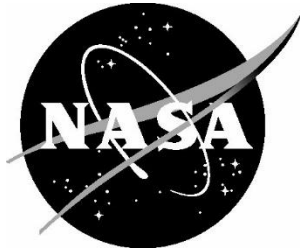


NASA-TM-20250005489



# GroundWatch: Ground Station Tool for UAS Autonomy Research Flight Operations

*Andrew T. Turner*

*ViGYAN, Hampton, Virginia*

*Cuong C. Quach, Yamira Santiago-Espada, Kyle M. Smalling, Sixto L. Vazquez, Laura Smith*

*Langley Research Center, Hampton, Virginia*

---

August 2025

# NASA STI Program Report Series

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA scientific and technical information (STI) program plays a key part in helping NASA maintain this important role.

The NASA STI program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NTRS Registered and its public interface, the NASA Technical Reports Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA Programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.

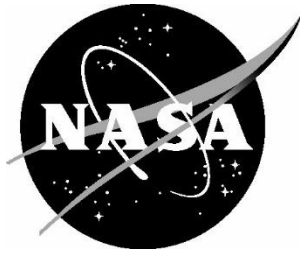
- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.
- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include organizing and publishing research results, distributing specialized research announcements and feeds, providing information desk and personal search support, and enabling data exchange services.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at <http://www.sti.nasa.gov>

NASA-TM-20250005489



## GroundWatch: Ground Station Tool for UAS Autonomy Research Flight Operations

*Andrew T. Turner*

*ViGYAN, Hampton, Virginia*

*Cuong C. Quach, Yamira Santiago-Espada, Kyle M. Smalling, Sixto L. Vazquez, Laura Smith*

*Langley Research Center, Hampton, Virginia*

# NASA STI Program Report Series

## Acknowledgments

The authors would like to thank NASA's Aeronautics Research Mission Directorate for its leadership, support, and sponsorship regarding the subject of this guide. In particular, the Program and Project Managers, Akbar Sultan, John Koelling, Misty Davies, and Kyle Ellis. Without their support, outside-the-box thinking, and constructive critiques, the concept exploration leading to this guide would not have been possible. Special thanks to Safety-Critical Avionics Branch Managers Eric Cooper and Roger Bailey for their support in securing getting physical access to research facilities during COVID restrictions.

Very special thanks to Steve Young, the Sub-Project Manager of Emerging Operations Technical Challenge for the valuable insights and helpful engaging discussions which set that helped shape the direction of the work, and for guiding the team along the way with insight and energy.

Finally, sincere thanks to Dr. George Hagen for his contributions to the original work, as well as to the many engineering interns who have also played a role in this effort. They contributed to the original concept for fixed wing traffic testing, various communications interfaces, and graphical user elements to improve this ground stations software.

The use of trademarks or names of manufacturers in this report is for accurate reporting and does not constitute an official endorsement, either expressed or implied, of such products or manufacturers by the National Aeronautics and Space Administration.

Available from:

NASA STI Program / Mail Stop 050  
NASA Langley Research Center  
Hampton, VA 23681-2199

## Table of Contents:

---

1	Background .....	6
2	Operations Context.....	7
3	Run Configuration.....	8
4	Getting Started .....	10
5	Starting the GroundWatch Application .....	11
5.1	Select GroundWatch Session Type .....	11
6	Preflight Checks .....	12
6.1	Vehicle Configuration Panel.....	14
6.1.1	SDSP Details Panel .....	15
6.2	On-Board Details Panel.....	18
6.3	Pre-Flight Panel.....	19
6.3.1	Selecting Flight Date and Time .....	20
6.3.2	Weather SDSP .....	22
6.3.3	RFI SDSP .....	24
6.3.4	Using the Layers Menu .....	26
6.3.5	Battery Prognostics SDSP.....	29
6.3.6	Proximity SDSP.....	29
6.3.7	GRASP SDSP .....	29
6.3.8	Nav-Q SDSP .....	30
6.3.9	Ideal Workflow for Creating Usable Flight Plan.....	31
7	Connecting to the Vehicle.....	33
7.1	Configuring the Vehicle Connection Settings .....	33
7.2	Selecting Files to Upload to the Vehicle .....	35
7.3	Creating the Connection .....	36
8	In-Flight Panel .....	41
8.1	Vehicle Status Bar .....	42
8.1.1	Power Health .....	42
8.1.2	Motor Health .....	43
8.1.3	Link Performance .....	43
8.1.4	Aircraft State .....	45
8.1.5	Nav Performance .....	48
8.1.6	Airspace Conformance.....	49

8.1.7	Air Traffic.....	50
8.1.8	Geospatial Constraints.....	50
8.1.9	Weather (MET) .....	52
8.1.10	Population Density.....	52
8.2	Live Map Viewer Window.....	52
9	Post-Flight Panel .....	53
10	Troubleshooting.....	55
11	Appendix A: Description of the Mission Configuration File (MCF) .....	56
12	References .....	60

List of Tables:

---

<b>Table 1: Software Compatible with GroundWatch Rev 1.0.....</b>	<b>9</b>
<b>Table 2: GroundWatch usage workflow .....</b>	<b>10</b>
<b>Table 3: Auto-Pilot Enumeration Values .....</b>	<b>46</b>

Table of Figures:

---

<b>Figure 1.1 Prototype IASMS architecture for flight testing .....</b>	<b>6</b>
<b>Figure 2.1 Workflow context for mission planning and execution phases of drone operation .....</b>	<b>7</b>
<b>Figure 3.1: Software components for testing software in Playback Mode.....</b>	<b>9</b>
<b>Figure 3.2: Software components for configuring to test in Live Mode .....</b>	<b>9</b>
<b>Figure 5.1: Flight Type Selection Window .....</b>	<b>11</b>
<b>Figure 5.2: Initialization Window .....</b>	<b>11</b>
<b>Figure 6.1: Location of Mission Configuration file opener in Startup Panel .....</b>	<b>13</b>
<b>Figure 6.2: Vehicle Configuration Panel - Vehicle Selection .....</b>	<b>14</b>
<b>Figure 6.3: Vehicle Configuration – Weather SDSP Constraints .....</b>	<b>15</b>
<b>Figure 6.4: Vehicle Configuration – RFI SDSP Constraints .....</b>	<b>15</b>
<b>Figure 6.5: Vehicle Configuration – BP SDSP Constraints .....</b>	<b>16</b>
<b>Figure 6.6: Vehicle Configuration – Proximity SDSP Constraints .....</b>	<b>16</b>
<b>Figure 6.7: Vehicle Configuration – GRASP SDSP Constraints .....</b>	<b>17</b>
<b>Figure 6.8: Vehicle Configuration – Nav-Q SDSP Constraints .....</b>	<b>17</b>
<b>Figure 6.9: Vehicle Configuration – On-Board Details Panel .....</b>	<b>18</b>
<b>Figure 6.10: Pre-Flight Panel. Map view provided by OpenStreetMap [13] .....</b>	<b>19</b>
<b>Figure 6.11: Pre-Flight – Select Planned Flight Date &amp; Time .....</b>	<b>20</b>
<b>Figure 6.12: Date &amp; Time Picker .....</b>	<b>20</b>
<b>Figure 6.13: Weather Forecast.....</b>	<b>21</b>
<b>Figure 6.14: Weather SDSP – Select Vehicle .....</b>	<b>22</b>

Figure 6.15: Weather SDSP – Check Weather Forecast .....	22
Figure 6.16: Weather SDSP – Select Wind Model .....	22
Figure 6.17: Weather SDSP – Select Altitude Spacing .....	23
Figure 6.18: Weather SDSP – Hazards - Map view provided by OpenStreetMap [13] .....	23
Figure 6.19: RFI SDSP – Select Vehicle .....	24
Figure 6.20: RFI SDSP – Select Frequency .....	24
Figure 6.21: RFI SDSP – Hazards - Map view provided by OpenStreetMap [13] .....	25
Figure 6.22: Pre-Flight – Add a Layer - Map view provided by OpenStreetMap [13] .....	26
Figure 6.23: Pre-Flight – Select Layer Type .....	26
Figure 6.24: Pre-Flight – Flight Plan Layer - Map view provided by OpenStreetMap [13] .....	27
Figure 6.25: Pre-Flight – Flight Plan Editor .....	28
Figure 6.26: Pre-Flight – Flight Plan Export .....	28
Figure 6.27: GRASP SDSP – Select Flight Plan .....	29
Figure 6.28: GRASP SDSP – Layer View - Map view provided by OpenStreetMap [13] .....	30
Figure 6.29: Nav-Q SDSP – Select Flight Plan .....	30
Figure 6.30: Nav-Q SDSP – Layer View - Map view provided by OpenStreetMap [13] .....	31
Figure 7.1: Vehicle Settings – Settings Selection .....	33
Figure 7.2: Vehicle Connection – Configuration Settings Panel .....	34
Figure 7.3: Vehicle Connection – New Connection Window .....	34
Figure 7.4: Mission Configuration Panel .....	35
Figure 7.5: Vehicle Configuration Panel – Connect to Vehicle .....	36
Figure 7.6: Vehicle Configuration Panel – Connecting View .....	36
Figure 7.7: Vehicle Connection Panel – Vehicle Connection Error Window .....	37
Figure 7.8: Vehicle Connection Panel – Vehicle Connected .....	37
Figure 7.9: Vehicle Connection – Confirm Flight Number .....	38
Figure 7.10: Vehicle Connection – Confirm Motor Battery .....	38
Figure 7.11: Vehicle Connection – Confirm Avionics Battery .....	38
Figure 7.12: Vehicle Connection – Upload Success .....	39
Figure 7.13: Vehicle Connection – Version Roll Call .....	39
Figure 7.14: Vehicle Connection – Ready for Takeoff .....	40
Figure 8.1: In-Flight Panel- Map view provided by OpenStreetMap [13] .....	41
Figure 8.2: In-Flight Panel – Vehicle Status Bar .....	42
Figure 8.3: Power Health Widget .....	42
Figure 8.4: Link Performance Widget .....	43
Figure 8.5: Link Performance Widget. – Map view provided by OpenStreetMap [13] .....	44
Figure 8.6: Aircraft State Widget .....	45
Figure 8.7: Auto-Pilot Mode – Map Legend .....	47
Figure 8.8: Airspace Conformance Widget .....	49
Figure 8.9: Geospatial Constraints Widget .....	51
Figure 8.10: Airspace Conformance Widget – Map View - provided by OpenStreetMap [13] .....	51
Figure 8.11: In-Flight Panel – Map Viewer - provided by OpenStreetMap [13] .....	52
Figure 9.1: Startup Panel - Start PostLand Phase .....	53
Figure 9.2: Startup Panel - End of Flight Messages .....	54
Figure 11.1 Top level tags in the MCF .....	56
Figure 11.2 Breakout for selectedVehicle group in the MCF and two of the encapsulated structures. ....	57

**Figure 11.3 Break out data groups in the “sdspThresholds” JSON. ....58**  
**Figure 11.4 Details of the “vehicleParameters” data in the MCF file. ....59**

## List of Acronyms

---

BP	Battery Prognostics
cFS	Core Flight Systems
CST	Contingency Select and Trigger (on-board decision software component)
GUI	Graphical User Interface
GW	GroundWatch, the software described in this report.
NAV-Q	Navigation Quality
PtT	Proximity to Threat
GRASP	Ground Risk Assessment
RFI	Radio-Frequency Interference
RSO	Range Safety Officer
SDSP	supplemental data service provider
SFCs	services, functions, and capabilities
SWS	System-Wide Safety Project
TC-2	Technical Challenge 2. A subproject in SWS which develops technologies for drone operations.

# 1 Background

Recent advancements in drone technologies have enabled realization of low volume use cases ranging from first responder to commercial logistic operations. NASA is facilitating further transformation by developing technologies which help operators address safety hazards attendant to high volume drone operations in urban and sub-urban communities. This research is performed by the System-Wide Safety (SWS) Project within the Airspace Operations Safety Program (AOSP) portfolio under NASA’s Aeronautics Research Mission Directorate (ARMD). The SWS Project proposes using an In-Time Aviation Safety Management System (IASMS) to help operators mitigate hazards during various phases of flight operations [1, 2]. The concept for the IASMS deploys several Services, Functions, and Capabilities (SFCs) which, together, help to monitor, assess, and mitigate safety hazards. [3] gives a study of the flight hazards which need to be addressed. As described in [1], these SFCs may be deployed in the aircraft, on the ground station, or as on-demand cloud services.

Figure 1.1 illustrates a simplified view of the prototype architecture instantiated at NASA for developmental testing of SFCs in the IASMS concept. The cloud based SFCs represent cloud deployed supplemental data service providers (SDSP) which offer an array of safety metrics calculations to the operator. [4, 5, 6] describes an example of a cloud deployed service to provide safety metric for Radio Frequency Interference, Ground Casualty Risk, and Navigation Quality (NAV-Q) respectively. The IASMS concept includes SFCs deployed on-board. [7] summarizes the on-board architecture and the risk assessment SFC while [8] describes the algorithm for the on-board battery prognostic SFC. This report focuses on the ground station role and usage in the IASMS architecture.

The ground station is the key interface between the vehicle, operator, and the cloud infrastructure. In this development effort, it can also represent the software interfaces in the operations control center such as would be operated for a port-to-port air lift or air taxi operation. There are several SFCs which can be deployed at the ground station for safety checks which are closely coordinated with what is happening on the vehicle.

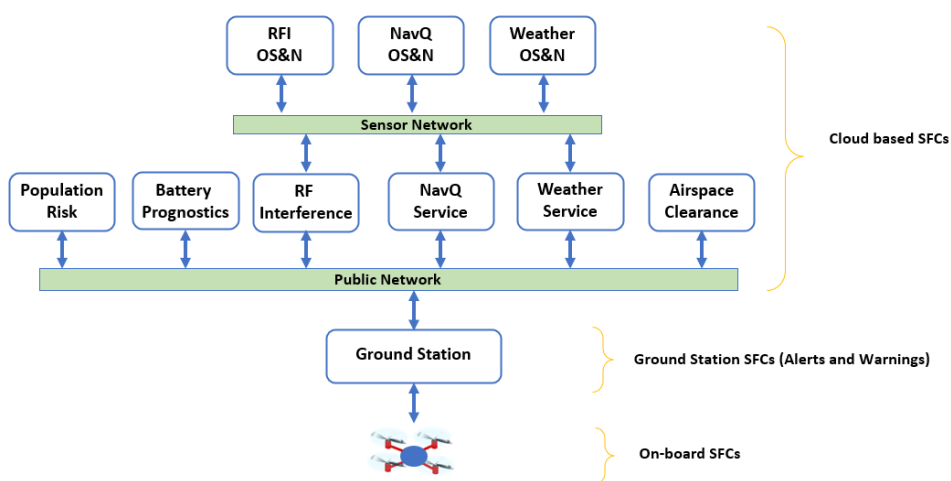


Figure 1.1 Prototype IASMS architecture for flight testing

The prototype architecture shown in Figure 1.1 is used in a series of flight tests conducted for the SWS project under Tech Challenge 2 (TC-2) sub project [10]. The testing provides opportunities to develop and tailor SFCs for emerging UAS operations in urban environments. The SFCs provide safety metrics for UAS operators to facilitate hazards mitigation during planning, pre-flight, and in-flight phases of operation. GroundWatch allows the test engineer to

interact with the flight vehicle and the cloud-based services during pre-flight activities. During flight, the software gives test engineers situational awareness of the performance of the on-board SFCs tested.

This GroundWatch (GW) software development leveraged work from an earlier version of GW used for fixed wing UAS traffic incursion flight tests. This version restructures the GUI to support interactions with the vehicle during pre-flight phase and displays for validating SFC functions during in-flight phase. The restructuring enabled enhancements such as adding display layers for maps, flight plans, and safety-related panels from on-board and cloud-deployed SFCs. This version allows the operator during pre-flight to upload mission information to the vehicle. Additionally, user security and tokenized access have been added to address information security. The GW version described in this guide is designated Release Version 1.0 and corresponds to the version used in the most recent flight-testing effort under TC-2. This report gives an overview of the operational context and a user’s guide to its functions and capabilities. It serves as part of the review process to eventually release the software as an exemplar of the interfaces to various IASMS components on-board and in the cloud.

## 2 Operations Context

In the context of a generic drone operations workflow, GroundWatch is an engineering ground station used in the pre-flight and in-flight phase of the drone operation. As illustrated in Figure 2.1, GW is used after an Operation Planning activity which defines the mission information needed for GW. The Operation Planning activity described [9] finishes with creating a Mission Information Baseline (MIB). The MIB conveys a safe mission baseline at time of planning. During mission execution, the operator may use GW to verify the baseline safety metrics and adjust safety thresholds to account for conditions (such as traffic and weather) which changed since mission planning. The MIB consists of 4 files which include a building model, terrain model, population model, and Mission Configuration File (MCF). The building and terrain models are GeoJSON files describing the terrain and existing buildings in the flight area. The population model is a table describing population density in the operating area. The MCF contains the desired mission flight path, vehicle systems information, and safety thresholds used during mission planning when interacting with ground-based services.

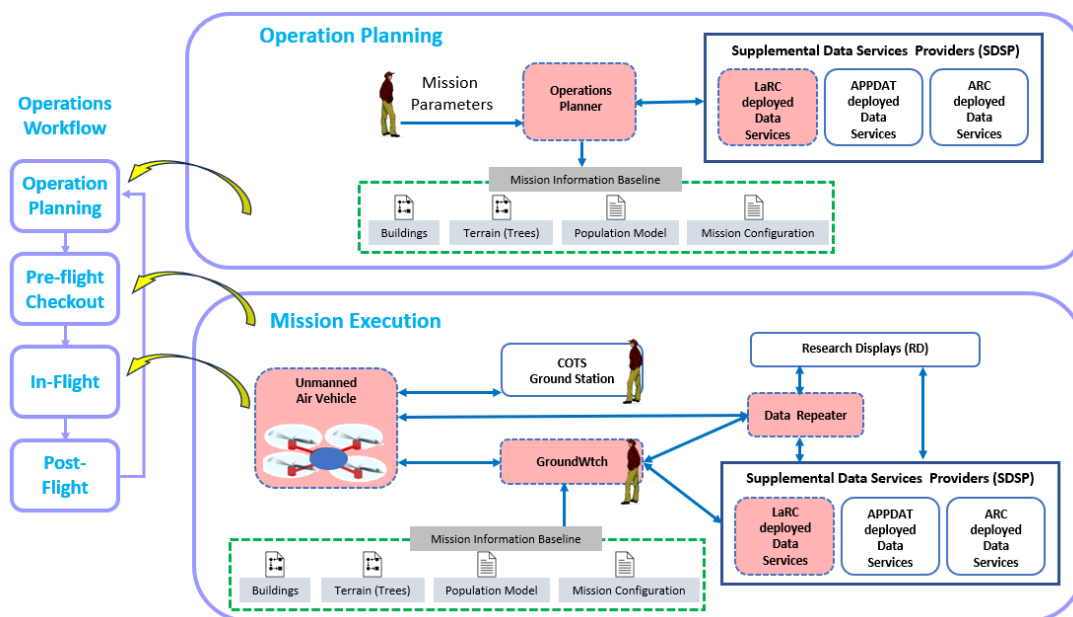


Figure 2.1 Workflow context for mission planning and execution phases of drone operation

The Mission Configuration file is loaded into GW at the start of the GW operations to make final updates and if necessary, re-evaluate the mission risk profile. When the operator updates flight number and final battery assignments, GW fetches updated battery parameters from the appropriate SDSP to be included with the MCF. GW also queries separate SDSP to retrieve weather and operation area details for the mission to be displayed in the GW display panels. The operator at this point has an opportunity to update the various safety thresholds in the MCF by directly interacting with one of the various SDSPs using their respective interface panels within GW. This lets the operator make a final “go” or “no go” decision based upon updated safety metrics for the mission. If the computed safety metrics meet the required thresholds, the operator can connect to the vehicle and proceed with uploading the MCF and other baseline files to the vehicle.

GW operates in three phases corresponding with the generic mission workflow in Figure 2.1, starting with the pre-flight phase. The operator controls coordinated transition from pre-flight to in-flight and finally to post-flight phase. These phases frame the operator’s interactions with the vehicle and SDSPs. The loading and evaluation of configuration files, connecting to vehicle, uploading files on board, and monitoring on-board software startup status occur in the pre-flight phase. After the pre-flight activities are done, the operator can command the on-board code to transition from pre-flight to in-flight phase based in coordination with the pilot and range safety officer (RSO).

In the in-flight phase, GW serves mostly as a display device for the on-board system. It interacts with the vehicle onboard software and SDSPs to display data in formats which enhance the situational awareness of the UAS operator. The on-board autonomy logic communicates software status, safety alerts, and mitigation decision options to the operator while the vehicle is flying. Raw sensor signals such as battery voltage, current, and temperature are also downlinked for display; later sections of this guide give details of those display panels. Additionally, GW internally tracks communication link status and reports data transmission rates. One notable display is the Live Virtual Constructive (LVC) which is a map display showing the ownship vehicle traversing in the city environment in which the vehicle is operating. In the LVC display, the operator can turn on layers which show range boundaries, vertiports, and no fly areas. When a traffic simulator is operated as part of the testing, GW also displays traffic in the LVC. This gives operators awareness of other UAS traffic operating in the area.

Once the mission is complete and the vehicle has landed, the GW operator may command the change from in-flight to post-flight phase. This alerts the on-board system to finalize and close log files and then shutdown. Status is reported to the operator when this process is completed.

### 3 Run Configuration

---

GW can be run with either live data or flight playback data. The live configuration connects to the communications software running on-board, which corroborates the data from the on-board applications. This configuration is typically used for flight activity and integrated system software testing. GW may also be run in playback configuration to support software and system testing. This allows a previous flight to be repeated without conducting an actual flight, which is useful for assessing how updated on-board software monitors, assesses, mitigates, and creates decisions using a previous flight. This run configuration provides a cost and time efficient way to test end-to-end functionality of new or modified IASMS SFC’s.

Figures 3.1 and 3.2 illustrate GW run configurations for the playback and live configuration respectively. The configuration differences between these two modes are minimal. Playback configuration uses a set of Playback applications to stream data from previous flight logs whereas Live configuration uses applications which communicate with hardware. The playback logs may also be generated by other tools. The playback applications

synchronize messages from raw sensors and the autopilot system by placing them on the software bus in the same order which they appeared during the flight. This allows all IASMS software components downstream of the playback applications to be tested; this eases the transition to flight testing. For flight testing in Live configuration, Bridge applications are used in place of the Playback applications. There is no difference from the perspective of downstream software components.

