# GNSS Antenna Calibration at the National Geodetic Survey

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January 14, 2021

# Antcal Team
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### Engineering / Software

- Andria Bilich
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- Phillip MacFarland

### Operations / Analysis

- Charlie Geoghegan
- Ben Erickson
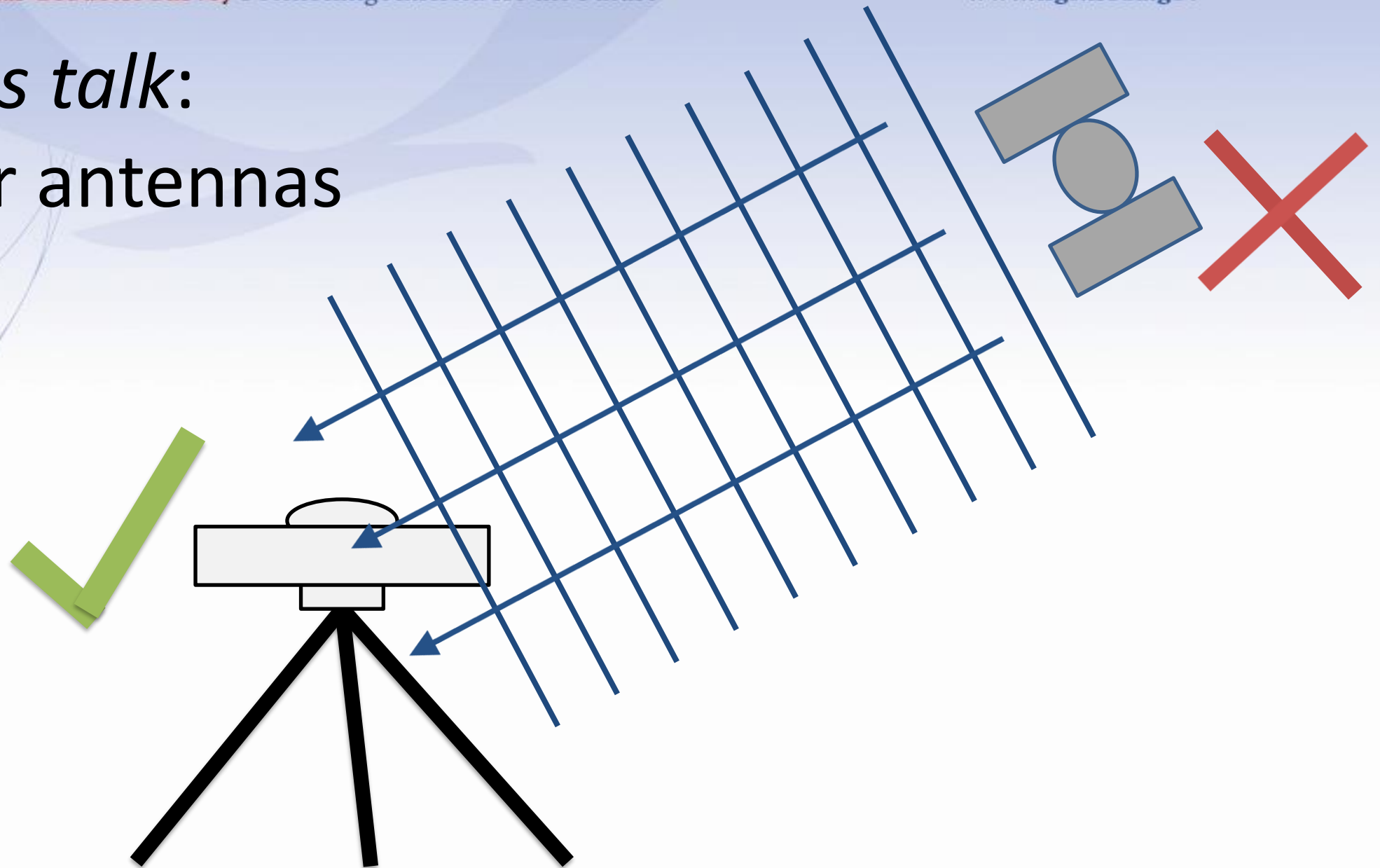
### Antenna Calibrations

