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Department of Defence
Science and Technology

An Azimuth Elevation Survey of DST Group Edinburgh 71 Labs Platform

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DST-Group-TN-1690

ABSTRACT

The National Security and Intelligence, Surveillance and Reconnaissance Division of the Defence Science and Technology Group Edinburgh had installed Ultra High Frequency band antennas on the 71 Labs small experimental platform. These antennas were used to test communications to and from an engineering model of a small satellite. This report presents the findings of an azimuth elevation survey to determine the minimum safe elevations for antenna pointing and signal transmission.

Produced by

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Executive Summary

The National Security and ISR Division small satellite project developed an antenna system and automated antenna tracking software to communicate with the first satellite mission. The original testing mount for the command and control antenna was located on 71 Labs, above the western veranda facing 205 Labs.

The tracking software drives the antenna rotator from horizon to horizon, to maximise the communication duration for each satellite pass. Located in a high traffic area and amongst populated office buildings, there is a potential radiation hazard if antenna pointing is not properly controlled.

On the 16 September 2016, an azimuth elevation survey was conducted at height of 165 cm above the deck on the 71 Labs platform to determine the safe pointing elevations for the antenna system.

The results of the azimuth elevation survey reveal:

1. The tree line (looking north) varies in height, obstructing the clear line of sight to the horizon between 5 or 10 degrees.
2. The tree line beyond 71 Labs saw tooth roofline (looking east) obstructs the line of sight to the horizon by 5 degrees,
3. The height of the skybridge (looking south) obstructs the clear line of sight to the horizon by 7 degrees, and
4. The height of the 205 Labs building (looking west) obstructs the clear line of sight to the horizon by 10 degrees. The closest infrastructure to the antenna site, the concrete stairwell, obstructs the line of sight by 17 degrees.

The best viewing azimuth is between 177 – 182 degrees, looking due south, with infrastructure obstructing view to the horizon by 01°51'33". The best range of viewing azimuth from the 71 Labs platform is 55 - 115 degrees recording 5° elevation or less.

These survey results can be reused for future antenna trials work conducted from the 71 Labs platform.

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Contents

Abbreviations

DST Group	Defence Science and Technology Group
GPS	Global Positioning System
IS Branch	Intelligence Systems Branch
NSID	National Security and ISR Division
RPE Group	Radar Processing and Exploitation Group
PED	Portable Electronic Device
SLR	Single Lens Reflex
UHF	Ultra High Frequency
WCSD	Weapons and Combat Systems Division

1. Introduction

The National Security and ISR Division (NSID) of Defence Science and Technology (DST) Group Edinburgh is establishing a ground control station as part of the NSID Small Satellite Program.

The Ground Station will utilise Ultra High Frequency (UHF) yagi and helical antenna for communication with the small satellite mission Buccaneer. These antennas have been designed and constructed by a DST Group Communications Engineering team. The antenna was positioned on the 71 Labs platform for convenience whilst in the design and test phase.

The 71 labs experimental platform is a small structure immediately above the western veranda of 71 Labs. The platform is located in a sheltered location with 205 Labs to the immediate west.

Ground Station software is being developed for the automation of communicating commands to the Buccaneer satellite. All test command and control communication will be transmitted from the UHF antenna that was originally mounted on 71 Labs platform. The software does not cater for the constrained line of sight. With a 100 W power amplifier installed to increase the power of the transmission signal, it is important to maintain a clear line of sight to the sky, and not point the antennas directly at windows in nearby office buildings.

A TOPCON OS-103 On-board Total Station surveying instrument was borrowed from the Weapons and Combat Systems Division (WCSD) trials team. The surveying instrument was set up alongside the antenna mast on the platform, as close to the height of the antenna as possible[1]. On 16 September 2016, the surveying instrument was operated by an experienced geomatics engineer from Land Division to output azimuth, elevation and distance to notable features on the horizon.

A bearing measurement to a known location on site was calculated and recorded to orientate the instrument and serve as a rough alignment check (if needed) for the antenna.

Any obscuration limits that are integrated into software should take into account the antenna gain pattern, particularly the main lobe beamwidth and side lobe structure. Figure 1 shows the trigonometry calculation for the difference in angle (in degrees) of the main antenna mast and viewing point of the Topcon total surveying workstation. The difference in height is not going to pose any issues; rather, the height of the instrument and measurements provide a conservative result that will increase the factor of safety of the minimum elevation for antenna pointing and signal transmission.

[1] The TOPCON OS-103 was setup at 165 cm (tripod 140 cm), not the same height as the cross boom of the antenna mount (2.25 m). The instrument recorded elevations from a position that was 40 cm below the actual height. So results are slightly more "pessimistic".

