Surveillance of Space in Australia

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ABSTRACT

This paper has been written to provide some background for ongoing discussions between Australia and the US on collaboration on space situational awareness, especially its technical aspects. To this end the paper briefly reviews the history of surveillance of space in Australia, considers some lessons that might be drawn from it, and describes some current actual and latent surveillance of space capabilities in Australia along with the present state of play.

1. INTRODUCTION

For a country that does not run a space program, Australia has a surprisingly diverse record of activity in surveillance of space and an unexpectedly large collection of actual and latent capabilities. This paper will review the current situation and how it came about, and note some new initiatives currently under consideration. The paper does not claim to be a definitive or authoritative history of surveillance of space in Australia; rather its purpose is to provide some background to and help inform decisions on possible future activities in this area.

The situation at present is perhaps best described as the result of an ongoing tussle between two opposing forces. The first is summarized in the title of Des Ball's early survey of US bases and facilities in Australia, *A Suitable Piece of Real Estate* [1]. Most of the bases the book covered were connected with space operations in one way or another: they were command, control, communications or tracking sites, and they were in Australia as its large, isolated land mass roughly antipodal to the continental US provided line-of-sight access to space craft and satellites at times in their missions or orbits when they could not be seen from the US, or indeed from many other locations. This was particularly important for manned missions, and for geostationary satellites positioned over the Indian ocean. In addition Australia's vast empty spaces provided an ideal test range for the UK's ballistic missile program and the associated tracking stations required to support this. Finally Australia's unimpeded views of the southern hemisphere of the celestial sphere and its sparse population have long made it an attractive site for astronomers, especially those from more crowded European countries.

In short Australia's size and location, along with good infrastructure, a well-educated, English speaking population, and an enthusiastic and effective local scientific community, saw it out of the blocks early in surveillance of space, and indeed the space race in general: with the launch of WRESAT (see section 2.1 below) Australia was the fourth nation to put a satellite into orbit. However, the UK's final decision not to develop its own missile and to scale back its space program along with the end of the US manned space-flight program saw a countervailing force come into play. The Australian public and Australian government have never seen space as critical national interest: both were happy to host and support UK and US space initiatives and so contribute to what are still seen as essential alliances, but were not prepared to carry an expensive torch for space themselves in the absence of a strong overseas lead. Consequently, outside of certain niche services of definite national interest and of what the scientific community can maintain out of general funding for research, surveillance of space capabilities and infrastructure in Australia have declined since their heyday at the beginning of the `70's. In the course of this decline many expressed the view that Australia was failing to take full advantage of the early seat at the table it had gained due to its location, but these calls for greater engagement have generally gone unheeded.

In the last decade, however, a greatly increased tempo of operations and a significant number of overseas deployments have made the Department of Defence in Australia more alive to its growing dependence on space capabilities. This was reinforced by the government's decision in October 2007 to buy a share of the overall capacity of the US DoD's Wideband Global Service (WGS) communications satellite constellation: the A$975 million project is by far the largest direct Australian investment in military or civilian space capability to date. Consequently in the last two years Defence has started to explore ways in which it might make effective contributions to increased cooperation on space. Space situational awareness, and in particular Australia's hosting of one or more nodes of the US Space Surveillance Network, was quickly identified as perhaps the most promising possibility for such a contribution: discussions have since begun on options for this.

Unfortunately no sooner did these discussions get serious than they were temporarily placed on hold at the Australian end due to the newly elected Labour government commissioning a major review of Defence early in 2008: the resulting Defence White Paper is expected to appear at the beginning of 2009. White papers are written roughly once a decade and set out a policy framework aimed at guiding Defence decisions for the next ten to twenty years. The forthcoming White Paper is expected to give specific consideration to space policy, so definite decisions on major space-related initiatives are in abeyance until it is released: all that can be done in the interim is some anticipatory spade-work for them.

A further complicating factor is that the above-mentioned lack of national interest in space has resulted in the absence of a definite whole-of-government position on space (there is no Australian equivalent of the National Security Space Office). Therefore, while Australia's latent surveillance of space capability includes a range of civilian and military programs and activities, there has been little cooperation between them in the past (in particular little experience in shared use of joint facilities), there is no overall policy or framework for coordinating them, and thus there is no agreed position on how Australia might get most leverage from the opportunities provided by its location in any space-related engagement.

The remainder of the paper is structured as follows. The next section describes the early flowering of space related programs and technology in Australia in the `60's; Section 3 describes their subsequent decline; Section 4 describes current latent surveillance of space technologies and programs in Australia; while Section 5 outlines the next steps that will be taken to explore technical aspects of any future increased engagement on surveillance of space.