### Infrastructure

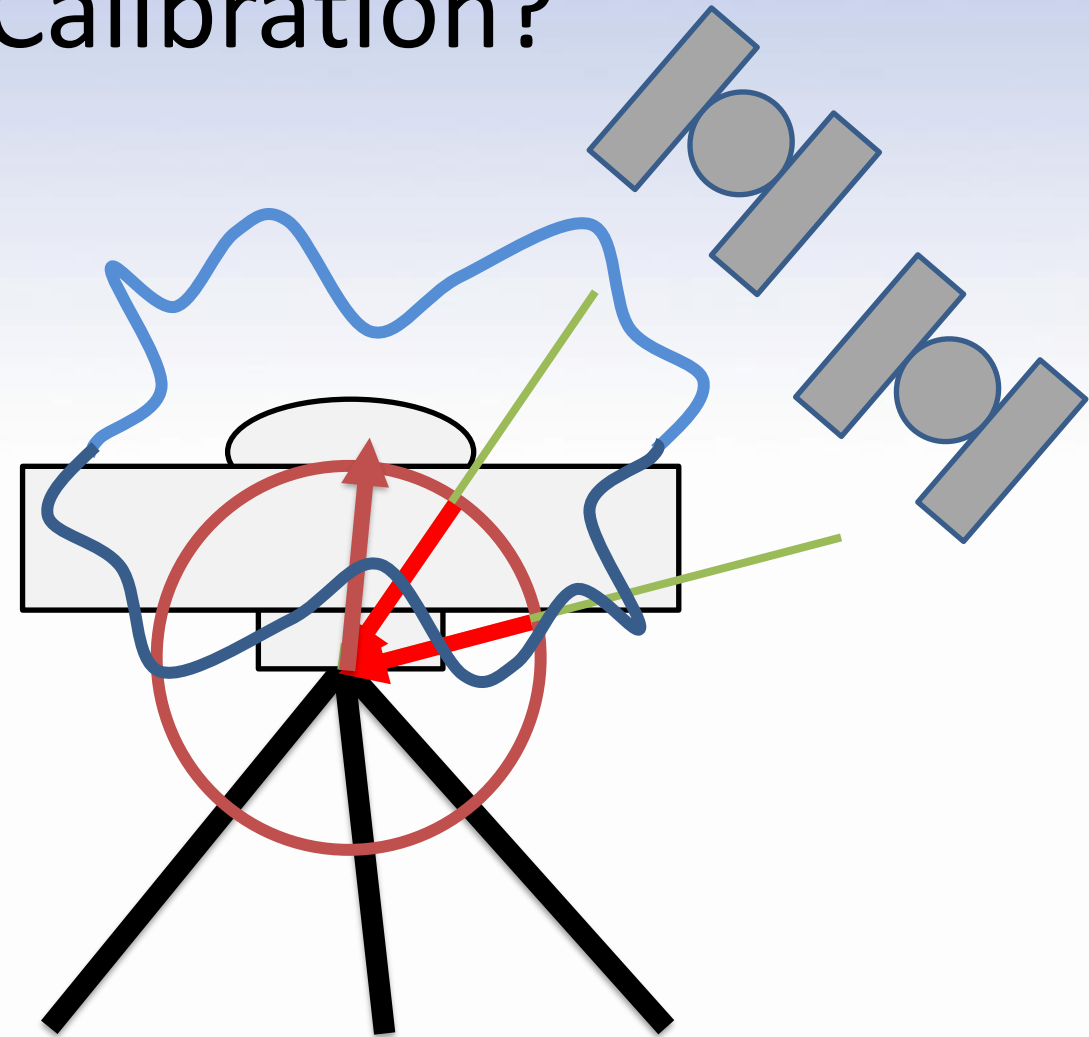- Steven Breidenbach

### 