

the power of
where
drives NZ's success



**Presented at the FIG Working Week 2016,
May 2-6, 2016 in Christchurch, New Zealand**



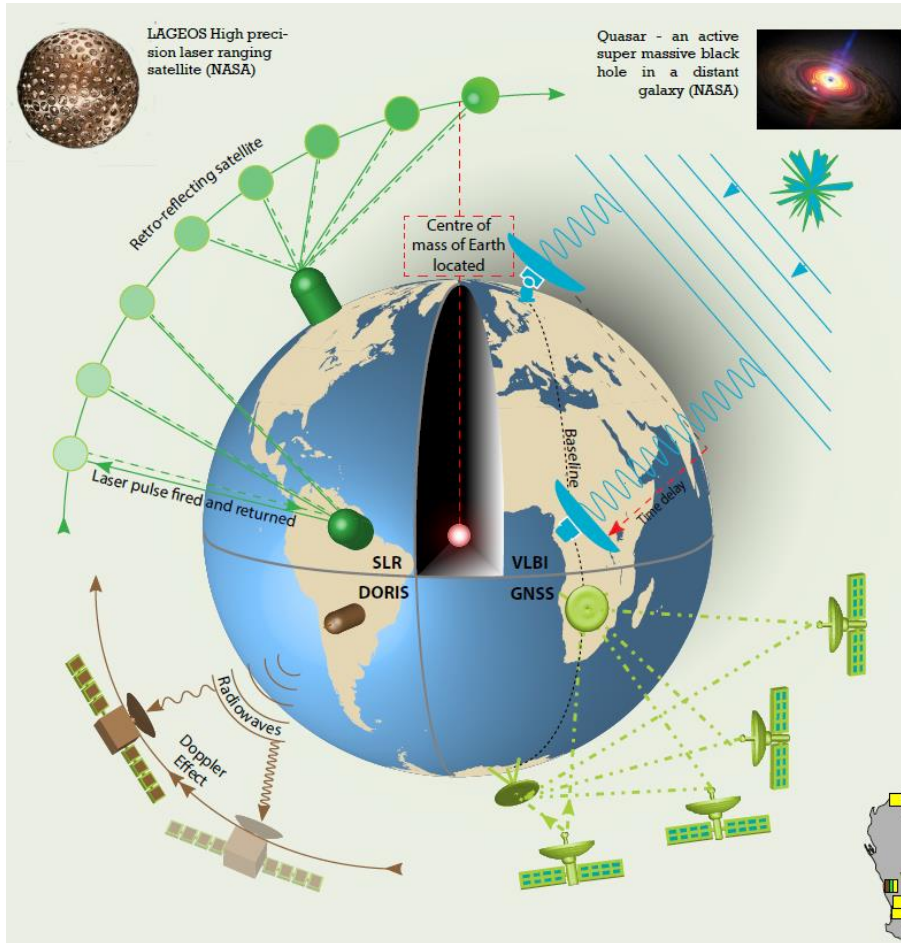
How accurately can the relationship between a VLBI and a GNSS antenna be determined?

Paula Gentle | Geodetic Surveyor
Chris Crook | Senior Geodetic Analyst
Ryan Ruddick | Geodetic Analyst





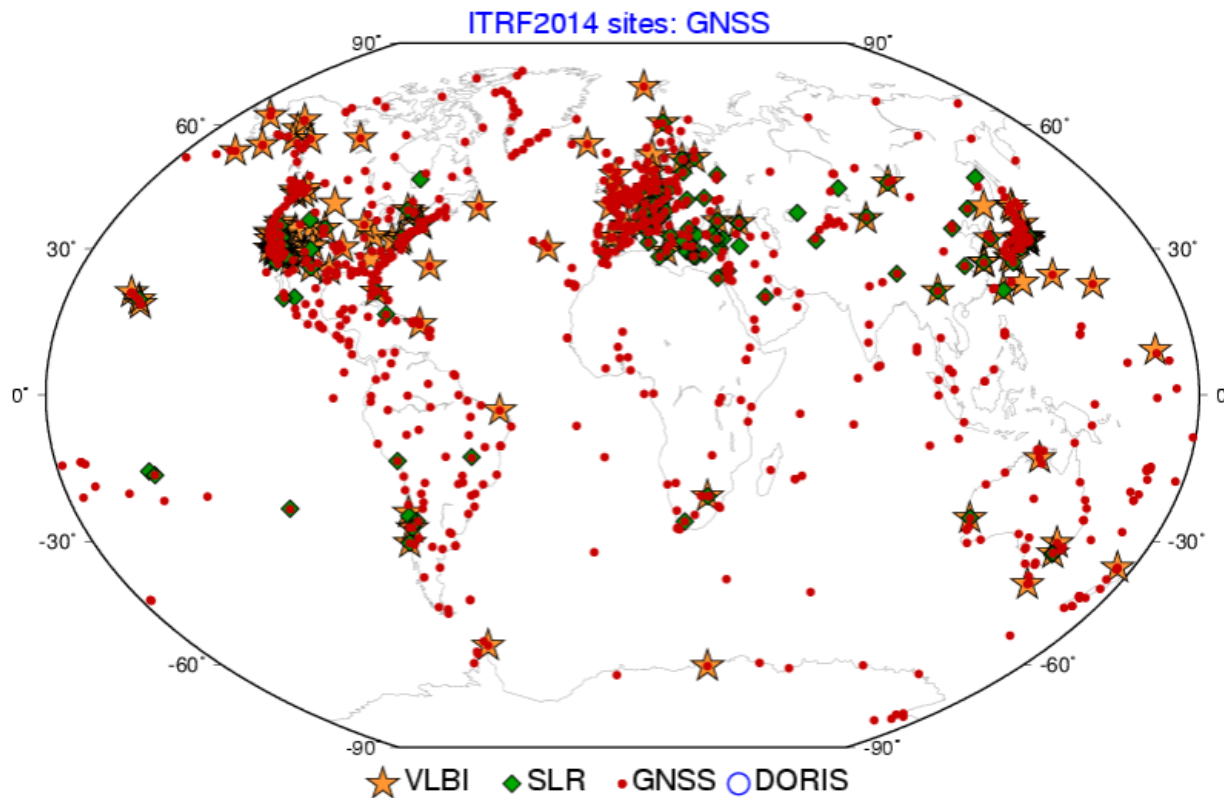
Why do you need
to know this
relationship?



