Chapter 4: Flight Modes & Failsafes for USVs

Part A – Flight Modes

What are Flight Modes?

Flight modes define how the USV behaves during operation. Each mode determines how much control the pilot has and how much is handled automatically by the autopilot. Some modes are fully manual, others are fully autonomous, and some are mixed. Choosing the right mode ensures safe and effective operation.

Flight Modes for USVs

Mode	Pilot Control	Autopilot Role	GPS Required	Use Case
Manual	Full	None	No	Testing, fallback
Acro	Partial (heading hold)	Stabilized turning	No	Tuning, smoother manual control
Steering	Partial (speed-aware)	Turn radius management	Yes	Safer high-speed driving
Hold	None	Stops motion	No	Arming, emergency pause
Loiter	None	Position hold with GPS	Yes	Station keeping
Guided	From GCS or companion	Target-based movement	Yes	Remote commands, scripts
Auto	None	Mission execution	Yes	Waypoint navigation
RTL	None	Return to home location	Yes	Emergency return

Mode Behavior Overview

- **Manual**: Direct RC control. No GPS needed.
- **Acro**: Autopilot holds heading. Good for tuning and smoother control.
- **Steering**: Speed-based turn limits. Heading hold when stick is centered.
- **Hold**: Cuts throttle and centers steering. May drift on water.
- **Loiter**: Maintains position using GPS. Applies thrust only if drifting.
- **Guided**: Responds to real-time commands from a GCS or onboard computer.
- **Auto**: Executes full mission with waypoints.
- **RTL**: Navigates back to the home location automatically.

Flight Mode Setup in Mission Planner

Follow these steps to properly configure flight modes using a FlySky FS-i6X transmitter:

1. **Turn on the transmitter**

2. **Open Mission Planner** on your computer

3. **Connect** to the autopilot via USB or telemetry

4. **Insert the battery** into the USV to power the receiver

5. Go to **Setup > Mandatory Hardware > Radio Calibration**

6. Choose a **3-position switch** on your transmitter

7. Move the switch and observe **which RC channel responds** (in this setup, it is **Channel 8**)

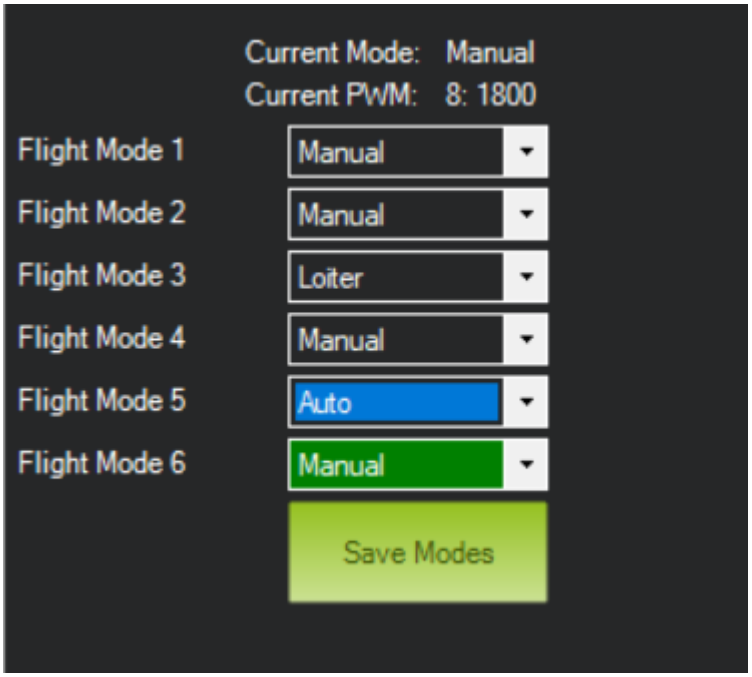
8. Go to **Config > Full Parameter List**

9. Find the parameter `MODE_CH` and set it to the correct channel (e.g., `8`)

10. Click **Write Params**

11. Go to **Setup > Mandatory Hardware > Flight Modes**

12. Flip the 3-position switch and observe which flight mode positions activate (typically 1, 3, and 5)



13. Assign the desired flight modes (e.g., Manual, Loiter, Auto) to those positions and click **“Save”**

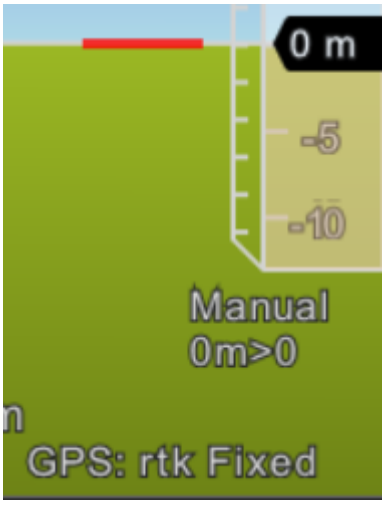
14. Disconnect the autopilot

15. **Reboot the USV** by cycling the battery

16. **Reconnect** to Mission Planner

17. Insert the battery again to power on the system

18. Flip the switch and look at the **HUD (gyroscope, bottom right)** to verify that the mode changes correctly and matches the modes you assigned



Up to 6 modes can be assigned using multiple switches or advanced mixing.

