Remote Internet Protocol Communication Flight Testing
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Purpose
These tests were devised to assess whether the jointly developed USDA Forest Service/NASA technology RIPCom meets the needs of the National Infrared Operations group (NIROPS) to deliver data during airborne wildland fire monitoring.

RIPCom is a wireless communication system that makes a UAV look like a network node in the sky. RIPCom provides an Ethernet to radio frequency (RF) connection solution for real-time data transmission, and its design allows the end points of the communication system to become nodes on a network with an assigned Internet-Protocol address (figure 1). RIPCom’s versatility makes it valuable for any system that requires a high-speed, digital wireless network.

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NASA–GSFC has modified the original RIPCom design so that it can meet Forest Service requirements, which differ somewhat from NASA’s needs. This adaptation includes the ability to dump data at much faster rates and greater ranges. RIPCom is now able to do the following:

- Provide a long-distance wireless network that can also maintain a connection with a moving target.
- Provide a wireless network connection at a distance of at least 10 miles.
- Plan for aircraft that is 10,000 feet above ground level.
- Acquire data on the ground from an aircraft operating at 300 miles per hour.
- Supply a data rate of at least one megabyte per second.

RIPCom consists of commercial off the shelf components from different vendors chosen because their unique performance characteristics match Forest Service goals. Numerous wireless network technologies are potential candidates for RIPCom, and many factors, such as frequency, RF power output, size, and cost, were considered for the Forest Service system design. The aircraft and ground station were designed individually due to their unique characteristics. Figure 2 illustrates the major components of the ground station and the aircraft.

Figure 2—Detailed diagram of Forest Service RIPCom solution.
The central component of the airborne elements is the antenna, which must be very aerodynamic while still providing a workable radiation pattern (figure 3). In addition the antenna must be placed to minimize shadowing by the wings or other aircraft components. A 2.4 GHz 5dBM gain-blade antenna was installed on the Citation airplane just aft of the forward landing-gear bay, which gives the antenna an excellent field of view.

RIPCom’s ground station is designed to provide bi-directional communication using a lower gain antenna 10 miles away. Specifically, the ground station utilizes a three-sector, omni directional antenna. The resulting system can supply a point-to-point connection for high-speed data transfer at an affordable cost ($7,500 for the ground station, less tripod and $3,200 for the aircraft station, less installation). Because RIPCom is platform independent (it does not matter which operating system is used), the only requirement is that ground station and aircraft have a TCP/IP connection.

**Flight Tests**

RIPCom was deemed ready for flight tests with the NIROPS Cessna Citation Bravo in late 2002, and the tests were scheduled for February 2003 but had to be postponed due to NIROPS deployment in Australia. While RIPCom is compatible with both NIROPS airplanes, the Citation is better suited to testing because it already has a 2.4 GHz antenna. However, the Citation is also capable of flying at high speeds, which may subject the data stream to an unwanted Doppler effect. A circular flight profile was developed that minimizes the anticipated Doppler effect while maximizing the range where file transfers can take place (figure 4).

Flight testing took place at and near Boise, Idaho, during the week of 14-19 April 2003 (figure 5). Monday was spent going over the test plan with all the involved parties, setting up the ground station for the first time, and conducting ground tests with the plane. The ground tests confirmed that the ground and air components could communicate with each other properly and transfer files back and forth. The ground tests were a huge success in spite of the test location: The National Interagency Fire Center (NIFC) tarmac is situated between metal buildings to the north and east and a metal blast fence to the south.
The actual flight tests took place 18 miles west of Boise International Airport so that interference from other electronic equipment and air traffic could be minimized. During the tests, the aircraft orbited the ground station, whose location was precisely known through the use of GPS coordinates. Tests were conducted for orbits of 6, 8, 9, 10, 11, 12, and 15 miles. During the flight tests several issues had to be evaluated, checked, and recorded:

- Determining the strongest channel (there is a choice of 11 channels).
- Pinging each network device for each throughput setting (11, 5.5, and 2 megabytes per second) and transmitting a 36 megabyte and 77 megabyte file from the plane to the ground station.
- Determining the time needed to transmit the data.
- Characterizing the location and duration of any data drops during transmission.

In other tests, the pilots flew elliptical orbits directly over or to the sides of the ground station to characterize its radiation pattern and determine if there was any Doppler interference in the data transmissions.

RIPCom exceeded expectations during flight testing as it had in the ground tests. Data rates of 3.2 megabytes per second were routinely seen at 11 miles and nearly 500 kilobytes per second at 15 miles. The system was robust; file transfer protocol transfers could be completed without errors even if the transmission was interrupted (up to 45 seconds). It was also found that the jet could fly directly to and from the ground station at 300 miles per hour without the data transmissions being affected by Doppler.

Summary and Recommendations

RIPCom performed better than expected during the ground and flight testing with the NIROPS Citation Bravo, even though these tests were conducted under less than optimal conditions. The RIPCom system is now on loan from NASA–GSFC to allow the Forest Service to evaluate it during controlled burns or actual fires. A team of NIFC and RSAC personnel has been assembled to perform the evaluation. RSAC has submitted a request to WO–IRM for NTIC permission to use five-watt amplifiers during incident support. RSAC was able to obtain a similar exemption during the development of the infrared data downlink (IRDL) in the 900 MHz band and is confident that an exemption in the 2.4 GHz ISM band is also possible. NASA–GSFC engineers believe that the addition of five-watt amplifiers will boost the throughput to at least 5.5 megabytes per second and the range to perhaps 50 to 60 miles. This additional capability will make RIPCom an excellent new tool for NIROPS and the aviation fire-fighting community.

Action Items

RSAC/NIROPS
1. Develop procedures for delivering the RIPCom system to controlled burns and actual fires.
2. Coordinate RIPCom training for infrared interpreters.
3. Identify RIPCom components that can be redesigned for Forest Service use.

NASA–GSFC
1. Compute new parameters based upon the addition of five-watt amplifiers.
2. Provide RIPCom technical assistance as needed.