Air-to-Ground Data Link: Proof of Concept Test Report

CoE-17-003.1

Scope of the Report

The Center of Excellence for Advanced Technology Aerial Firefighting (CoE) is charged with researching, testing, and evaluating technologies related to aerial firefighting. This report represents a preliminary analysis of a device temporarily made available to the CoE free of charge for testing purposes. The CoE has no affiliation with goTenna beyond testing their product and providing feedback. Please direct any questions regarding this report to Brad Schmidt, Wildland Fire Technology Specialist at brad.schmidt@state.co.us or (970) 665-0038.

Introduction

After the 2015 fire season, an After-Action Review of the State of Colorado's Pilatus PC-12 Multi-Mission Aircraft (MMA) program was conducted. This review identified the need for an air-to-ground (A/G) data link with the ability to provide intelligence products to firefighters in areas that lack an Internet connection. The CoE has been researching options for an A/G data link since then and has identified possible solutions for both a high-bandwidth data link that can support streaming video, and a low-bandwidth data link that can transmit mapping data.

The CoE conducted a test of high- and low-bandwidth data-transmitting radios on the ground in March 2016 (CoE-16-001). Operating with 1 watt of power in the 2.4 GHz unlicensed band, we found that the high-bandwidth radio struggled to transmit video more than 1 mile with an omnidirectional antenna, but could transmit video up to 8 miles with directional antennas on both ends of the link.

The CoE also tested the goTenna, a 2-watt VHF data radio, as a low-bandwidth radio and found that this product can transmit data at least 16 miles in a line-of-sight environment. However, the version of the goTenna we tested cannot accommodate an external antenna and operates in the Multi-Use Radio Service radio band, which is not authorized for use aboard an aircraft. Recently a prototype of the forthcoming goTenna Pro became available, which can accommodate an external antenna and operates in VHF and UHF radio bands that are frequently licensed to public safety agencies. This report provides results from preliminary, proof of concept air-to-ground testing.

Figure 1. Multi-Mission Aircraft in Flight

Test Goal

The goal of this test was to assess the usefulness of the goTenna Pro as an air-to-ground data link. This assessment was based on answering the following questions: (1) Can the goTenna Pro transmit information from the MMA to ground and vice versa when the aircraft is orbiting a ground contact at its normal mission altitude? (2) How far downrange can the MMA be from a ground contact and still support an air-to-ground data link?

Methods

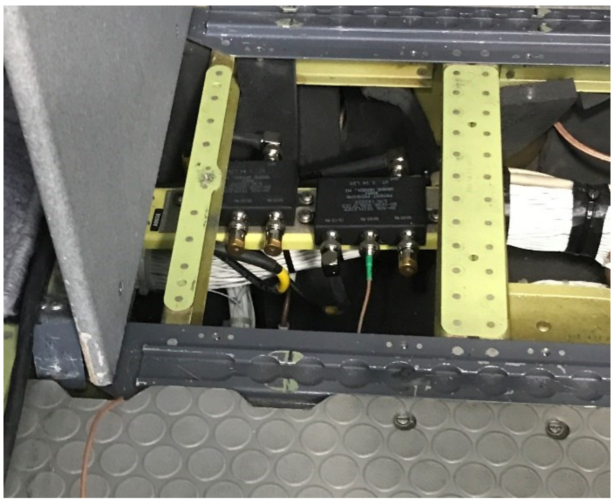
Figure 2. Testing Cable with Green Connector Integrated into Antenna Triplexer

If this project is pursued further, the CoE plans to transmit points, lines, polygons collected by the MMA to firefighters on the ground. However, the goTenna Pro prototype is currently limited to sending position reports and text messages. As a result, the "information" for this test was defined as a person-to-person text message sent using the stock goTenna app. The character limit of the text message is 160 characters and messages of that length—representing the maximum allowed file size—were transmitted during the test.

The goTenna Pro prototype was provided to the CoE the day before the test. This radio includes an SMA connector, allowing the goTenna Pro to function with a variety of antennae. For this test, the prototype was temporarily integrated into an unused antenna on the underside of the right wing of the MMA. This antenna is connected to a triplexer located in the aircraft cabin under the floorboard, which splits out signals in the VHF, UHF, and 700–800 MHz range. Of these three outputs, only the VHF band was currently in use. The UHF band was utilized for this test and integration involved replacing a cap on the UHF output of the triplexer with a cable that terminated in an SMA connector, into which the prototype was connected.


Figure 3. Antenna Used in Test (located immediately aft of the landing gear)

Electromagnetic interference testing was conducted to ensure that the prototype would not compromise the avionics of the MMA. This involved transmitting data through the prototype while the aircraft was sitting on the ground with the engine running, with the pilot simultaneously monitoring the avionics and voice radio systems. No issues were identified during this test, so we proceeded to the aerial test.