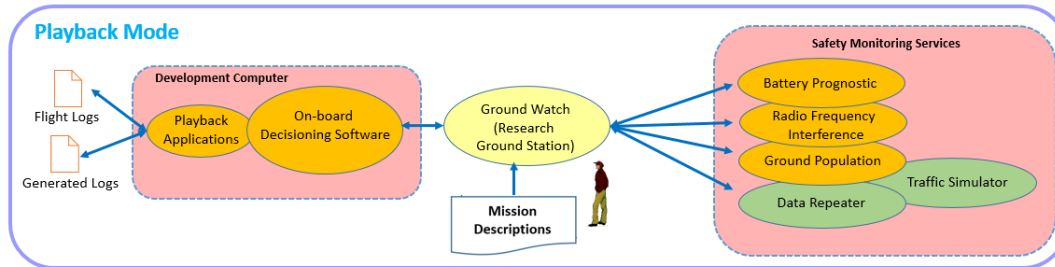


Figure 3.1: Software components for testing software in Playback Mode

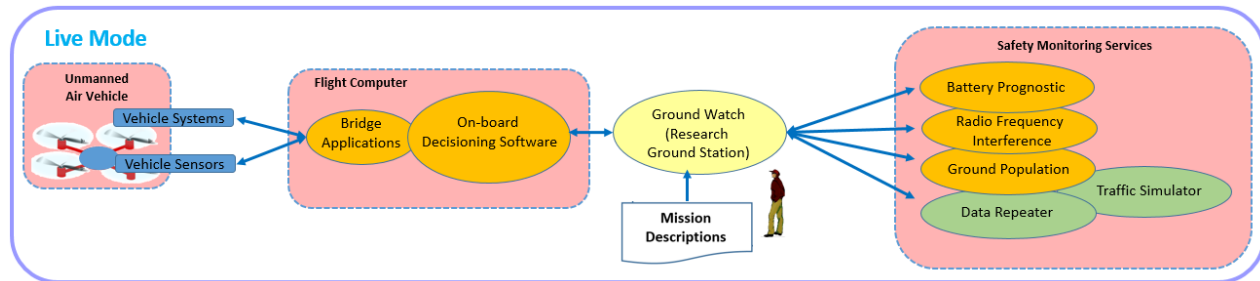


Figure 3.2: Software components for configuring to test in Live Mode

In both the Flight and Playback modes, it is possible to test the software components in the orange ovals as seen in Figure 3.1 or 3.2. As indicated in the figures, GW runs on a computer with network or serial access to the on-board software components. When testing with Safety Monitoring Services, then standard TCP network connection to those services is assumed.

As with all software testing, compatibility of all components being used and tested must be assured. Compatibility with SDSP is defined by the message model revision for each of the SDSP services. When testing the on-board software, the primary concern is compatibility with the GCOM component of the on-board suite. See Table 1 for compatible software.

Table 1: Software Compatible with GroundWatch Rev 1.0

Component	Compatible Version
GCOM (cFS)	2.1.2.1
Gateway	1.0
RMS SDSP	1.0
RFI SDSP	1.0
BMS SDSP	1.0
WIND SDSP	1.0
GRASP SDSP	1.0
NAV-Q SDSP	1.0

## 4 Getting Started

---

To setup the environment to run Ground Watch, the user needs to obtain either the standalone executable jar file or copy the application repository. The software is due to be release in NASA GitHub soon. The standalone executable jar file for the GroundWatch 1.0 software release corresponds to information in this report.

GroundWatch may be hosted on any operating system which supports Java. Prior to running the GW, it is necessary to verify that prerequisites are installed. Below is a list of required software needed to run the software as a standalone or within an integrated-development environment (IDE).

- Java OpenJDK or Oracle Java version 11 or better.
- Eclipse Integrated Development Environment or similar IDE for running Java software.

Additionally, to use GW software’s network information retrieval features, e.g., Supplemental Data Service Providers, Messaging Queue Telemetry and Transport, or to run a playback and connect to the vehicle, the computer hosting GW must be able to connect to these services as described in [10].

GroundWatch uses a 4-step workflow modeled from a flight operation. The activities for these 4 steps (Startup, Pre-flight, In-Flight, and Post-Flight) are described in the Table 2. The user panels for these activities are described in subsequent sections in this document. It should be noted that the on-board and/or the SDSP systems are up and running prior to leaving the Startup step of the workflow.

*Table 2: GroundWatch usage workflow*

<b>Startup →</b>	<b>Pre-Flight →</b>	<b>In-Flight →</b>	<b>Post-Flight</b>
1) Starting the GroundWatch software. 2) Selecting Live or Playback operation 3) Loading Mission Description files (MCF, Obstacle Model, Terrain Model, Population Model)	1) Review/Modify Flight number. 2) Review/Modify Vehicle parameters. 3) Review/Modify SDSP parameters. 4) Connect to vehicle. 5) Upload Mission Configuration files to the vehicle.	1) When ready, engage the in-flight button to notify on-board software to enter in-flight mode. 2) Monitor test activity. The display panels of interest will depend on the objective of the testing. (See Section 7)	1) Close the flight.

## 5 Starting the GroundWatch Application

---

Starting GW is the first step in the cluster of activities in the “**Startup**” portion of the GW workflow given in Table 2. To execute the application, run the main method within the class located at:

**InstallDirectory>> gov/nasa/larc/GroundWatch.java**

Alternatively, the user may run the standalone jar file located within the root directory of the project by double clicking the **GroundWatch\_1.0.jar** file.

### 5.1 Select GroundWatch Session Type

---

Once the application starts, the user will need to select the session type. If the user plans to run a simulated flight of playback data, select the “Playback” option. If the user wants to connect to a vehicle in real-time, select the “Live” option.

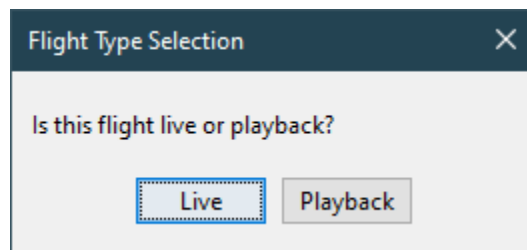


Figure 5.1: Flight Type Selection Window

After selecting a session type, the initialization screen appears showing the status of the user interface and the server connections. This screen will indicate whether the SDSPs (supplemental data service providers) and MQTT (Messaging Queue Telemetry and Transport) servers have been successfully accessed. The user will need to press the “OK” button to continue into the main user panels.

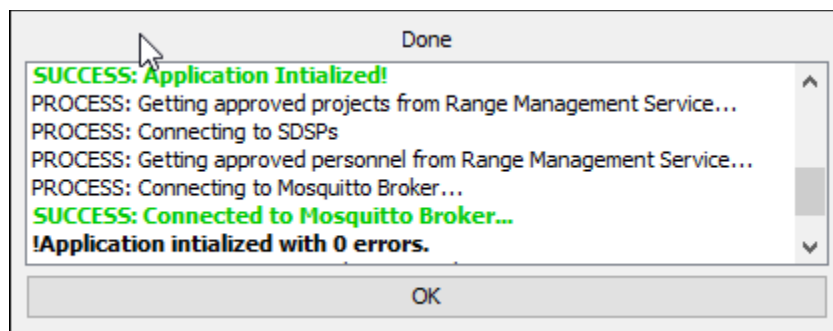


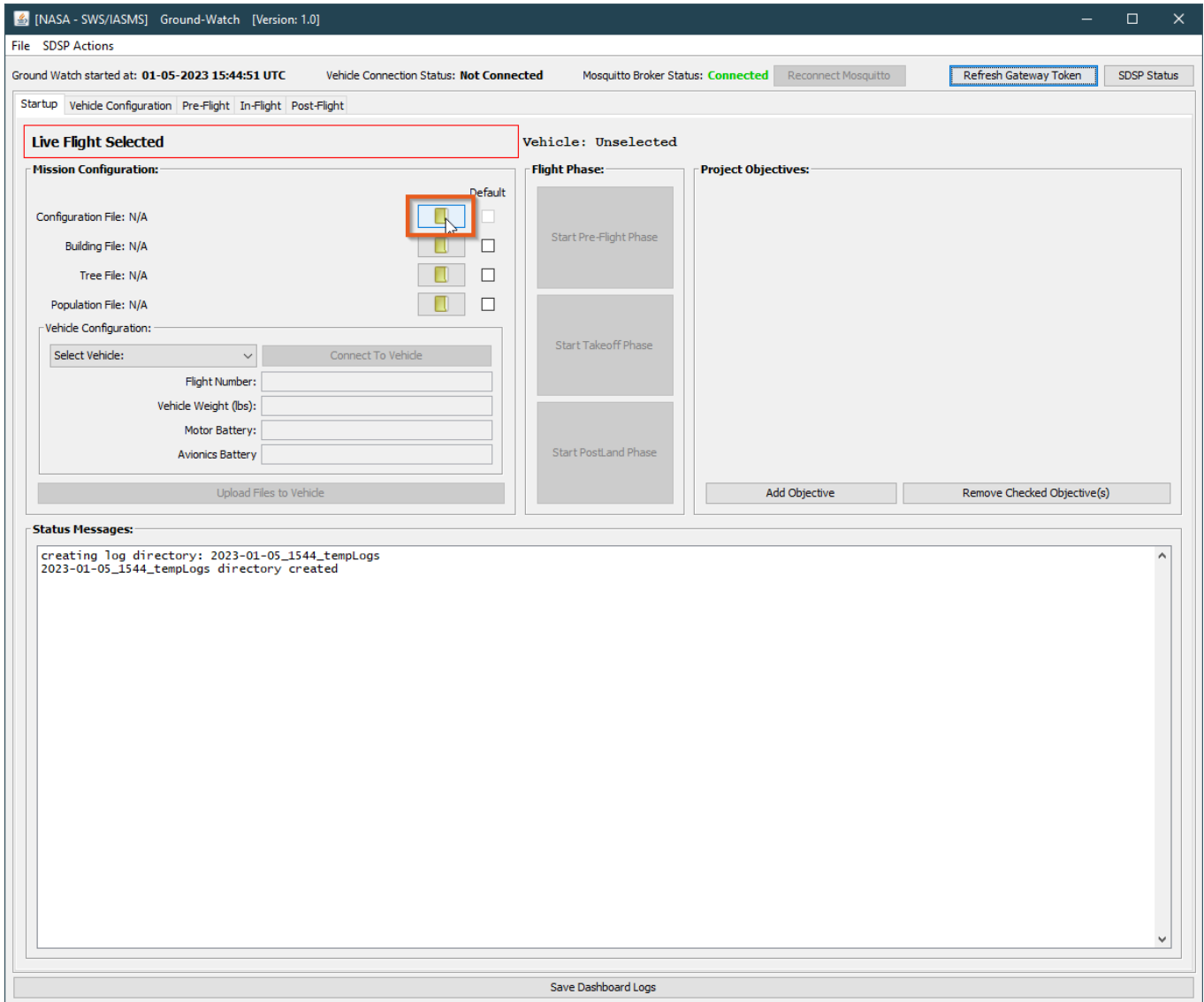
Figure 5.2: Initialization Window

## 6 Preflight Checks

---

**“Preflight”** checks are the second cluster of activities in the GW workflow as given in Table 2. This section can be skipped if the preflight checks are already complete. See “Connecting to the Vehicle” section to continue. Preflight checks are typically done during the creation of the Mission Configuration File within the Operations Planning Software.

To start the preflight checks, the user must initially select the Mission Configuration File that will be used during the live flight or playback session. This can be done by selecting the folder icon next to the Configuration File section in the Mission Configuration panel on the Startup tab shown below in Figure 6.1.



*Figure 6.1: Location of Mission Configuration file opener in Startup Panel*

Once the file has been selected and loaded into the interface, the user will select the “Vehicle Configuration” tab to begin the preflight checks. The data in the vehicle configuration tab will be prefilled with the information from the Mission Configuration File such as available vehicles, batteries used, flight plans, services used, etc.

## 6.1 Vehicle Configuration Panel

Within the Vehicle Configuration panel (Figure 6.2), the user can select a vehicle and define thresholds applied to parameters in various supplemental data service providers (SDSPs). These vehicles must be previously defined in the Mission Configuration File.

1. Select a vehicle panel, by clicking on its corresponding tab.
2. Select and modify information in the SDSP Details and On-Board details panel.

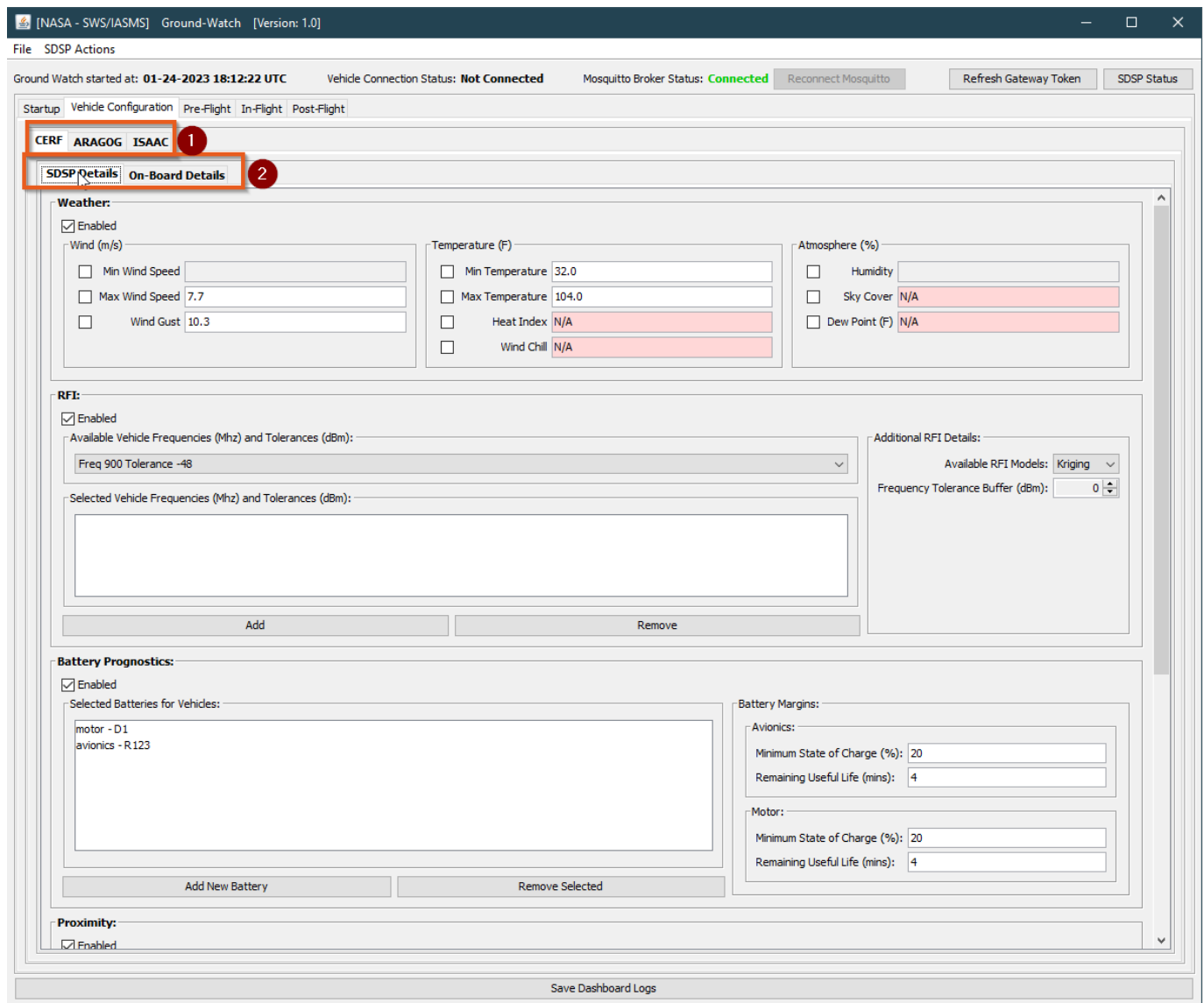


Figure 6.2: Vehicle Configuration Panel - Vehicle Selection

### 6.1.1 SDSP Details Panel

Through the SDSP Details panel, the user can define the vehicle’s thresholds for the various SDSPs that will be used during flight. Since this tool is for planning the flight, much of the inputs are used with forecasted data instead of live data. The different services provided include Weather, Radio-Frequency Interference (RFI), Battery Prognostics (BP), Proximity to Threat (PtT), Ground Risk Assessment (GRASP), and Navigation Quality (Nav-Q). Each of the services can be set to “Enabled” using the checkbox; this will indicate on the Mission Configuration File output that this service is intended to be used during the flight.

#### 6.1.1.1 Weather

The screenshot shows the 'Weather' configuration panel. It is titled 'Weather:' and has a checked 'Enabled' checkbox. Below this, there are three columns of settings, each with a checkbox and a text input field. The first column is 'Wind (m/s)' with 'Min Wind Speed' (checkbox), 'Max Wind Speed' (checkbox, value 7.7), and 'Wind Gust' (checkbox, value 10.3). The second column is 'Temperature (F)' with 'Min Temperature' (checkbox, value 32.0), 'Max Temperature' (checkbox, value 104.0), 'Heat Index' (checkbox), and 'Wind Chill' (checkbox). The third column is 'Atmosphere (%)' with 'Humidity' (checkbox), 'Sky Cover' (checkbox), and 'Dew Point (F)' (checkbox).

Figure 6.3: Vehicle Configuration – Weather SDSP Constraints

The Weather SDSP requires setting input parameters to determine where a hazard may occur (Figure 6.3). By default, many of these parameters are set according to the data within the vehicle table in the range management service (RMS). To add additional parameters or override existing values, check the box beside the given value and input the desired value.

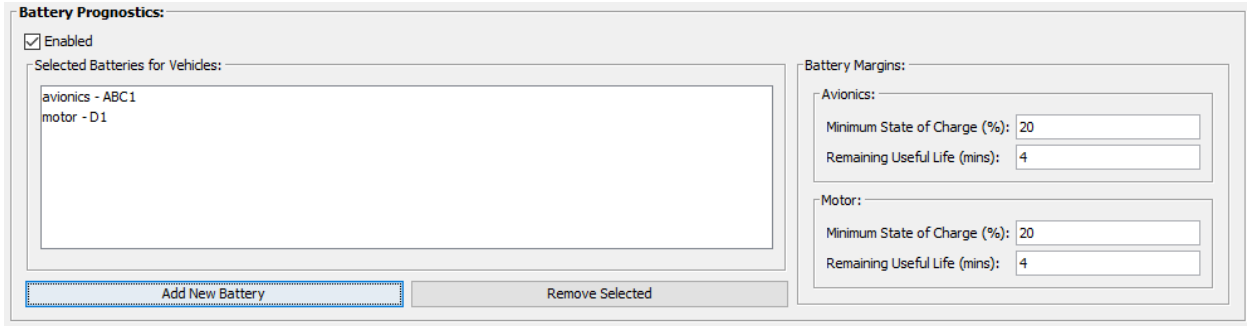
#### 6.1.1.2 RFI (Radio Frequency Interference)

The screenshot shows the 'RFI' configuration panel. It is titled 'RFI:' and has a checked 'Enabled' checkbox. Below this, there are two main sections. The first is 'Available Vehicle Frequencies (Mhz) and Tolerances (dBm):' with a dropdown menu showing 'Freq 900 Tolerance -48'. Below this is 'Selected Vehicle Frequencies (Mhz) and Tolerances (dBm):' with a list box containing 'Freq 900 Tolerance -48'. At the bottom of this section are 'Add' and 'Remove' buttons. The second section is 'Additional RFI Details:' with 'Available RFI Models:' set to 'Kriging' and 'Frequency Tolerance Buffer (dBm):' set to '3'.

Figure 6.4: Vehicle Configuration – RFI SDSP Constraints

The RFI SDSP requires the user to select from the available vehicle frequencies and add them to the selected list using the “Add” button to check from potential hazards (Figure 6.4). The RFI model selection allows the user to determine which database to obtain frequency data from and the Frequency Tolerance Buffer allows the user to obtain data within a specified buffer range around the tolerance value specified by the available vehicle frequencies.

### 6.1.1.3 BP (Battery Prognostics)



**Battery Prognostics:**

Enabled

Selected Batteries for Vehicles:

- avionics - ABC1
- motor - D1

**Battery Margins:**

Avionics:

Minimum State of Charge (%):

Remaining Useful Life (mins):

Motor:

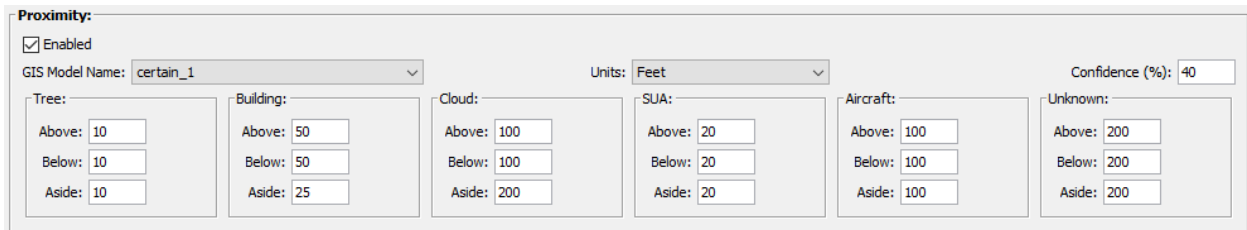
Minimum State of Charge (%):

Remaining Useful Life (mins):

Figure 6.5: Vehicle Configuration – BP SDSP Constraints

The BP SDSP requires users to select a battery for the available vehicle systems on-board. By selecting the “Add New Battery” button, the user can select the system and battery based upon data on the Battery Management Service (BMS) database. The user is not allowed to add the same battery to more than one vehicle or system. The user can then set the minimum state of charge and remaining useful life values for each of the systems. These values will be used to alert the user if there are any locations within the flight plan in which these thresholds are met or exceeded.

### 6.1.1.4 PtT (Proximity to Threat)



**Proximity:**

Enabled

GIS Model Name:

Units:

Confidence (%):

Tree:	Building:	Cloud:	SUA:	Aircraft:	Unknown:
Above: <input type="text" value="10"/>	Above: <input type="text" value="50"/>	Above: <input type="text" value="100"/>	Above: <input type="text" value="20"/>	Above: <input type="text" value="100"/>	Above: <input type="text" value="200"/>
Below: <input type="text" value="10"/>	Below: <input type="text" value="50"/>	Below: <input type="text" value="100"/>	Below: <input type="text" value="20"/>	Below: <input type="text" value="100"/>	Below: <input type="text" value="200"/>
Aside: <input type="text" value="10"/>	Aside: <input type="text" value="25"/>	Aside: <input type="text" value="200"/>	Aside: <input type="text" value="20"/>	Aside: <input type="text" value="100"/>	Aside: <input type="text" value="200"/>

Figure 6.6: Vehicle Configuration – Proximity SDSP Constraints

The Proximity SDSP requires the selection of various input values to be used in determining the vehicles’ location relative to objects within the flying area given a specified flight plan. The user will select a geographic information system (GIS) model that contains footprints for buildings and trees along with the desired units and the confidence value in positioning from the obstacles. Currently, there is not a way for the user to add any additional GIS Model data; to inquire about adding data, use the contact information at the end of this guide. The distance thresholds for each type of object can be specified for above, below, and aside. The user will be alerted based upon these values.

