Frequently Asked Questions:

Hotspots Mapping on NAFI

August 2024

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How are the fires on the NAFI site detected?

All “hotspots”, the red, blue and pink spots that mark active fires, are initially detected by sensors mounted on orbiting satellites. These sensors create digital heat images of the land which can be beamed down to receiving stations on the ground.

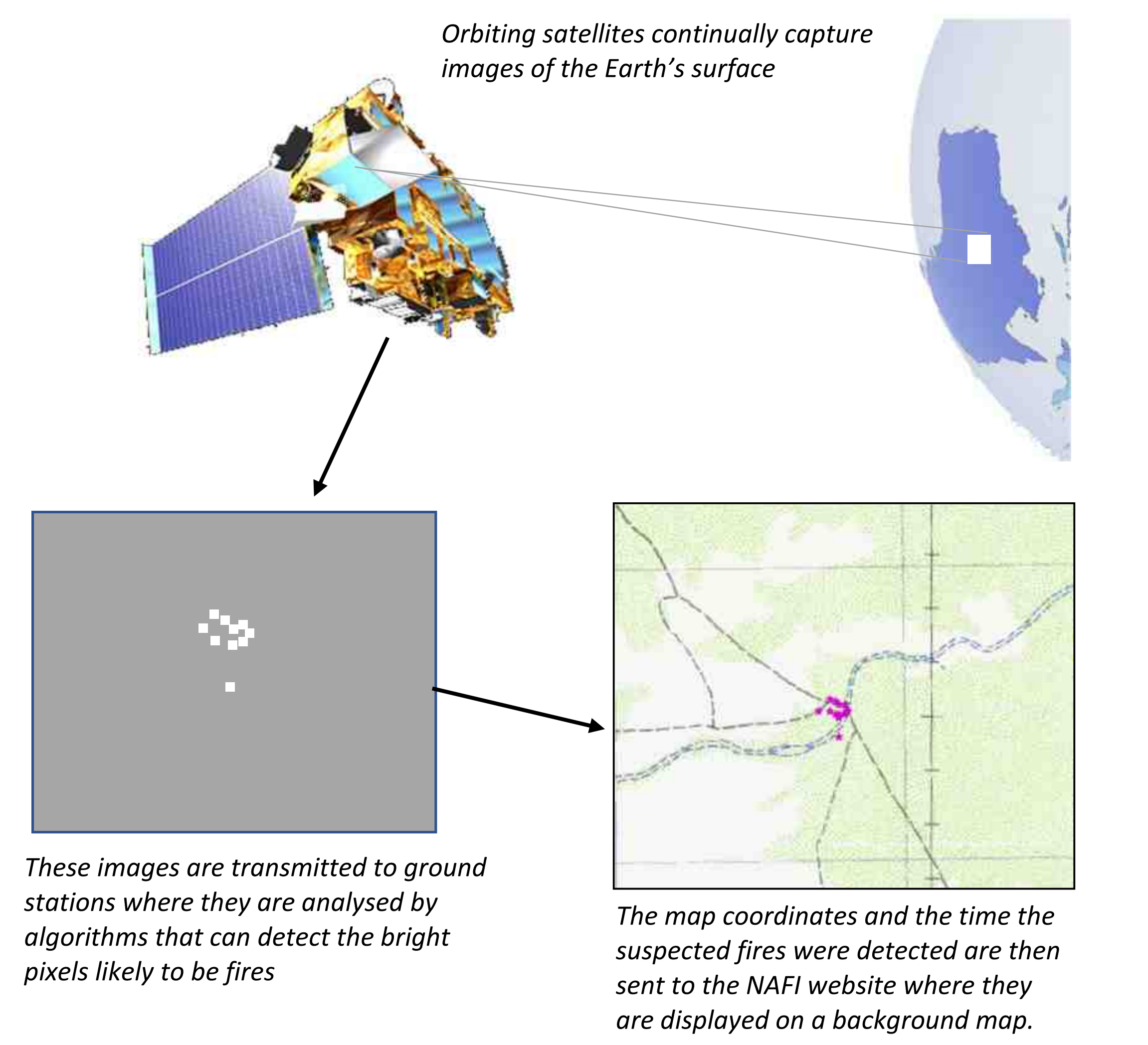


Figure 1. How hotspots are mapped

A computer then examines these images and detects fires by checking each of the small elements or “pixels” that make up the image (you can think of these pixels as being like the small squares that make up a television image). Pixels that are much brighter than neighbouring pixels and that have some other heat characteristics are identified as fires (see *How accurately do hotspots show the location of a fire?* page 4).

The latitudes and longitudes of these bright spots or hotspots are then sent to the NAFI website and displayed as suspected fires on maps.

What satellites are used to detect hotspots?

The satellites used to monitor fires that are mapped by NAFI are international Earth Observing satellites. One of these, the Suomi NPP satellite, is shown below.

