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Around the world in ninety minutes—what an Australian satellite surveillance system could do

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Introduction

One of the capability announcements in the recently released 2009 Defence White Paper was a new satellite intelligence collection system:

> … the Government places a high priority on assured access to high-quality space-based imagery to meet Defence's needs for mapping, charting, navigation and targeting data. It has decided to improve Australia's intelligence collection capabilities by acquiring a satellite with a remote sensing capability, most likely to be based on a high-resolution, cloud-penetrating, synthetic aperture radar.[1]

Wide area surveillance is a demanding task. With the resources of a nation of only twenty-one million people spread across a continent and its surrounds, Australia has to be smart in its approach to surveillance. This ASPI *Policy Analysis*[2] looks at the potential for such an Australian-owned satellite to contribute to the national surveillance capability. It also demonstrates that a suitably-chosen orbit has the potential to provide cost-effective surveillance over a geographical region of great importance to Australia.

Surveillance

By surveillance, we mean the systematic observation of an area. That doesn't mean constant vigilance of every square kilometre of land or ocean. That is a task too large to be practical. Instead, we are talking about the ability to be able to revisit an area often enough to have a high probability of spotting activities of interest.

There is no single solution to the wide area surveillance problem. The Defence Science and Technology Organisation has conducted numerous studies over the years into the right mix for Australia. Generally speaking, a range of platforms with different but complementary capabilities is required to conduct effective wide area surveillance.

Satellites in low-Earth orbits make regular passes (about ninety minutes apart) that allow them to provide regular coverage over large areas. Australia's geography means that there is potential for satellites placed in orbit near the equator to significantly enhance our surveillance capability.

Of course, they cannot be the whole answer and would be used in conjunction with other sensors and platforms.

A key parameter for surveillance is the area swept out by a sensor as it moves over the area to be monitored. That area depends on the ‘swath width’ (the side-to-side detection distance of the sensor—see Figure 1) and the speed of the platform carrying it. The longer a surveillance asset can remain on task and the faster it moves over the Earth’s surface, the greater the area that will be swept out as it moves and the more effective it will be, provided that the data collected can be processed in a timely way. That is why satellites are very useful surveillance assets. Satellites with modern sensor suites (and wide swath widths) and high-speed datalinks can cover large areas systematically.

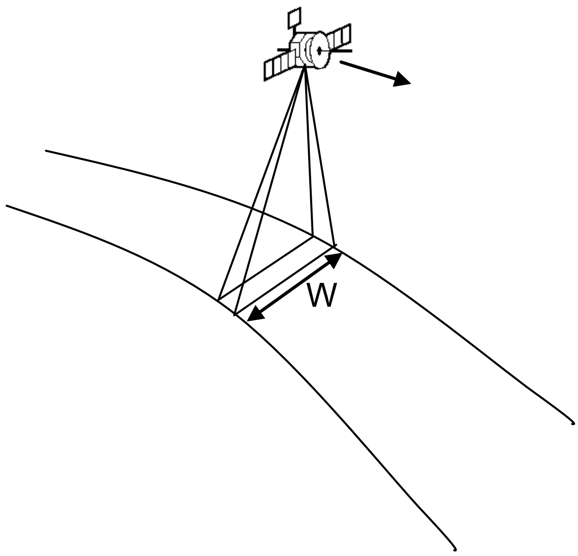


Figure 1. The swath width (W) of a satellite sensor.

Australia already has many surveillance assets. The ADF and other government agencies operate ships and planes that patrol our oceans. As well, we have the Jindalee Over the Horizon Radar Network (JORN). With a range of at least 3,000 km; it is capable of providing coverage over a very broad area. But, while it is a very powerful tool, JORN is not the final word in surveillance. Vagaries of the atmosphere mean that coverage is not uniform and it can be restricted at various times. JORN works best against fast moving targets such as aircraft, which allows for easier separation from background clutter. Smaller and/or slow-moving targets are harder to see.