6.1.1.5 GRASP (Ground Risk Assessment Service Provider)

---

The screenshot shows a configuration panel titled "Population Risk". It contains a checked checkbox labeled "Enabled" and a text input field labeled "Probability of Casualty Threshold (%)" with the value "50" entered.

Figure 6.7: Vehicle Configuration – GRASP SDSP Constraints

The GRASP SDSP allows the user to gain situational awareness of any highly populated areas that the vehicle may be flying over. The user will set the value of the Probability of Casualty Threshold to receive hazard warnings related to high population risk due to vehicle failure.

6.1.1.6 Nav-Q (GPS Navigation Quality)

---

The screenshot shows a configuration panel titled "GPS Navigation Quality". It contains a checked checkbox labeled "Enabled" and several input fields: "Unit Name" with the value "Primary", "Satellites in View Warning Threshold" with the value "8", "Satellites in View Failure Threshold" with the value "6", "Horizontal Dilution of Precision Warning Threshold" with the value "5", and "Horizontal Dilution of Precision Failure Threshold" with the value "10".

Figure 6.8: Vehicle Configuration – Nav-Q SDSP Constraints

The Nav-Q SDSP requires input regarding the number of visible satellites and the Horizontal Dilution of Precision (HDOP) values. These values represent the minimum requirements for the vehicle’s GPS receiver to resolve accurate positions. They may also represent the threshold that the operator would like to be alerted. For a given flight plan, the vehicle may be in areas with a limited number of satellites in view, the SDSP will return areas in which this value has been met or exceeded.

## 6.2 On-Board Details Panel

The on-board details panel contains specific information about the vehicle obtained from the RMS database. Additionally, the user can specify the “Safe to Land Power Threshold” and the “Post Flight Recording Period”. These two values are currently not being used and are a place holder for a future version of this software.

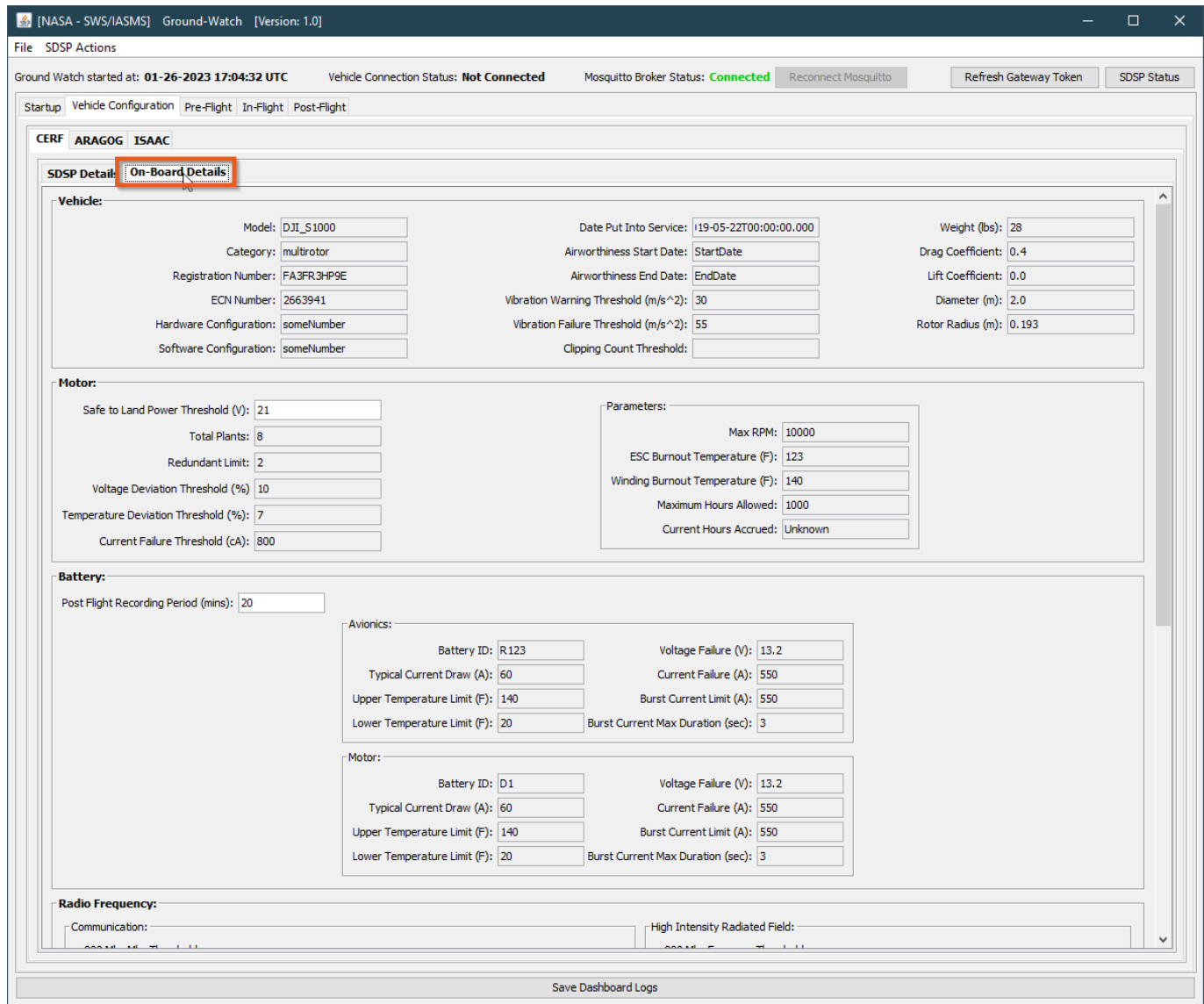


Figure 6.9: Vehicle Configuration – On-Board Details Panel

### 6.3 Pre-Flight Panel

The Pre-Flight Planning Panel (Figure 6.10) is used during the flight planning and pre-flight phase of the operations workflow (Figure 2.1) to determine if an intended flight plan meets available safety metrics. It allows the user to iteratively adjust the flight plan based on safety metrics checks from multiple SDSPs, to obtain the best flight path for a given vehicle and set of objectives. Each Supplemental Data Services buttons, in the SDSP section of the pre-flight panel (Figure 6.10), allows the user to assess hazards based on corresponding thresholds from the Service Details panel, as described in Section 6.1.1. If the button is not enabled, that means that the GroundWatch application has determined that the service is not reachable and, therefore, cannot be used to assist in pre-flight planning. The map view, by default, automatically adds the flight plan for each of the vehicles included in the selected Mission Configuration File.

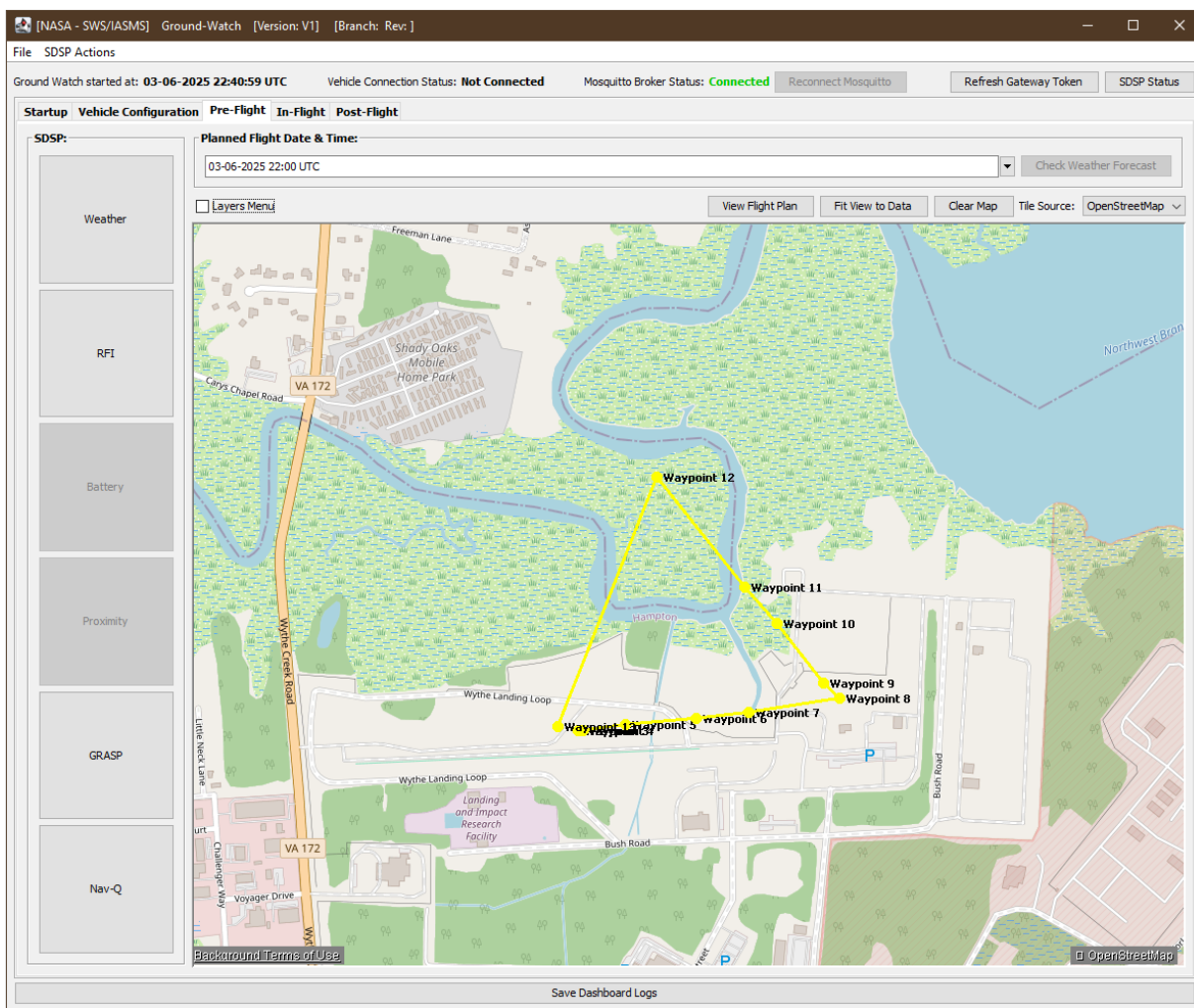


Figure 6.10: Pre-Flight Panel. Map view provided by OpenStreetMap [13]

If the vehicle does not have a flight plan and the user would like to create or modify the existing flight plan, the process below describes how to do this. For this GW release, a flight plan may be created using Mission Planner™ [12] software. The waypoints file is then added to a layer (Section 6.3.4) during the analysis.

The following outlines the procedure for analyzing a flight plan to verify that it meets safety metrics before flying the vehicle. Additional details for each step are given in Section 6.3.9. Note that the first few steps fetch data prior to loading the flight plan.

1. Determine the date and time of the flight that shows in the Planned Flight Date & Time textbox; steps are described in the next section “Select flight date and time”.
  - a. Check the weather forecast and make sure that the input values are those desired.
2. Run the Weather SDSP by clicking the Weather Button.
3. Run the RFI SDSP by clicking the RFI Button.
4. Add user’s desired flight plan using the “Add Layer” button within the “Layers Menu”.
5. Run the Battery Prognostics SDSP using the Battery Button.
6. Run the Proximity SDSP using the Proximity Button.
7. Run the GRASP SDSP using the GRASP Button.
8. Run the Nav-Q SDSP using the Nav-Q Button.
9. Check that user’s flight plan falls within the desired parameters, if not, adjust flight plan and start again from number 4.

The next section will explain in detail how to use each of the services and manipulate the map layers.

### 6.3.1 Selecting Flight Date and Time

---

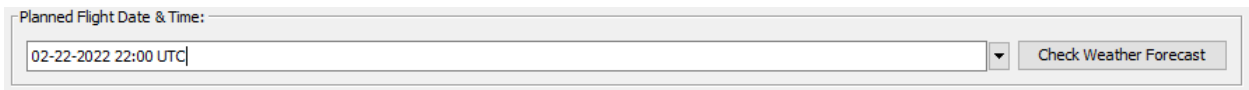


Figure 6.11: Pre-Flight – Select Planned Flight Date & Time

First, select a date and time from the down arrow selection with the date time picker.

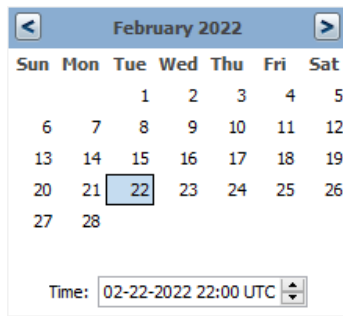


Figure 6.12: Date & Time Picker

If using the Weather SDSP, be sure not to go beyond the forecast window. Ideally, the planned flight date and time will be within 5-7 days. Once the user has selected an appropriate date and time, the weather forecast for the given time can be checked by clicking the “Check Weather Forecast” button.

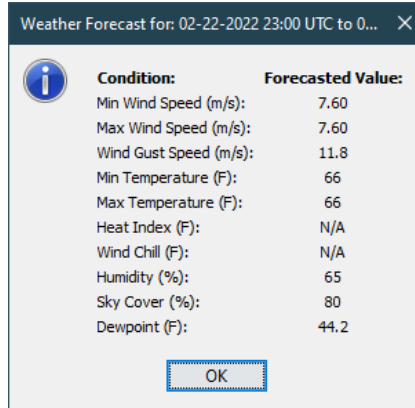


Figure 6.13: Weather Forecast

If the selected date time's weather forecast values look good the user can move on to the Supplemental Data Services.

### 6.3.2 Weather SDSP

By clicking the Weather button under the Supplemental Data Services section, the user can check the weather forecast against a chosen vehicle's weather thresholds and obtain any potential hazardous locations within the flying range.

Select a vehicle:

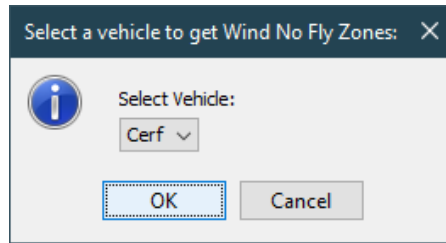


Figure 6.14: Weather SDSP – Select Vehicle

Verify forecast against thresholds:

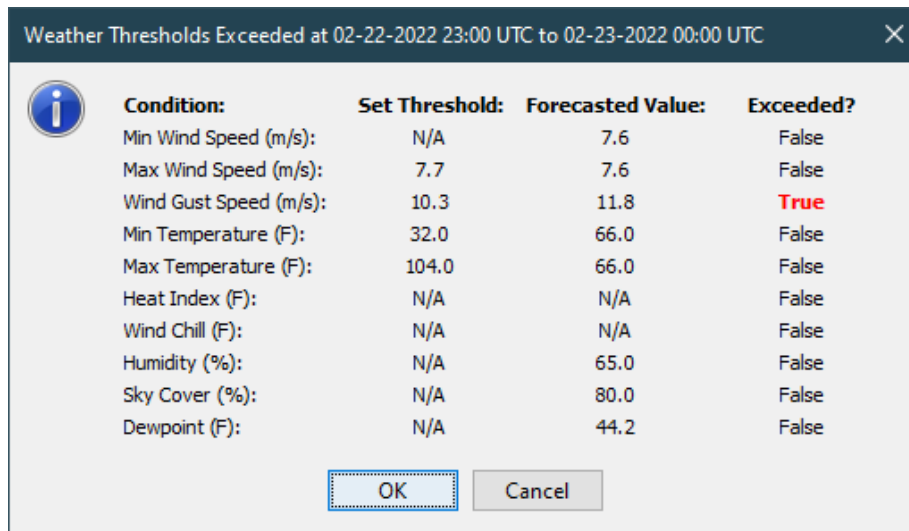


Figure 6.15: Weather SDSP – Check Weather Forecast

Select the wind model from which to obtain hazard polygons.

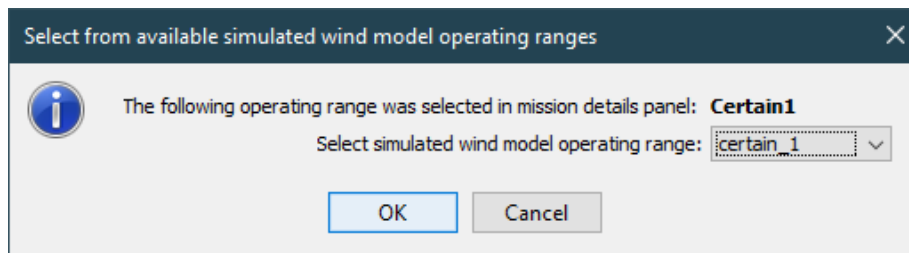


Figure 6.16: Weather SDSP – Select Wind Model

Choose an altitude separation value. This value represents the z-value distance between the 2D layers denoting potential wind hazards.

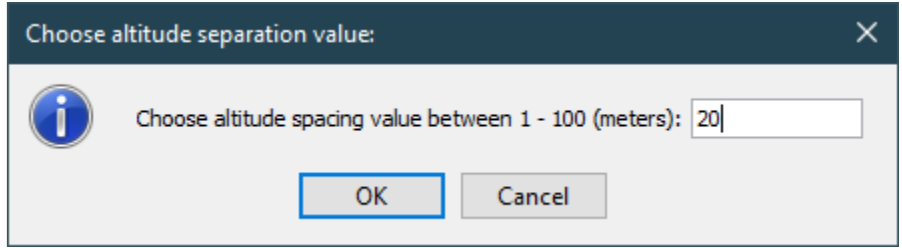


Figure 6.17: Weather SDSP – Select Altitude Spacing

After selecting OK, the Ground Watch application will make a request to the WIND SDSP located on the chosen server and attempt to obtain any hazardous polygons within the selected wind model. This will be indicated by a popup showing that it is processing.

If there are any polygons to display, they will be shown within the map viewing panel as seen in Figure 6.18 below.

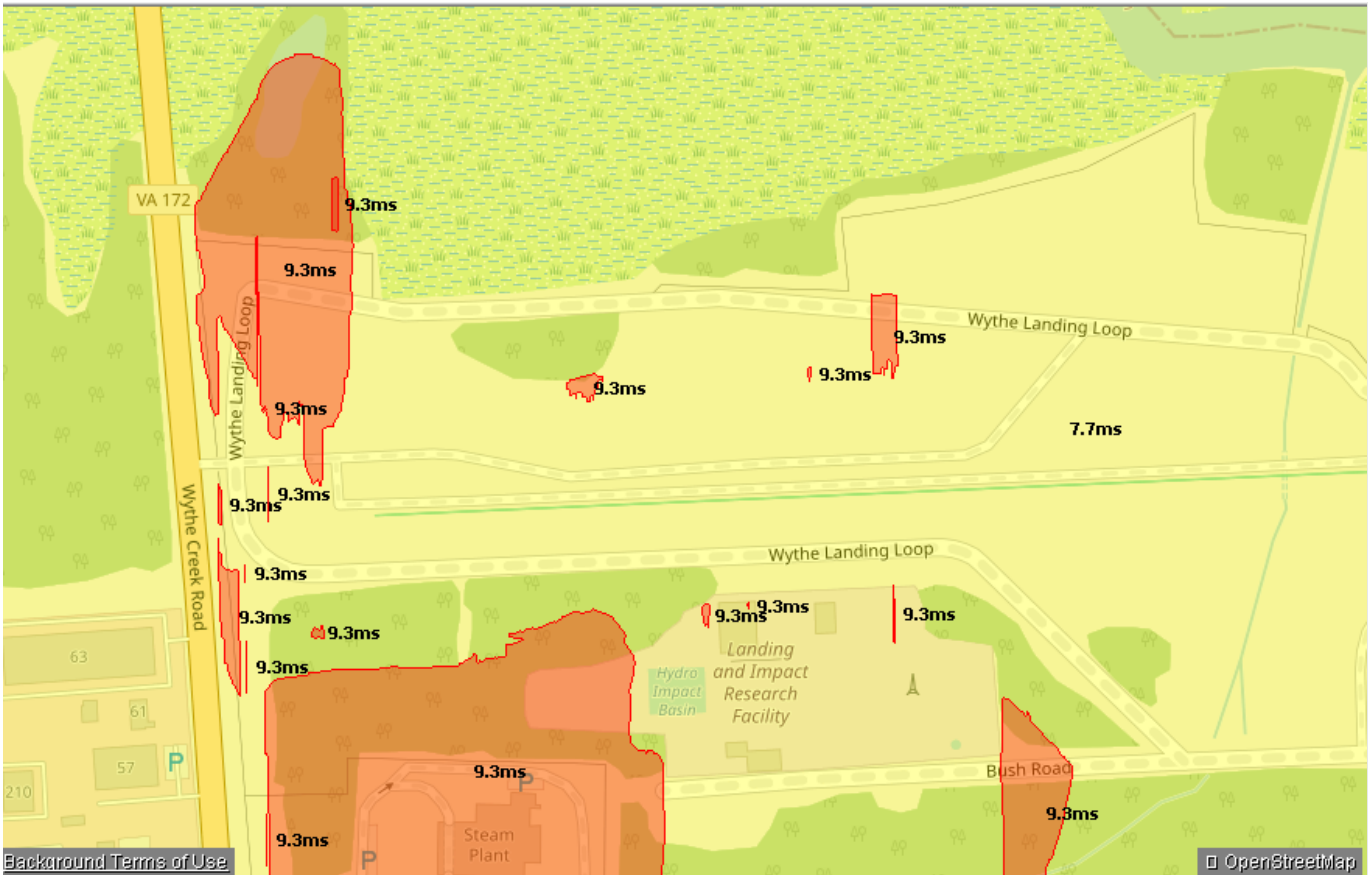


Figure 6.18: Weather SDSP – Hazards - Map view provided by OpenStreetMap [13]

Yellow polygons indicates that the wind speed at those locations is at the threshold while red polygons indicate that the wind speed is above the threshold. Note in Figure 6.18 that the entire area displayed is under a yellow wind caution threshold. The number of layers added depends on the altitude separation value specified earlier. Since the wind model only contains values from 1 meter to 100 meters altitude, the separation value can limit the amount of return.