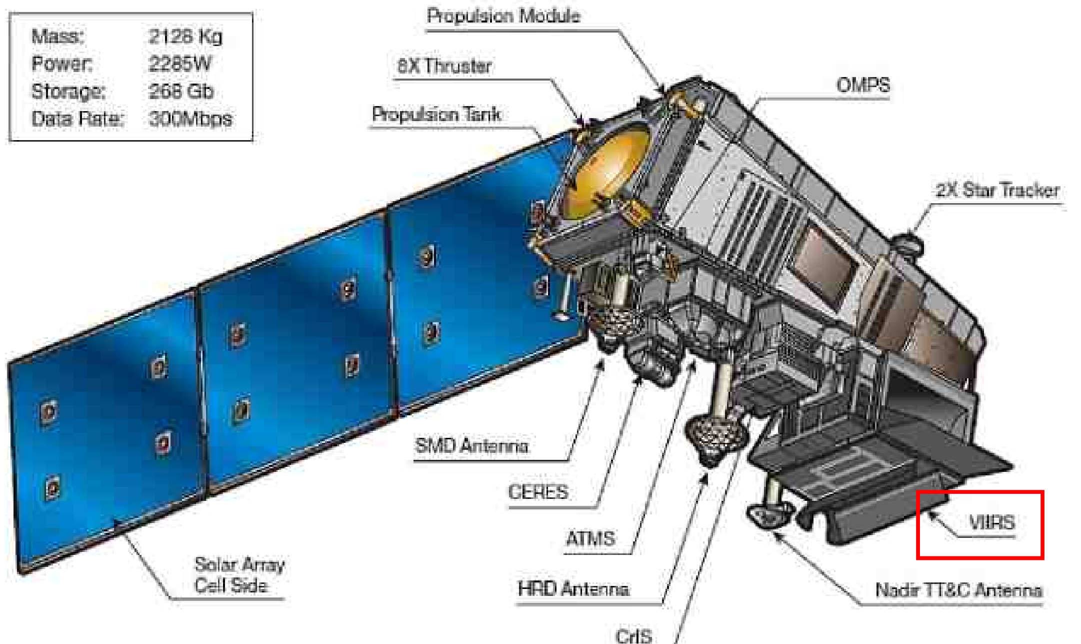


Image credit: NASA

Figure 2. The Earth Observation satellite Suomi-NPP.

These are large satellites weighing over 2 tonnes and carry a range of instruments for measuring various attributes of the atmosphere, land and oceans from cloud temperatures to precipitation rates, cloud particle properties, ocean surface temperatures and surface reflectance. These EO satellites are mainly used for weather information and are operated by the US agencies NASA and NOAA, the European Space Agency and the Japanese Meteorological Agency.

As scientists have developed algorithms that can accurately identify fires (hotspots) from the surface imaging instruments carried on these satellites (the VIIRS or Visible Infrared Surface Radiometer in Figure 2) these satellites have become vital tools for broad-scale fire management in the open landscapes of countries like Australia.

The usefulness of these satellites for fire monitoring depends partly on when they pass overhead in the day and this depends on how the satellite programs are managed – when satellites are retired and when new ones are launched. For example, fire monitoring in the morning is not as effective as it used to be as a key satellite is starting to malfunction on its way to retirement. As outlined below this situation should improve once the replacement satellite is in place in a year or so. As these multi-billion-dollar weather satellite programs are not dedicated to fire monitoring and are not operated by Australia, there is little we can do about these variations.

In mid-2024 the NAFI website was receiving hotspot data from nine satellites:

- two polar-orbiting satellites operated by NASA: *Terra* and *Aqua*,
- a polar-orbiting satellite operated by NOAA: *NOAA-19*
- three polar-orbiting satellites operated jointly by NASA and NOAA: the *Suomi NPP* satellite and the *JPSS-1 (NOAA-20)* and *JPSS-2 (NOAA-21)* satellites.
- two polar-orbiting satellites operated by the European Space Agency *Metop B and Metop C,* and
- the geo-stationary satellite *Himawari 9* which updates hotspots every 10 minutes but has a coarser resolution than the polar-orbiting satellites and does not detect smaller fires as well.

How often are fires detected?

You may have noticed that sometimes the location of a fire hotspot on the website is updated a few times in a few hours and at other times there are longer gaps between updates. This timing depends on the orbits of the satellites that monitor the fires.

