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Looking Up

A Strategy to Develop Space Science and Technology Opportunities in Southland

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Space Swamp

The European Space Agency-commissioned
Tracking Station at Awarua

Sometimes you find a place
where a superabundance of light
blisters, peels horizons bare …
here is such a place.
Skies, clean-rinsed, and hung out to dry
or heavy on the outstretched land.
Skies that lift your gaze
and in this place force you to feel
you teeter on the cusp of space.

Migratory birds have splintered these skies
with the beat of their wings.
Before calendar time have unravelled this air
as they landed to feed on the broth of the swamp.
Now an ungainly bird, unlike them, perches here
on tripod legs. Turns the dish of its eye
to report on the passage of vessels in Space,
otherwise lost round the Earth's southern curve.

They've named this one *Jules Verne*,
his mind's journeys told
as the white-canvassed ships were anchoring close
to this sky-empty land.
Now astronauts stand where our forebears strained forward
across this bleak plain – and the fragments of our little lives
briefly intersect the stars.

Lynley Dear, March 2008

Cover photo courtesy of ESA

Looking Up: A Strategy to Develop Space Science and Technology Opportunities in Southland

For the past seven years, Venture Southland has been actively involved in the development and building of space science and advanced telecommunications projects. The aim is not only for Southland to participate in world class, commercial science, but to develop national and regional capacity in order to actively participate in the commercialisation of the technologies associated with these projects.

New Zealand now has a number of significant opportunities to develop a dynamic range of business and technology initiatives resulting from participation in space science. These opportunities will:

- allow New Zealand to obtain near real-time data to allow comprehensive monitoring of the 20 million square kilometres of ocean that New Zealand is responsible for, including all of the Exclusive Economic Zone, improved land management and emergency management,
- involve New Zealand in affordable, leading-edge science,
- stimulate our children to study science, engineering and mathematics,
- establish Southland as the leading space science facilities location in New Zealand.

The opportunities take advantage of the present facilities at Venture Southland's Awarua Station, which was established in conjunction with the French Space Agency for the European Space Agency to track the on-going Ariane 5 ATV launch series, and the relationships Venture Southland has forged over the last five years with the European Space Agency, French Space Agency, German Space Agency, Swedish Space Corporation, In-Snec, Landcare Research, LF & EM Research, AUT, VUW, Rocket Lab and others.

Suggested work

This strategy proposes that the following projects be initiated and/or facilitated by Venture Southland.

Remote sensing satellite earth station

It is proposed that New Zealand's first satellite ground station for downloading medium and high resolution remote sensing satellite images be established at Awarua Tracking Station, in Southland. It is also proposed to establish an associated satellite image value-added service at Invercargill to process the image data downloaded at the station.

Contingent on adequate commercial demand, it is further proposed to install and operate additional equipment for providing tracking, telecommunications and control of low earth orbit satellites, direct tasking of remote sensing satellites, and tracking polar-orbiting spacecraft launches and New Zealand sub-orbital launches (such as proposed by Rocket Lab).

Primarily, the proposed station and facilities will provide affordable, easily accessible optical and radar satellite images which may be used by central and local government, universities, research organisations and commercial users for, amongst other things, monitoring fishing in the Southern and Pacific Oceans, activities in the Exclusive Economic Zone, maritime search and rescue, forestry, pollution and land use compliance. Having a station in New Zealand will also allow for near real-time access to images of natural disasters, oil spills, forest fires and suchlike and so greatly assist with disaster management and mitigation.

The installation, maintenance and on-going operation of the station would create highly skilled jobs in Invercargill. Further highly skilled jobs dealing with image interpretation and production can be expected along with a number of associated marketing positions. Significant downstream product developments can be anticipated.

The cost of establishing the facility is estimated at $5.9M with annual operating costs of $1M - $2M. These costs will be recovered from present annual central government expenditure on satellite image products, estimated at over $2M pa, new users in the private sector and local and central government, education institutes, and new commercial activities. Significant benefits can also be expected by using near real-time satellite images to more efficiently task EEZ management activities, much of which uses aircraft time at $1,000/minute and are currently budgeted in the order of $350M pa.

Radio astronomy

Because of the region's attractive geographic location, modern radio astronomy and in particular the proposed Square Kilometre Array offers Southland the chance to host significant "sexy science" radio astronomy facilities. Besides providing economic stimulus, radio astronomy will precipitate high performance infrastructure development for the region, provide a focal point to engage and excite local secondary school pupils in engineering, physics, mathematics and astronomy, and earn prestige for the region.

Possibilities for Southland include hosting the Square Kilometre Array, a SKANZ Pathfinder antenna, conventional radio telescopes and low frequency radio telescopes.

Ionospheric research

A wide range of ionospheric research is already undertaken and further research possibilities range from augmenting present facilities to developing new facilities.

Tourism

Southland offers opportunities for natural tourism, such as viewing auroras and dark skies star gazing, and industrial tourism for visiting space research facilities.

Education

Through the New Zealand – European Space Agency Arrangement, Southland schools have the potential to enjoy special privileges when studying space topics. These and other initiatives have still to be fully exploited.

Table of Contents

Acronyms: Please note that the convention of not spelling out acronyms in the text has generally been adopted, even for proper nouns. This is in part because many of the organisations, programmes and components used in this field are only ever known by their acronyms. All acronyms used in this proposal are listed in Section 1.

1. Acronyms used and glossary

ACRES	Australian Centre for Remote Sensing, part of GA since 2000
ALOS	Advanced Land Observing Satellite, which was launched by Japan Aerospace Exploration Agency in 2006.
Ariane 5	ESA launcher presently in use for inserting major payloads into orbit
ATV	Automated Transfer Vehicle
AUT	Auckland University of Technology
CME	Coronal Mass Ejection, a form of solar flare, which deleteriously impacts on the ionosphere
CNES	Centre National d'Etudes Spatiales, French Space Agency
CRI	Crown Research Institute
DLR	Deutschen Zentrums für Luft und Raumfahrt, German Space Agency
DLT	Digital Linear Tape. A type of magnetic tape used for backup
DMR	Digital Microwave Radio
EEZ	Exclusive Economic Zone
EIRP	Effective Isotropic Radiated Power
EMI	Electromagnetic Interference (radio interference)
ENVISAT	ESA remote sensing satellite
ESA	European Space Agency
eVLBI	electronic Very Long Baseline Interferometry radio astronomy
FTP	File Transfer Protocol, an Internet format for downloading files
GA	Geoscience Australia, Australia's primary public-good remote sensing organisation
Galileo	ESA satellite global positioning system which is currently being deployed
GEO	Geosynchronous Earth Orbit (satellite), also known as Clarke Orbit
GeoEye	GeoEye, satellite services provider based in Dulles, VA, USA.
GHz	Gigahertz, 1,000,000,000 cycles per second
GIO	New Zealand Defence Force Geospatial Intelligence Organisation
G/T	Gain over noise temperature, a figure of merit for antennas
HF	High Frequency radio waves, between 3 MHz and 30 MHz
HRPT	High Rate Picture Transmission weather satellite service provided by NOAA
Ionosphere	The uppermost part of the atmosphere, beginning at an altitude of about 50 km and extending out to 500 km, distinguished because the gases there are ionized by solar radiation and, amongst other things, so capable of reflecting HF radio waves.
InverNet	Invercargill metropolitan urban fibre-optic network
Ka-Band	26.5 – 40 GHz
KAREN	Kiwi Advanced Research and Educational Network
KiwiImage	Whole of Government satellite image consortium
L-Band	950 MHz - 1450 MHz
Landsat	Land remote sensing satellite, a series of satellites managed as part of NASA's Earth Observing System
LDCM	Landsat Data Continuity Mission

LEO	Low Earth Orbit (satellite)
LHCP	Left Hand Circular Polarisation
LUCAS	Land Use and Carbon Analysis System, a cross-government programme led by the Ministry for the Environment (MfE) in partnership with the Ministry of Agriculture and Forestry (MAF) to meet New Zealand's reporting requirements under the Kyoto Protocol.
MHz	Megahertz, 1000,000 cycles per second
MIT	Massachusetts Institute of Technology
MWD	Moving Window Display
M&C	Monitor and Control
NOAA	National Oceanic and Atmospheric Administration, USA
NPOESS	National Polar-orbiting Operational Environmental Satellite System, to be operated by NOAA
NZDF	New Zealand Defence Force
OTB	A division in Denel Aerospace Group, South Africa
POP	Point Of Presence
RAID	Redundant Array of Independent Disks
RAS	Receive and Archiving Subsystem
REANNZ	Research and Education Advanced Network New Zealand Ltd, the Crown-owned company which owns and operates KAREN
Restec	Remote Sensing Technology Centre of Japan
RF	Radio Frequency
RHCP	Right Hand Circular Polarisation
RSS	Remote Sensing Satellite
SAR	Synthetic Aperture Radar
S-Band	2 GHz – 2.5 GHz
SIX	Southland Internet Exchange
SKA	Square Kilometre Array radio telescope
SKANZ	Square Kilometre Array New Zealand, the New Zealand steering group for New Zealand's involvement with SKA
SPOT	Satellite Pour l'Observation de la Terre, a high-resolution, optical imaging earth observation satellite operated by SPOT-Image.
SPS	Search and Processing Subsystem
SSC	Swedish Space Corporation
SuperDARN	Super Dual Auroral Radar Network
TIGER	Tasman International Geopspace Enviroment Radar
TT & C	Telemetry, Tracking and Control
USN	Universal Space Network, a commercial organisation that operates a network of satellite ground stations around the world offering space operations and TT&C services.
VLF	Very Low Frequency radio. In radio astronomy circles, this is considered to cover the decametre wavelengths, equating roughly to 10 MHz – 300 MHz. In normal parlance, VLF is considered to describe the frequencies between 3 kHz and 30 kHz.
VPG	Value-added Product Generator
VSAT	Very Small Aperture Terminal, a particular kind of small satellite earth station used for telecommunications.
X-Band	8 GHz – 8.5 GHz

2. Why Southland?

Southland is ideally located to host space science, radio astronomy and spacecraft tracking. This largely comes about from Southland's geographic location, for the region is the:

- south-west corner of New Zealand,
- south-east corner of Australasia,
- closest landmass to the Southern Ocean.
- closest landmass outside of Antarctica to the South Magnetic Pole,
- closest populated landmass to Antarctica other than South America,

As can be seen from Figure 1, Southland's location means that any space, or radio observation platform in Southland has a clear vista of the Southern Ocean, the southern Pacific Ocean and the skies above them. The Southern Hemisphere location gives the best views of the Milky Way, considered by many to be where some of the most interesting astronomy observations are to be made.

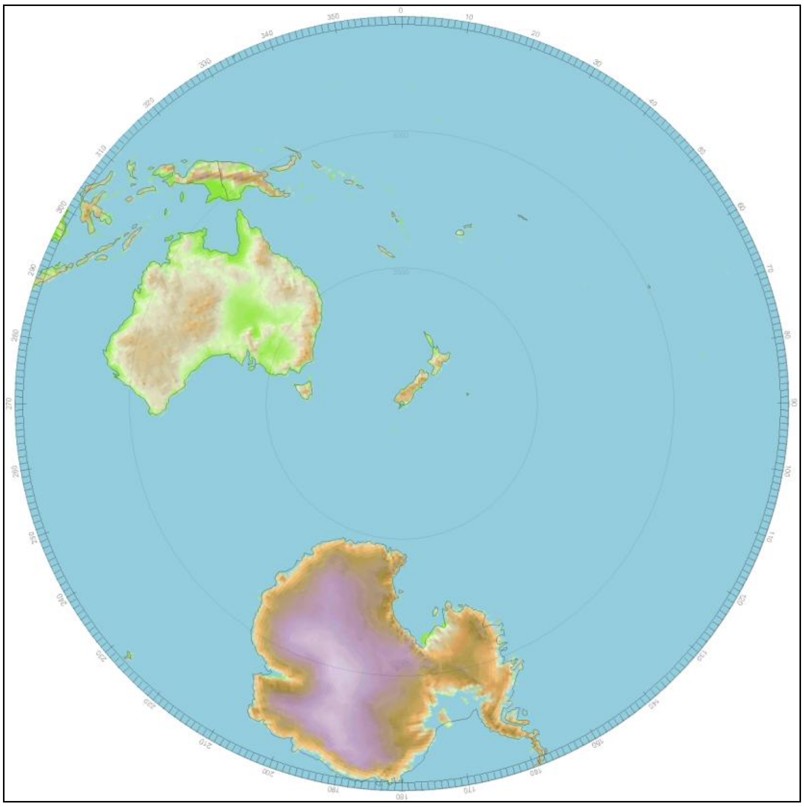

Figure 1. Great Circle Map centred on Invercargill. Range scale is 2,500 km per division.

Not immediately apparent from Figures 1, but more clear from Figures 2 and 3 is that Southland offers a wider field of view of polar rotating spacecraft than anywhere else in New Zealand, due to its southerly location.

Not at all obvious from these maps is that Awarua, just south of Invercargill, serendipitously has excellent views of the European Space Agency Ariane 5 ATV launches to the International Space Station- indeed, payload separation for these launches takes place due south of Bluff and can only be viewed from Southland (see Figure 4).

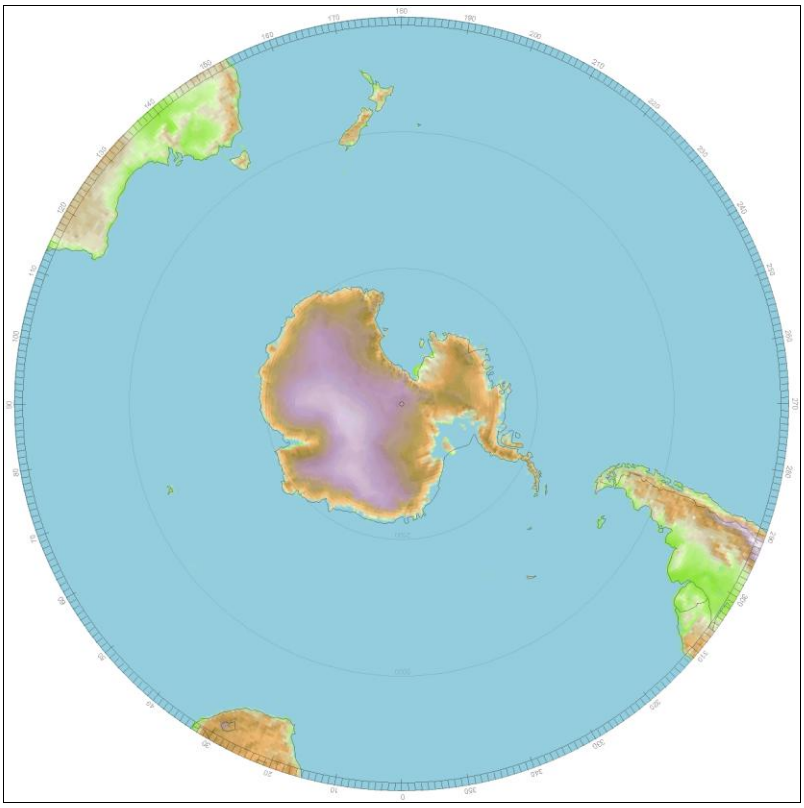

Figure 2. Great Circle map centred on South Pole. Range scale is 2,500 km per division.

Not widely appreciated is that Southland is the closest landmass to the South Magnetic Pole outside of Antarctica and Invercargill is thus the nearest city in the world (see Figure 5), with the magnetic latitude of 54˚S (compared to the geographic latitude of 46˚S). This means that Southland is best positioned to view Aurora Australis.

Southland also has a relatively sparse population outside of the built-up areas at around three people per square kilometre[1], which means that relative "radio quiet", where there is minimal radio interference, can be experienced in many areas (see Appendix 4).

Southland is nonetheless well served by world class infrastructure, including nearly ubiquitous broadband Internet access. A number of businesses in and around Invercargill are well equipped to deal with the construction and maintenance of space and radio science facilities (see Appendix 1).

Southland's best known centre for space, radio and ionospheric work is Awarua. Other than its ideal geographic location for such activities, perhaps Awarua's most important attribute is that it is known of by space agencies around the world. Awarua's importance can be traced back to 1913 when NZ Post & Telegraph Department awarded the contract to construct a high-powered radio station to Telefunken Company from Germany there. This station, also known as Awarua ZLB, operated up until 1989 providing telecommunications to shipping around New Zealand waters and the Island Service telephone links to Scott Base, Chatham Island and a number of Pacific Island countries.

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[1] The 1996 population density for the mesh-block containing Awarua is 3 – 5 permanent residents per square kilometre. However, as the mesh-block is relatively large, a more realistic population density around the site is estimated to be less than ½ permanent resident per square kilometre.

Awarua's importance continues with a number of existing space and ionospheric research facilities at Awarua and these continue to attract further interest amongst researchers and space services providers. The success of these facilities provides the necessary trust that can be conveyed by word of mouth between researchers and their agencies. In particular, through its association with ESA, SSC and CNES, Awarua Tracking Station has a credibility with European and other space agencies that other sites in New Zealand would struggle to achieve.

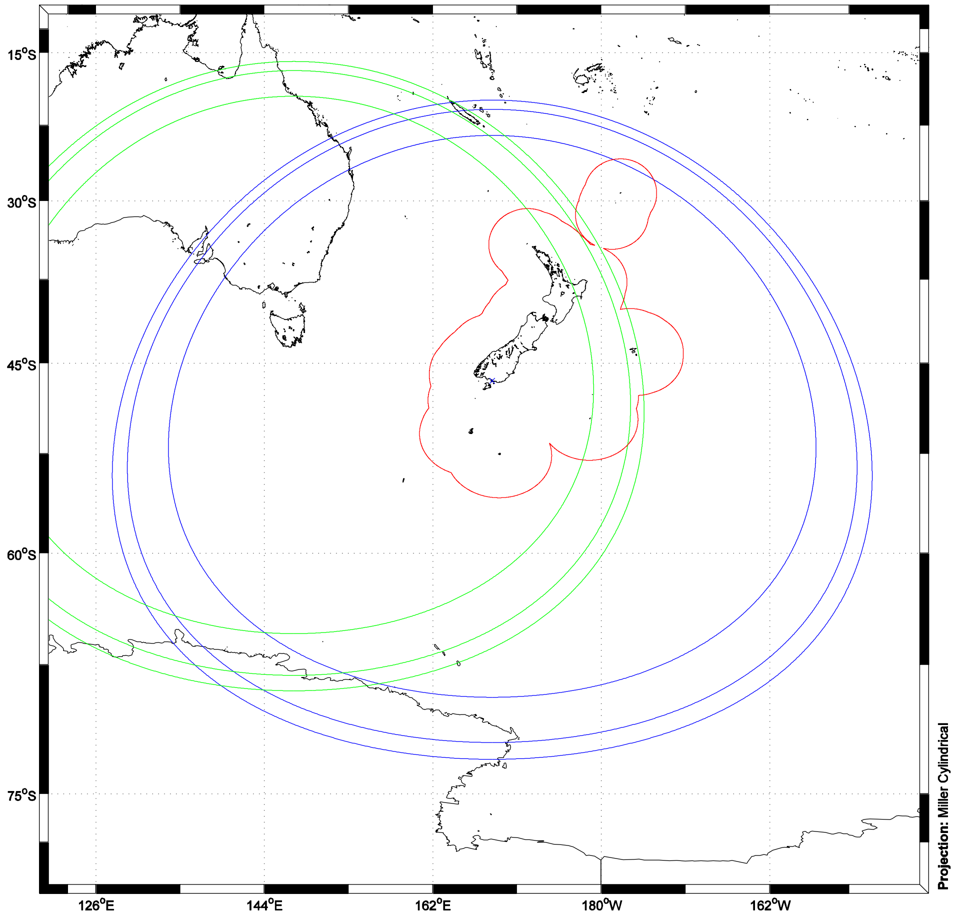

Figure 3. RSS satellite reception coverage for Awarua (blue lines), with New Zealand's EEZ shown in red. Coverage is shown for 5°, 2° and 1° minimum antenna elevations from Awarua. The satellite reception coverage for a station located at Hobart is shown in green. (Courtesy S McNeill)

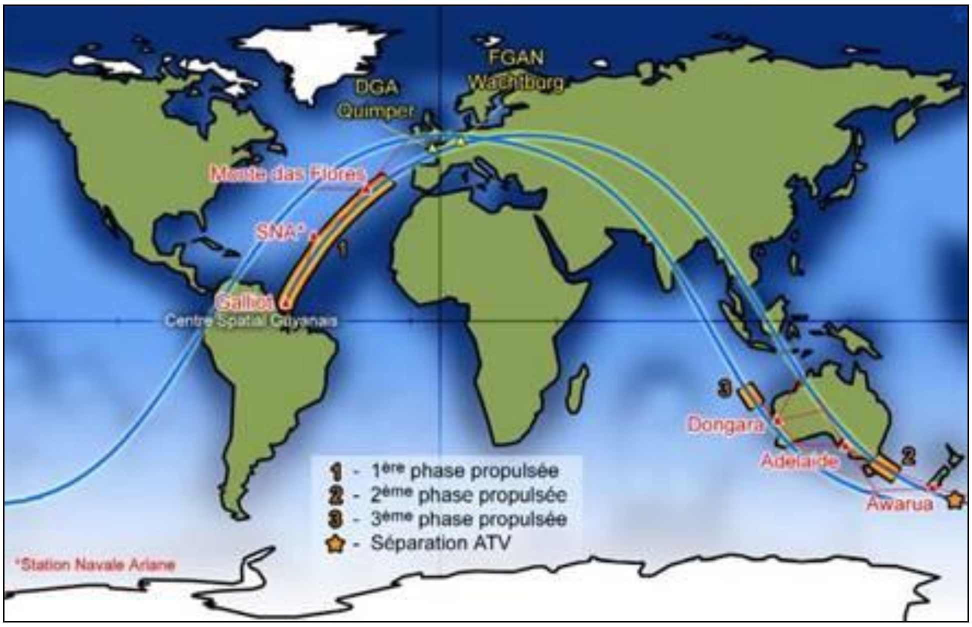

Figure 4. Ariane 5 ATV launch path showing the importance of Awarua (Courtesy CNES).

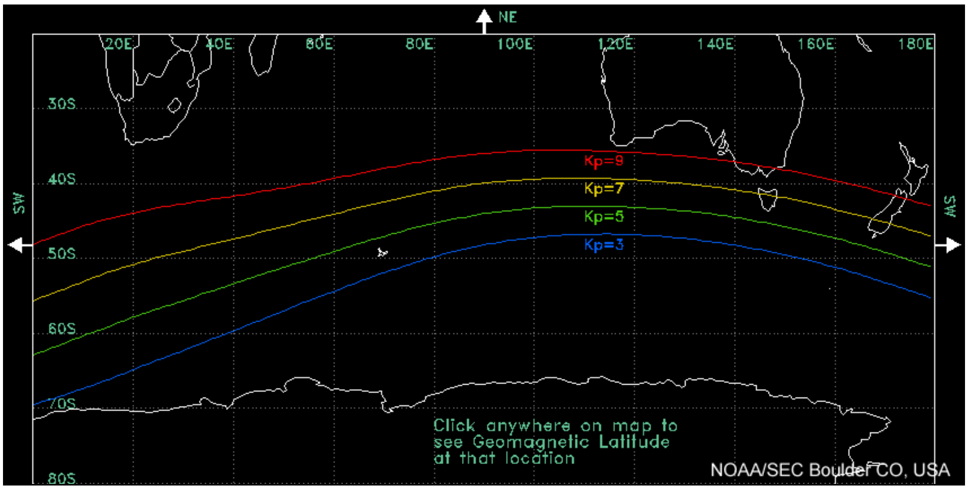

Figure 5. Auroral visibility map, showing Southland's proximity to the South Magnetic Pole. Kp is a measure of magnetospheric disturbance causes by solar events, centred on the South Magnetic Pole (after NOAA).

3. Suitable space and radio science for Southland

Internationally, space research and development is considered to be highly beneficial to both national and local economies. Some reports claim that the economic multiplier for space activities is between six and seven. Significant "spillover" and "catalyst" benefits are also recognised, where work in the space industry benefits the wider community and economy. A useful, but not definitive, list of these benefits are summarised in a recent study by South East England Development Agency[2], the executive summary of which is set out in Appendix 21.

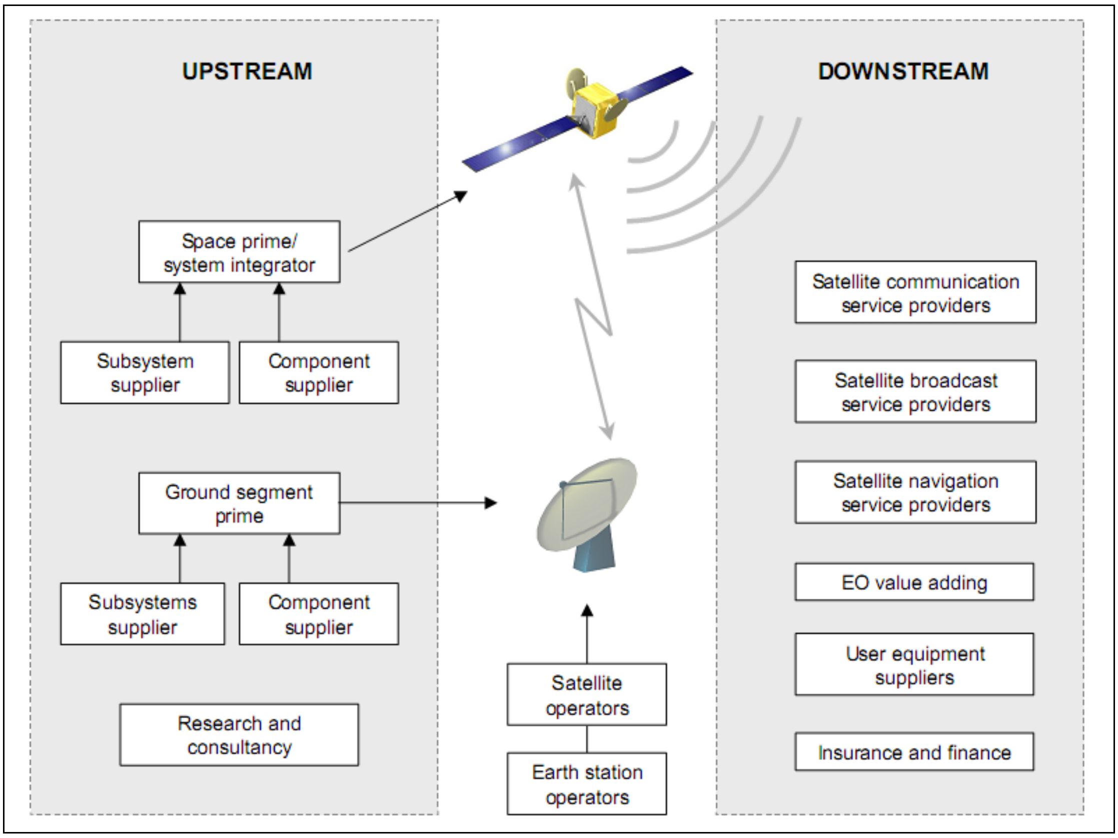

Figure 6. Definition of the Space Industry (after Size and health of the UK space industry 2008 (BNSC)).

The space industry consists of companies who provide the technology (the upstream sector), as well as companies that exploit the technology (the downstream sector). Upstream companies include those involved in the space segment prime and their suppliers, as well as those companies involved in ground segment prime and subsystems and components. Companies who provide support products and services and research and consultancy to these companies are also included in the upstream definition. Southland is in a position to support the ground segment prime upstream sector (see Figure 6).

[2] Oxford Economics, *The Case for Space: The Impact of Space Derived Services and Data*, Final Report, July 2009.