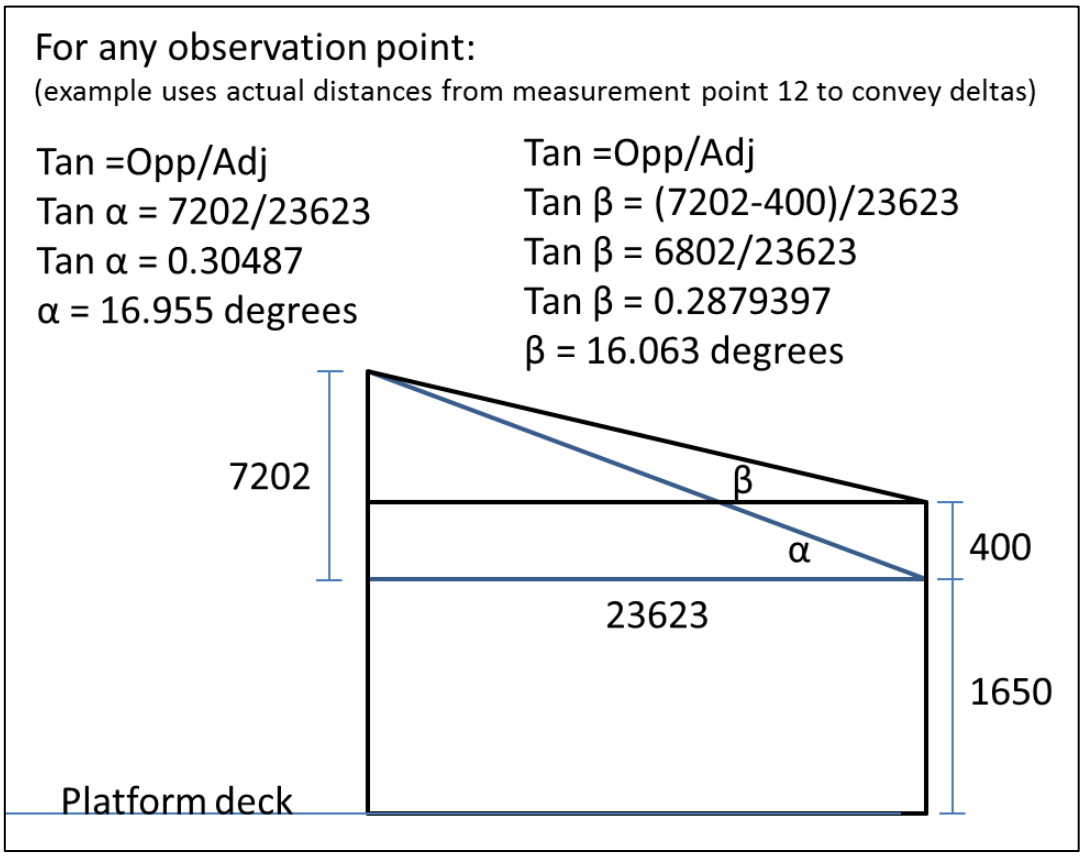

Figure 1: Angle of measurement vs Angle for viewing

2. Description of Site

The 71 Labs platform is operated by the Intelligence Systems (IS) Branch Radar Processing and Exploitation (RPE) Group. The primary purpose of the platform is for testing new concepts and designs in antenna technology to support airborne sensors.

The Small Satellite Program has been able to utilise the services of an Antenna Engineer and technical staff to design and construct the UHF antennas. These antennas were mounted on the 71 Labs platform for testing and integration within the antenna lab (located in close proximity). A computing rack is located in the lab below the platform, positioned to minimise the cable run and potential cable signal loss.

Figure 2: The 71 Labs platform

The small platform pictured in Figure 2 has a deck 2 metres wide by 4.8 metres long. The deck extends from the building out towards the road, and stands 5 metres above the ground, positioned above the western veranda of 71 Labs. On one end, the platform is secured into the external brickwork of 71 Labs, and at the other, founded into the ground.

The decking surface is stainless steel checker plate tray, close to the building, and galvanised (non-slip) mesh grating closer to the access ladder. The deck has a 900 mm balustrade safety guard rail around the perimeter. The access ladder is located on the western side, and is fitted with a ladder cage for staff protection.

3. Equipment

3.1 TOPCON OS-103 On-board Total Station

As pictured in Figure 3, the Topcon OS-103 On-board Total Station is a professional grade compact total (surveyors) station that can be used for building layouts, land surveying, and earthwork volumes. The OS-103 software allows the user to view points, lines and icons.

Figure 3: TOPCON On-board Total Station surveying instrument

In the NSID Small Satellite Project application, the instrument was used to gather azimuth, elevation and distance measurements from the platform to known structures that will obscure the line of sight.

Figure 4: Close up photograph of the OS-103 touch panel display

Figure 4 shows the Total Station touch panel display for one of the measurements. For each position, the instrument was programmed to output the following five parameters:

SD = distance

VD = Vertical Distance

HD = Horizontal Distance

ZA = Vertical Angle (Elevation)

HA-R = Horizontal Angle (Azimuth)

3.2 Global Positioning System (GPS)

As pictured in Figure 5, a DST Group Land Division Fugro 9205 GPS receiver and Trimble GA-810 dome antenna were used to collect all GPS measurements.

The GPS antenna was placed on the same tripod used for the Topcon OS-103 instrument after finishing the azimuth and elevation measurements. The GPS antenna remained on the tripod for a period of 10 minutes to provide a GPS location to accuracy of 10 cm.