Finally it should be stressed that any views or opinions expressed in this paper are the author's only: they do not represent official positions of the Defence Science & Technology Organisation (DSTO), the Australian Department of Defence or the Australian government. For the reasons noted above, government policy on this issue is, somewhat paradoxically, at once both in flux and in stasis: the purpose of the paper is just to provide some background and context for those engaging with it.

2. THE GLORY DAYS: SPACE AND AUSTRALIA IN THE `60's

This and following sections mention a number of locations in Australia where surveillance of space capabilities have existed, currently exist or might exist in the future: Fig. 1 on the next page provides a reference map for the more important of these.

2.1 Launch programs at Woomera

Thanks to its location and its close war-time alliances with the UK and the US, Australia got in on the ground floor of the space race. The first steps were made on the military side with the decision to establish the Woomera test range in 1946. Even before the end of the war Britain had decided to develop an independent nuclear capability and was considering the use of long range ballistic missiles as the delivery system for it. Australia, with its vast empty spaces, was an ideal location for testing both elements of this weapon system. The nuclear testing program at Maralinga and elsewhere is not relevant to this paper, but the ballistic missile development program was to lead to a significant Australian, UK and European investment in space related technologies as sketched out below and comprehensively described in [2]. Moreover the existence of a rocket program in Australia, its size and the cutting-edge technologies involved, all generated great excitement and interest in space among the local scientific and technical community, leading to commitments (and indeed in some cases to quixotic dedication) to keeping programs and facilities alive long after the original drive had well and truly dissipated.

By 1947 the shape of the Australian element of the missile development program was already clear. A range had been designated, covering a roughly rectangular area of ~1,850km long by ~400 km wide with its base at a range head in South Australia about 400km north-west of Adelaide and stretching north-west from this though Western Australia to meet the Indian Ocean just south of Broome. A rather barren, empty site just north of the transcontinental railway was chosen as the immediate support base for the range, becoming the town of Woomera: a large munitions factory at Salisbury just north of Adelaide that had been constructed in haste during the war and was now no longer needed was chosen as the technical support base, becoming the Long Range Weapons Establishment (LRWE). Over the coming two decades these would become substantial establishments: at their height Woomera had a population of over 6,000 while roughly the same number were employed at Salisbury.

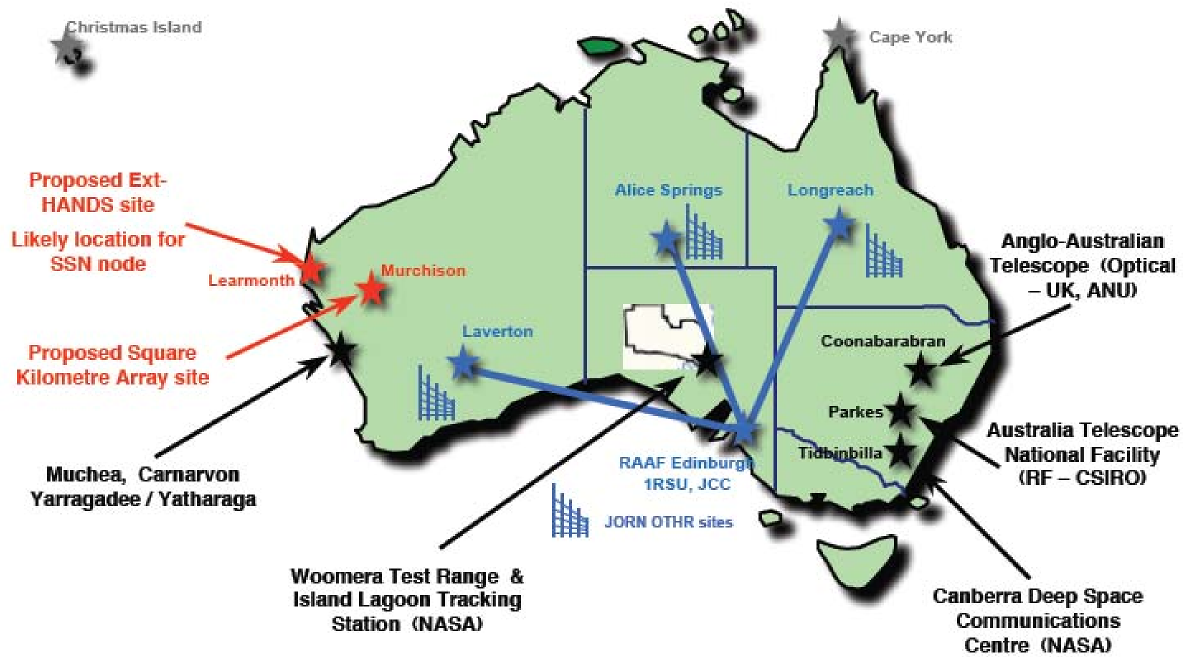

Fig. 1. Past, present and future surveillance of space installations in Australia.

