The Nautilus Institute *for Security and Sustainability*

Expanded Communications Satellite Surveillance and Intelligence Activities utilising Multi-beam Antenna Systems

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Summary

The recent expansion of FORNSAT/COMSAT (foreign satellite/communications satellite) interception by the UKUSA or Five Eyes (FVEY) partners has involved the installation over the past eight years of multiple advanced quasi-parabolic multi-beam antennas, known as Torus, each of which can intercept up to 35 satellite communications beams. Material released by Edward Snowden identifies a 'New Collection Posture', known as 'Collect-it-all', an increasingly comprehensive approach to SIGINT collection from communications satellites by the NSA and its partners. There are about 232 antennas available at identified current Five Eyes FORNSAT/COMSAT sites, about 100 more antennas than in 2000. We conclude that development work at the observed Five Eyes FORNSAT/ COMSAT sites since 2000 has more than doubled coverage, and that adding Torus has more than trebled potential coverage of global commercial satellites. The report also discusses Torus antennas operating in Russia and Ukraine, and other U.S. Torus antennas.

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Glossary

ACTi	Antenna Technology Communications Inc.
AFB	Air Force Base
AFN-BC	Armed Forces Network Broadcast Center
AFRTS	American Forces Radio and Television Service
ARABSAT	Arab Satellite Communications Organization communications satellite
ARC	Archive/Retrieval/Catalogue
ASD	Australian Signals Directorate
BND	Federal Intelligence Service (Germany; *Bundesnachrichtendienst*)
CDAA	Circularly Disposed Antenna Array
CIA	Central Intelligence Agency
COMSAT	communications satellite; COMSAT Corporation
COTS	Commercial off the shelf
CSE	Communications Security Establishment
CSOS	Composite Signal Organisation Station
DCA	Defense Communications Agency
DMA	Defense Media Activity
DNI	Digital Network Intelligence
DoD	Department of Defense
DSCS	Defense Satellite Communications System
DSP	Defense Support Program
EUTELSAT	Eutelsat S.A. communications satellite
FLTSATCOM	Fleet Satellite Communications System satellite
FORNSAT	Foreign Satellite
FVEY	Five Eyes
GCHQ	Government Communications Headquarters
GCSB	Government Communications Security Bureau
GRU	Main Intelligence Directorate (Russia; *Glavnoye razvedyvatel'noye upravleniye*)
HF DF	High Frequency Direction Finding
INTELSAT	INTELSAT Corporation
ISRG	Intelligence, Surveillance and Reconnaissance Group
IOG	Intelligence Operations Group
JCSAT	SKY Perfect JSAT communications satellite
KGB	Committee for State Security (Soviet Union; *Komitet gosudarstvennoy bezopasnosti*)

LES	Lincoln Experimental Satellite
LNB	Low Noise Block
MBTA	Multi-beam Torus Antenna
MHS	Menwith Hill Station
MVR	Massive Volume Reduction
NASA	National Aeronautics and Space Administration
NIOC	Naval Information Operations Command
NRO	National Reconnaissance Office
NSA	National Security Agency
OSD-PA	Office of the Secretary of Defense for Public Affairs
RF	Radio Frequency
RGS	Relay Ground Station
RSI	Radiation Systems Inc
SATCOM	Satellite Communications
SBIRS	Space-Based Infrared System
SBU	Security Service of Ukraine (*Sluzhba Bezpeky Ukrayiny*)
SCA	Service Cryptological Agency
SCE	Special Collection Elements
SI	Special Intelligence
SIGAD	SIGINT Activity Designator
SIGINT	Signals Intelligence
SZRU	Foreign Intelligence Service of Ukraine (*Sluzhba zovnishn'oyi rozvidky Ukrayiny*)
UKUSA	UKUSA Agreement(s); see Endnote 2.
XKS	XKeyscore

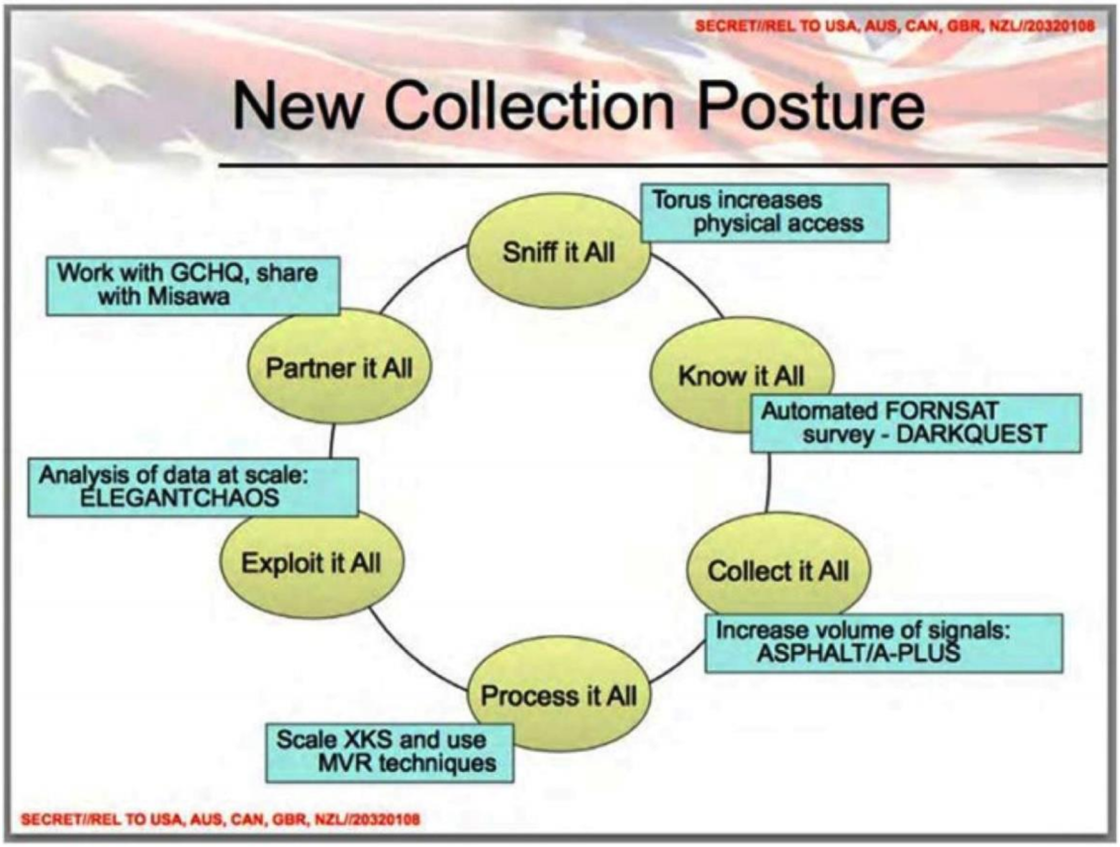
1. Introduction

The recent expansion of FORNSAT/COMSAT[1] (foreign satellite/ communications satellite) interception by the UKUSA (Five Eyes or FVEY) partners – the U.S. National Security Agency (NSA), the British Government Communications Headquarters (GCHQ), Canada's Communications Security Establishment (CSE), the Australian Signals Directorate (ASD), and New Zealand's Government Communications Security Bureau (GCSB) – has involved the installation over the past eight years of multiple advanced quasi-parabolic multi-beam antennas, known as Torus, which can simultaneously intercept up to 35 satellite communications beams from single antenna installations.[2] This report identifies sites now performing Torus FORNSAT/COMSAT collection activity and some of their operational parameters.

Public awareness of the Torus program is largely a product of revelations by former NSA contractor Edward Snowden. The first published reference to the use of Torus technology for SIGINT appears in a slide published in a book by Glenn Greenwald in May 2014. A Top Secret SI Powerpoint presentation to the 2011 Five Eyes Annual Conference outlined a 'New Collection Posture', known as 'Collect-it-all' then being pioneered at NSA's Menwith Hill Station (MHS) in Britain as Project ASPHALT. The slides describe a new and increasingly comprehensive approach to SIGINT collection from communications satellites (COMSATs) and state that 'Torus increases physical access', enabling the MHS station team to 'sniff it all' before collecting and processing everything of interest.[3] (Figure 1)

In March 2015, a set of Snowden documents concerning New Zealand's GCSB and its communications satellite interception station at Waihopai, South Island (covername IRONSAND) included a GCSB presentation dated 22 April 2010 stating that Torus was 'now enabling an increase of COMSAT/FORNSAT collection', and linking this to Menwith Hill's 'Collect-it-all' initiative.[4] (Figure 2)

Figure 1. NSA's New Collection Posture, 2011

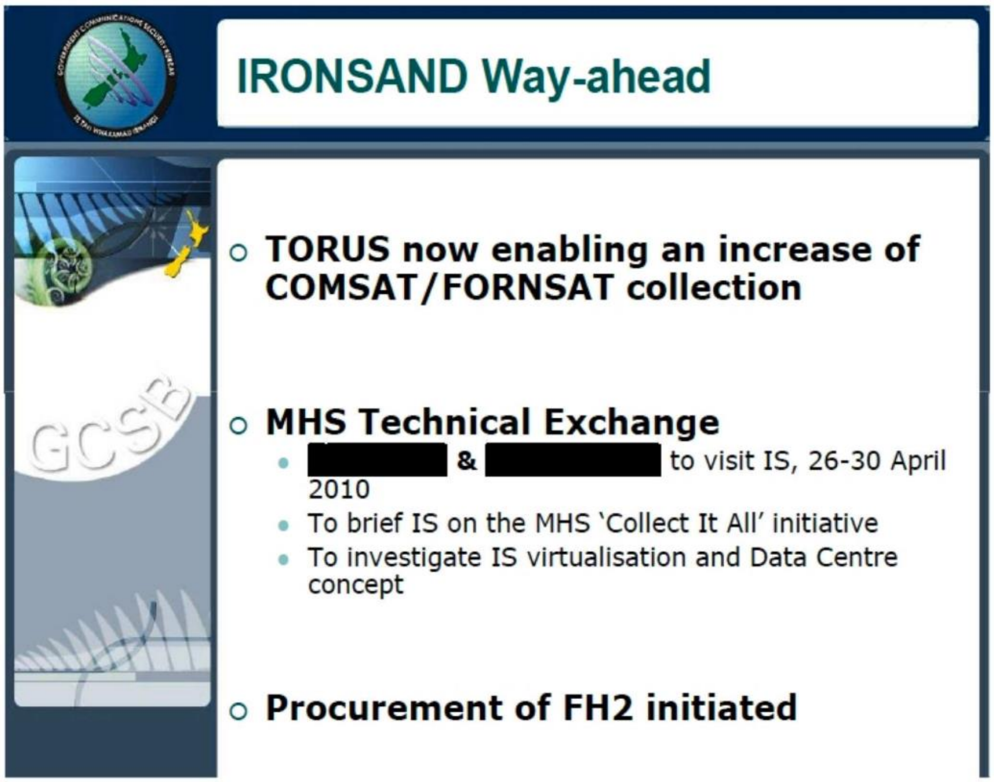


Source: Glenn Greenwald, *No Place to Hide: Edward Snowden, the NSA, and the U.S Surveillance State*, (Metropolitan Books, New York, 2014), p. 97; and Glenn Greenwald, 'Documents from *No Place to Hide*', at http://glenngreenwald.net/pdf/NoPlaceToHide-Documents-Compressed.pdf.

In March 2015, a set of Snowden documents concerning New Zealand's GCSB and its communications satellite interception station at Waihopai, South Island (covername IRONSAND) included a GCSB presentation dated 22 April 2010 stating that Torus was 'now enabling an increase of COMSAT/FORNSAT collection', and linking this to Menwith Hill's 'Collect-it-all' initiative.[4] (Figure 2)

A key goal for NSA in promoting the use of Torus antennas has been to increase access to global Internet traffic (Digital Network Intelligence or DNI) carried by satellite, utilising the now well known X-Keyscore analysis system (XKS) in association with a Massive Volume Reduction (MVR)[5] technique so as to 'Exploit it All'.[6] According to the slide, the work at Menwith Hill (covername MOONPENNY) was carried out in conjunction with GCHQ, and 'share[d] with' NSA's large eastern Pacific FORNSAT collection site at Misawa, Hokkaido, Japan (covername LADYLOVE).

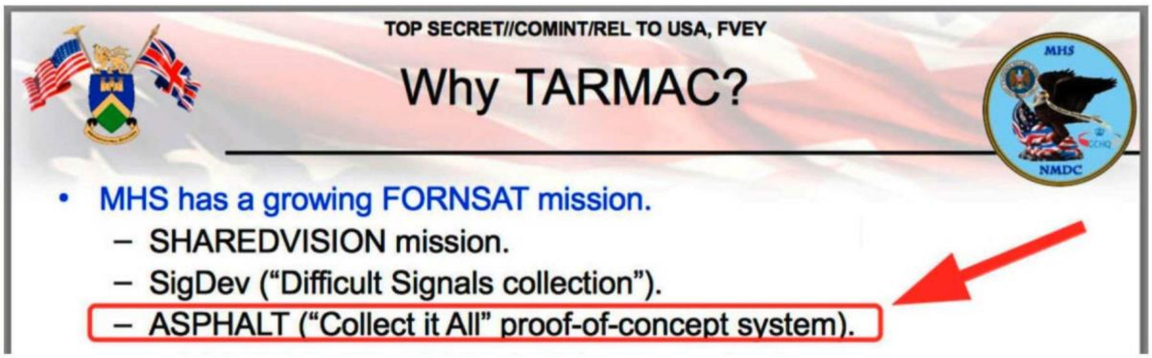
Figure 2. GCSB Update, 22 April 2010



Source: COMSAT Advisory Board (CAB), *GCSB Update*, 22 April 2010, *Cryptome*, March 2015, at http://cryptome.org/2015/03/gcsb-xkeyscore-nz-star-times-15-0308.pdf

The unique technical features of the Torus design enable beams from multiple satellites in geostationary equatorial orbits to be received and processed simultaneously by receiving horns arranged in an arc of principal foci. In the installations used at the sites identified here, beams from up to 35 satellites spaced 2 degrees apart in geostationary orbit along the Clark Belt can be received by a single Torus antenna, in principle replacing 35 traditional steerable or fixed parabolic antennas.

