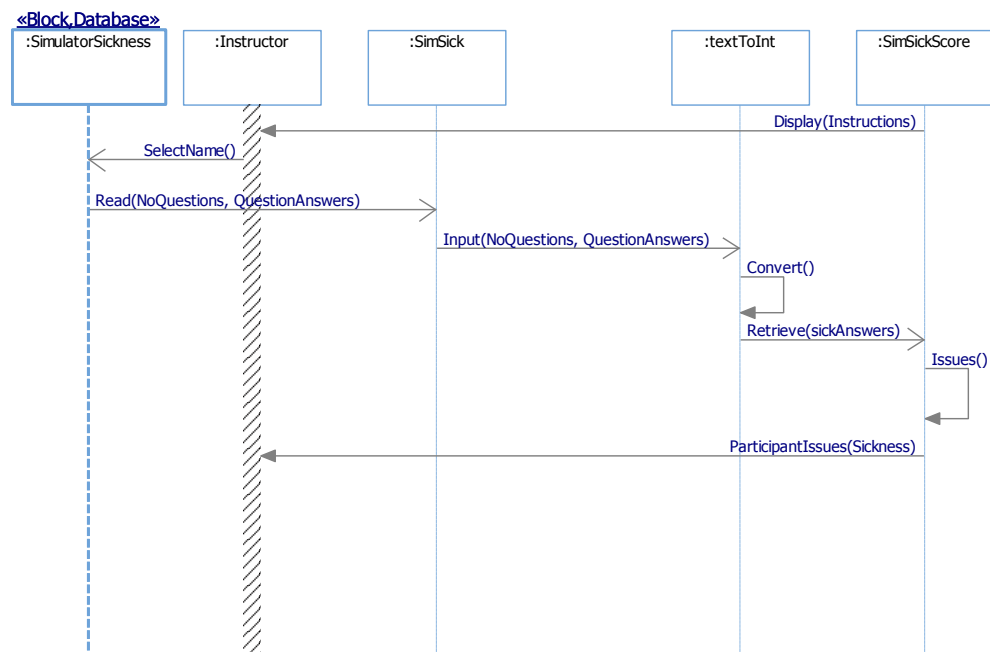


Figure I 3 Behaviour of Assess Simulator Sickness Use Case

Assessment Form 1 Pre-Study Participant Questionnaire (Sample)

Pre-Study Participant Questionnaire (Simulator Fidelity Assessment)

You are invited to participate in a research study conducted by Trevor Holden from the Systems Engineering Department of the EESE School at Loughborough University. Recruitment is for males and females aged 18 to 35 years with an interest in game based learning for transfer-of-training to the real world or interests in gaming possibilities in general. You should read the information below, and ask questions about anything you do not understand, before deciding whether to participate.

Confidentiality

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. You will be assigned a subject reference number, which will be used on all related documents to include databases, summaries of results, etc. Only one master list of subject names and numbers will exist that will remain only in the custody of the research investigator.

Identification of Investigators

If you have any questions or concerns about the research, please feel free to contact the principal investigator, Trevor Holden: [REDACTED] Research Supervisor: Charles Dickerson, email [REDACTED]

* Required

Participation and withdrawal

Your participation in this study is completely voluntary and you are free to choose whether to be in it or not. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind.

Purpose of Study

The study is designed to evaluate how effective different fidelity of simulators, similar to those used by the RAF and other military pilots, are for training pilots for the front line. The outcome of the study should assist in the acquisition management and use of technology within a flight training system.

The experimentation is a subset of a larger research project focussing on pre-assessment of technology mix for use to train pilots as they progress through the flight training system pipeline. The results obtained will be used to optimise a dynamic 'real-time' framework for the management of student performance and technology choice, to improve the effectiveness of pilot readiness.

Potential Risks and Discomforts

There are no anticipated physical or psychological risks in this study

Procedure

1. Pre-study: Fill in a computer based questionnaire to determine general background information and viability as a candidate.
2. Attend a training session to learn about the mission scenarios; this will involve group discussions with all successful participants and explanation of the different simulator configurations.
3. Practice with the simulation software to become familiar with the visual fidelity and the controls to gain knowledge of the 'perks and features' of the simulator.
4. Pre-flight brief and computer based questionnaires (~5-10min): to determine your understanding, current disposition and assurance that you are comfortable to proceed.
5. A number of experimental flights (~5-15min each including questionnaires). These will form the main experiment and will consist of standard flight manoeuvres, search and rescue mission (CSAR), and possible combat scenarios. Each experiment will be used to examine workload intensity for each participant with flying a different simulator configuration. Your flight data, head and eye position will be measured and analysed; you will also be asked to complete some computer based questionnaires and paper questionnaires after each flight to determine, by self-assessment, cognitive function and physical performance, for workload analysis. (~5-10mins).
6. Debrief: Replay of your flights and discuss performance with the principle investigator and complete some self-assessments relating to your interpretations of the simulator and your performance.
7. Due to the nature of the experiment it may be probable to complete the flight experiments on separate days for convenience and additional statistical analysis.

Potential Benefits

While there is limited foreseeable benefit to you as a participant in this study, your efforts will provide critical insight into the ability of feedback and technology driven performance feedback to help in the design of future flight training family of systems.

Confidentiality

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. You will be assigned a subject reference number, which will be used on all related documents to include databases, summaries of results, etc. Only one master list of subject names and numbers will exist that will remain only in the custody of the research investigator.

Identification of Investigators

If you have any questions or concerns about the research, please feel free to contact the principal investigator, Trevor Holden [REDACTED]; Research Supervisor: Charles Dickerson, email [REDACTED]

1. Please insert your first name followed by surname initial *
example: TrevorH
-

Personal Details

2. Please provide your preferred contact e-mail address *
example: anon@unknown.com
-

3. What Gender are you? *
Mark only one oval.

- ☐ Male
☐ Female

4. 1. What is your age? *
Mark only one oval.

- ☐ 18-25
☐ 26-30
☐ 31-35
☐ 35+

5. 2. What is your education background *
Mark only one oval.

- ☐ GCSE
☐ A-level
☐ Degree
☐ Advanced Degree
☐ Other:

6.

3. If Student which subject / domain area are you studying

example: software engineering, Aeronautics, physics

.....

.....

.....

.....

.....

7.

4. What is your visual acuity (if Known)

example: 20/20, 20/100

.....

8.

5. Do you wear any of the following for corrected vision*Mark only one oval.*

- ☐ Glasses
- ☐ Contact Lenses
- ☐ none

Gaming Experience

This page will ask you about your game playing experience and interests

9.

6. Have you or do you play computer games **Mark only one oval.*

- ☐ 1. Yes
- ☐ 2. No

10.

7. Please list the types of computer games you most often play

example: first person shooter, strategy, microsoft flight simulator, Role play

11.

8. Do you have any experience with flight simulators? *

if no goto question 10.

Mark only one oval.☐ 1. Yes☐ 2. No

12.

9. How many years experience of using PC based flight simulators*Mark only one oval.*☐ 1. Less than 1 year☐ 2. Between 1 and 3 years☐ 3. Between 3 to 5 years☐ 4. 5 years +

13.

10. Do you have any experience with goal / mission related computer games *

if no goto question 12

Mark only one oval.☐ 1. Yes☐ 2. No

14.

**11. How many years experience of using
goal / mission based games**

Round to nearest year!

15.

12. How often do you play video games per week? **Mark only one oval.*☐ 1. Never☐ 2. Less than 1 hour per week☐ 3. Between 1 and 4 hours per week☐ 4. Between 5 and 10 hours per week☐ 5. Between 11 and 15 hours per week☐ 6. 16 hours per week +

16.

13. When was the last time you played more than 3 hours of computer games per week *

Mark only one oval.

- ☐ 1. This week
- ☐ 2. Last week
- ☐ 3. Last Month
- ☐ 4. Last Year
- ☐ Other:

17.

14. As a rough estimate, how long have you been playing computer games *

Round to nearest year!

.....

Real life experience

18.

15. Do you drive or ride a motorbike? *

Mark only one oval.

- ☐ 1. Yes
- ☐ 2. No

19.

16. If so, how long have you been driving or riding *

Round to nearest year!

.....

20.

17. Have you ever piloted a real aircraft? *

Mark only one oval.

- ☐ 1. Yes
- ☐ 2. No

21.

18. If so, how long have you experience in piloting an aircraft *

Round to nearest year!

.....

22. 19. Roughly in your flight career, how many flying hours have you *
Round to nearest hour!

.....

Personal Availability and Health

This page is intended to provide information regarding any motion sickness and availability for experimentation

23. 20. Would you be available for experimentation during the period of 13st April 2015 - 24th April 2015 and Mon-Sat 9am to 6pm? *

Mark only one oval.

☐ 1. Yes

☐ 2. No

24. 21. If not available during these dates and times stated in the previous question, please give an indication of your availability
example: Date-time ranges

.....
.....
.....
.....
.....

25. 22. Do you have any physical or psychological disabilities such as epilepsy, limited movement, visual impairment beyond correctable solutions (please list if applicable)? *

.....
.....
.....
.....
.....

26. 23. Please sign the form below with your name *
example: David Johnson

.....

27. 24. Please date the form? *

Example: December 15, 2012

.....

Assessment Form 2 Simulator Sickness Pre-Screen Questionnaire

Simulator Sickness Pre-Screen Questionnaire

This training program will require you to operate a low fidelity flight simulator (FSTD), under different configurations and display sizes and settings. It has been known that some participants, in similar studies have felt uncomfortable and suffered symptoms of nausea after participating in studies using the simulator. To help identify people who might be prone to this feeling, we would like to ask the following questions:

* Required

1.

Name? (First name, Surname Initial) *

e.g. TrevorH

.....

2.

1. Do you or have you had a history of motion sickness *

Mark only one oval.

☐ 1. Yes

☐ 2. No

3.

2. If yes to Motion Sickness, please describe details

.....

.....

.....

.....

.....

4.

3. Any health problems that affects a similar activity, such as driving a car? *

Mark only one oval.

☐ 1. Yes

☐ 2. No

5.

4. Any inner ear problems, dizziness, vertigo, or balance problems *

Mark only one oval.

☐ 1. yes

☐ 2. No

6.

Please sign the form below with your name *

example: David Johnson

.....

7.

Please Date the Form *

Example: December 15, 2012

.....

The Index of learning style questionnaire, described in Assessment Form 3, attempts to gather the preferred learning style of each student pilot to identify any potential issues with them acquiring knowledge from strict lecture material. The questions are developed with just two possible answer options, these options have a value of either '1' or '2' rather than the accepted mechanism of 'a' or 'b'. The prospective student pilot concentration is on the descriptive answers to each question and is prompted to answer as honest as possible as the result may affect training programs and mission planning objectives specifically planned for them. The quantitative answers given are used in a specific algorithm that organises the questions and answers into learning style dimensions by the 'ScoreSort' operation of the 'ILSScore' block, described in Figure I 4. The 'GenerateQuad' operation is used to combine learning style dimensions score into two dimensions to permit analysis of the student pilot's ability to learn with concentration given to domain specific strengths needed to perform the job. The 'identifyRating' operation uses the score to visually rate the student pilot on their ability to acquire knowledge based on strict classroom learning for quick identification using colour coded representations on a quadratic graph. The decision maker can then use the graph to perform some additional analysis on the results, using the qualitative answers as the basis for analysis. Once the results are accepted, the ILS grade is saved within the main student database file.

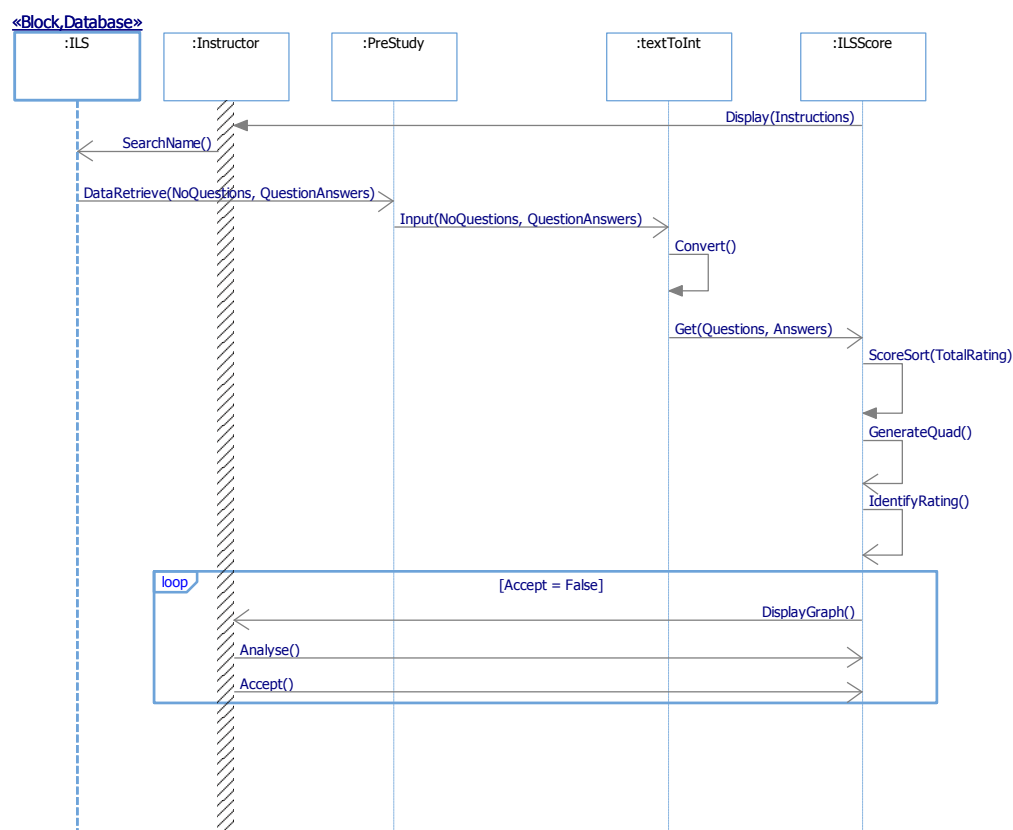


Figure I 4 Behaviour of Evaluate Student Pilot Learning Style Use Case

Index of Learning Styles

This assessment is to discover your preferred learning style mainly for the lecture material. Please enter your answers to every question on the scoring sheet (form). Please choose only one answer for each question. If both 'a' and 'b' seem to apply to you, choose one that applies more.

* Required

1.

Name? (first name, Surname intitial) *

e.g. TrevorH

.....

2.

1. I understand something better after I *

Mark only one oval.

☐

1. Try it out

☐

2. Think it through

3.

2. I would rather be considered *

Mark only one oval.

☐

1. Realistic

☐

2. Innovative

4.

3. When I think about what I did yesterday, I am most likely to get *

Mark only one oval.

☐

1. A picture

☐

2. Words

5.

4. I tend to *

Mark only one oval.

☐

1. Understand details of a subject but may be fuzzy about its overall structure

☐

2. Understand the overall structure, but may be fuzzy about the details

6.

5. When I am learning something new, it helps me to *

Mark only one oval.

☐

1. Talk about it

☐

2. Think about it

7.

6. If I were a teacher, I would rather teach a course **Mark only one oval.*

- ☐ 1. that deals with facts and real life situations
- ☐ 2. that deals with ideas and theories

8.

7. I prefer to get new information in **Mark only one oval.*

- ☐ 1. Pictures, diagrams, graphs, or maps.
- ☐ 2. Written directions or verbal information

9.

8. Once I understand*Mark only one oval.*

- ☐ 1. All the parts, I understand the whole thing
- ☐ 2. the whole thing, I see how the parts work.

10.

9. In a study group working on difficult material, I am more likely to **Mark only one oval.*

- ☐ 1. Jump in and contribute ideas
- ☐ 2. Sit back and listen

11.

10. I find it easier **Mark only one oval.*

- ☐ 1. to learn facts
- ☐ 2. to learn concepts

12.

11. In a book with lots of pictures and charts, I am likely to **Mark only one oval.*

- ☐ 1. look over the pictures and charts carefully
- ☐ 2. focus on the written text

Untitled Page

13.

12. When I solve math problems **Mark only one oval.*

- ☐ 1. I usually work my way to the solution one step at a time
- ☐ 2. I often just see the solutions but then struggle to figure out the steps to get to them

14.

13. In classes I have taken **Mark only one oval.*

- ☐ 1. I have usually gotten to know many of the students
- ☐ 2. I have rarely gotten to know many of the students

15.

14. In reading nonfiction, I prefer **Mark only one oval.*

- ☐ 1. Something that teaches me new facts or tells me how to do something
- ☐ 2. Something that gives me new ideas to think about

16.

15. I like lecturers **Mark only one oval.*

- ☐ 1. who put a lot of diagrams on the board
- ☐ 2. who spend a lot of time explaining

17.

16. When I'm analysing a story or a novel **Mark only one oval.*

- ☐ 1. I think of the incidents and try to put them together to figure out the themes
- ☐ 2. I know what the themes are when finished, then go back and find the incidents that demonstrate them

18.

17. When I start a problem outside of work / university, I am more likely to **Mark only one oval.*

- ☐ 1. start working on the solution immediately
- ☐ 2. try to fully understand the problem first

19.

18. I prefer the ideas of **Mark only one oval.*

- ☐ 1. certainty
- ☐ 2. theory

20.

19. I remember best **Mark only one oval.*

- ☐ 1. what I see
- ☐ 2. what I hear

21. **20. It is more important to me that an instructor ***
Mark only one oval.
- ☐ 1. lay out the material in clear sequential steps
- ☐ 2. give me an overall picture and relate the material to other subjects
22. **21. I prefer to study ***
Mark only one oval.
- ☐ 1. in a study group
- ☐ 2. alone
23. **22. I am more likely to be considered ***
Mark only one oval.
- ☐ 1. Careful about the details of my work.
- ☐ 2. Creative about how to do my work.

Untitled Page

24. **23. When I get directions to a new place, I prefer ***
Mark only one oval.
- ☐ 1. a map
- ☐ 2. written directions
25. **24. I learn ***
Mark only one oval.
- ☐ 1. at a fairly regular pace, if I study hard, I'll 'get it'.
- ☐ 2. in fits and starts. I'll be totally confused and then suddenly it all 'clicks'.
26. **25. I would rather first ***
Mark only one oval.
- ☐ 1. try things out
- ☐ 2. think about how I'm going to do it
27. **26. When I am reading for enjoyment, I like writers to ***
Mark only one oval.
- ☐ 1. clearly say what they mean
- ☐ 2. say things in creative, interesting ways

28.

27. When I see a diagram or sketch in training classrooms, I am more likely to concentrate on *

Mark only one oval.

- ☐ 1. the picture
- ☐ 2. what the instructor said about it

29.

28. When considering a body of information, I am more likely to *

Mark only one oval.

- ☐ 1. Focus on details and miss the big picture
- ☐ 2. Try to understand the big picture before getting into the detail

30.

29. I more easily remember *

Mark only one oval.

- ☐ 1. Something I have done
- ☐ 2. Something I have thought a lot about

31.

30. When I have to perform a task, I prefer to *

Mark only one oval.

- ☐ 1. Master one way of doing it
- ☐ 2. Come up with new ways of doing it

32.

31. When someone is showing me data, I prefer *

Mark only one oval.

- ☐ 1. charts or graphs
- ☐ 2. text summarizing the results

33.

32. When writing a paper, I am more likely to *

Mark only one oval.

- ☐ 1. work on (think about or write) the beginning of the paper and progress forward
- ☐ 2. work on (think about or write) different parts of the paper and then order them

34.

33. When I have to work on a group project, I first want to *

Mark only one oval.

- ☐ 1. have 'group brainstorming' where everyone contributes ideas
- ☐ 2. brainstorm individually and then come together as a group to compare ideas

Untitled Page

35.

34. I consider it higher praise to call someone **Mark only one oval.*

- ☐ 1. Sensible
☐ 2. Imaginative

36.

35. When I meet people at a party, I am more likely to remember **Mark only one oval.*

- ☐ 1. what they looked like
☐ 2. what they said about themselves

37.

36. When I am learning a new subject, I prefer to **Mark only one oval.*

- ☐ 1. stay focussed on that subject, learning as much about it as I can
☐ 2. Try to make connections between that subject and related subjects

38.

37. I am more likely to be considered **Mark only one oval.*

- ☐ 1. Outgoing
☐ 2. Reserved

39.

38. I prefer training courses that emphasise **Mark only one oval.*

- ☐ 1. Concrete material (facts, data)
☐ 2. Abstract material (concepts, theories)

40.

39. For entertainment, I would rather **Mark only one oval.*

- ☐ 1. Watch television
☐ 2. read a book

41.

40. Some lecturers start their courses with an outline of what they will cover. Such outlines are **Mark only one oval.*

- ☐ 1. Somewhat helpful to me
☐ 2. Very helpful to me

42.

41. The idea of doing homework in groups, with one grade for the entire group **Mark only one oval.*

- ☐ 1. Appeals to me
- ☐ 2. Does not appeal to me

43.

42. When I am doing long calculations **Mark only one oval.*

- ☐ 1. I tend to repeat all my steps and check my work carefully
- ☐ 2. I find checking my work tiresome and have to force myself to do it

44.

43. I tend to picture places I have been **Mark only one oval.*

- ☐ 1. easily and fairly accurately
- ☐ 2. with difficulty and without much detail

45.

44. When solving problems in a group, I would be more likely to **Mark only one oval.*

- ☐ 1. think of the steps in the solution process
- ☐ 2. think of possible consequences or applications of the solution in a wide range of areas

Error! Reference source not found. is directly from the Felder Learning Styles and strategies research conducted by Richard Felder¹. It is an advice sheet to be given to student pilots to assist them in adapting to learning styles that they are weak or too strong in to achieve a more balance type of learning. The ILS assessment is to enable identification of student pilots that will struggle with the learning material and the manner in which it is presented. The evaluation of the results also gives early indication of any possible future interventions or 1-to-1 teaching, not due to the student pilot's skill ability but due to the weaknesses in learning styles. The advice sheet is a generic list of strategies that might find utility in some student pilot's to work on weaknesses that is affecting on the job performance due to the inability to acquire knowledge through normal teaching means. For Further details on ILS evaluation, refer to Volume I, Chapter 7.2.3.

¹ Felder, R.M., & Silverman, L., "Learning and Teaching Styles in Engineering Education", *Engineering Education*, 78(7), pp. 674-681, 1988.

The personal attention assessment examines the ability of individuals to cope with stressful conditions and how performance is affected by ‘startle’ effect; the questionnaire can be seen in Assessment Form 4. The questionnaire is produced with a modified Likert scale to allow the prospective student pilot a wide variance of attitudes and personal characteristics to real world conditions posed by the questions. The questions and answers are converted to integer values for mathematical manipulation for quick analysis. Of interest is the average percentage score the individual obtains and the ‘CalcPercentage’ operation of the ‘PAAScore’ block of Figure I 5 is to transform the answers into a percentage and display this to decision maker and update the main student database file. If the individual’s score is less than 50% an additional warning virtual led is illuminated on screen to direct the decision maker to further assess the individual’s suitability to train as a pilot. For detailed discussions of the assessment, refer to Volume I, Chapter 7.2.4.

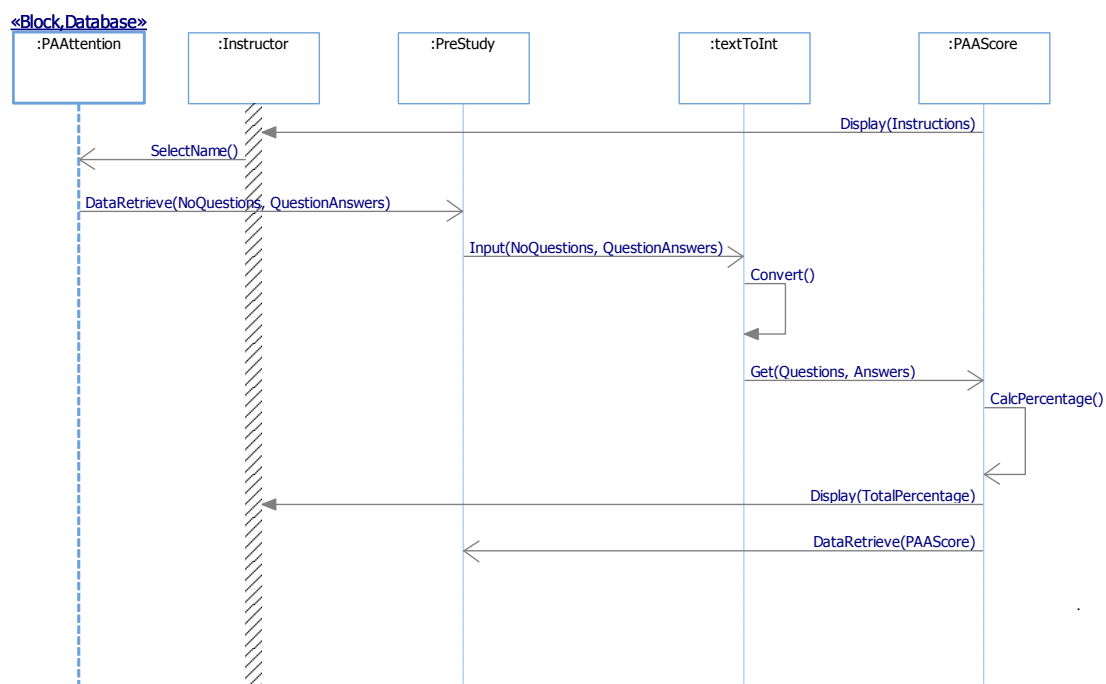


Figure I 5 Behaviour of Assess Personal Allocation Attention Use Case

Assessment Form 4 Personal Allocation Attention Questionnaire for Pilot Characteristics

Personal Allocation Attention Questions (Performance)

This questionnaire is used to determine mission accuracy tolerance from ideal performance for each student

* Required

1. **Name (Firstname Surname initial) ***
e.g. TrevorH

2. 1. How efficient are you at detecting mistakes or unusual conditions occurring during tasks? *

Mark only one oval per row.

[illegible]

3. 2. How do you manage / handle errors or unusual conditions? *
- Mark only one oval per row.

1. Feel anxiety 2 3 4. Level Headed 5 6 7. Gracefully

Handling levels ☐ ☐ ☐ ☐ ☐ ☐ ☐

4. 3. How good are you at sharing errors / unusual conditions and their resolutions with other people? *
- Mark only one oval per row.

	1. Keep to self	2 3	4. Not too bad (average)	5 6	7. Very good
Sharing effectiveness	<input type="radio"/>	<input type="radio"/> <input type="radio"/>	<input type="radio"/>	<input type="radio"/> <input type="radio"/>	<input type="radio"/>

4. How would you rate your ability to resist personal or organisational pressures to test marginal conditions? *

Marginal conditions are a requirement that must be fulfilled to achieve the required level of efficiency.

Mark only one oval per row.

	1. Blindly Follow Orders	2	3	4. Challenging	5	6	7. Very Good
Ability level	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

APPENDIX J HANDLING QUALITIES WORKLOAD SCALE EVALUATION (PSE)

The Handling Qualities Workload Scale (HQWS) is used to enable the decision maker responsible for planning the mission to account for real world workload conditions in relation to aircraft handling qualities. The functionality of the ‘Assign Difficulty Metrics to Task’ Use Case, which is responsible for assignment of the qualities metrics, is illustrated in Figure J 1. As this stage is the beginning of the feedback system, the decision maker is asked to select the relevant student file for the student currently being assessed to obtain a pilot specific rating that gives an indication of pilot’s ability to cope with pressure situations, from previous executed missions. The behaviour of the Use Case then permits the decision maker to evaluate the difficulty of performing certain activities involved in all mission tasks. This stage should be used in conjunction with planning the tasks and flight plan of the mission scenario in an effort to keep control of various pilot activities.

The start of the behaviour requests for new information regarding mission reference, task number and details, otherwise just the latter i.e. after the initialisation of loop (Loop > 0). Operator prompts are then used to direct the decision maker to enter their objective opinion on the difficulty of certain pilot activities/operations in the cockpit when it relates to pilot qualities needed to action them. As not all qualities are needed to perform certain operations in the cockpit, the behaviour uses decisions based on what operations are required by the current task to assess on those qualities relevant by using a reference sequence diagram, seen in Figure J 2, to identify which operator prompts are displayed to the decision maker for them to make an assessment on. Each operator prompt within the loop of Figure J 1 relate to the mental effort involved to action current aircraft operations. The average task score for each quality is then calculated by the ‘HQWS’ block to give a clear indication of the assigned difficulty of each pilot quality that may affect decisions. The percentage pilot specific rating (PSR) is then calculated for each task based on previous mission PSR and current assessed tasks. Once all the operations in the task have assigned difficulty metrics, the decision maker will be asked to confirm that all the tasks in the mission have been assessed. If not, the behaviour returns to the beginning of the loop to assess pilot qualities for the next task in the mission, otherwise all the assessments for all the tasks are collated within a 2D array by the ‘CollateResult’ operation that is displayed on screen for the decision maker to view and the total for each quality for all tasks in the mission is saved within the main student database file

for the respective student. The collated results are further saved in a database within the 'MissionRelatedHQWS' files within the respective student directory, and the task details 2D array is saved in a separate directory(s) for use in further assessment stages.