The satellite orbits

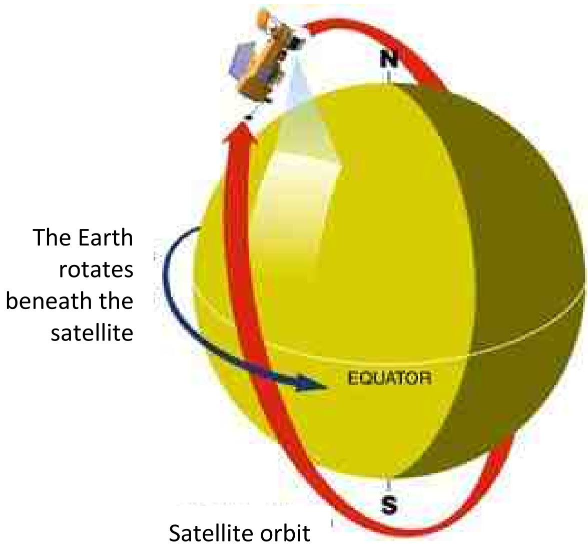


Figure 3. The polar orbits of the satellites used by the NAFI website

As shown in the list above, the hotspot data is mostly sourced from polar-orbiting satellites which move in orbits designed to monitor the entire globe – roughly north-south paths that pass close to the poles and are synchronised with the rotation of the earth (Figure 2). As the satellites follow these paths at around 20,000 kilometres an hour, on-board sensors continually generate images of the earth below in strips 2,300-2,400km wide depending on the satellite. After the images are created, they are beamed down to receiving stations.

These orbits allow the satellites to have views of almost the entire globe in daylight and pass over a given point at roughly the same angle to the sun each day (so images from different days are lit by the sun in the same way and can be more easily compared). They actually get views of most locations on the ground twice day – once on the daylight side and once on the night side of the earth 12 hours later. As fires can be detected at night this means most fires in

Australia could be seen twice a day by each of the eight polar-orbiting satellites that feed the NAFI site.

In practice, the coverage is not nearly as good as this because often a fire will be obscured by clouds, smoke or haze or it may not be large enough or hot enough to be detected, particularly if it lies near the edge of a satellite view. Also, some satellites, such as the *NOAA-19* and *Metop* satellites detect relatively few hotspots.

Hotspot update times

In the fire season a large fire in north Australia is typically detected perhaps two to four times in daylight hours and two or three times at night. However, for a given region on the ground the satellite passes are not evenly spaced through the day. In the morning, the first hotspot data reaching NAFI will usually be from the *Terra* satellite in the late morning from around 11:30 am to 12pm. The *Metop* and *NOAA-19* satellites also overpass in mid-morning but detect few hotspots at this time of day.

The late morning hotspot update is followed by hotspots from *Aqua*, *NPP*, *JPSS-1*, and *JPSS-2* satellites arriving on NAFI from around 2pm onwards. Hotspots from these satellites will continue to arrive well after the initial update as ground-based satellite receiving stations in eastern Australia will pick up data first, and then receiving stations further west will pick up data from subsequent more westerly overpasses until around 5pm.

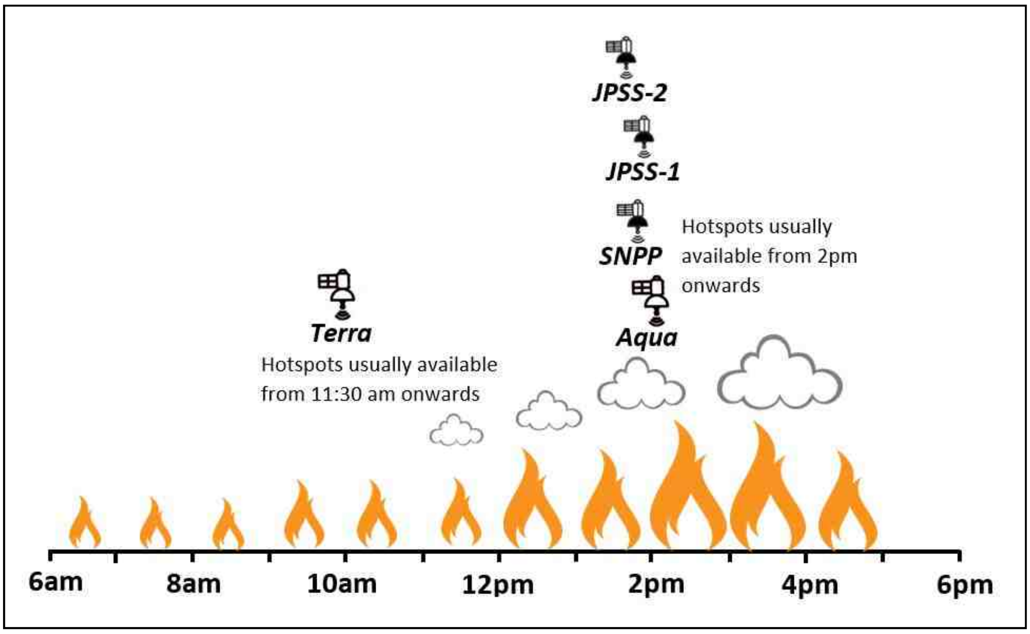


Figure 4. The daily overpass times of the main satellites that provide hotspot data for the NAFI service. Currently the Terra satellite is the main satellite that overpasses in the morning when fires tend to be less intense and cloud cover and smoke haze are reduced. The Metop and NOAA satellites also overpass in the morning put detect relatively few hotspots).

