National Geodetic Survey Positioning America for the Future geodesy.noaa.gov

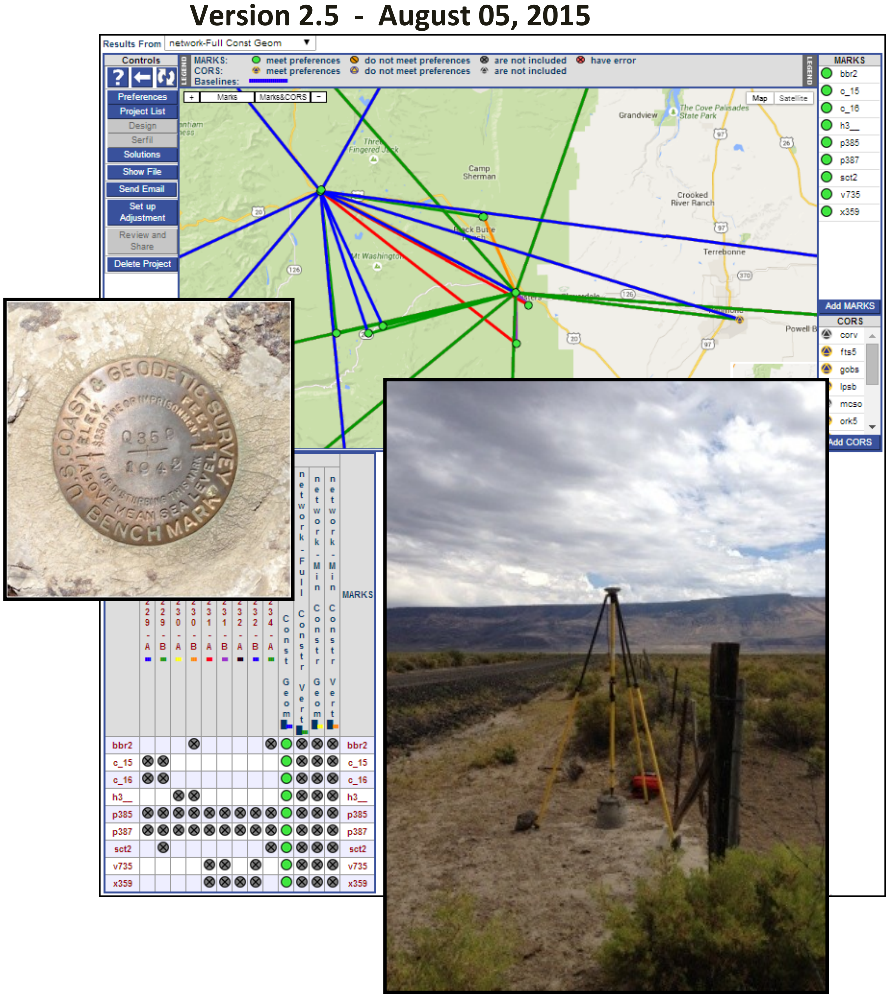
2015 Edition

OPUS Projects

Online Positioning User Service
Baseline Processing and Adjustment Software

User Instructions and Technical Guide

Version 2.5 - August 05, 2015



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National Oceanic and Atmospheric Administration • National Geodetic Survey

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Abstract

This document contains a brief history of program development, user instructions, result interpretation, and technical guidelines for the National Geodetic Survey (NGS) tool OPUS Projects (OP). OP extends the existing OPUS tools for uploading, processing, and sharing (previously call publishing) to include geodetic network solutions by baseline processing of simultaneous GNSS observations, called sessions, followed by a least squares adjustment containing one or more sessions. Collectively, the data, session solutions, least squares adjustment and results are called a project. Like OPUS, OP is web-based software implying that a user must have access to the Internet and the use of a web browser in order to use this tool. Access to OP is through the Projects link on the OPUS upload web page at http://geodesy.noaa.gov/OPUS/, or directly using the URL: http://geodesy.noaa.gov/OPUS-Projects/.

In order to create OP projects, the user must have received OPUS Projects Manager Training either through an NGS live workshop, webinar or one-one instruction from another OP manager. To see the availability of and register for a live workshop, go to the NGS Corbin Training Center's Calendar of Upcoming Classes (http://geodesy.noaa.gov/corbin/calendar.shtml). Registration for a class is on a first come, first served basis till the class is full, typical class sizes are 25 – 30 people. These workshops provide hands-on training using a sample project provided as part of the training. The basic workshop is two days in length; extended workshops, up to five days in length, covering the additional steps needed to publish to the NGS integrated database (NGSIDB) also are available. Through this training, an attendee's email address is registered with OP (similar to registering to share your solution thru OPUS) and they can begin creating projects.

Once created, projects are stored on an NGS server and web pages specific to each project are created. A user uploads static GNSS (currently only GPS observations are used), dual-frequency observation files and records the antenna models and ARP heights used in their project through OPUS-S[1] by providing a unique identifier assigned to the project when it was created. All subsequent project activity is through the project's web pages. Baseline processing is performed by the PAGES program and the least squares adjustment by the GPSCOM program (both built into OP) in a combined process where the results of the PAGES baseline processing are passed directly to GPSCOM for the least squares adjustment. Solution reports contain coordinates for the observed project marks (monuments) as well as Continuously Operating Reference Stations (CORS) included in the project's processing. These coordinates are reported in the current geometric (aka "horizontal") datum realization of the National Spatial Reference System (NSRS). In the future the project manager may have the option to share (sharing is still in development) the project mark solutions with the OPUS-DB (OPUS database). It is possible with additional training to formally submit mark solutions via the bluebooking process (currently external to OP) into the NGS Integrated Database. OP supports the bluebooking process by preparing output files (b-file, g-file, and serfil) for use with the bluebooking process utilizing the least squares adjustment program ADJUST.

OP was created to provide all users with NSRS three-dimensional coordinate results for GNSS networks. The NGS and others have begun testing to use OP to process FAA, height modernization, regional networks, real-time networks and other special survey projects.

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[1] Although there are other current processing engines (OPUS-RS) and future planned processing engines, OPUS-S is currently the only processing engine in the OPUS suite of products supporting the upload of data into a project of OPUS Projects.

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Living Document

This 'OPUS Project User Instruction and Technical Guide' is designed to be a 'living document' and will be updated with new information and resources as the OPUS suite of programs and OP evolve over time.

Document Design

This document was created primarily to assist in teaching the OP workshops and is divided into three primary sections. It assumes the user is already familiar with uploading and sharing (incorrectly termed "publishing" prior to 2014) through OPUS-S.

Section 1.	'OPUS Projects - User Instructions' is designed as a desk reference learning aid and follows the OPUS Projects Manager Training presentation series which steps the user through the learning process in an orderly fashion.
Section 2.	'OPUS Projects – Analyzing Results' provides basic information about session and network adjustment reports including some additional unique reports which may be used in the bluebooking process.
Section 3.	'OPUS Projects – Technical Guide' provides some background about survey network planning, session strategy and survey styles associated with height modernization, FAA airport surveys, and real-time network positioning.
Appendix A.	Contains a FAQ troubleshooting Q and A designed to support user self-help
Appendix B.	Using various Internet browsers
Appendix C.	Session Solution and Network Adjustment Summary Report
Appendix D.	PAGES (Session Solution) Processing Log
References.	Contains references used in this document

Contact Information for Revision to Document

If there are topics that you would like the NGS to add, cover in more depth, clarify, or if you discover an error in the content, or would like to suggest a particular workflow, please contact the National Geodetic Survey Corbin Training Center.

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Acronyms and Abbreviations

ANTEX - Antenna Exchange Format
ARP – Antenna Reference Point
CORS – Continuously Operating Reference Station(s)
DOP – Dilution of Precision
ECEF – Earth Centered, Earth Fixed
GPS – Global Positioning System
GPSCOM - A least squares adjustment program
GLN – *Global'naya Navigatsionnaya Sputnikovaya Sistema / Global Orbiting Navigation Satellite System (GLONASS)*
GNSS – Global Navigation Satellite System
IGS – International GNSS Service
ITRF – International Terrestrial Reference Frame
NAVD 88 – North American Vertical Datum of 1988
NGS – National Geodetic Survey
NGSIDB – National Geodetic Survey Integrated Database
NOAA – National Oceanic and Atmospheric Administration
NSRS – National Spatial Reference System
OPUS – Online Positioning Users Service
OPUS-RS - A.K.A. OPUS Rapid Static
OPUS-S – A.K.A. OPUS Static
OPUS-DB – OPUS Database (for shared solutions. Not the NGS IDB)
OP – OPUS Projects
ORGN - Oregon Real Time GNSS Network
NAD 83 – North American Datum of 1983
PAGES – Program for Adjustment of GPS Ephemerides
RT – Real Time Positioning
RTCM – Radio Technical Commission for Maritime Services
RTCM SC-104 – RTCM Special Committee 104 for Differential GNSS Positioning
RTK – Real Time Kinematic
RTN – Real Time GNSS Network(s)
SINEX - Solution Independent Exchange Format
TEQC – Translation, Editing, Quality Checking (Used as a front end to OPUS)
WSRN – Washington State Reference Network

Understanding NGS key terminology used in this manual

The growing use of online NGS tools has allowed for new situations to occur. For example, some OPUS users wish to see their work immediately impact the published coordinates on points. Unfortunately the publication of coordinates by NGS requires time consuming reviews, and comparison of new surveys against historic ones. In response to user demand for more immediate public access to the results of their surveys, NGS has offered the ability of users to share their results through OPUS-DB. NGS encourages this, but such solution-specific information does not create *published* coordinates. Nor should the solution-specific information on a mark be called a *datasheet*. The NGS incorrectly labeled the user function of *sharing* these *solutions* as *publishing datasheets* on the OPUS DB page. That error has now been corrected). Furthermore, the act of placing such a shared solution on an NGS-provided computer and distributed through an NGS web page does not constitute *submitting* the data to NGS (though methods are being investigated to combine the share and submit actions). This situation of sharing solution-specific information online has no significant historical context with regard to other NGS products and services. Note that sharing a solution via OPUS-DB is not a *datasheet* but a shared mark solution. In the future, it may be possible to both *share* a solution mark sheet via OPUS-DB and *submit* the same survey to NGS for possible inclusion in the IDB.

As such, NGS will adopt the use of the following definitions:

Share: ***The act of a user releasing to NGS the observations (via OPUS or OPUS Projects), metadata and results of geodetic surveys <u>tied</u> to the NSRS for public dissemination.***

Publish: ***The action of NGS providing to the public, the official, National Spatial Reference System (NSRS) time-dependent geodetic coordinates set on a mark.***

Submit: ***The act of a user releasing to NGS the observations, metadata and results of geodetic surveys tied to the NSRS for the express purpose of the NGS evaluating the survey and publishing if appropriate.***

Datasheet: ***A report containing the published NSRS time dependent coordinates on a mark, as well as subsidiary information and metadata such as superseded coordinates, descriptions and recovery history of the mark.***

Table of contents

Caution - Pay attention to items marked with this symbol as they may be of critical importance in how you proceed as you work through a project.

Noted changes to the program OPUS Projects

v2.5 - Update applied 7-8-15	GEOID12B added

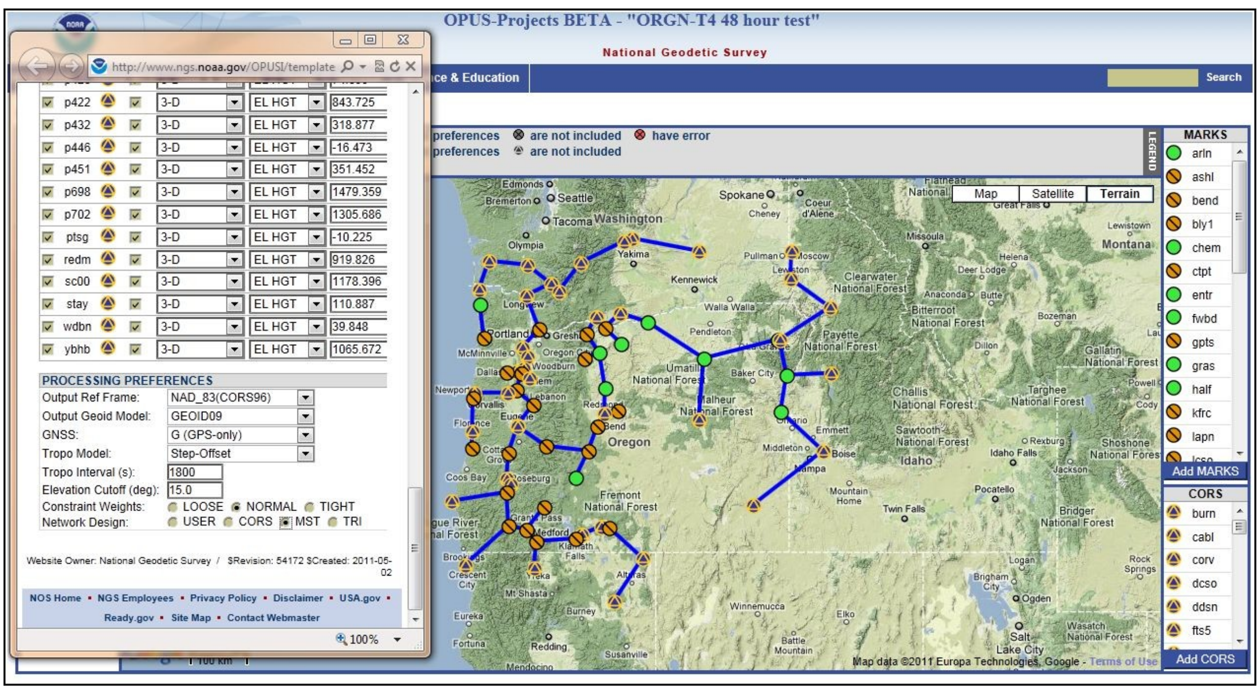
Introduction

History and Development of OPUS Projects

OP developed as a natural extension of OPUS. The ability to process geodetic networks has always been present through software available from the NGS [Geodetic Tool Kit](http://geodesy.noaa.gov/TOOLS/) (http://geodesy.noaa.gov/TOOLS/) and the PAGES_NT package. OP enhances this capability by offering to the public a GNSS network adjustment package with web-based access to simple visualization, management and processing tools for multiple project marks and multiple occupations. OP performs best with projects of "short" duration, i.e. "days to months" rather than "long" duration "months to years" because no a priori velocity model is applied to project marks at this time. Some of its advantages include:

- Data uploading through OPUS.
- Coordinate results aligned to the NSRS.
- Processing using the PAGES and GPSCOM software.
- Graphical visualization and management aids including interactive maps, like the one shown in Figure 1.0, using Google Maps™ mapping service. Google Maps and the Google logos are registered trademarks of Google Inc., and used with permission.
- Most Internet browsers may be used. Some display the map and project data faster than others. Internet browser programming changes frequently. If you see an issue with one browser then try another and refresh often.

Figure 1.0 - OP graphic visualization with interactive maps



OPUS Projects Development Timeline

2005: Weston and Gwinn began initial development on OP.
2006: Several projects were completed as part of a proof-of-concept.
2007: Development restarted by Mark Schenewerk.
2009: Feedback from an invited group of participants resulted in a better defined set of desirable capabilities.
2010: OP BETA released. First OP Workshop for Managers held in December
2012: Major programming upgrade completed 2012-11-27 by Mark Schenewerk. Ability to create g-files and b-files (as part of "bluebooking") added, to begin the process of aligning OP with long-standing FGCS policy that only bluebooked data, run through ADJUST, may be submitted to NGS for consideration of inclusion in the NGS Integrated Database.
2013: OP became operational with an initial limited set of available tools.

OPUS Project Flowchart

The flowchart depicts the series of events that happen as you progress from uploading observation files to OPUS, then process groups of project mark observations as sessions and finally adjust the sessions to get the final network solution. Ultimately the project manager may elect to submit and bluebook to the NGSIDB using the b- and g- output files (a process currently external to OP). The NGS encourages managers to submit their project control marks to perpetuate their coordinates through time. As new datum realizations develop, the NGS will automatically update the published coordinates on the datasheets. This provides for an ever increasing number of marks that will be aligned with the National Spatial Reference System (NSRS).

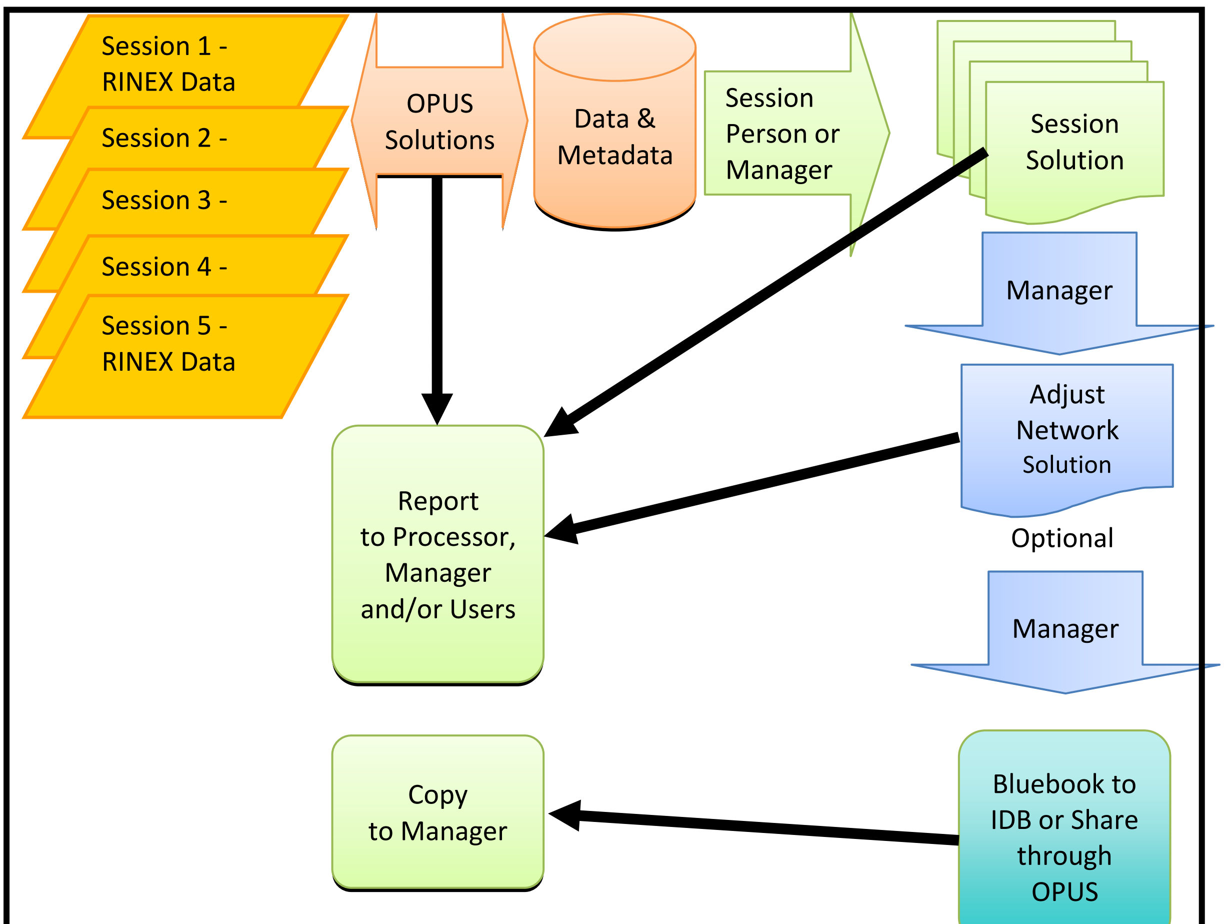


Figure 1.01 - OP flow chart

Disclaimers

OP is a web-based utility implying that access to the Internet and use of a web browser are required. JavaScript must be enabled in your browser and pop-up blocking may have to be turned off.

There is no implied guarantee that your browser will be compatible with OP. If you have difficulty configuring your browser, try a different browser or contact your workshop (or webinar) instructor or the OPUS Projects team.

Your email address is registered with NGS when you attend an OPUS Projects for Managers Workshop. Registering your email address allows you to create projects in OP. This is similar to registering to share a solution dependent result through OPUS. If your email address changes or you wish to add an additional email address (other than the one you used for training) then contact the OPUS Projects Team.

The Manager Training presentation series in PDF and XPS formats, and sample project data for OP may be downloaded here:
ftp://geodesy.noaa.gov/pub/opus-projects/

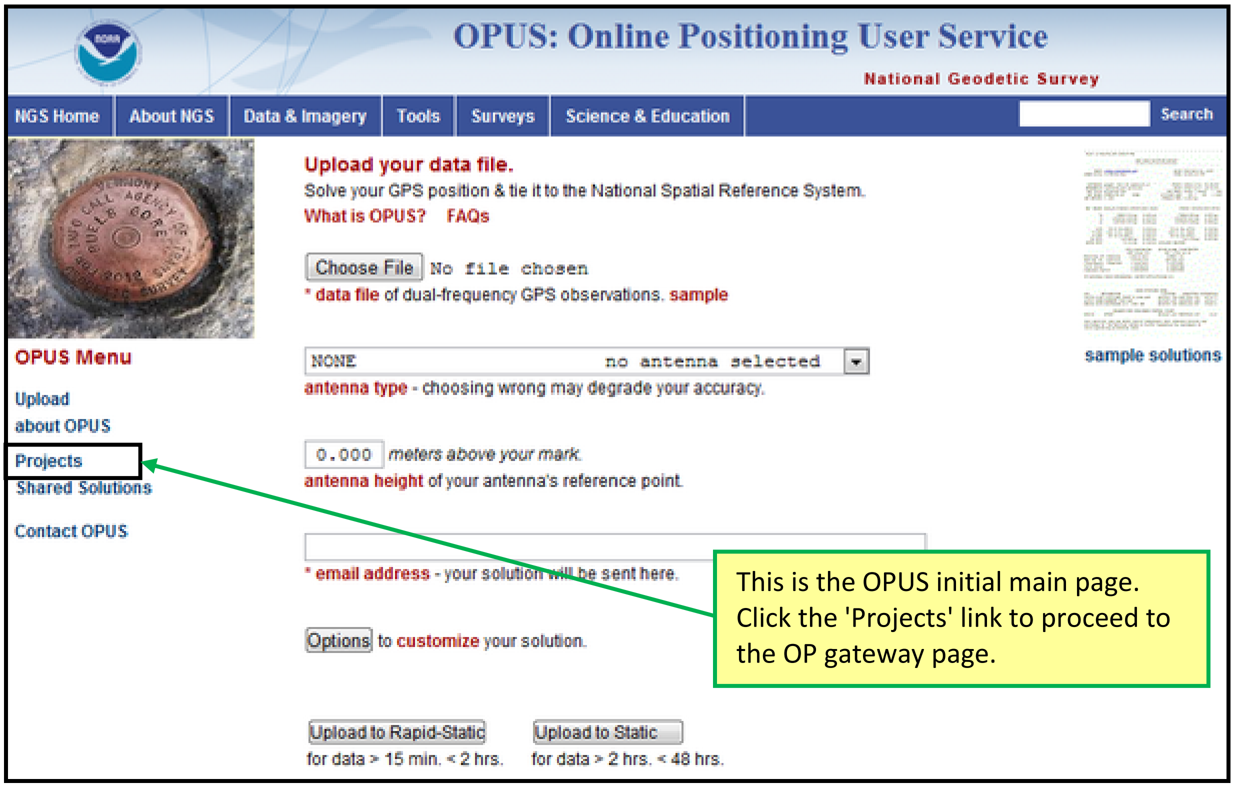
Always follow your project's specifications. These 'User Instructions' for OP should not be considered an endorsement for any specific project network design, field technique, hardware or software. Nor does it represent specific NGS project guidelines. The following web sites provide guidance for some project types:
http://www.fgdc.gov/
http://geodesy.noaa.gov/AERO/aero.html
http://geodesy.noaa.gov/heightmod/

Section 1 OPUS Projects User Instructions

1.0 Creating a project

Start at the OPUS web page (http://geodesy.noaa.gov/OPUS/) and click the Projects link in the menu on the left or navigate directly to the OP gateway web page: http://geodesy.noaa.gov/OPUS-Projects/

Figure 1.1 - Access the OP gateway page



On the gateway web page (Figure 1.2), select the 'Create' button to begin creating a project. Remember that OP Manager's Training is required to create a project.

Figure 1.2 - Create a new project

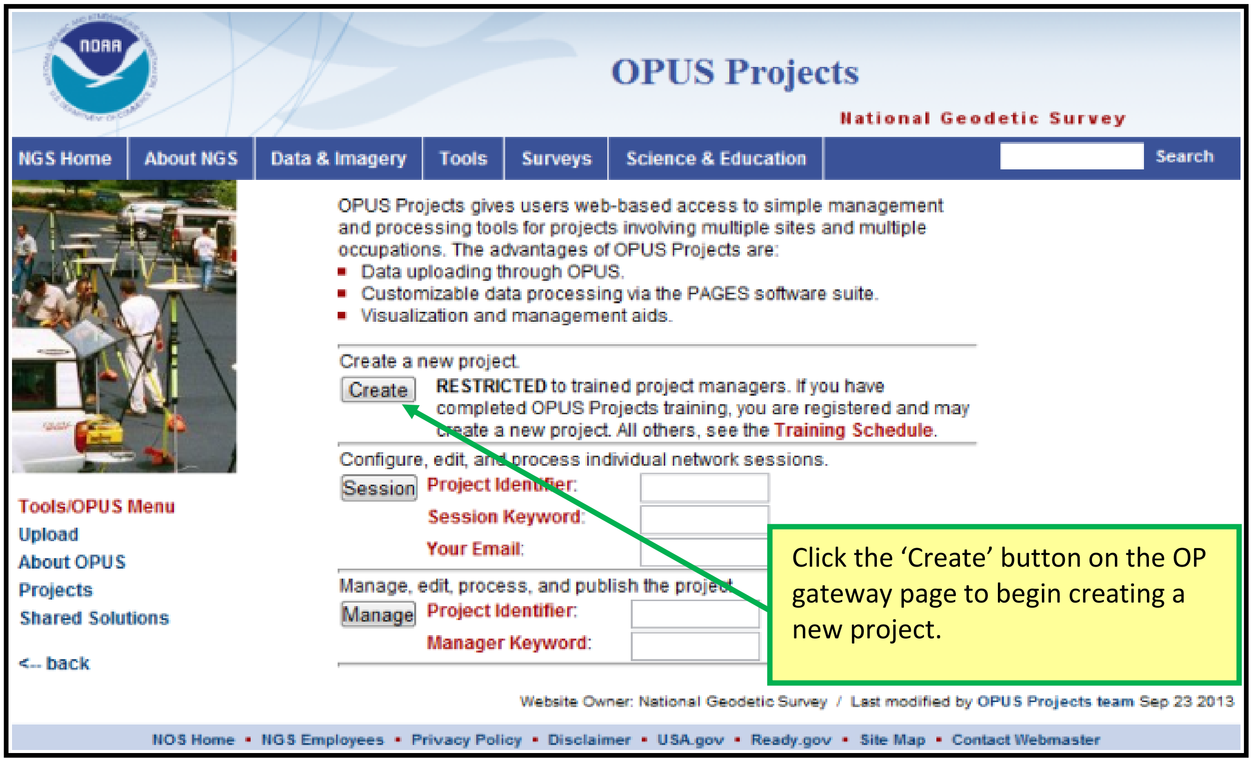
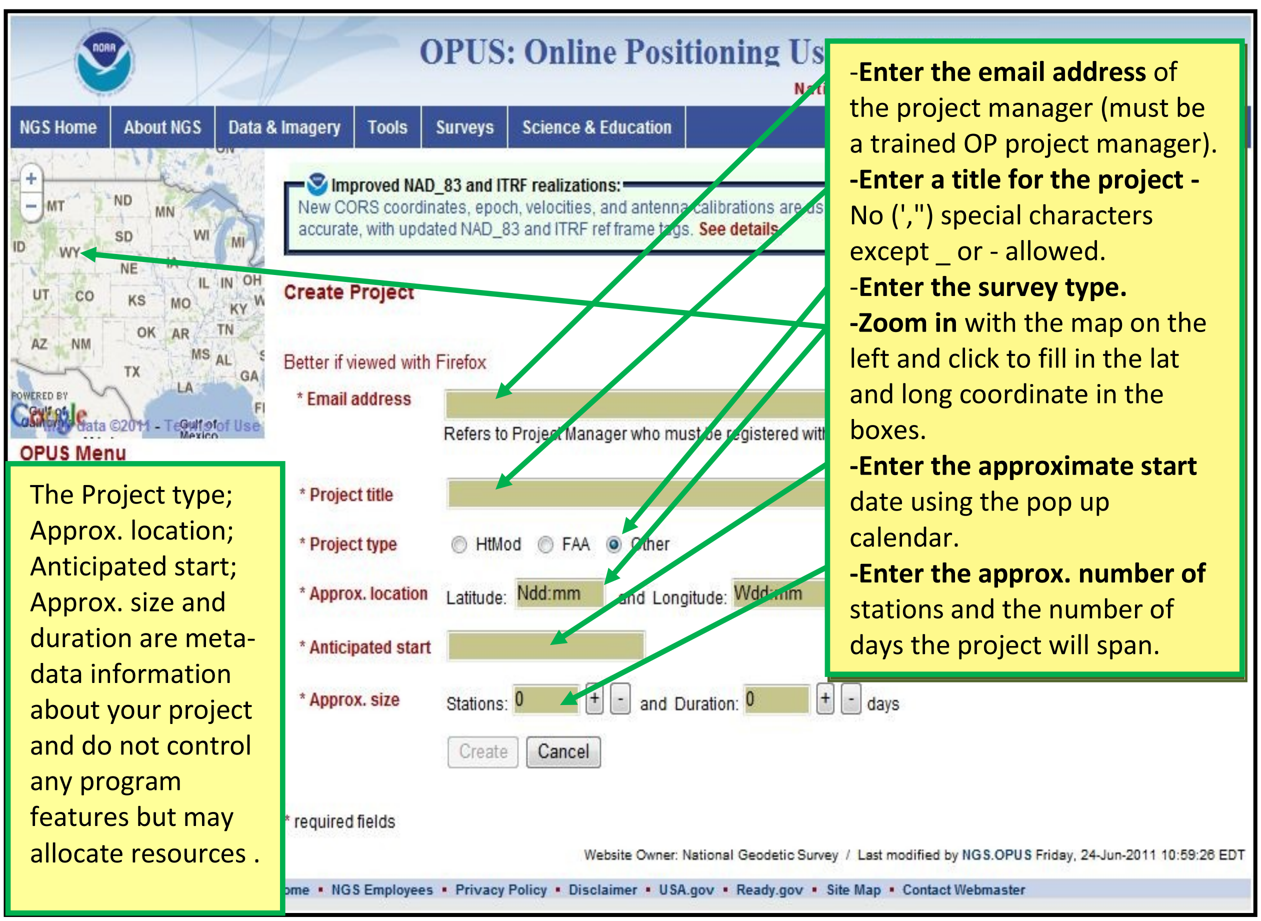


Figure 1.3 - Enter project details



When the form is completed, the 'Create' button will be enabled. Clicking the 'Create' button assigns a unique project identifier and keywords, and allocates resources on the NGS servers for the project. The project ID and keywords are emailed to the project manager using the email address provided. Then a confirmation web page is displayed (see Figure 1.5). The entire task takes only a few seconds.

Figure 1.4 - Click the 'Create' button

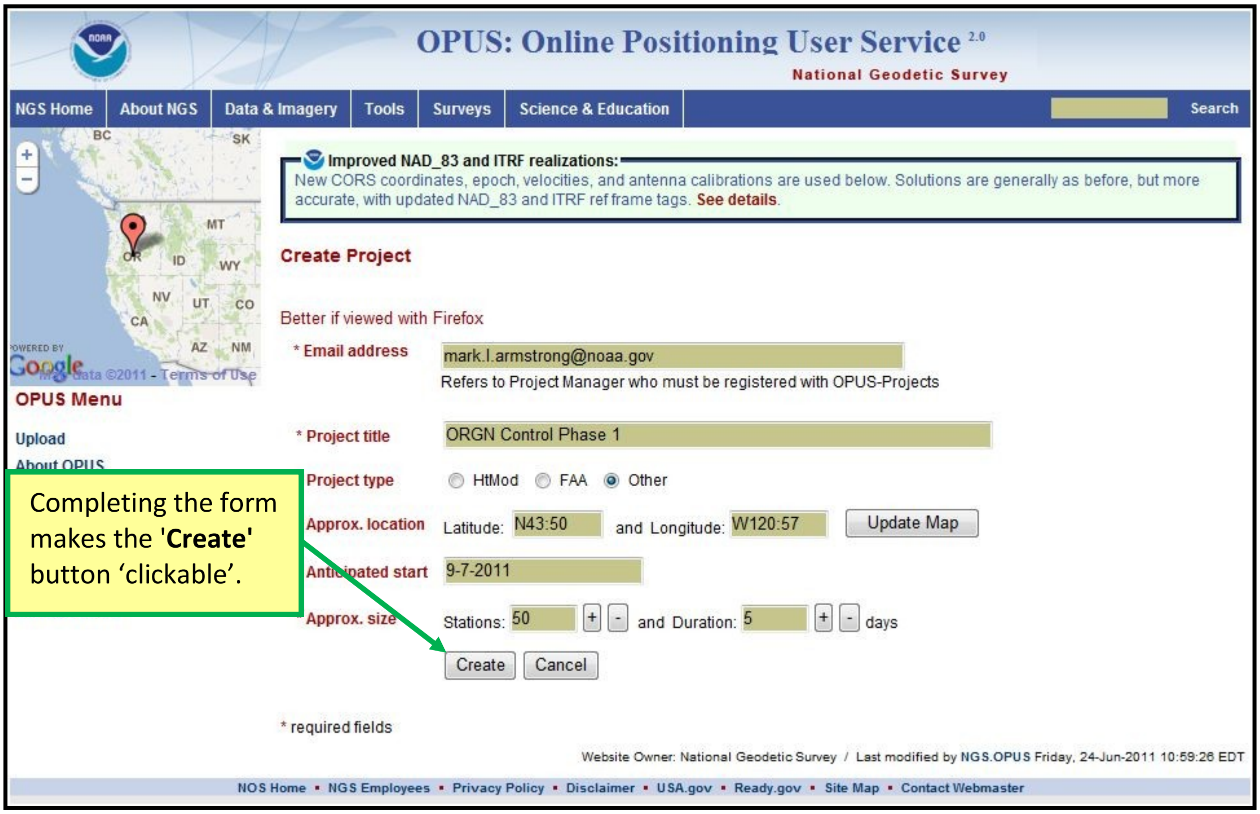
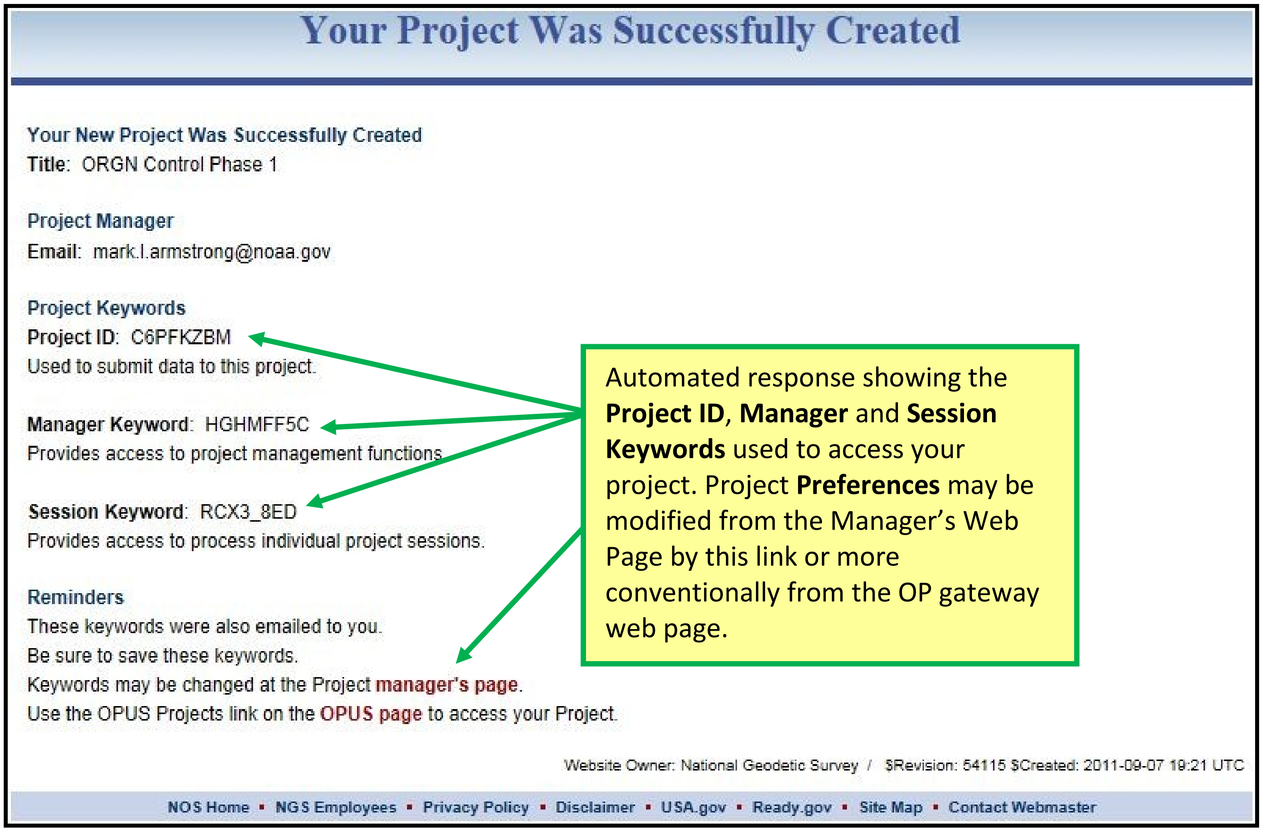


Figure 1.5 - Your project was created

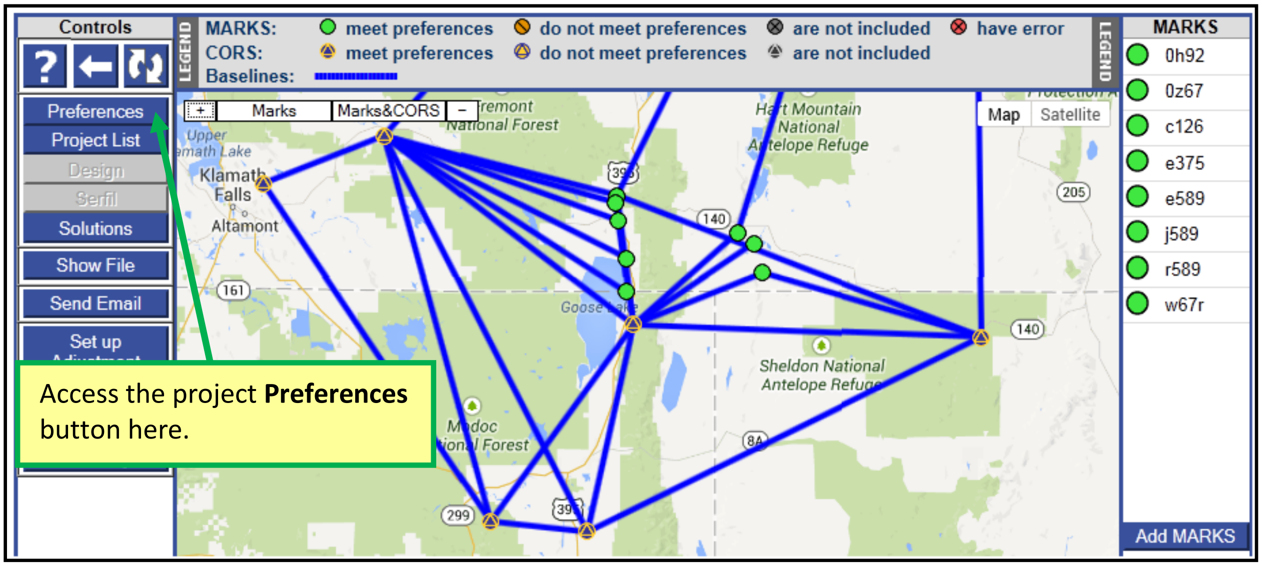


1.0.1 Project Keywords

When a project is created, a unique identifier and keywords are randomly generated for the project. The ID and keywords are sent to the project manager in an email and displayed on the screen. It is recommended that this information be printed or otherwise saved because the ID and keywords are used to access to the project:

- The **Project ID** may be shared thereby permitting other people (such as field crew members) to upload data to your project.
- The **Project ID** and the **Manager Keyword** give the project manager complete access to all parts of the project.
- The **Project ID** and **Session Keyword** give limited access to the project's session web pages. This is useful if other people will help with session processing who do not need full access to the manager's functions.
- The **Project ID** must be unique for each project but the manager and session keywords are allowed to be the same for more than one project.
- The **Project ID** and keywords can be challenging because they are randomly generated, but the project manager can replace them through the project’s **Preferences**. A project's preferences can be accessed from the project manager’s web page (Figure 1.6).

Figure 1.6 - Preferences



1.1 Before Any Data Are Uploaded

Before any data are uploaded into a project, the manager should assign the appropriate project preferences. Preferences allow the appropriate flag and project mark icon to be set. Changing some preferences after the data is uploaded may not result in the correct display. All project preferences are described in section 1.3.5.2.3, but those of particular interest immediately after a project is first created are:

Data & Solution Quality Thresholds (section 1.3.5.2.3): define how processing results are displayed on the project's web pages. This includes the OPUS processing results produced when data files are uploaded to the project. In these cases, a notification is emailed to the person uploading a data file if its OPUS results exceed any of these preferences. This gives OP a limited near real-time problem detection capability if data files can be uploaded while teams are still in the field. Although these preferences can be changed at any time, setting them before any data are uploaded enhances their usefulness.

Data Processing Defaults: define the defaults offered on the processing controls. While these preferences can be changed at any time or overridden for individual processing requests, they are most effective when set before any processing begins thereby helping to impose consistency in the processing.

Session Definition: defines how data files are grouped into sessions, i.e. logical associations of data files that overlap in time. Sessions define the context of project processing and cannot be changed after processing begins without invalidating that processing.

Mark Co-location Definition (section 1.3.5.2.6): defines how data files are associated with project marks. This cannot be changed after session processing begins without invalidating that processing.

1.2 Uploading Data to a Project

Currently all data are uploaded to a project through OPUS-S. *[NGS is currently considering a future version of OP to allow the use of OPUS-RS for shorter occupation times perhaps down to 30 minutes for short baselines.]* OPUS-S provides an easy and accurate way for the project field crew members to upload data files to a project and the project manager can review the quality of each solution.

If OPUS-S cannot process a data file, an unusual but not impossible circumstance, OP almost certainly won't be able to either. So, if OPUS-S aborts processing for any reason, the data file is not uploaded to the designated project. If OPUS-S succeeds in processing a data file, the project will indicate the quality of the OPUS-S result based upon the project's preferences for data and solution quality (Section 1.3.5.2.3). The project indicates the quality using the appropriate icon on maps and in lists and by background/foreground colors in tables.