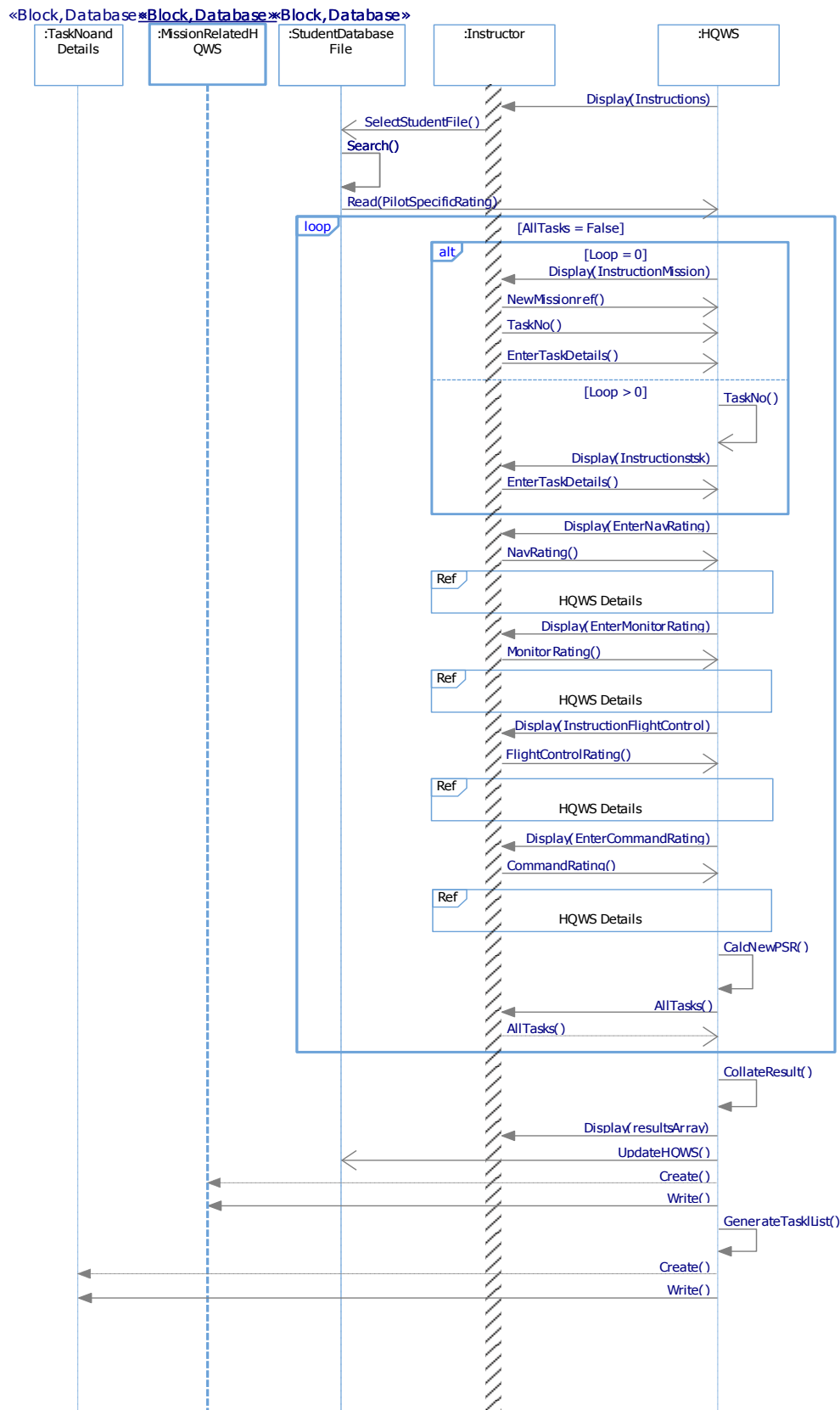


Figure J 1 Behaviour of Assign Difficulty Metrics to Tasks Use Case

The reference sequence diagram ‘HQWS Details’ illustrated in Figure J 1, is described in Figure J 2 that expresses the behaviour of the ‘Enter Difficulty Metrics’ Use Case. Every time the reference sequence diagram is called from the parent, the decision maker (instructor) will be asked to enter the mental effort difficulty for the current operation. Once entered the Use Case has some decision to make about what additional operator prompts are offered to the decision maker. The first interaction operator queries the previous operation from the parent diagram and asks: has the NavRating, MontorRating or FlightControlRating been asked for?; if the answer is ‘yes’, then the behaviour within the ‘box’ is executed and the decision maker will be asked to enter the physical difficulty followed by the time criticality for the relevant aircraft operation within the current task. However, if all options are false the behaviour within the ‘box’ does not execute. It can be seen in Figure J 2, the CommandRating option only executes once within the main loop of Figure J 1 and thus has only three quality metrics associated with aircraft operation (one for mental effort (main loop) and two (time available and Information Usefulness) from the option described in Figure J 2. For more details discussions on the GUI, refer to Volume I, Chapter 7.3.

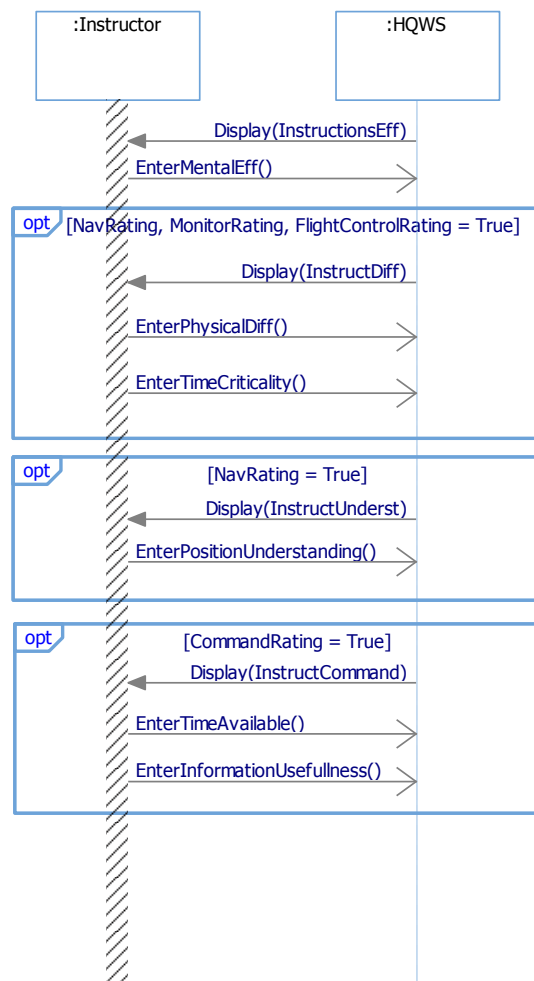


Figure J 2 Behaviour of Enter Difficulty Metrics Use Case

APPENDIX K ROSETTA 0 ASSESSMENT

ROSETTA 0 involves the identification of relevant training attributes that need to be associated with the mission tasks and then asks the decision maker about the suitability of the training technology for evaluation of the training attributes for transfer of training (ToT) for operational environment. There are two stages involved in this assessment stage, one for design and one to assess suitability at the highest non-technical level. Figure K 1 describes the sequence of events for the behaviour of ROSETTA 0 assessment, which consists of four reference sequence diagrams. The first concerns retrieving a list of training attributes from Table VI (Page 63) that are relevant for the mission tasks; or retrieve a list of previous relationships from previous planned missions. The selection of training attributes and relevant training technology, selected from Table VII (Page 63), are then used to scale and structure the framework. Once the size of the framework and relationships between parameters of the framework have been generated, the relationships between requirements and design metrics are displayed to the decision maker in graphical form within the framework to permit analysis of the sensitivities between parameters for the purpose of trade studies. Elimination of technology concerns the analysis results based on efficacy of training attributes to MECs for each technology. For full details of GUIs for this assessment stage, refer to Volume I, Chapter 7.4.

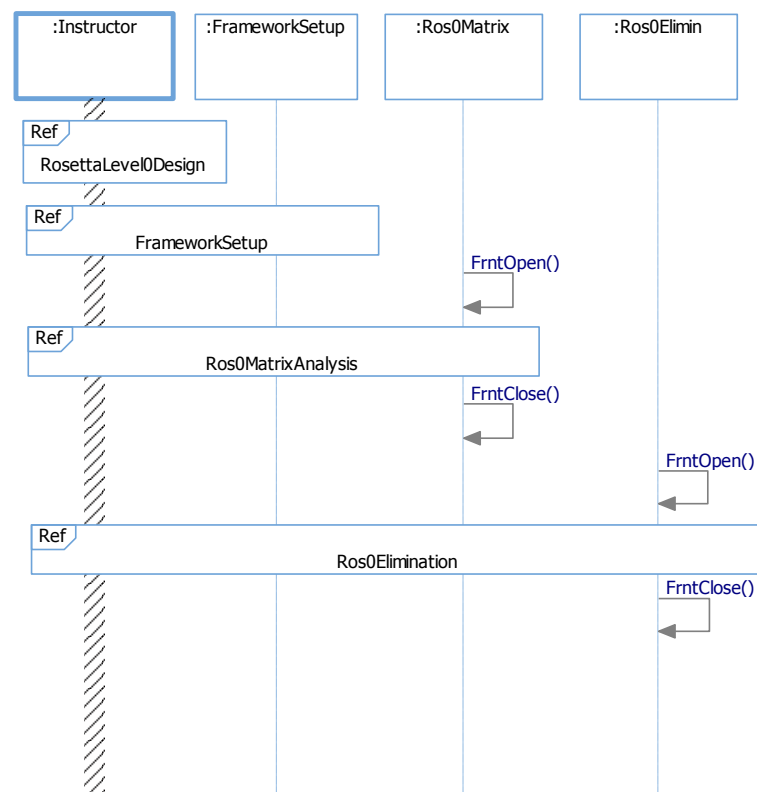


Figure K 1 Behaviour of Perform High-Level Rosetta 0 Assessment Use Case

Table VI List of MECs and Knowledge and Skills used for Verification of Workflow Process

MECs	Supporting C	Knowledge	Skills	Experiences
Assess and integrate information	Adaptability	Aircraft characteristics	Adapts to changing environment	Operating area restrictions
Process and Analyse information	Communications	Time restrictions	Anticipates problems	Restrictions to visibility
Dynamic execution	Decision Making	Phase of Mission	Interprets sensor output	Mountainous terrain
Decisiveness	Flight Management (Battle)	Mission objectives and goals	Makes assessment	Fatigue / Time on task
Assessment/reconstitute-initiate follow on Actions	Identification	Commit criteria	Manages mission timing	Task Saturation
Remain oriented to mission requirements	Information Management	Understanding process and functions	manages stress and pressure	Limited time to act/react to situation
Recognise trigger events that require shift in phase	Situation Awareness		Multi-tasks	Various initial conditions
	Timeline		Sorts information	Dynamic retasking
	Negotiation		Switchology	Various employment altitudes
	Quality Control		Assesses risk	

This table produces the list of Knowledge and Skills used for planning tasks and training attributes for the mission and located in database KnowledgeAndSkill <<Block, Database>>

Table VII Subset of Training Devices Available within the FTS

FoS Configuration							
Number	Reference	Make	Type	Display	Control	Cost	FOS category
1	BTD	HP	Laptop	15.6 anti-glare	K&M	1023.53	Desktop trainer
2	DTH-24	HP	Laptop	LA2405x 24" anti-glare	HOTAS	3064.9	Desktop trainer
3	DT-KS	HP	Laptop	LA2405x 24" anti-glare *3	HOTAS	3530.9	Desktop trainer
4	DTCC	Compusys	Desktop	LCD5220 52" * 6	HOTAS	7871.85	Desktop trainer
5	FTD	?	FTD	?	?	?	FTD
6	FMS	?	FMS	?	?	?	FMS
7	Hawk	?	Aircraft	?	?	?	Aircraft
8	Hawk Mk.2	?	Aircraft w. Synth	?	?	?	Advanced Aircraft

This table produces the technology lists for Technology Layouts <<Block, Database>>

Figure K 2 describes the behaviour of the ROSETTALevel0Design reference sequence diagram. The instructor is prompted to search for the task details file created from the HQWS stage along with retrieving the training attributes database to elicit knowledge of tasks involved in the planned mission. Each task number and details is then displayed to the decision maker in the UI in sequence along with instructions on how to select a subset of training attributes relevant to the current displayed task.

The first attribute required to be selected is for all the MECs relevant to the task, the column of MECs from Table VI are displayed within an array and scroll bars are used to scroll through each MEC. The decision maker then has to select all that apply (one or more can be selected); once all relevant MECs have been selected, the decision maker is required to acknowledge the selection by activating the virtual 'complete' button. The UI will then transfer to page 2 of the tabular display for a list of supporting competencies and the process is repeated for each training attribute. Once all have been selected for the task, if more tasks need training attributes associated with them the process is repeated; however, if all the tasks have training attributes assigned then all the information gathered is collated into a 2D array and the decision maker will be requested to save the data into the Ros0Design database .

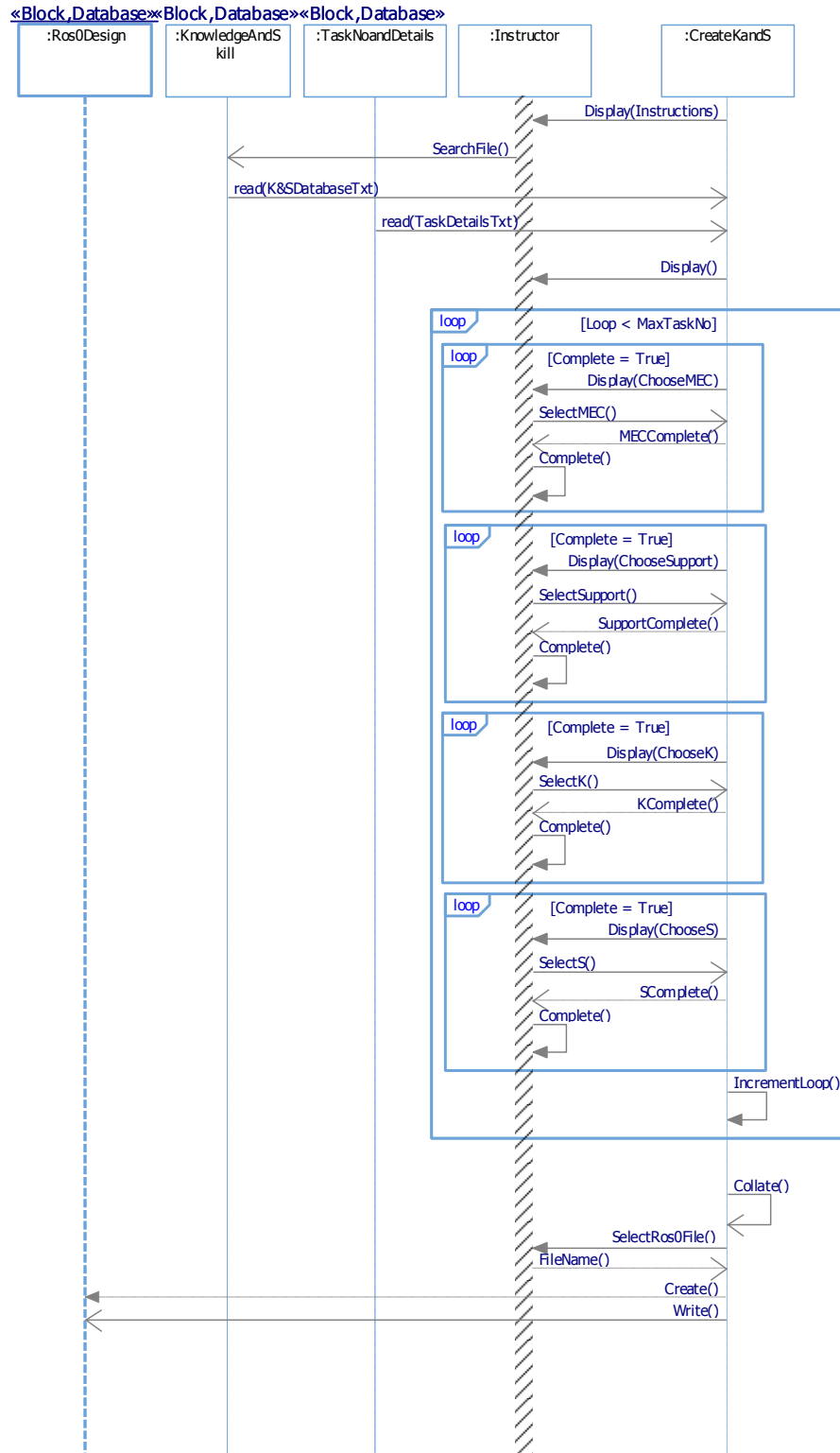


Figure K 2 Behaviour of Create K&S for Mission Use Case

The structure of ROSETTA 0 framework is directly dependent on the output of the ‘Create K&S for Mission’ Use Case. The technology list is gathered from Table VII to find the technology reference details and the number of available technologies to be used for the analysis. The training attributes gathered from Ros0Design database is organised to remove

duplicate attributes to assemble a list of K&S and MECs for the whole mission, hence, all duplications of descriptions are removed by the operation ‘RemoveDuplicates’ of the ‘FrameworkSetup’ block, illustrated in Figure K 3. The numbers of K&S together with the numbers of training technologies are then used to scale and structure the ROSETTA framework.

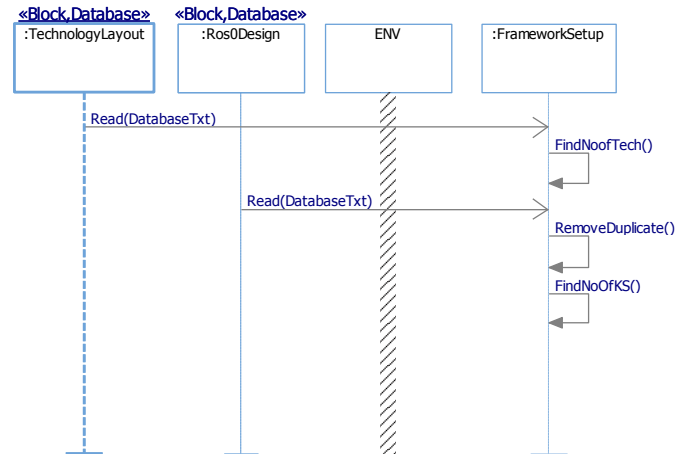


Figure K 3 Behaviour of Setup Framework Use Case

The data from the ‘FrameworkSetup’ block is then exchanged with the ‘Ros0Matrix’ block that organises both lists in order, as seen in Figure K 4. Each training attribute is then assessed by the decision maker for each training technology. The technology reference is displayed within a sentence along with a K&S; the decision maker will then select a semantic description of the suitability of the technology to train the currently displayed K&S. The semantic description is directly associated with a discrete value, this value describes the objective relationship between the K&S and the training technology. The next K&S in the list is then displayed and the sequence continues until all the K&S relevant to the mission has been assessed for the current technology. The identical assessment process is then repeated for the next training technology indicated by the outer loop. The suitability of a technology to all the training attributes is then calculated and a 2D array representing the framework is created, displayed to the decision maker and saved within the Ros0Analysis database directory.

For the purposes of technology elimination, the 2D array saved within the database is retrieved and the decision maker will be asked using the information displayed within the 2D array whether the current technology presented within a sentence is a suitable solution for training the K&S. Once a decision has been made, the next technology within the 2D array is displayed within the same sentence and the same choice needs to be made; as described by

the loop in Figure K 5. The results are collated and added to the 2D array and then saved within the ROSETTA 0 elimination directory to be used as identification of training technologies remaining for further elimination stages.

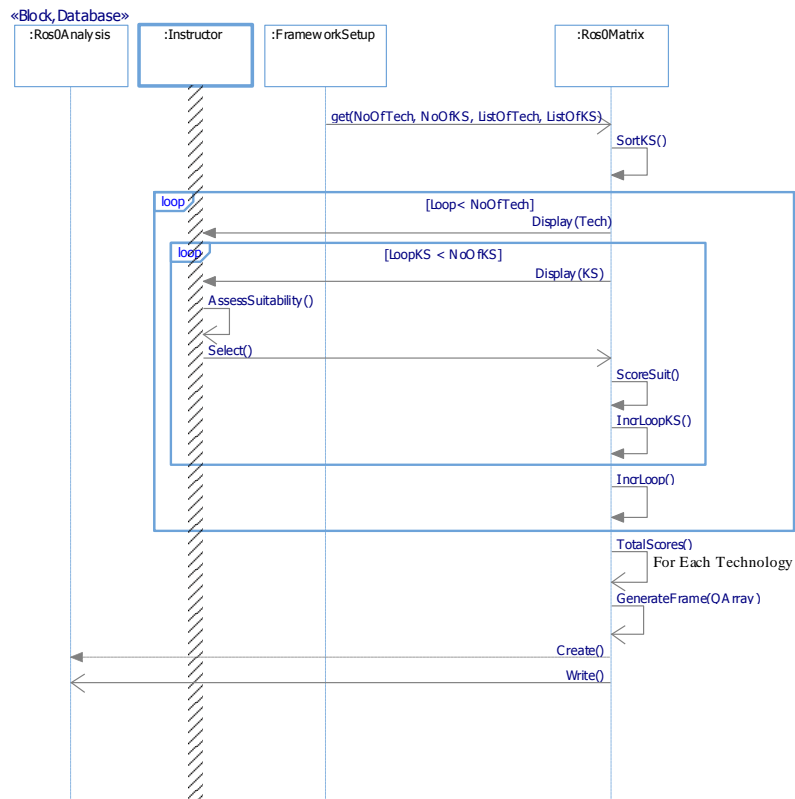


Figure K 4 Behaviour of Assess K&S with Technology Configuration Use Case

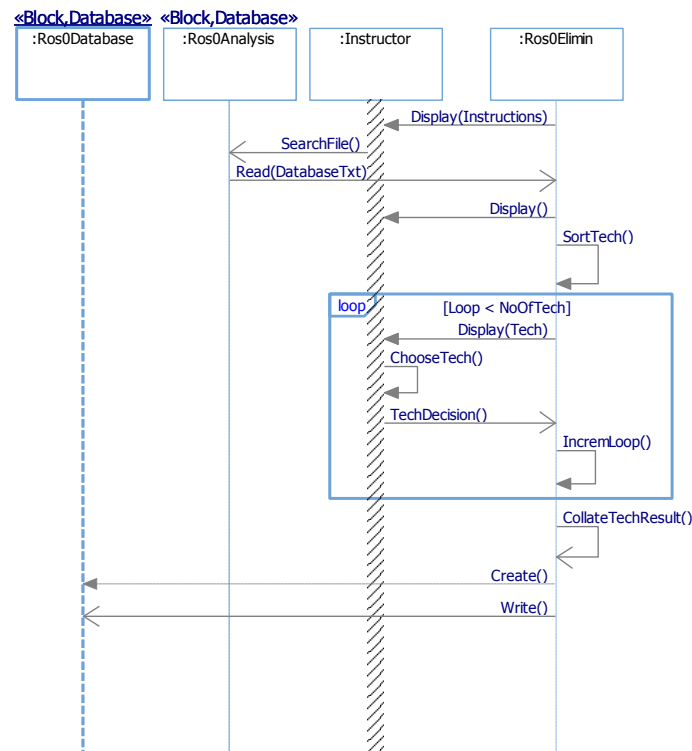


Figure K 5 Behaviour of Eliminate Technology in Rosetta0 Use Case

within Table VIII (Page 71) as the basis for grading; this however can be realised in greater detail by considering workload values at the activity levels depending on the level of analysis required. The workload values per task are collated into a 2D array to be used as the basis for assigning task importance.

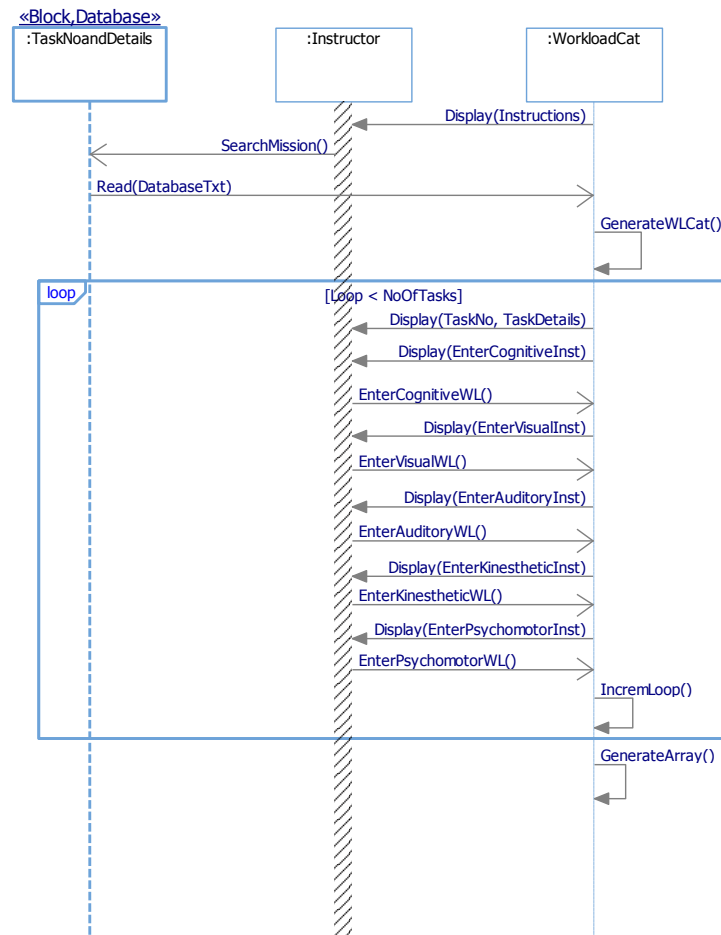


Figure L 2 Behaviour of Grade Workload per Task Use Case

The identical database as in the ‘Grade Workload per Task’ Use Case is used to ensure the decision maker is fully aware of the number of tasks and the task details for assignment of the task importance. The decision maker uses a scroll function to select his objective opinion of how critical the task is to the successful completion of mission goals using a scale of 1: not important-to-10: mission critical. Once the value of mission criticality has been accepted, by operating the virtual ‘Select’ button, the ‘TaskImp’ block, illustrated in Figure L 3, generates a matrix array to visually identify all workload assignment values along with task importance levels.

Both arrays from previous workload assessments are used to calculate the total workload value per task, as seen in the internal loop of Figure L 4, and then for the whole mission as

seen by the ‘CalcWorkload’ operation of the ‘Workload’ block. The whole mission workload value is taken as a percentage of maximum to be used to update the main student database file. The full description of the entire GUI used for this assessment stage can be found in Volume I, Chapter 7.5.

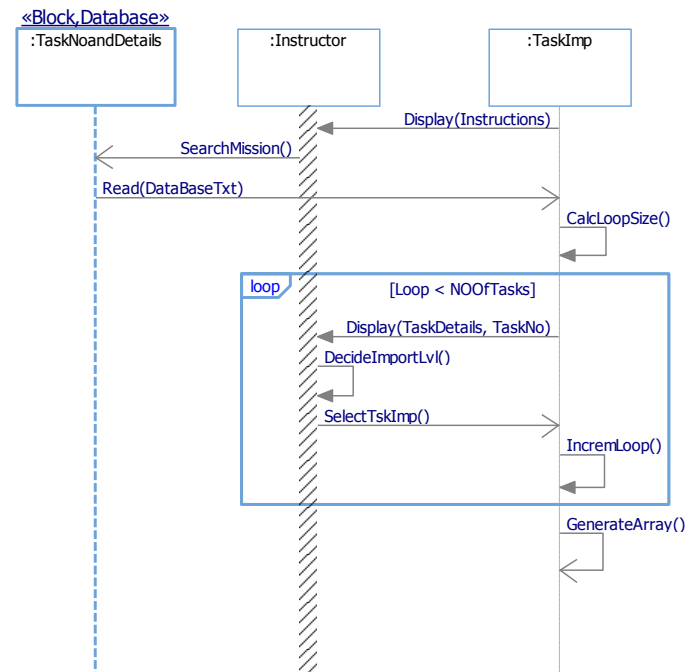


Figure L 3 Behaviour of Assign Task Importance Metric Use Case

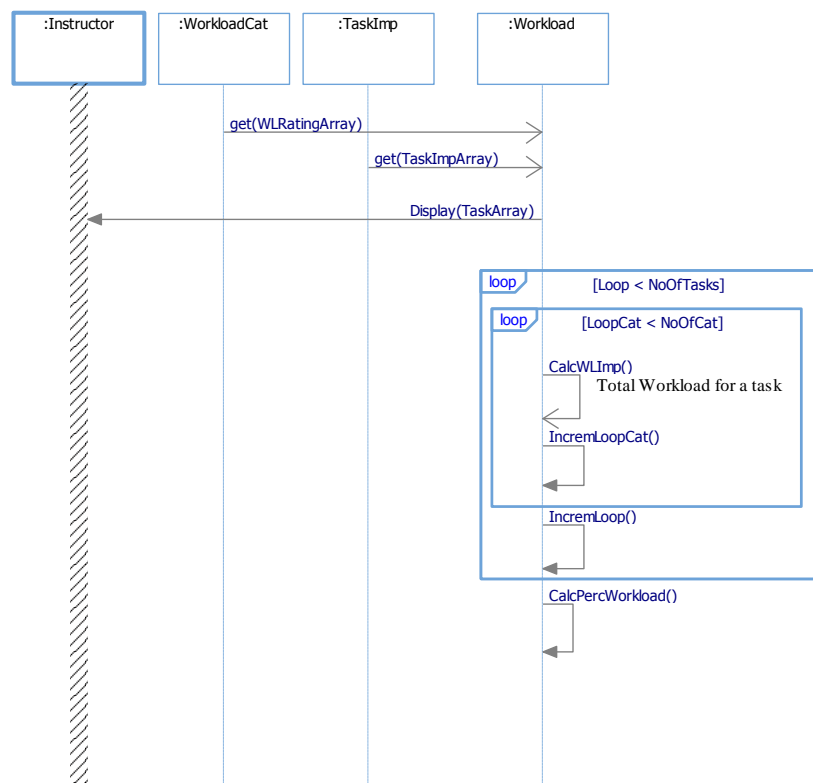


Figure L 4 Behaviour of Calculate Workload Importance Use Case

Throughout all stages amending the main student database file gives a decision maker a quick summary of difficulty and performance metrics for each student; as a result the functionality is required to be repeated throughout the behaviour of other stages. The reference sequence diagram used for updating the main student database file is seen in Figure L 5. The first operation needed is for the decision maker to select the relevant student file (for the current student being assessed), followed by searching for the current mission scenario reference that should be within the student file. The heading name used to search is realised from the parent use case, shown in Figure L 1, along with the attribute value to update. The ‘StudentFile’ block searches the database file for the heading and updates the file with the new attribute value within the identified mission scenario reference row.