By clicking the RFI button under the Supplemental Data Services section, the user can obtain polygons for potential RFI hazard areas for a selected vehicle and frequency tolerance combination.

Select a vehicle:

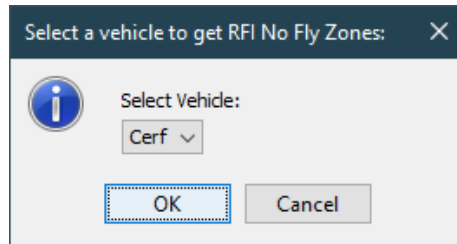


Figure 6.19: RFI SDSP – Select Vehicle

Select a frequency:

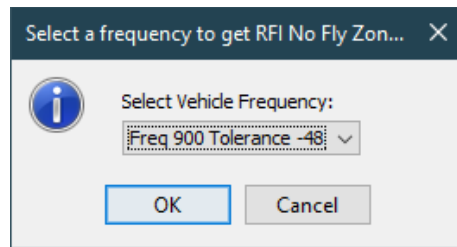


Figure 6.20: RFI SDSP – Select Frequency

After selecting OK, the Ground Watch application will request all available data using the input values from the selected frequency and tolerance values with the buffer value applied from the Service Details panel. This will be indicated by a popup showing that it is processing.

If there are any polygons to display, they will be shown within the map viewing panel in Figure 6.21.

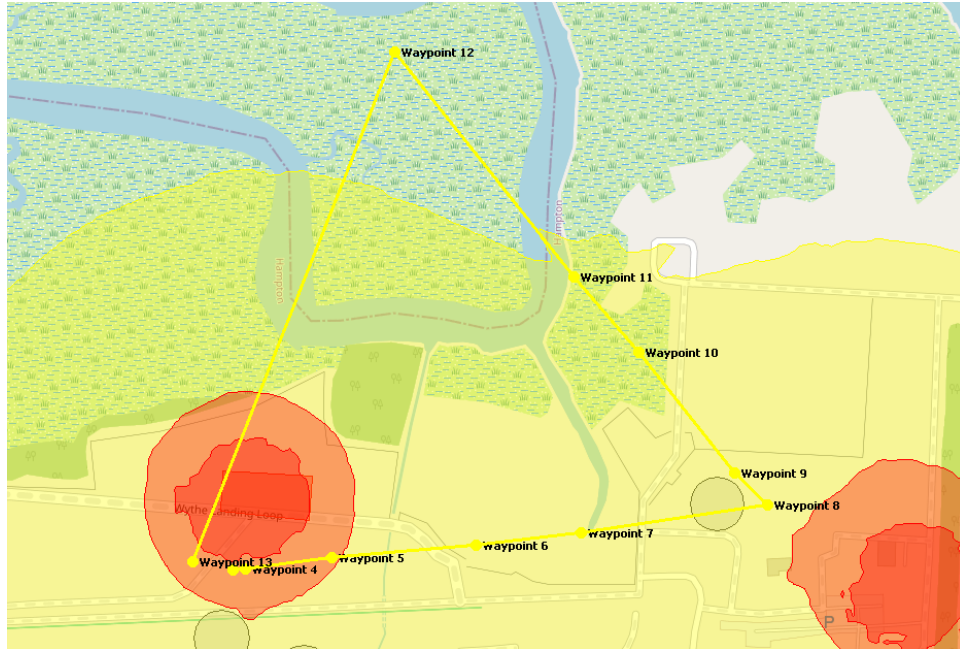


Figure 6.21: RFI SDSP – Hazards - Map view provided by OpenStreetMap [13]

Multiple layers can be seen for individual altitude layers that are available in the database. For each layer shown, the red polygons represent areas in which the dBm values are above the threshold value and the yellow polygons indicate areas in which the dBm values are at or below the tolerance and at or above the buffer value.

### 6.3.4 Using the Layers Menu

After running the Wind and RFI SDSPs, the user's flight plan can be analyzed with regards to the displayed hazard data. To add the flight plan to the map, the user must check the "Layers Menu" checkbox to see the current layers added to the map and gain access to the Add and Remove Layer buttons.

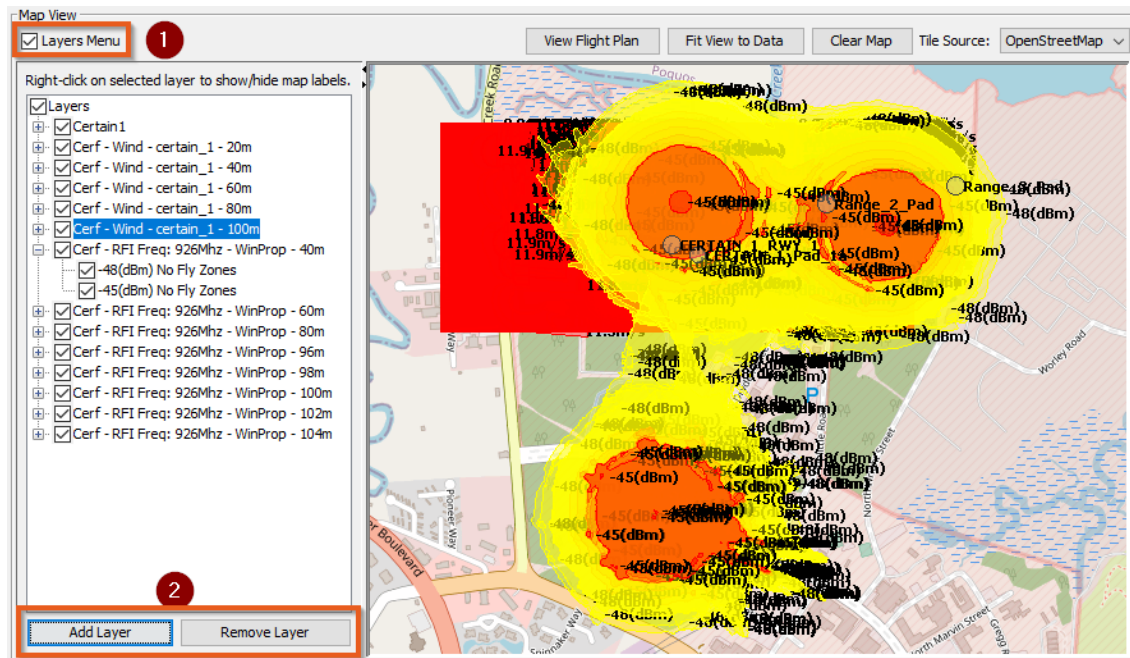


Figure 6.22: Pre-Flight – Add a Layer - Map view provided by OpenStreetMap [13]

1. After clicking the "Layers Menu" checkbox, the Layer Tree window will appear. Each layer can be manually turned on and off using the respective checkboxes. By right clicking a layer, the labels may be turned on or off, or the layer may be removed. Additionally, the layer can be removed by selecting it and clicking the "Remove Layer" button.
2. Clicking the "Add Layer" button brings up a new window that will prompt the user to select which type of layer to add. The options are explained below.

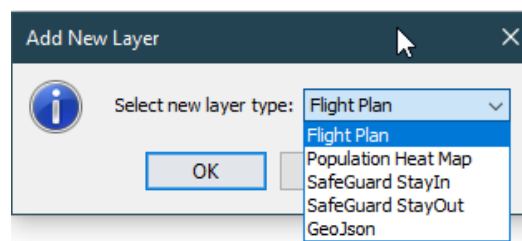


Figure 6.23: Pre-Flight – Select Layer Type

- a. Flight Plan – the types of flight plans that are currently allowed to be added include:
  - i. MAVLINK [11] Mission Planner flight plan output.
  - ii. JSON Flight Plan
  - iii. KML

- b. Population Heat Map – A csv file that contains latitude and longitude points with an identifier for the population at that point.
- c. SafeGuard StayIn – A single polygon provided in safeguard format to denote the boundary for the vehicle to stay within.
- d. SafeGuard StayOut – A set of polygons provided in safeguard format to denote the boundaries of areas to keep out of.
- e. GeoJson – A standard GeoJSON file. This is mostly used to add building and tree polygons to the map viewer.

Once the user has supplied a flight plan to the file chooser in one of the acceptable formats, the waypoints will be added to the map as shown below in Figure 6.24.

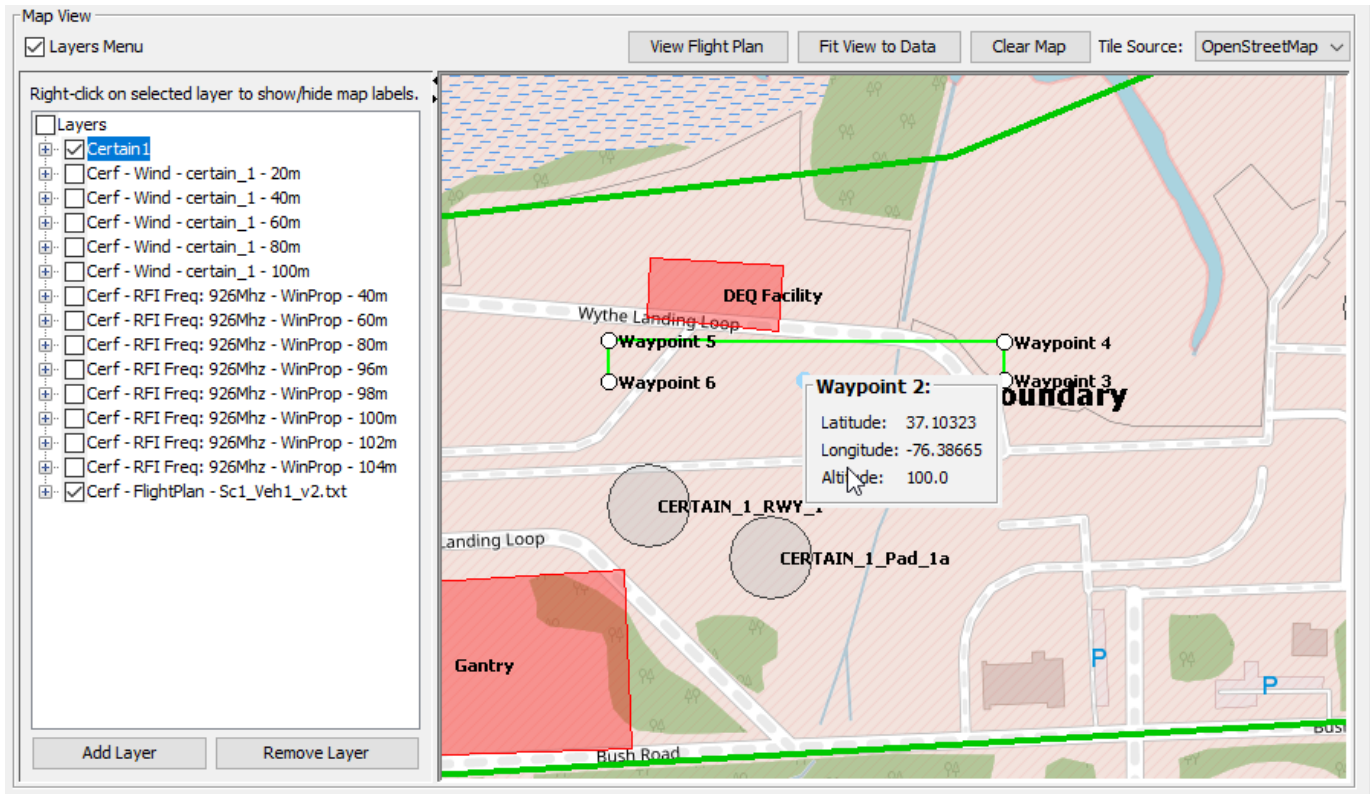


Figure 6.24: Pre-Flight – Flight Plan Layer - Map view provided by OpenStreetMap [13]

The flight plan will be added to the Layers Menu with the selected vehicle’s name as a prefix. Each of the waypoints can be selected on the map to get more details. If necessary, the flight plan can be viewed in all its given details within the “View Flight Plan” button.

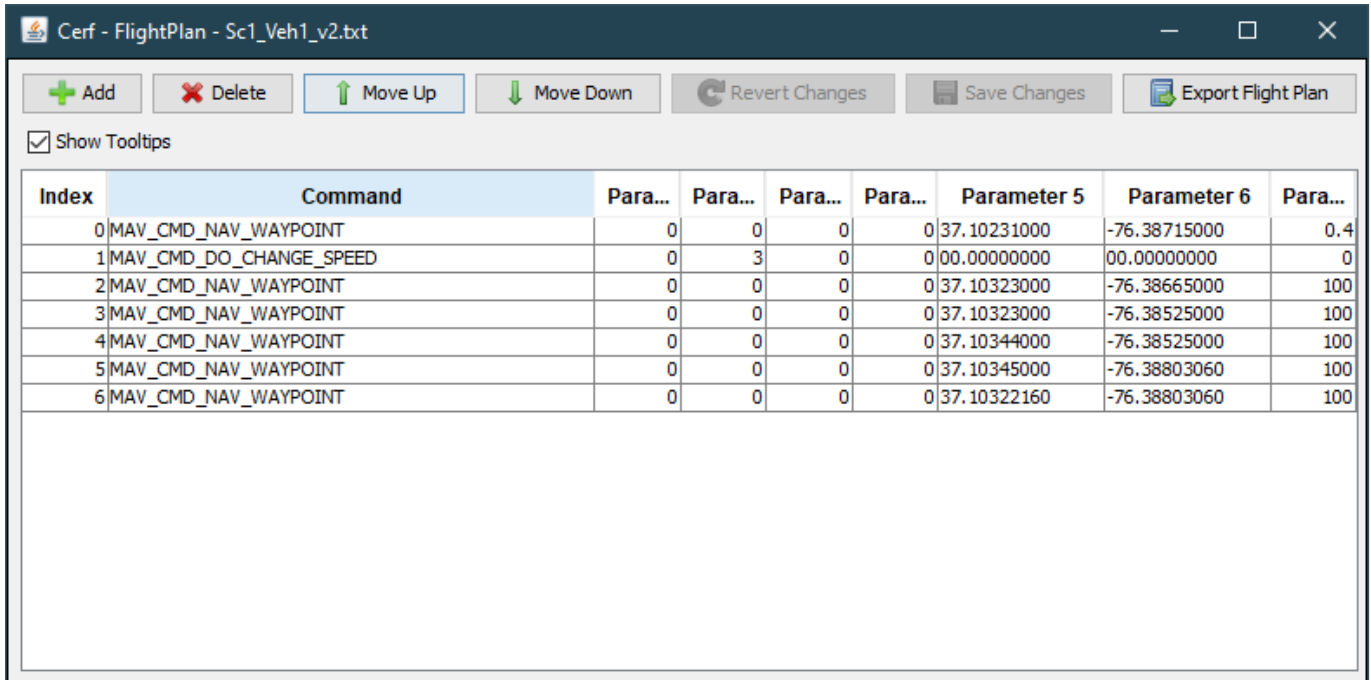


Figure 6.25: Pre-Flight – Flight Plan Editor

This view will allow the user to manually edit any of the flight plan data via the “Add”, “Delete”, “Move Up”, and “Move Down” buttons. Additionally, each table value can be selected and edited using manual entry. Once any changes have been made, the user must click the “Save Changes” button to apply the changes. This action will add a new layer to the map using the same naming convention as before but adding an additional suffix to the layer name to indicate that it is edited from the original. The original flight plan will remain on the layers menu so that the user can backtrack the changes if needed. If the user has made changes but does not want to save them, then the user may use the “Revert Changes” button to return all values to their original values.

Lastly, the user may need to export the flight plan into various formats for other use cases outside of the Ground Watch application. This may be done by selecting the “Export Flight Plan” button. The export options are explained below:

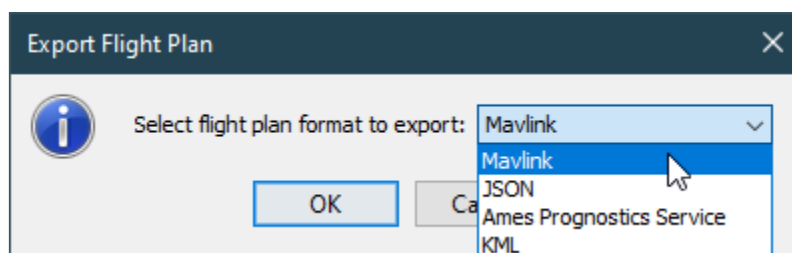


Figure 6.26: Pre-Flight – Flight Plan Export

1. MAVLINK – This is the standard output format of the Mission Planner application.
2. JSON – This is a popular format used in various applications.
3. Ames Prognostics Service – this is the format used by Ames Battery Prognostics and Proximity services.
4. KML – This format works within various Google Applications.

There are many more layer-types, export-types, and flight plan input types planned to be added in the future.

### 6.3.5 Battery Prognostics SDSP

---

Will be implemented in a later version.

### 6.3.6 Proximity SDSP

---

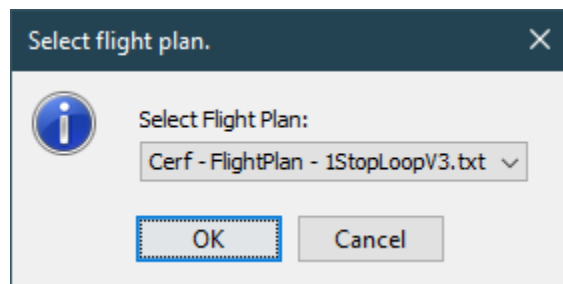
Will be implemented in a later version.

### 6.3.7 GRASP SDSP

---

By clicking the GRASP button under the Supplemental Data Services section, the user can obtain the potentially hazardous areas along the flight path that fall within the specified ground risk casualty threshold entered in the service details panel.

Select a flight plan:



*Figure 6.27: GRASP SDSP – Select Flight Plan*

After selecting OK, the Ground Watch application will make a request to the GRASP server to send back data that exceeds the ground risk casualty threshold along the selected flight plan.

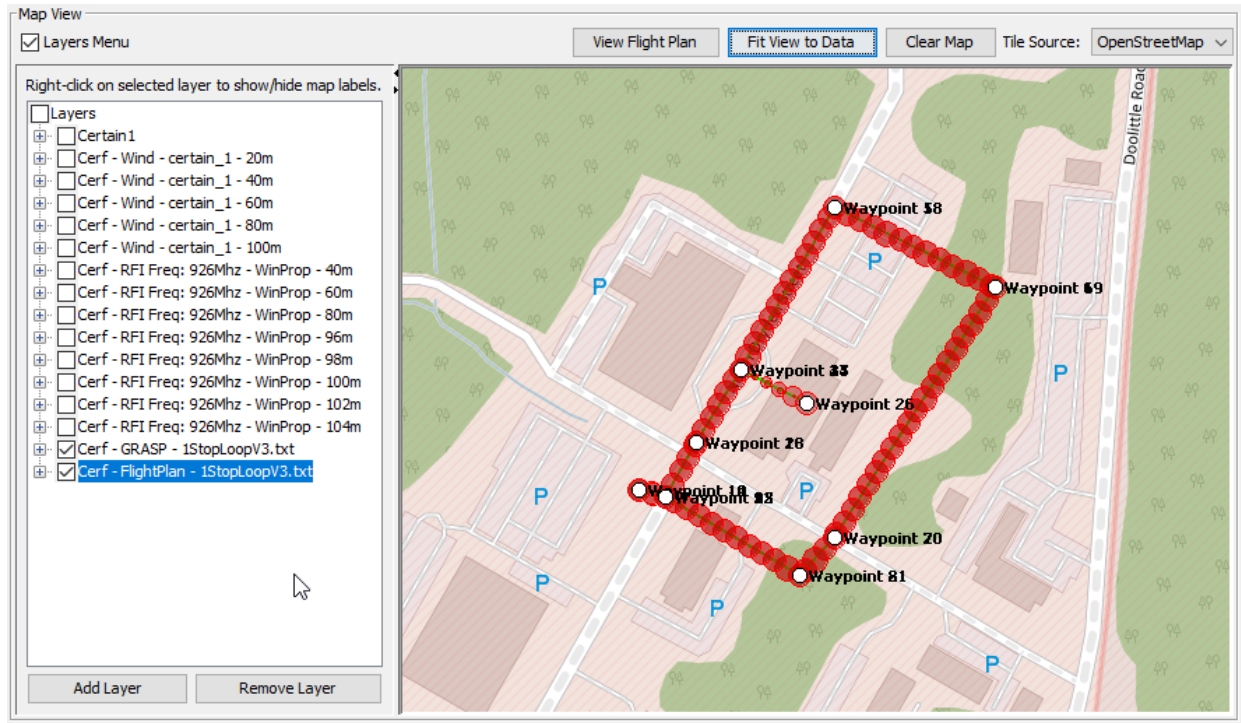


Figure 6.28: GRASP SDSP – Layer View - Map view provided by OpenStreetMap [13]

Shown above, is the resulting output of specifying a ground risk casualty of “-1”. This will return all possible values along the flight plan. The impact radius and probability of casualty can be seen by clicking on any of the GRASP return circles shown in Figure 5.28.

### 6.3.8 Nav-Q SDSP

By clicking the Nav-Q button under the Supplemental Data Service section, the user can obtain the potentially hazardous locations throughout the flight plan that will result in a low-quality GPS signal. The warnings are directly related to the thresholds set on the service details panel regarding the satellites in view warning threshold. Each of the returned points (shown as green dots on the map) are locations in which the number of satellites in view are lower than the set threshold value.

Select a flight plan:

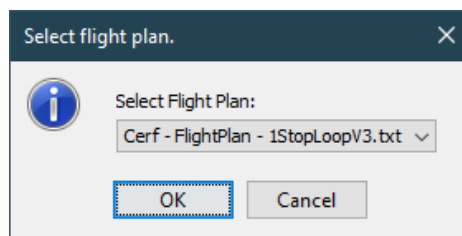


Figure 6.29: Nav-Q SDSP – Select Flight Plan

After selecting OK, the Ground Watch application will make a request to the Nav-Q server to send back data that represents a potential risk due to low satellites in view.

