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Requirements definition for 12pz18 UAV control simulator

Final report

Mike Meakin

Defence R&D Canada – Ottawa

Canada

Contract Report
DRDC Ottawa CR 2010-092
August 2010

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Abstract

DRDC Ottawa has developed over the past several years a very capable Unmanned Air Vehicle (UAV) Research Test Bed (RTB) that provides a simulated UAV environment for a variety of UAV-related experiments. This tool is well suited to support the goals of the DRDC TIF Project “Self-Healing Networked Control Systems for Enhanced Reliability and Safety of Multivehicle Missions.” The objectives of this project are to develop and evaluate a variety of self-healing methodologies as applied to a UAV team. These include stigmergy to address the loss of communications as well as algorithms to coordinate search missions under varying conditions. This particular effort focused on identifying the necessary modifications to the UAV RTB to support of this research. The final result was: the development of two distinct, realistic and challenging search scenarios within which the self-healing UAV swarm may be run; the development of a full set of requirements needed to be supported by the UAV RTB to support the defined scenarios; and the creation of a high level design that not only supports those scenarios within the UAV RTB but also supports the third party development of the various algorithms and controls that are the goal of the experiment.

Résumé

Ces dernières années, RDDC Ottawa a mis au point un banc d’essai de recherche (RTB) sur les véhicules aériens sans pilote (UAV) très performant procurant un environnement UAV simulé pour une vaste gamme d’équipement lié aux UAV. Ce outil convient bien à l’atteinte des objectifs du projet du FIT RDDC « Systèmes de contrôle autorégénérateurs en réseau pour l'amélioration de la fiabilité et de la sécurité des missions faisant appel à plusieurs véhicules ». Les objectifs de ce projet consistent à mettre au point et à évaluer une vaste gamme de techniques d’autorégénération comme celles appliquées à l’équipe des UAV. Ces techniques incluent la stygmergie pour remédier à l’interruption des communications ainsi que les algorithmes de coordination des missions de recherche dans diverses conditions. Cet effort en particulier se concentrait sur l’identification des modifications nécessaires pour que le RTB sur les UAV soutienne cette recherche. Le résultat final a été le suivant : l’élaboration de deux scénarios de recherche réalistes et stimulants distincts selon lesquels le groupe d’UAV autorégénérateurs peut fonctionner; l’élaboration d’un ensemble complet d’exigences devait être soutenue par le RTB sur les UAV en appui aux scénarios établis; la création d’une conception évoluée appuyant non seulement les scénarios impliquant le RTB sur les UAV, mais aussi l’élaboration par une tierce partie de divers algorithmes et contrôles correspondant à l’objectif de cette expérience.

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Executive summary

Requirements definition for 12pz18 UAV control simulator: Final report

Mike Meakin; DRDC Ottawa CR 2010-092; Defence R&D Canada – Ottawa; August 2010.

This report describes the scenario development, requirements definition and high level design effort undertaken for the Unmanned Air Vehicle (UAV) Research Test Bed (RTB) in support of the DRDC TIF Project 12pz18, “Self-Healing Networked Control Systems for Enhanced Reliability and Safety of Multivehicle Missions.” The experimental goals of the project include the development and evaluation of various self-healing approaches and algorithms. Their evaluation will require the use of a modified UAV RTB simulation environment.

The required modifications to the UAV RTB were identified by:

- First, developing some real-world scenarios that exemplify the kinds of tasks that need to be executed;
- second, using those scenarios to identify and derive the requirements that must be placed on the UAV RTB to support such an experiment;
- finally, using those requirements to develop a high level design for the modifications needed to the UAV RTB.

The two scenarios helped to focus the requirements for the simulator modifications. The first describes a search and rescue mission for a downed aircraft near the coast. The second describes the use of micro-UAVs to search for a lost child in a crowd. Requirements derived from these descriptions were captured and documented within a system modelling language tool called Enterprise Architect (EA). EA allows graphical representation, derivation and linking of requirements and design elements. With requirements derivation complete, the high level design was likewise captured within EA to support traceability from requirements to design.

The resulting requirements and high level design provide an outline of the necessary code modifications that will be necessary to support the over-all Self-Healing Swarming UAV experiment within the UAV RTB simulation environment.

Sommaire

Requirements definition for 12pz18 UAV control simulator: Final report

Mike Meakin; DRDC Ottawa CR 2010-092; R & D pour la défense Canada – Ottawa; Août 2010.

Ce rapport décrit les efforts d’élaboration, de définition des exigences et de conception évoluée des scénarios déployés pour le banc d’essai de recherche (RTB) sur les véhicules aériens sans pilote (UAV) en appui au projet 12pz18 du FIT RDDC « Systèmes de contrôle autorégénérateurs en réseau pour l'amélioration de la fiabilité et de la sécurité des missions faisant appel à plusieurs véhicules ». Parmi les objectifs expérimentaux de ce projet, on compte l’élaboration et l’évaluation de diverses méthodes et de divers algorithmes d’autorégénération. Leur utilisation nécessitera l’emploi d’un environnement de simulation de RTB sur les UAV modifié.

Les modifications requises au RTB sur les UAV ont été identifiées :

- premièrement, par l’élaboration de scénarios réels illustrant les genres de tâches devant être exécutées;
- deuxièmement, par l’utilisation de ces scénarios pour identifier et calculer les exigences relatives au RTB sur les UAV, afin d’appuyer une telle expérience;
- pour terminer, par l’utilisation de ces exigences pour l’élaboration d’une conception évoluée des modifications requises au RTB.

Ces deux scénarios ont aidé à orienter les exigences relatives aux modifications du simulateur. Le premier décrit une mission de recherche et sauvetage d’un aéronef tombé près de la côte. Le deuxième décrit l’utilisation de micro-UAV pour rechercher un enfant perdu dans une foule. Les exigences calculées à partir de ces descriptions ont été saisies et documentées dans un outil de modélisation linguistique de système qui s’appelle Architecte d’entreprise (AE). L’AE permet une représentation graphique, un calcul et des liens entre les exigences et les éléments de conception. Une fois le calcul des exigences terminé, on a saisi dans l’AE la conception évoluée pour soutenir la traçabilité des exigences de conception.

Les exigences résultantes et une conception évoluée donnent un aperçu des modifications de codes qui seront nécessaires au soutien de l’ensemble de l’expérience sur le groupe d’UAV autorégénérateurs dans l’environnement de simulation du RTB sur les UAV.

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1 Summary of Accomplishments During this Effort

This project commenced in late November with a descriptive meeting from Paul Hubbard and Adrian Taylor on the goals and intentions for the over-all project. During this meeting the tasks identified for work were:

1. Development of at least one operational scenario that described the use of a self healing UAV swarm, including elements of that scenario that would exercise and leverage the self-healing aspects, especially stygmergy;

2. Working from the agreed-upon scenarios, derivation of requirements necessary to be supported by the UAV RTB to allow the scenario to be supported within the simulation environment;

3. Upon completion of the requirements derivation task, these requirements would then be used to develop a high level design against which an implementation effort could be worked to modify the UAV RTB in support of the Self-Healing UAV Swarm experiment.

The scenario development was completed during December with two scenarios developed; one describing a wide area search for a downed air craft over a sparsely populated coast line of Labrador; and one describing the search for a lost or abducted child within a large crowd at a major outdoor event. These scenarios were reviewed by the TA and forwarded to the lead project scientist and agreed to be suitable for further development.

The extraction and derivation of UAV RTB requirements from these scenarios was conducted in the second half of December and large part of January, resulting in the identification and derivation of 123 specific requirements. These requirements were captured using a SysML syntax within the tool Enterprise Architect. This requirements derivation included the development of quasi-protocol definitions for interactions between the internal control model of a single vehicle and the simulated vehicle as well as interactions between the sim and the internal control model with the external coordination authority.

