



On-going Wildland Fire Work at the National Research Council of Canada With a Focus on the use of COTS RPAS for Reduction of Non-Fire Pilot Workload

George Leblanc^{1,2}, Gabriela Ifimov¹, Margaret Kalacska^{2,1}, Oliver Lucanus^{2,1}, Juan Pablo Arroyo-Mora¹, Janine Gorman¹, Melanie Wheatley³ and Colin McFayden⁴

¹ Flight Research Laboratory, Aerospace Research Center, National Research Council of Canada, Ottawa, Ontario, Canada

² Applied Remote Sensing Laboratory, Department of Geography, McGill University, Montreal, Quebec, Canada

³ Ontario Ministry of Natural Resources and Forestry, Aviation Forest Fire and Emergency Services, Sault Ste. Marie, Ontario, Canada

⁴ Great Lakes Forestry Centre, Canadian Forest Service, Natural Resources Canada, Sault Ste Marie, Ontario, Canada

Abstract

The effective use of aircraft crew duty day is a major consideration for airborne asset operators including during disaster relief efforts. During wildfire operations, crew duty day is impacted by non-fire suppression activities, such as reconnaissance and intelligence gathering of the active fire and burned regions. The National Research Council of Canada and supporting partners, the Applied Remote Sensing Laboratory (McGill University), the Ontario Ministry of Natural Resources and Forestry, and the Canadian Forest Service, have on-going collaborative activities to provide assessments of the utility of Commercial off-the-shelf (COTS) Remotely Piloted Aircraft Systems (RPAS) for general non-fire suppression support to the wildfire management team. These areas of support include assessing active fire and smouldering detection distances and accuracies, nighttime RPAS visible and thermal IR-based intelligence gathering operations, general situational overview of the fire front and determining practical limitations with COTS RPAS in these environments.

Here we present the on-going work, over the last 2 years of a multi-year effort to assess these fires using controlled fire experiments under various conditions, including under snow. Thermal imaging has been the primary tool for our work to date, however, we also include the use of 4K video, VisNIR (visible to near-infrared) hyperspectral imaging and LiDAR pre/post burn assessments. To date, there have been effective detection distances of up to 9 km from a number of relatively small (~40 m x 10 m being the largest) slash pile burns, as well as a high degree of active fire detection with a hyperspectral imager detecting a potassium emission feature in the radiance spectra – indicating high energies enough to allow for fire-induced emission to occur. Ground validation of fire intensity and temperatures were achieved by the simultaneous use of a FLIR thermal imager and in-situ temperature probes. The use of a realistically affordable satellite communications link allows for immediate display of the RPAS data to any base camp at any distance from the fire location. This communications net is planned to be extended in the lifetime of this project to multi-node, multi-location simultaneous dissemination.

Overview

Several fire-related campaigns over the last 2 years have focused on the use of RPAS for intelligence support as a method to reduce pilot time on non-fire activities. In our view, the most impactful applications for RPAS use in the near-term, are not in direct suppression – purely as a result of volume carried – e.g. a CL-415 airtanker can deliver over 6000 liters (or 6000kg) of water/suppressant per drop (much more than is possible with any COTS RPAS). RPAS may serve an important role as an intelligence gathering tool. Take for example the case of large fire operating under an Incident Command Team. In these larger, longer lasting fires, helicopters ferry firefighters onto the fireline, drop water on flare ups, perform aerial ignition operations and host of direct

suppression roles. With the fixed resources of the number of helicopters and pilot duty day, the time taken away from these suppression activities to do intelligence gathering (e.g., monitor sections of fireline, scan for smouldering hotspots, investigate spotfires) has a direct impact on the ability to control the fire. Utilizing RPAS in an intelligence gathering capacity may support the targeted use of limited aircraft and duty time to priority direct suppression support activities.

Focused on determining the abilities of COTS RPAS sensors and airframes for fire intelligence gathering, selected results from an on-going 2 year project are shown in Figures 1-3 below. In Figure 1, a slash pile fire (~ 40m x 10m) was constructed in 2022 at site 1 (Blue Lake Provincial Park, Ontario, Canada) and set alight on the evening of October 4th. The ground validation using a FLIR SC-8303 thermal imager system is shown in Figure 1A, with Figure 2B showing a resulting FLIR thermal image that is colored as a function of temperature. Figure 1C is the XT-2 thermal sensor image acquired from a DJI M600 RPAS airframe at distance of 6 km, showing the location of the fire as a bright pixel within the dark green circle. The image in Figure 1C was taken in the direction of the setting sun to assess the sensor's ability to resolve a single pixel target at a time that is most difficult to detect if night-time operations are being considered (a secondary motivation for the work). All images in Figure 1 (A, B and C) were captured near simultaneously - within a few seconds. All temperatures in this work are shown in brightness temperature with emissivities set to 1 (as if it were an idealized black body). Flame emissivity is a very difficult parameter to quantify even in a laboratory environment, let alone under real-world conditions. In order to acquire the true temperature from the radiative temperature, emissivity is used as a proportionality factor, which has a very large impact on the outcome, especially at higher temperatures. As the variability in flame emissivity is large [1], we have chosen to use the brightness temperature as a means of identifying "hotter vs colder" sections of the fire. In detection of the fire (Figure 1C) we rely on the relative contrast of the fire to the surrounding forest, which is well-indicated by the brightness temperature.

