Natural Resources Canada / Ressources naturelles Canada

WildFireSat e-Bulletin

Issue 2, May 2024 | The Great Lakes Forestry Centre (GLFC)

# The path to WildFireSat

*On the path to understanding the needs for Canadian wildfire management*

The Canadian Space Agency and Natural Resources Canada have been partners in space-based wildfire monitoring for decades. The WildFireSat mission is an outcome of this collaboration which will enable Canada to be the first country to have its own purpose-built operational satellite system for wildfire monitoring. WildFireSat is a Government of Canada initiative between the Canadian Space Agency, Natural Resources Canada (Canadian Forest Service and the Canadian Center for Mapping and Earth Observation) and Environment, and Climate Change Canada, supported by leadership at all levels.

## History of WildFireSat

*The ability to measure wildfires using Earth-orbiting satellites was first demonstrated in the 1980s. This edition explores some of the history that has led to the development of the WildFireSat mission, enabling Canada to be the first country to have its own purpose-built operational satellite system for wildfire monitoring.*

**Denis Dufour and Tim Lynham, 2024**

The ability to measure wildfires using Earth-orbiting satellites was first demonstrated in the 1980s using the Advanced Very High-Resolution Radiometer (AVHRR) instrument on board the American NOAA-6 satellite. Flannigan (1986) published the first paper on the use of single frames of AVHRR data for fire monitoring over Canada[1]. By 1995, the Canada Centre for Remote Sensing (CCRS) in Ottawa developed an automated system called GEOCOMP for geocorrecting and compositing AVHRR images daily over Canada[2]. The CCRS work also led to development of an algorithm for detecting hotspots from the AVHRR data. That algorithm was transferred to Natural Resources Canada (NRCan) in Edmonton in the late 1990s to initiate a daily process of tracking hotspots from wildfires and posting them on the Canadian Wildland Fire Information System (CWFIS). Success of the AVHRR instrument for monitoring wildfires led to the design of two further US satellite instruments: the Moderate Resolution Imaging Spectroradiometer (MODIS) launched on two different satellites in 1999 and 2002, and the Visible Infrared Imaging Radiometer Suite (VIIRS) launched on three different satellites in 2011, 2017 and 2022. MODIS and VIIRS are still commonly used today for wildfire measurements in addition to sensors from other countries. These instruments are able to measure wildfire intensity due to sensitivity to a region of the infrared spectrum known as the Mid-Wave InfraRed (MWIR) band, where fire signals are the strongest. To explain why this is the case, one must consider a law of physics known as Planck's Law, which states that objects emit electromagnetic energy at decreasing spectral wavelengths as their temperature increases.

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[1] Flannigan, M.D. and Vonder Haar, T.H., "Forest fire monitoring using the NOAA satellite AVHRR". Canadian Journal of Forest Research, 16, 975-982 (1986).

[2] Robertson, B. & Erickson, A. & Friedel, J. & Guindon, B. & Fisher, T. & Brown, R. & Teillet, P. & Cihlar, Josef & Sancz, A., "GEOCOMP, a NOAA AVHRR geocoding and compositing system". Proceedings of the ISPRS Conference (1992).

In the case of wildfires, their average radiant temperature typically corresponds to a peak in the MWIR band.

In 1997, under funding from the Canadian Space Agency (CSA), Canada helped create an international team of remote sensing and fire specialists. This Fire Implementation Team under the Global Observations of Forest and Land Cover Dynamics (GOFC-GOLD) seeks to refine and articulate the international observation requirements and encourage the best possible use of fire products from existing and future satellite observing systems, for fire management, policy decision-making and global change research.

In 2004, at a GOFC-GOLD Fire meeting in Darmstadt Germany, the group was introduced to the concepts of Fire Radiative Power (FRP) and Fire Radiative Energy (FRE) by King's College London (KCL- Prof. Martin Wooster) and how these measurements could be retrieved from thermal infrared remote sensing. It was clear that FRP and FRE could be used to estimate fire intensity, fuel consumption and carbon emissions from wildfires.