Furthermore, if the project's preferences are not met, OP will send a warning message to the project member who uploaded the file. Receiving one of these warning messages *does not* prevent a data file from being uploaded to or used in a project. It simply helps highlight potential issues. It is the project manager's responsibility to make other project members aware of this possibility and its implications.

The project manager should carefully review each project mark's OPUS-S solution. The coordinate for the first OPUS-S solution for a project mark will be used as the a priori input for the processing. In the rare occurrence that the project manager wishes to change the a priori coordinate for a mark, it should be done now before any sessions are processed that contain the mark. This may be accomplished by navigating to the project mark's web page and editing the a priori coordinate values (Section 2.2).

As data files are uploaded and marks appear in a project, its manager should also verify the data files and related information associated with the project marks. Quick checks can be made by clicking the project mark icons on the manager's page map. This will cause an information "bubble" to appear displaying the list of data files associated with the project mark and related information such as antenna name and ARP height entered with the upload. A more thorough check can be made from the project mark web pages. There, the data files are also listed along with their related information, and the information can be changed, if needed, or data files moved from one project mark to another. Very rarely, other information associated with a project mark, such as the state plane coordinate zone, may need to be changed. This can be done through the 'Manage Coordinates' control on the project mark page (Section 1.5.6.2.1).

This is also a good time for the project manager to insert appropriate project mark ID if desired. <u>Recall that the four character project mark ID are normally taken from the first four characters of the vendor proprietary file type or RINEX file uploaded through OPUS to your project</u>. If inconsistencies are found, mark ID's such as a001, a002, etc. will appear. These are "placeholder" names automatically generated by OP. While there is no programmatic reason to change these automatically generated names, it is usually preferable to do so to keep project nomenclature as consistent as possible with field logs, datasheets and the like. A mark's ID can be changed on its web page.

Finally, although session processing can begin before all data for the session are uploaded, this is *not* recommended. Processing before all data are available may be prudent if errors or inconsistencies are found and cannot be otherwise rectified, but should be avoided otherwise.
Please always bear in mind that if a session is processed before all of its data are uploaded, it is almost certain that the session will need to be reprocessed after all data has been uploaded. The user has the option to delete individual sessions or overwrite the session by reprocessing using the same session name or reprocessing the session but changing the session name thus keeping both sessions.

1.3 The Project Manager's Web Page

At the bottom of the Manager, Session and Project Mark web pages, an email link to the OPUS Projects Team always appears providing a convenient method to ask questions or make comments. The manager may receive more than one reply from NGS staff depending on the subject of the email.

1.3.1 Notices

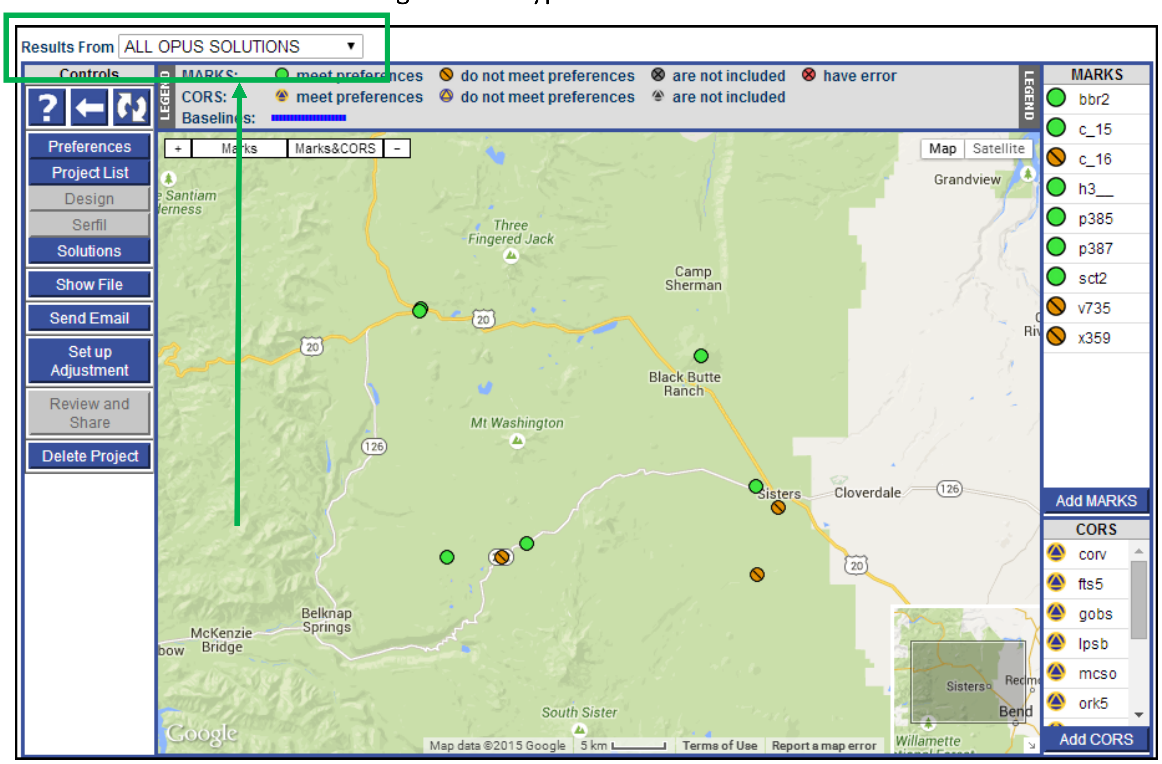
Notices about OP and, very rarely, a message specific to a project (no other project will see these specific messages) may appear at the top of the Manager, Session and Project Mark web pages. An email link to the OPUS Projects Team will appear with any notices and messages so that follow-up questions can be asked if needed.

1.3.2 Results Selection Menu

Below the web page's banner (and any notices) is a pull down menu to select from a list of the solution results available (Figure 1.7). Broadly, there are three categories: network adjustment, session solutions, and OPUS-S solutions. As work in a project progresses, displaying all types of results simultaneously becomes confusing. This menu provides a simple "filter" to help emphasize the results of most interest.

1.3.3 Project Map

Figure 1.7 - Types of Solution Results Available



The manager, session and project mark web pages are built around a Google Map Services™ interactive map to help orient users within the project and its geographic region. As project members upload observation data to the project through OPUS, icons representing the project marks will appear on the map. CORS stations used by OPUS during its processing of the project data will be added to the project at upload or can be added to the project later. Different icons are used to reflect a mark's status in the project.

A legend defining each icon type is shown just above the map (Figure 1.8).

Figure 1.8 - Mark icon legend

For Project Marks:

 A **green, open circle** icon means the preferences set by the project manager have been met. The project mark icon may be green immediately based on the OPUS-S solution, or become green based on the session solution, or network solution.

 An **orange, barred circle** icon (with a line through it) means that the preferences set by the manager have not been met in processing using this projects mark data. This most often occurs with the initial OPUS solution submission; less commonly from session processing. <u>This condition does not prevent the project mark's data from being used in the project</u>.

 A **grey, crossed circle** icon means that the project mark was not included in the processing results being displayed.

 A **red, crossed circle** icon notes an error with the project mark. This condition is seldom seen but signifies a more serious problem with the project mark's data or solution.

For CORS:

 A **blue** with **yellow trim** icon means that the CORS data have met the preferences set by the manager.

 A **yellow** with **blue trim** icon means that the CORS solution result does not meet the preferences set by the manager. This condition does not prevent the CORS data from being used in the project.

 A **grey** icon means that the CORS was not available or not included in the results being displayed.

For Baselines:

Once a session solution completes, the baselines defined in the processing appear on the map. Each session processed will automatically be assigned a different color. This provides the Manager with an intuitive view of multiple sessions presented on the map display. Similarly, after a network adjustment, the baselines defined in the constituent session solutions of that adjustment will be shown as blue lines on the map.

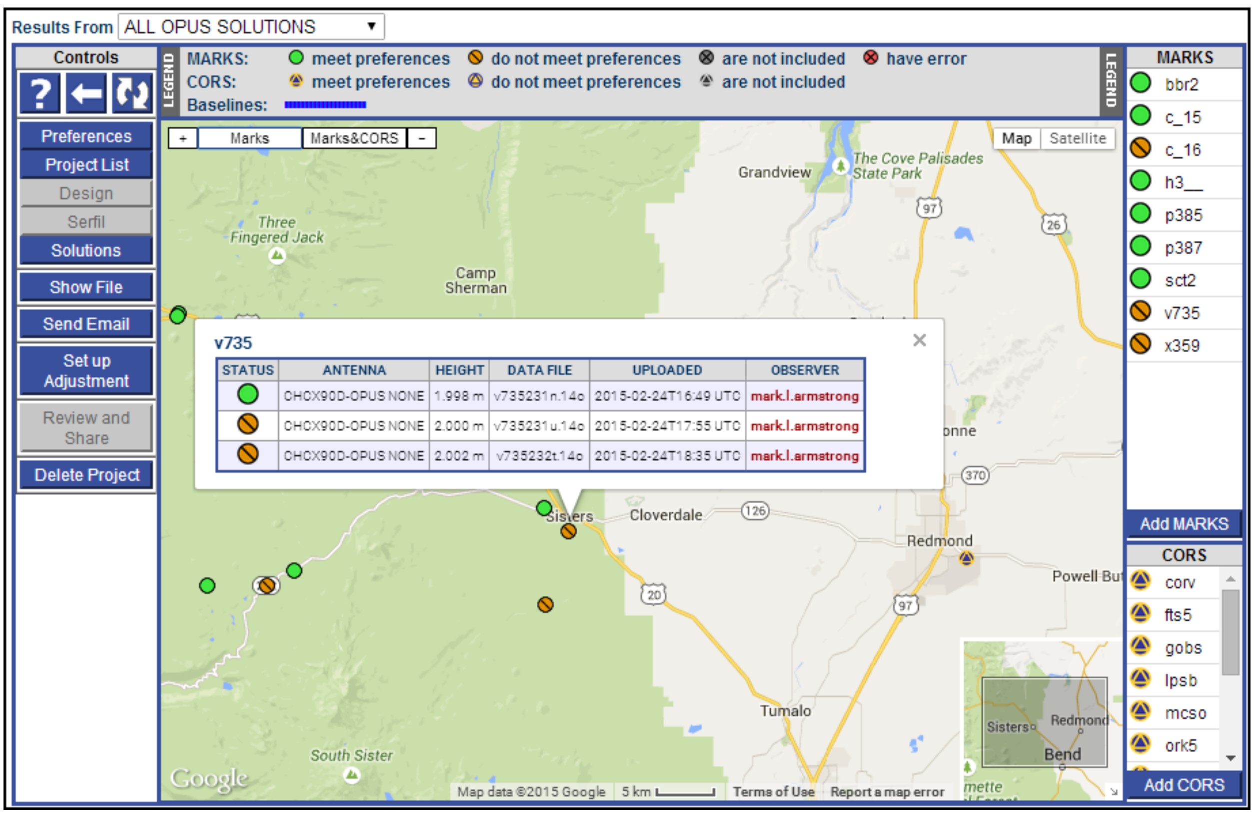
Figure 1.9 - Mark icon action

Within the map display to the upper-left, there are typical zoom controls (+/-) and controls to zoom specifically to the project's 'Marks' or 'Marks & CORS'. At the upper-right corner of the map (Figure 1.7) you may set the map background as either Terrain (digital elevation model), Satellite (satellite imagery if available), or Map (towns, streets & highways). You also have the option to click and drag (pan) the map to view nearby areas.

Holding the cursor over a project mark icon will cause the icon to "brighten" (lighten in color) and the project mark's ID to appear (Figure 1.9). Clicking (typical left mouse button) a mark icon on the map will cause information about the data files associated with that project mark to appear in an information 'bubble'. At the top of the bubble, the mark ID is given. If the mark is a project mark, the ID acts as a convenience link to navigate to the summary web page of that mark. A table listing all of the uploaded data files for a particular project mark is also shown in the bubble (Figure 1.10 , 1.11). More than one file for a mark means data observed at the mark is in multiple sessions. Note that the antenna name and ARP height associated with each file are also shown for the record. The project team member who uploaded the files is assigned as the 'OBSERVER'. Their name is a convenience link to send them an email message.

Figure 1.10 - Observation mark uploaded files

Figure 1.11- Multiple observation mark uploaded files



1.3.4 MARK and CORS lists

To the right of the map are lists of project marks and included CORS. Like the map icons, holding the cursor over a mark's ID in the list will cause the icon to brighten, and clicking (typical left mouse button) a mark ID in the list causes that project mark's information bubble to appear on the map identifying its location.

Figure 1.12 - Mark information bubble

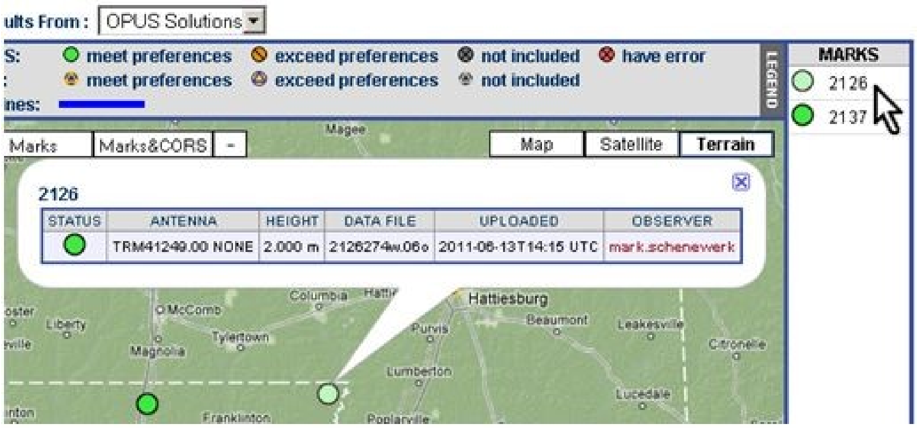
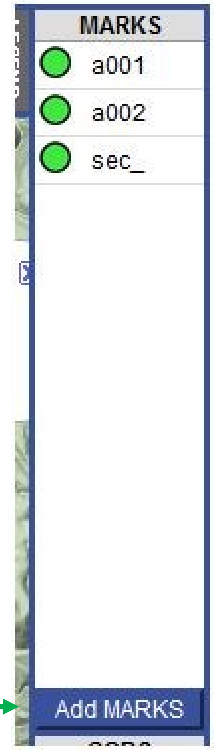


Figure 1.13 - Add Marks

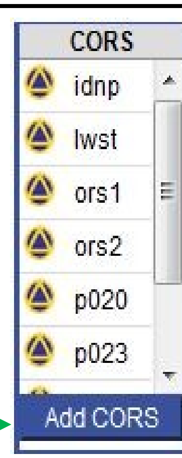


Click the '**Add MARKS**' button to be directed back to the OPUS upload page

1.3.4.1 Adding additional marks to the project

Below the project marks list to the right of the map is the '**Add MARKS**' button (Figure 1.13). This button acts as a link and re-direction to the OPUS Upload web page where more GNSS observations on passive geodetic control marks may be added.

Figure 1.14 - Add CORS

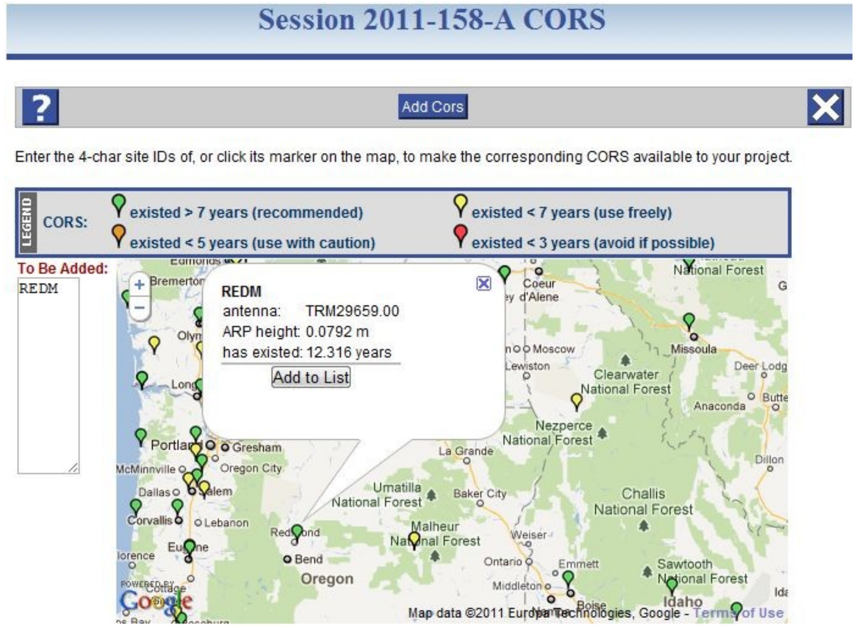


1.3.4.2 Adding additional CORS to the project

Below the CORS list, at the bottom right of the map, is the '**Add CORS**' button (Figure 1.14). Clicking this button opens a new window with controls to add additional CORS to this session (Figure 1.15).

Click the '**Add CORS**' button and a pop-up CORS window will display.

Figure 1.15 - The 'Add CORS' popup window



The map appearing in the **Add CORS** window (Figure 1.15) is similar to the map on the primary web page. You may zoom in and out and drag the map to other areas. Notice the CORS icons are color coded to reflect how long they have existed as a CORS. As you zoom in to the map notice that the sites that have been operational for shorter periods of time begin to appear. This a subtle way of encouraging the Manager to add CORS that have existed longer, have more years of archived data, and which may overlap the session timelines for projects with older observations.

Always use CORS that are at least three years old as this ensures that they will have computed velocities for OP to use. CORS can be added to the entire project from the manager's web pages after all project data has been entered. This insures that the CORS data will overlap the timeline of all of the mark data in the project.

When in the **Add CORS** window, move the cursor over the CORS icon to see the CORS ID. Clicking on the CORS icon gives you the option (within the information bubble) to add it to a list on the left. When you have completed adding CORS to that list, click the **Add CORS** button at the top of the web page to populate your current session with those additional CORS.

Remember that if you add CORS after the session has been processed you will have to go back and process that session again as you have now added data which should generate additional baselines for processing.

1.3.5 Controls

Controls for common manager tasks appear on the left side of the map (Figure 1.11).

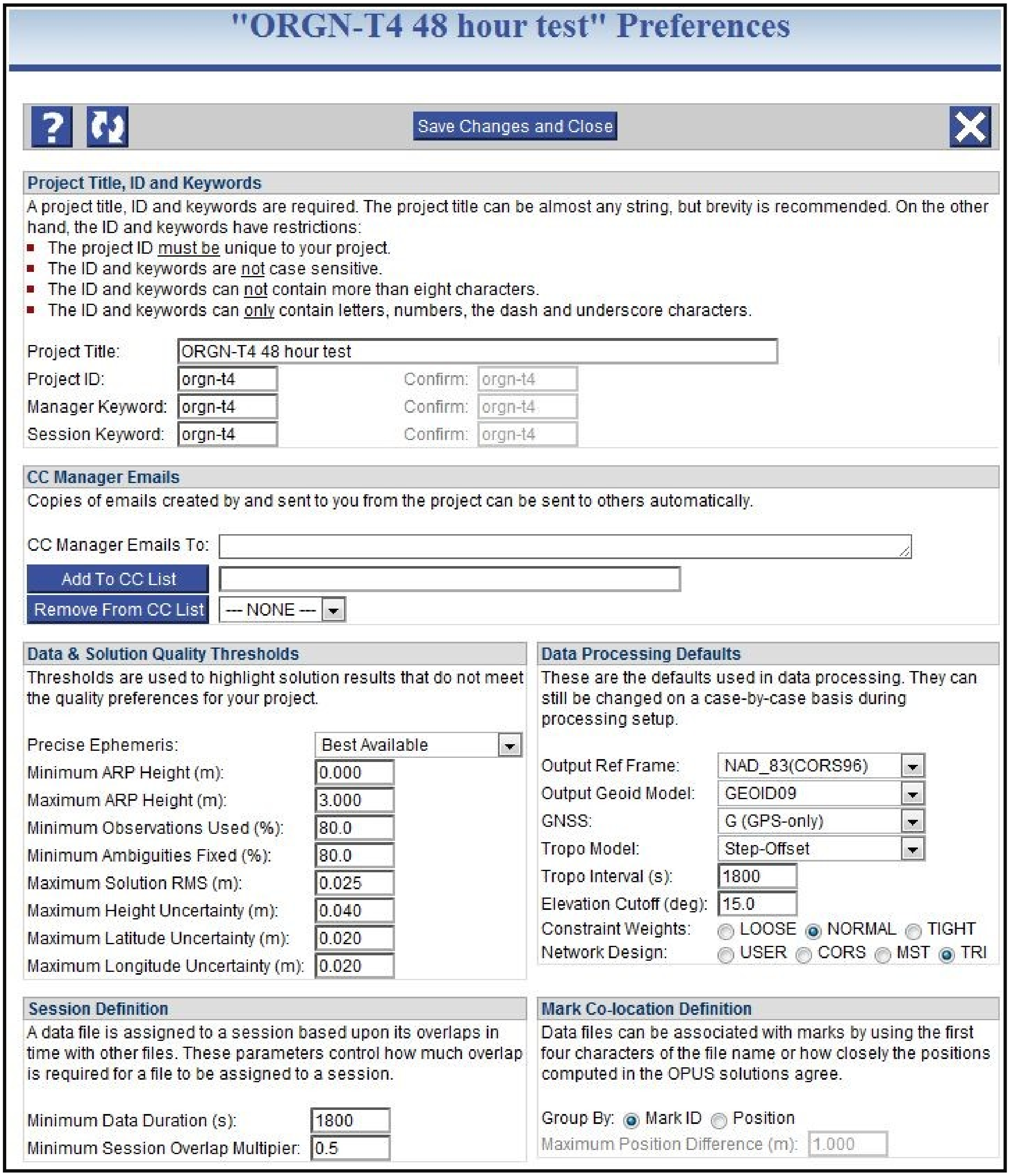
1.3.5.1 Help, Back and Refresh

Help, **Back**, and **Refresh** buttons appear at the top of the controls. The **Help** button is under development and may ultimately provide the same resource as this document. The **Back** "moves back" to the previous web page in the browser's history. Its action is identical to the browser's back control. The **Refresh** button forces the project to be scanned and the manager's web page to be reloaded. Use this OP refresh button rather than the one for the browser.

1.3.5.2 Preferences

By carefully setting the preferences for a project, the project manager can control the automated grouping of data files, guide data processing, and more easily identify potential problems. Some logistical items are also controlled through the preferences. Each section within the preferences web page will be described individually. Across the top of the window, and typical of all pop-up windows available in OP, are controls (Figure 1.16). The two buttons on the top-left are for **Help** with and to **Refresh** the window. The **Save Changes and Close** button at the top-center of this window is self-explanatory. The (X) button on the top-right closes the window without saving.

Figure 1.16 - Preferences

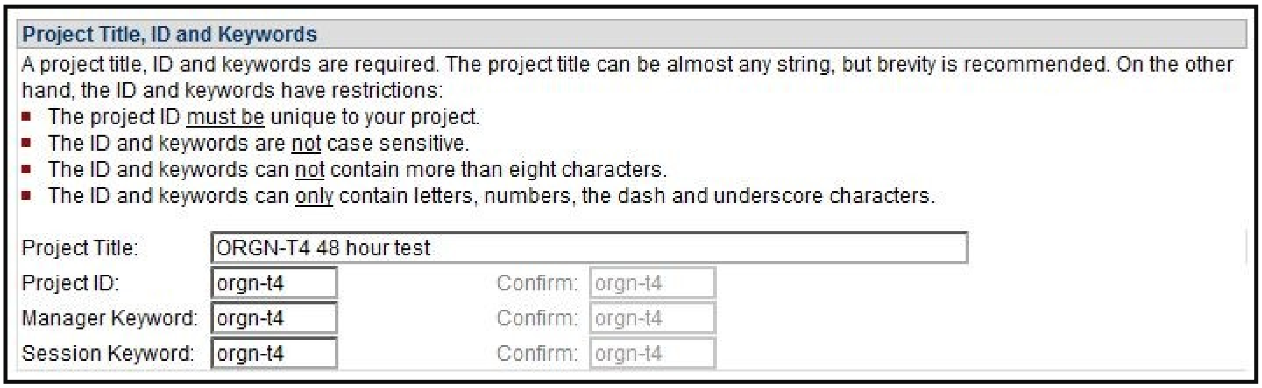


1.3.5.2.1 Project Title, ID and Keywords

The **Project Title, ID and Keyword** enable a project manager to change the project title as well as the project ID and keywords. Some find the automatically generated, random project ID and keyword strings challenging to work with and prefer something more specific to a project or more memorable. One may make the ID and keywords all the same or, perhaps, make the project ID and session keyword the same, but make the manager keyword different thereby limiting access to the manager’s web page. Changing these will cause an updated copy of the email introducing the project to be sent to the project manager. Project IDs are unique among all projects currently in existence. The manager's email address is associated with the project at creation and they are associated together for the life of the project. Manager and session keywords exist only inside the project and so might be duplicated in other projects. Just as when the project was created, it is strongly recommended that this information be saved in your own project records.

Note the rules for the ID and keywords (Figure 1.17).

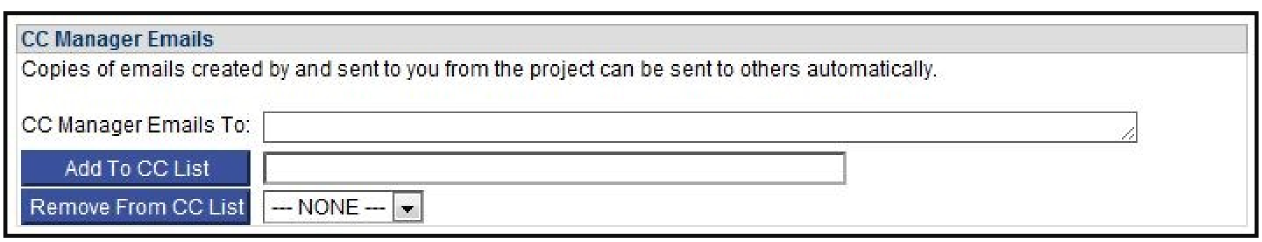
Figure 1.17 - Project title, ID and keywords



1.3.5.2.2 Manager Emails

Network adjustment results and, occasionally, other reports and notices will be sent to the project manager's email address. The manager can have copies of these emails automatically copied (CC) to others using the **Manager Emails** control. Please be courteous - only add email addresses for folks that really want to see them.

Figure 1.18 - Manager emails



1.3.5.2.3 Data and Solution Quality Thresholds

These thresholds are used to help identify project mark processing results that do not meet the project’s preferences. Data files whose processing results exceed a threshold *are not* automatically excluded. They *are*, however, visually identified by their icon style and color and in the background/foreground in table entries on the web pages. Note that the initial (default) threshold

values for new projects along with the recommended values are shown in Figure 1.19. The default values are aggressive (tight), i.e. more likely to trigger a notification (flag) on the mark page and an icon change. The manager has the option of replacing these values with ones better suited to a particular project thereby shedding light on potential problems. It is recommended that you use preferences that match those for "sharing" a solution with OPUS.

Under preferences if the "Precise" ephemeris is selected from the pull down rather than "Best Available" but the user has not waited the ~13 days an warning message is generated. Every time a processing request is submitted, OP tries to "improve" the ephemeris. These thresholds are also applied when data files are uploaded to the project.

The **Data Processing Defaults** (Figure 1.19) are just that - default values appearing in the project's processing forms. Like all defaults, they can be changed at the time of processing, but selecting the appropriate defaults for a project may simplify and help guide the processing. Nevertheless, the size, location and type of survey project may dictate which selections you make. Always follow your project's specifications.

Figure 1.19 - Default Data and solution quality thresholds.

Data & Solution Quality Thresholds

Thresholds are used to highlight solution results that do not meet the quality preferences for your project.

Precise Ephemeris:	Best Available ▼
Minimum ARP Height (m):	0.000
Maximum ARP Height (m):	3.000
Minimum Observations Used (%):	80
Minimum Ambiguities Fixed (%):	80
Maximum Solution RMS (m):	0.025
Maximum Height Uncertainty (m):	0.04
Maximum Latitude Uncertainty (m):	0.02
Maximum Longitude Uncertainty (m):	0.02

Figure 1.20 - Data processing suggested alternatives

Here are some recommended values based on those for sharing a mark via OPUS. Consider your choices for these defaults carefully.

Data & Solution Quality Thresholds

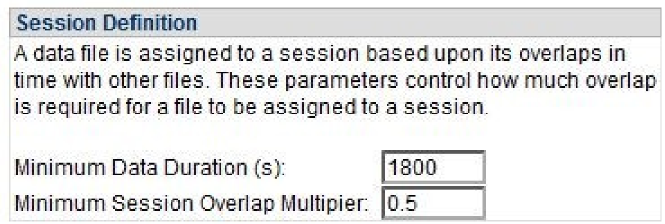
Thresholds are used to highlight solution results that do not meet the quality preferences for your project.

Precise Ephemeris:	Best Available ▼
Minimum ARP Height (m):	0.000
Maximum ARP Height (m):	2.002
Minimum Observations Used (%):	70.0
Minimum Ambiguities Fixed (%):	70.0
Maximum Solution RMS (m):	0.030
Maximum Height Uncertainty (m):	0.080
Maximum Latitude Uncertainty (m):	0.040
Maximum Longitude Uncertainty (m):	0.040

1.3.5.2.4 Session Definition

The **Session Definition** gives project managers some control over how data files are grouped together to form sessions for processing. The **Minimum Data Duration** (in seconds) sets a minimum data file duration for use in OP processing. These values can only be changed before session processing has begun. After processing has begun, this section is disabled (grayed out) and an explanatory message appears. If you want to go back and change the value after processing sessions you will need to delete those sessions first.
If you have two or more sessions in one day then you may need to change this preference such that the sessions appear in OP as a reflection of the way you planned the survey. For more information consult Section 2 of this guide prior to making any changes.

Figure 1.29 - Session definition



The **Minimum Data Duration** default setting is 1800 seconds (30 minutes). This means that in order for a RINEX file to be considered for grouping to a session, it must be at least 1800 seconds in duration. Currently, the de facto minimum duration for ANY RINEX file to exist in OPUS Projects is 7200 seconds (two hours), which is the minimum duration for an occupation that will enable it to be loaded to OPUS and thereby into your project. So a default setting of 1800 seconds at this time will force OP to consider any RINEX file that exists in your project. In the future, OP may allow the processing of shorter occupations, e.g., OPUS RS, thereby requiring the need to accept shorter duration files. Changing the Minimum Data Duration to something larger than 7200 seconds will instruct OP to filter your data to meet that requirement. For example, if you only wanted to consider data files that were three-hours in length, then the Minimum Data Duration could be set at 10,800 seconds (three hours). This would exclude any file between two and three hours in duration.

The **Minimum Session Overlap Multiplier** is a factor applied to the shorter occupation duration of two (or more) data files being considered for inclusion in the same session. If the two (or more) occupations overlap in time by at least the product of the multiplier and the duration of the shorter occupation, then the marks are grouped in the session. *For instance, let's say that we have one occupation that starts at 10:00 and goes until 12:00, and another that starts at 11:00 and goes until 13:00. The shortest occupation is two hours, and if the Minimum Session Overlap Multiplier is 0.5, then the minimum session overlap would be one hour. Both of these files include data from 11:00 to 12:00 so they would be grouped together in a session.*

CAUTION - Changing these defaults may result in unintended consequences. Setting the Minimum Session Overlap Multiplier too low or failure to closely adhere to a project's observation plan and schedule could potentially cause data to be unintentionally grouped together within a session and/or create sessions of very short duration.

The conditions set by both the **Minimum Data Duration** and the **Minimum Session Overlap Multiplier** must be met in order for marks to be included in sessions.

Although the defaults can be changed at any time, changes made after processing may not be reflected in the already completed processing results requiring one to reprocess some or all of the session solutions and network adjustments.

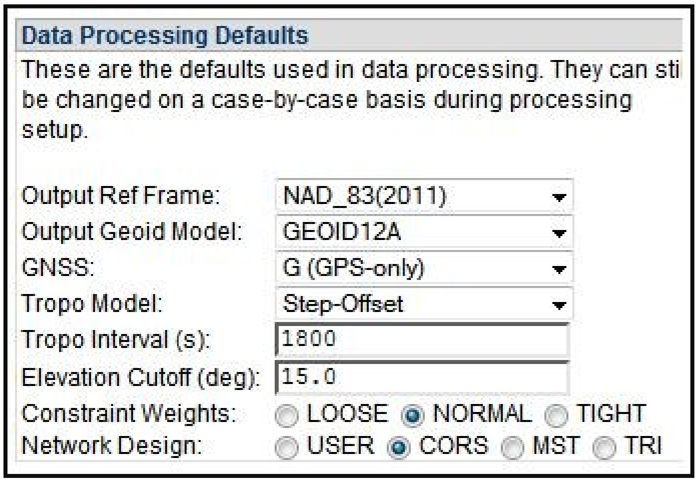


Figure 1.201 - Data processing defaults

Each of these processing defaults is examined individually over the the next few sections.

1.3.5.2.4.1 Output Reference Frame

Coordinates in the current ITRF/IGS are always included in the processing reports, but the coordinates in an additional reference (user selected) will be reported if possible. The default for this additional **Output Reference Frame** is selected using a pull-down menu (Figure 1.201). Note that the default in newly created projects is 'LET OPUS CHOOSE' and causes the latest NAD 83 realization for the regions covered by the North American Datum of 1983, to be reported. Your project's specifications or location may require the use of a different reference frame so other menu items are provided for prior realizations of NAD 83, and current and legacy realizations of ITRF, IGS, and WGS84 global reference frames. It is recommended that you use the default when your project is in the United States or its territories.

1.3.5.2.4.2 Output Geoid Model

A pull-down menu is also used for the **Output Geoid Model** (Figure 1.201). Note that, here too, the default in newly created projects is 'LET OPUS CHOOSE' causing the latest NGS hybrid geoid model, to be used if possible, but other choices are available including some gravimetric geoids. It is recommended that you use the default when your project is in the United States or its territories.
A point of clarity is worthwhile here: *The conversion from ellipsoid heights to orthometric heights is done as a purely algebraic removal of the geoid undulation from the ellipsoid height. Those users familiar with "Height Modernization" should not confuse this conversion with an actual least squares adjustment performed in the orthometric height domain.*

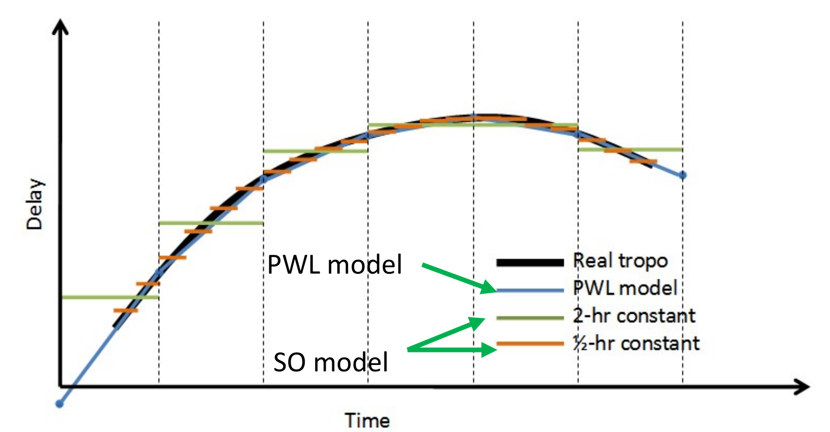
1.3.5.2.4.3 GNSS

Currently the only choice in the **GNSS** pull-down menu (Figure 1.201) is **G (GPS-only)**, but the capability to use other GNSS in the data processing may be added in the future. Note that you may upload data files (RINEX) containing GLONASS data and the NGS may archive it, but the GLONASS data is currently stripped out automatically when processed by OPUS.

1.3.5.2.4.4 Tropo Model

OP provides limited user control over how the effects of water vapor on the satellite signals as they traverse the tropospheric portion of the atmosphere, commonly called the tropo corrections, are parameterized (or modeled) in order to remove them (Figure 1.16). One strategy fits line segments, representing the tropo corrections, to the data within specified time spans with the requirement that the endpoints of the different segments connect. When plotted, this can create a continuous line, but one composed of linear pieces (Figure 1.21). OP uses the jargon **piecewise linear (PWL)**. This is a realistic way to represent a time-dependent effect like this, but it can be a poor choice if the data are sparse or have gaps. For sparse data, a simpler but less realistic alternate strategy is offered. With this alternate strategy, only a step offset, rather than an offset and slope as in the PWL strategy, is fit to the data in each time segment.

Figure 1.21 - PWL and SO modeling methods



When plotted, these corrections collectively look something like stair steps, thus OP calls this the **step-offset (SO)** method which is currently the default preference setting. The general rule-of-thumb is use the program default **SO** method if you have clear weather (high pressure) over your entire project and few mask obstructions. If not, then use the **PWL** method.

1.3.5.2.4.5 Tropo Interval(s)

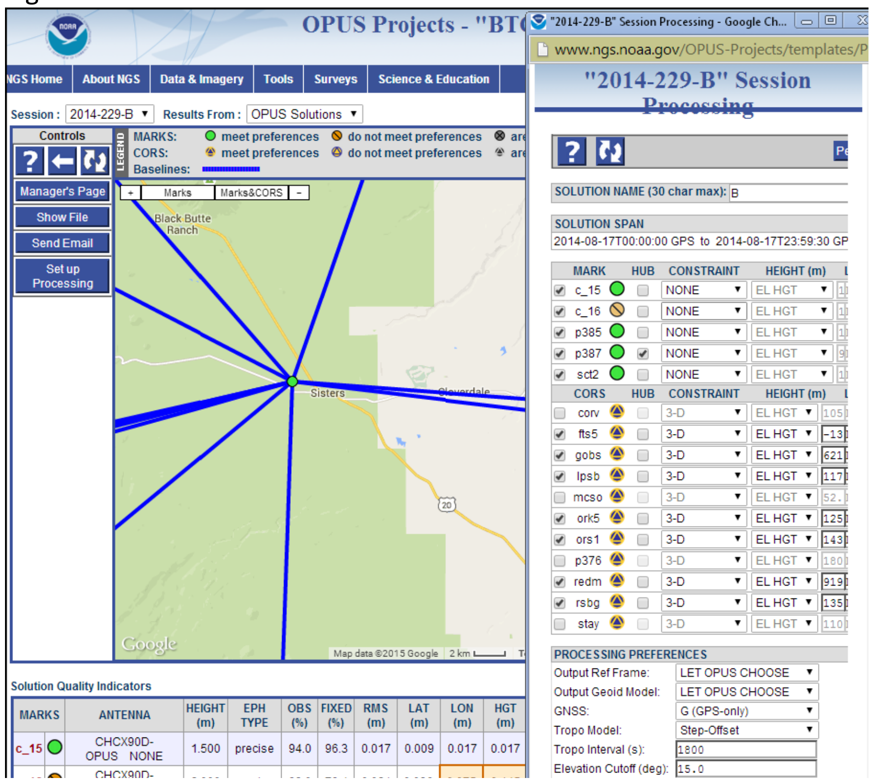
The data intervals, mentioned in the preceding section, can also be specified by users (Figure 1.201). For the **SO** and **PWL** methods the default interval is 1800 seconds (30 minutes). These values should not be changed unless the user has a specific reason.

1.3.5.2.4.6 Elevation Cutoff (deg)

The default **Elevation Cutoff** mask, in degrees above the horizon, can be specified (Figure 1.201). Data from satellites below the specified mask will be ignored. The default for new projects is a conservative but common value of 15 degrees. By eliminating low elevation satellites, some of the problematic effects of the troposphere and ionospheric delays may be avoided. Pre-planning the GNSS observations on each project mark by preparing a 'mark obstruction diagram' will produce a cleaner data set for each observation. Trees, buildings, hilly topography, etc. reduce satellite visibility, and may cause cycle slips because of temporary losses of signal from a satellite. Most survey grade receivers allow the elevation cutoff to be specified for an individual observation. A common strategy it to set the *receiver's* elevation cutoff mask at a lower value, such as 10 degrees, then apply a higher elevation cutoff mask for individual session processing. You will be given the opportunity to adjust the Elevation Cutoff mask seperately for each session you process which is a good idea for sessions containing marks with impared visibility masks.

1.3.5.2.4.7 Constraint Weights

Figure 1.22 - Session solution Constraints



Constraint weights are applied only to project marks or CORS selected to be held as constrained points in the processing. Again, any value initially shown here will only be a default that can be changed when the processing is performed. Please be aware that currently there is no differentiation between the weights applied to horizontal and vertical constraints.

Before defining the available **Constraint Weight** choices, it may be beneficial to preview constraints being set for session processing so that the implications of **Constraint Weights** default can be more fully appreciated. At the bottom of Figure 1.22 one sees that a **Constraint Weight** of NORMAL was selected. This could be the default for this project, or might have been chosen specifically for this session processing. The three choices for **Constraint Weights** are:

LOOSE -allows up to <u>one meter</u> of float for the constrained points in the adjustment.
NORMAL -allows up to <u>one centimeter *</u> of float for the constrained points in the adjustment.
TIGHT -allows up to <u>one-tenth of a millimeter</u> of float for the constrained points in the adjustment (effectively fixing and not allowing the constrained control points to move).

TIGHT (sometimes called fixed) is the default for new projects, but, as the name implies, NORMAL should be considered a recommendation allowing up to 1 cm* of float for the constrained control points to be adjusted to a true best-fit solution. *The constraints are not barriers. The NORMAL constraints instruct the program to limit the adjustment to less than about 1 cm, but if it "wants" to be greater than 1 cm, it will, although the constraint will increasingly hinder taking on larger and larger values. Think of it as a rubber band. For adjustments less than a couple cm, the rubberband is not stretched tightly and the adjustment can "easily" reach (take on) any of those values if the solution demands. Beyond that, the rubber band is stretched tighter and tighter. The adjustment can reach (take on) larger values, but its got to work harder to do so. Be aware that the rubber band is <u>never</u> slack. It is always "pulling" towards the specified constraint value to some extent.

Continuing with the preview, at the center-right of Figure 1.22 example, we see that project marks and CORS have been chosen to be constrained as either 3-D, HOR-ONLY, VER-ONLY, or NONE (i.e. completely unconstrained). The default settings for <u>new</u> processing is 3-D constraints on all CORS; NONE for all project marks. The session processing should always follow the intent of the field survey plan.