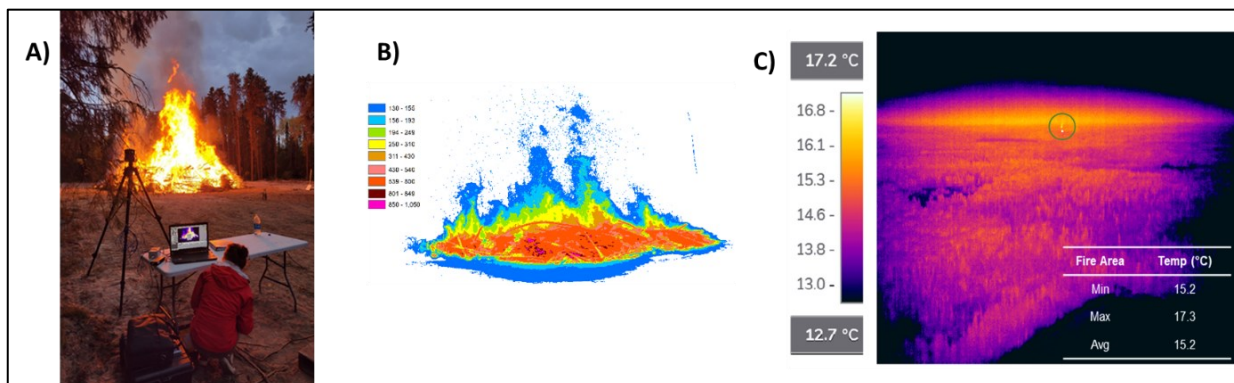


Figure 1 - Site 1 (Blue Lake Provincial Park) showing: A) ground operations with a FLIR thermal camera and operator, B) an example of the thermal image produced by the FLIR and C) the RPAS thermal image of the fire into the direction of the setting sun (shown by the bright pixel within the dark green circle) at a distance of 6 km. All images (A, B and C) were taken within a few seconds of each other.

One of the objectives of this work is to investigate and develop a more robust method of fire front localization. As fire fronts and adjacent areas, are clearly very treacherous regions for personnel, merely gathering intelligence observations utilizing RPAS is a safer method. The RPAS's ability to not create significant downdraft (compared to rotary aircraft) thereby increasing smoke obstruction, allows for the acquisition of the best observable data. We were able to investigate the potential to use advanced sensor technology (hyperspectral imaging) on-board COTS RPAS systems. Figure 2 shows a spectrum of amplitude (radiance) vs wavelength (nm) of an example output from a single hyperspectral image pixel (shown in the inset image) of a burn pile with active flame. This work was carried out at site 2 (Aaron Provincial Park, Ontario, Canada on October 5, 2022). The active flame area of a fire (yellow regions in the inset image) is known to provide the energy necessary to allow the potassium in vegetation to undergo spectral emission [2]. Having a spectroradiometric instrument (hyperspectral imager for example) that is capable of mapping (via airborne/spaceborne vehicles) these emissions, allow for localization of the active fire region to within the defined geometric size of the pixels being collected. Furthermore, these spectral emissions are present even when there is considerable smoke obscuring the view of the ground [2].

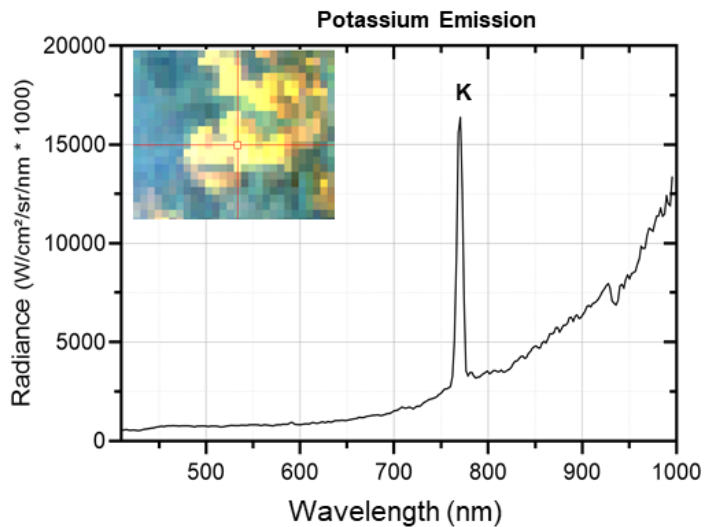


Figure 2 - Radiance vs wavelength spectra from a single hyperspectral imager pixel at Site #2 (Aaron Lake Provincial Park). The hyperspectral image is shown as an inset image with yellow representing the active fire region, and the pixel that contains the displayed spectra is shown by the red box and cross-hairs within the image. The spectrum clearly show the potassium (K) emission feature at ~768 nm, which arises from the burning vegetation.