Geodetic techniques used in the International Terrestrial Reference Frame (ITRF)

- Satellite Laser Ranging (SLR)
- Global Navigation Satellite Systems (GNSS)
- Doppler Orbitography Radio-positioning Integrated by Satellite (DORIS)
- Very Long Baseline Interferometry (VLBI)

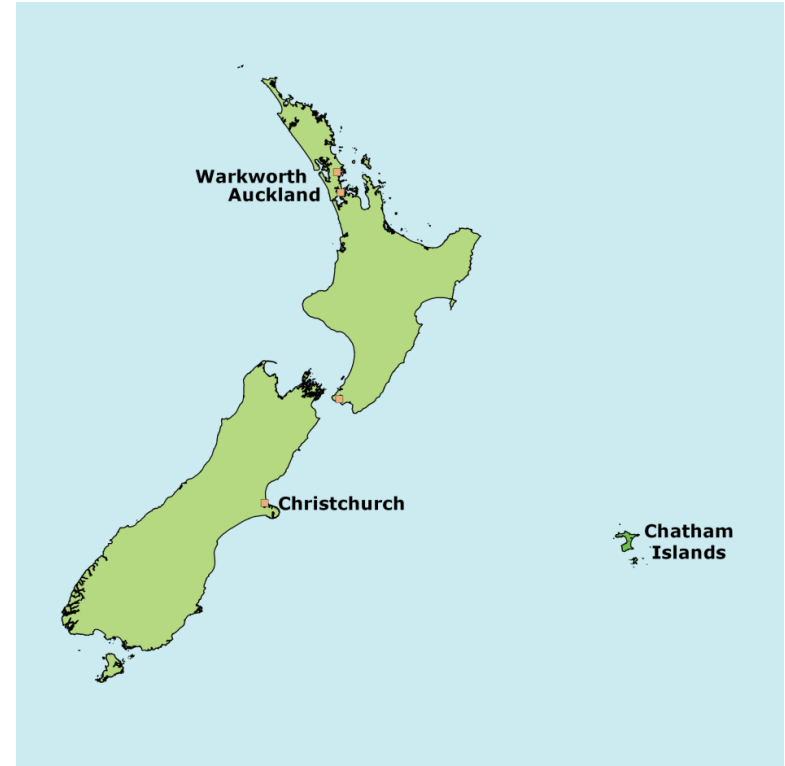
International Terrestrial Reference Frame





Warkworth Radio Astronomical Observatory

Warkworth Radio Astronomical Observatory



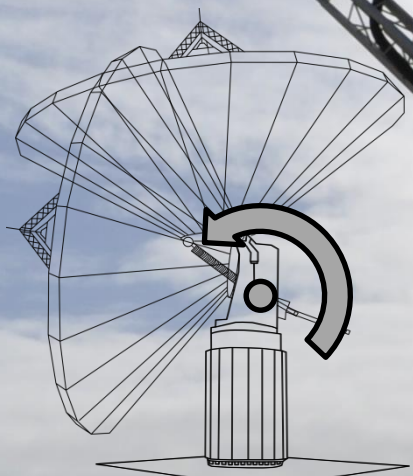
A large, white, rectangular radio telescope dish antenna structure is shown against a cloudy sky. The dish is composed of many small panels and is supported by a complex metal truss structure. A smaller, circular antenna is visible on the left side of the main structure. The text "VLBI Invariant Point (IVP)" is overlaid on the left side of the image.

VLBI Invariant Point (IVP)

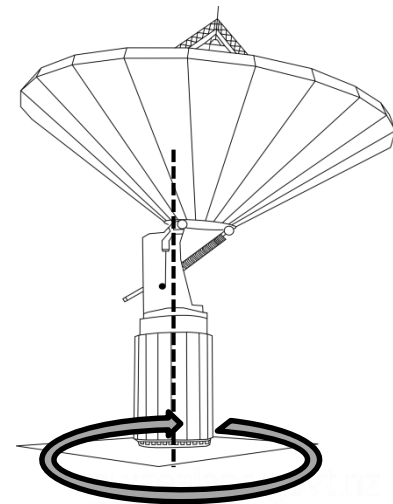
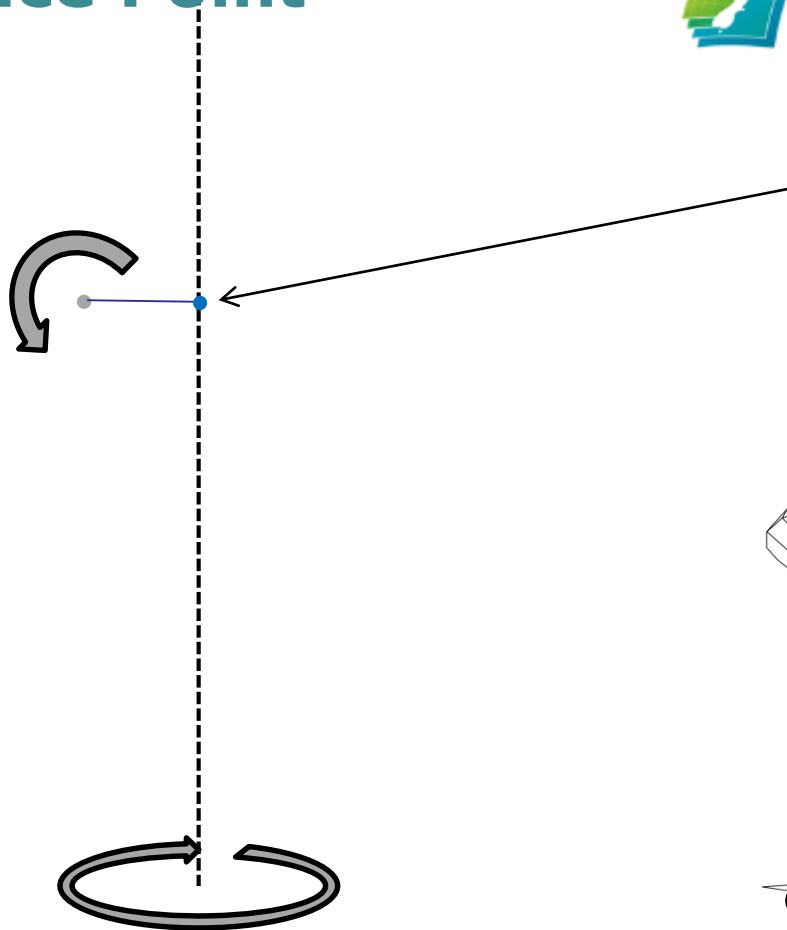
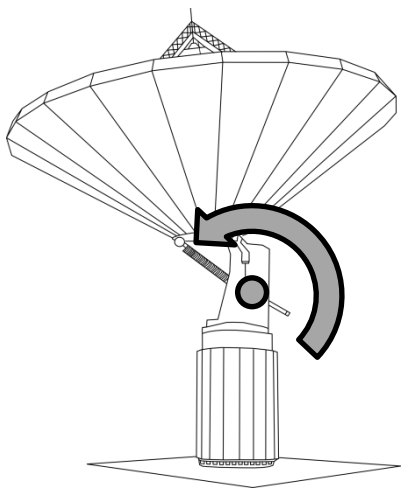


