



Space Industry Innovation Council

Synthetic Aperture Radar

Working Group Report

June 2010

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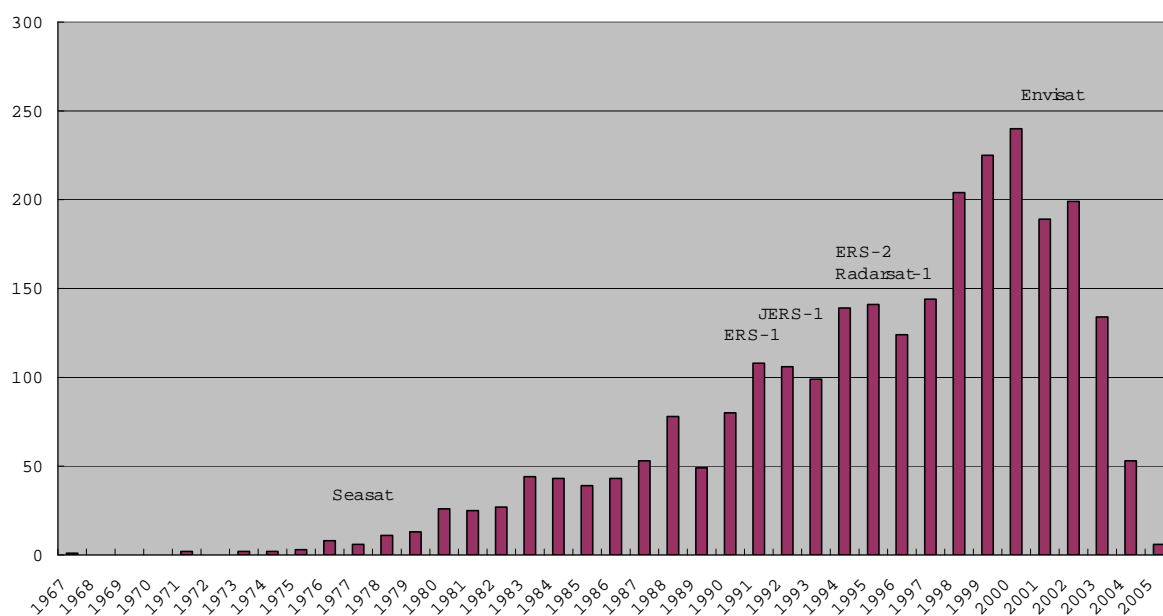
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Introduction

The first Synthetic Aperture Radar (SAR) satellite was launched by the USA in 1978. A renaissance in space-based SAR systems began in 1990 when countries including the Soviet Union, the USA, Japan, Canada, Germany, China, India, Israel, Italy and a consortium in Europe launched their own capabilities. Future launch countries for SAR systems include Argentina and South Korea. The diagram below shows the 30 year 'explosion' in research and publications underpinning this important area of technology development from the mid 1970s through until 2004. The apparent 'tailing-off' in publications over the past several years is probably best explained by the maturity of the research which is increasingly being applied to systems either in development or already launched.

Yearly Publication



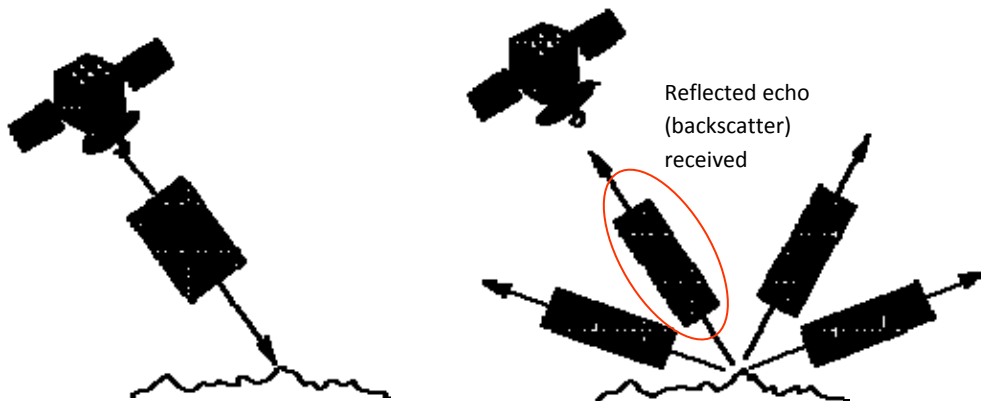
SAR systems are now quite mature, and with their unique capabilities and applications, they form an increasingly important asset for military and commercial users. Australia's experience with SAR technology includes early work done by the Defence Science and Technology Organisation, albeit using an airborne system, and the exploitation of SAR data by Government departments, academia, and some industry sectors such as mining. This data is sourced from other countries' systems through either classified agreements, in the case of the Department of Defence, or commercial contracts. The Defence White Paper released in April 2009 points to the possible acquisition of a SAR capability, it is hoped this can occur by 2019.¹

