



# GNSS Antenna Calibration at the National Geodetic Survey

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# Antcal Team

[ngs.antcal@noaa.gov](mailto:ngs.antcal@noaa.gov)

## Engineering / Software

- Andria Bilich
- Jacob Heck
- Clement Ogaja
- Phillip MacFarland

## Operations / Analysis

- Charlie Geoghegan
- Ben Erickson

## Antenna Calibrations

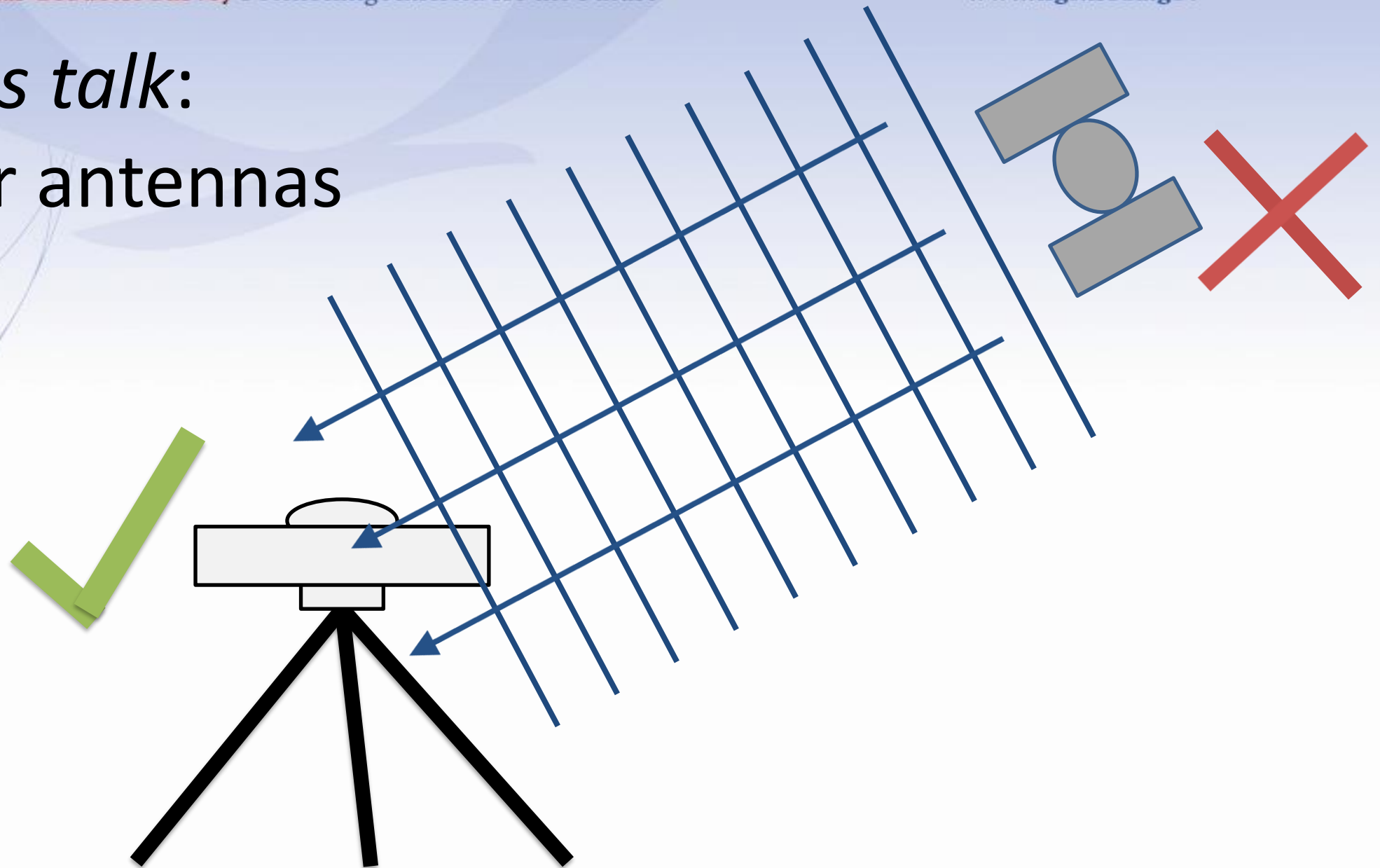
## Infrastructure

- Steven Breidenbach

## Applications/Program Support

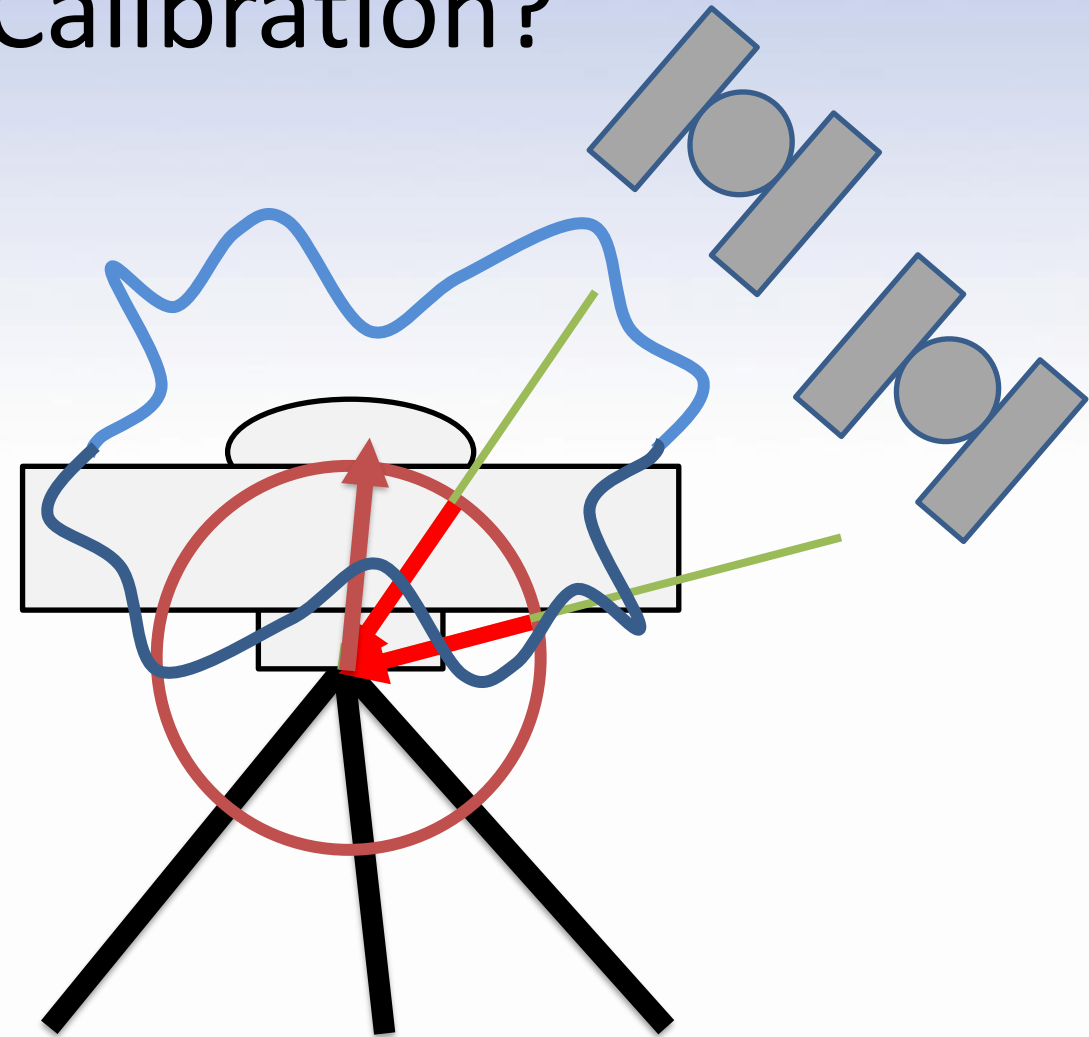
- Bruce Tran
- Giovanni Sella

# *This talk:* receiver antennas



# What is Antenna Calibration?

- Antennas introduce additional “length” to the ranging signal
- Determine point of reception for **carrier phase** signals
- Calibration composed of:
  - Average phase center
  - Corrections to the phase center



# Phase Center

- Antenna “phase center, i.e., the mathematically best fitted non-physical point that relates the incoming electromagnetic signals’ time of arrival to the tangible structure.” [Bergstrand et. al, 2020, Jour. of Geodesy](#)