In February, these requirements were then mapped to the various user interfaces necessary to allow observation of the experiment as well as to the parameters of the X-Plane application that would be simulating the vehicle and the payload. This high level design was also captured within the EA tool.

Upon completion of this mapping, the EA tool was configured to generate rtf documents capturing the requirements and high level design as well as a detailed description of the model itself.

Deliverables:

4. Two scenarios developed for this experiment (.doc files)

5. Enterprise Architect Model- UAV Swarming (.eap file)

6. UAV Swarming Requirements & High Level Design (.rtf file)
7. UAV Swarming Detailed Model (.rtf file)
8. Final Report (.pdf file)

2 Description of UAV RTB Architecture

The basic architecture of the DRDC Ottawa UAV RTB to be used in this project is shown in Figure 1. In this architecture, the vehicle and payload (including visualization) is modelled by the X-Plane application. The operator interface is an existing STANAG 4586 Control Station (such as OpenUMI) and the translation between these two interfaces is performed by a Vehicle Specific Module (VSM). This VSM translates as many of the X-Plane parameters into parameters of the STANAG 4586 core message set as possible; those parameters which do not have a corresponding parameter within this core message set are made available to the operator through use of an X-Windows interface.

The modifications necessary to this architecture to support the intended Self Healing Swarming UAV experiment are shown in Figure 2.

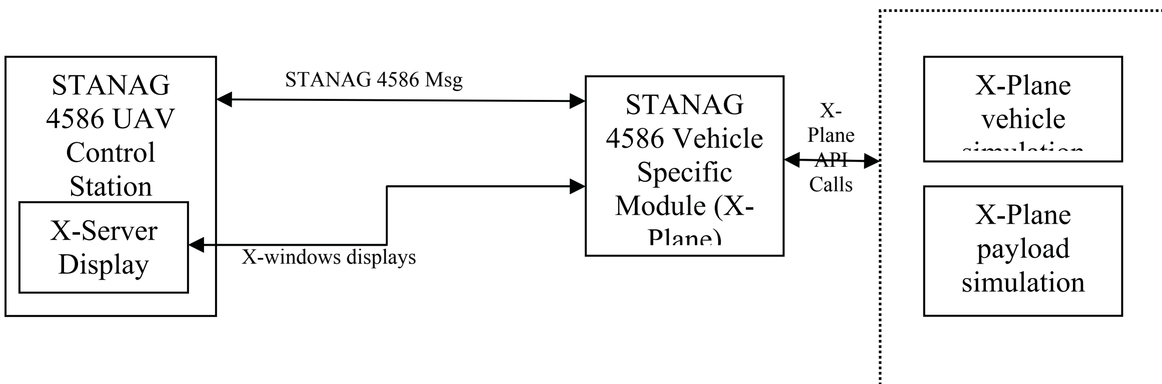

Figure 1: Basic UAV RTB Architecture

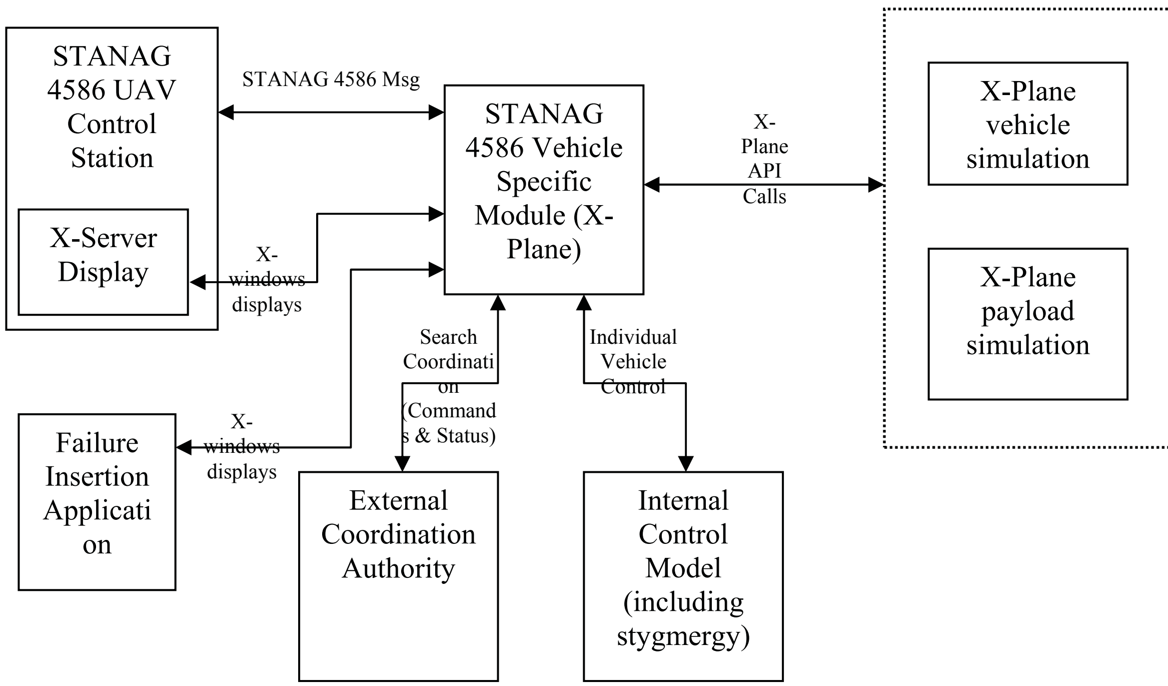

Figure 2: UAV RTB Architecture for Self-Healing UAV Swarm Experiment

These modifications include the addition of a Failure Insertion Application, an internal control model and an external coordination authority.

The Failure Insertion Application enables the experimenter to set fault conditions under which the "self-healing" aspects of the experiment can be stimulated and examined. Many of these fault conditions are supported directly within the X-Plane simulation but there are several which must be modelled within the VSM itself, including datalink degradation and loss. This application would be developed as part of the specific VSM development in support of this experiment (see Section 5: Failure Insertion Application).

The existence of the Internal Control Model is necessary to allow the experimenter a means by which automated responses- particularly to failures- can be implemented and the simulation directed accordingly. Thus, a primary element of this requirements and design effort has been the definition of a reasonable Internal Control Protocol that allows an independently developed control model to interface to the VSM in order to exercise such control (see Section 4.2: Internal Command Protocol).

Finally, the existence of the External Control Authority was derived from the requirement that this be a UAV "swarm", not just a single UAV. This "authority" is not assumed to be either centralized or distributed- this is left to the experimenter to decide- but the need for a swarm means that multiple instances of this UAV RTB simulation must be run simultaneously and some sort of communication is necessary between each of these instances to accomplish the over-all task. The definition of a reasonable protocol by which such external coordination communications can be executed was another primary element of this requirements and design effort (see Section 4.1: External Command Protocol).

3 Potential Scenarios for Execution

The following are the two scenarios developed as examples around which the experiment may be conducted.

3.1 Scenario 1- Wide Area Search Over Remote and Non-homogeneous Area

A search and rescue mission for a missing small aircraft along the coast of Labrador.

A small aircraft carrying three people, two adult males and a young male teen have been reported over due at Gander Airport. There last known location was along the east coast of Labrador that contains areas of tundra and forest. Bad weather has hit the area so it is not known whether the air plane was able to land or was forced to ditch in the water. A search area is set up but- due to the risk posed by the inclement weather to the search team- the search will at least initially be conducted by a team of UAVs working on coordination. There are postulated to be a total of nine (note: this number is chosen arbitrarily and is not meant to be a restriction on the final experimental set up in any way) UAVs in the team.