In light of Southland's geographic advantages, the following space and radio science work presents itself as suitable for ongoing and future development:

Ionosphere and space weather research and monitoring

- Auroral radar
- Geomagnetic activity
- Auoral observations

Atmospheric research

- Lightning detection and location
- High frequency radio seascape observations and measurement
- Meteorological and climate imaging

Radio astronomy

- Decametre radio astronomy interferometry
- eVLBI radio astronomy with Auckland and/or Australia
- SKA radio telescope remote station

Satellite data downloading

- Remote sensing satellite earth station for near real-time imaging
- Remote sensing satellite earth station for archival imaging

Spacecraft tracking and telemetry

- Ariane 5 ATV launch tracking
- Galileo global navigation system ground station
- Polar orbiting satellite launch tracking
- Satellite Telecommunications Telemetry and Control
- Sub-orbital launch site and down-course tracking

Satellite services

- Locator beacon development

Hitherto unknown opportunities undoubtedly also exist.

4. Current situation in Southland

4.1. Venture Southland initiatives to date

Venture Southland is a combined committee of Invercargill City Council, Southland District Council and Gore District Council, and is a formal legal entity in its own right (See Appendix 1). Amongst its varied roles, Venture Southland takes the responsibility for advancing and facilitating innovative major engineering projects that may benefit the region. Venture Southland is also the lead agency assisting business development in Southland.

Venture Southland takes a strategic approach to business development, with a keen interest in promoting high-tech business opportunities. A good example is the $3.5 million Unwin Radar (discussed later) where Venture Southland was able to identify a good operating site and successfully introduce local engineering, technical, construction and fabricating businesses to the Australian client.

Venture Southland's strategic approach encourages leverage of related high-tech projects to facilitate further space and ionospheric business, such as the VLF Lightning observatory established by LF & EM Research in February 2009 at Awarua Tracking Station, again making use of local engineering expertise. As the skills and projects undertaken by local businesses become more widely known, further opportunities present themselves: Venture Southland currently has a Memorandum of Understanding with the Swedish Space Corporation for two significant projects that the Swedish Space Corporation are actively pursing, which should provide a significant stimulus to Southland's space science sector when they eventuate and is working with GeoEye to establish a satellite earth station.

Meanwhile, making use of the income streams generated by existing projects, local high-tech businesses are able to direct resources towards other technology development, such as ASI Ltd's 'X-detech' portable radio intermodulation detectors, which are now used world-wide.

Arising from the work undertaken to date in a number of space and upper atmosphere science research and operational projects, where Southland is now developing a sound reputation, Venture Southland has strong working relationships with space agencies, universities and research organisations in New Zealand and around the world, particularly those in Europe and Australia. The space agencies that Venture Southland work with include the European Space Agency, French Space Agency, German Aerospace Agency and the Swedish Space Corporation. Venture Southland also collaborates with AUT, SKA Consortium, La Trobe University, Swinburne Technical University and LF & EM Research.

Venture Southland is a founding member of SKANZ in order to facilitate the establishment of an SKA telescope station in Southland, most likely at Awarua.

Venture Southland space and ionospheric projects to date include:

- Facilitating the establishment of the TIGER Unwin Auroral Radar at Awarua
- New Zealand implementing agency under the European Space Agency – New Zealand Arrangement, 2007
- Project management for designing, building and responsibility for ongoing maintenance of Awarua Tracking Station
- Assisting Tuatapere Locater Beacon Trust develop and patent an advanced satellite emergency locator beacon.
- Facilitating establishment of VLF lightning detection equipment at Awarua Tracking Station
- Establishment of decametric radio interferometer radio telescope at Awarua Station

- On-going involvement in planning for SKA though SKANZ and various working groups.
- Collaboration with AUT and VUW for VLF radio astronomy.

4.2. Unwin Radar

Unwin Radar at Awarua is part of the TIGER Radar project lead by La Trobe University, investigating radio auroras, the ionosphere and seascapes towards the South Magnetic Pole.

In 1955 Dr Robert Unwin was the force behind a project that used radar to observe various aspects of the Aurora Australis, radio propagation, the ionosphere, physics, geomagnetism and meteorology. He established a radio transmitting station at Scott Base, Antarctica and one of six receiving stations was established at Slope Point to receive radio signals passing through the auroral zone. The present radar at Awarua is named for him.

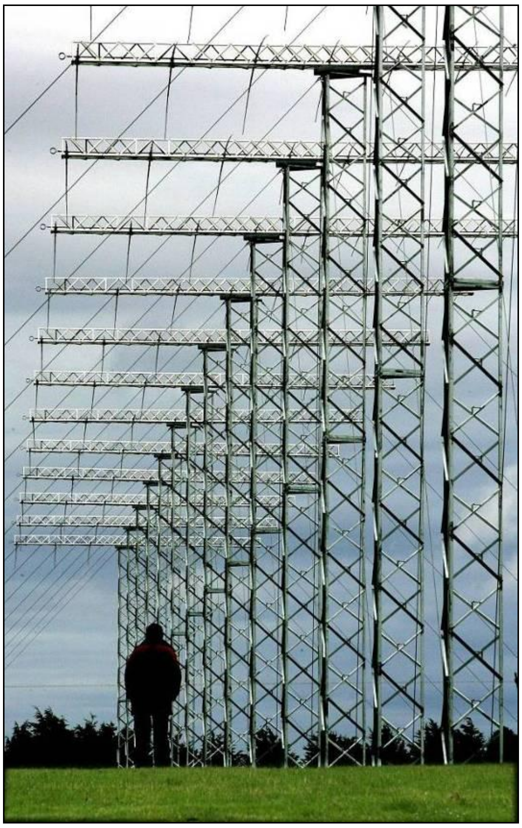

Figure 7. Unwin Radar antennas.

The Unwin radar operates at high frequency radio frequencies (8 – 20 MHz) detecting echoes from aurora and other space weather phenomena. It is important to better understand these phenomena as they can have severe impacts on many modern technologies, such as GPS navigation, that rely on satellite operations[3].

The Unwin Radar operates in conjunction with a similar installation on Bruny Island, Tasmania and is part of the world-wide SuperDARN network of auroral radars in both the northern and southern hemispheres. The radar is owned and operated by La Trobe University and cost $3.5million to establish. It was facilitated by Venture Southland, who own the radio

[3] Severe space weather events can be particularly severe: a repeat of the so-called Carrington CME solar flare of 1859 would cost an estimated $30 billion to $70 billion in destroyed satellites alone. Electricity supply and all manner of telecommunications would also be badly disrupted, or destroyed.

transmitting licence for the radar, and was commissioned in February 2005. A second, complementary radar is planned to be established at Awarua within the next five years.

4.3. Awarua Tracking Station

Venture Southland, in conjunction with CNES, establishing Awarua Tracking Station in 2007 for tracking between five and eight Ariane 5 ATV launches over the subsequent nine years, the first of which occurred in March 2008. ESA provided all capital investment and design requirements for the station. The project was facilitated, planned and project managed by Venture Southland. Once the station was built ESA gifted the station to Venture Southland with ESA taking first priority on its use. ESA have undertaken to pay for the site maintenance, leases and suchlike for the next nine years.

Awarua Tracking Station consists of an equipment and staff facilities building, and a storage shed with a large concrete pad for mounting transportable tracking antennas, as set out in Appendices 2 and 3. The compound is secured and is monitored by a security system.

The station has resource consent to erect up to four 11 metre dish antennas, to a height of 15 metres.

Figure 8. Awarua Station with an OTB 3.5 metre S-Band tracking antenna

Awarua Tracking Station is surrounded by farmland. Less than 500 metres to the south of Awarua Tracking Station lies part of the extensive Waituna wetlands, which are recognised in the Ramsar Convention as having international importance. Some 600 metres to the east, the farm (known as Awarua Station) has been bought by Invercargill City Council for an industrial park: the southern 2- 3 kilometres of this farm- that nearest Awarua Station- are planned to be set aside for reverting to wetlands.

The existing tracking station building is adequate to accommodate up to eight 19” equipment cabinets. There are sufficient staff amenity areas to accommodate up to six staff, including two offices. Additional accommodation for another 10 equipment cabinets could be easily constructed within the compound.

In addition to launcher tracking, Awarua Station currently hosts a decametre radio astronomy interferometer instrument, in conjunction with AUT, and a real-time Very Low Frequency Lightning Observation Station for LF & EM Research.

Venture Southland has an open-door policy for hosting allied space and ionospheric research projects at the station and two further radio astronomy projects are planned to be hosted in the next 12 months. Venture Southland is also keen to host commercial users of the station facilities.

Figure 9. Awarua Station equipment room: OTB tracking and RF equipment (left) and CNES Ariane Telemetry kit (right).

4.4. Other Southland sites

Two other sites have historically been used in Southland for space science, namely Slope Point and Bluff Hill. Slope Point, the most southern part of mainland New Zealand was where Dr Unwin carried out his radio aurora studies, but nothing now remains, Likewise, at Bluff Hill the World War II radar station where radio aurora work was also undertaken no longer exists. It would not be possible to re-establish any facilities on Bluff Hill and the remoteness of Slope Point limits its suitability for future space research.

Two potential sites for a further southern station which are geographically separated from most interfering radio sources and with good sky views are at:

- Fortrose in the vicinity of Lake Vincent, 45 kilometres east of Invercargill, 46˚ 34.9' S 168˚ 49.1' E. Telecom New Zealand have longer term plans to lay fibre-optic cable in this area from Invercargill and the site is about 40 minutes drive from Invercargill airport on good roads.
- Waituna, just north of the Waituna wetlands in the vicinity of 46˚33.5'S 168˚ 29.0', some 20 km south east of Invercargill. The site is about an half hour drive from Invercargill airport. The wetlands are recognised under the Ramsar Convention and should provide security with respect to good sky views and low EMI.

Both these sites have yet to have EMI measurements undertaken and no planning or consenting action has been initiated at this stage.

Other sites may also exist and the rigorous SKA site selection process due to start in 2010, based on filtered GIS data and radio propagation modelling to calculate likely EMI will likely identify other potentially useful locations in Southland.

4.5. Emergency locater beacon development

The Southland Locator Beacon Charitable Trust was formed in 1995 to hire human emergency locator positioning (HELP) beacons in the lower half of the South Island. Because of the increasing search and rescue activities in the area, the beacons were developed as a community initiative to meet local operating conditions. The beacons are unique inasmuch that they can be activated remotely by searching helicopters in the vicinity. The trust is presently developing new beacons to operate on the new international 406 MHz distress frequency.

5. Southland infrastructure and facilities

5.1. Data backhaul

Data is required to be transferred from space tracking and research facilities in Southland to the rest of the world. Present data transmission requirements range from 64 kbps for down-range rocket tracking, to 150 Mbps for RSS earth stations. The proposed SKA radio telescope will require 1 Tbps circuits.

A number of methods are available to deliver the data to users and these are discussed below.

5.1.1. Local data backhaul

ISDN

Awarua Tracking Station is presently served by a 4RF Aprisa XE L-Band radio link, which provides ISDN and telephone service for CNES, and a Woosh Wireless Internet connection (See Appendix 3). ISDN is no longer well supported by New Zealand telecommunications service providers and should only be used to connect legacy equipment as a last resort.

Broadband ADSL

Woosh Wireless wireless service provides cheap, reliable coverage into Awarua from their Bluff Hill site. Bandwidth is modest at between 1 Mbps – 2 Mbps down link and 500 kbps uplink. Static IP addresses are available. Woosh Wireless also provide telephony service via their network.

VSAT

VSAT provides relatively low capacity and moderately expensive backhaul. Unwin station has been served by a 64 kbps VSAT link, but connectivity is soon to be upgraded to Woosh Wireless wireless broadband service.

Microwave local backhaul

It is straightforward to install a microwave radio link from Woosh Wireless, or Telecom New Zealand towers on Bluff Hill to any of the stations at Awarua, after which existing microwave links are available to Invercargill. Bandwidths of up to 100 Mbps are straightforward and up to 1Gbps are possible.

Fibre-optic local backhaul

It would be straightforward to mole-plough 3 km of fibre optic-cable from Awarua Station eastwards along the mostly unformed Awarua Siding Road to the Bluff Highway. Telecom New Zealand has left a jointing loop in the Bluff – Invercargill fibre-optic cable at the Awarua Siding Road intersection to allow for such a joint, or cabinet for connection.

TelstraClear has longer term plans to extend their fibre-optic cable network to Awarua Industrial Park. It would be straightforward to further lay 2 km of fibre-optic cable to connect Awarua Station and Unwin Station.

A proposed extension to the Invercargill City Council fibre-optic network, InverNet, would connect both stations at Awarua to the KAREN POP (see below).

5.1.2. National data backhaul

A ladder network from Invercargill provides three physically separate fibre-optic routes to Auckland, from where there are fibre-optic cables to Europe via Australia and Asia, and via USA:

- Telecom New Zealand has fibre-optic cables between Dunedin and Invercargill, and Invercargill to Queenstown and through to Alexandra and north. Both cable routes follow the main roads (see Figure 10).
- TelestraClear have a fibre-optic cable between Dunedin and Invercargill following the railway line and this continues through to Queenstown and north beside the main road.

It should be noted that TelstraClear and Telecom New Zealand share the same cable sheath around Lake Wakatipu and so do not provide full route diversity from each other for this section of cable.

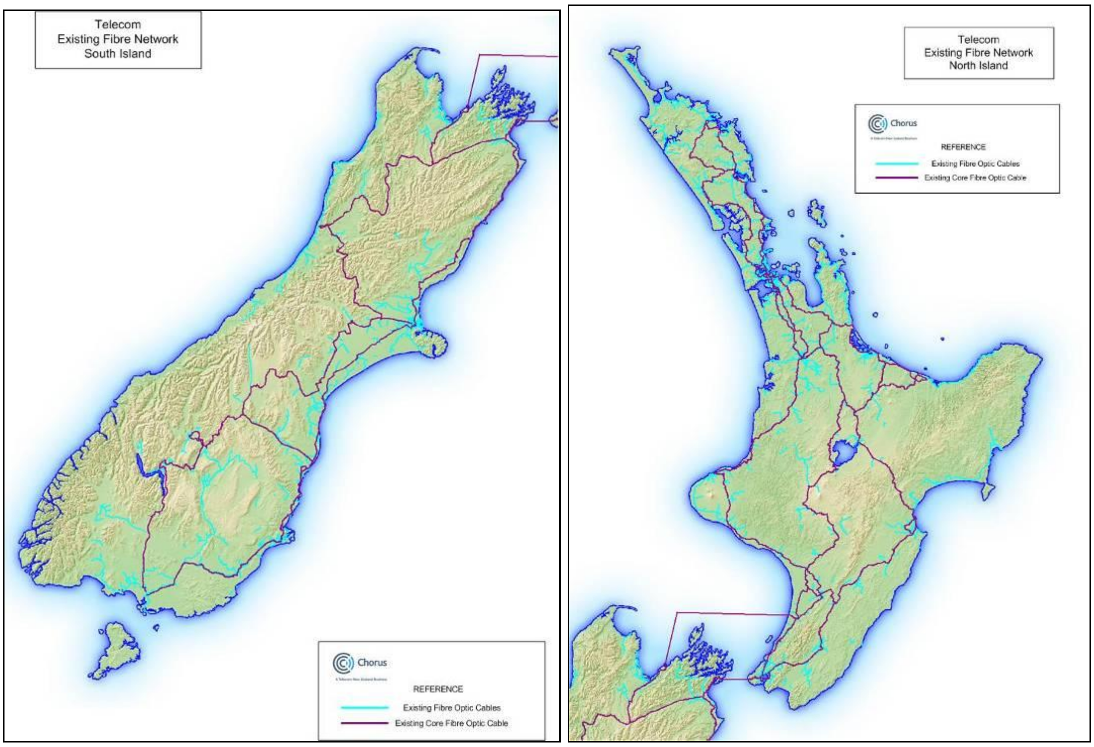

Figure 10. Telecom New Zealand fibre-optic trunk network. The TelstraClear network is very similar.

At present the KAREN network (see below) is provided over the TelstraClear network.

Kordia provide a DMR bearer from Invercargill through to Auckland.

5.1.3. International data backhaul

International data services are normally provided over the Southern Cross fibre-optic cable owned by Telecom New Zealand, Verizon and Optus. The cable provides a ladder network (see Figure 11) with two independent connection points in New Zealand:

- Whenuapai connects to Australia-Fiji-Hawaii (Kahe Point)-USA (Hillsboro);
- Takapuna connects to Hawaii (Spencer Beach)-USA (Morro Bay).

Latency to London via USA is 142 ms by fibre-optic cable and 560 ms by satellite.

Backhaul costs to the West Coast of the USA currently are in the order of:

- STM-1 (155 Mbps) protected circuit $NZ 96,000 per month
- DS3 (45 Mbps) protected circuit $NZ 65,000 per month

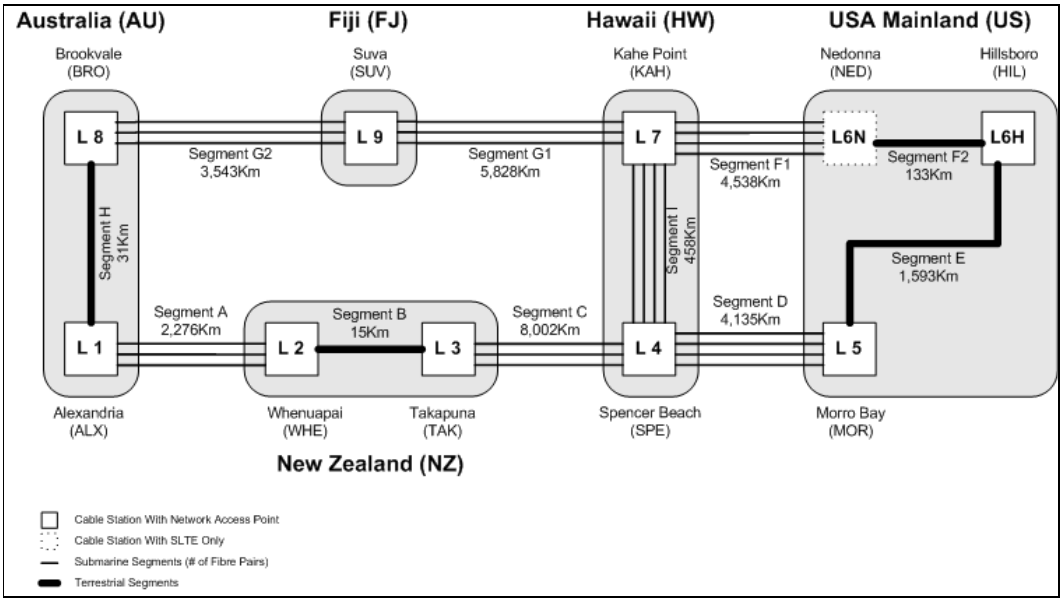

Figure 11. Southern Cross network

5.1.4. KAREN

KAREN is a data network providing high capacity, ultra high speed connections between New Zealand's universities, polytechnics, Crown research institutes, schools, libraries, museums and archives, and out to the rest of the world. It is only available for research and education purposes.

Southland is shortly (2009) to have a KAREN POP installed in the Southland Internet Exchange. Connection to the Awarua sites is possible through accessing Telecom New Zealand’s Invercargill-Bluff fibre optic cable at Awarua Siding Road, accessing TelstraClear’s proposed fibre-optic cable passing by the Invercargill City Council Awarua Industrial park, or from a proposed spur to the Invercargill municipal fibre optic network, InverNet.

On-going operation of the KAREN POP would be undertaken by REANNZ.

5.2. Southland Internet Exchange

In 2005, Venture Southland established a carrier grade equipment room at the Invercargill City Library for housing SIX and a KAREN POP. The equipment room provides the hub for the Invercargill metropolitan fibre network, InverNet, off-site data storage and several servers. The room could accommodate additional cabinets beyond that already spoken for.

5.3. Electricity supply

Southland is well served by a reliable electricity power supply[4].

The electricity supply to Awarua Tracking Station is currently a single phase 11 kV pole line terminating in a 240 V transformer and underground lead-in rated at 20 kVA. It is possible to upgrade the line to three phase rated at 50 kVA for a cost of $30,000 plus gst.

For mission critical events, the Awarua Tracking Station power supply wiring is presently configured so that a generator can easily be connected. A self-contained generator and fuel tank on a separate concrete pad to provide a backup power source for the station has been allowed for. Depending on the nature of the reliability required and load, a suitable generator and fuel tank could be installed for between $20,000 and $30,000.

5.4. Road and rail access

There is good road access to Awarua Tracking Station: State Highway 1, the main north-south highway in New Zealand passes a little over three kilometres from the site. Currently a gravel road of some 7 kilometres leads from State Highway 1 to the site itself, but an unformed legal road some 4 kilometres long provides more direct access for network services.

The Bluff Branch Railway, which joins the Main Trunk Line at Invercargill, runs a little over three kilometres away from the site. The nearest goods siding is located 8 kilometres by road from the site. There is no passenger service.

Equipment imported to Awarua could normally be expected to be shipped to the port of Bluff and transported by road from there, though rail could be used. The port of Bluff is 16 kilometres away by road. (see Appendix 2).

5.5. Air access

The nearest airport to Awarua Station is Invercargill Airport, 15 kilometres away by road. At present the airport is primarily used for domestic travel with direct routes to Christchurch. Travel times from Invercargill to the main New Zealand airports are:

- Christchurch 1hr 10min,
- Wellington 2hrs,
- Auckland 2hrs 30 mins.

Invercargill airport is the closest New Zealand airport to Hobart, Melbourne, Sydney and Brisbane.

Invercargill airport runway is sufficiently long to enable unrestricted direct trans-Tasman operations based on current and likely trans-Tasman deployed aircraft, including Airbus A320, and Boeing 737-700 and 737-800 aircraft. The airport is currently used as a standby international airport when Queenstown airport is closed by poor visibility. Negotiations are currently underway with several airlines for direct flights to and from Australia.

5.6. Resource planning

The conservation areas to the west and south of Awarua are managed under the Department of Conservation's *Conservation Management Strategy*.

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[4] Not well understood outside of rural circles is the importance of an extremely reliable electricity supply to dairy farms, where failure of the supply can prove extraordinarily expensive in the milking season. The local power lines company is well aware of this and manages their network accordingly.

The remaining land and the site is managed under the *Invercargill District Plan* and the *Southland District Plan*.

6. Current situation in New Zealand

6.1. Ionospheric research

Ionospheric research and radio astronomy in New Zealand has been carried out for many years with some pioneer work carried out in the immediate post World War II era and arising from International Geophysical Year, in 1957.

Ionospheric research has principally been undertaken on a sustained basis by the Physics Department the University of Canterbury, most notably at their Birdlings Flat station and Arrival Heights at Scott Base, and on a smaller scale by the University of Otago. In 2005 La Trobe University established the Unwin Radar at Awarua, but at present this supports only off-shore research.

6.2. Atmospheric and weather research and monitoring

Weather

New Zealand's isolated island geography means that weather forecasting is predominantly dependent on satellite imagery as any weather observations to the south and west of New Zealand – the prevailing direction for weather – are difficult to obtain.

Currently NIWA and MetService use L-Band NOAA HRPT satellite services for weather monitoring. HRPT has a limited life, since it only applies to the current generation of NOAA satellites. The last of these has now been launched and the new NPOESS generation of low-earth-orbit satellites is anticipated for 2013. The new generation of NPOESS will transmit free-to-air as for NOAA-HRPT, but the primary frequency will be at X-band. An L-band downlink will be available, but it is intended for "lesser capable" nations and uses where data compression and loss of some products can be tolerated. MetService and NIWA will already have, or will have planned, upgrades to their reception capability for NPOESS. Both of these organisations like to operate independently of outside data delivery sources.

Lightning

LF & EM Research have a special interest in monitoring lightning which uses networked VLF radio receivers to process and forward GPS time-stamped data to a central server to triangulate lightning incidences around the world.

6.3. Radio astronomy

A lack of facilities has deterred radio astronomy from attracting much of a following in New Zealand, which in turn has not encouraged the development of facilities. This situation has significantly changed over the last five years with, first, Auckland University of Technology and more lately Victoria University of Wellington devoting resources to radio astronomy. In August 2009, AUT's 12 metre radio telescope at Warkworth saw "first light". No other research grade radio telescopes are currently operational. The number of active radio astronomers in New Zealand would currently number less than a dozen people.

Radio astronomy in New Zealand has suddenly reached prominence through the Australian government seeking New Zealand support for hosting the €1B SKA radio telescope. However, it is unlikely that much infrastructural development will take place in New Zealand before 2014, even should the Australia-New Zealand bid to host SKA be successful. Nonetheless, New Zealand will want to participate in so-called pathfinder projects and the AUT efforts reflect this.

The Ministry of Economic Development is the lead agency for SKA in New Zealand. A number of advisory groups and working groups have been established in Australia, which now has New Zealand membership. SKANZ has been the major supporter of SKA in New Zealand. Venture Southland is a founding member of SKANZ.

A joint collaborative project between AUT, VUW and Venture Southland under the KAREN fund has received funding to develop and monitor a (sky) Transient Radio Events Sensor Network. A further collaborative project between these organisations for a decametre radio telescope looking at carbon recombination lines in the galactic plane is waiting for funding approval, perhaps in 2010/2011.

Through the efforts of AUT and others, a number of decametre radio telescopes are under construction, or operational for educational purposes. The better known is the NASA RadioJOVE kitset 20 MHz receiver which records radio emissions from the Sun and Jupiter. An AUT "Zaphod" decametre radio telescope is under construction at Awarua Tracking Station by the Southland Astronomical Society.

AUT and Venture Southland are promoting the possibility of a "demonstrator" project for the SKA to work with ASKAP (see later).

6.4. Remote sensing satellite imaging

Remote sensing imaging satellites photograph the earth at a variety of optical and radio frequencies, measure magnetic anomalies and other such inverse probing measurements. The spacecraft may be passive, such as the satellites imaging at optical frequencies, or may transmit radio, or ultra-violet signals towards the Earth from which the reflected signals returned to the satellite are able to be analysed.

There are no medium, or high resolution remote sensing satellite ground station facilities in New Zealand for civilian, or commercial use. Currently New Zealand government departments purchase satellite image products from overseas satellite operators and agencies. Generally, relatively unprocessed images are purchased, which are then further processed by the end users with commercial satellite image software. Appendix 12 outlines the process of image manipulation. The image products may be single datasets, or full country coverages collected over time intervals of a year or more.

It is understood that New Zealand purchases satellite image products costing in the order of $2M each year. Included within this is a Whole of Government contract with SPOT-Image, costing, it is understood, $1M per dataset, purchased and held by the Ministry for the Environment. The KiwImage Project is worth $5M over five years.

Both optical and SAR images are currently purchased in New Zealand, dominated by optical remote sensing data. Optical images are bought from SPOT-Image Australia, Geoscience Australia, the USGS, SKM, and Restec in Japan. SAR images are usually purchased from the ESA (for ENVISAT), MDA Spatial Sciences (for Radarsat), and Restec/JAXA (for ALOS). The images are downloaded from spacecraft using direct reception at Hobart as the RSS over-flies the target area, or from on-board tape recorders at a number of stations around the world, including Montreal, Kiruna, Tromsø, Svalbard, and Grimstad. The pre-processed images are then couriered to New Zealand in DVD format, or the data is stored at a downloadable FTP site and recovered using the Internet (See Appendix 12).

Response times for one-off contracts to fly a required area varies from one to three days. Post-processed images are generally available a day, or so after the satellite overpass. Because there are no earth station facilities in New Zealand, New Zealand agencies currently have no "shutter control" of spacecraft above the country, or environs.

New Zealand poses some problems for optical satellite imaging due to cloud cover levels that are much more frequent than for some other parts of the world, for instance Australia. It is thus a little surprising that most purchased New Zealand images are optical, rather than radar images, which are immune to cloud cover and do not require the target area to be illuminated by sunshine. This may partly be explained by the level of expertise required to properly interpret radar images associated with the relatively low profile radar satellite imaging enjoys in comparison to optical imaging.

Because of New Zealand's comparatively small size and lack of a developed satellite industry, aerial photography is often the preferred image capturing technique for GIS and environmental monitoring.

New Zealand satellite earth stations

In spite of at least two known civilian groups previously attempting to establish a satellite earth station in New Zealand for medium and high resolution satellite image downloading since 1980, no infrastructure exists. Nonetheless, a small, but capable group exists at Landcare Research at Lincoln, who have developed considerable expertise in on-selling satellite imagery- in particular that obtained from SSC- and have done considerable work in the remote sensing imaging area. A number of universities have post-graduate students working in the field. The number of practitioners in New Zealand would be less than around 20 people. Because RSS has such a low profile, potential users are unaware of its possibilities to provide a wide range of solutions to existing problems.