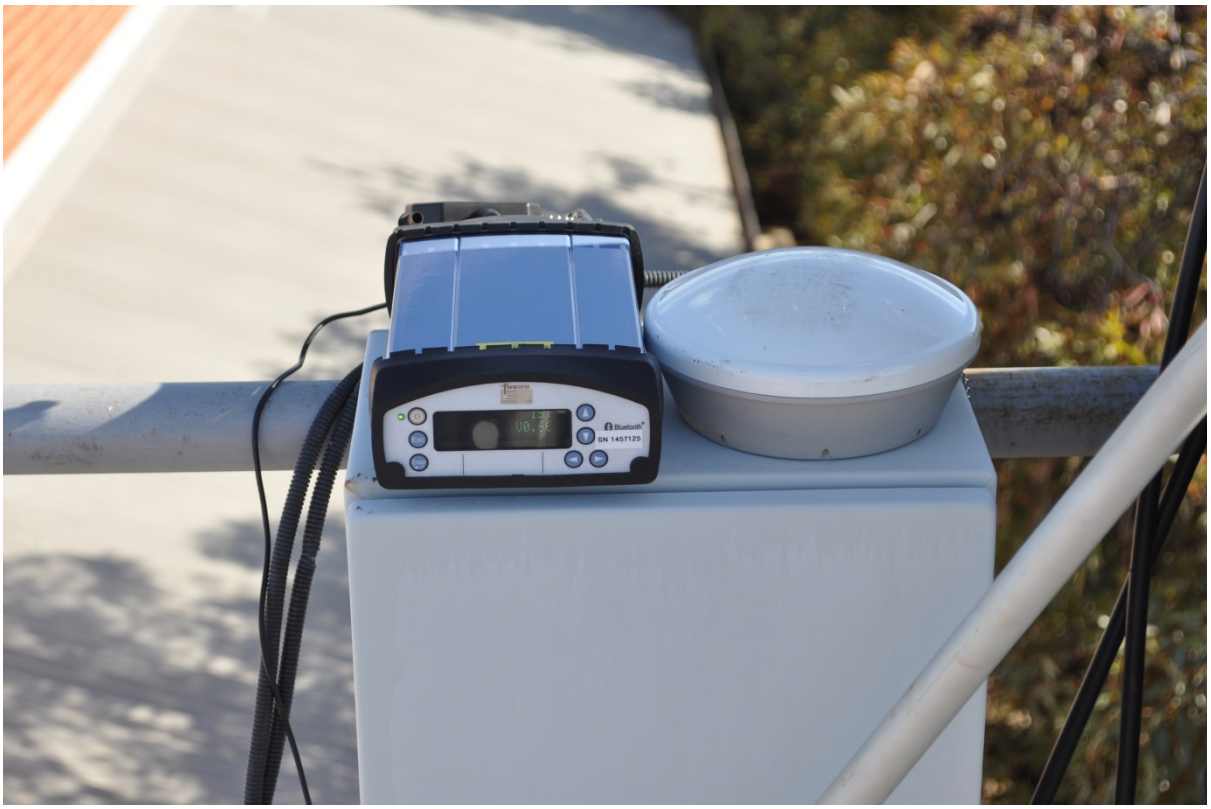

Figure 5: The Fugro 9205 GPS receiver and dome antenna

3.3 Nikon D90 Digital Camera

Figure 6 shows the NSID Nikon D90 digital Single Lens Reflex (SLR) camera fitted with an 18-55 mm lens that was used to capture photographs of the horizon for marking and labelling the surveyed points.

The digital SLR camera was used to photograph significant markings and features required for the documentation.

Authorisation for the use of Portable Electronic Devices (PEDs) to allow use of the camera was granted by Research Leader Imagery Systems Branch for the period covering 6 – 23 September 2016. Annex A has a scanned copy of the signed authorisation.

Figure 6: The NSID High Frequency Radar Branch D90 SLR Camera

4. Methodology

The work performed can be described in the following methodology:

1. Instrumentation setup

   The instrument is to be set up as close to the height of the antenna as possible. The instrument is fastened to the tripod then centred and levelled using the view finder to guide the directions.

2. Calibration of Equipment

   The Total Workstation may require configuration of the touch panel after performing a cold boot. This can be performed by holding the stylus on the centre of the target (as it appears on the touch panel). This is required for pointing accuracy to the target location.

3. Measurements of significant points on the horizon

   Each measurement location is recorded with a mark on a photograph of the horizon for reference. The measurements are collected with two passes of the instrument – the first azimuth pass to obtain the infrastructure elevations, the second to add finer detail regarding the tree heights.

4. Global Positioning System (GPS) locations

   A precise GPS reading of the instrument location and at least one other point within line of sight to the instrument is required to provide a correction factor to the azimuth readings.

   The GPS bearings of known locations (or significant points on the horizon) provides the antenna with a known bearing (in case of antenna pointing breakdown)

There are three precision GPS reference points on DST Group Edinburgh site.

- 180 Labs NSID Position Navigation and Timing GPS antenna.
- Blocks and Ponds on the laser range.
- Statue north of 180 labs.

One of these locations is in line of sight to the 71 labs experimental platform.

Effort was made to obtain a reading from the 180 Labs Position, Navigation and Timing GPS Antenna location, but on the day of the survey, the clear line of sight was obstructed by tree canopy. After three attempts at getting a reading on the location using the prism on a surveyor's level staff, the activity was abandoned and replaced by another location within clear line of sight.

Figure 7: Location of the GPS calibration point

The DST Group Edinburgh 180 Labs platform located on the eastern side of 180 Labs was used as the substitute GPS reference point. As depicted in Figure 7, the level staff was placed on the bolt head with height of staff set at 1.5 m. The GPS position was measured on the bolthead to ascertain its precise location. The GPS receiver was set up for 30 minutes duration to provide a better quality estimate of the precise location.