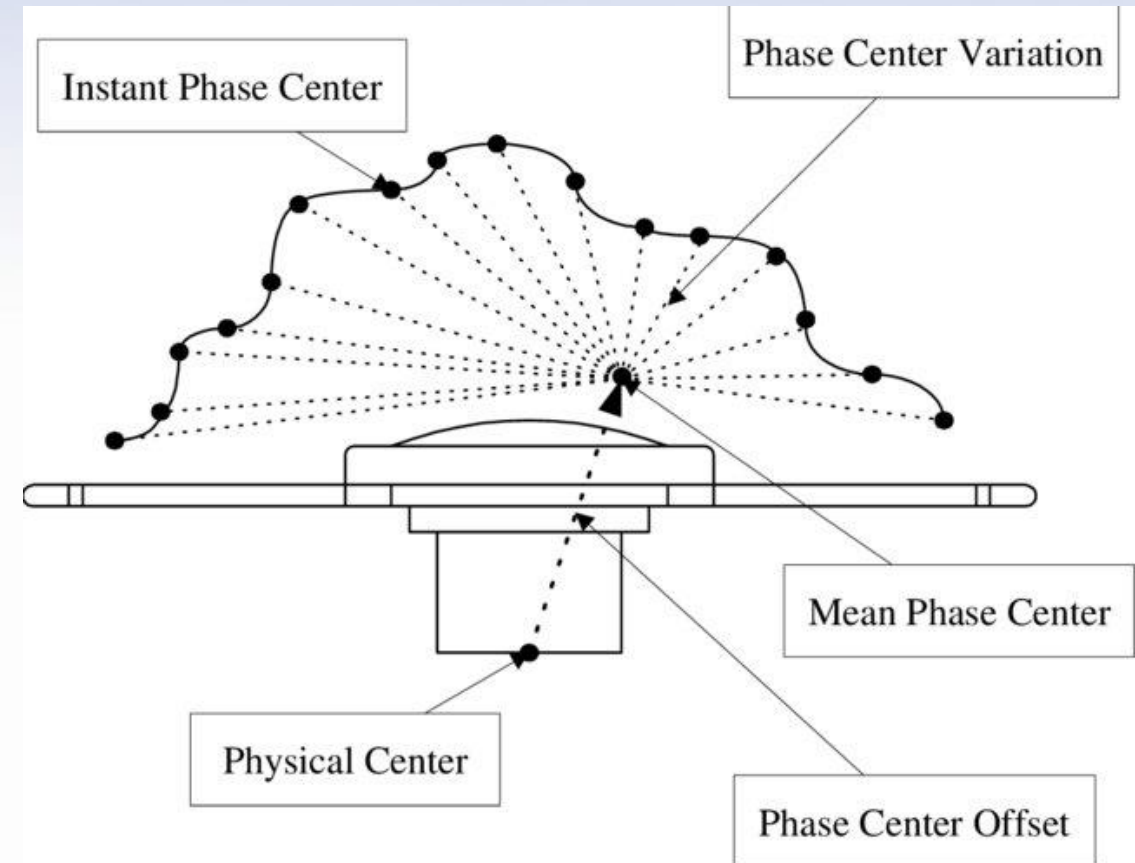
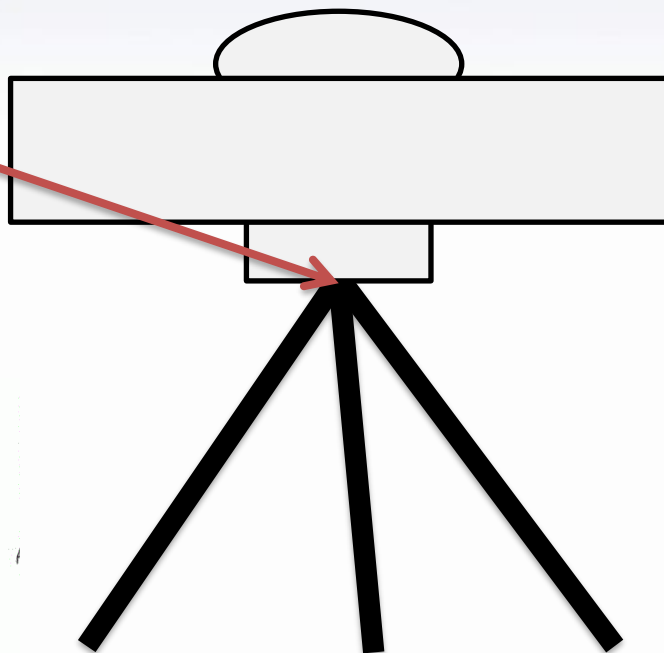


Figure from Chen et al (2000), *The impact of GPS antenna phase center offset and variation on the positioning accuracy*, *Bollettino di Geodesia et Scienze Affini* 9(1):1-22

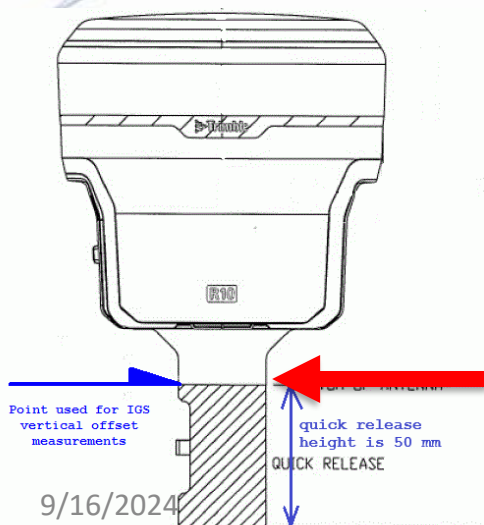
# Antenna's "tangible structure"

North reference point  
(NRP)

Antenna  
reference  
point  
(ARP)



MMI (man-machine interface)



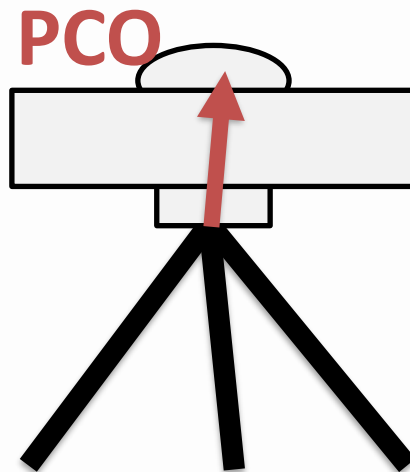
RXC  
(receiver  
connector)