Horizontal axis

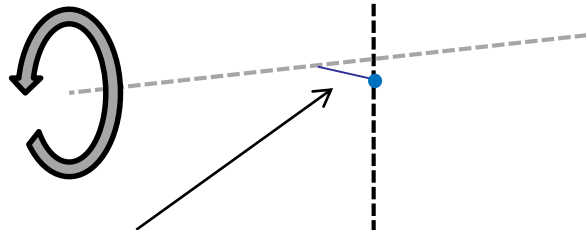
Vertical axis



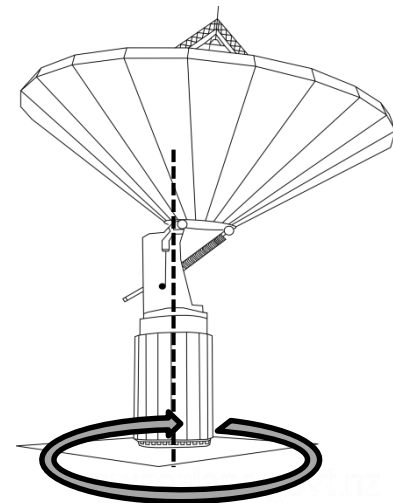
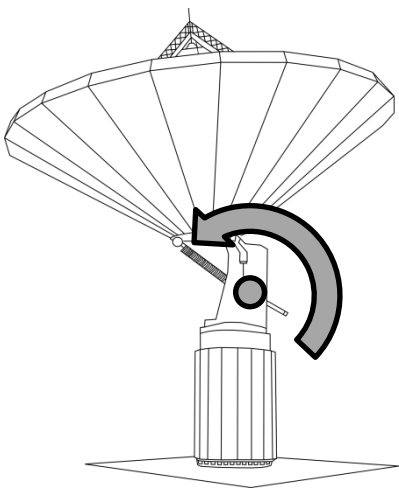
Invariant Reference Point (IVP)



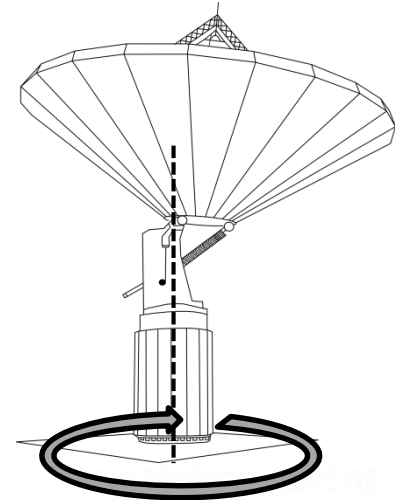
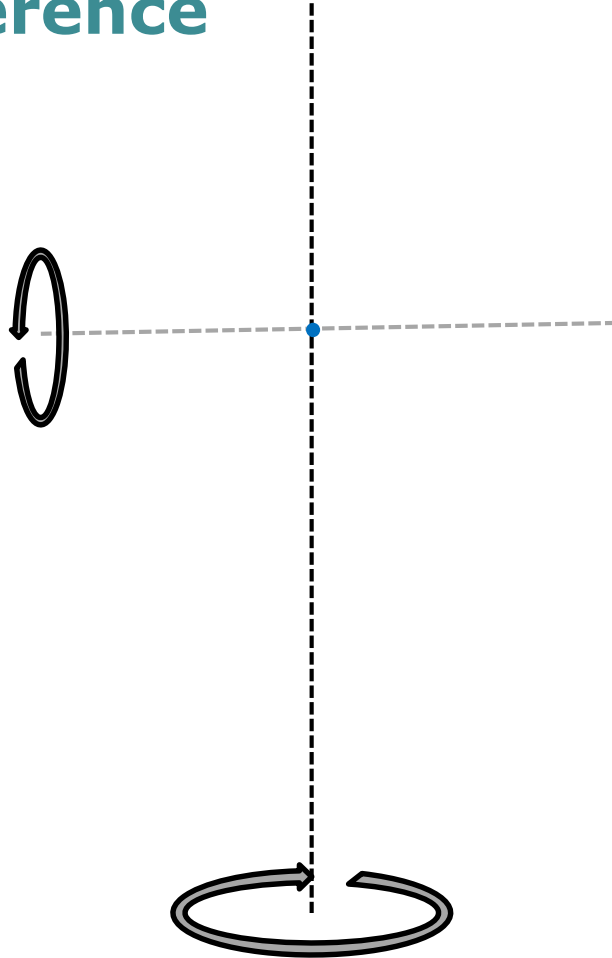
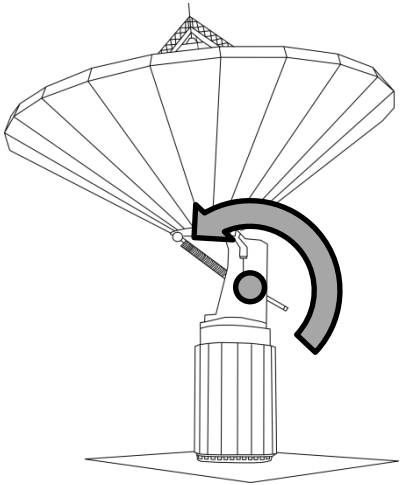
Invariant Reference Point (IVP)