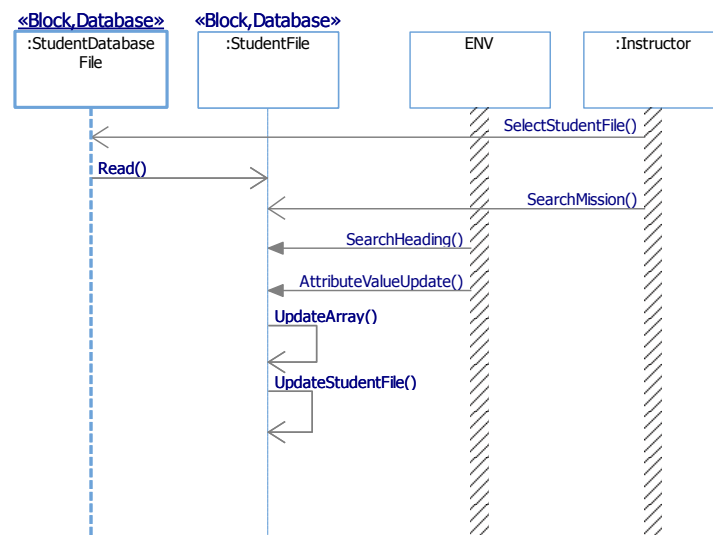


Figure L 5 Behaviour of Amend Student file Use Case

Table VIII Workload Component Scales (Amended from Wojciechowski (2006))

Visual, Auditory, Cognitive, and Motor Channel Values and Descriptors			
Value	Visual scale Descriptor	Value	Auditory Scale Descriptor
0.0	No Visual Activity	0.0	No Auditory activity
1.0	Register / detect image	1.0	Detect/register sound
3.7	Discriminate or detect visual difference	2.0	Orient to sound, general
4.0	Inspect/check (discrete inspection)	4.2	Orient to sound, selective
5.0	Visually locate/align (selective orientation)	4.3	Verify auditory feedback (detect occurrence of anticipated sound)
5.4	Visually track/follow (maintain orientation)	4.9	Interpret semantic content (specify)
5.9	Visually Read (symbol)	6.6	Discriminate sound characteristics
7.0 – 7.9	Visually scan/search/monitor (continuous/serial inspection, multiple conditions)	7.0 – 7.9	Interpret sound patterns (pulse, rates, etc.
	Cognitive Scale Descriptor		Psychomotor scale Descriptor
0.0	No cognitive activity	0.0	No motor activity
1.0	Automatic (simple association)	1.0	Speech
1.2	Alternative selection	2.2	Discrete actuation (button, toggle, trigger)
3.7	Sign/signal recognition	2.6	Continuous adjusting (flight control, sensor control)
4.6	Evaluation/judgement (consider single aspect)	4.6	Manipulative (constant adjustment of position human/technology)
5.3	Encoding/decoding, recall	5.8	Discrete adjusting (rotary, vertical thumb wheel, lever position)
6.8	Evaluation/judgement (consider several aspects)	6.5	Symbolic production (writing)
7.0 – 7.9	Estimation, calculation, conversion	7.0 – 7.9	Serial discrete manipulation (keyboard entries)
Kinaesthetic Scale Descriptor			
0.0	No Kinaesthetic activity	5.5	Serial movements (Keyboard Entries)
1.0	Simple switch activation (Toggle, button, touch)	6.1	Kinaesthetic cues conflicting with visual cues.
4.0	Status of object or switch position	6.7	Continuous adjustment of switches (rotary, lever)
4.8	Adjustment of switch or lever	7.0 – 7.9	Continuous adjustment of Controls

APPENDIX M ROSETTA 1 FRAMEWORK

ROSETTA 1 includes two sub-stages: design and analysis. The design of the framework is seen in Figure M 1 where the databases generated from the previous ROSETTA assessment are acquired to obtain a list of remaining systems (training technology) and training attributes to assess; each training technology is assessed independently. Each MEC is assigned an importance value to the successful completion of the mission and combined with the K&S levels to create a structure for the framework that calculates the number of loops and the number of graphs required to be created or loaded from previous files. Once the RSEs have been generated, data is uploaded to three different database locations for ease of viewing and traceability: one for the original RSE, one for additional sample points within the RSE, and one for the training attribute importance levels.

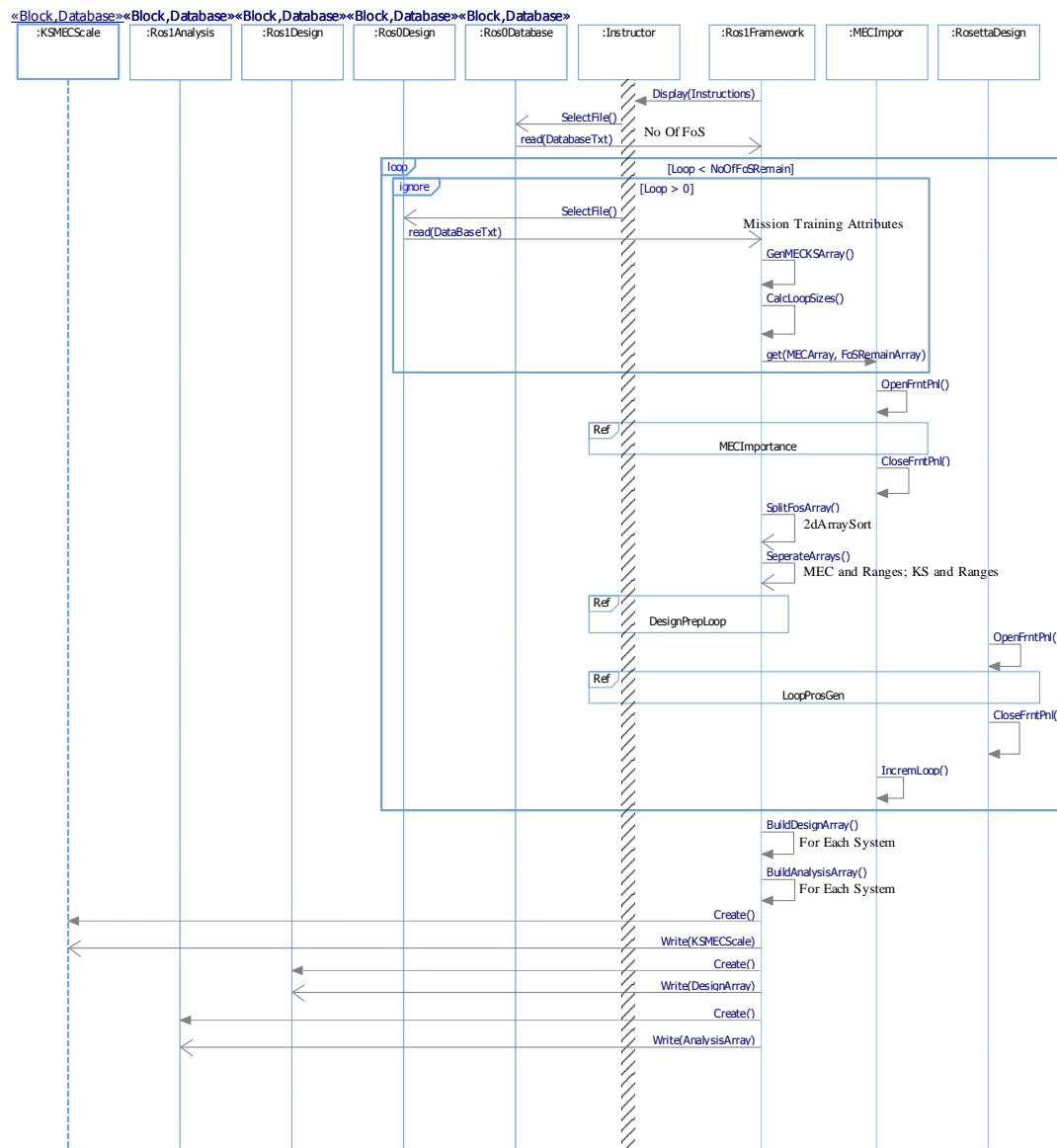


Figure M 1 Behaviour of Produce ROSETTA 1 Framework Use Case

For allocation of the maximum MEC to evaluate for the planned mission, seen in Figure M 2, the current system of the FoS is displayed to the decision maker along with the current MEC description to assess. A new window will be presented on the UI requiring the decision maker to enter the max level of MEC for preparedness that the technology can satisfy. The decision maker uses the scroll bars to select a value (limited to 1-5) based on their subjective opinion on pilots ability using the technology. Once the range has been accepted the next MEC in the array is presented and the assessment continues until all MEC for each technology is completed. A 2-D array is then generated, which forms the basis of the size and structure of the framework.

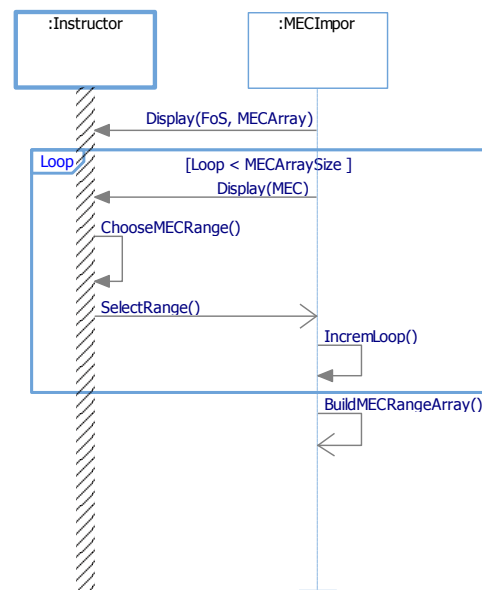


Figure M 2 Behaviour of Allocate MEC Grade Use Case

The DesignPrepLoop reference sequence diagram, described in Figure M 3, uses the information within the generated array to separate the K&S and MEC arrays to create the axis scales and names for the creation of the RSE's. One K&S and importance value is used to generate the first column of an array signified by the outer loop in the figure. Each MEC and importance range is then used to create the other columns within the 2-D array; thus, one K&S is associated with one or more MECs. Once the first K&S has all identified MECs assigned, the outer loop repeats for the next K&S within the K&S array; the process is repeated for the number of K&S stored in the K&S array. A large 2-D array with all the K&S and multiple MECs of the same description is created by the 'GenerateFoSKSMECArray' operation within the 'DesignLoop' block.

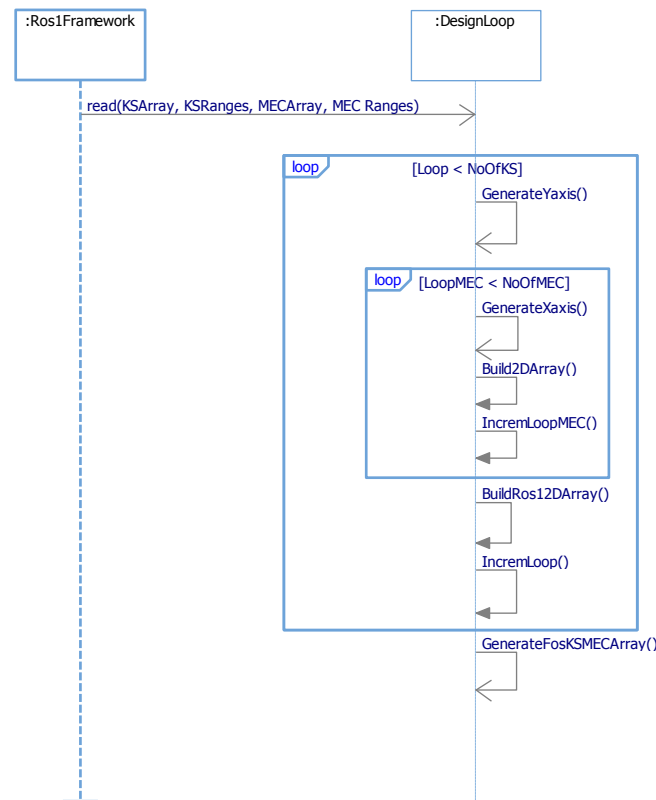


Figure M 3 Behaviour of Prepare Sample Points for RSEs ROSETTA 1 Use Case

The LoopProsGen reference sequence diagram, shown in Figure M 4, uses data generated by the 'Ros1Framework' and 'DesignLoop' blocks to create a graphical representation of the sensitivities between the non-functional worker oriented requirements and the MEC design metrics. As in the previous behaviour of this stage, each K&S is assessed with respect to all the identified MECs. The number of K&S controls the outer loop whilst the numbers of MECs control the inner loop within Figure M 4. A default RSE shape is created from the importance values given in the previous sub-stage and the x and y axis are constructed and displayed to the decision maker. Using the importance values a linear RSE array is created and presented within the graph generated by the Ros1DesignGraph reference sequence diagram. The decision maker(s), using RSEs for additional knowledge, has an opportunity to amend the RSE for one requirement (K&S) to one design metric (MEC). Once the shape is accepted, the next MEC in the list is assessed to the same K&S. Once all MECs in the list have an RSE associating the K&S to the MECs, the RSE mathematical function is saved within a 2-D array. The next K&S in the list is then assessed with the same MECs with the 2-D array updated on each K&S assessed. Once all K&S have been assessed with all MECs, the RSE sample points are increased to smooth the shape to assist in the analysis phase. Both the original RSEs and the new RSE with additional sample points are then separated out into

independent 2-D arrays that will then be saved within separate database directories illustrated in Figure M 1.

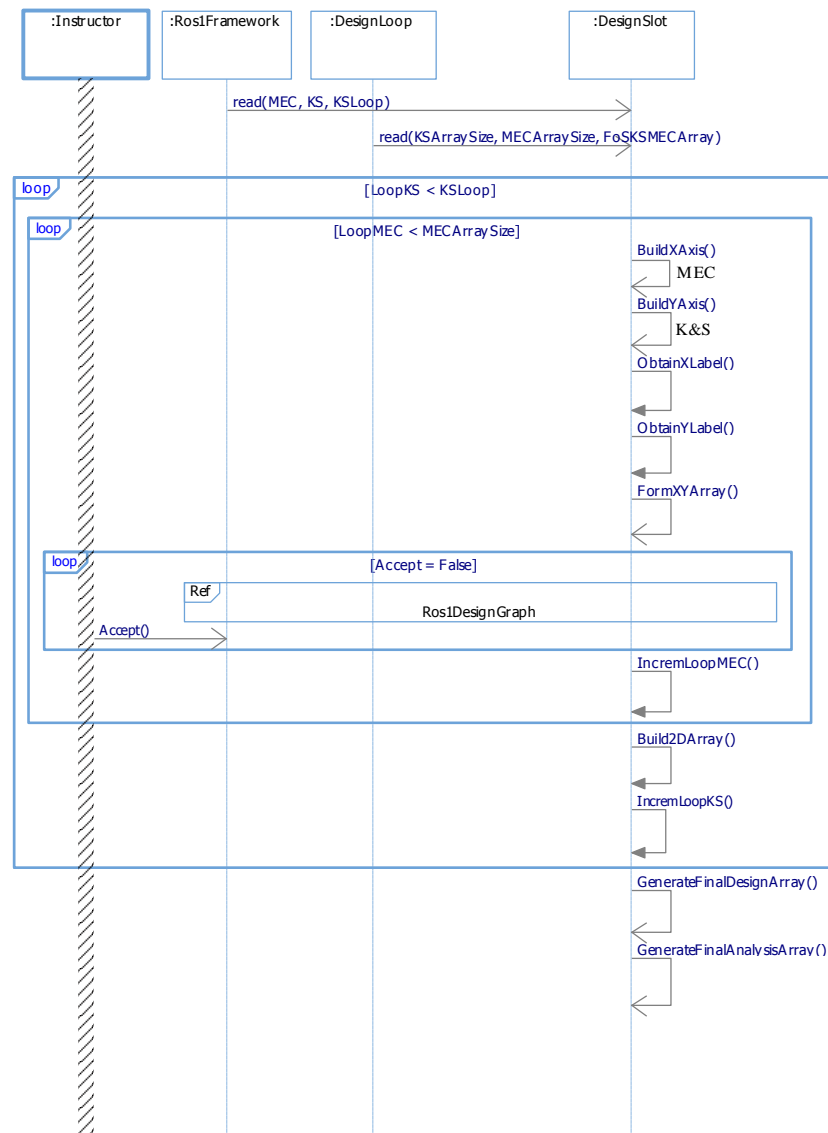


Figure M 4 Behaviour of Generate ROSETTA1 RSE Arrays Use Case

The Ros1DesignGraph reference sequence diagram of the ‘Create RSE for Manipulation’ Use Case can be seen in Figure M 5. The importance metrics for both the K&S and MECs are used to scale the axis of the graphs and the linear plot is created using the values from the importance metrics (alternatively the decision maker can upload previous RSEs from the database(s)). The graph is displayed in a separate window and allows the decision maker to adjust the current K&S array values associated with the sample points that are used to generate the linear plot. There is no time limit of the decision maker to alter the shape of the RSE, as indicated within the first loop of Figure M 5; once the shape has been accepted a new array is generated from the sample point location values on the graph. The RSE array is

streamed through a filter function that adds additional values to the array and filters the RSE shape ready for the analysis sub-stage. Within the final loop, a decision is made relating the names of K&S stored in the K&S array; if experience hours name is identified, the RSE shape describing the relationship between the MECs does not run through the filter process (as experience hours executes a separate software filters). The final graph for analysis is presented to the decision maker for a period of 5seconds before the 1st inner loop in Figure M 4 is executed again.

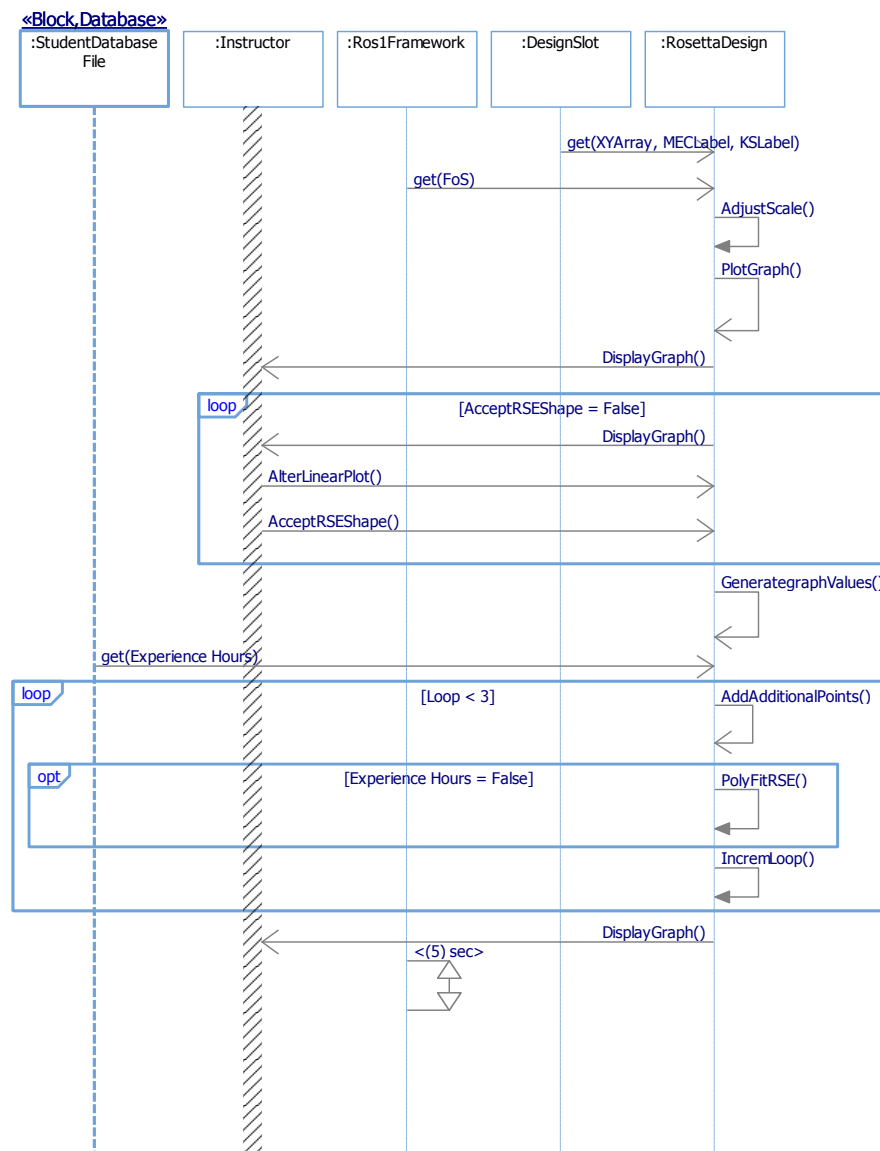


Figure M 5 Behaviour of Create RSE for Manipulation Use Case

ROSETTA 1 analysis stage is a combination of two sub-stages: one for analysis of the RSE shape for training level trade studies and one for elimination of training technology, as illustrated in Figure M 6. Once the analysis phase has been complete, all the data generated from the framework is simplified and presented to the decision maker within a spreadsheet

table. The metric values describing the analysis information within the table is then used for the purpose of elimination of technology.

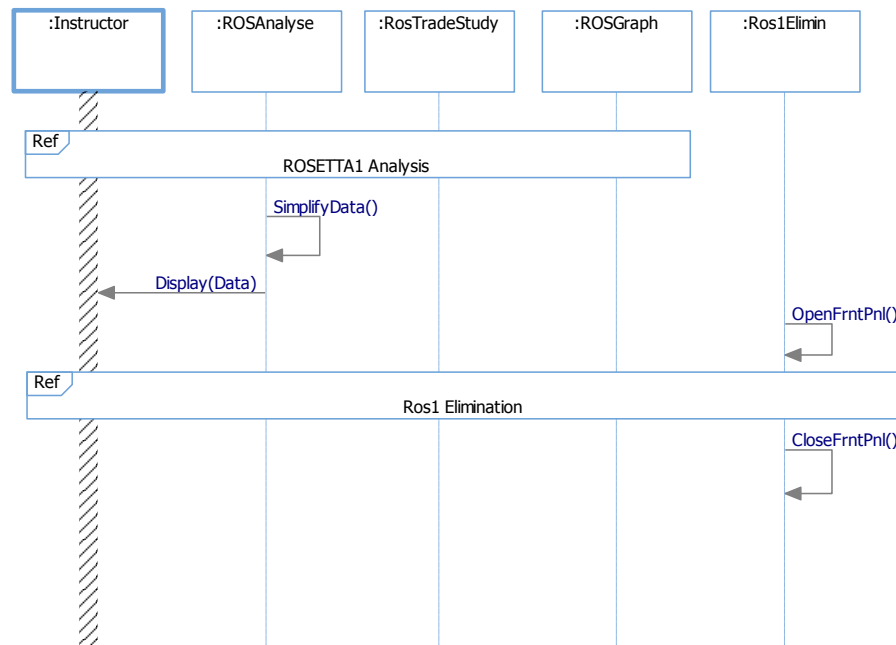


Figure M 6 Behaviour of Perform High Level ROSETTA1 Analysis Use Case

For ROSETTA 1 analysis, described in Figure M 7, specific instructions as to the method of using the framework for the purpose of analysis, is given. The decision maker has two options: 1) to use the original RSEs developed from the design; and 2) to use the filtered RSE shapes for a more detailed analysis. The conclusion of which RSEs to use in the framework is highly dependent on how detailed the analysis needs to be and on the performance capability on the computer being used for this stage of analysis. Once a decision has been made, the 'ROSanalyse' block will obtain a list of systems with the remaining FoS and use the number of technologies from this list to set the number of loop iterations. If the analysis stage is being executed separately to the design stage then the training attributes database is used to retrieve a list of training attributes. The 2-D arrays are used to scale the framework and identify the graph labels for each axis and to determine how many slots (that contain the graphs) are required to be displayed. The framework and associated graphs/slots is then displayed within a separate window using the functionality of the TradeStudy reference sequence diagram, described in Figure M 8. Once the trade study has completed, the values associated with the partial differentials, which describe the robustness of the relationship, and the K&S value levels decided on are stored within a 2-D array and the total suitability value of the current training technology is calculated and added to the bottom of the array. The next remaining technology in the FoS systems array is then assessed in the identical manner

and the result of the trade study is added to the 2-D array. The end result is one large 2-D array, which incorporates all partial differential values along with K&S level values including total suitability values for all technologies: this is then saved within RoS1Analysis Solution database file within the ROSETTA 1 directory.

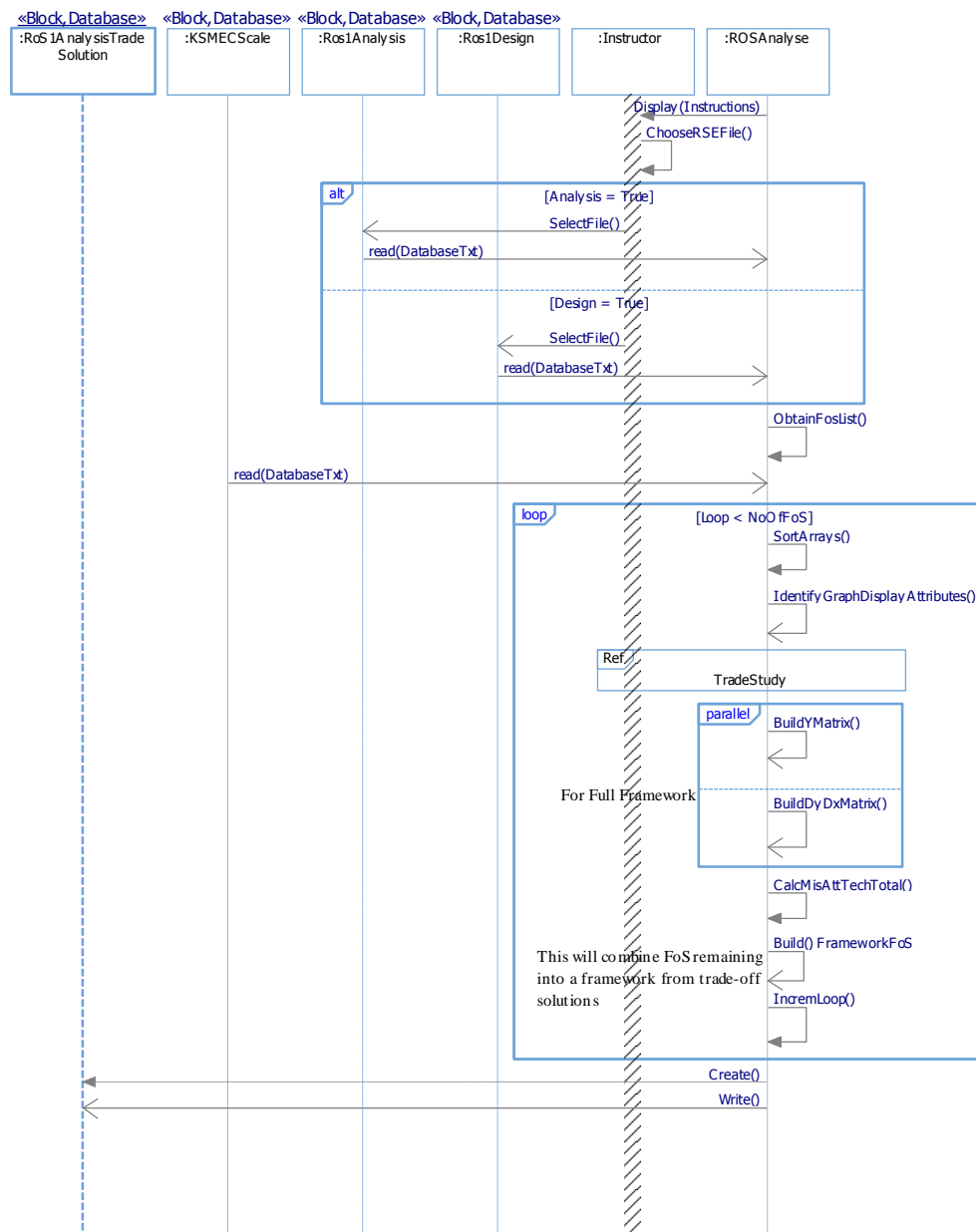


Figure M 7 Behaviour of Perform ROSETTA 1 Analysis Use Case

The trade study reference sequence diagram behaviour is described by the 'Perform Trade Study' Use Case behaviour of Figure M 8. The graph attributes are gathered from the 'ROSanalyse' block that is used to scale the graphs of the framework within the display. The sensitivities are directly dependent of the functionality of the crosshairs within the graphical displays; consequently, as the decision maker performs the trade study by adjusting

the location of the cross hairs within the graphs, each slot (containing a graph) within the framework is then updated with the current design metric values to match the critical parameters being studied. Once the decision maker has concurred with the values associated with the relationships and sensitivities between all non-functional worker oriented requirements and functional MEC design metrics the values of all parameters, which is dependent on the location of the crosshairs, is extracted and stored within two 2-D arrays: one for the K&S level values and one for the partial differential (sensitivities values). The framework display is then closed to be ready for the next technology or MEC (if resource constraints limit the number of graphs being displayed – columns of data are used for each technology) in the list that requires trade studies to be performed.

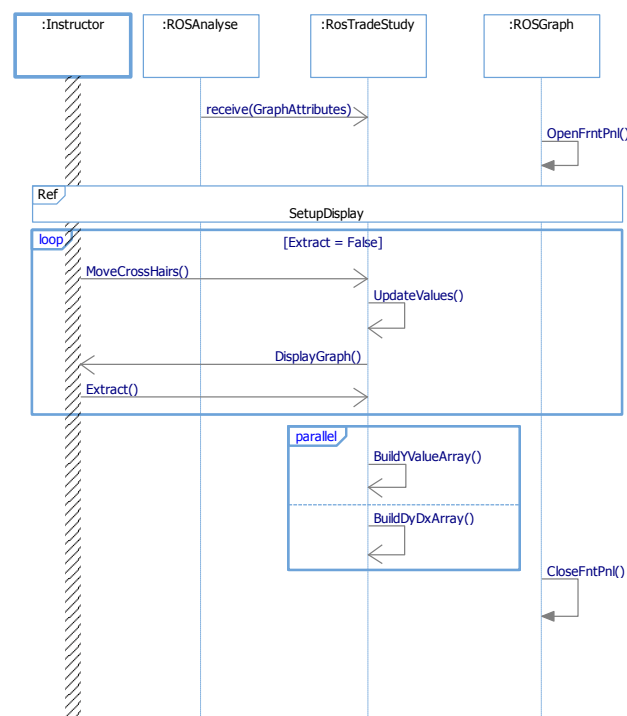


Figure M 8 Behaviour of Perform Trade Study Use Case

The SetupDisplay reference sequence diagram behaviour, illustrated in Figure M 9, is used to scale the framework and decide on the slot label names. Issues with the size of the display is resolve by extending the functionality by permitting the decision maker to scale all the graphs and hence control the location of each graph using one ‘ScaleGraph’ operation which alters the size and location of each graph on screen; thus, permit graphs to be presented adequately on any monitor size and each graph location will ensure that each is side-by-side each other whether it be horizontal or vertical. The graphs are then refreshed on the display with new physical sizes and labels that describe the framework parameters.

