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Guidelines for New and Existing Continuously Operating Reference Stations (CORS)

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Guidelines for New and Existing Continuously Operating Reference Stations (CORS)

National Geodetic Survey

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Summary of Updates

Guidelines Effective: 1 January 2006
Document Updated: 22 May 2018
Revisions:
22 May 2018 Updated URLs

08 Jan 2013 Removed Section F on Assessment of National vs Cooperative CORS.

Removed all references to Cooperative and National CORS and just refer to CORS network. Added minimum distance requirement. Appendix 2 corrected URL. Removed URL Appendix 3 and Appendix 4. Clarified language on antenna +radome pairs allowed in CORS network to only those sites for which IGS absolute antenna calibrations are available. Removed sample and blank logs in Appendix D and E and just provided URLs. Added restriction that antenna +radome pairs must have IGS absolute calibrations and not just NGS. Miscellaneous typos corrected. Explicitly added requirement that new stations or replacement equipment must be under manufacturer support. Added preference for GNSS over GPS only equipment. E.1 added date to photograph naming convention.

08 Feb 2006 Procedures: Added explanation for appeals of SST modification request; Added

explanation of applicability of guidelines to existing stations. Section B.5, added explanation for the need of a leveling and orienting device, restricted use of tribrachs, corrected filename how to modify a tribrach adaptor; C.2. Defined PCV; D corrected GPS wrt to UTC time; D. National archiving by site operator of native binary files increased from 14 days to 30 days; E.1 Azimuthal photographs must include the antenna in the picture if at all possible; Appendix 1 Revised completely to make it consistent with sections in this document

15 Dec 2005 Expanded section on procedures for becoming a CORS. Clarified language in Sections

B.3.a., B.4.b., B.5., B.7 expanded on possible antenna cable problems and lightning arrestors. E.1. specified photograph resolution

04 Nov 2005 Corrected 1 typo
14 Oct 2005 Corrected typos and wrong URL's.
07 Oct 2005 Added section on monument stability
22 Sep 2005 Added cover page
20 Sep 2005 Expanded section on procedures for becoming a
CORS **19 Sep 2005** Reordered sections switched A with C

NGS welcomes comments on any part of these guidelines. Please contact ngs.proposed.cors @ noaa.gov

Introduction

This document outlines the requirements and recommendations for the establishment and operation of GNSS stations in the Continuously Operating Reference Station (CORS) network, managed by NOAA's National Geodetic Survey (NGS). The CORS network is a multi-purpose cooperative endeavor involving more than 220 government, academic, commercial, and private organizations. Although participation in the CORS network is voluntary site operators must adhere to certain basic standards and conventions. CORS sites have a fundamental role in establishing and giving access to the National Spatial Reference System (NSRS). Implementing these guidelines aims to minimize GNSS signal distortion and maximize the quality of calculated positions, in accordance with models used in processing GNSS data, to obtain centimeter to sub-centimeter accuracy.

It must be emphasized that NGS will not automatically include a station in the CORS network simply because it meets the criteria described in this document. Selection is made on a case-by-case basis; taking into account current CORS network coverage needs, the quality of data and robustness of communication of existing or potential nearby stations.

Conventions and Definitions

The following conventions have been adopted for this document.

The term "**must**" means that compliance is required; the term "**should**" implies that compliance is strongly recommended, but not required.

***Monument*:** The structure (e.g., pillar, building, etc.), including the mount, which keeps the GNSS antenna attached to earth's surface.

***Mount**:* The device used to attach the antenna to the monument.

***Mark*:** This is a unique and permanent point on the monument to which the antenna reference point is measured. This mark must remain invariant with respect to the monument.

***Antenna Reference Point (ARP)*:** The point on the exterior of the antenna to which NGS references the antenna phase center position.

***Antenna phase center*:** The electrical point, within or outside an antenna, at which the GNSS signal is measured. The realization of the phase center is determined by the set of antenna phase center variations (PCV) corrections that have been defined/adopted by NGS to account for the non-ideal electrical response as a function of elevation and azimuth angles.

***Antenna eccentricity**:* The vertical and horizontal distances from the mark to the ARP.

Site operator: Point of contact responsible for operating the CORS site

Timeline of Applicability of Guidelines

CORS sites accepted **after 1 January 2013** must abide by all sections of the guidelines.

These guidelines are revised periodically to address changes in technology, and NOAA-NGS needs. NGS will be responsible for ensuring that site operators are informed of any needed changes and giving site operators an appropriate time-frame to incorporate any changes.

Summary of Procedures for Becoming a CORS

1) Site operators should ensure that the site meets all the criteria outlined in sections A-E of this document. NGS **strongly recommends** that **before** a CORS site is built NGS is contacted, ngs.proposed.cors@noaa.gov to obtain site specific advice on the proposed location, choice of equipment, and installation method; this should significantly reduce the chance that a site is rejected or require major and costly modifications
2) Send e-mail to **ngs.proposed.cors@noaa.gov** with "Proposed CORS Site" in the subject line and in the body of the e-mail a short description of the site, its location, and contact information. By using this e-mail address rather than an individual NGS employee's site operators will ensure a more timely response.
3) Proposed CORS will be no closer than 70 km from an existing CORS

   WHY? NGS has decided that it can meet and support its mission requirements with a CORS spacing at this distance. A higher density of sites results in excessive redundancy and a significant impact on already limited resources.