Meanwhile, during the period of AVHRR, MODIS, LANDSAT, and Satellite Pour l'Observation de la Terre - Végétation (SPOT-VGT) data in the early 2000s, CCRS and the Canadian Forest Service (CFS) (both part of NRCan) worked with these satellite data sources to map wildfires and to track hotspots from fires.

Although instruments such as AVHRR, MODIS and VIIRS are well capable of measuring wildfires, they are large, heavy, power-hungry (and expensive) instruments that require cooling systems for their MWIR band photonic detectors. Hence, they are not ideal as a cost-effective and reliable detector solution in a purpose-built operational wildfire monitoring constellation of multiple satellites to meet the needs of wildfire managers.

By 2005, after CSA had been very successful with designing and launching RADARSAT missions, the agency started to consider smaller satellite missions which led to a new era of thermal infrared detector technology, developed in Canada by CSA: the microbolometer.

## Microbolometers

*Home-grown technology for wildfire sensing.*

Microbolometer detectors consist of a two-dimensional array of tiny platforms (in the tens of microns in size, smaller that the diameter of human hair) that convert incoming heat into electrical signals. Although they are quite commonly used today, in commercial applications such as thermography to measure heat leaks in houses and in night-vision systems, bolometer technology was still in its infancy in the early 2000s. At that time, the Institut National d'Optique (INO) in Quebec City had started developing custom-made microbolometer detectors and cameras, and as such they were one of the early pioneers of this technology.

Realizing the potential of this home-grown technology for wildfire sensing, CFS and CSA started investing in furthering the development of INO's bolometer technology towards space-based wildfire sensing. Two technical hurdles to overcome were: (1) to make them sensitive to the MWIR band, since the vast majority of bolometers at that time were designed for Long-Wave InfraRed (LWIR) band sensing where the peak signal corresponds to room-like ambient temperatures around 20°C, and (2) to make them ready for deployment in the harsh environment of space.

## Canadian technology developments towards WildFireSat (2005-2020)

*Feasibility studies and the Canadian Wildland Fire Monitoring System concepts.*

The first fruits of this investment by CSA in space-based microbolometer sensors for wildfire sensing was the New InfraRed Sensor Technology (NIRST) instrument[3]. NIRST was a dual microbolometer camera system, consisting of one LWIR and one MWIR camera, developed by INO as a space-based technology demonstrator instrument. The objective of NIRST was to determine the ability of microbolometer sensors to measure wildfires (using the MWIR camera) and sea-surface temperature (using the LWIR). NIRST was launched on the SAC-D Aquarius satellite, a joint venture between NASA and the Argentinian Space Agency (CONAE), in 2011. It operated successfully until 2015 when a hardware failure on the satellite ended the mission prematurely. Wildfires and hotspots measured by NIRST confirmed the ability to perform such measurements using microbolometer sensors and pointed towards avenues for further improvement.

In parallel with the NIRST microbolometer technology development and demonstration activities, the CSA started looking at what a microbolometer-based satellite system that is custom-designed for the needs of Canadian wildfire managers could look like. The first of these concept studies was the Platform for the Observation of the Earth and for in-orbit Technology Experiment (POETE) in 2009[4], led by INO, NGC Aerospace and the Université de Sherbrooke. Unlike NIRST, which had two separate MWIR and LWIR cameras, the POETE instrument had a combined dual band optics with a scene selection mirror and an onboard calibration system. The importance of accurately calibrating microbolometers had been seen in NIRST, and from this point onward the implementation of a high-performance calibration system was deemed an essential feature of any microbolometer-based wildfire sensor in order to measure FRP.

Further feasibility studies were undertaken in the mid 2010s, under the name of the Canadian Wildland Fire Monitoring System (CWFMS). The CWFMS studies, led by NGC Aerospace and with INO leading the development of the infrared payload, involved researchers from the CFS such as Tim Lynham and Dr. Joshua Johnston, and support from wildfire science experts such as Dr. Martin Wooster and Dr. Mike Flannigan, who helped define the first version of the User Requirements for such a system. Notably, the importance of accurately measuring FRP during the late-afternoon peak burning time was emphasized. The CWFMS user requirements document eventually became the foundation for the WildFireSat user requirements, which were described by Dr. Joshua Johnston in a 2020 article (Development of the User Requirements for the Canadian WildFireSat Satellite Mission). The CWFMS satellite concepts took several forms, since at the time it was uncertain what level of funding would be available to build a wildfire monitoring system, and thereby it was unknown whether such a system would consist of small-size (i.e. microsat-class) satellites with several cameras each, or even smaller satellites (nanosat-class) with one camera per band[5]. In all these potential options, it

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[3] Hugo Marraco, Linh Ngo Phong, "NIRST: a satellite-based IR instrument for fire and sea surface temperature measurement," Proc. SPIE 6213, Non-Intrusive Inspection Technologies, 62130J (24 May 2006).