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
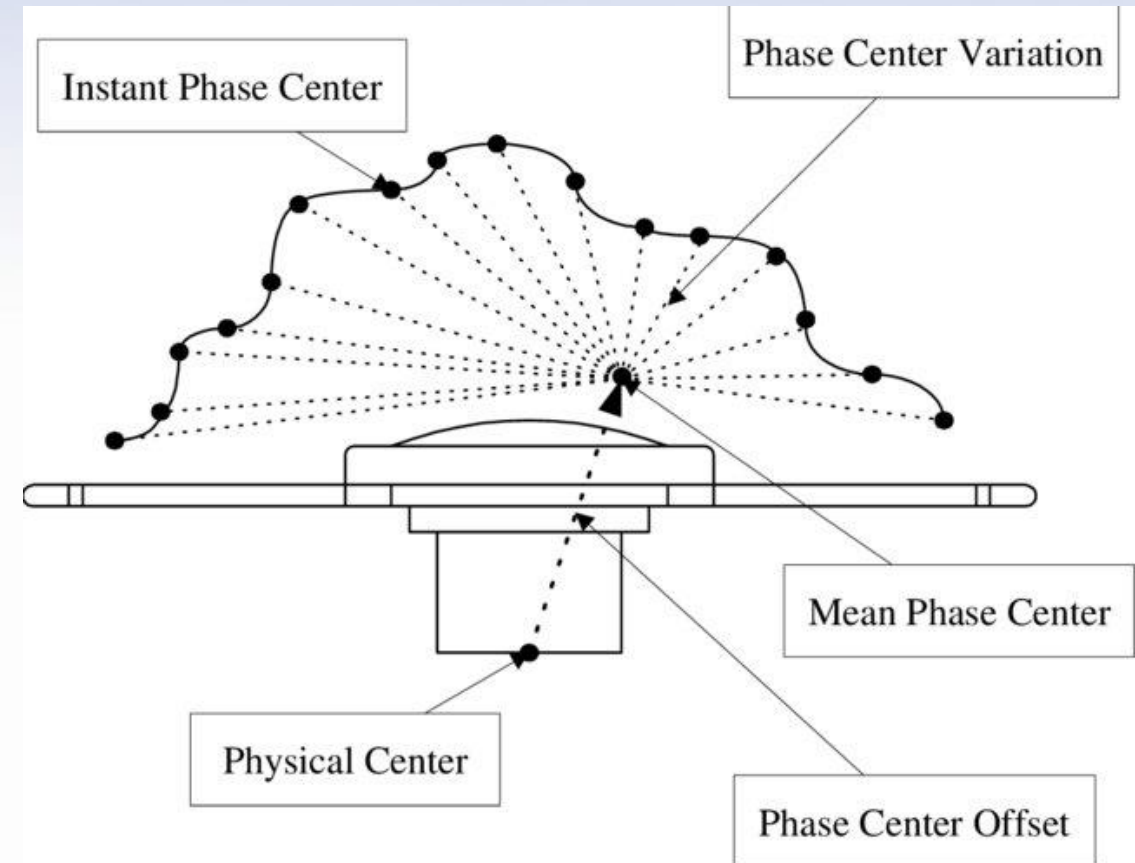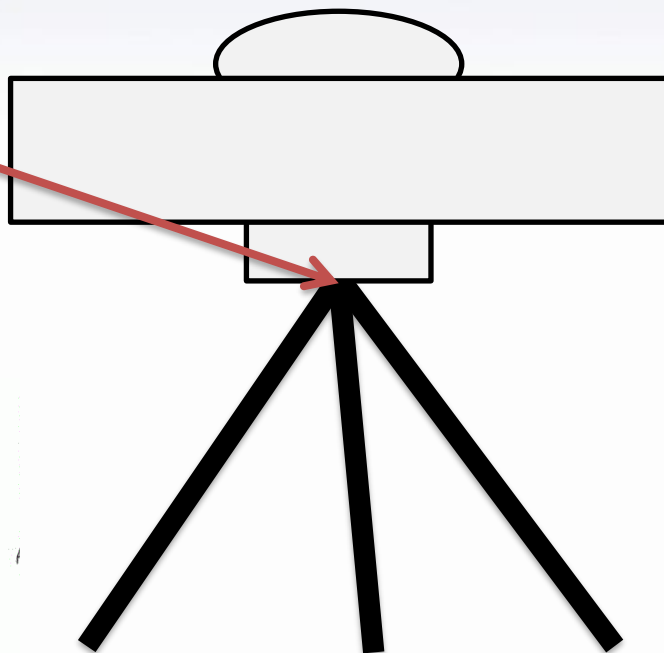