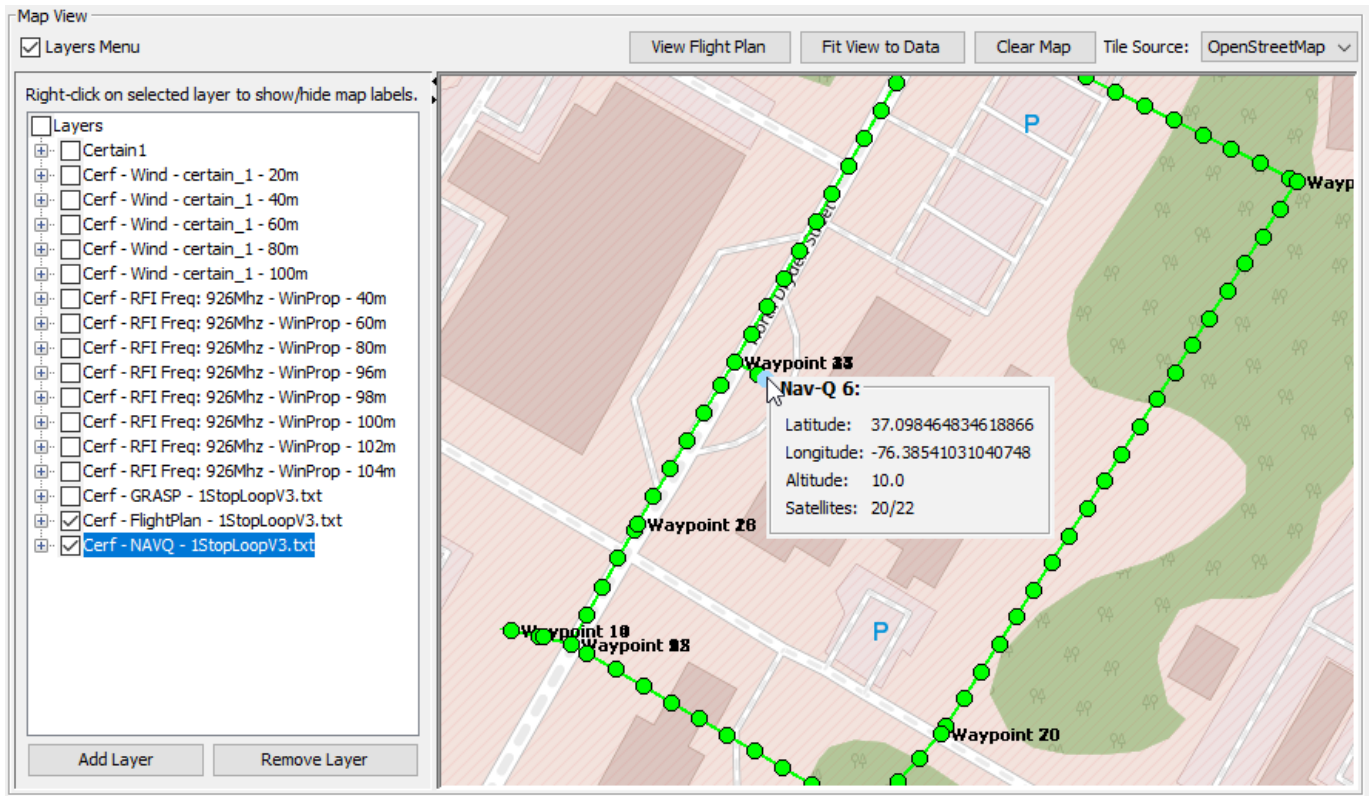


Figure 6.30: Nav-Q SDSP – Layer View - Map view provided by OpenStreetMap [13]

Shown in Figure 6.30 is the resulting output from the Nav-Q service given a specified number of satellites in view warning threshold of 50. The clicked marker shows the position and the number of satellites in view out of the available satellites.

### 6.3.9 Ideal Workflow for Creating Usable Flight Plan

Using the Ground Watch application is an iterative process that requires the user to constantly adjust and rerun multiple processes to obtain the level of safety mitigation required for a given mission.

Assuming the user has finalized the Mission Details, Personnel, and Service Details panels, the Flight Planning panel will be the most heavily used in creating the flight plan.

The suggested workflow is as follows:

1. Select flight date and time.
  - a. Check the weather – If not good, select a new date and time.
2. Run the Weather SDSP
  - a. Check vehicle thresholds against forecast values.
  - b. Obtain hazard polygons.

3. Run the RFI SDSP
  - a. Obtain hazard polygons.
4. Add user generated flight plan from alternate source.
  - a. Check flight plan's location relative to Wind and RFI and make determination on any changes that may need to occur and reload or edit flight plan as needed.
5. Run the Battery SDSP
  - a. Check that the flight plan allows the user to maintain the flight within battery thresholds.
  - b. Edit flight plan as needed.
6. Run the Proximity SDSP
  - a. Check that the flight plan allows vehicle to maintain appropriate distance from objects of interest.
  - b. Adjust flight plan if necessary.
    - i. NOTE: Any adjustment at this point will require user to rerun the Battery SDSP as well.
7. Run the GRASP SDSP
  - a. If there are any returns, user must make determination of acceptable risk.
  - b. Adjust flight plan as needed.
    - i. NOTE: Any adjustment at this point will require user to rerun Battery and Proximity SDSPs.
8. Run the Nav-Q SDSP
  - a. If there are any returns, user must make determination of acceptable risk.
  - b. Adjust flight plan as needed.
    - i. NOTE: Any adjustment at this point will require user to rerun Battery, Proximity, and GRASP SDSPs.
9. Finalize the flight plan and move on to the next vehicle if needed.

## 7 Connecting to the Vehicle

---

As given in Table 2, Pre-Flight column, connecting to the vehicle computer system should be performed after the user has completed the preflight checks as outlined in section 6.3.9. This ensures that the mission still meets all safety metrics given the updated conditions (date, time) of the operation. The safety checks summarily include:

- 1) Updating date and time of operation and confirming appropriate vehicle safety thresholds for operating conditions
- 2) Confirming weather conditions, and other SDSP warning thresholds for the operations date and time
- 3) flight plan is clear of hazards.

As illustrated in Figure 3.2, GW can be run in playback mode or live mode. In both cases, a computer hosting the flight code is expected as part of the runtime environment for GW. From the GW perspective, the computer running the flight code is the vehicle. Connecting to the computer is, in essence, connecting the ground station to the flight vehicle. To setup the vehicle to receive a connection from the GroundWatch software, the user must confirm that the cFS (Core Flight Systems) based flight software running on the vehicle's computer. More information on the flight software is given in [10].

### 7.1 Configuring the Vehicle Connection Settings

---

Use the "Settings" Menu located under the File -> Settings menu tab.

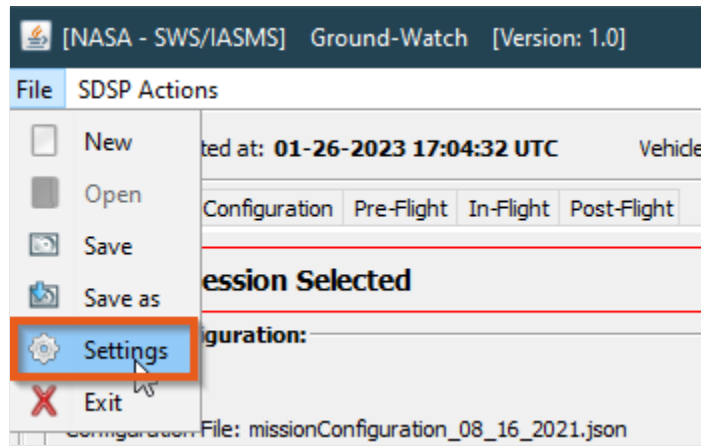


Figure 7.1: Vehicle Settings – Settings Selection

The user can specify the host address and the port number for which the vehicle's on-board application is listening.

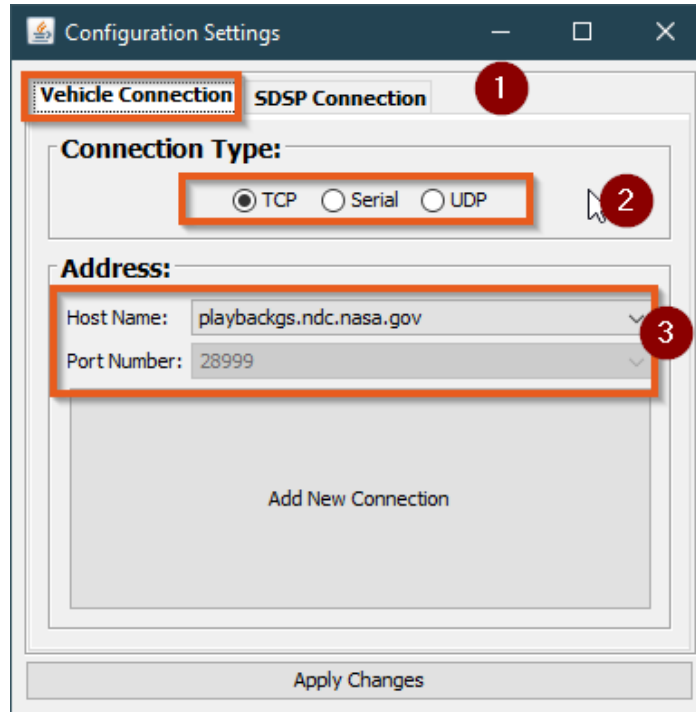


Figure 7.2: Vehicle Connection – Configuration Settings Panel

1. Be sure the “Vehicle Connection” tab is selected.
2. Select the connection type that the vehicle is expecting. TCP is the default setting.
3. Choose for a list of known address and port combinations for the vehicle software.

If the host address and port number is not located in the known list of addresses, the user may add a new address by clicking the “Add New Connection” button.

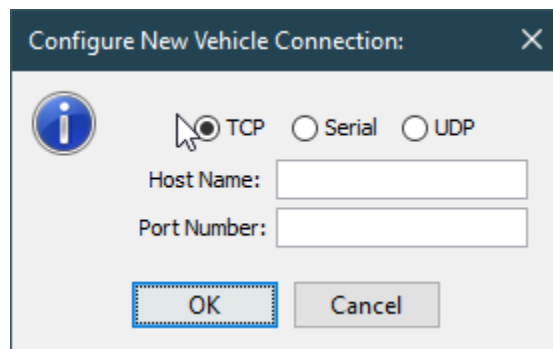


Figure 7.3: Vehicle Connection – New Connection Window

After clicking the button, the vehicle connection configuration window will appear, enter the host address, and port number for the given connection type and select “OK”. This will add the new connection details to the drop down so that the user can select the new option.

Once the user has selected the correct host address and port number combination, the user will need to click the “Apply Changes” button to save the connection configuration.

## 7.2 Selecting Files to Upload to the Vehicle

After confirming the vehicle connection configuration, the user will need to select the files to upload to the vehicle on the Startup Panel. This is done within the Mission Configuration section of this panel.

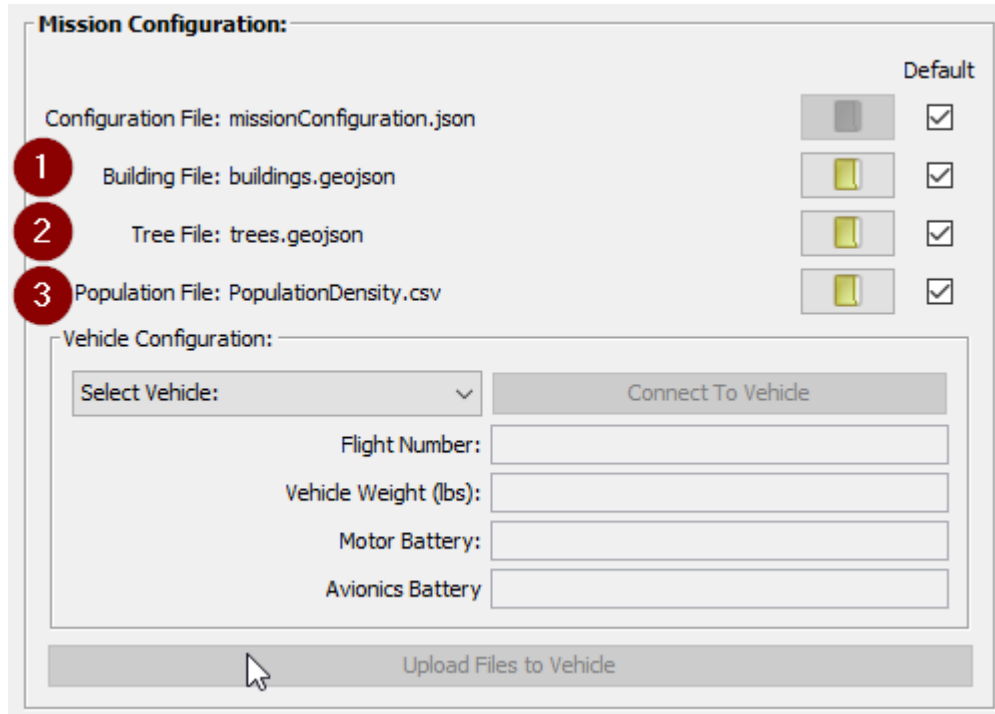


Figure 7.4: Mission Configuration Panel

Since the preflight checks require the user to select a mission configuration file, this selection should already be complete. Next the user will need to select files to represent the obstacles within the planned flying area.

1. Select a building file that contains all the building objects in the flying area. The approved type of file is a GeoJSON file that contains an array of 3D polygons for each building, and, for each item in the array, it should contain a properties node that includes the "Name" and "height" (in meters) values for each polygon.
2. Select a tree file that contains all the tree objects in the flying area. The approved type of file is a GeoJSON file that contains an array of 3D polygons for each tree and, for each item in the array, it should contain a properties node that includes the "height" value in meters.
3. Select a population csv file that contains the x and y locations with the expected population value. [14] gives more details on the populations model represented in csv file used by GW.

The checkbox options to the right of the file selector buttons are configured to fetch default files from a folder called "GndWatchConfiguration". This folder is currently created at the same location as the executable jar file for GW.

### 7.3 Creating the Connection

Following the selection of the files listed in the previous section, the user will need to choose a vehicle within the Vehicle Configuration portion of the Mission Configuration Section of the Startup Panel. Once the vehicle has been selected, the “Connect to Vehicle” button should be enabled. It is worth noticing that the values for the flight number, vehicle weight, motor battery, and avionics battery are filled in with information from the Vehicle Configuration panel that was used during the Pre-Flight checks. If the user is attempting to run a playback session, the flight number will be changed based upon the playback data on the simulator server, otherwise, the user may manually enter a flight number of their choice.

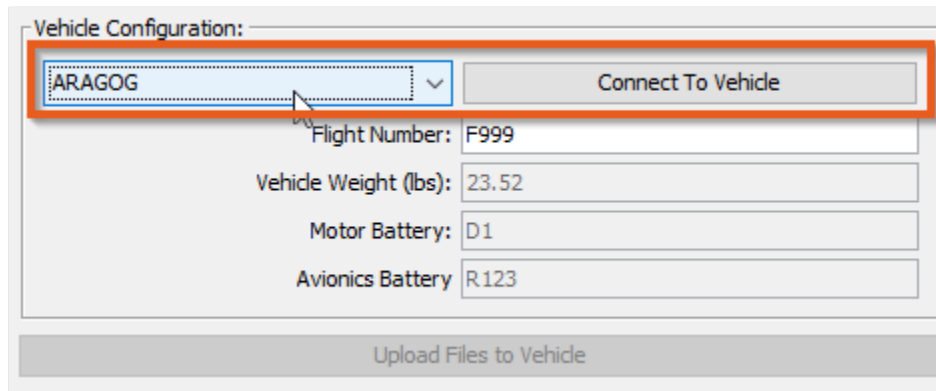


Figure 7.5: Vehicle Configuration Panel – Connect to Vehicle

Clicking the “Connect to Vehicle” button attempts to make a connection using the configuration settings that were applied during the vehicle connection configuration section described above.

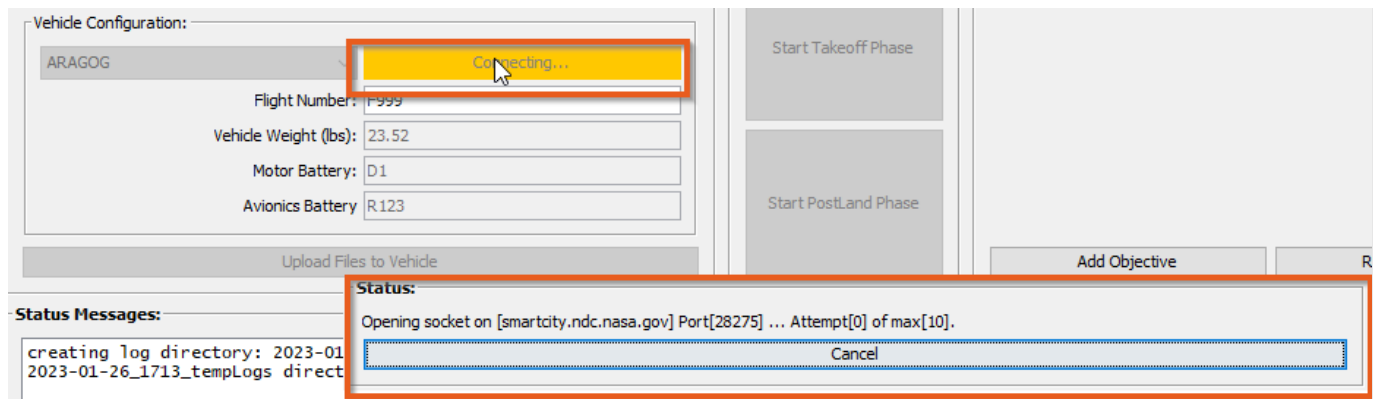


Figure 7.6: Vehicle Configuration Panel – Connecting View

Details on the connection status can be seen in the pop-up status window. After clicking the connect button, the user must wait for the status window to either be complete or cancelled before interacting with the user interface. The connection will be attempted a max of 10 times before asking the user to “Try Again” or “Cancel”.

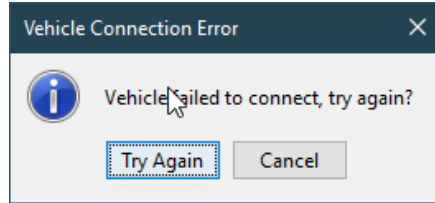


Figure 7.7: Vehicle Connection Panel – Vehicle Connection Error Window

If the user selects “Try Again” the connection will retry another 10 times. Selecting “Cancel” will unlock the user interface and allow the user to make any changes necessary to the vehicle connection configuration.

A successful connection will result in the “Connect to Vehicle” button changing from “Connecting...” to “Connected” with a green background indicating a successful connection.

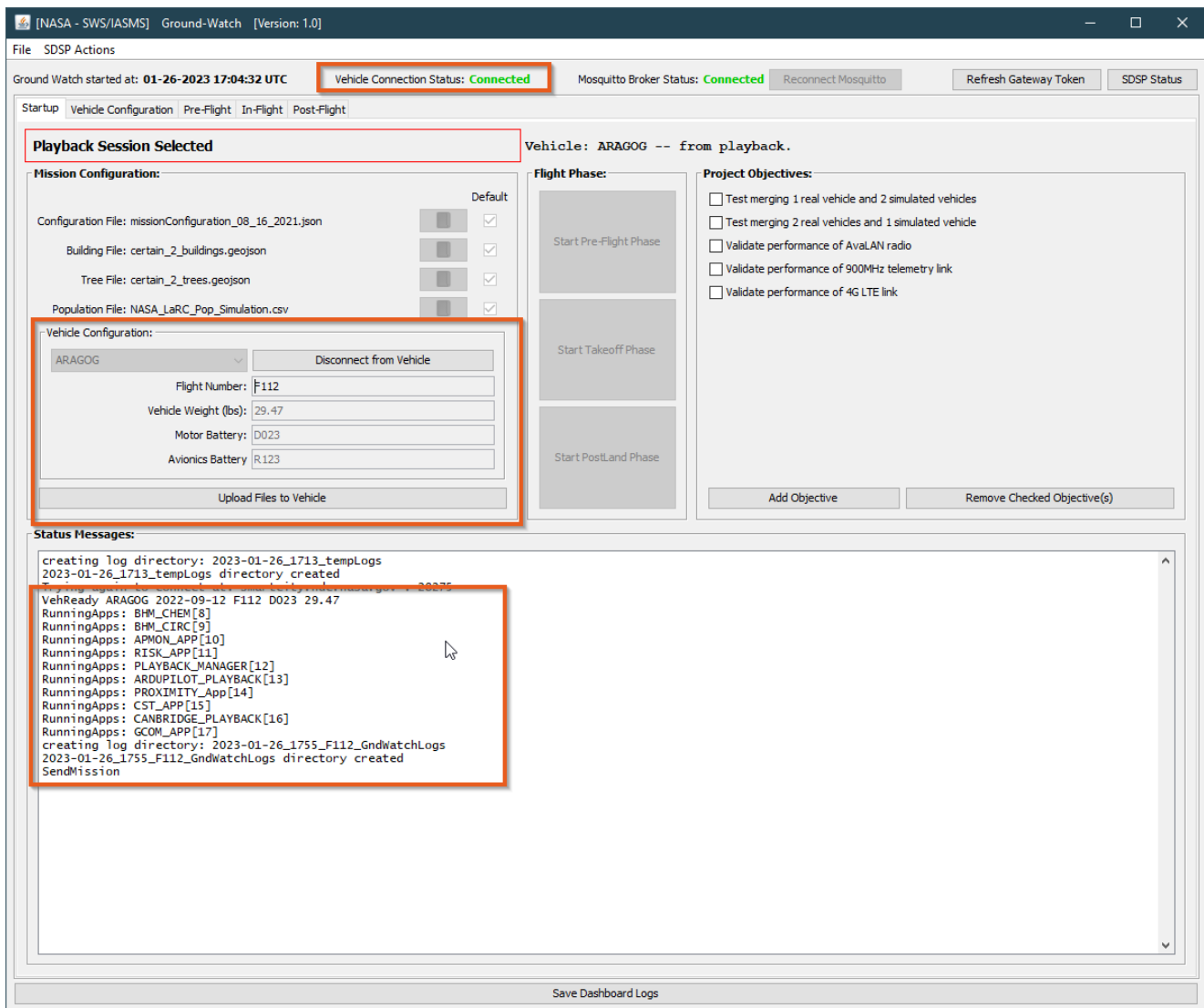


Figure 7.8: Vehicle Connection Panel – Vehicle Connected

At the top of the application window, the Vehicle Connection Status text value will be highlighted in green, and show “Connected”. Additionally, within the vehicle configuration section, the “Connect to Vehicle” button will

change to “Disconnect from Vehicle”. Lastly, the Startup Panel Status Message pane will show messages from the vehicle listing which applications are running on board and that the vehicle is ready to receive files; this is indicated by the “SendMission” message located at the bottom of the screenshot above.

At this point, the user may click the “Disconnect from Vehicle” button if the connection was made in error. This action causes the system to return to the state that precedes connecting to the vehicle. It may be necessary to restart the on board cFS software should the user decide to try to connect to the same vehicle again.