[4] Christian Proulx, et. al. "An uncooled mid-wave and thermal infrared payload for fire Monitoring", Proc. of SPIE Vol. 7474 (2009).

[5] Linh Ngo Phong, et. Al. "A low resource imaging radiometer for nanosatellite based fire diagnosis", Proc. SPIE 10765, Infrared Remote Sensing and Instrumentation XXVI, 1076502 (18 September 2018)

was ensured that essential requirements such as spatial resolution, coverage, daily overpass time and FRP measurement accuracy were met.

Despite NIRST's demonstrated ability to measure wildfires, there remained doubts by some experts in the wildfire research community about the ability of microbolometer sensors to measure FRP as accurately as the conventional large cooled infrared sensors in MODIS and VIIRS. An opportunity to validate the performance of microbolometers vs cooled IR sensors in FRP measurement arose in the summer of 2019, when CSA and CFS planned airborne flights with the Experimental Multispectral Imaging Radiometer (EMIR) over a fire test site near Sault-Ste-Marie, Ontario, to verify the performance of INO's latest wildfire-configured microbolometer sensors. On the tower next to the fire site were mounted side-by-side an INO microbolometer camera specially configured for wildfire measurement, and a conventional cooled IR sensor camera. Over three days, several fires of various intensities were lit and measured by the two side-by-side cameras. The results showed nearly identical FRP measurements for a wide range of fire intensities produced over the three days, thus validating the choice of microbolometer sensors for a space-based wildfire monitoring system[6].

**WildFireSat**

*As part of the Budget 2022, the Canadian government plans to deliver and operate a new wildfire monitoring satellite system.*

Building on the knowledge gained from the previous decades, in 2019 CSA awarded two contracts to industrial teams, led by Honeywell and MDA, to develop more detailed concepts for a Canadian wildfire mission, now officially re-named "WildFireSat". The goal was to develop concepts for a pathfinder mission, which would provide an initial wildfire measurement capacity that could later be expanded towards a fully operational system. Both companies provided concepts that were based on the latest INO microbolometer sensors, which had significantly improved in pixel resolution and performance since the NIRST years.

In 2022, realizing the importance of having a national space-based wildfire monitoring system, the Canadian government announced funding in its budget for a fully operational system. The scope for this funding goes well beyond a pathfinder mission, and includes funding to three government agencies (CSA, NRCan and Environment and Climate Change Canada (ECCC)) to deliver: (1) a sufficient number of satellites to ensure daily coverage of Canada during the late afternoon when wildfires are typically most intense and which represents a time-window that lacks overpasses from other existing wildfire monitoring satellites; (2) the ground infrastructure (antenna stations and data processing centers) needed to rapidly process the satellite data and produce a full suite of science-based wildfire intelligence products tailored for fire managers ; and (3) improved carbon emission and smoke forecasting data products based on WFS measurements. This funding also includes the costs for 5 years of operations once the satellites have been launched and commissioned.

In early 2023, separate consulting contracts were awarded to three industrial contractors, MDA, Earth Daily Analytics, and Spire/Ororatech, to enable these contractors to get feedback from CSA and CFS on their proposed solutions while providing them the opportunity to better understand (and challenge) the mission requirements. These consulting contracts ended in the