Figure 3 "Why TARMAC?", GCHQ, 2010[7]



Source: Glenn Greenwald, *No Place to Hide: Edward Snowden, the NSA, and the U.S Surveillance State*, (Metropolitan Books, New York, 2014), p. 97; and Glenn Greenwald, 'Documents from *No Place to Hide*', at http://glenngreenwald.net/pdf/NoPlaceToHide-Documents-Compressed.pdf.

Surveys for this report show that Torus antennas have been installed at five acknowledged and one covert Five Eyes FORNSAT/COMSAT collection sites between 2007 and 2013. These developments form part of a recent NSA and Five Eyes project, SHAREDVISION (SV), to enhance and further expand collection capability at designated sites. A successor Five Eyes program, SHAREDQUEST, is intended to exploit the features of the new Torus installations as well as a new generation of receivers and digital modems to carry out detailed research on new satellites and satellite configurations, as part of a SIGINT Development (SD) program covernamed DARKQUEST.[8] This is associated with a shared satellite-based geo-location system, APPARITION (see Figure 3).[9] NSA and its partners have also expanded the collection capability of their stations by the supplementary and low cost route of also adding multiple small 'COTS' (Commercial off the shelf) antennas typically of 3 to 5 metre diameter at many sites (See Annexe 1).

FORNSAT/COMSAT collection assets currently available to NSA and its partner agencies, in terms of antennas on the ground, require to be matched to a large potential target set. According to the satellite monitoring group Satbeam, there are 'over 400 geostationary satellites' currently in use. The Satbeam website provides a detailed database identifying 272 communications satellites operating in the Clark Belt, providing 9,890 downlink transponders (signal relays) or beams.[10] Many of the downlinks are split into different regional patterns and into selected spot beams so as to best use available satellite power.

A survey using published historical imagery compiled for this report and appearing in Annexe 1 suggests that there are currently about 232 antennas available at identified current Five Eyes FORNSAT/COMSAT sites, including the new Torus antennas, but excluding collocated antennas believed to be used for orthodox satellite communications or for satellite ground control and processing.

Some antennas provide orthodox satellite communication for their host site(s). At least one antenna on each FORNSAT/COMSAT site is typically allocated to target (or SIGINT) development. This total is around 100 antennas larger than measured in 2000 at the time of the ECHELON controversy[11], and does not include the multi-beam capability provided by Torus. The constellation of 6 Torus antennas identified in this report have a maximum capacity of 210 additional beams in the Ku- or C-bands.

We therefore conclude that development work at the observed FVEY FORNSAT/COMSAT sites since 2000 has more than doubled coverage, and that adding Torus has more than trebled potential coverage of global commercial satellites.

Although these developments have taken place in open sight, the deployment of the Torus antennas has mostly gone unheralded.[12]

To co-ordinate and prioritise the use of shared assets, NSA tasks priority beams of interest to each Five Eyes FORNSAT site in accordance with a directed survey plan drawn from a classified beam database similar to Satbeam, GLOBALVIEW.[13] The agencies operating the sites then assign antennas to collect and then analyse and relay the beams required by NSA. In broad terms, a comparison of satellites in orbit with ground assets suggests that only half of the available beams for survey could have been collected until the advent of Torus systems and additional COTS terminals; and that the Torus installations reported here, covering a potential maximum of 210 targets, may have doubled Five Eyes' capacity to cover the global satellite constellation.

Little information has been published concerning specific tasking and sharing arrangements for satellite interception between Five Eyes partners and Third Party nations. Germany is a significant exception. In 2004, the German foreign intelligence agency BND took over NSA's large FORNSAT site at Bad Aibling, Bavaria (former covername GARLICK), but continued to allow NSA remotely to task 'selectors' to the equipment operated at the site. In April 2014, a German parliamentary enquiry determined that BND had improperly allowed NSA to use tens of thousands of selectors to collect intelligence on the European Commission, and other European government and commercial targets. Other reports quote claims by BND staff that some improper and potentially unlawful targeting by NSA had been detected and blocked.[14]

Surveys for this report of 11 previously reported Soviet COMSAT SIGINT sites[15] suggest that the former Soviet KGB installed Torus antennas for simultaneous interception of multiple satellites in the geostationary arc at a much earlier date, probably in the late 1980s. A massive multi-beam antenna is installed at the Ovidiopol-2 SIGINT site, near Dobroaleksandrovka near Odessa in Ukraine, and may have been in operation as early as 1987. A second multi-beam antenna was installed at the same site in 2009-2010. The site is now operated by Ukraine's Foreign Intelligence Service (SZRU) (see Figures 31-34).

Russian military intelligence (GRU) installed a large multi-beam antenna near Klimovsk, south of Moscow, in 2005-06 (see Figures 27-30). These Soviet/Russian/Ukrainian multi-beam activities are briefly described in the fourth section of this report. Chinese intelligence agencies have been reported to be carrying out satellite interception activities from sites including Changji, near Urumqi in Xinjiang Province, western China.[16] Available satellite images of Chinese COMSAT interception sites do not show multibeam or Torus-type antenna installations.

Civil corporations, including broadcasters and communications providers, and many U.S. military or government agencies have used Torus-style antennas since the early 1990s. The U.S. Department of Defense and intelligence community make extensive use of multi-beam antennas for purposes other than SIGINT. These include two multi-beam antennas installed at NSA HQ at Fort Meade, Maryland (see Figures 36 and 37). There is no public evidence that these installations are used for direct intelligence collection from targeted satellites 'on cover'. Two further multibeam antennas are located at the CIA HQ at Langley, Virginia (see Figure 38). Multi-beam antennas also provide the principal satellite communications (SATCOM) capability for the American Forces Radio and Television Service (AFRTS) and, specifically, its Armed Forces Network Broadcast Center (AFN-BC), which has its control elements at Fort Meade and March Air Force Base in Riverside, California. The U.S. Air Force's Space Command has a multi-beam antenna at Schriever Air Force Base, Colorado, which it uses for its space surveillance and control mission (see Figure 39). Some are used for Department of Defense SATCOM Gateway/Teleport services, such as at the Torii Station Teleport in Okinawa (see Figure 42). These multi-beam operations are briefly reviewed later in this report in order to clarify their purposes and to clearly distinguish them from Torus antennas used for FORNSAT/COMSAT interception.

2. Five Eyes FORNSAT/COMSAT interception sites

The current SHAREDVISION/SHAREDQUEST communications satellite interception program is managed by NSA's FORNSAT division at Fort Meade, Maryland, and by GCHQ's COMSAT division based at their Bude station. The program began in 1966 as Project ECHELON, and was (and still is) targeted at civil satellite communications, starting with the INTELSAT satellite series first launched in 1965. A counterpart but distinct NSA program targeting Soviet satellites began at the same time as ECHELON in 1966. NSA agreed to pay (and still pays for, and owns) most of the satellite interception equipment used, while its Second Party allies in the UKUSA alliance agreed to pay personnel, operating and maintenance costs.[17]

The first ECHELON site, run by GCHQ at Bude, Cornwall, England (covername CARBOY) was financed by NSA and began operating in 1970. The second ECHELON site, Yakima Research Station in Washington state, U.S. (covername JACKKNIFE) started operating in May 1973, and was also targeted on INTELSAT satellites. Bude's facilities were expanded during the 1980s as CARBOY II, as part of the ECHELON 2 program.[18] GCHQ currently operates two other COMSAT collection sites supported by U.S. funding, at Ayios Nikolaos in eastern Cyprus (covername SOUNDER) and at a covert site in Oman covernamed LECKWITH. LECKWITH is sited within the township of Al Maabilah, about three km west of Seeb, on the north coast of Oman (23.675 N, 58.122 E). The COMSAT function at LECKWITH supplemented earlier GCHQ activity at multiple sites in Oman.[19]

Additional 'Cyber' functions and construction at LECKWITH for intercepting multiple fibre cables passing through the Gulf of Oman were added from 2008 onwards as part of GCHQ's Project TEMPORA for acquiring and inputting digital network intelligence into the XKEYSCORE network. A sequence of DigiGlobe images of the LECKWITH site taken from 2001 to 2014 show the construction of the Internet processing facilities (covernamed CIRCUIT) from 2008, and the installation of a Torus and nine additional COTS small antennas by 2013.[20] GCHQ has designated CIRCUIT as Overseas Processing Centre 1 (OPC-1).

By 2002, according to an NSA slide provided by Edward Snowden (Figure 4) and published in Brazil in 2013, the expanded FORNSAT network operated by NSA and UKUSA Second Parties included 16 manned sites around the world, as shown in Table 1.[21]

Figure 4. FORNSAT interception sites, NSA 2002

Source: 'File:NSA Primary FORNSAT Collections.jpg', Wikimedia Commons, at
http://commons.wikimedia.org/wiki/File:NSA_Primary_FORNSAT_Collections.jpg

The sites listed include two sites in U.S. diplomatic premises (in Brazil and New Delhi) and operated by the Special Collection Service (SCS), a joint activity of CIA and NSA. Since the slide was prepared in 2002, two sites appear to have closed: GCHQ's Nairobi station and the NSA site in Sabana Seca, Puerto Rico. Evidence described below suggests that staff deployed at Sabana Seca moved to a new FORNSAT facility in Pine Gap, Australia (covername not known), around the very beginning of the 2000s. Pine Gap, a SIGINT satellite control station in central Australia, has been used for COMSAT collection since then. The Torus antennas were all installed between 2007 and 2013. (Table 1, Map 1).

No Canadian intercept sites are shown on the 2002 map of primary FORNSAT sites, but CSE does have a significant satellite monitoring facility at

Canadian Forces Station Leitrim, located within the Ottawa city limits. No multibeam or Torus-type antennas are present at the station, but it does host 13 satellite dishes, all or most of which are likely to have COMSAT missions, and the station is listed as a source of Internet data in at least one of the Snowden documents. It appears to have a standard FVEY SIGAD (Sigint Activity Designator), CAC-98.[22] In addition to monitoring satellite communications, the 500 staff at Leitrim, including 25 U.S. Navy personnel, remotely operate the Canadian intercept sites at Alert, Gander, and Masset.

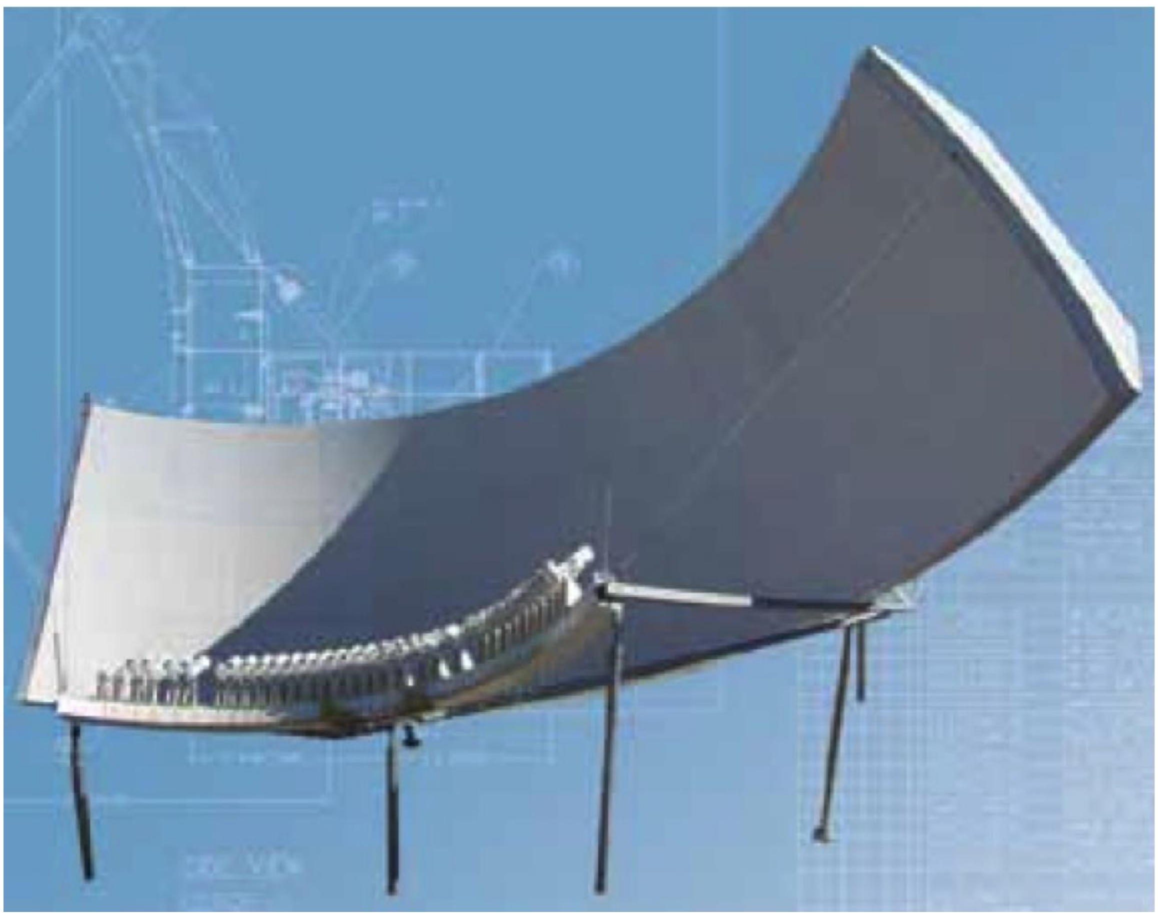
First and Second Party FORNSAT/COMSAT sites are supplemented by a large number of Third Party COMSAT intercept sites operated by 35-40 other nations linked to NSA, GCHQ and/or other Five Eyes partners through separate and secret bilateral intelligence co-operation and sharing agreements. Countries known to operate COMSAT stations and reported to have intelligence sharing agreements with NSA and/or GCHQ include Spain, Italy, France, Germany, the Netherlands, Denmark, Sweden, India, Israel, Jordan, Oman, Saudi Arabia, South Africa, and Switzerland.

