UxV/35 Radar Project

Introduction

This document provides an overview of the Kairos UxV/35 radar project and looks at our current implementation of the technology. An in-depth background is provided on the communication protocol for integration into the Ardupilot autopilot software.

The Radar Sensor

The A121, built by Acconeer, is an advanced radar sensor in a compact size with low power consumption. The 60 GHz wavelength allows for the sensor to identify objects in challenging conditions (including fog or direct sunlight) and can operate behind materials such as plastic or glass.

Specs:

- Distance measurements up to 20m
- FOV of roughly 55° natively and a range from 30° - 80° with the use of lenses
- Typical current consumption of <60 mA during long range measurements

XS121 Satellite Board

Figure 1 The XS121 Satellite Board utilizing the A121 Radar Sensor

The XS121 board, built by Acconeer, provides the ability to power and control an A121 radar sensor through a single flexible flat cable. Each UxV Radar Board can control 8 of these satellite boards. Kairos plans to utilize this prebuilt board while development of a custom board continues.

The Kairos UxV/35 Radar Board

For radar use on the Uxv/35 platform, Kairos has created a solution that allows a user to place up to 8 sensors around a vehicle using flexible flat ribbon cables.

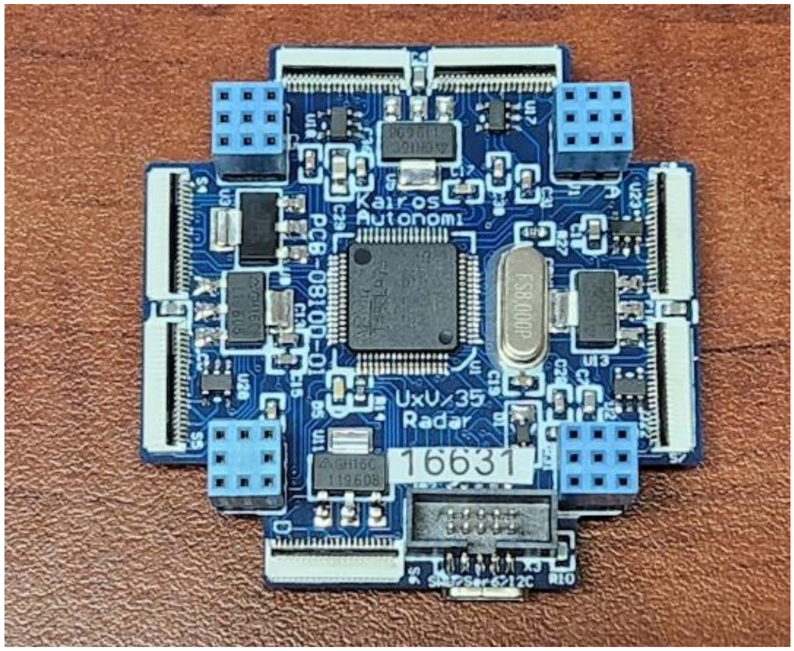


Figure 2 UxV/35 Radar Board with I/O for 8 radar modules. 7 FFC connectors can be seen at the edges of the boards. An 8th connected is located on the back side of the board.