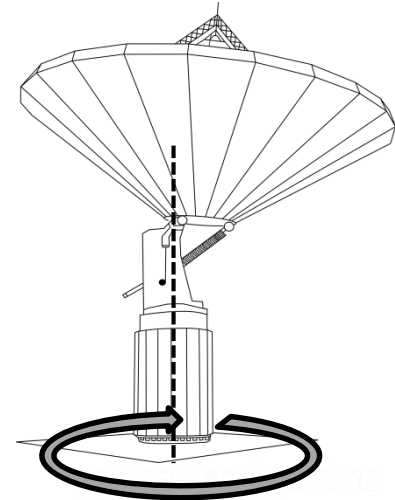
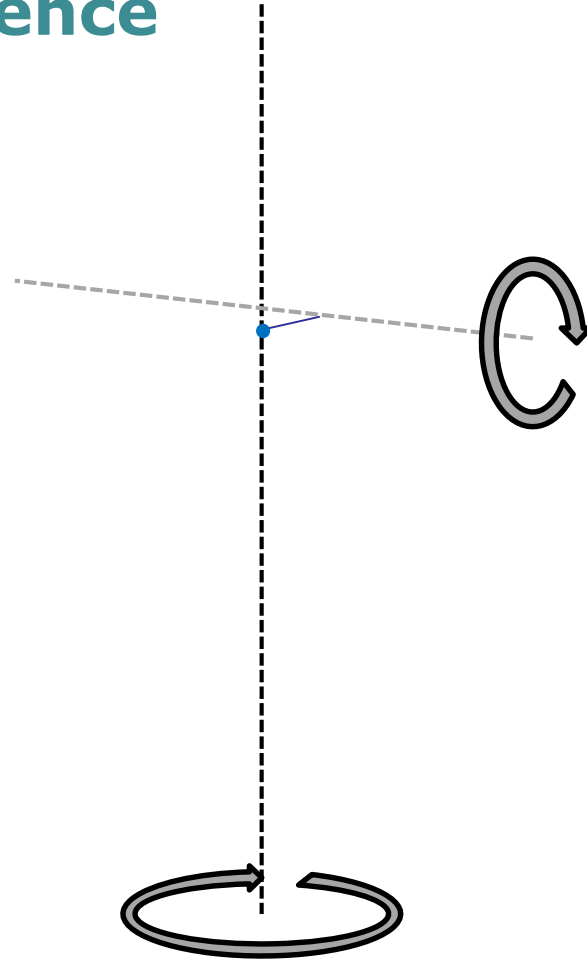
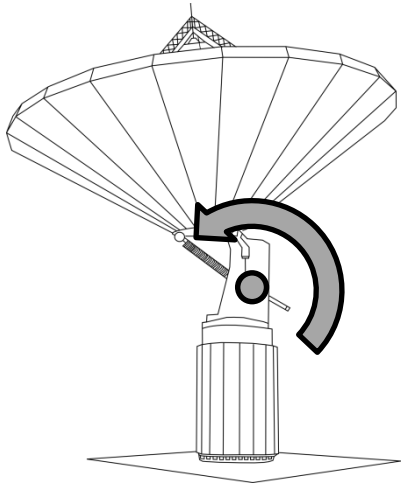
Orthogonal vector
or offset



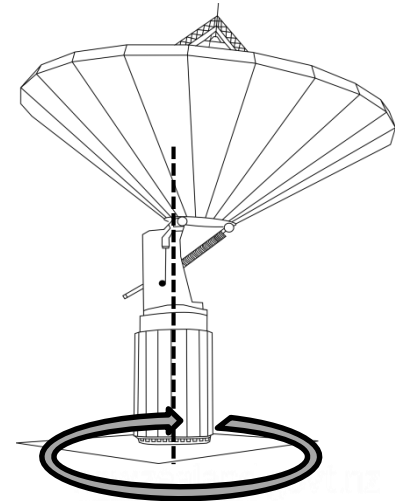
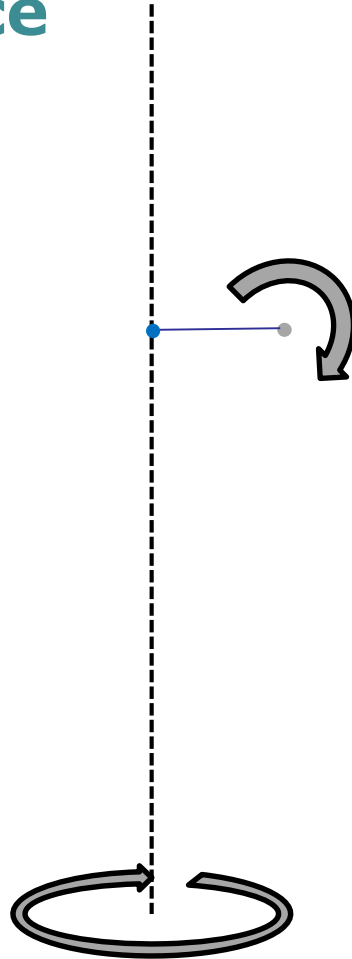
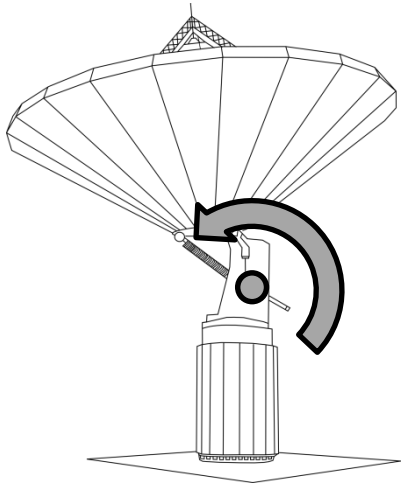
Invariant Reference Point (IVP)