# Calibration Terminology

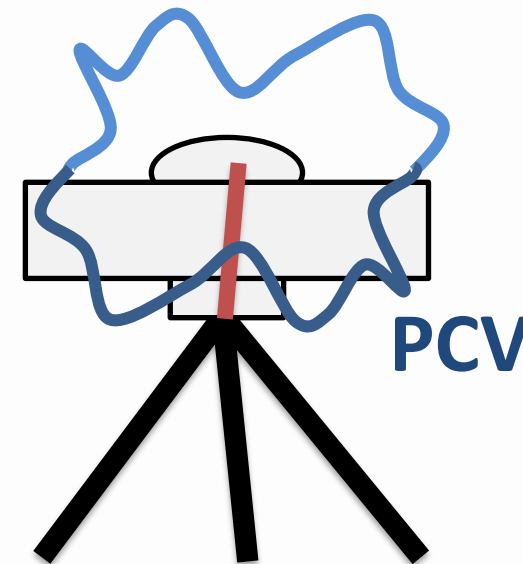
**PCO** = phase center offset

- Mean point at which carrier phase is received
- cm level correction, mostly up



**PCV** = phase center variations

- Variations around PCO
- mm-cm level correction



# ANTEX (ANTenna EXchange format)

- Large ASCII data tables
- Used as model in processing software
- Distributed by IGS and calibration facilities

```

TRMR8-4      NONE
ROBOT        Geo++
             5.0
             0.0 90.0 5.0
             4
IGS14_2045
# Number of Calibrated Antennas GPS:
# Number of Individual Calibrations GPS: 016
# Number of Calibrated Antennas GLO: 005
# Number of Individual Calibrations GLO: 016
# GLONASS PCV
# derived from Delta PCV per 25.0 MHz
# for frequency channel number k=0
G01
+1.06 -0.78 +84.07
NOAZI +0.00 +0.00 -0.03 -0.17 -0.45 -0.84 -1.21 -1.40 -1.33 -1.07
0.0 +0.00 -0.10 -0.24 -0.46 -0.81 -1.22 -1.55 -1.64 -1.39 -0.87
5.0 +0.00 -0.11 -0.26 -0.50 -0.86 -1.29 -1.64 -1.74 -1.50 -0.99
10.0 +0.00 -0.12 -0.28 -0.53 -0.91 -1.36 -1.72 .62 -1.12
15.0 +0.00 -0.13 -0.30 -0.56 -0.96 -1.42 -1.80 .74 -1.27
20.0 +0.00 -0.14 -0.31 -0.59 -1.00 -1.48 -1.88 .85 -1.41
25.0 +0.00 -0.14 -0.33 -0.61 -1.03 -1.53 -1.94 -2.11 -1.95 -1.53
    
```

**Software Developers:**  
 email  
[ngs.antcal@noaa.gov](mailto:ngs.antcal@noaa.gov)

**PCO**

**PCV**



# <https://geodesy.noaa.gov/ANTCAL/>

**Antenna Calibrations**  
National Geodetic Survey

NGS Home | About NGS | Data & Imagery | Tools | Surveys | Science & Education | Search

Browse Antenna Information by Company Brand and Model | **Access Calibrations for All Antennas** | Help Links

**AeroAntenna Technology Inc.**  
Individual calibrations for Antenna Types (Antenna Code + Radome Code) with images and orientation definitions.  
**NOTE:**  
Expand an ARP or NRP abbreviation, by hovering the mouse cursor over the 3-letter code. On a mobile device follow link at top of column.

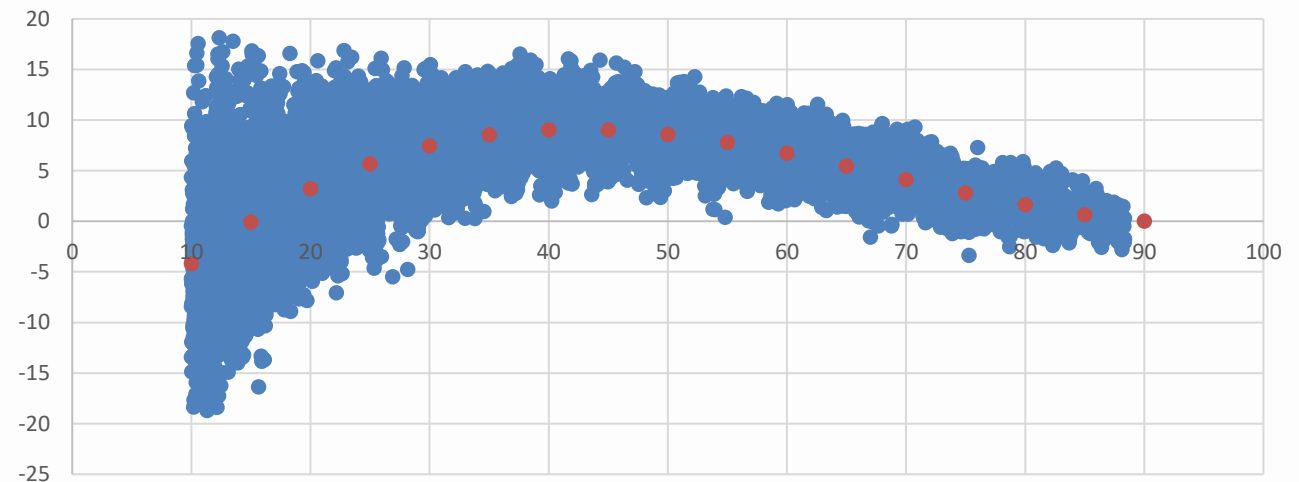
Antenna Code	Radome Code	Images	Calibrations	Description	Date Calibrated	ARP	NRP
AERAT1675_120	SPKE	Drawing Label Side Top	ANTEX ANTINFO	Aeroantenna GPS choking antenna GPS: L1/L2/L5 GLO: G1/G2	04-AUG-14	BAM	NOM
AERAT1675_120	NONE	Drawing Label Side Top	ANTEX ANTINFO	Aeroantenna GPS choking antenna GPS: L1/L2/L5 GLO: G1/G2	09-JAN-12	BAM	NOM
AERAT1675_180	NONE	Drawing Label Side Top	ANTEX ANTINFO	L-Band GPS Glonass Airborne	08-FEB-13	BAM	BTD