There will then be a long gap before hotspots from the same satellites appear 12 hours after their earlier overpasses. Hotspots from the *Terra* satellite appear before midnight, followed by hotspots from *Aqua*, *NPP*, *JPSS-1, and JPSS-2* in the early – mid morning.

The satellite overpasses are earlier than the hotspot arrival times (Figure 4) as it takes between 30 minutes and two hours for the hotpots to reach the NAFI site once they've been detected. In the case of *Terra* data, the minimum delay is over 90 minutes later as outlined below.

The Himawari Geo-stationary satellite

Hotspots are also sourced from imagery provided by the geo-stationary satellite *Himawari 9* operated by Japan's meteorological agency. This satellite orbits around 35,800 km above the earth allowing it to rotate with the earth and hold station relative to the earth's surface – so it can continually update views of the same very large area as shown in Figure 4.

This means the Himawari satellite can provide an update on hotpots every 10 minutes throughout the day – and they are referred to as "10 minute hotspots" on NAFI. However, because it has a very high altitude the spatial resolution is coarser than that of the polar-orbiting satellites – around 2km. Consequently, this satellite tends to detect larger, more intense fires, and may not pick up the smaller patchy fires.

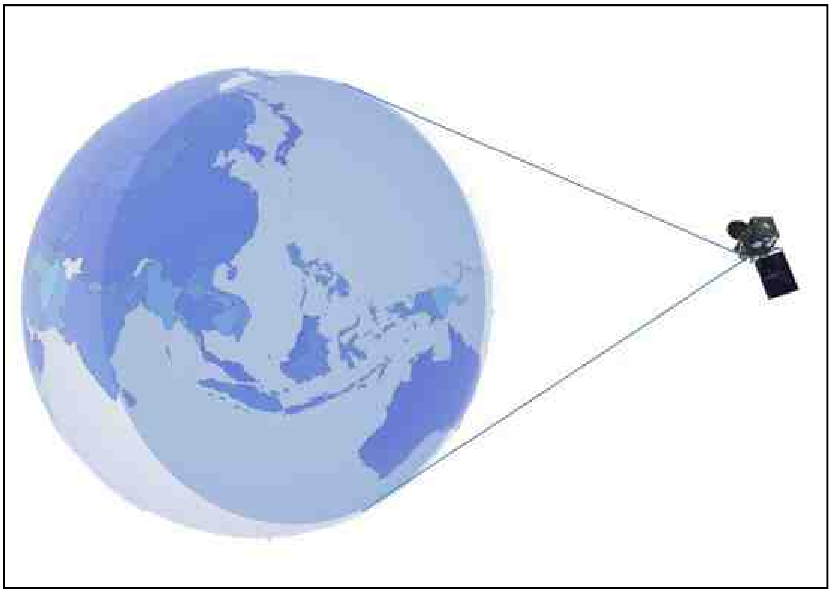


Figure 5. The Himawari 9 satellite has a very high-altitude orbit which allows it to rotate with the earth so it can be stationary above the same point on the earth. The view footprint of the satellite is very large and covers all of Australia.

This coarser mapping of hotspots also means that for smaller fires the Himawari-sourced hotspots do not cluster neatly into fire fronts like the finer-resolution hotpots sourced from the polar-orbiting satellites. For this reason, the Himawari hotpots are displayed on NAFI with distinct, hollow symbols**.**