Defence has plans to acquire unmanned aircraft for maritime patrol and other surveillance. The aircraft will be able to be fitted with a suite of sensors, including electro-optical (photography), radar or signals intelligence. The radar mode (described in more detail in the next section) is especially suitable for automated maritime surveillance. The area coverage that is possible with these aircraft provides a benchmark for surveillance performance. For example, the *Global Hawk* aircraft can provide radar coverage of approximately 10,000,000 square kilometres in a mission of 20–30 hours duration.[3]

However, the government announced earlier this year that the unmanned aircraft acquisition had been deferred beyond the original planned entry into service early next decade. While the White Paper reiterates the intention to proceed with that acquisition in time, no date is provided.

Satellites

There are a variety of means by which satellites can produce surveillance data. Optical photography is a well-known technique, though it is of limited value at night or when there is cloud cover, which is often the case in the tropics and the southern oceans. As well, optical techniques are not easily automated, so that some kind of human interpretation is often required in order to identify objects that are photographed, or to pick out vessels against the ocean surface. For those reasons, optical photography is best suited to investigation of specific areas of interest when there is some *a priori* reason for looking there.

Radar is a technique that shows considerable promise for automated satellite-based surveillance. A satellite in low-Earth orbit can emit a radar beam and look for reflections from structures or other features on the land or from vessels on the ocean surface. For maritime surveillance, vessels can be identified by automated algorithms as bright spots against a dark background.

There are several advantages to employing this technique. Radar beams can cover a wider swath of ocean than optical systems and they are not limited by daylight or cloud factors. As with other detection methods, small wooden hulled vessels, with low radar reflectivity, remain a very difficult target. Large vessels with more than one strong radar reflector (such as a container ship with bridge, funnels, cranes etc.) can give reflections with internal structure, allowing a degree of classification of the vessel. Figure 2 shows a radar image of the Isle of Wight and its surrounds during an International Fleet Review. The assembled vessels are clearly visible as bright spots. Several spectator craft are visible further out to sea.

A project that shows the potential of such a satellite-based approach is the Canadian Space Authority's *Radarsat* 2. The Canadian Government has invested over a billion dollars to develop *Radarsat* 2 and its predecessor *Radarsat* 1. The aim was an improved capability to surveil Canada's northern waters, especially the Northwest Passage through the Arctic Archipelago.

Orbits

Satellites can orbit at different altitudes. For ocean surveillance, the most useful satellites are those in low-Earth orbits at heights between 200 and 2,000 kilometres. At those altitudes, the orbital time is about 90 minutes. Satellites that pass over or close to the poles will make successive passes of the equator about 15 degrees of longitude (almost 2000 kilometres) apart. That means that it takes many orbits before the satellite passes over the same area of ocean. Over time the satellite will pass over the entire surface of the Earth. That is why *Landsat* and other environmental monitoring satellites are in polar orbits. To give another example, the polar-orbiting *Radarsat* revisits equatorial regions only after two or three days. (See Figure 3a.) Near both the poles the coverage is better—up to four or five daily revisits.