One big ANTEX file for all receiver antennas in NGS database

Individual calibrations, in ANTEX and ANTINFO formats

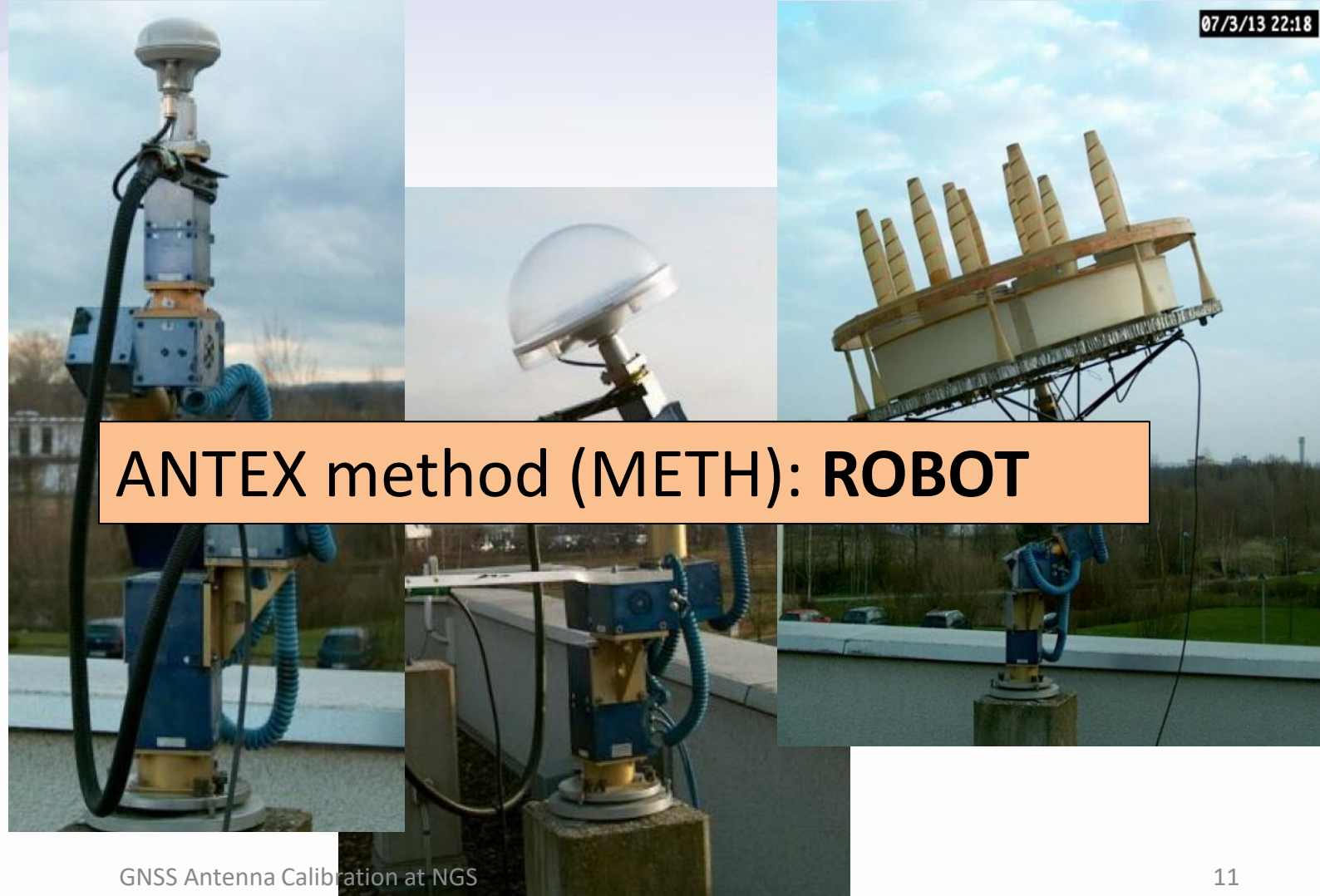
# Calibration History

- NGS developed *relative* calibration technology in 1994
- Adopted by IGS in 1996
- Use GNSS receivers and signals from space



# Geo++: the original *absolute*

- Developed ~ 2000
- Adopted by IGS in 2006
- Robot + software used at many IGS calibration institutions
- GNSS receivers and signals from space



# Why Does NGS Do Antenna Calibration?

- Antenna calibration is necessary to obtain the most precise and accurate GNSS positions possible.
- Antenna calibration supports NGS's mission to define, maintain, and provide access to the National Spatial Reference System (NSRS).

# NGS Calibration Products

- Consistently combines IGS and NGS data
- Antenna metadata
  - Descriptions
  - Photos & drawings
  - ARP and NRP

**Antenna Calibrations**  
National Geodetic Survey

NGS Home | About NGS | Data & Imagery | Tools | Surveys | Science & Education | Search

Browse Antenna Information by Manufacturer and Model | Access Calibrations for All Antennas | Help Links

### Topcon

Individual calibrations for Antenna Codes (Antenna Model + Radome) with images and orientation definitions.