Exception to this minimum distance will be made on an individual basis based on two criteria:

   a) NOAA and other Federal agency needs
   b) Data quality of nearby CORS is poor compared to proposed site.

4) Supply the following (Appendix 1 will help):
   - 3 days of data as three 24 hr RINEX files with UTC day-of-year included in the file name.
   - Site photographs (Section E.1.)
   - Completed site log (Section E.2.)

5) If between the time the site is proposed and the site is accepted any changes are made to the site or equipment the site operator must immediately send an e-mail to **ngs.proposed.cors @noaa.gov** with the **site id** in the **subject line** and a description of the changes, including serial numbers or firmware versions and updated pictures if necessary.
6) NGS's Site Selection Team (SST) meets twice a month and evaluates site's using the criteria outlined in Appendix 1. The site will be accepted, conditionally accepted, or declined. The SST consists of 3-6 volunteer members from NGS, who are involved in a variety of tasks including daily analysis of CORS data, archiving of CORS data, and installing CORS sites.

   If the site is **conditionally accepted**: The site operator must comply with the requested changes, which may require changing the equipment setup, removing nearby obstructions, or modifying metadata after which the information is resubmitted with updated photographs, if needed, to the SST.

7) Once a site is accepted the site is turned over from the SST to the CORS Data Management Team, which will coordinate data ingestion to NGS. Any changes that are made to the site or equipment must be immediately sent via e-mail to **ngs.corscollector@noaa.gov** with the **site id** in the **subject line** and a description of the changes e.g. new serial number(s) or firmware versions and updated picture(s)
8) NGS will shortly begin analyzing the data and upload all site metadata to NGS's internal database
9) NGS will publish the official coordinate for the site within a few weeks, add the site to the CORS web page and put a notice in the weekly CORS newsletter

If a site operator disagrees with the SST decision they are encouraged to appeal the decision to the SST. They should explain in detail why they believe the decision is not appropriate and how the guidelines should be modified or reconsidered.

Guidelines for Establishing and Operating a CORS

A. General Site Operator Requirements

All correspondence about an **accepted and operating** CORS site must be sent to: **ngs.corscollector@noaa.gov** with the 4-character site id in the subject line, or city and state name if no 4-chacter site id is assigned. By using this e-mail address rather than an individual NGS employee's site operators will ensure a more timely response.

The site operator provides and maintains all CORS equipment. Since NGS does not operate the site(s) NGS should not be considered the primary verifier of a site's data quality, the site operators should have their own data integrity checks.

The site operator must inform NGS of any planned outages, changes in equipment and firmware -- **especially changes in antenna, radome, and physical space surrounding the antenna** -- as soon as they become known to the site operator.

A CORS site is expected to have high data quality and a lifetime of at least 15 yrs. The latter also applies to the critical volume of space around the antenna that should remain undisturbed throughout the lifetime of the CORS site. Power and internet outages should be infrequent and short-lived.

B. Monument

Since there is no "perfect" monument, these guidelines only aim to avoid designs that are known to cause (or are likely to cause) data quality issues, based on designs used in CORS/IGS (International Global Navigation Satellite System Service) during the last 12 years.

GOALS: *First, ensuring that the antenna is well anchored to the ground is essential so the position and velocity associated with a given site represents the crustal position and velocity of the site, not just of the antenna. Second, minimize multipath and differences in antenna phase center position as compared to models used in data analysis.*

B.1. Stability

A CORS monument should be designed to maximize its stability (maintain a fixed position in three dimensions) and minimize measurement of near-surface effects. The uppermost part of the ground is subject to the greatest amount of motion e.g. soil expansion and contraction due to changes in water saturation, frost heave, soil weathering, thus **increasing the depth of the monument improves its stability**. A detailed discussion of benchmark stability that is equally applicable to CORS monuments is given in "NOAA Manual NOS NGS 1 Geodetic Bench Marks" especially pages 1-11 (*https://geodesy.noaa.gov/PUBS_LIB/GeodeticBMs*).

CORS sites should be designed to be at least Class B and hence minimize the impact of:

-Caverns, sink holes, and mines
-Areas where there is active fluid/gas pumping.
-Frost heave, shrinking and swelling of soil and rock
-Soil expansion and contraction
-Slope instability
-Soil consolidation
-Motion intrinsic to a monument e.g. thermal expansion and contraction

NGS strongly recommends that if in doubt about the soil and geologic conditions, a conservative "worst case" scenario be assumed.

B.2. Location, Obstructions and Radio Frequency Environment

Proposed CORS will be no closer than 70 km from an existing CORS (NGS Executive Steering Committee on 22 September 2012).