Establishment of a missile program and associated rocket range laid the foundations for a serious space program, and so of surveillance of space capabilities. In the 40's, 50's and 60's large numbers of British scientists, engineers and technicians were recruited to LRWE: the establishment was a magnet for expertise, skills and interests developed in the war but no longer needed in peace. In addition LRWE and the programs it supported acted as a huge training establishment for Australian expertise in space-related technologies. In particular, the need to instrument the test range and to track missiles for up to 2,000km required significant investment in purpose-built optical and radar tracking systems, resulting in the establishment of large electro-optical and radar communities and associated research programs at Salisbury.

The early '50's saw a range of tests of surface-to-air and air-to-air missiles, unmanned aerial vehicles and small scale rockets conducted at Woomera: test of a true ballistic missile had to wait until September 1958 and the launch of the first Black Knight rocket. Black Knight was the prototype for the even larger Blue Streak, which was to be Britain's nuclear deterrent delivery vehicle. But by the late 1950's the strains of imperial overstretch and keeping up with rapidly evolving and multiplying defence-related technologies were telling on Britain: in April 1960 Blue Streak[1] was abruptly cancelled.

Nevertheless Woomera got a second lease of life with the first pan-European space program, the European Launcher and Development Organisation (ELDO). ELDO aimed to develop a European launch vehicle, Europa, capable of putting a one tonne payload into a 600km orbit, or a 200kg satellite into geostationary orbit. Britain was the major partner, contributing over a third of the funds, Blue Streak as stage 1 of Europa, and its accumulated expertise:

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[1] A land-based missile with a liquid-fuelled engine, Blue Streak couldn't be launched within the four minutes that was all the warning silos in the UK would get of a Soviet first strike. The UK would eventually settle on the submarine-launched Trident as the survivable delivery vehicle for its independent nuclear deterrent.

while not initially a partner in ELDO nor contributing any funds, Australia nevertheless eventually secured a seat at the table in return for the use of Woomera. Ten Europa trial launches were made during the `60's, indirectly propelling Woomera and associated infrastructure to the height of their development. However most of these trials were not successful and Europa never launched a satellite, due primarily to problems with the third stage coupled with issues such as chronic under-funding and an appallingly cumbersome multi-national bureaucracy. Ultimately, however, divergent national interests, lack of a joint shared will to see ELDO succeed and the fact that Woomera was not suitable for launching the geostationary communications satellites that had become ELDO's *raison d'être*, saw the end of ELDO at Woomera in 1971.

Nevertheless two satellites were successfully launched from Woomera during this period. The first, WRESAT in 1967, was an opportunistic event, driven by a US offer to Australia of a spare Redstone rocket from the Sparta project and the enthusiasm of scientists at what was now Weapons Research Establishment (WRE was the successor to LRWE) and the University of Adelaide. The second, Propsero, was a UK project launched in 1971 on a Black Arrow, the successor to the Black Knight and Britain's last independent rocket program.

2.2 NASA tracking stations

The investment in Woomera had drawn NASA to town: in June 1957, before the launch of Sputnik, NASA established a Minitrack Radio Tracking Station at Woomera. By 1960 the decision had been made to expand this into a seriously capable tracking station, Deep Space Station 41, at Island Lagoon just south of Woomera. The primary space surveillance elements at Island Lagoon were a 23.5m radio dish and a very substantial Baker-Nunn optical tracking telescope. The commitment of the US to a manned space program, the need to track and communicate with manned satellites throughout their missions, and the primitive communications capabilities of the time all led to NASA expanding its presence in Australia during the '60's from Woomera to a necklace of stations scattered across the continent. In addition to Island Lagoon, at different times during the `60's NASA had stations at Carnarvon and Muchea in Western Australia, Cooby Creek in Queensland, and Honeysuckle Creek, Orroral Valley and Tidbinbilla in the Australian Capital Territory (ACT).

Perhaps the high point of NASA's presence in Australia was the use of Honeysuckle Creek and the Parkes radio telescope (see below) to collect and retransmit Neil Armstrong's first steps on the moon, an event and connection evocatively recalled in the Australian film *The Dish*.