1.3.5.2.4.8 Session Network Baseline Design

The **Session Network Baseline Design** provides a basic network design strategy for the baselines created during session processing. These network baseline design options for processing should be kept in mind during the survey design and preparation stage so that simultaneous observations of project marks and CORS, constrained and unconstrained marks will form baselines that are <u>purposely occupied and processed</u>. The **Session Network Design** default can be changed at processing and, to a limited extent, modified by selecting project marks to be excluded from the processing or to be assigned as **HUBs**. You can only process baselines for marks or hubs that have been simultaneously occupied. The term "hub" is NGS jargon meaning a mark that is preferentially selected for inclusion in baselines. In other words, an included project mark that is a hub is more likely to be connected to other project marks. The four **Session Network Baseline Designs** are:

Figure 1.23 - 'USER' network design

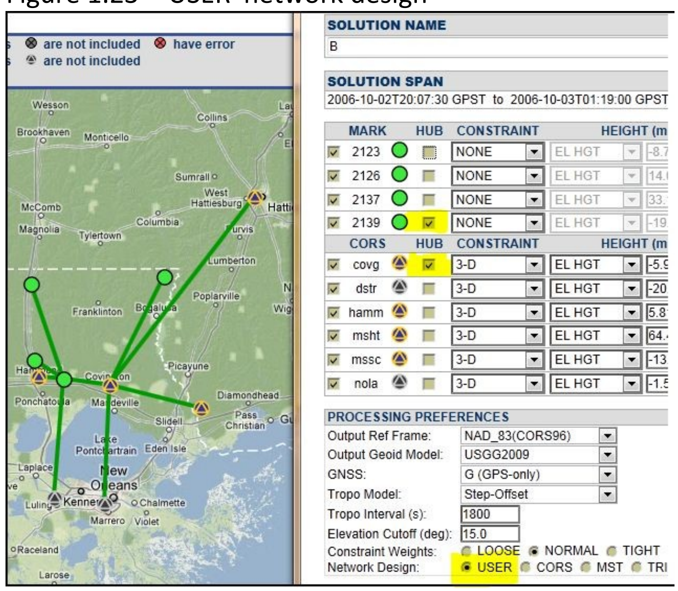
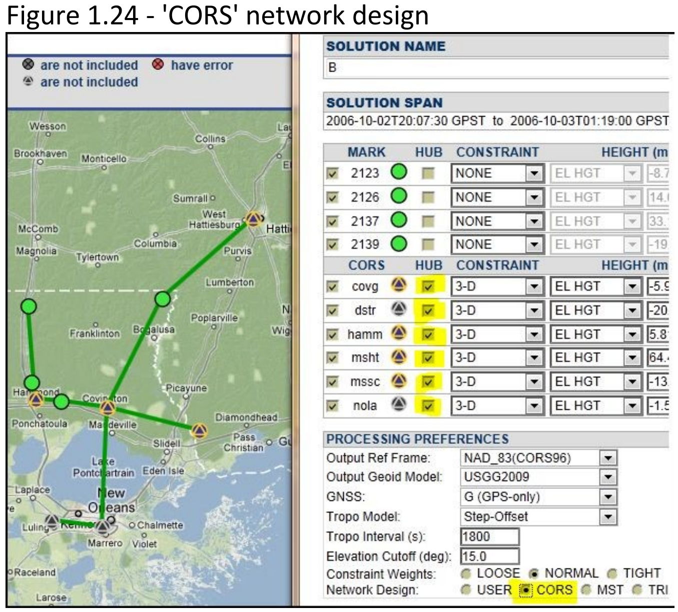


Figure 1.24 - 'CORS' network design

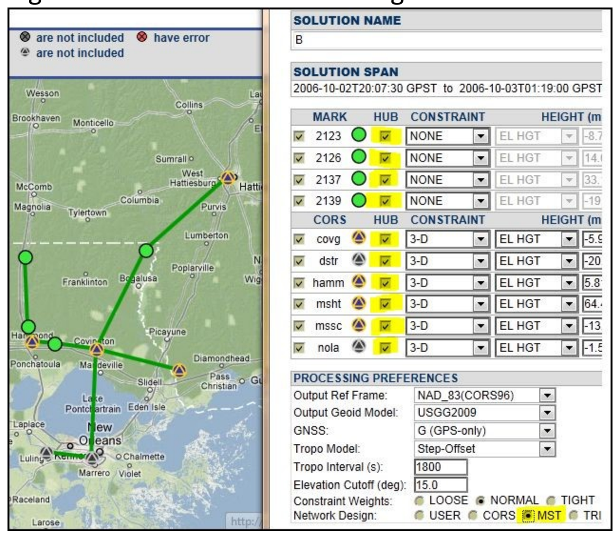


USER: Any or all included project marks or CORS can be selected as hubs offering a limited opportunity to customize the network design for the session. However, it is recommended that a hub(s) selected be CORS or other active stations with 24 hour files. While any selection of one or more hubs is possible it is recommended to select just <u>one hub per session</u>. This strategy is explained fully in the Technical Guide portion of this document. When this happens, the Session Network Baseline Design selection will change to **USER** simply to indicate that the selections no longer conform to one of the other strategies. Figure 1.23 is an example in which the user selected one mark (2139) and one CORS (covg) as hubs. As a result, the **Network Design** selection changed to **USER**, since these choices are not standard to any of the other options and the resulting baselines are indicated on the map. Processing should follow the intent of the field survey plan.

CORS: The CORS Network Design strategy automatically selects <u>all</u> included CORS, and only the CORS, as hubs (Figure 1.24). This emphasizes the number of baselines to the CORS which can be a useful design if the CORS are to be constrained in the processing. CORS are monitored daily, have well determined NSRS coordinates and provide strong ties to the global network. <u>Furthermore, CORS that have been in existence for more than 3 years have computed (measured) rather than modeled velocities, a characteristic that is desirable. Managers should weigh CORS quality when planning their surveys.</u>

MST: A 'minimal spanning tree' (c.f., e.g., Wang et al. 1977) connects all the project marks and CORS together seeking the fewest and shortest possible unique baselines. All project marks and CORS are designated as hubs. "Generally speaking, a shorter baseline leads to a better common view of the satellites. For a network, an optimal choice should be that the summation of the weighted lengths of all independent baselines should be minimal".[2]

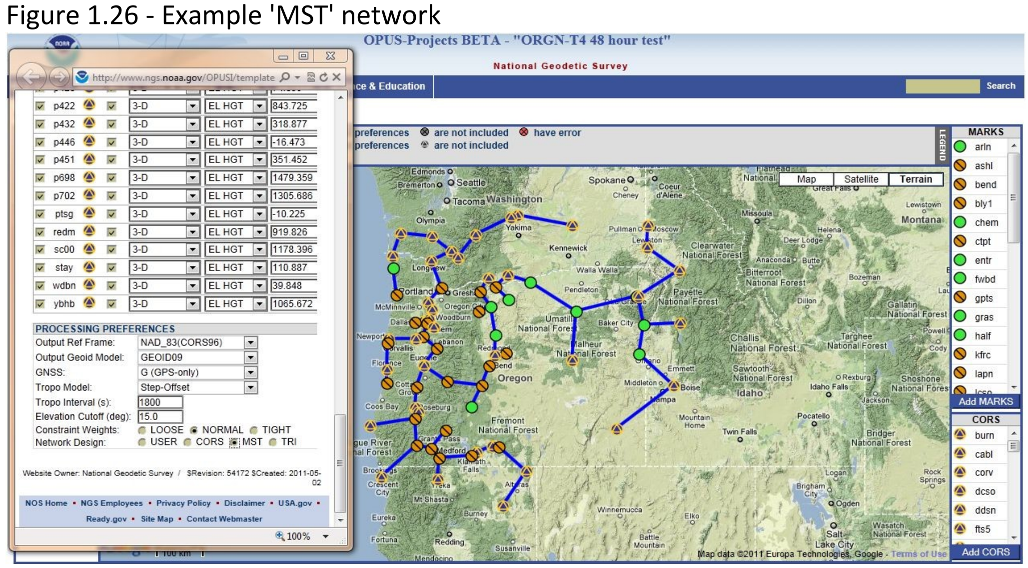
Figure 1.25 - 'MST' network design



For a network with n stations, there are [n(n-1)/2] possible baselines, of which only $n-1$ can be truly independent baselines. The task is to find exactly those $(n-1)$ possible baselines which are absolutely independent from each other and are as short as possible. This is especially useful for ambiguity fixing because there are usually some remaining baseline length-dependent effects that can be mitigated by this network design strategy. Figure 1.25 shows the baselines selected using the MST Network Design. Because the number of project marks is small, the minimal spanning tree looks identical to the CORS design in Figure 1.24.

Figure 1.26 shows a larger network using the MST Network Design. In this case, it is obvious that only the shortest baselines between all points (project marks and CORS) are considered. Solution results using this network design may be very dependent on which stations are constrained. Successive chains of unconstrained project marks can lead to poor coordinates because of the propagation of coordinate

Figure 1.26 - Example 'MST' network



uncertainties through the chain. The MST method may be most appropriate for networks with a few project marks or with well distributed constrained marks.

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[2] Xu, G., GPS: Theory, Algorithms and Applications Solutions, 2003, 2007, Springer

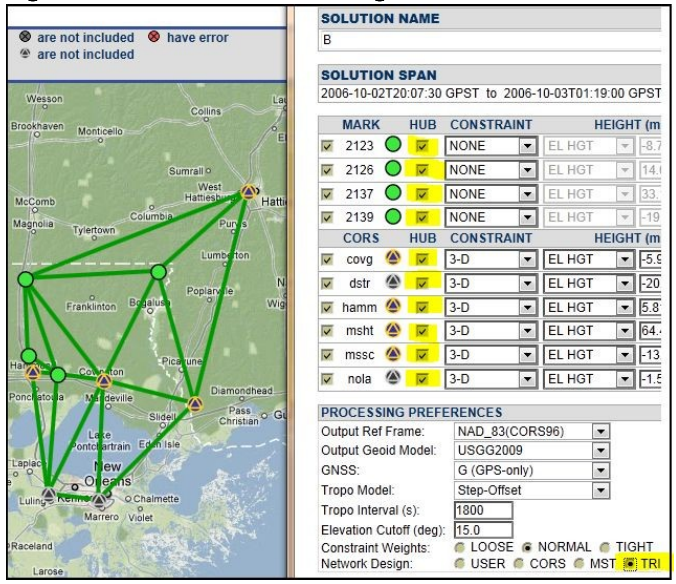
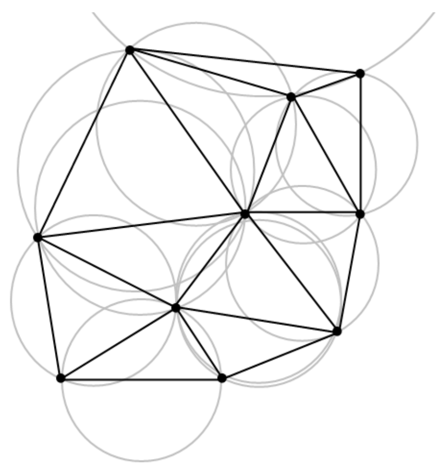


Figure 1.27 - 'TRI' network design

TRI: The triangle network design (Figure 1.27) selects baselines using the Delaunay triangulation algorithm. Invented by Boris Delaunay in 1934(2), this algorithm selects lines connecting points such that no point falls inside the circumscribing circle of any triangle, i.e. the circle connecting the three vertices of the triangle. Other possible lines connecting points are ignored. This is represented in the example shown in Figure 1.28. Delaunay triangulation maximizes the minimum angle of all the angles of the triangles defined thereby avoiding "skinny triangles" as much as possible. This design may also permit the possibility of a station being several successive stations removed from a constrained station. Planning the location of constrained CORS stations within the overall network design is very important. Note the example in figure 1.27 shows that all project marks and CORS are automatically selected hubs. Note that this method is the only choice within OP where baseline independence is no longer a limiting factor in the number of baselines being formed. This method also incorporates some trivial (dependent) baselines and the mark confidence statistics (uncertainties) have been compensated for the dependent baseline occurance.

Figure 1.28 - Delaunay algorithm

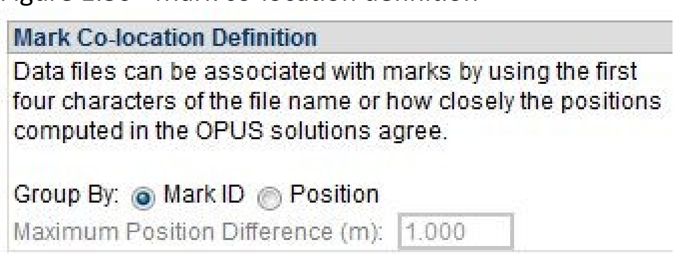


⚠ **General Limitations:** For the **USER**, **CORS**, and **MST** network design there is currently a programmed limit of 99 project marks plus (including) CORS maximum per session (this limit may change in the future). For the TRI network design there is no size limit at this time. However, there are also practical size limits dictated by the fact that OP is a Web-based tool (cloud program). Experience indicates this practical size limit is about 50 project marks per session.

More information about network design and specific survey types may be described more fully in Section 3 (OPUS Projects Technical Guide) and appendices of this document.

1.3.5.2.6 Project Mark Co-location Definition

Figure 1.30 - Mark co-location definition



The **Project Mark Co-location Definition** gives project managers some control over how data files are associated together with a mark ID. Here again, this definition will be disabled (grayed out) after session processing has begun and cannot be changed. Two strategies are available.

⚠ **Mark ID**: RINEX and other proprietary data file types use a mark identifier string as the first four characters of the file name. If you are confident that this will be the case for <u>all</u> of your project's data files, select '**Mark ID**', then OP will group similarly named data files together and name the project marks by the four character mark identifiers from the GNSS data file names.

Position: On the other hand, if project mark identifiers are not the first four characters of the GNSS data file names, the '**Position**' selection will cause OP to group data files by their OPUS solution coordinates. Data files whose OPUS solution positions fall within the **Maximum Position Difference** specified (1 m is the new project default and is shown in Figure 1.30) will be grouped together. OP will attempt to name each project mark uniquely. If all the data files associated with a mark, and only the data files associated with that mark use the same first four characters in their file names, the project mark will be given that four character name. If not, a name will be automatically generated starting with "a001". If "a001" is already in use, the numeric portion will be incremented until a unique name is created. *<u>The most common error users make is to not properly name the marks by editing the first 4 characters of the file name</u> (RINEX).*

1.3.5.2.7 Saving Project Preferences

Figure 1.31 - Save project preferences

Once you've reviewed all of the preferences and made the necessary changes, click the **Save Changes and Close** button at the top of the web page to <u>apply these preferences to your project</u>.

1.3.5.3 Project List

The **Project List** button sends an email to the project manager listing all her or his projects.

1.3.5.4 Design

A placeholder for future enhancements. Currently this control is disabled (grayed out).

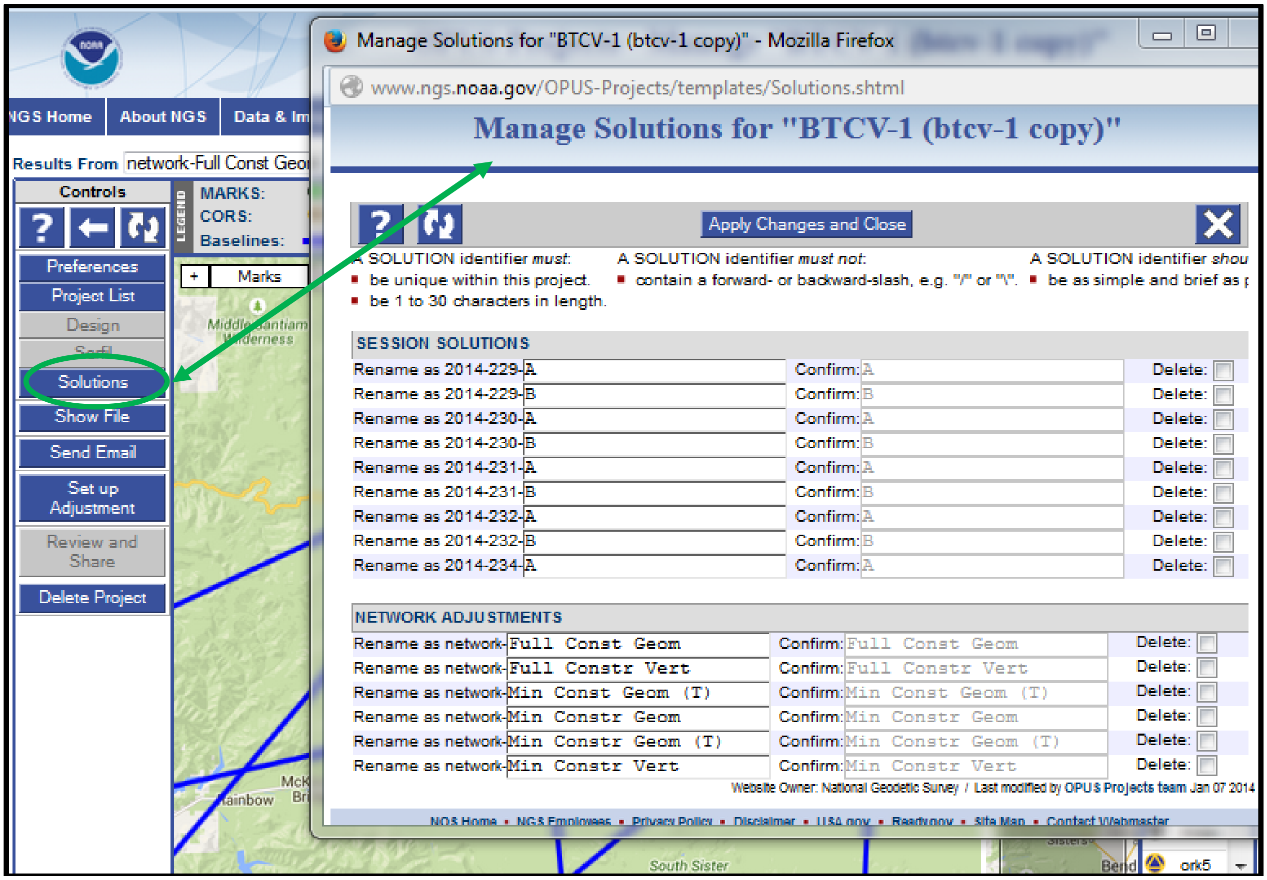
1.3.5.5 Serfil

A placeholder for future enhancements. Currently this control is disabled (grayed out).

1.3.5.6 Solutions button

The Solutions button displays a pop-up window with controls to rename or delete session solutions or network adjustments. The standard pop-up window controls appear at the top of the window (Figure 1.32) with the **Help** and **Refresh** buttons to the top-left, the **Apply Changes and Close** button at the top-center, and the **Close** button to the top-right. Rules and guidelines for solution names are listed next. This window identifies the lists of solutions and network adjustments that have been completed. Each item in these lists includes **Rename** and **Confirm** fields which are used to change those names, and a **Delete** checkbox. Changes are validated before they are applied. If errors are found, the changes will not be applied and a message describing the problems appears. If any session solution included in a network adjustment is deleted, the dependent network adjustment will be deleted also.

Figure 1.32 - Manage solutions button and popup window

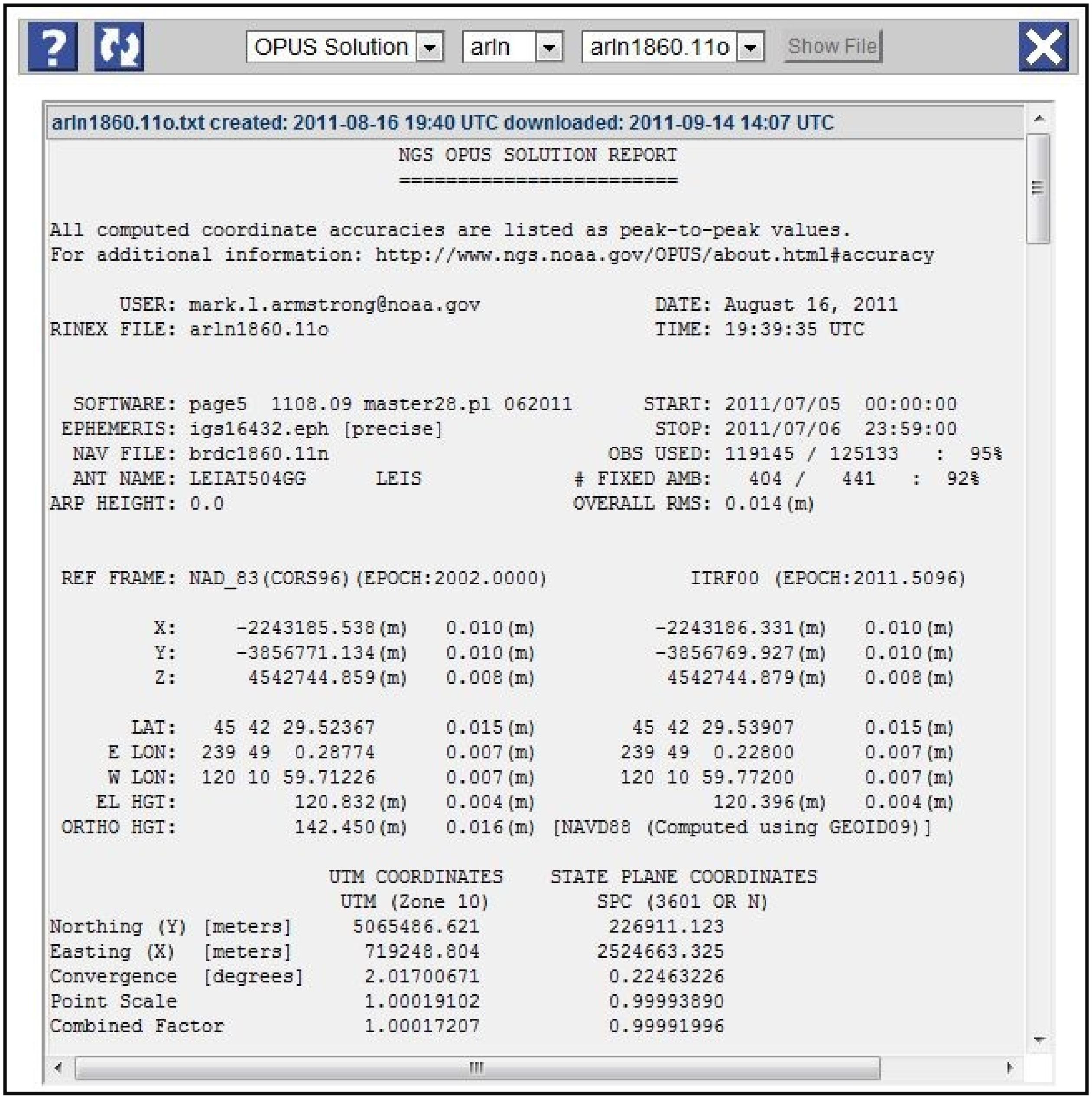


1.3.5.7 Show File

The **Show File** button reveals a pop-up window for displaying solution reports. Across the top of the window are (Figure 1.33) standard pop-up window controls, but instead of a single button at the top-center to initiate an action, this window offers a choice of available reports: OPUS-S, Session Processing, or Network Adjustments. Below the controls is a header providing the report's name, its creation and download (current) times. Then the report is displayed.

Some browsers offer a print option by right-clicking (right mouse button) anywhere in the report. All browsers should allow the report's text to be copied and pasted into another file using the method typical of the operating system. See Appendix B for more information about printing reports.

Figure 1.33 - Show file solution report

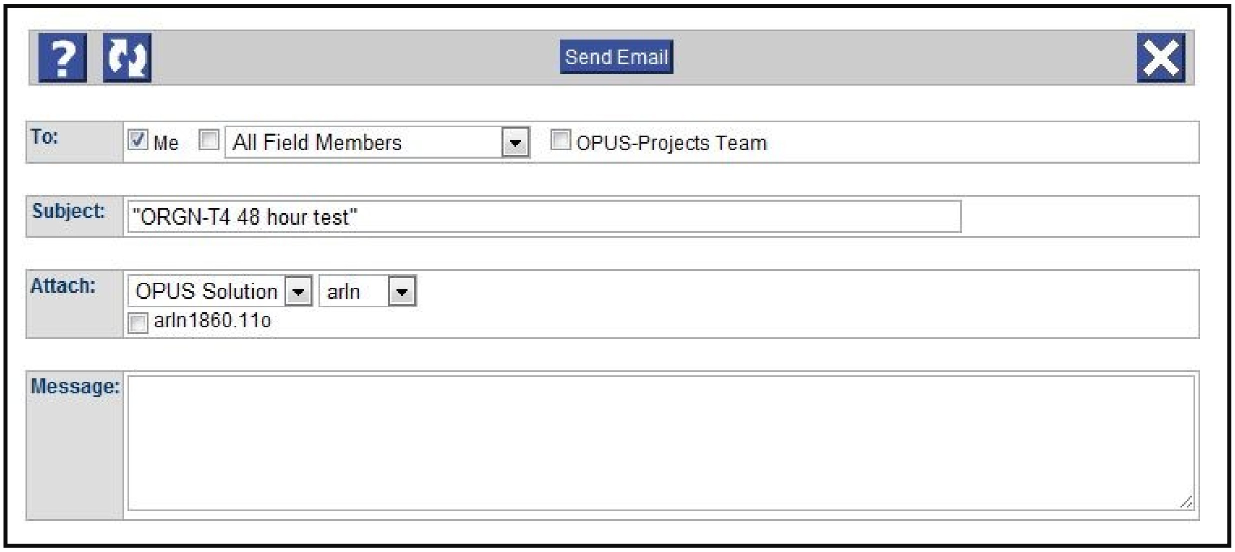


arln1860.11o.txt created: 2011-08-16 19:40 UTC downloaded: 2011-09-14 14:07 UTC

```
                          NGS OPUS SOLUTION REPORT
                          ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.html#accuracy

      USER: mark.l.armstrong@noaa.gov              DATE: August 16, 2011
RINEX FILE: arln1860.11o                           TIME: 19:39:35 UTC


  SOFTWARE: page5  1108.09 master28.pl 062011     START: 2011/07/05  00:00:00
 EPHEMERIS: igs16432.eph [precise]                 STOP: 2011/07/06  23:59:00
  NAV FILE: brdc1860.11n                       OBS USED: 119145 / 125133   :  95%
  ANT NAME: LEIAT504GG      LEIS             # FIXED AMB:    404 /    441   :  92%
ARP HEIGHT: 0.0                              OVERALL RMS: 0.014(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)          ITRF00 (EPOCH:2011.5096)

         X:     -2243185.538(m)   0.010(m)         -2243186.331(m)   0.010(m)
         Y:     -3856771.134(m)   0.010(m)         -3856769.927(m)   0.010(m)
         Z:      4542744.859(m)   0.008(m)          4542744.879(m)   0.008(m)

       LAT:   45 42 29.52367      0.015(m)        45 42 29.53907      0.015(m)
     E LON:  239 49  0.28774      0.007(m)       239 49  0.22800      0.007(m)
     W LON:  120 10 59.71226      0.007(m)       120 10 59.77200      0.007(m)
    EL HGT:          120.832(m)   0.004(m)               120.396(m)   0.004(m)
 ORTHO HGT:          142.450(m)   0.016(m) [NAVD88 (Computed using GEOID09)]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)         SPC (3601 OR N)
Northing (Y) [meters]     5065486.621           226911.123
Easting (X)  [meters]      719248.804          2524663.325
Convergence  [degrees]     2.01700671           0.22463226
Point Scale                1.00019102           0.99993890
Combined Factor            1.00017207           0.99991996
```

1.3.5.8 Send Email

Send Email (Figure 1.34) displays a pop-up window with basic controls permitting the manager to send emails to members of the project team, including herself or himself, or the OPUS Projects team. Pop-up window controls appear across the top. Below these controls, the email's recipients can be selected and subject added. The emails can include available reports as attachments. These can be selected by using the next controls. Finally, there is an entry field for a short text message. If you believe you have a problem with OP you can check the OPUS-Projects Team box and your email will reach several OP support people.Figure 1.34 - Send email



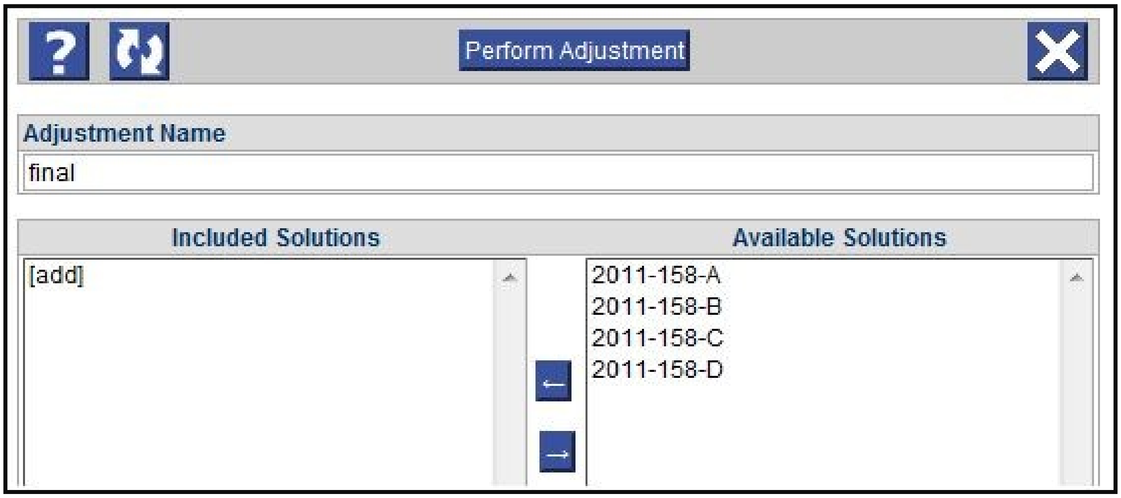
1.3.5.9 Setup Adjustment (Preferences menu)

Setup Adjustment from the preferences menu displays a pop-up window containing controls to configure and submit a network adjustment to the processing queue. The now familiar controls appear across the top of the window (Figure 1.35).

The name for the adjustment is entered using the **Adjustment Name** input field found immediately below the window controls. An adjustment can be "tweaked" and overwritten by submitting a processing request with the same name as an existing adjustment, or alternate adjustments created by entering different, unique names for each.

Next are **Included Solutions** and **Available Solution** list boxes. In order to perform a least squares adjustment of the processed baselines (vectors) one or more sessions must have been processed to appear in the **Available Solutions** box. One or all of the **Available Solutions** can be highlighted, then moved to the **Included Solutions** box, using the upper button, with the left pointing arrow, between the two boxes.

Figure 1.35 - Perform adjustment window



Once selected for inclusion in the adjustment, the marks and CORS in those solutions are listed and available to have their horizontal (**HOR-ONLY**), vertical (**VER-ONLY**) or (**3-D**) coordinates constrained (Figure 1.36). **NONE** is the default value and means that no constraint is to be applied for that project mark or CORS. Note that mark and CORS positions (lat., long., height) may be modified from the values provided, but changing them will change the adjustment results and may make them inconsistent with the National Spatial Reference System.

Figure 1.36 - Perform adjustment window showing marks, CORS and constraint options.

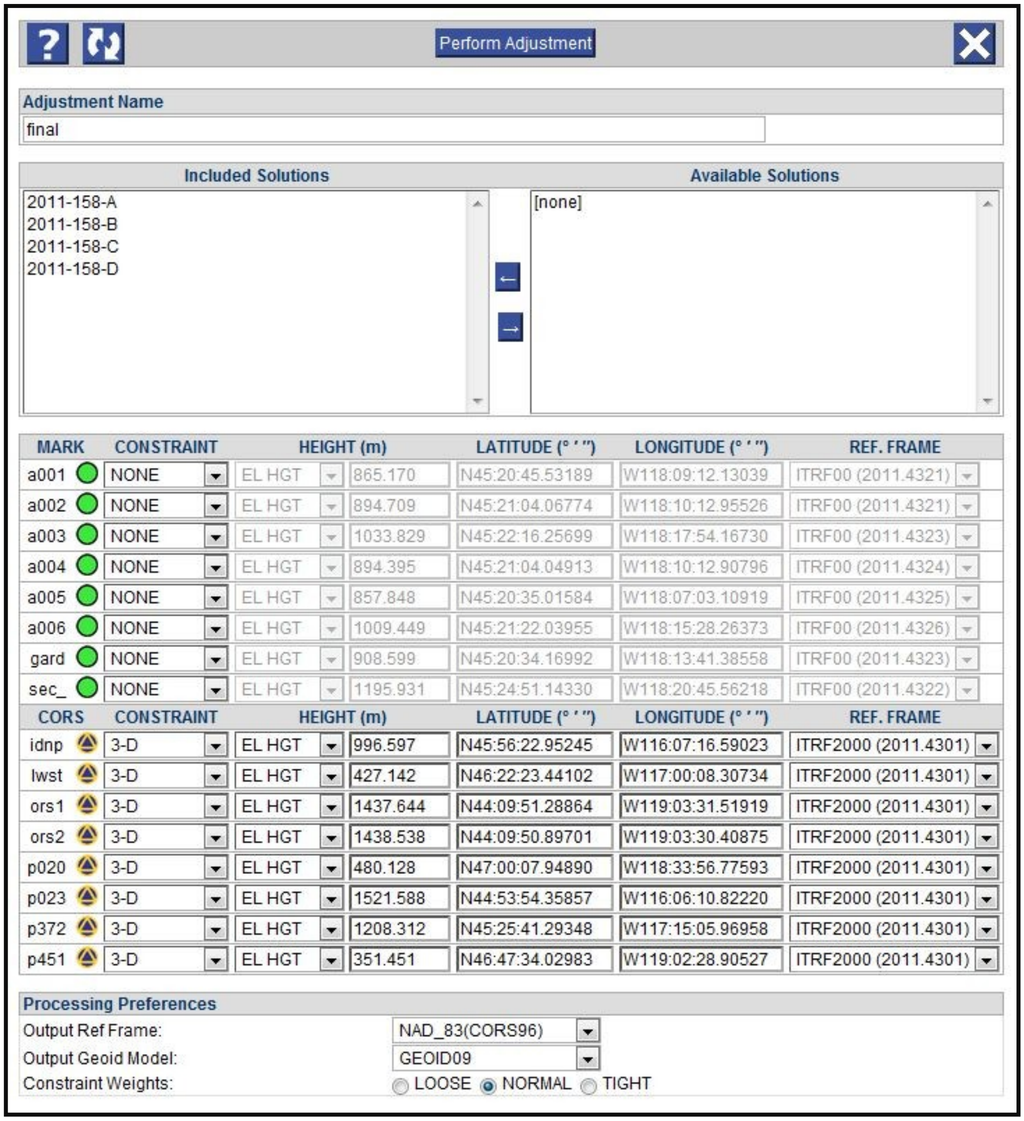
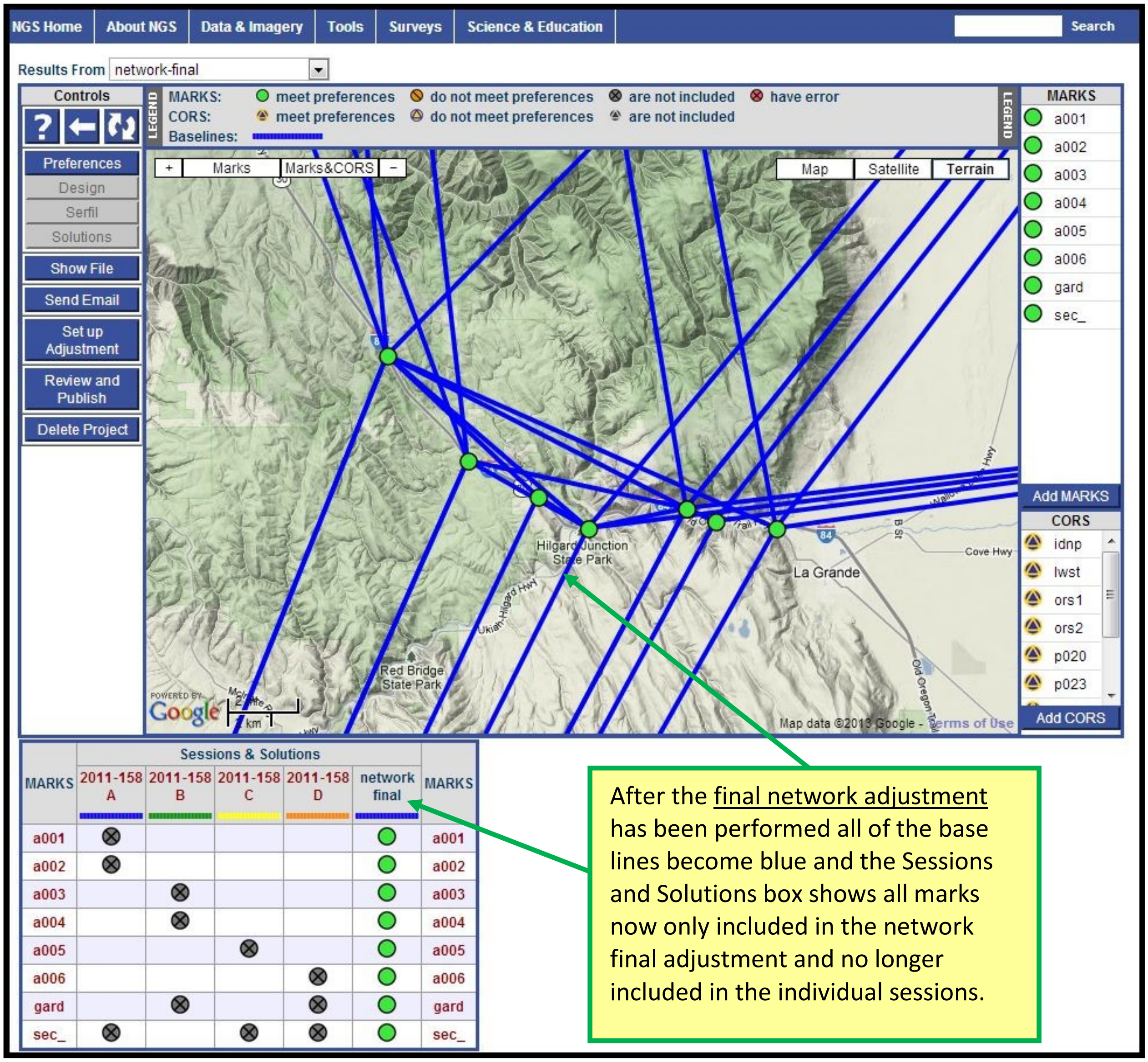


Figure 1.37 - Network final adjustment map



The project marks shown under each session (Figure 1.37) reflect the 'are not included' icon style but have been included in the network final adjustment and all project marks reflect the green icon having met the Manager's preferences established for the project.

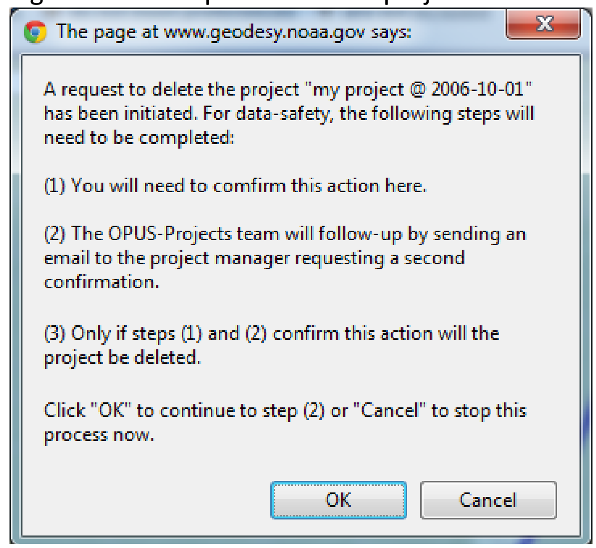
1.3.5.10 Review and Share

Sharing the project-specific results of your final adjustment to the OPUS database using OP is not currently operational. The **Review and Share** button (Figure 1.37) is currently grayed out (not active). IF SHARING YOUR PROJECT MARKS WITH THE OPUS DATABASE IS IMPORTANT TO YOU PLEASE CONTACT YOUR NGS ADVISOR, OP TRAINER, AND THE OPUS PROJECTS GROUP (ngs,opus.projects@noaa.gov).

1.3.5.11 Delete Project

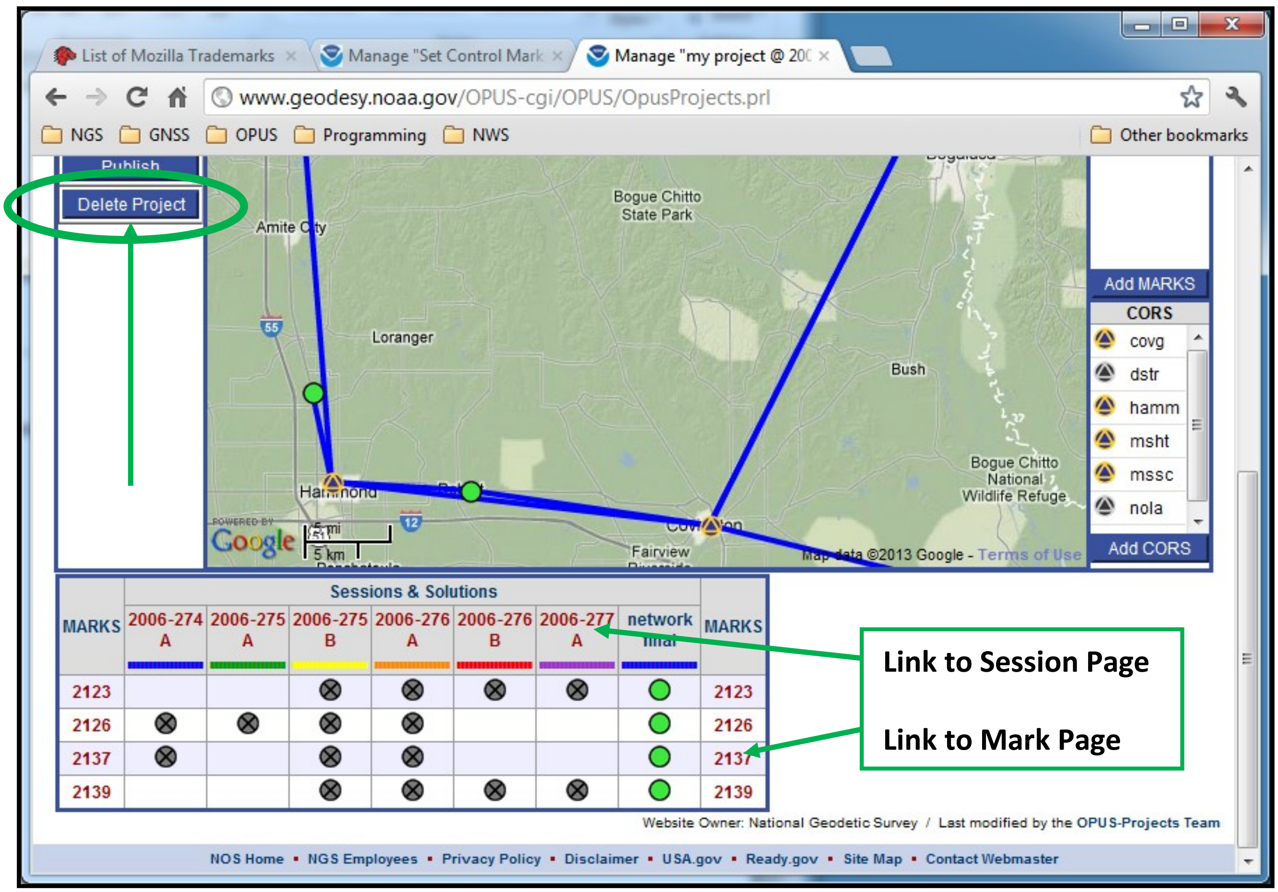
The NGS may archive the observation files from projects for future use in performing regional or national adjustments. The primary method of expanding and improving the NSRS has been through the submission of projects by external users. Nonetheless, the right to delete a project does reside with the project's manager.