Default Boot Mode

Use the parameter `INITIAL_MODE` to define the mode used at startup. Recommended: `5` (Loiter mode)

Part B – Failsafes

What is a Failsafe?

A failsafe is a safety mechanism that activates when something goes wrong (e.g., signal loss, low battery, GPS failure). The autopilot responds by switching the vehicle to a safe mode such as Loiter or RTL.

Common Failsafe Types

Failsafe	Trigger	Typical Action
RC Loss	No signal from RC transmitter	Loiter or RTL
Battery Low	Voltage below threshold	RTL
GPS Loss	GPS fix lost	Switch to Manual/Loiter
GCS Loss	GCS/telemetry disconnected	Loiter or RTL
Geofence Breach	Exiting virtual boundary	Loiter or RTL

These transitions help maintain control or bring the vehicle to safety.

Configuring Failsafes in Mission Planner

Navigate to **Config > Full Parameter List** to set the following:

Parameter	Function	Suggested Setting
`BATT_FS_CRT_ACT`	Battery failsafe	`1` = RTL
`BATT_FS_LOW_ACT`	Battery failsafe	`1` = RTL
`FS_GCS_ENABLE`	GCS communication loss	`1` = Enabled
`FENCE_ENABLE`	Enable geofence	`1` = Enabled
`FENCE_ACTION`	Action on geofence breach	`1` = Report Only

You can also set voltage limits to tell the system when the battery is low or very low:

- `BATT_LOW_VOLT`: sets the voltage at which a **low battery warning or failsafe** is triggered.

- `BATT_CRT_VOLT`: sets the voltage at which a **critical battery action** occurs.

Summary

Understanding and configuring flight modes and failsafes ensures safe, flexible, and reliable USV operation.

Key takeaways:

- Use Manual, Acro, and Steering for tuning and direct control.

- Use Auto, Guided, and RTL for autonomous operation.

- Loiter helps pause or stabilize the USV.

- RC switch must include at least one fallback mode (Manual or Loiter).

- Failsafes trigger automatic mode changes to protect the vehicle.

- Geofences can stop the vehicle or force it to return within limits

Chapter 5: Designing an Autonomous Mission Using the PLAN Menu

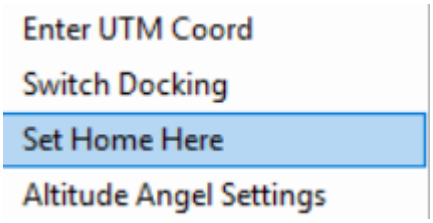
This chapter explains how to design, configure, and upload an autonomous mission for a USV using the PLAN menu in Mission Planner. It follows a clear step-by-step process, covering waypoint creation, command insertion, speed and loiter controls, and how to properly launch a mission. Additional planning tools are also introduced.

Step-by-Step Mission Design

1. Open PLAN Menu and Set Home

1. Connect to the USV via USB or telemetry
2. Open the **PLAN** tab in Mission Planner

3. Right-click on the map → **"Set Home Here"** to define the home location



4. Alternatively, long-press left-click on the point to move Home

   This is the point the USV will return to if RTL (Return to Launch) is triggered

2. Add Waypoints

1. Left-click on the map to place waypoints

Each click creates a point with a number and lines between them

2. Choose **WAYPOINT** command (altitude is ignored for USVs)
3. Avoid placing points on land or unsafe zones
4. Add intermediate waypoints to smooth out sharp turns

3. Insert Special Commands

Mission Planner allows you to add special commands between or after waypoints to control vehicle behavior. These commands add logic, timing, speed changes, or payload actions.