The six Torus-equipped FORNSAT/COMSAT interception sites identified here appear together to provide complete coverage of the geostationary arc from at least 45 degrees West longitude, over the mid-Atlantic Ocean, to about 160 degrees West longitude over the mid-Pacific Ocean. The stations are each equipped with Model 700-70TCK Torus Multiple Band Antenna systems, produced by General Dynamics. (Figures 5 and 6) These measure 24.1 metres wide by 7 metres high, and are curved spherically in their horizontal plane and parabolically in their vertical plane; they are able to monitor 35 satellites and hundreds of satellite channels (perhaps as many as 1,000) simultaneously, in the C-band (3.4-4.2 GHz) and Ku-band (10.95-12.75 GHz).[23]

The new Torus network has complemented other FORNSAT collection activity monitoring high-data-rate multi-beam communications satellites, such as

LADYLOVE at Misawa in Japan, STELLAR at Kojarena, near Geraldton in Western Australia, and IRONSAND at Waihopai in New Zealand. At Waihopai, for example, the primary target has always been the main INTELSAT international communications satellite stationed over the mid-Pacific Ocean, to which one of the station's parabolic dishes has always been dedicated. This is currently the INTELSAT 18 (IS-18) communications satellite, launched on 5 October 2011 and stationed in orbit at 180.0 degrees East longitude.

Figure 5: General Dynamics SATCOM Technologies Model 700-70TCK Torus antenna



Source: Model 700-70TCK Torus Multiple Band Antenna, General Dynamics, SATCOM Technologies, 2010, at
http://www.gdsatcom.com/Antennas/Data_Sheets/655-0037C_7M_Torus.pdf

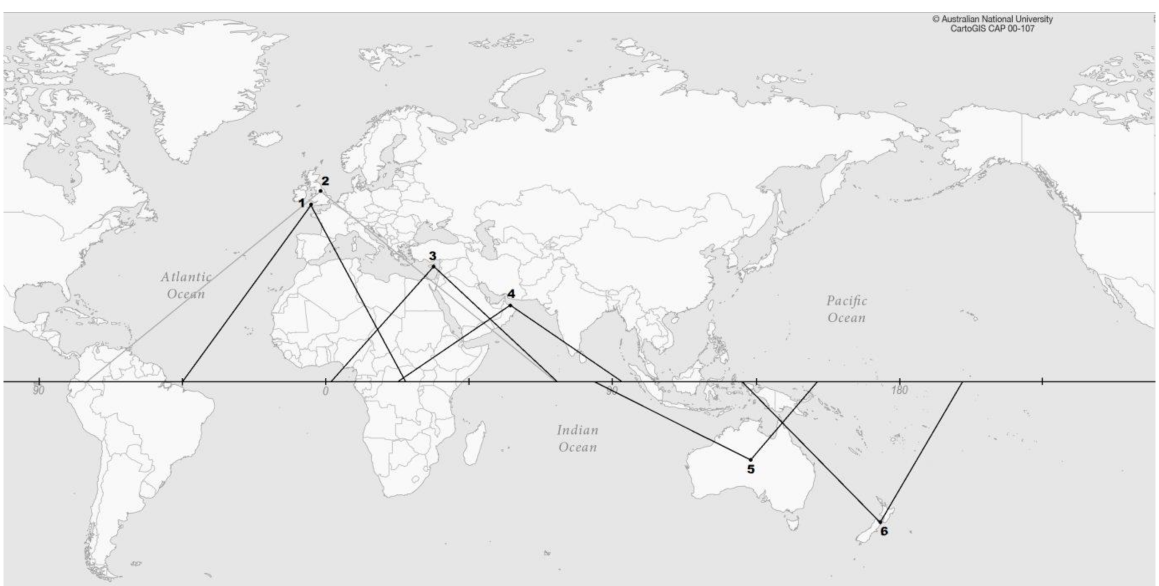
Figure 6. Feed box of General Dynamics Model 700-70TCK Torus Multiple Band Antenna system installed at DirectTV distribution centre, Los Angeles

2.1 GCHQ Bude, Cornwall

GCHQ Bude, located at Sharpnose Point on the northwest coast of Cornwall, covernamed CARBOY, is the GCHQ's largest FORNSAT/COMSAT interception station. Formerly called CSOS (Composite Signals Organisation Station) Morwenstow, the site initially consisted of two 30-metre Standard A dishes, pointing at INTELSAT communications satellites stationed over the Atlantic and Indian Oceans. By the early 1990s, 'it had nine satellite dishes; two inclined towards the two main Indian Ocean INTELSATs, three towards Atlantic Ocean INTELSATs, three towards positions above Europe or the Middle East and one dish covered by a radome'.[24] Google Earth imagery dated 30 December 2010 shows at least 19 dishes, ten in the northern sector (including two in radomes) and nine in the southern sector (including one in a radome).

Table 1 NSA first and second party FORNSAT/COMSAT sites (2002)				
Location	**Country**	**Agency**	**Covername**	**Notes**
Ayios Nikolaos	Cyprus	GCHQ	SOUNDER	Torus added
Bad Aibling	Germany	NSA	GARLICK	Transferred to BND, 2004
Brasilia	Brazil	NSA/CIA - SCS	*n/a*	Covert embassy site
Bude	U.K.	GCHQ	CARBOY	Torus added
Geraldton	Australia	ASD	STELLAR	
Khon Kaen	Thailand	NSA	LEMONWOOD	
LECKWITH (Seeb)	Oman	GCHQ	SNICK	Torus added
Menwith Hill	U.K.	NSA	MOONPENNY	Torus added
Misawa	Japan	NSA	LADYLOVE	
Nairobi	Kenya	GCHQ	SCAPEL	Closed
New Delhi	India	NSA/CIA - SCS	*n/a*	Covert embassy site
Sabana Seca	Puerto Rico	NSA	CORALINE	Closed
Shoal Bay, Darwin	Australia	ASD	*not on slide*	
Sugar Grove	U.S.A.	NSA	TIMBERLINE	
Waihopai	New Zealand	GCSB	IRONSAND	Torus added
Yakima	U.S.A.	NSA	JACKKNIFE	

Map 1. Torus sites and coverage of the geostationary satellite belt



Torus sites: 1 Bude, U.K.; 2 Menwith Hill, U.K.; 3 Ayios Nikolaos, Cyprus; 4 Seeb, Oman; 5 Pine Gap, Australia; 6 Waihopai, New Zealand. The grey lines extending from Menwith Hill show the entire section of the geostationary arc visible from that site. Like the antennas at the other Torus sites, the

Torus at Menwith Hill is capable of monitoring only 70 degrees of the arc. Its orientation cannot be determined because the antenna, uniquely, is inside a radome.

The multi-beam antenna at Bude was built sometime in 2012. It is not in Google Earth imagery dated 30 December 2010 (the most recent available), but Terraserver's image of 29 March 2012 appears to show construction activity underway. It is clearly shown in Terraserver's image dated 30 April 2013 (See Figure 9). There are some good photographs available on the Web. Figure 7 is dated 23 June 2013; Figure 8 is undated.[25]

The new Torus is located in the southeast of the site close to the entrance security gate and uses concrete hardstanding created for the second INTELSAT interception dish. It is positioned at an azimuth of 187 degrees, which corresponds to 10 degrees West on the geostationary arc.

Figure 7. Morwenstow, Bude, 23 June 2013

Source: "Poodle" UK: MPs to Quiz GCHQ Spies Over $150Mln Payments from US Government', 3 August 2013, at http://rt.com/news/nsa-gchq-mps-questions-007

Figure 8. Morwenstow, Bude

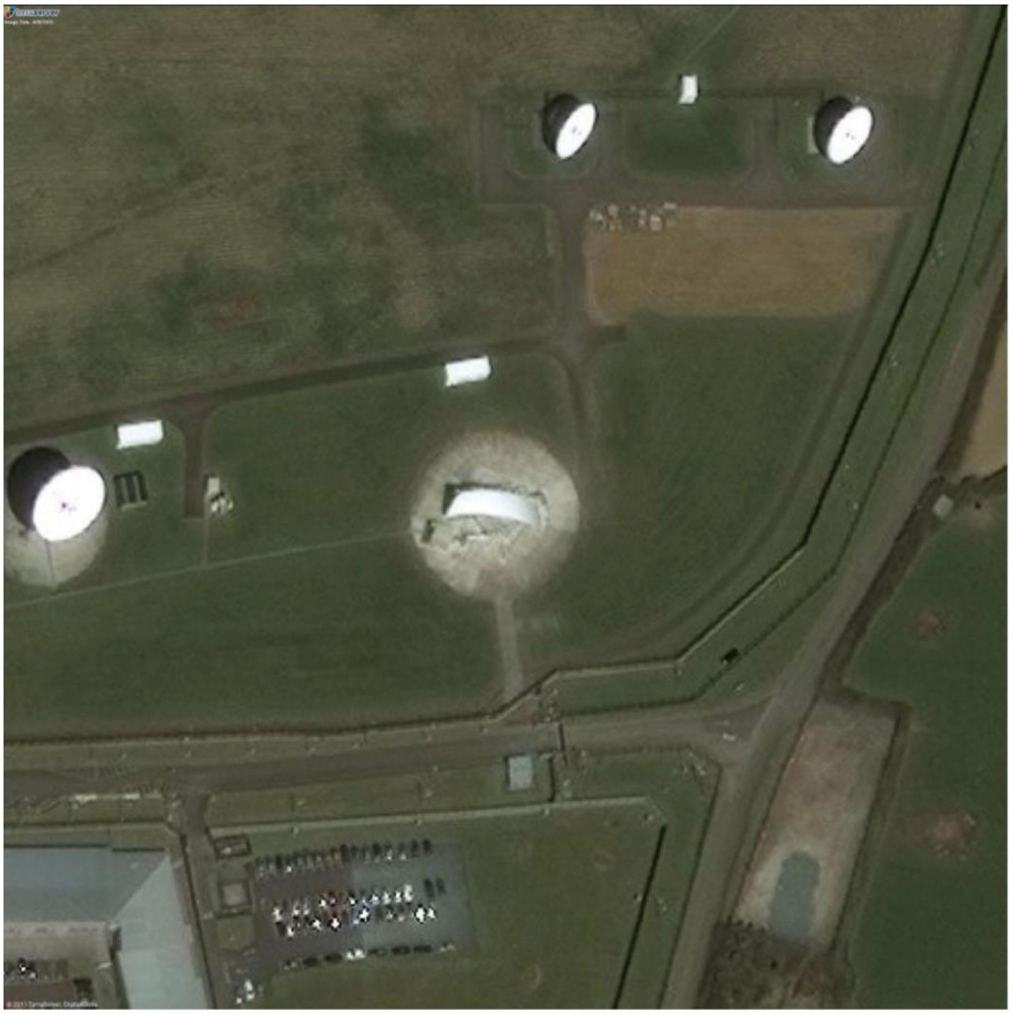
Source: Oliver Zimmermann, at
http://www.oliverzimmermann.com/colour35mmfilm/0zr2p76acyhrrvfpcco4m9urhowqj1

2.2 Menwith Hill Station, Harrogate, Yorkshire

Menwith Hill Station, also called Field Station 83 (F83), is the NSA's largest SIGINT collection station in the world. It had 1,800 personnel (including 400 British) in 2011, which was expected to increase to 2,500 by 2015. It had 33 radomes in 2011.[26] It has two principal missions. First, it is one of NSA's largest FORNSAT/COMSAT interception sites, second only to the LADYLOVE station at Misawa. Second, its RUNWAY project has served since the late 1970s as the ground control station for geosynchronous SIGINT satellites initially covernamed CHALET and VORTEX, and more recently MERCURY and ADVANCED ORION. In addition, the station also hosts two radomes, GT8 and GT9, installed in 2000, for reception of data from Space-Based Infrared System (SBIRS) missile launch detection satellites (Project *Grapnel*). By 1996, the MOONPENNY site, located to the north of the Operations Buildings, had 10 dishes/radomes. Google Earth imagery dated 24 May

2009 showed 14, including a small dish that was not yet installed; it is in place in Bing imagery dated 30 September 2011. There are now 15.