Figure 1.39 - Request to delete project



Clicking the **Delete Project** (Figure 1.37) button will initiate a three-step process that, if completed, will delete the project from your own manager list of projects. First a confirmation message, similar to that shown in Figure 1.39, appears. **Cancel** will immediately end this process without the project having been deleted. **OK** will proceed to step 2. In step 2, an email is sent to the project manager. If the email is ignored, the process is canceled without the project having been deleted. A reply to the email implies consent and the process will proceed to step 3. In step 3, the project is deleted and a notification sent to the project manager.

Figure 1.40 - Delete project button



1.3.6 Sessions & Solutions

At the bottom of the manager's page, the **Sessions & Solutions** table is shown (Figure 1.40). Graphically, this table is a census of the project marks, and the sessions and solutions in which they appear. The session and network adjustment names (if any) act as column headers, mark names are row labels thereby creating a grid. An icon in a specific cell of the grid signals that the project mark, associated with the row, is included in the session or network adjustment associated with the column. Furthermore, the icon type indicates the project mark's solution status relative to the project's preference.

Practically, this table is also a critical navigation tool. The name of each session or session solution name is a link to navigate to its web page where the manager may process each session. Likewise, the mark ID's are links for navigating to the project mark pages.

This table is modified by the **Results From** menu selection (Section 1.2). If a specific network adjustment or session solution is selected, all icons in the other columns of the table change, indicating that they are not included (grey crossed-circle) in that specified solution.

The table and the project map also interact. If more than one solution is being shown, moving the cursor over a solution's name in this table will hide all other solution baselines shown in the project map (Section 1.3) thereby more clearly indicating the solution of interest. Likewise, moving the cursor over the project mark's ID brightens (lighten the color) the corresponding icon on the project map.

The following section beginning with **1.4 Session Web Page** presents an additional set of webpage menus and processes for use by project members (field crew) and/or the Project Manager. The text has been edited to direct program use by project members. Although many processes seem similar to the manager pages they may be distinctly different in menu appearance and process flow. They have been provided here for rapid access and clarity.

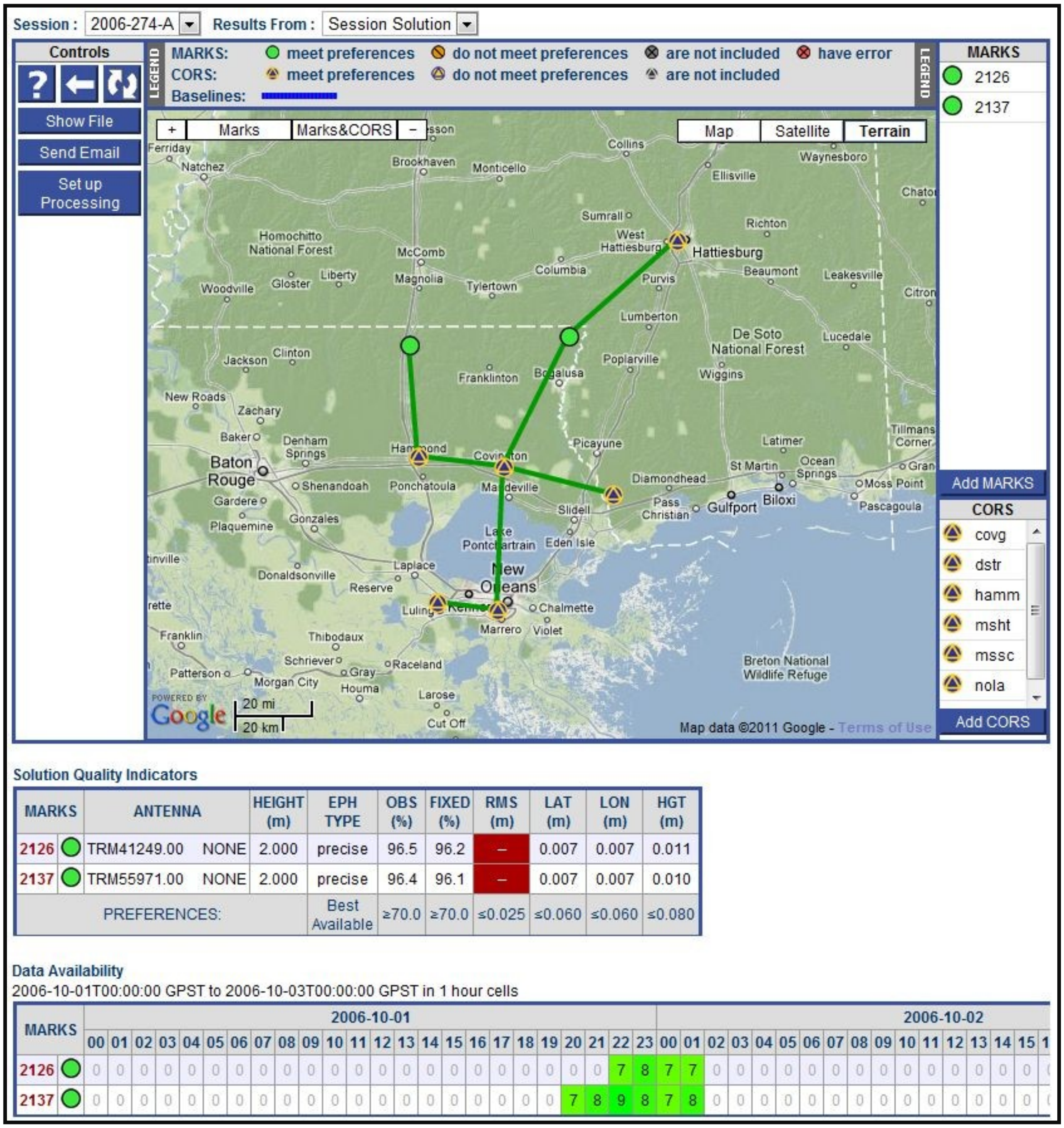
This next section is repetitive and designed for field crew members (who are not managers) to read who may only upload data and process a sessions and nothing else.

1.4 The Session Web Page

The Session Web Page may be accessed by other project members (field crew) that have been supplied with the **Project ID** and **Session Keyword** by the manager using the session entry fields on the OP gateway page (Figure 1.2).

The project manager can access a session web page from the project manager's web page. A session web page is associated with the indicated session only. Like the manager and project mark web pages, an email link to the OPUS Projects Team appears at the bottom of the web page.

Figure 1.41 - The Session Web Page



1.4.1 Notices

Notices about OP and, very rarely, a message specific to a project (no other project will see these specific messages) may appear at the top of the manager, session and project mark web pages. An email link to the OPUS Projects Team will appear with any notices and messages so that follow-up questions can be asked if needed.

1.4.2 Session Map

Like the manager's web page, the session web pages are built around a Google Map Services™ interactive map to help orient you within the session and its geographic region. Unlike the manager's web page map, only information for the indicated session is shown here. Different icons are used to reflect a project mark's status in the session. A legend defining each icon type is given just above the map (Figure 1.42).

Figure 1.42 - Legend icons

For MARKS:

A **green, open circle** icon means the preferences set by the project manager have been met. The project mark icon may become green based on the OPUS, session, or session solution.

An **orange, barred circle** icon (with a line through it) means that the preferences set by the manager have not been met in processing using this project mark's data. This most often occurs with the initial OPUS solution submission; less common from session processing. <u>This condition does not prevent the mark's data from being used in the project</u>.

A **grey, crossed circle** icon means that the project mark was not included in the processing results being displayed.

A **red, crossed circle** icon notes an error with the project mark. This condition is seldom seen but signifies a more serious problem with the mark's data or solution.

For CORS:

A **blue** with **yellow trim** icon means that the CORS data have met the preferences set by the manager.

A **yellow** with **blue trim** icon means that the CORS solution result does not meet the preferences set by the manager. This condition does not prevent the CORS data from being used in the project.

A **grey** icon means that the CORS was not available or not included in the results being displayed.

For Baselines:

If a session solution was completed, the baselines defined in the processing appear as color lines on the map.

Within the map display to the upper-left, there are typical zoom controls (+/-) and controls to zoom specifically to the session's 'Marks' or 'Marks & CORS'. At the upper-right corner of the map (Figure 1.41) you may set the map background as either Terrain (digital elevation model), Satellite (satellite imagery if available), or Map (towns, streets & highways). You also have the option to click and drag (pan) the map to view nearby areas.

Holding the cursor over a project mark icon will cause the icon color to lighten and the mark's ID to appear (Figure 1.43). Clicking (typical left mouse button) a project mark icon will cause information about the data files associated with that mark for this session only to appear in an information 'bubble'. At the top of the bubble, the mark ID is given. If the mark is a project mark, the ID acts as a convenience link to navigate to the summary web page of that mark. A table listing all of the uploaded data files is also shown in the bubble (Figure 1.44). Note that the antenna name and ARP height associated with each file are also shown for the record. The project team member who uploaded the files is given as the 'OBSERVER'. Their name is a convenience link to send them an email message.

Figure 1.43 - Mark icon action

Figure 1.44 - Mark data files bubble

1.4.3 Project mark and CORS lists

To the right of the map are lists of project marks and CORS included in the session. Like the map icons, holding the cursor over a mark's ID in the list will cause the icon color to lighten, and clicking (typical left mouse button) a mark ID in the list causes that project mark's information bubble to appear on the map, identifying its position.

Figure 1.45 - Click on the mark ID in the right column

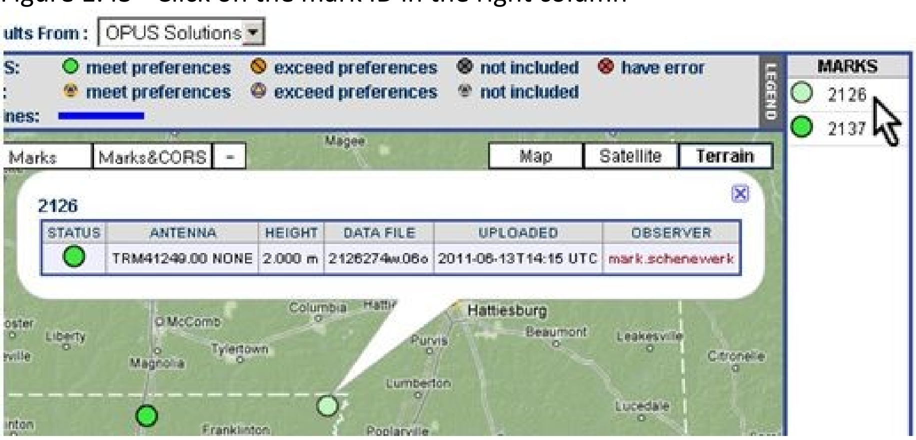
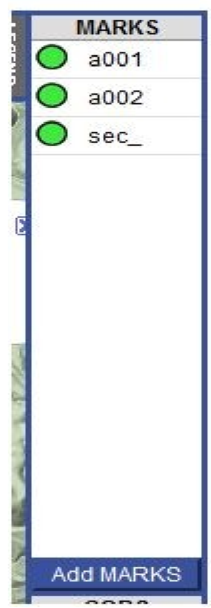


Figure 1.46 - Add marks



1.4.3.1 Adding additional marks to the project

Below the project marks list to the right of the map is the '**Add Marks**' button (Figure 1.46). This button is a link to the OPUS Upload web page where you may upload additional GNSS occupation data files to OPUS and assign them to your project.

1.4.3.2 Adding additional CORS to the session

Below the CORS list, at the bottom right of the map, is the **Add CORS** button (Figure 1.47). Clicking this button opens a new window with controls to add additional CORS to this session (Figure 1.48).

Figure 1.47 - Add CORS

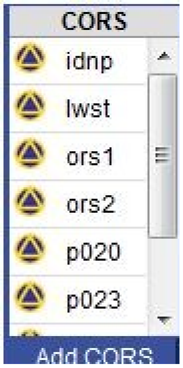
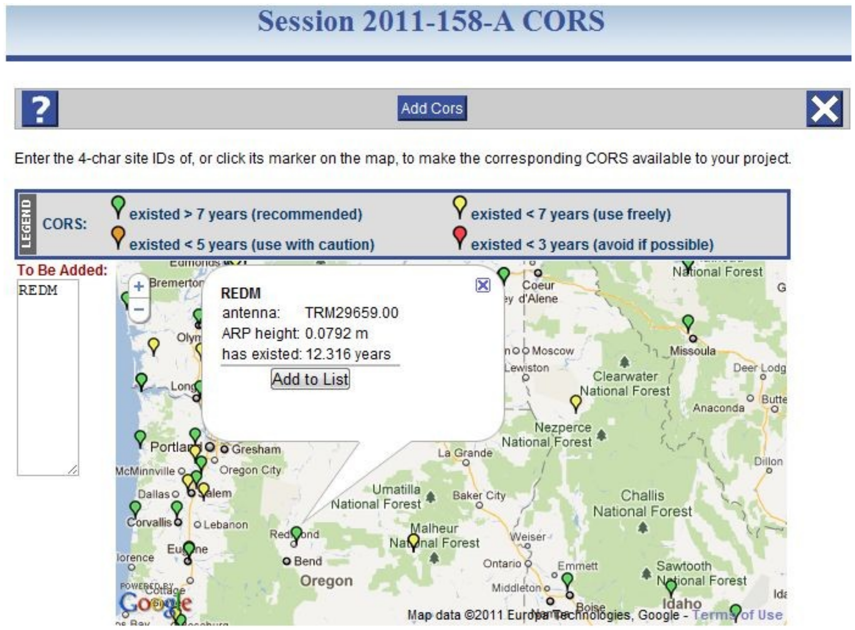


Figure 1.48 - The 'Add CORS' popup window



The map appearing in the **Add CORS** window (Figure 1.48) is similar to the map on the primary web page. You may zoom in and out and drag the map to other areas. Notice the CORS icons are color coded. As you zoom in to the map notice that the sites that have been operational for shorter periods of time appear. CORS icons are color coded to reflect how long they have existed as a CORS. As you zoom in to the map notice that the sites that have been operational for shorter periods of time begin to appear. This a subtle way of encouraging the addition of CORS that have existed longer, have more years of archived data, and which may overlap the session timelines for projects with older observations. It is recommended to use CORS that are at least three years old which will have computed (measured) velocities which OP will make use of.

⚠ Any CORS added while on a session page, will be added only to a session. You may wish to add the same or different CORS to other sessions within the project. CORS added from the Managers page will overlap all of the sessions in the project at the time the CORS are added. It may be prudent for team field members to consult the project manager before uploading data files to OPUS so that a set of specific CORS may be used throughout the project.

When in the **Add CORS** window, move the cursor over the CORS icon to see the CORS ID. Clicking on the CORS icon gives you the option (within the information bubble) to add it to a list on the left. When you have completed adding CORS to that list, click the **Add CORS** button at the top of the web page to populate your current session with those additional CORS.

⚠ **Remember, adding CORS after the session has been processed will require the session to be reprocessed for the added CORS with associated baselines to be included in the session results**.

1.4.4 Controls

At the top of the Session Web Page there are two pull-down menus that identify the Session name (ID) and the type of results being displayed. In addition to acting as an identifying label for the web page, the session menu can be used to navigate to other Session Web Pages. Other controls for this web page appear on the left side of the map.

1.4.4.1 Help, Back and Refresh

Help, **Back**, and **Refresh** buttons at the top of the controls. The **Help** button is under development and may ultimately provide the same resource as this document. The **Back** button "moves back" to the previous web page in the browser's history. Its action is identical to the browser's back control. The **Refresh** button forces the project to be scanned and the session web page to be reloaded.

1.4.4.2 Manager's Page

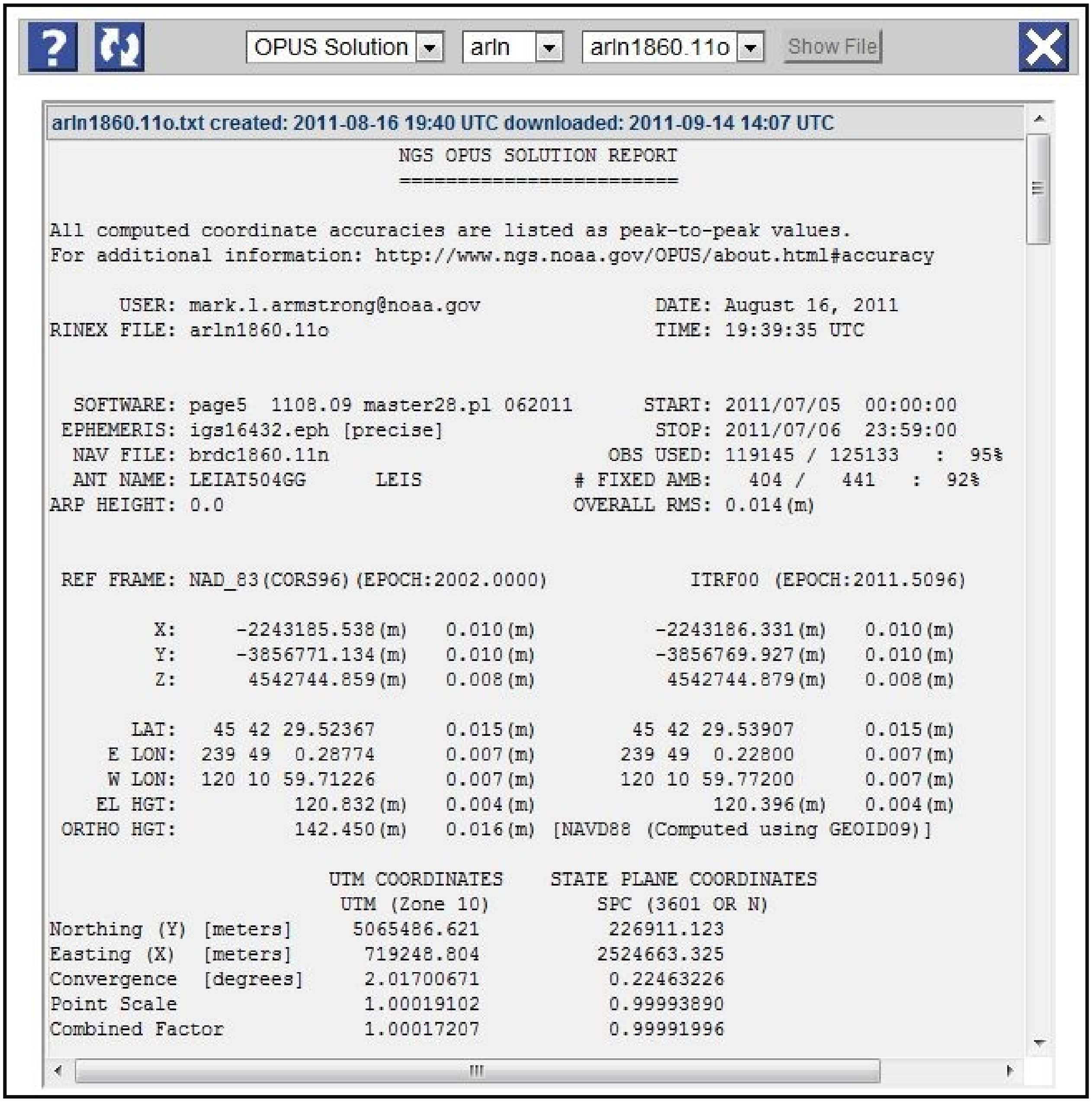
If the project manager has accessed from the project manager's web page, the Manager's Page button appears providing a convenient, direct link back to the project manager's web page.

1.4.4.3 Show File

The **Show File** button reveals a pop-up window for displaying solution reports. Across the top of the window are controls (Figure 1.49). Standard pop-up window controls appear at the top, but instead of a single button at the top-center to initiate an action, this window offer a choice of available reports: OPUS, session processing, or network adjustments. Below the controls is a header providing the report's name, its creation and download (current) times. Then the report is displayed.

Some browsers offer a print option by right-clicking (right mouse button) anywhere in the report. All browsers should allow the report's text to be copied and pasted into another file using the method typical of the operating system. See **Appendix B** for more information.

Figure 1.49 - Solution report



OPUS Solution | arln | arln1860.11o | Show File

arln1860.11o.txt created: 2011-08-16 19:40 UTC downloaded: 2011-09-14 14:07 UTC

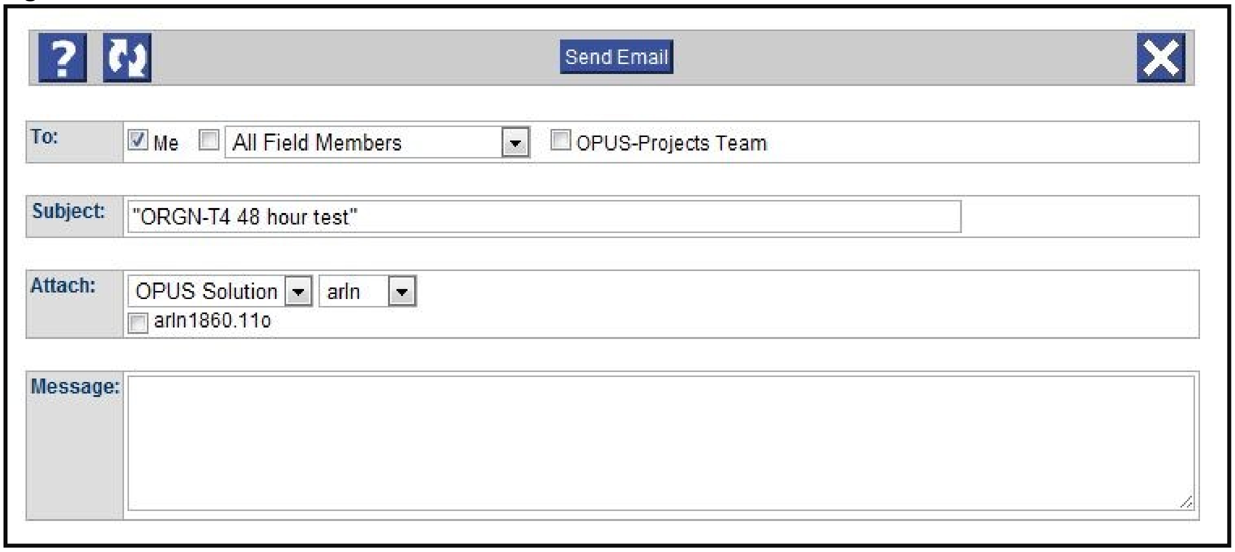
```
                         NGS OPUS SOLUTION REPORT
                         ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.html#accuracy

      USER: mark.l.armstrong@noaa.gov               DATE: August 16, 2011
RINEX FILE: arln1860.11o                            TIME: 19:39:35 UTC


  SOFTWARE: page5  1108.09 master28.pl 062011      START: 2011/07/05  00:00:00
 EPHEMERIS: igs16432.eph [precise]                  STOP: 2011/07/06  23:59:00
  NAV FILE: brdc1860.11n                        OBS USED: 119145 / 125133    :  95%
  ANT NAME: LEIAT504GG      LEIS             # FIXED AMB:    404 /    441   :  92%
ARP HEIGHT: 0.0                              OVERALL RMS: 0.014(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)           ITRF00 (EPOCH:2011.5096)

         X:     -2243185.538(m)   0.010(m)          -2243186.331(m)   0.010(m)
         Y:     -3856771.134(m)   0.010(m)          -3856769.927(m)   0.010(m)
         Z:      4542744.859(m)   0.008(m)           4542744.879(m)   0.008(m)

       LAT:   45 42 29.52367      0.015(m)        45 42 29.53907      0.015(m)
     E LON:  239 49  0.28774      0.007(m)       239 49  0.22800      0.007(m)
     W LON:  120 10 59.71226      0.007(m)       120 10 59.77200      0.007(m)
    EL HGT:           120.832(m)  0.004(m)                120.396(m)  0.004(m)
 ORTHO HGT:           142.450(m)  0.016(m) [NAVD88 (Computed using GEOID09)]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)         SPC (3601 OR N)
Northing (Y) [meters]     5065486.621           226911.123
Easting (X)  [meters]      719248.804          2524663.325
Convergence  [degrees]     2.01700671           0.22463226
Point Scale                1.00019102           0.99993890
Combined Factor            1.00017207           0.99991996
```

1.4.4.4 Send Email

Send Email (Figure 1.50) displays a pop-up window with basic controls permitting the project member viewing this page to send emails to members of the project team, including herself or himself, or the OPUS Projects team. Pop-up window controls appear across the top. Below these controls, the email's recipients can be selected and subject added. The emails can include available reports as attachments. These can be selected by using the next controls. Finally, there is an entry field for a short text message.

"Field Members" are the email addresses supplied with the OPUS uploads so there will always be email addresses under the "All Field Members" selection.

Figure 1.50 - Send email

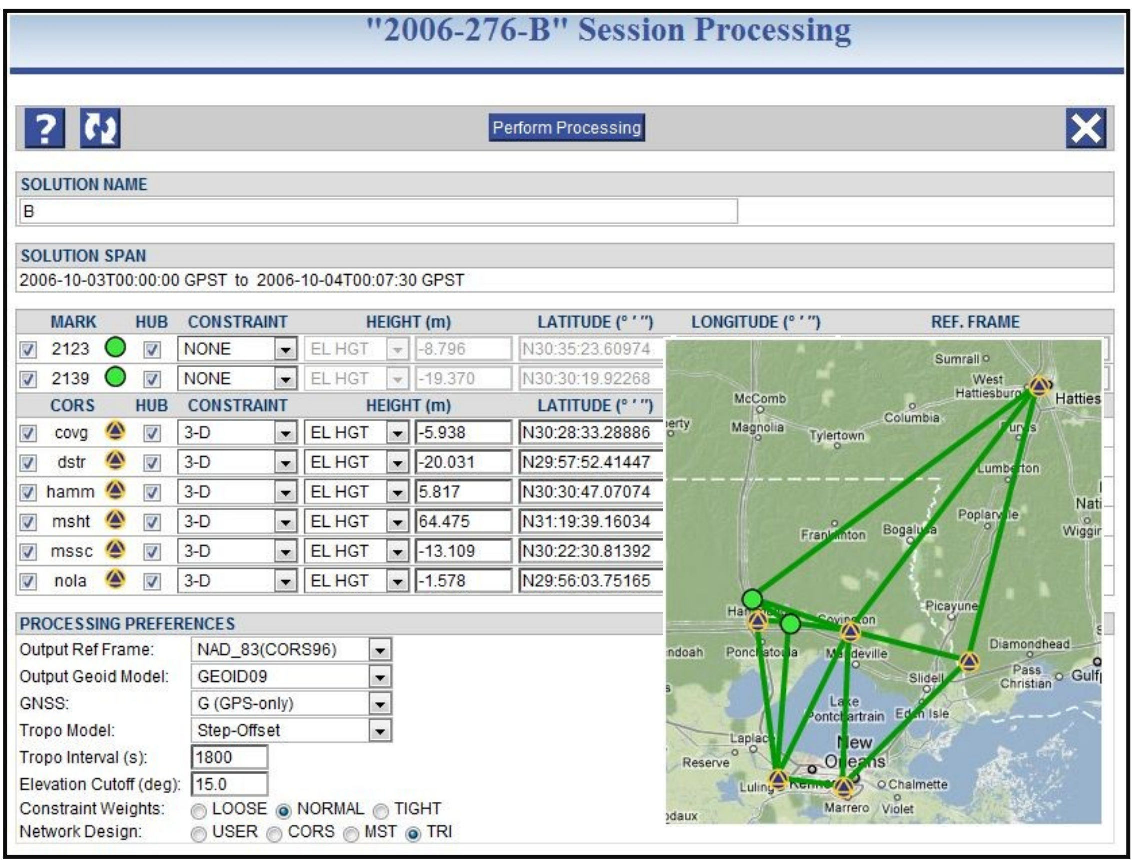


1.4.4.5 Setup Processing

Clicking the **Setup Processing** button from the Session Page causes two things to happen: the session process setup window appears and the baselines implied by the processing selections are shown on the session map (shown as an inset map here in figure 1.51).

Note that, although not required, two computer monitors are handy so the user can interactively see the baseline map configuration choices on one monitor while selecting hub sites and constraints on another monitor.

Figure 1.51 - Session processing



As always, pop-up window controls appear across the top (Figure 1.51).

Note that the **Solution Name** box offers a way to identify the processing results. The initial automated default is the program assigned session letter which, in the example shown in figure 1.51, is 'B'. A custom name may be used, but it is recommended that the session letter be used as part of that name for traceability. If processing has already been completed for this session, the session name used in that processing will become the default. This allows you to reprocess a particular session, change the name it is saved to, and then compare the session solution results.

Next, the **Solution Span** is given. The **Solution Span** is based solely upon the project mark GNSS data files in this session (CORS data files are always assumed to contain "full days" so including them in calculating the time span would mask meaningful information). The processing span cannot be edited and is provided as a convenience.

Below the **Solution Span,** are lists of the project marks and CORS included in this session with controls for each. The controls, from left to right are:

- A checkbox that, when checked, indicates that this project mark's data file is to be used in the processing. If a project mark is omitted from the processing by unchecking this box, the other controls for this mark are disabled (greyed out) to help indicate this condition and avoid confusion.
- A checkbox ("HUB") indicates the option that the project mark is to be used as a "hub" in network design. The significance of hub marks is discussed in Sections 1.3.5.2.4.8 and

  3.4, but, in short, hubs are preferentially selected for forming baselines (a network radial design with a single hub mark can look like the spokes on a wheel with the hub mark as the hub of the wheel), and give some control over the automated network design.
- The constraint pull-down menu specifies if the project mark's coordinates are to be constrained (their adjustment limited in the solution). The available choices are:

NONE	- no constraint is to be applied.
3-D	- the horizontal and vertical coordinates are to be constrained.
HOR-ONLY	- the horizontal coordinates are to be constrained.
VER-ONLY	- only the vertical coordinate is to be constrained.

WARNING: Although possible to do it is recommended the user not seed alternate heights or latitude, longitude coordinates for session processing. That should be left for the final series of network adjustments only.

- A pull-down menu designating that the ellipsoid (EL HGT) or orthometric height (indicated by the name of the geoid model used to relate the orthometric to ellipsoid heights) is found in the next box to the right. If a project mark is not selected to be constrained vertically, this menu will be disabled.
- **The ellipsoid or orthometric height**, in meters, depending upon the selection in the menu to the immediate left. This is an input field and the value can be changed, but doing so may/will make the solution results inconsistent with the National Spatial Reference System. If the project mark is not to be constrained vertically, this input field will be disabled.
- **The latitude and longitude** in degrees, minutes and seconds. These are input fields and their values can be changed, but doing so may/will make the solution results inconsistent with the National Spatial Reference System. If the project mark is not selected to be constrained horizontally, these input fields will be disabled.
- **The Reference Frame and Epoch** is pull-down menu giving the reference frame and epoch of the height, latitude and longitude. If the project mark is not selected to be constrained, this menu will be disabled.

At the bottom of this web page are **Processing Preferences**. The defaults for these preferences are defined by the project manager, but can be overridden by these controls for this session processing only. Consult with the project manager before overriding these preferences.

1.4.4.5.1 Output Reference Frame

Coordinates in the current ITRF/IGS are always included in the processing reports, but the coordinates in an additional datum reference frame will be reported if available and selected in the drop down box. Possibilities include **LET OPUS CHOOSE** which will be the latest NAD 83 realization for the regions covered by the North American Datum of 1983, NAD 83(2011), other prior realizations of NAD 83, and current and legacy realizations of ITRF, IGS, and WGS84 global reference frames.

1.4.4.5.2 Output Geoid Model

Select the geoid model used to convert the adjusted ellipsoid height to an orthometric height. Historically speaking hybrid geoid models are meant to be pared with specific realizations of NAD 83. Possibilities include **LET OPUS CHOOSE** which causes the latest NGS NSRS hybrid geoid model, to be used. The manager also has the option of selecting legacy hybrid geoid models, and some gravimetric geoid models. A point of clarity is worthwhile here: *The conversion from ellipsoid heights to orthometric heights is done as a purely algebraic removal of the geoid undulation from the ellipsoid height. Those users familiar with "Height Modernization" should not confuse this conversion with an actual least squares adjustment performed in the orthometric height domain.*

1.4.4.5.3 GNSS

Specifies the GNSS whose data are to be used. Currently the only choice is **G (GPS-only)**.

1.4.4.5.4 Tropo Model

Specifies the tropo model parameterization (implementation). Two choices are available: **Piecewise Linear** or **Step-offset**. Piecewise linear will instruct the program to parameterize the tropo correction as a series of connected straight lines; step-offset as a simple series of stepped values. See Section 1.3.5.2.4.4.

1.4.4.5.5 Tropo Interval(s)

Specifies the time interval between corrections mentioned in Section 1.3.5.2.4.4.

1.4.4.5.6 Elevation Cutoff (deg)

Specifies the elevation cutoff mask, in degrees above the horizon. Data from satellites below the specified mask will be ignored. Each session processing is allowed to have a unique elevation cut off mask based on the manager's survey plan.

1.4.4.5.7 Constraint Weights

Specify approximately how much constrained coordinates are allowed to shift in the solution. The three choices for **Constraint Weights** are:

LOOSE -allows up to one meter of float for the constrained points in the adjustment.
NORMAL -allows up to one centimeter of float for the constrained points in the adjustment.
TIGHT -allows up to one-tenth of a millimeter of float for the constrained points in the adjustment (effectively fixing and not allowing the constrained control points to move).

1.4.4.5.8 Session Network Baseline Design

The manager may select a basic network design strategy for the baselines created during session processing. The four **Session Network Baseline Designs** are:

USER: - the design no longer conforms to one of the other strategies.
CORS: -automatically selects all included CORS, and only the CORS, as hubs.
MST: -a 'minimal spanning tree' connecting all the included marks and CORS together using the fewest and shortest possible unique baselines.
TRI: -included marks and CORS are connected to their neighbors forming triangles (closed loops).

1.4.5 Solution Quality Indicators

Below the map, near the bottom of the web page (Figure 1.41), is a table listing selected solution quality values for all project marks in this session. The values are checked against the project's solution quality thresholds. If a value exceeds its preference threshold it is highlighted using an orange background color and border. In addition, the mark's icon is changed to reflect this condition. The **Solution Quality Indicators** table in figure 1.41 shows that the processing results for this session meet the project's preferences with green open-circle icons and no highlighted cells.

1.4.6 Data Availability

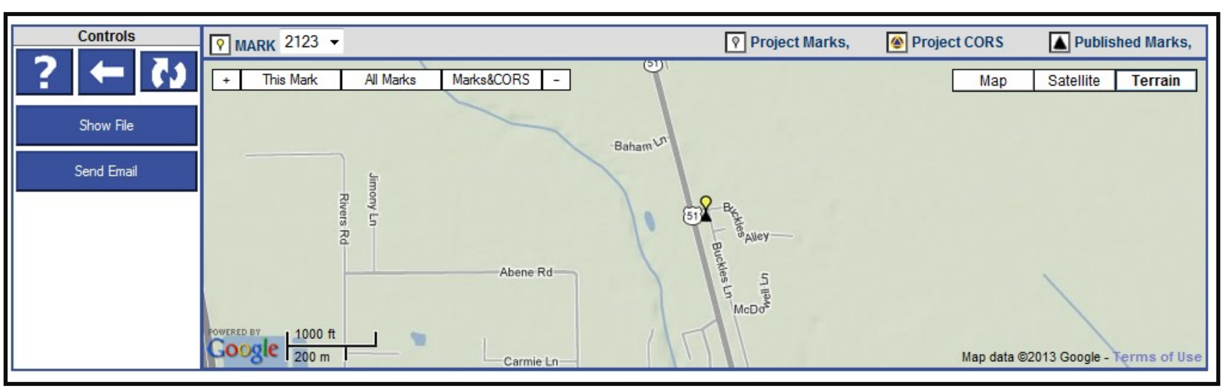
At the bottom of the web page (Figure 1.41) is the **Data Availability** table creating timeline-style graphics indicating data availability for each mark's data file in that session. Each cell represents a time span and number therein is the most common number of satellites (mode) for that span. If the number of satellites is greater than 9 (10, 11, 12, …) the cell will contain the hexadecimal representation (A, B, C, …). The cells in the table are color-coded. White for less than four satellites tracked, implying processing during the indicated time span is not possible. Then yellow through dark green indicating four or more satellites respectively.

1.5 Individual Project Mark Web Pages

Descriptions, photographs and occupation information, i.e. metadata, and processing results for individual project marks appear on dedicated web pages for those marks. A project manager can navigate to these **individual mark web pages** using the links provided in the **Sessions & Solutions** table (Section 1.3.6); others can navigate to these pages using the links in the **Solution Quality Indicators** table (Section 1.4.5) or the Data Availability table (Section 1.4.6). These tables always appear directly under the map on their respective web pages. In all cases, the mark IDs that serve as row labels in these tables are links to the corresponding project mark web page. Project members can also navigate to individual project mark web pages using the mark ID in the pop-up bubbles that appear when a mark icon on a map is clicked.

The individual project mark web pages have several sections and most have controls specific to the section. Furthermore, additional controls appear or are enabled if a mark's web page is accessed by the project manager.

Figure 1.52 - Project mark web page



1.5.1 Notices

Notices about OP and, very rarely, a message specific to a project (no other project will see these specific messages) may appear at the top of the project mark web pages. An email link to the OPUS Projects Team will appear with any notices and messages so that follow-up questions can be asked if needed.

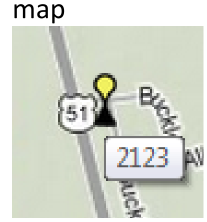
1.5.2 Map of the Project Mark Area

Similar to the manager's and session web pages, the project mark web pages include a Google Map Services™ interactive map to help orient users within the project and its geographic region (Figure 1.52). However, because its uses are different, the map looks different than those on the other web pages.

A legend appears above the map (Figure 1.52 & 1.53). Clicking an icon type symbol in the legend will hide/display those mark types on the map. The mark ID is also given in the legend. This is a pull-down menu, one of several such menus on the page, used to navigate to other mark web pages.

Figure 1.53 - Mark display options

Figure 1.54 - Mark display on map



Within the map display to the upper-left, there are zoom controls (+/-) plus three preset controls to zoom to see '**This Mark's**' immediate vicinity, '**All Marks**' or all '**Marks & CORS**' in the project. At the upper-right corner of the map (Figure 1.5.2), the map background can be set as either Terrain (digital elevation model), Satellite (satellite imagery if available), or Map (towns, streets & highways). Clicking on the map and holding the mouse button down will drag (pan) the map to view nearby areas as the cursor is moved across the web page. Holding the cursor over an icon without clicking will reveal the mark's ID (Figure 1.54).

As is described in the legend for the map, four types of marks may appear on the map:

 -A yellow "pin" identifies the location of the mark to which this web page refers.

 -Gray pins show the locations of other marks in this project. Initially, the map shows only a small area so other marks in the project may not appear until the map is shifted or "zoomed out".

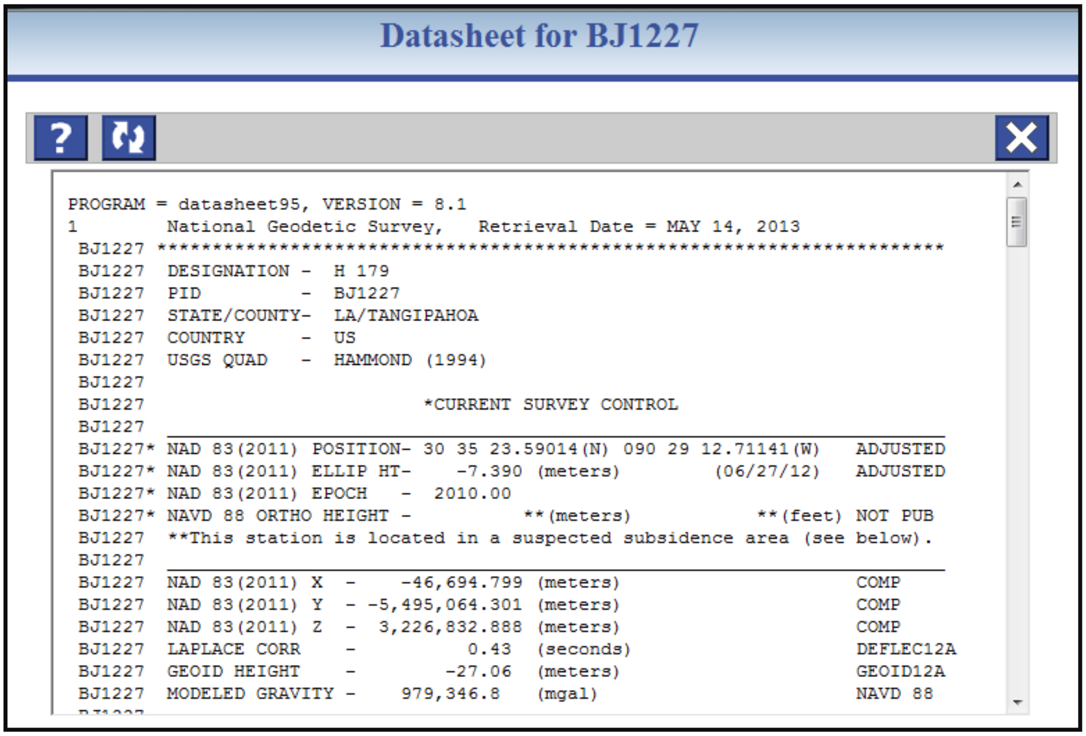
 -The standard blue with yellow trim icon identifies CORS. Again, the map shows only a small area so the CORS may not appear until the map is shifted or "zoomed out".

 -Black triangles appearing in the map indicate the locations of nearby marks for which published NSRS information exists in the NGSIDB. These published marks are not necessarily part of the project, but are shown because they help form the reference frame like the CORS. However, if this project mark has a PID, the published mark's icon will still appear, but as a yellow triangle (), thereby indicating this association. Clicking on one of these mark icons reveals a pop-up window displaying the mark's datasheet (Sections 1.5.2.1 and 1.5.2.2). Recall that a PID can be associated with a project mark either when its data files were uploaded or by using the controls on the projects mark's web page.

1.5.2.1 Standard Datasheet Pop-up Window

The banner for this window provides the mark's **Permanent Identifier** or **PID**. Typical pop-up window controls are located just below the banner: '**Help**' and '**Refresh**' buttons on the left; a '**Close**' button on the right. Below the controls, the datasheet is given.