LOITER_TIME

- Holds position using GPS for a set time (seconds)
- Used to pause and collect data or observe environment

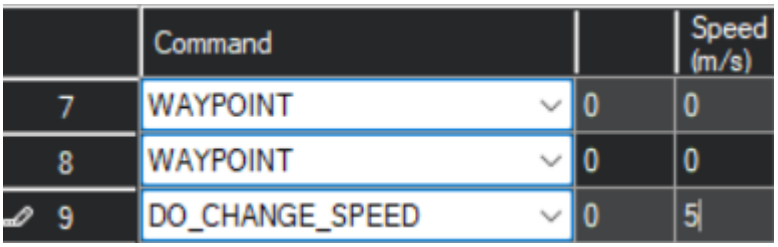
	Command	Delay
10	WAYPOINT	0
▷ 11	WAYPOINT	0
12	WAYPOINT	0
13	LOITER_TIME	5

LOITER_UNLIM

- Holds position until manually interrupted
- Used when external input is needed before proceeding

DO_CHANGE_SPEED

- Sets a new cruise speed (m/s) from that point onward
- Useful before entering narrow areas or approaching turns



To add or remove any of these commands, **right-click** on a waypoint in the mission list and choose **Insert** or **Edit Command**.

4. Add Mission End Action

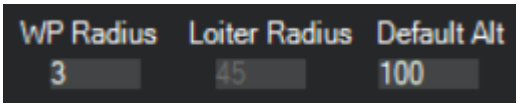
- Add a **RETURN_TO_LAUNCH (RTL)** command at the end

- If not added, the boat enters **Loiter** mode at the final waypoint
- RTL is strongly recommended during early testing

5. Set Mission Parameters

Adjust key parameters to define mission behavior:

- `WP_RADIUS`: How close the boat must get to a waypoint (2–5 m typical)



- `CRUISE_SPEED`: Target speed in AUTO mode (e.g., 1.0–1.5 m/s)
- `CRUISE_THROTTLE`: Throttle value to maintain cruise speed

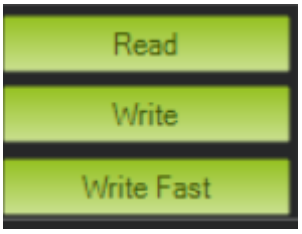
Optional tuning:

- `WP_SPEED`
- For most cases, use defaults unless specific adjustment is needed

Tip: Larger WP_RADIUS values reduce overshooting and help in current.

6. Upload the Mission

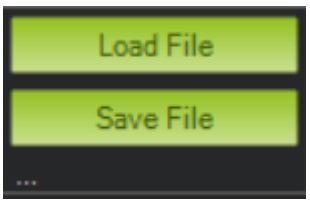
- Click **Write** to send the mission to the autopilot
- Click **Read** to verify the mission is stored correctly



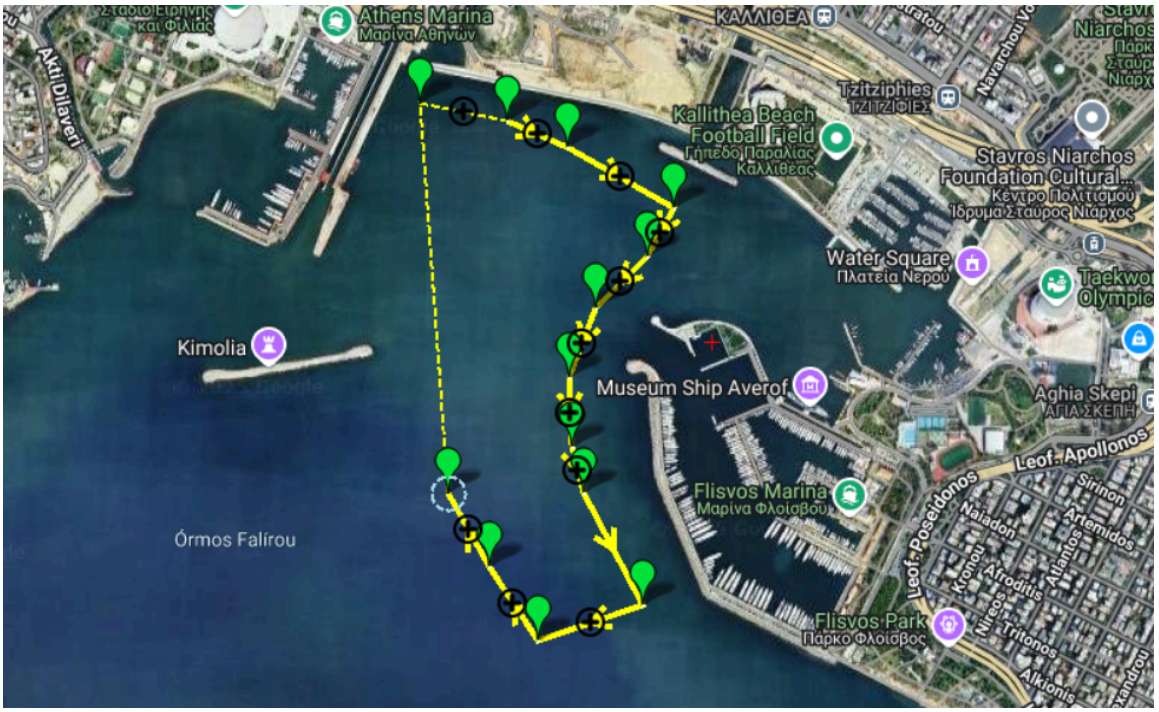
- The mission stays in memory until overwritten