Figure 9. Torus multi-beam antenna (centre), Morwenstow, Bude, Terraserver imagery, 30 April 2013



A proposal to erect a new radome and Torus antenna was submitted to the Harrogate Planning Department by a U.S. official at Menwith Hill Station on 21 December 2010. The proposal stated that the new radome would be 19.5 metres high and 30.5 metres in diameter, and would be 'located within the existing operational compound complex of some 32 radomes.[27] (Figure 11) The circular concrete pad is shown under construction in the Bing imagery of 30 September

2011. The Torus was presumably installed later in the year. It is located in the northeast part of the base, on the eastern side of the MOONPENNY area. Its 'squashed' radome is clearly identifiable in aerial photographs taken on 18 June 2012 (Figure 12). It is also clearly shown in a photograph taken on 3 May 2013 (Figure 13). Figure 10 shows Terraserver imagery dated 25 July 2014.

Figure 10. Torus multi-beam antenna radome at Menwith Hill (centre), Terraserver imagery, 25 July 2014

Figure 11. Location of Torus antenna radome, Menwith Hill Station

Source: ARP Associates, Planning Application, Appendix A, November 2010

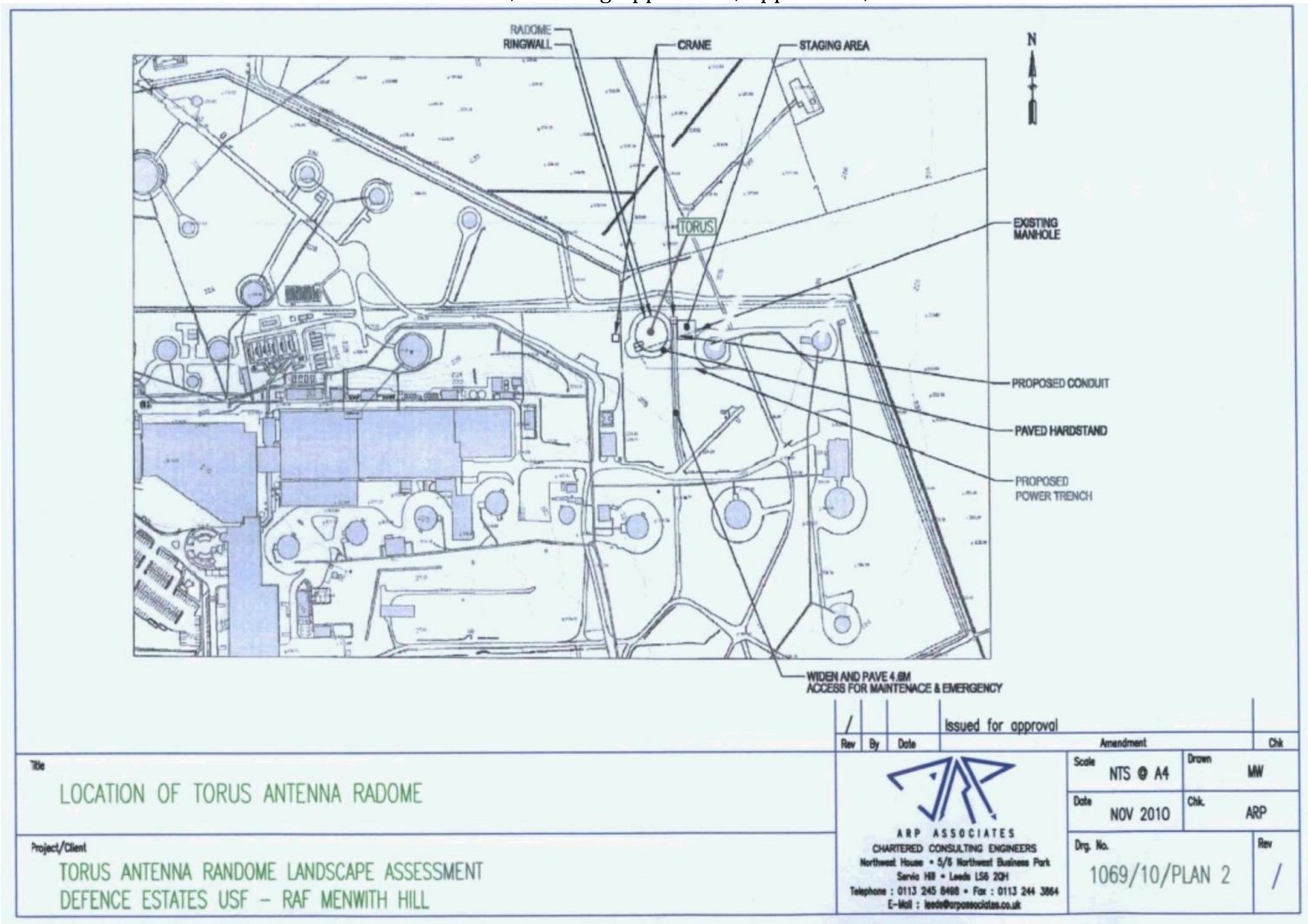


Figure 12. Radomes, including Torus multi-beam antenna (centre right), at Menwith Hill, 18 June 2012

Source: Aerial Photographix

Figure 13. Torus multi-beam antenna radome at Menwith Hill (centre), 3 May 2013

Source: Barry Skilbeck, at https://www.flickr.com/photos/barrytaxi/8712304638/.

The orientation of the Torus antenna inside the radome is unknown. Assuming it was pointed directly south, its coverage along the geobelt would be little different, just a few degrees eastwards, from that of the GCHQ Torus system installed at Bude a year or so later. If it was pointed towards the southwest, it could potentially extend coverage out to around 70 degrees West over South America, while if it was pointed towards the southeast it could extend coverage out to around 70 degrees East, effectively duplicating that of the Torus system at Ayios Nikolaos in Cyprus. By providing overlapping coverage across much of the equatorial arcs in view from Bude and Oman, the Five Eyes would expect to be able fully to cover multiple closely spaced satellite targets.

2.3 Ayios Nikolaos, Cyprus

GCHQ operates a major FORNSAT site in Cyprus, covernamed SOUNDER, and located at Ayios Nikolaos in the U.K.'s Eastern Sovereign Base Area, near Famagusta. It provides high frequency collection for Five Eyes' global Wideband GLAIVE terrestrial radio (HF) interception system and inputs to the associated shared geo-location network, BORESIGHT. Ayios Nikolaos also operates a remote VHF, UHF and space collection site high in the Troodos mountain range of Cyprus, and provides (separately) the receiving site for the COBRA SHOE U.S. Air Force over the horizon (OTH) radar system using three giant arrays sited to the southeast of the SOUNDER area. The SOUNDER project was discussed at a meeting between General William Odom and Peter Marychurch, directors of the NSA and GCHQ, in 1988, at which it was agreed that NSA 'will share part of costs'.[28] The Torus multi-beam antenna at SOUNDER appears to have been installed between 2008 and 2010. It was not present in Google Earth imagery dated 28 May 2008, but it is shown in a Terraserver image dated 16 August 2010. The first Google Earth imagery showing the new antenna is dated 11 April 2011.

The Torus antenna is located in the northwest part of the main COMSAT compound, south of the old Pusher CDAA. (Figures 14 and 15) Google Earth imagery of Ayios Nikolaos dated 7 February 2015 shows 27 satellite dishes/radomes in addition to the Torus system. Seventeen dishes/radomes are in the main COMSAT compound, on the northeastern side of the station – three 18-metre dishes, one 33-metre dish, one 12-metre, one 8-metre, one 4-metre, a cluster of six about 2.5-metres, and four 4-metre radomes in a north-south line, installed in 2014. Six dishes are located on the southeast part of the station – one 12-metre, two 8-metre, one 4-metre and two 3-metre. And four dishes/radomes are in the southwest part of the station – two 5-metre dishes, one 4-metre dish and a 6-metre radome.

The Torus antenna is boresighted at 175 degrees to the south, corresponding to 37 degrees East on the geostationary belt, and covering satellites stationed from 2 degrees East to 72 degrees East.

Figure 14. Torus multi-beam antenna at Ayios Nikolaos, Cyprus, November 2013

Source: 'Cyprus a Hub for Spying on Private, Diplomatic and Business Communications', Famagusta Gazette, 7 November 2013, at famagusta-gazette.com/cyprus-a-hub-for-spying-on-private-diplomatic-and-business-communications-p21264-69.htm.

Figure 15. Torus multi-beam antenna (top left) at Ayios Nikolaos, Cyprus, Google Earth imagery, 21 May 2013

Figure 16. Torus multi-beam antenna at Seeb, Oman,

Google Earth imagery, 10 December 2014

2.4 Seeb, Oman [LECKWITH]

Google Earth imagery for GCHQ's Oman COMSAT site, SNICK, dated 10 December 2014 shows six larger dishes and ten or eleven small ones, as well as the large Torus multi-beam antenna. (Figure 16) Five of the larger dishes (16, 12, 12, 15, and 18 metres in diameter) are in a northwest-southeast line, on the western side of the satellite communications compound. The sixth larger dish, about 12 metres in diameter, is on the northern side of the compound. There are three smaller dishes (one about 8 metres and the other two about 3 metres in diameter) just to the west of this 12-metre dish, and a 5-metre dish between this dish and the Torus antenna. Just south of the line of five larger dishes are two 5-metre dishes and 4 or 5 with diameters of only 2-3 metres.

The Torus antenna was installed in 2012. It is present in the Google Earth image dated 11 December 2012, but not present in the Terraserver image dated 12 October 2011. It is oriented almost directly to the south, corresponding to 58 degrees East on the geostationary belt, and covering satellites stationed at from about 23 degrees East to about 73 degrees East.

2.5 Pine Gap, Northern Territory, Australia

The Pine Gap satellite ground station is located about 19 km southwest of Alice Springs in central Australia. Managed by the U.S. National Reconnaissance Office (NRO), its original and still principal purpose is to serve as the ground control station for geosynchronous signals intelligence (SIGINT) satellites developed by the U.S. Central Intelligence Agency (CIA); it probably remains the CIA's most important technical intelligence collection station in the world. The first of the CIA's geostationary SIGINT satellites, then called RHYOLITE, was launched on 19 June 1970. Its successors have been called AQUACADE, MAGNUM, ORION and ADVANCED ORION. Increasing numbers of civilian NSA personnel joined the activity through the 1990s. A reorganisation of the management structure in 1997 established Special Collection Elements (SCEs), comprising personnel from not only the CIA but also the NSA and Service Cryptological Agencies (SCAs). In the case of the U.S. Navy, for example, an Information Operations Detachment was established, with three officers and 40 enlisted men, in March 1998. A detachment of the U.S. Army's 743rd Military Intelligence Battalion, a detachment of the U.S. Air Force's Air Intelligence Agency's Intelligence Operations Group (IOG), and a sub-unit of the U.S. Marines' Cryptologic Support Battalion were also posted to Pine Gap in the late 1990s.[29] There are now 38 satellite dishes/radomes at Pine Gap. Most are still concerned with the core function of controlling geosynchronous SIGINT satellites and processing and analysing the intercepted intelligence.[30]

On 1 October 1999, the U.S. Air Force officially opened a Relay Ground Station (RGS), which relays data from U.S. missile launch detection/early warning satellites – formerly called the Defense Support Program (DSP) but now the Space-Based Infrared System (SBIRS) – to both U.S. and Australian HQs and command centres. (It replaced the USAF's DSP ground control station at Nurrungar). Six of the satellite terminals at Pine Gap (four in radomes and two unshielded) belong to the RGS. Another three radomes are probably associated with the U.S. Missile Defense Agency's Space Tracking and Surveillance System (STSS).

Figure 17. Multi-beam antenna compound, Pine Gap, Terraserver imagery, January 2010

Pine Gap appears to have acquired a FORNSAT/COMSAT interception function in the early 2000s. This was probably presaged with the arrival of SCA elements at the end of the 1990s. Two 23-metre dishes suitable for COMSAT SIGINT Development (Sigdev) were installed inside 30-metre radomes in 1999-2000. Of significant interest, it appears that Detachment 2 of the U.S. Air Force's Air Intelligence Agency's 544th Intelligence Operations Group, previously located at the U.S. FORNSAT station at Sabana Seca, Puerto Rico, was transferred to Pine Gap in the early 2000s. Detachment 2 ceased operations at Sabana Seca around 2000. The site was officially disestablished on 31 January 2003. The CORALINE COMSAT interception dishes/radomes were dismantled in 2004. We infer that the transfer of Detachment 2 from Sabana Seca to Pine Gap signified that Pine Gap had become a new FORNSAT site.[31]

From August 2005 to July 2007, Detachment 2 of the 544th IOG at Pine Gap comprised 28 personnel.[32] The detachment includes a Geospatial Metadata Analysis unit which 'optimizes information flow to the warfighter', and especially Special Operations Forces teams.[33] The unit is now designated Detachment 1 of the 566th Intelligence Squadron at Buckley AFB, under the 544th Intelligence, Surveillance and Reconnaissance Group (ISRG) at Peterson AFB in Colorado Springs.[34]

A Torus multi-beam antenna was installed at Pine Gap in 2008. It is located a little more than 200 metres south of the main compound in an entirely separate fenced compound measuring 55 m x 50 m. It was the first satellite antenna at Pine Gap to be located outside the principal antenna compound. The antenna is installed on top of a concrete pad approximately 17 metres wide, and is fixed on top of a steel frame, next to a small building. (Figures 17 and 18)

The antenna faces north-northwest, boresighted at 329 degrees towards the equator, corresponding to 120 degrees East on the geostationary belt. Its purview extends from about 85 degrees East to about 155 degrees East longitudes, fitting the gap between Seeb and Waihopai.