Invariant Reference Point (IVP)



Invariant Reference Point (IVP)





GNSS Antenna Reference Point (ARP)

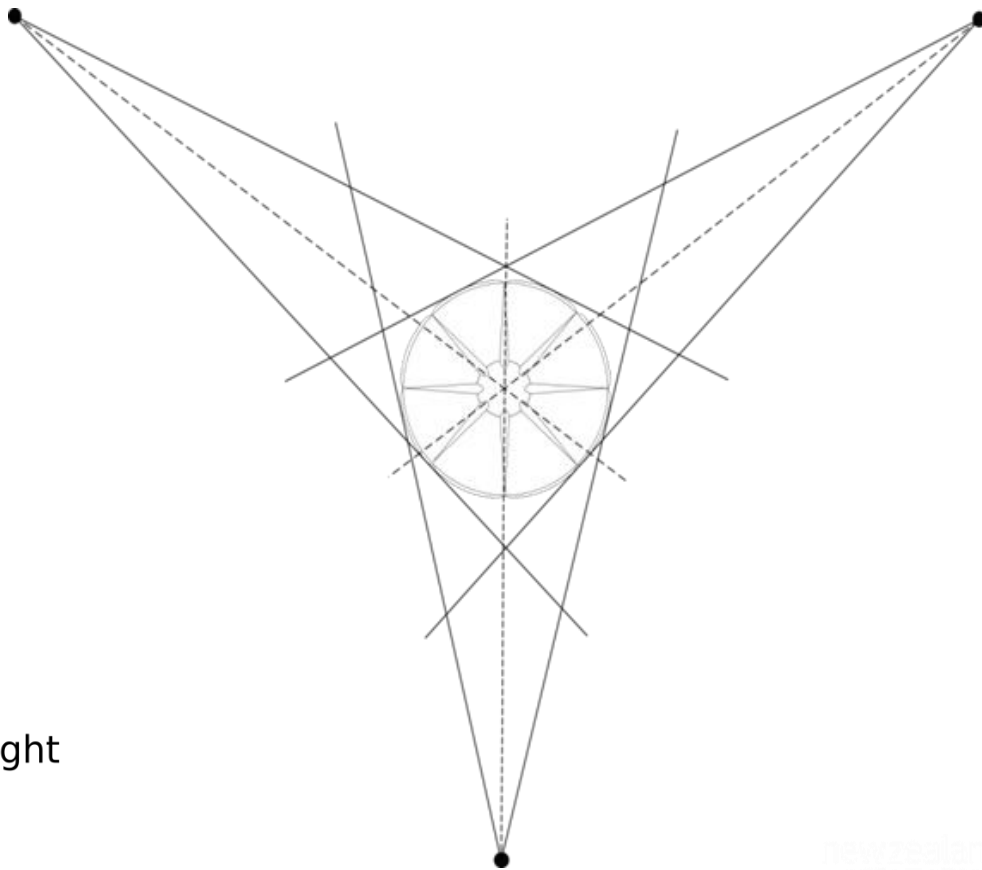
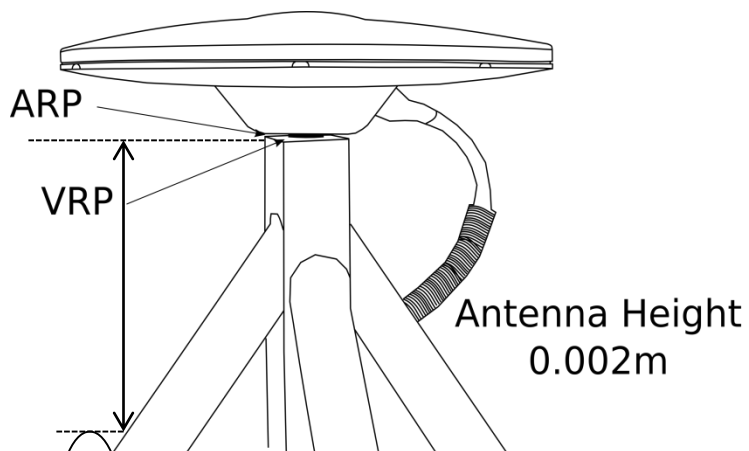
The Survey



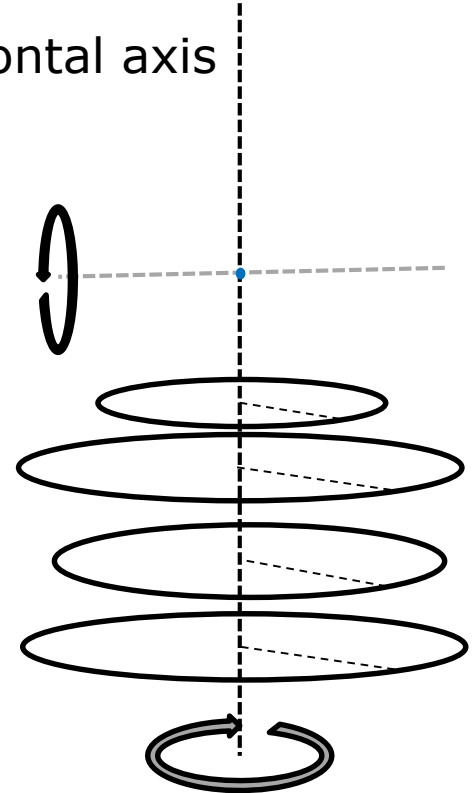


GNSS Antenna Reference Point (ARP)