This paper will discuss SAR technology in the context of space applications, rather than SAR systems made for aircraft.

¹ <http://www.defence.gov.au/whitepaper/>

Technology Description

An imaging radar works very much like a flash camera in that it provides its own 'light' to illuminate an area on the ground using radio waves. A camera flash sends out a pulse of light and records, on film, the light that is reflected back through the camera lens. A SAR uses a transmitter to send out a microwave pulse, and a receiver collects the echo of that pulse reflected back to the satellite. Radar wavelengths are much longer than those of visible or infrared light, and, for this reason, a SAR can 'see' through cloud, smoke haze and humidity; it can take images by day or night; and depending on the signal frequency, SAR systems can penetrate through foliage to map the topology of the land below, penetrate below the earth's surface or through shallow water.



Reference: Freeman, T. *What is Imaging Radar*. Jet Propulsion Laboratory, Pasadena, USA. January, 1996.
<http://southport.jpl.nasa.gov/desc/imagingradarv3.html>

SAR systems and purpose-designed software exploitation tools have been developed for a vast range of applications to detect, monitor, map and measure phenomena on land, sea, ice and in the atmosphere. However, it should be noted that space-based SAR capabilities are limited by satellite revisit rates. SAR satellites and constellations are not built for controllable real-time tracking of individual objects. Instead, these systems track objects and make measurements over time and space. This issue can be addressed by sizing a SAR constellation to include multiple satellites to reduce revisit times. Where a single satellite might adequately meet most commercial application requirements a military SAR mission might employ two or three satellites to provide adequate coverage and revisit times,

Keeping this in mind, examples of SAR applications in the land domain include measuring the subsidence effects on the surface of the earth from mining operations deep underground; mapping the extent of flooding in an area despite the continued presence of heavy rain clouds; monitoring the spread of bushfires even though the area may be covered by dense smoke; measuring tree heights and density to underpin carbon accounting and management activities; and the mapping of areas by soil type and moisture content to better plan cultivation and crop development.