Figure 18. Pine Gap, with multi-beam antenna at rear, 12 October 2013

Source: Richard Tanter

2.6 Waihopai, New Zealand

The GCSB FORNSAT/COMSAT interception station, covernamed IRONSAND, is located at Waihopai, near Blenheim, in the northeast part of New Zealand's South Island. It features two 18-metre parabolic dishes, mounted on 8-metre pedestals and covered by 33-metre radomes. These were installed in 1989 and 1995. The first dish has always been focussed on the primary INTELSAT communications satellite stationed over the mid-Pacific, beginning with IS-510, which had been launched in 1985 and was stationed at 174 degrees East; it carried 26 C-band and 6 Ku-band transponders, providing 15,000 voice circuits. On 15 January 1994, the station transitioned to IS-701, which was launched in October 1993 and which replaced IS-510 at 174 degrees East; it carried 26 C-band and 10 Ku-band transponders, with

96,000 voice circuits.[35] At the beginning of 2012, the station moved to IS-18, launched in October 2011 and placed at 180 degrees East, replacing IS-701 as INTELSAT's primary satellite over the Pacific.[36] It has 24 C-band and 12 Ku-band transponders.

The second dish, uncovered for 15 months from April 2008, when anti-war protesters destroyed the radome, was not fixed on one satellite, but shifted between satellites for periods of weeks or months. However, it always pointed towards East Asian rather than Pacific satellites. On 10 July 2009, for example, it was pointed to 132 degrees East.[37] It was probably monitoring a Japanese communications satellite, JCSAT-5A, but may have been monitoring Vietnam's first communications satellite, Vinasat 1, stationed nearby.

Figure 19. GCSB COMSAT interception station, Waihopai

Source: COMSAT Advisory Board (CAB), GCSB Update, 22 April 2010, Cryptome, at http://cryptome.org/2015/03/gcsb-xkeyscore-nz-star-times-15-0308.pdf

The Torus antenna was installed about June 2007 and was scheduled to be 'up and running' around September/October 2007. According to Air Marshal Bruce Ferguson, the then Director of the GCSB, the new antenna cost less than $1 million and 'was very good value for money'. He said that: 'It's simply an enhancement of our capabilities. It's a new, modern aerial which will increase our ability to conduct the tasks we do'. He said that unlike the previous two dishes, which were covered by radomes 'to ward off the weather', the new Torus antenna would 'remain in the open'.[38]

Figure 20. GCSB communications satellite interception station, Waihopai, 16 August 2008

Source: Southgate Images, 'Waihopai Valley Spy Station', Panoramio, 16 August 2008, at http://www.panoramio.com/photo/13169830.

The Torus antenna faces to the north-northwest, with an azimuth of 348 degrees, commensurate to 166 degrees East above the equator, and hence providing coverage from about 130 degrees East to about 160 degrees West in the geostationary arc. (Figures 19-24) It is somewhat surprising that it is not oriented further to the west, given the dearth of satellites at the far east end of its coverage. A photograph of it taken on 3 May 2008 shows relatively few feeds and associated Low Noise Block sub-systems slotted into the feed-box. There is a small cluster (perhaps only four) at the western end of the box and then a large gap before a single feed/LNB at the eastern end.[39] Waihopai may have been selected as the site for the first Torus FORNSAT system because the limited number of secondary targets of interest over the mid-Pacific at that time would have required simpler feed designs and much less signal processing capability than those at the subsequent sites. The GCSB Update of 22 April 2010 suggested that additional feeds/LNBs may eventually be slotted into the feed-box, but a photograph taken on 2 March 2013 shows that the number remained small at that date (Figure 24).

Figure 21. GCSB communications satellite interception station, Waihopai, Google Earth imagery, 8 May 2013

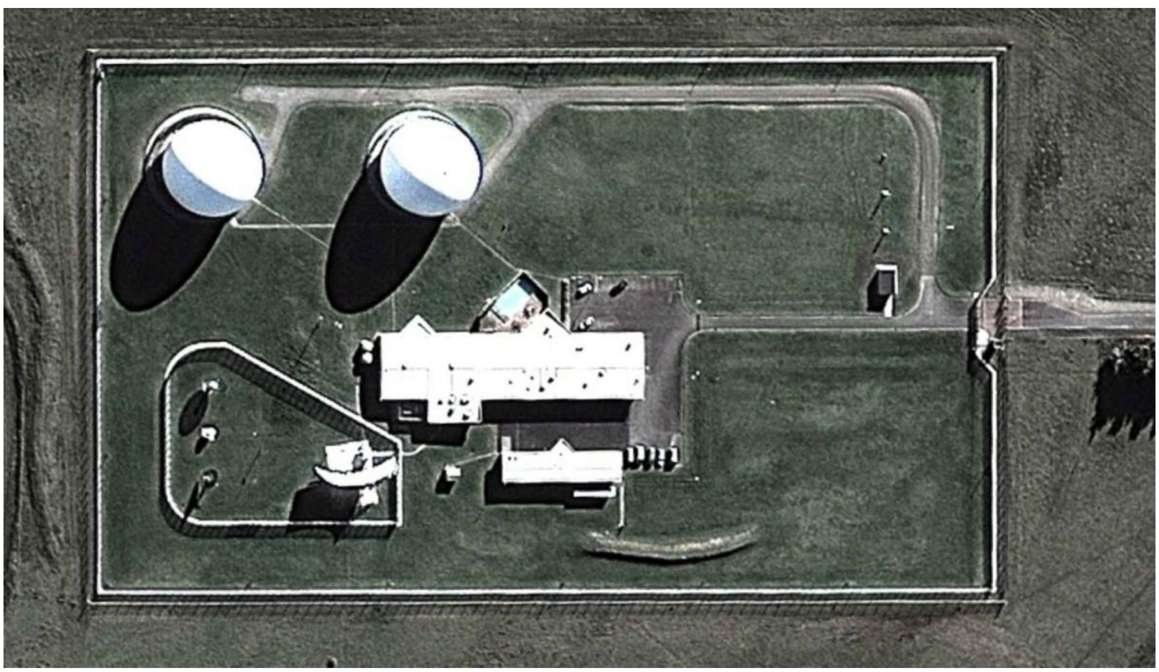


Figure 22. GCSB COMSAT interception station, Waihopai, 3 May 2008

Source: Tim Cuff, 'Spy base attack', Free to Air Satellite Forums (Asia-Pacific), 3 May 2008, at http://www.vetrun.net/forums/attachment.php?s=6eb58187871c49e68f5810eb75145da8&attachmentid=6324&d=1209807879.

Figure 23. Torus antenna, GCSB COMSAT interception station, Waihopai, 2 March 2013

Source: Setford News Agency, at http://snpa.photoshelter.com/gallery-image/General/G0000vh71zIyJvc8/I000088hpgpMt.tc/C0000.XoHjDQnaBE.

Figure 24. GCSB COMSAT interception station, Waihopai, 20 June 2012

Source: Gilbert van Reenen, Clean Green Images Ltd, Wanaka, New Zealand

3. Technical and historical aspects of multi-beam systems

3.1 Technical aspects

Multi-beam antennas are different in both shape and operation from most other satellite communications antennas, which are usually parabolic in shape. Parabolic dish antennas are designed to have a single focal point to optimise the directivity of the reception of radio waves from one particular source: the parabolic reflects all incoming radio waves to a feed antenna located at the dish's focal point. To receive efficiently from another satellite in a different location, the antenna must be rotated horizontally and/or vertically.

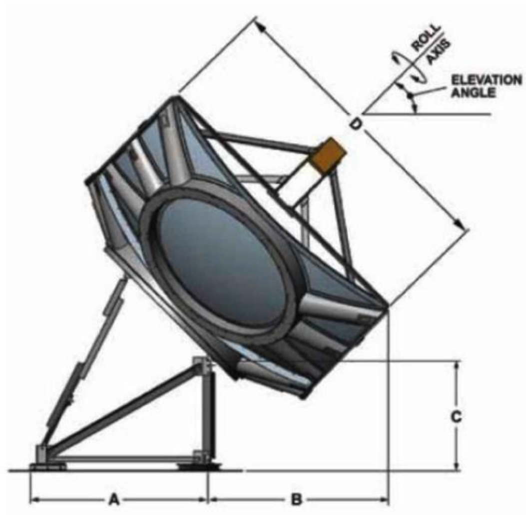
In multi-beam antennas which are fixed in position and have no moving parts, the reflector, shaped spherically in its horizontal plane, reflects incoming radio waves back toward their source, to be captured at their particular focal points by feeds and attendant Low Noise Blocks (LNBs) slotted into the arc of the feed-box (Figures 25 and 26). The LNBs receive the very low level microwave signals from the satellite feeds, amplify them, change the signals to a lower frequency band and send them down the cable to the indoor receiver.

Figure 25. Simulsat multi-beam antenna schematic and specifications

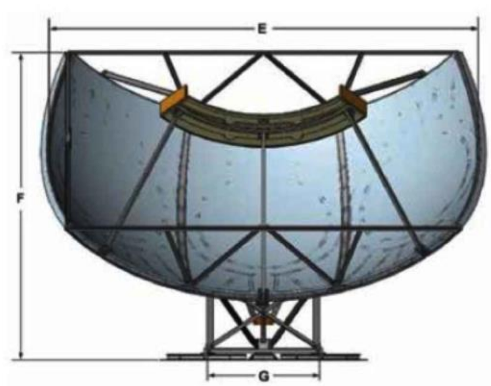
Note:

General Pictorial View,
For example, "B" and "F"
vary with elevation angle.

Contact ATCi
for site specific configurations



ANTENNA	Simulsat 5B	Simulsat C/Ku	Simulsat 7
A	9'-10" (3.00m)	9'-10" (3.00m)	17'- 4" (5.29m)
B	10'- 1" (3.10m)	7'-11" (2.42m)	14'-10" (4.53m)
C	6'- 2" (1.88m)	6'- 2" (1.88m)	8'- 6" (2.60m)
D	16'- 8" (5.08m)	16'- 7" (5.05m)	23'- 0" (7.02m)
E	29'- 1" (8.86m)	30'- 8" (9.35m)	43'- 5" (13.24m)
F	20'-10" (6.36m)	21'- 5" (6.53m)	32'.6"- 0" (9.90m)
G	7'- 11" (2.42m)	7'- 11" (2.42m)	20'- 0" (6.10m)



Source: Simulsat Multibeam Earth Station Product Family, (ATCi, 2012), at
http://www.atci.com/assets/simulsat_brochure2012.pdf.

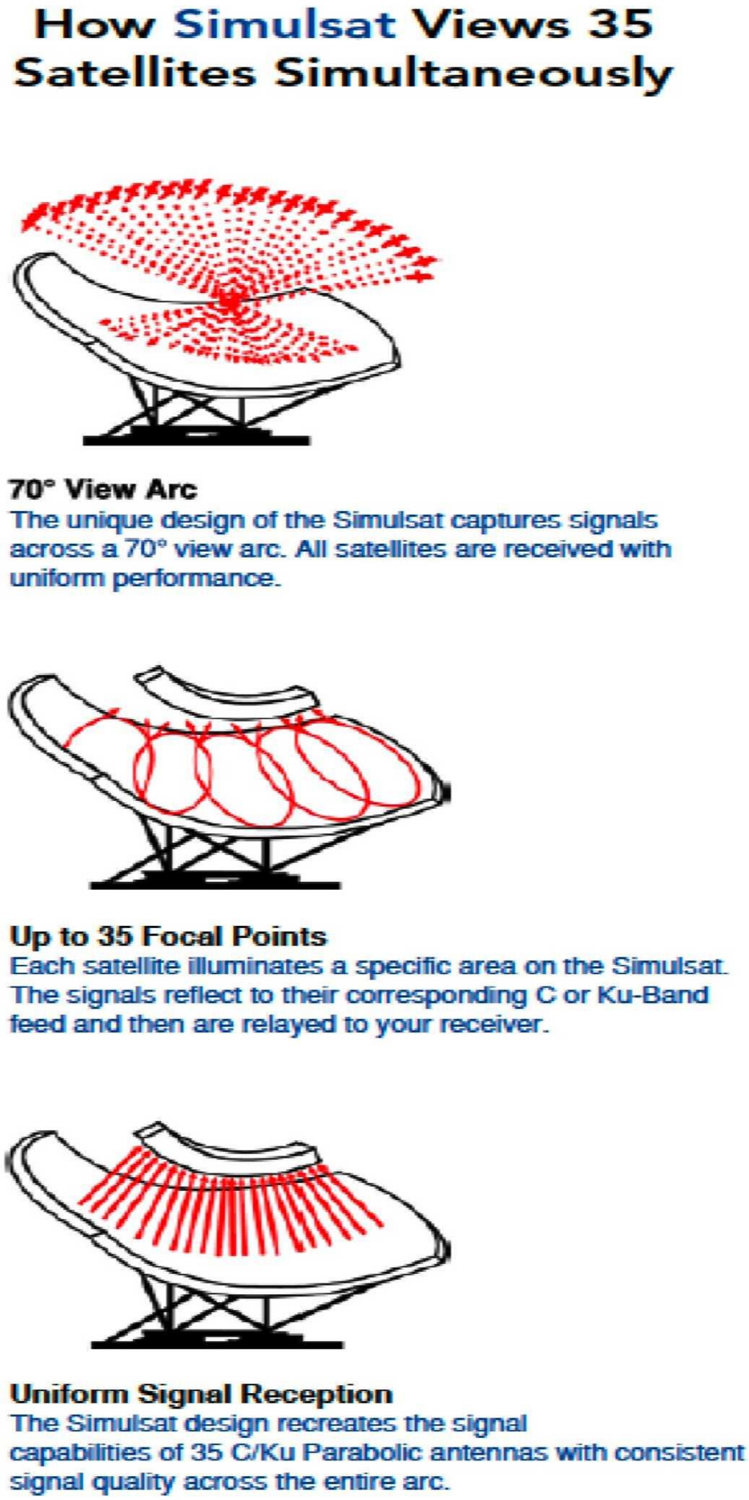
The virtue of a multi-beam antenna, compared to the more common parabolic dish type, is that it is has an arc of view of between 70º and 75º, and is consequently able to receive satellite transmissions from 35 or more satellites simultaneously without degradation in performance (given a nominal separation between satellites of 2 degrees).[40] Moreover, a large number of transponders on all of these satellites can each be monitored simultaneously, meaning, for example, that even a smaller commercial ATCi-manufactured Simulsat antenna of this type can receive almost 1,000 satellite channels simultaneously (compared with 24-32 simultaneously received channels for a comparable parabolic antenna).[41]