2.3 Astronomical capabilities

Looking up into the night sky from Australia, one sees the sun's nearest neighbours, Alpha and Proxima Centauri and the bulk of the Milky Way[2]. These views have long excited a local academic and amateur optical astronomical community, and garnered increasing interest from European astronomers. A federally funded observatory was set up on Mt. Stromlo in the ACT in the 1920's; following the creation in the late `40's of the Australian National University (ANU) with its strong research mandate, the observatory was handed over to the ANU. As light pollution from a growing Canberra reduced the Mt. Stromlo observatory's effectiveness, the ANU capitalised on its strong links with the research community in Britain (much of ANU's founding faculty were recruited from the UK) to set up the Anglo-Australian Observatory at Siding Springs near Coonabarabran in northern New South Wales: this opened for business in 1973 [3].

On the RF side, during the war the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Australian federal government's civilian research agency, had recruited Edward "Taffy" Bowen [4] to its newly created Division of Radiophysics. Bowen was a key figure in the small bunch of self-effacing but remarkable men who drove the very rapid development of radar in Britain in the late 1930's, and in so doing contributed more to the ultimate Allied victory than perhaps any other group of scientists or soldiers. In particular he had been the radar expert in Sir Henry Tizard's seven man mission to the US in 1940, during which he kick-started the US radar program through his proselytisation of UK inventions such as the cavity magnetron. As subsequent chief of the Radiophysics Division, among other initiatives Bowen set up a research program in radio astronomy that drew on UK and Australian expertise developed during the war. The infrastructure investment needed to replicate something like Jodrell Bank down under were far beyond CSIRO's budget, so Bowen capitalised on the contacts he had made

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[2] Indeed the Australian and New Zealand flags both pay (no doubt unintended) homage to astronomy and surveillance of space in that both prominently display the Southern Cross. Nevertheless to date neither government has shown any interest in making any territorial claims implicit in the flags a reality.

during the war in the US to get support from the Carnegie Corporation and Rockefeller foundation (this were conditional on matching funds from the Australian government, which were eventually forthcoming). The immediate result was the erection of a massive 64m radio dish at Parkes: the longer term outcome was the creation of a strong and enduring radio astronomy research program in Australia and the establishment of a number of radio telescopes now linked together in CSIRO's Australian Telescope National Facility [5].

3. THE LEAN YEARS: THE `70's – `00's

With the end of ELDO, Woomera ceased to be an active space launch site, and therefore an active surveillance of space site. Nevertheless the Woomera Prohibited Area still covers ~127,000 sq km (the area is outlined in black within the white square in Fig. 1), making it by far the largest and least restricted test range in the western world. Unfortunately these advantages are offset by its relative isolation and the lack of an anchor tenant in the form of an indigenous space program. It has hosted occasional space related activities since, such as a series of NASA sounding rockets in 1987-88 and 1995 and the Japanese tests of a one-third scale model of a proposed recyclable orbiting space plan in 1996, but no further sustained launch programs.

Consequently much of the surveillance of space infrastructure at Woomera was scattered to the four winds. At the core of the range's instrumentation were two very capable FPS-16 radars that the US had donated back in 1959; these were small cousins to the AN/FPQ-14 tracking radar at Kaena Pt, Hawaii whose possible relocation to Western Australia has been tabled in current discussions (see below). In 1979 these were removed, one going to Salisbury (where DSTO still operates it), and one being sold back to the US. When NASA closed the Island Lagoon tracking station in 1972, the Baker-Nunn camera was first relocated to Orroral Valley and then eventually given to the University of New South Wales. NASA offered the radio dish to the Australian government as a radio telescope, but the offer was rejected due to high maintenance costs (much to the dismay of Australian scientists) and the dish was broken up for scrap.

At Salisbury LRWE evolved into a wider defence science research laboratory, undergoing various departmental reshuffles and name changes to become what is now DSTO Edinburgh [6,7]. As with Woomera town, numbers fell markedly: today there are only ~1,500 on the area, which itself is substantially reduced in size from its heyday. Of the original surveillance of space related technologies at Salisbury, the radar program flourished, guidance and control continued, but the programs in rocketry, optics and heavy engineering are shadows of their former selves. R&D programs in relevant new technologies took their place; DSTO Edinburgh is now the centre for defence related R&D in IT, communications and systems engineering in Australia.

Likewise the end of the manned space program, improved communications and the development of capabilities such as the Tracking and Data Relay Satellite System (TDRSS) saw NASA gradually consolidate all its activities in Australia at Tidbinbilla in what is now the Canberra Deep Space Communications Complex [8]. This, however, is still a very active site, communicating and controlling a number of NASA space missions to the planets and beyond through several large antennae, towering among them the massive 76m central dish that dominates the valley.