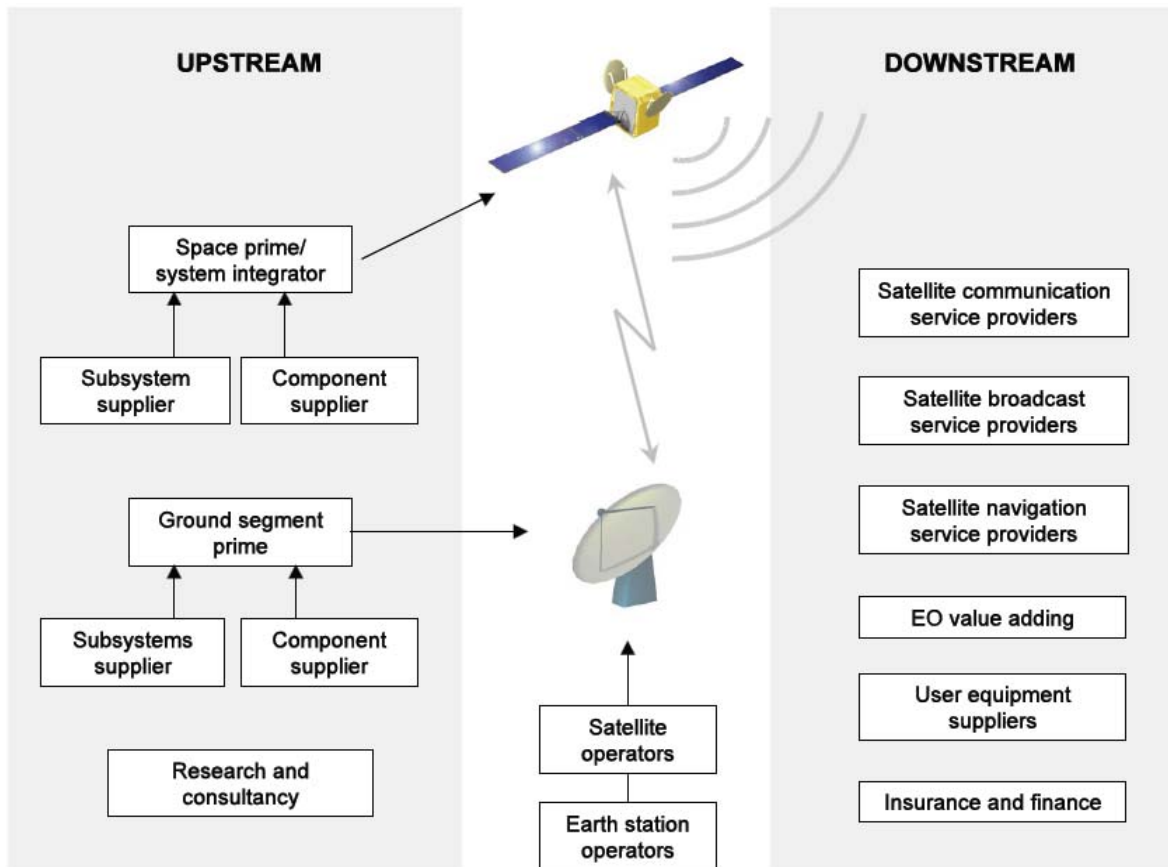
In sea environments, SAR systems can be used to monitor the passage of ships outside designated traffic lanes; detect illegal fishing activity and movement of refugees in defined areas of interest; detect and measure the extent of oil spills; and monitor ocean activity critical to weather patterns.

SAR systems are used widely to map sea ice and the movement of ice shelves, monitor glacial activity, or image the topography of ice even though it may be covered by deep snow. Finally, SAR technology is used to augment weather measurements and predictions.

In the military sphere, SAR satellites provide a vital, complimentary capability to electro-optic (photo reconnaissance) satellites. As previously stated, SAR systems can image military targets through rain, cloud or vegetation, by night or day. Radar systems are ideal for detecting man-made objects because of the high returns achieved from metallic surfaces or sharp edges. Where military targets are habitually obscured by cloud (northern hemisphere winters or in equatorial regions), SAR technology has, without doubt, the premier strategic reconnaissance and target acquisition capabilities.

Space activity value chains

Studies conducted in the UK, Europe and the USA have quantified the upstream and downstream impacts of a national space industry. The model presented below characterises the satellite and ground station operators as sitting in the middle of the two value chains. This construct provides a useful model for the Space Industry Innovation Council to assess the national investment case for a SAR capability. By pitching the technologies involved in the ground segment and/or the satellite, both upstream and downstream investments are feasible. If a country possesses neither ground segment capabilities nor space based platforms, then the upstream value creation business case is severely weakened. Downstream value can still be created in the absence of either ground segment or platforms, by accessing other nation's capabilities and assets, but the value chain is likely to be weak, missing important links or based on sporadic, demand-pull rather than dynamic, innovation-push business models.



Reference: Davies, A. *Relationship of the UK Space Industry Upstream and Downstream Sectors*. Sunwynd, Dorset, UK. November 2009. Page 4.