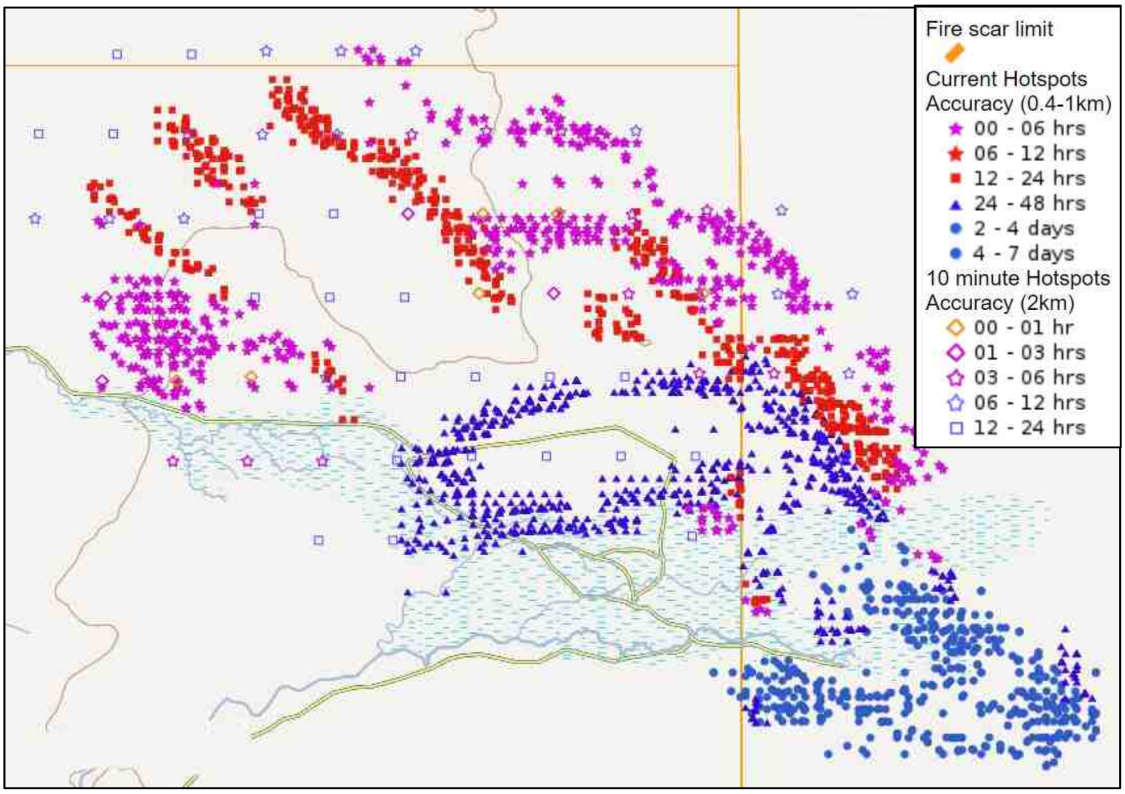


Figure 6. The Himawari hotspots (hollow symbols) display with a broader scatter than the more finely mapped hotspots from the polar-orbiting satellites. But for larger, intense fires the Himawari 10-minute hotpots are very useful for tracking the rapid spread of these fires.

How has hotspot coverage changed?

Since the NAFI service started in the mid-2000s the hotspot coverage has changed. We now have 10-minute hotspots available from the Himawari geo-stationary satellite. For the regular hotspots sourced from polar-orbiting satellites, there are now more of these recorded for a given fire, but the coverage of these hotspots across the day has narrowed as older satellites are retired or start to fail.

New and old polar-orbiting satellites

The increase in hotspots per fire has largely come from the introduction of the *SNPP* and *JPSS* satellites which can detect hotspots with a spatial resolution of 375m compared to the 1km spatial resolution of the *Terra* and *Aqua* satellites. When combined with newer algorithms that allow this high resolution to be effectively used, more hotspots can be detected per fire now compared to the early 2000s.

As shown in Figure 4, these newer polar-orbiting satellites all overpass in the early afternoon. The main morning pass satellite, *Terra*, along with *Aqua*, is nearing the end of its operational life and is due to be retired in early 2027. However, components are starting to fail: *Terra* can no longer send data directly to receiving stations in Australia as it overpasses as its direct broadcast antenna has a fault. It can only download its data to the main receiving station in the US, but this adds an hour or more to the delay between detection and appearing on NAFI. The *Terra* update now appear on NAFI from around 11:30 am onwards as opposed to 10 or 10:30 am. This issue should improve with time as to save fuel, NASA are allowing *Terra* to “drift” in its orbit before it is retired. This means it will overpass progressively earlier in the day until 2027 – offsetting the late hotspot update issue.

The SNPP satellite is also over 10 years old and at time of writing is starting to suffer component failure. Its GPS locator has had problems and it has been unavailable for much of July 2024.

Waiting for the new morning-pass satellites

Under the global plan for Earth-Observing satellites, the European space agencies will be responsible for morning-pass satellites that will replace *Terra*. The first of these satellites is *Metop-SG-A1* due for launch in late-2025. Like the JPSS satellites, this is primarily a weather satellite and it is hoped it will provide a hotspot coverage similar to Terra. Like the *JPSS* satellites, it will then be joined every few years by a replacement satellite.

It is hoped that *Terra* is still able to provide its late-morning hotspot updates until *Metop-SG-A1* takes over this role, however, as with all these large Earth-Observing satellite systems, Australia has very little influence on launch schedules or back-up plans in case *Terra* fails. The Chinese Fengyun 3F satellite has a morning pass and is similar to Terra. It is possible that imagery from this satellite may be able to be accessed and a hotspot algorithm developed for this satellite.

Websites:

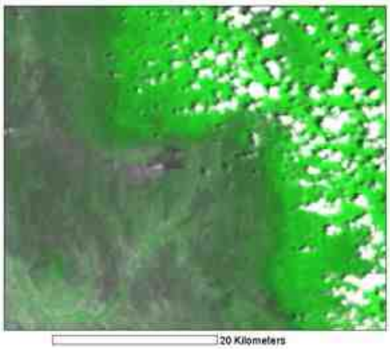
Terra Satellite: http://terra.nasa.gov
Aqua Satellite: http://aqua.nasa.gov
NOAA-JPSS Satellites: https://www.nesdis.noaa.gov/content/our-satellites

How accurately do hotspots show the location of a fire?