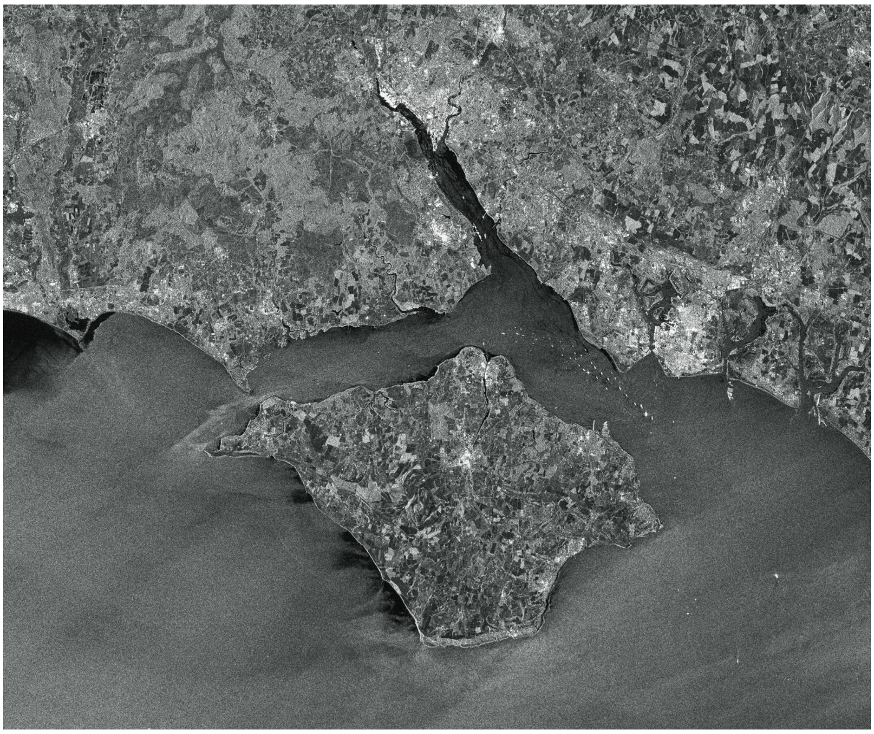


Figure 2. International Fleet Review assembling in the Solent between the Isle of Wight and Portsmouth, 2005, Radarsat image at 30m resolution. The bright spots on the ocean are ships. (Photo courtesy European Space Agency.)