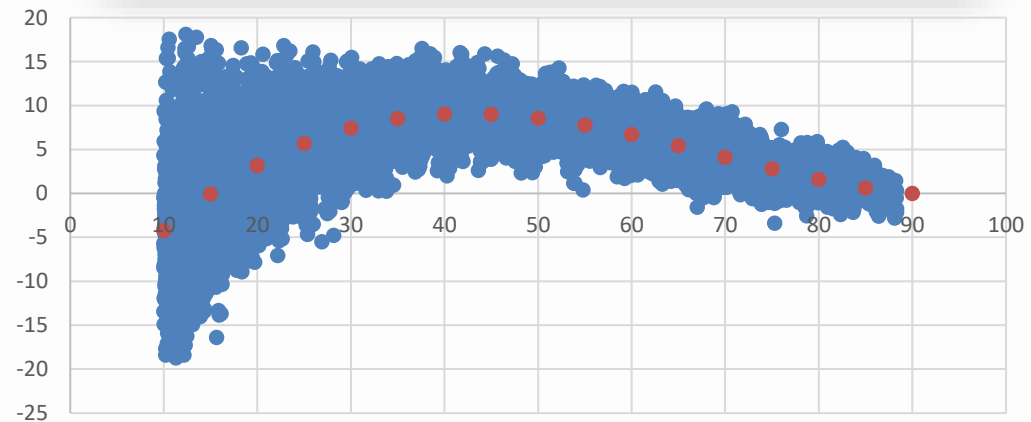
**NOTE:**  
To get ARP and NRP abbreviation explanation hover your cursor over the 3-letter code. On a mobile device follow link at top of column.

Antenna Model	Radome	Images	Calibrations	Description	Date Calibrated	ARP	NRP
TOP700779A	NONE		<b>ANTEX</b> <b>ANTINFO</b>	Model 700779.A (same as ASH700718A)	29-JAN-17	BPA	UNK
TOP72110	NONE	<b>Side</b> <b>Top</b>	<b>ANTEX</b> <b>ANTINFO</b>	Model 72110, used with the TURBO-SII receiver small radius with Dome Margolin element	29-JAN-17	BAM	NOM
TPSCR.G3	SCIT	<b>Drawing</b> <b>Side</b> <b>Top</b>	<b>ANTEX</b> <b>ANTINFO</b>	Topcon GPS/GLONASS/Galileo choke ring antenna	04-DEC-10	BPA	NOM

[geodesy.noaa.gov/ANTCAL/](https://geodesy.noaa.gov/ANTCAL/)

# NGS Relative Calibrations

- Calibration of test antenna determined *relative to the reference antenna*
- Calibrated > 500 antenna types and configurations to date



# NGS Absolute Calibrations



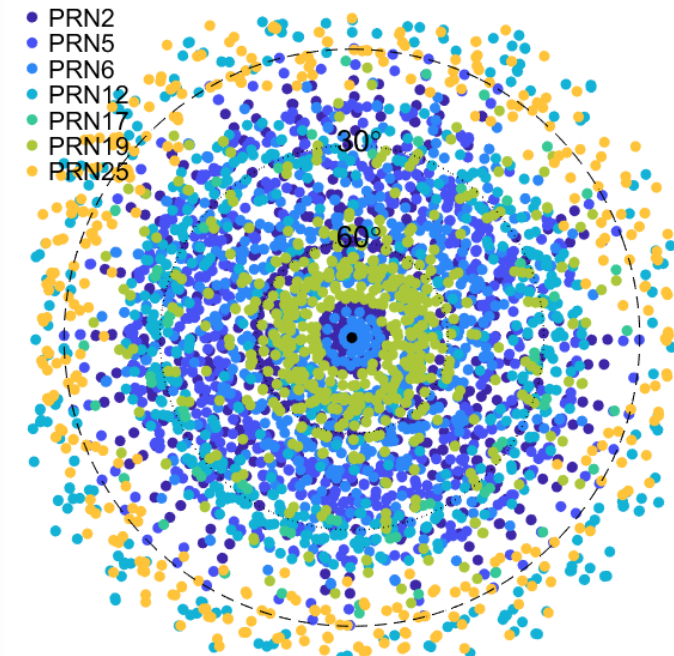
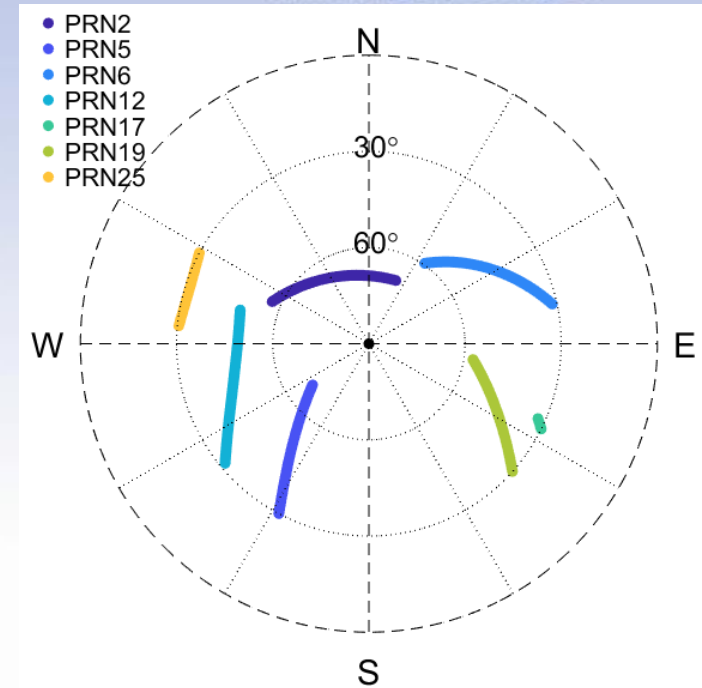
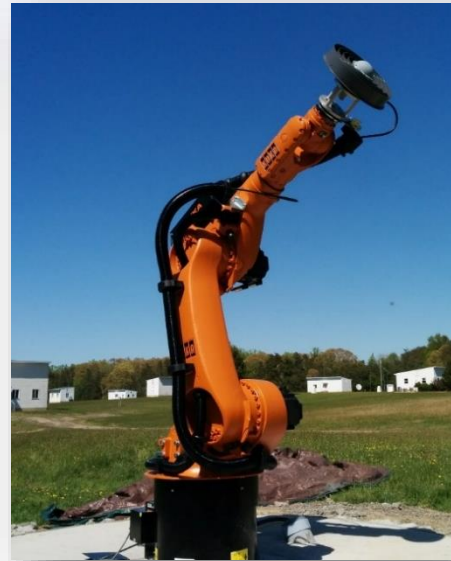
NGS's Testing and Training Center near Fredericksburg, VA