The search area is broken up into 35 (note: this is another arbitrary number chosen for the purposes of this example only and not intended to be a restriction on the final experimental set up) sections, with each section containing a single type of search terrain (i.e. water, tundra, forest, marsh, etc.). A UAV will be assigned to each section and will perform a search of its section before moving to the next unsearched section. The search pattern may be a comprehensive grid search, a coarse grid search followed by a comprehensive grid search, a spiral search from the last known position or some other algorithm, as appropriate. The team will execute the search pattern in the most time and fuel efficient manner- not necessarily sequentially- with each UAV receiving direction to its next section as it finishes its current section. If a UAV overflies an unsearched section in the process of transiting to its next assigned section, then this overflight path will be searched by the UAV and recorded as having been searched by the coordinating search algorithm (note: this algorithm is unknown and for the purposes of this scenario is treated as TBD. E.g. If the UAV has a □blank□spot on its overflight, does it circle around to research, properly covering the area or does it continue on and the over-all search algorithm finds another way of covering that area?). A section may be completely or largely searched by a series of such overflights without any UAV having been assigned to that section or it may be treated as a bisected section with only a portion remaining to be actively assigned for search.

Beyond the complexity of calculating an efficient, team approach to the wide area search, each UAV must also perform the search of each given section with maximum efficiency and thoroughness. As such, the UAV must adjust not only its flight path but also its sensor field of view (FOV), altitude and dwell time to adjust for varying clutter densities within the section. As fixed wing UAVs, the amount of circling necessary to complete a grid pattern greatly affects the fuel economy of the search and the associated ability to cover the maximum area in the shortest time. Wind- and wind changes- also must be factored in to the search algorithm to maximize fuel efficiency. As the wind changes, the pattern may also need to change but the area must be fully covered.

The inclement weather would affect not only the flight pattern but also the sensor utilization. As visibility is affected, sensor FOV and vehicle altitude would need to be adjusted. Also, for sudden changes in visibility for which the system did not calculate quickly enough, a specific area may need to be searched again to ensure coverage.

Problems that are likely to be encountered and need to be addressed by the self healing network in this scenario include:

1. Wind changes, including wind changes as a result of changes in vehicle altitude;

2. Search terrain changes in clutter density (“clutter” is defined as objects in the field of regard that are similar size and magnitude as the objects being searched) requiring changes in dwell time (i.e. more time to determine if object of interest is present), FOV (i.e. less coverage in a given pass) and/ or changes in altitude (less coverage, possibly changed winds, changed fuel efficiency);

3. Visibility changes requiring changes in FOV, change of altitude and/ or re-visit of area already overflown;

4. Diminishing UAV resources as some vehicles use up their fuel faster than others;

5. Diminishing UAV resources due to failures on-board individual vehicles (e.g. icing, servo failures, engine problems, etc.);

6. Possible loss of UAV resources due to communication failures- uplink and/ or downlink- requiring determination of whether a UAV is still successfully executing a thorough search or whether and how much of the area assigned to it needs to be re-searched by another asset with positive communications.

3.1.1 Detailed Scenario

A small plane carrying three personnel has been reported missing. Their last known position was 12 km SE of South Stag Island, travelling in a NW direction. Based on that position plus wind and current patterns, a search area has been defined by SAR HQ covering an area from 54 00 N to 54 19 N and 57 10 W to 57 48 W. The size of this search area is 425 square nautical miles or about 40 km x 40 km.

The area encompasses water as well as land, including barren tundra, forest, snow covered, etc. Also, the ocean may contain ice bergs and growlers that could be confused for flotsam.

Due to inclement weather, the decision was made that manned search assets would not be deployed due to unacceptable risk to the personnel so a team of 9 UAVs has been tasked to conduct the immediate search. Should a positive identification of the last air craft be made, the SAR teams will deploy to attempt a rescue.

Figure 3: Labrador Search Region- 54 00 N to 54 19 N, 57 10 W to 57 48 W (425 nm^2)

The search region is divided into grid squares for assignment to each UAV. The coordinating team authority then assigns the grids to specific UAVs to complete the search in the most efficient manner possible. The UAVs must adapt to changing clutter densities as well as changing atmospherics by adjusting camera FOV, dwell times, air speed and altitude. The latter two- as well as wind changes- will affect fuel consumption which must be relayed to the coordination authority to accommodate as part of the grid assignment.

The individual UAVs can also be expected to experience individual system failures that require withdrawal from or modification of their search.

The coordination authority must coordinate the individual UAVs dynamically as they complete- or fail to complete- their assigned searches to most quickly and efficiently cover the whole search area. The coordination authority must consider factors such as the likely clutter density within an assigned grid square, anticipating more time for more cluttered regions and less time for less cluttered regions. As individual UAVs report changes in operating parameters (e.g. search altitude, search footprint/ FOV size, fuel consumption rate, fuel status, system failures, etc.) the coordinating authority must incorporate these changes into the over-all search plan and the grid squares to be assigned to each UAV upon completion of their current grid square.

3.1.2 Failure Scenarios Encountered

The following failure scenarios will be encountered during the execution of this simulated mission.

3.1.2.1 Failure Scenario 1- Increased clutter density

During all stages of the search, each UAV can be expected to have varying clutter densities within its search grid. Over land, this will be the result of change of terrain and vegetation, with clear snow and tundra representing low clutter density and therefore maximum search efficiency and brush and forest representing high clutter density and minimum search efficiency. Over water, changes in clutter density occur due to the presence of both icebergs and growlers as well as due to the presence of white caps on the water as a result of high wind.

In all cases, when an individual UAV encounters an increased clutter density, this must be addressed by either increasing the dwell time (defined as the time during which the payload footprint remains effectively stationary for examination) or decreasing the footprint area (through zoom and/ or altitude changes) or both. Increase of dwell time and decrease of footprint area both result in an increase in the projected time needed to finish the search of the assigned area and change in altitude results in a change of fuel consumption. These changes need to be communicated to the search team coordinating authority to be factored into a revised assignment strategy of the remaining grid squares.

3.1.2.2 Failure Scenario 2- Wind Change

During some stages of the search, several UAVS can be expected to encounter changes in wind direction, either as a result of local atmospheric conditions or as a result of changes in altitude. These wind changes not only affect the fuel consumption of the UAV (in addition to the changes in fuel consumption as a function of altitude) but may result in the UAV needing to re-calculate a new search pattern for the remaining portion of the grid square in order to complete the search most quickly and efficiently. At the very least, changes in wind will affect the predicted fuel remaining at the completion of the grid square search and if the pattern itself is changed then it may also affect the predicted location of the UAV at the completion of the grid square search.

The necessary alterations resulting from wind changes must be communicated to the search team coordination authority to factor into the grid square allocation order across the team. If a specific UAV finishes its search in a different location then this may result in it being assigned a different subsequent grid square than was initially planned. Likewise, the information regarding the expected fuel remaining may affect the assignation of subsequent grid squares for search.

Finally, the team coordination authority may be able to track wind changes across several grid squares as a result of reports from the UAVs and thus anticipate a pending wind change to UAVs that have not yet experienced a change. This pending change can be communicated to the UAVs likely to be affected and can allow the search team coordination authority to anticipate these changes in the over-all search plan.

3.1.2.3 Failure Scenario 3- Decreased visibility

With the assumption of inclement weather, it is reasonable to expect all of the UAVs to experience variations in visibility during the course of the search. When visibility decreases, this will require a reduction of altitude and/ or a decrease in payload footprint size and possibly an increase in dwell time to allow detection of items of interest from within a noisy return. Increase of dwell time and decrease of footprint area both result in an increase in the projected time needed to finish the search of the assigned area and change in altitude results in a change of fuel consumption. These changes need to be communicated to the search team coordinating authority to be factored into a revised assignment strategy of the remaining grid squares.

Likewise, an increase in visibility will allow larger footprint sizes, higher altitude and decreased dwell time resulting in a faster and more efficient search. These changes also need to be communicated to the search team coordinating authority.

It can be expected that this failure scenario is occurring to multiple UAVs pretty much continuously and the search team coordinating authority is continually updating the search coordination plan accordingly.