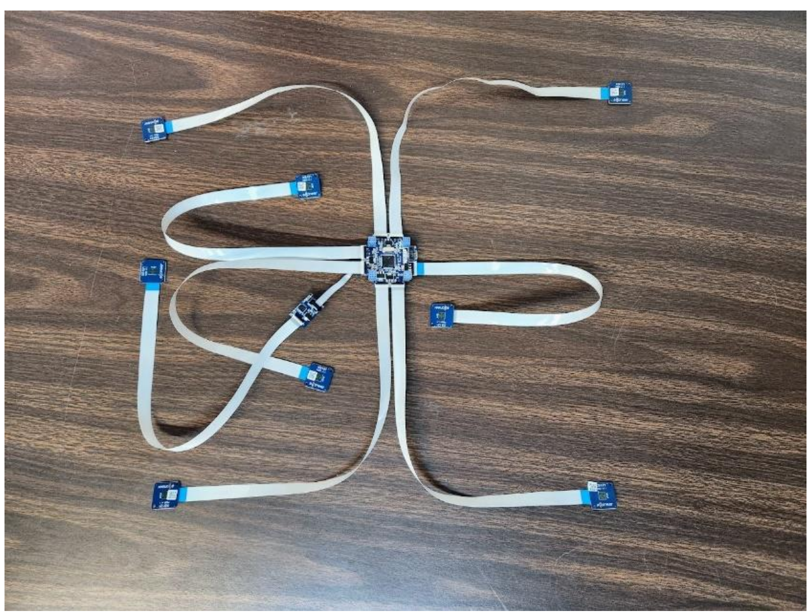


Figure 3 Demonstration of 8 radar sensors connected to the UxV/35 Radar Board

The following screenshot is taken from the Mission Planner GCS in the proximity window which is displaying the active distance measurements being sent from the Radar Carrier board. The FOV and orientation of the sensor is represented here which provides insight into potential blind spots. Kairos plans to install lenses that widen the FOV and add additional sensor which will provide 360° horizontal coverage. There is also potential to include multiple upward facing sensors to protect a UAV in forward flight.

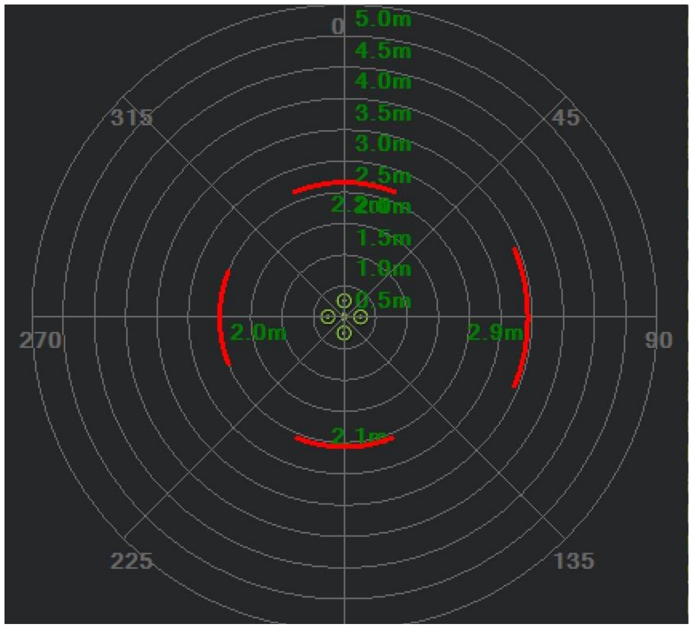
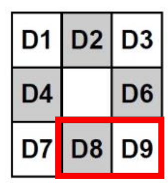


Figure 3 Mission Planner Proximity Window Representing UxV/35 Radar Data

Communication Protocol

Kairos uses Serial Channel D (Pins D8 and D9) on the Mission Controller board to receive the distance measurements from all 8 sensors. This channel is configured in ArduPilot for Mavlink2 protocol at a baud rate of 115200. A message format, defined in the MavLink2 library, allows all radar messages to be sent on the same channel. The following is an outline of the message with a live capture:



Mavlink Distance Sensor Message

- Time since boot
- Minimum distance
- Maximum distance
- Distance Measurement
- Sensor Type

- Sensor ID
- Orientation
- Covariance
- Horizontal FOV
- Vertical FOV
- Signal quality
- Quaternion

The result is a 55-byte string shown here with a logic analyzer capture.