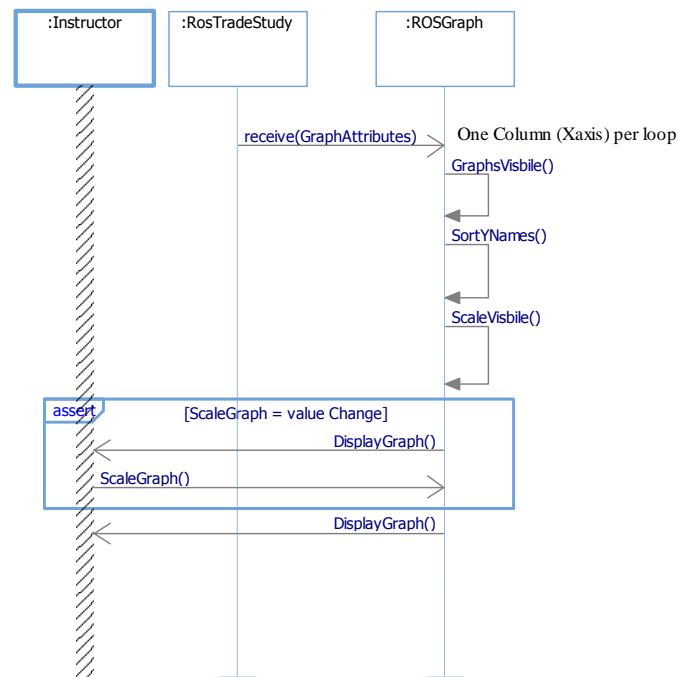


Figure M 9 Behaviour of Setup Display Use Case

The results from the analysis are then used for the purpose of technology elimination; the 2-D array of sensitivities and K&S level values are retrieved then simplified. Like in the previous ROSETTA elimination stage the decision maker will be asked, using the information displayed within the 2D array whether the current technology presented within the displayed sentence is a suitable solution for training the levels of MEC and/or K&S decided by the trade studies. This decision is based on which technology concerning both the MEC value and the value of the partial derivative when it relates to importance values described within the design sub-stage. Once a decision has been made based on the current displayed technology, the next technology within the 2-D array is displayed to the decision maker within the same sentence and the identical decision needs to be made; as described by the loop in Figure M 10. Once all technologies have been evaluated on suitability for training attribute levels, the results are collated and added to the 2-D array that is then saved within the ROSETTA 1 elimination directory to be used as identification of training technologies remaining for the last elimination stage. For detailed information regarding this assessment stage, refer to Volume I, Chapter 7.6.

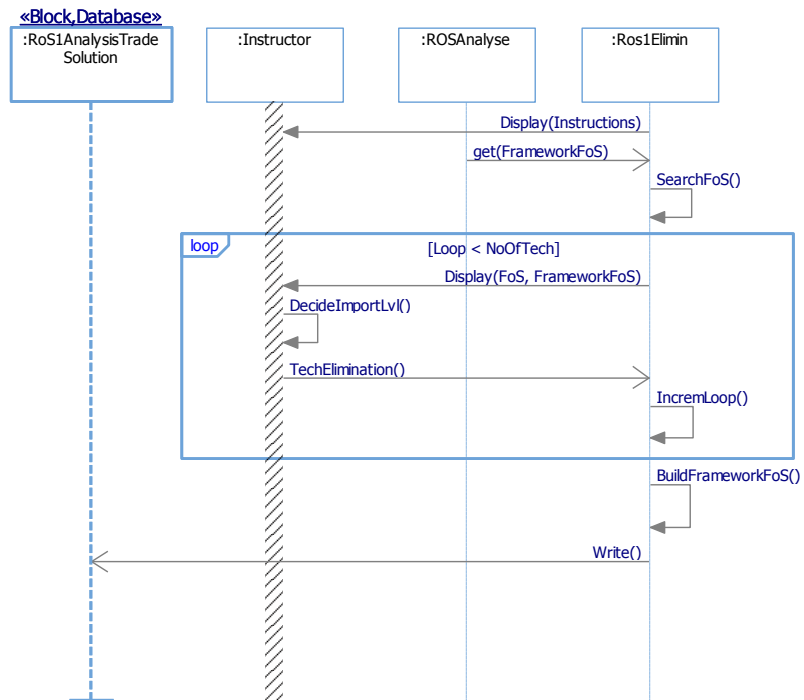


Figure M 10 Behaviour of Perform Technology Elimination ROS1Use Case

APPENDIX N PILOT AWARENESS RATING

To obtain a subjective view on the student pilot of their understanding of the mission scenario, each student pilot completes Assessment Form 5 online and the results are then saved within the PARS database directory, which describes an evaluation relating to their perceived SA based on information presented to them in the per-mission brief.

In this assessment stage, the decision maker will search a student pilot's name from the database file to retrieve the answers, which are then converted to integer values to permit calculations. The questionnaire is categorised to allow different dimensions of SA to be assessed, as a result the answers are also categorised to calculate the percentage of understanding for each. Once all the calculations in the assessment have been completed, the main student database file is updated with relevant values, as seen in Figure N 1.

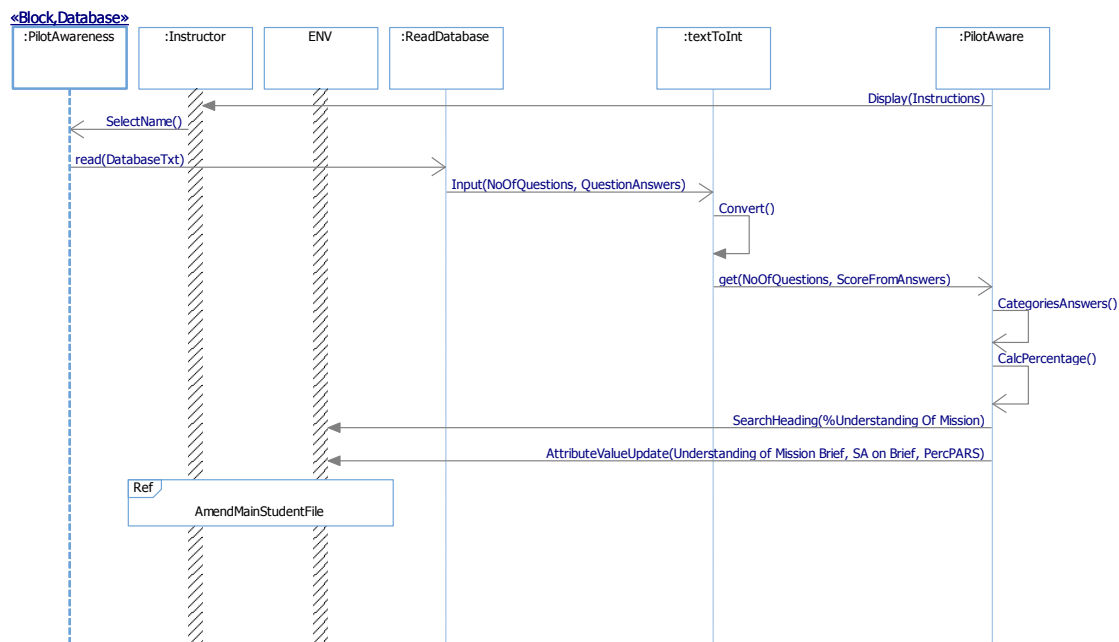


Figure N 1 Behaviour of Obtain Student Pilots Understanding of Mission Use Case

The results of Assessment Form 5 can also be used for feedback as to how effectively the instructor has presented the pre-mission brief to each student pilot. The results can be correlated to the results of ILS questionnaire to clarify those students who have been identified within the pre-pilot assessments as having the potential of difficulty in understanding strict course material and whether the results concur with those who find it difficult to comprehend the goals of the planned mission scenario. If so, interventions or additional instruction can be offered to those student pilot's to assist them in gaining confidence and more understanding of the specifics being evaluated within the mission. For details of the GUI for the assessment stage, refer to Volume I, Chapter 7.7.

Assessment Form 5 Pilot awareness Rating Scale Questionnaire

Pilot Awareness Rating Scale

This assessment considers subjective Situation Awareness (SA) rating to address both the mental content and mental processing of SA with regard to Perception, Comprehension, Projection and integration. This is to give feedback to the instructor how you (the pilot) views the context of the planned mission scenario in relation to the understanding of the difficulty of the task.

* Required

1.

Name (first name Surname Initial)

eg, trevorH

.....

Perception - The Assimilation of New information

2.

1. The context of Perception - Is it reliable and accurate? *

identification, and interpretation of sensory information in order to represent and understand the environment

Mark only one oval.

1 2 3 4 5 6 7

Not reliable /
difficult to
understand

☐
☐
☐
☐
☐
☐
☐

very Reliable and
easy to
understand

3.

2. The processing of perception - Is it easy to maintain? *

Processing is how you receive, store, retrieve, and use information

Mark only one oval.

1 2 3 4 5 6 7

Difficult to
maintain

☐
☐
☐
☐
☐
☐
☐

very easy to use
and maintain

Comprehension - The understanding of information in context

4.

3. The content of comprehension - Is it reliable and accurate? *

comprehension can be thought of as the measurement of understanding

Mark only one oval.

	1	2	3	4	5	6	7	
very unreliable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	very accurate

5.

4. The processing of comprehension - is it easy to maintain? **Mark only one oval.*

	1	2	3	4	5	6	7	
Difficult to maintain	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	very easy to use and maintain

Projection - The anticipation of possible future developments

6.

5. The content of projection - Is is reliable and accurate *

in anticipation of a course of action

Mark only one oval.

	1	2	3	4	5	6	7	
Difficult to anticipate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	very easy to anticipate and reliable

7.

6. The processing of projection - Is it easy to maintain? **Mark only one oval.*

	1	2	3	4	5	6	7	
difficult to maintain	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	very easy to maintain

Integration - The synthesis of preceeding with one's course of action

The process of combining separate entities or elements experienced into a single unified whole to understand the context of the mission

APPENDIX O ROSETTA 2 FRAMEWORK

Table IX Training Device Fidelity Characteristics with ROI Boundaries

Organisational factors	Minimum	Maximum	Type of Fidelity	Minimum	Maximum	Simulator fidelity characteristics	Fidelity Min	Fidelity Max
Practice emergency procedures	0	10	Visual	10	100	Human Perspective / focussed View	20	100
Ease of Distributed Training	0	10				Quality of information	10	100
Availability	10	100				Level of Distortion / Minification	20	100
Affect on Attention Weight	1	10				Confined Training View	1	100
Affect of Situational Awareness	1	20				Visual Refresh Rate	50	240
Affect on Saliency	1	20				Response time	10	100
Direct Operating Cost	1	100				Visual Display Resolution	10	100
						Visual Immersion	10	100
						Field of Regard	10	100
						Detectable Lag in Display View	10	100
						Motion / Vestibular Cues	0	100
						Resemblance to real cockpit configuration	20	100
						Environment temperature / pressure	0	100
						Environmental lighting	20	100
			Physical Fidelity	20	100	Pilot Position / Seating	0	100
			Functional Fidelity	10	100	Buttonology	20	100
						Switchology	10	100
						Pilot Control	0	100
						Feedback Relationship	0	100
			Task Fidelity	10	100	Aircraft / Environment model accuracy	10	100
			Psychological Fidelity	0	100	Performance Feedback to Baseline	0	100
			Verbal Fidelity	0	100	Auditory Cues	0	100

This table is used for the database Training Device Fidelity <<Block, Database>>. (Please refer to Pages 94-108 for detailed descriptions of parameters in the table).

As with ROSETTA 1, ROSETTA 2 assessment stage includes two sub-stages: design and analysis. The design of the framework is seen in Figure O 1 where the decision maker has an option of how detailed the analysis needs to be and is based on the data held in Table IX; the high-level analysis is based on the types of fidelity, whereas the detailed analysis is based on the fidelity characteristics, as described in Figure O 2. For each of the remaining training technologies, ROSETTA 2 will structure and scale a framework with the information gathered from the Level of Detail Rosetta Level 2 reference sequence diagram. Once one technology has assigned RSEs, describing the relationship between parameters, the behaviour of ROSETTA 2 will repeat the design stage for any other technology remaining. Once all the technologies have RSEs assigned, the loop will exit and information is stored in two arrays: one design which are the original RSEs for each parameter to each technology; the other is the analysis array which contains the RSEs with additional sample points. The arrays are uploaded to two different database locations for ease of viewing and traceability: one for the original RSE and one for additional sample point within the RSE.

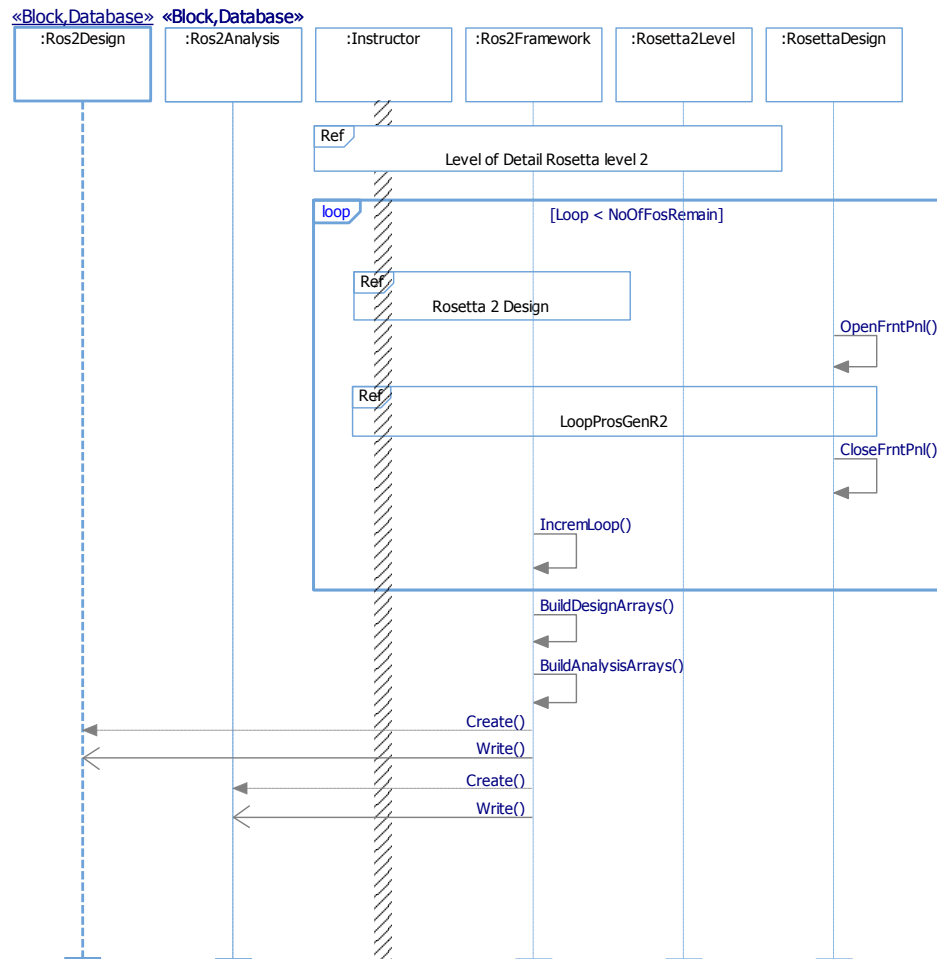


Figure O 1 Behaviour of Obtain Sensitivities and Correlations between FoS Use Case

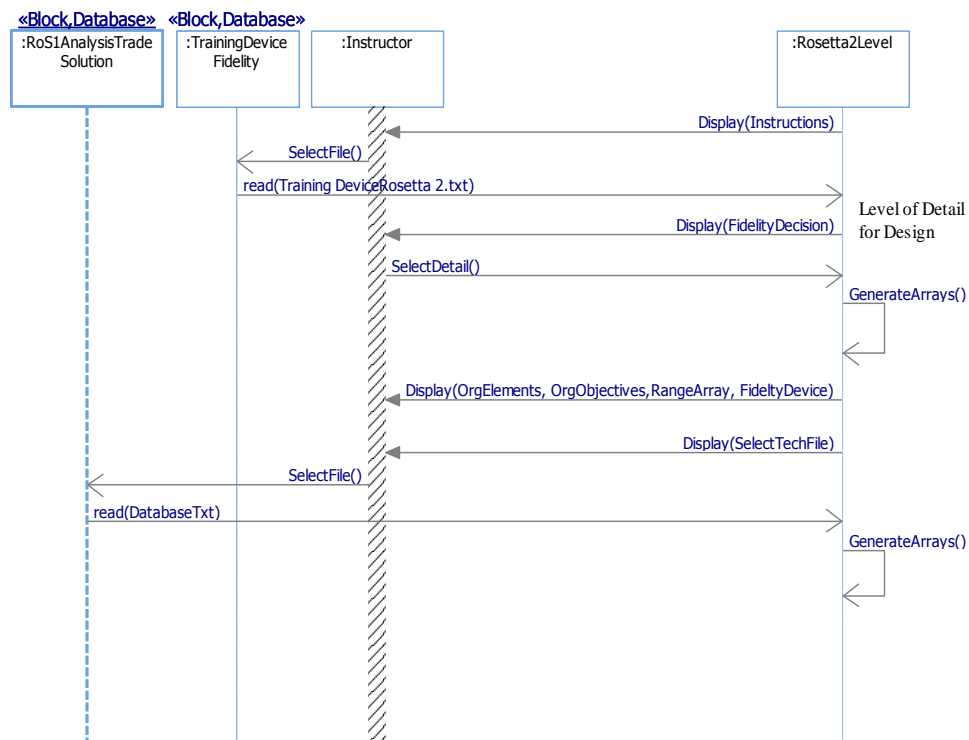


Figure O 2 Behaviour of Select Level of Detail for Analysis Use Case

The Rosetta2Design reference sequence diagram, described in Figure O 3, uses the information within the generated array of Figure O 2 to create the axis scales and names for the creation of the RSE's. One organisational objective requirement is used to generate the first column of an array signified by the outer loop in the figure. Each fidelity range is then used to create the other columns within the 2-D array; thus, one KSOrg is associated with one or more fidelity attributes. Once the first KSOrg has all identified fidelity's assigned, the outer loop is repeated for the next KSOrg in the array; the process continues for the number of KSOrgs' within the KSOrg array. A large 2-D array is then created with all the KSOrg and multiple fidelity types/characteristics of the same description by the 'GenerateFidelityOrgArray' operation within the 'DesignLoop' Block.

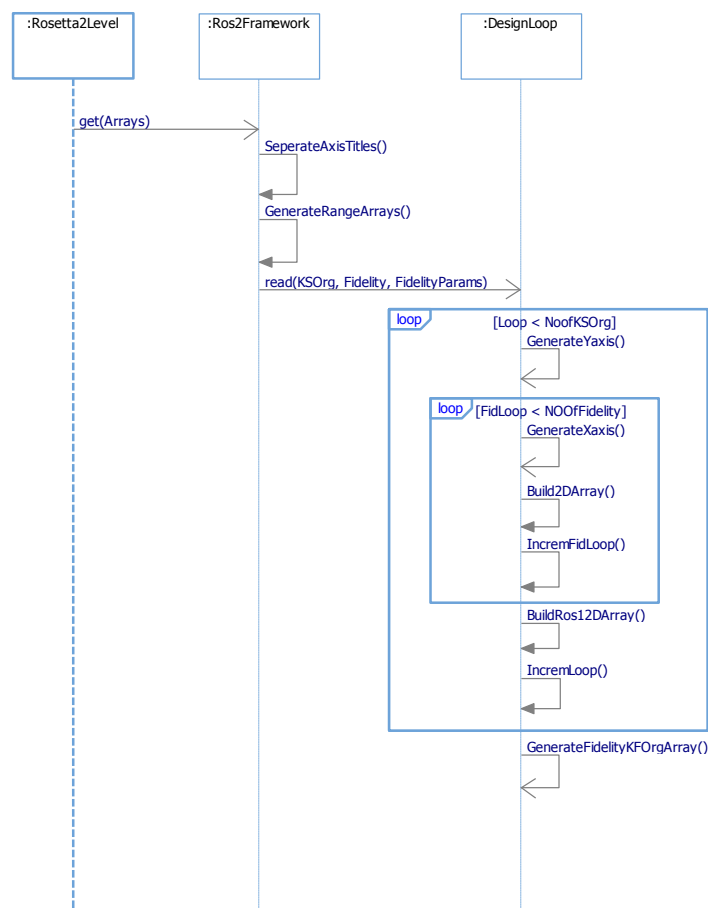


Figure O 3 Behaviour of Prepare Sample Points for RSE ROSETTA2

The LoopProsGen2 reference sequence diagram, shown in Figure O 4, describes the identical behaviour of Figure M 4 that uses data generated by the 'Ros2Framework' and 'DesignLoop' blocks to create a graphical representation of the sensitivities between the Organisational objective requirements and the fidelity design metrics. As in the previous behaviour of this stage, each KSOrg is assessed with respect to all the identified fidelity characteristics. The number of KSOrgs' controls the outer loop whilst the numbers of fidelity attributes control

the 1st inner loop within Figure O 4. A default RSE shape is created from the selected values given in Table IX and the x and y axis are constructed and presented to the decision maker. A linear RSE array is created within the graph generated by the Ros2DesignGraph reference sequence diagram. The decision maker(s), using RSEs for additional knowledge, has an opportunity to amend the RSE for one requirement to one design metric parameter. Once the shape is accepted, the next fidelity in the list is assessed to the same KSOrg. Once all Fidelity attributes in the list have an RSE associating the KSOrg to the fidelity values the RSE mathematical function is saved within a 2-D array. The next KSOrg in the list is then assessed with the same Fidelity types/characteristics, with the 2-D array updated with each KSOrg assessed. Once all KSOrg's have been assessed with all fidelity values, the RSE sample points are increased to smooth the shape to assist in the analysis phase. Both the original RSEs and the new RSE with additional sample points are then separated out into separate 2-D array that will then be saved within separate database directories illustrated in Figure O 1.

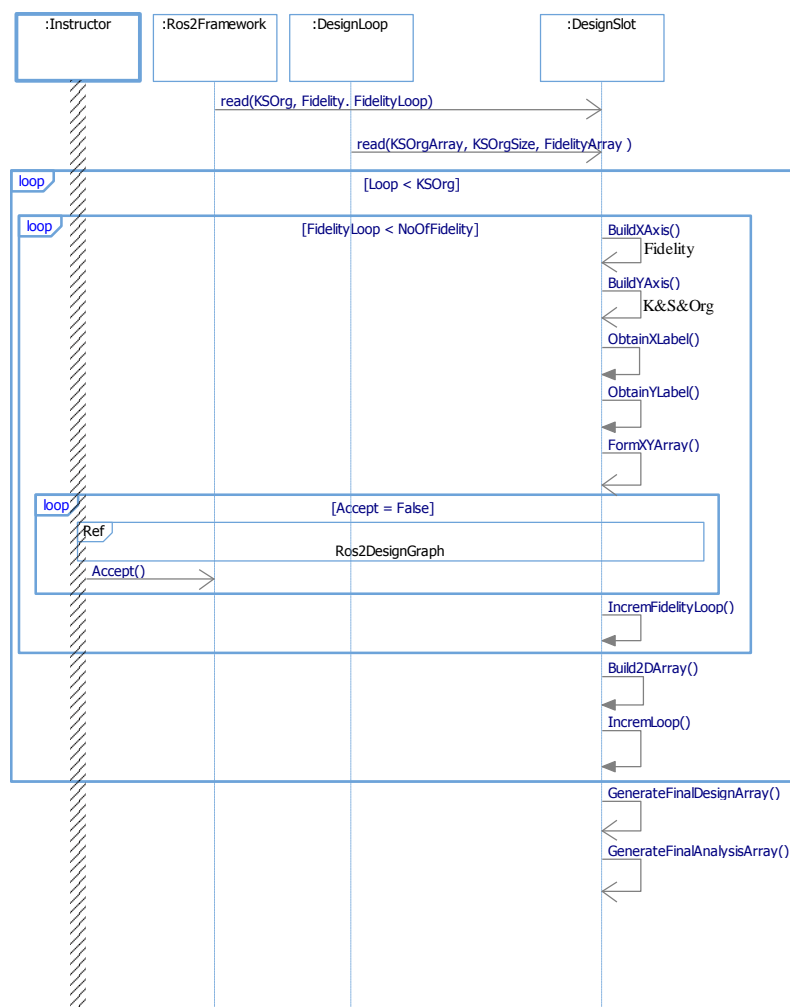


Figure O 4 Behaviour of Generate ROSETTA 2 RSE Arrays Use Case

The Ros2DesignGraph reference sequence diagram of the ‘Create RSE for Manipulation Ros2’ Use Case can be seen in Figure O 5; the behaviour follows the identical process as those described in Figure M 5. The graphs and the linear plot is created using the values from Table IX, (alternatively the decision maker can upload previous RSEs from the database(s)). The graph is presented in a separate window and allows the decision maker to adjust the current array values associated with the sample points that are used to generate the linear plot. There is no time limit of the decision maker to alter the shape of the RSE as indicated within the first loop of the figure; once the shape has been accepted a new array is generated from the sample point location values on the graph. The RSE array is streamed through a filter function that adds additional values to the array and filters the RSE shape ready for the analysis sub-stage. The final graph for analysis is displayed to the decision maker for a period of 5seconds before the 1st inner loop in Figure O 4 is executed again.

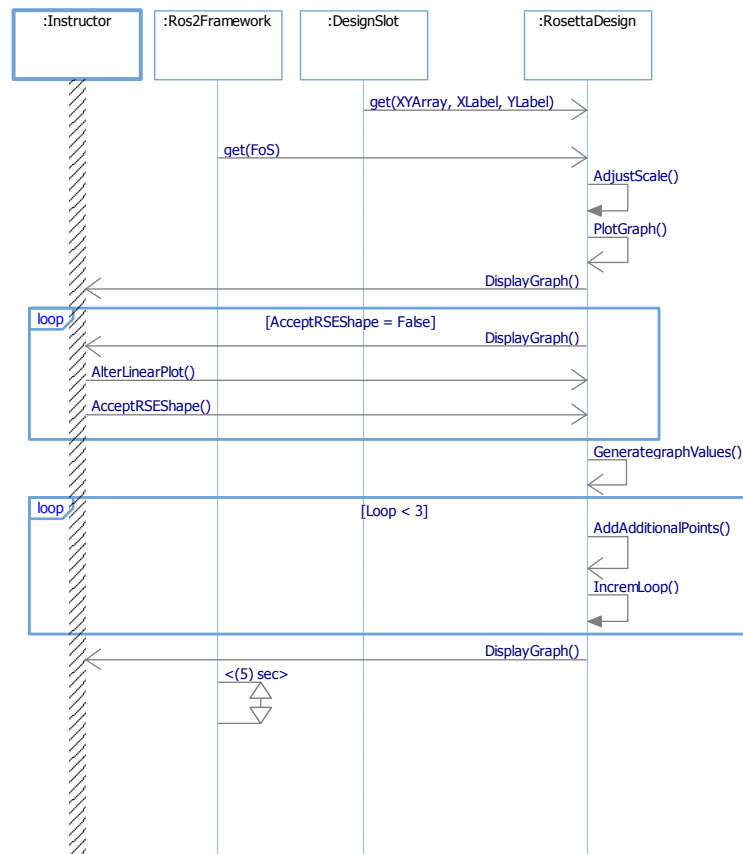


Figure O 5 Behaviour of Create RSE for Manipulation Ros2 Use Case

For ROSETTA 2 analysis, described in Figure O 6, specific instructions as to the method of using the framework for the purpose of analysis, is given. The decision maker has two options: one to use the original RSEs developed from the design; second to use the filter RSE shapes for a more detailed analysis. The decision of which RSEs to upload to the framework

depends on how detailed the analysis needs to be and on the performance capability on the computer being used for this stage of analysis. Once a decision has been made, the 'ROS2Analyse' block will obtain a list of systems with the remaining FoS and use the number of technologies from this list to set the number of loop iterations. If the analysis stage is being executed separately to the design stage then the training attributes database is used to retrieve a list of training attributes. The 2-D arrays are used to scale the framework and identify the graph labels for each axis and to determine how many slots (that contain the graphs) are required to be displayed. The framework and associated graphs/slots is then displayed within a separate window using the behaviour of the TradeStudy reference sequence diagram, described in Figure M 8. Once the trade study has completed, the values associated with the partial differentials, describing robustness of the relationship, and the KSOrg value levels decided are stored within a 2-D array and the total suitability value of the current training technology is calculated and added to the bottom of the array. The next technology in the technology remaining array is then assessed in the identical manner and the result of the trade study is added to the 2-D array. The end result is one large 2-D array, which incorporates all partial differential values along with KSOrg level values including the value of total suitability for all technologies.

The trade study functionality is described by the 'Procure Effective Blending Training Mix' Use Case diagram of Figure O 7. The results from the analysis are then used for the purpose of technology elimination, the 2-D array of sensitivities and KSOrg level values are retrieved then simplified. Like in the previous ROSETTA elimination stage the decision maker will be asked, using the information displayed within the 2D array, whether the current technology presented within the displayed sentence is a suitable solution for training based on the organisational requirements. Along with being asked the question, a warning is also displayed indicating that only one system from the FoS can be chosen. This decision is based on which technology on both the KSOrg value and the value of the partial derivative. Once a choice has been made, it is saved within the main student database file as the technology that is being used to execute the mission scenario. The information is used to assess the suitability of the blended mix solution, using the performance outcomes for comparison, as the student pilot progresses through the pipeline. For detailed discussions of the assessment stage including the GUIs, refer to Volume I, Chapter 7.8.

