# <u>ArduPilot SmartRTL Vehicle Platform Request</u>

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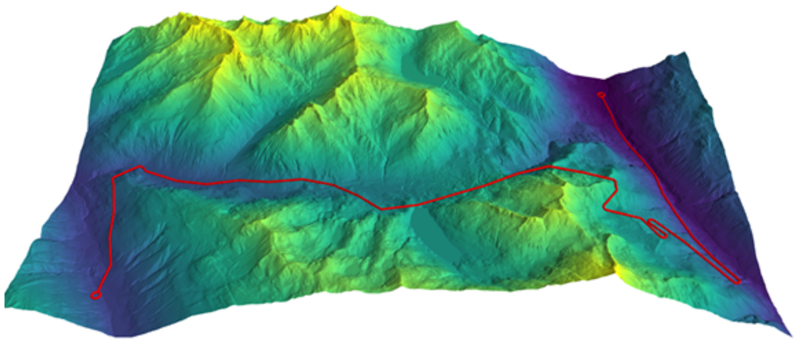

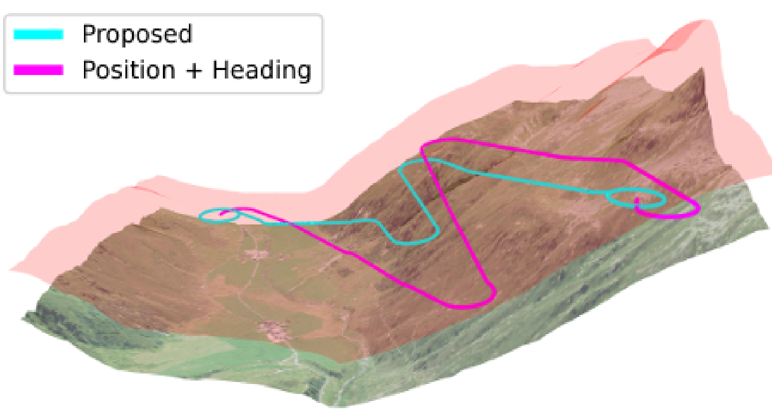


Figures from "[Safe Low-Altitude Navigation in Steep Terrain with Fixed-Wing Aerial Vehicles]"

## Purpose

The purpose of this document is to propose an official platform for developing, testing, and maintaining the SmartRTL and similar navigation features for fixed wing and to request funding for a hardware platform.

## Prior Work

Rhys has maintained many of the Software in the loop (SITL) models platforms for ArduPilot and presented his latest updates here at the 2023 ArduPilot developer conference. Ryan started his contributions to ArduPilot with the merge of initial ROS 2 support and also presented his work at the 2023 developer conference. Over summer 2023, Rhys and Ryan menoted two GSoC students to develop the ROS 2 interface for ArduPilot. The projects were GPS denied navigation  and improving native DDS support. In the Fall of 2023, the ROS 2 interface had an addition to support fixed wing waypoint control and numerous sensors. Ryan and Rhys currently work on ArduPilot in their free time for fun and the benefit of the open source community. Both are active members of the ROS aerial working group.

Recent research at ETH Zurich from Jaeyoung (Jay) Lim on fixed wing navigation has been released for ROS 1. Rhys and Ryan have ported it to ROS 2. This feature allows for fixed-wing navigation in mountainous terrain, which will enable a host of ArduPilot capabilities not currently possible without the use of a companion computer.

The first major feature planned is SmartRTL #2380, which allows a companion computer to plan a safe and optimal path home around terrain in the event of a failsafe and prevent catastrophic behavior or exhausting the battery. As seen in the Smart RTL Github issue, implementing such a feature on the embedded ArduPilot flight controller is not yet possible, and some users have faced crashes due to the missing capability. While this feature works on ArduCopter, it does not exist for ArduPlane due to increased computational complexity, and is unsolved in the open-source community despite being requested in 2015.

Jay's research used a MAKEFLYEASY FREEMAN 2+2 2300MM tiltrotor quadplane to demonstrate the terrain planning and navigation capability. Tiltrotor quadplanes have key advantages for mapping and survey compared to dedicated fixed wing or copter platforms, including long endurance,  takeoff and landing in restricted environments, and heavy payload capacity. Additionally, dual tractor props increase airflow over the wing for improved low-speed control margin near the stall point. These performance advantages make it a suitable platform for mapping in mountainous terrain where unpredictable weather and wind cause high variability in the environment.

## Request

Ryan and Rhys are looking for a suitable hardware platform to form the basis of the ArduPlane SmartRTL feature. Due to the expense of these platforms, it is prohibitive for us to purchase these vehicles with our personal funds. Thus, we would like to request partial or complete funding from a quadplane manufacturer to support deployment of this capability on representative hardware. Ideally, the manufacturer will supply two Plug and Play (PNP) quadplanes capable of carrying 600 gram payload capacity. By having two aircraft, this will enable two developers to work on, test, and maintain the feature, with duplication increasing the likelihood of success.

## Desired platform hardware specifications

- Mandatory VTOL or optional bungee launch takeoff
  - Hand launch is not required
- Capable to carry 600 grams payload
  - Nvidia Jetson Orin Nano Development Kit Companion Computer (176g)
  - Sony A6000 mapping camera (344g)
  - 2-axis servo gimbal for mapping camera (~100g)
  - 4G LTE radio (~50g)
- TRIM_ARSPD_CM greater than 10 m/s to combat wind
- Able to hover for 2 minutes
- 1 hour minimum flight time
- Electric propulsion to reduce noise and transport issues of gasoline engines
- Foam construction to ease of repair and reduce upfront costs

## Planned Scope of work

- Create a representative SITL model for use in Gazebo of the chosen Quadplane that can be used for development, continuous integration, and as a teaching tool
- Document a hardware bill of materials to build a vehicle capable of SmartRTL
- Document a wiring diagram for additions to the PnP kit to enable SmartRTL including the companion computer, camera payload, and additional radio equipment
- Finish development of the terrain navigation port to ROS 2, navigation controller for ArduPlane, terrain server in grid_map_geo, and implement the SmartRTL feature in ArduPlane
- Create tuned ROS 2 configuration and ArduPilot parameters that will enable SmartRTL features on the target platform
- Create necessary dockerfiles or OS images for the companion computer for users to easily deploy the feature
- Write an ArduPilot wiki entry on how to enable, configure, and tune SmartRTL
- Demonstrate the platform in flight performing SmartRTL at the 2024 ArduPilot developer conference
- Merge all relevant code as it is completed
- Test the SmartRTL feature as part of ArduPilot beta firmware testing
- Assist the ArduPilot developer team maintain SmartRTL through either code changes, flight testing, continuous integration, or documentation updates

## Key advantages of funding this proposal

- Proven platforms are more likely to be purchased by others
- Developer team members can contribute documentation and improvements to make it easy for users to replicate behaviors
- Benefit the open source community to enable SmartRTL and prevent potentially illegal airspace breaches
- Having the chosen aircraft support in SITL makes it easier to develop and improve features
- Provide a reliable platform to improve on further mapping capabilities such as active gimbal control in mountainous terrain
- Creating a common and stable reference platform like the 3DR Iris accelerates development on inter-operable technology rather than proprietary solutions that fracture development
- Open the door to using fixed wings VTOL platforms in mountainous terrain for avalanche monitoring, wildfire monitoring, and search and rescue to protect and save human lives