3.1.2.4 Failure Scenario 4- Low Fuel

Either as a result of adapting to changing environmental or potentially as a system-specific failure or inefficiency, it can be expected that a few of the UAVs may declare low fuel situations earlier than expected. The individual UAV must then communicate with the search team coordination authority to identify the best manner in which to finish off as much of its remaining grid square as possible and then the search team coordination authority must re-plan the search execution strategy to cover the area- including any partial grid square left by the low fuel UAV- to maximize use of the remaining UAV assets.

3.1.2.5 Failure Scenario 5- System Failures- Complete

During the course of this search scenario, some outright system failures can be injected that require the complete, immediate and unexpected withdrawal of one or more individual UAVs. This loss of an asset must be communicated to the search team coordinating authority and must then be incorporated into the over-all search plan, including completion of the remaining portion of the grid square previously assigned to the lost asset.

3.1.2.6 Failure Scenario 6- System Failures- Partial

During the course of this search scenario, some outright system failures can be injected that allow an individual UAV to continue to operate in some degraded mode but requires a level of adaptation on the part of the individual UAV as well as re-planning by the search team coordinating authority to identify a modified search plan that accommodates the new limitations of this individual UAV.

Some examples of these kinds of failures could be:

1. Aileron failure- results in compensation required by rudder to maintain straight and level flight. Increases fuel consumption and decreases top speed.

2. Carb icing- until condition is cleared, UAV is restricted in altitude changes and engine efficiency is affected. Possibility of loss of engine if condition is unable to be cleared.

3. Payload gimbal failure- payload may be restricted in movement requiring UAV to modify flight pattern to achieve coverage. The resulting inefficiency in searching needs to be accommodated by the search team coordination authority to re-plan the over-all search strategy.

4. Airspeed sensor failure- UAV may need to estimate air speed using external sources of wind information with ground speed calculated by on-board GPS. UAV needs to ensure that it stays above stall speed so may need to increase its safety margin above stall speed due to latency and uncertainty associated with calculating air speed on external information.

3.1.2.7 Failure Scenario 7- Loss of Communications

During the course of this search scenario, a communications failure with one or more individual UAVs can be injected to explore the possible response mechanisms using stigmergy. Since RF communications is explicitly bi-directional, it is possible for communication in either direction individually to be experienced or for both directions to be lost at once. Since the loss of communications would not affect the efficiency or efficacy of each individual UAV in its search task, an ability to continue using this asset through some other means of communication would be desirable.

The various scenarios for communication loss that could be explored would include:

1. Loss of the ability to receive all external RF communications by an individual UAV- this is the situation that occurs when the datalink receiver on board an individual UAV fails such that it can receive no communication from any external source;

2. Loss of the ability to transmit all external RF communications by an individual UAV- this is the situation that occurs when the datalink transmitter on board an individual UAV fails such that it can send no communication to any external source;

3. Loss of the ability to receive or transmit all external RF communications by an individual UAV- this is the situation that occurs when the datalink receiver and transmitter on board an individual UAV fails such that it can neither receive from nor send to any communication with an external source;

Note: the following failure scenarios assume that communication with one or more individual UAVs does not constitute communication with the over-all search team coordination authority. That is, the search team coordination authority is either centralized with a separate communications link to the individual UAVs or, possibly, may be distributed but requires communication with a minimum set of nodes. In either of these cases, the following scenarios may differ from the first three scenarios; however, if communication with a single other UAV constitutes communication with the search team coordination authority then the following scenarios are not relevant.

4. Loss of the ability to receive only search team coordination authority communications by an individual UAV- this is the situation that occurs when an individual UAV loses the ability to receive communications directly from the search team coordination authority but retains the ability to communicate with other UAVs on the search team;

5. Loss of the ability to transmit to only the search team coordination authority by an individual UAV- this is the situation that occurs when an individual UAV loses the ability to send information directly to the search team coordination authority but retains the ability to communicate with other UAVs on the search team;

6. Loss of the ability to transmit or receive communications only with the search team coordination authority by an individual UAV- this is the situation that occurs when an individual UAV loses the ability to send or receive communications directly with the search team coordination authority but retains the ability to communicate with other UAVs on the search team.

These communication failures allow the exploration of a variety of recovery mechanisms for retaining the ability to use the compromised UAV within the search.

3.2 Scenario 2- Search for Lost or Abducted Child at an Outdoor Public Event

During a major outdoor event (e.g. Calgary Stampede, Ottawa Bluesfest, Toronto Exhibition, etc.) a lost child is reported. Local first responders are equipped with multiple rotary wing micro air vehicles (MAVs) that can be deployed immediately and operated as a team to search for the lost child.

The search must be conducted against the moving flow of people such that a specific region can only be considered as "searched" for some finite period of time and then it must be re-assigned for another search. Unless there is a specific interest in exploring auto-target identification, it can be assumed that the child has something truly distinctive and readily identifiable for which the vehicles may search.

It is likely reasonable to assume that the search should be conducted from the outer perimeter inwards to the event gates first in order to ensure that- if the child has been abducted- the areas of maximum risk have been covered first. Therefore, a search of the parking lots and outer perimeters of the event would be conducted first, moving in to the gates. Once that search has been conducted, then a set of vehicles may be assigned permanent picket duty at each of the gates to watch for the child passing through. Another small team of MAVs can be assigned perimeter surveillance duties to patrol the perimeter between the gates to guard against the child or abductor exiting by a make-shift exit rather than one of the official exits. Finally, the remainder of the vehicles would be assigned the task searching the event itself, with fixed machinery but moving crowds such that each region of the event can only be designated as searched for some period of time after which it has to be assumed as having enough changeover of personnel that it requires searching again.

Problems that are likely to be encountered and need to be addressed by the self healing network in this scenario include:

1. Efficient planning and re-planning of search patterns for the various regions (i.e. parking lot, perimeter, exits, crowds, outlying areas, etc.) including time period over which specific regions need to be re-examined due to crowd flow;

2. Coordination of search task, including timeliness- how is this performed? All through direct taskings or through individual vehicles sharing information regarding the present confidence in a specific search area (i.e. stygmergy?)?

3. Changes in clutter density (clutter is defined as objects in the field of regard that are similar size and magnitude as the objects being searched so parking lots would be low clutter density but crowds would be very high clutter density) requiring changes in dwell time (i.e. more time to determine if object of interest is present), FOV (i.e. less coverage in a given pass) and/ or changes in altitude (less coverage, possibly changed winds, changed fuel efficiency);

4. Wind changes, including wind changes as a result of changes in vehicle altitude;

5. Diminishing MAV resources as some vehicles use up their fuel faster than others, especially those assigned to hover at places like the entrances or over dense crowds;

6. Efficient management of MAV resources such as rotating vehicles from hovering duty at the gates to search duties with less fuel requirements to maximize number of units in the air at all times;

7. Rotation of MAVs back to ground units for refuel/ recharge/ battery changes in an efficient manner that keeps the maximum number of vehicles in the air at all times;

8. Diminishing UAV resources due to failures on-board individual vehicles (e.g. payload failures, engine problems, etc.).

3.2.1 Detailed Scenario

A small child with a distinctive shirt is reported missing at a large outdoor event. The police units around the event immediately launch all of their micro air vehicles- totalling 20- to search for the child. All vehicles are initially used to search the surrounding parking lots, bus stops and walkways to establish a perimeter within which the child can safely be assumed to be. Upon completion of this primary task, several units are assigned picket duty at each of the exits, several other units are assigned perimeter duty around the event to prevent any exits through other, unauthorized areas and the remainder of the units are deployed to search the event itself.

The search coordination authority must set up search regions for the vehicles to cover, prioritizing those areas by risk (i.e. secluded areas first, etc.) and coordinate the vehicles to cover the areas in as efficient a manner as possible. These areas must be assigned some assessment of confidence that is communicated to the other units and degrades with time as a function of crowd flow so as to lead to a re-search later.

The search coordination authority must rotate the vehicles for most efficient use, moving those performing primarily hover duties- and therefore using far more fuel- with those performing forward flight duties. The search coordination authority must also rotate the vehicles back to their ground units for rapid refuel/ recharge/ battery swap in a planned and efficient manner that keeps the maximum number of vehicles available at all times.