Exception to this minimum distance will be made on an individual basis based on two criteria:

a) NOAA and other Federal agency needs

b) Data quality of nearby CORS is poor compared to proposed site (See G)

B.2.a. Location

Choose an open area with minimal obstructions and minimum likelihood of change in the environment surrounding the monument; e.g. avoid sites with future tree or shrub growth, building additions, rooftop additions, new antenna masts, satellite dishes, parking lots, chain link fences, etc.

B.2.b. Obstructions

No obstructions 10 degrees above the horizon from the ARP and minimal obstructions from 0 to 10 degrees.

WHY: *The greater the volume through which uninterrupted/unreflected signal can reach the antenna, the greater the likelihood of a robust position estimate. No lightning rods, RTK broadcast antennas, or any other objects should extend above the antenna or be anywhere within 3 m of the antenna and all should be below the 0 degree of the horizontal surface containing the ARP.*

B.2.c. Radio Frequency Environment

The signals received by CORS antenna and receivers can be detrimentally affected by interference from other radio frequency sources (e.g. TV, microwave, FM radio stations, cellular telephones, VHF and UHF repeaters, RADAR, high voltage power lines). This can cause additional noise, intermittent or partial loss of lock or even render sites inoperable. Every effort should be made to avoid proximity to such equipment now and in the future, and all such equipment **must be documented in the site log**.

B.3. Ground-based Monument

B.3.a. Pillar

-Should be approximately 1.5 m above the ground surface to mimic the geometry used at NGS's antenna phase center calibration facility. However, in light of possible obstructions (see B.2. Location, Obstructions, and Radio Frequency Environment), a taller monument may be necessary.

-Must have a deep foundation, Class B, that extends at least 4 m below the frost line and/or the center of mass of the pillar must be below the frost line (see B.1. Stability).

-The top of the pillar **MUST** be narrower than the widest part of the antenna, and the smaller the surface the better. In constructing the pillar, consider that future antennas may be smaller; hence the narrower the top of the pillar the better. The distance between the top of the pillar (if it has a surface) and the antenna should be less than 5 cm or greater than 1 GPS wavelength (~20 cm). This will allow enough room to manipulate a leveling and orienting device (see B.5. Attaching Antenna, Mount, and Monument). These recommendations apply to the top of the pillar only; a very narrow pillar would be unstable and not recommended, however tapered pillars are good.

WHY: *This will mitigate multipath issues.*

B.3.b. Braced

These monuments are especially stable and well anchored to the ground, although more expensive than pillars. Extensive diagrams with details of all aspects of constructions are available at: *http://www.unavco.org/instrumentation/monumentation/types/types.html*

B.4. Roof-based Monument

B.4.a. Building characteristics

Only masonry buildings are permitted. Solid brick or reinforced concrete ones are recommended. The building should have been built at least 5 years previously, to increase the likelihood that all primary settling of the building has occurred. There should be no visible cracks on the outside or inside walls. Buildings taller than two stories are not recommended. No wood or simple metal frame with metal walled buildings, and no metal roofs.

> **WHY:** *This will minimize the effects of thermal expansion as well as multipath issues. The following links are instructive but not exhaustive:*
> *https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/pccp/thermal.cfm*
> *https://www.engineeringtoolbox.com/linear-expansion-coefficients-d_95.html*

B.4.b. Location and Attachment to a Building

-Stainless steel is recommended for longevity (Angle iron or circular pipe). Aluminum is not recommended as it has approximately twice the thermal expansion of steel/concrete.

-The mount must be bolted **directly** to the main part of the building; a load-bearing wall near a corner is recommended.

-The use of epoxy and threaded lock adhesives fasteners (bolts/anchors/rods) is **strongly recommended**.

-Mounting on a chimney is not recommended unless it has been filled with concrete or if it is particularly robust.

-The mount should not interfere with the building's replaceable roof. This will minimize the chance that the mount will be disturbed when the roof is replaced.

Attaching laterally to a load bearing wall:

The mount should extend about 0.5 m above the roofline and be attached to the building for a length of at least 1 m, with at least 3 anchors/bolts. The ratio of freestanding part to bolted part should be approximately 1:3.

The bolts/anchors must penetrate directly through the mount, e.g. no u-bolts, channel lock systems, brackets with metal ties/clamps. Spacers to keep the mount from sitting flush against the wall are acceptable.

> *WHY: An antenna mast must be attached in a manner to eliminate all possible mast/building motion. U-bolts and channel-lock systems although convenient and flexible are by design adjustable in multiple points and therefore are inherently unsuitable in meeting this requirement. Motion of u-bolts/channel-lock systems has been observed at a number of CORS sites, either through gradual loosening or by active unlocking of the systems. If site operators choose to use a channel lock system they must still have 3 bolts/anchors that serve as the primary load-bearing attachment system of the mount to the building.*

Attaching vertically to a master wall:

A bolt or rod must be anchored into a load-bearing wall. Take care not to void a roof warranty. Avoid metal flashing on a parapet wall.