KiwiImage image library

KiwImage, an all of government satellite acquisition project was established to provide government agencies with high resolution Digital Globe satellite imagery of the New Zealand mainland, off shore islands, the Ross Dependency and selected South West Pacific Islands. It utilises DigitalGlobe QuickBird satellite imagery, with two products:

- 2.4 m multi-spectral and 0.6 m panchromatic strips of ortho-rectified 16-bit imagery,
- 0.6 m natural colour, ortho-rectified, colour balanced seamless RGB mosaic in 8-bit. The mosaic is delivered in tiles as defined by NZ Topo 50 map sheets.

The KiwiImage consortium works through GIO, who have a contract with SKM (Melbourne) to provide the imagery. GIO have a memorandum of understanding with each member of the consortium to supply an agreed amount of imagery product, which GIO distributes to consortium members. GIO maintains the imagery, which when complete will consist of over 10TB of data, and provide updates.

There are some difficulties with KiwiImage. New Zealand's high latitude creates "blackout periods" during winter due to sun elevation angle restrictions. For the lower South Island, this period lasts for all of winter and much of spring and autumn. There would also appear to be some widespread disappointment in KiwiImage through very slow delivery of images for a number of factors.

A one-off subscription to KiwiImage costs $250,000 per consortium member, which allows access to all the images in the database in perpetuity. For all of New Zealand, images are contracted to be less than five years old and for urban areas with populations greater than 10,000 inhabitants, the images are contracted to be less than three years old. At this stage the five year contract for images from QuickBird is expected to be renewed.

Swedish Space Corporation Virtual South Pole satellite earth station

Polar rotating space craft orbiting over a spinning Earth can only reliably download data on each orbit to satellite earth stations at the North Pole and the South Pole. A number of satellite earth stations sufficiently near the North Pole with fibre-optic telecommunications back-haul have been established to this end.

As the data gathering capacity of remote sensing satellites grows beyond what can be downloaded during a 10 minute satellite pass and the increasing need for imagery to be downloaded without having to wait for an hour until the satellite completes an orbit, the desire has arisen for satellite earth stations near the South Pole. Providing data back-haul from Antarctica is problematic as there is no fibre-optic cable from Antarctica and even at Arrival Heights, Scott Base at 77° 51' S, geostationary telecommunications satellites appear to lie almost on the horizon.

A solution is to establish a network of these satellite earth stations as close as possible to the South Pole that have fibre-optic backhaul, which between them capture all satellite passes. SSC have identified Awarua as a key location for the third station in their so called 'Virtual South Pole Satellite Earth Station', to complement their existing Southern Hemisphere stations at San Diego and Mauritius. These three stations would capture 11 of 12 ½ satellite passes each day.

SSC has an memorandum of understanding with Venture Southland to establish an X-Band satellite earth station at Awarua, and is currently pursing a promising commercial opportunity which would see a 7.8 m antenna installed at Awarua.

GeoEye satellite earth station

GeoEye of Dulles, Virginia, USA owns and operates GeoEye-1, the highest resolution civilian optical satellite currently in use and have the contract to provide imagery to Google Earth using GoeEye-2, due for launch in late 2012. To meet increased demand they require more downloading facilities and to this end they are upgrading five of their sites around the world and establishing three new sites. As a result GeoEye is currently evaluating Southland for their upgrade earth station network for much the same reason that SSC have for their Virtual South Pole Station. Such a station would have to be built in 2011.

The GeoEye-2 spacecraft will download at 2 Gbps over a 10 minute period, once every 1 ½ hours. To accommodate the data downloaded, an STM-1 / OC-3 (155 Mbps) dedicated telecommunications circuit is required between the satellite earth station and GeoEye offices in Dulles, Virginia, USA. The GeoEye stations operate at X-Band and/or Ka-Band.

Indications from GeoEye indicate that they would be prepared to lease time slots on their station to other users.

6.5. Launch tracking

ESA launch tracking

Awarua Tracking Station was established specifically to monitor ESA Ariane 5 ATV launches and in particular engine re-ignition and launcher/payload separation. This is the only known launch tracking station in New Zealand. The antenna and electronics used for launch tracking are on site only for the launch and launch preparation and are operated by an independent operator (OTB in 2008) under contract to CNES. The station is owned by Venture Southland and is only used for tracking Ariane 5 ATV launches, operating in S-Band

Other orbital launch tracking

A number of polar orbit launches take place each year that pass over New Zealand. Because there are no permanent tracking facilities here, it is too expensive for all but the largest launcher services to establish one-off facilities here and work-arounds elsewhere in the world are used instead. Venture Southland is aware of at least one launch that would have used facilities in New Zealand had they been available.

Sub-orbital launch tracking

Australia has attempted to position itself as the Southern Hemisphere preferred launch site, taking advantage of its closeness of the Northern Territory to the Equator, which provides special advantages for geostationary spacecraft launches. While this has never been exploited, the compliance fees for launches of any nature are in the order of $1M per launch. Consequently, for sub-orbital launches, the compliance fees can be many times greater than the material cost of the launch.

New Zealand does not have such compliance costs, which makes it attractive for low-cost launches, which RocketLab are looking to exploit with their Ātea suborbital rocket currently under development.

Launch protection exclusion zones are considerable and are set out in Appendix 19. Southland is a possible launch site for RocketLab, though the launch pad itself would have to be offshore, probably from a barge.

7. Opportunities for Southland

7.1. Ionospheric research

Auroral radar

The establishment of Unwin Radar marks the first step in La Trobe University's auroral and ionospheric research developments at Awarua. Within the next five years La Trobe University plans to establish the TIGER 4 radar (see Figure 11). New digital technology will give the new radar greater range than the existing radars. It is proposed to establish TIGER 4 at Awarua, some 500 m from the existing site.

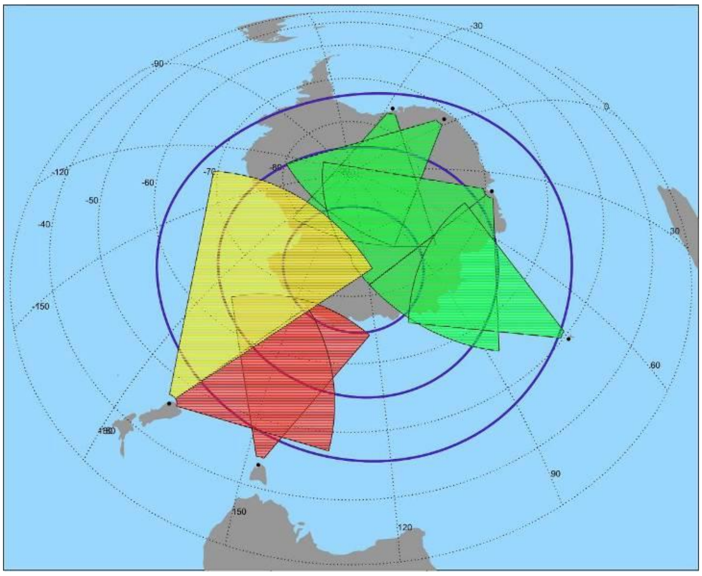

Figure 12. Southern Hemisphere SuperDARN radars. Existing TIGER radars are red and other existing radars are green. Proposed TIGER 4 radar is shwon in yellow.

Geomagnetic field measurements

Disturbance of the Earth's geomagnetic field due to solar events may also be measured by a magnetometer. Typically, dozens of observations are made in one minute intervals around the world to calculate the Planetary Index, Kp, in near real-time.

The Simple-Aurora-Monitor (SAM) developed by amateurs in Germany[5] can provide measurements of movements of the Earth's magnetic field which can estimate Kp and so provide advance warnings about possible aurora sightings (see Figure 5).

As well as providing useful information to researchers, HF and VHF radio users and others, the data could also be used for tourism purposes to encourage auroral observations from Southland.

7.2. Atmospheric and weather research and monitoring

ESA are to launch ADM-Aeolus, the first satellite capable of performing global wind-profile observation in 2010 to accurately measure wind velocity in real time (See Appendix 14). ADM-Aeolus is developed within ESA's 'Living Planet Programme' and will fly in a low Sun-synchronous orbit of 400 kilometres so that it will always be in the dusk, or dawn

[5] www.sam-europe.de/en/index_en.html

position. The data will be disseminated to the main Numerical Weather Prediction centres in near-real-time, allowing for more accurate weather and climate forecasts.

At this stage the image downloading will only be through Svalbard Station in X-Band at 10 Mbps. However, additional X-band stations might also be used and a facility at Awarua Tracking Station would be of significant benefit to New Zealand weather forecasters in predicting approaching weather systems.

7.3. Radio Astronomy

Resolution- the ability of a telescope to distinguish between close objects- is directly proportional to the aperture of the telescope, and inversely proportional to the wavelength of the imaging process[6]. In the past, radio telescopes were made as large as possible to maximise their resolution as well as to improve sensitivity. The availability of relatively cheap high performance computers has allowed modern radio astronomy to instead make use of disperse, relatively small antennas connected to highly accurate time bases to gather data sufficient to allow synthesis of images that could otherwise only be achieved with a single, very large antenna.

To maximise resolution, the baseline between any two radio telescope antennas should be as far apart as possible. For operation in New Zealand, a baseline running the length of New Zealand - some 1,500 km - provides the best resolution and it is for this reason that Southland is ideally suited for modern radio astronomy for New Zealand radio telescopes.

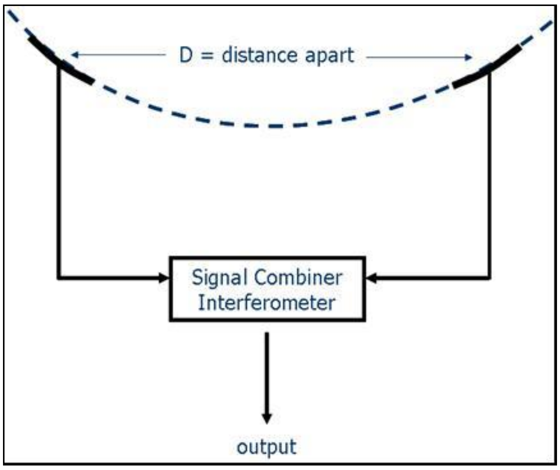

Figure 13. Modern radio astronomy utilizes two or more disparate antennas rather than a single large antenna. The resolution of two smaller antennas at distance D apart is the same as a single antenna of diameter D.

The baseline can be extended to Australia to achieve baselines up to 4,500 km. At the south-east corner of Australia, Southland is ideally suited for developing long baselines to Australian radio telescope facilities.

As indicated earlier, it is widely held that the southern skies present the most interesting science for radio astronomy. Interest in the southern skies is in part due to the paucity of radio telescopes in the Southern Hemisphere compared to the Northern Hemisphere.

The radio astronomy world is basically split into two: "VLF radio astronomy" where (conventionally understood) HF, VHF and UHF radio frequencies are observed. The antennas

[6] To gain a feel for this, a radio telescope operating at 1.4 GHz would have to be two kilometres across to match the resolution of the human eye and 4,500 km across to match the 12 m Keck optical telescope in Hawaii.

deployed for such telescopes can be made of wire, or lengths of rod. The largest VLF radio telescope looks more like a vast kiwifruit orchard. "(Conventional) radio astronomy" operate at microwave and millimetre radio frequencies using more recognisable dish antennas.

7.3.1. VLF Radio astronomy

VLF radio astronomy is an attractive field of investigation in New Zealand as the equipment is relatively inexpensive compared to higher frequency radio telescopes. Off the shelf GPS units provide adequate time sources for even dispersed interferometry type telescopes. The equipment requires minimal specialist test, and alignment equipment and the skill levels required to work on the radio frequency components are not unfamiliar to many telecommunications radio technicians and engineers. Indeed, simple educational grade VLF radio telescopes are able to be built and operated by senior school pupils, such as RadioJOVE.

Figure 14. Pushchino VLF radio telescope consists of 16,384 wire dipoles, occupying 7ha.

VLF radio telescopes are more susceptible to local EMI, such as electric fences and cellphones, than other radio telescopes and can take up considerable space (see Figure 15).

As noted previously, AUT and VUW are intending to establish VLF radio telescopes at Awarua for:

- A station in the TREAD-P (Transient Radio Emission Array Detector) network. The proposed telescope will register, map and possibly image galactic transient radio events at 15 - 20 MHz in mid to late 2010 – 2011. It is funded under KAREN.
- Detecting carbon line C271α at 328.78 MHz using reconfigured MIT D-Array equipment, proposed for 2010/11. Funding is still to be confirmed.

Southland would be well suited to other VLF radio telescopes because of its wide vistas, low horizons, lack of population and EMI sources. It is anticipated that as observations from these telescopes are published, further interest in VLF radio astronomy will be generated.

7.3.2. eVLBI

In 2006 Venture Southland took possession of a redundant 11 metre dish antenna from Telecom New Zealand for a nominal amount. The intention has been to install it at Awarua for eVLBI work in conjunction with the AUT and Australian radio telescopes.

The antenna currently has feed horns for C-Band and K-Band. The dish has a limited azimuth, 'El over Az' mount, which is not suited for all-round radio astronomy. However, a science case for the antenna has been prepared (see Appendix 6) taking this limitation into account.

As an eVLBI telescope, it would provide the basis for teaching and somewhat mundane, but useful observations of variable radio sources that would not warrant observation time on larger telescopes. If pointed south, some 30 radio sources could be monitored by the antenna and would thus allow for a Southern Hemisphere Celestial Polar Cap Survey to be undertaken.

To be of use, the radio telescope would need to be fitted to an atomic clock and KAREN access. A GPS-tempered rubidium clock is barely adequate, but it may be possible to extract a very high quality time base at no cost from a hydrogen maser required for the proposed Galileo GSS station. It is estimated that it would cost in the order of $100,000 to refurbish, mount and equip the 11 m antenna for eVLBI work.

7.3.3. ASKAP Pathfinder

As part of their bid to host the SKA, the Australian National Telescope Facility has been preparing so-called ASKAP pathfinder projects, which would demonstrate Australian commitment to radio astronomy and institutional capacity. Now that New Zealand has joined the Australians in the bid, it is possible that the ASKAP pathfinder projects could be extended to include New Zealand. This would demonstrate trans-Tasman bilateral cooperation, adequacy of telecommunications and equipment in New Zealand and to Australia, and New Zealand's commitment. The important outcomes from establishing ASKAP facilities in New Zealand are not, in the sort term, of great scientific importance, but are extremely important for capacity building.

A useful project has been proposed by AUT to this end: it would comprise of one to four 12 m antennas being installed in Warkworth and a single 12 m antenna at Awarua. Such an ASKAP station could be established at Awarua Station at little local cost (see Appendix 7).

It is highly unlikely that any of the ASKAP facilities would be reusable for SKA. At this stage the technology for SKA has not even been designed; one can be sure that any equipment installed now will be obsolete by the time SKA is installed.

Once SKA goes ahead, it is unlikely that the New Zealand SKA stations will be available for local researchers and teaching as the time demands for the SKA stations will take priority. However, the New Zealand ASKAP stations will be available for such use including testing of new hardware before migrating it to SKA.

The greatest risk in establishing a New Zealand ASKAP facility is for Australia not to win SKA. This risk seems moderately low. Even should Australia not win SKA, the infrastructure established through the proposed New Zealand ASKAP projects would provide a strong base for a wide variety of radio astronomy projects and research into the future and develop strong capability. It would also provide a good model for other multi-agency and multi-institutional collaborations.

To mitigate risk, the New Zealand ASKAP facilities should be designed so that they can continue to provide useful radio astronomy observations and teaching use without being part of ASKAP i.e. the equipment should be configured so that it can undertake ASKAP and eVLBI observations.

It is possible that the proposed "pathfinder" radio telescopes would be owned by a Qango (Quasi-Autonomous Non-Government Organisation) on behalf of the New Zealand Government. AUT and Venture Southland would be implementing agencies and could supply their existing facilities at Warkworth and Awarua under contract to a governed by a board of directors comprising a Ministerial appointed chairman, and appointments from AUT, VUW, MoRST, MFAT, MED and RSNZ. Venture Southland would have an advisory seat.

7.3.4. The Square Kilometre Array

The Square Kilometre Array (SKA) – a €1 billion deep-space radio telescope with one million square metres of collecting area – is planned to be built by a consortium of 17 countries. The Square Kilometre Array (SKA) will be an ultra-sensitive radio-telescope, built to further the understanding of the most important phenomena in the Universe, including some pertaining to the birth and eventual death of the Universe itself. Over the next few years, the SKA will make the transition from an early formative to a well-defined design. The SKA will be an array of coherently connected antennas spread over an area about 3000 km in extent, with an aggregate antenna collecting area of up to 1060 m^2 at centimetre and meter wavelengths.

A key scientific requirement is the ability to carry out sensitive observations of the sky over large areas (surveys).The survey speed of the SKA will be enabled by the application of the most up-to-date signal-processing technology available. The SKA science impact will be widely felt in astro-particle physics and cosmology, fundamental physics, galactic and extragalactic astronomy, solar system science and astrobiology[7].

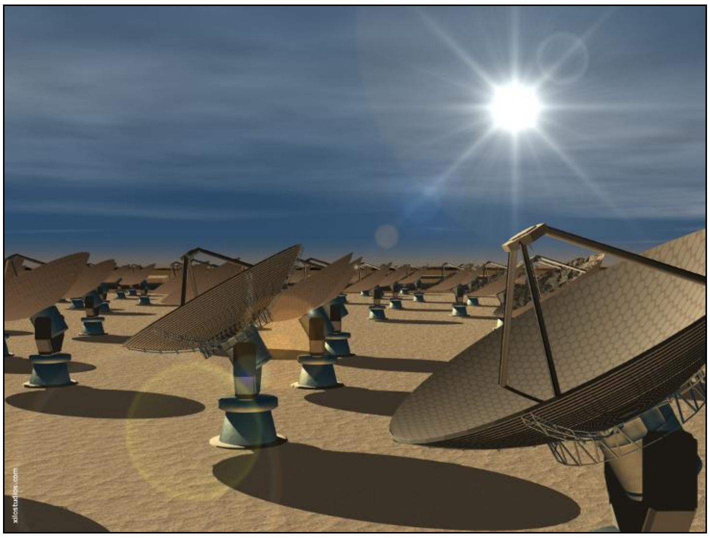

Figure 15. Visualisation of an Australian SKA station. A station in Southland would look the same, except there would be grass underneath the antennas. (Courtesy ANZSKA)

New Zealand has been asked by ASKAC to assist with their bid to site the central part of the SKA in Western Australia, the rest of the array across Australia and two SKA Remote Sites in New Zealand. New Zealand's contribution is important as its geographic location makes it possible to extend the baseline from 3,000 km to almost 6,000 km, thus greatly increasing the maximum spatial resolution of the SKA telescope. The New Zealand stations need to be as distant from each other, which favours a station being developed at Awarua.

The benefits to New Zealand accruing from the project are very large in the areas of science, engineering and ICT research and development, ICT capacity building, secondary and tertiary education opportunities, and national and provincial economic stimulation.

The benefit to Southland from having an SKA station have not been quantified. However, a remote station in Invercargill would be worth in the order of \$10M - \$50M and would

[7] Dewdney, Peter, *et al*. *The Square Kilometre Array*, Proc of the IEEE, Vol. 97, No. 8, Aug. 2009, pp 1482 - 1496.

precipitate the extension of a new, very high bandwidth national fibre optic telecommunication backbone to Invercargill which could be used for many other users also.

Given that most of the SKA stations will deliberately be located in very remote parts of Australia, the Awarua station will be one of the few that could be easily visited by tourists and scientists. The prestige the project will accrue cannot be underestimated and it is expected that high-technology jobs will be created in Southland to support the station and conduct research.

New Zealand's participation in SKA is now lead by Ministry of Economic Development. A rigorous site selection survey using ASKAP protocols is to be conducted throughout New Zealand in late 2010. It is anticipated that two stations would be built in New Zealand and as distant from each other as possible. Preliminary work indicates that the Awarua area would be acceptable (see Appendices 4 and 8). Other Southland areas east of Fortrose and north of Waituna also promise to be suitable candidate sites.

7.4. Remote sensing satellite earth station for Awarua

7.4.1. Ground station facilities

Most RSS spacecraft are polar orbiting at around 800 km altitude. They orbit the earth approximately 14 ½ times each day. Because the earth rotates underneath the spacecraft, there are only two places in the world where these spacecraft can download data on each pass: near the North and South Poles. While ground stations for downloading satellite data near the North Pole are well established, this is not true for the South Pole. With increasing RSS data acquisition and consequent downloading payloads, demand for sites near the South Pole has become apparent[8]. A 'Virtual Antarctic' station consisting of Santiago, Mauritius and Awarua would provide coverage of 12 orbits per day for RSS spacecraft going either to, or from the South Pole. To this end, the Swedish Space Corporation is actively engaged in seeking commercial customers to take up such a service through their word-wide ground station network joint-venture, PrioraNet (See Appendix 17).

Ground station facilities in New Zealand would enable near real-time (typically in the order of three hours after flyby) availability of images, made possible by directly downloading the images as they are captured by the spacecraft. This is not currently possible for medium and high resolution imaging.

Venture Southland has been advancing the prospect of an RSS satellite earth station in Southland that would provide near real-time imaging, in conjunction with a "virtual" south pole station.

7.4.2. Perceived demand for remote sensing services

Satellite imaging in New Zealand does not enjoy a high profile and it is clear that opportunities to make better use of it have often been overlooked. This is likely to because of the current high price of images (See Appendix 15), the small pool of users who have been comfortable with interpreting satellite images, perceived difficulties in obtaining near real-time images, high cloud cover and a general lack of awareness of the technology.

Historically, there have been several occasions in New Zealand where satellite images could have been used to better effect in monitoring, managing, and mitigating natural disasters, such as the February 2004 storm that affected the Lower North Island. The principal difficulty with the acquisition of imagery during the immediate hours and days after a natural disaster is that there is a considerable time delay between the event and the eventual delivery of the imagery. This is because the data must be tasked by the satellite agency, acquired by the satellite,

[8] Current remote sensing satellites download at between 10 Mbps and 500 Mbps, once per orbit. The next generation spacecraft will download at up to 2 Gbps, twice each orbit.

downloaded to a facility at some later time, processed to standard products, then electronically delivered to New Zealand. This time delay must be added to any delay in the decision to purchase. Total delays of three to four days are not uncommon, and delays of a week, or more are routine.

Reception of an image locally would reduce the time delay to waiting for the next satellite flypast and the subsequent processing to standard products. It would thus be possible to provide near real time image delivery to end users and, in most cases, updated images at typically 1 ¾ hourly intervals from subsequent passes.

A station in New Zealand would provide important strategic benefits in that it would both raise the profile of satellite imaging so that more use could be made of it and to reduce the costs in procuring images and so make them more widely affordable. Consequently, significant growth in the New Zealand satellite imaging industry could be anticipated.

In addition, a station in New Zealand would likely be able to provide hyperspectral satellite services; these are currently seldom available, but may become more prevalent in the medium-future.

7.4.3. Demand by New Zealand government departments and agencies

There is understood to be interest by a number of New Zealand departments and agencies for near real-time images X-Band remote sensing images as well as conventional archived data sets. Some likely uses of satellite imagery that have been identified are listed below:

Near real time data

- Oil spill detection. This would be useful now, but especially useful should any development in the Southern Ocean take place
- Monitoring of shipping in the Pacific and Southern Oceans, the New Zealand Exclusive Economic Zone and Benthic Protection Areas, including fishing and whaling fleets. Radar satellite imaging operates regardless of cloud cover and in the dark.
- Maritime search and rescue
- Customs maritime surveillance
- Flood water monitoring
- Forest fire management and reporting, such as Sentinel, the Australian national bushfire monitoring system
- Avalanche and snow-pack monitoring in the back-country
- Hydrology monitoring
- Maritime sea conditions reporting for shipping forecasts
- Natural disaster management
- Post-earthquake slip and landslide measurement
- Insurance claims, especially after widespread flooding, or landslides
- Farm management, including effluent and irrigation monitoring
- Detection of favourable oceanographic fishing conditions

Scheduled, or archive data

- Road asset management by New Zealand Transport Agency
- Oil seep detection and landform mapping for oil exploration

- LUCAS monitoring of forestry for Kyoto Accord compliance, every year
- GIS support
- Land-use and cadastral mapping
- Seasonal crop monitoring
- Environmental monitoring
- Habitat monitoring for rehabilitation of conservation lands
- Monitoring of and assisting with reinstatement of mining operations
- Urban planning and infrastructure management
- Ice mapping, including of Antarctic ice-sheets and New Zealand glaciers
- Sea-state measuring, possibly in conjunction with Unwin Radar
- Terrain deformation monitoring, including fault-lines and landslips
- Land-cover time-sequence database production, to augment the 1996 and 2001/2 databases.
- Climate data

Government departments and CRIs that have been identified as using, or potentially using satellite image products include:

- Antarctica New Zealand
- Civil Defence
- Geospatial Office
- Land Information New Zealand
- Landcare Research
- MAF
- Maritime New Zealand
- Ministry for Economic Development
- Ministry for Fisheries
- Ministry for the Environment
- New Zealand Electricity Commission
- New Zealand Fire Service
- New Zealand Land Transport Authority
- NIWA
- Regional councils
- Territorial local authorities
- Universities

Private industry also make use of satellite imagery and remote sensing value-added services from time to time, but are currently not significant. Given the inherent high security requirements should a station be also used for defence purposes, at this stage no attempt has been made to engage with New Zealand Defence staff on this matter.

7.4.4. Government benefits

It is extremely difficult to asses the savings to New Zealand government departments and, indeed, the wider economy, that an earth station in Southland would provide because of the present low usage of RSS images. This means that the avoided costs arising from RSS imaging are hard to quantify and the opportunity cost is no easier to discover. It is even harder to identify the considerable improvements to productivity that could be expected, especially as the potential users are to be found in many varied departments.

The examples listed below give a flavour for how in just one area that timely satellite imagery obtained from the proposed Awarua earth station could improve operating efficiency and save costs.

Maritime surveillance

- New Zealand is responsible for the co-ordination of Class III search and rescue in one the world's largest search and rescue regions, covering approximately 20 million square kilometres of ocean, extending from just south of the Equator to Antarctica and from half-way to Chile in the east to half-way to Australia in the west. Searches for smaller craft are relatively common in the Pacific Ocean and can involve many hours of grid searching by New Zealand, Australian and French P3 Orion aircraft when locater beacons are not used, or activated. Satellite radar imaging is often able to identify such craft, regardless of weather, or time of day or night. This should result in considerable cost savings.
- Much offshore maritime surveillance carried out from New Zealand is undertaken by RNZAF P3 Orion aircraft and some $250,000 is budgeted each year for this work. The P3 Orions have an operating cost of around $NZ1,000 per minute and it is understood that for surveillance in the Southern Ocean, reconnaissance in the target area is usually limited to one or two hours, preceded by perhaps three to five hours flying time to get to the target area. The net cost of effective surveillance in the target areas in the Southern Ocean is thus in the order of $5,000 per minute. One estimate is that even with this effort, only around 10% of the desired surveillance is able to be undertaken. Using near real-time satellite images of shipping from the proposed Awarua earth station would allow for more targeted flight plans. In this case, there would be no savings to be made in reducing flying time, but the flights undertaken would be much more productive than at present and could provide the level of coverage needed.
- Maritime New Zealand is currently unable to meet its target of risk profiling all of the estimated 1600 foreign vessels entering New Zealand each year. As shipping arriving to New Zealand tends to follow a small number of well defined routes, which could be routinely monitored by radar satellite, it should be possible to categorize vessels so that risk profiling efforts could be more directed and effective.

Geophysical monitoring

On-shore, satellite imaging would have been useful in assisting manage Fiordland National Park this year:

- The July 2009 force 7.9 earthquake in Fiordland had the potential to cause major slips to make unstable dams blocking rivers that could burst and destroy huts. GNS subsequently flew over much of Fiordland looking for slips and suchlike for several days. This reconnaissance could have been carried out by SAR satellite in near real-time, overnight.
- When tasking field parties in winter, DoC is not easily able to ascertain the conditions of the snow pack in the more remote back country and so ensure staff safety. It is too expensive (at over $2,000 per hour) to fly in by helicopter to check first. Satellite imaging could be first viewed.