5. Tabulated Measurements

The results of the survey are listed in Table 1. Each line of the table corresponds to a measurement which includes a description of the point, and azimuth / elevation angles and distances away from the platform. Photographs of the skyline record the location of the observation point at the time of the survey.

Table 1: Tabulated results of the survey

Number	Measurement ID	Description	Azimuth (in deg) (HA-R)	Elevation (in deg) (ZA)	Distance (in m) (SD)	Vertical Distance (in m)	Horizontal Distance (in m)	Location
1	1	Corner of building above Canteen	202°17'29"	83°7'27"	211.933	25.1897647	210.409	Figure 8
2	2	Intersection of skybridge fascia and base of WCSD 205 Labs antenna	39°35'36"	89°12'39"	232.455	3.225	232.433	Figure 8
3	3a	Intersection of skybridge fascia with the 205 Labs southern atrium	194°5'51"	85°33'56"	62.579	4.835	62.392	Figure 8
4	3b	Southern most visible edge of the 205 Labs atrium	222°17'31"	85°36'17"	63.006	4.828	62.821	Figure 8
5	4	Top of 205 Labs southern atrium air vent pipe	228°23'30"	85°44'4"	65.201	4.848	65.02	Figure 8
6	5a	Intersection of the 205 Labs southern atrium fascia and the southern concrete stairwell	228°42'7"	85°39'51"	117.985	8.921	117.647	Figure 8
7	5b	Corner of the southern concrete stairwell in line with the 205 Labs southern atrium roof line	230°42'43"	84°41'5"	107.757	9.98	107.294	Figure 8
8	6	Upper south eastern corner of the southern concrete stairwell	236°32'6"	84°10'30"	88.135	8.946	87.68	Figure 8
9	7	Upper north eastern corner of the southern concrete stairwell	241°34'59"	81°9'22"	38.668	5.944	38.208	Figure 8

10	8a	Corner of the southern concrete stairwell in line with the 205 Labs northern atrium roofline	249°11'40"	82°3'8"	42.934	5.935	42.522	Figure 8
11	8b	Intersection of the 205 Labs northern atrium fascia and the southern concrete stairwell	249°20'23"	82°1'39"	64.457	8.94	63.834	Figure 8
12	9	Top of southern concrete stairwell vent	261°9'2"	79°16'57"	53.433	9.935	52.501	Figure 9
13	10a	Intersection of the 205 Labs northern atrium roofline with the northern concrete stairwell	276°15'19"	78°56'7"	46.569	8.935	45.703	Figure 9
14	10b	Corner of the northern concrete stairwell in line with the 205 Labs northern atrium roofline	276°19'31"	78°55'28"	23.361	4.488	22.926	Figure 9
15	11	Upper south western corner of the northern concrete stairwell	276°18'1"	75°30'57"	23.689	5.924	22.936	Figure 9
16	12	Upper south western corner of the balustrade on top of the northern concrete stairwell	280°26'36"	73°2'43"	24.696	7.202	23.623	Figure 10
17	13	Upper north western corner of the balustrade on top of the northern concrete stairwell	289°49'54"	72°25'13"	23.904	7.22	22.788	Figure 10
18	14	Upper north western corner of the 205 Labs northern concrete stairwell	293°9'12"	74°33'45"	22.238	5.919	21.436	Figure 10
19	15	Intersection of 205 Labs northern atrium roofline with the northern concrete stairwell	294°1'6"	78°9'38"	43.618	8.949	42.69	Figure 10
20	16	North eastern corner of the 205 Labs northern atrium	326°42'45"	79°34'55"	49.649	8.975	48.831	Figure 10
21	17	Gutter of the 205 Labs second floor office block immediately below the north east corner of the 205 Labs atrium	326°42'49"	85°3'6"	27.017	2.331	26.916	Figure 10

22	40	Gutter on 205 Labs above the southern edge of the second office window	340°35'28"	85°52'16"	32.253	2.324	32.169	Figure 11
23	18	Upper north eastern corner of the 205 Labs second floor office block (within the tree line)	348°14'44"	86°26'4"	37.237	2.316	37.165	Figure 11
24	39	Highest point on the tree canopy above the north eastern corner of 205 Labs	345°47'3"	82°40'23"	139.580	17.799	138.44	Figure 11
25	19	Highest point of the upper canopy on a gum tree (looking roughly north)	7°30'40"	79°35'28"	78.717	14.215	77.422	Figure 11
26	38	Low point between a gum tree and pine tree	16°13'16"	86°46'0"	144.062	8.131	143.833	Figure 12
27	37	Highest point in the canopy of a tree looking north easterly of 71 Labs	31°23'9"	80°11'47"	96.453	16.16	95.045	Figure 12
28	Bearing Reference Mark	Position on the 180 Labs Eastern tower	222°17'29"	83°7'27"	211.933	25.1897647	210.409	Figure 12
29	36	Eastern edge of the higher tree canopy	52°30'7"	84°5'11"	114.713	11.814	114.103	Figure 12
30	35	Northern edge of the lower tree canopy	55°53'25"	85°41'32"	140.946	10.581	140.548	Figure 13
31	34	Eastern edge of the lower tree canopy	91°27'28"	84°41'42"	233.752	21.519571	232.751	Figure 13
32	33	Adelaide Quarry	102°49'39"	87°56'35"				Figure 14
33	32	Highest canopy position of a single grouping of trees	110°21'28"	85°9'50"	56.299	4.746	56.099	Figure 14
34	31	Tree line immediately below the northern most point of the closest (largest) tree	117°34'40"	86°35'1"	304.408	18.1080142	303.867	Figure 14
35	20	Northern tip of the tree canopy on the closest (largest) tree	117°10'45"	78°33'58"	47.314	9.378	46.375	Figure 14