GNSS Antenna Calibration at NGS

# Why an industrial robot?

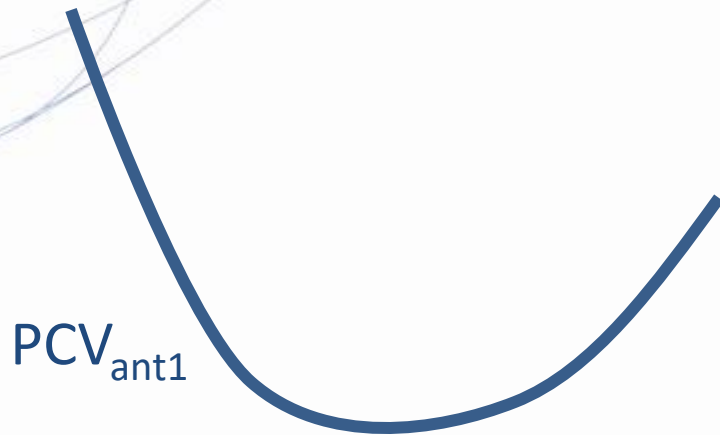
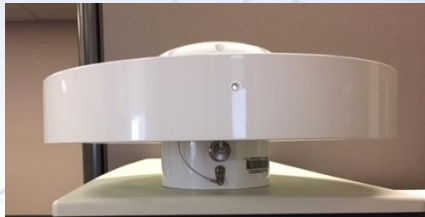
- Receive signals at all possible angles
- Move antenna precisely (0.2 mm or better)
- Keep antenna fixed in space
- Cancel out factors affecting the signal...



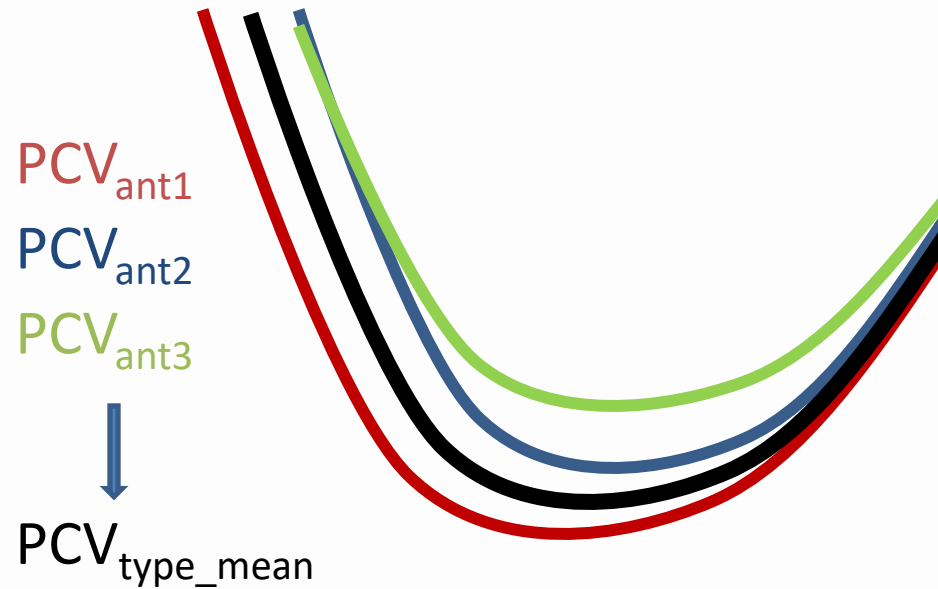
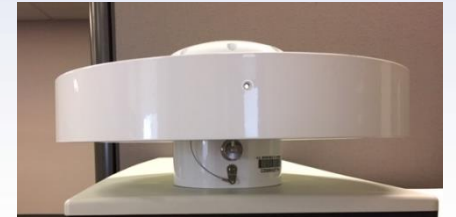
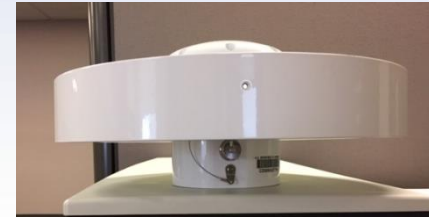
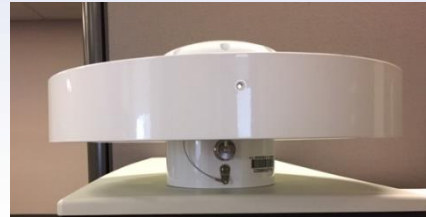