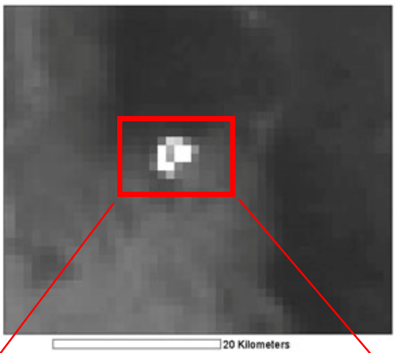
Whether or not a fire is detected and the accuracy with which it is mapped is partly related to the sensors carried by the satellites that detect the fires (see above). Various types of sensors are used to detect fires:

- the NASA *Terra* and *Aqua* satellites use a MODIS or "Moderate Resolution Imaging Spectroradiometer" which can detect fires to within around 1km
- the *NPP*, *JPSS-1* and *JPSS-2* satellites use a VIIRS or "Visible Infrared Imaging Radiometer Suite" which can detect fires with within 1km or 375m depending on the algorithm used.
- The *NOAA* and *Metop C* satellites use a similar instrument of older vintage – the "Advanced Very High Resolution Radiometer" (AVHRR) which was presumably an apt description when it was designed in the 1970s. This can also detect fires to within around 1km.
- The Himawari 9 geo-stationary satellite uses the Advanced Himawari Imager which can detect fires to within around 2km.

As shown in Figure 7 while the regular satellite image may have a particular spatial resolution, the wavelengths used to detect the heat from fires, the thermal bands, may have a coarser resolution.



250m resolution satellite photo of a scene 45km across, showing a fire just left of centre – with grey smoke streaming to the left



Lower 1km resolution thermal MODIS image showing same fire

The same fire as shown on the NAFI site with hotspot symbols when zoomed in. The area shown is only around 10km across.

Figure 7 How hotspots are detected

These satellite images in the key thermal bands are then analysed by computers to detect the tell-tale heat signals of burning fires. Once detected, the latitude and longitude of the fires – the “hotspots” – are then sent to fire-tracking websites including the NAFI site.

When displayed on the NAFI site these hotspots will have spatial accuracies ranging from around 375m to over 2km. The accuracies will be highest when the satellite is overhead but can be reduced when the satellite detects the fire on the edge of the image, so the actual accuracies may be slightly less than the figures above. So when you zoom right in on a hotspot on the NAFI site as shown in Figure 7 you can get a false impression of precision because the hotspot symbols can end up being a lot smaller than the actual accuracy uncertainty. There is a warning about this imprecision on the NAFI site.

As the polar-orbiting satellites orbit 700 - 800km above the earth and the geo-stationary satellites are even higher, the fires need to be reasonably hot compared to their surroundings to be detected in this way. Nevertheless, quite small “fires” can be picked up – for example the heat signals from the top of the stacks in Mt Isa are detected despite being only a few metres across. While other islands of heat such as warm water in dams and hot rock outcrops can sometimes register as fires, the great majority of hotspots appear to be real fires.

Why can’t fires be tracked more accurately and frequently?

The hotspots are detected by orbiting satellites and we hear a lot about advances in satellite technology so it may come as a surprise that we still have gaps of many hours during the day when we can’t track fires by satellite.

It turns out very frequent tracking of burning fires with satellites at a continental and global scale is difficult. While there are thousands of active satellites orbiting Earth, the great majority are not set up to frequently track natural processes like fires across the entire globe. The satellites need to have appropriate orbits such as the polar obits, described above, that allow the satellite to pass over every point of the earth’s surface within a day. They also need to have the appropriate sensors that can detect burning fires.

There are still quite a number of these satellites including those launched by countries including China and India. However, it is only the NASA, NOAA, European and Japanese satellite systems, described above, that have been set up with the appropriate hotspot detection algorithms and distribution processes that then make this data freely available for agencies around the world to use.

What about the new constellations of micro- and nano-satellites or "cubesats" being launched? Groups like Planet have now launched hundreds of these tiny satellites into low earth orbit and the sheer number of these satellites means that in theory they can combine high resolution imagery with frequent updates of fire activity for a given location. Planet imagery is already being used to assist fire management in Australia. However, Planet are a commercial operation and currently there is no system set up involving hotspot detection and free distribution equivalent to the NASA and NOAA satellites. But there are many other cubesats being launched and this technology could be used more broadly for hotspot detection in the future.