Finally, the search coordination authority must also accommodate systems failures such as payload or engine problems, rotating those units back to their ground units for repair and/ or removal from the task and compensating for their absence with the remaining units.

3.2.2 Failure Scenarios Encountered

The following failure scenarios will be encountered during the execution of this simulated mission.

3.2.2.1 Failure Scenario 1- Crowd Flow Adaptation

During this search, one of the most difficult tasks will be to estimate the time-dependent confidence factor associated with a search of a given area. A reasonable estimate of this may be to measure the number of individuals passing in and out of the edge of a frame in a short period of time and scale this by an estimate of the number of individuals within the frame during that period. In this way, some quantifiable value can be assigned as a rate of change for this particular area and the confidence value for any search of that area can be degraded at that same rate. It may be that when the confidence value falls below some threshold then the area is re-searched or perhaps each unit simply continues to search the area of lowest confidence within its assigned region regardless of the actual confidence value itself. The search coordination authority must somehow monitor the various regions- perhaps re-sizing and/ or re-assigning them to other vehicles as the over-all region's confidence changes- so as to most efficiently search and re-search the entire area of interest until the child is found.

It may be that only the edges of crowds are searched at all, on the assumption that abducted or just lost, a child is not at risk in the middle of a crowd and can therefore be safely awaited at the edge of a crowd so long as coverage is continuous.

3.2.2.2 Failure Scenario 2- Increased clutter density

Clutter density will be a function of the crowd density for the region being searched. Although the parking lots are not empty, a car will not be mistaken for a child so their clutter density with respect to the target being sought is low. However, the crowds within the event will represent a very high clutter density, requiring a much longer dwell time and smaller FOV, either by camera zoom or decrease in altitude or both.

Increase of dwell time and decrease of FOV both result in an increase in the projected time needed to finish the search of the assigned area and change in altitude results in a change of fuel consumption. These changes need to be communicated to the search team coordinating authority to be factored into a revised assignment strategy of the remaining grid squares.

3.2.2.3 Failure Scenario 3- Wind Change

During some stages of the search, several MAVS can be expected to encounter changes in wind direction, either as a result of local atmospheric conditions- such as rotors or wind shadows off buildings- or as a result of changes in altitude. These wind changes not only affect the fuel consumption of the MAV (in addition to the changes in fuel consumption as a function of altitude) but may result in the MAV needing to re-calculate a new search pattern for the remaining portion of the grid square in order to complete the search most quickly and efficiently. At the very least, changes in wind will affect the predicted fuel remaining at the completion of the grid square search and if the pattern itself is changed then it may also affect the predicted location of the MAV at the completion of the grid square search.

The necessary alterations resulting from wind changes must be communicated to the search team coordination authority to factor into the grid square allocation order across the team. If a specific MAV finishes its search in a different location then this may result in it being assigned a different subsequent grid square than was initially planned. Likewise, the information regarding the expected fuel remaining may affect the assignation of subsequent grid squares for search.

3.2.2.4 Failure Scenario 4- Low Fuel

Either as a result of extended hovering, adapting to changing local environmental conditions or potentially as a system-specific failure or inefficiency, it can be expected that a few of the MAVs may declare low fuel situations earlier than expected. The individual MAV must then communicate with the search team coordination authority to identify the best manner in which to finish off as much of its remaining grid square as possible and then the search team coordination authority must re-plan the search execution strategy to cover the area- including any partial grid square left by the low fuel MAV- to maximize use of the remaining UAV assets.

3.2.2.5 Failure Scenario 5- System Failures- Complete

During the course of this search scenario, some outright system failures can be injected that require the complete, immediate and unexpected withdrawal of one or more individual MAVs. This loss of an asset must be communicated to the search team coordinating authority and must then be incorporated into the over-all search plan, including completion of the remaining portion of the grid square previously assigned to the lost asset.

3.2.2.6 Failure Scenario 6- System Failures- Partial

During the course of this search scenario, some outright system failures can be injected that allow an individual UAV to continue to operate in some degraded mode but requires a level of adaptation on the part of the individual UAV as well as re-planning by the search team coordinating authority to identify a modified search plan that accommodates the new limitations of this individual UAV.

Some examples of these kinds of failures could be:

1. Payload gimbal failure- payload may be restricted in movement requiring MAV to modify flight pattern to achieve coverage. The resulting inefficiency in searching needs to be accommodated by the search team coordination authority to re-plan the over-all search strategy.

2. Engine failure- MAV may have one or more engines fail, requiring either emergency recovery or degraded operations.

3.2.2.7 Failure Scenario 7- Loss of Communications

During the course of this search scenario, a communications failure with one or more individual MAVs can be injected to explore the possible response mechanisms using stygmergy. Since RF communications is explicitly bi-directional, it is possible for communication in either direction individually to be experienced or for both directions to be lost at once. Since the loss of communications would not affect the efficiency or efficacy of each individual MAV in its search task, an ability to continue using this asset through some other means of communication would be desirable.

The various scenarios for communication loss that could be explored would include:

1. Loss of the ability to receive all external RF communications by an individual MAV- this is the situation that occurs when the datalink receiver on board an individual MAV fails such that it can receive no communication from any external source;

2. Loss of the ability to transmit all external RF communications by an individual MAV- this is the situation that occurs when the datalink transmitter on board an individual MAV fails such that it can send no communication to any external source;

3. Loss of the ability to receive or transmit all external RF communications by an individual MAV- this is the situation that occurs when the datalink receiver *and* transmitter on board an individual MAV fails such that it can neither receive from nor send to any communication with an external source;

Note: the following failure scenarios assume that communication with one or more individual MAVs does **not** constitute communication with the over-all search team coordination authority. That is, the search team coordination authority is either centralized with a separate communications link to the individual MAVs or, possibly, may be distributed but requires communication with a minimum set of nodes. In either of these cases, the following scenarios may differ from the first three scenarios; however, if communication with a single other MAV constitutes communication with the search team coordination authority then the following scenarios are not relevant.

4. Loss of the ability to receive only search team coordination authority communications by an individual MAV- this is the situation that occurs when an individual MAV loses the ability to receive communications directly from the search team coordination authority but retains the ability to communicate with other MAVs on the search team;

5. Loss of the ability to transmit to only the search team coordination authority by an individual MAV- this is the situation that occurs when an individual MAV loses the ability to send information directly to the search team coordination authority but retains the ability to communicate with other MAVs on the search team;

6. Loss of the ability to transmit or receive communications only with the search team coordination authority by an individual MAV- this is the situation that occurs when an individual MAV loses the ability to send or receive communications directly with the search team coordination authority but retains the ability to communicate with other MAVs on the search team.

These communication failures allow the exploration of a variety of recovery mechanisms for retaining the ability to use the compromised MAV within the search.

4 Protocol Development

The two protocols developed to support the externally developed models- one for the swarm interaction in support of the mission and the other for individual air vehicle control in response to various failures- are detailed below. It is intended that these protocols serve as a starting point for this kind of model development to ensure that the models themselves are not developed in a manner that does not allow easy integration with the simulated environment.

Note that it may very well be that much of the external coordination authority actually becomes embedded in the internal control model, especially if the approach to this coordination is to solve it in a distributed manner between all instances of simulated UAVs. Even in this approach, however, an external protocol is still necessary for each UAV to communicate its decisions to the other UAVs such that they may address their own actions in a manner supported the over-all mission. This effort has attempted to not make any assumptions about the manner in which this problem is solved but only to define the interface that each individual UAV simulation will require to communicate this intent outside of its own instantiation.

4.1 External Command Protocol

The following is a requirements-level description of the quasi-protocol developed for communications with the external search coordination authority. These tables include the higher level requirement text, followed by subsequent derivations that result in a protocol level definition, including units, range and parameter size/ type.