Federal interoperability UHF frequencies were utilized during the test, including the UCALL and UTAC frequencies. One frequency was assigned as the control channel, with three frequencies assigned as data channels. These frequencies were programmed into the goTenna Pros using the goTenna app and a successful link was benchtop-tested prior to the aerial test. A high-pass filter was utilized on each prototype to mitigate any interference from VHF radios in the aircraft and on the ground, or any other low-band interference that could affect the test.

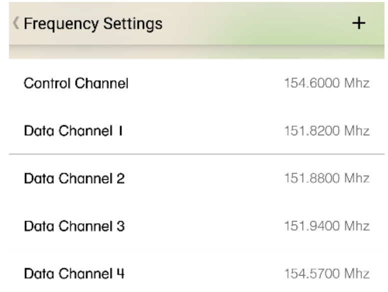

Figure 4. Frequency Settings Dialogue Within goTenna App

The test was conducted over the Eastern Plains of Colorado to take advantage of the quiet radio frequency environment and lack of terrain or forest canopy obstacles and to avoid congested airspace over the Front Range urban corridor. A ground party was stationed at exit 336 on Interstate 70, midway between the towns of Deer Trail and Agate. The ground party utilized a goTenna Pro prototype with an omnidirectional whip antenna and an Android tablet running the goTenna app. A VHF radio on DFPC TAC 1 was used for coordination. The ground party placed their prototype in the vertical position on the tailgate of a pickup truck and ground personnel maintained a clearance of 2 feet from the radio during testing. (Note: at one point in the test, a student did bring a smartphone into proximity with the goTenna for a short period; however, no indication of interference was observed.)

Figure 5. goTenna Pro Prototype Undergoing Testing in MMA

The MMA arrived overhead at the ground party's location at an altitude of 15,000 feet above ground level and established a 5-mile orbit. Five identical 160-character text messages were transmitted from MMA to ground, and five from ground to MMA. To test the interactivity of the link, messages were alternated so the order of the message sender was MMA -> ground -> MMA -> ground and so on until each party had attempted to send five messages each. Test data was collected on a spreadsheet and the exact location of the MMA was captured for each of the messages transmitted from air-to-ground. Exact aircraft locations could not be captured for messages sent from ground-to-air. However, the ground-to-air transmissions occurred between the air-to-ground transmissions, so the approximate location could be identified.

Figure 6. Ground goTenna Pro Prototype on Bed of Truck

When testing in a 5-mile orbit around the ground party was complete, the MMA was instructed to establish a 10-mile orbit around the ground party, although this orbit was ultimately closer to 7 miles. At this point, the aircraft crew was informed of a potential mission to respond to a wildland fire in Kansas, so testing was expedited by moving to an orbit 20 miles from the ground party. Upon completion of this test, the aircraft was instructed to respond to the fire incident and could no longer establish orbits for thorough testing. However, as the aircraft began to travel east, testing of the link continued as parties exchanged messages.

Results

A total of 60 text messages were exchanged during the test, with 30 messages sent from air-to-ground and 30 messages sent from ground-to-air. Of the air-to-ground messages, 29 of 30 were transmitted with no issues, though the penultimate message of the test—which was transmitted at a link distance of 45.4 miles—did require resending twice before it was successfully transmitted. The person-to-person text messages utilized for this test provided receipts indicating successful or failed transmissions (i.e., a check mark for a successful transmission or an exclamation point for a failed one). In the case of the penultimate message, the aircraft tester quickly saw that messages were not being transmitted successfully and tried again twice. At approximately this same distance, the ground party also experienced 2 messages that failed to successfully transmit to the aircraft. Otherwise, the ground party also transmitted 29 of 30 messages without any failures.

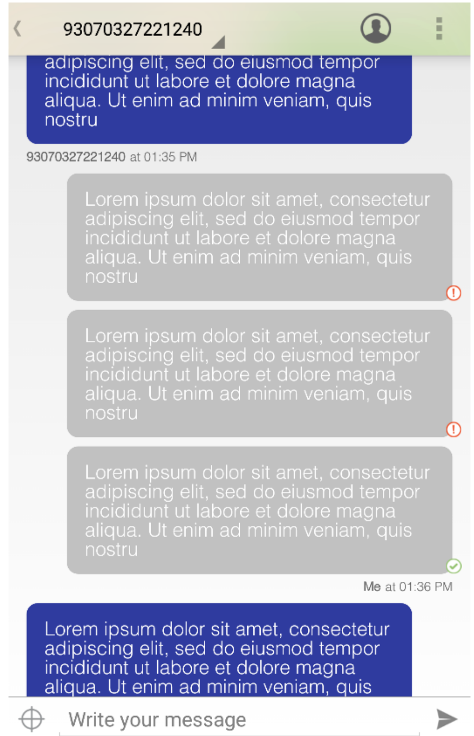

Figure 7. Screen Capture of Message Exchange at 45.4 Miles

After adjusting for the 15,000-foot altitude of the aircraft and the downrange link distance, the maximum link distance achieved during the test was 46.75 miles. The mean link distance of the test was 23.47 miles, with a minimum link distance of 4.72 miles. Figure 9 shows locations of the aircraft on air-to-ground transmissions. Not shown are the ground-to air-transmissions, but since a ground-to-air transmission occurred between each air-to-ground transmission, the locations can be approximated.

