

Interactive Web-based GPS Network Processing and Adjustment Using NGS' OPUS-Projects

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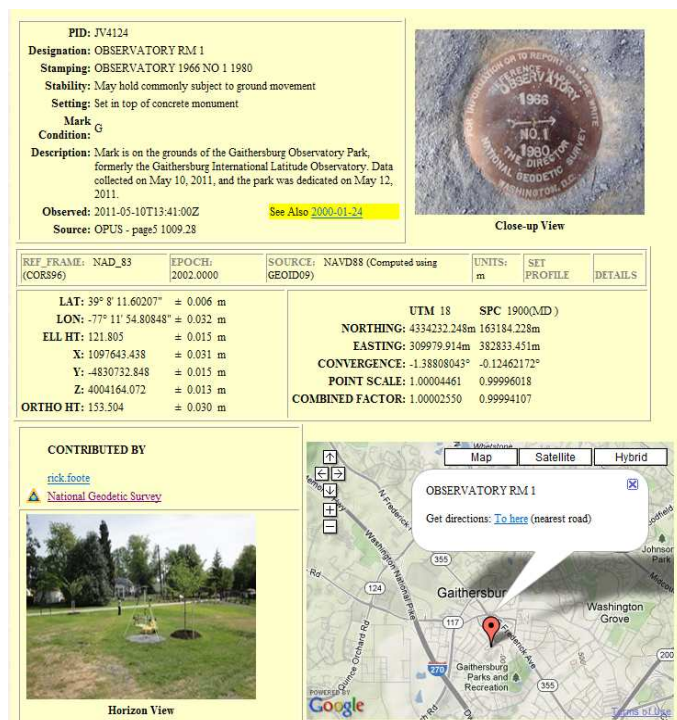
SUMMARY

OPUS-Projects is a web-based utility that provides access to the National Geodetic Survey's (NGS) precise GPS positioning software for processing and adjusting survey projects spanning multiple observing sessions. Although still a beta product, OPUS-Projects will eventually be a part of the Online Positioning User Service (OPUS) program suite. It provides geodetic network solutions utilizing baseline processing of project sessions comprised of simultaneous GPS observations followed by a least squares adjustment of all project sessions. OPUS-Projects begins with a Project Manager creating projects on the OPUS-Projects home page. This reserves disk space on NGS's computers and provides Key Words for the data submittal, processing and project management. Project data is then uploaded through the standard OPUS web page with the project Key Word generated at project creation. Project managers receive copies of the OPUS reports and can monitor project performance and progress via maps and tabular formats as the project is taking place. Once a project's data has been uploaded, session processing provides options for designing baseline connections and mark constraints. The position solutions from each session may be viewed and evaluated graphically prior to the final network adjustment. OPUS-Projects allows for the input of accompanying metadata (photographs and descriptions) so that project solutions may eventually be efficiently published in OPUS-Data Base. OPUS-Projects offers a user-friendly interface to the NGS GPS processing tools and is rapidly achieving wide popularity. This new capability provides the redundancy and enhanced quality assurance not readily provided by the single mark capability of the current OPUS.

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Since 2001 the National Geodetic Survey (NGS) has operated the Online Positioning User Service (OPUS) as a means to quickly and accurately determine positions with respect to the National Spatial Reference System (NSRS). Users upload GPS data to OPUS via a web page where it is processed on NGS computers using NGS software and data from several Continuously Operating References Stations (CORS). The results are emailed to the user within a few minutes. OPUS has proven to be a very popular service within the surveying and engineering communities in the U.S. and is currently processing about 30,000 positions each month.



For the past few years OPUS has also featured a “Publish My Solution” option (known as OPUS-DB). This option allows OPUS users to publish results meeting certain solution quality control standards. Along with selecting the calibrated antenna type and entering the antenna height, users can also enter descriptions and photos of the mark they occupied. These metadata and the solution results can be publicly shared after review by the user and NGS. An example of a published solution is shown in Figure 1. The time to publish can be as short as the same day the data are submitted. Due to its simplicity and efficiency, NGS expects this feature to eventually replace the more laborious “Blue Book” process where results are submitted to its data base.