In practice, many geostationary satellites are closer than 2 degrees apart. Indeed, with more than 400 active satellites currently in geostationary orbit, the average separation is only 0.87 degrees.[42] Comprehensive coverage of all satellites in some 70^{o} segments of the geostationary belt therefore requires more than one multi-beam system.

A major disadvantage of Simulsat-type antennas is that maintenance of systematic coverage of the relevant purview, keeping abreast of all new satellite launches, requires frequent re-peaking of the feeds and sometimes re-alignment of the antenna itself. Minor adjustments can be done by hand, using 'only a satellite receiver and video monitor and peaking to minimize noise in the video'. However, it is usually best to use a spectrum analyser, attached to the LNBs, to 'optimize signal strength'.[43] ATCi has produced a line of spectrum analysers for this purpose (the TE900, the TE1200, the TE2000HD and, introduced in January 2015, the TE3000). Sooner or later, systematic monitoring efforts require re-peaking of all of the feeds/LNBs across the whole feed-box. This usually takes a contractor-provided field technician about two days to perform.

Realignment of the Simulsat antenna to a new 70^{o} arc is usually done every several years, depending on the rapidity of changes in satellite positions. It involves using a crane to raise the reflector assembly from the mount and change its roll angle and elevation angle to the desired values, and pivoting the mount to the new azimuth angle. The ATCi Simulsat mount 'affords ± 10^{o} of azimuth adjustment'. In some cases, the desired azimuth is sufficiently different from the previous azimuth as to require re-setting of the mount and its concrete support pad. The final step in

Figure 26: How multiple beam satellite antennas work



Source: Simulsat Multibeam Earth Station Product Family, (ATCi, 2012), at http://www.atci.com/assets/simulsat_brochure2012.pdf the realignment process is to adjust each of the feeds/LNBs 'for the desired 70° satellite view' so that they 'peak within the confines of the feed box'.[44]

3.2 Historical development for orthodox satellite reception

Torus multi-beam antenna designs were pioneered by Comsat Laboratories at Clarksburg, Maryland, in the 1970s. An experimental Torus system, 16.5 metres wide and 9.6 metres high, was installed at Clarksburg in 1973. It was able to receive transmissions from 'as many as seven' communications satellites simultaneously.[45] A two-volume, 420-page technical study prepared by COMSAT Laboratories for the Defense Communications Agency (DCA) in March 1977 showed that four appropriately-spaced Torus sites (for example, at Saint Margaret near Nairobi, Sweden, Iceland and Ascension Island) provided communications with all the LES-9, FLTSATCOM, NATO-II, NATO-III and DSCS satellites then in geostationary orbit. It noted, however, that 'a major disadvantage of the fixed reflector MBTA [Multi-beam Torus Antenna] is the lack of pointing flexibility', hence constraining it to satellites in well-defined orbital positions within 'a fixed position of the geosynchronous arc'.[46]

A report by a COMSAT engineer in 1982 noted that there were 16 satellites in orbit in the 70-143° geostationary arc at that time, three Canadian and thirteen U.S. domestic communications satellites, and that this was expected to increase to 27 by 1985. The total U.S. domestic communications satellite capacity in orbit amounted to about 250 transponders in 1982, and was expected to exceed 400 by 1985. It provided 'technical details, specifications and test data on the SatCom Technologies 4.5 meter Torus antenna', and suggested that one of these could provide simultaneous reception of a large proportion of this traffic well into the 1980s.[47]

In 1981, COMSAT Corp reached an agreement with Radiation Systems Inc (RSI) which allowed the latter to manufacture and sell a variety of Torus multi-beam antennas, ranging in size from 3 to 8.5 metres.[48] RSI was acquired by COMSAT Corp in 1994. In 1998-2000, RSI was amalgamated with Vertex Communications Inc, forming VertexRSI, which produced a highly regarded 7-metre Torus multi-beam antenna system. VertexRSI was acquired by General Dynamics SATCOM Technologies in 2004.

Several other companies also entered the multi-beam market in the 1980s, of which the most important was Antenna Technology Communications Inc (ATCi), based in Chandler, Arizona. By the mid-1980s, ATCi had emerged as a leader in the design of small Simulsat [Simultaneous Multiple Satellites] antennas, producing two principal models, the Simulsat 5 and Simulsat 7 systems, each with several variants in antenna dimensions.[49]

GTE Communications Products Corp was also interested in the new technology in the early 1980s. For example, it produced a study of the design and performance of a Torus multi-beam antenna for the U.S. Army Satellite Communications Agency at Fort Monmouth, New Jersey, the results of which were published in March 1984.[50]

The first U.S. Department of Defense agency to deploy Simulsat multi-beam antennas for its core mission was the Armed Forces Radio and Television Service (AFRTS). It installed two ATCi Simulsat antennas at its Broadcast Center (AFRTS-BC) at Sun Valley in California in the 1980s. One was a 7-meter receive-only reflector, set on a 60- x 40-foot foundation; the other was a 5-meter receive-only reflector on a 50- x 25-foot foundation.[51] A report by the Department of the Air Force in February 1995 stated that the AFRTS was 'a DoD field activity under the direction of the Assistant to the Secretary of Defense for Public Affairs' and that its mission 'is to provide radio and television news, sports, religious, information and entertainment programming to 1 million DoD personnel and their families stationed overseas or at sea where English language broadcast service is unavailable or inadequate'.[52]

4. Russian and Ukrainian multi-beam communications interception antennas

4.1 Russian multi-beam system, Klimovsk

Russian military intelligence (GRU) has also invested in Torus multi-beam technology. For example, a large multi-beam antenna was installed at the GRU's Central SIGINT Facility and COMSAT interception station near Klimovsk, Podolsk, about 50 km south of Moscow, in 2005-06. Terraserver imagery dated 6 July 2005 shows signs of construction. Terraserver imagery dated 23 July 2008 shows it emplaced.

The reflector is about 30 metres wide, while the secondary reflector at the front is about 15 metres across, substantially larger than the General Dynamics Model 700-70TCK at the UKUSA stations. (Figures 27-30) The antenna azimuth is slightly to the west of due south, around 183 degrees, corresponding to 35 degrees East longitude on the geostationary arc. Assuming a 70-degree purview, this would provide coverage of satellites stationed from about 0° East to about 70° East longitudes on the geostationary arc.

Figure 27. Russian multi-beam antenna, Klimovsk, Google Earth imagery, 13 July 2014

Figure 28. Russian multi-beam antenna, Klimovsk

Source: Igor Pekon, Panoramio, 27 August 2011, at http://www.panoramio.com/photo/58018428

Figure 29. Russian multi-beam antenna, Klimovsk

Source: Igor Pekon, Panoramio, 27 August 2011, at
http://www.panoramio.com/photo/58018511

Figure 30. Russian multi-beam antenna, Klimovsk

Source: Андрей Хромых, Panoramio, 13 June 2010, at
http://www.panoramio.com/photo/36716056

4.2 Ukrainian multi-beam system, Ovidiopol-2, Dobroaleksandrovka

Ukraine's Foreign Intelligence Service (SZRU) maintains a COMSAT interception station called Ovidiopol-2 near Dobroaleksandrovka in Ukraine which has two multi-beam antennas, one of them of staggering dimensions. The station is located about 4 km southwest of the town of Dobroaleksandrovka and 18 km southwest of Odessa. It was established by the Soviet KGB's 16th Directorate, originally for HF radio interception, but began COMSAT interception activities in 1978. It was apparently taken over by Ukraine's Security Service (SBU) after the collapse of the Soviet Union in 1991, and then by the SZRU after its creation in 2005.[53] There are now nine parabolic antennas at the station, most of which are oriented to the southeast towards communications satellites stationed over the Indian Ocean.[54]

The very large multi-beam antenna is 80 metres wide, and points towards the southwest, with an azimuth of about 220 degrees, corresponding to about 1 degree West longitude at the equator. The system is informally called the 'Comb'. It was evidently installed around 1987.[55] (It was not there in 1983. The earliest Google Earth image of the site is dated 29 September 2003, at which time it looked like it had already been there for a long time). Photographs of the site on the Web show that major renovations were undertaken between 2005 and 2008. The associated Operations Building was renovated, the main reflector was re-painted, and the feeds on rails on the feed-box may have been re-peaked. However, photographs taken in 2005, 2008 and 2011 show only 11-13 feeds on the feed-box, indicating that it was monitoring 13 satellites simultaneously. (Figures 31-34)

The second, smaller multi-beam antenna, located in the southeast part of the base, measures about 17 metres wide. Terraserver images show that it was installed sometime between 24 July 2009 and 6 June 2010. It points to the southeast, with a boresight around 150 degrees, corresponding to about 53 degrees East.

Figure 31. 80-metre multi-beam beam antenna, Ovidiopol-2, Dobroaleksandrovka, Ukraine, 3 July 2005

Source: Sergei Leshchinsky, Panoramio, 14 July 2008, at http://www.panoramio.com/photo/11188910

Figure 32. 80-metre multi-beam antenna, Ovidiopol-2, Dobroaleksandrovka, Ukraine, 23 April 2011

Source: Cage-Creed, Panoramio, 4 May 2011, at
http://www.panoramio.com/photo/52165942

Figure 33. 17-metre and 80-metre multi-beam antennas, Ovidiopol-2, Dobroaleksandrovka, Ukraine, 8 August 2011

Source: Михаил ковальчук, Panoramio, 20 September 2011, at http://www.panoramio.com/photo/59304107

Figure 34. 80-metre multi-beam antenna, Ovidiopol-2, Dobroaleksandrovka, Ukraine, 29 March 2008

Source: "Радиоразведка СЗР", Український мілітарний портал [Ukrainian military portal], posted 6 February 2011, at http://www.mil.in.ua/forum/download/file.php?id=1272&sid=b3ca0b38ce7a83f272b9bf0edf9625b2

5. Non-SIGINT U.S. military multi-beam antennas

5.1 March Air Force Base, Riverside, California

The AFRTS and its AFRTS-BC, now called the Armed Forces Network Broadcast Center (AFN-BC), together with the 5-metre and 7-metre Simulsat antenna systems, were moved to March AFB in Riverside, California, in March-September 1995.[56] In August 2010, the Defense Media Activity (DMA) under the Office of the Secretary of Defense for Public Affairs (OSD-PA) announced the award of a sole-source contract to ATCi for the replacement of the Simulsat 7 at Riverside. It said that:

> The proposed procurement is to replace the American Forces Network (AFN)-Broadcast Center (BC) Engineering's ATCi 7 meter Simulsat satellite antenna and Low Noise Block (LNB) assemblies. The antenna is located at 23755 Z Street, Riverside CA 92518. The ATCi 7 meter Simulsat antenna is the primary source for AFN-BC Operations Branch to acquire broadcast television command information, news and entertainment programming for distribution to the 900,000 Department of Defense personnel, stationed in 176 countries around the world.[57]

The Simulsat 7 was to be replaced by a similar 7-metre system, with installation of the new system to begin no later than 15 September 2010. The contract involved a 'new reflector, feedbox, spar legs, side braces, mount elevation jack, columns and hardware kit', as well as 'peaking' of the individual feeds.[58]

Figure 35 shows the ATCi Simulsat 5 and Simulsat 7 antennas together at Riverside.[59]