*Figure from Chen et al (2000), The impact of GPS antenna phase center offset and variation on the positioning accuracy, Bollettino di Geodesia et Scienze Affini 9(1):1-22*
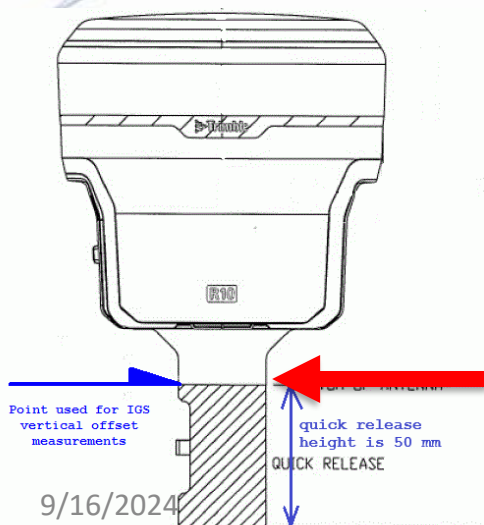
# Antenna's "tangible structure"

**North reference point (NRP)**

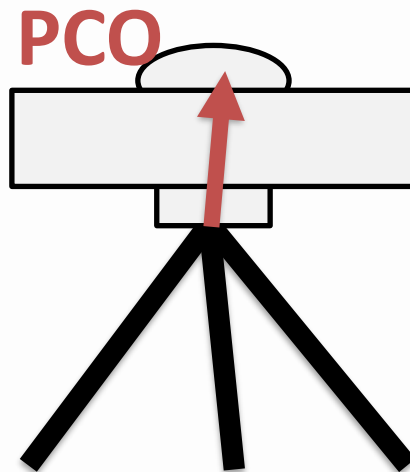**Antenna reference point (ARP)**



MMI (man-machine interface)

RXC (receiver connector)

Point used for IGS vertical offset measurements

quick release height is 50 mm
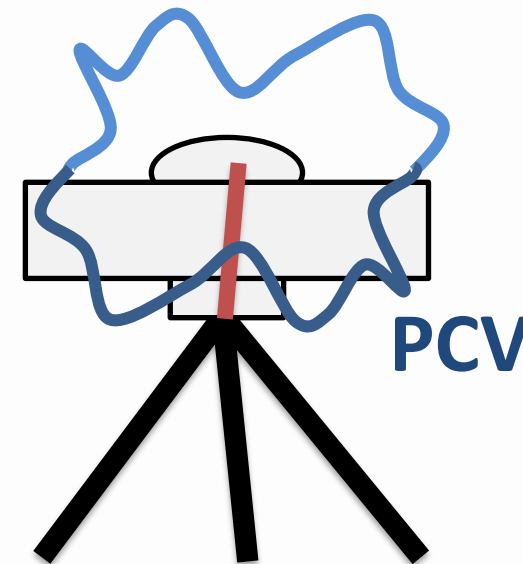QUICK RELEASE

# 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

```
                                            START OF ANTENNA
TRMR8-4            NONE                      SERIAL NO
ROBOT                     Geo++                  / DATE
    5.0                                          / DZEN
    0.0   90.0    5.0                         ES
    4                                         DE
IGS14_2045
# Number of Calibrated Antennas GPS:             COMMENT
# Number of Individual Calibrations GPS:   016   COMMENT
# Number of Calibrated Antennas GLO:       005   COMMENT
# Number of Individual Calibrations GLO:   016   COMMENT
# GLONASS PCV                                    COMMENT
#  derived from Delta PCV per 25.0 MHz           COMMENT
#  for frequency channel number  k=0             COMMENT
  G01                                        START OF FREQUENCY
    +1.06     -0.78     +84.07               NORTH / EAST / UP
```