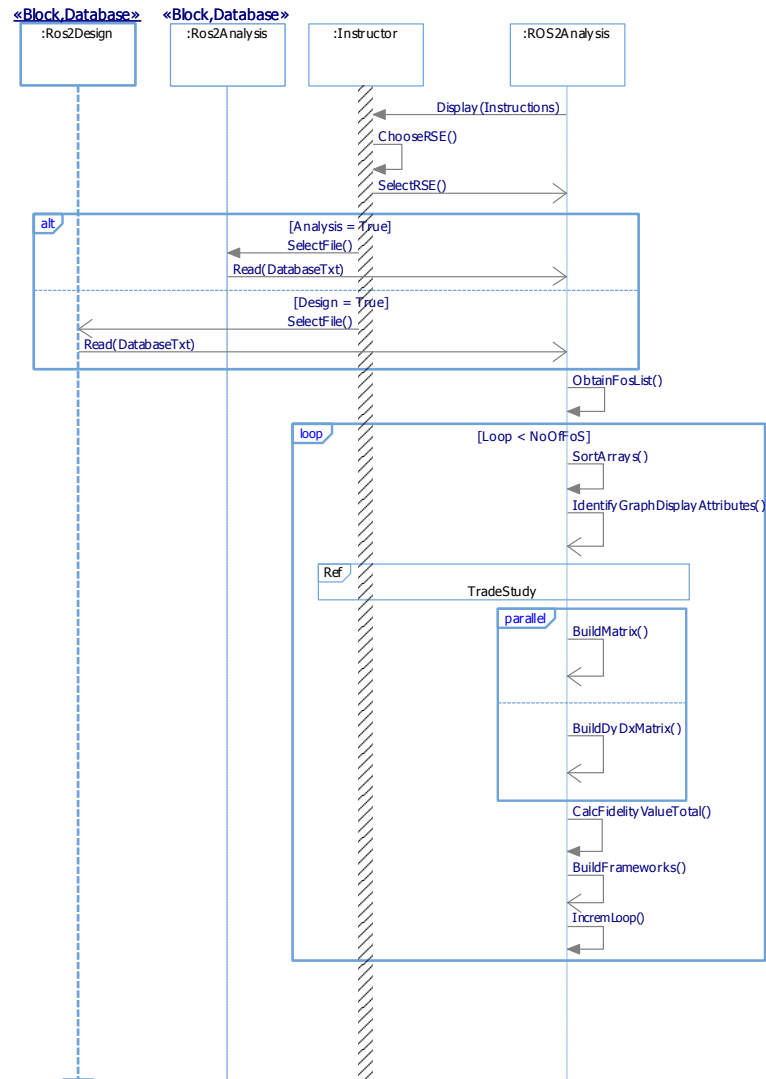


Figure O 6 Behaviour of Attain Fidelity Value Of Systems Use Case

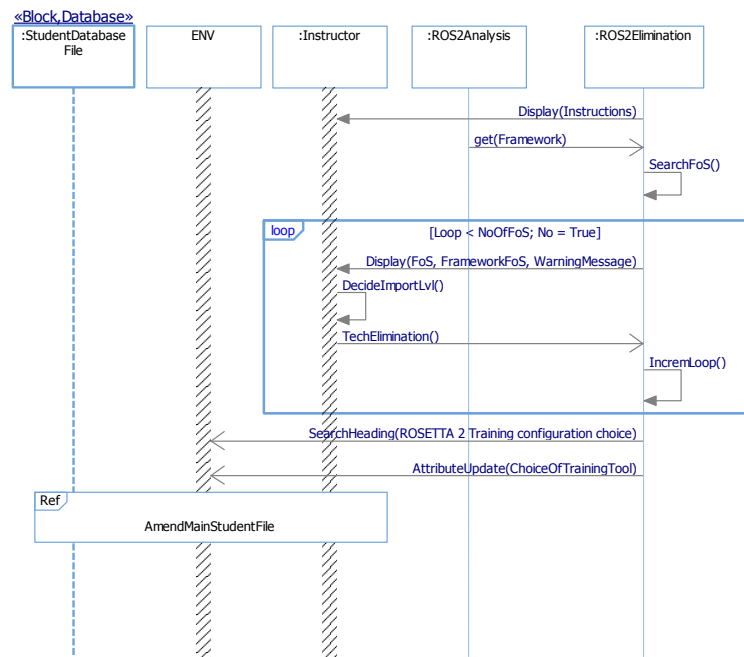


Figure O 7 Behaviour of Procure Effective Blended Training Mix Use case

This appendix describes the parameters used for ROSETTA level 2 analyses that concentrate on the technology characteristics of the systems within the FoS mix. The description and grades give an indication of the details that need to be reflected when creating the RSEs that describe the relationship between design and technology variables. The description of the fidelity and design variables bounds the problem in an easy to understand approach for the generation of the method aimed at evaluation of technology suitability for the current training mission.

Technology Viewpoint

Visual Fidelity

Visual Fidelity describes the visual accuracy of real world objects emulated by a simulation. The smoothness of recognition, size aspect ratio and distance of the object from the avatar (a simulation object controlled by human interaction) account for this fidelity dimension; a further abstraction of visual fidelity is described by the sub-headings below. Generally, visual fidelity is incorporated with physical fidelity; however, due to the complexity and cost of accuracy of software objects representing the entire simulation environment displayed to a human user, the dimension is perceived to be important and considered independently to its parent dimension. For high-level design and analysis, a grade of 100 signifies the simulation model is an identical visual replica of the real world object, both in size and aspect (not feasible at the moment due to limitations of technology), a grade of 10 indicates poor visual replication of the object both in size and dimensions, but, a human user can still recognise what the software object is attempting to emulate. A grade less than 10 is deemed unsuitable for training in synthetic devices.

Human Perspective / Focussed View:

This is the field of view for region of interest, which the human eye is required to focus on during the execution of the mission scenario. The vertical field of view has approximately 135deg, and horizontally ~270deg (without head being turned). Assessment of relationship between the design variables to this technology parameter is based on SME opinion on the effect of display and control assemblage with respect to the details the human eye can recognise from the horizontal field of view. The scale is based on whether all information needed to complete the mission tasks is available without the need to re-focus pilot's eyes in a different location. A grade of 100 means all information is available in horizontal view, a

grade of 20 infers that required information needs eye and head rotation on a regular period to execute mission operations – (associated to screen size, software configuration of display). This dimension is directly associated with pixel pitch, which is the term that correlates the display resolution and optimal viewing distance.

Quality of Information Presented:

The information presented to the pilot is to be based on the fitness of use for the pilot to make decision whilst flying the plane. This is a subjective measure which can be varied to align to specific pilots. The dimension has to be based on the suitability for the given mission task and/or objectives. This information presented to the pilot is an imperative part of a model known as the DIKAR model. The data displayed by the simulation leads to information the pilot can use to gain, use or advance knowledge that the pilot has been taught, which leads to actions (corrective or otherwise) that will perceive to obtain the correct result.

Data → Information → Knowledge → Actions → Results

The scale has to be based on accuracy, consistency, timeliness, reliability, usability and value added quality given to the pilot from the chosen technology. A grade of 100 means the quality of information given to the pilot is identical to the experience gained in the real world. A 10 means that the information presented to the pilot is not reminiscent of a real world experience and should only be used to gain a ‘feeling (a vague idea)’ of flying an aircraft in an unrealistic environment.

Level of Distortion / Minification:

Minification is often seen as the removal of unnecessary information without affecting the functionality. With reducing the size of real world images to display on monitors a level of distortion and the perception of objects in the environment within the simulation might infer some disorientation for the pilot. This measure is used, to some degree, to determine the level of visual workload needed to obtain proficiency for the real world operation. A grade of 100 presents exact visual projections experienced in real world operation; a score of 20 presents maximum minification of detail to fit simulation to the display (10.4” (800*600), 1.3:3). This dimension is strongly correlated with aspect ratio.

Confined Training View:

‘ignorance may be less fatal than a small degree of knowledge, because this adds, to the evil of ignorance, the inevitable errors of a confined view of things.’

- (Priestley and Vanstone, 2010: 12)²

The dimension concentrates on what perspectives the pilot may gain on using current configuration of equipment, and possibly the incorrect knowledge accrued from continued practice. If left to the pilots own devices, bad habits, modified (incorrect) procedures could be continuously practiced. This dimension concentrated on the possibility of unsupervised use of the equipment to practice or execute mission scenarios. A grade of 1 indicates fully unsupervised use of the technology and 100 indicates fully supervised at all times.

Visual Refresh Rate / Frame rate:

Refresh rate represents how many times the screen image (or frame) is completely reconstructed every second. The more times a screen image is refreshed every second the smoother the image is in terms of motion rendering and flicker reduction. In flight simulation used for training it is important that the pilot is not distracted by flickering of the image. A grade of 240 represents monitors with a refresh rate of 240Hz, a grade of 120 represent monitors and projectors with a refresh rate of 120Hz, 50Hz is the lowest refresh rate.

Display Response Time:

Response time is described as the total time the monitor takes to respond to a request for service. In a monitor the response time is directly dependent on the amount of time a pixel in a display takes to change state. Response time is measured in milliseconds. For smooth rendering using the monitors/projectors for training it is preferable to have a low refresh rate, this means faster transitions between states and thus fewer visible blurs between frames. A response time of 2ms will score 100, response rates of 16ms scores 10; slower response rates are deemed unsuitable for flight training.

Visual Display Resolution:

Visual resolution describes the amount of detail that can be distinguished in an image by the human eye. Within the display of a VRTE the detail is stored in a video file called resolution.

¹Priestley, P. & Vanstone, M., “Offenders or Citizens?”, *Readings in Rehabilitation*, Cullopmtton: Willan, 2010.

Often the display resolution is measured in the number of vertical and horizontal pixels in a grid (vertical, horizontal) pixel. The sharpness of the displayed image is fully dependent on the resolution, the higher the better in all axes. The resolution of displays has constraints to the size of the screen, referred to as the aspect ratio. Some monitors are rectangular in shape and therefore incur a pixel aspect ratio which represents its width to height ratio. The display aspect ratio (DAR) refers to the shape of a video frame (this is how the video will be displayed on the monitor (4:3, 16:9, etc.). A grade of 100 represents monitors/projectors with 4K ultra high resolution definition (3,840*2,160), a grade of 10 represents monitor/projectors of (490*320). A grade of zero represents the lowest resolution rate (320*200)

Visual Immersion:

Visual immersion can be described as the object level of fidelity of the sensory stimuli produced by a technology system; in other words is it the perception of being present in a non-physical world. The perception is created by the use of images that should engross the pilot into the environment. Within flight training, the method of visual immersion is to enable the pilot to experience performing operations that involve skill, knowledge and decision making by creating a realistic emulation of the real world entity. The general consensus in the scientific community is that immersion can be measured by studying the eye movements of a participant. Immersion can be affected by picture quality, size, and comfort of pilot. A disadvantage of VRTEs, however, is something called simulator sickness (similar to motion sickness) where external reference points are missing or blocked from vision creating a disorientated feeling. Boredom distractions and an unchallenging environment can lead to poor (visual) immersion. Visual immersion is important dimension to consider when deciding which technology to use to train at which level. A grade of 100 signifies high visual immersion, score of 1 means little visual immersion in the training activity and a high degree simulator sickness symptoms occurring.

Field of Regard:

Field of regard (FoR) is generally considered as a forgotten brother of field of view. It describes all the points of the visual environment that can be perceived by a human eye. In this context when considering FSTD technology and indeed real flight, the field of regard includes not only the image the pilot needs to focus on to complete the current task but also the objects within the image which are not relevant to the task that may lead to distractions whilst performing the mission. For training, the pilot has to be directed to which area he or

she needs to maintain focus on, and temporarily ignore the other less relevant information that his vision can see. This dimension is graded using subjective viewpoint on real world flight field of regard. A real world flight would be perceived as a high level of FoR and score a maximum of 100, a VRTE and its environment would score a percentage of maximum depending on the size, location, and environment (enclosed, open plan, colour). This dimension is graded using data from analysis of VRTE location to the visual field outside the focussed field of View. A grade of 100 indicates full visual immersion throughout the field of regard, a grade of 10 indicates the presence of ‘small’ monitors within an office environment.

Detectable lag in display view:

This dimension primarily deals with an estimate of control-display lag that may be detectable by the pilot. This dimension is directly related to the speed, memory and CPU architecture used as the driving force of the training device. The feedback to the pilot on the movement of the aircraft has to be accurate and concise enough to replicate real world dynamics of the aircraft to facilitate pilot decision making; commonly referred to a latency or lag. This dimension is comparable to the application response time of a software program using events generated from a key press. For military FSTDs an established 150msec is set as the maximum allowable display latency for all basic flight information, however it has been found that a total system latency of 150-250ms is tolerable in landing approach tasks where symbology is providing the primary flight guidance and command information (ref: AC-120-28, Appendix 2). However, for HUD systems the capability for reduced latency for a large field of view is required to be as low as 20msec. For the purpose of subjective analysis, a technology using HUD with low latency of 20msec is graded at 100, the maximum latency of 250ms grades a 10.

Physical Fidelity

Simulation and VRTE technology is concerned with the ‘fit’ between technology users, their tools and environment. This this dimension considers ergonomics and the physical environment both within the VRTE but also the physical effect on the human user given cues from the simulation. The similarity between the VRTE and its environment and the real world aircraft and environment is considered; a further abstraction of physical fidelity is described by the sub-headings below. For high-level design and analysis, a grade of 100

signifies the VRTE replicates the physical and environmental appearance the real world aircraft and cockpit, a grade of 20 indicates poor replication of the real world cockpit, displays and switches. A grade less than 20 is deemed not to provide any physical recognition of a real world aircraft or cockpit.

Motion / Vestibule Cues:

This dimension refers to the realism of non-visual cues normally associated with moving through an environment. The lack of normal cues (expected by the pilot) may contribute to cyber-sickness and may affect pilot performance. When a pilot is flying he/she expects not only visual cues provided by the displays, but also motion cues to clarify that the manoeuvre being executed is actually happening. With only visual cues the pilot is presented with two contradictory cues to their motion; this leads to disparate cues experienced by the pilot, causing inter-sensory conflict that may be the cause of nausea leading to simulator sickness. The distinct lack of motion cues experienced by the pilot will grade a 0, maximum motion cues experienced grades 100.

Resemblance to real cockpit configuration:

There is a general consensus that more a human is familiar with their surroundings, the better job performance. Furthermore, it stands to reason that the more accurate the training technology working environment matches the real world operating environment for the pilot, the better transfer of training. However, this is strongly related to the amount of immersion the pilot feels whilst executing mission tasks through the chosen technology. Depending on what specifics are being trained, the more disparate a training environment is to the real world it causes a risk of negative transfer of training that could affect the training outcome and mask the performance of the pilot. This dimension uses the subjective opinion of SME'S and feedback from the student (with respect to the flown mission) to assess whether the resemblance of the training configuration effected or will affect the desired outcome. A grade of 100 indicates the cockpit matches the operational aircraft, grade of 20 indicates a low level of resemblance to said operation aircraft. (a grade of 0 is reserved for VRTEs which have no emulation to the real world).

Environmental temperature/pressure:

The temperature within the cockpit of most modern military jets is generally controlled to be comfortable working temperature: most have air conditioning and heating. Thus, emulating

temperature working conditions can be seen as being somewhat irrelevant. However, in dome FSTDs most of the technical equipment produces heat in a confined area and could cause unnecessary discomfort. Flying a military fighter jet, blackouts and g-loc (loss of consciousness) are a risk in high speed (combat) manoeuvres, thus the pilot wears a g-suit: the pilot movement is restricted by his g-suit and oxygen mask. The g-suit is tightly fitted to restrict the draining of blood away from the brain during high period of acceleration, which may add additional discomfort for the pilot whilst flying the mission. When an aircraft is at high altitude, supplementary oxygen is required via the face mask to compensate for the differential pressure caused by the increase in altitude. This additional equipment added to the pilot can cause additional thermal stress/blood pressure which the pilot needs to cope with whilst concentrating on completing the mission goals. Some FSTDs permit the display to change to a shade of red to indicate that high G's are being pulled³. This dimension needs to consider the training mission and the tactical manoeuvres required and whether the chosen technology is suitable for the pilot to gain an understanding of effects on the human body of high g-force manoeuvres. A grade of 100 indicates training is being conducted on a real aircraft, a grade of 70 indicates the FSTD can emulate g-forces by vestibule feedback to pilot, and allows alteration to pressure within a g-suit. A grade of 0 signifies no replication of pressure effects on the human body either visually or physically.

Environmental Lighting:

Cockpit lighting has been under considerable discussion. White light tends to be used more, the red light to allow for a more natural visual environment within the aircraft. Problems such as, errors in course plotting are thought to be caused by incorrect lighting in the cockpit. For night flights the night vision goggles are generally used to provide additional view capability with light amplification. On the ground, the VRTEs are generally placed in a room with fluorescent lights and the more basic FSTDs can be located in a number of environments with disparate lighting effects. A subjective analysis is required for each mission to be performed as to the effect of environmental lighting on what specifics are being trained. This dimension considers the training effect of artificial lighting in the location of the FSTD and the effect on pilot's performance or additional distraction caused by reflections/ strobe lighting effects, etc.

³Banerjee P.K., Chowdhary, S, & Jain P.K, "Studies on heat stress in military flying", AR&DB Project report: 769/93, 1993.

A grade of 100 is a perfect match for the operational environment, a grade of 20 indicates minimal lighting with unrealistic panel lighting and symbology illumination from the technology.

Functional Fidelity

Functional fidelity concentrates on the look, feel and familiarity with controls when compared to the real world aircraft. The layout of FSTD cockpits, the identical displays, switches and levers, which all correspond to the same operation within the real world aircraft, are important to enable consistency and reduce confusion for student pilots. Therefore, this dimension concentrates on the recreation of operational characteristics from the real world to the user interfaces of the VRTE; a further abstraction of functional fidelity is described by the sub-headings below. For high-level design and analysis, a grade of 100 signifies the VRTE user interfaces perform the identical operation as the real world object and the layout of switches, levers, and displays etc. are identical to those found in the aircraft cockpit. A grade of 10 indicates that different switches in disparate locations have been used to perform some function that replicates the real world object and the cockpit layout does not replicate the real world cockpit.

Pilot Position / Seating:

The environment of the pilot is important to the success of the training for the transfer of training (ToT) to the real world. The position of the pilot whilst flying a virtual aircraft is an important factor to consider. The seating could span from a wooden chair to an office seat to a replica simulator pilot seat, to an emulated cockpit chair to a real cockpit chair. Measurements from the seat locations/positions to the display and additional controls are important to consider for successfully completing mission goals and learning the corresponding knowledge and skills. A seating position which correctly resembles a real aircraft is graded 100, a seating position which does not take into consideration real world ergonomics (measurements of seat position to controls and display) of the pilot to controls grades a zero.

Buttonology:

This dimension concentrates on the additional information and knowledge the pilot has to acquire in order to fly the planned mission with respect to the control of the virtual / real

aircraft. An FSTD needs to emulate each operation of a real aircraft in order for pilots to gain the necessary knowledge and skills to exercise the correct procedures on a real world aircraft. The switches / key-presses / buttons needed for which type of function / operation is required to be known. Different configuration will require new explanation of which control does which function and thus requires some time for familiarity, especially if locations of these controls are in disparate locations. This dimension has to be graded with respect to the real world aircraft ultimately being trained for. A replication of operations using identical switches/buttons etc. is graded a maximum of 100, the controls which do not match the same switches/buttons with respect to the aircraft grades a minimum of 20. (The actuator may perform a similar task but a pushbutton switch in replacement of a toggle switch may cause some confusion for the pilot even though they perform the same function).

Switchology:

This dimension concentrates on the setting of switches to perform some function, which will hopefully promote ease of use during flight. This dimension concentrates on the knowledge given to the student pilot before they undertake the task to gain familiarisation of the configuration. As with buttonology, this dimension has to be graded in relation to the real world 'set-up'. Some VRTEs permit certain functions to be performed automatically, for instance, raise landing gear can be done automatically – especially if no control switch has been set to work for this functionality. The difference in settings between the training equipment and the aircraft being trained for has to be considered so that a subjective assessment can be made about certain aspects of familiarization for the pilot. As with buttonology, a setting configuration which matches the real aircraft will grade a maximum of 100, a setting which is not capable of being emulated by the VRTE, or done automatically within the VRTE grades 20. A grade below 20 indicates that the function cannot be programmed in to do manually or in doing so causes addition distraction and workload to the pilot which can affect performance during mission tasks.

Pilot control:

In a real aircraft, rudder and brake controls are provided for by pedals operated by pilot's feet. In some FSTDs, pilot control functionality may be provided by key presses or various types of yoke and throttle controls. The assessment considers the importance of the control to the success of the mission, attaining relevant K&S and the ability for the pilot to maintain focus on the goals of the mission rather than be distracted on operating the controls of the aircraft.

The quality, handling capability, ergonomic design, and location of the control are under assessment also. A grade of 100 indicates the controls are identical to the real world aircraft being trained for operational readiness; a grade of 0 indicates no resemblance to aircraft controls and provides additional distraction and workload to the pilot.

Task Fidelity

Task fidelity concentrates on the correspondence between tasks and operations that is performed on the real world object and the tasks and associated actions performed in the VRTE. The essence of task fidelity is to assess the realism of behaviour of the VRTE both in the simulation and the effects of perception of changes in state of the simulator objects on the human user; a further abstraction of task fidelity is described by the sub-headings below. For high-level design and analysis, a grade of 100 signifies the simulation model provides feedback to the pilot which directly emulates the real world experience of the pilot, a grade of 10 indicates that some feedback mechanisms to the pilot are missing or poorly represented by the VRTE technology and associated equipment.

Feedback relationship:

This dimension refers the accuracy of information or additional cues for control feedback to the pilot. Examples of which include how accurate the virtual aircraft operates with and without flaps, g-force rating in turns and climbs, tactile feedback to HOTAS system, etc.. This dimension has a strong correlation with the aircraft model dimension. This subjective assessment is conducted with SMEs who assesses the degree of realism in pilot actions to the FSTD and back to the pilot. A technology which gives an unrealistic feedback to the operator for the respective design variables is graded a 0, the most accurate feedback for each design variable grades a 100.

Aircraft / Environment model accuracy:

The physics of flight is what needs to be reproduced within FSTDs in order to give a realistic feel to the pilot. Substantial work has been conducted to emulate stall, acceleration, drag, momentum, etc. One of the major issues still outstanding in VRTEs is reproducing the feeling of movement which gives feedback to the controls. Landing an aircraft, crashing an aircraft and the feeling of g-force characteristics still requires substantial research to reproduce. However, most aircraft models are good for training muscle memory and

checklist familiarisation in conditions that simulate time durations and distractions of real flying. As a general rule of thumb the more expensive the FSTD, the better emulation of the real aircraft model. The restriction of a real feeling of aircraft is strongly dependent on size of monitors, speed of processor, size of memory, control inputs etc. As with all FSTD simulated aircraft models, some aircraft models are more accurate than others. Due to higher-order dynamics on the aircraft attitude control, the pilot has to perceive the attitude as well as the angular rate, angle of attack, sideslip using visual perception from monitors, projector displays, and others. This dimension has to consider not only the accuracy of the model within the FSTD, but, also the possible pilot perception of accuracy of the model. A grade of 100 indicates the FSTD model of the aircraft and environment and the pilot's perception of the model is extremely accurate, a grade of 10 indicates the model is a poor replication of the real world aircraft model and pilots have a poor perception of the real world aircraft using the virtual simulated model.

Psychological Fidelity

Performance feedback to Baseline:

This dimension concentrates on real statistical feedback to be given to pilots on the success of the mission. Generally, feedback is given by SME/instructor observations. Most modern, low fidelity simulators can give an accurate feedback describing pilot performance with numerical data. Most modern aircraft have the ability to record every stage of the mission and every action of the pilot, which can be used to de-brief personnel on the mission. During training it is important to ensure pilots are given information that can be used to strengthen their weaknesses or to gain confidence on certain aspects of their knowledge and skills (K&S) to improve mission success and their own performance. This dimension is graded on the technologies capability to feedback accurate data to the pilot and SMEs on the performance of the flight. A grade of 100 indicates that FSTD replicates the real world aircraft model precisely and gives an accurate playback 'situation' with all actions of the pilot being recorded in a time dimension to reflect workload and SA. A grade of 0 indicates little or no feedback mechanism available and fully reliant on instructor opinion and possible bias.

Verbal Fidelity

Auditory Cues:

This dimension concentrates on the realistic sounds experienced by the pilots as they execute the mission scenario. Aspects of this dimension include the quality of the sound, stereo,

clarity, sound definition, volume, and physical properties of sound (vibration). The subjective analysis is based on real world sound quality experienced by the pilot live flying the mission scenario. A fully realistic sound quality grades 100, and unrealistic sound quality grades 10, and no sound feedback to the pilot grades 0.

Organisational Design Variables

Mathematical RSEs are used to describe the relationships between the design variables and the technology fidelity. The grades are an indication of the maximum and minimum levels to give the relationship a region of interest and bound the RSE to enable the SMEs the ability to adjust the shape of the RSE to give a more accurate relationship between the organisational design variable and the technology fidelity parameters of the VRTEs for trade studies; to choose the most appropriate training technology to use for each respective student pilot.

Non-Functional ‘Worker-oriented’ requirements

Knowledge under assessment:

This dimension considers Knowledge as the body of information applied directly to the performance (or function) of a task in the mission scenario. Knowledge is given to the pilot through the training programme which uses the technology and the instructor’s opinions to assess performance in relation to the mission goals. The SME opinion, in this case, is to identify the relationships between the knowledge under assessment to the technology fidelity dimensions. A mathematical function is then used to describe the relationship. The level of knowledge varies between weak (1) to outstanding (10) and is dependent of the mission tasks.

Skills under assessment:

This dimension considers skills as the observable competence to perform a learned psychomotor act. The term psychomotor is the relationship between cognitive functions and physical movement of a task in the mission scenario. Skills are trained within the training programme which uses the technology and the instructor’s opinions to assess acquired skills in relation to the mission goals. As with the knowledge dimension, the SME opinion, is to identify the relationships between the skills under assessment to the technology fidelity dimensions. A mathematical function is then used to describe the relationship. The level of skills varies between novice (1) to expert (10) and is dependent of the mission tasks.

Operations

Practice Emergency Procedures:

Emergency procedures can be extremely difficult to train due to the inherent dangers. The circumstances in which a fault/problem occurs requires a quick response time from the pilot to determine what is wrong, how critical it is, and how much time does the pilot have to fix or otherwise circumvent the problem. This dimension, therefore, concentrates on the ease, safety, and practice of the remedy of emergency situations. Under consideration is how effective the VRTE is at accomplishing the remedy of emergency procedures using the technology fidelity dimensions. . A mathematical function is then used to describe this relationship. The grade varies between excellent fault diagnostic and rectification emulation capability grades a 10 to poor fault replication and poor emulation capability grades a 0 and is dependent of the emergency procedure being assessed.

Ease of Distributed Simulation:

With the advent of large scale military operation involving numerous forces cooperating and working side by side on the identical mission goals; it is advantageous for pilots from disparate backgrounds/countries to learn to fly and perform mission tasks as a combined unit. The networking of communications and tactical information to create a collective mission environment is an advantage for real world operations. This dimension concentrates on how effective the technology fidelity is at achieving collective mission training using distributed simulation. Overall functionality, networking, and cost are considered at delivering this type of training. A grade of 10 indicates that the technology provides excellent effective DIS ability, a grade of 0 indicates DIS is unavailable.

Availability:

Availability in this context refers not only to the number of VRTEs that are available, but also how reliable the VRTE is, the ease of maintenance and upgradeability. VRTEs and aircraft are expensive not only to operate but also to maintain. This dimension is an subjective assessment of these attributes with reference to the technology fidelity of the system in focus. The more available a technology is, the more the pilots can use the technology to practice the mission tasks and gain additional knowledge and skills to prepare the student for readiness. However, availability does not necessarily mean that practice should be open-ended without supervision. Assessment of this dimension should also include

the supervisor availability to ensure that the student pilot does not gain any unwanted actions in the cockpit/ aircraft operations. A grade of 10 indicated full availability, low cost, ease of maintenance, and adequate supervisor control; a grade of 0 indicates minimum availability, high cost, poor maintenance and little supervisor control.

Performance Factors

Effect on attention weight:

It is common knowledge that good SA guides attention towards relevant information, whereas poor SA guides attention towards less relevant information and possible errors and poor pilot performance. SME are therefore required to place weight to events which student pilot will come up against in support of guiding the student pilot's attention to prevalent events relevant to complete mission objectives. Thus, attention weight is directly related to information visual, verbal, or otherwise given to the pilot by the FSTD. This dimension considers the attention of events given by the technology fidelity and is strongly correlated to the Situation Awareness (SA) dimension. A grade of 10 indicates that the attention cues given by the technology fidelity is identical to the real world aircraft, a grade of 1 indicates a poor emulation of the real world aircraft, cockpit and displays.

Effect on Situation Awareness:

Situation Awareness consists of the allocation of attention to events and an understanding of the belief regarding the current state and probable future state of the aircraft within the environment. This dimension concentrates on the technology's fidelity ability to provide the pilot with enough quality information considering the effort and ability of the pilot (head, eye, hand movement) to obtain such information. A training device that accurately replicates the real world SA experience grades a 20, those that do not infer the real world conditions with respect to the workload requirements grade a minimum of 1.

Effect on Salience:

The pilot is required to reach a decision based on the information received/feedback from the training device. Certain cues from the training device should permit the pilot to perform cognitive retrieval of strategies to use upon certain received cues. These cues should allow the pilot to quickly and efficiently guide pilot's attention to the salient events. The salience of the event is described as the state of an object (e.g. warning on panel) which stands out

relative to its neighbours. Saliency of event become more of an issue the closer the cues/warning lights are to each other as well as the colour/luminance differences are to each other. A grade of 1 indicates that the saliency of the events are hard to capture pilots attention due to closeness and size of visual cues, a grade of 20 indicates good identification of salient events and ample distances between visual cues.

Economics

Direct Operating Cost:

The direct operating cost covers a diverse range of different definitions. This dimension concentrates on a subjective rating of fixed and variable costs, including acquisition cost, maintenance cost, lifetime upgrade costs and support costs, and personnel training costs. Typical operation cost can vary between £5000 per hour for a Mk2. hawk aircraft (typhoon ~ £70000/hr) to £300 to a full equipped VRTE to zero for a basic desktop simulator. Typical cost of acquisition can vary to the ranges of £18million for a hawk aircraft to ~£2000 for a suitable desktop simulator with basic flight simulation software. There is a high disparity in price between real world application and the ground based simulator DOC. Thus, it is imperative that the mission task importance and the K&S levels for pilot training to play an important role in the choice of technology to use for K&S acquisition for mission readiness. The DOC has a natural trade-off with K&S and is potentially the most important factor that is used for the cost of training for governments to budget air-force training. For the huge disparity, a grade in this dimension of 100 indicates a high acquisition and high running cost of technology (such as typhoon), a grade of 1 indicates minimum cost of acquisition and minimum cost of maintenance. (The hawk Mk.2 aircraft will be graded a 70, with blended synthetic mix added - 80).