36	21	Highest point in the canopy of the closest (largest) tree	130°5'41"	71°5'12"	49.862	16.164	47.17	Figure 14
37	30	Southern tip of the tree canopy on the closest (largest) tree	136°1'29"	73°51'19"	50.807	14.128	48.803	Figure 15
38	22	Northern point of the tree canopy on the southern side of the closest (largest) tree	138°57'17"	80°7'51"	76.420	13.095	75.289	Figure 15
39	23	Tallest canopy in the centre of the tree line on the southern side of the closest (largest) tree	160°50'43"	79°1'25"	63.318	11.8355412	62.16	Figure 15
40	24	The tallest canopy of the southern end of the tree canopy on the southern side of the closest (largest) tree	173°15'20"	80°24'50"	66.037	10.996	65.115	Figure 15
41	25	The eastern edge of the roofline of a building that is not obscured by trees	177°47'12"	88°8'27"	31.549	1.024	31.532	Figure 15
42	26	The southern edge of the roofline of a building that is not obscured by trees	182°1'20"	88°4'27"	30.356	1.02	30.339	Figure 15
43	27	The top centre of a chimney flue on a building to the south	186°51'24"	82°49'56"	30.361	3.789	30.124	Figure 15
44	28	Highest point in the tree canopy to the south of the chimney flue (point 43)	191°25'25"	83°11'2"	119.972	14.251	119.124	Figure 16
45	29	Eastern corner of the guttering on a building immediately below the tree canopy (point 44)	189°35'48"	87°10'2"	45.444	2.246	45.388	Figure 16

6. Photographs of the horizon

A series of photographs of the horizon were taken at the time of the survey to record the measurement points. The right hand column of Table 1 indicates the figure number where that measurement can be found. Combining the table description column with the visual marking of the location on the figure will assist in determining the location of some of the tree canopy measurement locations.

Figure 8: Photo of the horizon looking south from the 71 labs platform

Figure 9: Photo of the horizon looking south south west from the 71 Labs platform

Figure 10: Photo of the horizon looking west from the 71 labs platform

Figure 11: Photo of the horizon looking north from the 71 Labs platform

Figure 12: Photo of the horizon looking over 71 Labs roof from the 71 Labs platform