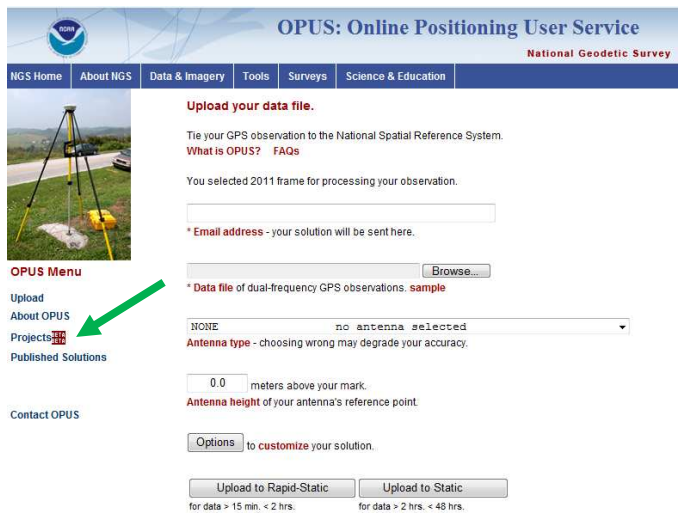
Figure 1. A sample OPUS published solution.

OPUS offers NGS and users significant advantages over previous methods of GPS processing and data base submittal, foremost of which is consistency. Previously, and continuing to the present, NGS accepted *vectors* along with covariance information for adjustment at NGS and inclusion in its data base. However, there is no rigorous control how these vectors are determined. For example, the modeling used within the user's processing software, the parameterization of the troposphere, the number of ambiguities fixed to integers, and the use of single or ion-free frequencies, etc. is not controlled, allowing a variety of biases and precisions to be combined in the data base. As sub-centimeter accuracies are becoming commonplace and are increasingly expected, these unregulated discrepancies are not acceptable.

OPUS avoids these problems and achieves essential consistency by accepting user's *raw data*, rather than user's results (*vectors*), for processing using NGS's highest precision software. In addition, OPUS archives all project files including the raw data files uploaded to it so that in the event of any software improvements or reference frame updates, the entire data base can be quickly reprocessed, preserving this consistency. By ingesting user's data directly from their GPS receivers or computers into NGS's computers and minimizing the metadata input required from the user, OPUS provides a nearly automated, highly precise positioning and publishing service.

While each single OPUS upload is computed with respect to 3 CORS, many OPUS users would prefer the redundancy of multiple occupations within a network adjustment. As such, NGS began development of a new option for beta-testing known as OPUS-Projects. This option offers significant advantages for easy data submittal, file management, session processing and project adjustment.

OPUS-Projects can be accessed from the OPUS home page located at <http://www.geodesy.noaa.gov/OPUS/> as seen in Figure 2. Data uploaded to a project will require the same input as usual to OPUS. The users will



enter their email addresses and then browse to the data file to be submitted. This data file can be a RINEX file or a binary file in one of the recognized receiver formats. The user must also select the antenna type used to collect these data from the pull down menu provided on the screen. This menu includes all the antennas likely to be used for precise positioning that have been calibrated to locate their phase centers and the variation of these phase centers with direction. The user next enters the height of the antenna's reference point above the mark that is being occupied. This antenna information is all that is necessary for the accurate processing of the data. Users needing some help

Figure 2. The OPUS home page. accuracy, or related research.

identifying their antenna or looking for further information on calibrated antennas may go to the NGS Antenna Calibration web page at <http://www.geodesy.noaa.gov/ANTCAL/>.

Clicking “Projects” on the OPUS page brings up the OPUS-Projects home page, Figure 3. This page provides access to each of the major OPUS-Projects functions. The first step is to create a project. This will reserve disk space on NGS computers where the data uploaded to this project will reside, where the processing will be performed and where all files relevant to this project will be kept. In order to *create* a project, a user must have attended a training session for Project Managers. Session processing and network adjustments using OPUS-Projects is not particularly complicated but it does require some familiarity with all the features of the system. NGS and a few other agencies offer workshops where OPUS-Projects is described in detail and practice data sets are provided.