Once the vehicle is connected, the user may upload the files to the vehicle using the “Upload Files to Vehicle” button located at the bottom of the Vehicle Configuration section of the Startup Panel.

After the user clicks the button to upload files, the application will confirm the selections for the flight number, motor battery, avionics battery, and intended flight plan if there are more than one flight plans for the connected vehicle.

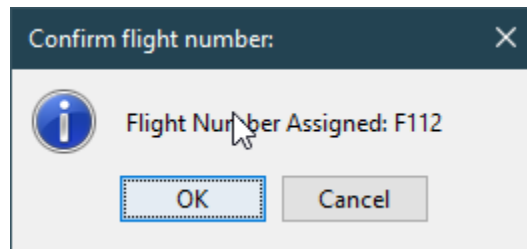


Figure 7.9: Vehicle Connection – Confirm Flight Number

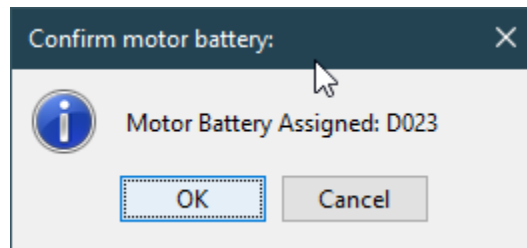


Figure 7.10: Vehicle Connection – Confirm Motor Battery

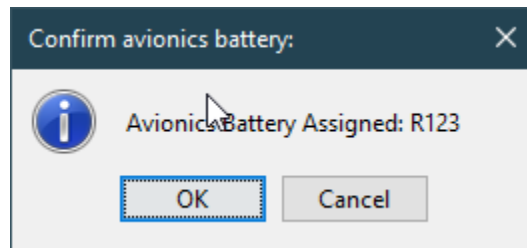


Figure 7.11: Vehicle Connection – Confirm Avionics Battery

After selecting “OK” and confirming all the selections for the mission, the vehicle should send messages back to Ground Watch indicating that the files were successfully received. The Startup Panel status messages window, shown in Figure 7.12, displays the messages received by the Vehicle using green text.

```
Caution: BMS database not updated with parameters for Battery: R123
Successfully uploaded: certain_2_buildings.geojson
Successfully uploaded: certain_2_trees.geojson
Successfully uploaded: NASA_LaRC_Pop_Simulation.csv
Successfully uploaded: missionConfiguration_08_16_2021_ARAGOG_F112.json
```

Figure 7.12: Vehicle Connection – Upload Success

Shortly thereafter, the vehicle will respond with “MissionOK” and give a report of the PREFLIGHT of the vehicle along with the version and IDs for each of the on-board application that are running. This can be seen in the Figure 6.13.

```
Status Messages:
Successfully uploaded: missionConfiguration_08_16_2021_ARAGOG_F112.json
MissionOK
PREFLIGHT: All Apps report preflight phase
PREFLIGHT: All Apps report preflight phase
Version BHM_CHEM id(08) tid(4102) Version 2.1.0.0
Version BHM_CIRC id(09) tid(4103) Version 2.1.0.0
Version APMON_APP id(10) tid(4104) Version 2.0.0.0
Version RISK_APP id(11) tid(4105) Version 2.1.0.0
Version PLAYBACK_MANAGER id(12) tid(4106) Version 2.0.1.0
Version ARDUPILOT_PLAYBACK id(13) tid(4107) Version 2.0.1.0
Version PROXIMITY_App id(14) tid(4108) Version 1.0.0.0
Version CST_APP id(15) tid(4109) Version 3.1.0.0
Version CANBRIDGE_PLAYBACK id(16) tid(4110) Version 2.0.1.0
Version GCOM_APP id(17) tid(4111) Version 2.1.2.1
Vehicle Ready for INFLIGHT Phase
Vehicle Ready for INFLIGHT Phase
Vehicle Ready for INFLIGHT Phase
```

Figure 7.13: Vehicle Connection – Version Roll Call

Once the preflight reports and the application role call are received from the vehicle, the vehicle will send a message indicating that the software is ready to fly. This is denoted by the “Vehicle Ready for INFLIGHT Phase” message seen in the Status Message Window on the Startup Panel.

Upon receiving this message, the Ground Watch application will enable the “Start Takeoff Phase” button within the Flight Phase section of the Startup Panel, as seen in Figure 6.14.

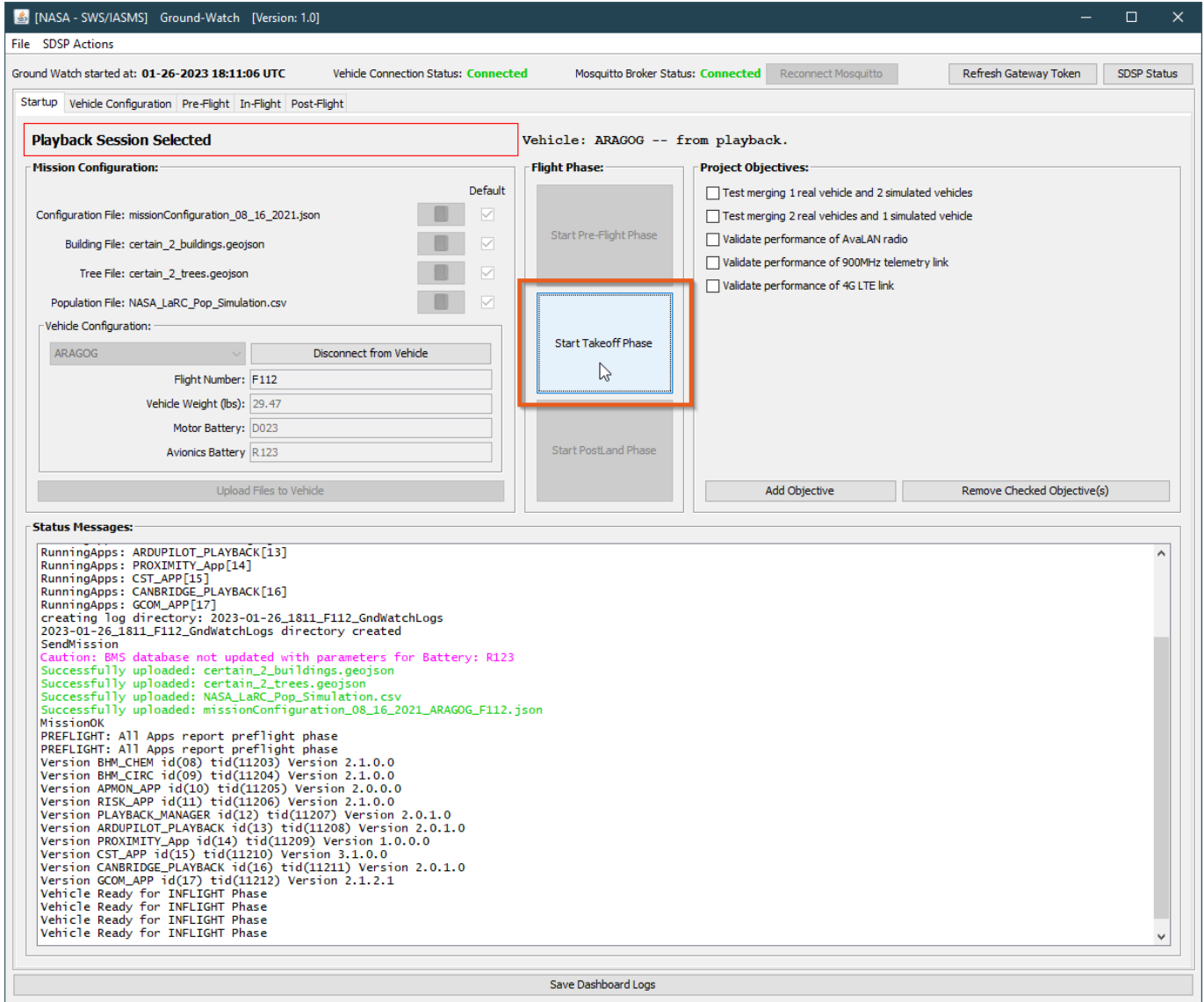


Figure 7.14: Vehicle Connection – Ready for Takeoff

The user will need to click this button to begin the In-Flight section of the process.

## 8 In-Flight Panel

Once the vehicle connection has been initialized and the “Start Take-off Phase” button has been clicked, the user can begin observing the data from the vehicle in real-time. First, the user will need to select the In-Flight Panel tab from the user interface, as shown in Figure 8.1, to maintain visual reference of the connected vehicle’s status during flight. The user can configure the Flight Panel map display by turning on or off any layers using the “Layer Menu” button on the top left. This lets the user declutter or show relevant data for the on-going activity. The map display in Figure 8.1 shows trees and population data layers. The tree layer contains numeric identifications for each area with trees. The numeric ID may be disabled if decluttering is desired.

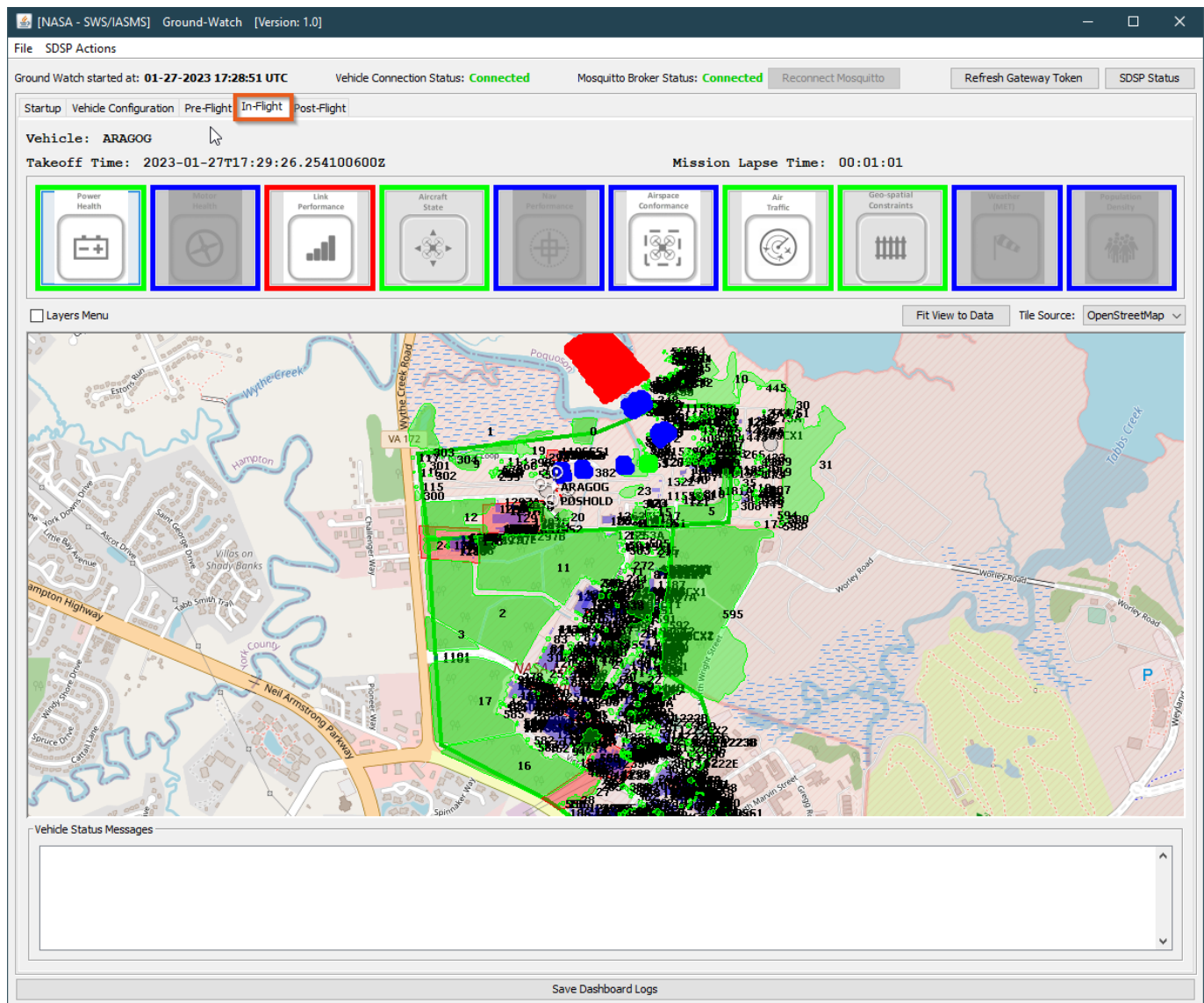


Figure 8.1: In-Flight Panel- Map view provided by OpenStreetMap [13]

## 8.1 Vehicle Status Bar

Shown in Figure 7.2 is the vehicle status bar. Each of the widgets represent the safety status of various vehicle health monitoring algorithms. The widgets are power health, link performance, aircraft state, navigation performance, airspace conformance, air traffic, geospatial constraints, weather (MET) and population density. By clicking the buttons, the user can observe the real-time data for different vehicle subsystems. The widgets are highlighted in colors that represent the status of the safety metric; blue indicates the service is not initialized, green indicates the service has no issues, and red indicates there are some potential problems occurring with that specific safety metric. The buttons can be clicked to obtain more information about the safety metric in question.



Figure 8.2: In-Flight Panel – Vehicle Status Bar

From left to right, each of the buttons are explained in more detail in the next section.

### 8.1.1 Power Health

Clicking the power health button will open the Power Widget window. This window allows the user to see the real-time data coming from the vehicle that describes the battery's current state, as seen in Figure 7.3.

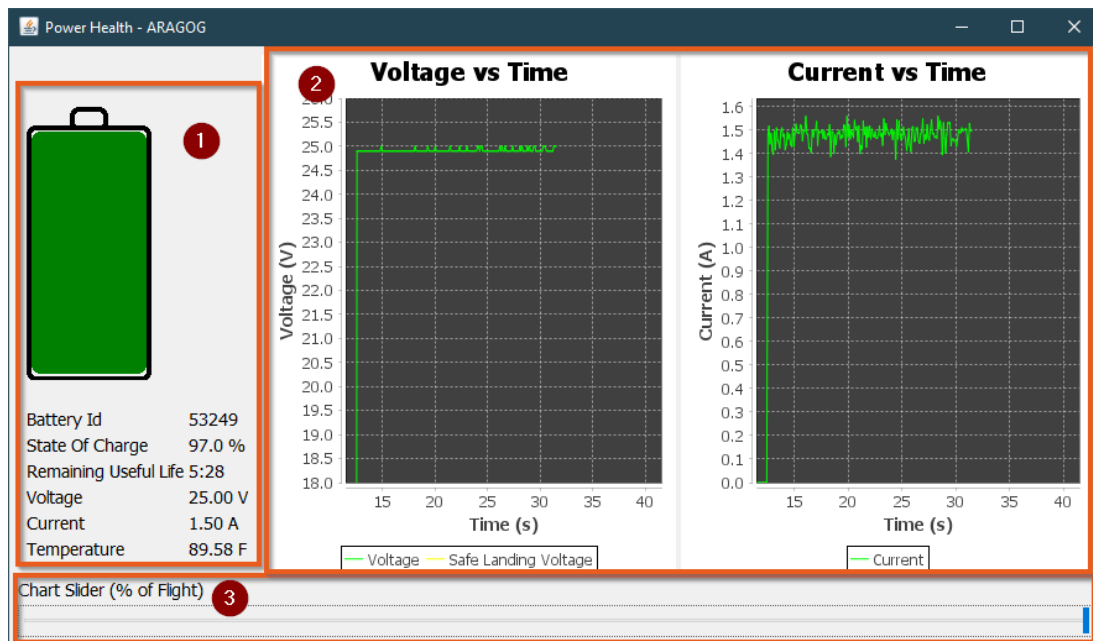


Figure 8.3: Power Health Widget

In the first section denoted by the circle with a “1”, in the figure the user can observe the battery's current state of charge (SOC), remaining useful life (RUL), voltage, current, and temperature values in real-time. The SOC and RUL

values require about 10 seconds of data before they initialize. These values will let the user know how much battery charge is left and how long the pilot has before the useful battery life reaches a critical point. The state of charge is a percentage based upon a full charge and the remaining useful life gives the amount of time remaining in minutes and seconds. The voltage value is read out in volts, the current in amps, and the temperature in degrees Fahrenheit. The thresholds for warnings are set within the Vehicle Configuration panel's battery section and are included in the selected mission configuration file.

In the second section denoted by the circle with a "2", the user can observe the voltage and current through time in seconds. If the user is interested in data that has moved before the left margin of the graph display, the user may interact with the chart slider at the bottom section denoted by the circle with a number "3". Moving the slider to the left allows the user to look back in time at the values that were recorded throughout the flight.

### 8.1.2 Motor Health

This safety monitoring widget is not available in this release and will be included in a future release.

### 8.1.3 Link Performance

Clicking the Link Performance button will open the Link Performance widget. This widget is used to monitor the connection quality between the vehicle and the ground station. Seen in Figure 8.4 below, the user can observe the connection quality using the two time versus signal strength graphs on the Link Performance tab of the widget.

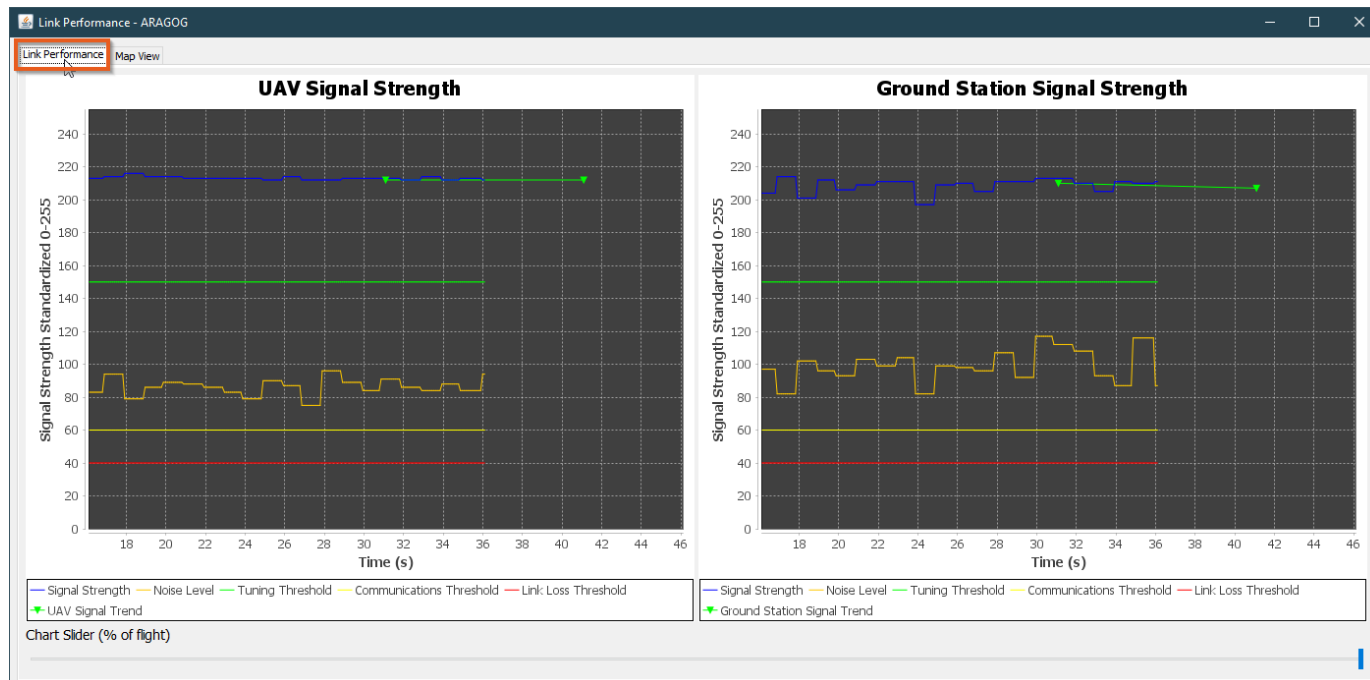


Figure 8.4: Link Performance Widget

In Figure 8.4, the graph on the left shows the signal strength of the vehicle and the graph on the right shows the signal strength of the ground station. The Y-axis of the graphs indicates the received signal strengths at the two

ends of the link. The plots are scaled to the 8-bit raw values as reported by the autopilot where, 255 represents a strength of 100 percent and 0 represents a strength of 0 percent. The signal quality is found by taking the signal to noise ratio. This value is calculated by dividing the blue line value by the yellow line value. In the graph legend show at the bottom, the colors of the line can be seen based upon these values. The signal value is represented in blue, and the noise value is represented in orange. The threshold values for tuning, communication, and link loss can be found in green, yellow, and red. These threshold values are obtained from the mission configuration file and cannot be adjusted during this release. The green moving bar located at the end of the signal strength (blue) line indicates the trending direction of strength, if the strength trends downward over time the prediction line will change to yellow or red depending on the drop in value preceding the trend line. The stored data in the graphs can be observed by moving the chart slider located at the bottom of the graph window.

Clicking the Map View tab will allow the user to observe the signal to noise ratio as the vehicle moves along the flight plan during flight, see Figure 8.5. The signal to noise ratio is plotted on the map using colored chevrons colored appropriately to match the signal to noise ratio legend values of which green represents a value of 2 or greater and red represents a value of 1.2 or lower. For the current release, the CST (Contingency, Select, and Trigger) diamonds are also shown on this map, these icons can be disregarded in this map view since they are not relevant to the signal strength. Shown in the red rectangle on the map view in Figure 8.5, the user can see the colored chevrons indicating signal to noise strength at those locations. The circle in the map shows the location of the vertiport in the test database. And as with other displays, the contents to fuse in the display can be selected from the Layers Menu.



Figure 8.5: Link Performance Widget. – Map view provided by OpenStreetMap [13]

## 8.1.4 Aircraft State

Clicking the Aircraft State button will open the Aircraft State widget. This widget is used to monitor the various data outputs from the vehicle in real-time. These data outputs include the CST (Contingency, Select, and Trigger), MavBridge, Auto-Pilot mode, Position, Radio Status, VfrHud, and Attitude. In Figure 8.6, each of these sections are explained in detail.