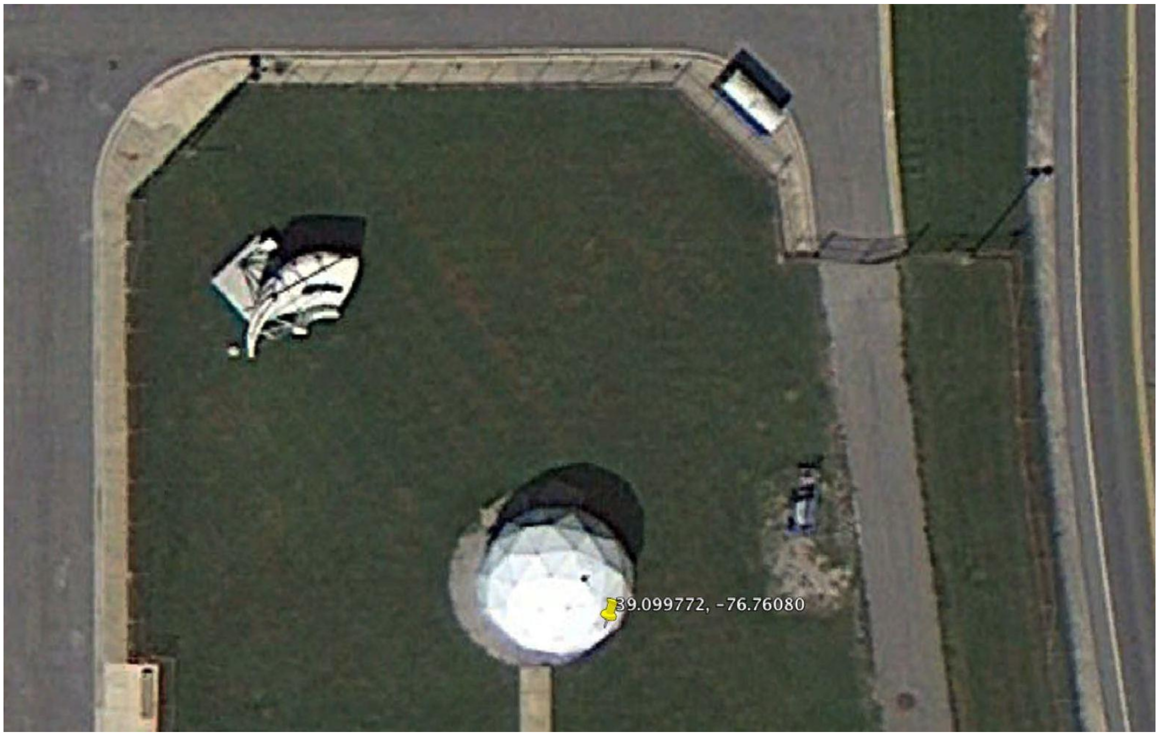
Figure 35. ATCi Simulsat 5 and Simulsat 7 antennas, March AFB, Riverside, California

5.2 NSA HQ, Fort Meade, Maryland

There are two Simulsat multi-beam antennas at the NSA HQ at Fort George G. Meade. They are both variants of the ATCi Simulsat 5 system, and both are mounted on 4-metre square pads. One is located near the corner of Samford and O'Brien Roads, across Samford Road from NSA's Public Affairs Office. It first appears in an image dated 28 February 2007 (it is not in the 27 May 2006 image). It faces to the southeast. (Figure 36)

The second is located at the DMA Satellite Antenna Facility at 6225 Rock Avenue. The requirement for this antenna was announced by the OSD-PA on 27 January 2010. It specified the following:

Figure 36. NSA HQ, Fort Meade, Maryland, Google Earth imagery, 30 August 2010



> ATCi Model Simulsat 5 C/Ku, precision series multibeam antenna with 70-degree arc, capable of receiving satellite transmissions from 35 or more satellites simultaneously without adjustment or degradation in performance from one satellite to the next, no less than 2-degree compliant with the ability to capture signals from all C and Ku Band satellites within a 70-degree view arc. Frequency: C Band 3.4-4.2 GHz and Ku Band 10.7-12.75 GHz.[60]

The reflector was to be no larger than 5.06 metres x 9.4 metres (16.6 feet x 30.7 feet). The contract included training of personnel in operating and maintaining the Simulsat 5 system, including 'hands-on practice installing and peaking feed assemblies with use of a spectrum analyser for various type feeds and LNBs [Low Noise Blocks] inside the Simulsat feedbox'. The contract was to be awarded on 23 February 2010.[61]

Figure 37. DMA Satellite Antenna Facility, 6225 Rock Avenue, Fort Meade, Maryland, Google Earth imagery, 24 October 2014

The announcement noted that the American Forces Network Broadcast Center (AFN-BC) is under the umbrella of the Broadcast Services Directorate (BS) located at Fort Meade, which is part of the Defense Media Activity (DMA) under OSD-PA, also based at Fort Meade.[62]

The DMA facility at 6225 Rock Avenue has seven parabolic dishes in addition to the Simulsat antenna (six pointing to the southwest and one to the southeast). The concrete pads and support posts for the Simulsat and the dishes were newly installed in Google Earth imagery dated 29 August 2010, although none of the antennas were emplaced. The next Google Earth imagery, dated 3 June 2011, is relatively low-resolution, but the Simulsat antenna is quite discernible. It faces to the southwest. (Figure 37)

The Simulsat 5 at the DMA facility provides 'over 50 satellite feeds'.[63]

5.3 CIA HQ, Langley, Virginia

There are two multi-beam antennas at the CIA HQ at Langley, Virginia, both located on the edge of the northeast car-park. One is about 14 metres wide and faces to the southeast. The other is about 8.5 metres wide and faces to the southwest. (Figure 38) Successive Google Earth images show that they have been there since at least April 2000.

Figure 38. Simulsat multi-beam antennas, CIA HQ, Langley, Virginia, Google Earth imagery, 1 February 2007

5.4 Fort Belvoir, Virginia

The OSD-PA also announced a contract on 27 January 2010, awarded to ATCi, for a Simulsat antenna for the AFRTS Pentagon Channel at Fort Belvoir in Virginia.[64] However, it is not apparent in currently available satellite imagery.

5.5 Naval Information Operations Command (NIOC), Suitland, Maryland

The Naval Information Operations Command (NIOC), located at 4251 Suitland Road in Suitland, Maryland, has a Simulsat 5 multi-beam antenna. It is located in the southwest part of the NIOC compound, and faces to the southwest. It is the largest variant of the Simulsat 5, with a width of 8.86 metres. Archival sequences of Google Earth images show that it has been there since the early 1990s.

5.6 Schriever Air Force Base, Colorado

The 50th Space Wing of the USAF's Space Command, based at Schriever Air Force Base near Colorado Springs, which maintains operational control of the Air Force Satellite Control Network and the USAF's space surveillance mission, was equipped with an ATCi Simulsat 5 C/Ku multi-beam antenna system around 2006-07. (It was not present in Terraserver imagery dated 31 August 2006. The earliest available image is on the Terraserver site on 27 January 2010). The system is operated by the 25th Space Range Squadron (SRS). (Figure 39)

On 28 April 2005, Space Command announced that it intended to procure a ATCi Simulsat multi-beam antenna for installation at Schriever AFB. It required a dual-band capability, covering both the C- and Ku-bands.[65] In August 2007, Space Command sought information from potential sources for 'feed-peaking' services for the ATCi Simulsat antenna at Schriever AFB. The source was expected to provide one qualified 'field technician' and 'all equipment necessary for the tune-up'.[66]

In September 2014, Space Command contracted with ATCi to re-align the antenna to a 'new 70 degree Arc … in order to align with the [current] geobelt'. It noted that 'the Simulsat antenna is currently looking at 28 different satellites using 96 individual feeds', and that all 96 feeds had 'to be re-peaked and polarized for the new satellites'. The Single Source Justification stated that 'ATCi is the sole vendor capable of performing 100% of [the re-alignment requirements]', and that two ATCi Field Engineers were required for the job. The Statement of Work noted that

repositioning of the Simulsat 'will cause the antenna structure to sit slightly off the current concrete pad', and hence 'concrete additions' were required. It also stated that Space Command 'will furnish a listing of satellites which the feeds will be peaked upon', as well as 'provide [the] contractor with new antenna look angle'.[67]
The Simulsat antenna at Schriever is 9.5 metres wide, the standard size of the ATCi Simulsat 5B system. It is located at 38.8006 North, 104.522 West, in the southeast part of the base, 25th Space Range Squadron's Advanced Capabilities Environment laboratory.[68] It is oriented towards the south.

Figure 39. Simulsat antenna, Schriever Air Force Base, Google Map imagery

5.7 U.S. Army Transmitter Facility, Egelsbach, Germany

There are two Simulsat multi-beam antennas at the U.S. Army's Transmitter Facility at Egelsbach in Germany. The facility is located in a forested area (50.004 North and 8.611 East) near Langen, about 5 km northwest of Egelsbach, 4 km southeast of Frankfurt Airport and about 15 km northeast of the Army's Intelligence and Security Command (INSCOM) Dagger Complex near Griesheim, just west of Darmstadt. High-resolution Google Earth imagery of the site dated 31 July 2013 shows three radomes and a small dish without a radome, as well as the two Simulsat antennas (Figure 40).

According to Terraserver imagery, the two Simulsat antennas were installed sometime between 19 August 2006 and 2 April 2009. They are both present in a ground-shot taken in February 2009 (Figure 41). Both Simulsat antennas are apparently ATCi.

Figure 40. U.S. Army Transmitter Facility, Egelsbach, Google Earth imagery, 21 July 2013

Figure 41. U.S. Army Transmitter Facility, Egelsbach, February 2009

Source: stimby23, 'Egelsbach Transmitter Facility Feb. 09', Panoramio, 22 February 2009, at https://ssl.panoramio.com/photo/19294505.

5.8 Torii Station Teleport, Okinawa

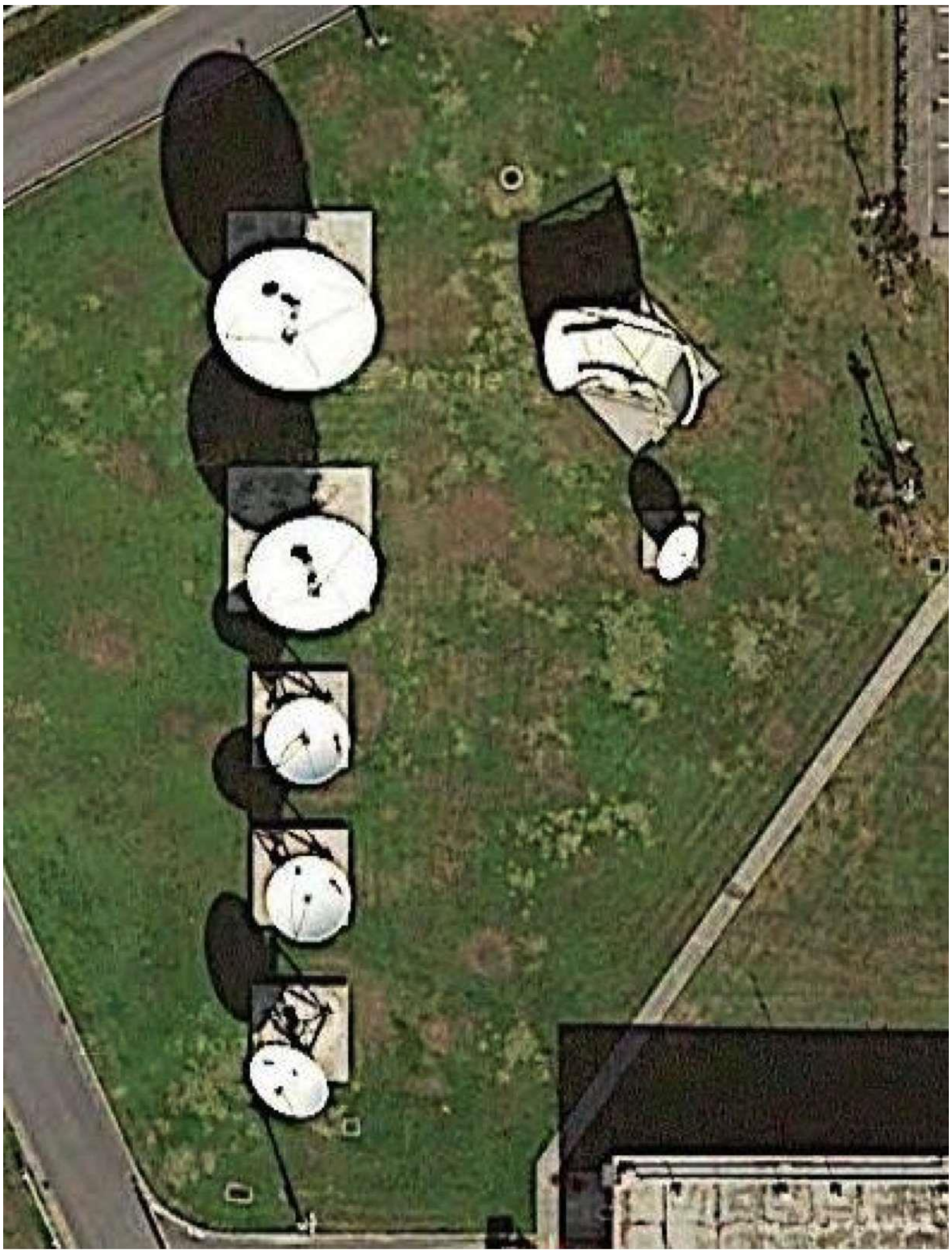
The Torii Station Teleport in Okinawa has an 8-metre-wide Simulsat multi-beam antenna. It is clearly shown in high-resolution Google Earth imagery dated 30 January 2014 (Figure 42). It has been there since at least 21 June 2007. The imagery before that (1 November 2005) pre-dates the construction of the entire teleport.