- Deterioration of the forest canopy though possum browsing should be straightforward to monitor through satellite optical imaging.

While it is recognised that Government has an agreement through KiwiImage, newer spacecraft provide next generation imaging that surpasses the QuickBird images in resolution and performance[9]. Access to such images would provide improved user satisfaction and utility.

7.4.5. Commercial benefits

While it is not straightforward to estimate the commercial benefits accruing from having an earth station in Southland, as discussed below, and indication can be gleaned from noting that ACRES has an annual commercial revenue of some $AUS1.2 million (see Appendix 16). This is in spite of ACRES focusing primarily on one-off, rather than on-going sales, and with little marketing effort.

It is estimated that at present there are some 12 positions in New Zealand CRI's and around 13 New Zealand academic staff and students primarily using satellite imagery. Outside of Defence and meteorology (both of whom have their own, specialised satellite needs), another 5 positions in Government are major uses of satellite imagery. Extrapolating from Landcare Research estimates, this sets the size of the present market for *ad hoc* image and data to around $750,000 per year in New Zealand.

7.4.6. Regional benefits

While the services first proposed to be offered by Awarua Station are modest and at first will not employ more than half a dozen people, it is instructive to compare the proposed operation with its existing counterpart in Australia, ACRES (See Appendix 16). ACRES comprises three sections–Services, Engineering and Science and Strategy. It has a staff of 39 with an annual cost of operations of approximately $AUS5 million, which is funded by appropriation of $AUS3.8 million and revenue of around $AUS1.2 million. It provides a much wider scope of services than initially proposed for Awarua, but as the demand for services from Awarua Station gathers momentum, similar developments could be expected there also. It would not be unrealistic to expect that the Awarua and Invercargill staff and operational budget could eventually reach roughly half of that for ACRES, i.e. around 15 to 20 staff with an annual budget of between $NZ2.5 million and $NZ3 million. Allowing for a Keynsian Multiplier of 2.7, this would inject around $NZ8 million into the Southland economy each year.

Such analysis overlooks that in Southland, there is a strategic approach to developing high-technology jobs in the region and the importance of forming "clusters" of expertise, one of which is already formed in Southland (See Appendix 20): the direct impact on the local workface arising from the radio and space science projects to date have not been fully analysed, but anecdotal evidence indicates that the present projects to date have alone seen the establishment of 1 to 1 ½ new full-time technical positions.

7.4.7. RSS Satellite Earth Station location and coverage

The reception coverage to an RSS spacecraft depends on the minimum elevation of the receiving station and for Awarua, with a less than 1° horizon in most directions, extends to almost 3,000km (see Figure 3 and Appendix 13). The coverage area extends over all New

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[9] WorldView-2, which was launched in October 2009, provides the four "standard" Landsat bands - blue (450-510 nm), green (510-580 nm), red (630-690 nm) and near-IR (770-895 nm) as well as a short-wavelength blue band. or "coastal" (400-450nm), "yellow" (585-625 nm), "red edge" (705-745 nm) and a second NIR. or "near-IR2" band (860-1040 nm). Images have a nadir swath of 16.4 km and a nadir resolution of 1.8 metres (multispectral) and 46 cm (panchromatic). The satellite has a very high slew rate, which gives it the capability to cover many areas in a single orbit.

Zealand's land mass and EEZ, and extends to the northern-most ice flows of Antarctica. An equivalent RSS station sited in the very north of New Zealand would lose valuable coverage of the sub-Antarctic region, and gain comparatively little advantage in coverage of Pacific Islands. The expected coverage from the station is shown in Figure 3.

Awarua can also be considered to be the most south-easterly part of Australasia and so provides commercial opportunities that would not exist for any ground stations further north in New Zealand.

For downloading RSS data-recorders, Awarua is the most southerly, useful site in New Zealand from which to operate a tracking station. It has a 2500–3000 km horizon for RSS space-craft, spanning some 54 degrees of longitude from 142˚E to 196˚E. This compares favourably with any East Coast, or Northland station, which would only span 46˚ and 44˚ longitude spans respectively (see Appendix 13).

7.4.8. Proposed Awarua station facilities

It is proposed to establish an antenna and Receive and Archiving Subsystem (RAS) at Awarua Station under the control of an operator either in the Invercargill SIX, or connected to SIX through the Invercargill Municipal Fibre Network. The Search and Processing Subsystem (SPS) and Value-added Product Generator (VPG), along with connection to the Internet and KAREN would be located at SIX, as set out in Appendix 12. The data transport between Awarua Station and SIX can be accomplished in a number of ways, as discussed later. However, as the RAS is dealing with gigabytes of data for each image, it makes sense at this stage to do near real time archiving at Awarua and mirror the data at SIX whenever there is spare capacity on the bearer.

Most day to day operations of the facility are proposed to be autonomous and require minimal staff input. This will, in the main, be restricted to equipment maintenance and some file management. Data flow is shown in Appendix 12. Note that the end user can be anywhere in New Zealand with suitable access. A key feature of this proposal is that products are designed to be delivered electronically, although physical products (e.g. DVDs) could also be produced. Thus, the design of the station recognises the high financial value associated with near real-time delivery of processed data to customers.

The equipment would be operated remotely from SIX, or by an operator connected via the Invercargill municipal fibre network.

Discussion of the proposed equipment follows is set out in Appendix 18. Indicative prices for the equipment have been received from Zodiac Aerospace, formerly In-Spec, who provide S-Band tracking for CNES and have considerable X-Band expertise. ESA has indicated a tentative interest in providing funding for enhancing the basic X-Band receive-only station facilities to include S-Band receive operation. SSC has expressed interest in expanding the station to include TT&C functionality.

7.5. Risks

Commercial risks to establishing a ground station at Awarua are set out below. It is considered that these risks are not major obstacles.

Lack of commercial support

As indicated earlier, it is not clear what the commercial demand for satellite data in New Zealand is. The major current contracts for MfE and KiwiImage are worth several million dollars over the next five years and these could and should transfer to Awarua Station. Supply of on-demand images and data for CRI's, New Zealand universities and government departments is estimated to be around $750,000 per year.

It is clear that at least one, major committed customer is required to guarantee the commercial viability of the station in the first instance. Anecdotal evidence indicates that as the services provided by the station become known, increased demand for these and new services can be expected and that after some years the station should be resilient to the vagaries of the market.

Competition for commercial applications

It is possible to establish permanent facilities on the Antarctic continent. That it is possible to construct and maintain large antennas there is evidenced by Telecom New Zealand's 11 metre dish at Arrival Heights, near Scott Base at 77.9˚S 166.8˚E and Kongsberg Satellite Services' Trollsat ground station facility, which is co-located at the Norwegian Polar Institute's research facility at 72˚S 2˚E.

At these latitudes, look-angles to geostationary telecommunications satellites are at very best less than 10˚ and more typically much closer to the horizon. At Arrival Heights, only a small range of GEO slots are able to be seen by the antenna due to obstruction by the Transantarctic Mountains, hundreds of kilometres away. Regardless, data download speeds from RSS spacecraft are now in the order of 500 Mbps, with a typical image being in the order of some gigabytes. Unless there is image processing taking place at the station, it would be expensive to provide raw data over dedicated GEO satellite links.

A further difficulty is to man such stations year round. Telecom New Zealand finds it extremely difficult to recruit a technician to maintain the Arrival Heights station over winter. Getting supplies and spare parts to these stations is not straightforward and any upgrades are difficult.

Because downloaded data is usually archived on tape, it is not possible to fully automate station operations. Getting staff to, and then keeping them at an Antarctic station just to undertake library duties would be significantly more expensive than using staff in New Zealand.

Competition for New Zealand coverage

Although some discomfort has been detected with the standards of service apparently being experienced from ACRES at Hobart and the northern hemisphere stations, it is possible that these stations could upgrade their facilities and service and/or reduce prices, potentially undermining the business case for any proposed New Zealand station.

While ACRES would be able to provide a good service to New Zealand, it is likely that priority focus will always be on Australian coverage. The ACRES station at Hobart is not in a good position to provide images from the east of New Zealand. A station at Awarua should be able to provide cheaper, faster near real-time coverage for delivering images of New Zealand, New Zealand's EEZ and the Pacific Ocean to the north and east. In part, Awarua should be able to provide cheaper service to New Zealand customers as the expense of international bandwidth will not apply.

If pricing for satellite image products cannot be provided at competitive levels, regional councils and others will continue to use aerial photography. Appendix 9 sets out some indicative prices.

Satellite unavailability

A number of RSS spacecraft are nearing the ends of their useful lives. In particular, Landsat 5 and Landsat 7 are both suffering from technical problems and have well exceeded their design lifetimes. The Landsat successor, LDCM, is not due for launch until 2011-12 and we do not know exactly what business model may be applied to it. We understand that international ground stations are intended to be supported in the LDCM model.

SPOT 5 has also exceeded its design lifetime. It could easily last for another 5 to 10 years, but no guarantees can be made. SPOT's successor will be the Pleiades programme, which will employ optical and radar sensors to provide near-real-time products for environmental applications.

ENVISAT is also nearing the end of its design lifetime. It is likely to remain in operation for many years yet, based on performance to date. The successors to Envisat are Sentinel-1 (a radar follow-on) and Sentinel-2 (optical multispectral). The former is due for launch in 2011.

ALOS, launched in 2006, is not yet available for commercial ground station downloading, but Restec have indicated that they intend to allow for this.

Radarsat-2, launched in 2007, has just started its useful operational life; Radarsat-1 is still operational, but well towards the end of its design lifetime. Successors to Radarsat-2 will be smaller spacecraft, but continuity is assured.

Radio interference

In order for an earth station to be technically successful, it must have a very low noise floor in the radio spectrum used for receiving signals from spacecraft and a very low horizon, in order to maximise the number of visible spacecraft passes. In most parts of the inhabited world, including New Zealand, these two requirements work against each other: a low horizon means that emissions from distant signal sources can potentially interfere with the station. The usual solution for this problem, to use nearby hills to shield the station from such distant emissions, defeats the requirement of a low horizon. Alternatively, if the surrounding landscape is flat for a sufficiently large area around the station, then the natural curvature of the earth will serve the same purpose. A low population density assists this latter approach as the number of interference sources is reduced and with this, the energy flux contributing to the noise floor is diminished.

Fortunately, the Southland Plains are very flat and with a low population density and there are no X-Band emission sources on any of the hilltops visible from Awarua. In short, Awarua is presently distant from any known X-Band emission sources and the radio noise floor is thus very low (see Appendix 4).

The farm upon which Awarua Tracking Station is located is presently covered by an encumbrance, which forbids the landowner, or occupier to carry out work that would cause problems for the station. This includes obstructing the look-angles of the antenna and causing radio interference.

Should this proposal go ahead, a Receive Protection Licence would be sought from Ministry of Economic Development for the Southland Plains and hills visible from the station to protect the spectrum between 8.0 GHz and 8.5 GHz, along with a suitable guard band.

Public anxiety

Some members of the public hold deep suspicions of satellite earth stations and sophisticated radio installations. To ally such suspicions, the approach successfully taken in Southland to date with both the Unwin Radar and Awarua Station has been to be very open with the public about the stations through the media and public talks, and to invite the public to visit the sites on open-days. There is no reason why the same approach should not work equally well into the future. Indeed, apart from a little initial suspicion by a very few people, Southlanders have enthusiastically endorsed the projects to date.

Continued availability of station land

Presently Awarua Station is on leasehold land, which expires with right of renewal in nine years time. Should this proposal go ahead, the station land would be purchased outright.

Access to the station is via a public road and the proposed route for laying fibre-optic cable directly to the Bluff Highway follows an unformed public road. No problems present themselves in this regard.

Budgetary considerations

The costs of establishing a RSS station are set out in Appendix 15. They are summarised here:

X-Band receive-only station, with image-processing in Invercargill and SPOT licence	$5,300,000
KAREN connection	$200,000
	$5,500,000

It is understood that currently New Zealand Government departments are paying around $2M per year for satellite image products. If the assumption is made that the present expenditure could all be provided by the proposed facilities, then the capital costs should pay back within the life of the hardware.

Further to this assumption, it is extremely likely that having an earth station in New Zealand would stimulate demand for services and so the station could be expected to run at a modest profit. As mentioned elsewhere, such additional demand could come from providing near real-time radar imaging to assist Civil Defence manage natural disasters more effectively. It is not straightforward to quantify the benefits of having a station such as Awarua providing these images, but it could be that the station pays for itself in the course of one disaster in terms of overall cost savings to the Government.

In addition, it is recognised that there is potential demand for satellite imaging services that are still to be qualified. For instance, it is not at all certain how the Ministry for the Environment will be able to monitor the ocean areas they are now responsible for and it is very likely that satellite surveillance will prove the only viable option. Using Awarua facilities to this end would likely be cost-effective for the Ministry for the Environment and further assist with the station viability.

The commercial use of the station has not be explored at this stage, but there is no doubt that commercial users- perhaps forestry owners, mining companies and oil prospectors to name just a few, would be interested in making use of services for a fee.

7.6. Satellite and launcher tracking station

7.6.1. Ariane 5 ATV launches

Subsequent to the March 2008 Ariane 5 ATV launch, informal discussions with ESA have indicated a willingness for ESA to contribute towards a permanent tracking station at Awarua and, in particular, for funding any upgrade required to allow for tracking future launches. To accommodate Ariane 5 tracking, S-Band receiving and tracking equipment would need to be mounted on the antenna and feed. Opportunities to track other launch vehicles also exist.

7.6.2. Tasking and TT&C of remote sensing satellites

Southland's location means that it is suitable for S-Band RSS TT&C and tasking applications. It is also suitable for such functions for a range of other spacecraft. At this stage it is not possible to fully quantify these opportunities, though Venture Southland has had some discussions with potential users and Invercargill is presented as a proposed station in the PrioraNet ground station network (See Appendix 17).

Although Awarua is currently used for Ariane 5 ATV launch tracking, the specialised antenna and control equipment is only on site for the launch and pre-launch testing. It is thus not readily available for tracking other spacecraft or launchers. Already one opportunity to track another launch has had to be declined for lack of this equipment and once it became known that Awarua was capable of tracking launches, other launch tracking would likely eventuate.

Two types of launch and satellite tracking may be undertaken: passive reception of telemetry from the spacecraft, which is then relayed to launch control, and TT&C where the station would also transmit data to the spacecraft. Unlike RSS earth stations which operate on X-Band, tracking stations operate on S-Band. While the antenna and antenna pointing and steering equipment is common, all subsequent equipment is different.

The present market rate for providing tracking facilities for launches is in the order of $200,000 per launch.

ESA have volunteered that they are prepared to assist in funding the marginal cost to upgrade an X-Band RSS earth station at Awarua to dual X- Band / S-Band operation, and so making it suitable for Ariane 5 ATV launches. Such a station would be able to track most other launches that pass within 1000 km – 2,000 km of the station.

The New Zealand company, RocketTech, is developing its own sub-orbital launch vehicle. Stringent requirements for the launch trajectory severely limit possible launch sites in New Zealand. Venture Southland has proposed that Southland could be a suitable launch site. To avoid risk to inhabited areas, the launch would have to take place from a seaborne launch-pad, possibly a barge.

7.6.3. Launcher tracking equipment

Dual S-Band, X-Band receive only

This station would receive data from RSS satellites, including at the minimum SPOT, ENVISAT and Ariane 5 launcher tracking. This option is only viable if CNES and ESA are prepared to contribute to the cost of the additional equipment for S-Band. Equipment would comprise:

- Dual S-Band, X-Band antenna, with auto-track capabilities in both bands, including special frequency diversity features required for Ariane 5 launchers,
- Full RF and baseband equipment for reception and demodulation in X-Band,
- Downlink RF in S-Band with interfaces to connect to the "RTR-PTM" kit that CNES would provide for Ariane data reception and re-transmission,
- Monitor and Control system for automatic operations.

The cost of this option is $5,900,000.

Dual S-Band, X-Band receive with S-band transmit

As above, but with transmit operation in S-Band that will allow TT&C of LEO satellites and direct tasking of RSS satellites:

- TT&C baseband units, to be connected to the S-Band downlink RF output,
- S-Band uplink capability.

The antenna and receiver system would incorporate all tracking, auto-tracking, receiving, down-conversion and demodulation components.

Budgetary costs

Dual S- and X-Band receive-only station, with image-processing in Invercargill, SPOT licence and integration with Ariane 5 kit	$5,900,000
KAREN connection	$200,000
	$6,100,000

Dual S- and X-Band receive with S-Band transmit station with image-processing in Invercargill, SPOT licence, integration with Ariane 5 kit	$6,500,000
KAREN connection	$200,000
	$6,700,000

As the S-Band receive and transmit options are dependant on a committed client to use the service, only the X-Band receive-only option need be examined here. Any income from S-Band operations can be regarded as windfall.

Assuming a 10 year life for the station requiring a return of 15% pa to meet the cost of capital, i.e. $1.2M pa, and allowing for worst case $1.4M annual operating costs, the station revenue needs to exceed $2.6M pa. (These costs assume paying full price for SPOT licences and hardware).

7.7. Education

One of the ambitions for the Southland Space Science projects is that local secondary school pupils will become better informed and enthused to study physics, science and mathematics at secondary school and university. This is because there is no university in Southland and only the Tiwai Point Aluminium Smelter to showcase high-profile engineering projects and so engender interest in engineering and physics.

A qualitative study[10] of two Invercargill schools shows that over the last five years, the number of students studying physics has more than doubled. This increase is understood not to be reflected in other parts of New Zealand and seems to be at least, in part directly attributable to the space science projects undertaken in the region.

New Zealand –ESA Arrangement

Under the New Zealand – ESA Arrangement (See Appendix 10), worthwhile opportunities are available for Southland students. Benefits to Southland from the Arrangement have been few, primarily because ESA are unsure what Southland educational institutes and schools want from the Arrangement and Southland organisations have been unable to determine how anything that could be offered by ESA could be incorporated in their syllabuses. As a first step, the EDUSPACE[11] and EDUCATION@ESA[12] programmes have been offered by ESA.

The next Ariane 5 ATV payload is "Johannes Kepler". Preliminary discussions with the Department of Conservation have been initiated to see how this could be linked for effect to

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[10] McNeill, R. *A Preliminary Investigation into Science and Engineering Education Stimulus for Southland Secondary School Pupils*, Unpublished (September 2008).

[11] http://www.eduspace.esa.int/

[12] http://www.esa.int/SPECIALS/Education/

the Kepler Mountains in Fiordland and in particular the well known Kepler Track, both of which are named for Johannes Kepler.

RadioJove

AUT supplied a NASA RadioJove decametre radio astronomy kit to Venture Southland for use by a local school. The completed kit is capable of observing radio emissions from the Sun and Jupiter. It has become apparent that without an enthusiastic teacher to support it, such a project languishes, even when outside assistance is made available.

7.8. Tourism

Tourism arising from space an science projects fall into two categories:

- Natural attractions,
- Industrial tourism.

Natural tourism in Southland is necessarily confined to aurora watching and star gazing. The South Coast of Southland is best suited for aurora watching, but because of the often cloudy skies, unsuitable for reliable sky gazing. Central Southland is well suited for star gazing.

Industrial tourism, where engineering and scientific structures provide the attraction for visitors, is often overlooked in New Zealand, in part because the highly effective "100% Pure" marketing brand focuses on natural phenomena. However, industrial tourism is well understood elsewhere to provide incentives for visitors to assist local economies by getting them to stay longer. There are, of course, also a minority of visitors whose prime reason for travel is to visit such sites: visits to breweries and distilleries are always popular industrial tourism destinations. In this light it is salutary to note that the Parkes Dish in Australia, made famous in the Sam Neil movie, "The Dish", attracts nearly half the visitors each year of Milford Sound. Perhaps it is not surprising that the fifth highest grossing film in the history of Australian cinema is "The Dish". Local interest in open days to Unwin Radar and suchlike has always ensured good patronage.

Aurora watching

For reasons outlined earlier, Southland provides the best opportunity in the world for viewers to see Auroral Australis from land, outside of Antarctica. It is no coincidence that the Maori name for Stewart Island is *Rakiura*, Land of the Glowing Skies.

Figure 16. Aurora Australis viewed from mainland Southland. (Photo courtesy S Voss).

While a number of Stewart Island home-stays and lodges mention in their advertising that they offer possibilities to view aurora, there has yet to be an integrated mechanism put in place to alert southern viewers of auroras. Equally, the tourism industry has not embraced sky viewing due to a lack of understanding of the principles involved in producing auroras. It should be straightforward to develop the geomagnetic (Kp) sensor network described earlier to assist Southland and Stewart Island/Rakiura tourism operators develop new and improved tourism products. The chief difficulty in marketing any aurora viewing product is the unreliability of auroras and that the tend to come in an 11 year cycle matching the sunspot cycle, and then only for 2 to 4 years in that cycle.

Star gazing

Southern skies are excitingly different to visitors from the Northern Hemisphere who are used to their own constellations and polluted, sometimes nearly opaque skies worsened by light pollution. The skies visible in inland Southland are significantly clearer than those even in residential Auckland and much of the North Island where light pollution noticeably hides dimmer stars, as can be seen from Figure 17.

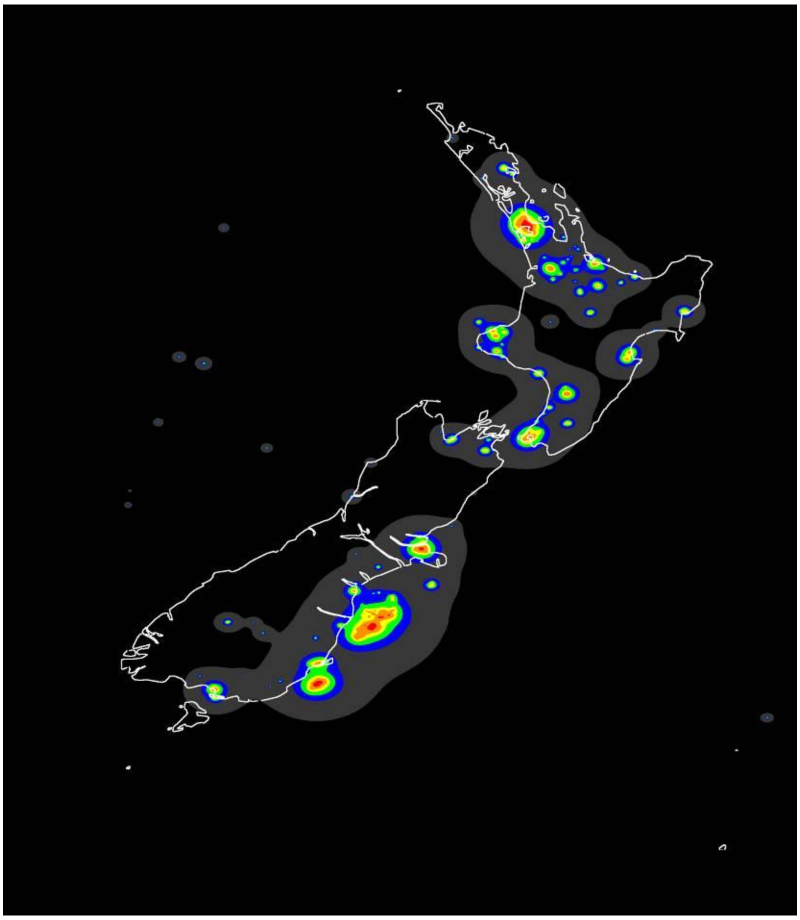

Figure 17. Satellite monitoring of the artificial night sky brightness and the stellar visibility[13]. (After P. Cinzano, F. Falchi (University of Padova), C. D. Elvidge (NOAA National Geophysical Data Center, Boulder). Copyright Royal Astronomical Society.

At least one operator provides a commercial service in Fiordland to star gaze.

The Southland Astronomical Society has an observatory in Invercargill, but its location is not good and the society is considering relocating it. Awarua heritage area has been considered as a possible site.

[13] www.lightpollution.it/dmsp

Astronomers in Invercargill are seeking to make Invercargill free of light pollution, citing the initiative of McKenzie District Council in seeking the McKenzie Basin to be recognised as the world's first UNESCO World Heritage Dark Sky Park, or "starlight reserve".

Square Kilometre Array

An SKA station in Southland would provide a solid tourism destination, especially as most of the SKA stations will be in very remote and difficult to reach locations.

Heritage - Southland P&T Communications Museum

The Southland Post & Telegraph Communications Museum has undertaken a feasibility study as part of its intention to develop a quality community educational heritage resource at its historic Awarua Marine Radio Station site. The Museum has leased the standby transmitting station hall, built in the 1970's, for this purpose.

The feasibility study recommended that the proposed museum place emphasis on the national radio communications significance of the Awarua site, past, present and future. It also recommended that an interpretation plan be a prerequisite of any development. To this end preliminary work has been carried out to identify the tourism values of Awarua facilities.

The preliminary work identified that Awarua is poised to capitalise on increasing educational awareness about and interest in 'space age' communication. Overview interpretation about the development of communication in Southland in general – and Awarua in particular – should be engaging, interactive and easily understandable for Years 6 and 7 upwards.

Probis, U3A, Rotary, Lions and other special interest groups would be attracted to a well-presented interpretation facility that not only reinforces the familiar aspects of communication, but generates awe and pride as Southland strides into new, high profile territory.

Invercargill's outstanding facilities are attracting an increasing number of national conferences and events which, in turn, create a market for sight-seeing and special interest opportunities. Its easy access off Sate highway 1 between Bluff and Invercargill means the Awarua Communications Experience would fit comfortably into this package.

8. Environmental considerations

8.1. Health and safety

The guidelines for exposure to RF fields is shown as Figure 11. For the frequency range used by Unwin, this shows that for 8MHz the “safe” exposure level is below about 250V/m, whilst at 20MHz the level falls to around 100V/m. For the proposed RSS satellite earth stations, safe levels are around 200V/m.

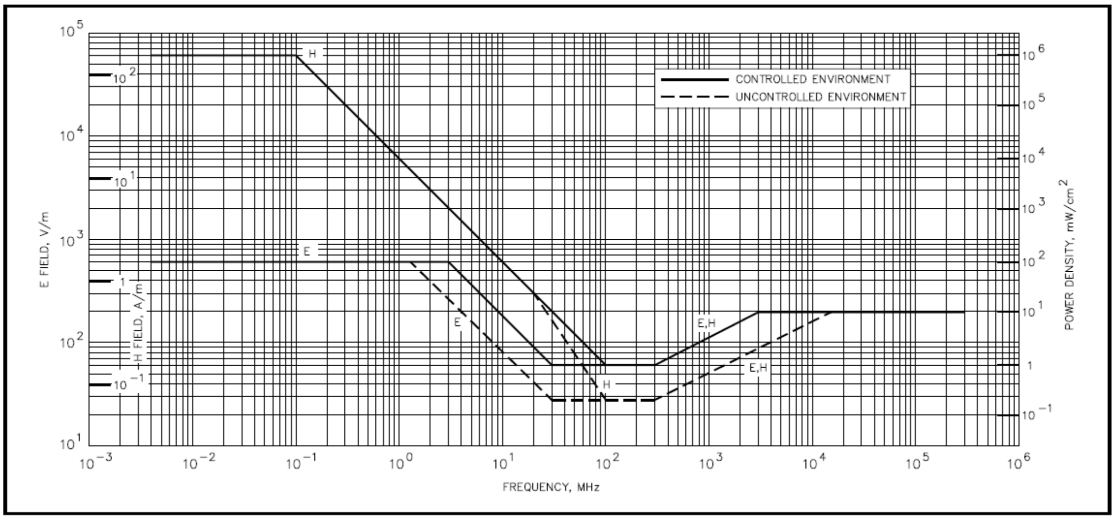

Fig 9.8—1991 RF protection guidelines for body exposure of humans. It is known officially as the “IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.”

Figure 18. Safe Exposure levels for RF fields. Reprinted from the 1997 ARRL Handbook for Radio Amateurs, Copyright ©1996 American Radio Relay League, Inc.