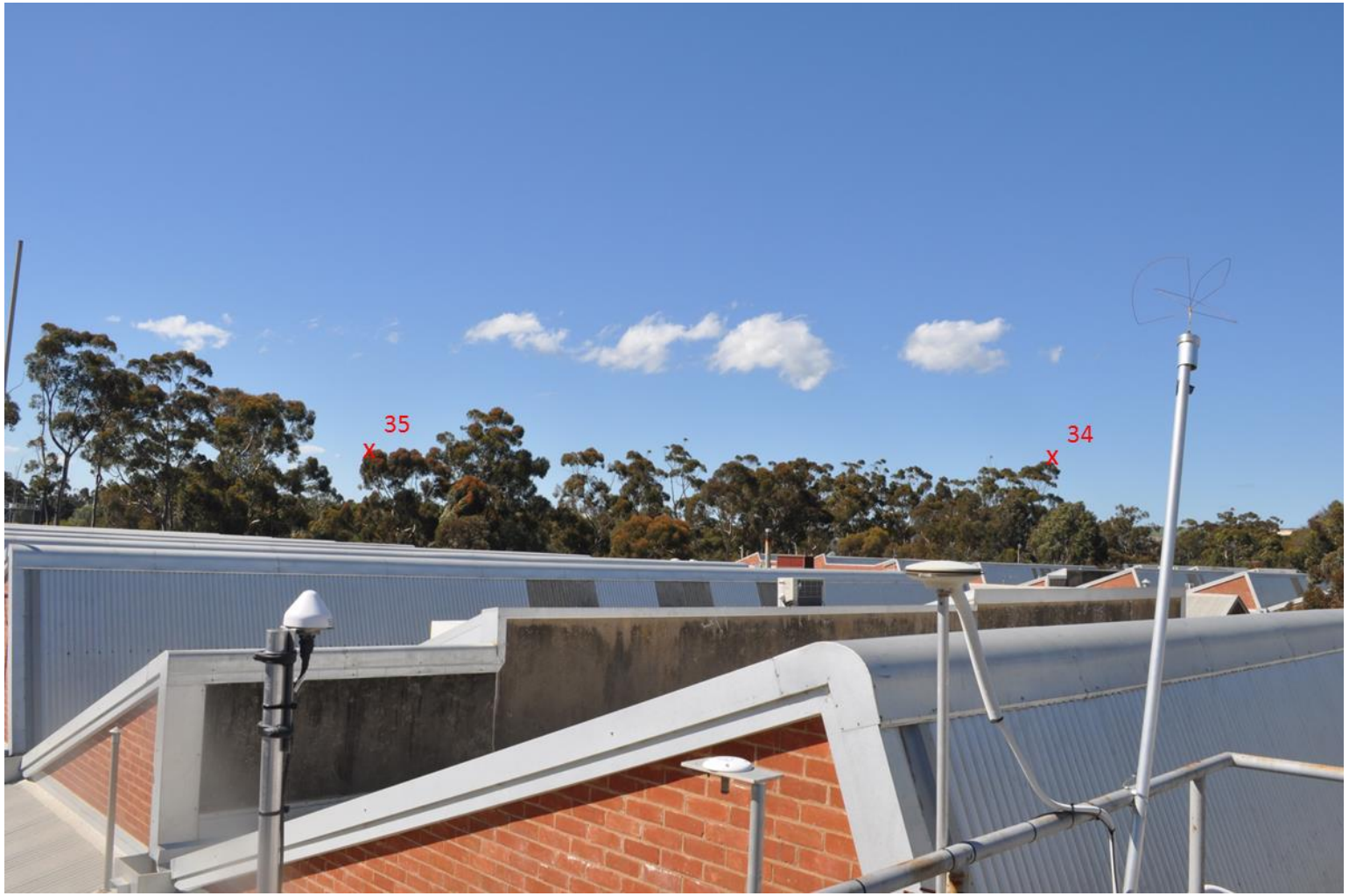

Figure 13: Photo of the horizon looking toward 200 labs from the 71 Labs platform

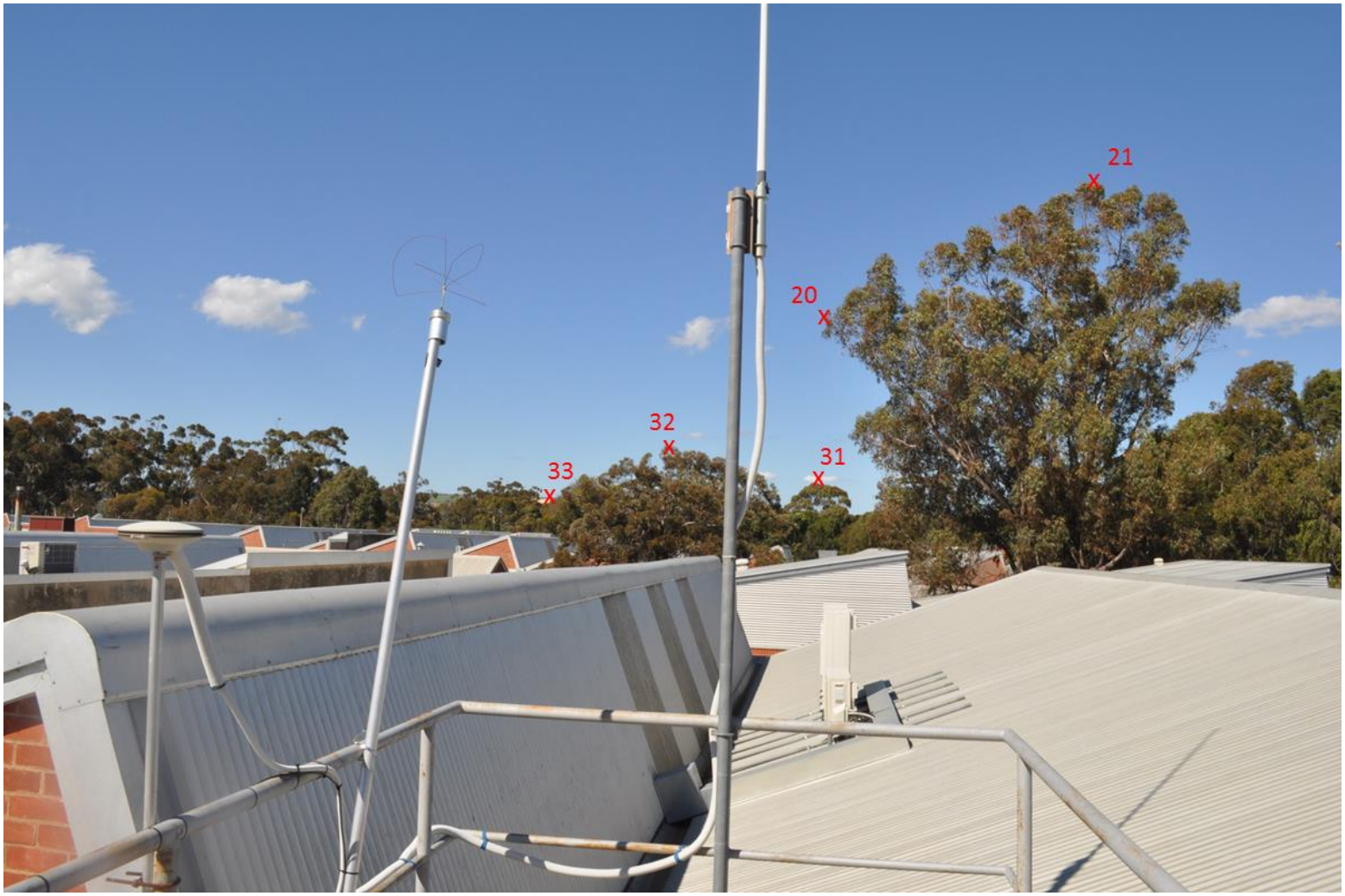

Figure 14: Photo of the horizon looking east from the 71 Labs platform

Figure 15: Photo of the horizon looking south east from the 71 labs platform

Figure 16: Photo of the horizon looking south from the 71 Labs platform

7. Results

Figure 17 is a graphical representation of the azimuth elevation mask. The area shaded grey represents the obscuration to the horizon caused by existing infrastructure and vegetation.