Determining the Antenna Reference Point

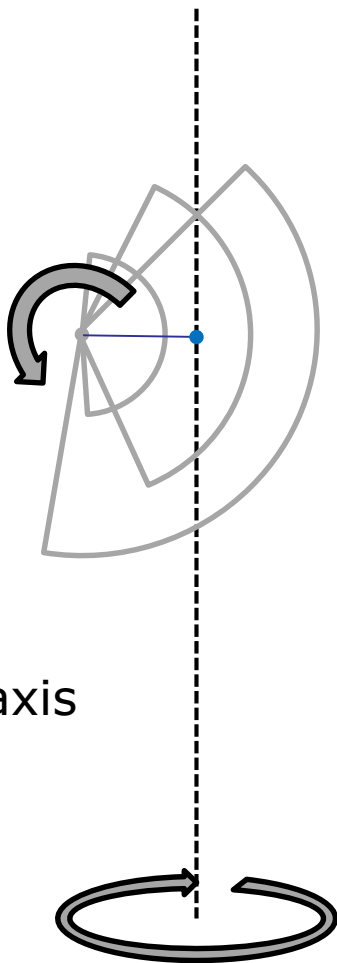


Horizontal axis



WARK30M

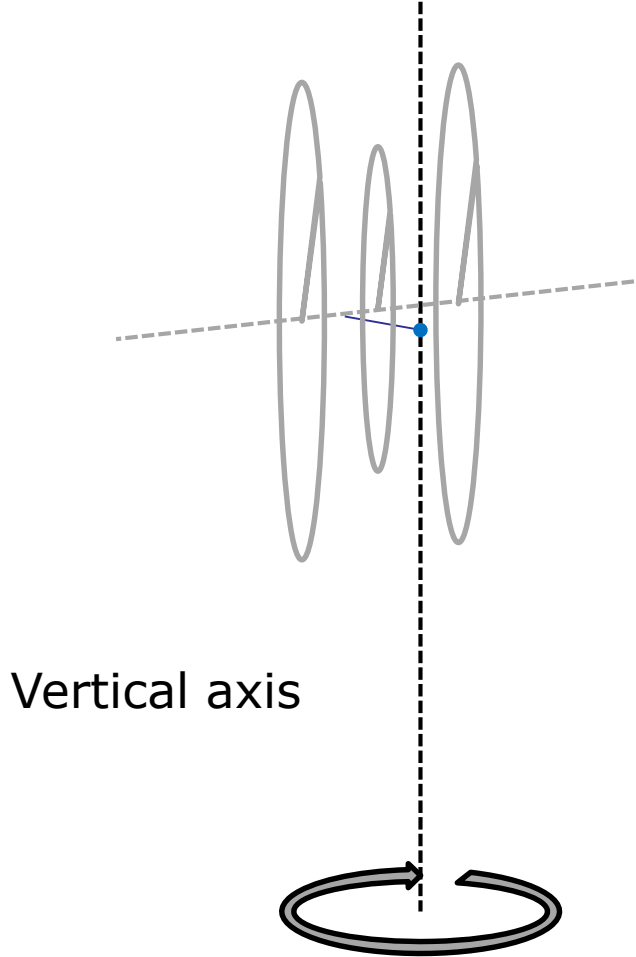




Vertical axis

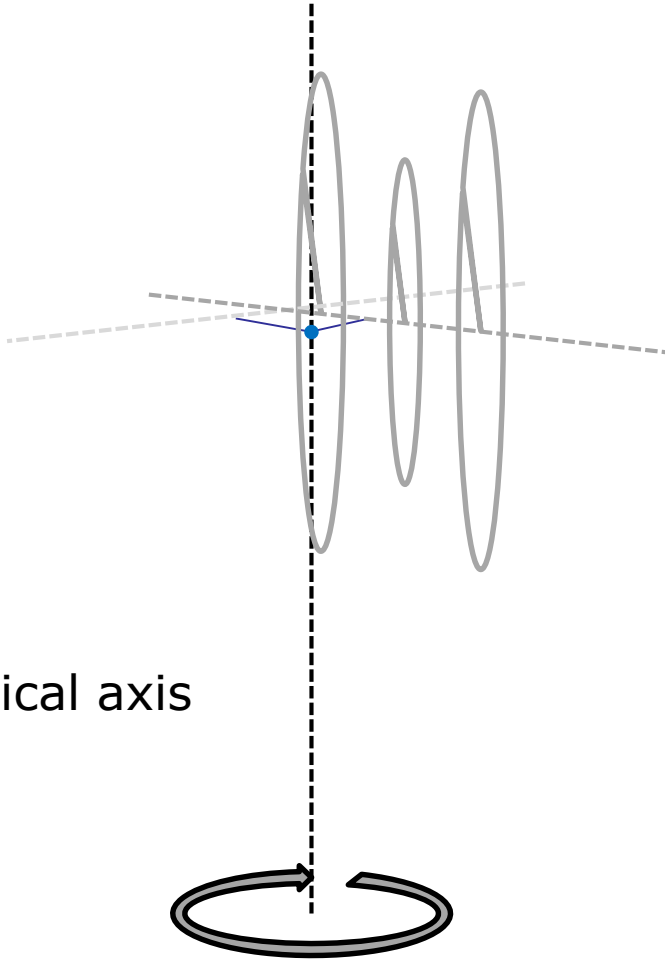


WARK30M



WARK30M [land.govt.nz](http://www.land.govt.nz)