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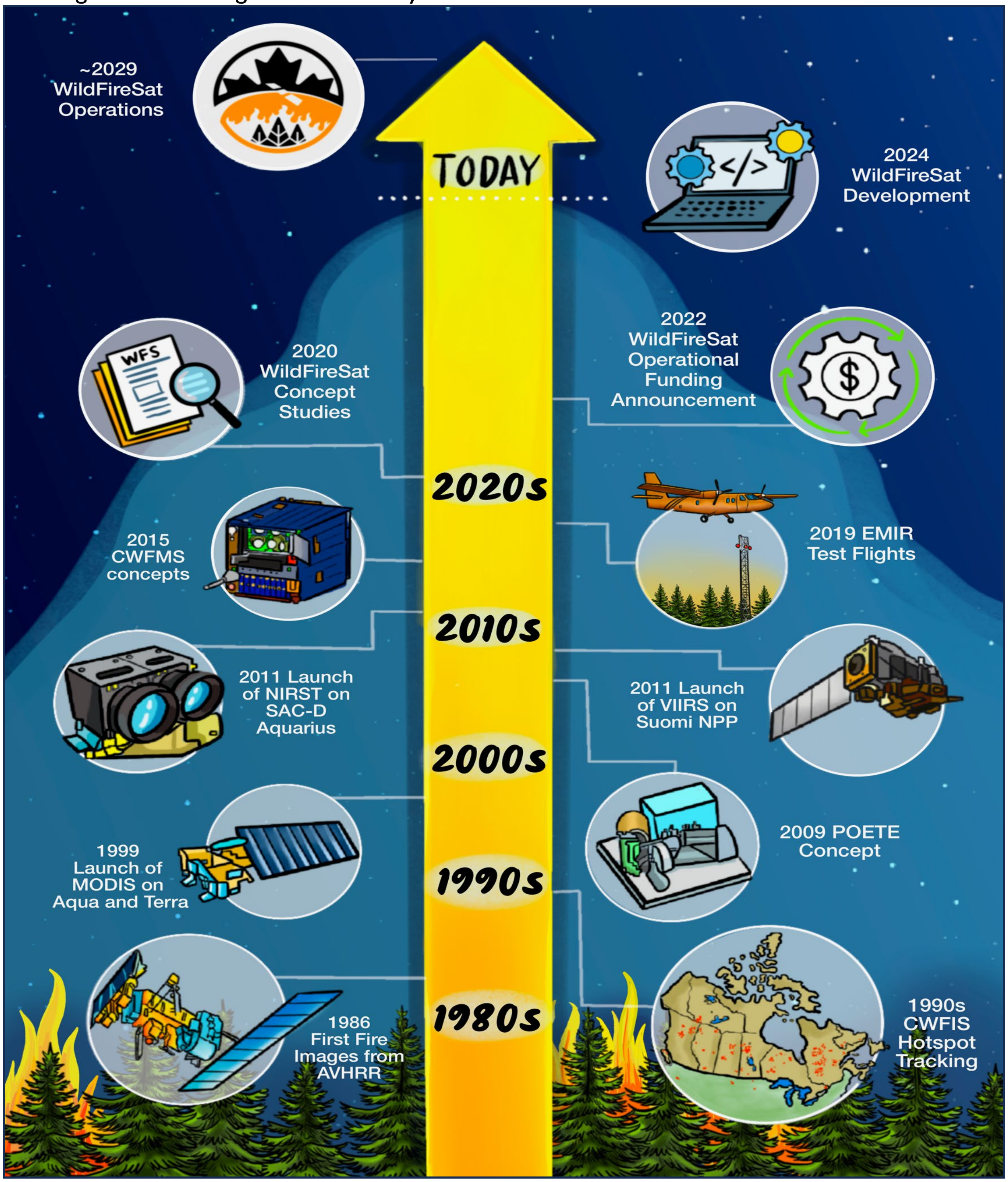
[6] Denis Dufour, et. al. "A Bi-Spectral Microbolometer Sensor for Wildfire Measurement", Sensors 2021, 21, 3690 (2021).

fall of 2023, and were followed by a request for proposals, limited to the same 3 contractors, to build and launch the satellite system. The winner is expected to be announced in 2024, followed by the start of detailed design, build, test, launch and commissioning activities for the satellites and their related ground systems.

It is planned for WildFireSat to be operational by 2029, which will enable Canada to be the first country to have its own purpose-built operational satellite system for wildfire monitoring. It will undoubtedly prove its worth in helping wildfire managers make better decisions to meet the challenges of increasing wildfire severity in Canada and across the world.

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