Despite the decline of Woomera, the `90's saw several attempts to set up a commercial space launch business in Australia. Twice Kistler [9] has tried to set up a launch business at Woomera, first in the 1990's when it bid for the contract to launch Motorola's Iridium satellites, and then more recently when it sought NASA and other funding of a reuseable launch vehicle. Other consortia looked at setting up launch facilities on Cape York at the northern tip of Australia, and on Christmas Island, an Australian territory just south of Java. These were always long shots, however, and their path was not made any easier by the fact that the lack of an existing Australian space program meant they had to break much new ground on policy, safety, etc., in the course of getting government approval for their proposals.

During this period debris from de-orbiting satellites highlighted the need for surveillance of space for disaster monitoring: in 1979 Skylab scattered itself across the south-west corner of Western Australia. Nevertheless, while impending de-orbits of large objects generate considerable publicity and consequent political attention, their rarity, transitory nature and low perceived risk mean that this has not translated into any major, long term commitment to surveillance of space. Indeed in 2001 Emergency Management Australia found a perfectly adequate way to manage problems presented by the Mir de-orbit through simply posting an observer with a mobile phone into the Mir control centre just outside Moscow.

Much further up the risk scale, the linkage of the extinction of the dinosaurs with a major meteorite strike in 1979 by the Alvarez led to a major reconsideration by the scientific community of the role asteroids played in the earth's history. Again due to its location, Australia is a natural site for a node in any planet-wide surveillance system to detect asteroids on a potential collision course with earth. In the `90's an astronomer at the University of Adelaide, Dr Duncan Steel, made a number of attempts to publicise this risk and get Australia to invest in such a surveillance system. Dr Steel garnered definite interest and support from AFRL and NASA in setting up a node in Australia, but in this instance no matching funds were forthcoming from any Australian agency.

In contrast to the marked decline in Australian defence-related surveillance of space capabilities, the civilian astronomical community in Australia quietly flourished over these decades. Indeed it became increasingly integrated into what is now an international scientific endeavour with shared data collected remotely operated facilities built and supported with joint funding.[3] Its focus, however, is on deep space: there is not much interest in the solar system or local space.

Looking at Australia's wider engagement with space, the period saw Australia become an increasingly sophisticated user of an ever widening range of services provided from space, such as remote sensing for weather prediction and environmental monitoring, communications, and precision navigation and tracking. However at no point in the period did the Australian government or the larger Australian businesses feel a pressing need to invest in the actual systems to provide these services: while proposals (in some cases quite strong ones) were put up to government by enthusiasts from CSIRO or the small Australian space industry, these were developed on the proposers' own initiative and not in response to government solicitations. From Defence's viewpoint, Australia's prime strategic concerns were instability in South East Asia and in particular Indonesia: the country did not directly face a potential adversary with either nuclear arms or a space force, so Defence saw no need for an independent nuclear deterrent or space and missile surveillance capabilities.

Both at the time and in retrospect, many saw a lost opportunity in this unwillingness to take advantage of the substantial presence in Australia of other countries' space programs to engage more closely with them. Nevertheless not even NASA's uncontroversial mission and the excitement generated by its programs and programs led to any substantive engagement. The resulting lack of a national stake in space effectively guaranteed the run down of a number of space related capabilities previously created within Australia once the original driving forces withdrew.

Disengagement also contributed to the changes over time in the public perception of US space-related bases in Australia. Despite a solid consensus on the prime importance of the US alliance between the two main political parties (Liberal and Labour) that has endured since the Second World War, the Vietnam war and concerns about Australia becoming a nuclear target through its hosting of US bases saw large sections of the Australian public view US bases, especially those with obvious military or intelligence roles, with increasing suspicion and concern. This resulted in (at some times quite sizeable) demonstrations outside some of these bases, in particular Pine Gap and Nurrungar, from the '70's on. As documented in [10], these concerns were inflamed when it emerged that governments' claim that US bases operated only with Australia's "full knowledge and concurrence" were untrue: while implicit concurrence there may have been, full knowledge there was not. In hindsight this lack of knowledge was perhaps as much due to Australia's unwillingness to invest the necessary effort and resources to fully engage with highly technical and complex capabilities as to any other reason (and perhaps to a lesser extent to the US's understandable reluctance to press for such an engagement for security reasons, a decision which in retrospect looks debatable).

The unfortunate legacy of this lack of engagement is an ongoing suspicion among some quarters in Australia of any new engagement with the US that involves space, defence and sites in Australia. This makes establishing joint defence facilities for surveillance of space politically sensitive, even given their obvious importance for civilian space programs.

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[3] As in many areas of modern science, this cooperation has been driven by the increasing size of telescopes needed to advance the frontiers of known space relative to any one country's budget. There are no doubt lessons for defence science in this.