Figure 1.54 - Mark NGSIDB datasheet


Datasheet for BJ1227

```
PROGRAM = datasheet95, VERSION = 8.1
1        National Geodetic Survey,   Retrieval Date = MAY 14, 2013
 BJ1227 ***********************************************************************
 BJ1227  DESIGNATION -  H 179
 BJ1227  PID         -  BJ1227
 BJ1227  STATE/COUNTY-  LA/TANGIPAHOA
 BJ1227  COUNTRY     -  US
 BJ1227  USGS QUAD   -  HAMMOND (1994)
 BJ1227
 BJ1227                       *CURRENT SURVEY CONTROL
 BJ1227  ______________________________________________________________________
 BJ1227* NAD 83(2011) POSITION- 30 35 23.59014(N) 090 29 12.71141(W)   ADJUSTED
 BJ1227* NAD 83(2011) ELLIP HT-    -7.390 (meters)        (06/27/12)   ADJUSTED
 BJ1227* NAD 83(2011) EPOCH   -  2010.00
 BJ1227* NAVD 88 ORTHO HEIGHT -          **(meters)           **(feet) NOT PUB
 BJ1227  **This station is located in a suspected subsidence area (see below).
 BJ1227  ______________________________________________________________________
 BJ1227  NAD 83(2011) X  -    -46,694.799 (meters)                     COMP
 BJ1227  NAD 83(2011) Y  - -5,495,064.301 (meters)                     COMP
 BJ1227  NAD 83(2011) Z  -  3,226,832.888 (meters)                     COMP
 BJ1227  LAPLACE CORR    -          0.43  (seconds)                    DEFLEC12A
 BJ1227  GEOID HEIGHT    -        -27.06  (meters)                     GEOID12A
 BJ1227  MODELED GRAVITY -    979,346.8   (mgal)                       NAVD 88
```

1.5.2.2 Project Manager's Datasheet Pop-up Window

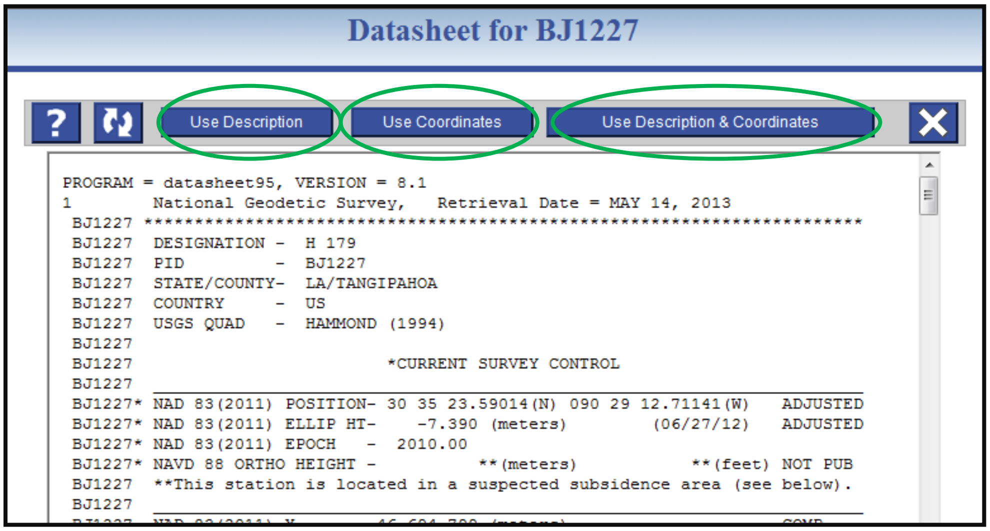
If the project manager accesses a record mark page and views a published mark datasheet, then in that window's controls are included three special function buttons (Figure 1.55):

'Use Description' applies information from the datasheet to the *empty* description elements for this project mark. Restating, the published description can be applied to this mark, but it will not supplant/replace information previously entered at upload or by the project manager.

'Use Coordinates' replaces the a priori coordinates for this project mark (based on the OPUS solution) with the record mark's datasheet coordinates. **<u>Be aware that changing the a priori coordinates for a project mark invalidates all existing project processing. Changing the a priori coordinates for a mark should be done cautiously before any processing is completed</u>. If you choose to change the a priori coordinate you have decided that the mark coordinate from the datasheet is BETTER than the coordinate created when you uploaded your mark data to the project through OPUS. This would be a very rare occurrence. USE WITH CAUTION!**

'Use Description & Coordinates' is a simple convenience activating both the other controls simultaneously.

Figure 1.55 - Datasheet function buttons



1.5.3 Controls

The web page's controls appear to the left of the map. Standard controls, Section 1.5.3.1, are always available, but additional controls are provided for the project manager, Section 1.5.3.2.

1.5.3.1 Standard Controls

Figure 1.52 shows the basic controls for an individual project mark's web page.

1.5.3.1.1 Help, Back and Refresh

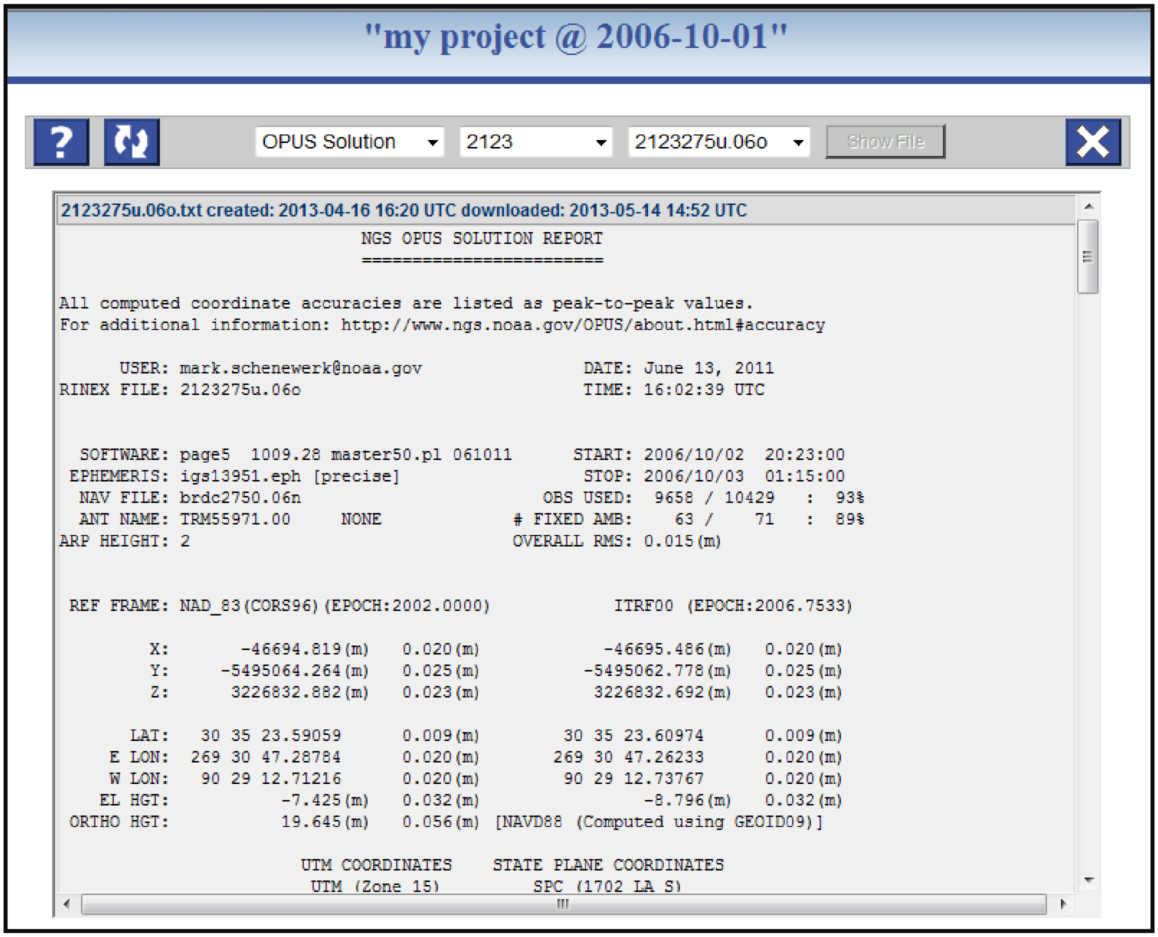
Help, **Back**, and **Refresh** buttons at the top of the controls. The **Help** button is under development and may ultimately provide the same resource as this document. The **Back** button "moves back" to the previous web page in the browser's history. Its action is identical to the browser's back control. The **Refresh** button forces the project to be scanned and the session web page to be reloaded. Its action is usually stronger than the browsers refresh button which may only bring up a previously cached version.

1.5.3.1.2 Show File

The **Show File** button reveals a pop-up window for displaying solution reports. Across the top of the window are controls (Figure 1.49 and 1.56). Standard pop-up window controls appear at the top, but instead of a single button at the top-center to initiate an action, this window offer a choice of available reports: OPUS, session processing, or network adjustments. Below the controls is a header providing the report's name, its creation and download (current) times. Then the report is displayed.

Some browsers offer a print option by right-clicking (right mouse button) anywhere in the report. All browsers should allow the report's text to be copied and pasted into another file using the method typical of the operating system. See **Appendix B** for more information.

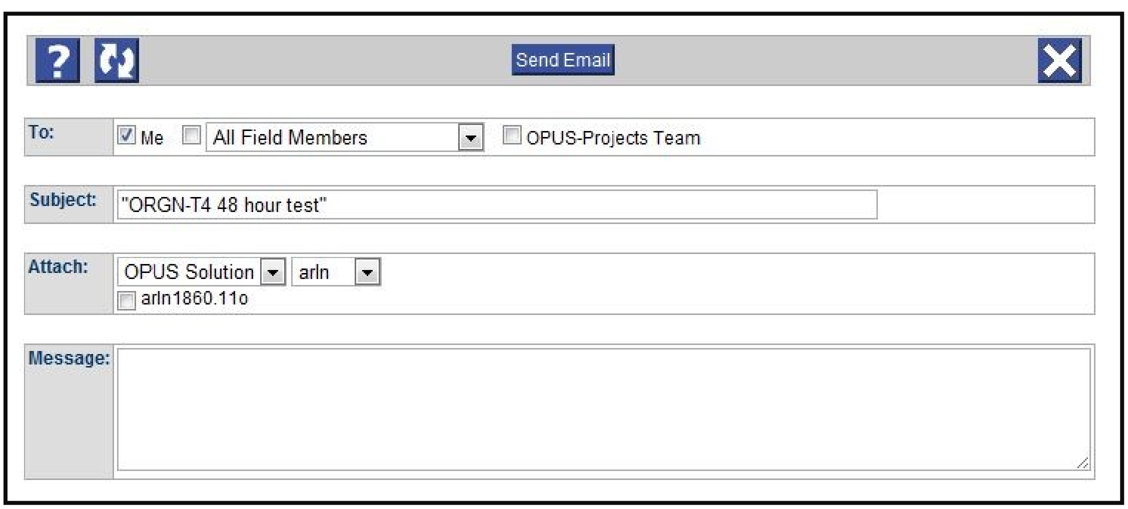
Figure 1.56 - Show file solution report which may be printed



1.5.3.1.3 Send Email

Send Email displays a pop-up window with basic controls permitting the project member viewing this page to send emails to members of the project team, including herself or himself, or the OPUS Projects team. Pop-up window controls appear across the top. Below these controls, the email's recipients can be selected and subject added. The emails can include available reports as attachments. These can be selected by using the next controls. Finally, there is an entry field for a short text message.

Figure 1.57 - Send email for project members

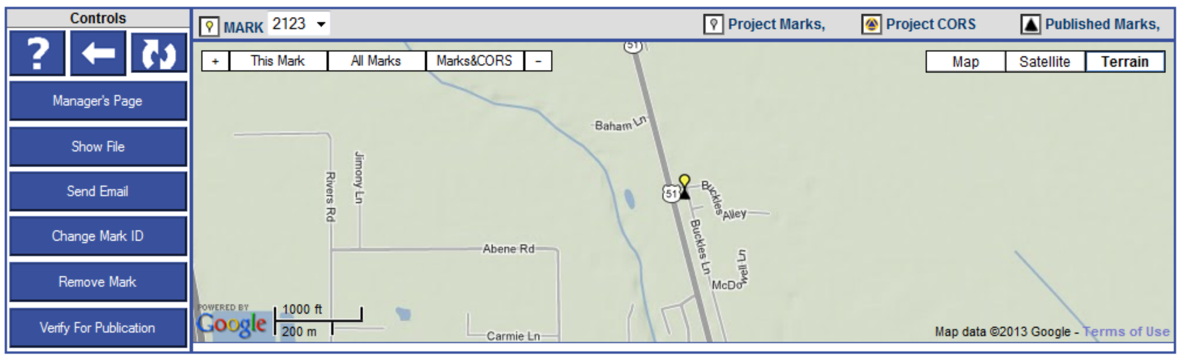


The following section beginning with **1.5.3.2 Manager Controls** discusses features available to the project manager starting with the Project Mark Page. The text has been edited to direct program use by the project manager. Although many processes seem similar to the session pages, accessible by project members, they may be distinctly different in menu appearance and process flow. They have been provided here for rapid access and clarity.

1.5.3.2 Project Manager Controls

If a project mark's web page is accessed by the project manager, additional controls are provided (Figure 1.58). These include:

Figure 1.58 - Project manager controls for the mark web page



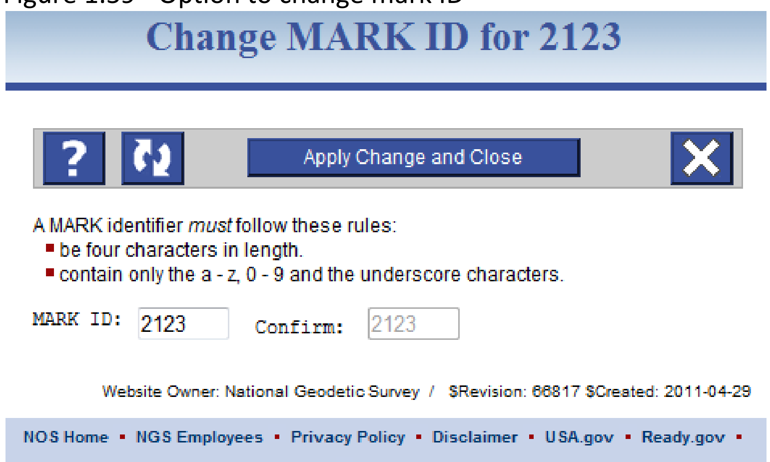
1.5.3.2.1 Manager's Page

A shortcut directly to the project manager's web page.

1.5.3.2.2 Change Project Mark ID

The '**Change Project Mark ID**' button reveals a pop-up window with controls to change this mark's four character ID. Typical pop-up window controls appear across the top of the window (Figure 1.59). Below those controls are the rules for a mark ID, then two entry fields: an entry and confirmation field. When the new mark ID field is changed, the confirmation field is enabled (no longer grayed out). To '**Apply Change and Close**', the input and confirmation IDs must match.

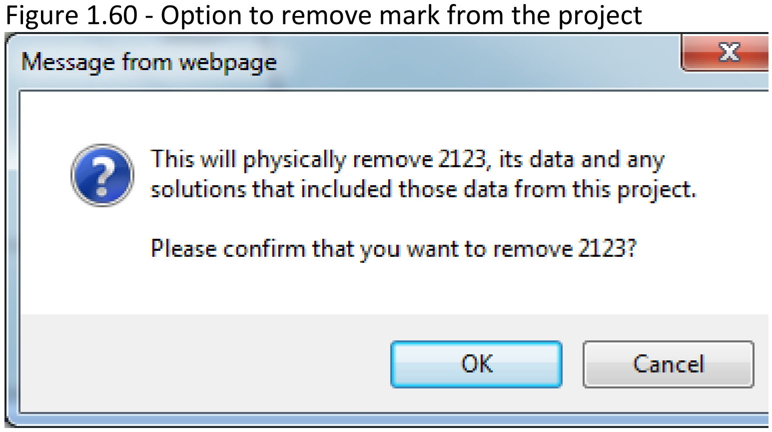
Figure 1.59 - Option to change mark ID



1.5.3.2.3 Remove Project Mark

The '**Remove Project Mark**' button will display a message requesting confirmation before removing the mark (Figure 1.60). If confirmed, the mark, its data files, all processing solutions and network adjustment that include those mark data files are permanently removed from the project and the updated project manager's page is displayed.

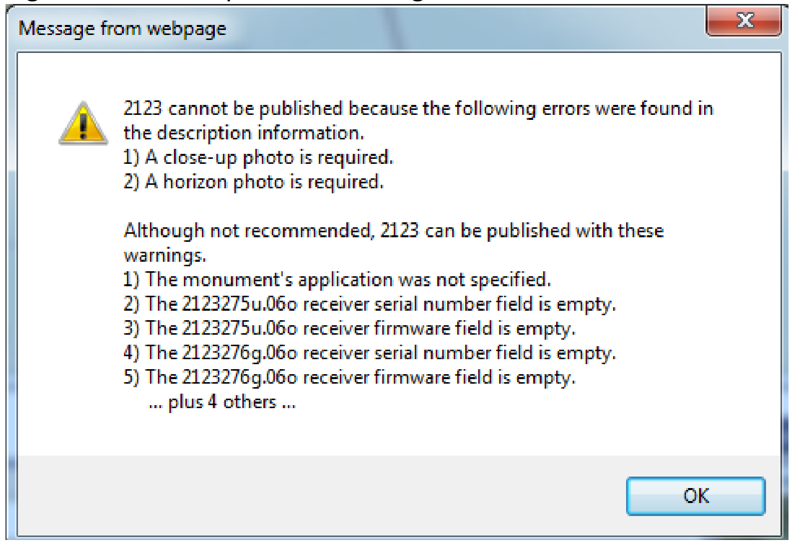
Figure 1.60 - Option to remove mark from the project



1.5.3.2.4 Verify For Submission and Sharing of Results to NGS

The '**Verify For Submission and Sharing** button is currently greyed out and inactive.

Figure 1.61 - Example error message



1.5.4 Shared Mark Web Page Mock-up

Below the map is a mock-up of a shared mark webpage. Note that in the label identifying this section is another pull-down menu used to navigate to other project mark web pages (Figure 1.62). The overall layout of this section of the web page is consistent (Section 1.5.4.1). Additional controls, specifically related to the mark description, are provided for the project manager (Section 1.5.4.2).

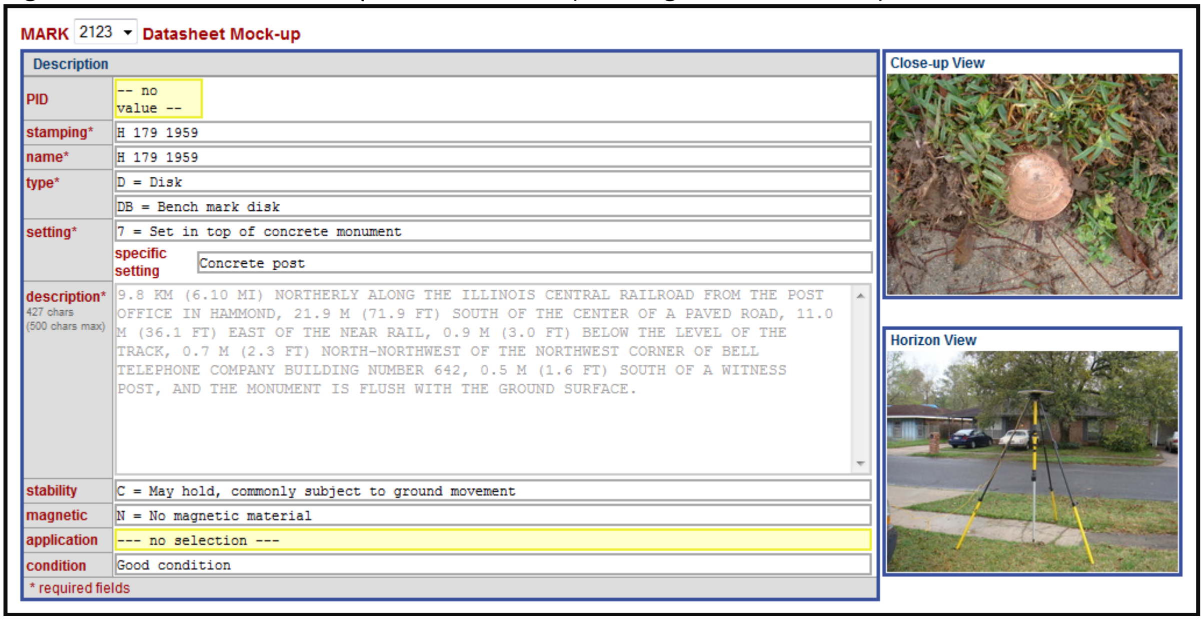
1.5.4.1 Standard Shared Mark Web Page Mock-up Information

This mock-up mimics the OPUS-DB shared mark web page in that it contains a minimal amount of information:

- **PID**: -permanent Identifier assigned when new project marks are observed and their data submitted to NGS.
- **stamping**: -the unique mark ID, if any, that the original mark-setter struck into the disk (brass or aluminum cap) when the mark was set and/or reset.
- **name**: -is a user-friendly identifier, unique for the area and usually descriptive of the mark stamping or location.
- **type:** -a physical description of the type of surveyed monument.
- **setting**: -the structure to which a mark is affixed. There is a **specific setting** optional field to add comments about the setting.
- **description**: -(for new project marks) state distances and directions (swing ties) to local features (posts, trees, building corners, street centerlines, etc.) along with any other salient features (recommended approach, hazards, etc.). This will help future surveyors recover and assess the suitability of the mark for use in their project. The description may be updated.
- **stability**: -estimate of the long-term stability of the mark.
- **magnetic**: -specifies any magnetic material in or alongside the setting to aid in mark recovery.
- **application**: -use to identify marks for specific special applications.
- **condition**: -a basic estimate of the project marks condition.

Empty or erroneous fields are highlighted to help visually identify problems: red for errors in required fields; yellow for optional fields. Also required are two photos: a close-up such that the mark disk surface is readily visible and any stamping is readable and a horizon shot aligned to show the most recognizable local features: witnesses, visibility obstructions, equipment in use or to clarify the mark location. Thumbnails (smaller images representative of the full-sized images) of these photos, if they have been provided, are shown to the right of the description. Clicking on one of the thumbnails reveals a pop-up window with the full sized image.

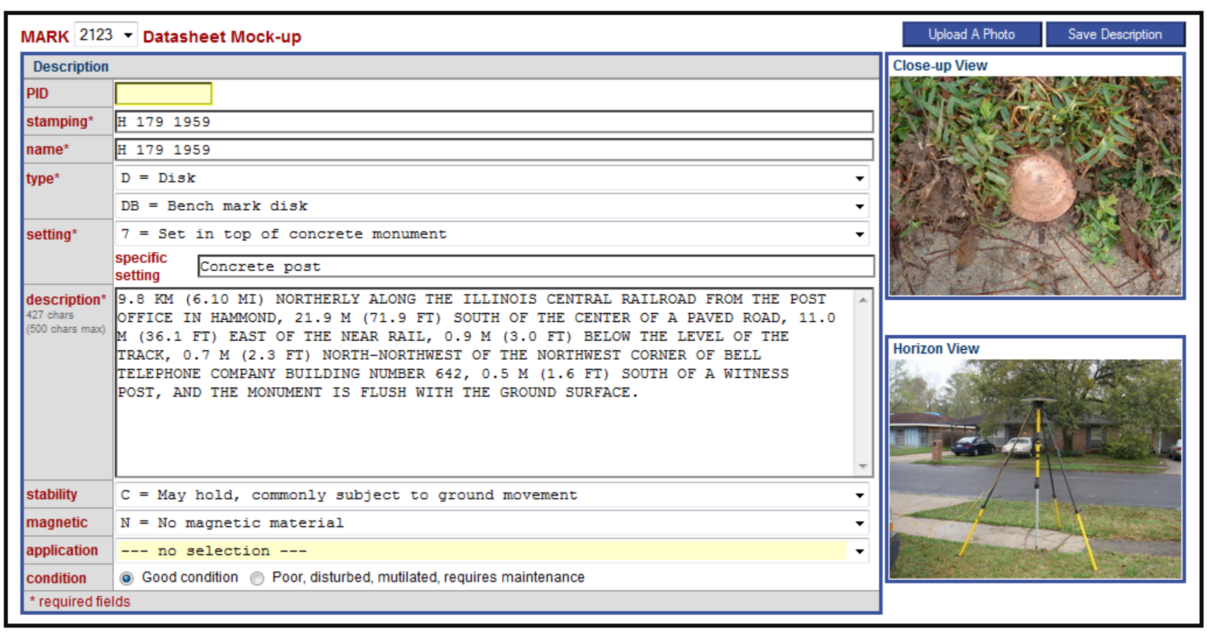
Figure 1.62 - Photo and description mark sheet (showing erroneous fields)



1.5.4.2 Project Manager Mark Sheet for Sharing (Mock-up)

The appearance of the project-specific mark sheet for future sharing to OPUS-DB (datasheet) mock-up is very similar for the project manager, but the fields can be edited offering a means to correct or complete the description provided as part of the data file uploading process.
Be aware that as fields are edited, they might become highlighted indicating erroneous input: red for required fields, yellow for optional fields. When corrected, the fields will return to their normal appearance. Most fields have a limited number of standard values they can assume, so their input is through pull-down menus thereby insuring valid input is provided (Figure 1.63). If changes are made, be sure to save those changes before leaving this web page (Section 1.5.6.2). Two additional controls, ("**Upload a Photo**" and "**Save Description**"), in line with the section label in the upper right corner, are provided and described below.

Figure 1.63 - Photo and description mark sheet for editing



1.5.4.2.1 Upload A Photo

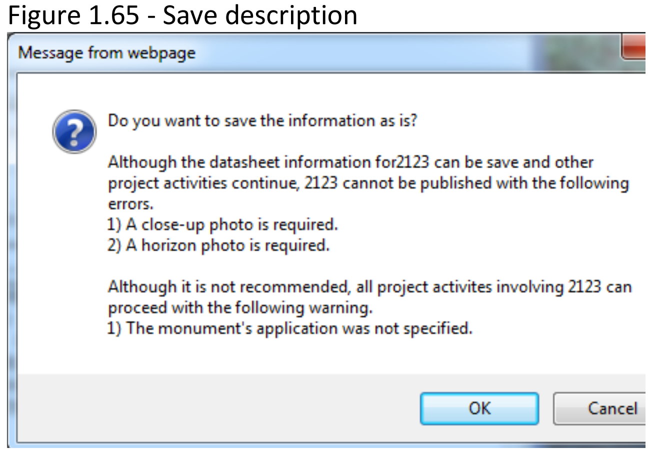
The purpose of the **Upload A Photo** button is to select (your) photos to upload. When clicked, a pop-up window appears providing controls to upload photos of the mark into the project (Figure 1.64). The pop-up window controls across the top of the window are the standard Help, Refresh and Close buttons plus the button to upload the selected files. The file names of photos to be uploaded can be entered manually, but it is easier and safer to use the **Browse** control to navigate to and select the files interactively.

Figure 1.64 - Upload photos

1.5.4.2.2 Save Description

Once changes to the description are completed, those changes must be saved to the project using the <u>Save Description</u> button. The description is checked and any issues reported in a message window. As indicated by the example shown in Figure 1.65, incomplete descriptions can be saved, but they cannot be uploaded to NGS until they are complete.

Figure 1.65 - Save description



1.5.5 Occupations

The occupations summary is next on the web page. Here the occupation times and hardware associated with each data file for this project mark are listed. Again, the label identifying this section contains another pull-down menu used to navigate to other project mark web pages (Figure 1.66). Like the previous sections of the web page, additional controls are available for the project manager.

1.5.5.1 Standard Occupations

The occupations summary is essentially a table (Figure 1.66). To the far left, spanning two rows and acting as a label for those two rows, the data file name is given. Next are the data spans starting and ending epochs. The rest of the information describes the hardware used to collect the data. The antenna model name, serial number and the height of its ARP above the mark are on the first line; the receiver's model name, serial number and firmware identifier are on the second. The antenna model name and ARP height are required; all other values are optional, but providing them is recommended. Missing or erroneous values are highlighted: red for required values, yellow for optional values.

Figure 1.66

MARK 2123 Occupations

DATA FILE	SPAN		HARDWARE						
2123275u.06o	Start	2006-10-02T20:23:30 GPS	Antenna	Model:	TRM55971.00 NONE	S/N:	30212716	Height (m):	2.000
	End	2006-10-03T01:15:45 GPS	Receiver	Model:	TRIMBLE NETR5	S/N:	-- no value --	Firmware:	-- no value --
2123276g.06o	Start	2006-10-03T06:23:30 GPS	Antenna	Model:	TRM55971.00 NONE	S/N:	30212716	Height (m):	2.000
	End	2006-10-03T10:40:45 GPS	Receiver	Model:	TRIMBLE NETR5	S/N:	-- no value --	Firmware:	-- no value --
2123276s.06o	Start	2006-10-03T18:23:15 GPS	Antenna	Model:	TRM55971.00 NONE	S/N:	30212716	Height (m):	2.000
	End	2006-10-04T00:07:30 GPS	Receiver	Model:	TRIMBLE NETR5	S/N:	-- no value --	Firmware:	-- no value --
2123277g.06o	Start	2006-10-04T06:23:15 GPS	Antenna	Model:	TRM55971.00 NONE	S/N:	30212716	Height (m):	2.000
	End	2006-10-04T10:23:30 GPS	Receiver	Model:	TRIMBLE NETR5	S/N:	-- no value --	Firmware:	-- no value --

1.5.5.2 Project Manager's Occupations

For the project manager, there are two additional controls which appear to the upper-right in line with this web page section's label, and the table's hardware fields may be edited (Figure 1.67). *This includes the antenna type name and ARP height entered when the data files were uploaded.* The antenna model name field is a pull-down menu consisting of all tested antenna types. The other fields are simple text entry fields.

Missing or erroneous values will be highlighted: red for required fields, yellow for optional fields. Be sure to save any changes (Section 1.5.5.2.1) before leaving the web page. Note that any changes here may affect previous session processing and network adjustment.

Figure 1.67 - Manage occupation data files and save

MARK 2123 Occupations Manage Data Files Save Occupations

DATA FILE	SPAN		HARDWARE						
2123275u.06o	Start	2006-10-02T20:23:30 GPS	Antenna	Model:	TRM55971.00 N(	S/N:	30212716	Height (m):	2.000
	End	2006-10-03T01:15:45 GPS	Receiver	Model:	TRIMBLE NETR5	S/N:		Firmware:	
2123276g.06o	Start	2006-10-03T06:23:30 GPS	Antenna	Model:	TRM55971.00 N(	S/N:	30212716	Height (m):	2.000
	End	2006-10-03T10:40:45 GPS	Receiver	Model:	TRIMBLE NETR5	S/N:		Firmware:	
2123276s.06o	Start	2006-10-03T18:23:15 GPS	Antenna	Model:	TRM55971.00 N(	S/N:	30212716	Height (m):	2.000
	End	2006-10-04T00:07:30 GPS	Receiver	Model:	TRIMBLE NETR5	S/N:		Firmware:	
2123277g.06o	Start	2006-10-04T06:23:15 GPS	Antenna	Model:	TRM55971.00 N(	S/N:	30212716	Height (m):	2.000
	End	2006-10-04T10:23:30 GPS	Receiver	Model:	TRIMBLE NETR5	S/N:		Firmware:	

1.5.5.2.1 Manage Data Files

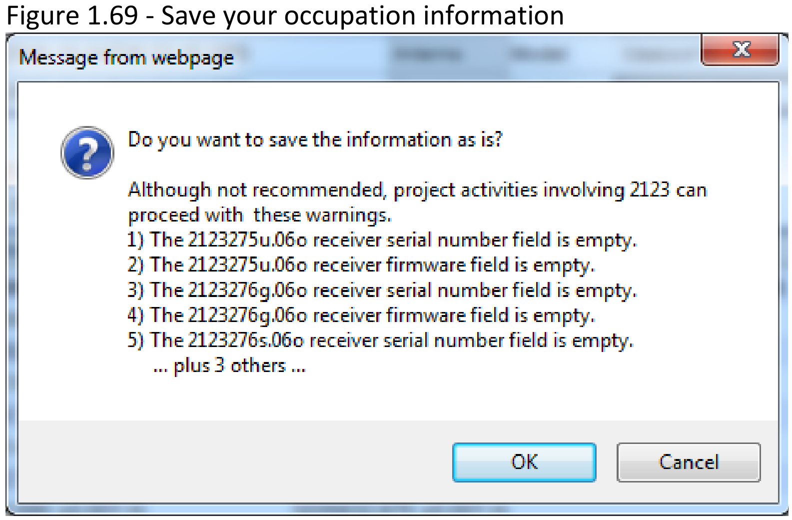
The **Manage Data Files** pop-up controls are used on those rare occasions when unwanted data files appear in a project, or are incorrectly associated with a project mark. Standard pop-up window controls, **Help**, **Refresh** and **Close**, are provided near the top of the window. Next, the data files associated with this mark are listed. Beside each data file name are controls to make **Available** to or be **Removed** from the project. When a data file is removed, it is only moved to an alternate storage location in the project, so it can be made available again if desired. To the far right of each line is a control that will associate the data file with ("Group With") an existing mark ID in your project. **Any changes must be explicitly applied for them to take effect.**

Figure 1.68 - Manage RINEX file associated with mark ID's

1.5.5.2.2 Save Occupations

⚠ If changes were made to the hardware information (Figure 1.67), they must be saved using the **Save Occupations** button. At that time, the hardware information is checked and any issues reported. If errors are found, they are reported using a message window like that shown in figure 1.69. If errors are found in any required field, i.e. the antenna names and ARP heights, the information cannot be saved. Missing or erroneous optional information can be saved although it is not recommended.

Figure 1.69 - Save your occupation information



1.5.6 Processing Results

Below the occupations table are the **Processing Results**. This section repeats results from the desired solution for completeness and as a convenience so the solution report does not have to be opened and searched. The label identifying this section of the web page, like the other section labels, contains a pull-down menu used to navigate to other mark web pages (Figure 1.70). Another pull-down menu is used to select the specific OPUS, session processing or network adjustment solution results to be displayed. For the project manager, controls to change selected preferences *for this mark only* are provided.

1.5.6.1 Standard Processing Results

Immediately below the label for this section is a pull-down menu giving limited control of scaling for the reported coordinate uncertainties (Figure 1.70). The default for all projects is one sigma[3] , but a project's specifications may differ. Note that this menu is linked to similar menus in the Processing Results Plots (Section 1.5.7) and Tables (Section 1.5.8) sections. Changing the uncertainty scaling here will change the scaling in these other sections.

Figure 1.70 - Processing results

MARK 2123 Processing Results From network-final

Scale uncertainties by 1.0x (68.3%).

Coordinate Source: network-final					
REF FRAME:	ITRF2000 (2006.7552)	NAD_83(CORS96) (2002.0000)	COORDINATE SYSTEM:	SPC 1702 LA S	UTM 15
LAT:	N30:35:23.60935 ±0.000 m	N30:35:23.59020 ±0.000 m	NORTHING:	231955.820 m	3386842.990 m
EAST LON:	E269:30:47.26263 ±0.000 m	E269:30:47.28814 ±0.000 m	EASTING:	1081182.801 m	740977.297 m
WEST LON:	W090:29:12.73737 ±0.000 m	W090:29:12.71186 ±0.000 m	CONVERGENCE:	0.42324521°	1.27952544°
EL HGT:	-8.788 ±0.002 m	-7.417 ±0.002 m	POINT SCALE:	0.99997843	1.00031642
X:	-46695.478 ±0.000 m	-46694.811 ±0.000 m	COMBINED FACTOR:	0.99997960	1.00031759
Y:	-5495062.791 ±0.001 m	-5495064.277 ±0.001 m	U.S. NATIONAL GRID:	15RYP4097786843(NAD 83)	
Z:	3226832.686 ±0.001 m	3226832.876 ±0.001 m			
ORTHO HGT: 19.653 ±0.012 m (H = h - N WHERE N = GEOID09 HGT)					

DATA FILE	ANTENNA	HEIGHT (m)	EPH TYPE	OBS (%)	FIXED (%)	RMS (m)	LAT (m)	LON (m)	HGT (m)	SOLUTION
2123275u.06o	TRM55971.00 NONE	2.000	precise	93.9	92.2	—	0.000	0.000	0.002	network-final
2123276g.06o	TRM55971.00 NONE	2.000	precise	93.9	92.2	—	0.000	0.000	0.002	network-final
2123276s.06o	TRM55971.00 NONE	2.000	precise	93.9	92.2	—	0.000	0.000	0.002	network-final
2123277g.06o	TRM55971.00 NONE	2.000	precise	93.9	92.2	—	0.000	0.000	0.002	network-final
Preferences			Best Available	≥80.0	≥80.0	≤0.025	≤0.030	≤0.030	≤0.060	Preferences

The remainder of this section is composed of two tables. The first table lists the coordinates from the designated solution report for this mark. Recall that coordinates in a global reference frame, the ITRF 2000 in the example shown in figure 1.70, are used in the processing and always reported, but an alternate reference frame or datum can be selected and, if possible, will be reported. The coordinates will be listed in a column with the reference frame or datum, and epoch of the coordinates on the first row acting as a column label. Beneath these, the orthometric height and the geoid model used to compute this value are given. Similarly, UTM coordinates are always given, but State Plane Coordinate System (SPCS) coordinates will also be given if the mark is located inside a SPCS zone. Below these, the U.S. National Grid designation is also given when appropriate.

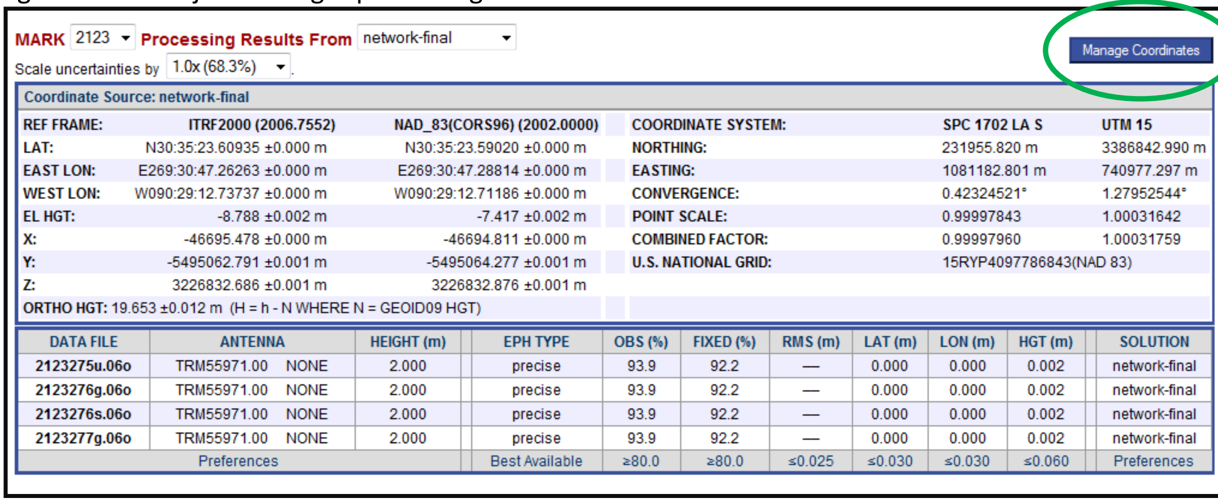
The second table lists all data files associated with this mark and indicates which are used in the selected solution along with the values against which the solution quality thresholds are tested. Any of these values that do not meet these thresholds are highlighted.

[3] One sigma, or "1 σ" refers to the standard deviation about some mean value.

1.5.6.2 Project Manager's Processing Results

Like the other sections, the appearance of this section when the mark page is accessed by the project manager is essentially identical to the display allowed to team members that are not managers. A new control called **Manage Coordinates** appears to the upper-right, in line with the section label (Figure 1.71).

Figure 1.71 - Project manager processing results



MARK 2123 Processing Results From network-final

Scale uncertainties by 1.0x (68.3%)

Manage Coordinates

Coordinate Source: network-final

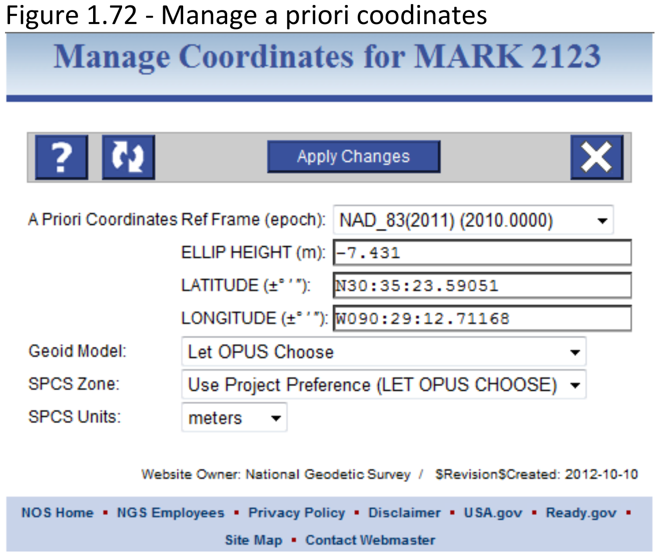
REF FRAME:	ITRF2000 (2006.7552)	NAD_83(CORS96) (2002.0000)	COORDINATE SYSTEM:	SPC 1702 LA S	UTM 15
LAT:	N30:35:23.60935 ±0.000 m	N30:35:23.59020 ±0.000 m	NORTHING:	231955.820 m	3386842.990 m
EAST LON:	E269:30:47.26263 ±0.000 m	E269:30:47.28814 ±0.000 m	EASTING:	1081182.801 m	740977.297 m
WEST LON:	W090:29:12.73737 ±0.000 m	W090:29:12.71186 ±0.000 m	CONVERGENCE:	0.42324521°	1.27952544°
EL HGT:	-8.788 ±0.002 m	-7.417 ±0.002 m	POINT SCALE:	0.99997843	1.00031642
X:	-46695.478 ±0.000 m	-46694.811 ±0.000 m	COMBINED FACTOR:	0.99997960	1.00031759
Y:	-5495062.791 ±0.001 m	-5495064.277 ±0.001 m	U.S. NATIONAL GRID:	15RYP4097786843(NAD 83)	
Z:	3226832.686 ±0.001 m	3226832.876 ±0.001 m			
ORTHO HGT: 19.653 ±0.012 m (H = h - N WHERE N = GEOID09 HGT)					

DATA FILE	ANTENNA		HEIGHT (m)	EPH TYPE	OBS (%)	FIXED (%)	RMS (m)	LAT (m)	LON (m)	HGT (m)	SOLUTION
2123275u.06o	TRM55971.00	NONE	2.000	precise	93.9	92.2	—	0.000	0.000	0.002	network-final
2123276g.06o	TRM55971.00	NONE	2.000	precise	93.9	92.2	—	0.000	0.000	0.002	network-final
2123276s.06o	TRM55971.00	NONE	2.000	precise	93.9	92.2	—	0.000	0.000	0.002	network-final
2123277g.06o	TRM55971.00	NONE	2.000	precise	93.9	92.2	—	0.000	0.000	0.002	network-final
	Preferences			Best Available	≥80.0	≥80.0	≤0.025	≤0.030	≤0.030	≤0.060	Preferences

1.5.6.2.1 Manage Coordinates

The **Manage Coordinates** control permits the project manager to change the a priori coordinates and selected preferences *for this mark only*. The standard pop-up window controls are provided near the top of the window (Figure 1.72). Below these, the **a priori Coordinates** are given. These can be presented in one of several reference frames and epochs in use in the project. Changing the a priori coordinates is <u>not</u> recommended for the following reasons. The a priori coordinates for all project marks come from the OPUS solution for the first data file associated with the mark and OPUS solutions are known to be reliable and accurate. However, although rare, OPUS solutions can be of noticebly poorer qualtiy especially if GPS satellite visibility is obstructed. For those rare instances when an OPUS solution is more than 1 meter in error, improving the a priori coordinates can improve the processing results.