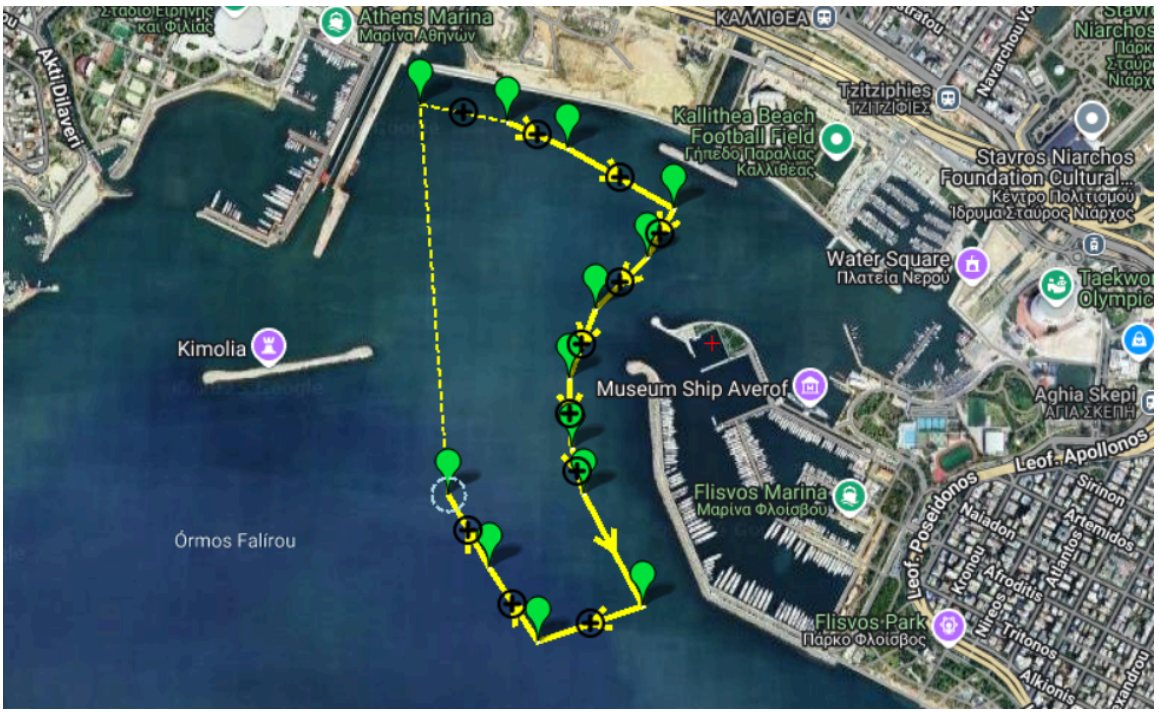
You can also:

- Click **Save File** to store the mission (.waypoints file)
- Click **Load File** to upload it later



- This is useful when preparing multiple missions in advance





7. Pre-Mission Checklist

- Double-check waypoint order and locations

- Use SITL simulation
- Mission Planner shows active waypoint during execution

8. USV-Specific Planning Tips

- **Account for Drift**: Leave space near shorelines, avoid tight channels
- **Smooth Turns**: Add extra waypoints around corners
- **Speed Control**: Use **DO_CHANGE_SPEED** to slow down before turns
- **Loiter in Safe Zones**: Use **LOIT_RADIUS** to keep boat drifting safely
- **No Obstacle Avoidance**: USVs do not avoid obstacles automatically with mission's commands only.

9. Launching the Mission

1. Place boat at the launch (home) point
2. Arm motors (usually in MANUAL mode)
3. Switch to **AUTO** mode
4. The USV will begin the mission automatically

   Keep RC control ready to switch to Manual at any time.