5.9 NASA Langley Research Center, Virginia

The National Aeronautics and Space Administration (NASA) Langley Research Center at Hampton, Virginia, has a 7-metre-wide Simulsat antenna. It is located on the western side of the Center, close to Highway 172 (Commander Shepard Boulevard). Low-resolution Google Earth imagery suggests that it has been there since at least the early 1990s. It points towards the southwest.

On 1 April 2007, NASA awarded a contract to Lockheed Martin Government Services for a variety of communications and computing services at the Langley Research Center, including replacement of the LNBs on the Simulsat antenna.[69]

Figure 42. Simulsat multi-beam antenna, DoD Gateway/Teleport, Torii Station, Okinawa, Google Earth imagery, 30 January 2014



5.10 ATCi Warrior Satellite Surveillance System

In January 2008, ATCi announced that it had developed the Warrior Satellite Surveillance System for simultaneously monitoring satellites across the geostationary belt, designed specifically 'for the unique requirements of government and military entities'. (Figure 43) In May of that year, ATCi's CEO, Gary Hatch, stated that 'Warrior's core technology is an already proven and delivered solution that is key to many large Department of Defense Systems as well as other government, military and multimedia systems in operation today'. He also noted that the company 'has a long standing history in successfully implementing sensitive surveillance and monitoring systems for the Department of Defense and other like government and military agencies in the US'.[70]

In addition to its standard Simulsat capabilities for simultaneously monitoring RF [radio frequency] transmissions from multiple geostationary satellites, the Warrior system is able 'to automatically analyse, manage, control, and archive the content being carried on any given transponder on any given satellite in its viewing arc'. Moreover, the Warrior system uses two Simulsat antennas with azimuths angled 70 degrees apart to monitor the signals of 70 or more satellites over an arc of 140 degrees. It is able to 'simultaneously process thousands of RF carriers' in the X-band, C-band, Ka-band and Ku-band. It can be networked with other stations to provide complete global coverage. A 'full satellite arc RF jamming' capability can also be provided. Mobile systems are also available.[71]

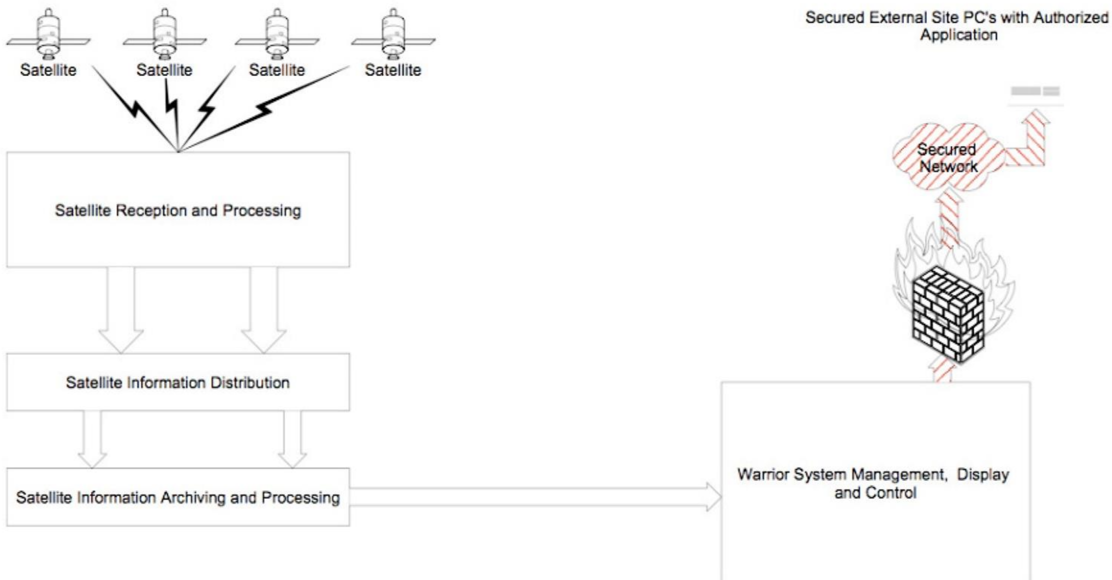
The Warrior system incorporates a new ARC (Archive/Retrieval/Catalogue) Sentry feature, which displays the status of the satellites being monitored and can automatically trigger various alarms. According to ATCi, the advanced system 'enables planned and non-planned event analysis of activities transpiring over any of the satellites simultaneously within the 140 degree view arc'. It says that the 'proprietary search and retrieve technology loads key information METADATA into an interlinked network of IP storage servers to provide unparalleled surveillance tools for today's fluid and ever-changing communication markets'. The system enables 'geo-location and tracking of rogue RF [carriers]' as well as 'voice/data interdiction' and storage of the metadata 'over many years'.[72]

The ATCi CEO, Gary Hatch, an enthusiastic advocate of multi-beam technology, has said that 'monitoring virtually everything in the sky has become critical in today's digital world', and that:

> It is not enough to simply monitor FSS [Fixed-Satellite Service] satellites; today's skyway and highway surveillance must also have the ability to associate and provide critical algorithms and patterning data. [The Warrior system] can ultimately process and index massive IP data troves thereby delivering greater relational data pattern information to make the best rational decisions [and provide] much greater security.[73]

In November 2008, ATCi announced that its Warrior system had been deployed in 'the Asian region'. It stated that 'several' Warrior-like systems were employed in 'Asian defense networks', but it did not identify the country or countries involved.[74] In January 2009, the Indian government announced that it had procured the Warrior system to cover the sub-continent region. Hatch said that following the terrorist attacks in Mumbai in November 2008, India had 'a heightened requisite for extensive monitoring and surveillance of everything in the sky'.[75]

Figure 43. Warrior Satellite Surveillance System schematic



Annexe 1: Analysis of satellite terminals at Five Eyes FORNSAT/COMSAT sites, 2000–2015

Site	Covername	Notes	Survey period 1: 1995-2004	Trad	COTS	Survey period 2: 2003-2010	Trad	COTS	Survey period 3: 2011 to present	Trad	COTS	Torus
Ayios Nikolaos	SOUNDER	-	1x33m, 1x18m, 2x12m, 3x8m, 1x6mr, 1x4m [2003]	8	1	1x33m, 3x18m, 2x12m, 3x8m, 1x6mr, 2x5m, 1x4m [2008]	10	3	1x33m, 3x18m, 2x12m, 3x8m, 1x6mr, 2x5m, 7x4m, 2x3m, 6x2.5m?, Torus [2015]	10	17	1
Bad Aibling	GARLICK	Transfer-red to BND 2004; not counted after 2004	1x30mr, 1x27mr, 1x21mr, 1x18mr, 4x16mr, 1x13mr, 4x12mr, 4x10mr, 2x9.5mr, 1x7mr, 1x5m [2002]	20	1	1x30mr, 1x27mr, 1x18mr, 4x16mr, 1x13mr, 1x12mr [2009]	(9)	(0)	1x30mr, 1x27mr, 1x18mr, 4x16mr, 1x13mr, 1x12mr, 1x8m [2012]	(10)	(0)	(0)
Bude	CARBOY	-	3x33m, 1x30mr, 3x19.5m, 3x14m, 2x13mr, 4x12m, 1x7.5m, 2x4m [2001]	17	2	3x33m, 1x30mr, 3x19.5m, 3x14m, 2x13mr, 4x12m, 1x7.5m, 1x5m, 2x4m, 3x2m? [2005]	17	6	3x33m, 1x30mr, 3x19.5m, 3x14m, 1x13mr, 4x12m, 1x9.5m, 1x7.5m, 2x4m, 1x2m?, Torus [2013]	17	3	1

Geraldton	STELLAR	-	4x37m, 1x27m, 1x5m, 3x3m? [2002/2005]	5	4	4x37m, 1x27m, 5x19m, 2x17m (under construction), 1x9m (under construction), 2x5m, 4x3m? [2010]	13	6	4x37m, 1x27m, 5x19m, 2x17m, 1x9m, 2x7.5m, 2x5m, 4x3m? [2013]	15	6	0
Khon Kaen	LEMON-WOOD	-	1x20m, 1x18m, 1x5m [2002]	2	1	1x22m, 2x20m, 1x18m, 1x5m, 1x4m, 3x2m [2012]	4	5	1x22m, 2x20m, 1x18m, 5x5m, 1x4m, 1x2m [2015]	4	7	0
Leitrim	N/A	-	2x21m, 2x8.5m, 2x12m, 1x4.5m, 1x3.5m, 1x3m [2003]	6	3	2x21m, 2x8.5m, 2x12m, 1x10.5m, 1x4.5m, 1x3.5m, 1x3m [2005/2008]	7	3	2x21m, 2x8.5m, 2x12m, 1x10.5m, 1x4.5m, 1x4m, 1x3.5m, 1x3m, 2x4m [2014]	7	6	0
Menwith Hill	MOON-PENNY	Excludes SBIRS, SCS, SIGINT satellite downlinks	3x28m, 1x20m, 2x18m, 1x16m, 3x13m, 2x10m, 1x8m, 1x2m? [2002]	13	1	3x28m, 1x20m, 2x18m, 1x16m, 3x13m, 2x10m, 1x8m, 1x5m, 1x2m? [2007]	13	2	3x28m, 1x20m, 2x18m, 1x16m, 3x13m, 2x10m, 1x8m, 1x5m, 1x2m?, Torus in [2014]	13	2	1
Misawa	LADYLOVE	Excludes DSCS	1x26m, 1x23m (DSCS), 1x20m (DSCS), 8x17m, 2x16m, 1x8m [1995]	12	0	1x26m, 1x23m (DSCS), 1x20m (DSCS), 8x17m, 2x16m, 1x8m, 2x4m, 2x2m [2006]	12	4	1x26m, 1x23m (DSCS), 1x22m, 2x21m, 1x20m (DSCS), 1x19m, 8x17m, 2x16m, 2x12m, 1x11m, 2x8m, 5x6m, 1x4m, 5x4m, 1x2m [2014]	25	7	0

Pine Gap	N/A	Excludes SBIRS, STSS, SIGINT satellite down-links, pre-1999 dishes	2x30m [2000]	2	0	2x30m, 1x6m, 2x5m (STSS?), 1x3m, 1x2.5m [2004]	3	2	2x30m, 1x18m, 1x6m, 3x5m (STSS?), 1x4m, 1x3m, Torus [2013]	4	2	1
Seeb	SNICK	-	1x16m, 1x15m, 3x12m, 1x8m, 1x5m [2001]	6	1	1x18m, 1x16m, 1x15m, 3x12m, 1x8m, 3x5m, 2x3m, 4x2-3m [2009]	7	9	1x18m, 1x16m, 1x15m, 3x12m, 1x8m, 3x5m, 2x3m, 5x2-3m, Torus [2014]	7	10	1
Shoal Bay	N/A	-	1x20m, 4x17m, 2x11m, 2x7m, 1x3m [2004]	9	1	1x20m, 3x18m, 4x17m, 1x11m, 2x7m, 1x3m [2005/2009]	11	1	1x20m, 3x18m, 4x17m, 1x11m, 1x10m (outside main compound), 2x7m, 1x3m [2014]	12	1	0
Sugar Grove	TIMBER-LINE	-	1x46m, 1x32m, 1x19m, 1x16m, 1x13m, 5x12m, 2x2m [2003]	10	2	1x46m, 1x32m, 1x20m, 1x19m, 1x16m, 1x13m, 5x12m, 2x5m, 3x2m, 2x1.5m [2011]	11	7	1x46m, 1x32m, 1x20m, 1x19m, 1x16m, 1x15m, 1x13m, 5x12m, 5x5m, 1x3m, 3x2m, 2x1.5m [2013]	12	11	0
Waihopai	IRONSAND	-	2x30m [1995]	2	0	2x30m, 2x8m [2004]	4	0	2x30m, 2x8m, 2x3m?, 2x2m?, Torus [2013]	4	4	1
Yakima	JACKKNIFE	-	1x30m, 1x13m, 2x12m, 1x8m,1x5m [1996]	5	1	1x30m, 1x13m, 3x12m, 4x11m, 1x8m, 1x6m, 1x3m, 2x2m [2003]	11	3	1x30m, 1x13m, 4x12m, 4x11m, 1x8m, 1x6m, 3x5m, 3x3m, 2x2m [2013]	12	8	0
Antenna	total by type (Trad, COTS, Torus)			117	18		123	51		142	84	6

Antenna	totals for period	135		174		232	
Potential satellites covered		135		174		436	
COTS % of antennas		13.64%		28.80%		33.74%	

Methodology: The table was compiled by one of us (BR) using publicly available satellite imagery from Google Earth, Bing, and Terraserver, so as to enumerate the numbers and sizes of satellite terminals seen. Terminals that the authors know or have reason to believe are associated with orthodox satellite communications, SBIRS, or other space-based warning systems, or with the control and downlinking of SIGINT satellites have been excluded. The numbers of antennae at the former NSA Bad Aibling site have not been included in the totals after handback to BND in 2004. Satellite terminals at other Five Eyes sites such as CSO Ascension Island, JSSU Digby (U.K.), NSA Hawaii, and CFS Masset (Canada) have not been included.

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