Upstream Activities

Current State

Since the early 1990s the Defence Science and Technology Organisation (DSTO) has been researching SAR technology using an airborne radar (built by DSTO) and software tools acquired or developed in-house. The primary purpose of this research has been to expand Defence's understanding and exploitation of SAR capability. Universities around the country, and particularly in South Australia, have been conducting research in the field of SAR for some years. Other than theoretical course work in academia, Australia has no platform or subsystem design programs of any significance in progress.

Mission planning and ground segment management of SAR satellites is a much more sophisticated and complex task than Australia has experienced to date through its control of civil communications satellites. The flexibility and versatility of SAR satellites requires very high levels of system understanding, target acquisition techniques, mission planning and execution to achieve the best out of a single satellite or a constellation of satellites working cooperatively. This level of ground segment and mission planning experience and knowledge does not exist in Australia, although within Defence the complexities of this area are well understood. In the non-military area, this

expertise exists to a very limited extent in Government agencies, and with expatriate individuals who may have worked in similar programs for other nations and now reside in Australia.

Resources

Upstream resources *specific* to SAR technology are deemed to be of marginal significance for a national development program. This is an informed but anecdotal assessment due to the lack of data that might measure current commitments by Federal and State Governments and in industry.

Skills

Skills have been assessed to be largely theoretical in the area of space-based SAR and concentrated in Defence and selected universities. Outside the Defence and academic areas, the skill base is best described as piecemeal and unfocussed.

Capabilities

Capabilities are somewhere in the range of non-existent to rudimentary compared to what is necessary to run an independent, national capability.

Future State

Australia's upstream activity is sufficiently robust to launch a generation of space technologists, starting in schools and universities and leading to employment in space-related industry or Government sponsored programs. Key areas include SAR systems design, associated software exploitation tools, SAR satellite management and mission planning, tasking and delivery.

Resources

Initial investment in ground segment technology, and experience in real time exploitation of data received directly from other nation's systems. This base of resources could be expanded through a collaborative venture to invest in satellite system design, build and launch activities as a shared activity with a lead technology nation or company. The next incremental step might see the development of a sovereign system owned and operated by Australia but designed and built overseas to Australian specifications.

Skills

To develop skills that progress beyond being an informed user of third party technology and systems to a contributor and developer of systems designed for Australian civil and military purposes.

Capabilities

A deeper level of understanding and experience in the design, development and utilisation of space based SAR capabilities.

Downstream Activities

Current State

On a very small scale, DSTO and the academic sector have been successful in applying their knowledge and expertise to a range of downstream military and commercial activities. Other Government departments and organisations such as Geosciences Australia, CSIRO and, more recently, the Department of Climate Change have been utilising their knowledge and skills for a range of public sector programs in the areas of the environment, urban planning and land use monitoring. Commercial entities have established a downstream market for SAR imagery products to support agricultural, mining and development planning activities.

The downstream market in Australia for radar-based products and services is largely based on the demand pull of a small number of user groups that apply this technology to discrete problem sets. Australia lacks the dynamics and innovation that would flow from a SAR satellite or constellation of satellites optimised for Australia's geospatial challenges and dual commercial/defence mission requirements.

Resources

Resources are based entirely on foreign owned, operated and tasked SAR satellites.

Skills

Skill sets in Australia are currently based primarily on data exploitation and the innovative application of other nation's SAR capabilities to unique Australian problems. Unlike electro-optic satellites that take photos and are therefore interpreted quickly and intuitively by lay users, SAR images require significant manipulation in order to be useful. This requires a very specific skill set and tools which are currently specialised in a few Government and academic institutions.

Capabilities

In both military and commercial markets, Australia has developed sound capabilities tailored to our specific needs. The foundation exists for a broadening of these capabilities into a more dynamic downstream industry.

Future State

As nations around the world continue to develop the capability of space-based SAR satellites, improve the software tools for exploitation and find new applications for the technology in a wider range of fields, Australia's reliance on this type of data is almost certain to grow. The research necessary to understand how great this demand might be does not exist at present, although the Defence user community has a clearer picture of where their demands might be headed over the next 10 years or so and are able to articulate these plans through high level documents such as the Defence White Paper.