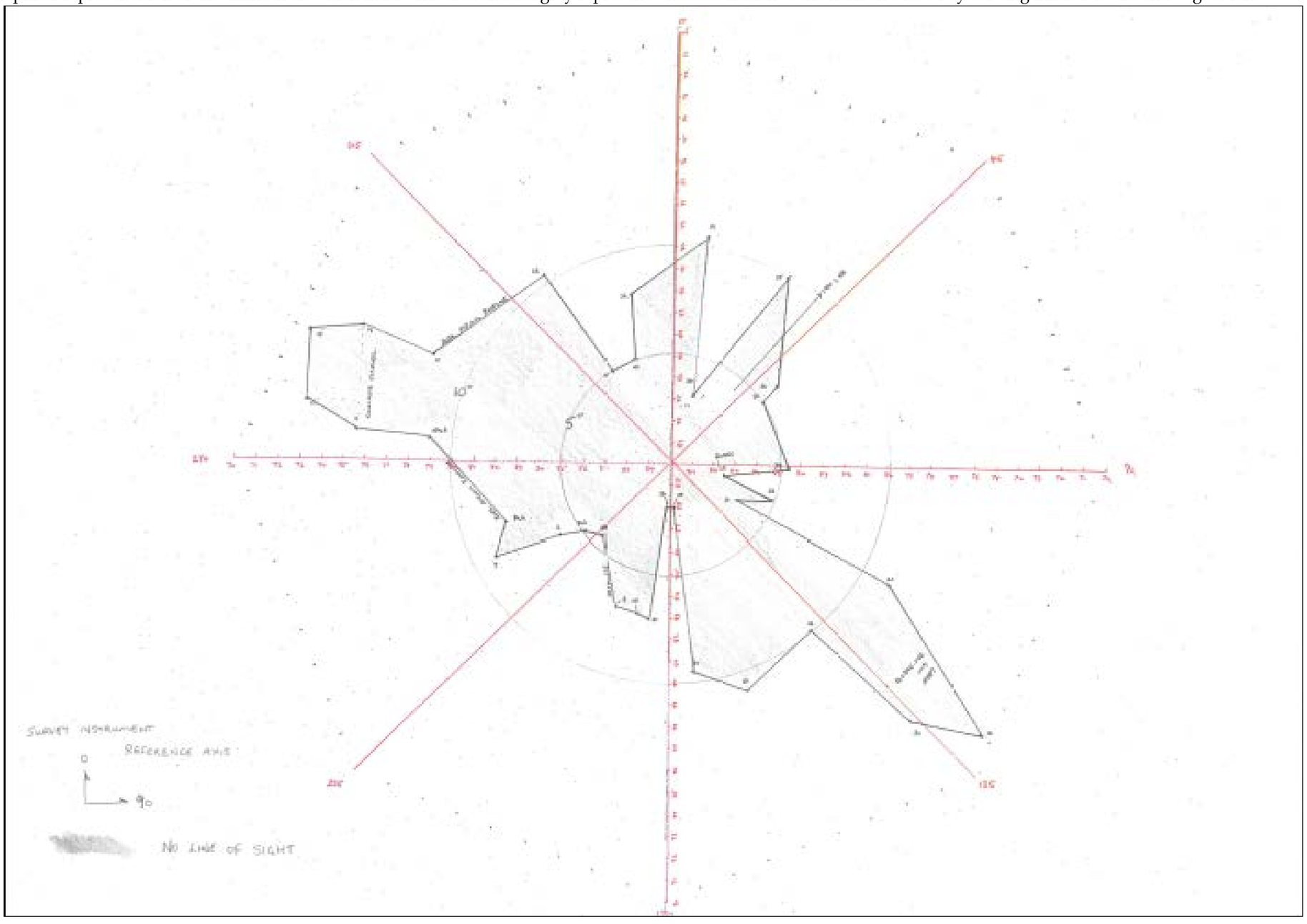

Figure 17: Plot of the AZEL mask with 5 and 10 degree markers

8. Outcomes

The infrastructure and roof services in plain view are static and form a permanent obscuration for any antenna installation on the platform. The main building on the western side, running the entire length of view from north to south, blocks the western line of sight by between 8 and 11 degrees elevation to the horizon.

The 205L northern-most concrete stairwell at 285 degrees azimuth is the largest obstacle to the west affecting the clear line of sight. This concrete structure blocks the line of sight below 17 degrees elevation.

The tree canopy to the north limits the clear line of sight to between 5 and 10 degrees. There are two small azimuth ranges between the trees where it is possible to maintain a line of sight at 5 degrees, otherwise, the line of sight becomes clear at 10 degrees elevation.

Looking east, the building roof line is below the tree line and does not impact the clear line of sight. The tree canopy blocks line of sight below 5 degrees elevation. One exception is the large gum tree centred at 130 degrees azimuth. This gum tree blocks line of sight below 20 degrees elevation between azimuth range 117 - 138 degrees.