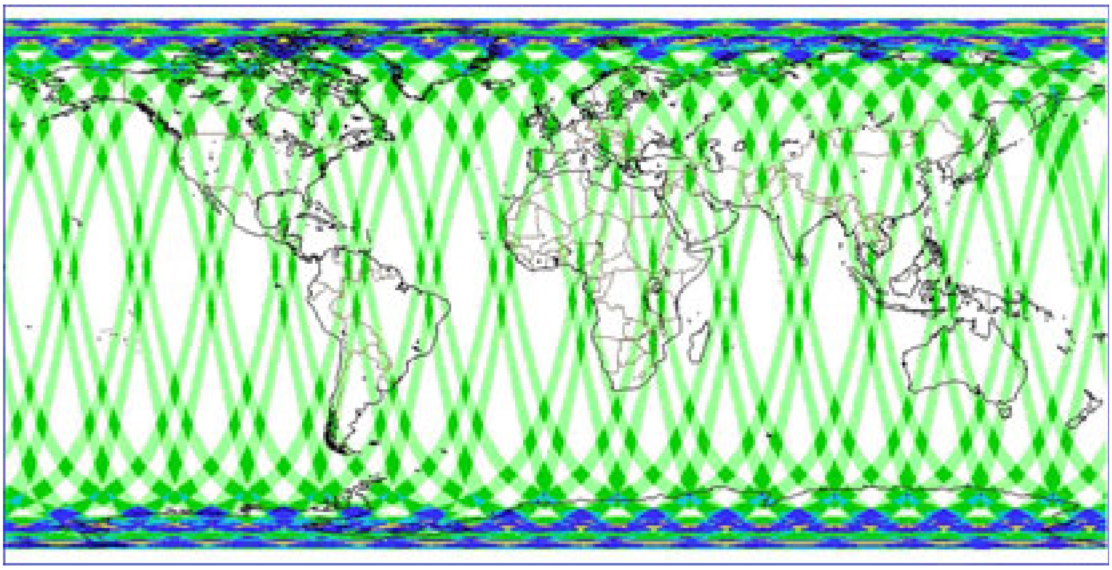


Diagram courtesy of EADS Astrium

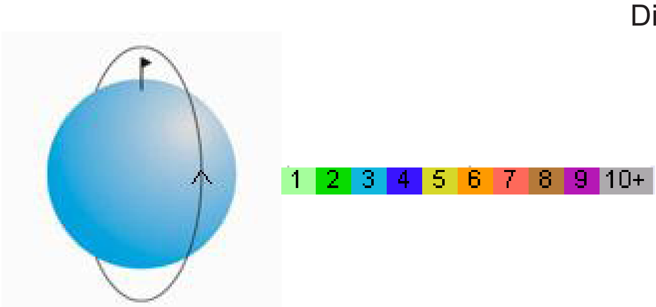
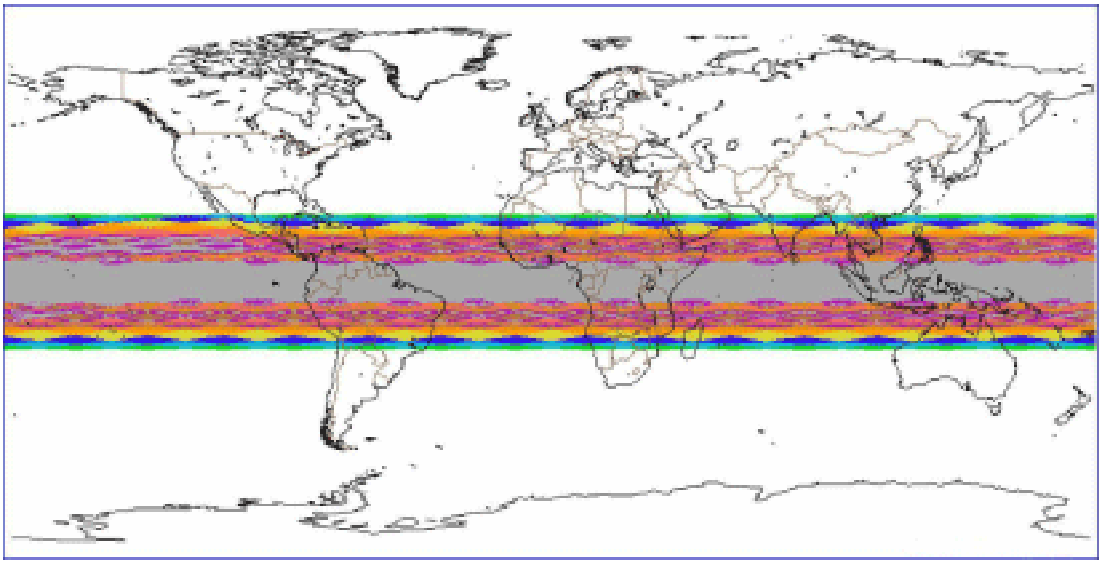


Figure 3a. Number of daily revisits from a satellite in a polar orbit.

But satellites need not necessarily orbit around the poles. If placed in low-Earth orbits near the equator, their groundpath is constrained to a relatively narrow band and they make many more passes per day over a given area. (See Figure 3b.) With a modest constellation of three or four satellites, areas near the equator can be overflown almost hourly. (Satellites cannot easily be placed in low-Earth orbit exactly on the equator. Typically their path will be inclined at an angle of ten degrees or more, which means that they will track above and below the equator as they orbit.)

Of course there is a trade-off in choosing orbits. Near-equatorial orbits give regular coverage near the equator but reduced or no coverage at higher latitudes. Polar orbits give complete coverage of the globe over time, but revisit times are much increased.



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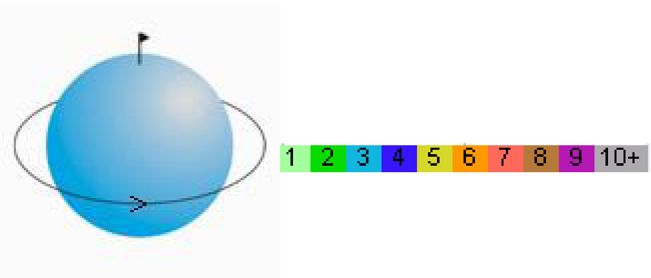

Figure 3b. Daily coverage of the equatorial regions from a radar satellite in near equatorial-orbit. The entire northern approaches to Australia receive six to ten revisits per day. (The data used to calculate this figure makes some reasonable assumptions about swath widths.)

For coverage of southern latitudes, Australia already has access to data from polar orbiting satellites. Since Canada has no particular interest in the southern oceans, Australia and other customers are able to buy surveillance time from the *Radarsat* operators. As well, there is a wide range of commercial providers.[4] While there are few reliable details about the capability of current intelligence satellites in the public domain, there are constellations of polar low-Earth orbiters operated by allies—well documented by amateur astronomers—that could presumably provide

data to Australia.
There are limitations to the efficacy of commercially-provided imagery as far as use in surveillance is concerned. Usually there is a time lag between capturing the data and subsequently obtaining it, as well as a lack of control over revisits. Those factors make such an approach more suitable for applications other than real-time surveillance.