Figure 1.72 - Manage a priori coodinates



<u>Changing a priori coordinates invalidates any existing processing which includes data from that mark. so that those processed results will be deleted.</u>

Below the a priori coordinates are preferences for the **Geoid Model**, **SPCS Zone** and **SPCS Units**. Usually, the preferences will apply to all marks, but exceptions can occasionally occur. One example is the SPCS zone. Normally, OP will select the appropriate SPCS zone to use, but, if one is working near the border between zones, an incorrect zone might be selected, or the project specifications could require the same SPCS zone be used for all marks. Results using these preferences are derived from the processing results in the global reference frame, so changing these preferences does *not* invalidate existing processing.

1.5.7 Processing Results Plots

Towards the bottom of the web page are **Processing Results Plots**. This section of the web page also begins with an identifying label. Like all the section labels, it contains a pull-down menu used to navigate to other project mark web pages (Figure 1.73).

Below this label are controls for the plots. To the far left is a pull-down menu controlling the scaling of coordinate uncertainties shown in the plots (Figure 1.73). The default for all projects is one sigma. In addition to being linked to the **Processing Results Tables**, this menu is linked to the **Processing Results** (Section 1.5.6) in such a way that changing the uncertainty scaling here will change the scaling for values given in those sections. To the right are buttons showing the symbols used in the plots for different classes of results. These buttons toggle display of the corresponding class of results. These are "linked" to the controls for the **Processing Results Tables** (Section 1.5.8) such that toggling a class of results here will similarly affect the tables. The symbols used in the plots are:

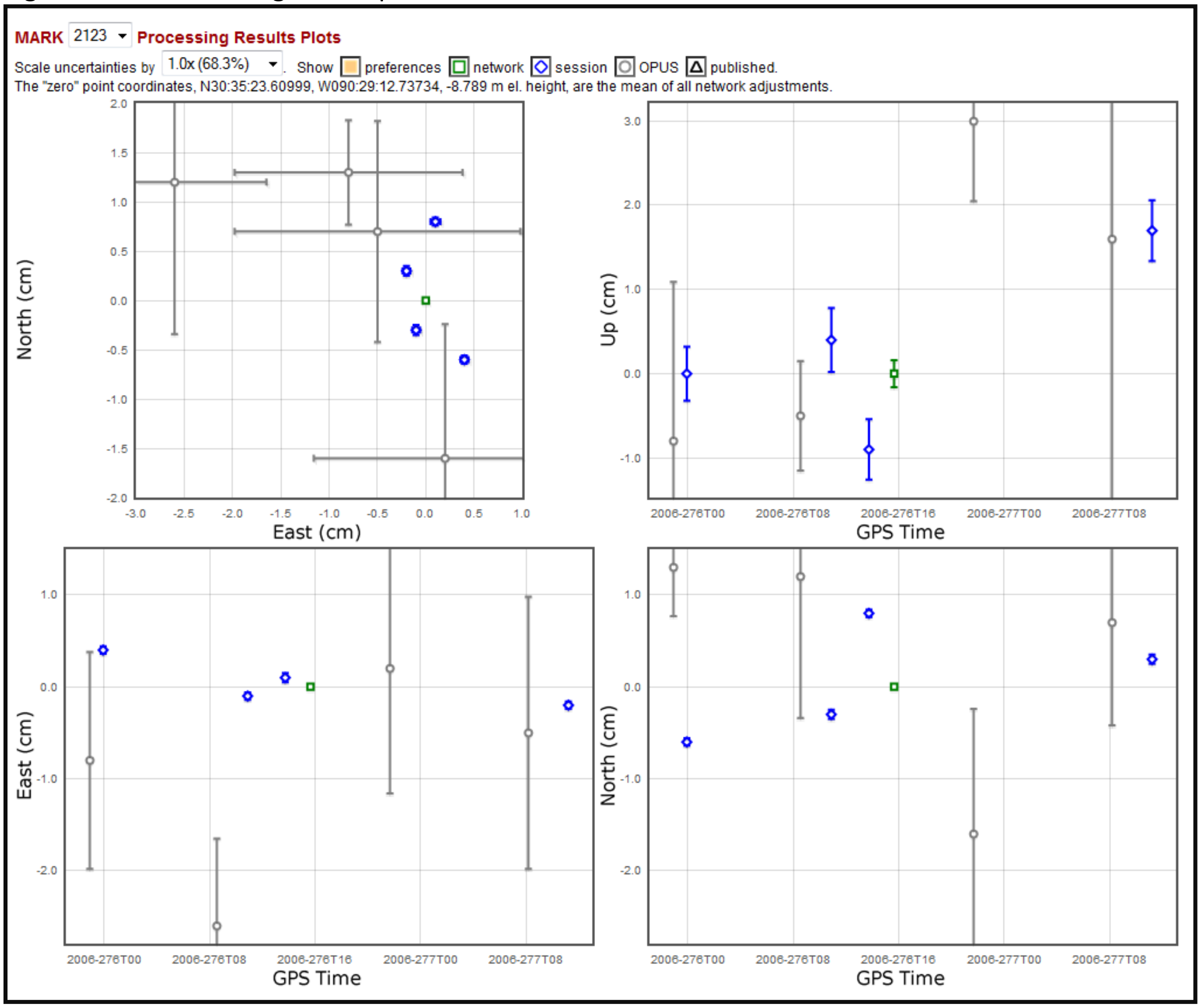
-Orange shaded areas indicate where results that fail to meet project preferences will appear.
-Gray circles are used for OPUS solution results.
-Blue diamonds are used for session processing solution results.
-Green squares are used for network adjustment results.

Immediately below the plot controls, the zero point coordinates of the plots and the source of this zero point is given. The zero point source will change as processing in the project progresses: first an un-weighted mean of the OPUS solutions from the mark's data files is used, then an unweighted mean of any session processing results, finally, an unweighted mean of any network adjustment results.

The plot axes are automatically defined to encompass all points plus the error bars for session solution and network adjustment results only. As a result, the error bars for OPUS solutions may extend beyond the plot and not be entirely visible. There is logic to this design. Although it is unlikely, there are cases where the OPUS error bars are so large that they would shrink the meaningful part of the plot, the points themselves, to inscrutability. Note that the orange shaded regions that indicate solutions that fail to meet the project's preferences may not appear if all solutions meet those preferences (see the examples in Figure 1.73).

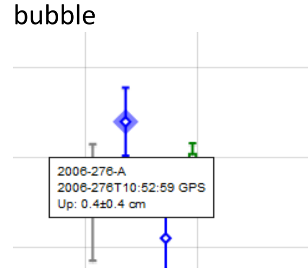
Four plots are shown: **North versus East** (sometimes called a horizontal coordinate scatter plot) to the upper-left, **Up versus GPS Time** (ellipsoid height time series plot) to the upper-right, **East versus GPS Time** (longitude time series plot) in the lower-left and **North versus GPS Time** (latitude time series plot) in the lower-right. Each point in these plots will have the corresponding uncertainties plotted as error bars. There are three items to note. First, the results displayed are in centimeters not meters. Second, the uncertainties for a result can be so small as to make the error bars difficult to distinguish. Finally, the North versus East plot will always be a square with identical tick intervals to facilitate visual comparison of the north and east results. For this same reason, the east and north axes on the East versus GPS Time and North versus GPS Time plots will be the same size with the same tick interval.

Figure 1.73 - Processing results plots



The plots are interactive. Moving the cursor over a point causes the point to be accentuated and an information bubble to appear providing information about the point and identifying its source solution (Figure 1.74). The plots also interact with the **Processing Results Tables** (Section 1.5.8). Moving the cursor over a table row causes the corresponding point in the plots to be accentuated.

Figure 1.74 - Point Info bubble



1.5.8 Processing Results Tables

At the bottom of the web page are **Processing Results Tables**. Like all the others, this section of the web page begins with an identifying label containing a pull-down menu used to navigate to other mark web pages (Figure 1.75). The table presents in tabular form the identical information provided in the plots.

Below this label are controls for the tables. To the far left is a pull-down menu controlling the scaling of coordinate uncertainties shown in the tables. The default for all projects is one sigma. This menu is linked to the Processing Results (Section 1.5.6) and Processing Results Plots (Section 1.5.7) in such a way that changing the uncertainty scaling here will change the scaling for the uncertainties shown in those sections. To the right are buttons showing the symbols used in the plots for different classes of results. These buttons toggle display of the corresponding class of results. These are "linked" to the controls for the **Processing Results Plots** (Section 1.5.7) such that toggling a class of results here will similarly affect the plots. The symbols used are:

-Orange shaded areas indicate where results that fail to meet project preferences will appear.
-Gray circles are used for OPUS solution results.
-Blue diamonds are used for session processing solution results.
-Green squares are used for network adjustment results.

Immediately below the table controls, the zero point (0,0) coordinates of the plots and the source of this zero point is given. Similar to the plots, the zero point source will change as processing in the project progresses: first an unweighted mean of the OPUS solutions from the mark's data files is used, then an unweighted mean of any session processing results, finally, an unweighted mean of any network adjustment results.

Figure 1.75 - Processing results table

MARK 2123 Processing Results Table

Scale uncertainties by 1.0x (68.3%) Show preferences network session OPUS published.

The "zero" point coordinates, N30:35:23.60999, W090:29:12.73734, -8.789 m el. height, are the mean of all network adjustments.

OPUS SOLUTIONS	NORTH (cm)	EAST (cm)	UP (cm)	REFERENCE FRAME	EPOCH (GPS)
2123275u.06o	1.3 ±0.5	-0.8 ±1.2	-0.8 ±1.9	IGS08	2006-10-02T22:54:28
2123276g.06o	1.2 ±1.5	-2.6 ±0.9	-0.5 ±0.6	IGS08	2006-10-03T08:32:38
2123276s.06o	-1.6 ±1.4	0.2 ±1.4	3.0 ±0.9	IGS08	2006-10-03T21:41:02
2123277g.06o	0.7 ±1.1	-0.5 ±1.5	1.6 ±3.2	IGS08	2006-10-04T08:11:45
SESSION SOLUTIONS	NORTH (cm)	EAST (cm)	UP (cm)	REFERENCE FRAME	EPOCH (GPS)
2006-275-B	-0.6 ±0.0	0.4 ±0.0	0.0 ±0.3	IGS08	2006-10-02T23:54:51
2006-276-A	-0.3 ±0.1	-0.1 ±0.0	0.4 ±0.4	IGS08	2006-10-03T10:52:59
2006-276-B	0.8 ±0.0	0.1 ±0.1	-0.9 ±0.4	IGS08	2006-10-03T13:44:12
2006-277-A	0.3 ±0.1	-0.2 ±0.0	1.7 ±0.4	IGS08	2006-10-04T11:14:01
NETWORK SOLUTIONS	NORTH (cm)	EAST (cm)	UP (cm)	REFERENCE FRAME	EPOCH (GPS)
network-final	0.0 ±0.0	0.0 ±0.0	0.0 ±0.2	IGS08	2006-10-03T15:39:13

The table displays the OPUS-S session processing and network adjustment results, if they are available and toggled on for display. The results are relative to the zero point coordinates (at the epoch of the zero point coordinates), and include the reference frame and epoch of the results. Note that these differences are in centimeters. The classes of results are grouped together to facilitate comparisons. In other words, all the OPUS solution results are together, all session processing solutions together and all network adjustment solutions are together. Each results row in the table uses the associated data file name as the label for that row. Moving the cursor over a row will accentuate the corresponding point in the **Processing Results Plots** (Section **1.5.7**). Note that changing the scale uncertainties (1 to 5 sigma) from the pull down box will also change the error bars on the plots as well as the data in the tables.

Section 2 OPUS Projects - Analyzing Results

2.0 Preparation

More than anything else, good OP project results will follow from a well thought-out project plan and good field practices.

The icons and highlights used on the project web pages can help with analysis if the preferences were set appropriately for the project. The Data Processing Defaults (Section) will help insure consistency in the processing, while the Data & Solution Quality Thresholds (Section 1.3.5.2.3) will visually highlight potentially problematic results.

Take the time to review the OPUS solution results generated after the project data are uploaded. Although it is unusual, OPUS does occasionally produce a poor solution. A poor OPUS solution can mean poor data, and rarely do poor data produce good results no matter how they are processed. It is worth investigating any anomalous results before attempting session processing that includes those data. The processing results plots (Section 1.5.7) and tables (Section 1.5.8) can help identify these cases if they occur.

Furthermore, the OPUS solutions can subtly affect project processing. The OPUS solution coordinates from the first data file associated with a project mark become the a priori coordinates for that mark. A poor OPUS solution can result in poor a priori coordinates that can, in turn, degrade session processing and network adjustments. If such a case is confirmed using the processing results plots and tables, or some other tool, changing the a priori coordinates for the mark is justified (Section 1.5.6.2.1). More time consuming, but potentially safer: remove the mark from the project, then upload its data again, but exclude the problematic data file.

By the time processing begins, the project manager should have verified all project mark names and their associated data files. Recall that unless changed by the project manager, the four character mark ID are taken from the associated data files, if possible, or but may be generated automatically if inconsistencies in the file names are found. If inconsistencies are found, mark ID such as "a001", "a002", etc. are automatically generated by the project as “placeholders” (Section 1.2). If names like "a001", "a002", etc. occur, data collected at a single mark may be inappropriately split between two project marks, and will not correctly contribute to the estimation of the mark’s coordinates. Occurrences of these placeholders must be corrected before data processing begins.
Section 1.1 offers other recommendations.

2.1 Session and Network Solution Report Summaries

Evaluating processing results is an essential activity. Usually, this only entails reviewing the processing report summaries. Figure 2.0 shows the start of a session processing summary. Figure 2.1 shows a final network solution summary. A more complete description of these summaries can be found in Appendix C. Summaries like this are appended to processing report emails and can be viewed using the **Show File** control on the Manager’s Page as well as all session and MARK web pages. These summaries are similar to an OPUS report and can be evaluated in much the same way.
Criteria to evaluate "success" in a solution include:

- The **STANDARD ERROR OF UNIT WEIGHT**[4] should be near 1. The acceptable range is 0.1 to 1.1. Differences are tolerable, but be wary of order of magnitude differences: 0.725 is OK, but 7.25 and 0.072 are not!
- The **OVERALL RMS** should be less than the project preference threshold (Section 1.3.5.2.3). Each baseline's **RMS** should be less than the project preference threshold (Section 1.3.5.2.3).
- The **OBS** count (number of observations used) for each baseline should be near the expected number based upon data duration and field logs.
- The percentage of **OMITTED** observations should be smaller than the implied preference. If the **Observations Used** preference (Section 1.3.5.2.3) was set at 80%, then the **OMITTED** should be less than 20%.
- Ambiguities **FIXED** to integers should also meet the preference set (Section 1.3.5.2.3). The uncertainties for the coordinates should be less than the project preference thresholds (Section 1.3.5.2.3).

Figure 2.0 - OP solution report

```
       NGS OPUS-PROJECTS SESSION SOLUTION
REPORT

===========================================

 All coordinate accuracies reported here are
1 times the formal
 uncertainties from the solution. For
additional information:
 dev.ngs.noaa.gov/OPUS/Using_OPUS-
Projects.html#accuracy

 These positions were computed without any
knowledge by the National
 Geodetic Survey regarding the equipment or
field operating procedures used.

 SUBMITTED BY:
mark.l.armstrong
 SOLUTION FILE NAME:                2006-275-
B.sum
 SOLUTION SOFTWARE:
page5(1212.04)
 SOLUTION DATE:                     2013-05-
15T17:09:23 UTC
 STANDARD ERROR OF UNIT WEIGHT:     0.742
 TOTAL NUMBER OF OBSERVATIONS:      45498
 TOTAL NUMBER OF MARKS:             8
 NUMBER OF CONSTRAINED MARKS:       4

 OVERALL RMS:                       1.5 cm
 START TIME:                        2006-10-
02T00:00:00 GPS
 STOP TIME:                         2006-10-
```

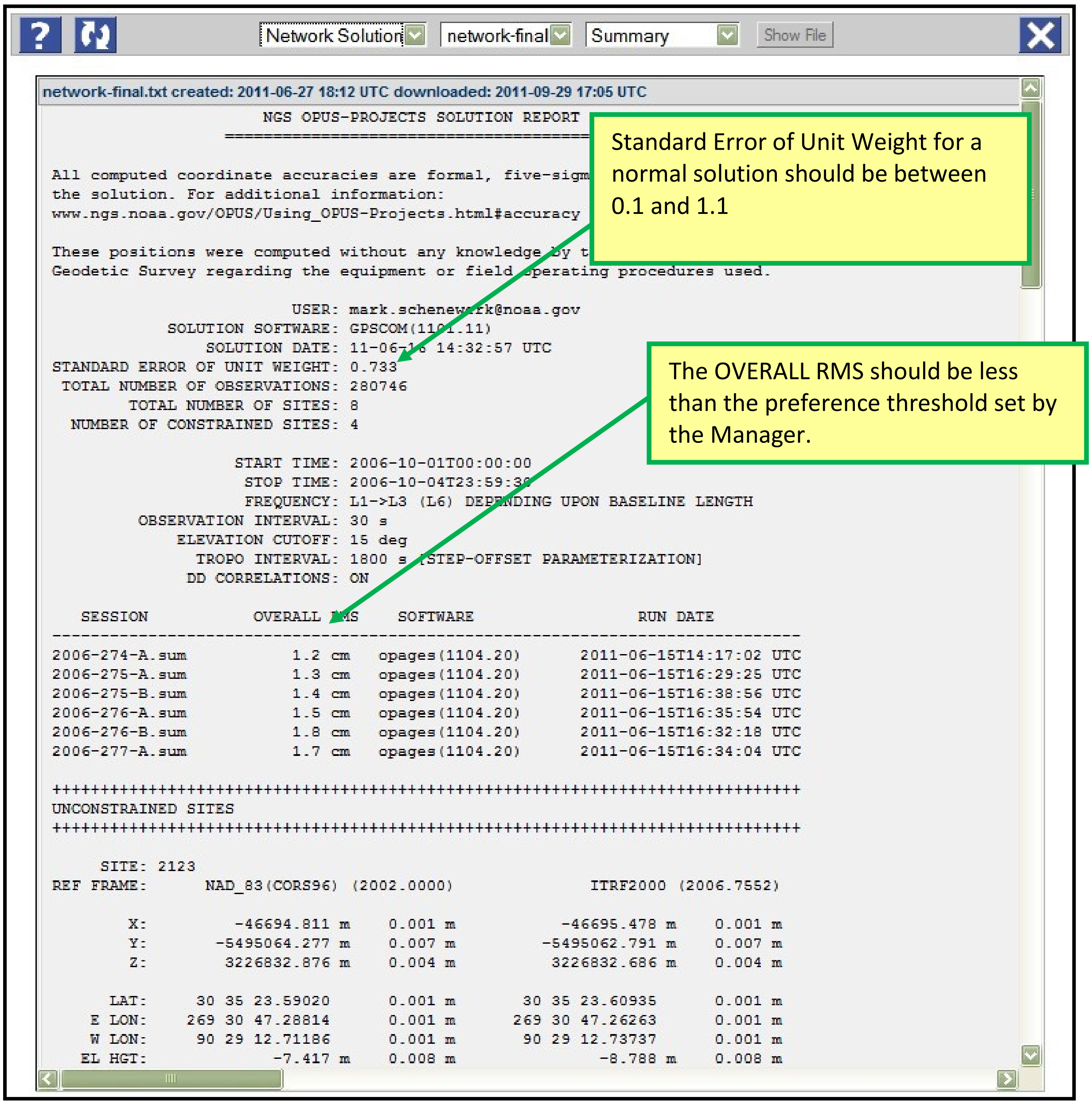
[4] The standard error of unit weight is a scale factor generated from the least squares adjustment which (in effect) judges how well your a-priori weights were set. If you set them too low, the standard error of unit weight will be greater than 1; if you set them too high, it will be less than 1.

2.1.1 Other Solution Reports

Processing reports sent via email from sessions include the report summary in both text (*.txt) and Extensible Markup Language (*.xml) formats, the output from the processing engine (*.sum) file, a **Solution Independent Exchange** (*.snx) formatted file, and several files (serfil, g-file, b-file) useful for submitting to the NGS, i.e. "bluebooking". All files may be open with Notepad, TextPad or some other similar text reading program. The solution summary is described in Section 2.1 and Appendix C. The Extensible Markup Language, or XML, file may be used to create a custom formatted report or be read by other software. The processing engine output is challenging to read, but contains the most complete description of the solution. The Solution Independent Exchange, or SINEX, file is commonly used in academic applications. It contains enough information to derive the solution or combine the results with others to create new solutions. The serfil provides a list of four digit mark IDs for use in a separate post processing scenario.

2.1.2 The Bluebooking Reports

Figure 2.1 - Example final network solution summary




```
                     NGS OPUS-PROJECTS SOLUTION REPORT
                 ========================================

All computed coordinate accuracies are formal, five-sigm
the solution. For additional information:
www.ngs.noaa.gov/OPUS/Using_OPUS-Projects.html#accuracy

These positions were computed without any knowledge by t
Geodetic Survey regarding the equipment or field operating procedures used.

                         USER: mark.schenewerk@noaa.gov
             SOLUTION SOFTWARE: GPSCOM(1101.11)
                 SOLUTION DATE: 11-06-16 14:32:57 UTC
STANDARD ERROR OF UNIT WEIGHT: 0.733
 TOTAL NUMBER OF OBSERVATIONS: 280746
        TOTAL NUMBER OF SITES: 8
  NUMBER OF CONSTRAINED SITES: 4

                    START TIME: 2006-10-01T00:00:00
                     STOP TIME: 2006-10-04T23:59:30
                     FREQUENCY: L1->L3 (L6) DEPENDING UPON BASELINE LENGTH
          OBSERVATION INTERVAL: 30 s
              ELEVATION CUTOFF: 15 deg
                TROPO INTERVAL: 1800 s [STEP-OFFSET PARAMETERIZATION]
               DD CORRELATIONS: ON

   SESSION             OVERALL RMS    SOFTWARE                 RUN DATE
-------------------------------------------------------------------------------
2006-274-A.sum            1.2 cm   opages(1104.20)      2011-06-15T14:17:02 UTC
2006-275-A.sum            1.3 cm   opages(1104.20)      2011-06-15T16:29:25 UTC
2006-275-B.sum            1.4 cm   opages(1104.20)      2011-06-15T16:38:56 UTC
2006-276-A.sum            1.5 cm   opages(1104.20)      2011-06-15T16:35:54 UTC
2006-276-B.sum            1.8 cm   opages(1104.20)      2011-06-15T16:32:18 UTC
2006-277-A.sum            1.7 cm   opages(1104.20)      2011-06-15T16:34:04 UTC

+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
UNCONSTRAINED SITES
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

     SITE: 2123
REF FRAME:      NAD_83(CORS96) (2002.0000)             ITRF2000 (2006.7552)

        X:        -46694.811 m     0.001 m          -46695.478 m     0.001 m
        Y:      -5495064.277 m     0.007 m        -5495062.791 m     0.007 m
        Z:       3226832.876 m     0.004 m         3226832.686 m     0.004 m

      LAT:     30 35 23.59020      0.001 m      30 35 23.60935      0.001 m
    E LON:    269 30 47.28814      0.001 m     269 30 47.26263      0.001 m
    W LON:     90 29 12.71186      0.001 m      90 29 12.73737      0.001 m
   EL HGT:            -7.417 m     0.008 m             -8.788 m     0.008 m
```

For every session solution, a GPS data transfer file, more commonly called a g-file, is created using the NGS standard SINEX2G program. A complete description of this file format is found in the FGCS Blue Book document "Annex N: Global Positioning System Data Transfer Format (G-File)". The g-files are stored with the session solutions and, as mentioned, included in the reports emailed to the individual performing the processing. The SINEX2G program also creates several useful supporting files. Most important of these is the serfil. This is a simple text file providing a cross-reference between station serial numbers (SSNs) and mark ID (see "Annex L: Guidelines For Submitting GPS Relative Positioning Data"). The *.pos files contain a list of mark coordinates. The *.r80 files also contain the marks' horizontal coordinates, but in a specific (*80*) format. The *.vec files contain the baseline vector components.
After network adjustments, the g-files from the included session solutions are combined thereby creating the g-file for the adjustment; while the adjustment's HORIZONTAL OBSERVATION (HZTL OBS) DATA, commonly called the b-file ("Chapter 2: Horizontal Observation (HZTL OBS) Data") is created using the network adjustment plus the occupation information from the marks included in that adjustment. Remember that the occupation information for a mark defaults to the information in and provided with the mark's data files when they were uploaded. Also remember that this default information can be modified through the mark web page (Section 1.5 and 2.2). Needless to say, the more complete and accurate the occupation information, the more complete and accurate the b-file will be created. The network adjustment b- and g-files are stored with the adjustment and included with the reports emailed after the adjustment. All session processing and network adjustment reports are also available through the project's web pages. Once the b- and g-files are in hand, it remains the project manager's responsibility to verify the files and to complete the other steps required to submit to the NGS for bluebooking.

2.2 Project Mark Web Pages

The project mark web pages offer two critical tools for evaluating and analyzing processing results: the Processing Results Plots (Section 1.5.7) and Tables (Section 1.5.8). These display the resulting coordinates for a mark from all or selected project processing results. Provided that consistency was maintained in the processing, similar classes of results, for example session processing results, should "cluster" together. Outliers can be identified, and the occupation and source processing solution scrutinized. This "repeatability" does not guarantee, but it is necessary for, a valid adjustment.

Figure 2.2 shows a contrived case, but one based upon actual incidents, where a vertical outlier is found. The outlier is evident in the Up versus GPS Time, the plot on the right, at approximately 2006-276T20. In this case, both the OPUS-S solution and session solution gave similar results, and there is no similar issue in the North versus East plot on the left. A hypothesis explaining this evidence is an ARP height error. A comparison of the Occupation information for this mark to the field log for the offending data file confirmed an ARP height input error at upload. Correcting this on the mark's page and reprocessing gave the results shown in figure 2.3. After the correction, the horizontal and vertical session processing results agree. The OPUS-S solution corrupted by the incorrect ARP height remains serving as a reminder of the original error. Another possible response would have been to upload the offending data file again using the correct ARP height. The data file and information from the re-upload would have replaced the original and, after reprocessing, the OPUS-S and session processing results would all agree.

Figure 2.2 - Processing results plots showing an ARP height error

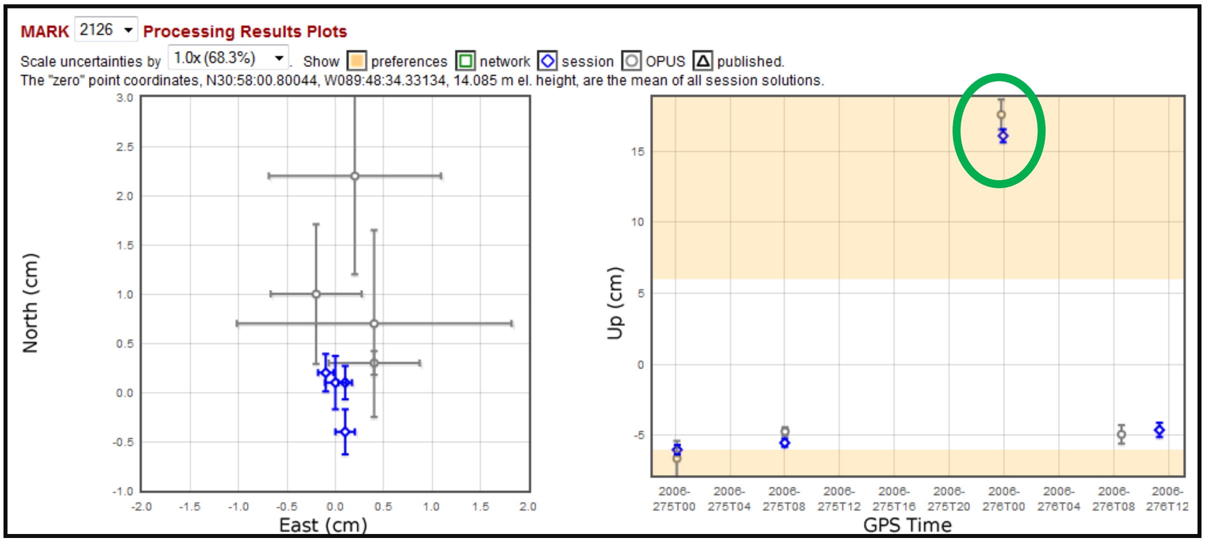
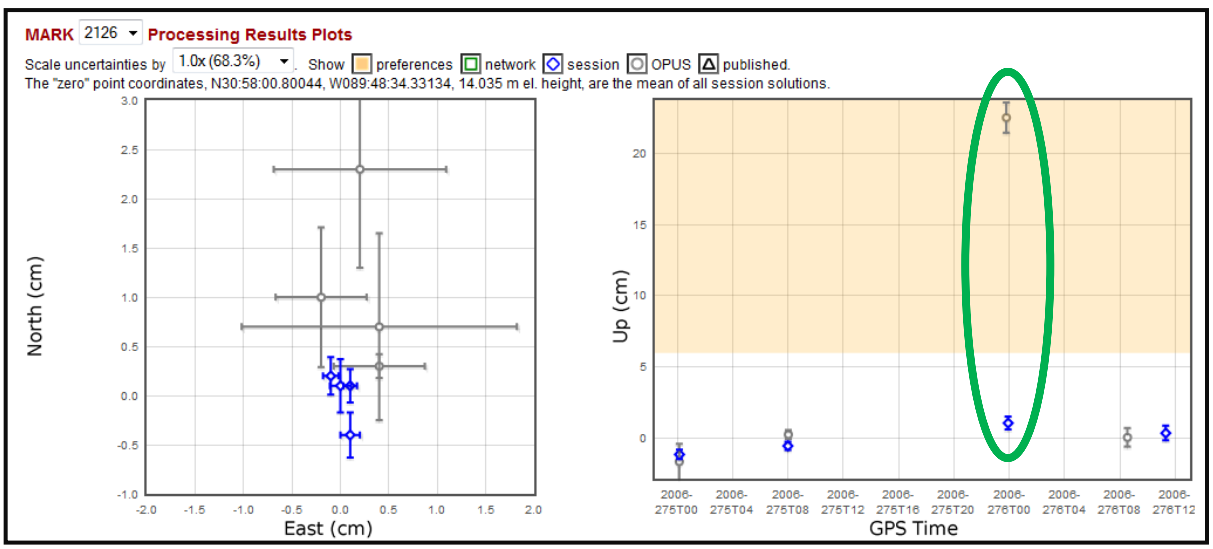


Figure 2.3 - Processing session results plot after ARP height correction



Section 3 OPUS Projects Technical Guide

Section 3 provides some general guidance and help with making the best decisions while planning a GNSS survey and using OP. This is not meant to be a "survey planning" guide, but only to provide some key steps in obtaining good survey data in preparation for use with OP.

3.0 Network and Session Design Considerations

Network Design

- Each session requires that baselines be defined.
- Baselines are defined by selecting Hub marks.
- Every mark that is not a Hub tries to connect directly to a Hub.
- Only 1 Hub per session is recommended. A different Hub for a second session where the same marks were observed a second time provides closure. Make the Hub a CORS or other active station with 24 hour files if at all possible.
- Observed mark positions are relative to constrained marks.

Hub mark selection

- Minimize observations lost to the need for mutual visibility by keeping the distance to the Hub < ~100 km.
- To meet the previous requirement, spatially large projects might require different Hubs be used in different sessions.
- Do not connect a project mark with just a few hours of data to distant CORS (too few mutual observations).
- Take advantage of their continuous data collection by using CORS as Hub(s).

Troposphere Modeling

- Model style can be either Step-offsets (SO) between intervals or Piecewise Linear (PWL).
- In the spirit of avoiding discrete steps transitioning from one tropo interval to the next, PWL troposphere adjustments are preferred - nature does not move in discrete steps.

Constraint Weighting

- The choice is almost always between Tight or Normal constraint weight for the CORS.
- Hubs (even if CORS) should not be constrained. Rather the other constrained CORS should position the hubs.
- Many CORS display seasonal motion which makes Tight constraint weight suboptimal.
- Because multiple CORS will always be used (at least 1 Hub + 1 distant CORS), Normal constraint weight seems preferred. There maybe exceptions to this in places of excessive plate motion (velocities) occuring over relatively short periods of time causing unexpected results reflected in the coordinates. If this occurs it is recommended to use Tight constraint weighting.

Network Components

- Think of a project as having two components:
    - **Local Network** - Think precision and get the best relative positions
        - ✓ Use common-mode errors to your advantage.
        - ✓ Use identical antennas when possible.
        - ✓ Keep baselines short maximizing simultaneous observations.
        - ✓ Use a single Hub per session.
        - ✓ Use alternate second Hub for next session with observations on the same marks as the first session. Creates closing vectors to marks from two hubs.

- ✓ Include at least one distant CORS to stabilize tropo corrections and do not constrain it.
- ✓ Use 'Normal' constraint weighting.

- o **Reference Network** - Think accuracy (truth) by tying the local network into the NSRS (CORS/IGS network).
  - ✓ Include the Hub(s) and distant CORS in all sessions.
  - ✓ Multiple CORS remove single reference mark bias.
  - ✓ Normal constraint weights allow for small variations in positions typical of CORS or any group of active stations. If large variations occur (several cm) use 'Tight' constraint weighting.

The plan is to expand this Technical Guide section in the future with more detailed guidelines for performing specific types of common NGS surveys using OPUS Projects. Over time, OP may evolve to provide automated specification guidance for people planning to perform NGS-specific surveys. If you are using OP to perform FAA, GNSS Height Modernization surveys, have a good understanding of the requirements, and would like to contribute additional "how to" text to this section, please contact the OPUS Projects Team at ngs.opus.projects@noaa.gov.

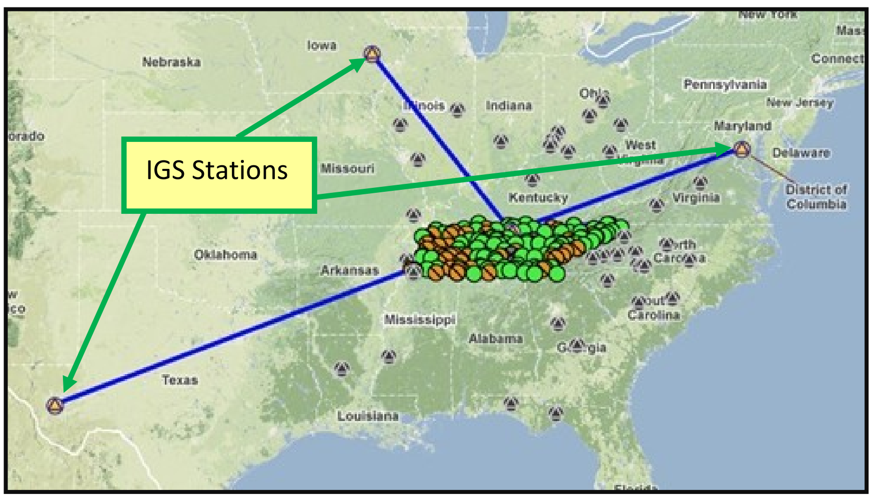
3.1 IGS Stations

For large and/or important projects, include IGS (International GNSS Service) stations (sites) as part of the global network control. This:

- Provides for an alignment of your survey to an accurate global reference frame.
- Some IGS stations are also NGS CORS.
- Include long and short baselines to IGS/CORS stations.

The few IGS stations within the USA are part of the CORS network, but in general, CORS stations are *not* IGS stations. Be sure to review the site log file and history of the station on the IGS web site: (http://igscb.jpl.nasa.gov/network/list.html).

Figure 3.1 - Using IGS stations in your survey



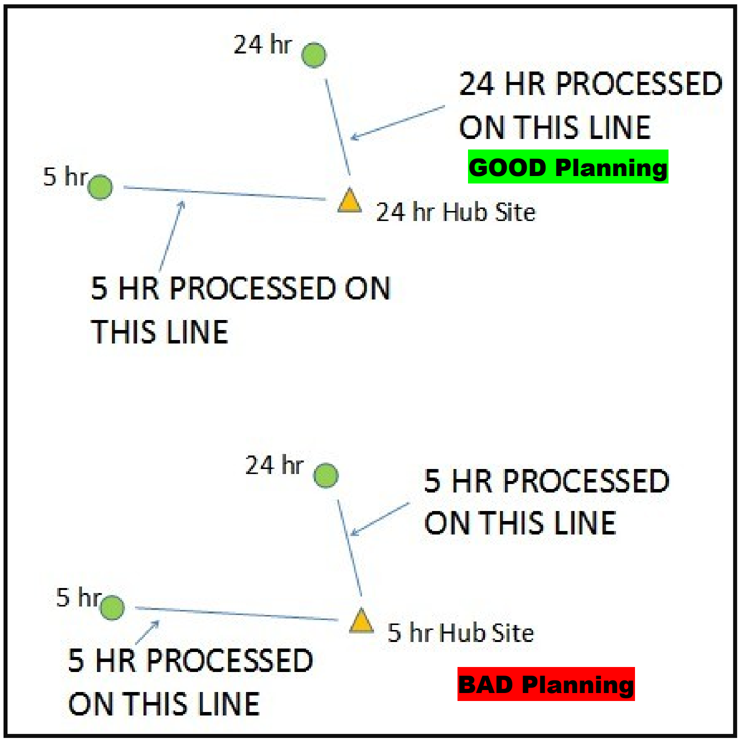
3.2 Verify Correct Antenna Model

⚠ Verify with the CORS site owner that the 'log file' with antenna model named is up to date and correct. Remember that CORS are mostly owned by private firms, city, county and state agencies. Site owners are responsible for maintaining the CORS log file. The log file reports the current station GNSS antenna and receiver equipment, mount details, and owner contact information. It is prudent to check with the owner to make sure the antenna named in the log file is correct. Processing a project with the wrong antenna at any active station, IGS or CORS can introduce large errors into the processing.

3.3 Observation Data Spans

Consideration for observation data spans (observation timeline) between observations at hubs together with other marks is important in planning each session and the overall network. Occupation time on a hub (typically CORS or other active station) should be more than the minimum time occupied on any other connecting mark in order to make full use of the time observed. Only data overlapping the hub site can be processed (Figure 3.2). Project specifications may dictate minimum observation times for baseline length.

Figure 3.2 - Observation data span overlap between "hubs" and "marks"



3.4 'User' Network Baseline Design Strategy

Given adequate survey planning and sufficient occupation time on each mark, the user has non-trivial control over baseline selection in session processing. Planning each session in concert with the overall network design is critical to achieving the best results for the project. The following hub site strategies offer ideas to consider when designing a network. It is anticipated that most local project networks will be "USER" defined with unique baseline design strategies with project specific local control marks together with CORS. Local project marks may be constrained with predefined horizontal values and/or project leveled vertical values.

3.4.1 Basic Hub Site Single Session Strategy

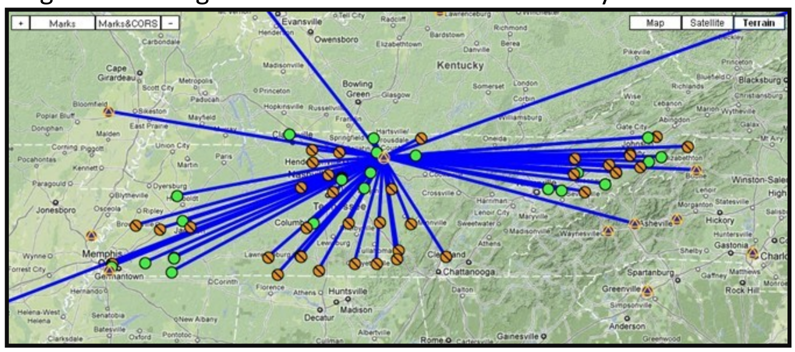
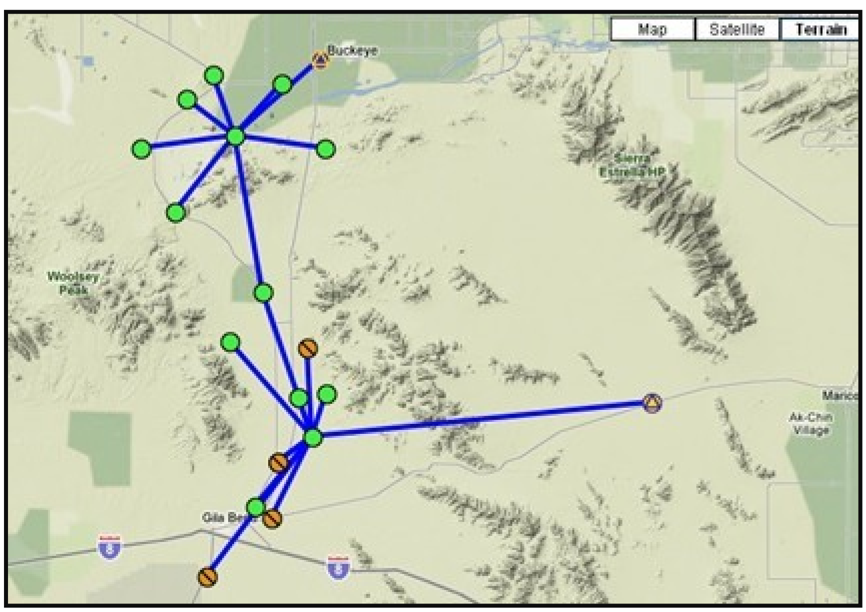


Figure 3.3 - Single session one hub constrained by IGS stations

In Figure 3.3, a single CORS (hub) with 24 hours of data is connected to several IGS stations (outside the mapped region) so the network is strongly connected to the global reference frame. The IGS sites are tightly constrained while the hub is not constrained and is free to be positioned by the IGS or CORS sites selected by the manager to use in the adjustment. The other marks are also adjusted relative to the IGS sites because of their connecting baselines to the hub. This provides a consistent reference frame for marks and is suitable for projects up to several hundred kilometers with between 2 and 4 hours of data.

3.4.2 Basic Hub Site Strategy

Figure 3.4 - Small project radial survey



Some types of surveys may depend on a radial hub site strategy that meets certain survey specifications. Figure 3.4 shows a project spanning less than 20 kilometers and with marks which were occupied less than 4 hours. Multiple hubs are chosen and constrained. The other project marks are adjusted relative to the constrained marks. Including more distant CORS or IGS sites is still a valid choice although the connection to the global reference frame is more tenuous because of the limited data spans.

Figure 3.5 – Hub site strategy using two hubs, but only one hub per session. In this case hubs are PBO active stations with 24 hour data files. Figure shows the Marks &CORS view.