The third site of this study was at Sandbar Lake Provincial Park, Ontario, Canada, and carried-out between October 31st and November 1st, 2023. On this site, several slash piles were freshly sourced from general maintenance of the forest. Immediately prior to data collection (overnight on October 30th), there was a deposit of ~ 10 cm of fresh snow. Figure 2 A-D, shows various stages of the burn including the following morning (November 1st 2023) in D.

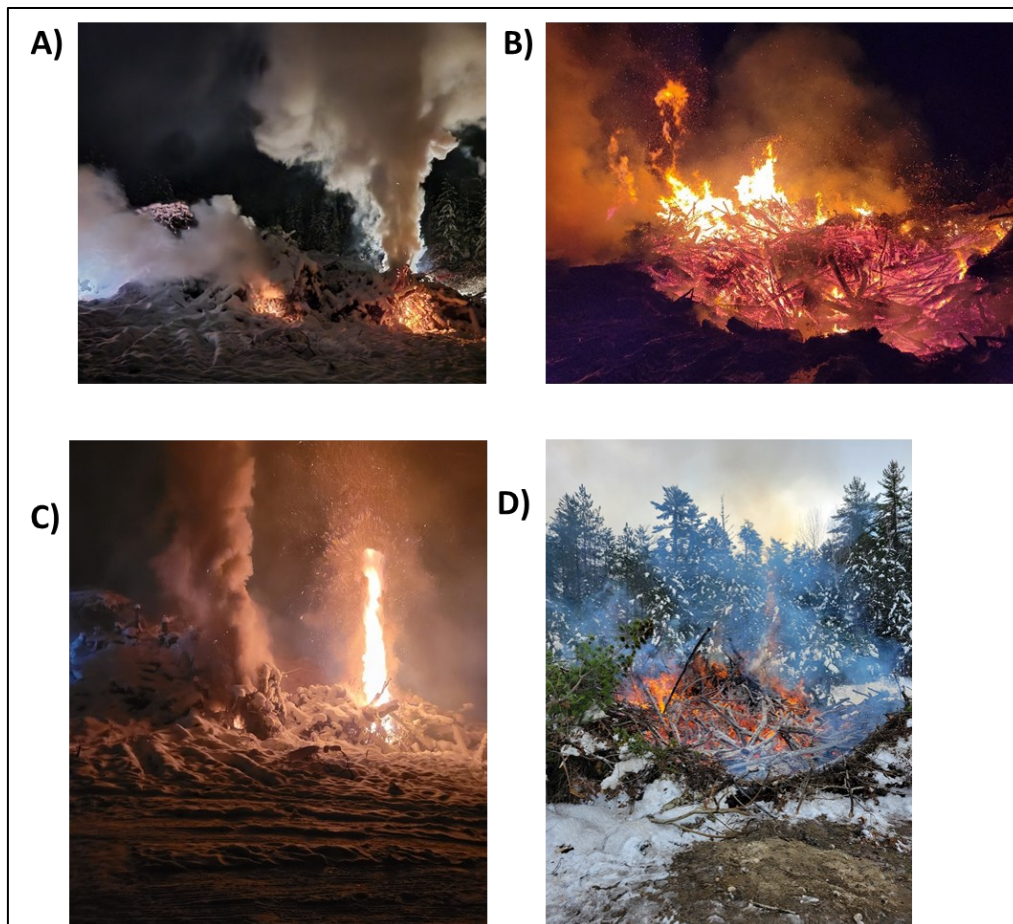


Figure 3 - Ground-based imagery of the slash fires at site #3 (Sandbar Lake Provincial Park). Images A-C showing various examples of the October 31st 2023 evening burn with D showing the slash pile ignited in the morning. Note, the slash piles received ~ 10 cm of fresh snow on the evening of October 30th 2023.

The presentation will include the evaluations of these data (Figures 1-3) as well as an overview of work that is being planned for the July-August 2024 and September-October 2024 timeframes related to air tanker drop effectiveness and the continuation of the RPAS intelligence work, respectively.

Contact Author Email Address

All inquiries related to this work should be sent to: George.LebLANC@nrc-cnrc.gc.ca

Copyright Statement

The authors confirm that they, and/or their company or organization, hold copyright on all of the original material included in this paper. The authors also confirm that they have obtained permission, from the copyright holder of any third party material included in this paper, to publish it as part of their paper. The authors confirm that they give permission, or have obtained permission from the copyright holder of this paper, for the publication and distribution of this paper as part of the ICAS proceedings or as individual off-prints from the proceedings.

References

- [1] Àgueda A., Pastor E., Pérez Y., Planas E. Experimental study of the emissivity of flames resulting from the combustion of forest fuels, *Int. J. Therm. Sci.*, 49 (3), pp. 543-554, 2010
- [2] S. Amici, M.J. Wooster, A. Piscini. Multi-resolution spectral analysis of wildfire potassium emission signatures using laboratory, airborne and spaceborne remote sensing *Remote Sens. Environ.*, 115, pp. 1811-1823, 2011