**PCO** (red box)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 |

**PCV** (blue box)

**Software Developers:**
email
ngs.antcal@noaa.gov

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



One big ANTEX file for all receiver antennas in NGS database

Individual calibrations, in ANTEX and ANTNFO formats

# Calibration History

- NGS developed *relative* calibration technology in 1994

- Adopted by IGS in 1996

- Use GNSS receivers and signals from space
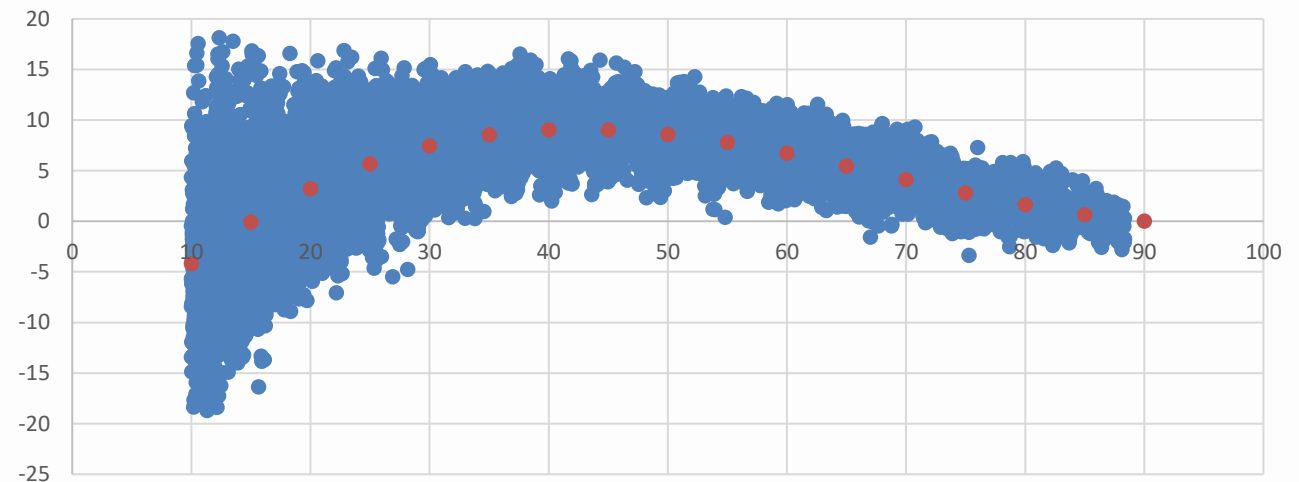
# Geo++: the original *absolute*

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



07/3/13 22:18

ANTEX method (METH): **ROBOT**

GNSS Antenna Calibration at NGS
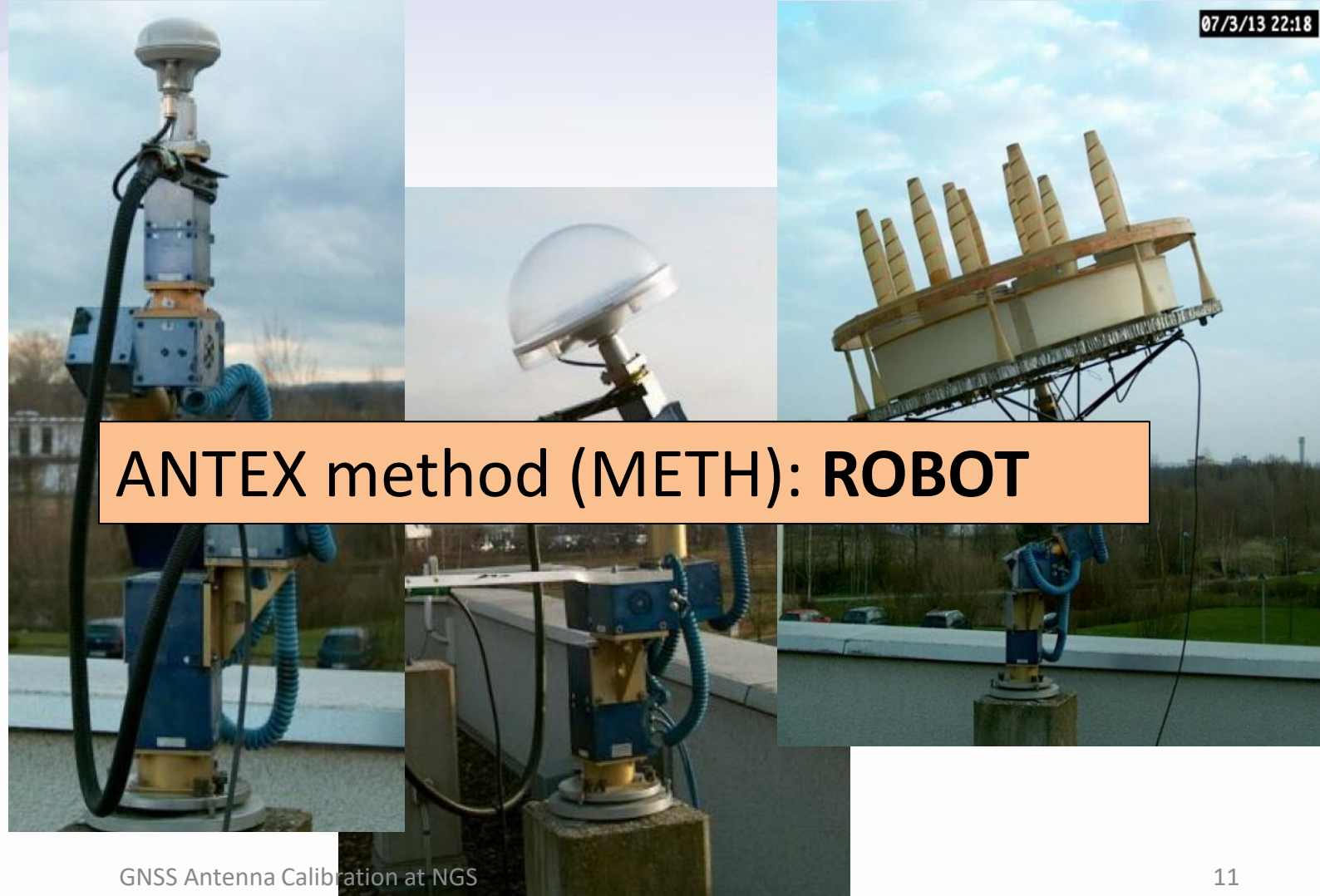
# Why Does NGS Do Antenna Calibration?