A future state might see a dynamic and growing industry in the supply of data, value added products and services utilising SAR technology across a wide range of civil and military uses. SAR tools would be routinely employed to significantly improve Australia's knowledge of and actions required, to

address environmental issues, monitor land use and resources exploitation, react to disaster relief and monitor the vast land, littoral and ocean areas of sovereign interest to Australia.

Resources

For the dynamic growth of a downstream industry sector there needs to be better access to systems and mission priorities through a sovereign capability owned through either a collaborative program or through a standalone development program.

Skills

From the upstream development of a full suite of skills to manage, maintain, task and collect SAR imagery, the downstream industry sector develops a wider range of commercial applications, products and services to support an industry based on SAR data inputs as either a primary or supporting input to work where remote, space based sensors are the most cost effective and efficient means of data collection.

Capabilities

Industry develops a deep level of understanding and capability to plan for, acquire and exploit SAR data.

Risks / Vulnerabilities

A national investment in SAR technology focused on military requirements, to the exclusion of commercial users (as in the USA with their military programs), is a risk to the development of both upstream and downstream value chains. The risk is greater if a military system is owned by a foreign partner, with Australia getting privileged access, as has occurred with Australia's investment in the USA's military wide-band communications network of satellites. Such arrangements lock users into highly restricted access and exploitation arrangements.

The intellectual property associated with SAR capability will need to be readily available to users in both upstream and downstream value chains in order to maximise the potential use of the technology and system capabilities.

Self-Sufficiency

To a large extent, industrial self sufficiency is achieved through market forces. Existing downstream industry is largely self sufficient because its size and scale has developed to match the availability of data accessed from foreign owned satellites, and is consistent with the 'demand pull' from the specialised customer base that exists today. Operators are characterised at present by a few specialised small to medium enterprises such as Apogee in South Australia to global companies such as Geo-eye and others that sell product and services through local agents.

Self sufficiency in the upstream value chain is linked more directly to investment by Government and the existence of ground-based and space-based systems. Current upstream activity appears to struggle to sustain itself through limited commercial activity in Australia, research grants and offshore contracts for other space agencies such as NASA.

Growth in both value chains is likely to follow a cautious investment and growth path consistent with leadership, commitment and investment from Government in the first instance.

Sustainability

An investment to build a sovereign SAR capability of around four satellites might run to an estimated A\$430m, which includes maintenance costs for around ten years. A single satellite would be cheaper, but would be of limited use due to delays in revisit times over geographic areas of interest. Investments into additional satellites start to generate exponential value in terms of revisit times and options for different orbits, payloads and flexibility in mission options.

Getting a national return on such an investment is best achieved by ensuring that a future SAR system is designed and managed from the outset as a dual-use system for both classified military missions and unclassified commercial applications. Italy has successfully developed and implemented such a model that maximises their investment in a constellation of four SAR satellites that provide full access for both the Italian military and commercial users. Italy has extended the capabilities of this dual-use model to allow access by other countries' military customers (in the case of France) to the classified side of the system and provided other nations' (in the case of Argentina) access to the commercial side of the system without compromise to either user base.

The dual-use Italian model demonstrates a way to maximise the return on investment made in a SAR system by broadening the national customer base and extending the model to the classified and commercial users of other nations. Revenue generation from this arrangement is arguably more innovative than any other system operating in the world, apart from some select communications satellite operators. It certainly provides a model for sustainable operations that is worthy of deeper analysis.

Benefit to the Community

SAR technology is rapidly becoming as ubiquitous as other forms of space based technology. As the science has evolved, SAR capabilities have been applied to an extraordinary range of problems and applications which makes the technology highly versatile. By its nature, the technology is complex, and this requires a vibrant group of companies with the skill and experience base to maximise the utility of SAR data across the full range of potential uses. Australia's unique challenges include remoteness and geo-location in the southern hemisphere; maintenance of sovereign control over vast land and ocean areas, and management or exploitation of resources in remote areas of the country. Based on these challenges, Australia can arguably achieve its strategic and national policy objectives only through the extensive use of space based capabilities.