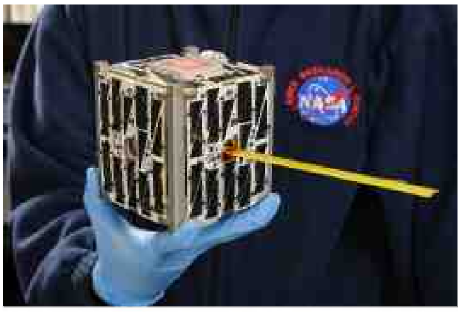


Figure 8. A NASA Cubesat

Who creates the hotpot data?

The NAFI website receives the hotspot data from two agencies in Australia: Landgate WA (Part of the WA's Land Information Authority) based in Perth and Geoscience Australia, based in Canberra. These agencies receive continually updated satellite imagery from the Earth Observing satellites (listed above) from various ground stations around Australia that have received the imagery as the satellites pass overhead. In the case of *Terra*, in August 2024 Landgate WA was receiving the imagery direct from the Goddard Space Flight Center in the US as *Terra* could no longer transmit its data to local receiving stations. Geoscience does not use these Goddard data and no longer supplies *Terra* hotspots.

Once the satellite imagery is received, algorithms are used to detect hotspots from each image. Different algorithms are used depending on the type of imagery from the different sensors (e.g. MODIS imagery *Terra/Aqua*, VIIRS imagery from the *JPSS* satellites). Some of these algorithms are global ones produced by NASA and others are local algorithms produced by Landgate WA optimized for detecting fires in Australian landscapes. RMIT University in Melbourne have developed an algorithm for detecting hotspots from imagery produced by the Himawari geo-stationary satellite.

These algorithms then produced the latitude and longitude of the suspected fire, along with its time of detection and other attributes. Once the NAFI site receives these data over the internet the NAFI map display is automatically updated.

This entire process is automated from satellite detection to display on the NAFI website. There is , however, regular manual checking of the hotspot feed across each day to ensure it is functioning correctly.

Websites:
Landgate: https://firewatch-pro.landgate.wa.gov.au (This site also has a lot of useful data on it for managing fires)
Geoscience Australia: https://hotspots.dea.ga.gov.au/

How long does it take between hotspot detection and display on NAFI?

The delay is usually between 30 minutes and two hours.

- Once the satellites have completed their pass the thermal image is transmitted to a receiving station where the hotspots are identified by computer programs (see ***How accurately do hotspots show the location of a fire?*** page 9)

- Then, the latitude and longitude of the hotspots detected are calculated and delivered via the internet to the NAFI site where they are immediately uploaded to the database and become visible on the map display. However, because of the chain of events involved in getting hotpots to the website various delays can occur (see ***What can delay the hotspot data getting to the NAFI site?*** below) Also there are various reasons the satellites may not detect a fire soon after it ignites, so it can be several hours between the ignition of a fire and its appearance on the NAFI site. (see ***How often is a fire detected?*** page 4).

What can delay the hotspot data getting to the NAFI site?

Because the hotpots signals are relayed from an orbiting satellite to a ground station, to a computer and then through a complex internet network to the NAFI site, any problems in this long series of events can prevent the hotpots from reaching the website (see Figure 9, next page).

Occasionally there are technical problems with the satellites or the receiving stations. For example, as of mid-2024 the *Terra* satellite is unable to transmit its imagery directly to the local receiving stations as it overpasses Australia as its direct broadcast antenna is not working, so instead the imagery is sourced direct from the Goddard Space Flight Center in the US which receives all Terra data from each orbit. This adds at least an hour to the time between detection and when the hotspot data arrives on NAFI.

Accidental damage to Telstra cables, power failures, and network issues are also reasons why hotspot signals may not reach the NAFI site as scheduled and may take several hours instead. If you need information on a fire at short notice, these long delays are effectively the same as missed fires. However, for the great majority of hotspots it should take between 30 minutes and two hours for an image signal to be sent from the satellite to the various ground stations around Australia, decoded into hotspots and then sent through the network to the NAFI site.