DRDCSwarm::Vehicle:ExternalCommand

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

Each instance of a single unmanned vehicle system initiated on the UAV RTB shall be capable of taking direction from an external command authority.

DRDCSwarm::Vehicle:ExternalCommand:Protocol

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

Each instance of a single unmanned vehicle system initiated on the UAV RTB shall support a defined protocol for communication with an external command authority.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:SearchArea

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can supply an area for the vehicle system to search.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:SearchArea::NumberOfVertices

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can inform the vehicle system of the number of vertices that will define the search area.

8 bit integer
3..255
no units

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:SearchArea::VertexLocation

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can transfer the vertices of the area to be searched.

2D array of float32 with NumberOfVertices entries
[1] latitude: -pi/2..+pi/2, [2] longitude: -pi..+pi
radians

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:SearchConfidenceLevel

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can command the vehicle system to search an area until a specified confidence level is reached.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:SearchConfidenceLevel:Confidence

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can designate the confidence level to which the vehicle must search the designated search area.

8 bit integer
0..100
percent

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:SearchWhileTransit

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can command the vehicle system to search a swath of designated width while transiting to next search area.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:SearchWhileTransit:Width

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can designate the width of the path centred on the transit path that the vehicle will search while transiting to next search area.

32 bit float
0..100000
metres

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:TransitPath

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can supply an path by which the vehicle is commanded to transit to next search area.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:TransitPath::NumberOfVertices

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can inform the vehicle system of the number of vertices that will define the transit path.

8 bit integer
3..255
no units

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:TransitPath::VertexLocation

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can transfer the vertices of the path to be transited.

2D array of float32 with NumberOfVertices entries
[1] latitude: -pi/2..+pi/2, [2] longitude: -pi..+pi
radians

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:TurbulenceForecast

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can supply the vehicle system with a turbulence forecast for a specified location, time and altitude.
The vehicle system can then use this information to take proactive action to prevent coverage gaps in the search area.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:TurbulenceForecast::Forecast

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can transfer the forecasts of turbulence at various locations.

5D array of float32 with NumberOfVertices entries
[1] latitude: -pi/2..+pi/2 radians, [2] longitude: -pi..+pi radians, [3] altitude: -1000..+30000 metres, [4] turbulence intensity (larger number means greater turbulence): 0..100 [6] time (when forecasted turbulence is expected, relative to

current message time): -86400..+259200 seconds

NOTE: negative time means "forecast" is actually a measurement that was taken

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:TurbulenceForecast::NumberOfForecasts

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can inform the vehicle system of the number of turbulence forecasts that will be supplied.

8 bit integer
3..255
no units

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:VisibilityForecast

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can supply the vehicle system with a visiblity forecast for a specified location, time and altitude.
The vehicle system can then use this information to take proactive action to prevent coverage gaps in the search area.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:VisibilityForecast::Forecast

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can transfer the forecasts of visibility at various locations.

5D array of float32 with NumberOfVertices entries
[1] latitude: -pi/2..+pi/2 radians, [2] longitude: -pi..+pi radians, [3] altitude: -1000..+30000 metres, [4] visibility: 0..100000 metres, [6] time (when forecasted visibility is expected, relative to current message time): -86400..+259200 seconds

NOTE: negative time means "forecast" is actually a measurement that was taken

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:VisibilityForecast::NumberOfForecasts

Functional | *Status:* Proposed | *Priority:* Medium | *Difficulty:* Medium

Phase: 1.0 | *Version: 1.0*

The external command protocol shall support a means by which the external authority can inform the vehicle system of the number of visibility forecasts that will be supplied.

8 bit integer
3..255
no units

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:WindForecast

Functional | *Status:* Proposed | *Priority:* Medium | *Difficulty:* Medium

Phase: 1.0 | *Version: 1.0*

The external command protocol shall support a means by which the external authority can supply the vehicle system with a wind forecast for a specified location, time and altitude.
The vehicle system can then use this information to take proactive action to prevent coverage gaps in the search area.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:WindForecast::Forecast

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can transfer the forecasts of wind at various locations.

6D array of float32 with NumberOfVertices entries
[1] latitude: -pi/2..+pi/2 radians, [2] longitude: -pi..+pi radians, [3] altitude: -1000..+30000 metres, [4] wind speed: 0..500 km/hr, [5] wind direction (with respect to True North): 0..2pi radians, [6] time (when forecasted wind is expected, relative to current message time): -86400..+259200 seconds

NOTE: negative time means "forecast" is actually a measurement that was taken

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Command:WindForecast::NumberOfForecasts

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the external authority can inform the vehicle system of the number of wind forecasts that will be supplied.

8 bit integer
3..255
no units

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:CoverageConfidence

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report the confidence level with which a search ahs been completed.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:PercentageCoverageConfidence::ConfidenceLevel

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can inform the external authority of the confidence level currently being achieved by the search the vehicle system is being conducted.

8 bit integer
0..100
percent

NOTE: This allows for reporting of search approaches such as a quick, lower confidence search of the whole area first before executing a more detailed search at higher confidence level.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:CoverageGap

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report the an area within which the search has not been completed to an acceptable confidence level.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:CoverageGap::NumberOfVertices

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can inform the search coordination authority the number of vertices that will define the area within which the search has not been completed to an acceptable confidence level.

8 bit integer
3..255
no units

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:CoverageGap::VertexLocation

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can transfer the vertices of the area within which the search has not been completed to an acceptable confidence level.

2D array of float32 with NumberOfVertices entries
[1] latitude: -pi/2..+pi/2, [2] longitude: -pi..+pi
radians

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:CurrentAltitude

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report the altitude at which the vehicle is currently operating.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:CurrentAltitude::Altitude

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can inform the external authority of the altitude currently being maintained by the vehicle system as the search is being conducted.

32 bit float
-1000..+30000
metres

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:CurrentTurbulence

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report the turbulence currently being experienced.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:CurrentTurbulence::Turbulence

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report the turbulence currently being experienced.

5D array of float32
[1] latitude: -pi/2..+pi/2 radians, [2] longitude: -pi..+pi radians, [3] altitude: -1000..+30000 metres, [4] turbulence intensity (larger number means greater turbulence): 0..100 [6] time (when turbulence was measured, relative to current message time): -86400..+0 seconds

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:CurrentVisibility

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report the visibility currently being experienced.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:CurrentVisibility::Visibility

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle systems can transfer the current visibility being experienced at the present location.

5D array of float32
[1] latitude: -pi/2..+pi/2 radians, [2] longitude: -pi..+pi radians, [3] altitude: -1000..+30000 metres, [4] visibility: 0..100000 metres, [6] time (when visibility was measured, relative to current message time): -86400..0 seconds

NOTE: negative time means "forecast" is actually a measurement that was taken

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:CurrentWind

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report the wind velocity (direction & speed) currently being experienced.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:CurrentWind::Wind

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report the wind velocity (direction & speed) currently being experienced.

6D array of float32
[1] latitude: -pi/2..+pi/2 radians, [2] longitude: -pi..+pi radians, [3] altitude: -

1000..+30000 metres, [4] wind speed: 0..500 km/hr, [5] wind direction (with respect to True North): 0..2pi radians, [6] time (when wind was measured, relative to current message time): -86400..+0 seconds

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:EstimatedLocationAtCompletion

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report an estimated location at which the vehicle expects to be when the current search task is completed.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:EstimatedLocationAtCompletion::Location

Functional ***Status:*** **Proposed** ***Priority:*** **Medium** ***Difficulty:*** **Medium**

Phase: 1.0 ***Version: 1.0***

The external command protocol shall support a means by which the vehicle system can report the estimated location of the vehicle when the current search has been completed.

3D array of float32
[1] latitude: -pi/2..+pi/2 radians, [2] longitude: -pi..+pi radians, [3]altitude: -1000..+30000 metres

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:EstimatedSearchTime

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report an estimated search time for the area provided.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:EstimatedSearchTime::Time

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can inform the external authority of the estimated length of time it will take to conduct a search of teh specified area to the specified confidence level.