Satellites generally cannot operate for the entire orbital period. They need to recharge their batteries over part of the orbit. So, with commercial or allied systems, we will necessarily be competing with the owner of the satellite for priority in getting time allocated. And in times of heightened tension, foreign governments may withhold satellite time due to either higher priority tasks elsewhere, or for political reasons.

However, Australia could develop an indigenous satellite capability to augment the data collected by allied or commercial satellites. We have a geographical advantage over Canada or other countries at mid to high latitudes. The northern approaches to Australia are within ten degrees of the equator. That means that so-called near-equatorial orbits (see Figure 3b) can spend a much greater proportion of their orbital time over areas that we want to surveil.

Performance

Depending on exactly how the sensors are configured, and what modes are used, satellite surveillance systems can provide high-resolution data or lower-resolution broad area coverage. Modern systems can provide a single-pass coverage of approximately 1,000,000 km^2 of ocean (somewhat less over land). With fifteen passes per day, the total area coverage is around 15,000,000 km^2, making it very competitive with a platform like *Global Hawk*.

A constellation of four satellites would make frequent revisits to equatorial regions, around 30 minutes apart. That is frequent enough to allow for high-resolution follow-up passes for slow moving targets such as ships.

Costs

Like the competing wide area surveillance systems, satellites are not cheap. The cost of *Radarsat* 1 is estimated by the Canadian Space Agency as C$620 million.[5] That figure includes R&D costs. The launch cost was about C$50 million. *Radarsat*-2 costs were similar. However, these numbers are commensurate with the costs of other surveillance systems such as the unmanned aircraft of AIR 7000 or JORN. And the performance estimates earlier suggest that satellites may offer a cost-effective alternative or adjunct to those systems.

If Australia were to launch its own satellites, there is also the potential to recoup some of the outlay by selling satellite time to other customers who have an interest in the geographic areas covered. It is also possible that Australia could participate in an international consortium with other equatorial nations to launch a surveillance constellation. In recent years there has been an increasing interest in near-equatorial satellite constellations, and there are commercial firms providing proposals to suitably located countries.

Like all projects designed to add to national capability, choices we make about the system to be deployed will greatly affect the cost and risk of the project. For example, satellite sensors that are able to be steered to either side are more expensive to implement than ones that look straight down at all times. Of course that would increase their operational effectiveness as well.

Similarly, the mix of sensors is a driver of the cost. Adding electro-optical sensors to a radar payload will increase the complexity and weight (and therefore the construction and launch costs) of the satellite. And electro-optical recognition algorithms designed to work for polar-orbiting satellites that always cross the equator at a constant angle to the sun will not necessarily transfer directly to near-equatorial orbits. As ever, the trick would be to find the cost-effective solution rather than 'gold-plating' the capability requirements. Such reasoning may be behind the White Paper statement that Australia's satellite capability is 'most likely to be based on a high-resolution, cloud-penetrating, synthetic aperture radar'.

Conclusions

Ocean surveillance is a challenging task for a country that is large and sparsely populated and there is no single solution that meets all of our needs. We have already developed a mix of surveillance assets and a national capability to pull the information together. Future additions to the mix will include unmanned patrol aircraft and improved manned platforms. The planned satellite will provide a complementary and likely cost-effective capability to the national surveillance system. And, as this paper shows, the dynamics of orbits may allow us to exploit the accident of geography that placed Australia near the equator.

Endnotes

1 *Defending Australia in the Asia Pacific century: Force 2030*, Paragraph 9.80
2 This paper is a revision of an ASPI brief that received limited distribution in late 2006.
3 Data provided by Northrop Grumman.
4 Geoscience Australia lists the prices for a wide range of satellite imagery products on its web site: http://www.ga.gov.au/acres/prod_ser/raradpri.jsp
5 http://www.asc-csa.gc.ca/eng/satellites/radarsat1/construction.asp

About the Author

Andrew Davies is the Director of the ASPI Operations and Capability Program.

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