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IN FOCUS

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U.S. Satellite Capabilities for Tracking the Wildfire Life Cycle

Satellite capabilities support virtually every aspect of the wildfire life cycle: characterizing the prefire environment (e.g., seasonal climate predictions, vegetation structure); detecting and monitoring wildfires; and assessing postfire hazards (e.g., debris flows, flash floods) and ecosystem recovery. In particular, the National Oceanic and Atmospheric Administration (NOAA) finds that satellites provide "information about the location, duration, size, temperature, and power output of those fires that would otherwise be unavailable" through approaches such as ground-based sensors, aerial technologies (e.g., drones), or aircraft. These approaches may provide complementary data to satellites, particularly when satellite data are limited in spatial and/or *temporal* (i.e., the time between observations of the same area) resolution and given the money and time to develop and deploy new satellites.

NOAA, the National Aeronautics and Space Administration (NASA), and the U.S. Geological Survey (USGS) contribute to satellite observation systems across the wildfire life cycle, including detecting and monitoring fires in *near real-time* (NRT; i.e., data available within about one to three hours). The 119th Congress has introduced legislation to improve satellite observations with the aim of increasing U.S. resilience to the harmful effects of wildfires. This In Focus describes current and planned U.S. civil satellite observation systems that may contribute data and information about the prefire environment, the early detection and monitoring of fire, as well as the assessment of post-wildfire hazards.

Satellite Wildfire Applications

Satellites can collect environmental information about conditions conducive to fire weather (see CRS In Focus IF12884, *Fire Weather: Background and Forecasting*) as well as fuel (grasses, brush, timber, slash) condition (e.g., live versus dead biomass, soil and biomass moisture content). These pre-wildfire observations guide predictions of the likelihood and intensity of wildfire outbreaks. Post-wildfire observations can help land managers and scientists assess wildfires' severity, extent, and impact. These assessments may inform efforts to improve safety, prevent further damage, estimate pollution risks, support postfire hazard risk assessments, and monitor landscape recovery.

Satellites also can be used to detect wildfires, generally in concert with existing wildfire detection techniques. Some satellites can make NRT observations to support early wildfire detection, which increases the likelihood of timely response. To be useful for this purpose, satellites must provide data with the necessary frequency and spatial resolution to users on the ground. *Data latency*, the total time between data acquisition and public availability, may vary among satellite missions and may affect the use of observations for wildfire applications.

Both geostationary orbit (GEO) and low-Earth orbit (LEO) satellites provide wildfire-related observations but do so at different frequencies and spatial resolutions. GEO satellites remain over the same location on the Earth and provide continuous coverage of a large area but at a lower resolution relative to LEO satellites, due to their altitude. LEO satellites provide a more limited field of view, as they are closer to the Earth. Their proximity to Earth, however, allows for relatively higher spatial resolution. LEO satellites complete several orbits of the Earth each day; each orbit allows data collection for different locations and times of day, but observations at each location have a lower temporal resolution. To aim for a similar spatial or temporal coverage as a GEO satellite, multiple LEO satellites, or a *constellation*, may be required. Coupling LEO and GEO data may provide a more comprehensive approach to early detection of wildfires and monitoring.

NOAA GEO Satellites

NOAA's Geostationary Operational Environmental Satellites (GOES)-R Series hosts the Advanced Baseline Imager (ABI), which produces a 1,000 by 1,000 kilometer scan of the Earth every 60 seconds (s) with a spatial resolution of 500 to 2,000 meters (m). These rapid scans help experts detect smoke plumes and heat signatures to identify and respond to fires in NRT. Monitoring smoke plumes in NRT is useful in directing firefighting efforts from the air. GOES-R Series also hosts the Geostationary Lightning Mapper to improve detection of wildfires initiated by lightning.

NOAA anticipates that its future GEO satellite mission, Geostationary Extended Observations (GeoXO), will include a new imager with improved spatial resolution and data latency on the order of a few minutes. The improved imager may detect wildfires that are four times smaller than what ABI can detect while also providing data to first responders more quickly. NOAA anticipates the GeoXO satellites will deploy beginning in 2032 (see CRS In Focus IF12898, *NOAA's Future Geostationary Extended Observations (GeoXO) Mission*).

Selected U.S. LEO Satellites

NOAA's Joint Polar Satellite System (JPSS), a fleet of three satellites, provides global environmental observations twice a day for short- and long-term weather forecasts. JPPS satellites host an instrument, the Visible Infrared Imaging Radiometer Suite (VIIRS), which has a 375 m spatial resolution. This spatial resolution allows for the detection of small, lower-temperature (compared with background levels) fires. VIIRS also has a Day-Night Band that enhances the detection of fires at nighttime. VIIRS data can be produced in *ultra real-time* (URT), with a data latency of about 50 s, a speed that rivals non-satellite wildfire detection methods. NOAA's future polar-orbiting satellites include JPSS-4, which is to host the latest version of VIIRS with an anticipated 2032 launch readiness date.