4. CURRENT DISCUSSIONS AND CAPABILITIES

As noted in the introduction, in the last few years Defence in Australia has become increasingly aware both of its reliance on capabilities provided from space and that its future adversaries may also have their own significant space capabilities. This led to renewed discussion with the US on how Defence might engage more with US space programs to the mutual benefit of both countries. The author was not privy to the initial stages of this discussion, but it appears that the US identified space situational awareness as perhaps the most promising area for engagement very early on in them.

Once again a key factor in the US interest is Australia's location: a surveillance of space node on the west coast of Australia would plug a significant current gap in the US Space Surveillance Network (SSN). To this end early on in discussions the US tabled an offer to relocate to Western Australia the AN/FPQ-14 tracking radar at Kaena Pt. in Hawaii that had just been decommissioned. The US also flagged the longer-term possibility of expanding the node's capability by making it an element of the proposed Space Fence program.

In rapidly focussing attention on to a couple of specific options and so driving discussions forward, these offers also unfortunately raised the risk of history repeating itself. That is Australia might once again simply host US facilities without entering into a lasting, wider engagement that would see it also buy into developing the depth of technical and operational expertise needed to be a real mission partner.

In this light the temporary stasis on decisions about space situational awareness imposed by the White Paper is rather fortuitous. DSTO now has a chance to gain a better understanding of priorities and technical issues in surveillance of space through discussions with AFRL and other US experts, to review Australia's own nascent surveillance of space capabilities against this understanding, and to develop more options that would contribute to a deeper engagement. The remainder of this section briefly reviews some relevant capabilities that have been identified to date.

4.1 DSTO radar research programs

With the closure of Woomera, DSTO's radar community had to strike out in new directions in the `70's. Perhaps the most successful of these was the decision to champion over-the-horizon-radar (OTHR) as an answer to the problem of surveilling the wide reaches of the sea-air gap and Australia's northern approaches. OTHR effectively uses the ionosphere as a mirror to conduct HF surveillance at ranges out to several thousand kilometres. After DSTO ran a successful technology demonstrator program in the `70's and `80's [6], in the early `90's Defence committed to building an operational system. This is now a three radar system (locations are shown in Fig. 1) and has been fully operational for most of this decade.

Ramping up the transmission frequencies in an OTHR system reduces ionospheric refraction and will eventually see the beam penetrate the ionosphere, in which case any returns will be from objects in space. These have been detected: while the current radars are not operated against this mission, the scientists working on the next generation systems were sufficiently intrigued to explore it further. Earlier this decade they took this as far as defining what they felt would be an effective system for surveillance of space: a series of VHF arrays spaced several hundred miles apart, each surveilling a solid angle of 60˚ around the vertical. A simple proof-of-concept system was then built as a first stage validation of the concept. However, in the absence at the time of any formal Defence requirement for a surveillance of space capability, this was taken no further.

Nevertheless it looks increasingly likely that any new OTHR systems in Australia will be able to carry out surveillance of space and may well be tasked to do so. For example, technical collaboration for the last five years between Australia and the US on missile defence has focussed on the use of OTHR systems for this role. This has led to a number of successful SKYLOS (SKY-wave transmission, Line-Of-Sight return) trials in which OTHR systems were run in modes outside normal operations against missiles in boost phase. Moreover DSTO's current vision is that the next generation radars will be full 2D arrays, as opposed to the linear or L-shaped arrays in the current radars, and so be able to beam-form in elevation as well as azimuth. This also would greatly facilitate surveillance of space.

Running an OTHR system requires accurate models of the ionosphere to support effective real time frequency management, consequently DSTO has developed extensive models of the lower ionosphere. Moreover Australia has a second source of specialist expertise in this area in the Ionospheric Prediction Service (IPS) [11]: originally set up to support long distance HF communications (a capability of considerable importance to Australia given its large size and sparse population), the IPS has developed an international reputation as a knowledgeable centre of expertise and reliable provider of space weather prediction services.

In microwave radar DSTO's current main research thrust centres on phased array systems: while the primary driver is maritime surveillance, the system parameters for the technology demonstrators have been deliberately chosen to allow them to also be trialled on surveillance of space as well. The technology demonstrator currently under construction is an array of 64 dual polarised, fully independently programmable elements that can both transmit and receive. Associated with the hardware program is a DARPA funded joint Australian-US signal processing research program [12] to develop diverse waveforms that would allow the radar to carry out multiple missions (e.g. surveillance and object characterisation) with the one signal. Moreover the microwave radar program has considerable experience with imaging objects using inverse synthetic aperture radar (ISAR).