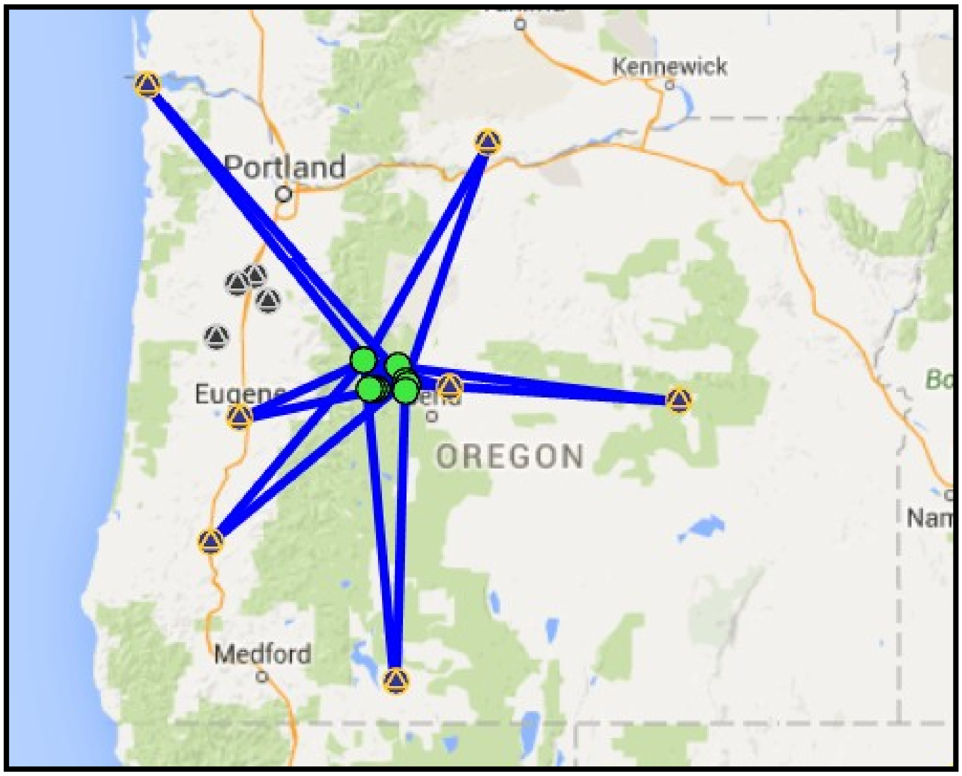
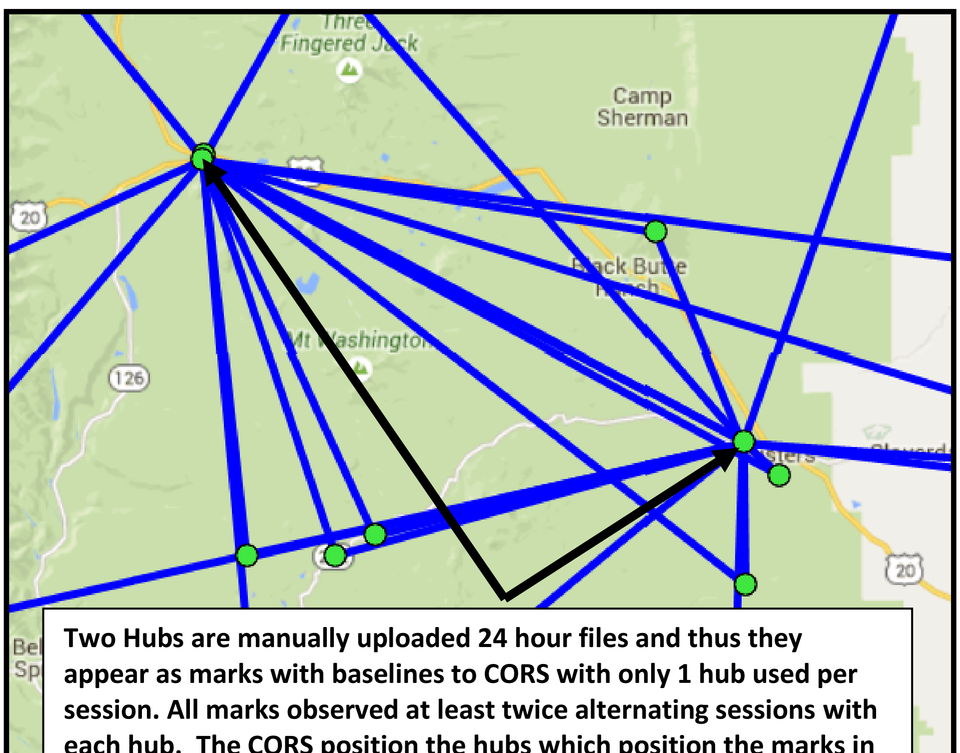


Figure 3.51 – Same project as figure 3.5. Hubs are shown as marks because they are active stations from the Plate Boundary Observatory (PBO) that are not CORS.



Two Hubs are manually uploaded 24 hour files and thus they appear as marks with baselines to CORS with only 1 hub used per session. All marks observed at least twice alternating sessions with each hub. The CORS position the hubs which position the marks in the adjustment. Figure shows mark view.

3.5 The Normal Adjustment Sequence

Network least squares adjustments of GNSS networks are generally performed in steps. As a recommendation the following four adjustments should be considered the normal adjustment sequence.

Step 1. Minimum constrained geometric (horizontal) adjustment

Constrain one CORS* (3D) LLh

- Checks the internal consistency of the network
- Allows the comparison of adjusted vs. published CORS coordinates

*Select the best CORS near the center of the project

Step 2. Fully constrained geometric (horizontal) adjustment

Constrain all desired CORS (3D) LLh

- **Produces the final set of adjusted geometric (LLh) coordinates for the project**

Step 3. Min. constrained orthometric height (vertical) adjustment

Constrain one CORS (2D) LL only for alignment

- Provides horizontal orientation

Constrain to one NAVD 88 bench mark (Vert-only) and then
Select GEOID12A (for current NSRS results)
Enter the published NAVD 88 leveled orthometric height from the IDB mark datasheet (or from your project levels)

- Compare computed orthometric heights to the published orthometric heights for all other bench marks observed in the project. Checks validity. Do the computed and published heights agree within some tolerance (from project specifications or your comfort level?). *This may be trial and error process. Determine which one held bench mark fits the majority of the other bench marks the best.

Step 4. Fully constrained orthometric height (vertical) adjustment

Constrain one CORS (2D) LL only for alignment

- Provides horizontal orientation

Constrain to all "valid" NAVD 88 bench marks (Vert-only) and then Select GEOID12A (for current NSRS results)

Enter the published NAVD 88 leveled orthometric heights from the IDB mark datasheets for each bench mark.

- Compare each computed orthometric height to the published orthometric heights for all bench marks constrained in the project. The difference or shift of the computed orthometric heights for unconstrained stations from the minimum and full vertical constrained adjustment should be less than what your vertical tolerance is.

<u>This adjustment produces the final set of adjusted NAVD 88 orthometric heights for the project marks.</u>

*This is normally a trial and error process and you may want to not constrain all of the NAVD 88 heights on every bench mark but only select those that seem to provide the best solution. Ask yourself these questions. Which bench marks seem to be the most stable? What are their order classifications? Are some in bedrock, or rods driven to refusal etc? Do some bench marks in the same level line appear to have subsided or have been uplifted? Do some bench marks have a status of "posted" meaning that there were issues with either the original field work or with adjustment processing?

Final coordinates from steps 1-4 above

Your <u>final horizontal coordinates</u> will come from the fully constrained geometric (horizontal) adjustment (Adjustment Step 2).

Your <u>final vertical heights</u> will come from the fully constrained orthometric height (vertical) adjustment (Adjustment Step 4).

3. 5.0.1 Considering Constraint Weighting in Network Adjustments

A. First, remember that the results are from a least-squares solution. By its nature, least-squares will "push" errors anywhere it can to minimize residuals. The partials used in creating the observations equations (and, in turn, the matrix to be solved) try to direct where those errors should go, but they'll go anywhere they can. A least-squares solution is not a collection of averages - at least in the way we think of averages. If the models are good, the errors are random, the unknowns fit the problem and the adjustments are small, it can act like a collection of averages, but it is not.

B. The individual session solutions probably "fit" very well. In other words, each individual sessions' residuals are small. So, again, we have an inconsistency. Each session solution is saying that the mark is exactly where it should be with high confidence - by the way, so high that we're fixing ambiguities = fixing distances to satellites whose positions we do not allow to shift at all - and we're rewarded with small residuals from the sessions solution. Except that we, in our position to know all thanks to the plot, know that a mark appears to be in two different places. The session solutions don't know this and don't care. They only know their data fits their adjustments very well.

C. But then we put the session solutions together in a network adjustment. Now think about what we're telling the network adjustment to do. We're saying that even though the session results clearly put the offending mark in two different vertical locations, the network adjustment is given no means for that to happen. So where can that inconsistency go? Not into the ambiguities, those were fixed by session. That really only leaves the coordinates of the thing(s) that are defining the frame in which the measurements were made, i.e. the CORS, and the tropos which strongly alias into the heights.

D. The constraints are not barriers. The NORMAL constraints instruct the program to limit the adjustment to less than about 1 cm, but if it "wants" to be greater than 1 cm, it will although the constraint will increasingly hinder taking on larger and larger values. Think of it as a rubber band. For adjustments less than a couple cm, the rubber band is not stretched tightly and the adjustment can "easily" reach (take on) any of those values if the solution demands. Beyond that, the rubber band is stretched tighter and tighter. The adjustment can reach (take on) larger values, but its got to work harder to do so. But be aware that the rubber band is never slack. It is always "pulling" towards the specified constraint value to some extent.

3.5.1 Height Modernization Surveys

OP may support height modernization surveys and is suited for processing GNSS observations based on a survey plan that follows the NOS NGS-58 and 59 guidelines although those guidelines are currently being updated. The current version of PAGES is the limiter.

Height Modernization is an initiative focused on establishing accurate, reliable heights using Global Navigation Satellite System (GNSS) technology in conjunction with traditional leveling, gravity, and modern remote sensing information. Read more about the role of NGS in modernizing heights, the history and science of Height Modernization, as well as its applications and benefits.

The goals of the **National Height Modernization Program** (NHMP) are to provide access to accurate, reliable heights nationally; to develop standards that are consistent across the nation; to provide data, technology, and tools that yield consistent results regardless of terrain and circumstances; and to establish a system or process that is maintainable over time.

Guidelines for performing GNSS height modernization surveys maybe found in the following NGS documents:

NOAA Technical Memorandum NOS NGS-58 [PDF]
Guidelines for Establishing GPS-derived Ellipsoidal Heights (Standards: 2 cm and 5 cm) Version 4.3.

NOAA Technical Memorandum NOS NGS-59 [PDF]
Guidelines for Establishing GPS-derived Orthometric Heights (Standards: 2 cm and 5 cm). These guidelines address the establishment and densification of vertical control networks through the use of GPS surveys and valid NAVD 88 orthometric control.

OP has been developed for and is suited for processing those 2+ hour GNSS observations based on a survey plan that follows the NOS NGS-58 and 59 guidelines. OP supports the blue-booking process for GNSS height modernization surveys by producing a b-file, g-file and serfil for use with the NGS program ADJUST.

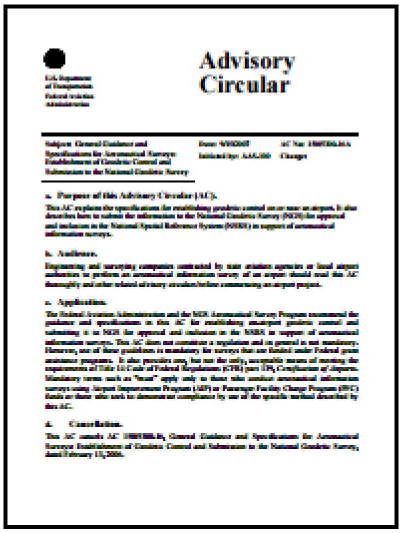
Because the surface of the Earth is so complex, geodesists use simplified, mathematical models of the Earth for many applications. The current Height Modernization program uses orthometric heights from traditional leveling and ellipsoid heights from GNSS to create a hybrid geoid height model referenced to the North American Vertical Datum of 1988 (NAVD 88). Conventional geodetic leveling is precise but labor intensive, so it is not feasible or practical to level across the country today as has been done in the past; additionally, leveling yields cross-country error build-up. It is possible to obtain accurate heights through GNSS, and NGS has published guidelines that define equipment requirements, field procedures and data collection parameters, basic control requirements, and processing and analysis procedures. Accuracy of GPS-derived orthometric heights depends on both the accuracy of the geoid model, the accuracy of the NAVD 88 control and the accuracy of the measured ellipsoid heights. NGS produces a gravitational geoid model based on gravity data collected from a variety of sources and a hybrid geoid model that constrains the gravitational model to U.S. bench marks to enable a fit to NAVD 88.

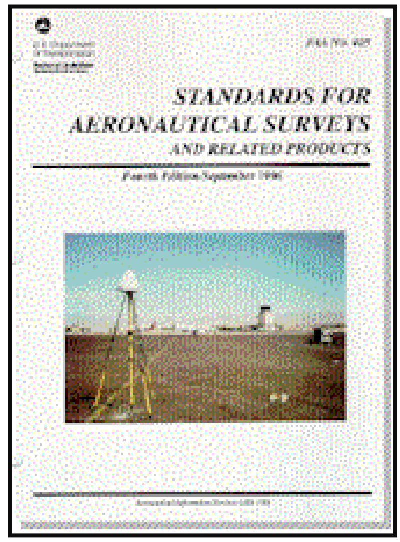
3.5.2 FAA Airport Surveys

OP has been developed with FAA airport survey control in mind and is suited for processing GNSS observations based on a survey plan that follows the series of guidelines for surveys found on the NGS web site: http://geodesy.noaa.gov/AERO/aerospecs.htm

Figure 3.5 - Advisor Circular and older Standards for Aeronautical Surveys

The NGS, in accordance with a series of interagency agreements with the Federal Aviation Administration (FAA), provides airport geodetic control, as well as runway, navigational aid, obstruction, and other aeronautical data that is critical to the operation of the National Airspace System. Most of this data is source information obtained using field survey and photogrammetric methods. This data is used to develop runway approach procedures and obstruction charts.





The National Geodetic Survey contracts survey work for Area Navigation Approach (ANA) charts to the private sector on a funds available basis. Survey specifications are provided in AC No: 150/5300-16A (2007) and the older "FAA No. 405, Standards for Aeronautical Surveys and Related Products," 4th edition, September, 1996; and "General Specifications for Aeronautical Surveys, Vol. I. Establishment of Geodetic Control on Airports." Funding for these surveys is provided to NGS by the FAA. Currently OP supports the bluebooking process for FAA surveys by producing a b-file, g-file and serfil for use with the NGS program ADJUST.

3.5.3 Real-time Network Positioning

OP may be effectively used for aligning coordinates of real-time network active stations to the NSRS and is suited for processing GNSS observations based on a survey plan that follows certain best practices. A more formal NGS NSRS validation process may be available in the future.

The following is an outline of general 'best practices' identified as important for aligning an RTN to the NSRS. Additionally, some recommendations for RTN users are included. Individuals or agencies administering RTNs may wish to consider these and/or other practices. These 'best practices' have been concatenated from current general guidelines outlined in Section V. (Snay) of the "NGS Guidelines for Real Time GNSS Networks." [6]

A. Determining RTN Station Coordinates using OPUS Projects

It is recommended that the RTN Administrator perform a rigorous least squares network adjustment to compute three-dimensional coordinates (LLh) for each station in the real-time network. It is recommended that a minimum of five (5) twenty-four (24) hour data sets be used for each station in the network adjustment. [6.-pg.35, 6b.] Within OP the weighting for CORS in the adjustment may be performed using the NORMAL (1cm - 3D) constraint selection within the preferences available on the Manager's

Web Page. CORS specifically selected by the Manager to be constrained in the RTN network adjustment should be CORS that have existed longer than 2.5 years and therefore have computed velocities. The list of these station coordinates with computed velocities is updated weekly and available here: ftp://cors.ngs.noaa.gov/cors/coord/coord_08/igs08_geo.comp.txt

For more information on CORS with computed vs. modeled velocities go to the NGS CORS web page here: http://geodesy.noaa.gov/CORS/coords.shtml.
Remember that OPUS and OP are rigorous geodetic tools in that they always begin processing with global coordinate values. CORS coordinates are automatically seeded into OP projects when RTN active station data is uploaded through OPUS to an OP project. However, when CORS are automatically included in the project when mark data is uploaded or are added later using the Add CORS window the reported ellipsoid height for those CORS will be at the MON position and not the ARP. This is always the case and not typically important for normal projects but in the case of an RTN project where CORS may also be part of the RTN the Project Manager must be aware of this MON vs ARP condition.

OPUS keeps track of the MON to ARP vertical offset (even if it is 0.000m) but will always only report the MON ellipsoid height for CORS. This may cause confusion as typically RTN network software wants the ellipsoid heights at the ARP to be entered for all stations. This can be controlled within OP by manually uploading the RINEX files to OPUS for the CORS considered part of the RTN and entering 0.000m for the antenna height. When that is done the final adjusted ellipsoid height in the reports will represent the ARP (bottom of the antenna).
For RTNs the least squares adjustment result typically provides a best-fit scenario between adjacent stations in the real-time network. This is preferred over independent station processing using several days (typically at least 10) of data sets sent to OPUS. That said the use of OPUS to independently position active stations within an RTN may still provide good results and alignment with the NSRS.

The TRI method on the OP Manager's Preferences Web Page (Section 1.3.5.2.4.8) creates a set of closed loops consisting of baselines formed from the Delaunay triangulation algorithm. Here each RTN station is connected to all adjacent stations in a triangle shaped network which is important since typically the RTN network software will be internally checking the quality assurance of the same baselines to confirm that the vector distances are within the specified tolerances prescribed by the network accuracy standards. This TRI method option may be used for large real-time network adjustments that contain more than 100 marks plus CORS in a session. This is because the algorithm processes in stages and can more successfully handle the large amount of station data. Networks containing up to 150 active stations plus CORS have been successfully completed as one OP project although the limits of both processing and internet browser capabilities are stretched to the limit. Larger real-time networks can be completed in OP by creating multiple projects containing RTN clusters that overlap each other providing the ability to check same station coordinates in different projects. Each cluster project must use identical constraining CORS. While this multi-project technique produces good results, adjusting the entire RTN as one project produces the best results.

Since manufacturer vendor real-time QC network monitoring of the RTN is typically on baselines between adjacent stations a least squares adjustment of all baselines present in the TRI method has proven to provide optimal results.

1. Use the latest Absolute Antenna Calibrations
The NGS CORS group began using IGS08 Absolute Antenna calibrations upon the release of the new CORS coordinates in IGS08 epoch 2005.00 and NAD 83(2011,MA11,PA11) epoch 2010.00. The latest absolute antenna patterns are automatically used in OPUS and thus OP as well. Within each antenna calibration file there are north and east orientation values. For best results, during field observations, orient each antenna to north. Normally all active stations and CORS are orientated to north when they

are installed. The NGS maintains an antenna calibration web page to reflect the new absolute antenna calibrations associated with NSRS global frame.
For more information go to: http://geodesy.noaa.gov/ANTCAL/

2. Collect Station Data During Optimal Weather Conditions
Typically the errors remaining in GNSS after model-able effects are removed result from signals going through the troposphere. It is recommended to collect RTN station observation data (to use in processing) from active stations during a dry weather season when high pressure may dominate the entire RTN coverage area and tropospheric conditions are uniformly stable. *Care should also be exercised not to use data taken during periods of high ionospheric disturbance. For information and warnings from the National Weather Service Space Weather Prediction Center on these periods see:* http://www.swpc.noaa.gov/

3. Align RTN Stations to the NSRS using select CORS
It is recommended that the RTN be aligned to NGS CORS. This is very easy to achieve within OP as the access to the entire CORS network is available within the program. At least 10% or a minimum of three (whichever is greater) of the RTN active reference stations should be NGS CORS. This provides a continuous real-time network tie to the CORS Network, the NSRS and the geometric datum.(6.-pg.35, 7.) The NGS CORS sites to be constrained in the network should be distributed as uniformly as possible around and throughout the RTN service area. For the best adjustment of the RTN use CORS that have the most stable mounts, have proven themselves to be reliable over time (more than 2.5 years old), and have up to date log files with photos. Constraining the RTN to CORS with unknown mounts or unreliable log files can lead to unsatisfactory results. Verify that the antenna and radome in the log file are the ones actually on the mount during the time you performed the survey. Include constraining to one or more IGS CORS sites and refer to the IGS web site for more information on the IGS site locations:
http://igscb.jpl.nasa.gov/network/netindex.html

B. Considerations for RTN Users
1. Real-time networks that are adjacent to one another may want to consider coordinating their efforts to position their networks such that rover operators may cross RTN borders and expect to work effectively with common, homogeneous coordinates. Thorough testing of the network correctors, supported by empirical data may provide some assurance of common coordinates corroborated by independent OPUS Static solutions.

2. RTN Administrators may elect to occupy a subset of passive marks with rovers to compare RTN derived positions with the NGS national adjustment positions in the same reference frame. <u>However, the correctors any given RTN provides may yield coordinates for an RTN rover, at passive control, that disagree with NAD 83(2011)2010.00 coordinates</u>. *Note that the processed vectors used in the national adjustment of 2011 (NA2011, which yielded NAD 83(2011)) are from surveys spanning nearly 20 years and therefore based on equipment and software used at the time of the original survey. Additionally the adjustment will not account for possible mark disturbance or movement since the observation date. Western states' passive marks may be subject to significant tectonic plate motion which complicates efforts to assign long-lasting, stable coordinate positions. In fact, even in the most "stable" part of the North American Continent, residual interpolate motions are known to exist.* For checking RTN correctors after adjusting the RTN is better to perform an OPUS-S occupation on the passive mark, noting but disregarding the published coordinate on the datasheet and comparing the new OPUS-S coordinate to the RTN-rover-based coordinate value. This method uses identical epoch for your observations and software, and only the method (OPUS-S verses RTN) is the source for any disagreement.

3. RTN rover users should fully understand the four primary elements that provide for reliable consistent RTN positioning;

a. Communication: Strong robust wireless, or WiFi low latency communication is essential between the RTN and rovers during point locations. This technology continues to expand and become more robust.
b. Check-in often on known project marks: Checking in on a known mark with expected results before collecting new data and during the session, leads to confidence in the RTN correctors applied and prevents blunders from being a bias throughout the entire initialization.
c. Redundancy needed: Being able to acquire redundant coordinates on marks within expected accuracy requirements provide reliable results and confidence in the RTN station coordinates.
d. Avoid Multipath: Gathering or staking out project coordinates under varied satellite geometry will help mitigate multipath error. Rover users should avoid collecting data or staking points under tree canopy, near metal structures, water surfaces, signs or other reflective surfaces above the antenna height.

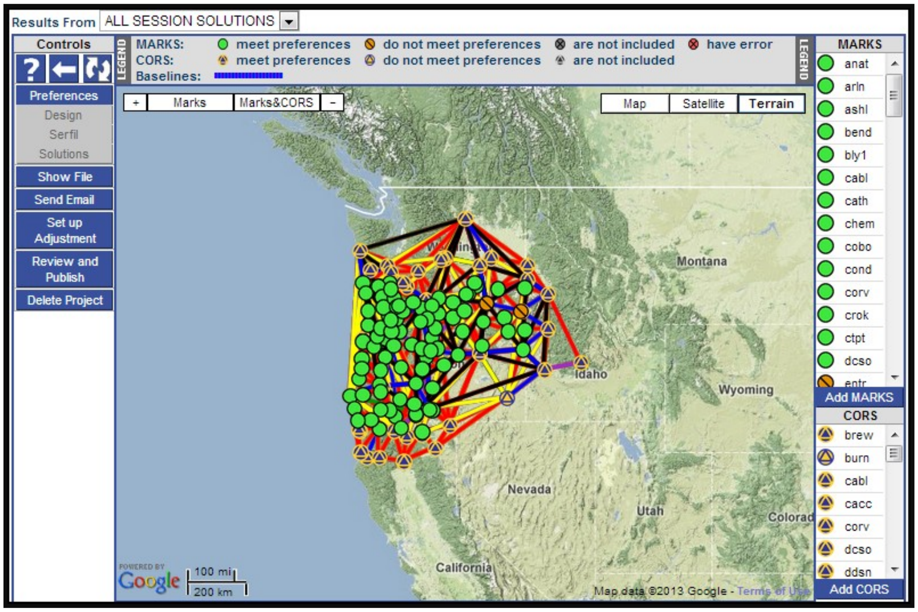
C. NSRS Validation for RTN

The NGS proposes simple methods for RTN Administrators to provide confirmation that their network is aligned with the NSRS. This confirmation would advance the way toward a "validation" whereby after a technical review the NGS would corroborate the RTN station coordinates. Further validation guidelines and dialogue may be adopted over time. If OP is used to adjust an RTN then NSRS alignment and validation may be easily verified and confirmed.

D. Monitoring RTN Station Coordinates

The RTN Administrator should plan to monitor the positions of all RTN stations utilizing network quality assurance software for any given day of RTN operation, and provide assurance to users that the positions do not vary by more than an expected amount. How much variance or movement in position is acceptable? What are the seasonal effects on station positions? Each RTN should determine acceptable normal limits and beyond those limits consider re-positioning the station. For consistency, consider adopting procedures for updating the station's coordinates and/or velocity if coordinate differences in excess of 2 cm in either horizontal dimension and/or 4 cm in ellipsoid height persist over a period of several days.
After completing a new RTN adjustment or updating individual station coordinates the RTN Administrator should consider publishing each stations position on the RTN web site. Include metadata about the adopted coordinates and relative positioning network accuracies for the RTN stations based on the assumption that CORS are errorless. Network accuracies should be published for each station so that users may include those errors when performing local project static network adjustments using the RTN stations. Thus local project network error will include the RTN network error. The network error should be normally reported at the 95% (2 δ) confidence level.
To answer the question: "Do users achieve coordinates in the field from an RTN that are consistent with the NSRS?". RTN users should consider creating (check-in) passive marks at their office on projects so that they can check-in with their rovers on a daily basis to confirm alignment with the RTN.

Figure 3.6 - Example project showing the Oregon RTN (ORGN) adjustment in OP



3.6 What's Under the Hood - Processing Baselines with PAGES

The PAGES (Program for Adjustment of GPS Ephemerides) is the orbit/baseline estimation software used within OP. Using double-differenced phase as its observable, PAGES should be suitable for most projects requiring the highest accuracy. Many types of parameters can be estimated including tropospheric corrections, station (marks and CORS) coordinates, linear velocities, satellite vectors and polar motion. An analysis strategy summary that includes a terse description of the PAGES program is kept at the IGS Central Bureau.

3.7 Adjusting Networks with GPSCOM

GPSCOM is a program for the combined adjustment of multiple GPS data sets initially processed by the program PAGES. The program GPSCOM is a simple Helmert Blocking, normal equation processor which combines multiple GPS data sets that have initially been processed by the program PAGES to form and partially reduce normal equations eliminating numerous nuisance parameters which are not generally of interest in a large global adjustment. The normal equation elements for the global parameters, those to be passed on to a combined adjustment, are written by PAGES into a normal equation file which becomes the basic input data for the program GPSCOM. One or more of these files as well as its own output normal equation files can then be processed by GPSCOM to provide a combined adjustment of the global parameters.

3.8 Making Combined Adjustments

Making combined adjustments using the programs PAGES and GPSCOM is a process usually called Helmert blocking in the traditional geodetic community. The technique was first described by Friedrich Helmert (1880) and a good description of the application of his paper was presented by Wolf (1978) including the original instructions given by Helmert for using this approach. The program GPSCOM used here for combining the normal equation matrices is in many ways a direct descendent of a prototype program (Dillinger 1978) coded many years ago for doing the same type of task.

Once some initial processing of data through the PAGES program is complete, one can begin making combined adjustments using GPSCOM and the normal equation files that have been generated. Since the normal equation files generated by the program GPSCOM are identical in structure to those made by PAGES, one can combine partial normal equations from an execution of the GPSCOM program with those from PAGES or other runs of GPSCOM. This allows one to use a pyramid type structure to build up combined adjustments with larger and larger amounts of data.

3.8.1 Helmert Blocking

Helmert blocking is basically a technique for breaking up a least squares adjustment problem that is too large to be managed as a single computation with the resources available, into many smaller computational tasks that can be managed. Not only are the computational problems thus smaller individually, but, with a good blocking strategy, there is actually much less computation to be done as the technique introduces and takes advantage of scarcity in the normal equation system. In fact, the technique is very similar to the method for solving sparse normal equation systems known as nested dissection (George 1973) and, with the right blocking strategy, should have the same advantages. From a computational point of view, it is probably better to break the problem into quite small blocks, i.e. groups of marks for PAGES to process. Small blocks run much faster in the PAGES program and usually result in a more sparse normal equation system thus reducing the overall computational task. However the concept of making many smaller blocks to be individually processed with the PAGES program does have a potential disadvantage. This is because the double differencing method used by PAGES introduces correlations between the observations. The PAGES program has an algorithm (Hilla and Milbert 1989) that will correct for these correlations. For the de-correlation method to work, all observations at a given epoch must be handled simultaneously by the PAGES program. Using the Helmert blocking method with double difference observations prevents the correlations for those observations, of a baseline that spans two blocks, from being handled completely correctly. Practical tests performed with blocked data indicate that results from a Helmert blocked adjustment versus one in which all data was processed through PAGES, so all correlations could be handled correctly, show differences within the normal noise level of our GPS adjustments.

While the above discussion describes one short coming of the Helmert blocking system as incarnated in this software, the counter point is that it allows much larger problems to be solved than could otherwise be handled and it allows inclusion of much larger amounts of real data in adjustments. While the numerical tests done thus far do not prove that the technique will always provide good results they do indicate that it is adequately working in all current applications provided the data are of reasonable quality and the problem is structured correctly.

The nature of the network and the problem to be solved usually suggest an approach as to how the data should be divided for this blocking strategy. The process of designing the groups of data called blocks is often thought of in terms of regions or geographical areas but there are other ways to think about how to divide up the observational data. Time, for example, is another dimension which is a natural blocking factor routinely employed in OP in the form of session processing.

Geographical Blocking - However, if geographical blocking is necessary, because of the size of the project or available resources, one concept would be to divide the marks in the network into logical geographical regions, for example areas where marks are clustered such as in some urban areas. Each block can then be processed independently with the PAGES program as is usually done for any network, with one exception. In order to connect the regions into one complete network, marks common to all blocks should be included. A natural choice would be one or more CORS or, perhaps, dedicated marks that are continuously occupied for the duration of the project. These serve to tie the individual blocks together into a “whole” with the added potential benefit of improving tropo corrections because of their longer data spans.

Appendix A.

FAQ – Troubleshooting Help

Q. The Internet browser I am using fails to refresh my project map and it appears that my project session or adjustment has not been processed by OP?

A. Click the refresh button provided in the 'Control' menu within OP. This forces the Internet browser to reload (submit) and update the map with the most recent project changes.

Q. I submitted a session for processing and then realized a mark name was incorrect and changed it. Will this confuse OP processing?

A. Yes, most likely. Because OPUS Projects uses a web interface rather than a "true" GUI interface, every action is distinct and separate from any other action. If you inadvertently create a situation where two actions may be trying to do the same thing a conflict can occur with only one action winning. For example: I believe you said you were renaming marks while processing was on-going. Broadly, that is OK, but if you happened to rename a mark in the project's information about itself at the same time that the processing is trying to write its results to the project's information, then only one will "win" and get written. This may cause your project to lock up or fail to write to completion or fail to refresh information about itself.

Q. I have seen a mark ID a001 in my project but I didn't upload a file with that mark ID. Where did a001 come from?

A. At least two of your uploaded files have the same mark ID, but their OPUS solutions indicate different locations so OP named it as a001 or where two files have different mark IDs, but the OPUS solutions indicate they are the same mark. You may wish to change the mark name to the correct one by going to the mark web page. This can be avoided at the outset by making sure you label the first four characters of the RINEX (or receiver file) with the correct name of the mark. When you initially planned your survey you should have identified what you will name each mark. That four character name or number should be perpetuated through the OP project starting with the uploading of the named files to OPUS.

Q. I uploaded a file, but the mark doesn't appear in the table at the bottom of the Manager's page. Why doesn't the mark show up in the table?

A. First refresh the Manager's web page. If the mark still doesn't appear, check the data file and its OPUS results. In this case, the data span of the file is probably shorter than the minimum session length. If you uploaded a file that is named exactly the same as a previously uploaded file then the original will be overwritten. Make sure each uploaded file contained the correct mark name.

Q. I received a processing solution email, but it is (mostly) empty and has no attachments. What should I do?

A. The processing failed catastrophically. This is probably a problem in OPUS Projects that you can help fix. Send an email to the OPUS Projects Team with the project ID, session ID and a short summary of the processing setup. The OPUS Projects Team will respond with additional questions or confirmation that the problem has been fixed.

Q. I processed a session, but received a message saying "Unable to retrieve or create a precise ephemeris at this time." What should I do?

A. This is a symptom of a temporary drop in communication between OPUS and CORS. Wait a few minutes and try again.

Q. Why didn't OPUS Projects add the CORS named "abcd" into my project as I instructed?

A. The most like reason is that a CORS data file doesn't exist for that particular day. Check the availability of the CORS site "abcd" on the day in question by looking here: http://www.ngs.noaa.gov/CORS/. If you find the file there please contact the OPUS Projects Team with your concern.

Q. The Manager web page has appeared, but no marks are shown and a popup has appeared saying: "Stop running this script? A script on this page is causing the browser to run slowly." What should I do?

A. Your project is probably large or complex thereby requiring many seconds to display the web page. This is more common in older versions of Internet Explorer, but can happen with any browser. Click "No" as often as needed until the web page fully displays. Projects this complex may result in slow browser response.

Q. I just uploaded, in my haste, a file that processed fine but I put in the wrong ANTCAL code and wrong ARP height. How can I change or remove this out of my project?

A. There are several options:

1) Upload the file again using the correct ANT name and ARP height. The re-uploaded file and its information will overwrite the existing file and information.

2) Navigate to the mark page as the project manager. Look for the Mark occupation table below the description. Most of the fields in that table are editable. Change the ANT name and ARP height there. The OPUS solutions will remain, but the updated information will be used in all subsequent processing in your project.

3) Navigate to the mark page as the project manager. Look for the Mark occupation table below the description. To the upper-right of that table is a button labeled "Manage Data Files." Click that button and a popup window appears listing the data files for that mark. Find the offending data file in the table, click Removed and Apply Changes. But then you have to upload the file again if you still want to use it, so see (1) or (2).

Appendix B.

Using Various Internet Browsers

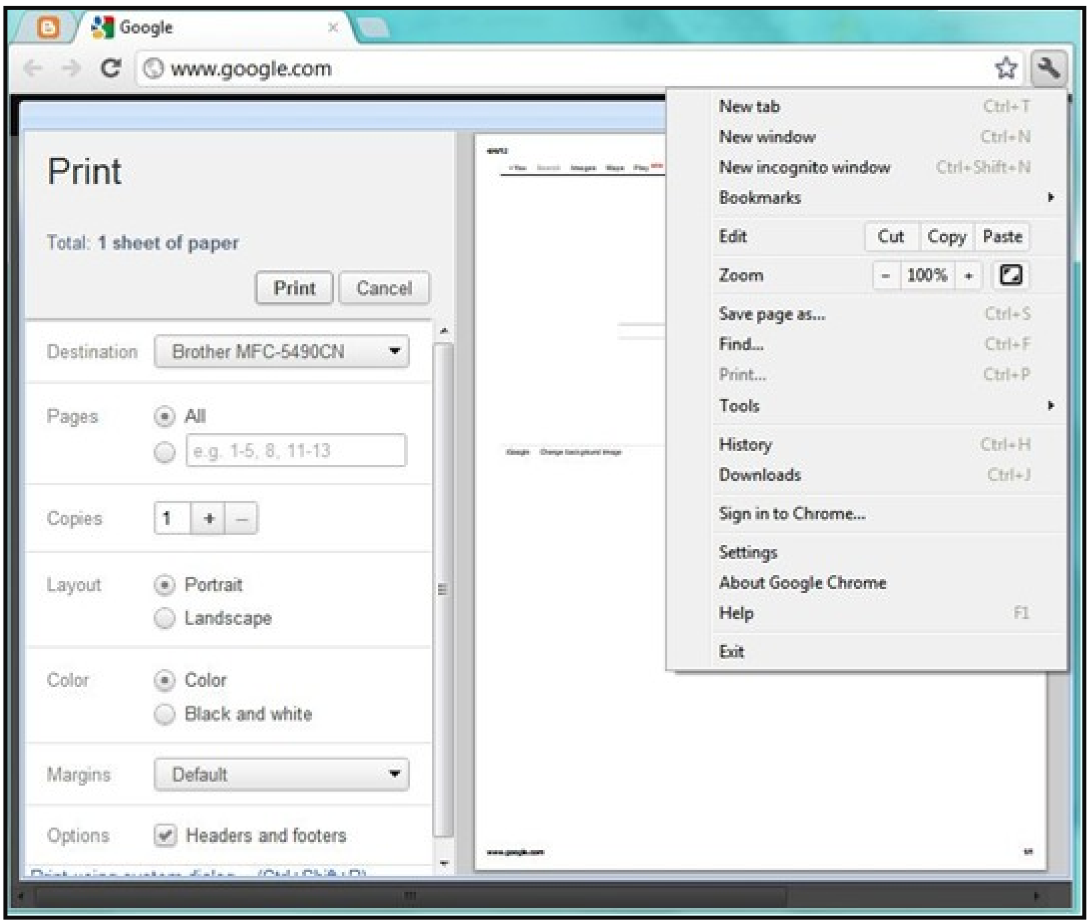
B.1 Print reports displayed by the project web pages

The reports displayed using the Show File control can be printed using instructions specific to the browser being used. The following may be helpful printing.

B.1.1 Printing with Google Chrome™

With Google Chrome™, there is an extension to enable printing a text box frame, i.e. the report text, to a local printer (Figure B.1), but this has not been tested. Without this extension to the browser, the remaining option is to copy and paste the report text into a file.

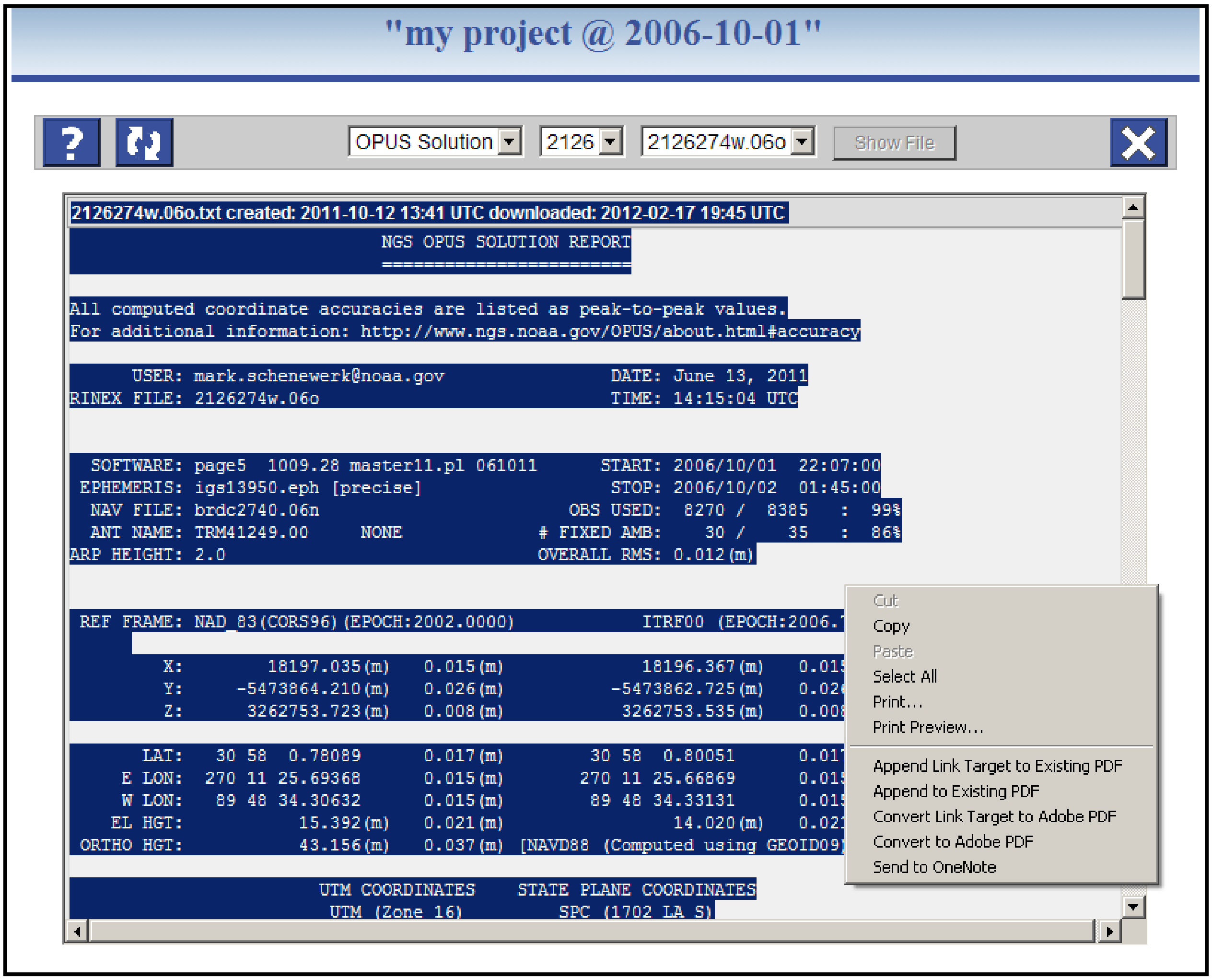
Figure B.1 - Printing with Google Chrome™



B.1.2 Printing with Microsoft Internet Explorer®

Select all the report's text, then right-click on any part of the selected text. A menu will appear (Figure B.2). Select "Convert to Adobe PDF" to save the selected text as a PDF file. After saving, open the PDF and print the PDF file normally.