B.5. Attaching Antenna, Mount and Monument

A device must exist between the monument and the antenna that allows: First, the antenna to be leveled and oriented to north (see B.6. Orienting Antenna). Second, if the antenna is changed, the new ARP must return to the **exact same point in 3-dimensional space** as the previous ARP, or the change in position between the mark (See definitions) and the ARP must be measured to within 1 mm.

WHY: If the antenna is simply attached to a threaded rod when it is replaced the new antenna may not return to the same 3-D position or may be oriented differently (the latter would be immaterial only if the phase center variation model is perfectly symmetrical). Both events would require a new position to be computed, which is undesirable.

The antenna must be leveled to within 0.15 degrees or 2.5 mm/meter (This is easily achieved using a good quality spirit level available in most hardware stores)

Tribrach adaptors are not permitted because there is no mechanism of which we are aware to lock the adjustable wheels in place.

A number of devices exist that will do this:
https://geodesy.noaa.gov/CORS/Establish_Operate_CORS.shtml

B.6. Orienting Antenna

The antenna must be oriented to true north using the convention of aligning the antenna cable attachment point, unless the antenna has a different inscribed North point. Remember that declination is the angle between magnetic north and true north. A magnetic declination calculator for setting a compass correctly is available at:

https://geodesy.noaa.gov/CORS/Establish_Operate_CORS.shtml

The declination used must be recorded in the log file (see E.2. Site Log).

WHY: *All antenna phase center patterns assume an oriented antenna, and phase center values can differ between north and east by up to a centimeter.*

B.7. Antenna Cable

The antenna cable should not be under tension. Looping the first section of cable next to the antenna and attaching it to the mount can best avoid this problem. If the cable is not encased in conduit, then care should be taken that it will not move around and be damaged. Take particular care at any point where the cable is subject to increased friction, e.g. edges and egress points. Typical GPS antenna cables for CORS (RG213/RG214) have a signal loss of 9 db/100ft/30m at 1Ghz. Total loss for installed length of cable at a CORS must be 9 db or less, implying a maximum cable length of 100ft/30m. If a longer cable is needed then a lower loss cable must be used (The type, manufacturer, and length of cable must be listed in the site log).

The antenna cable should directly connect to the receiver and antenna, no connectors should be inserted e.g. TNC to N-type. The junction point of the antenna cable and antenna after the two have been connected should be sealed with waterproof material e.g. butyl wrap.

Site operators are strongly recommended to insert a lightning arrestor in the antenna cable between the antenna and the receiver with its own independent ground. The arrestor should be located on the outside of the building at or near the egress point of the cable into the building. This should protect the receiver in the event of a lightning strike on or near the antenna. The following URL may be

helpful, although old, and clearly indicates the potential signal loss created by a poorly selected arrestor:
http://kb.unavco.org/kb/article.php?id=461

C. Equipment

Site operators must keep all receiver firmware updated, and inform NGS as soon as updates occur by e-mailing *ngs.corscollector@noaa.gov*, please specify 4-character site-id in the subject line. NGS strongly recommends that equipment be upgraded and/or replaced as the technology changes, e.g. new GPS signals added. Equipment changes should however be minimized as they have the potential of resulting in a change in position. If data quality decreases and the site operator is unable to replace /upgrade equipment or otherwise mitigate a problem, NGS may choose to remove the site from the CORS network (see G. Quality Control and Day-to-Day Site Operation)

C.1. Antenna

New/Proposed sites must have receivers that are currently supported by the manufacturer.

-The antenna must be at least dual-frequency (L1 and L2).

-An IGS absolute antenna calibrated phase center model for the antenna model must be available. If the user chooses to install a radome (see C.2. Antenna Radome), an IGS absolute calibrated antenna phase center model for the antenna and radome pair must be available. A list of calibrated antenna and radome combinations is available at:
https://geodesy.noaa.gov/Establish_Operate_CORS.shtml

WHY: *A consistent phase center and ARP for the antenna is essential to tie the GPS measurements to the mark. Ignoring the phase center variations can lead to multi-centimeter errors. To ensure consistency in data analysis with other analysis groups, NGS uses only IGS absolute antenna calibration values. This is a smaller set of calibrations than the full list of NGS validated antenna calibration available at https://geodesy.noaa.gov/ANTCAL. The use of IGS absolute antenna calibrations began with the release of CORS revised coordinates (IGS08 epoch 2005.00, NAD 83(2011/MA11/PA11) epoch 2010.00 on 6 September 2011.*

Antennas must be inspected regularly for damage.

C.2. Antenna Radome

NGS strongly recommends that no antenna radome be used.

WHY: *It is well documented that an antenna radome changes the antenna phase center position. Its benefit is limited as antennas are constructed so they do not need the "protection" of a radome. The choice of material used, the effects of UV radiation, as well as possible manufacturing inhomogeneities in the thickness of certain radomes, may create additional problems in using a single Phase Center Variation (PCV) model for a particular radome model. These two problems imply that either a time-dependent effect on the PCV exists as the radome deteriorates or a calibration of each individual radome is needed as a general model calibration would not be valid.*

If a radome is used, the antenna and radome pair **must** have an IGS absolute antenna calibration (see C.1. Antenna).