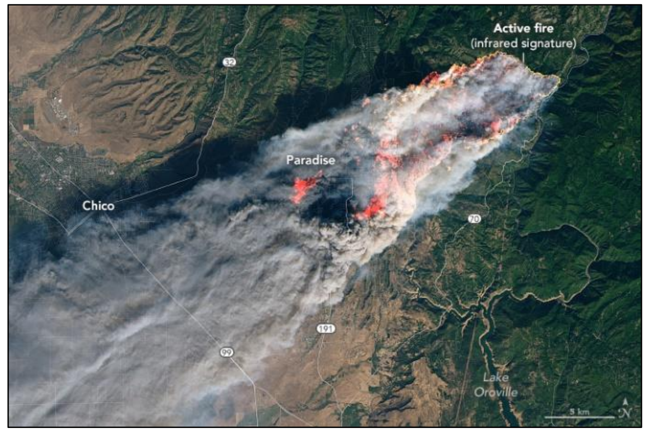
NASA's Terra and Aqua satellites host the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument, which measures visible and infrared radiation with a spatial resolution of 250 to 1,000 m and a temporal resolution between 1 and 2 days. NASA reports that MODIS can detect fires as small as 30 by 30 m (about a quarter acre). MODIS data can be produced in URT, with a data latency of about 25 s. The Fire Information for Resource Management System (FIRMS), a joint effort between NASA and the U.S. Forest Service, couples data from MODIS and VIIRS, as well as other satellites, to provide NRT detection of wildfires in the United States and Canada.

Terra also hosts the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument, a collaboration between the United States and Japan. ASTER data is collected by request, unlike other Terra instruments, which continuously collect data. ASTER has a spatial resolution of 15 to 90 m, which is sufficiently detailed—compared with other instruments—to inform wildfire containment or suppression. Terra and Aqua are nearing their end of life (EOL); NASA expects their data acquisition will cease in FY2027 and FY2026, respectively.

Under the Sustainable Land Imaging Program, NASA develops and launches Landsat satellites and the USGS operates the satellites and manages their data. For over 50 years, Landsat satellites have captured remotely sensed imagery that has been used for wildfire-related applications (**Figure 1**). Landsats 8 and 9 are operational and have a combined temporal resolution of eight days. They host the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) with spatial resolutions of 30 m and 100 m, respectively. OLI imagery helps scientists assess vegetation distribution, abundance, and health and track changes in land cover—factors used to understand wildfire risk and recovery. TIRS detects heat anomalies that can help spot wildfires. Experts use both TIRS and OLI to produce highly detailed maps of burned areas following a wildfire, which are used to assess risk of post-wildfire debris flows and monitor landscape recovery. While Landsat data generally has a data latency of four hours or more, FIRMS includes a Landsat Fire and Thermal Anomalies product using OLI data that supports active fire detection data within 30 to 60 minutes. NASA and the USGS are developing Landsat Next, the follow-on in the Landsat series, designed to comprise three satellites to provide improved temporal, spatial, and spectral resolutions. Landsat Next is envisioned to be "super-spectral," including new spectral bands to improve its wildfire capabilities (see CRS Insight IN12281, *Landsat Next on the Horizon*).

NASA plans to launch NASA-ISRO Synthetic Aperture Radar (NISAR), a joint mission with India, in April 2025. NISAR is anticipated to provide information about vegetation structure, fuel condition, and soil moisture over the entire planet every 12 days with a 200 m resolution. In addition, NISAR's technology is to provide observations at times when optical imaging methods are ineffective (e.g., during cloudy or nighttime conditions).

Figure 1. Landsat 8 Image of the Camp Fire near Sacramento, CA, November 8, 2018



Source: NASA Earth Observatory.

Issues for Congress

In the 119th Congress, some Members have introduced legislation to improve wildfire detection and wildfire resiliency through the use of satellites (e.g., H.R. 527; H.R. 753; H.R. 471). A challenge for developing major satellite programs is the need for Congress to provide multiyear appropriations. If a satellite program experiences delays and cost overruns, which have occurred for some federal programs, Congress may consider whether to conduct increased oversight of satellite mission developments to determine whether the satellite program meets congressional goals with its appropriated funds.

Some U.S. satellites, such as NASA's Terra and Aqua, are nearing EOL, and Congress may consider the consequences of possible data gaps. For example, the JPSS VIIRS instruments collect afternoon observations and the Terra MODIS instrument collects morning observations over the United States. Congress may consider options to fill the impending morning observation gap, which could include partnerships with U.S. commercial interests or foreign governments. For example, some experts have proposed that Europe's Sentinel-3 mission could fill this gap. FireSat, a planned U.S. commercial constellation of more than 50 small satellites, is anticipated to detect 5 by 5 m fires within 20 minutes. Congress could consider whether to address anticipated satellite data gaps from such sources.

Apart from satellites, data information programs, such as FIRMS, also contribute to federal agency dissemination of wildfire data to federal and local response agencies. Congress may consider if the level of support for FIRMS is sufficient to meet congressional goals. In addition, Congress may examine the federal role, if any, in developing advanced detection products for wildfires, such as satellite-based fire detection algorithms, which could send alerts as soon as fires start.

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