Vertical axis



WARK30M

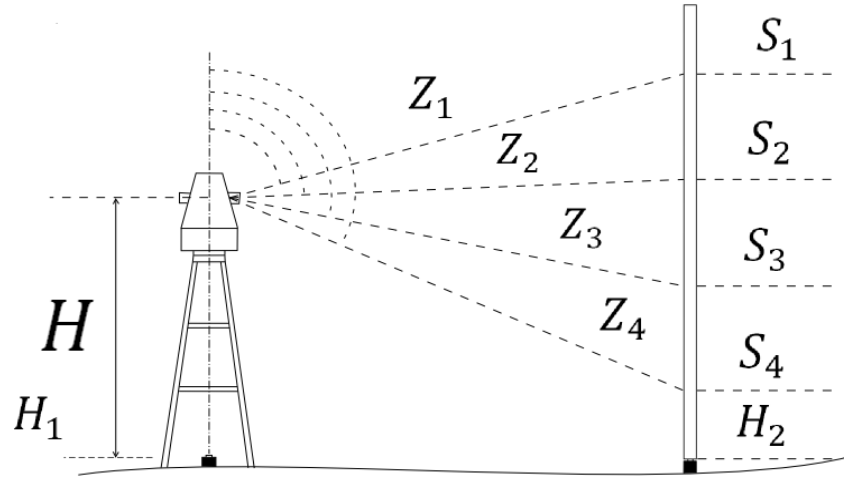
WARK12M



The survey equipment



Height of Instrument Determination



$$H = \frac{S_2 \cot Z_1 - S_1 \cot Z_2}{\cot Z_1 - \cot Z_2} - (H_1 - H_2)$$

Rueger heighting technique

Bringing it all together

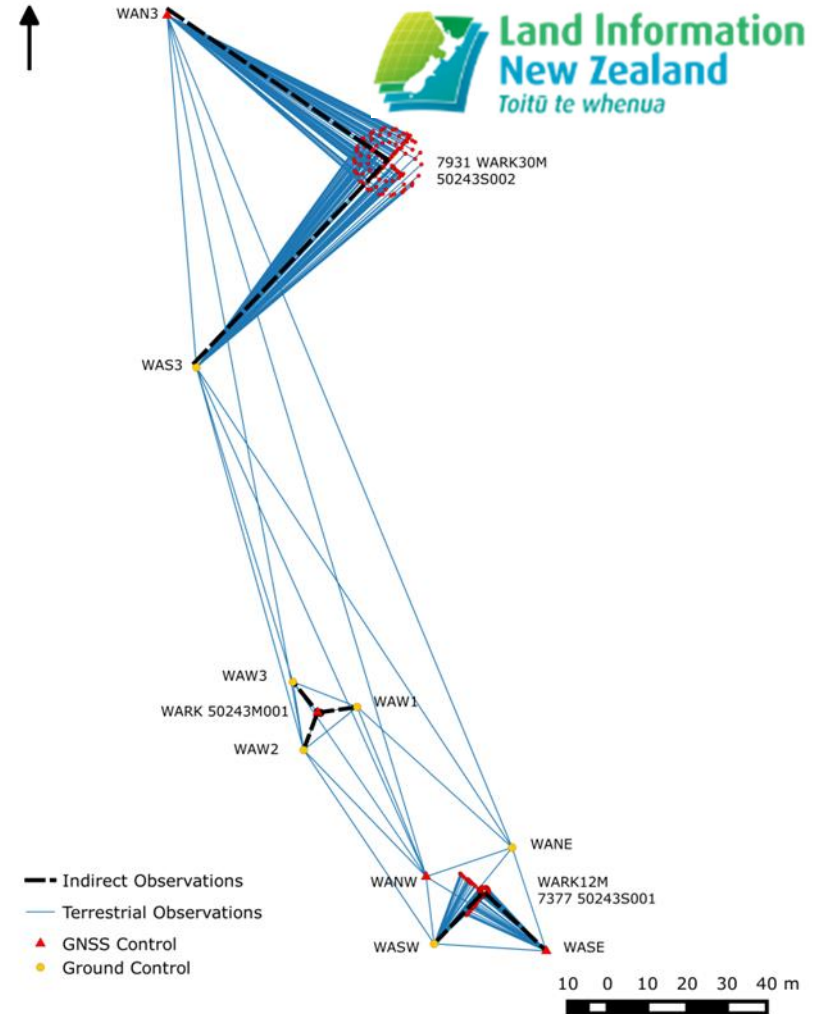
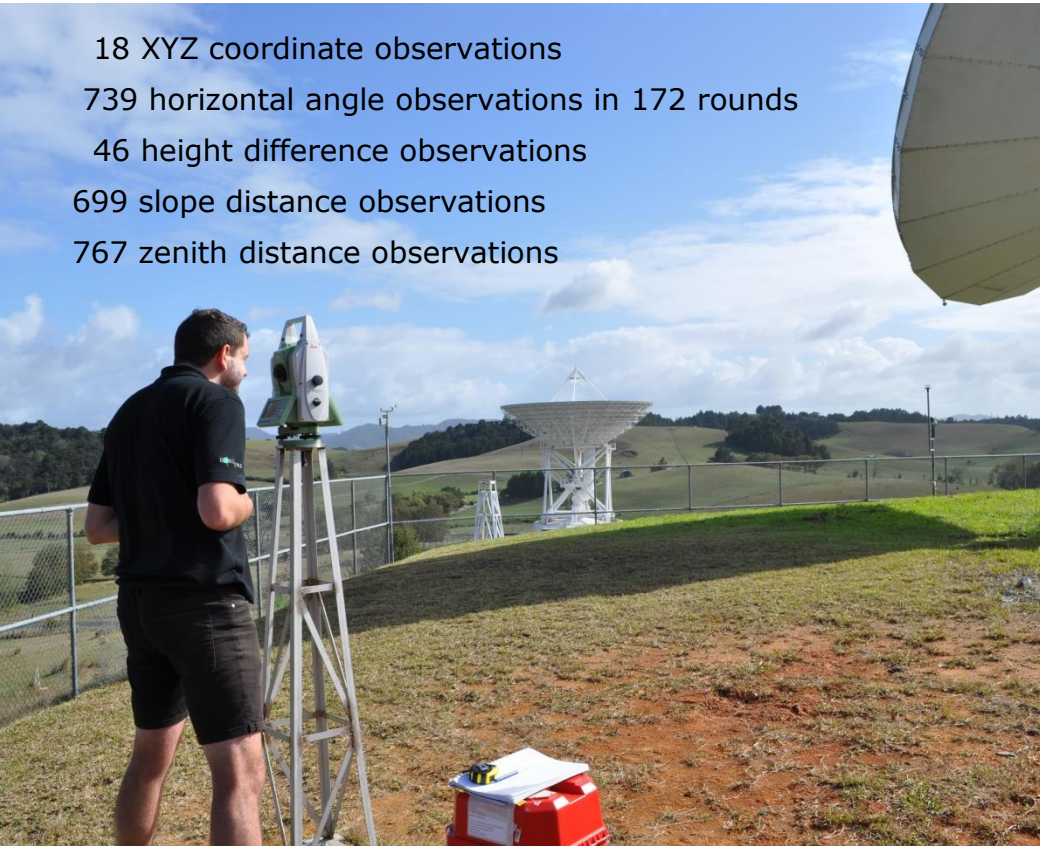
18 XYZ coordinate observations