APPENDIX P TASK LOAD

Task load is used to gather further information regarding workload and time allotted to complete tasks. The workload database, described in Appendix K, and the baseline scenario data is retrieved using the ‘Readfromfile’ reference sequence diagram in Figure P 1, described by Figure P 2. The number of tasks within the mission and the workload dimension values for each task are gathered along with the timelines available for each task. The information is used to calculate task load per task with each loop calculating task load for each task respectively; the result of which are saved within an array. This array is saved within the workload TaskNoAndDetails file and the average task load for the whole mission is saved within the main student database file. For details, refer to Volume I, Chapter 7.9.

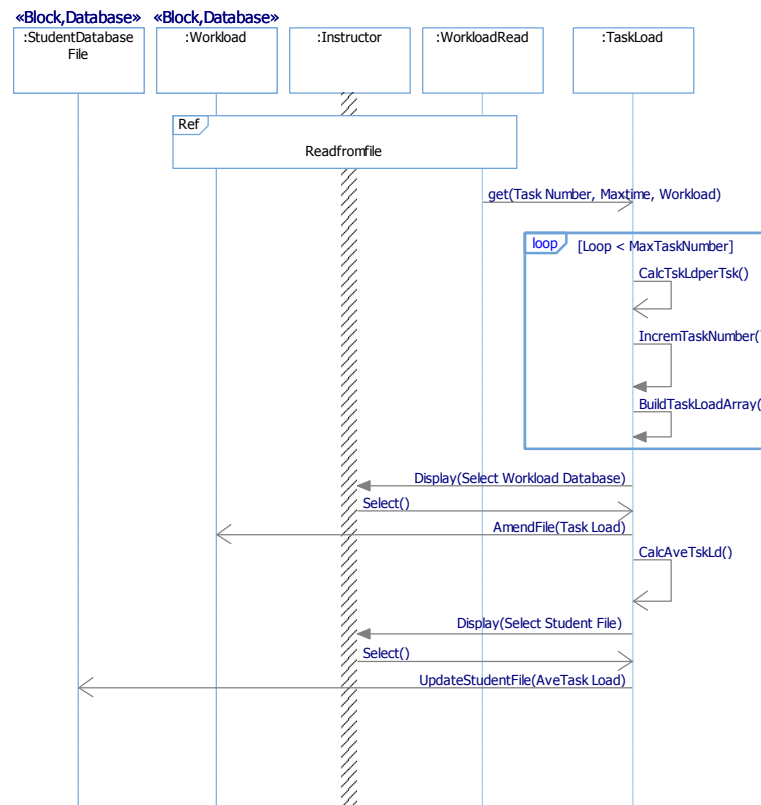


Figure P 1 Behaviour of Assess Task Load for Each Task within the Mission Use Case

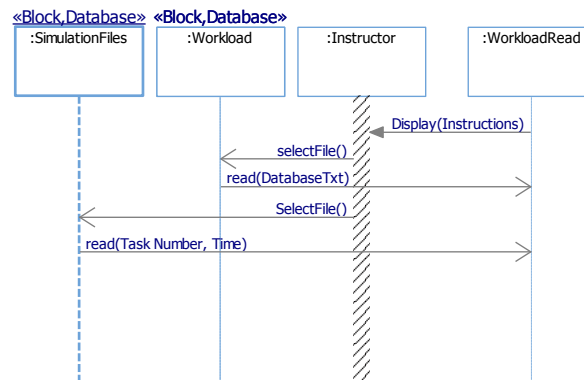


Figure P 2 Behaviour of Read from Workload File Use Case

APPENDIX Q PERFORMANCE PREDICTION ASSESSMENT

It is important to estimate the pilot's ability to keep the aircraft under control to satisfy mission requirements. The behaviour of 'Estimate MoP of Student' Use Case is seen in Figure Q 1, which uses Gaussian distributions to assist the decision maker in predicting both accuracy and precision of pilots actions. Data from previous assessments is retrieved to obtain a default value for the standard distribution for the generation of the Gaussian curves. For the PhD research, this assessment has been limited to three accuracies: altitude, aircraft position and time; however, additional assessments can be easily supplemented. The number of tasks in the mission controls the loop iterations and there is a feature that permits the instructor to amend the automatically calculated standard deviation for each accuracy distribution to allow subjective opinion to influence performance tolerance. Each distribution for accuracy for each task is saved within a 2-D array within the PlotDistributionFiles Database that will be used for further assessment upon completion of the planned mission scenario.

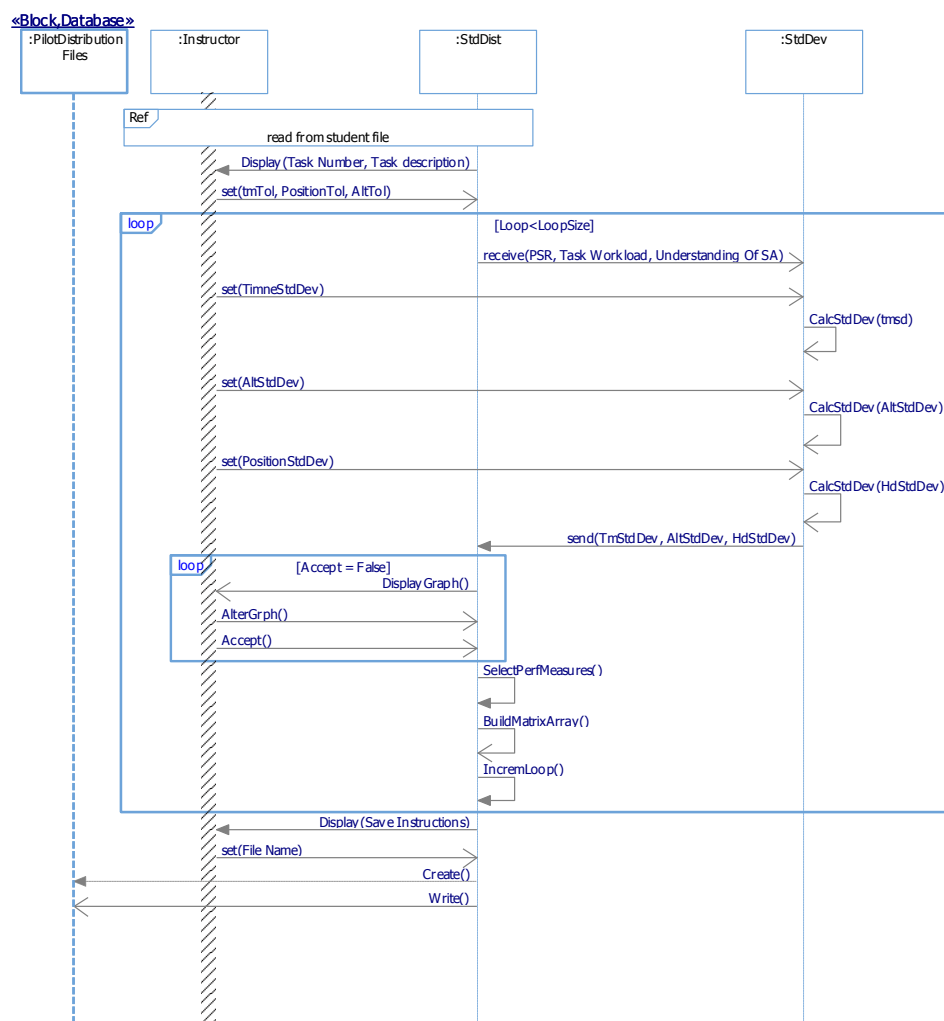


Figure Q 1 Behaviour of Estimate MoP of Student Use Case

The ‘readfromstudentfile’ reference sequence diagram is illustrated in Figure Q 2. The ‘StdDist’ block initially displays instructions to the decision maker of the aspects of this assessment stage. Upon receipt of the instructions the decision maker will retrieve the pilot specific rating and the percentage understanding from the main student database file, which will be used within an algorithm to alter the default accuracy setting of the Gaussian curves that visually indicates the performance accuracy for each pilot operation during execution of tasks or activities. The decision maker will then be asked to retrieve the workload file that obtains the number and details of the tasks within the mission; this will be used to specify the loop size that is directly associated with the number of tasks in the mission. For more details on predicted performance assessment is found in Volume I, Chapter 7.10.

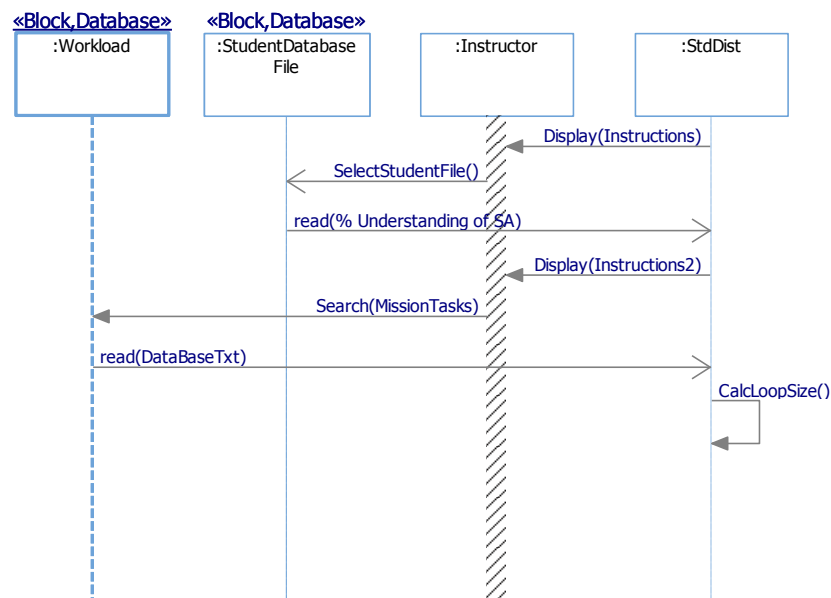


Figure Q 2 Behaviour of Read from Main Student File Use Case

APPENDIX R PRE-FLIGHT SA

The pre-flight assessment asks the student pilot to give information regarding their current state of mind just before executing the mission. This information is provided via Assessment Form 6 that is retrieved from the pre-flight database for each pilot within the Student_Pilots directory. The answers are in the form of a Likert scale that is transformed to an integer value for calculation of percentage performance SA to give an indication of how the current state can affect the predicted performance with respect to successfully completing goals of each task within the mission. The total percentage is saved within the main student database file on the respective mission scenario reference row. Further details can be found in Volume I, Chapter 7.11.

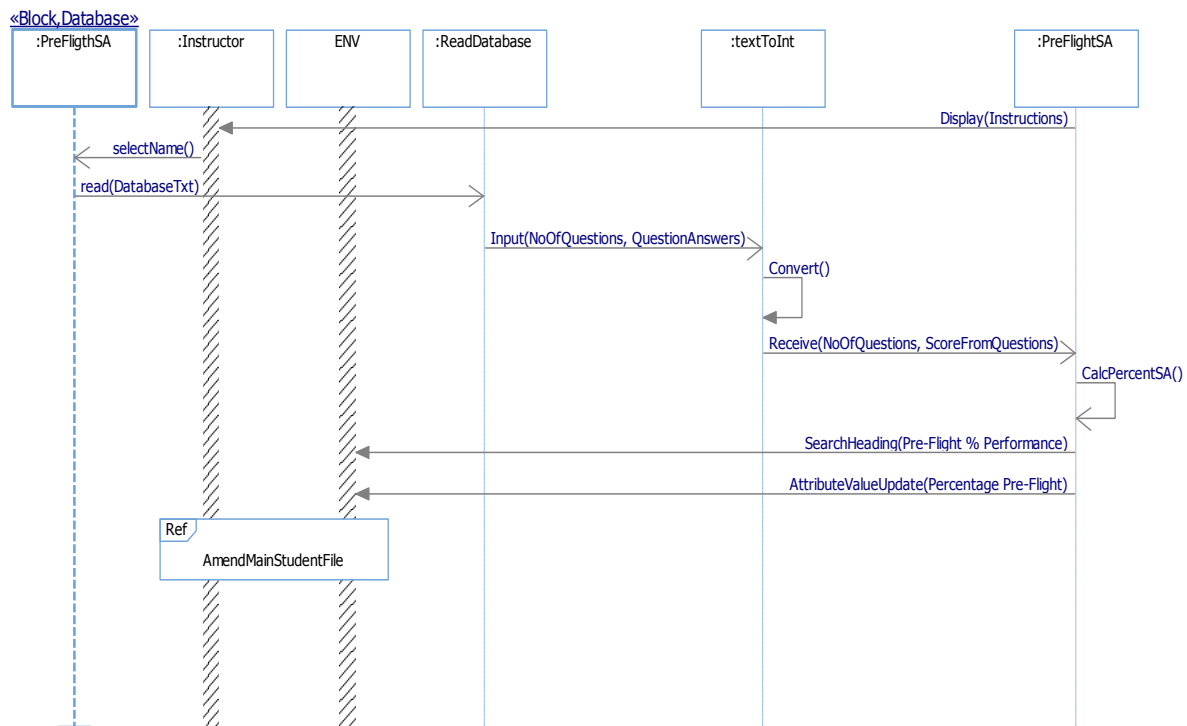


Figure R 1 Behaviour of Obtain Situation Awareness Use Case

Assessment Form 6 Pre-Flight Situation Awareness Questionnaire

Pre-Flight SA

This Questionnaire is used to determine the current state of mind of the pilot before undertaking the flight mission scenario, to give an indication of performance vectors that will be used to determine the degree of success of successfully completing mission and task goals.

* Required

- 1.

Name? (First name surname initial *

e.g. TrevorH

- 2.

Flight scenario reference ^{*}

This is given in the preflight brief (ask instructor if unsure)

- 3.

1. How many hours of sleep did you have last night *

Mark only one oval per row.

	1 Two Hours and Under	2	3	3 Around five hours	4	5	6 Eight hours and over
Number of Hours	()	()	()	()	()	()	()

- 4.

2. How well did you sleep? *

Mark only one oval per row.

[illegible]

- 5.

3. How do you feel today? *

Mark only one oval per row.

1 Have a cold / ill 2 3 4 Not too bad 5 6 7 Feel Great

General Feeling ☐ ☐ ☐ ☐ ☐ ☐ ☐

- 6.

4. How well is your day going? *

Mark only one oval per row.

	1 One thing after another	2 3	4 Not too bad	5 6	7 great day
Todays experience	<input type="radio"/>	<input type="radio"/> <input type="radio"/>	<input type="radio"/>	<input type="radio"/> <input type="radio"/>	<input type="radio"/>

7.

5. How do you feel about you planned flight and mission scenario goals? *

Mark only one oval per row.

	1 Just want to do it	2	3	4 No Hurry	5	6	7 Calm but Nervous
Confidence Level	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

8.

6. How well do you think you will succeed with this flight with respect to mission goals? *

Mark only one oval per row.

	1 Not at all	2	3	4 Average	5	6	7 Very well
Estimated success level	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

9.

7. How motivated are you to perform this flight? *

Mark only one oval per row.

	1 Not at all	2	3	4 Average	5	6	7 Very motivated
Motivation Level	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

10.

8. How difficult do you think the flight will be? *

Mark only one oval per row.

	1 Not at all	2	3	4 Average	5	6	7 Very Difficult
Difficulty Level	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

11.

9. How would you characterise this flight, what are the typical aspects of the flight that you can expect?

You can think of the workload, level of concentration needed, etc.

.....

.....

.....

.....

.....

APPENDIX S GOAL MODELLING

Goal modelling provides an easy visual way to predict success of student pilots on an activity or task basis based on both instructor and pilot subjective and objective assessments; the goal assessment behaviour is visually described in Figure S 1. The number of tasks and details are retrieved and used to set the number of loops with which to obtain triangular distributions describing the decision makers view on the satisfaction of the student pilot on achieve the task or activity goal. In an attempt to alleviate complication with the assessment criteria, the decision maker is presented with three windows asking for input data: the first is for maximum satisfaction of the goal believed that on an exceptional day the student pilot is capable of achieving; the second for the minimum satisfaction level acceptable; the last is the most likely satisfaction level based on previous assessment results and instructor opinion. Once these values are accepted, the ‘GoalModel’ block generates the triangular distribution that best describes the goal satisfaction of the task or activity. This distribution is displayed in graphical form allowing the decision maker to alter the shape of the distribution, if required, to describe more accurately the satisfaction; this may be primarily based on the Pre-Flight SA assessment that might affect the accuracy predictions completed previously. Once the shape has been accepted the next task or activity is assessed using the identical process.

Once all the tasks or activities have been assessed, all the distributions are stored within a 2-D array using the ‘BuildGoalArray’ operation. The array is then used to obtain a distribution for whole mission satisfaction based on the details entered within the loop using the point value propagation algorithm executed by the ‘CalcPointValueDist’ operation. The triangular distribution for the mission is presented to the decision maker that could highlight areas of concern or areas that required detailed concentration on during mission execution. The mean satisfaction point is calculation for whole mission and saved within the main student database file for further analysis as the student progresses through the pipeline. For further details on the assessment, goal modelling techniques and associated GUI, refer to Volume I, Chapter 7.12.

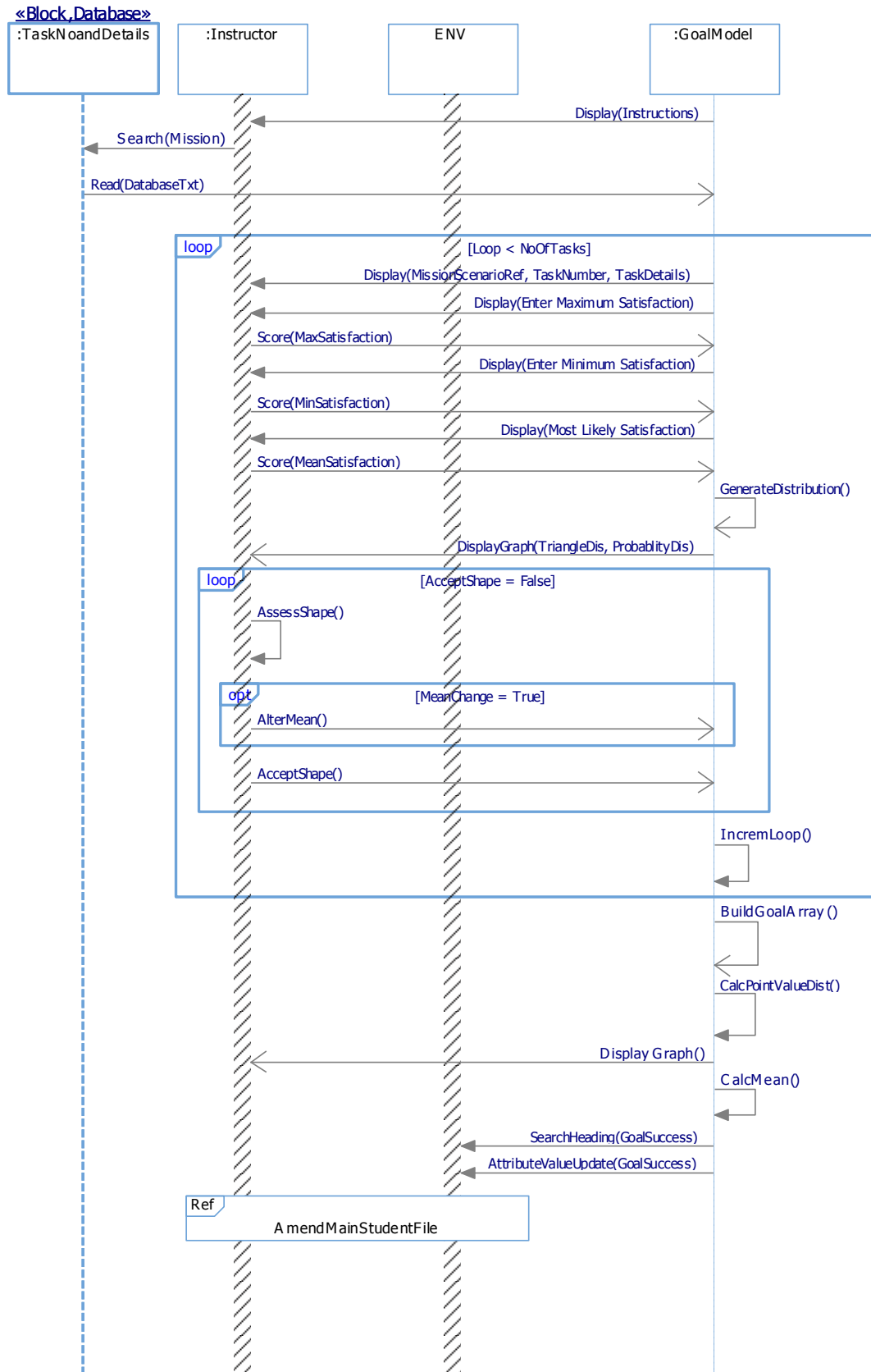


Figure S 1 Behaviour of Estimate Mission Success Use Case

APPENDIX T SUPERVISOR ASSESSMENTS

During execution of the mission scenario the decision maker (instructor) will observe the actions of the student pilot along with the outcomes of the activities. This will form the basis for the information that the decision maker will enter within Assessment Form 7. The answers from the form are converted to integer values that are used for the calculation of the percentage performance outcome of the mission and is saved within the main student database file, as seen in Figure T 1.

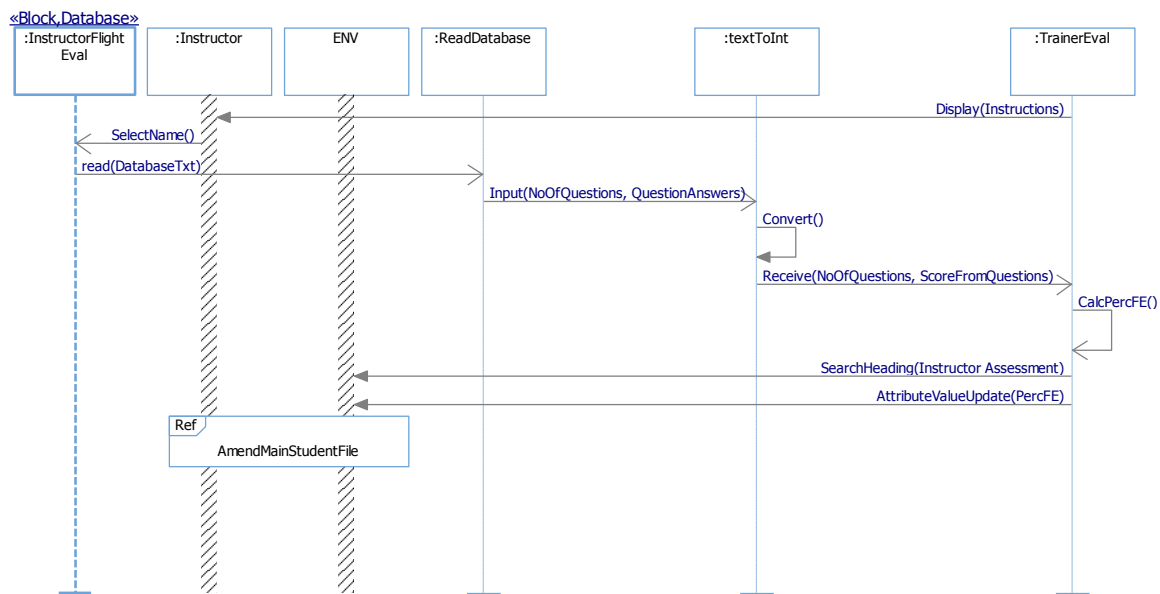


Figure T 1 Behaviour of Conduct Subjective Flight Evaluation Use Case

Assessment Form 7 is completed for each student pilot and can be used to focus training attributes to each of them. This form should be completed after the mission using notes made by the decision maker during execution of the mission with which to base the objective assessment on. The form also takes into account the instructor's own opinion whether the needs of the student was taken into account during the pre-mission brief. The results of the form can be compared to the student pilot equivalent (Assessment Form 8) with significantly different (or opposite) opinions forming the basis for part of the post-mission brief on the mission performance. Interventions can be planned on the difference of opinion between decision maker and student pilot with open debates on which aspects of the mission or pre-mission brief caused the most confusion and thus assist in creating a plan to remedy the identified weakness. Further information on observer assessment method can be found in Volume I, Chapter 7.14.1.

Assessment Form 7 Supervisor Assessment on Pilots Ability from Execution of Scenario

Supervisor opinion of pilots ability during the mission scenario

The camera and HOTAS / rudder feedback can be used to clarify grading on instructor opinion questionnaire. This assessment considers the instructor opinion of the understanding of the brief for each student pilot and the assessment needs to be compared with the answers given on the Pilot Awareness Rating Scale (PARS) questionnaire.

* Required

- 1.

Name of student *

first name followed by surname initial

- 2

Flight scenario reference? *

see pre-flight brief

- 3

1. How comprehensive was the brief in relation to pilot understanding? *

Mark only one oval per row.

1 2 3 4 5 6 7 8 9 10
(poor) (average) (Excellent)

Scale

- 4.

2. How effective did the pilot monitor the environment for changes, trends, and abnormal conditions? *

Mark only one oval per row.

[illegible]

- 5.

3. How well did the pilot demonstrate awareness of where he or she was? *

Mark only one oval per row.

[illegible]

6. 4. How well did the pilot recognise the need for action given appropriate events/cues? *

Mark only one oval per row.

1 2 3 4 5 6 7 8 9 10
(poor) (average) (Excellent)

Scale

7. 5. How effective were the tactics / actions employed during the mission? *

Mark only one oval per row.

[illegible]

6. To what extent did the pilot demonstrate knowledge of tasks in relation to mission goals? *

Mark only one oval per row.

[illegible]

9. 7. How well were the needs, workload and time constraints of the pilot taken into account during planning? *

Mark only one oval per row.

[illegible]

10. 8. To what extent did the pilot exhibit skill time-sharing attention among tasks?

Mark only one oval per row.

[illegible]

11. 9. How effective was the pilot in monitoring his own workload? *

Mark only one oval per row.

[illegible]

APPENDIX U TECHNOLOGY FEEDBACK

Student pilot performance stage consists of three sub-stages of analysis as seen in Figure U 1: the first reference sequence diagram concerns retrieval of performance data from the chosen training technology identified from ROSETTA 2 assessment followed by reading data from the baseline scenario assessed in Appendix H; The data is used for quick comparison of the mission using 3-D visual displays to efficiently identify phases of the flight that caused undesirable outcomes; The data is then used for more detailed analysis using 2-D graphical plot that can be focussed to the phases of flight causing issues for the pilot. The predicted performance distributions are then retrieved from the ‘PilotDistributionFiles’ database for the respective student pilot and used to give a metric score for each task or activity within the mission to grade the student pilot on the satisfaction of achieve the task or mission goal(s). The performance array is then saved within the ‘Performance Results’ database file for the mission located in the Flight Analysis directory. The final reference sequence diagram’s behaviour concentrates on the monitoring information from pilot control gathered from the training technology to identify any potential ‘startle’ conditions which affected smooth control of the aircraft for a short period of time.

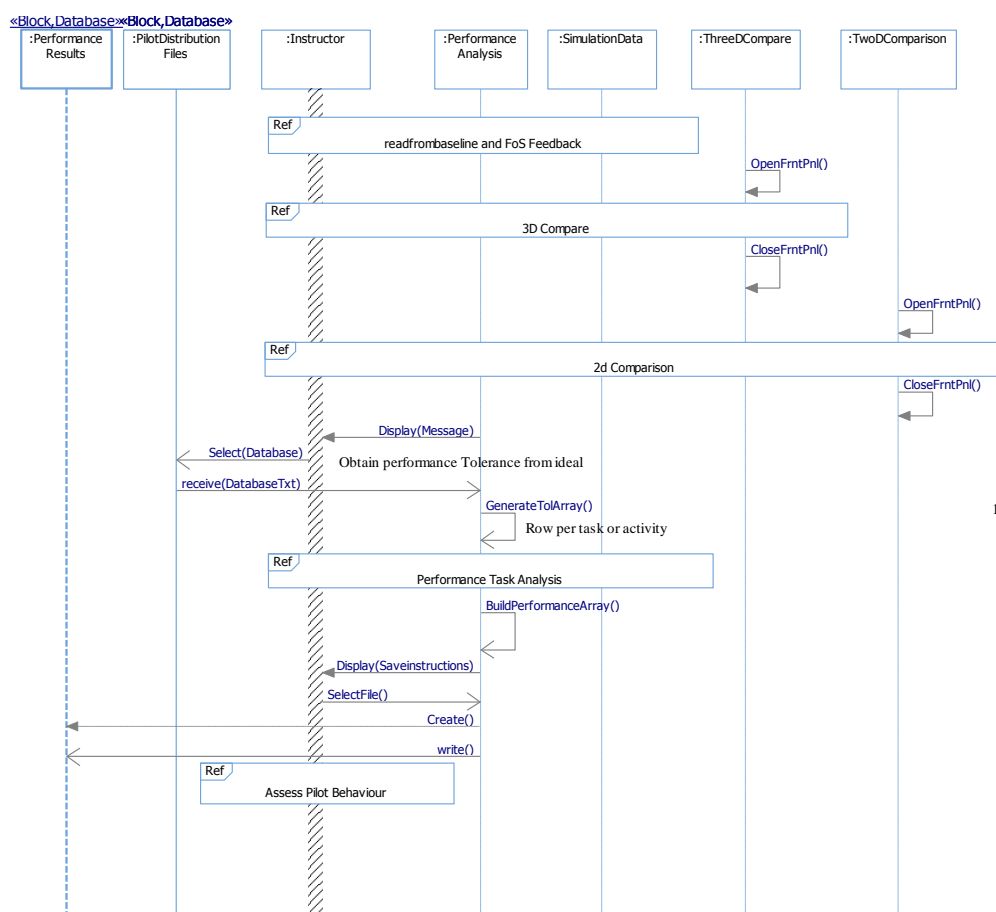


Figure U 1 Behaviour of Assess Student Performance Use Case

Figure U 2 described the ‘readfrombaseline and FoS Feedback’ reference sequence diagram illustrated in Figure U 1. The previously simulated (or flown) mission data is retrieved from the ‘SimulationFile’ Database file for the respective mission and stored within a 2D array. The executed mission file will then be retrieved from the ‘FoSExecutionData’, which is stored within 2 separate arrays: one for aircraft positional information; on one for pilot actuator behaviour, as described in Figure U 2.