- 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 | | ANTEX ANTINFO | Model 700779.A (same as ASH700718A) | 29-JAN-17 | BPA | UNK |
| TOP72110 | NONE | Side Top | ANTEX ANTINFO | Model 72110, used with the TURBO-SII receiver small radius with Dorne Margolin element | 29-JAN-17 | BAM | NOM |
| TPSCR.G3 | SCIT | Drawing Side Top | ANTEX ANTINFO | Topcon GPS/GLONASS/Galileo choke ring antenna | 04-DEC-10 | BPA | NOM |

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
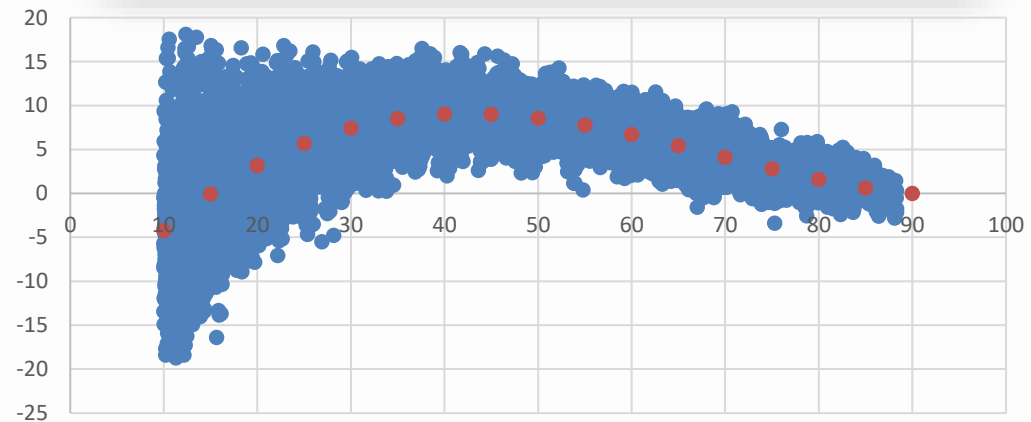
# NGS Absolute Calibrations