The electric field may be calculated from:

$$E = \frac{\sqrt{30 * P_t}}{d}$$

Where E is the electric field at distance ‘d’ from an antenna transmitting a power of P_t.

Calculations show that the electromagnetic fields around Unwin Radar are safe[14]. The nature of operation for antennas used for TT&C for space craft means that they would also be safe.

8.2. Electromagnetic Interference to researchers

EMI may be caused by research and operational transmitters in two significant modes:

- blocking of nearby receivers, where filters in the receiver are incapable of stopping the signal from the transmitter entering the receiver electronics and so affect reception, and
- intermodulation products, where strong radio frequency signals are rectified by corrosion in metalwork and produce interfering signals.

EMI to research and operational receivers can be caused by:

- car ignitions

[14] Devlin, John. *E-Field Calculations for the Unwin Radar*, La Trobe University, Unpublished (2008)

- electric fences
- dirty insulators on power lines arcing
- cellphones and other personal telecommunications devices

There are currently 488 licensed radio transmitters within 15 kilometres of Awarua. Transmitters that operate outside of HF, VHF and UHF frequencies, and are not point-to-point microwave links, within 15 kilometres of the site are:

- Meteorological radar, Invercargill Airport, 5625 MHz, 54dBW eirp, 14 km to the north
- Unwin auroral radar, Awarua, 8 – 20 MHz, 70 dBW eirp, 2.5 km to the north.

The farm from which Awarua Tracking Station leases land is subject to an encumbrance negotiated by Venture Southland to prevent the occupier from interfering with the operations of the station.

8.3. Climate

Rainfall: The probable maximum precipitation (PMP) for Invercargill Airport, which can be expected to reflect Awarua, is calculated to be:

0.5 day 141 mm

1 day 196 mm

2 days 233 mm

Wind: The frequency of vigorous depressions passing over seas south of New Zealand means that situations capable of producing strong winds occur many times each year. There is a high probability that a windstorm with 10 minute mean wind speeds of 48 - 55 kts will occur in the next 50 years. There is a significant risk that wind speeds could reach "violent storm" force (56-63 kts). Brief gusts exceeding 80kts will probably occur in the strongest wind storms (highest recorded data to date, 77 kts in May 1994).

	Average Monthly Rainfall (mm)	Highest Ever Recorded Daily Rainfall (mm)	Average Daily MAX Temperature (deg)	Average Daily MIN Temperature (deg)	Mean Relative Humidity 9am (%)	Mean Relative Humidity 3pm (%)	Peak Relative Humidity (%)	Mean Daily Amount of Cloud 9am (oktas)	Average Wind Speed	Average Wind Speed Direction	Max Wind Gust Ever Recorded (km/h)	Direction of Max Wind Gust	Mean Number of Days with Thunder	Mean Number of Days with Hail	Mean Number of Days with Frost	Mean Number of Days with Snow	Mean Number of Days with Lightening	Severe Weather Flood	Mean Number of Days Strong Winds >= 24 knots	Mean Number of Days with Gail Force Winds	Mean Daily Global Solar Radiation (MJ/m2)
Jan	110.1	152.3	18.33	10.07	81.17			6.208	5.828		11.167	260	0.929	1.054	0.75	0.037	0.926		19.22	2.375	20.6
Feb	77.64	63.4	18.45	9.915	83.1			5.842	5.507		10.722	288	0.411	0.661	0.885	0	0.611		16.86	1.75	17.2
Mar	92.34	66.1	17.05	8.656	83.73			5.872	5.357		11	250	0.764	1.291	1.931	0.038	0.943		17.97	2.382	12.2
Apr	104.2	66.6	14.77	6.62	85.32			5.862	5.087		10.444	270	0.818	1.655	4.081	0.094	1.038		16.35	2.455	7.6
May	118.2	49.5	12.18	4.741	86.73			6.1	5.363		11	250	1.055	3.018	6.392	0.642	1.434		17.68	3.418	4.5
Jun	99.5	67.2	9.958	2.614	87.52			5.669	4.578		10.861	250	0.673	2.6	12.22	0.792	0.962		15.1	1.564	3.2
Jul	85.37	43	9.56	1.764	88.01			5.605	4.125		10.861	270	0.745	2.455	15.38	0.792	0.83		13.21	1.382	4.2
Aug	70.59	60	10.93	2.662	85.71			5.57	4.433		10.583	250	0.455	2.6	12.91	0.868	0.623		14.87	1.273	6.4
Sep	86.27	73.6	12.81	4.416	81.35			5.697	5.402		11.167	260	0.741	2.648	7.849	0.462	0.865		18.19	2.574	11.0
Oct	96.49	56.5	14.22	6.113	79.79			5.91	5.998		12.861	260	0.481	2.722	4.487	0.288	0.577		20.48	2.833	15.3
Nov	86.05	52.5	15.49	7.401	78.26			5.937	6.289		13.444	311	0.778	2.537	2.26	0.173	0.885		19.74	2.963	18.8
Dec	96.58	62.3	17.18	8.983	78.84			6.041	5.852		11.583	280	1.148	1.389	0.917	0.038	1.25		20.3	2.019	21.4
Yearly Total	**1123**												**8.997**	**24.63**	**70.05**	**4.225**	**10.94**		**210**	**26.99**	

ASKAC STIPULATED DATA **CW**

Snow: Heavy snowfalls are uncommon due the coastal nature of the site. Although snowfall is recorded in most winters, accumulations greater than 5 cm are uncommon and the maximum reliably measured fall is 8 cm.

8.4. Seismic Activity

Fault Rupture: There are no known active faults within the vicinity of the proposed site.

Ground shaking: Peak Ground Accelerations (PGA) of 0.1 – 0.3 g can be expected at 10% probability in 50 years (approximately 475 year return period) from all earthquake sources.

A 475 year return period earthquake is expected to have a felt intensity of MMVII (Modified Mercalli intensity VII) in Invercargill. Amplification of earthquake shaking often occurs in softer, unconsolidated sediments that can result in the intensification of shaking by one, or possibly two levels on the Modified Mercalli scale, which means that the site may experience earthquake shaking in the order of MMVIII from a 475 year return event.

An Alpine Fault event is likely to produce lower intensity ground shaking, but has a higher probability in the next 50 years, with a maximum probability of approximately 35% in 50 years at MMVI, or MMVII if amplification occurs.

Liquefaction: The site may be susceptible to liquefaction during a seismic event of MMVII.

Tsunami: For land adjoining Bluff Harbour, it is recommended that planning should be for minimum tsunami water levels of 2.53 m amsl. At 11 m amsl, the site comfortably meets this requirement.

Volcanic Eruption: The two volcanoes in the area have been extinct for 1 – 2 million years. The possibility of volcanic eruption posing a hazard to the site is considered remote.

8.5. Political stability and security

New Zealand and Southland in particular is politically very stable and the actual incidence of crime is low.

8.6. Native Title (Treaty of Waitangi claims)

All claims for redress by the indigenous peoples for the southern part of the South Island of New Zealand were resolved with the Ngai Tahu Deed of Settlement in July 1998. The settlement provides full, final and enduring settlement for Ngai Tahu claims, including land claims. The settlement was endorsed by the New Zealand parliament through the Ngai Tahu Claims Settlement Act 1998.

9. Suggested way forward

9.1. Projects

While most of the projects suggested in this strategy can and will continue under their own merits and momentum, they can all assist each other. However, a number of the projects described here will only be viable if they are able to take advantage of infrastructure developed for other projects. These are shown in Table 1.

Project	KAREN POP	Fibre-optic access	Accurate clock	New antenna	New site
Unwin radar upgrade	✓	✓			
Second TIGER radar	✓	✓		✓	✓
SKA station		✓	✓	✓	✓
ASKAP Pathfinder	✓	✓	✓	✓	
eVLBI radio astronomy	✓	✓	✓		
VLF radio astronomy	✓	✓		✓	
ESA launch tracking					
Launch tracking		✓		✓	
Galileo Ground Station		✓	✓		
RSS satellite earth station		✓		✓	
GeoEye satellite earth station		✓		✓	✓

Table 1. Project interdependence.

While some of the projects contained in this strategy will progress through commercial imperatives, or availability of research funding, others will need nurturing in order to become initiated. Those projects that will need additional assistance are now discussed.

eVLBI radio telescope

To bring the 11m dish owned by Venture Southland up to standard and operational for eVLBI work, between $50,000 and $100,000 of work is required and a connection to KAREN. Funding for the project needs to be secured before any further work can be undertaken. Getting this antenna operational is a fallback position should an ASKAP Pathfinder telescope in Southland not go ahead.

ASKAP Pathfinder

Central Government funding for establishing ASKAP Pathfinder telescopes in New Zealand will be required to make them viable due to the cost. A case for establishing them will need to be supported by all other New Zealand radio astronomy groups and Ministry of Economic Development.

RSS satellite earth station

Establishing an RSS satellite earth station in Southland is a classic “Little Red Hen” project: no-one is much interested in assisting with establishing, or contributing to the station, but it is anticipated that large number of potential users will want to use the images it will provide.

At this stage, it seems likely that SSC, supported by a commercial customer, have a business case which will make the project viable. For New Zealand to maximise the benefit of such a station, local financial contributions will be needed to form a joint venture company.

To progress the project, New Zealand funders should now be sought.

SKA

SKA is a moderate risk - high return project and can only benefit Southland if the Australasian bid is successful, the project is fully funded and a suitable sites in Southland can be confirmed to comply with SKA requirements. There may be competition from other regions to host the array.

Venture Southland is a member of SKANZ and has been assisting MED. This involvement should continue to ensure a sound outcome.

Other projects

One benefit already experienced from hosting space and ionospheric science facilities is that they attract other potential users and one can never be sure what approach will be next as the space, space weather, ionospheric and remote sensing fields are wide and fruitful. Equally, Southland has now been independently approached by at least three different space and ionospheric agencies, which means that the region's geographic advantages are obvious to those with specialist needs. The challenge is to educate distant researchers and businessmen to understand that while Southland may be remote, the infrastructure is world class and the region is stable and safe to work in.

9.2. Timetable

The projects have various drivers that will govern their timetables for starting and completion. Likely start times for the projects are shown in Figure 2.

Project	Likely start time
Unwin radar upgrade	2010
Second TIGER radar	2015
SKA station	2018
eVLBI radio astronomy	?
VLF radio astronomy	2008- 2010
ESA launch tracking	2008
Launch tracking	2011
Galileo Ground Station	2010
RSS satellite earth station	2010
GeoEye satellite earth station	2011

Table 2. Possible project timings.

9.3. Constraints

While the other projects will progress as funding allows, the assistance Venture Southland is able to provide in facilitating site establishment in Southland, manage contracts and provide technical expertise should not be undervalued. A difficulty Venture Southland has is that staff have been limited to engaging with overseas experts, engineers and astronomers through infrequent conference attendance in New Zealand and meetings in New Zealand. It would be useful if staff were able to visit existing sites and facilities in other countries to gain a wider appreciation of the technologies, emerging developments and to cement the trust already established.

10. Acknowledgements

Preparation of this report has only been made possible with the financial assistance of New Zealand Trade and Enterprise, whom Venture Southland wishes to particularly thank and acknowledge.

Venture Southland also wishes to thank the following people for their support, advice and assistance in preparing this report:

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John Devlin, La Trobe University

Prof. Richard Dowden, LF & EM Research

Prof. Peter Dyson, La Trobe University

Prof. Sergei Gulyaev, AUT

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Pier Michele Roviera, European Space Agency

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Michel Starozinsky, Centre National d'Etudes Spatiales

Herman Steenkamp, OTB

Jean-Philippe Thomarat, Zodiac Aerospace, formerly IN-SNEC

Steven Voss, Southland Astronomical Society

In addition, Venture Southland warmly acknowledges Pat Helm of Department of Prime Minister and Cabinet for his encouragement to not only our space science projects, but also the wider radio and space science sector in New Zealand.

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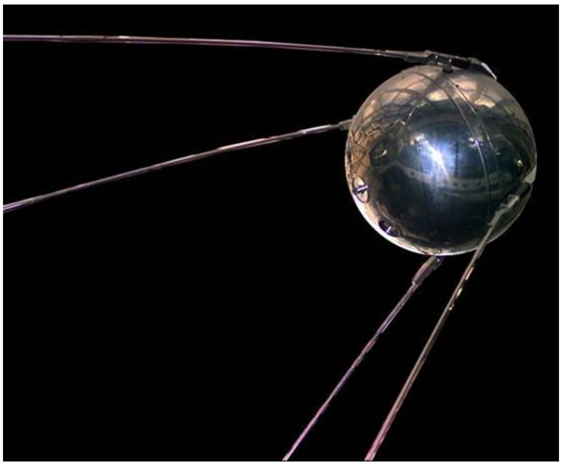

Sputnik I, which on 4th October 1957 forever changed how we view the world.

Appendix 1. Southland Capability

Venture Southland

Venture Southland is a formal legal entity in its own right under Section 114(s) of the Local Government Act 1974 and was formally constituted on 9 June 2001 by way of a Heads Of Agreement signed and executed under seal by the Invercargill City Council, the Southland District Council and the Gore District Council.

Contact details

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Staff involved with the project

The Venture Southland project engineer who would work on this project is Robin McNeill. Mr McNeill has had some 30 years involvement in the telecommunications sector. He was involved in the establishment of an 11 metre INTELSAT Standard B dish at Arrival Heights, Antarctica for Telecom New Zealand in 1991 and, as ITU BDT Senior Expert/Project Manager, planned and managed the construction of three 4.5 m INTELSAT Standard F-1 dishes in Tokelau in 1996 along with the other network components. He provided the design and project management for Awarua Station development between 2003 and 2007, and assisted with the establishment of the Unwin Radar.

Stephen Canny, Venture Southland Group Manager Enterprise and Strategic Projects, has considerable experience in establishing satellite and terrestrial television and radio broadcasting networks and services. Mr Canny was pivotal in attracting La Trobe University to Awarua for the Unwin Radar project and for ESA to establish Awarua Station. He is highly respected within New Zealand government and the telecommunications sector for his pioneering work in establishing policy for rural telecommunications and subsequently implementing it in Southland.

Experience

Venture Southland has been involved in a number of radio and space science projects at Awarua. Of these, the Unwin Auroral SuperDARN radar (See Appendix 11) and Awarua Station have so far been commissioned. Venture Southland has also taken active involvement in the SKA radio telescope project and has been working on establishing radio astronomy facilities at Awarua.

Venture Southland has worked with a number of space agencies, including CNES, ESA, OTB and SSC, many New Zealand universities and a number of overseas universities, including La Trobe University, Swinburne University of Technology and Massachusetts Institute of Technology, and a number of private companies working in the space sector.

Venture Southland has successfully developed and managed several technology projects including Southland Whole of Community Broadband Project ($NZ8M) with Woosh Wireless to provide affordable broadband Internet service to 93% of all Southland dwellings; an on-farm dairy shed energy efficiency study ($0.6M) with the Centre for Advanced Engineering; Topoclimate, an extensive soil and climate map and database covering Southland; and an investigation into renewable electricity supply for Stewart Island. Venture Southland has also developed and managed the preparation of a number of strategic plans for Southland, including strategies for energy, transport, telecommunications and tourism.

The Southland Whole of Community Broadband Project was a runner-up in the 2005 IPENZ New Zealand Engineering Excellence Awards.

Southland engineering capability

This list is not exhaustive.

Site surveying	True South Ltd
Civil works design	Opus Consulting
Civil Works	AG Horrell Ltd
Telecommunications cabling and installation	Foveaux Communications Ltd
Electrical installation	Telepower Ltd
Radio equipment installation and maintenance	ASI Ltd
Telecommunications rigging	ASI Ltd
ICT installation	Gen-I, CodeBlue
Mechanical engineering planning and design	Heaslip Consulting
Electrical engineering planning and design	Venture Southland
Telecommunications engineering planning and design	Venture Southland
Project Management	Venture Southland

Appendix 2. Awarua Station location and environment

Location

46º 31.730 S 168º 22.870 E

11 m amsl

Climate

Temperate climate.

Mean max, January: 18.6 ˚C
Mean max, July: 9.5 ˚C
Mean min, January: 9.4 ˚C
Mean min, July: 0.9 ˚C
Max: 32.3 ˚C
Min: -9.0 ˚C

Mean annual rainfall: 1,111 mm

Wet days, 1.0 mm: 159
Mean wind speed: 18 km/hr
Gust days >93 km/hr: 17

ITU-R 'K' zone rainfall rate profile

Horizon and obstructions

There are no elements that obstruct visibility above 9˚, including buildings.
From the station, excluding station buildings, the maximum obstruction to the horizon in any direction is Bluff Hill, at 1.5˚ elevation.
Bluff Hill (265 m amsl) is 10.0 kilometres away from the site and is suitable for installing a station calibration transmitter.

Site security

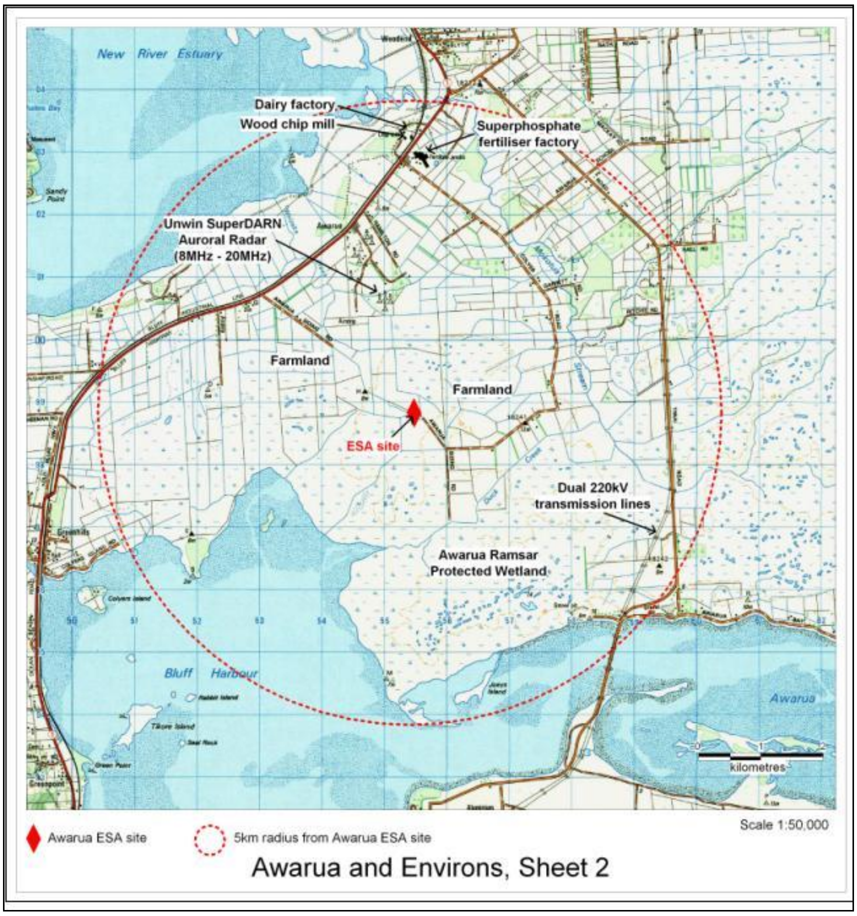
Awarua Station is continually remotely monitored by an Invercargill security company. Presently deer fencing topped with barbed wire and a locked gate is used to keep unauthorised persons out of the station. Leading up to ESA launches, a security guard is at the station at all times.

Access and transport

Invercargill is 15 km from the site, and 20 minutes away by car. The port of Bluff is 20 minutes from the site. Heavy and/or oversize vehicles can easily access the site.

Currently there are seven daily flights to Christchurch and Wellington with onwards flights to Auckland. The flight time to Christchurch is 1 hour 10 minutes (the first arriving at 7:50 am) and the direct flight time from Invercargill to Wellington is 1 hour 50 minutes (the first arriving 8:20 am).

For freight, Christchurch International Airport is 460 km from the site. Overnight delivery from Christchurch by truck is usual. Between three and seven days are required to clear equipment through Customs at Christchurch.



Locality map of Awarua Station, showing a 5 kilometre radius

Locality map of Awarua Station, showing a 50 kilometre radius

Panorama from Awarua Tracking Station

Appendix 3. Awarua Station facilities

Telecommunications

A 4RF L-Band microwave bearer links Awarua Station to Invercargill. It is limited to 800 kbps with a design reliability of 99.99%. The link is currently set up to provide 64 kbps ISDN circuits for CNES use.

For general Internet access, a Woosh Wireless connection at the station typically connects at around 1 Mbps down-stream and 256 kbps up-stream. Speeds of up to a total of 10 Mbps are possible with a minor equipment upgrade.

It is possible to establish a digital microwave radio bearer to either Bluff Hill, or Invercargill, capable of bandwidths of up to 100 Mbps.

It would be straightforward to mole-plough fibre-optic cable from the Bluff Highway to the station, which would allow connection to a Telecom New Zealand cable to Invercargill.

Earth mat

The station has an earth mat with earth resistance measured at 5.3 Ω.

Station accommodation

The main equipment and personnel accommodation building is shown below. A separate generator shed is currently in use as a storage area.

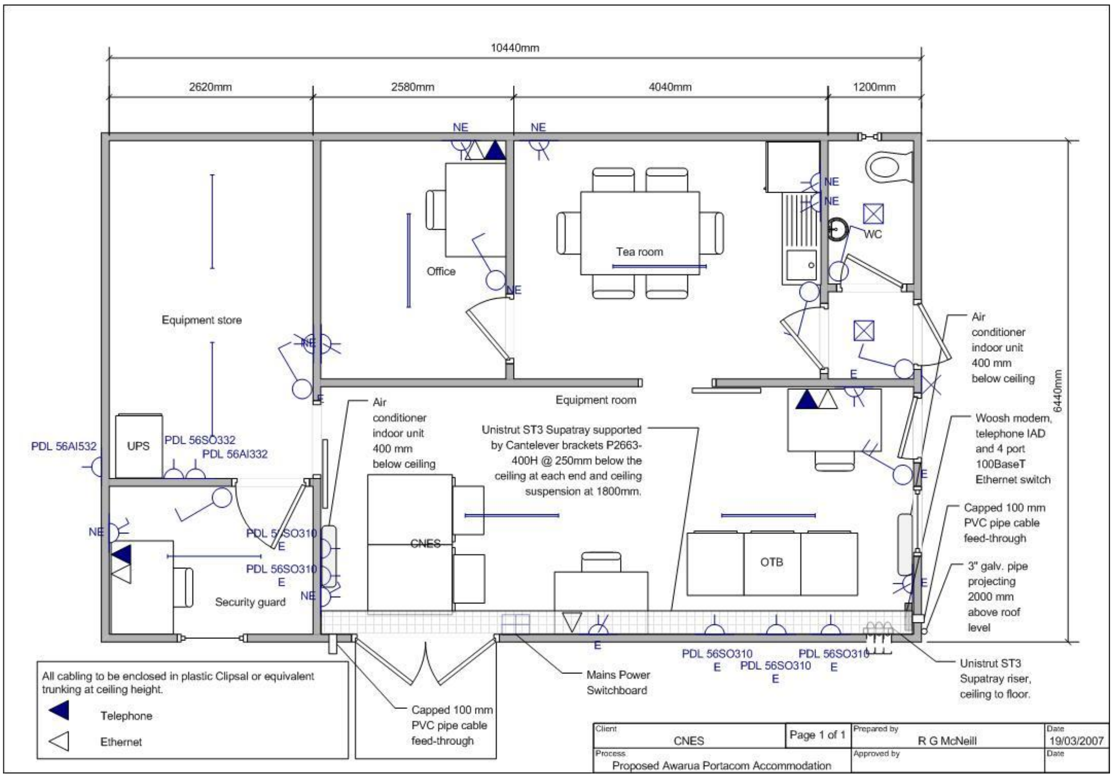
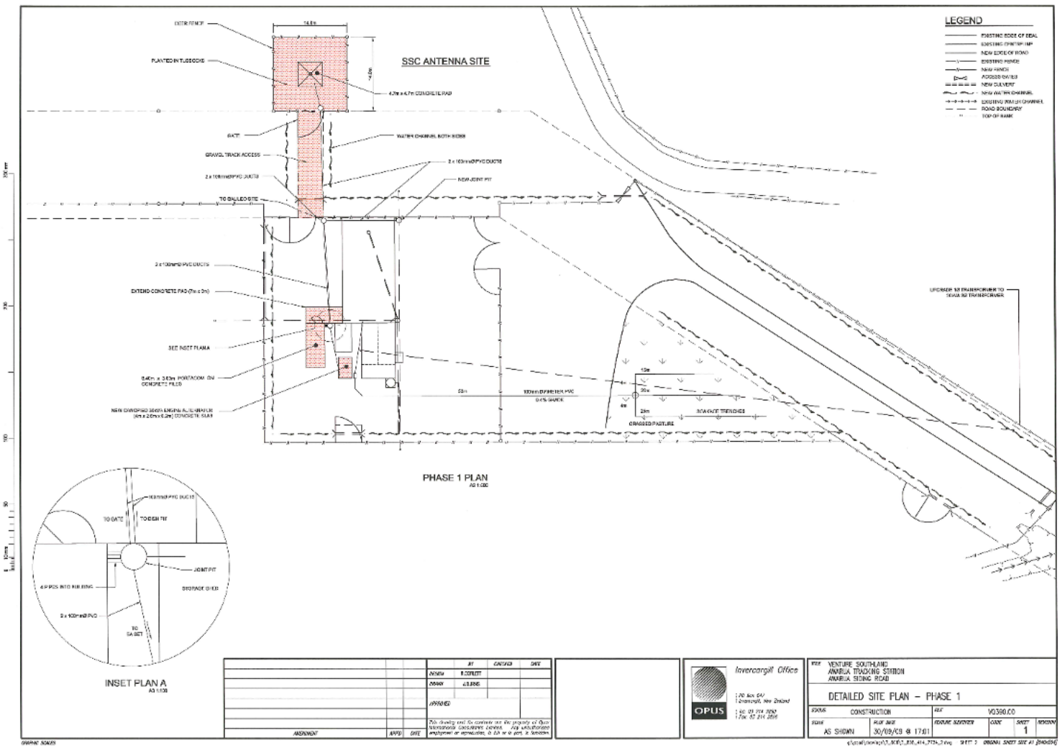


Figure 19. Awarua Station equipment building



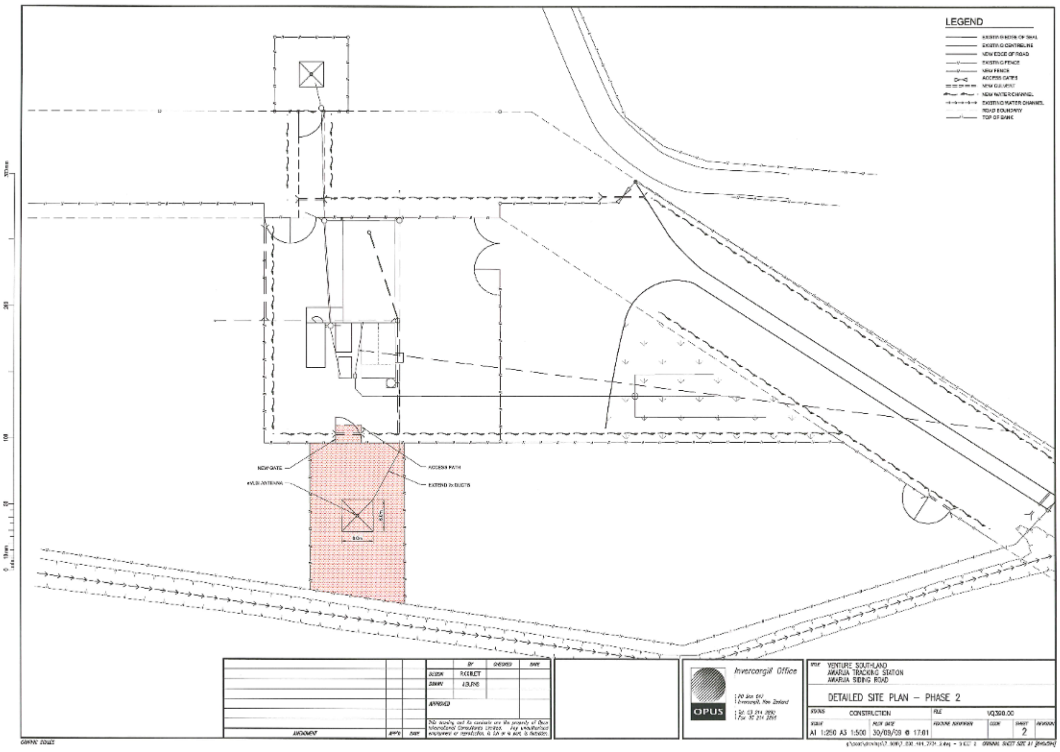
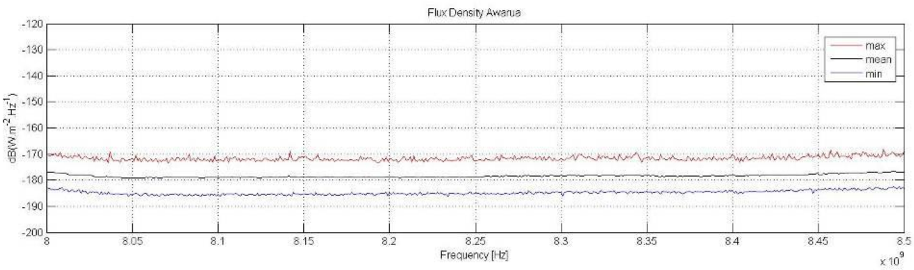


Figure 20. Awarua Tracking Station site plan. Top: Proposed phase I developments for SSC, bottom: Proposed phase II developments for eVLBI, or ASKAP antenna.