16 bit integer
0..65535
seconds

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:EstimatedTimeToComplete

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report an estimated remaining time for search of teh currently assigned area.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:EstimatedTimeToComplete::Time

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can inform the external authority of the estimated length of time it will take to complete the remainder of the search of the specified area to the specified confidence level.

16 bit integer
0..65535
seconds

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:PercentageCoverageComplete

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report the percentage of the search that is completed.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:PercentageCoverageComplete::Percentage

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can inform the external authority of the percentage of the search area that has been covered to the specified confidence level.

8 bit integer
0..100
percent

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:SystemFailures

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report any system failures currently being experienced.
This includes:
-low fuel
-engine helath
-engine failure
-airframe failures
-navigation system failures

-payload systems failures
-communication system health problems
-communication system failures
The search coordination authority can then use this information to re-task other vehicles and modify their various search areas.

DRDCSwarm::Vehicle:ExternalCommand:Protocol:Report:SystemFailures::Failures

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The external command protocol shall support a means by which the vehicle system can report any system failures currently being experienced.

32 bit bitmap
Bit 1: Engine RPM Fault
Bit 2: Engine Temp Fault
Bit 3: Excessive Roll
Bit 4: Excessive Pitch
Bit 5: Low Altitude
Bit 6: Low Airspeed
Bit 7: Low Fuel
Bit 8: Bus Voltage Fault
Bit 9: Flap Failure
Bit 10: Aileron Failure
Bit 11: Engine Failure
Bit 12: GPS Failure
Bit 13: Stall Warning
Bit 14: DeIcing Failure
Bit 15: Intermittent Uplink
Bit 16: Loss of Uplink

4.2 Internal Command Protocol

The following is a requirements level description of the quasi-protocol developed for communications with the control model developed by a third party to adjust to various system failures, including communications failures. These tables include the higher level requirement text, followed by subsequent derivations that result in a protocol level definition, including units, range and parameter size/ type.

DRDCSwarm::Vehicle:InternalControlModel

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

Each instance of a single unmanned vehicle system initiated on the UAV RTB shall be capable of integrating an internal control model that exercises control over the vehicle and payloads.

DRDCSwarm::Vehicle:InternalControlModel:Protocol

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

Each instance of a single unmanned vehicle system initiated on the UAV RTB shall support a defined protocol for communication with an internal control model.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Airspeed

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the vehicle system to a specific airspeed.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Airspeed:CommandedAirspeed

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the internal control model can command the vehicle system to a specific airspeed.

16 bit integer
0..65535
metres/ sec

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Altitude

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the vehicle system to a specific altitude

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Altitude:CommandedAltitudeAGL

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal control protocol shall support a means by which the internal control model can command the vehicle system to a specific altitude above the ground.

16 bit integer
0..65535
metres

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Attitude

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the vehicle system to a specific attitude with respect to the earth.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Attitude:Pitch

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the internal control model can command the vehicle system to a specific pitch angle with respect to the earth.

32 bit float
-pi..+pi
radians

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Attitude:Roll

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the internal control model can command the vehicle system to a specific roll angle with respect to the earth.

32 bit float
-pi..+pi
radians

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Course

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the vehicle system to a specific course with respect to True North.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Course:CommandedCourse

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the vehicle system to a specific course with respect to True North.

32 bit float
0..2*pi
radians

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Destination

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the vehicle system to a specific destination.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Destination:CommandedDestination

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the vehicle system to a specific destination.

3D array of float32
[1] latitude: -pi/2..+pi/2 radians, [2] longitude: -pi..+pi radians, [3]altitude: -1000..+30000 metres

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Groundspeed

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the vehicle system to a specific ground speed.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Groundspeed:CommandedGroundspeed

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the vehicle system to a specific ground speed.

16 bit integer
0..65535
metres/ sec

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Heading

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the vehicle system to a specific heading with respect to True North.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::Heading:CommandedHeading

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the vehicle system to a specific heading with respect to True

North.

32 bit float
0..2*pi
radians

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::PayloadDeployment

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the payload system to deploy itself at a specific location.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::PayloadDeployment:DeployCommand

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the payload system to deploy itself at a specific location.

3D array of float32
[1] latitude: -pi/2..+pi/2 radians, [2] longitude: -pi..+pi radians, [3]altitude: -1000..+30000 metres

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::PayloadFOV

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the payload system to set it's field of view to a specified size.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::PayloadFOV:CommandedFOV

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the payload system to set it's field of view to a specified size.

32 bit float
0..2*pi
radians

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::PayloadLocation

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the payload system to examine a specific location.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::PayloadLocation:CommandedStarepoint

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the payload system to examine a specific location.

3D array of float32
[1] latitude: -pi/2..+pi/2 radians, [2] longitude: -pi..+pi radians, [3]altitude: -1000..+30000 metres

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::PayloadMode

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the payload system into a specific mode of operation.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::PayloadMode:CommandedPayload

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can identify the specific payload system for which the mode command is valid

16 bit discrete
0 ==> Electro-optical
1 ==> Infra-red
2 ==> Radar
4 ==> SAR
8 ==> Deployable Cannister 1
16 ==> Deployable Cannister 2

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Command::PayloadMode:CommandedPayloadMode

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the control model can command the identified payload system to a specific mode of operation

16 bit discrete
0 ==> Off
1 ==> Standby
2 ==> On
4 ==> Calibrate
8 ==> Polarity- White Hot
16 ==> Polarity- White Hot
32 ==> Spot Mode
64 ==> Auto track
128 ==> Image Hold
256 ==> Release One Deployable Element
512 ==> Release All Deployable Elements

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Airspeed

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the control model a specific airspeed.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Airspeed:ReportedAirspeed

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the internal control model the current airspeed.

16 bit integer
0..65535
metres/ sec

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Altitude

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the control model a specific altitude

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Altitude:ReportedAltitudeAGL

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal control protocol shall support a means by which the vehicle system can report to the internal control model the current altitude above the ground.

16 bit integer
0..65535
metres

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Attitude

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the control model a specific attitude with respect to the earth.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Attitude:Pitch

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the internal control model the current pitch angle with respect to the earth.

32 bit float
-pi..+pi
radians

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Attitude:Roll

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the internal control model the current roll angle with respect to the earth.

32 bit float
-pi..+pi
radians

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Course

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the control model a specific course with respect to True North.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Course:ReportedCourse

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the control model the current course with respect to True North.

32 bit float
0..2*pi
radians

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Destination

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the control model a specific destination.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Destination:ReportedDestination

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the control model the current destination to which it is flying.

3D array of float32
[1] latitude: -pi/2..+pi/2 radians, [2] longitude: -pi..+pi radians, [3]altitude: -1000..+30000 metres

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Groundspeed

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the control model a specific airspeed.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Groundspeed:ReportedGroundspeed

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the control model the current ground speed.

16 bit integer
0..65535
metres/ sec

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Heading

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the control model a specific heading with respect to True North.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::Heading:ReportedHeading

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the vehicle system can report to the control model the current heading with respect to True North.

32 bit float
0..2*pi
radians

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::PayloadDeployment

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the payload system can report to the control model the specific location at which it will deploy.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::PayloadDeployment:DeployReport

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the payload system can report to the control model the location at which it is currently set to deploy

3D array of float32
[1] latitude: -pi/2..+pi/2 radians, [2] longitude: -pi..+pi radians, [3]altitude: -1000..+30000 metres

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::PayloadFOV

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the payload system can report to the control model the field of view to which it is currently set.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::PayloadFOV:ReportedFOV

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the payload system can report to the control model the current field of view.

32 bit float
0..2*pi
radians

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::PayloadLocation

Functional

Status: Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the payload system can report to the control model the specific locationcurrently being examined.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::PayloadLocation:ReportedStarepoint

Functional

Status: Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the payload system can report to the control model the current location being examined.