C.3. Receiver, Settings, and Power Supply

New/Proposed sites must have receivers that are currently supported by the manufacturer.

Receivers must be able to:

- Track at least L1 and L2
- Track at least 10 satellites above 0 degrees
- Automatically switch between operating modes to retain full wavelength L2 when Antispoofing (AS) is switched on
- Provide L1 C/A-code pseudorange or P-code pseudorange and L1 and L2 full wavelength carrier phase

The ability to track additional GPS signals e.g. L2C and L5 as well as other GNSS systems are all **strongly encouraged**.

Receivers must be programmed:

- So that no smoothing is applied to the observables
- Track with an elevation cutoff angle of 5 degrees and **0 degrees is strongly preferred**
- Record at 30, 15, 5 or 1-second sampling intervals
- Create hourly sessions (strongly preferred), or 24hr sessions of GPS time.
- Track all satellites regardless of health status

  WHY: *The criteria used by the Department of Defense for designating an unhealthy satellite are not always applicable to certain CORS users.*

Receivers must have an uninterrupted power supply with a minimum of 5 minutes backup power, 30+ minutes strongly preferred.

D. Communications and Data availability and online storage

All data transfers between NGS and the operator's site **must be done via the Internet**.

NGS must be able to retrieve or receive the data immediately after the hour if logging hourly or after 2400h GPS time.

Site operator's web and ftp server must operate 24hrs a day.

All data must be made freely available to the public for distribution.

CORS Data Ingestion and Distribution
NGS will create RINEX-2 files that will be archived by NOAA-NGS, indefinitely.
Native binary data must be made available to NGS immediately after the hour if logging hourly, or after 2400h GPS time.
Site operator must keep native binary data on-line and accessible by NGS for at least 30 days, (NGS does not archive native binary data).

All file names and associated dates must be recorded with respect to GPS time (UTC plus ~14s) **NOT** local time.

Directory structure at operator's site **MUST** use the following convention and be all in lowercase**:**

/base_directory/native/yyyy/ddd/ssss/ssssdddh[mm].[c]
/base_directory/rinex/yyyy/ddd/ssss/ssssdddh[mm].yyt[c]

Files **must** use the following convention all in lowercase:

ssssdddh[mm].yyt.[c]

base_directory – can be any directory on the site operator's ftp server where data are going to be stored.
ssss - the four-character site id (see E.2. Site Log)
ddd - the GPS day of year,
yyyy – four digit GPS year
h - a letter that corresponds to an hour-long GPS time block (see below) or 0 (zero) for a full 24hr GPS time block.
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23
a b c d e f g h i j k l m n o p q r s t u v w x
mm applies only to sites that record in less than 1 hour time blocks and consists of the minutes after the hour that the file begins e.g. if 30 minute files are collected then 00 and 30 would be used.
yy - the last two digits of four digit GPS year (e.g. 2004 is 04)
t - the file type as:
o – observation
d – observation Hatanaka compressed. The source code for creating and uncompressing this format is available at: http://terras.gsi.go.jp/ja/crx2rnx.html
m – meteorological
n – navigation
s – summary
c - compression is optional, but recommended as it saves bandwidth, but must be one of the following three types:
zip – zip
gz – gzip GNU zip (preferred) and available at: http://www.gnu.org/software/gzip/manual/gzip.html
Z – unix compressed

The native binary files will obviously have the manufacturer specific extensions but should mimic the afore mentioned format as closely as possible.

E. Site Metadata

E.1. Digital Photographs

A set of sharply focused digital photographs, at least 300 dpi at 5"x7", are required to evaluate and document a site. When taking photographs, please remember that their purpose is to give a clear view of the equipment being used, how it is assembled, as well as the space around it for someone who has not visited the site. Photographs **must be named as described** below. The date specification must correspond to when the photograph was taken. If you are unsure please use the letter x as necessary e.g. 201206xx or 2012xxxx. The convention to use for azimuth direction is 000

- north, 090 - east, etc. Jpeg format is preferred. In the file name omit the [] which indicate a variable: ssss is the 4-alphanumeric site id, yyyymmdd is the 4-digit year, 2-digit month and 2-digit day that the photograph was taken. The photographs must include:

[ssss]_monu_[yyyymmdd].jpg - A photograph showing the monument (pillar/braced/building) and antenna. **The ground surface of the building or monument and antenna must be visible.**

[**ssss]_mark_[yyyymmdd].jpg -** A photograph showing the mark. If no unique mark exists then a photograph of the threaded section of the mount, either laterally or from above the monument should be taken. (If the site has been collecting data then **DO NOT REMOVE the antenna** and instead ignore this photograph.

[ssss]_ant_monu_[yyyymmdd].jpg - A close-up photograph that shows how the antenna is attached to the monument.