4.2 <u>Electro-optic capabilities</u>

The limitations on viewing imposed by the lack of suitably high mountains mean no major new telescopes will be built on the Australian continent, so the local optical astronomical community is pinning much of its hopes on international collaborations: for instance ANU is a partner in the Giant Magellan Telescope project. Nevertheless, even with this focus and while not currently being particularly interested in surveillance of space, the community has several projects underway that are now contributing, or may in future contribute, to this mission. One such is the Skymapper project [13], with its goal of regular multi-colour, multi-epoch surveys of the entire southern sky south of the equator to support astrometry and astro-photometry. A second is the a well-developed proposal to establish one or more infra-red telescopes on Australian Antarctic territory [14] due to the uniquely good seeing conditions in this part of the spectrum created by the very dry atmosphere on the Antarctic plateau.

Another niche capability has grown out of GeoScience Australia's long-standing involvement in international programs on the use of satellite laser ranging for geodesy [15]. This engagement spun off a small company, Electro-Optics Systems Ltd (EOS) [16], when one of the founders of EOS, Dr Ben Green, left GeoScience Australia in the 1980's to make commercial laser range-finders. While the company's main business in Australia is now in making advanced optical sights for weapon systems, Dr Green has retained a strong interest in lasers, space and satellites. EOS run the Moblas 5 satellite ranging system at Yarragadee [17] north of Perth in Western Australia under contract to NASA (who in turn manage it on behalf of the International Laser Ranging Service [18]), and has a contract to do satellite catalogue maintenance using the laser tracking and ranging system at its Mt Stromlo facility in the ACT. With guidance and funding from DSTO, Defence and the USAF, EOS has developed their tracking and ranging system into a true (albeit limited) surveillance and tracking system, comprising a wide-field-of-view passive sensor to detect objects coupled to a laser for precision ranging and tracking. In trials this system has proved capable of detecting and tracking objects smaller than 10cm at distances greater than 1,000km. EOS also claims to be developing a laser ablation capability for changing the orbits of space debris, but DSTO has yet to assess this capability.

4.3 <u>The Square Kilometre Array</u>

While unable to compete with the high Andes or similar locations for optical astronomy, Australia is still an ideal location for radio astronomy: its vast stretches of empty, sparsely inhabited, essentially flat, low value land are ideal for hosting very large array radio arrays. In particular Australia is a serious contender to host the Square Kilometre Array (SKA) project [19]. The SKA is the international radio astronomy community's attempt to do for their field what the Large Hadron Collider at CERN is expected to do for particle physics. If all goes as planned, the project will build an enormous irregular array of some 5,000 12m dishes, each dish containing a 96 element receiver array, scattered over a baseline up to 6,000 km long and imaging over the frequency range 0.3 – 20GHz. If built, the full array is estimated to cost ~$A2 billion, with the money mainly coming from the European radio astronomy community. At present the choice of the principal site has been narrowed down to Western Australia or South Africa: Australia has a strong case both in the quality of the proposed location (impressively radio quiet) and in the strength of the local radio astronomy community described above.

The SKA program will in fact see a family of arrays built in western Australia, not just a single array. The first of these, which is already being installed, is the Murchison Wide Field Array [20]: it will be a VHF array imaging in the frequencies 80 – 300MHz, will have ~8,000 dual polarised dipole antennae, cost around ~A$20 million and is being built primarily with US funds with Lincoln Labs being the project lead. The second is the Australian SKA 1% Pathfinder program [21], which will be a ~$A100 million project to build 45 dishes, each containing an ~100 element receiving array and covering the 0.7 – 1.8GHz spectrum. This will primarily be a technology demonstrator program to prove the performance of dishes, receivers and other components which would need to be manufactured in bulk to populate the full array. The Australian government has already approved funding for it and CSIRO is already well into developing the equipment required. If the technology performs as expected and Australia is selected as the site for the full SKA, this would then be followed by a 10% Australian SKA Pathfinder project that would spend ~$A400 million to build 500 dishes covering the 0.3 – 10GHz spectrum, and finally by the full SKA.

Such a collection of RF arrays will clearly constitute a considerable surveillance of space capability: the question facing DSTO is how best to engage with the SKA program to the mutual benefit of both the astronomical community and Defence. One promising proposal to this end is to install an appropriate transmitter at the JORN OTHR site in Laverton in Western Australia to help calibrate the array (a perpetual problem for such large arrays) by illuminating calibration spheres in known orbits. The transmitter could then also illuminate objects of interest to the surveillance of space community. Nevertheless, while DSTO has technical contacts with the local scientists involved in SKA and is represented on the AuSKA technical review panel, to date neither DSTO or Defence in Australia has had no need to make use of civilian astronomical facilities, and so has little experience in joint use of them.