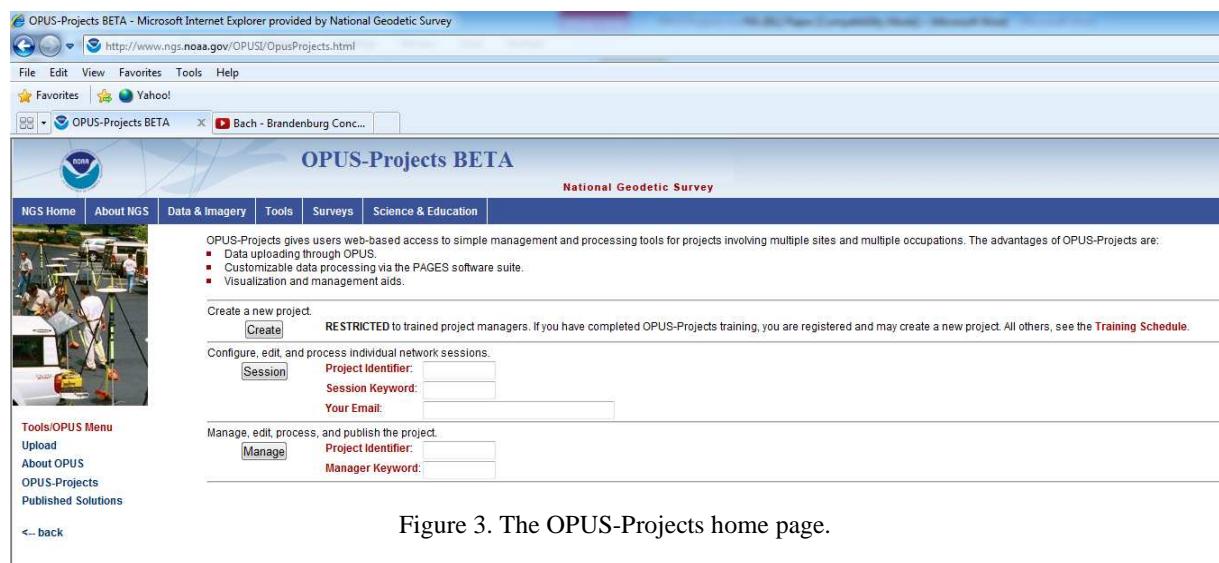
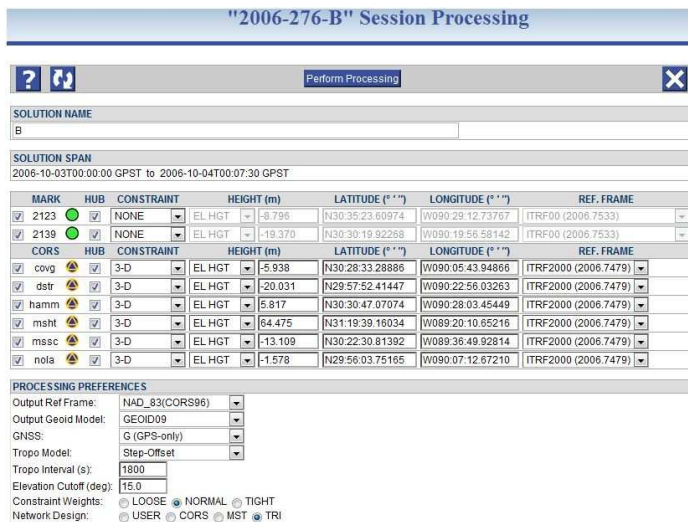


Figure 3. The OPUS-Projects home page.

When a project is created, the Project Manager will provide a project title and some basic information about the project which may help NGS plan for required resources. The Project Manager will receive a set of Key Words that provide or restrict access to the various project functions. A Key Word is required to identify a project and upload data to it. Another Key Word allows processing the individual project sessions, and a third Key Word allows network adjustment, publishing and overall project management. The Project Manager may customize these Key Words and distribute them as seen fit.

The field personnel collecting the data and uploading to the project are not required to have taken OPUS-Projects training. Once given the Key Word by their Project Manager, they will use the “Options” link on the OPUS home page and enter the Project Key Word as shown in Figure 4. As usual the uploaded data file will be processed by OPUS and a report emailed to the user. However, for data uploaded to a project,



In order to use PAGES correctly, the user must specify certain parameters. This is done by accessing the session processing page shown in Figure 6. The details of how to use this page are thoroughly explained in the OPUS-Projects workshops. Briefly, there are check boxes to include or not include a mark's data in this session processing and how each mark's a priori position may be constrained. There is also a list of processing preferences which allow the user to select some basic parameters used in the session processing.

Since PAGES uses double differences to process data, the user is offered some flexibility in how he wants the baseline

Figure 6. The OPUS-Projects session processing page. The user is offered some flexibility in how he wants the baseline. The user may designate the desired HUB(s) or use some standard network designs offered by OPUS-Projects. In all cases, the baseline design will be displayed on the map on the session page. Different parameterizations of session solutions may be saved by designating the solution name allowing the user to search for optimal performance. Each session solution generates a detailed report that may be viewed within OPUS-Projects and is also emailed to the user processing the session.

The Manager's Page allows control of project functions including the final network adjustment. The initial view of the Manager's Page, Figure 7, shows a map of all the contributions to the project and a table summarizing the sessions in which each mark is present. This is a convenient way for the Project

TS05B - GNSS CORS Infr Figure 7. The OPUS-Projects Manager's Page.



Manager to monitor the progress of the project as it is taking place provided the project data is uploaded to OPUS in a timely fashion.