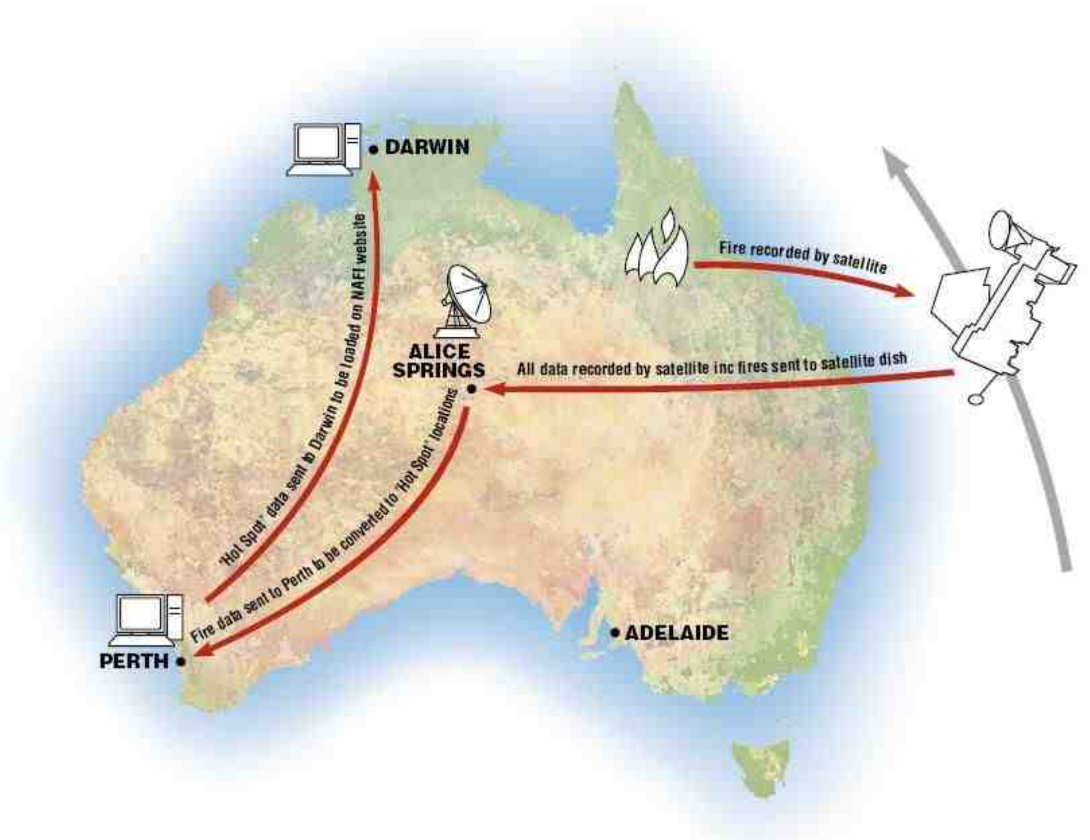


Figure 9. The path from detection to website – in this case via Landgate in Perth.

Do all burning fires show up as hotspots?

Although most major fires are detected by the satellites, for various reasons not all fires may be detected. The main reasons are:

- *The fire is too small or too low in intensity*. The satellite sensor detects fires through the radiant heat they give off, so fires that give off intense heat signals will be more easily detected than low intensity fires. Thus, the larger more intense fires towards the end of year will be more easily detected than the cooler, patchy fires in the early dry season. This also means that fires may need to grow in size before they are detected and may be difficult to detect on cool mornings. However, even very small fires that are sufficiently intense will be detected – for example the chimney emissions from Mt Isa are usually picked up.

- *The fire is obscured by clouds or smoke*. The satellite sensors are not good at seeing through clouds, thick smoke or haze. This means that when there are large fires that produce thick smoke, other fires downwind under the smoke plume may not be detected and at times when many fires are active and there is a thick smoke haze across the landscape, more fires than usual may not be detected. Cloud cover can be a problem in northern Australia from October to December when there may still be quite a few fires on the ground.

- *There is no satellite in view when the fire is burning* This can occur for short-lived smaller fires as the satellites overpass only at certain times of day and it may not be intense enough to be detected by the Himawari geo-stationary satellite. (see ***How often are fires detected?*** page 4)

Are all hotspots shown on the map actually fires?

From the orbiting satellites that capture images of the Earth, to the algorithms that detected hotspots, to the network and database processes that display these data on the NAFI maps, the entire process is automated, so it's reasonable to ask how often this process gets it wrong and displays hotspots that are not actual fires.

Evidence to date indicates that the great majority of hotspots are actual fires, although the accuracy with which they are located will vary (see ***How accurately do hotspots show the location of a fire?*** Page 9). Whether a hotspot is not related to a fire will depend on the satellite instrument and algorithms used and the time of year.

- The MODIS and VIIRS instruments used on the polar-orbiting satellites and the algorithms used to detect hotpots rarely register heat signals in the landscape as fires when they are actually not fires.
- The AHI sensor on the Himawari geostationary satellite and the algorithms used for the "10-minute" hotpots can be more susceptible to registering false hotpots, particularly in the warmer and wetter times of year.

The issues that can produce false hotspots include:

- very high temperatures producing anomalous patches of heat in some landscapes that the algorithms interpret as fires;
- patches pf warm ground between clouds that can be interpreted as fires;
- faults in the satellite's GPS systems that result in hotspots being mapped at the wrong location.

We make efforts to remove these errors as soon as they are detected, to ensure that the NAFI hotspot dataset is as accurate as possible.

These issues underscore the fact that the hotspots should always be viewed with a measure of caution, particularly if they are isolated and not part of an established fire –

and if they have only been detected by one satellite pass. You can see which satellite pass (and hence which instrument) was used to detect a hotspot by going to the “Tools” tab and using the “Query hotspots” tool at the bottom of the “Map Layers” menu on the left. For more information go to the “Help” tab and “Using NAFI” and select “Help on viewing current fires”.