Advanced Planning Tools

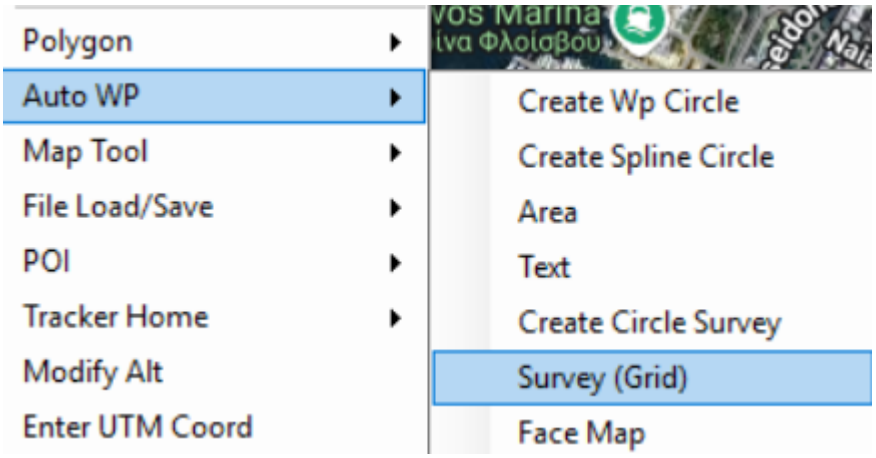
Mission Planner provides more advanced mission design options:

Survey Grid Planning

- Click the **polygon icon** (left side toolbar)

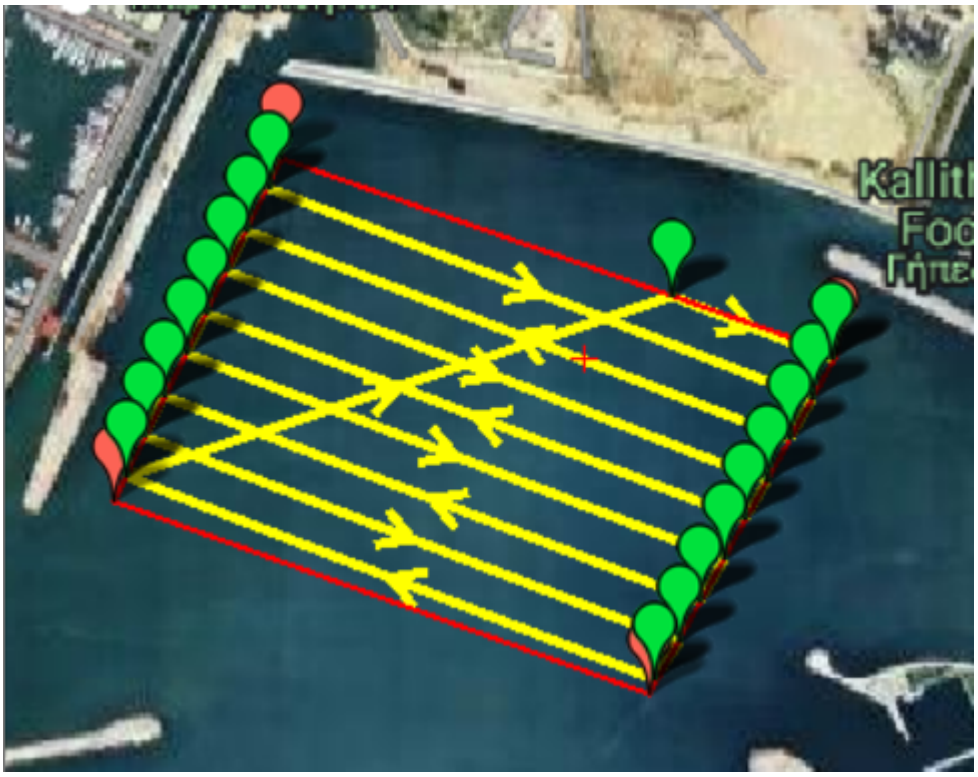
- Draw the area of interest directly on the map

- Right-click inside the area → **AUTO WP > Survey (Grid)**

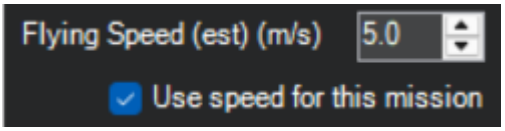


This opens a configuration window:

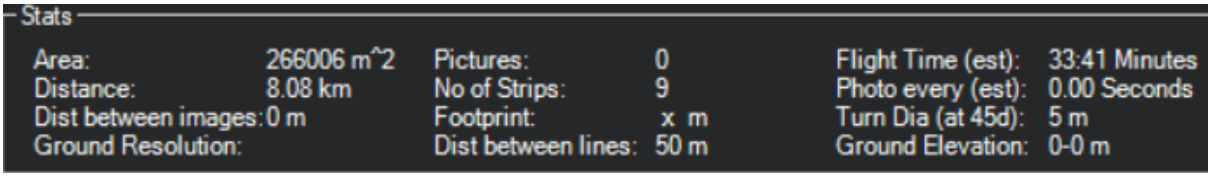
- Set grid spacing, angle, overlap, and direction



- Adjust mission speed and check “Use speed for this mission”



- Estimated mission duration and other infos are shown in the window



This method is ideal for covering areas evenly (e.g., for mapping).