# Terminology

## Individual



## Type Mean



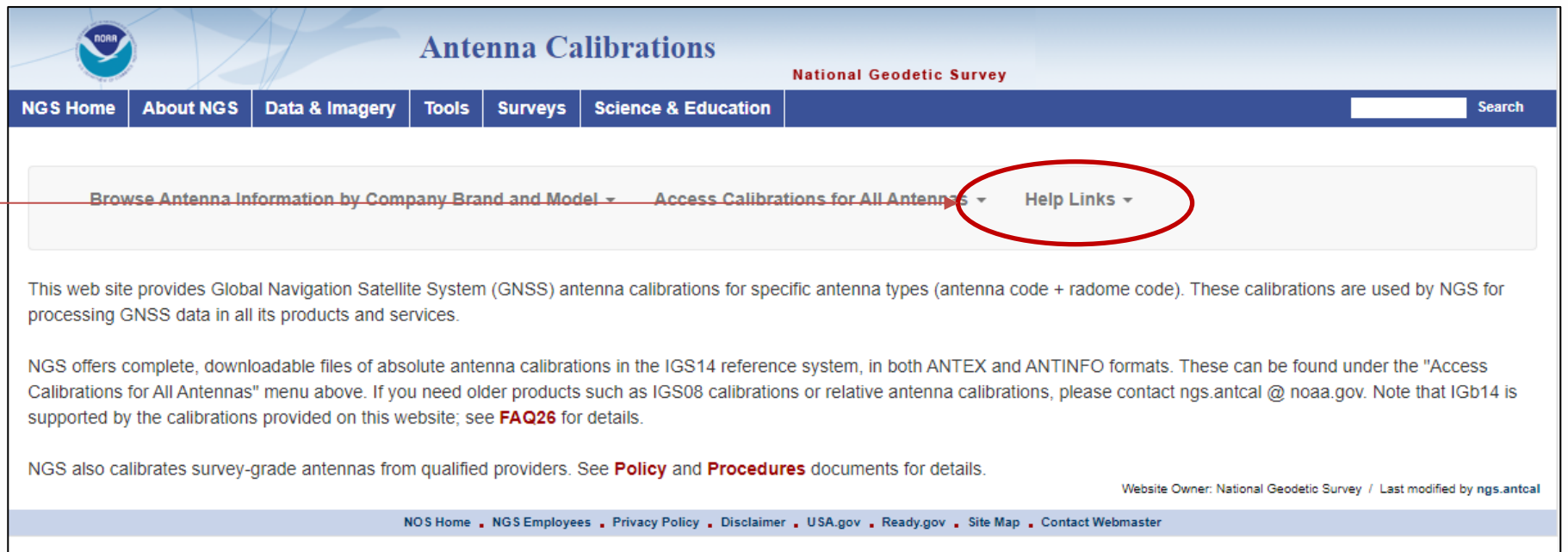
# Thank You!

For more information

- <https://geodesy.noaa.gov/ANTCAL/>

- Policy
- Procedures
- FAQ

- Email [ngs.antcal@noaa.gov](mailto:ngs.antcal@noaa.gov)



The screenshot shows the NOAA National Geodetic Survey website for Antenna Calibrations. The page title is "Antenna Calibrations" and it is part of the "National Geodetic Survey". The navigation menu includes "NGS Home", "About NGS", "Data & Imagery", "Tools", "Surveys", and "Science & Education". A search bar is located on the right. Below the navigation menu, there are three main menu items: "Browse Antenna Information by Company Brand and Model", "Access Calibrations for All Antennas", and "Help Links". The "Help Links" item is circled in red. Below the menu items, there is a paragraph of text: "This web site provides Global Navigation Satellite System (GNSS) antenna calibrations for specific antenna types (antenna code + radome code). These calibrations are used by NGS for processing GNSS data in all its products and services." Another paragraph follows: "NGS offers complete, downloadable files of absolute antenna calibrations in the IGS14 reference system, in both ANTEX and ANTINFO formats. These can be found under the 'Access Calibrations for All Antennas' menu above. If you need older products such as IGS08 calibrations or relative antenna calibrations, please contact ngs.antcal @ noaa.gov. Note that IGS14 is supported by the calibrations provided on this website; see **FAQ26** for details." A third paragraph states: "NGS also calibrates survey-grade antennas from qualified providers. See **Policy** and **Procedures** documents for details." At the bottom right, it says "Website Owner: National Geodetic Survey / Last modified by ngs.antcal". The footer contains links for "NOS Home", "NGS Employees", "Privacy Policy", "Disclaimer", "USA.gov", "Ready.gov", "Site Map", and "Contact Webmaster".