Looking due south provides the best line of sight to the horizon. Between the trees, with a hard stop of brickwork (infrastructure), a line of sight above 2 degrees elevation is possible. At 160 degrees azimuth, tree canopy blocks the line of sight to 10 degrees in elevation. At 200 degrees azimuth, the skybridge blocks the line of sight to 7 degrees in elevation.

The second best line of sight to the horizon is at an azimuth of 102°49'39", looking towards the Adelaide Quarry, which obstructs the view to the horizon by 02°03'25".

9. Summary

The azimuth elevation survey of the 71 Labs platform was conducted on the 16 September 2016 to support the NSID small satellite project. At that time, a UHF antenna was to be installed on this platform at height of 180 cm above the deck, to track and communicate with a small satellite orbiting from horizon to horizon.

This report presents the findings of the azimuth elevation survey. Although now not required for the small satellite project, these measurements can be used for information by NSID RPE Group when planning their future antenna trials.

The main outcomes of the survey include:

1. The best line of sight of 2 degrees elevation is achieved looking due south, only for an azimuth range of 5 degrees, between 177 and 182 degrees.
2. The second best line of sight of 2-5 degrees elevation is looking east between azimuth range of 55 and 117 degrees.
3. The worst line of sight of 19 degrees elevation is at azimuth of 130 degrees, where a large gum tree blocks line of sight.
4. The second worst line of sight of 17-19 degrees elevation is at azimuth 280-290 degrees, where line of sight is blocked by the 205 Labs concrete stairwell.

Airborne communication starting in the south western quadrant, transiting across and exiting line of sight in the eastern quadrant will enjoy a clear line of sight to the horizon limited to 5 degrees. Whereas, communications starting in the west and exiting in the south east are limited to a 20 degree line of sight from the horizon. The north west to north east quadrant is variable, largely dependent on tree growth.

The expected 5 year growth of trees is not viewed as problematic, as most of the trees are at a sufficient distance away that excessive growth will have minimal impact on line of sight.

The tree immediately south of the platform is currently at the height of the deck. Depending on its' growth pattern, this may require trimming or lopping in 5 years to allow access and clear line of sight to the south.

Appendix A PED Approval Form

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
IP VIDEO CONFERENCE FACILITIES
PORTABLE ELECTRONIC DEVICE/EQUIPMENT AUTHORISATION

Instructions:
Portable Electronic Device (PED) is a device that can process, store or communication information (e.g.: mobile phones, laptops, pagers, personal digital assistants and cameras). Personally owned PEDs must not be used to conduct Defence business or be connected to Defence networks.
PEDs are not permitted in DSTO Audio Secure Venues with signage indicating that it is a PED Prohibited Area without prior approval. PED Prohibited Areas are identified with RED signage indicating 'PED Prohibited Area' and have storage cabinets to secure PEDs. If it is unclear if an area permits PEDs, the PED should not be taken into that area. Permission to take a device into a PED Prohibited Area must be sought through the appropriate local Security Office. Only PEDs or other equipment identified and authorised in this request can be used in the nominated area during the timeframe indicated.
Once completed, this form is to be returned to the local Security Office.

Details

Employee No: 8121461 **Last name:** EARL **First name:** Robert
Position: EL1 **Organisation:** DST Group
Telephone: 7389 6625 **Email:** Robert.earl@dsto.defence.gov.au
Location/Venue: 200 labs **From:** 6/9/2016 **To:** 23/9/2016

Device

Type/Model	Asset No/Serial No	Security Classification
NSID/HFRD Digital Camera Nikon D90	ECD-P-NSID-23584	Unclassified

Justification:
The small satellite program is using the 71 Labs platform to house a communications antenna. Control software is being developed, at the moment the antenna will steer to 0 degrees elevation and try to connect with the satellite. This equates to transmitting into 205Labs top floor. An azimuth/elevation survey will be performed to update the starting elevation for successful (safe) communication to the satellite. A camera will capture a record of the horizon (from the 71 Labs platform) and document the survey measurement locations.

Acknowledgement

☒ I acknowledge my security responsibilities to protect Defence assets and material in my custody.
☒ Only authorised devices/equipment listed above will be taken into the nominated PED Prohibited Area during the timeframe.
☒ All PEDs/equipment will be removed from the PED Prohibited Area at the end of the activity.
☒ All suspicious occurrences and security incidents (suspected or not) are to be reported to the relevant Security Officer.
☒ All valuable, security classified and sensitive material in my custody will be provided the appropriate level of protection.

Authorisation

An approved request will be returned to the originator by email by an authorising officer responsible for the PED Prohibited Area. A copy of this authorisation, with valid email details of the authorising officer, must be available when taking an approved device/equipment into the nominated PED Prohibited Area.

Authorisation is provided for the PED/Equipment identified above to be taken into the nominated PED Prohibited Area during the timeframe nominated above.

Name: Nick Stacey **Appointment:** RLSE
Date: 6/9/16

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19. ABSTRACT The National Security and Intelligence, Surveillance and Reconnaissance Division of the Defence Science and Technology Group Edinburgh had installed Ultra High Frequency band antennas on the 71 Labs small experimental platform. These antennas were used to test communications to and from an engineering model of a small satellite. The platform is located between buildings. This report presents the findings of an azimuth elevation survey to determine the minimum safe elevations for antenna pointing and signal transmission			