NGS's Testing and Training Center near Fredericksburg, VA
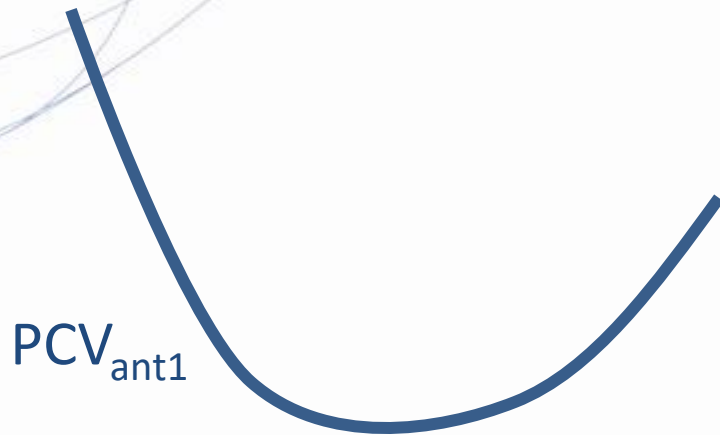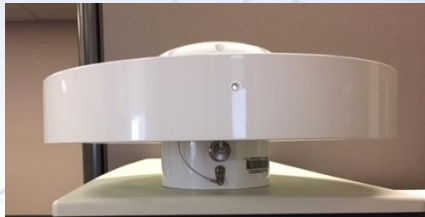
# Why an industrial robot?

- Receive signals at all possible angles

- Move antenna precisely (0.2 mm or better)

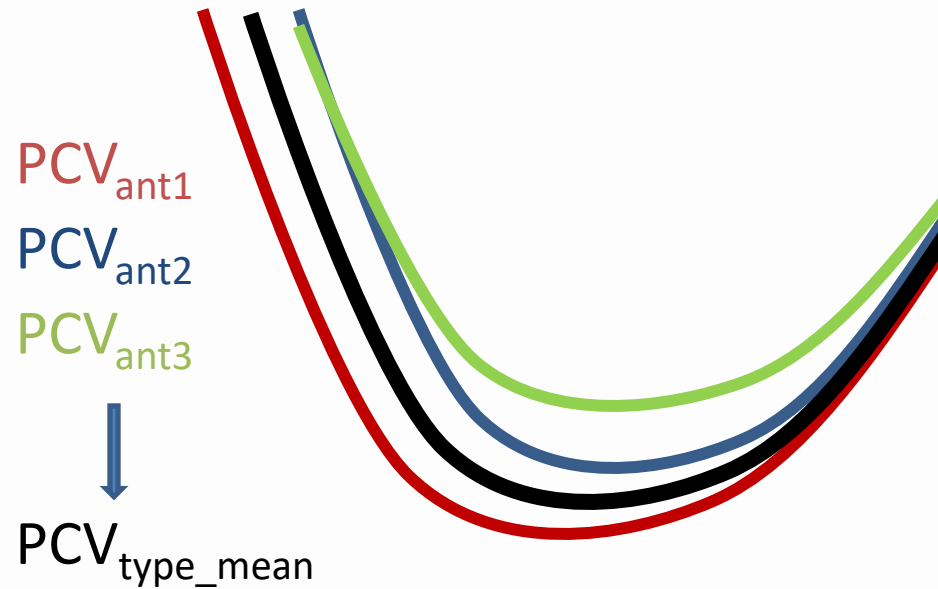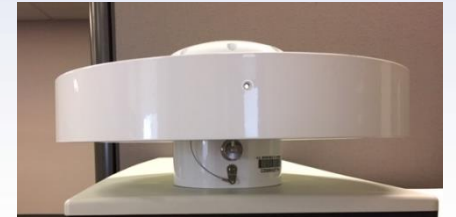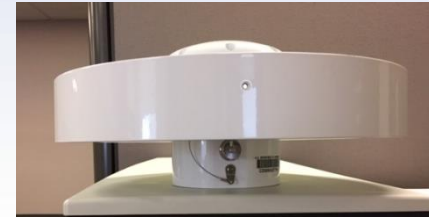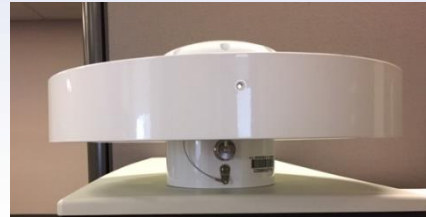- Keep antenna fixed in space

- Cancel out factors affecting the signal…

# Terminology

## Individual

## Type Mean



$PCV_{ant1}$

$PCV_{ant1}$
$PCV_{ant2}$
$PCV_{ant3}$

$PCV_{type\_mean}$

# Thank You!

For more information

- <u>https://geodesy.noaa.gov/ANTCAL/</u>
  - Policy
  - Procedures
  - FAQ

- Email
  <u>ngs.antcal@noaa.gov</u>