Note: For USVs, disable altitude-related options. Only horizontal movement is used.

This is one of the most common methods for area coverage, besides manually adding each waypoint.

Summary

Mission Planner provides a structured and flexible way to plan autonomous USV missions.

Key Points:

- Waypoints and commands define the mission path and behavior
- Use special commands for loitering, speed, and actions
- Always end missions with RTL during testing phases
- Upload (Write) and verify (Read) missions before launch
- Save and load missions to plan in advance
- Use Survey Grid tools for automatic area coverage

Best Practices:

- Avoid land and narrow spaces
- Tune `WP_RADIUS` to suit current and boat agility
- Test missions in simulation before deploying
- Only one mission can be stored on the autopilot at a time

Chapter 6: USV Simulation with Mission Planner SITL

What is SITL?

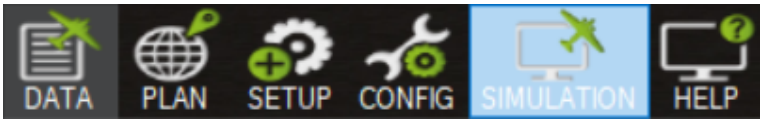
SITL (Software-In-The-Loop) is a powerful feature of Mission Planner that allows you to simulate a USV using ArduPilot firmware directly on your computer, without any physical hardware. It provides a full virtual environment to:

- Practice autonomous missions and manual control (if a joystick controller is available)
- Test parameter settings safely
- Understand behavior in different flight modes
- Train for emergency procedures

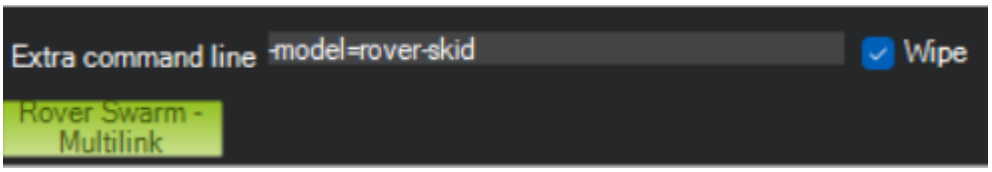
Using SITL helps reduce the risk of accidents and equipment damage by validating setups in a controlled space before field deployment.

How to Start a USV Simulation

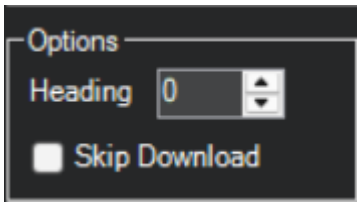
1. **Open Mission Planner** and go to the **Simulation** tab.



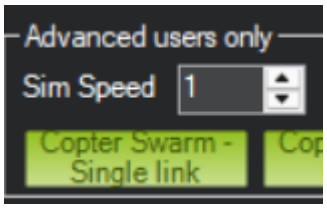
2. Move the **Home Point** to the area of interest
3. **Enter "`--model=rover-skid`"** in the **Extra Command Line** field.
    - This ensures the correct simulation model is loaded for a boat with differential thrust (skid steering).



4. **Set other simulation options**:
    - **Options Heading**: Choose the heading your boat will face at startup.

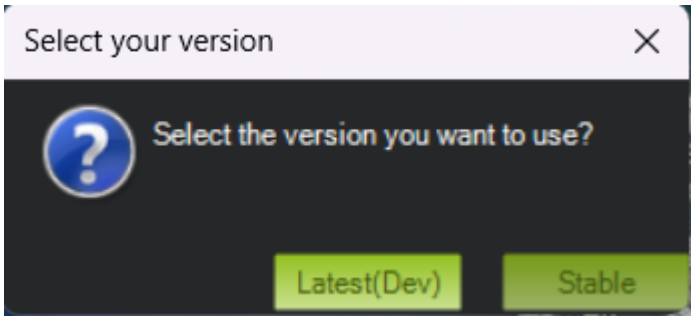


    - **Simulation Speed**: Set to `1` for real-time. You can increase it if testing under time constraints.