-Four oriented photographs taken at the height of ARP surface the antenna should be included in the photograph but it should not significantly block the ability to view what lies behind the antenna, stand about 3-5m away, If you cannot take a photograph including the antenna place the camera directly at the top center of the antenna, and point the camera in the required direction:

[ssss]_ant_000_[yyyymmdd].jpg	North	(000)
[ssss]_ant_090_[yyyymmdd].jpg	East	(090)
[ssss]_ant_180_[yyyymmdd].jpg	South	(180)
[ssss]_ant_270_[yyyymmdd].jpg	West	(270)

(If photographs from additional directions are useful please use the appropriate azimuth in the file name.

[ssss]_ant_sn_[yyyyddmmdd].jpg - A close-up photograph of the antenna showing its model and serial number.

[ssss]_rec_sn_[yyyymmdd].jpg - A close-up photograph of the receiver showing its model and serial number.

[ssss]_rec_[yyyymmdd].jpg - A photograph of the receiver location.

If the antenna is on a roof, you must include the following:

[ssss]_ant_bldg_[yyyymmdd].jpg - A photograph showing "clearly" how the antenna is attached to the building.

[ssss]_ant_roof_[yyyymmdd].jpg - A photograph showing the antenna and the roof surface.

These photographs must be updated if the equipment changes or changes occur in the physical space around the antenna.

E.2. Site Log

The site log used at NGS follows the format specified by the International Global Navigation Satellite System Service (IGS). This file contains all the historical information about a site and details the equipment and monument used. **The site log is of equal importance as the GNSS data collected at a site**. Detailed instructions are given in APPENDIX 2; a blank log is given in APPENDIX 3; and a completed sample log is given in APPENDIX 4. Please fill out **ALL** parts for which you have information. DO NOT DELETE any empty or inapplicable sections. Please remember that these files must be "machine readable" and therefore should be saved as **ASCII files and have the exact spacing as described in the instructions** (APPENDIX 2). **Most entries can**

only be on one line, if more information is needed please enter it in the "Additional Information" part of each section**.** A log checker is available at:
https://geodesy.noaa.gov/CORS/Establish_Opearate_CORS.shtml

F. Quality Control and Day-to-Day Site Operation:

To ensure data quality the following verifications will be made on a daily basis using TEQC (Translating, Editing, Quality Checking) to check the quality of the incoming 24hr RINEX files decimated to 30-s epochs. TEQC is freeware available for a variety of computer platforms and operating systems from: https://www.unavco.org/software/data-processing/teqc/teqc.html

- MP1 represents the RMS multipath in meters on the L1 pseudorange observable, averaged for a 50-point moving window (25 minutes for 30-s epochs).
- MP2 represents the RMS multipath in meters on the L2 pseudorange observable, averaged for a 50-point moving window (25 minutes for 30-s epochs).
- o/slp represents the average number of complete observations before a slip occurs simultaneously on the derivative of the ionospheric delay observable and/or both MP1 and MP2.
- IODslp represents the number of slips on the derivative of the ionospheric delay observable.

The TEQC statistics will be supplemented with those obtained by forming the ionospheric free linear combination of the L1 and L2 phases by the method of double differences. This is the method used by NGS to calculate daily site coordinates. Note that double differences are dependent on data quality from two sites, unlike TEQC statistics.

The combination of the aforementioned performance measures will be used to recommend equipment upgrades for prospective or existing sites whose data under-perform compared to its established peers (CORS network). In addition, these results will be used to search for systematic effects in the CORS network, such as a tendency for a model of receiver or antenna to under-perform when compared to its peers.

Starting in FY 12-13 quality control metric plots will be created to allow station operators to compare their stations with the rest of the existing CORS network.

APPENDIX 1: Form for Evaluating Proposed CORS

Dear,

Thank you for submitting your GNSS site, **_____**** to be considered as part of the National Geodetic Survey's CORS network. The Site Selection Team (SST) has reviewed your site and has the following comments.

If you have any questions or once you have updated the missing or updated information please:

1) e-mail **ngs.proposed.cors@noaa.gov**

2) Ensure you include the 4-character Site-ID** or city and state in the subject line.

These steps will result in all members of the SST receiving your e-mail.

Unless otherwise specified "Sections" refer to those in Guidelines for New and Existing CORS available at: **https://geodesy.noaa.gov/CORS/Establish_Operate_CORS.shtml**

**This is a proposed SITE ID unless NGS has already assigned you this 4-character site-id. Otherwise, once your site has been accepted the NGS Data Management Team will check if your preferred 4-character site id is available in a global database of GNSS 4-character site id's and reserve it or offer an alternative one.