Appendix 4. Radio noise floor at Awarua Station

Comprehensive radio frequency noise measurements between 0 GHz and 10 GHz were undertaken at Awarua Station by Paul Banks, a Masters student at Auckland University of Technology supervised by Professor Sergei Gulyaev, under contract to the Ministry of Economic Development in November 2007. In the worst case azimuth, the peak flux density measured between 8.00 GHz and 8.50 GHz was -162 $Wm^{-2}Hz^{-1}$ (dB) with average flux density in that direction being less than -172 $Wm^{-2}Hz^{-1}$ (dB). In other directions the average flux density was less than -178 $Wm^{-2}Hz^{-1}$ (dB). The noise floor results presented here are in 60˚ azimuth segments.

8.00 GHz – 8.50 GHz, Vertical polarisation



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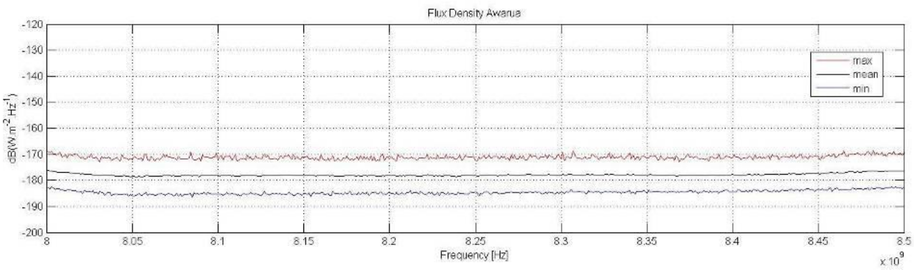
Resolution Bandwidth:	1000 kHz
Technician:	Paul
Polarization:	V
Bearing:	330-30



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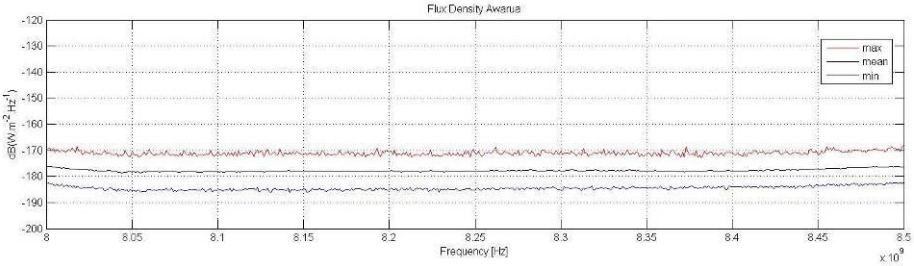
Polarization:	V
Bearing:	30-90



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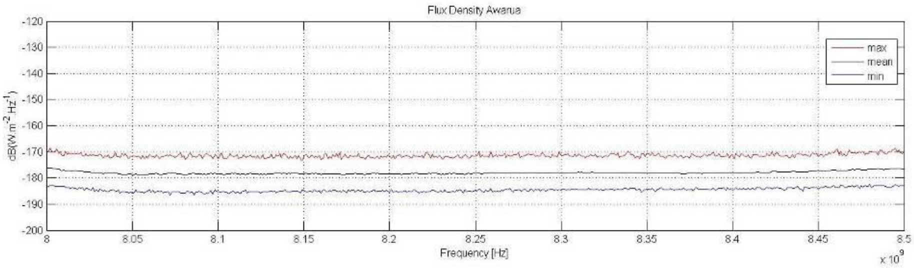
Polarization:	V
Bearing:	90-150



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Resolution Bandwidth:	1000 kHz
Technician:	Paul
Polarization:	V
Bearing:	150-210

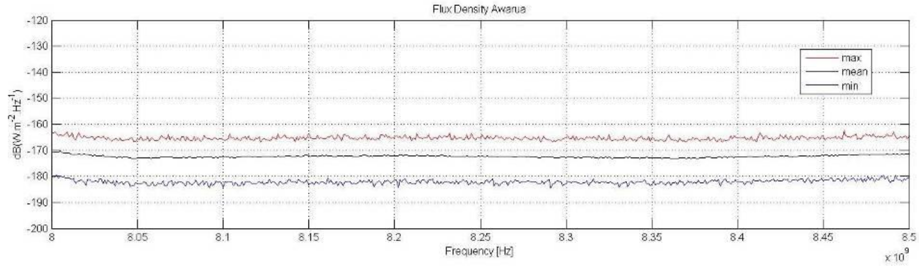

Table Name:	t_20071101t220739
Antenna:	HF LPDA, LNA on Miteq AFS30010080014S4S, 9 m H&S MF141 cable, FSU preamp on attn 0
Sweeps:	1000
Resolution Bandwidth:	1000 kHz
Technician:	Paul
Polarization:	V
Bearing:	210-270

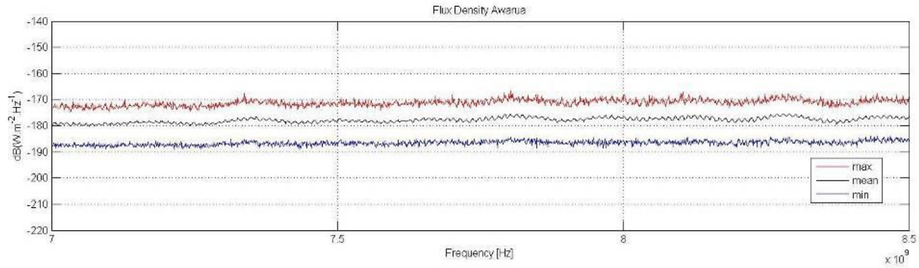

Table Name:	t_20071103t170912
Antenna:	HF LPDA, LNA on Miteq AFS30010080014S4S, 8 m coaxial cable, short flex, FSU preamp on attn 0
Sweeps:	500
Resolution Bandwidth:	1000 kHz
Technician:	Paul
Polarization:	H
Bearing:	270-330

1 GHz – 10 GHz, Vertical polarisation

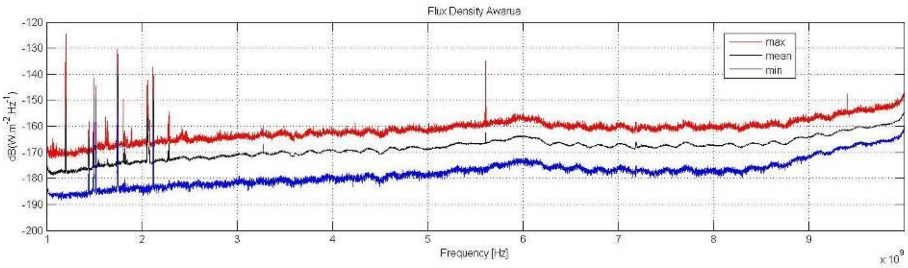

Table Name:	t_20071031t211414
Antenna:	HF LPDA, LNA on Miteq AFS30010080014S4S, H&S MF141 9 m cable, FSU preamp on attn 0
Sweeps:	1000
Resolution Bandwidth:	1000 kHz
Technician:	Paul
Polarization:	V
Bearing:	270-330

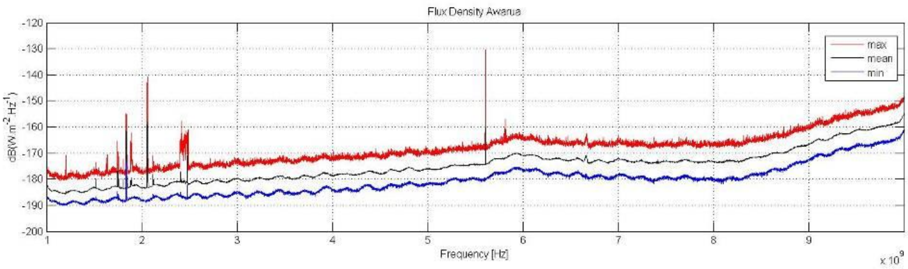

Table Name:	t_20071028t205514
Antenna:	HF LPDA, LNA on Miteq AFS30010080014S4S, H&S MF141 9 m cable, FSU preamp on attn 0
Sweeps:	1000
Resolution Bandwidth:	1000 kHz
Technician:	Paul
Polarization:	V
Bearing:	150-210

The two directions presented here are worst case, looking north to Invercargill (top) and south to Bluff (bottom).

Appendix 5. TIGER auroral radar

Environment

Environmental requirements for TIGER stations are:

1. less than nominal 0.5µVrms noise level into 50Ω at the antenna in any direction and less than 0.125µVrms noise level into 50Ω towards the antenna pointing direction,
2. no development in the near field, i.e. within 400 m of the antennas, should be allowed to minimise impulsive noise,
3. no power lines, or other wires above ground within 500 m of the antennas,
4. no structures within 400 m of the antennas,
5. any structures further than 400 m of the antennas should project into a 2.5˚ elevation from the antennas (i.e. structures at 400 m must be less than 17.5 m high),
6. no heavy electrical power activity within several kilometres of the antennas.

Health and safety

Unwin Radar has an operating power of up to 70 dBW eirp (equivalent to 10 MW radiated power from an isotropic antenna). The resulting electrical fields are:

- At 100m from the antenna, at ground level, the electric field is: 3mV/m[15]
- At 1km from the antenna, at ground level, the electric field is: 0.3mV/m

These are 1000 and 10,000 times lower than the occupation limits given for safe exposure levels for RF fields.

The antennas have gain in an upwards direction and the resultant electrical fields in the direction of maximum gain are:

- At 100m from the antenna, at 17m above the ground, the electric field is: 3.6V/m
- At 1km from the antenna, at 17m above the ground, the electric field is: 0.3V/m

These are about 50 times and 500 times lower than the limits from part (a).

From the basic calculations made here, with the simplified approximations, the electric fields are much lower than occupational health and safety requirements at distances from the antennas where there is likely to be human activity.

It should be noted that any industry that makes sensitive electronic measurements should be aware of these electric fields generated by the radar, should they wish to set up business in the proposed Awarua Industrial Park.

[15] Devlin, John. *E-Field Calculations for the Unwin Radar*, La Trobe University, Unpublished (2008)

Appendix 6. eVLBI radio telescope at Awarua Tracking Station

Sky coverage, contribution to Trans-Tasman VLBI and SKA demonstration, and science possibilities for an 11 m radio telescope sited at Awarua, Southland

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Swinburne University of Technology

Introduction

In this document I examine some technical and science issues regarding the possible installation of an 11 m diameter radio telescope near Invercargill, at Awarua. In particular I:

1. Examine the impact of limitations of the existing mounting structure of the telescope. Guided by the engineering drawings, I assume a limited azimuth range of 60o and an elevation range of 10o to 90o. Further, I assume that the azimuth range is centred due south. This will allow the maximum observation of celestial sources near the south celestial pole.

2. Calculate example aperture sampling functions that examine the contribution that a telescope at Awarua will make to Trans-Tasman VLBI observations.

3. Briefly outline two long-term science projects that could utilise a radio telescope near Awarua and comment on this project as a demonstration project for the Square Kilometre Array (SKA).

Sky coverage of 11 m radio telescope at Awarua with existing mounting structure

Using knowledge of the mounting structure and the assumptions stated above, it is possible to calculate the range of celestial coordinates (Right Ascension and Declination) that the 11 m telescope will be able to observe.

Figure 1 shows the results of the calculation. White shaded areas indicate the right ascension and declination coordinates that can be observed at a Local Sidereal Time (LST) of 12:00:00. The figure shows that in the declination range of -70˚ to -90˚, the entire right ascension range can be continuously observed. Further north of this declination range, any given right ascension can be observed for a decreasing amount of time, with a northern limit for observation of -46.5˚.

Observing programs with this telescope should therefore primarily concentrate on sources south of a declination of approximately -60˚.

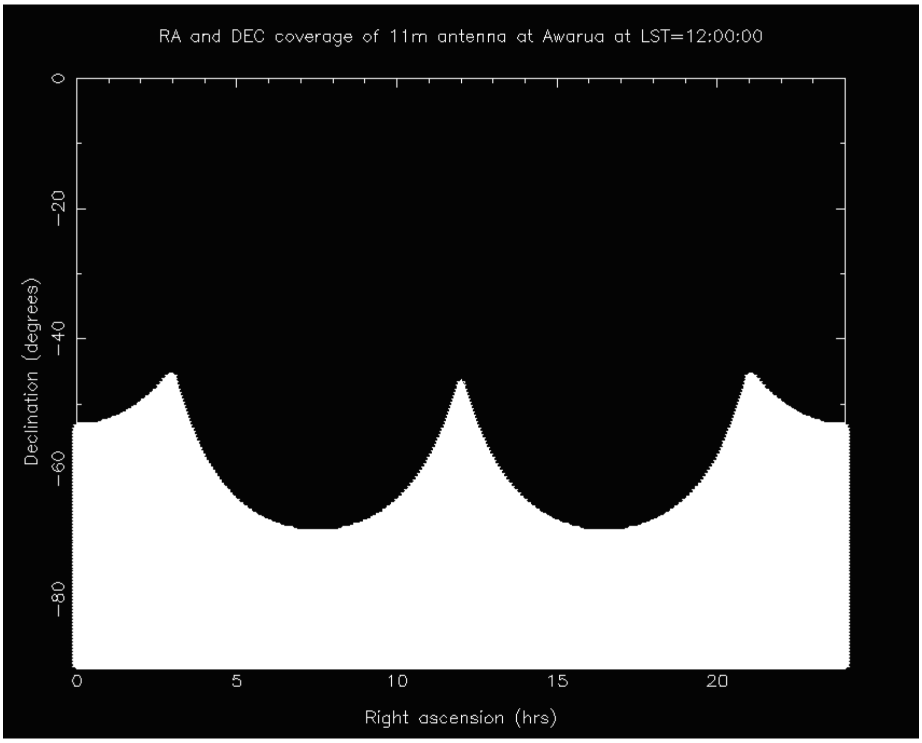


Figure 1: Calculated sky coverage for the 11 m radio telescope sited at Awarua, taking into account limitations in the azimuth and elevation ranges due to the mount design.

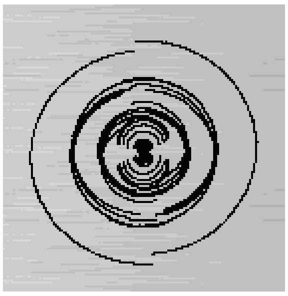
Aperture sampling function calculations

An 11 m radio telescope at Awarua can contribute to Very Long Baseline Interferometry (VLBI) observations with other telescopes in New Zealand and Australia.

In this section I quantify the improvement in the aperture sampling function for VLBI observations, due to the inclusion of the 11 m telescope in Awarua to the current Trans-Tasman VLBI array. Assumed here is operation at 2.3 GHz (stage 2 of proposed 11 m telescope project). The number and density of points in the aperture sampling function determine the quality of images that can be produced by a VLBI array. Maximising the number of points and the uniformity of their distribution is the aim in VLBI array design.

The existing array of telescopes in Australia and New Zealand is: Australia Telescope Compact Array (Narrabri, NSW: CSIRO), Mopra (Coonabarabran, NSW: CSIRO), Parkes (Parkes, NSW: CSIRO), Tidbinbilla (Canberra, ACT: NASA), Hobart (Hobart, Tasmania: University of Tasmania), Ceduna (Ceduna, South Australia: University of Tasmania), Auckland (Auckland, North Island: Auckland University of Technology).

Figures 2a and 2b show the improvement in the aperture sampling function when the 11 m radio telescope at Awarua is included as a part of this array. The number of points and the uniformity of the density of points in the sampling plane improve substantially with the inclusion of Awarua. This will lead to corresponding improvements in the imaging capabilities of the array.



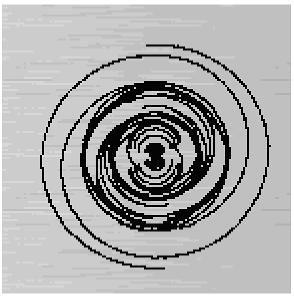


Figure 2: a) left: Aperture sampling function of the existing VLBI array in Australia and New Zealand. b) right: the improved aperture sampling function when the 11 m at Awarua is included in the array.

Long term science programs for the 11 m radio telescope at Awarua

The 11 m radio telescope, sited at Awarua, could be used for a number of long term scientific experiments, in collaboration with New Zealand and international astronomers. Two example science programs are briefly detailed here:

1. Regular monitoring of compact radio sources with a Trans-Tasman VLBI array (stage 1 and 2);

2. Long term monitoring of intraday variability in compact extragalactic radio sources with domestic New Zealand VLBI observations (stage 2);

Trans-Tasman VLBI (stage 1 and 2)

The 11 m Awarua telescope, after outfitted following the stage 1 plan outlined in section xxx, will be able to participate in regular Trans-Tasman VLBI observations at 1.6 GHz.

These observations are scheduled in week long blocks of time, 3 or 4 times a year. The Awarua telescope would observe in conjunction with the Australian VLBI National Facility which undertakes observations for a range of international users in a range of areas of radio astronomy.

The 11 m will be limited to observing at a frequency of 1.6 GHz (stage 1 and 2) and 2.3 GHz (stage 2) and at declinations according to those possible as shown in Figure 1. This would correspond to approximately 10 - 20% of observations made by the Australian VLBI array.

Further, due to the fibre connection to Awarua via KAREN, Awarua will be able to participate in e-VLBI observations, which involve the transmission of data from the telescope down high speed optical fibre networks to a central processing facility for immediate combination with the data from all other radio telescopes in the array. E-VLBI has become an important aspect of the Australian and New Zealand bid to host the Square Kilometre Array. The e-VLBI array that Awarua can participate in is considered a vital part of ASKAP, the Australiasian Square Kilometre Array Prototype and will be directly linked to Australia's \$A50m SKA demonstrator known as MIRANdA, located in Western Australia. CSIRO and the Australian Federal government have committed over \$A120m to SKA demonstration in order to secure the SKA site selection. The SKA will cost approximately \$2b and, if successful, New Zealand would likely host approximately 1% of the infrastructure of the SKA, 0.5% on the North Island and 0.5% on the South Island.

Monitoring of intraday variable radio sources (stage 2)

A large fraction of extragalactic radio sources exhibit variability in their apparent luminosity on timescales of years, months, weeks, and days. Sources that show variability on timescales of hours are known as intraday variable sources. The cause of the variability is two-fold: intrinsic, where physical processes in the extragalactic object itself modulate the apparent power output of the source; extrinsic, where the properties of the material the radio emission propagates through on the way to the Earth modifies the apparent strength of the radio source i.e. the ionised medium that exists in our galaxy.

A fundamental observation is therefore to monitor both the short term and long term variability of radio sources, in order to learn something about both the intrinsic and extrinsic physical processes at play. Observations are needed periodically on timescales of hours, days, weeks, months, and years, over the course of a 5 – 10 year period, at the least.

The 11 m radio telescope at Awarua could undertake such observations as part of a single baseline interferometer in conjunction with the 12 m telescope of the Auckland University of Technology. This could occur in stage 2 of the Awarua project, when the 11 m antenna has a 13 cm feed to frequency match the AUT 12 m.

Given the limitations on the azimuth pointing of the 11 m, a feasible program would be to concentrate on the declination region that is continuously visible to the 11 m, south of approximately -70˚. This region contains approximately 30 radio sources that can be monitored for variability and would allow a Southern Hemisphere Celestial Polar Cap Survey.

Sources at other more northerly declinations could be monitored, but less frequently and with less coverage than the polar cap sources.

Appendix 7. ASKAP Pathfinder radio telescope.

Item	Estimated cost ($000)	Estimated duration
Evaluate Awarua radio noise floor with Australian recommendations using existing unpublished MED survey	nil	1 week
Amend resource consent to allow for 12 m dish (currently four 11 metre dishes are consented).	1	2 weeks
Upgrade power line to Awarua Station to three phase	28	8 weeks
Install standby engine-alternator set at Awarua Station	30	6 weeks
Upgrade accommodation HVAC	2	2 weeks
Arrange lease for antenna on previously surveyed land	2	6 weeks
Extend lease for present station to continue beyond 2015	1	6 weeks
Establish foundations for antenna	50	5 weeks
Site civil works, including fencing, access, security upgrade	20	2 weeks
Order 12 m dish, mount and control equipment	Allow 1,100	Allow 52 weeks
Ship 12 m dish with turret mounted L-Band and S-Band feed horns	70	8 weeks
Install 12 m dish	40	4 weeks
Install hydrogen maser clock	Allow 600	Allow 26 weeks
Install station electronics, including LNA (single pixel)	Allow 70	4 weeks plus design
Station test equipment, including spectrum analyser and signal source	70	4 weeks
Install ICT equipment	60	12 weeks
Augment InverNet urban fibre-optic network to connect KAREN to Awarua Station	460	24 weeks
Total cost/ total elapsed time from order	2,604	64 weeks
Contingency @ 15%	391	10 weeks
Total cost / total elapsed time from equipment order excluding GST	**$2,995**	**17 months from order**

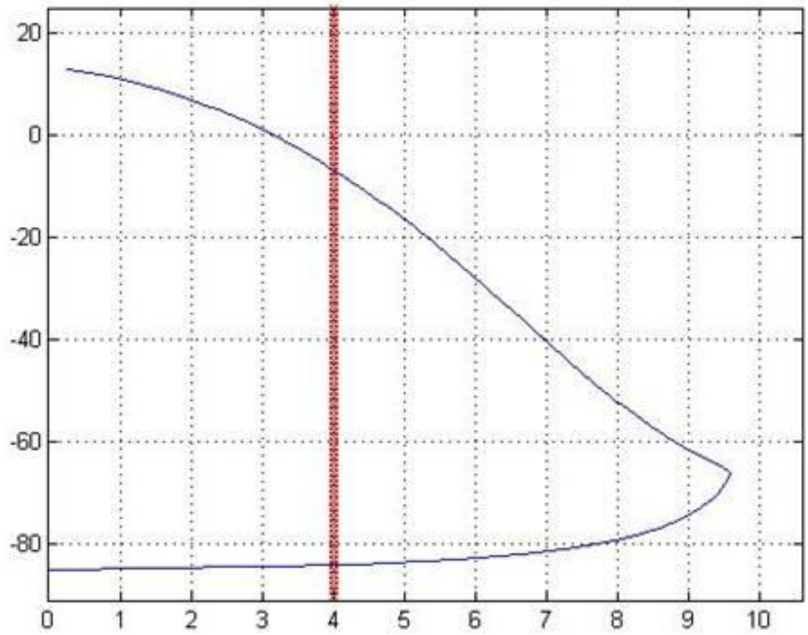
By way of comparison, it cost $440,000 to establish Awarua Station facilities for the European Space Agency, excluding the tracking antenna and equipment, but including a digital microwave radio link, lightning protection, extending the access road by 100 metres, establishing 1.7 km of power-line, equipment and personnel accommodation and all civil works.

Estimated operational costs, per year, excluding KAREN.

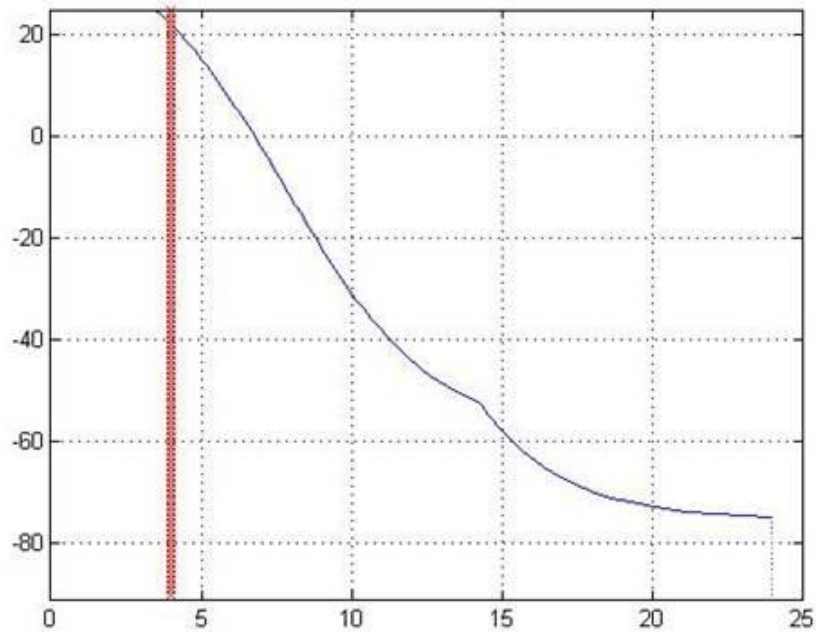
Item	Estimated cost ($000)
Site lease for antenna	10
Accommodation, including electricity, HVAC	18
Radio telescope equipment maintenance and reconfiguration requiring site visits	24
Total	**$52**

Appendix 8. SKA field of view from Awarua

Common visibility of 4 hours at -30° declination is required for SKA stations. Awarua meets this criteria.



Common Visibility plot for elevation limit of 30° (X-axis is in hours, Y-axis is declination).

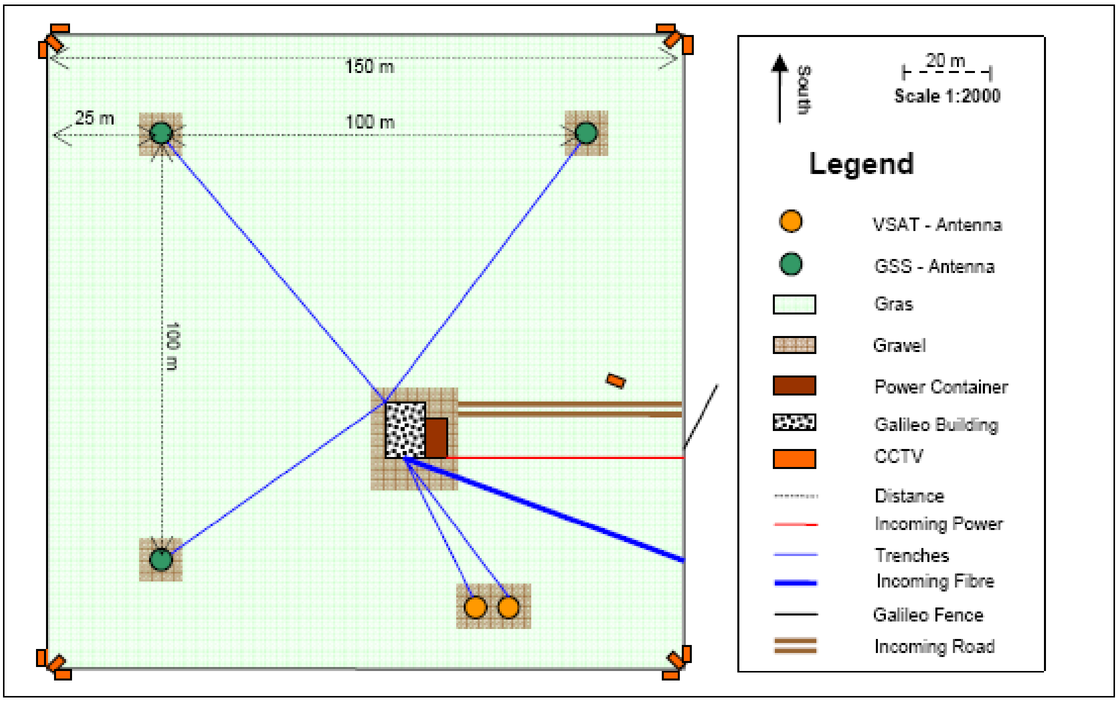


Common Visibility plot for elevation limit of 10° (X-axis is in hours, Y-axis is declination).