3D array of float32
[1] latitude: -pi/2..+pi/2 radians, [2] longitude: -pi..+pi radians, [3]altitude: -1000..+30000 metres

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::PayloadMode

Functional

Status: Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the payload system can report to the control model the specific mode of operation in which it is currently operating.

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::PayloadMode:ReportedPayload

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the specific payload system for which the mode command is valid can be reported to the control model.

16 bit discrete
0 ==> Electro-optical
1 ==> Infra-red
2 ==> Radar
4 ==> SAR
8 ==> Deployable Cannister 1
16 ==> Deployable Cannister 2

DRDCSwarm::Vehicle:InternalControlModel:Protocol:Report::PayloadMode:ReportedPayloadMode

Functional *Status:* Proposed *Priority:* Medium *Difficulty:* Medium

Phase: 1.0 *Version: 1.0*

The internal coontrol protocol shall support a means by which the the specific payload system can identify to the control model the mode in which it is currently operating

16 bit discrete
0 ==> Off
1 ==> Standby
2 ==> On
4 ==> Calibrate
8 ==> Polarity- White Hot
16 ==> Polarity- White Hot
32 ==> Spot Mode
64 ==> Auto track
128 ==> Image Hold
256 ==> Release One Deployable Element
512 ==> Release All Deployable Elements

5 Failure Insertion Application

The Failure Insertion Application is described in the high level design diagram shown in Figure 4:

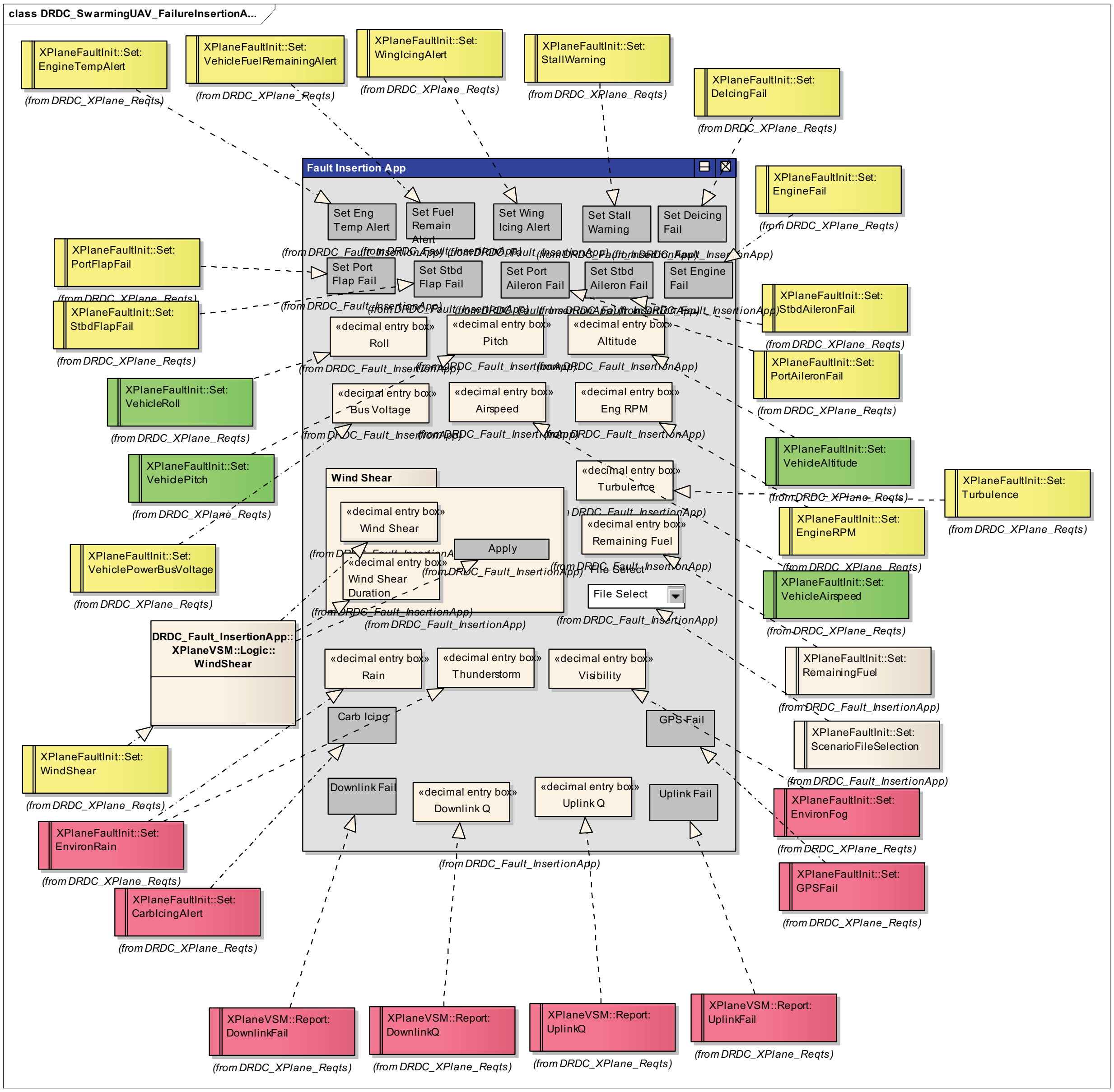

Figure 4: Failure Insertion Application- Design Drawing

This diagram describes the user interface layout, along with the requirements to which each user control must be mapped. Some of these requirements are explicitly X-Plane parameters that may be set; others describe behaviours that must be modelled and implemented within the VSM developed for this project.

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DRDC Ottawa has developed over the past several years a very capable Unmanned Air Vehicle (UAV) Research Test Bed (RTB) that provides a simulated UAV environment for a variety of UAV-related experiments. This tool is well suited to support the goals of the DRDC TIF Project “Self-Healing Networked Control Systems for Enhanced Reliability and Safety of Multivehicle Missions.” The objectives of this project are to develop and evaluate a variety of self-healing methodologies as applied to a UAV team. These include stigmergy to address the loss of communications as well as algorithms to coordinate search missions under varying conditions. This particular effort focused on identifying the necessary modifications to the UAV RTB to support of this research. The final result was: the development of two distinct, realistic and challenging search scenarios within which the self-healing UAV swarm may be run; the development of a full set of requirements needed to be supported by the UAV RTB to support the defined scenarios; and the creation of a high level design that not only supports those scenarios within the UAV RTB but also supports the third party development of the various algorithms and controls that are the goal of the experiment.

Ces dernières années, RDDC Ottawa a mis au point un banc d’essai de recherche (RTB) sur les véhicules aériens sans pilote (UAV) très performant procurant un environnement UAV simulé pour une vaste gamme d’équipement lié aux UAV. Ce outil convient bien à l’atteinte des objectifs du projet du FIT RDDC « Systèmes de contrôle autorégénérateurs en réseau pour l'amélioration de la fiabilité et de la sécurité des missions faisant appel à plusieurs véhicules ». Les objectifs de ce projet consistent à mettre au point et à évaluer une vaste gamme de techniques d’autorégénération comme celles appliquées à l’équipe des UAV. Ces techniques incluent la stygmergie pour remédier à l’interruption des communications ainsi que les algorithmes de coordination des missions de recherche dans diverses conditions. Cet effort en particulier se concentrait sur l’identification des modifications nécessaires pour que le RTB sur les UAV soutienne cette recherche. Le résultat final a été le suivant : l’élaboration de deux scénarios de recherche réalistes et stimulants distincts selon lesquels le groupe d’UAV autorégénérateurs peut fonctionner; l’élaboration d’un ensemble complet d’exigences devait être soutenue par le RTB sur les UAV en appui aux scénarios établis; la création d’une conception évoluée appuyant non seulement les scénarios impliquant le RTB sur les UAV, mais aussi l’élaboration par une tierce partie de divers algorithmes et contrôles correspondant à l’objectif de cette expérience.

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