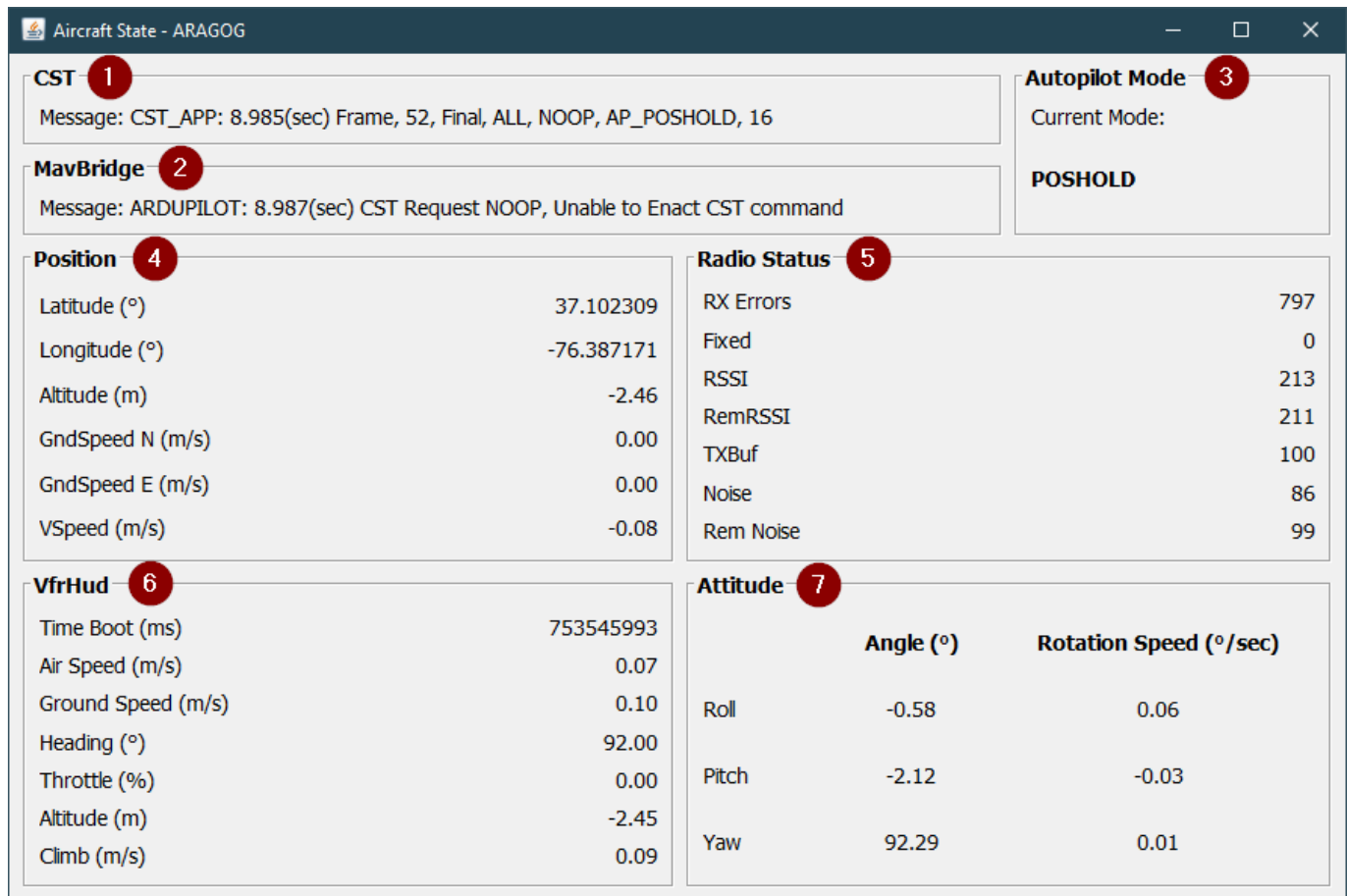


Figure 8.6: Aircraft State Widget

### 8.1.4.1 1. CST (Contingency, Select, and Trigger)

CST is the on-board application which determines if mitigation actions is needed when an alert is raised. The selected contingency action is based on a risk assessment of conditions monitored by other applications also running on board the vehicle's cFS (Core Flight System). Box 1 in the Aircraft State Widget (Figure 8.60) gives the status and function of the CST application. [10] gives more detail on how CST\_App uses on-board information to make mitigation decision and its interactions with other on-board components.

The message structure within the CST window can be described using the example in the image.

- CST\_APP: 8.985(sec) – this is the timestamp that was added to the message indicating how long the app has been running.

- Frame, 52 – this is the current frame count of the CST application.
- Final, ALL, NOOP, AP\_POSHOLD, 16 – these are the decision values that are used by the Risk RTRA (Real-time Risk Assessment) application to make a final decision for the vehicle’s automated safety mitigation application. The last value, 16, indicates the current Auto-Pilot mode, see Table 3 for all possible autopilot modes.

*Table 3: Auto-Pilot Enumeration Values*

Value	Description
0	STABILIZE
1	ACRO
2	ALT_HOLD
3	AUTO
4	GUIDED
5	LOITER
6	RTL
7	CIRCLE
8	UNDEFINED_8
9	LAND
10	UNDEFINED_10
11	DRIFT
12	UNDEFINED_12
13	SPORT
14	FLIP
15	AUTOTUNE
16	POSHOLD
17	BRAKE
18	THROW
19	AVOID_ADSB
20	GUIDED_NOGPS
21	SMART_RTL
22	FLOWHOLD
23	FOLLOW
24	ZIGZAG
25	SYSTEMID
26	AUTOROTATE
27	AUTO_RTL

#### 8.1.4.2 2. MavBridge

---

The MavBridge application on board the vehicle's cFS (Core Flight System) reports messages to the Ground Watch application indicating the current autopilot mode change request received from the decision-making application (CST\_APP). Block 2 in the Aircraft State Panel gives the mode request, whether the autopilot was able to safely switch to the requested mode. Block 3 reflects the current mode that the autopilot is set to. [11] gives more information on the decision logic in CST.

The message structure within the CST window can be described using the example in the image.

- ARDUPILOT: 8.987 (sec) – this is the timestamp that was added to the message indicating how long the app has been running.
- CST Request NOOP – this is the mode requested by CST application on board.
- Unable to enact CST Command – this message lets the user know that the CST request was not selected as the final mode.

#### 8.1.4.3 3. Auto-Pilot Mode

---

The CST, MavBridge, and RTRA applications work together to determine the best decision for the vehicle based upon perceived hazards. The selected auto-pilot mode from the CST message is displayed here. Each time this value changes to either POSHOLD, RTL, or LAND a colored diamond will be placed on the Live Map Viewer Panel in the In-Flight panel. The legend for these colors can be seen in the following diagram (Figure 8.7):

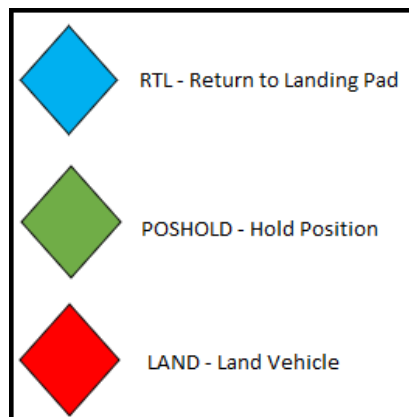


Figure 8.7: Auto-Pilot Mode – Map Legend

#### 8.1.4.4 4. Position

---

The on-board MavBridge software also relays the GPS position to the Ground Watch software. The position values displayed in Block 4 of the Aircraft State Panel, include latitude and longitude in degree-decimal and altitude in meters. Additionally, this message provides the velocity components of relative ground speed in meters per second as seen in Figure 8.6.

#### 8.1.4.5 5. Radio Status

---

The radio status section (section 5) of the aircraft state panel in Figure 8.6 denotes the current values of the Ardupilot radio link. The “rxerrors” value represents the number of radio packet errors that have occurred since the vehicle software started. The fixed value represents the number of radio packet errors that have been fixed since the vehicle started. The “rssi” value denotes the signal strength in an unsigned 8-bit integer, where 255 is the maximum strength. Next, the “remrssi” value represents the remote message receiver’s received signal strength as an 8-bit unsigned integer. The “txbuf” value represents the percent of remaining free transmitter buffer space as an 8-bit unsigned integer, where 255 represents a completely empty buffer. The noise value represents the background noise level as an unsigned 8-bit integer. The “rem Noise” value represents the noise received at the remote message receiver.

#### 8.1.4.6 6. VFRHud (Visual Flight Rules Heads up Display)

---

The VFRHud section of the aircraft state panel in Figure 8.6 displays the data from the Pixhawk’s Autopilot. These include airspeed in meters per second, groundspeed in meters per second, heading in degrees (0 indicates North), throttle in percent, altitude in meters, and climb in meters per second.

#### 8.1.4.7 7. Attitude

---

The Attitude section of the aircraft state panel in Figure 8.6 displays the data from the Pixhawk’s Autopilot. These values include, roll angle, pitch angle, and yaw angles in degrees, roll speed, pitch speed, and yaw speed in degrees per second.

#### 8.1.5 Nav Performance

---

This safety monitoring widget is not available in this release and will be included in a future release.

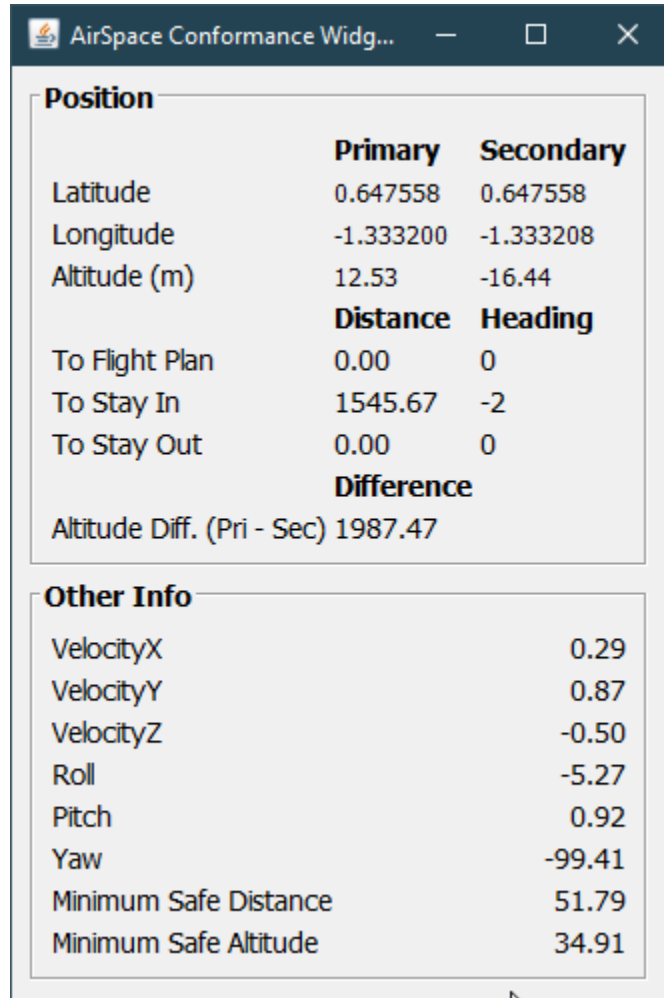


Figure 8.8: Airspace Conformance Widget

Clicking the Airspace Conformance button will open the Airspace Conformance Widget displayed in Figure 8.8. This widget is used to monitor the vehicle’s position information from the primary and secondary nodes in the SafeGuard system as relayed by the Safeguard Bridge application on-board the vehicle.

The position section of this widget gives the current GPS (Global Positioning System) location of the vehicle as reported by primary and secondary receivers on-board the vehicle. The latitude and longitude are given in radians and altitude in meters. This section also shows the relative distance to the flight, stay-in, and stay-out boundaries that have been specified for the vehicle flying.

Additionally, the other information section allows the user to see the velocity and angular orientation of the vehicle along with the minimum safe distance for the horizontal and vertical components.

### 8.1.7 Air Traffic

---

This safety monitoring widget is not available in this release and will be included in a future release.

### 8.1.8 Geospatial Constraints

---

Clicking the Geospatial Constraints button will open the Geospatial Constraints widget. The flight vehicle is equipped with an independent system called Safeguard which verifies that the vehicle stays within its operating range and alerts the operator if the flight path will soon exit the operations area. The Geospatial Constraints widget is used to monitor the current state of the Safeguard system. The first tab in the widget, AP1, shows all the available flags within the system and their current values, see Figure 8.9. On the second tab, the user can view the current location of the primary and secondary nodes as denoted by the safeguard message, see Figure 8.10. If the user needs more information on the Safeguard system and the definition of the various flags and the conditions and which they change, the user may consult SafeGuard documentation [15].

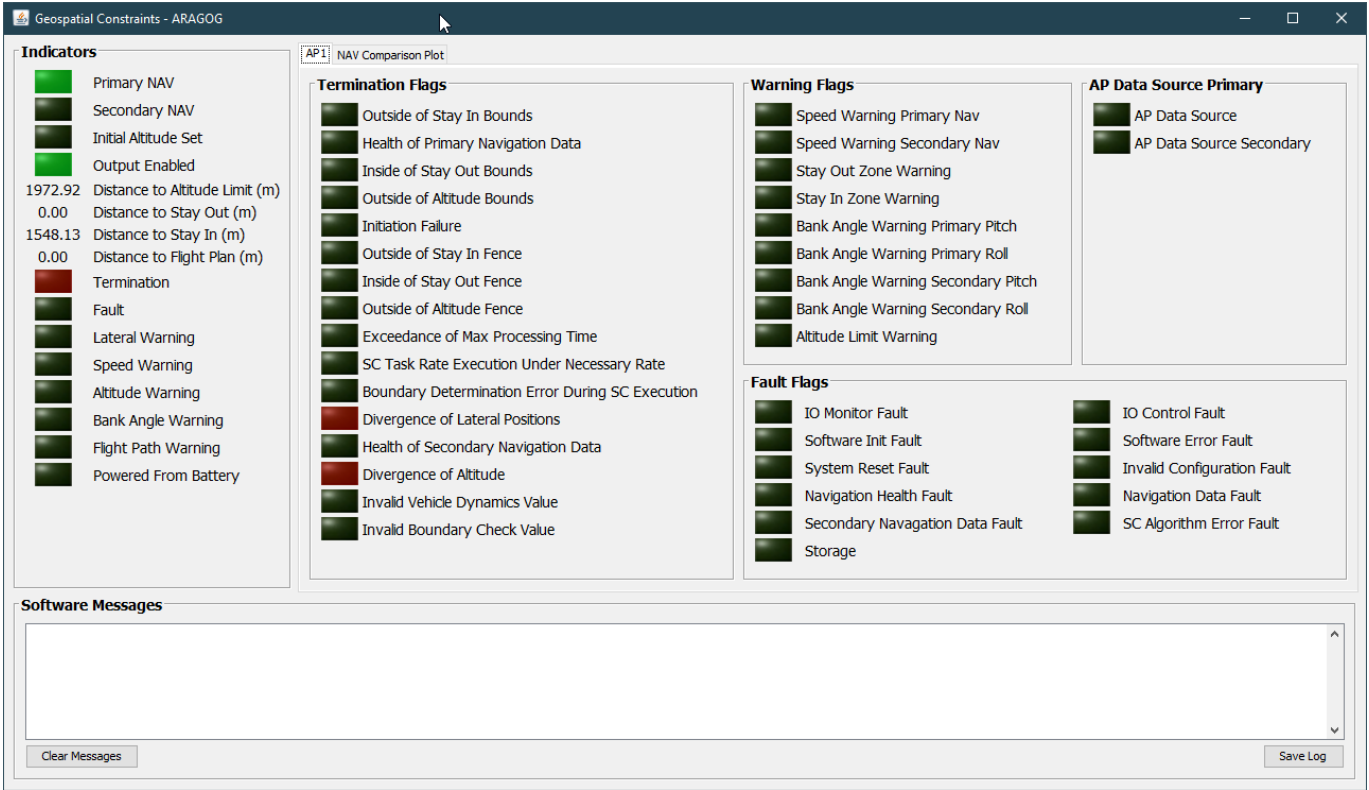


Figure 8.9: Geospatial Constraints Widget

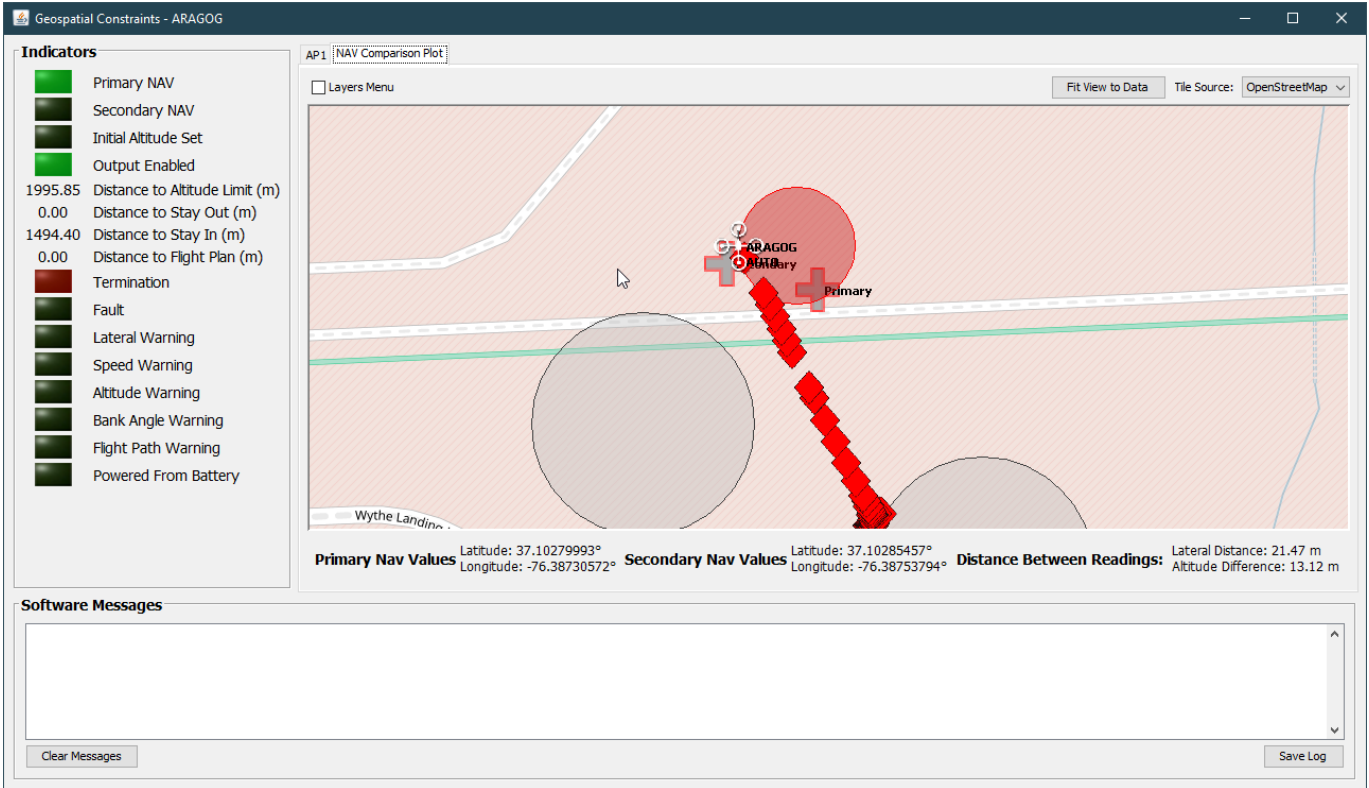


Figure 8.10: Airspace Conformance Widget – Map View - provided by OpenStreetMap [13]

### 8.1.9 Weather (MET)

---

This safety monitoring widget is not available in this release and will be included in a future release.

### 8.1.10 Population Density

---

This safety monitoring widget is not available in this release and will be included in a future release.

## 8.2 Live Map Viewer Window

---

The Live Map Viewer window is much like the Pre-Flight map viewer window, however there are a few differences. It is used while the vehicle is aloft to monitor safety metrics and alerts from the on-board software. The most notable difference is that the map objects that appear on the viewer are relative to during flight rather than pre-flight planning.

Layer control works the same as the Pre-Flight map viewer window, layers can be moved to the top, turned off or off, labels disabled or enabled, etc.

Additional layers are added to the map during flight to provide additional vehicle information that can potentially increase the situational awareness of the operator. Shown in Figure 8.11, the vehicle object approaches a building and displays a Proximity Alert between the vehicle and the building. Additionally, the large red circle shows the potential hazard impact area if the vehicle experiences a failure. Lastly, the user can observe the change of mode of the auto-pilot system as described above in the CST section of the aircraft state widget.

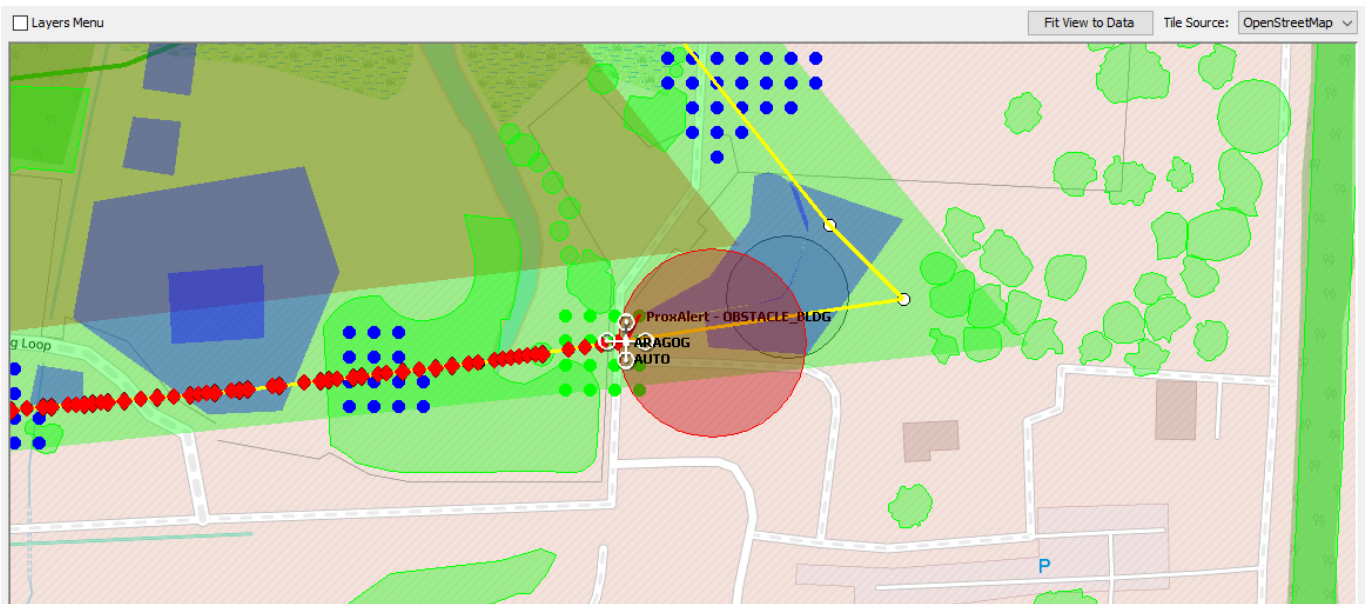


Figure 8.11: In-Flight Panel – Map Viewer - provided by OpenStreetMap [13]

## 9 Post-Flight Panel

Once the vehicle has landed and the flight has been completed, the vehicle will send the “Vehicle Ready for Post Flight Phase” message to the Ground Watch application, this can be seen in the Startup Panel (Figure 9.1). The “Start PostLand Phase” button can be selected to send a message to the vehicle to end the current flight session. The button to do this can be seen in Figure 9.1.