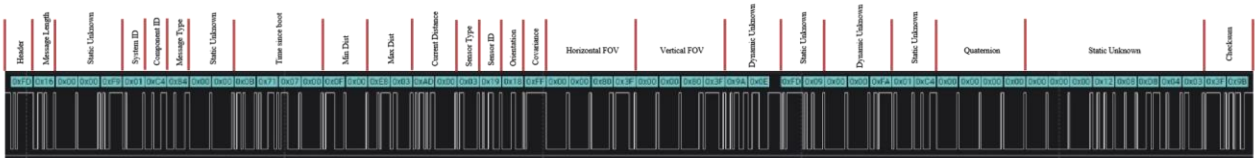


Figure 4 Capture of a Mavlink Distance Packet on the UxV/35 D9 Pin (RxD)

Data packets can also be viewed on the Mission Planner GCS. In the Mavlink Inspector window, ArduPilot will populate a list of components that are active on the vehicle. The following screenshot shows the Radar Controller (Comp 196) and the messages being sent from it. In this example, ID 25 is the downward facing radar which returned a distance measurement of 184 cm. Horizontal and Vertical FOV are represented in radians.

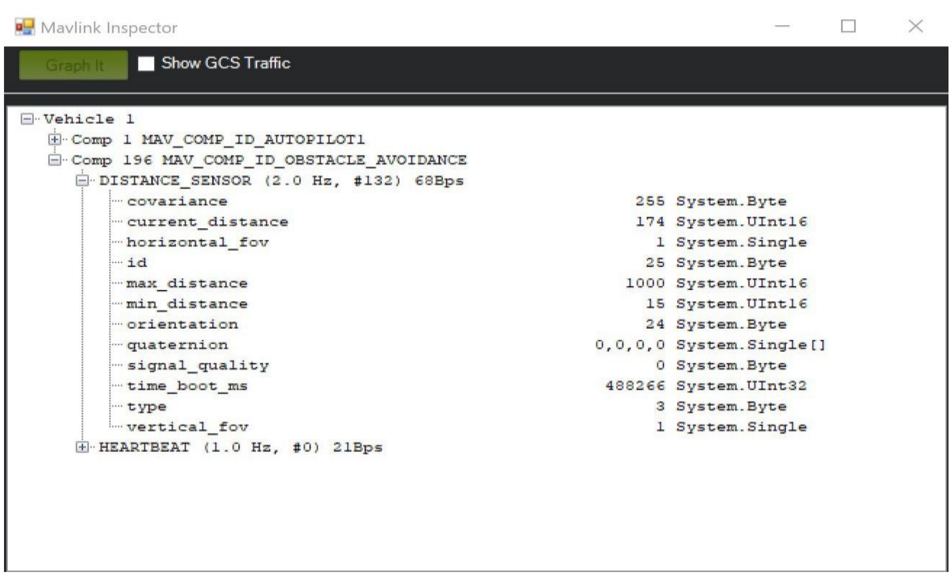


Figure 5 Mavlink Inspector window showing messages received from the UxV/35 Radar Carrier board

Ardupilot Obstacle Avoidance

Ardupilot, on the Mission Controller board, receives these mavlink distance messages and makes decisions based on the distance measurement and constraining parameters. There are various options for this decision making based on the mode the vehicle is in (Auto or Manual modes).

During Manual Operations:

- Stop
  - This mode brings the vehicle to a stop when an obstacle is detected. The vehicle then waits for the operator to command the vehicle away from the object.
- Backup
  - This mode attempts to keep a set distance away from the detected obstacle even with the object moving towards the vehicle.

During Auto Operations:

- BendyRuler
  - This algorithm looks at all the distance measurements and can attempt to navigate around the obstacle vertically or horizontally. After clearing the obstacle, the vehicle will continue to the next waypoint.
- Dijkstra's
  - This secondary algorithm can be used to improve the efficiency of the path planning around the object. While BendyRuler attempts to only solve the obstacle problem, Dijkstra's can help weight the next waypoint into the decision making to ensure the vehicle continues towards its objective.

Version History

Date and Signature	Revisions	Reasons for Revision
1/30/2024 Jack R.	Document was written. (v01.00.00)	
1/31/2024 Jack R.	Updated document to include captures of mavlink messages (v01.01.00)	
3/12/2024 Jack R.	Updated documents to include the new 8 sensor radar board and sensor specs (v01.02.00)	

Kairos Autonomi 8700
S. Sandy Pkwy.
Sandy, Utah 84070
801-225-2950 (office) 801-907-7870
(fax) www.kairosautonomi.com