739 horizontal angle observations in 172 rounds

46 height difference observations

699 slope distance observations

767 zenith distance observations



+SOLUTION/EPOCHS

```
7377 A 0001 C 15:073:00000 15:073:00000 15:073:00000
7391 A 0001 C 15:073:00000 15:073:00000 15:073:00000
WARK A 0001 C 15:073:00000 15:073:00000 15:073:00000
```

-SOLUTION/EPOCHS

+SOLUTION/STATISTICS

```
VARIANCE FACTOR 8.815667085239693e-01
SUM OF SQUARED RESIDUALS 1.604451409513624e+03
NUMBER OF OBSERVATIONS 2139
NUMBER OF UNKNOWNNS 319
```

-SOLUTION/STATISTICS

+SOLUTION/ESTIMATE

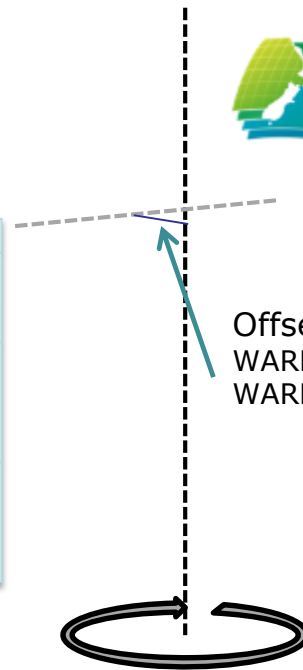
```
1 STAX 7377 A 0001 15:073:00000 m 2 -5.11532447399250e+06 2.94711e-03
2 STAY 7377 A 0001 15:073:00000 m 2 4.77843290755983e+05 1.55988e-03
3 STAZ 7377 A 0001 15:073:00000 m 2 -3.76719275004192e+06 2.28927e-03
4 STAX 7391 A 0001 15:073:00000 m 2 -5.11542578825616e+06 2.95660e-03
5 STAY 7391 A 0001 15:073:00000 m 2 4.77880255860794e+05 1.65223e-03
6 STAZ 7391 A 0001 15:073:00000 m 2 -3.76704216137259e+06 2.30150e-03
7 STAX WARK A 0001 15:073:00000 m 2 -5.11533336837370e+06 2.93919e-03
8 STAY WARK A 0001 15:073:00000 m 2 4.77886889801420e+05 1.54089e-03
9 STAZ WARK A 0001 15:073:00000 m 2 -3.76714727097382e+06 2.28930e-03
```

-SOLUTION/ESTIMATE

So how accurate is it?

The Results

SITE	X (M)	σ(MM)	Y (M)	σ(MM)	Z (M)	σ(MM)
WARK 50243M001	-5115333.3684	+/- 2.9	477886.8898	+/- 1.5	-3767147.2809	+/- 2.3
7377 50243S001 WARK12M IVP	-5115324.4740	+/- 2.9	477843.2908	+/- 1.6	-3767192.7500	+/- 2.3
7931 50243S002 WARK30M IVP	-5115425.7883	+/- 3.0	477880.2559	+/- 1.7	-3767042.1614	+/- 2.3

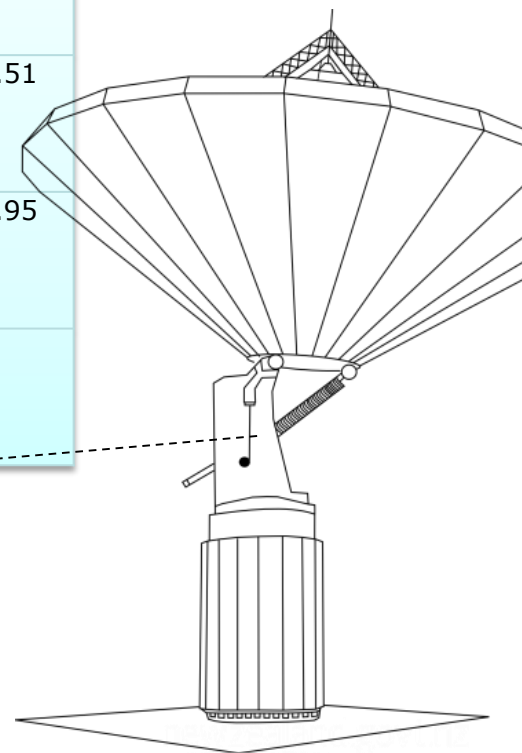
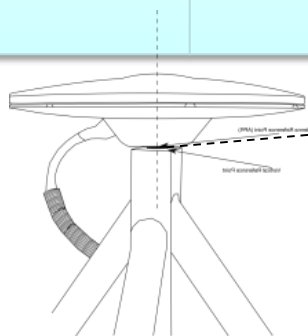


Offset:
WARK30M 2.5043 +/- 0.0003m
WARK12M -0.0010 +/- 0.0001m

WARK TO ...	Δ EAST (m)	σ(MM)	Δ NORTH (M)	σ(MM)	Δ UP (M)	σ(MM)
WARK12M (7377 50243S001)	42.58274	0.24	-44.25749	0.22	16.62280	0.95
WARK30M (7391 50243S002)	15.20170	0.66	138.84840	0.16	11.11313	0.95

How confident are we?

YEAR	WARK TO ...	Δ EAST (m)	σ (MM)	Δ NORTH (M)	σ (MM)	Δ UP (M)	σ (MM)
2012	WARK12M (7377 50243S001)	42.58316	0.87	-44.25775	0.84	16.62461	0.51
2015	WARK12M (7377 50243S001)	42.58274	0.24	-44.25749	0.22	16.62280	0.95
Difference		-0.00042		0.00027		-0.00181	



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Questions?