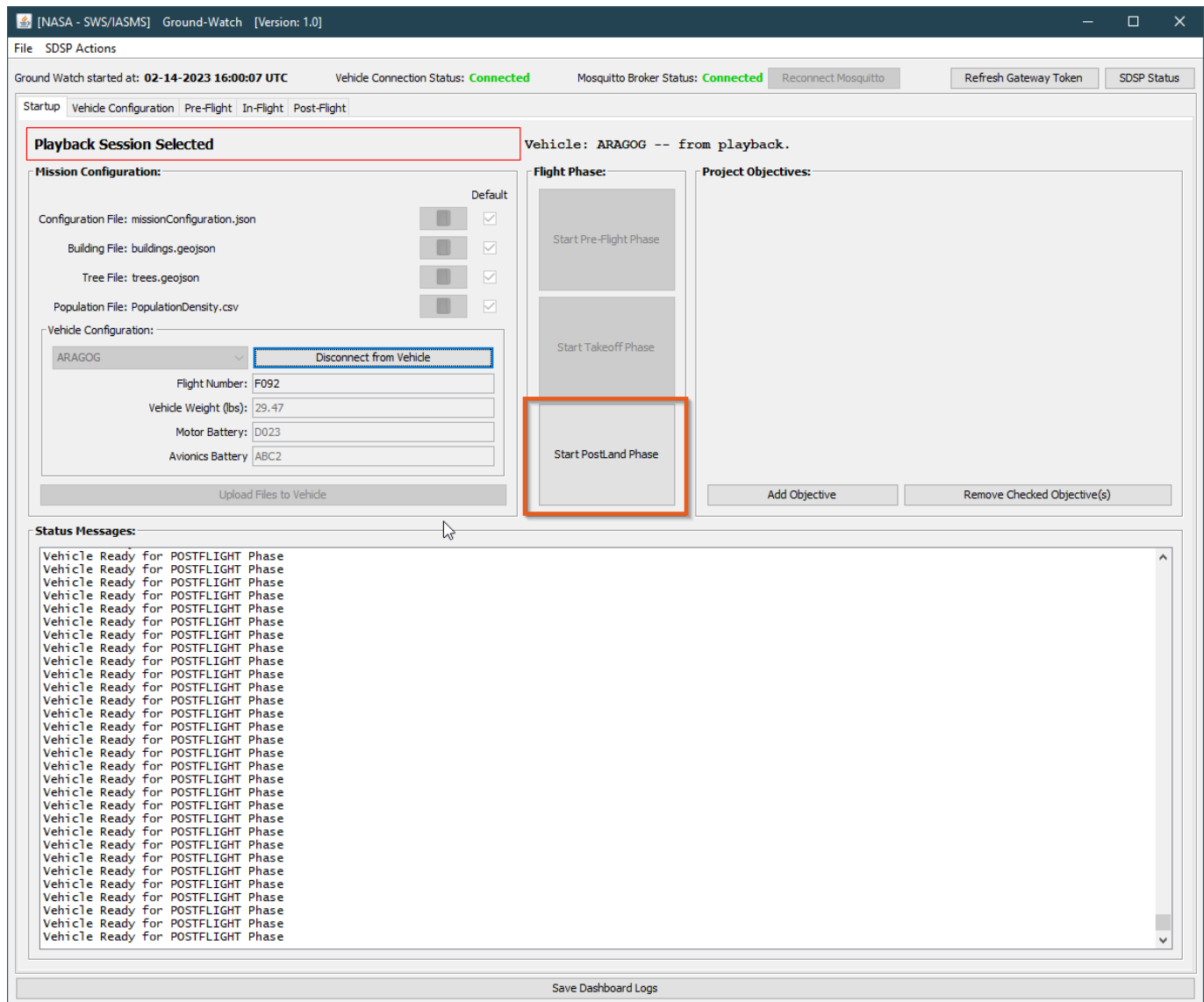


Figure 9.1: Startup Panel - Start PostLand Phase

After the Start **PostLand Phase** button is pressed, Ground Watch will send a message to the Ground Communications Application (GCOM) on-board the vehicle to let it know to start the post flight shutdown process. After Ground Watch receives the *EndFlight*, *PostFlight*, and *Termination* flags, the connection to the vehicle will be severed and the application will revert to the initial state upon opening; this allows the user to begin a new flight

as soon as the current one ends. Figure 9.2 shows an example of the end of flight output in the Startup Panel message panel.

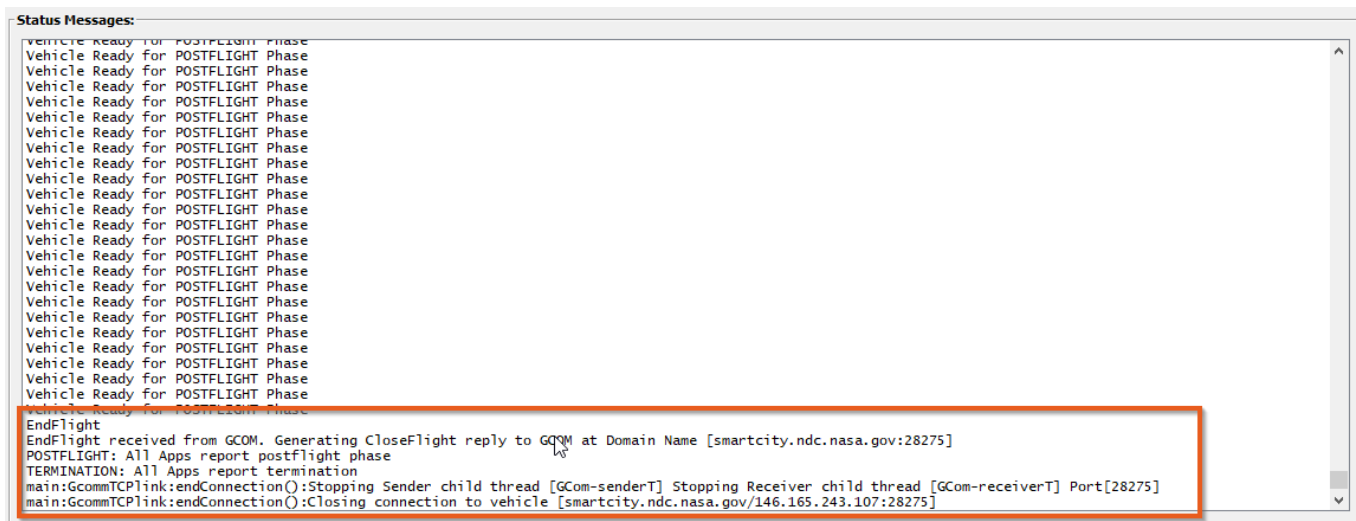


Figure 9.2: Startup Panel - End of Flight Messages

This release does not include any postflight functionality other than allowing the user to send the “Start Post-Flight Phase” message to the vehicle so that the vehicle software can shut down appropriately.

## 10 Troubleshooting

---

GW is a ground station tools developed for research flight testing of UAS tactical autonomy. It serves as the ground station for flight testing many of the safety algorithms being integrated into the IASMS to improve safety of drone operations. The tool has been used for several UAS test flights and continues to be adapted for future testing. The reader should consult the authors for features which are not intuitive.

## 11 Appendix A: Description of the Mission Configuration File (MCF)

The Mission Configuration File (MCF) is a configuration file used to transfer mission information from the flight planning process into the flight operations. It specifies the expected configuration of the vehicle, the mission flight plan, the safety thresholds used, the flight crew certifications, the terrain and structures models used, and the input assumptions submitted to the cloud services to obtain flight and safety clearance for the mission. Storing all this in a single file ensures that, at mission execution time, a consistent set of mission parameters and models are used by all IASMS SFC's involved in the mission. The file is uploaded on-board the mission vehicle to allow vehicle configuration verification and to set the safety thresholds. GW uses safety thresholds from the MCF in the display panels and for alert logic while the cloud service information tells GW what services are used and what parameters to feed to the services. This appendix gives an overview of the information contained in the MCF. The reader should consult Operations Planner [9] and the GroundWatch software and related documentation for usage details of each parameter.

A hierarchical JSON format is used to organize and group information in the MCF. JSON tags are used to identify the parameters by tag name and value. The highest level consists of a "Version" and "MissionConfiguration" tags as seen in Figure A1 in the bold print. The "Version" tag lets the on-board software verify that their parsing algorithms match the version of the MCF. The "MissionConfiguration" group contains the bulk of the mission information. As seen in Figure 11.1, there are several parameters describing the executing organization, air space for the mission, and the planned execution time. These are envisioned to be used for verification of airspace, coordination with airspace management authority, and the flight path conflict arbitration priority. As annotated in the figure, the "selectedProjectObjectives", "selectedVehicle", "selectedPersonnel", and "windForecast" contain the mission objective, vehicle, personnel, and anticipated wind information, respectively. The "selectedPersonnel" data gives the codenames for pilot, ground station officer, spotter, observer, and researchers. These roles are modeled after the UAS operations at NASA Langley. The roles are tailored to the safety needs of the flight operations.

```
Version : "V1"
MissionConfiguration {
  "deploymentName" : "ODOT",
  "projectName" : "Scenario 01 - Vehicle 1 Mission",
  "operatingRange" : "Columbus_Aero_Club",
  "missionPriority" : "Commercial",
  "plannedFlightDateTime" : "2024-03-05T16:25:51.350Z",
  "selectedProjectObjectives" : "MissionObjectives[ ]",
  "selectedVehicles" : [ {...} ]
  "selectedPersonnel" : { "pilots":[ ], "gcsos":[ ], "rsos":[ ], "spotters":[ ], "observers":[ ], "researchers":[ ] },
  "windForecast" : { "forecastSource":"Default", "windSpeed":"2 m/s", "windDirection":"90 deg", "windAltitude":"10 m" }
}
```

Figure 11.1 Top level tags in the MCF

The "selectedVehicles" group contains a few smaller groups as described in Figure 11.2. The "vehicleName" gives the desired vehicle from the planning process. This can be used by to verify that the vehicle executing the flight is the one expected from the planning process. The "flightSetup" (top right breakout box in Figure 11.2) gives the operator's actual assignments for several information items during pre-flight checkout. These include assignment of the flight number, the batteries used, the actual vehicle weight, and other communications connection information. "vehicleParameters" is a large group described later. The "sdspThresholds" contain the safety

threshold for the various systems. These are the parameters sent to the cloud services for analysis of this mission during planning. If there is a significant time lapse between the planning and the flight execution, these parameters allow the operator to repeat some of the analysis to ensure the safety margins computed during planning are still valid for updated conditions and that the flight may still be safely executed. Finally, the *“flightPlan”* contains an array of waypoint definitions which describe the flight path for this mission. The waypoint definitions are a JSONified version of the MavLink mission item.

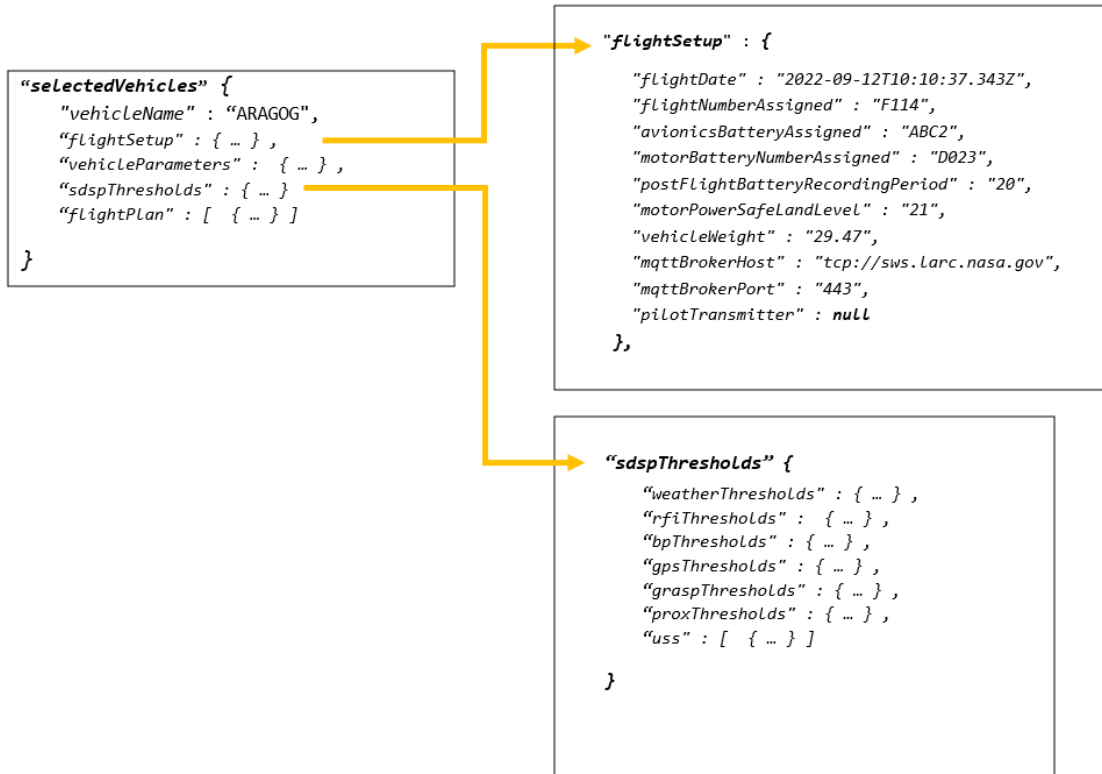


Figure 11.2 Breakout for selectedVehicle group in the MCF and two of the encapsulated structures.

Figure 11.3 shows breakouts for three of the configuration parameter groups contained in the *“sdspThreshold”* data. These parameters are exchanged respectively with the Wind, RFI, and Proximity service. The Wind service parameters are what was used to interact with the Wind service during operations planning. And likewise, the *“rfiThreshold”* and *“proxThreshold”* parameters.

A breakout of the vehicle information in the *“vehicleParameters”* group is shown in Figure 11.4. This parameter group contains several fields in the tops section to identify the vehicle, its configuration, and any trust related information for security evaluation. The second section contains fields for the vehicle’s overall mechanical specifications. This is followed by the overall mechanical safety thresholds. Following these fields, are parameter groups describing the vehicle’s battery, motor, navigation, RF, and autopilot systems. The breakout of the battery structure is given in Figure 11.4 top right inset. That consists of an array of batteries data, each of which identifies the battery name, the system it powers, the safety margin data, and the battery parameters. The array structure allows multiple batteries to be specified for a vehicle. The motor data group (lower right box) gives summary information first and followed by limits for each motor.

```

"weatherThresholds" : {
  "enabled" : true,
  "windModel" : null,
  "minWindSpeed" : "",
  "maxWindSpeed" : "7.7",
  "maxWindGust" : "10.3",
  "minTemperature" : "32.0",
  "maxTemperature" : "104.0",
  "heatIndex" : "",
  "windChill" : "",
  "humidity" : "",
  "skyCover" : "",
  "dewPoint" : ""
},

"rfiThresholds" : {
  "enabled" : true,
  "rf" : {
    "rfiModel" : "Kriging",
    "commFrequencies" : [
      {
        "linkName" : "GCS",
        "frequency" : "900 Mhz",
        "signalTolerance" : {
          "nominalSignal" : "150",
          "minSignal" : "60",
          "linkLoss" : "40"
        },
        "noiseTolerance" : "-48",
        "rssiFailureThreshold" : "0.5",
        "intermittentLossDuration" : "500"
      },
      { ... }, # Additional comm link
      { ... } # Additional comm link
    ], # End of comm link tolerance list
    "hirfFrequencies" : [
      {
        "frequencyBand" : "900 Mhz",
        "exposureThreshold" : {
          "power" : "60",
          "duration" : "10",
          "asmuthAngle" : "40",
          "elevationAngle" : "70"
        }
      },
      { ... } # Additional HIRF Thresholds
    ]
  } # End of along-Path and HIRF list
}, # End of rfiThreshold data

"proxThresholds" : {
  "enabled" : true,
  "thresholdUnits" : "Feet",
  "tree" : {
    "above" : "10",
    "below" : "10",
    "aside" : "10"
  },
  "bldg" : {
    "above" : "50",
    "below" : "50",
    "aside" : "25"
  },
  "cloud" : {
    "above" : "100",
    "below" : "100",
    "aside" : "200"
  },
  "sua" : {
    "above" : "20",
    "below" : "20",
    "aside" : "20"
  },
  "aircraft" : {
    "above" : "100",
    "below" : "100",
    "aside" : "100"
  },
  "unknown" : {
    "above" : "200",
    "below" : "200",
    "aside" : "200"
  },
  "confidence" : "40",
  "gisModelName" : "certain_1"
},

```

Figure 11.3 Break out data groups in the “sdspThresholds” JSON.

Figure 11.3 shows breakouts for weather, radio frequency interference, and proximity thresholds of the configuration parameter groups contained in the “sdspThreshold” JSON data. These parameters are exchanged respectively with the Wind, RFI, and Proximity service. The Wind service parameters are what was used to interact with the Wind service during operations planning. And likewise, the “rfiThreshold” and “proxThreshold” parameters.

A breakout of the vehicle information in the “vehicleParameters” group is shown in Figure 11.4. This parameter group contains several fields in the tops section to identify the vehicle, its configuration, and any trust related information for security evaluation. The second section contains fields for the vehicle’s overall mechanical specifications. This is followed by the overall mechanical safety thresholds. Following these fields, are parameter groups describing the vehicle’s battery, motor, navigation, RF, and autopilot systems. The breakout of the battery structure is given in Figure 11.4 top right inset. That consists of an array of batteries data, each of which identifies the battery name, the system it powers, the safety margin data, and the battery parameters. The array structure allows multiple batteries to be specified for a vehicle. The motor data group (lower right box) gives summary information first and followed by limits for each motor.



Figure 11.4 Details of the "vehicleParameters" data in the MCF file.

## 12 References

1. Young, Steven D.; Ancel, Ersin; Moore, Andrew J.; Dill, Evan T.; Quach, Cuong C.; Foster, John V.; Darafsheh, Kaveh; Smalling, Kyle M.; Vazquez, Sixto L.; Evans, Emery T.; Okolo, Wendy A.; Corbetta, Matteo; Ossenfort, John P.; Watkins, Jason; Kulkarni, Chetan S.; and Spirkovska, Lilly, "Architecture and Information Requirements to Assess and Predict Flight Safety Risks During Highly Autonomous Urban Flight Operations," NASA/TM-2020-220440, January 2020.  
<https://ntrs.nasa.gov/api/citations/20200001140/downloads/20200001140.pdf>
2. Ellis, Kyle; Krois, Paul; Davies, Misty; and Koelling, John, "In-Time System-Wide Safety Assurance (ISSA) Concept of Operations," Document ID 20190032480, Report Number ARC-E-DAA-TN4516-1, October 31, 2019.
3. Smalling, K. et al., "In-Time Safety Management Capabilities for Post Hurricane Disaster Relief and Recovery Aircraft Operations- A Gap Assessment" (Manuscript submitted to DASC 2025 for publication), 2025.
4. Darafsheh, K., Mackenzie, A., T. X. Nguyen, T. X., Morris, C. M., Smalling, K. M., Turner, A., Quach, C. C., "Ground-Based RFI Mitigation Approaches for UAS Flight Operations in Urban Environment", NASA-TM-20250003000, April 2025.
5. Ancel, E., Helsel, T. Heinich, C. M., Ground Risk Assessment Service Provider (GRASP) Development Effort as a Supplemental Data Service Provider (SDSP) for Urban Unmanned Aircraft System (UAS) Operations", IEEE DASC 2019.
6. Deckert, E., Gutierrez, J., Gilabert, R., and Dill, E. Integrating Advanced Visualization and Automated HPC Workflows for GNSS Prediction in Urban Air Mobility. AIAA Aviation 2025 Forum.
7. Ancel, E., Young, S. D., Quach, C. C., Haq, R. F., Darafsheh, K., Smalling, K. M., Vazquez, S.L., Dill, E. T., Condotta, R. C., Bailey E. E., Teska, L. R., Johnson, T. A., "Design and Testing of an Approach to Automated In-Flight Safety Risk- Management for sUAS Operations", AIAA Aviation 2022 Forum, June 27-July 1, 2022, AIAA 2022-3459
8. Hogge, E. F., Kulkarni, C. S., Eure, K., Darafsheh, K., Vazquez, S. L., Smalling, K. M., Quach, C. C., "Applications used by Two Octocopters for Safe Low Altitude Autonomous Flight Operations", NASA/TM-2023-0012868, June 2024.
9. Andrew T. Turner, Operations Planning Tool - User's Guide, NASA-TM-20230013498, December 2023
10. A. J. Moore et al., "Testing of advanced capabilities to enable in-time safety management and assurance for future flight operations", NASA TM-20230018665, Apr. 2024.
11. "MavLink Basics," ArduPilot Development Site [online], URL: <https://ardupilot.org/dev/docs/mavlink-basics.html> [retrieved 27 May 2025]
12. "Mission Planner Overview," ArduPilot Documentation [online], URL: <https://ardupilot.org/planner/docs/mission-planner-overview.html> [retrieved 27 May 2025].
13. "Open Street Map," OpenStreetMap Foundation [online], URL: <https://www.openstreetmap.org/copyright> [retrieved 27 May 2025].
14. Ancel, E., Helsel, T., Heinich, C. M., "Ground Risk Assessment Service Provider (GRASP) Development Effort as a Supplemental Data Service Provider (SDSP) for Urban Unmanned Aircraft System (UAS) Operations." 2019 IEEE/AIAA 38th Digital Avionics Systems Conference (DASC). IEEE, 2019.accessible at <https://ntrs.nasa.gov/citations/20200002732>
15. Dill, E., Hayhurst, K. J., Young, S. D., Narkawicz A. J., "UAS Autonomous Hazard Mitigation through Assured Compliance with Conformance Criteria", AIAA SciTech Conference, 2018.accessible at <https://ntrs.nasa.gov/citations/20180006283>.