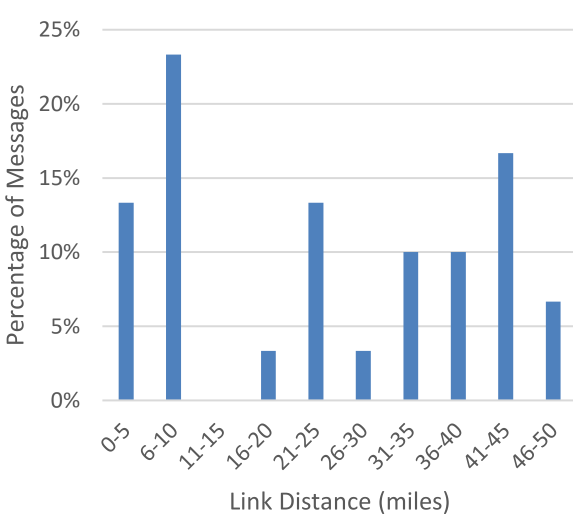

Figure 8. Distribution of Messages by Distance

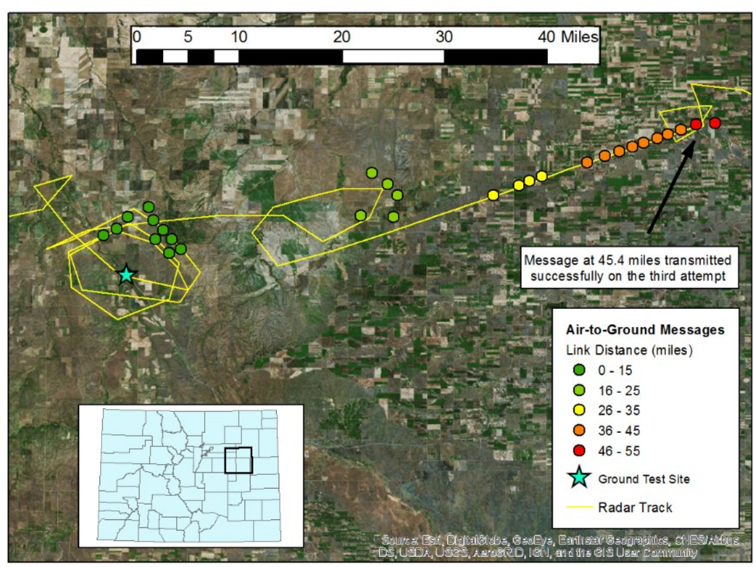

Figure 9. Map of Test

Discussion

Both goals of this proof of concept test of the goTenna Pro prototype were achieved, with enough data gathered to demonstrate the viability of this system as an A/G data link and to roughly establish the distances under which an A/G data link can be maintained. Both testing parties reported that the radios rapidly transmitted messages with no failures over link distances of up to 40 miles. In addition to 160-character text messages exchanged for testing, the goTenna app proved useful to help coordinate testing, as the VHF voice radio experienced technical difficulties, had scratchy reception, and was frequently preempted by voice traffic from Air Traffic Control. Indeed, a handful of short text messages were exchanged at distances beyond 46 miles as the test concluded, though the distances for these messages were not logged and the reliability of the link rapidly deteriorated at that distance.

Figure 10. Ground-Testing Party Reviewing Messages

While the rough limits of the goTenna Pro were established by this test, the nature of the prototypes and the abrupt end of the test as the MMA was reassigned to a wildland fire leaves room for future study of this system as an A/G data link. Once the goTenna Pro is commercially released, improvements to the radio may yield additional range. More thorough testing with orbits established at 40 miles and beyond would increase the sample size of the test and would provide more certainty regarding the distance limitations of a data link using this system. Finally, comparative testing in the VHF and UHF bands would likely reveal differences in the propagation of the signal and establish which band would be optimal for an A/G data link.

As this technology matures, additional testing of the bandwidth possible with the goTenna Pro and/or other similar wireless technologies should be conducted to ensure that spatial products captured by the aircraft—such as points, lines, and polygons—can be transmitted in a timely fashion. The utility of this system for non-aerial applications should be evaluated as well, with consideration given to the ability of the radio to transmit data in environments with terrain or vegetation obstacles and to utilize mesh networking to forward messages through intermediary radios.

Figure 11. Rendering of a Production-Ready goTenna Pro