Site Location and Obstructions Section B.2		**N/A**	**Invalid**	**Modify**	**Accept**
B.2.a	Location				
B.2.b	Obstructions				
B.2.c	Radio Frequency Environment				

Additional comments:

Ground-based Monument Section B.3.		**N/A**	**Invalid**	**Modify**	**Accept**
B.3.a	Top of pillar width narrower than antenna				
B.3.b	Braced monument				

Additional comments:

Roof-based Monument Section B.4.		**N/A**	**Invalid**	**Modify**	**Accept**
B.4.a	Building made of mortar				
B.4.b	Mount attachment bolts				
B.4.b	Mount bolted length to free standing length				

Additional comments:

Attach. Antenna, Mount and Monument, Orienting Antenna, Antenna Cable Section B.5-B.7.		N/A	Invalid	Modify	Accept
B.5	Leveling and orienting device				
B.5	Antenna level				
B.6	Antenna oriented to North				
B.7	Antenna cable tension				

Additional comments:

Equipment Section C.		N/A	Invalid	Modify	Accept
C.1	Valid antenna type				
C.2	Valid radome type				
C.3	Valid receiver type				

Additional comments:

Site Metadata: Digital Photographs Section E.1.		Photograph name	N/A	Missing	Modify	Accept
A	Photograph showing the monument (pillar/ braced/building) and antenna	**[ssss]_monu_[yyyymmdd]**				
B	Photograph showing the mark	**[ssss]_mark_[yyyymmdd]**				
C	Photograph that shows how the antenna is attached to the monument	**[ssss]_ant_monu_[yyyymmdd]**				
D	Photograph of view 000 (north)	**[ssss]_ant_000_[yyyymmdd]**				
E	Photograph of view 090 (east)	**[ssss]_ant_090_[yyyymmdd]**				
F	Photograph of view 180 (south)	**[ssss]_ant_180_[yyyymmdd]**				
G	Photograph of view 270 (west)	**[ssss]_ant_270_[yyyymmdd]**				
	If the antenna is on a roof, you must include the following:					
H	Photograph showing "clearly" how the antenna is attached to the building.	**[ssss]_ant_bldg_[yyyymmdd]**				
I	A photograph showing the antenna and the roof surface	**[ssss]_ant_roof_[yyyymmdd]**				
J	A photograph of the antenna showing model and serial number	**[ssss]_ant_sn_[yyyymmdd]**				
K	A photograph of the receiver showing model and serial number	**[ssss]_rec_sn_[yyyymmdd]**				
L	A photograph of the receiver location	**[ssss]_rec_[yyyymmdd]**				
M	Resolution and size of photographs					

Additional comments:

Site Metadata: Site Log **Section E.2** (S.1,S.3,S.4 are log file sections)		N/A	Missing	Modify	Accept
S.1	Detailed monument information				
S.1	Height of monument and dimensions of material				
S.1	Dimensions of building/monument foundations				
S.1	Description of materials used				
S.3	Receiver name and serial number match photograph				
S.3	Receiver install and removed dates are valid				
S.4	Antenna name and serial number match photograph				
S.4	Antenna install and removed dates are valid				
S.4	Antenna cable type and length				
S.11-12	Contact information				

Additional comments:

Data Quality and Geographic Location	N/A	Missing	Modify	Accept
3 24hr days of data				
TEQC results				
Distance to nearest CORS is more than 70km				

Additional comments:

Site is Recommended to be	Denied	Accepted
Site is recommended		

Additional comments:

APPENDIX 2: Instructions for Completing Site Log

Modified by NGS from IGS version of Sep 2012

To verify a log please go to*: https://geodesy.noaa.gov/CORS/Establish_Operate_CORS.shtml*

General

=======

Please prepare site logs in plain ASCII and keep line-length limited to 80 characters.

Date and time formats within the site log follow the basic format "CCYY-MM-DDThh:mmZ"
CC=2 digit century
YY=2 digit year
MM=2 digit month
DD=2 digit day of month
T=date/time separator (MUST BE INCLUDED
hh=2 digit hour
mm=2 digit minutes of hour
Z=UTC indicator (MUST BE INCLUDED)

A date without a time is specified like "2003-07-30", not "2003-07-30Thh:mmZ"

Latitude/Longitude formats are aligned to ISO 6709:
Lat: +/-DDMMSS.SS
Long: +/-DDDMMSS.SS
A + or - sign is required. Leading zeroes must be used as appropriate to maintain the DDMMSS and DDDMMSS format.

Valid longitude range is from -180 degrees to (infinitesimally less than) +180 degrees. Valid latitude range is -90 degrees to +90 degrees.

"etc" indicates you may enter any relevant answer, not just a choice of the suggestions shown.

"F7.4," "A4" and so on indicate the FORTRAN-style format which the response should have.
Example 12345.7 = F7.1 or ABED = A4

Blocks which have a "Nix" definition (namely sections 3-10) should always have the complete historic set of information; when a change is made, the previous information is left (for example in section 3.1) and the new information is placed in a new block numbered 3.2. Please leave the .x sections uncompleted to remind yourself of the format when the next change occurs.

Please remove the response hints such as "(F7.4 N/S)" as you fill out the log (except in the .x sections and Date Removed fields for currently installed equipment, which you must not alter). If an answer in an optional field is unknown, try to learn the answer for the next log update.

Special Instructions by section
==========

0. Form

If Update:

Previous Site Log : (ssss_CCYYMMDD.log)

ssss = 4 character site name, CCYY-4-digit year, MM 2-digit month, DD 2-digit day

If Update:

Modified/Added Sections : (n.n,n.n,...)