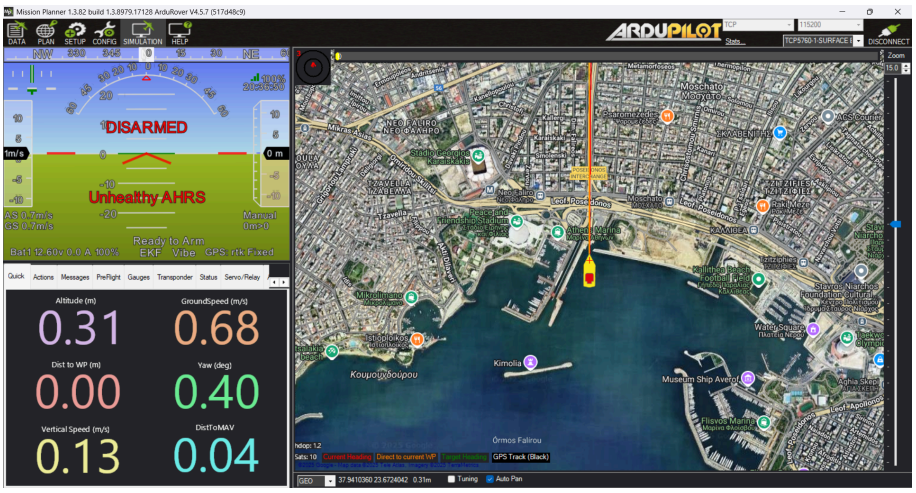


    - **Wipe**: Check this to start with default parameters (recommended).
5. **Select Vehicle and Firmware**:
    - Choose `Rover` as the vehicle type.

    - Click `Stable` to load the official firmware version (not a development release).



6. **Wait for SITL to initialize**. The vehicle will appear on the map in the selected location, with correct boat behavior and icon.



Load Parameters for Your Real USV

To simulate a specific boat configuration:

1. Go to **Config > Full Parameter List**
2. Click **Load from file**
3. Select your saved .param `.param` from your real USV setup
    - Keep all parameters **except those related to hardware calibrations** (compass, GPS offsets, IMU, etc.)
4. Click **OK** on any warning messages
5. Click **Write Params**
6. If needed, click **Refresh Params** to reboot the virtual vehicle and apply changes

First Movements in Simulation

1. Go to the **Data** tab
2. Open the **Actions** tab

3. Set a starting mode (e.g., **Manual**) and click **Set Mode**
4. Arm the vehicle by clicking **Arm/Disarm**
5. To test movement:
    - Right-click on the map
    - Choose **Fly To Here**
    - Ignore altitude (not relevant for boats)
    - Click **OK**

Tip: Choose a nearby point with a heading offset of less than ~90° to avoid erratic rotation.

Important Notes on Behavior

- **Waypoint Behind the Boat**: If the given target point is significantly behind the current heading, the USV may start spinning in circles. This is due to limitations in turn control with skid steering.
- **Ending in Loiter or No Next Waypoint**: When reaching the end of a mission or staying in Loiter mode, the USV may begin rotating in place. This happens because the autopilot continuously tries to correct its heading without real drag (like water resistance) to stabilize it.

- **Recommended Action**: After reaching a waypoint, **switch to Manual mode** or issue a new Guided command to prevent spinning.

- **Loiter is not ideal** in simulation without PID tuning. It works better in real-world conditions.

Adding Realism with SIM_xx Parameters

SITL supports various environmental effects to improve realism:

- **Waves:**
    - `SIM_WAVE_ENABLE = 1` (enable wave simulation)
    - `SIM_WAVE_AMP = 0.2` (wave height in meters)
    - `SIM_WAVE_DIR = 0` (wave direction in degrees)
    - `SIM_WAVE_SPEED = 0.5` (m/s)
    - `SIM_WAVE_LENGTH = 10` (m)
- **Wind:**
    - `SIM_WIND_SPD = 3` (wind speed in m/s)
    - `SIM_WIND_DIR = 180` (wind direction)
    - `SIM_WIND_TURB = 0.5` (turbulence)

These parameters affect vehicle stability and sensor performance in SITL. While they don't solve steering issues, they can simulate realistic environmental conditions for sensor validation or tuning experiments.

Connecting SITL with Mission Planning

The simulation environment in SITL works seamlessly with the mission planning tools introduced in Chapter 5. You can:

- Design a mission using the **PLAN** tab (with waypoints, commands, speed changes, etc.)

- Upload it to the simulated autopilot via **Write & Read**

- Switch to **Auto mode** and **Arm** the vehicle to run the mission

Using SITL allows you to **verify mission logic, waypoint order, speed adjustments, and RTL behavior** before any real deployment. It is especially useful for detecting issues such as:

- Waypoints placed too close to obstacles
- Turns that are too sharp for skid steering
- Wrong mission actions

By testing each mission in SITL first, you can be confident that the plan will behave as expected in the field.