Related Policies

In relation to SAR technology, Defence is clearly leading the pack. The need for a SAR capability for military purposes and the relatively surprising inclusion of this requirement in the last Defence White Paper signals the need for a whole-of-Government debate on the why, how, where and when

arguments. Whilst Defence's needs have had a clear voice through strategic planning documentation, there is a perceived need on the part of the academic and commercial communities to have greater access to and make greater use of SAR technology. The voice for this requirement is not easily heard because there is no natural focal point for this wider debate. Anecdotally, Government, from what ever side of politics, will face increasing pressure to manage environmental, resource, agricultural and border security issues into the future. A very large proportion of these issues can only be satisfied by timely and reliable access to space based systems. Although still undefined, it seems inevitable that the role of SAR and other satellite sensors in supporting Government policy and strategies will need to be linked. Considering the lead times to field a SAR capability (a minimum of three to five years depending on whether Australia were to take an existing system design off-the-shelf or develop a purpose designed system), this debate needs to be initiated soon.

Summary

From its early beginnings more than 30 years ago, SAR technology has reached a mature stage of development and is now widely deployed by northern hemisphere nations. These systems are not ideally designed or placed in orbits to support Australian military or commercial users.

Commensurate with the extent of access that Defence, other Government Departments and Agencies and commercial users have to SAR data from other nation's satellites, embryonic upstream and slightly more dynamic downstream value chains have been established.

As SAR technology is increasingly applied to a range of land, sea, ice and atmospheric science; strategic defence; and commercial uses, the current dependence on non-optimised, foreign owned systems will limit Australia's flexibility and independence of action. The cost of SAR systems continues to decline as the technology improves and is deployed on smaller and smaller satellites. The vast expanse of Australian land and sea interests lend themselves to SAR capabilities that have all weather, day/night capabilities and the flexibility to acquire data over small precise areas, down to sub-metre resolution, or in broad swaths covering many thousands of hectares in a single pass.

The Defence White Paper of 2009 has energised a debate around the need for a SAR satellite within ten years. This is a significant statement for an area of Government that is arguably better served with access to SAR Data, through strategic bilateral and commercial relationships, than any other user group. The Italian Government has employed a new and innovative way to maximise the return of their investment in SAR capabilities by building a genuinely dual-use system accessed by separate national military and commercial user groups and extended to foreign military and commercial customers.

Australia's dilemma is to determine whether to maintain the status quo or to initiate an upstream and downstream industry growth path through staged investment in ground segment and satellite systems.

Recommendations

The research for this paper revealed the existence of generalised material supporting the argument for a greater investment by Australia in space based capabilities, supported by specific literature on the business cases for space investment in the UK, Europe and the USA.

To further develop the themes in this paper and to provide a more authoritative submission to Government, the key recommendation is to launch a funded study to be completed before the end of 2010 which would address the following issues:

1. Determine the extent of SAR data currently accessible to Australian users, from all sources, and to see how this data, when integrated, can provide a composite picture of the coverage for current scientific, commercial and military purposes;
2. Conduct a gap analysis on this composite picture to determine how best to fill gaps in data availability through a cost effective investment by Government and industry;
3. Survey the existing SAR user skill base and technological capabilities in Government Departments and agencies (including Defence);
4. Determine the extent of current university teaching, research and consulting in the area of SAR technology and its application (including DSTO); and
5. Quantify the extent of the commercial industry around SAR data acquisition, exploitation and application.

This research should be sufficient to establish a solid picture of the current state upstream and downstream activities around SAR technology. The second phase of the same study is to scope the future intent to invest in SAR by participants in upstream and downstream activities based on three scenarios:

1. Continued reliance on access to the SAR assets of other nations with no investment by the Australian Government;
2. Investment by industry/ Government in ground segment facilities and technologies sufficient to allow direct reception and exploitation of SAR data from other nation's systems; and
3. Investment by the Australian Government in a sovereign capability, designed, built and stationed in an orbit (or orbits) optimised for Australian military and commercial mission requirements using a guaranteed, dual-use approach to system resources.