Enter the sections which have changed from the previous version of the log. Example: 3.2, 4.2

1. Site Identification of the GNSS Monument

Four Character ID : (A4)

This will be assigned by NGS

IERS DOMES Number : (A9)

This is **NOT** required. NGS may choose to assign one at a later time. Please DO NOT contact IERS

Monument Description : (PILLAR/BRASS PLATE/STEEL MAST/etc)

Enter one or more elements as necessary to describe the monument and mount.

Additional Information : (multiple lines)

Give a **short** paragraph description of the monument and mount used at your site. In particular describe: the materials and methods used in building the monument, age of building, depth of foundation.

2. Site Location Information

Approximate Position (ITRF)

This should be to a one meter precision. If the site is accepted official coordinates will be determined by NGS.

3. GNSS Receiver Information

Receiver Type : (A20, from rcvr_ant.tab; see instructions)

Please find your receiver at fftp://www.igs.org/pub/station/general/rcvr_ant.tab

Use the official name i.e.first column. Ensure all capital letters, hyphens, etc. are exactly correct.

Satellite System : (GPS+GLO+GAL+CMP+QZSS+SBAS)

Choose the combination that your receiver is actually tracking NOT what it can potentially track. Many receivers require special codes to access certain satellite systems.

Serial Number : (A20)

Do not enter "S/N 12345" instead of "12345". Ensure that 0(zero) are not O(ohs) or vice a versa). If letters are part of the S/N these should be included using the correct upper or lower case.

Firmware Version : (A11)

Ensure that 0(zero) are not O(ohs) or vice a versa. All letters, spaces etch should be included.

Elevation Cutoff Setting : (deg)

The specific receiver tracking cutoff angle, regardless of terrain or obstructions in the area. NGS requires that the receiver be set to 5 degrees or preferably 0 degrees.

Temperature Stabiliz. : (none or tolerance in degrees C.)

This refers to the temperature of the room in which the receiver is housed (usually none).

Date Removed : (CCYY-MM-DDThh:mmZ)

In the block for the receiver currently in operation, leave this line as is to remind yourself of the format when the next receiver change is made.

4. GNSS Antenna Information

Antenna Type : (A20; with A15 for antenna type A1 blank and A4 radome)

Please find your antenna type at *https://geodesy.noaa.gov/CORS/Operate_Establish_CORS.shtml*

Do not enter the antenna description. Ensure to use capital letters, hyphens, etc. exactly correct.

Serial Number : (A20)

Enter "12345" and not "s/n12345. Ensure that 0(zero) are not O(ohs) or vice a versa. Include all letters spaces or special characters e.g. -.

Antenna Reference Point : (BPA/BCR/XXX from "antenna.gra"; see instr.)

Locate your antenna in the file*: ftp://www.igs.org/pub/station/general/antenna.gra*

Marker->ARP Up Ecc. (m) : (F8.4)

Marker is the permanent and unique mark, dimple/cross hair, to which the antenna ARP is referenced. This is the antenna height measured to an accuracy of 1mm and defined as the vertical distance of the ARP from the mark described in section 1. If zero then enter 0.0000.

Marker->ARP North Ecc(m) : (F8.4)

Usually 0.0000

Marker->ARP East Ecc(m) : (F8.4)

Usually 0.0000.

Alignment from True N : (deg; + is clockwise/east)

The positive direction is clockwise, so that due east would be equivalent to a response of "+90"

Antenna Radome Type : (A4 from rcvr_ant.tab; see instructions)

Find your radome code at *https://geodesy.noaa.gov/CORS/Operate_Establish_CORS.shtml*

"NONE" indicates there is no external radome. If an antenna has a cover which is integral and not ordinarily removable by the user, it is considered part of the antenna and "NONE" is to be used for the radome code.

Date Removed : (CCYY-MM-DDThh:mmZ)

In the block for the antenna currently in operation, leave this line to remind you of the format when the next antenna change is made.

5. Surveyed Local Ties

Local ties to other marks on the site should be determined in ITRF coordinates to 1mm precision in all 3 dimensions. Offsets are given in geocentric Cartesian coordinates (ITRF). Usually left blank

8. Meteorological Instrumentation

Height Diff to Ant : (m)

Positive numbers indicate met instrument is ABOVE GPS antenna.

12. Responsible Agency (if different from 11.)

The primary contacts listed here should always be the first choice for questions about operation of the site. This person will receive automated emails regarding site log or RINEX errors and should be someone who can answer questions about the configuration and data delivery for this site.

13. More Information

Primary Data Center :

ftp://cors.ngs.noaa.gov/cors

Secondary Data Center :

ftp://alt.ngs.noaa.gov/cors

URL for More Information :

This would be the site operator's web page if any additional information exists.

Additional Information :

Anything you feel is important. (This could also be kept at your local www site and referred to by URL in the log).

APPENDIX 3: Blank Site Log

See log form at **ftp://cors.ngs.noaa.gov/cors/station_log/blank.log**

APPENDIX 4: Site Log Instructions

See log form at: **ftp://www.igs.org/pub/station/general/sitelog_instr.txt**