Summary

- SITL allows safe testing of your USV without real hardware.
- Use `--model=rover-skid` to simulate proper boat behavior.
- Upload your own parameter set (excluding calibration) for realism.
- Avoid sharp heading changes or "fly-to" commands directly behind the boat.
- Avoid using Loiter at the end of a mission unless it's tuned.
- Always monitor the simulation closely and switch to Manual if behavior becomes unstable.
- You can simulate environmental effects using `SIM_WAVE` and `SIM_WIND` parameters.
- SITL is fully compatible with the PLAN tab and helps verify the correctness of autonomous missions before deployment.

Chapter 7: Checklist for USV Deployment

Using Unmanned Surface Vehicles (USVs) requires careful attention to many details. Small mistakes can cause big problems during a mission. To avoid this, experienced teams always use a checklist before launching the USV. Checklists make sure every important step is checked carefully. They help teams spot problems early, keep equipment safe, protect the environment, and keep everyone safe.

In this chapter, you'll learn why using a checklist is important, how to use it correctly, and you'll get a clear, ready-to-use checklist for your USV missions.

Why a Checklist is Essential

Checklists are commonly used in aviation, boats, and robotics because they greatly reduce mistakes. They help teams stay organized and careful by making sure every important detail is checked. Checklists stop you from relying just on your memory, which can fail even experienced operators, especially when under stress or doing routine tasks.

Remember: once you launch the USV, fixing problems like a badly calibrated compass or loose battery becomes difficult or impossible. Using a checklist every time helps your team avoid these serious mistakes.

How to Use the Checklist Effectively

Always use a printed or laminated copy of the checklist when you're in the field.

Do the checklist right before launching the USV, after you've finished setting it up.

Clearly assign team roles:

- One person reads each step out loud.
- Another person checks and confirms each step.
- If you're alone, read each step aloud and confirm it carefully yourself.

Important: Never skip any steps. If something isn't clear or finished, stop and fix it before moving on.

Checklist Philosophy

This checklist uses short and clear instructions. It's designed for action, easy to follow, and straight to the point. Don't include extra explanations or theory when you're doing the checklist. The purpose is simply to confirm each step quickly and accurately.

Use this checklist exactly as provided. It has been tested and improved through real-world use.

Checklist

Field Checklist: Pre-Mission Checks

☐ **Mission Briefing:** Team roles clear, mission goals understood, emergency plan ready.

☐ **Weather Check:** Wind, waves, currents safe for mission.

☐ **Operational Area:** No swimmers, boats, or obstacles nearby.

☐ **Launch/Recovery Site:** Safe entry and tools ready.

☐ **Safety Gear:** Radios, phones, sun protection ready.

☐ **Hull Check:** Watertight, no damage, hatches sealed.

☐ **Propulsion Check:** Thrusters and rudders clean, secure, spinning freely.

☐ **Payload Check:** Secure, powered on, protective covers removed.

☐ **Power Systems:** Batteries fully charged, securely fastened.

☐ **Electrical Connections:** Secure, dry, undamaged.

☐ **Kill Switch/Safety Plug:** Tested and working.

☐ **Auxiliary Systems:** Pumps, lights, companion computer working.

☐ **Autopilot Startup:** Boots correctly, no warnings.

☐ **GPS Check:** 3D fix with HDOP under 1.5.

☐ **Compass & IMU:** No errors, horizon accurate.

☐ **Remote Control (RC):** Battery full, correct settings, sticks/switches working.

☐ **Control Mode:** Manual mode selected before arming.

☐ **Mission Plan:** Waypoints and home position loaded correctly.

☐ **Failsafes:** RC loss, battery, GPS failsafes ready.

☐ **Calibrations:** Compass, IMU, RC up-to-date.

☐ **Manual Control Test:** RC sticks move servos correctly (no motors).

☐ **Telemetry Link:** Ground station receives good data.

☐ **Ground Control Software:** Mission Planner or QGroundControl maps and missions loaded.

☐ **Emergency Stops:** RC kill switch or ground control disarm ready.

☐ **Companion Systems:** Cameras or video streaming functional.

☐ **Backup Communications:** Tested and working.

☐ **Final Decision:** Everything checked, fix or delay mission if needed.

☐ **Launch Confirmation:** Team clearly confirms readiness to launch.

☐ **Safe Launch:** Controlled release, props clear, safe distance.

Post-Mission Actions

☐ **Disarm and Power Down:** Motors off, electronics safely turned off.

☐ **Inspection:** Hull, battery, connections checked for issues.

☐ **Mission Logging:** Record any problems or observations.

☐ **Checklist Updates:** Note any new issues for checklist improvements.

☐ **Debriefing:** Team reviews mission success, problems, and areas for improvement.

Summary

The checklist is an essential tool for successful USV operations. It helps your team stay organized, disciplined, and safe. Use this checklist regularly and always look for ways to make it better based on your experiences.

Always trust the checklist—it protects your USV, your mission, and your team, every time.