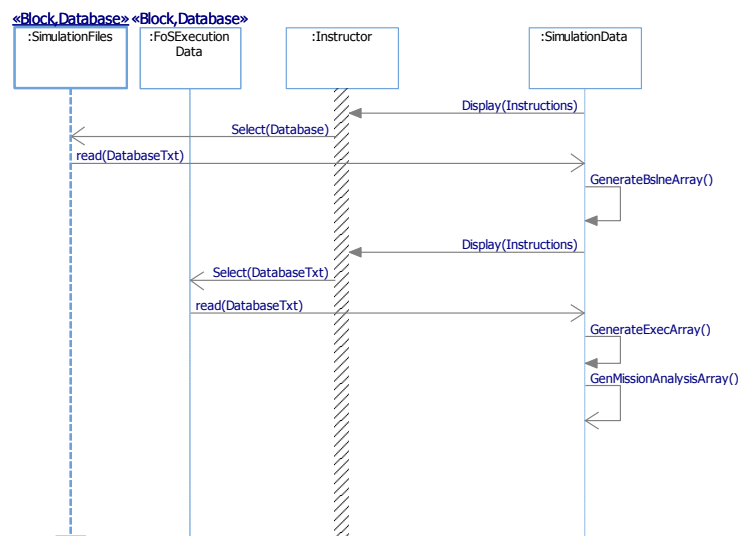


Figure U 2 Behaviour of Read from baseline Scenario and FoS Feedback Use Case

The 3DCompare reference sequence diagram behaviour is described in Figure U 3 that uses the aircraft position data from both the baseline scenario simulation and the training technology to generate 3D plots that are used to compare the ideal to actual executed mission scenario. The decision maker uses the plots to identify key areas of interest that require further analysis; information on the GUI for all assessment sub-stages is found in Volume I, Chapter 7.13.2.

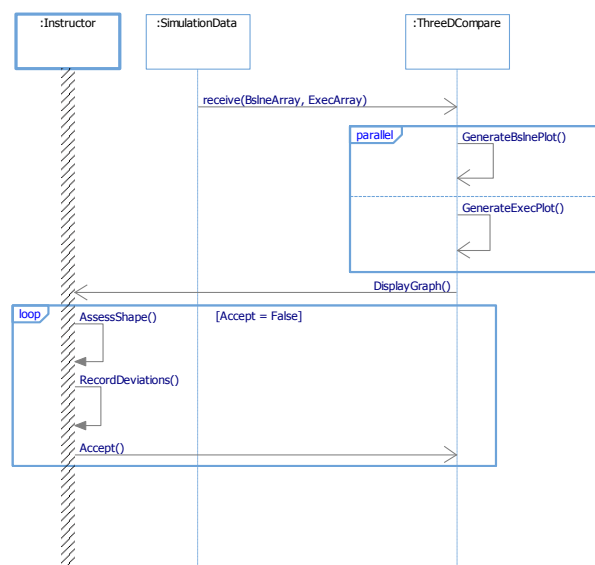


Figure U 3 Behaviour of Compare Mission Execution in 3 Dimensions Use Case

The key areas of interest identified from the 3D plots can be examined in more detail using the 2D multi-plot display described in Figure U 4. Each plot describes the full mission flight that will focus the decision maker on more specific details of the mission. The plots can be manipulated to focus more on aspects of the flight on a per task basis. The decision maker has to accept the analysis is complete before transferring to assess performance outcomes. These plots can be used for discussions in the post-mission brief.



Figure U 4 Behaviour of Compare Flight in Detail Use Case

Task performance occurs by the separation of the arrays into tasks, where each task is graded independently; this is a further assessment stage to the one described in Figure U 4. This further stage, described in Figure U 5, displays the analysis data in a 2-D form and uses the accuracy and precision data gathered from Appendix Q with which to grade the student pilot's accuracy to mission requirements. The scoring is completed at each time sample point and then averaged for the whole task. The outer loop continues to execute until all the tasks of the mission are scored. The score for the whole mission is then calculated using the average score per task for the basis of calculation; the result is consequently saved within the main student database file.

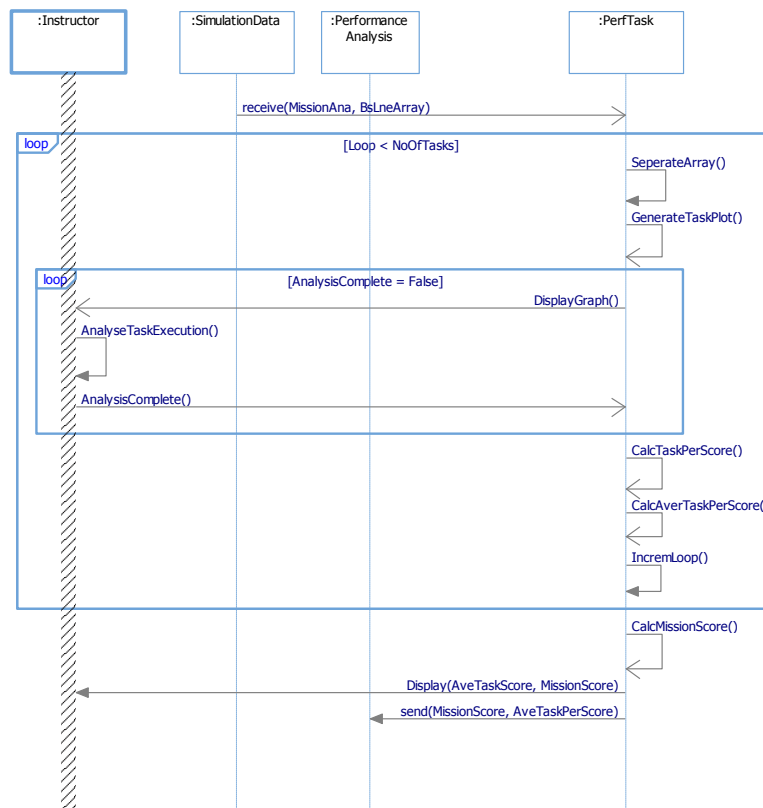


Figure U 5 Behaviour of Perform Performance Task Analysis Use Case

To monitor how the pilot interacts to control the aircraft, monitoring data from each input device is used to generate plots describing rate of change in movement of each with respect to time. The graphs are used to analyse how effectively the student pilot controlled the aircraft during the mission; any spikes in output indicate brief period that the student pilot lost control; of interest in how these period line up to objects of interest within the training exercise. The decision maker will make notes on the key areas to discuss with the respective student pilot on the post-mission brief.

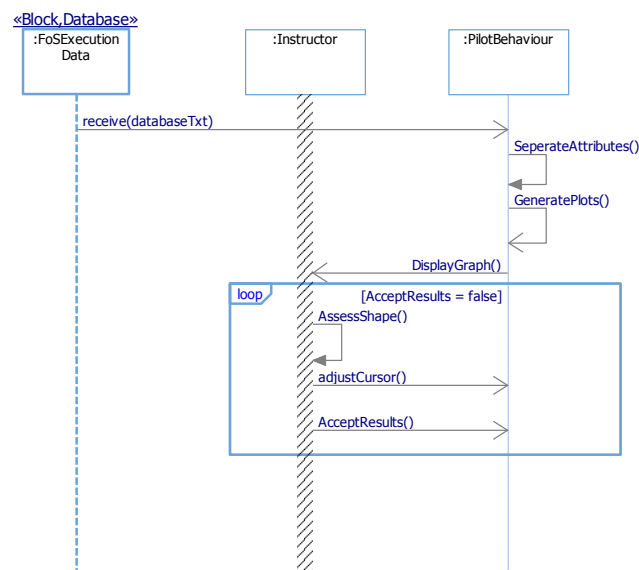


Figure U 6 Behaviour of Assess Pilot Operation Behaviour Use Case

APPENDIX V POST MISSION SUBJECTIVE ASSESSMENT

The post mission analysis consists of a number of subjective assessments directed at each student pilot, described in Figure V 1.

- The first assessment considers the pilots own opinion on the workload involved within the mission tasks, see Assessment Form 8.
- The second concentrates on the student pilots opinion on the success of the mission tasks with respect to using the training technology, see Assessment Form 9.
- The third concentrates on the training technologies effectiveness for task execution, see Assessment Form 10.
- The final assessment consists of a number of simple paper based questionnaires base on flowchart principles that guide the student pilot to the appropriate description and contains a scale concerning the training technologies usefulness in executing the various operations involved in the mission tasks.

All grades from the assessment is saved within the main student database file using the ‘AmendMainStudentFile’ reference sequence diagram.

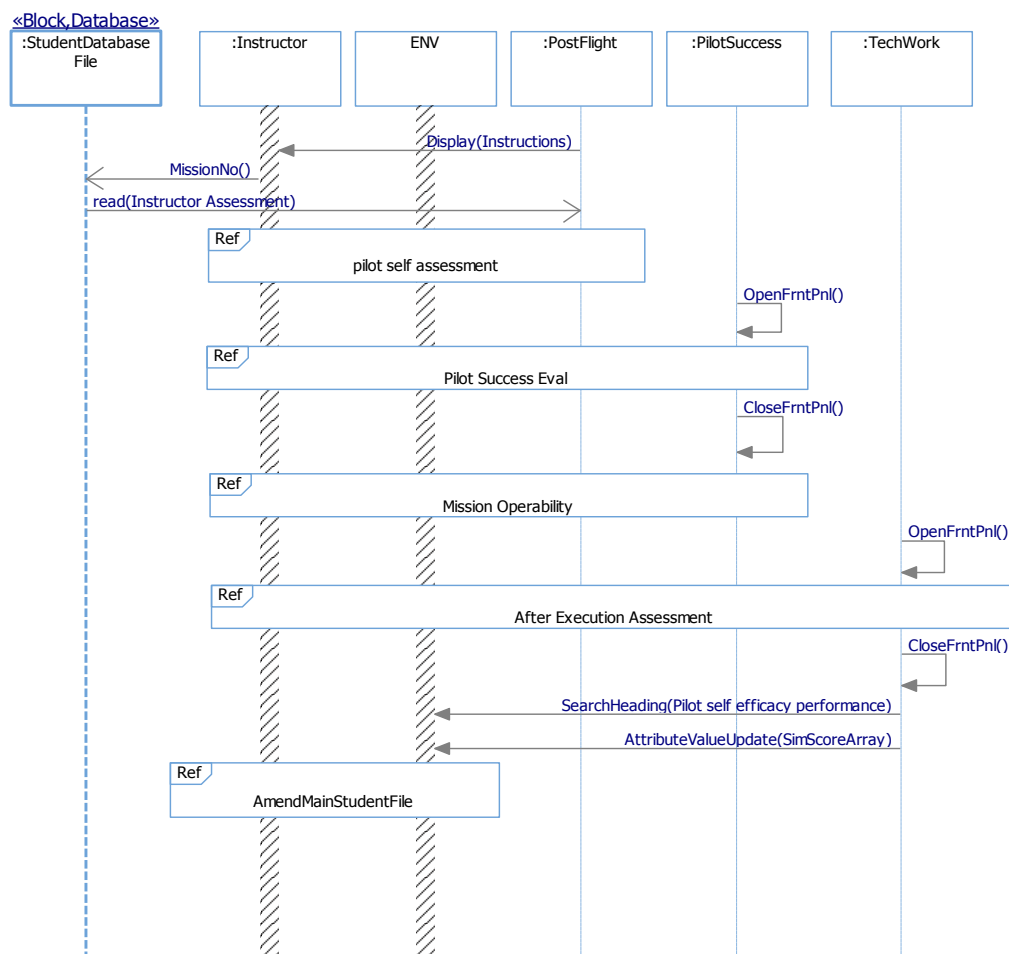


Figure V 1 Behaviour of Perform Post Mission Analysis Use Case

The ‘Pilot self-assessment’ reference sequence diagram is seen in Figure V 2. The student pilot’s answers are retrieved from the PostFlightSelf Assessment database and converted to integer values. The values are then used to calculate the percentage success the student pilot believes they have achieved with the technology; the score is then compared with the post flight assessment completed by the instructor, see Appendix T. The confidence rating is the result of the comparison analysis between the two assessment scores; if the confidence rating is low, discussions between the instructor and student pilot are required to clarify why there is such a high disparity in subjective opinions on the aspects of understanding of the mission to the respective student pilot’s views, along with confidence rating based on the comparison. Further detail on the behaviour of the assessment is found in Volume I, Chapter 7.14.2.

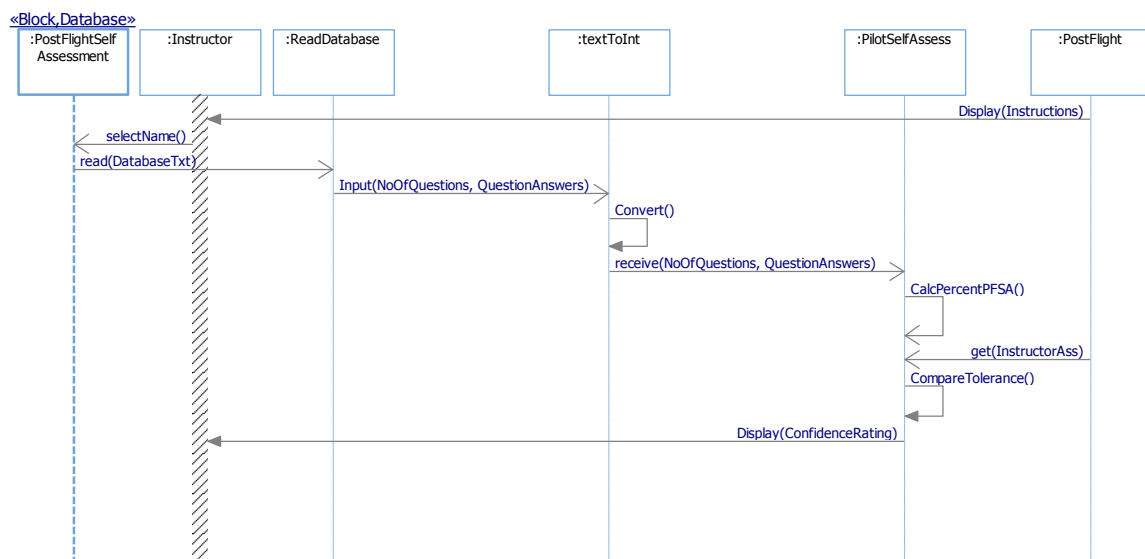


Figure V 2 Behaviour of Obtain Pilot Self-Assessment of Mission Use Case

The ‘Pilot Success Evaluation’ reference sequence diagram is described in Figure V 3. The student answers obtained from the ‘PilotSuccessEval’ database file in the Student_Pilots directory for the respective mission scenario is converted to integer values that is used to calculate the percentage success of the mission according to the feedback data. The data will be plotted using triangular distribution to match the goal modelling stage. These plots are used to analyse aspect of the mission: from the pre-mission brief to technology specific characteristics to the realism of flight. Any distribution where the mean is less than half way from minimum to maximum identifies a cause for concern and further analysis involving the student pilot is needed to clarify exactly what the issues are with using the technology for attaining the relevant K&S. The peak score is converted to a percentage value to assist in reading the results. Further information regarding this assessment is found in Volume I, Chapter 7.14.3.

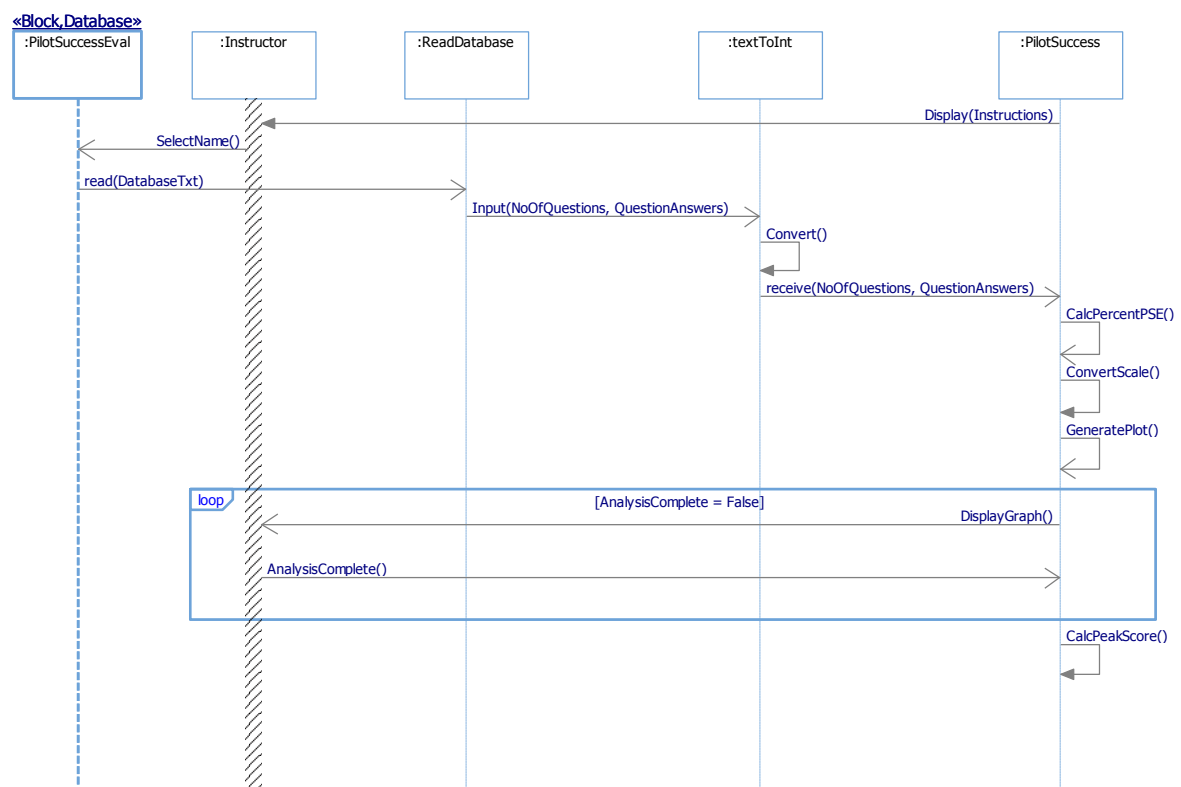


Figure V 3 Behaviour of Obtain Pilot Success Evaluation Use Case

Assessment Form 8 Student Pilot Post Flight Self-Assessment

Post Flight Self Assessment

This questionnaire is to gather your opinion (student pilot) on your own performance of the flight with respect to the mission goals mentioned in the pre-flight briefing. Please answer as honestly as possible

* Required

1. **Name? (First Name surname Initial) ***
i.e. TrevorH

2. **Flight Mission scenario reference?** *
This is given in the preflight brief (ask instructor if unsure)

3. 1. How difficult did you find this mission scenario? *
- Mark only one oval per row.

1. Very difficult 2 3 4. Average 5 6 7. Very Simple

Difficulty level ☐ ☐ ☐ ☐ ☐ ☐ ☐

4. 2. How well would you say you succeeded with the mission scenario (performance rating) *
- Mark only one oval per row.

[illegible]

5. **3. How would you assess the realism of the flight mission? ***
Realism can be defined as the tendency to represent something as they really are
Mark only one oval per row.

	1. Very Poor	2	3	4. Average	5	6	7. Very Good
Level of realism	<input type="radio"/>	<input checked="" type="radio"/> <input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/> <input type="radio"/>	<input type="radio"/>	<input type="radio"/>

6. 4. How much 'Spare Time' did you have during the mission? *
Mark only one oval per row.

Spare Time ☐ 1. None ☐ 2 ☐ 3 ☐ 4. Average ☐ 5 ☐ 6 ☐ 7. A lot

13. **11. Concerning the flight control task, did you ***
Mark only one oval per row.

	1. Think what to do	2	3	4. Average	5	6	7. Acted without conscious consideration
Response scale	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

14. **12. Concerning the navigation Task? ***
Mark only one oval per row.

	1. I needed to think what to do	2	3	4. Average	5	6	7. Acted without Conscious consideration
Response Level	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

15. **13. Did the mission scenario hold your attention ***
Mark only one oval per row.

	1. No	2	3	4. Average	5	6	7. Fully Engrossed
Attention level	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

16. **14. How much time pressure where you under completing the mission tasks? ***
Mark only one oval per row.

	1. Very Rushed	2	3	4. Average	5	6	7. None
Pressure Level	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. **15. What was the overall stress level experienced during the mission scenario? ***
Mark only one oval per row.

	1. Tense	2	3	4. Average	5	6	7. None
Stress level	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

18. **16. If average to tense, which task(s) caused the stress conditions. ***
 Task No. (from planning sheet) — Task Description (from planning sheet) — Why?

.....

.....

.....

.....

.....

Assessment Form 9 Pilot Success Evaluation Questionnaire

Overall pilot flight success evaluation

This assessment is your opinion (Student Pilot) of the outcome of the mission scenario. Under consideration is configuration of the simulator, the level of immersion experienced, the continuity between the experience and the pre-flight brief. Please answer as honestly as you can.

* Required

- 1.

Name? (First name, Surname Initial) *

i.e. TrevorH

- 2.

Flight Mission Scenario reference? *

This is given in the preflight brief (ask instructor if unsure)

- 3.

1. In your opinion, was the flight successful? *

Mark only one oval per row.

[illegible]

- 4.

2. In your opinion, was the flight safe? *

Mark only one oval per row.

[illegible]

- 5.

3. I would be comfortable repeating the flight in a different configuration of simulator or a real aircraft? *

Mark only one oval per row.

[illegible]

16.

14. I support the development of training using this technology in this configuration? *

Mark only one oval per row.

	-3. Strongly Disagree	-2. Disagree	-1. Somewhat Disagree	0. Neutral	1. Somewhat Agree	2. Agree	3. Strongly Agree
Degree of opinion	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

The ‘Mission Operability’ reference sequence diagram behaviour, described in Figure V 4, is a simple assessment involving just two questions to provide the student pilots view of technologies effectiveness in execution of the planned mission. The quantitative answers are converted to integer values that are used to calculate the percentage MO. Grades <50% invites further clarification by investigating the answers of the completed forms or by interviewing the respective student pilot for further details. The assessment is discussed in more detail in Volume I, Chapter 7.14.4.

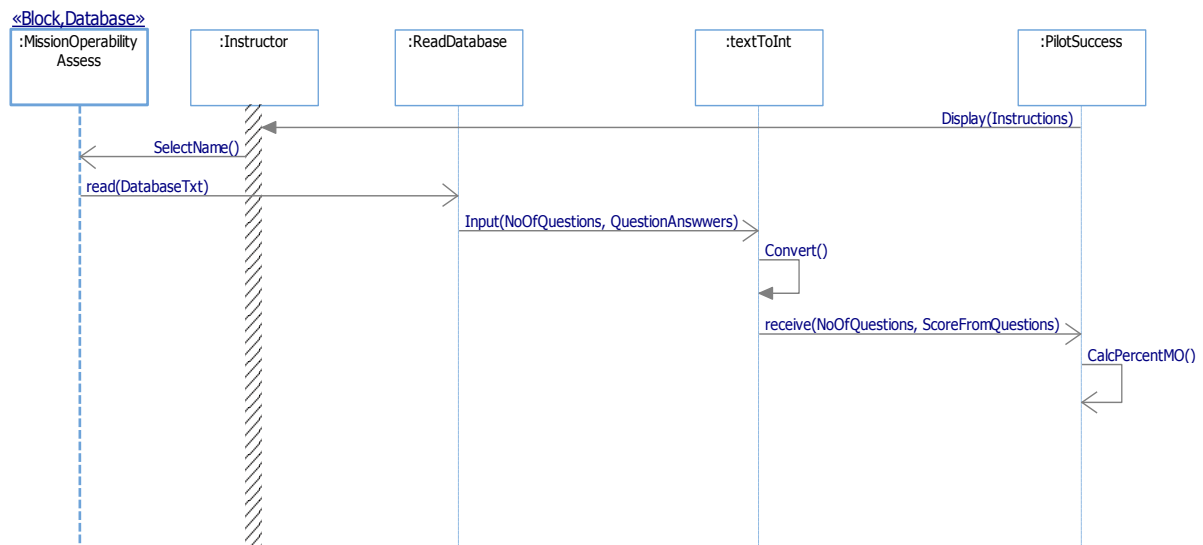


Figure V 4 Obtain Mission Operability Assessment Use Case

Assessment Form 10 Mission Operability Assessment Questionnaire

Mission Operability Assessment

This assessment provides a Technique for pilot's to efficiently assess workload and subsystem technical effectiveness using objective rating scales. This assessment should be completed for the use of the configuration of systems and technology in relation to goals of the mission or tasks.

* Required

1. **Name (first name, surname initials) ***
e.e. TrevorH

2. **Flight Mission Scenario reference? ***
This is given in the pre-flight brief (ask instructor if unsure)

For the whole mission scenario, rate the following sentences which describe workload and technical effectiveness to complete goals

Select on checkboxes on each category which best suits your view on the mission

3. **1. Pilot Workload ***
Mark only one oval.
- ☐ 1. The pilot workload required to perform the designated task is extreme (1 score of PW dimension)
- ☐ 2. The pilot workload required to perform the designated task is high (2 score of PW dimension)
- ☐ 3. The pilot workload required to perform the designated task is moderate (3 score of PW dimension)
- ☐ 4. The pilot workload required to perform the designated task is low (4 score of PW dimension)
4. **2. Subsystem technical Effectiveness ***
Mark only one oval.
- ☐ 1. The technical effectiveness of the required subsystem is inadequate for performing the desired task. Considerable redesign is necessary to attain task requirements (1 score of TE dimension)
- ☐ 2. The technical effectiveness of the required subsystem is adequate for performing the desired task. Some redesign is necessary to attain task requirements (2 score of PW dimension)
- ☐ 3. The technical effectiveness of the required subsystem enhances individual task performance. No redesign is necessary to attain task requirements (3 score of PW dimension)
- ☐ 4. The technical effectiveness of the required subsystem allows for the integration of multiple tasks. No redesign is necessary to attain task requirements (4 score of PW dimension)

The 'After Execution Assessment' reference sequence diagram, described in Figure V 5, involves paper based flow chart grading assessments visualised in Assessment Form 11 - 16 with a detailed technology assessment, shown in Assessment Form 17, concerning the ergonomics and design of the training technology to produce un-invasive opinions on the use of technology for gaining K&S for ToT. The results can also be compared to actual performance results to give an indication to the decision maker whether a student pilot is struggling with certain aspects of the chosen training technology to complete mission tasks. The paper based questionnaires data are inputted into a database file stored within the Student_Pilot directory, which is then used to calculate the percentage assessment score that is presented to the decision maker. The simulator configuration assessment is used to calculate the mean value along with the maximum and minimum value for each category. The location of the mean on the triangular plots is important: each one might determine the unsuitability of the technology or under-confidence in using the technology that is affecting student pilot performance. Once the data is accepted, the information is stored in the main student database file, see Figure V 1, and the workflow process is complete. All the data completed can be used for further assessment for each student pilot; further details can be found in Volume I, Chapter 7.14.5.

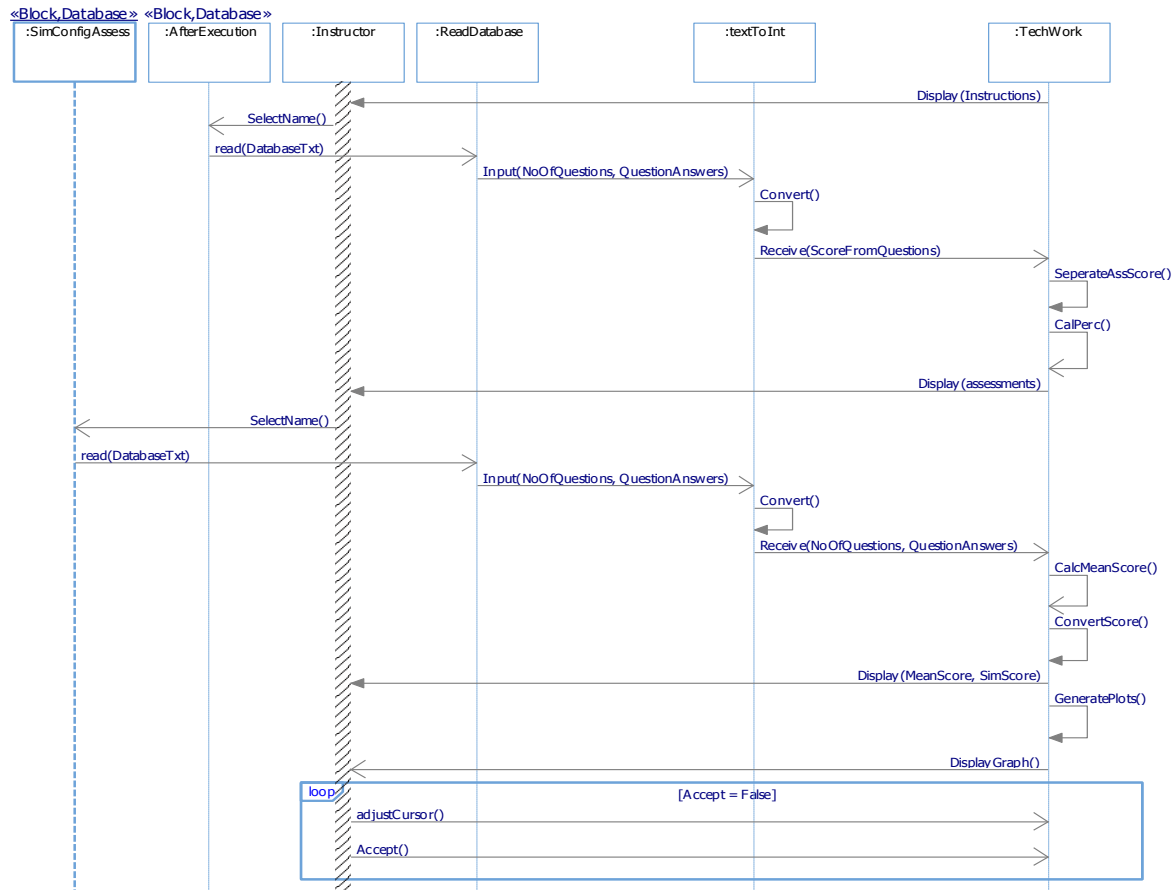


Figure V 5 Behaviour of Obtain After Execution Assessments Use Case

Rating Scale for Spatial-Manipulation Task

You may notice that the visual information you get from the monitors you are using effects how easy or how difficult it is to control and fly the aircraft as accurately as you can on the predetermined flight path. Please Judge whether the task using these monitors was difficult, medium, or easy to perform and mark the correct box below with an X.