Calculations courtesy S Gulyaev, AUT.

Appendix 9. Galileo Ground Station

The generic drawing below shows a simple solution for a Galileo GSS station in the FOC phase. The placement of a station in the Awarua area is flexible due to the flat character of theland that is made up of wide pastures. This also means that it would be no problem to extend the site for ULS or TTC. In addition, the number of antennas is flexible as there is the amount of land needed available. The drawing below shows a possible scheme for the 3 GSS antennas requested during FOC. The area is 150m*150m = 2,25 hectar. The distance between the GSS antennas is minimum 100 meters. The GSS antennas are connected to the Galileo building in a star shape. Additionally two redundant VSAT-antennas looking north are connected to the equipment in the Galileo building. From outside regular fibre and power come to the site. VSATs and power container insure redundancy and independence. The whole site is monitored by 13 CCTV antennas. A detailed site planning will be provided if a proposal is requested. The whole site is grass-covered and the most effective way in New Zealand to keep it short is to let a number of sheep graze on the site. The foreseen size of land would bearound 200m*350m = 7 hectares.



Appendix 10. New Zealand Government – ESA Arrangement

ESA were particularly anxious to negotiate a treaty between themselves and New Zealand in order to facilitate and protect their interests at Awarua for the Ariane 5 ATV launches. For simplicity, in the end ESA and the New Zealand Government instead signed an Arrangement, which has essentially the same effect as a treaty in this case. Venture Southland assisted the Department of Prime Minister and Cabinet and Ministry of Foreign Affairs and Trade in the negotiations for the Arrangement, which was signed in Brussels in May 2007.

The Arrangement includes a clause in favour of Southland:

> "The Government of New Zealand will inform the Agency of activities likely to be of interest to it. Representatives of the Government of New Zealand and the Agency will consult from time to time with a view to identifying and pursuing projects of common interest and in particular promoting educational opportunities for students from the Southland region…This may include the provision by the Agency of scholarships or the organisation of lectures involving European experts or of special events covering space activities".

Other clauses set out requirements for ESA and New Zealand Government to inform each other of developments that may be of interest and making Venture Southland the implementing agency for Awarua Station. This means that Venture Southland is responsible for maintaining access to radio spectrum, facilitating Customs clearance and such like.

Appendix 11. Ariane 5 ATV launcher requirements

RF signal characteristics

The launcher telemetry is transmitted on two different frequencies, but on the same polarization:

- F1: 2227 MHz
- F2: 2254.5 MHz

These values are used for the first ATV launch, but may be changed to other values in the 2200-2290 MHz band: 2203.0 MHz, 2206.5 MHz, 2218.0 MHz, 2249.0 MHz, 2267.5 MHz and 2284.0 MHz.

Polarization: Left hand circular for F1 and F2

The launcher has two antennas, one on opposite sides. Each antenna transmits the RF signal of one frequency. The launcher might be rotating, leading to a cyclic change-over between the two emitted RF signals.

EIRP: + 35dBm (for 99% of solid angle)

Max bandwidth at – 3dB: ± 500 kHz

Carrier Modulation type: PCM/FM

Modulation Index $\Delta f/Rb$: 0.7

Coding: NRZ-L

Maximum data rate: 1 Mbps

Minimum flux at any ground station: -109 dBm/m^2

Frame structure: CCSDS compliant, frame length 1279 octets

Coding: Reed-Solomon (255,223), Scrambling

Antenna pointing

- Frequency diversity auto-tracking (LHCP only) on both transmitted RF signals (Nominal mode)
- Processing of real time orbital data sent from Kourou Range system and usage of that data to steer the antenna. (Back-up mode). This data is sent ten times per second.

TM reception

- Simultaneous S-Band RF launcher telemetry signal (F1 + F2) acquisition, demodulation and frame synchronisation
- Time stamping of the TM

TM processing

- Recording, Sending of Immediate Visual Check (CVI) towards a dedicated telecommunication means
- Telemetry recording of the whole TM for the pass.

Ground communications

- Real time voice coordination with Kourou

- Real time transmission of de-commutated telemetry to Kourou
- Reception of real-time pointing data from Kourou
- The network protocol versus CSG is HDLC; the data streams are time-multiplexed.
- The communication lines (64 kbps) between Kourou and the stations shall be redundant (ISDN and Inmarsat).

Simulation of TM

- End-to-End validation of the TM chain shall be possible by injection of a test signal in S-band. Insertion of the test signal shall be done either by coupler before the LNAs, an antenna probe or a test antenna.

Usage of dedicated backend equipment (AR5 Kit)

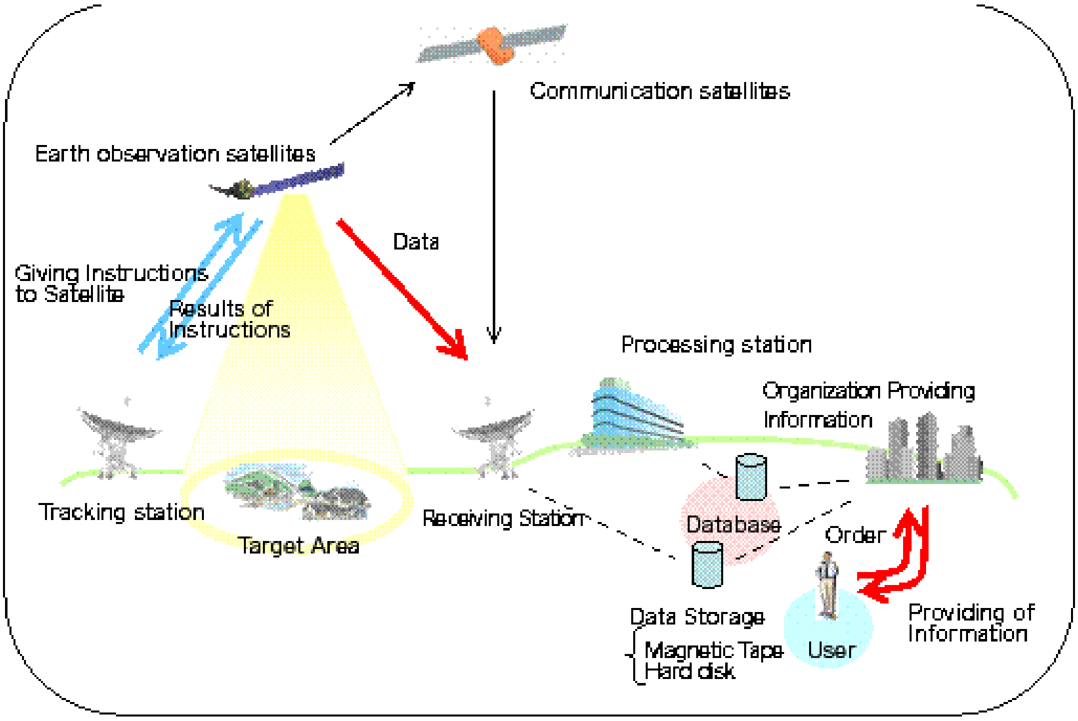
- In each "external" station the specially developed kit for Ariane 5 support shall be used. The station interfaces shall be adapted for the usage of this kit.

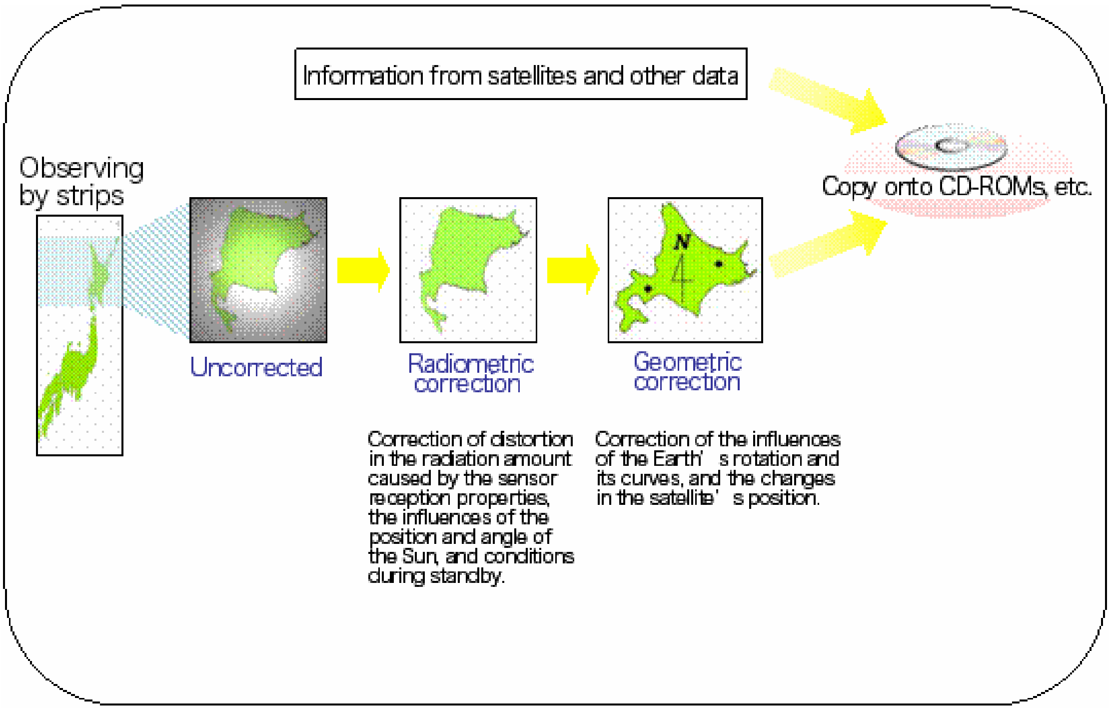
Reliability requirements

- The availability of the tracking service shall be more than 99% over one hour.
- Redundancy: all functions, except the antenna structure and related mechanics/electronics, shall be fully redundant.

Appendix 12. RSS image processing and distribution

The following two diagrams, sourced from the Restec website show pictorially the process of acquiring, processing and disseminating RSS images.





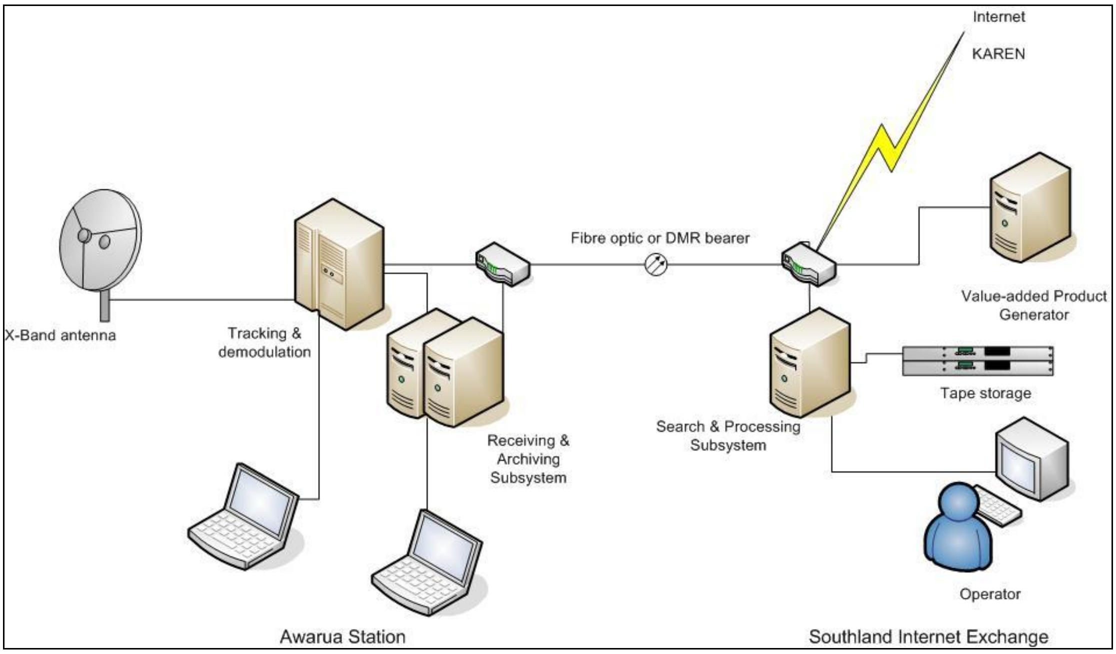


Figure 21. Proposed system block diagram

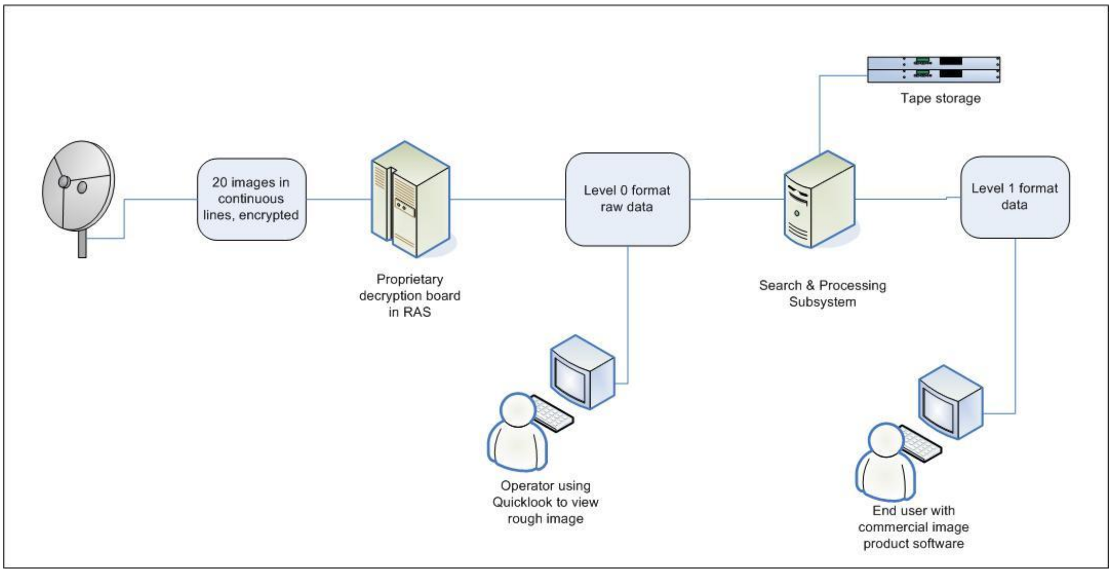


Figure 22. Proposed data flow

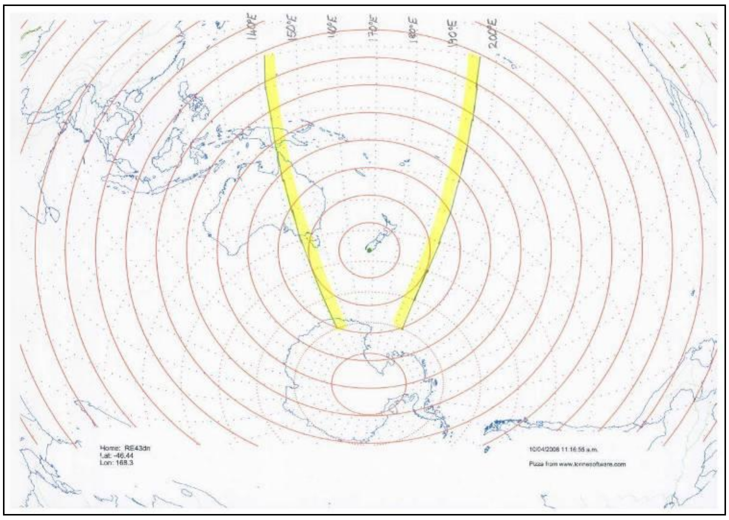
Appendix 13. Satellite coverage area

The coverage distance of a satellite, nominally orbiting at around 450 km above the earth is set out below.

Minimum antenna elevation	RSS satellite coverage distance
5˚	2530 km
2˚	2830 km
1˚	2930 km

As Awarua Station has a horizon of less than 1˚ in all directions, other than Bluff Hill at 1.5˚, an antenna at the station has a coverage distance of almost 3,000 km.

Should Awarua Station be used for downloading tape recorders as proposed for a Virtual Antarctic Station as well as direct download, a larger area is covered, as conservatively shown on the great circle map based on Awarua below.



Great-circle map of the South Pacific and Southern Oceans centred on Awarua. Distances from Awarua are in 1,000 kms.

Allowing for reasonable download times, approximate azimuths ranges that are observable at a 2,000 km horizon for various locations in New Zealand are:

Location	Western horizon	Eastern horizon	Longitude Span
Awarua	142˚E	196˚E	54˚
East Coast	154˚E	200˚E	46˚
Northland	152˚E	196˚E	44˚

Longitude coverage and spans for three sites in New Zealand at 2,000 km range

Appendix 14. ESA Missions

ADM-Aeolus mission

The central aim of the ADM-Aeolus mission is to further our knowledge of the Earth's atmosphere and weather systems. By recording and monitoring the weather in different parts of the world, ADM-Aeolus will allow scientists to build complex models of our environment, which can then be used to help predict how that environment will behave in the future. These predictions will be useful in the short-term, since they can be applied to Numerical Weather Prediction in order to make forecasts more accurate. The ADM-Aeolus mission will thus improve our knowledge of all sorts of weather phenomena, from global warming to the effects of pollution.

ADM-Aeolus will fly in a rather low Sun-synchronous orbit of 400 km and will always be in the dusk or dawn position. The wind will be measured at 90 degrees to the satellite ground track on the night side of the Earth.

Mission status

Phase A (feasibility study) was successfully completed by the end of 1999. At the end of Phase A technological work proceeded rapidly on laser and receiver design and breadbording. In July 2002, the ADM-Aeolos mission entered Phase B, which is the design specification stage. In May 2005, thermal tests on the structural model of ALADIN started.

The prime contractor is Astrium UK with Astrium France responsible for the payload (ALADIN). ADM-Aeolus is expected to launch in 2009.

Sentinel

Sentinel-1 C-band SAR

The Sentinel-1 series of satellites will address the issue of data continuity for SAR data at large. The immediate priority is to ensure such continuity for C-band data. Under the current scenario, provision of ENVISAT data to feed SAR-based services is likely to cease in the 2008-2010 timeframe. In order to meet the need for continuity, and taking into account the availability of Radarsat-2, the first Sentinel 1 satellite should be launched before the end of the Envisat operations.

The experience with ERS, Envisat and Radarsat constitutes the basis for the Sentinel-1 mission requirements and concept.

Sentinel-2 Superspectral

Numerous services of high strategic important and economic value are currently being provided based on data from the SPOT or Landsat series of satellites. The lifetime of SPOT-5 and Landsat is coming to an end. It is necessary to provide continuity and thus guarantee the availability of data to service providers and users. Enhancement as required by the growing user demand for higher service quality shall be considered. Action has to be started urgently as recognised also by ESA and EC, including the recent communication to European Parliament on Establishing a GMES Capacity by 2008.In addition, activities related to the accommodation of the IR sensor on Sentinel 2 will be added during the second part of the definition study.

Sentinel-3 Ocean

This mission, devoted to provision of operational oceanographic services has been baselined within GMES. It shall provide on an operational basis, data in support of services that have been developed since 1991 with ERS, and ENVISAT. The altimeter part of the mission will further complement that of Jason and others to contribute to a worldwide operational oceanographic service. Taking into account the global context and in particular the European needs, capabilities and plans, the Sentinel 3 should include first the elements which, being well defined and already exploited on a near operational basis, have no guaranteed operational continuity beyond ENVISAT. These elements are the high inclination altimeter and the visible-infrared element for ocean colour and sea-surface temperature based products.

In addition, activities related to the accommodation of the IR sensor on Sentinel 3 will be added during the second part of the definition study.

Sentinel-4/-5 Atmospheric Chemistry

Two pre-definition studies are to be conducted in parallel, one for Sentinel 4 and one for Sentinel 5.

The “EC’s White Paper on Space (COM(2003)673 identifies atmospheric monitoring as an area of high priority for GMES including real time services related to atmospheric chemistry, pollution, ozone and aerosols. The GMES Final Report of the Initial Period (annex to ESA/PB-EO(2004)18) restates the priorities and identifies the notional capabilities required.

ESA has identified two notional elements, the so-called Sentinel -4 and Sentinel -5, to meet these requirements. Sentinels -4 and -5 would be space-based systems operating from geostationary (GEO) and low Earth orbit (LEO) respectively.

Mission definition activities were initiated such as the “CAPACITY” study to identify the capabilities to be deployed. It is now necessary to define the system concepts for these Sentinels. Urgent action is required in the recent communication of the EC to the European Parliament on GMES (COM(2004)65) on Establishing a GMES Capacity by 2008.

The starting point is an analysis of the requirements as established mainly in IGACO theme and in the “CAPACITY” study which in turn builds in GMES, DUE and EUMETSAT related activities, the requirements derived from the need to monitor the implementation of the Montreal and Kyoto protocols, and the requirements of the Global Atmospheric Watch. Observation techniques and associated sensor concepts will be analysed. Requirements will be allocated to GEO and LEO systems and to the candidate techniques, e.g. nadir versus limb sounding, emission or absorption, etc. The spectral regions will be identified. Candidate concepts will be established and subject to trade-off. Maturity of the technology, reliability of the underlying science and experience in the user community will be criteria for selection of a baseline. The baseline will be defined in detail as required to establish consistent Mission and System Requirements and candidate system concepts

Appendix 15. Typical RSS image product pricing

The remote sensing market consists of the low-, medium- and high-spatial-resolution sectors. As a general rule, the market price for imagery is inversely proportional to the spatial resolution of the dataset (see Figure 12). Put another way, the dollar cost per area covered is resolution-dependent. Thus, low-resolution images (e.g. NOAA AVHRR, and geostationary satellite data from Envisat MERIS and EOS MODIS) are very inexpensive, or free. By contrast, medium-resolution satellite data (e.g. SPOT-XS, Landsat-ETM+ and ALOS-AVNIR) cost on the order of a few dollars per square kilometre of coverage. High-resolution imagery (e.g. Quickbird and Orbview) costs on the order of tens of dollars per square kilometre of coverage.

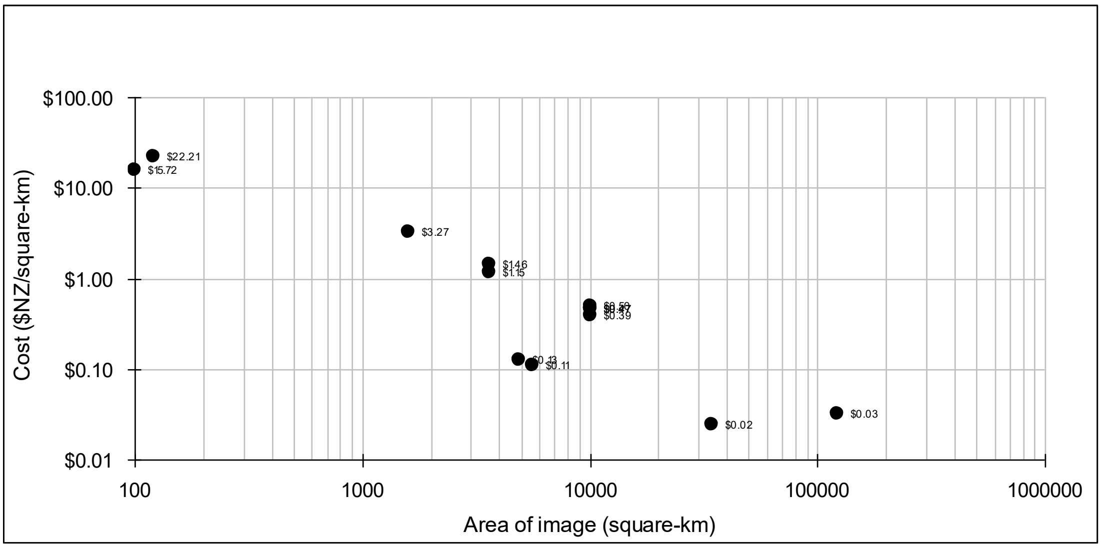


Figure 23. Current cost of a single remote sensing scene for a variety of sensors. Prices calculated as at May 2008, inclusive of GST, and excluding programming fees. Costs are for recent, not historical, data.

The size of the images provided in the different sectors (high-, medium-, or low-resolution imagery) also tends to be determined by the spatial resolution of the sensor. Low-resolution sensors provide frequent coverage (daily, or every few days) over vast areas (10,000,000 km^2), but at quite low resolution (hundreds to thousands of metres), while very-high resolution satellites provide infrequent coverage (every month, or so) over much more restricted areas (around 100 km^2), but with very fine detail (decimetres to metres). Medium-resolution satellite images fit somewhere in-between.

The cost of imagery is determined by the agencies, or companies that develop and launch the satellites. In some cases, e.g. Landsat-ETM+, the cost of imagery has been determined by legislation in the US Congress, while in other cases the price is determined by the market's ability to pay, e.g. fully commercial systems, such as Quickbird. Imagery from all remote sensing satellites falls somewhere between these extremes and so it is not surprising to find that the cost of imagery to the consumer can, in some cases, bear little resemblance to the true cost of acquiring the imagery and paying for the development and ongoing costs of the satellite development.

Prices are in New Zealand dollars unless otherwise noted and were correct at the time this report was prepared.

ENVISAT

Current ENVISAT prices from MDA Information Products are as follows:

Archived images	$664
New Acquisition images	$1,012
ENVISAT programming for specific images, 14 days notice	$291
ENVISAT programming for specific images, 3-7 days notice	$1,670
ENVISAT image processing, within 14 days	no charge
ENVISAT image processing, within 3 days	$506
ENVISAT image processing, within 14 days	$1,670

It should be noted that ENVISAT is owned and operated by ESA and so is run on more or less a not-for-profit basis and is thus ENVISAT images are rather cheaper than, say, SPOT-Image products. It is likely that the prices listed above could be reduced considerably by using a ground station and processing facility in New Zealand under the New Zealand – ESA Arrangement.

Radarsat-2

Radarsat-2 data prices vary from $4,600 to $7,000, depending upon beam mode, resolution, and processing level. Programming request fees range from $150 for non-time-critical to $4,600 for emergency programming. There are also additional fees for rapid delivery.

Scene sizes range for 56 km x 100 km to 400 km x 400 km images, depending on the acquisition mode.

SPOT-Image

SPOT-Image pricing for a typical recent image, 60 km x 60 km – 60 x 80 km, is approximately $6,000. Where the target area of lesser size falls laterally over, say, two image areas, both images need to be purchased. Some 160 images cover New Zealand, i.e. around $960,000 for full country coverage.

SPOT data of New Zealand is currently at full international pricing as the data is captured onto a tape recorder on the spacecraft which is downloaded at Kiruna. A station at Awarua would use direct reception of images and so avoid using of the on-board tape recorder. This would allow images from any pass to be available at a nominal marginal cost within New Zealand.

Restec ALOS

Typical Restec prices for ALOS synthetic radar images are:

End users, $300 per image.

Users who purchase standard products for development and sale of value added products, $600 per image.

Appendix 16. Australian Centre for Remote Sensing (ACRES)

ACRES comprises three sections–Services, Engineering and Science and Strategy. It has a staff of 39 with an annual cost of operations of approximately $AUS5million, which is funded by appropriation of $AUS3.8million and revenue of around $AUS1.2million.