5. THE NEXT STEPS

Recently there has been a push for greater Australian investment in space: a Senate inquiry into space science and industry in Australia [22] is currently compiling its final report, and this along with developments such as Defence's buy-in to WGS and discussions on surveillance of space has spurred the issue of policy papers such as [23], R&D proposals, and related attempts to raise the profile of space in Australia and increase investment in it. Unfortunately, however, there are yet few signs that these initiatives are likely to elicit a significant wider government or public response.

Focussing down on surveillance of space, while any significant new initiatives will have to wait on the forthcoming White Paper, DSTO and AFRL nevertheless plan to hold technical discussions early next year that will help prepare the ground for any such initiative. From DSTO's perspective, the discussions will help it to:

- gain a better overall understanding of the key technologies and technical issues in space situational awareness;
- identify which aspects of Australia's geography are of greatest value to surveillance of space, and what technical solutions might best capitalise on them;
- identify which elements of Australia's current latent surveillance of space capabilities would add significant value if integrated into the existing space situational awareness program, and how this might be best achieved;
- work out effective modes of engagement with the Australian and international astronomical communities. Clearly the expertise and facilities developed by astronomers are essential for effective surveillance of space: hopefully lessons learned in the US on how best to manage this engagement can be applied in Australia.

A major purpose of this paper is to provide some background for these discussions.

Finally, as the brief history sketched out here indicates, these discussions are really just part of an ongoing debate on a perennial unresolved question: the extent to which Defence and Australia as a whole wish to parley the opportunities provided by Australia's location and latent capabilities into an active, in-depth involvement in space programs (in this case surveillance of space) and how best to achieve this.

6. REFERENCES

1. Ball, D., *A Suitable Piece of Real Estate*, Hale & Iremonger, Sydney, Australia, 1980.
2. Morton, P.R., *Fire Across the Desert: Woomera and the Anglo-Australian Joint Project*, Australian Government Publishing Service, Canberra, 1989.
3. The Anglo-Australian Observatory, www.aao.gov.au/

4. Hanbury Brown, R., Minnett, H.C. and White, F.W.G, A Memoir of Edward George Bowen, www.science.org.au/academy/memoirs/bowen.htm
5. The Australia Telescope National Facility, www.atnf.csiro.au/
6. Donovan, P., *A Century of Australian Defence Science*, The Defence Science & Technology Organisation, 2007.
7. The Defence Science & Technology Organisation, www.dsto.defence.gov.au
8. Canberra Deep Space Communications Complex, www.cdscc.nasa.gov/
9. For a short history of Kistler see: www.globalsecurity.org/space/systems/kistler.htm
10. Ball, D., *Pine Gap: Australia and the US Geostationary Signals Intelligence Satellite Program*, Allen & Unwin, Sydney, Australia, 1988.
11. Ionospheric Prediction Service, www.ips.gov.au/
12. Adaptive Waveform Design for Detecting Low-Grazing-Angle and Small-RCS Targets in Complex Maritime Environments, http://signal.ese.wustl.edu/DARPA/index.html
13. Skymapper, Mt Stromlo Observatory, Australian National University, Canberra, ACT, Australia, www.mso.anu.edu.au/skymapper/index.php
14. National Collaborative Research Infrastructure Strategy: Draft Investment Plan for the Research Capability in Radio and Optical Astronomy, www.aao.gov.au/nca/files/InvestmentPlanAstronomy060908public.pdf
15. Satellite Laser Ranging Overview, GeoScience Australia, www.ga.gov.au/geodesy/slr/slroverview.jsp
16. Electro-Optic Systems Ltd (EOS), Canberra, ACT, Australia, www.eos-aus.com/
17. MOBLAS 5 Satellite Laser Ranging Station, www.ga.gov.au/geodesy/slr/moblas5.jsp
18. International Laser Ranging Service, ilrs.gsfc.nasa.gov/
19. The Square Kilometre Array Project, www.skatelescope.org/
20. The Murchison Widefield Array, MIT Haystack Observatory, www.haystack.mit.edu/mwa/
21. AuSKA: the Australian SKA project, www.ska.gov.au/
22. Senate Inquiry into The Current State of Australia's Space Science & Industry Sector, Parliament of Australia, www.aph.gov.au/senate/committee/economics_ctte/space_08/index.htm
23. Biddington, B., Skin in the Game: Realising Australia's National Interests in Space to 2025, Kokoda paper No. 7, The Kokoda Foundation (www.kokodafoundation.org), 2008.