Then follow the arrow below.

DIFFICULT ☐ **MEDIUM** ☐ **EASY** ☐

DIFFICULT

Now rate Carefully, exactly how difficult the task was.

Record you rating by marking anywhere on the line, on or between, the scale marks

MEDIUM

Now rate Carefully, whether the task is exactly medium or slightly in the direction toward difficult or easy.

Record you rating by marking anywhere on the line, on or between, the scale marks

EASY

Now rate Carefully, exactly how easy the task was.

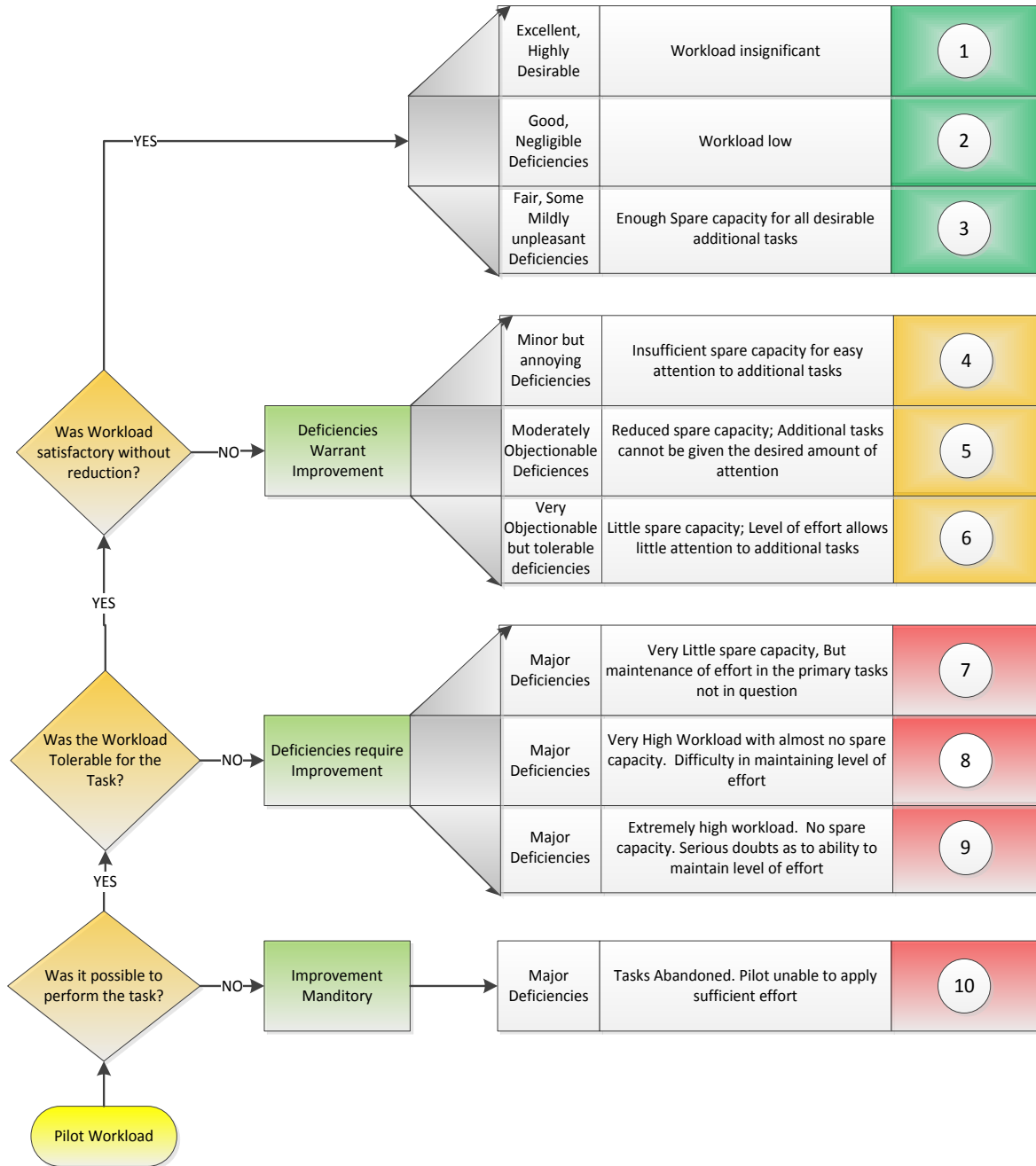
Record you rating by marking anywhere on the line, on or between, the scale marks

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Assessment Form 12 After Execution 2 - Workload Assessment Scale

Name of Pilot: _____

Mission Scenario Ref: _____



Assessment Form 13 After Execution 3 - Situation Awareness Rating Scale (Amended from Howarth-Newman)

Name of Pilot: _____

Mission Scenario Ref: _____

Pilot Situational Awareness

Was it possible to perform the task with respect to your SA?

YES

NO → Improvement Mandatory → Major Deficiencies → No Situational Awareness at all; All important aspects were out of my control → 10

YES

Was your level of SA on an acceptable level?

YES

NO → Deficiencies require Improvement → Major Deficiencies → 7, 8, or 9

YES

Was your SA on a satisfactory level?

YES

NO → Deficiencies Warrant Improvement → Minor but annoying Deficiencies (4), Moderately Objectionable Deficiencies (5), or Very Objectionable but tolerable deficiencies (6)

YES

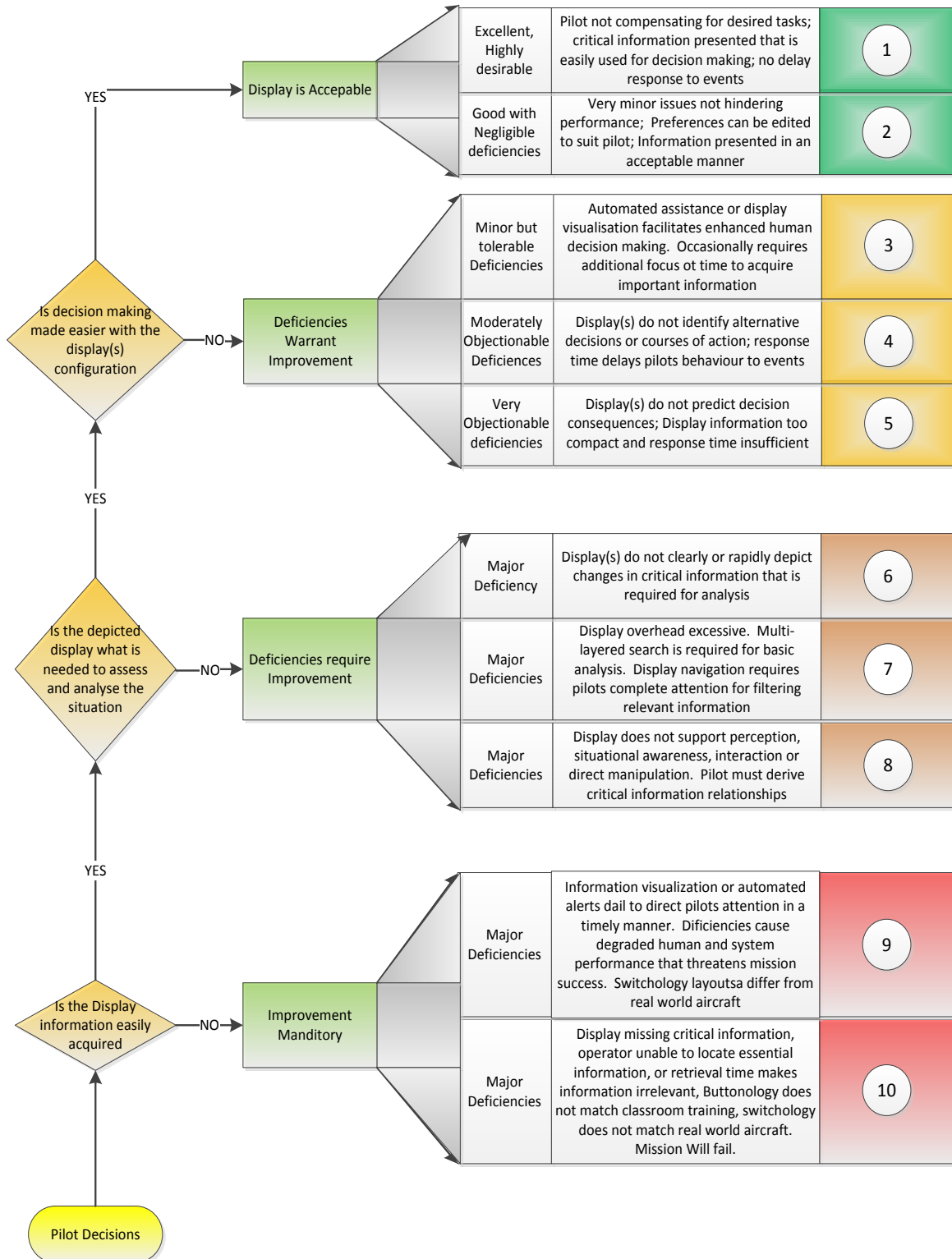
Excellent, Highly Desirable (1), Good, Negligible Deficiencies (2), or Fair, Some Mildly unpleasant Deficiencies (3)

Excellent, Highly Desirable	My Situational Awareness included all aspects of important as well as other aspects of the dynamic situation	1
Good, Negligible Deficiencies	My Situational Awareness included all aspects of important and some aspects of others in the dynamic situation	2
Fair, Some Mildly unpleasant Deficiencies	My Situational Awareness included all aspects of importance (neither more nor less) of the dynamic situation	3
Minor but annoying Deficiencies	My Situational awareness was sufficient. A few important aspects were out of my control	4
Moderately Objectionable Deficiencies	My Situational Awareness was reduced. Some important aspects were out of my control	5
Very Objectionable but tolerable deficiencies	My Situational Awareness was low. A lot of important aspects were out of my control	6
Major Deficiencies	My Situational Awareness was very low. About half of the important aspects were out of my control	7
Major Deficiencies	My SA was very low. Most important aspects were out of my control	8
Major Deficiencies	My Situational awareness was extremely low. Almost all important were out of my control	9
Major Deficiencies	No Situational Awareness at all; All important aspects were out of my control	10

Assessment Form 14 After Execution 4 - Display Configuration Rating Scale

Name of Pilot: _____

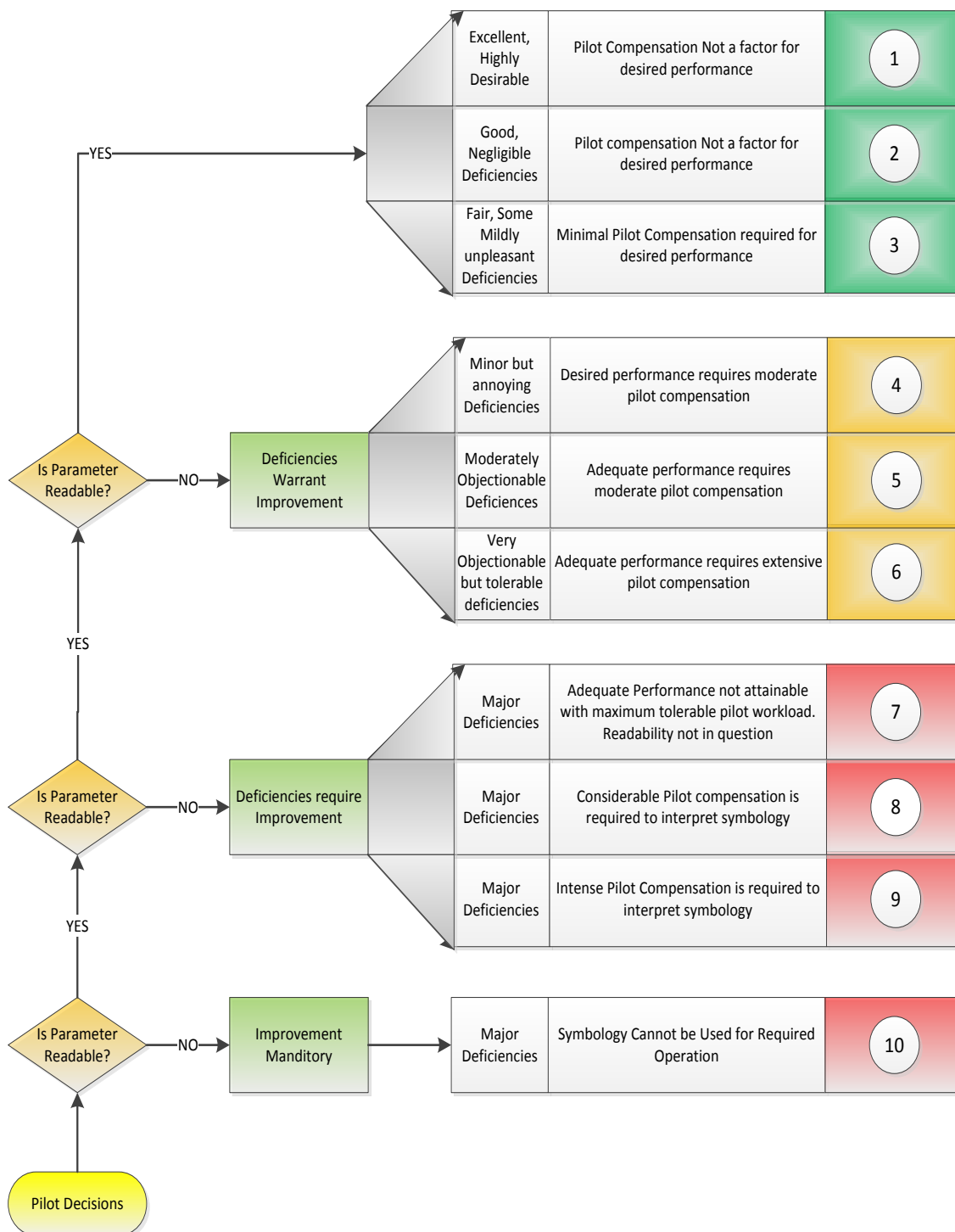
Mission Scenario Ref: _____



Assessment Form 15 After Execution 5 - Readability of Display Rating Scale (Amended from Howarth-Newman)

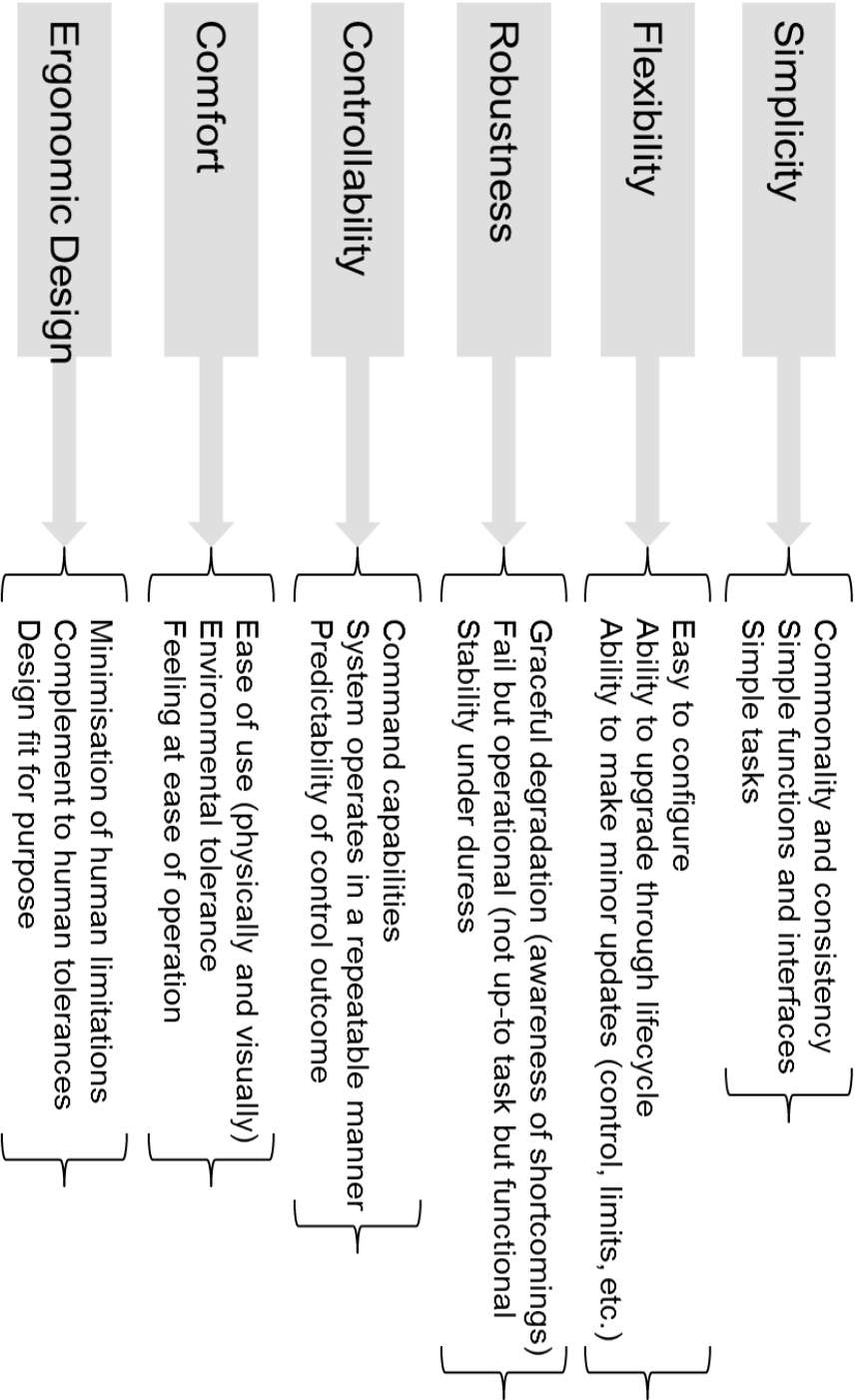
Name of Pilot: _____

Mission Scenario Ref: _____



[illegible]

KEY: Criteria ranges of concern



Grading is 1 (Good Operability evaluation) – 10 (unacceptable operability evaluation)
To be scored on one operational impact only on cockpit configuration & mission scenario design (25)

Figure V 6 Criteria for Flight Operability Rating Scale.

Assessment Form 17 After Execution 7 - Simulator Configuration Objective Assessment

Simulator configuration Assessment

This assessment is for student pilots to reflect on the layout and configuration of the training technology used for execution of the mission scenario. This includes the operation, function and usability of the human interfaces and consideration of the surrounding environment. The assessment is required to be completed in relation to the ease or difficulty in executing the mission scenario tasks using the chosen training device.

* Required

1. **Name (first name, surname initials) ***
i.e. TrevorH

2. **Flight Mission scenario reference?** *
This is given in pre-flight brief (ask instructor if unsure)

Chair

The seat is an important part of being comfortable during the execution of the scenario using the simulator. Place your feeling on the suitability of the seat in relation to operations

3. 1. Chair, seat and arms allow for comfortable sitting? *
- Mark only one oval per row.

	-3.	-2	-1	0.	1.	2	3.
	Unacceptable			Average			Excellent
suitability	()	()	()	()	()	()	()

4. 2. Does the seat pan/cushion allow for comfort for the duration of the mission scenario? *
- Mark only one oval per row.

	-3.	-2	-1	0.	1.	2	3.
	Unacceptable			Average			Excellent
suitability	()	()	()	()	()	()	()

5. **3. Mid/upper back support 'at various positions (if function allows)? ***
Mark only one oval per row.

	-3.		-2	-1	0.	1.	2	3.
	Unacceptable				Average			Excellent
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

6. **4. Overall ease of use of chair and attached controls (including movement, training suitability)? ***
Mark only one oval per row.

	-3.		-2	-1	0.	1.	2	3.
	Unacceptable				Average			Excellent
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

7. **5. Overall appearance and structure of chair for suitability for application? ***
Mark only one oval per row.

	-3.		-2	-1	0.	1.	2	3.
	Unacceptable				Average			Excellent
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

8. **6. Overall comfort of Chair? ***
Mark only one oval per row.

	-3.		-2	-1	0.	1.	2	3.
	Unacceptable				Average			Excellent
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

9. **7. Overall Stability of the chair with respect to the affects of completion of mission scenario? ***
Mark only one oval per row.

	-3.		-2	-1	0.	1.	2	3.
	Unacceptable				Average			Excellent
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Monitors / Displays

The display is a very important part of the immersion facility for simulators. Place your feeling on the suitability of the monitors/displays in relation to operations and tasks within the mission scenario flight.

10. **8. The layout and position of the monitor(s)/Display(s) acceptable and prevent excessive neck strain? ***
Mark only one oval per row.

	-3. Unacceptable	-2	-1	0. Average	1.	2	3. Excellent
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

11. **9. The brightness / contrast of the monitor(s)/display(s) are comfortable on the eye? ***
Mark only one oval per row.

	-3. Unacceptable	-2	-1	0. Average	1.	2	3. Excellent
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

12. **10. The image displayed, was it: clear, stable, sharp, free from flicker? ***
Mark only one oval per row.

	-3. Unacceptable	-2	-1	0. Average	1.	2	3. Excellent
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

13. **11. The image of cockpit and instruments in the simulation clear from any distortion? ***
Mark only one oval per row.

	-3. Unacceptable	-2	-1	0. Average	1.	2	3. Excellent
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

14. **12. Environmental (weather, buildings, terrain) distortion between all displays used for the flight simulation? ***
Mark only one oval per row.

	-3. Unacceptable	-2	-1	0. Average	1.	2	3. No issues
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

15. **13. If any, Please describe the distortion effects**
 (if non please goto question 16)

.....

.....

.....

16.

14. Is the distance between the screen suitable for the application to avoid being visually overwhelmed? *

Mark only one oval per row.

	-3. Too close	-2	-1	0. just right	1.	2	3. Too far away
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17.

15. The need to tilt head to see important information on the display(s)? *

Mark only one oval per row.

	-3. Excessive	-2	-1	0. Average	1.	2	3. Relaxed
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

18.

16. Did the screen glare, caused by windows or reflections affect feedback of information displayed on the display(s)? *

Mark only one oval per row.

	-3. Excessive	-2	-1	0. Average	1.	2	3. none
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

19.

17. The number of display(s) /monitor(s) used for the simulator was sufficient in number? *

Mark only one oval per row.

	-3. Unacceptable	-2	-1	0. Average	1.	2	3. Excellent
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

20.

18. Does the software, driving the simulation and information on the display(s) suitable for the task? *

Mark only one oval per row.

	-3. Unacceptable	-2	-1	0. Average	1.	2	3. no issues
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

21.

19. If the software is unsuitable for the task please indicate why.

.....

.....

.....

.....

38.

36. The visual fidelity provided a realistic flight experience? *

Consider terrain, weather, trees and buildings

Mark only one oval per row.

	-3.	-2	-1	0.	1.	2	3.
	Unacceptable			Average			excellent
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

39.

37. The software lends itself to training pilots on how to fly and operate a real aircraft? **Mark only one oval per row.*

	-3.	-2	-1	0.	1.	2	3.
	Unacceptable			Average			excellent
suitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

40.

38. Please explain you viewpoint on the used software for training. *

.....

.....

.....

.....

.....

APPENDIX W PHD PAPERS & ABSTRACTS

This appendix list a sub-set of published and one soon to be published papers with regards to the research areas covered for the PhD project. Other technical papers can be viewed on Research Gate website in relation to: digital communication, power-line communications, and smart vehicle communication systems.

Title:

Holden, T., Dickerson, C.E., Siyuan, J., “A Diesel Engine Power Train Model for Conceptual Vehicle Architecture for Analysis of Emissions in Transient Drive Cycles”, 2015. (*Pending Review Process*)

Abstract:

Due to the increasing complexity of the system of systems comprising automotive and aerospace vehicles, architecture modelling and analysis is becoming progressively more important to systems engineering and design. Conceptual Vehicle Architecture provides a rigorous basis and traceability for agile analysis and design of complex systems, in which system level models, analytics and simulations typically do not exist. The architecture also supports distributed and networked simulation of system of systems comprising the vehicle. In the case of a diesel engine, there exists a number of disparate fidelity system models, analytics and simulations but no coherent combination of models to support end-to-end analysis of the emissions problem in ‘transient’ drive cycles. This paper introduces a conceptual vehicle model for the diesel engine power train as part of a diesel vehicle architecture integrated with a relational framework that provides high level system description for representing models for use in distributed simulations directed at full vehicle virtual design and analysis.

Title:

Holden, T., Dickerson, C.E., Luff, R., “Preliminary Report: A Proposed Model Based Systems Engineering Approach To A Virtual Vehicle Architecture Model (V2AM) For Live-Virtual Testing and Prototyping”, *IEEE 17th International Symposium on Object-and-component-oriented Real-Time Distributed Computing*, Reno, NV, USA, 10-12 June, 2014.

Abstract:

Due to the increasing complexity of the system of systems within the aero-auto domains, architecture modelling and analysis is becoming progressively more important to systems engineering design. The drive from both domains is for more functionality and efficiency from vehicles. The resultant effect on system development means the complexity of the

designs has increased and thus the complexity of the virtual simulations used for test and analysis has also increased. When actual systems or their components are integrated with the simulation environment, live-virtual testing places real-time demands on the testing of the architecture and environment. This paper describes a proposed innovative approach, derived from aerospace engineering, where the vehicle requirements are allocated to relations between the elements in the architecture and not just to system elements. An approach to using the relational oriented modelling structure for test and analysis is also described. The requirements and system architecture models specified using relational orientation are therefore seen to provide an early demonstration of a rigorous new approach to system of systems design, test and analysis that uses requirements traceability at the architecture level. This approach promises to bring better traceability of system requirements to the simulation of vehicle behaviour in general and to real time behaviour in particular.

Title:

Holden, T., Dickerson, C.E., "Relation Oriented Systems Engineering Framework for Flight Training", *The Art and Science of Using Live-Virtual-Constructive Simulations for Analysis*", Journal for Defense Modeling and Simulation, 2013.

Abstract:

The integration of systems of systems associated with a flight training mission directly reflects the problem of developing a system engineering process for the design of LVC experiments. Due to the complexity and disparity of technology in a flight training system of systems (FTSoS) modelling and analysis of architecture is becoming increasingly important. Relational Oriented Systems Engineering (ROSE) methodology is used to develop a framework for simulation and analysis of a navigational system of systems for a typical aircraft. The framework can be used for both prescription of navigation systems entering and exiting the SoS and for analysis of pilot behaviour as navigation quality of service (QoS) changes. The rigorous repeatable method offered by the framework provides increased concordance between technical and human aspects of the FTSoS. ROSE offers a novel approach to developing a model based systems engineering (MBSE) process for simulation and analysis of this type of complex system of systems problem.

Title:

Holden, T., Dickerson, C.E., "A ROSETTA Framework for Live / Synthetic Aviation Trade-offs: Preliminary Report", *8th Annual International Conference on SoSE*, 4th June, Wailea-Makena, HI, USA, 2013.

Abstract:

In this paper a Relational Oriented Systems Engineering and Technology Trade-off Analysis (ROSETTA) framework is introduced for performing technology trade-off and design studies with respect to the live, virtual and constructive mixes for aircrew training. This novel, efficient and model driven repeatable approach to the present and future problem of live / synthetic mixes on-board a real aircraft concentrates on relationships between elements in models to support capability based decisions. The methodology described provides a framework and factorization of a family of systems (FoS) architecture for tactical situation/mission scenario and evaluation of pilot response models. ROSETTA provides a more rigorous mathematical framework for conducting decision support and advances current model based systems engineering (MBSE) process for simulation and analysis of a complex system of systems (SoS) problem.

Title:

Holden, T., & Dickerson, C.E., "*Relation Orientation for Requirements Traceability in System Architecture*", Internal Publication, Loughborough University, 2012 (Used to justify the case for the Program of Simulation Innovation Research Project)

Abstract:

Due to the increased complexity of a system of systems comprising an automotive vehicle, architecture modelling and analysis is becoming increasingly important to embedded systems engineering projects, especially for requirements engineering. In this paper, rigorous methods being developed in aerospace engineering based on relational orientation are applied to the requirements traceability problem in an elementary case study on a fuel monitoring system. In this innovative approach, requirements can be allocated to relations between components as well as directly to components based on considerations of the architecture and intended behaviour of the system. Requirements and system models specified using relational orientation support a rigorous approach to system analysis, design, and verification.

Title:

Holden. T, & Dickerson, C.E., "Relation Orientation with Functional Decomposition for Analysis of Emergent Behaviour", *IEEE Computer Architecture Letters*, pp. 1-6, 2012. In Systems Architecture Lectures, Loughborough University, 2012.

Abstract:

In legacy requirements traceability, functional decomposition is used for system partitioning into modular software components, each of which generally perform one function. However the emergent behaviour of the system is determined from both internal operations and interoperations with other components that make up the system. System Architecture has been defined as the fundamental conception of a system in its environment embodied in elements, their relationships to each other and to the environment, and principles guiding system design and evolution. Relational orientation is a viewpoint that can be used to bind software development and systems engineering by utilising graphical modelling languages. Elicited requirements can be modelled and relationally transformed for traceability in system specification, analysis and design. The specification of models associated with a system from a relational viewpoint has a natural compliance with the relational specification of system architecture. When models are used to capture the requirements and expose relationships in this way, contribution of the emergent behaviour can be traced through the designed system architecture.

Title:

Holden.T, "Model driven Aviation Training Enterprise Architecture", *Loughborough Internal Conference*, Loughborough University, Hollywell Park, 2012.

Abstract:

Conventional engineering approaches to meet the challenges of System of System Engineering (SoSE) are generally document based, and labour and time intensive. A flight training enterprise (FTE) is one example of the System of Systems (SoSE) technical problem. The enterprise includes PC based training, ground simulators, training aircraft and a number of other subsystems for flight realism. The technical problem of developing and assembling flight training SoS and the enablement of capabilities embodies the core challenges of SoSE. Using Model Driven Architecture (MDA) techniques as specified by the Object Management Group (OMG), the research will generate a flight training open architecture for the integration and interoperation of the Hawk T.Mk2 advanced training jet. The frameworks within the architecture will encompass the ability for reuse and the facilitation of real and virtual systems.