Data is acquired though ground stations in Alice Springs and Hobart from a variety of satellites including the NOAA series of meteorological satellites, Landsat-5, Landsat-7, ALOS, TERRA, AQUA, ERS-2, EO-1 and Radarsat-1. The Alice Springs station is located at near the centre of Australia to easily access data from low-earth orbiting satellites covering the entirety of Australia as well as Papua New Guinea and parts of Indonesia. Hobart proves coverage of New Zealand as well as much of the eastern and central Australia and islands in the Southern Ocean.

Current ACRES government programmes include:

- Bushfire detection and monitoring, providing near real-time information for Australia via the Internet (called Sentinel) through regular downlink of MODIS satellite imagery around ten times per day.
- Mapping imagery is provided by federal and state mapping agencies to update and produce content for a range of maps for use by emergency services, land development organisations, tourism industry and the general public.
- Greenhouse gas studies, providing satellite imagery to the Australian Greenhouse Office for the study of carbon accounting which is directly used to calculate greenhouse gas emissions.
- Monitoring land clearing. Several state governments rely on satellite imagery to monitor the extent of land clearing, predominantly in agricultural areas. The work is done from the perspective of environmental management and to monitor activities of individual landholders with some prosecutions relying on satellite imagery for evidence.
- Bureau of Meteorology relies on ACRES to download satellite data.
- Emergency service/disaster monitoring, where satellite data is used to provide before and after imagery of locations affected by natural disasters. The archive is used for pre-disaster imagery and post-disaster imagery is scheduled, acquired and provided to agencies involved in disaster recovery activities.
- Water quality monitoring, where data from several satellites are used to monitor sediment plumes arising from dredging in the Great Barrier Reef World Heritage Area. These data were provided to the park authority who we able to use them to prevent damage to sensitive regions.

Current ACRES industry activities include:

- Mineral exploration. ACRES satellite imagery has a long history in being used to discover and map minerals.
- Agriculture, where the private sector uses ACRES imagery to help provide agriculture services such as yield assessment, yield prediction and property management planning.
- Land use monitoring, including land-use assessment, mapping, modelling and change detection over time with a view to better resource management and future planning.
- Features mapping, where the private sector performs mapping functions that rely on satellite imagery, including preparing maps for urban planners, transport planners and telecommunications organisations.

Emerging government applications

Proof-of-concept projects have already demonstrated the use of ACRES radar satellite imagery as part of monitoring programmes in Australia's maritime zone to help detect:

- Daily monitoring of land and water environments, including the coastal zone,
- Illegal fishing vessels
- Potential illegal immigrants
- Dumping of oil into the ocean.

ACRES is also expecting to provide infrastructural support for Pacific Islands under the AusAid Pacific Governance Programme.

Appendix 17. PrioraNet

PrioraNet is a collaboration of worldwide satellite ground stations owned by the Swedish Space Corporation (SSC) and Universal Space Network (USN), as well as other international partners. Combining the strength of these two space communications industry leaders and third party collaborative partners, PrioraNet provides comprehensive satellite communications that offers near-global coverage of satellites in any Earth orbit.

Functioning as a single integrated service for all satellite TT&C and communications needs, PrioraNet includes ground stations that are owned and operated by USN, SSC and stations owned by worldwide affiliate partners at strategic geographical locations. PrioraNet operations management is provided by three geographically diverse Network Management Centers (NMC), two of which are in the US (California and Pennsylvania) and one in Sweden (Esrange in Kiruna). In addition to providing control and monitoring, the NMC also provides customers with a single point of access into the global network. One point of connection is all that is required to access a world of possibilities.

PrioraNet has become the largest commercial network for ground station services in the world and a leader for satellite communication support.

PrioraNet Services

PrioraNet services can be readily configured to meet various satellite mission needs, including routine on-station services and mission critical operations such as launch and early orbit. Integrating existing worldwide, multi-mission ground stations into a comprehensive network allows the PrioraNet team to provide system solutions in an efficient and cost-effective manner.

Mission Control Services

Mission control services for GEO and LEO satellites as well as payload tasking, testing and commissioning operations.

Telemetry, Tracking & Command Services

Ground station coverage for TT&C available for virtually any orbit in a variety of frequency bands (S, X, L, Ku and Ka services)

Payload Data Acquisition Services

Satellite Data Acquisition services to acquire data in direct downlink mode and for downloading on-board satellite memory, regardless of orbit location.

Mission Management Services

PrioraNet provides Mission Management Services related to satellite control, TT&C, data reception, data processing, teleport services and ground segment design. This involves technical development, installations, studies and other consulting work.

Features and Benefits

Contact on every orbit Unparalleled coverage including both high latitude stations for polar and high inclination coverage and strategically placed equatorial stations for low inclination coverage.

Cost-efficiency Highly automated, multi-mission ground stations that are controlled from Network Management Centres. Customers connect once and gain a world of satellite communications assets.

Network solutions A global wide area network interconnects the elements of PrioraNet. This network is sized to support most customer needs. However, additional communication circuits can be quickly deployed on a mission-by-mission basis to meet unique data communications needs.

Single access point Only one communication interface is required to be set up and only one contract to be signed for a world of PrioraNet services.

Reliability PrioraNet users benefit from a world of experienced ground station suppliers, some in operation since the 1970's.

Availability New station ground station assets are constantly being added to the PrioraNet global network to assure availability to our growing customer base.

Appendix 18. Satellite Earth Station Budgets

Antenna, receive and tracking system

It is proposed to establish a permanent antenna at Awarua Station. The nominal desired figure of merit is a G/T of 31 dB/K at X-Band, which in practice means a Cassegrain, or Gregorian (dish) antenna of around 5.5 meters diameter.

X-Band receive only

This station comprises the basic RSS station equipment and forms the basis for this proposal. The station would receive data from RSS satellites, including at the minimum SPOT and ENVISAT:

- X-Band antenna with auto-track capabilities,
- Full RF and baseband equipment for reception and demodulation in X-Band,
- M&C system for automatic operations.

The cost of this option is $5,300,000.

Receiving and archiving subsystem

The real-time RAS receives demodulated raw data from the receive system at a rate that will usually be in excess of 500 Mbps, displays a moving window display and archives the Level 0 raw data. The RAS is proposed to be hosted on a high speed, hot-standby server with RAID and DLT or AAT (tape) storage, connected to the receive system with a proprietary direct receiving card. The direct receiving card may include decryption firmware.

The RAS will require proprietary hardware for SPOT, costing around $1,500,000. Additional hardware to access ENVISAT is negligible.

Search and processing subsystem

The SPS software is responsible for generation, manipulation and distribution of image products. The SPS performs radiometric and geometric correction of image data and image data processing standard image product generation. It also provides orbit, attitude and sensor models to support data correction and processing. It includes a tool for catalogue searching to users and generates pre-processed image products. It is proposed to run the SPS on a server at SIX.

It is proposed that validated external users will be able to log into the SPS to order image products and have them delivered via either the Internet, or KAREN.

The cost of software licences for the SPS to extract and use images ranges from almost free for ENVISAT to between $500,000 and $1,000,000 per year for SPOT, depending on negotiations and access required.

Value added product generator

The VPG software produces value-added products from standard products, such as precision-correction image, ortho-corrected images, digital elevations models, and road and building networks from image data. These data are fed to the SPS for distribution to users. The VPG also receives work orders from the SPS. It runs on either the same server as the SPS, or on a separate server in SIX.

Capital expenditure

X-Band receive-only station

Engineering design and establishment	$140,000	
Site civil works	$70,000	
X-Band station equipment, incl. 5.5 m antenna, mount, RHCP feed, tracking, RSS subsystem with demodulator for SPOT and ENVISAT @ €930,000	$1,860,000	
Shipping	$70,000	
Installation	$100,000	
Spares @ €50,000	$100,000	
Spectrum analyser and other test equipment	$100,000	
Receive subsystem total		$2,440,000
SPOT processor	$1,500,000	
Server farm	$40,000	
Total Receiving & Archiving Subsystem		$1,540,000
Value-added Product Generator software		$400,000
		$4,380,000
Contingencies @ 20%		$880,000
Total capital investment		$5,260,000

S-Band receive-only upgrade

S-Band hardware incl. dichroic subreflector, monopulse feed, tracking and documentation @ €250,000	$500,000	
Spares @ €50,000	$100,000	
		$600,000

TT&C S-Band transmitter upgrade

S-Band hardware, incl. GPS receiver, 2 channel up-converter, 125W SSPA and documentation @ €250,000	$500,000	
Spares @ €50,000	$100,000	
		$600,000

KAREN connection

Establish local backhaul	$200,000	
		$200,000

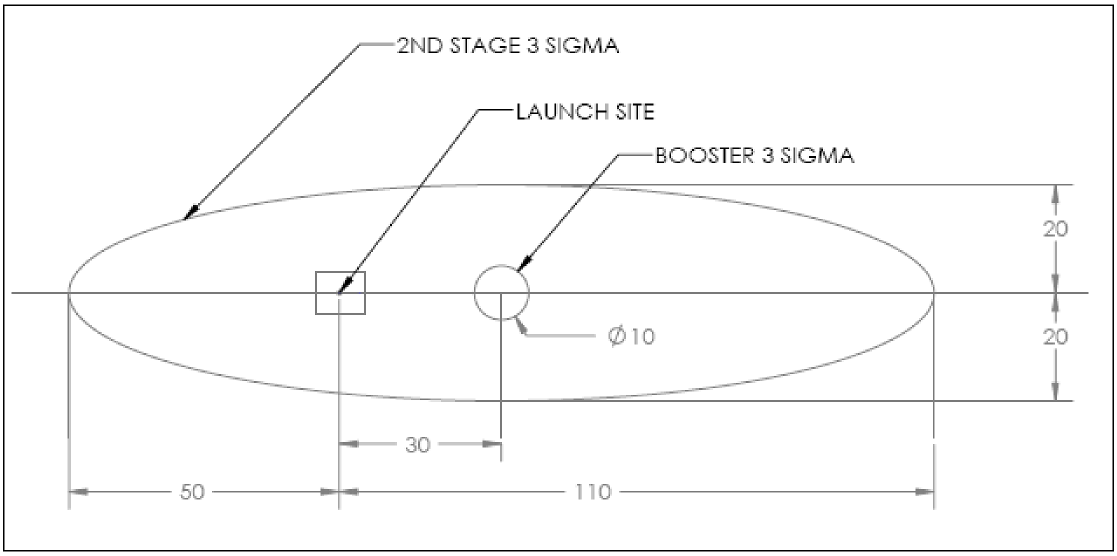
Operating expenditure

Annual operating costs are as follows. Prices exclude GST.

Awarua Station rental and maintenance at cost	$30,000	
SIX rental	$60,000	
Telecommunications	$30,000	
IT upgrades and maintenance	$40,000	
SPOT-Image licence (negotiable)	up to $1,000,000	
ENVISAT licence	nil	
Staff expenses, including salaries	$250,000	
Total OPEX		$1,410,000

Appendix 19 Suborbital launch site requirements

Downrange safety is paramount for any launch. An exclusion zone is required The exclusion zone extends 110 kilometres from the launch site in the direction of the launch and 50 kilometres away from the launch direction, as shown in the diagram below.



Downrange clearance requirements for suborbital launches with 86° launch elevation. Distances in kilometres.

Appendix 20. Southland economic benefits

Some benefits to the Southland economy arising from space and radio science

Robin McNeill
Enterprise Projects Manager
Venture Southland
1 April 2008

Venture Southland has been involved in the development and construction of two radio and space science projects at Awarua: the Unwin Auroral SuperDARN radar and the Awarua Rocket Tracking Station. Venture Southland has also facilitated the 'Zaphod' radio astronomy project, which is currently being implemented, and has taken active involvement in the SKA radio telescope project. Venture Southland has been working on establishing eVLBI radio astronomy facilities at Awarua and is now facilitating the installation of a proposed permanent dual S-Band / X-Band satellite and rocket tracking antenna at Awarua along with a local remote sensing image processing facility in Invercargill.

Direct tangible contributions to the local economy that arise from the completed projects total around $1.6M over ten years. At least $4.5M further contribution to the economy from down-stream projects are expected.

Indirect and intangible benefits arising from the projects completed to date are impossible to quantify, but are very significant.

Tangible benefits

Unwin Radar

The Unwin Auroral SuperDARN radar was constructed in 2003 and is managed by La Trobe University and cost around $3M to build. It measures ionospheric and seascape conditions to the south of New Zealand in conjunction with another station at Brunny Island, Tasmania. Some $½M of the construction was provided by Invercargill engineers, technicians and contractors and saw the development of a new design in lattice towers. Engineers from Australia visit Invercargill on average about 2 weeks each year to work on the station. An on-going maintenance contract exists with a local telecommunications construction and maintenance company, worth in the order of $10,000 per year and there is a site lease of around $5,000 per year.

Local CAPEX, 2003		**$500,000**
Local OPEX	$15,000 per year	
Local accommodation	$3,000 per year	
Ten year local contribution, excluding CAPEX		**$180,000**

[Addendum 2009] Since this paper was first published, ASI Ltd, the principal contractors for Unwin Radar, have been invited by La Trobe University to oversee the installation and commissioning of the new SuperDARN radar in Tasmania which is to be built in mid 2009.

Awarua Rocket Tracking Station

The Awarua Rocket Tracking Station was built in conjunction with CNES (French Space Agency) for ESA (European Space Agency), project managed and facilitated by Venture Southland. ESA paid for all CAPEX and have undertaken to pay for the site maintenance, leases and suchlike for the next 10 years. Once the station was built, ESA gifted the station to Venture Southland. Currently the station is solely used for tracking Ariane 5 ES ATV launches, the first of which occurred on 9th March 2008. At least 5 more launches are anticipated over the next 10 years.

Local CAPEX, 2007-8		**$400,000**
Local OPEX	$30,000 per year	
Local technical support for launches	$10,000 per year	
Local accommodation	$12,000 per year	
Ten year local contribution, excluding CAPEX		**$520,000**

Zaphod radio astronomy

Zaphod is a low frequency radio astronomy project, run from AUT Engineering Department in association with the Southland Astronomical Society. The telescope measures radio emissions from the Sun, Jupiter and a number of radio sources outside of our solar system. Jupiter's current declination makes southern hemisphere observations important.

The monetary cost of the project is in the order of $200 as all the facilities, equipment and expertise has been provided by AUT and Venture Southland (the latter through allowing free use of the Awarua Rocket Tracking Station facilities and a certain amount of expertise).

Local CAPEX, 2007-8	**$200**
Local OPEX	**nil**

It should be noted that although the economic contribution is non-existent, this project offers the potential for lay people to become familiar with radio science and at the same time make useful contributions to international science.

eVLBI radio astronomy

Venture Southland purchased an 11m antenna from Telecom New Zealand for a nominal sum in 2004, worth around $60,000. It is intended to use the antenna for eVLBI (electronic Very Long Baseline Interferometry) radio astronomy, working in conjunction with the new AUT 12m dish to be installed at Warkworth, as an important demonstrator project for the SKA project, working with Swinburne Technical University. A science proposal has been developed and preliminary budgets prepared. The project requires the use of KAREN: since the project was embarked upon, it has been decided elsewhere that although KAREN fibre will pass through Invercargill, there will not be a KAREN POP established, effectively stalemating the project. Around $50,000 is required to establish the antenna and facilities further to a KAREN connection.

Follow on projects

Arising directly from visits to, and leads from, the Awarua Rocket Tracking Station, a number of follow-on projects have identified and are being actively pursued by Venture Southland. These projects have only become viable through serendipitous connections and word of mouth from ESA engineers visiting the Awarua Station. The projects currently being worked on include:

1. the installation of an ESA Galileo GGS Ground Station worth $600,000.

2. the installation of an X-Band satellite tracking station as part of the Swedish Space Corporation (SSC) “Virtual Antarctic Station”, worth in the order of $1M. A Memorandum of Understanding has been signed between SSC and Venture Southland to this end. When this projects go ahead, which is dependant on SSC signing up sufficient customers, an SSC subsidiary will be established in Invercargill.

3. the installation of a dual S-Band / X-Band launcher and satellite tracking station, costing around $1.5M. The station would be used by ESA for subsequent Araine 5 ATV launches, contributing in the order of $300,000 in revenue for each launch, i.e. $1.5M over the next 10 years. The station would also provide remote sensing data (optical and synthetic aperture radar) for New Zealand Government departments, local government and CRIs. The station would require to be connected to KAREN. Savings of several millions of dollars a year could be expected to arise for New Zealand as well as providing 2- 4 full-time skilled jobs in Invercargill, i.e. around $3M over ten years.

4. SKA. Southland has been identified as being able to make a significant contribution to the SKA through extending the base-lines from Western Australia and so markedly improving resolution of the SKA telescope. The economic outcomes to the local economy arising from installing 50 to 100 12 metre dishes and maintaining them would amount to some $5M in civil works alone and another $5M, or so in installation effort. Ongoing contributions to the economy in the order of $1M per year would be a minimum.

Intangible benefits

It is almost impossible to quantify the enormous intangible benefits arising from the little work already done: arising from the Ariane 5 ATV launches, New Zealand Government and ESA have signed an ‘Arrangement’, which includes a clause of tremendous potential benefit to Southland:

> “The Government of New Zealand will inform the Agency of activities likely to be of interest to it. Representatives of the Government of New Zealand and the Agency will consult from time to time with a view to identifying <u>and pursuing projects of common interest and in particular promoting educational opportunities for students from the Southland region</u>…This may include the provision by the Agency of scholarships or the organisation of lectures involving European experts or of special events covering space activities”.

So far, this clause has only been exercised to the extent of organising a museum exhibition in the Southland Museum, a public talk in Invercargill by an ESA astronaut and senior ESA officials, and school visits. Southland does not have a tertiary research teaching organisation and thus these sorts of visits and interactions provide one of the few ways in which we can excite our youth to study science, engineering and mathematics.

Contrary to conventional wisdom, cities without research tertiary institutions are often attractive to academics, researchers and professionals for the lifestyle they offer. Often such professionals find it difficult to find jobs in places such as Invercargill unless there is a ‘critical mass’ of technology. There are many anecdotal stories: the renowned, late Professor RHT Bates chose to teach at the University of Canterbury, let alone New Zealand, only because Christchurch was the closest place he could teach with access to the fly-fishing on the

Mataura River. The present author considers himself extremely fortunate to be able to find work in his chosen field in Invercargill. At least two of the three technicians operating the Awarua Station for the Ariane 5 ATV launch were subsequently motivated to seek work in Southland. The present author is aware of at least two professional engineers who would very much like to move to Southland to work on space and radio science if and when possible. The contribution such people (the present author excluded) make to the fabric of society in smaller cities is often significant- from playing in local orchestras to participating in the affairs of NGO's.

That there are now useful facilities at Awarua and a cohort of expertise in Invercargill means that Awarua is attractive to base subsequent projects that could have gone elsewhere: instead of having to establish an entire station for their own purposes, researchers, or developers only need to fund upgrades, or provide their own specialised equipment. This can make significant savings on project budgets and can even move projects from being unaffordable to practicable. On this basis, there is at least one useful space project that Venture Southland has discussed and has had assurances of later involvement, that cannot be discussed here for commercial reasons, that would see the establishment of a whole new industry in New Zealand being set up in Southland. This project is worth perhaps 5 professional engineering jobs and millions of dollars each year.

The importance of serendipity and word of mouth, supported by a solid track record in undertaking like projects cannot be overemphasised. Purely on the strength of Awarua and Venture Southland's reputation in ESA, we have hosted visits from the Swedish Space Corporation with the express purpose of collaborating on further projects and are in serious discussion with other agencies.

The direct impact on the local workface arising from the radio and space science projects to date have not been analysed, but anecdotal evidence indicates that the present projects to date have seen the establishment of 1 to 1 ½ new full time technical positions.

Appendix 21. The Case for Space: The Impact of Space Derived Services and Data

Commissioned by South East England Development Agency (SEEDA), July 2009.

OXFORD ECONOMICS

The Case for Space:
The Impact of Space Derived Impact and Data
Final Report - July 2009

1 Executive summary

Further to the 2004/05 study on the economic contribution of the UK's space industry, this report supports the evidence that the sector is still among the UK's fastest growing…

- The UK space industry is a UK success story, growing in real terms by around 9% a year since 1999/00 – more than three times faster than the economy as a whole. And it has the potential to continue to grow as rapidly over the next decade as new technologies and applications are developed that rely on space derived data and services, including location based services for mobile phones, improved satellite data for weather forecasting and integrated applications involving more than one aspect of space data and services together with terrestrial complements.

- Strong growth in R&D investment will be needed to underpin future growth.

... and among the most productive…

- With GDP per worker around £145,000 in 2006/07, productivity is more than four times the UK average. In part, the space industry's high productivity reflects the very high levels of capital investment undertaken by firms in the sector. But the industry's labour force is also highly skilled, with more than 60% or workers being qualified to at least graduate level - compared to 30% for the UK active population.

…and a substantial industry in its own right…

- On a turnover of £5.9 billion, the UK space industry directly contributed around £2.8 billion to UK GDP in 2006/07. This means that it is comparable in size with the web design industry and larger than the market research industry, software publishing and even call centre activities.

- The presence of an upstream industry in the UK is likely to have stimulated benefits to the downstream sector that would not otherwise have materialised.

- Employment in the UK space industry reached 19,100 in 2006/07.

…supporting around 68,000 jobs in the UK both directly and through its spending…

- As well as being a substantial generator of activity in its own right, the space industry also helps to generate GDP and employment throughout the rest of the economy. For example, more than 35,000 UK jobs are supported by space industry purchases of goods and services from companies in its supply chain. And the spending of workers directly and indirectly employed by the space industry helps to support a further 13,600 UK jobs.

- In total, the space industry helps to support almost 68,000 jobs and generates about £5.6 billion in GDP through direct and economic multiplier impacts.

… and contributing to regional development throughout spending across the value chain…

- Despite the space industry being concentrated in a few regions (mainly the South East), it supports a high number of jobs in other UK regions through its purchases to suppliers and spending throughout the value chain.

The space industry also helps to improve the performance of the wider economy…

- But the contribution of the space industry to the UK economy goes much wider. In particular, there are a number of catalytic or spillover impacts whereby the space industry helps to facilitate improved supply-side performance of the UK economy, creating capabilities and enhancing productivity across the wider economy.

…partly through its substantial investment in R&D…

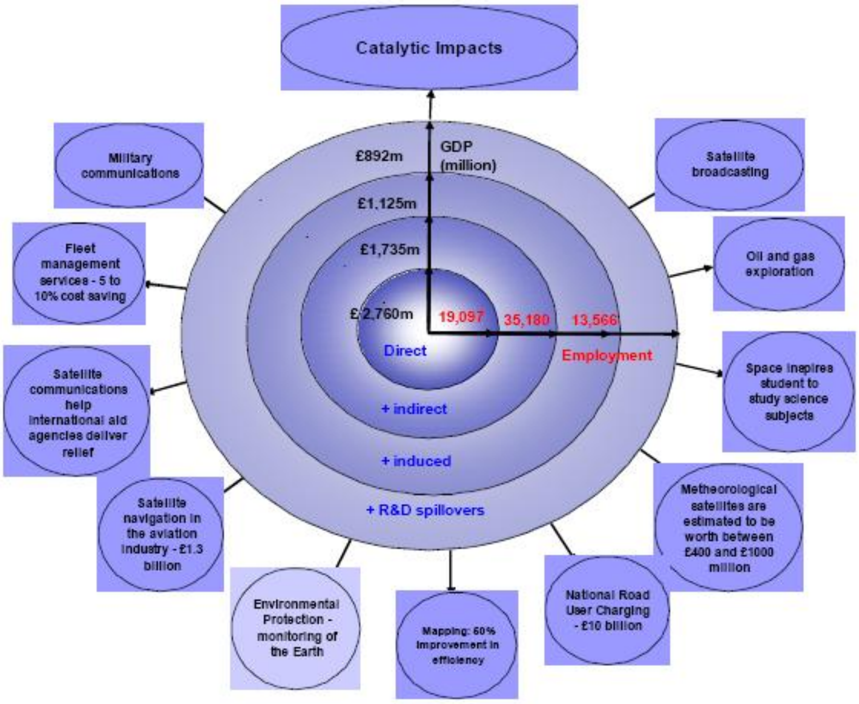
• Overall research and development (R&D) expenditure in the space industry was £130 million in 2006/07. This level of investment is equivalent in monetary terms to almost 5% of the industry's direct value added (i.e., its GDP contribution). This means that the UK space industry is about three times more R&D intensive than the economy as a whole.

• The technological advances that come about as a result of R&D investment in the space industry can be transferred to firms in other sectors in the form of 'spillover' effects. Previous research by Oxford Economics suggests that such spillover effects are very large, with R&D investment by the aerospace sector generating a social return of around 70% - i.e. every £100 million invested in R&D leads to an increase in GDP of £70 million in the longer term.

• On this basis, we estimate that the space industry helps to generate £900 million a year of GDP in the UK due to the spillover effects of its R&D, on top of its £5.6 billion of direct and multiplier impacts. So, we calculate that the space industry overall currently contributes at least £6.5 billion a year to UK GDP (see Figure 1-1).

• Additionally, the application of space derived services and data further contributes to the UK economy by facilitating the provision of a wide range of services to business and consumers, and by enabling the UK's economic infrastructure to be used more efficiently (see Figure 1-1 for some examples). It is not possible to accurately quantify the value of all the additional benefits.

Figure 1-1, The contribution of the UK space industry and examples of catalytic effects



…but also by enabling communications across the globe…

• Many UK organisations operate in parts of the globe where land based communication are poor. For these organisations satellite based communications are of key importance. Included here are; the offshore oil & gas industry, deep sea shipping, international aid agencies and the aeronautical industry. Satellite communications are also of significant importance in disaster recovery situations, or to businesses to offer guarantees of service continuity even if an event closes down land-based communication channels. This includes ensuring that "firms and markets can communicate with each other during an emergency, even if some lines of communication are not operational."

…improving the operation of the UK transport network…

• Improved transit based on satellite navigation will lead to time savings, falls in carbon emissions and less accidents, with a potential benefit to the UK economy of up to £10 billion a year.

• A National Road user charging (RUC) system, where charges are based on a combination of time, distance and space, using technologies based on satellite navigation, would bring benefits of £10- £12 billion to the UK.

• Location based services are applications that leverage the user's physical location to provide services. Although these applications are currently in their infancy, there exists the potential for large growth as it becomes commonplace to have a satellite positioning chip in mobile phones.

…enhancing the accuracy of weather forecasts…

• The weather affects all aspects of the UK economy, from causing delays in transport, to increasing demand for electricity, to loss of life due to unexpected weather patterns. The value of improvements to weather forecasting brought about by the use of satellite data is estimated at between £400 and £1000 million to the UK every year.

… helping protect the environment…

• Earth observation has become an essential tool for monitoring climate change (such as measuring water levels), emergency responses (by for instance, providing an accurate picture of areas affected by flooding), natural resources (such as sources of pollution), sustainable development (such as applications in agriculture), or population dynamics (observing air quality).

…and inspiring people to study science

• Space inspires young people to study science subjects - space was the second most popular factor motivating physics degree involvement. The additional taxation revenues, from a science graduate compared with a non-graduate, to the Exchequer over a graduate's working lifetime is around £135,000.

The UK space industry has a great growth potential…

• Despite the current economic slow down, the UK space industry is forecasted to grow, on average by about 5% a year until 2020. Raising R&D intensity could help sustain even stronger growth of perhaps 7% a year – in line with growth in the last 3 years. However, a sustained decrease in R&D, or if the recession impacts even more severely on UK companies, growth could fall to just 3%. These scenarios imply that the industry will directly employ between 22,000 and 30,000 people and contribute between £4.1 and £7 billion to GDP in 2020.

• Under these assumptions, the UK space industry is estimated to support between 72,800 and 115,000 jobs in total, including direct and multiplier (indirect and induced) impacts, with a value added contribution to GDP of between £8.4 and £14.2 billion in 2020.

… which can be realised with strong R&D investment.

• The scenario analysis shows that, under the current R&D spending patterns, the UK space industryin 2020 will support a further £1.3 to £2.2 billion of GDP in the UK due to spillover effects of the R&D it will undertake, and potentially much more if support to funding allows R&D intensity to be increased, by increasing productivity even further, and by allowing the UK space industry to remain competitive in the international marketplace.