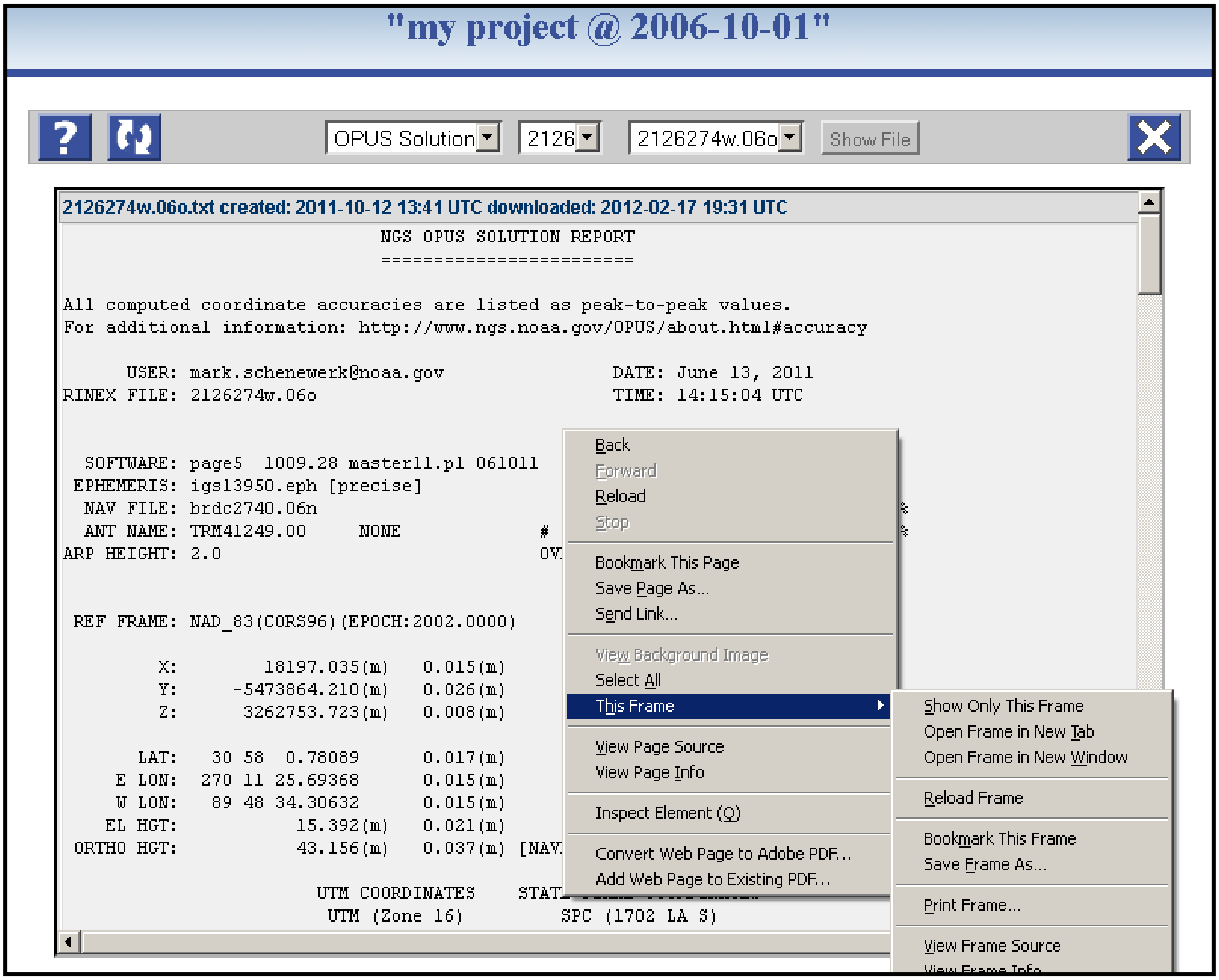
Figure B.2 - Printing with Internet Explorer®



B.1.3 Printing with Mozilla® based browsers such as Firefox®

Right-click anywhere on the report itself should cause a menu to appear. “This Frame” on that menu will open a submenu. Choose the “Print Frame” submenu item (Figure B.3).

Figure B.3 - Printing with Firefox®



Appendix C.

Session Solution and Network Adjustment Summary Report

The first section is an overall summary of the solution. An example report is shown in the shaded (gray) area. Artificial breaks were inserted into this example to make possible a description of the report in this format. The breaks are indicated using vertical ellipses. Annotations for each section follow that section, are identified by numbers on the far right and the corresponding text is highlighted.

```
                  NGS OPUS PROJECTS SESSION SOLUTION REPORT
                   ===========================================

All coordinate accuracies reported here are 1 times the formal                1
uncertainties from the solution.  For additional information:
geodesy.noaa.gov/OPUS/Using_OPUS-Projects.html#accuracy

These positions were computed without any knowledge by the National
Geodetic Survey regarding the equipment or field operating procedures used.

USER:                          your.name@your.address
SOLUTION SOFTWARE:             page5(1203.19)                                 2
SOLUTION DATE:                 2012-03-21T15:20:52 UTC
STANDARD ERROR OF UNIT WEIGHT: 0.722                                          3
TOTAL NUMBER OF OBSERVATIONS:  7048
TOTAL NUMBER OF MARKS:         2
NUMBER OF CONSTRAINED MARKS:   1

OVERALL RMS:                   1.4 cm                                         4
START TIME:                    2011-10-25T12:31:30 GPST
STOP TIME:                     2011-10-25T18:01:00 GPST
PROGRAM OPERATION:             FULL RUN
FREQUENCY:                     L1-ONLY TO ION-FREE [BY BASELINE LENGTH]       5
OBSERVATION INTERVAL:          30 s
ELEVATION CUTOFF:              15 deg                                         6
TROPO INTERVAL:                1800 s [STEP-OFFSET PARAMETERIZATION]          7
DD CORRELATIONS:               ON
                                     ⋮
```

1. Scaling of the formal uncertainties reported.
2. Processing program name and version.
3. The standard error of unit weight should be 1, but values between 0.1 and 1.1 are acceptable. No rescaling of the coordinate sigmas used in the constraints or assumed uncertainties of the observations is performed as part of the solution. As a result, the standard error of unit weight is dependent upon these and other a priori information used in the processing and is rarely exactly 1. Experience has shown that values nearer 0.1 should be expected when TIGHT constraints are used; values will be nearer 1.0 when NORMAL or LOOSE constraints are used. Values for the standard error of unit weight outside this range are not absolutely indicative of a processing problem, but do imply that additional evaluation of the solution is warranted.
4. Smaller is better. The project preference should supersede the following, but an overall RMS ≤ 2 cm is recommended because experience indicates that a value in this range is consistent with having no serious data processing problems. Values > 2 cm are not absolutely indicative of a processing problem, but do imply that additional evaluation of the solution is warranted.
5. As used in OP, PAGES shifts from using L1-only data for shorter baselines to the ionosphere-free combination for longer baselines. This helps insure that the lowest noise, and therefore conventionally preferred, observable is being used regardless of baseline length. The baseline length for this transition is at approximately 7 km.
6. The satellite elevation mask chosen in OP processing. This may differ from that set in the receiver.
7. The neutral atmosphere (tropo) correction parameterization interval and style.

```
                                  ⋮

 BASELINE      LENGTH      RMS        OBS    OMITTED    FIXED
------------------------------------------------------------------
0012-0014      2.8 km    1.4 cm      3496      1.1%     94.4%
fmyr-0014    146.0 km    1.2 cm      3552      1.0%     93.8%
                                  ⋮
```

8a, b, c, d

8a. RMS by baseline: smaller is better. See note 4 for additional information.

8b. OBS by baseline: bigger is better. The number of observations used depends upon conditions at the observing site. Obstructions and unusual conditions should have been noted in the field report and used in evaluating these values. In the absence of this type of information, a v*ery* broad range of expected values can be computed. For the minimum of this range, assume 4 observations per 30 second epoch; for the maximum, assume 11 observations per epoch. In this example, the assumed duration for each baseline is the span of the session, i.e. 5.5 hours (CORS to CORS baselines should be 24 hours regardless of the session span). 5.5 hours per baseline × 120 epochs/hour = 660 epochs per baseline. So, using 4 observations per epoch as the minimum and 11 observations per epoch as the maximum, the expected range is 2640 ≤ OBS ≤ 7260. The numbers reported in this example, ~3500, are at the lower end of this range, but do not explicitly indicate a problem.

8c. OMITTED by baseline: smaller is better. The accepted range is implied by the “Minimum Observations Used” project preference. In other words the percentage of maximum observations omitted = 100 – “Minimum Observations Used”. Generally, experience has shown that values < 10% are typical. Values substantially larger than this may indicate an obstruction or other issue – issues of the type often noted in the field report. Substantially larger values do not absolutely indicate a poor result, but the data and processing should be scrutinized.

8d. FIXED by baseline: bigger is better. The project’s preference for the “Minimum Ambiguities Fixed” should supersede the general guidance given here. Also be aware that the percentage of integers fixed can have weather and baseline length dependencies. Experience indicates that values ≥ 90% are typical for baselines < 10 km under almost all weather conditions. Values ≥ 80% are typical for baselines out to a few hundred kilometers. Beyond a few hundred kilometers, percentages could drop into the 60’s. Values significantly outside these ranges, do not absolutely indicate a poor result, but indicate that additional scrutiny is justified. Information in the field report can be useful in such investigations, as can correlating these values with other reported values such as the number of observations omitted for example.

```
                                  ⋮
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
UNCONSTRAINED MARKS
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                                                                              9
MARK:      0012
                                                                              10a, b
REF FRAME:      NAD_83(2011)   (2010.0000)                IGS08 (2011.8154)
X:                 941989.040 m    0.003 m         941988.317 m    0.003 m    11
Y:               -5607369.113 m    0.011 m       -5607367.521 m    0.011 m
Z:                2880032.721 m    0.006 m        2880032.534 m    0.006 m
LAT:          27 01 06.53888       0.001 m     27 01 06.55840      0.001 m
E LON:       279 32 10.13680       0.001 m    279 32 10.12050      0.001 m
W LON:        80 27 49.86320       0.001 m     80 27 49.87950      0.001 m
EL HGT:               -16.455 m    0.013 m            -18.044 m    0.013 m
ORTHO HGT:             10.214 m    0.019 m (H = h - N WHERE N = GEOID12A HGT) 12a, b

                        UTM COORDINATES    STATE PLANE COORDINATES            13
                         UTM (Zone 17)          SPC ( 901  T  FL E)
NORTHING (Y)  [meters]    2988595.457           297565.003
EASTING (X)   [meters]     553185.894           253204.047
CONVERGENCE   [degrees]    0.24356643           0.24356643
POINT SCALE                0.99963492           0.99997611
COMBINED FACTOR            0.99963750           0.99997869

US NATIONAL GRID DESIGNATOR: 17RNK5318688595(NAD 83)

++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

MARK:      0014

REF FRAME:      NAD_83(2011)   (2010.0000)                IGS08 (2011.8154)
X:                 940017.051 m    0.003 m         940016.328 m    0.003 m
Y:               -5606734.742 m    0.010 m       -5606733.150 m    0.010 m
Z:                2881901.988 m    0.006 m        2881901.801 m    0.006 m
LAT:          27 02 14.69392       0.001 m     27 02 14.71346      0.001 m
E LON:       279 31 03.39024       0.001 m    279 31 03.37393      0.001 m
                                  ⋮
```

9. The four-character mark ID.
10a. Derived coordinates in the requested reference frame and epoch appear on the left. These will only be reported if it is meaningful to do so. For example, NAD 83 coordinates are only meaningful in the United States and its territories; therefore, NAD 83 coordinates will not be reported outside the United States. In these cases, only the computed coordinates, see note 10b, will be reported. Similar limitations can exists for some other requested reference frames.
10b. Computed coordinates in the global reference frame at the mean data epoch appear on the right. These are taken directly from the processing results. The geographic coordinates are computed using the GRS−80 ellipsoid.
11. Adjusted monument coordinates are reported along with their formal uncertainties.
12a. Derived orthometric height, if possible, using the indicated gravimetric geoid or hybrid geoid model.
12b. The gravimetric geoid or hybrid geoid model used in the computation of the derived orthometric height.
13. Derived Universal Transverse Mercator and State Plane Coordinates. Like NAD 83 coordinates, State Plane Coordinates are not defined and won't be reported outside the United States and its territories.

```
                                   ⋮
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
CONSTRAINED MARKS
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

MARK:      fmyr (FORT MYERS; Fort Meyers, Florida, U.S.A.)
CONSTRAINT: PLh= N26:35:27.52643, W081:51:50.98729, -14.8503 m (EL HGT)        14
CONSTRAINT: XYZ SIGMAS=  0.50 cm,  1.78 cm,  0.97 cm (3-D NORMAL)
ADJUSTMENT: XYZ=  -0.014m (0.000m),   -0.023m (0.001m),   -0.014m (0.000m)     15
ADJUSTMENT: NEU=  -0.021m (0.000m),   -0.017m (0.000m),    0.012m (0.001m)

REF FRAME:      NAD_83(2011)   (2010.0000)                 IGS08 (2011.8154)
X:                  807700.692 m    0.000 m          807699.970 m    0.000 m
Y:                -5649862.909 m    0.001 m        -5649861.301 m    0.001 m
Z:                 2837755.977 m    0.000 m         2837755.774 m    0.000 m
LAT:              26 35 27.50745    0.000 m       26 35 27.52619    0.000 m
E LON:           278 08 09.02696    0.000 m      278 08 09.00936    0.000 m
W LON:            81 51 50.97304    0.000 m       81 51 50.99064    0.000 m
EL HGT:                -13.422 m    0.001 m             -14.852 m    0.001 m
ORTHO HGT:              10.884 m    0.014 m (H = h - N WHERE N = GEOID12A HGT)

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 17)         SPC ( 902  T  FL W)
NORTHING (Y) [meters]     2941423.669           250093.720
EASTING (X)  [meters]      413952.295           213530.516
CONVERGENCE  [degrees]    -0.38683724           0.06080492
POINT SCALE                0.99969141           0.99994344
COMBINED FACTOR            0.99969349           0.99994552
```

14. The constraint coordinates and sigmas used.
15. The computed adjustments to the constrained mark's coordinates.

Appendix D.

PAGES (Session Solution) Process Log

An example report is shown in the shaded (gray) area. Artificial breaks were inserted into this example to make possible a description of the report in this format. The breaks are indicated using vertical ellipses. Annotations for each section follow that section, are identified by numbers on the far right and the corresponding text is highlighted. Note that the term station as used here is synonymous with mark.

```
                    page5 VERSION: 1203.19                                          1

     DATE AND TIME OF THIS SOLUTION:   12/03/21  15:20:52

     ANALYST'S NAME:

     START TIME: 2011/10/25  12:31:30      (DAY-OF-YEAR: 298.521875)
     STOP TIME:  2011/10/25  18:01:00      (DAY-OF-YEAR: 298.750695)

     PROGRAM OPERATION:      FULL RUN
     FREQUENCY:              L1->L3 (L6)
     OBSERVATION INTERVAL:   30 (SECONDS)
     ELEVATION CUTOFF:       15 (DEGREES)
     TROPO INTERVAL:         1800 (SECONDS)
     TROPO GRADIENT INTRVL:  NONE
     X AND Y POLE INTERVAL:  NONE
     UT1 INTERVAL:           NONE
     DD CORRELATIONS:        ON

     OVERALL RMS =           0.0139 (METERS)                                        2
  ------------------------------------------------------------------------------
  NUMBER OF SATELLITES: 17   (PRN NUMBERS ARE LISTED BELOW)                         3

   01 02 03 04 06 07 08 09 10 11 13 16 17 19 20 23 28
  WARNING: G01 (G063) "BLOCK IIF          " ORGINALLY "BLOCK IIR-M         "

  PRECISE EPHEMERIS:        igs16592.eph (SP3AP)                                    4
                            PCV:IGS08_1657
                            OL/AL:FES2004  NONE     Y
                            ORB:CMB CLK:CMB
  REFERENCE FRAME:          IGS08                                                   5

  ------------------------------------------------------------------------------
  NUMBER OF STATIONS:   3    (FOUR CHARACTER ID'S ARE LISTED BELOW)                 6

   0012  0014  fmyr
                                          ⋮
```

1. The report starts with general information about this solution such as the program name and version number, the date and time the solution was created, the first and last data epochs, observable type, observation elevation cutoff and neutral atmosphere (tropo) parameterization.
2. The post-fit OVERALL RMS of the solution. Smaller is better. The project preference should supersede the following, but an overall RMS ≤ 2 cm is recommended because experience indicates that a value in this range is consistent with having no serious data processing problems. Values > 2 cm are not absolutely indicative of a processing problem, but do imply that additional evaluation of the solution is warranted.
3. A census of available satellites.
4. The ephemeris used.
5. The reference frame used in this processing.
6. A census of available marks.

```
                              ⋮
--------------------------------------------------------------------------------
NUMBER OF CONSTRAINED STATIONS:  1                                                  7

 fmyr

--------------------------------------------------------------------------------
UNKNOWN PARAMETER SUMMARY:                                                          8


NUMBER OF UNKNOWN STATION POSITIONS:                6
NUMBER OF UNKNOWN STATION VELOCITIES:               0
NUMBER OF CONSTRAINED STATION POSITIONS:            3
NUMBER OF CONSTRAINED STATION VELOCITIES:           0
NUMBER OF TROPOSPHERIC PARAMETERS:                 36
NUMBER OF TROPO GRADIENT PARAMETERS:                0
NUMBER OF PHASE AMBIGUITIES:                        2
NUMBER OF SATELLITE POSITIONS:                      0
NUMBER OF SATELLITE VELOCITIES:                     0
NUMBER OF RADIATION PRESSURE PARAMETERS:            0
NUMBER OF PHASE CENTER PARAMETERS:                  0
NUMBER OF PHASE CORRECTION PARAMETERS:              0
NUMBER OF EOP PARAMETERS:                           0

TOTAL NUMBER OF PARAMETERS:                        47
SINGULARITIES CAUSED BY NO DATA:                    0                               9
OTHER SINGULARITIES:                                0
NUMBER OF UNKNOWNS = PARAMETERS - SINGULARITIES:   47

================================================================================
CONSTRAINTS/OPTIONS
LU=  1, NAME= "pages.skl"
--------------------------------------------------------------------------------
TOLERANCE
LS Matrix Tolerance =  0.100E-05
ESTIMATED SITE COORDINATE ADJUSTMENT AT MONUMENT
RDFSI COUNTS ONLY COORDINATE CHANGES
                              ⋮
```

7. The subset of constrained marks.
8. The unknown parameters estimated in this processing grouped into categories.
9. Singularities are parameters that could not be successfully estimated. SINGULARITIES CAUSED BY NO DATA are permitted. These include, for example, a tropo correction computed during a time span for which no observations were taken. All other singularities <u>always</u> indicate a problem with the solution.

```
                                   ⋮
==============================================================================
 CONSTRAINTS/OPTIONS                                                          10
 LU=  1, NAME= "pages.skl"
 -----------------------------------------------------------------------------
 TOLERANCE
 LS Matrix Tolerance =  0.100E-05
 ESTIMATED SITE COORDINATE ADJUSTMENT AT MONUMENT
 RDFSI COUNTS ONLY COORDINATE CHANGES
 NEU COORDINATE CONSTRAINT                                                    11
   fmyr         X=     807700.0477 Y=   -5649861.3092 Z=    2837755.7679
   fmyr         LAT=  26:35:27.52573 E LON=  278:08:09.01209 EL HGT=   -14.8379
   fmyr         LAT=  26:35:27.52573 W LON=   81:51:50.98792 EL HGT=   -14.8379
   fmyr         SIGMA WEIGHT      HOR=   2.674000E-03    VER=   2.674000E-03
   fmyr         A PRIORI SIGMAS   N=     0.02090  E=     0.01000  U=     0.02935
 END-NEU-SITES
 WRITE SINEX FILE
 DESCRIPTION    OPUS-Projects : NOAA/NOS/NGS
 OUTPUT         2011-298-A
 CONTACT        your.name@your.address
 SOFTWARE       opages.e
 HARDWARE       gypsy (SunOS i86pc)
 INPUT          GNSS data
 WRITE NORMAL MATRIX,  for global unknowns, with file name extension   .nrm
 APPLY DD CORRELATIONS
 OBSERVATION STANDARD ERROR = A0 + A1 / SIN( ELV )
   WHERE A0 =   0.40000000E-02 AND A1 =   0.40000000E-02
 SELECT COORDINATES BY REFERENCE FRAME ID = IGS08
 OUTPUT INTEGER FILES
 STATION INFO , additional site info. files
 user.bin
 /ngslib/data/GPS/cors_08.bin
 /ngslib/data/GPS/igs08.bin
 AGENCY ID     NOAA
 FRAME ID     IGS08
 USE 2D ANTENNA PHASE CORRECTIONS WHEN AVAILABLE
 USE PHASE CENTER OFFSETS
 OCEAN-LOADING MODEL: EXTENDED (FROM SITE INFO FILE AND OCEAN-TIDE GRID)
-----------------------------------------------------------------------------
 STATION INFO     = "user.bin"
 STATION INFO     = "/ngslib/data/GPS/cors_08.bin"
 STATION INFO     = "/ngslib/data/GPS/igs08.bin"
 SATELLITE INFO   = "/ngslib/data/GPS/svnav.dat"
 DESCRIPTIVE TEXT = " "
 POLE POSITIONS   = " "
 UT1 - UTC VALUES = " "
 BROADCAST ORBIT  = "brdc2980.11n"
 ANTENNA PATTERN  = "/home/OPUS/files/ngs08.atx"
 ANTENNA PATTERN (CONT) FORMAT:      1.4,   DATE: IGS08_1673
                                   ⋮
```

10. Processing instructions that change infrequently. These are entered through the pages.skl file.
11. The coordinate constraints are parroted in several formats along with the latitude, longitude and height sigmas. The SIGMA WEIGHTS are scaling factors applied to the coordinate sigmas creating the constraint values used. Smaller sigma weights imply a smaller computed adjustment is permitted.

```
                                    ⋮
==============================================================================
 INPUT FILE
 LU=  1, NAME= "pages.inp"
 ------------------------------------------------------------------------------
 PROGRAM OPERATION      =   0 = FULL RUN
 FREQUENCY              =   6 = L1->L3 (L6)
 ADJUSTED EPHEMERIDES   = " "

 ------------------------------------------------------------------------------
 CONTROL BLOCK     1: FROM 2011/10/25 12:31:30.00 TO 2011/10/25 18:01:00.00
                          (298|  55859.52187500) TO (298|  55859.75069444)
 A PRIORI EPHEMERIDES   = "igs16592.eph" (SP3AP)
 ------------------------------------------------------------------------------
   PRN  P/V   RAD   Y-B   CLK |    ST             OBS     POS   TSF   VEL
 ------------------------------------------------------------------------------
   01   -     -     -     -   |   0012           DOUBLE   NEW   NEW   -
   02   -     -     -     -   |   0014           DOUBLE   NEW   NEW   -
   03   -     -     -     -   |   fmyr           DOUBLE   NEW   NEW   -
   04   -     -     -     -   |
   06   -     -     -     -   |
   07   -     -     -     -   |
   08   -     -     -     -   |
   09   -     -     -     -   |
   10   -     -     -     -   |
   19   -     -     -     -   |
   20   -     -     -     -   |
   23   -     -     -     -   |
   28   -     -     -     -   |

 ------------------------------------------------------------------------------
 DATABASE BLOCK    1: FROM 2011/10/25 12:31:30.00 TO 2011/10/25 18:01:00.00
                          (298|  55859.52187500) TO (298|  55859.75069444)
 ------------------------------------------------------------------------------
   1 DATABASE: "aaaa01"
     INTEGER:  "aaaa01.int"
     NO EXTERNAL MET FILES
 NUMBER OF ST'S:  2;   ID'S: 0012 0014
 REFERENCE STATION FOR DD:   0012
 NUMBER OF SV'S: 17; PRN #'S:  1  2  3  4  6  7  8  9 10 11 13 16 17 19 20 23
                              28
 REF PRN'S AND TIMES:
  07  2011/10/25 12:31:30 - 2011/10/25 16:10:00
  04  2011/10/25 16:10:00 - 2011/10/25 18:00:00
 ------------------------------------------------------------------------------
   2 DATABASE: "aaag01"
     INTEGER:  "aaag01.int"
     NO EXTERNAL MET FILES
 NUMBER OF ST'S:  2;   ID'S: 0014 fmyr
 REFERENCE STATION FOR DD:   fmyr
 NUMBER OF SV'S: 17; PRN #'S:  1  2  3  4  6  7  8  9 10 11 13 16 17 19 20 23
                              28
 REF PRN'S AND TIMES:
  11  2011/10/25 12:31:30 - 2011/10/25 15:58:30
  17  2011/10/25 15:58:30 - 2011/10/25 18:01:00
                                    ⋮
```

12

12. These control parameters change with each processing set up. Collectively they are stored in the pages.inp file.

```
                                  ⋮
==============================================================================
OVERALL STATISTICS:                                                            13

 L6 A PRIORI RMS:          0.0240 M  FROM   34843 OBSERVATIONS;    1013 OMITTED  14
 L6 POST-FIT RMS:          0.0139 M  FROM   34843 OBSERVATIONS;    1013 OMITTED
 L6 STD. ERROR:            0.7221    FROM   34843 OBSERVATIONS;    1013 OMITTED  15
------------------------------------------------------------------------------
 POST-FIT RMS BY SATELLITE VS. BASELINE
 BLOCK=  1 OVERALL      01      02      03      04      06      07      08      09
 ------------------------------------------------------------------------------
 0014-0012|  0.014  0.012  0.021  0.008  0.021  0.008  0.020  0.012  0.030
 0014-fmyr|  0.012  0.011  0.021  0.014  0.013  0.017  0.008  0.011  0.022
 RMS BY PRN         0.012  0.024  0.015  0.017  0.016  0.010  0.013  0.029

 ------------------------------------------------------------------------------
               10      11      13      16      17      19      20      23      28
 ------------------------------------------------------------------------------
 0014-0012|  0.023  0.009  0.006    ...  0.015    ...  0.023  0.012  0.012
 0014-fmyr|  0.024  0.017  0.010  0.021  0.008    ...  0.017  0.012  0.011
 RMS BY PRN  0.022  0.008  0.010  0.019  0.014    ...  0.021  0.012  0.013

 ------------------------------------------------------------------------------
 OBS BY SATELLITE VS. BASELINE
 BLOCK=  1 OVERALL      01      02      03      04      06      07      08      09
 ------------------------------------------------------------------------------
 0014-0012|   3496    544      81      98      55      37      31     449      37
 0014-fmyr|   3552    541      90     101     276      31     459     434      40
 OBS BY PRN          5425     838    1012    1816     325    2910    4460     286

 ------------------------------------------------------------------------------
               10      11      13      16      17      19      20      23      28
 ------------------------------------------------------------------------------
 0014-0012|     84     431     200     ...     455     ...     317      94     583
 0014-fmyr|     87      36     209      43     208     ...     313     114     570
 OBS BY PRN    779    1923    2037     418    3133     ...    3007     781    5693

 ------------------------------------------------------------------------------
 % OMITTED BY SATELLITE VS. BASELINE
 BLOCK=  1 OVERALL      01      02      03      04      06      07      08      09
 ------------------------------------------------------------------------------
 0014-0012|    1.1     0.0     9.9     0.0     1.8     0.0    45.2     0.2     0.0
 0014-fmyr|    0.0    47.2     0.5     0.0     0.0     ...     0.0     0.0     0.0
 % OMITTED    10.9    11.6     1.4     8.6     0.0     ...     5.6     ...     0.8
                                  ⋮
```

13. The OVERALL STATISTICS of the solution signals the end of the processing instruction summary and the beginning of information about the solution.
14. The statistcs include the POST-FIT RMS of the residuals after the solution. Post-fit RMS is the OVERALL RMS in the first block. Smaller is better. For more information, see note 2.
15. Also shown is the STD. ERROR. More correctly called the standard error of unit weight or normalized RMS, its value should be near 1, but values between 0.1 and 1.1 are acceptable. No rescaling of the coordinate sigmas used in the constraints or assumed uncertainties of the observations is performed as part of the solution. As a result, the standard error of unit weight is dependent upon these and other a priori information used in the processing and is rarely exactly 1. Experience has shown that values nearer 0.1 should be expected when TIGHT constraints are used; values will be nearer 1.0 when NORMAL or LOOSE constraints are used. Values for the standard error of unit weight outside this range are not absolutely indicative of a processing problem, but do imply that additional evaluation of the solution is warranted.

```
                                   ⋮
==============================================================================
 LIST OF PARAMETERS SOLVED FOR:                                                     16
 ------------------------------------------------------------------------------
 PHASE REF                EPOCH                 VALUE                               17
 ------------------------------------------------------------------------------
 aaaa01  PRN07    11/10/25 17:59:30.00        0.00000             DD PHASE REF
 aaag01  PRN11    11/10/25 18:00:30.00        0.00000             DD PHASE REF
 ------------------------------------------------------------------------------
 FIXED INTEGERS           EPOCH              L1 VALUE         L2 VALUE
 ------------------------------------------------------------------------------
 aaaa01  PRN01    11/10/25 17:01:00.00     -18113028.00     -14132689.00
 aaaa01  PRN02    11/10/25 17:59:30.00     -14902053.00     -11262860.00
 aaaa01  PRN03    11/10/25 13:27:00.00     -12023514.00      -9386366.00
 aaaa01  PRN04    11/10/25 17:59:30.00     -21132307.00     -16462465.00
 aaaa01  PRN06    11/10/25 12:55:00.00       -131016.00       -137373.00
 aaaa01  PRN08    11/10/25 17:27:00.00     -30950660.00     -24098229.00
 aaaa01  PRN09    11/10/25 17:59:30.00     -18857408.00     -14691265.00
 aaaa01  PRN10    11/10/25 17:59:30.00     -19188819.00     -14948035.00
 aaaa01  PRN11    11/10/25 16:21:00.00     -27508493.00     -21447708.00
 aaaa01  PRN13    11/10/25 14:17:30.00     -30576996.00     -23844172.00
 aaaa01  PRN17    11/10/25 17:59:30.00     -20877376.00     -16240119.00
 aaaa01  PRN20    11/10/25 15:36:00.00     -22873359.00     -16100095.00
 aaaa01  PRN20    11/10/25 16:16:00.00     -22873359.00     -16100095.00
 aaaa01  PRN20    11/10/25 17:59:30.00     -22873359.00     -16100095.00
 aaaa01  PRN23    11/10/25 13:30:30.00     -31973052.00     -24928305.00
 aaaa01  PRN28    11/10/25 17:59:30.00     -18559449.00     -14477591.00
 aaag01  PRN01    11/10/25 17:10:00.00      20237818.00      15728069.00
 aaag01  PRN02    11/10/25 18:00:30.00      26843498.00      20875409.00
 aaag01  PRN03    11/10/25 13:23:30.00      -4805596.00      -3722498.00
 aaag01  PRN04    11/10/25 18:00:30.00      18385238.00      14275351.00
 aaag01  PRN06    11/10/25 12:51:30.00      16967193.00      13242945.00
 aaag01  PRN07    11/10/25 16:33:00.00       6237195.00       4863931.00
 aaag01  PRN13    11/10/25 14:17:30.00      -8682609.00      -6748844.00
 aaag01  PRN16    11/10/25 12:53:00.00       6493688.00       5083330.00
 aaag01  PRN17    11/10/25 18:00:30.00      16535651.00      12884378.00
 aaag01  PRN20    11/10/25 18:00:30.00      21970766.00      17096524.00
 aaag01  PRN28    11/10/25 18:00:30.00      24728964.00      19251114.00
 ------------------------------------------------------------------------------
 PHASE AMBIGUITIES        EPOCH                 VALUE   SIGMA       GOOGE  NDX      18
 ------------------------------------------------------------------------------
 aaaa L6 PRN01-07 11/10/25 17:13:30.00   -3446793.27067(0.00304)M    .10+01    1
 aaag L6 PRN23-11 11/10/25 13:30:30.00    -791357.77515(0.00103)M    .89+00   33
                                   ⋮
```

16. Next comes lists of the estimated parameters. All parameters in this list are reported using a standard format.
17. This list always starts with the FIXED INTEGERS, i.e. the phase ambiguities held fixed to their integer values.
18. Note that in this example, two ambiguities could not be fixed to their integer values.

```
                                    ⋮
  ------------------------------------------------------------------------------
  STATION ADJUSTMENTS       EPOCH                  VALUE   SIGMA        GOOGE  NDX
  ------------------------------------------------------------------------------
  NOTE: X VALUES ARE TAGGED WITH THE WEIGHTED MEAN (GPS) EPOCH.
        Y VALUES ARE TAGGED WITH THE FIRST DATA (GPS) EPOCH.
        Z VALUES ARE TAGGED WITH THE REFERENCE (GPS) EPOCH.
  ------------------------------------------------------------------------------
  0012     X        11/10/25 15:20:40.93          0.04808(0.00051)M    .79+00   55
  0012     Y        11/10/25 12:31:30.00         -0.02042(0.00219)M    .68+00   56
  0012     Z        11/10/25 12:31:30.00         -0.03487(0.00114)M    .62-01   57
  0012     ZEN WET  11/10/25 12:45:00.00         -0.03790(0.00417)M    .99+00   52
  0012     ZEN WET  11/10/25 13:15:00.00         -0.08931(0.00387)M    .99+00   52
  0012     ZEN WET  11/10/25 13:45:00.00         -0.11549(0.00658)M    .10+01   52
  0012     ZEN WET  11/10/25 14:15:00.00         -0.06705(0.00730)M    .99+00   52
  0012     ZEN WET  11/10/25 14:45:00.00         -0.08029(0.01144)M    .99+00   52
  0012     ZEN WET  11/10/25 15:15:00.00         -0.05607(0.00817)M    .98+00   52
  0012     ZEN WET  11/10/25 15:45:00.00         -0.01976(0.00528)M    .99+00   52
  0012     ZEN WET  11/10/25 16:15:00.00         -0.02131(0.00470)M    .99+00   52
  0012     ZEN WET  11/10/25 16:45:00.00         -0.04164(0.00593)M    .99+00   52
  0012     ZEN WET  11/10/25 17:15:00.00         -0.05813(0.00412)M    .83+00   52
  0012     ZEN WET  11/10/25 17:45:00.00         -0.06315(0.00417)M    .99+00   52

  0014     X        11/10/25 15:18:12.44         -0.01559(0.00050)M    .77+00   58
  0014     Y        11/10/25 12:31:30.00         -0.00244(0.00210)M    .66+00   59
  0014     Z        11/10/25 12:31:30.00         -0.02278(0.00109)M    .63-01   60
  0014     ZEN WET  11/10/25 12:45:00.00         -0.03842(0.00411)M    .97+00   53
  0014     ZEN WET  11/10/25 13:15:00.00         -0.03368(0.00387)M    .96+00   53
  0014     ZEN WET  11/10/25 13:45:00.00         -0.04085(0.00599)M    .82+00   53
  0014     ZEN WET  11/10/25 14:15:00.00         -0.06080(0.00777)M    .80+00   53
  0014     ZEN WET  11/10/25 14:45:00.00         -0.07443(0.01229)M    .83+00   53
  0014     ZEN WET  11/10/25 15:15:00.00         -0.05293(0.00815)M    .95+00   53
  0014     ZEN WET  11/10/25 15:45:00.00         -0.01125(0.00527)M    .97+00   53
  0014     ZEN WET  11/10/25 16:15:00.00         -0.01596(0.00468)M    .96+00   53
  0014     ZEN WET  11/10/25 16:45:00.00         -0.03936(0.00587)M    .97+00   53
  0014     ZEN WET  11/10/25 17:15:00.00         -0.03942(0.00410)M    .95+00   53
  0014     ZEN WET  11/10/25 17:45:00.00         -0.04914(0.00417)M    .96+00   53
  0014     ZEN WET  11/10/25 18:00:45.00         -0.03442(0.02423)M    .97+00   53

  fmyr     X        11/10/25 15:17:36.45         -0.01418(0.00002)M    .10+01   61
  fmyr     Y        11/10/25 12:31:30.00         -0.02293(0.00005)M    .90+00   62
  fmyr     Z        05/01/01 00:00:00.00         -0.01373(0.00004)M    .92+00   63
  fmyr     ZEN WET  11/10/25 12:45:00.00         -0.04495(0.00378)M    .86+00   54
  fmyr     ZEN WET  11/10/25 13:15:00.00         -0.09064(0.00389)M    .84+00   54
  fmyr     ZEN WET  11/10/25 13:45:00.00         -0.11085(0.00699)M    .82+00   54
  fmyr     ZEN WET  11/10/25 14:15:00.00         -0.06080(0.00777)M    .80+00   54
  fmyr     ZEN WET  11/10/25 14:45:00.00         -0.07443(0.01229)M    .83+00   54
  fmyr     ZEN WET  11/10/25 15:15:00.00         -0.04919(0.00783)M    .77+00   54
  fmyr     ZEN WET  11/10/25 15:45:00.00         -0.01211(0.00509)M    .84+00   54
  fmyr     ZEN WET  11/10/25 16:15:00.00         -0.01628(0.00447)M    .84+00   54
  fmyr     ZEN WET  11/10/25 16:45:00.00         -0.03635(0.00546)M    .84+00   54
  fmyr     ZEN WET  11/10/25 17:15:00.00         -0.04531(0.00408)M    .80+00   54
  fmyr     ZEN WET  11/10/25 17:45:00.00         -0.04751(0.00419)M    .80+00   54
  fmyr     ZEN WET  11/10/25 18:00:45.00         -0.04536(0.02438)M    .82+00   54
                                    ⋮
```

19

19. For completeness, parameters associated with the marks are also reported here, but the mark coordinates with supporting information are repeated below in a descriptive format. Note that marks are labelled as stations to support other applications that use PAGES. ZEN WET rows show the tropo delay corrections applied to each mark/station.

```
                                    ⋮
==============================================================================
STATION NAME: 0012       1                                                      20
SITE INFO: "user.bin"
PHASE CENTER OFFSETS: "/home/OPUS/files/ngs08.atx"
RECEIVER:                              F/W=UNKNOWN        S/N=UNKNOWN
ANTENNA: ASH701945E_M    NONE                             S/N=-----
MONUMENT: ---------
PLATE: UNKNOWN

MET DATA WAS MODELLED USING STATION HEIGHT, STATION LATITUDE, DATE, AND TIME

INPUT VALUES VALID AT 2011/298 15:18 = 2011/298.63743 = 2011.8154               21
REFERENCE FRAME: IGS08
   941988.2690  -5607367.5010   2880032.5690  0012 MON @ 2011.8151 (M)
N=     -0.0000 E=      0.0000 U=      1.9990  MON TO ARP (M)
N=      0.0010 E=     -0.0001 U=      0.0905  ARP TO L1 PHASE CENTER (M)
N=      0.0000 E=      0.0006 U=      0.1190  ARP TO L2 PHASE CENTER (M)

A PRIORI COORDINATES AT 2011/298 15:18 = 2011/298.63743 = 2011.8154
   941988.2690  -5607367.5010   2880032.5690  0012 MON @ 2011.8151
        0.0000         0.0000         0.0000  VEL TIMES  0.0003 YRS
        0.2950        -1.7562         0.9081  MON TO ARP
---------------------------------------------
   941988.5640  -5607369.2572   2880033.4771  0012 ARP @ 2011.8154
        0.0132        -0.0791         0.0421  ARP TO L1 PHASE CENTER
---------------------------------------------
   941988.5772  -5607369.3363   2880033.5192  0012 L1 PHS CEN @ 2011.8154

ADJUSTED COORDINATES AT 2011/298 15:18 = 2011/298.63743 = 2011.8154             22
(USING DATA FROM 11/298 12:31:30.00 TO 11/298 18:01:30.00)
   941988.2690  -5607367.5010   2880032.5690  0012 MON @ 2011.8154
        0.0481        -0.0204        -0.0349  + XYZ ADJUSTMENTS
--------------------------------------------
   941988.3171  -5607367.5214   2880032.5341  NEW 0012 MON @ 2011.8154
        0.2950        -1.7562         0.9081  + MON TO ARP
--------------------------------------------
   941988.6121  -5607369.2776   2880033.4422  NEW 0012 ARP @ 2011.8154
        0.0132        -0.0791         0.0421  + ARP TO L1 PHASE CENTER
--------------------------------------------
   941988.6253  -5607369.3567   2880033.4843  NEW 0012 L1PC @ 2011.8154
                                    ⋮
```

20. Finally, the information known about each mark (STATION) is reported. The report for each mark starts with a report of the known hardware and a priori information for each mark.
21. From the a priori information, the coordinates for the critical physical or electrical points on the antenna are computed: the monument (MON), antenna reference point (ARP) and the L1 phase center (L1PC).
22. Next, the estimated adjustments to the MON are added and adjusted coordinates for the critical points are computed.

```
                                    ⋮
=========================================================================     23
        X             Y              Z      DESCRIPTION
-------------------------------------------------------------------------
   941988.6253  -5607369.3567   2880033.4843  NEW 0012 L1PC @ 2011.8154

   941988.6121  -5607369.2776   2880033.4422  NEW 0012 ARP @ 2011.8154

   941988.3171  -5607367.5214   2880032.5341  NEW 0012 MON @ 2011.8154
        0.0005         0.0022         0.0011  NEW 0012 MON SIGMAS @ 2011.8154

        0.0481        -0.0204        -0.0349  XYZ ADJ (M) FOR 0012
        0.0005         0.0022         0.0011  XYZ ADJ SIGMAS (M) FOR 0012
 -0.7618903373   0.7324828985  -0.9629222436  XY, XZ & YZ CORR FOR 0012

=========================================================================     24
        LAT           LON            HGT      COMPUTED USING GRS-80
                                              ELLIPSOID'S SEMI-MAJOR AXIS
                                              AND FLATTENING
-------------------------------------------------------------------------
 27  1  6.55844  279 32 10.12050    -15.9549  NEW 0012 L1PC (E) @ 2011.8154
 27  1  6.55844   80 27 49.87951    -15.9549  NEW 0012 L1PC (W) @ 2011.8154

 27  1  6.55840  279 32 10.12050    -16.0454  NEW 0012 ARP (E) @ 2011.8154
 27  1  6.55840   80 27 49.87950    -16.0454  NEW 0012 ARP (W) @ 2011.8154

 27  1  6.55840  279 32 10.12050    -18.0444  NEW 0012 MON (E) @ 2011.8154
 27  1  6.55840   80 27 49.87950    -18.0444  NEW 0012 MON (W) @ 2011.8154
        0.0003         0.0003         0.0025  NEW 0012 MON SIGMAS @ 2011.8151

 27  1  6.55840  279 32 10.12050    -18.0444  ALT 0012 MON (E) @ 2011.8151
 27  1  6.55840   80 27 49.87950    -18.0444  ALT 0012 MON (W) @ 2011.8151
        0.0003         0.0003         0.0025  ALT 0012 MON SIGMAS @ 2011.8151

       -0.0438         0.0440         0.0092  NEU ADJ (M) FOR 0012
        0.0003         0.0003         0.0025  NEU ADJ SIGMAS (M) FOR 0012
 -0.1033981199  -0.0625495332   0.0819394678  NE, NU & EU CORR FOR 0012

+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++     25
STATION NAME: 0014       1
SITE INFO: "user.bin"
PHASE CENTER OFFSETS: "/home/OPUS/files/ngs08.atx"
RECEIVER:                              F/W=UNKNOWN        S/N=UNKNOWN
ANTENNA: ASH701945E_M    NONE                             S/N=-----
MONUMENT: ---------
PLATE: UNKNOWN
                                    ⋮
```

23. The geocentric coordinates in the specified reference frame (see note 5 and 21) for critical points on the antenna are then listed. The estimated adjustments for each coordinate, their 1 sigma formal uncertainty and the X-Y, X-Z and Y-Z correlation coefficients follow immediately.
24. Then the corresponding geographic north latitude, east and west longitude, and ellipsoidal height are given in a table followed by the estimated adjustments for each coordinate, their 1 sigma formal uncertainty and the N-E, N-U and E-U correlation coefficients.
25. Similar information is reported for each mark in the solution.

```
                                   ⋮

 ==============================================================================
ADJUSTED BASELINE COMPONENTS
(MONUMENT TO MONUMENT; METERS; VALUES FOR 2011.8154)
NUMBER OF BASELINES:  2

 ST 1 TO ST 2      DELTA X         DELTA Y         DELTA Z         LENGTH
 ---------------------------------------------------------------------------
 0012 TO 0014     -1971.9887        634.3710       1869.2671       2790.2196
 fmyr TO 0014    132316.3582      43128.1504      44146.0270     146001.8072

 NORMAL TERMINATION
```

26

26. At the bottom of the file is a table listing the adjusted baseline (monument to monument) components and lengths.

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Online Positioning User Service (OPUS): http://geodesy.noaa.gov/OPUS/
Continuously Operating Reference Stations (CORS): http://geodesy.noaa.gov/CORS/
Height Modernization: http://geodesy.noaa.gov/heightmod/Definition.shtml
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