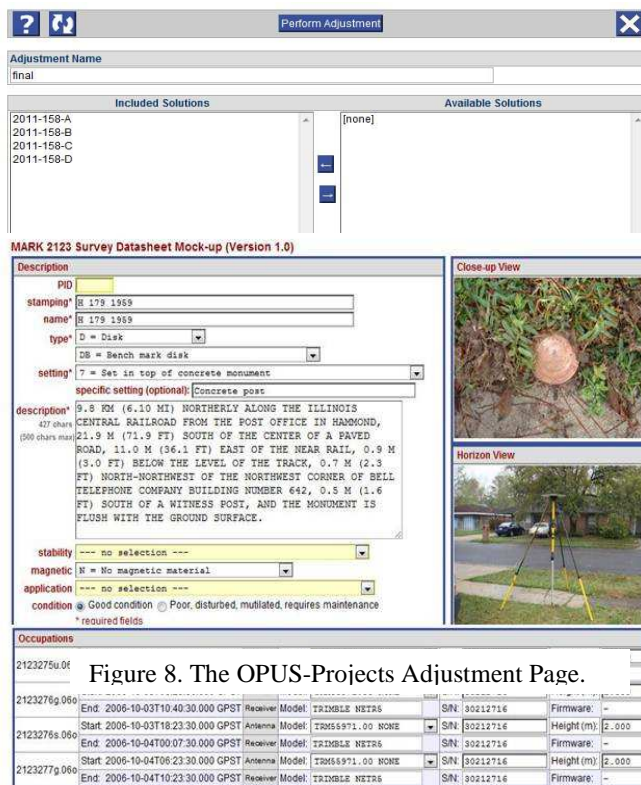


Figure 8. The OPUS-Projects Adjustment Page.

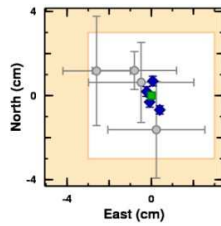
The menu on the left allows the manager to set project preferences that include the Key Words, processing parameterization, and basic quality indicators shown on the map display and tables. The manager can also review all OPUS and session solution reports as well as the data sheets prior to publication.

By selecting Set Up Adjustment, the manager brings up the Adjustment Page, Figure 8. On this page the manager selects the session solutions to be included in this adjustment and selects the marks to be constrained and the magnitude of those constraints. The adjustment generates a detailed report that is emailed to the Project Manager and may also be viewed online.

The Project Manager's page also allows each mark to be analyzed individually. By clicking on a mark identifier on the left of the summary table, the information for that mark is displayed. This is the most important step in evaluating how well each mark's position was determined and reviewing the

■ NETWORK SOLUTION			EAST (cm)	NORTH (cm)
network-final			0.0 ±0.0	0.0 ±0.1
◆ SESSION SOLUTION			EAST (cm)	NORTH (cm)
2006-275-B			0.4 ±0.0	-0.7 ±0.2
2006-276-A			-0.1 ±0.0	-0.3 ±0.2
2006-276-B			0.1 ±0.1	0.7 ±0.2
2006-277-A			-0.2 ±0.0	0.2 ±0.2
● OPUS SOLUTION			EAST (cm)	NORTH (cm)
2123275u 06s			-0.8 ±2.0	1.2 ±0.9
2123276g 06s			-2.6 ±1.6	1.2 ±2.6
2123276a 06s			0.2 ±2.3	-1.6 ±2.3
2123277g 06s			-0.5 ±2.5	0.6 ±1.9

The (0, 0) point represents W090:29:12.73738 by N30:38:23.69935.



■ NETWORK SOLUTION			EPOCH	UP (cm)
network-final			2006-275T23:59:45GPST	0.0 ±0.1
◆ SESSION SOLUTION			EPOCH	UP (cm)
2006-275-B			2006-275T23:54:51GPST	0.0 ±0.3
2006-276-A			2006-276T10:53:00GPST	0.4 ±0.3
2006-276-B			2006-276T13:44:12GPST	0.9 ±0.3
2006-277-A			2006-277T11:14:01GPST	1.7 ±0.3
● OPUS SOLUTION			EPOCH	UP (cm)
2123				
2123				
2123277g 06s			2006-277T08:11:45GPST	1.5 ±5.4

The UP 0 point represents -8.78753 m.

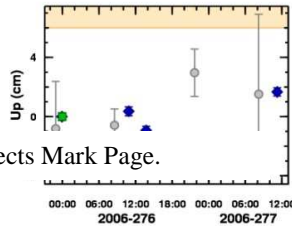
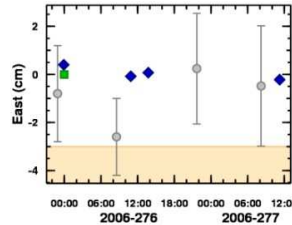


Figure 9. The OPUS-Projects Mark Page.

mark was not intended for publication and no metadata were entered, these entries will be blank. Checking that the correct antenna type and antenna height was used in the processing is crucial for finding problems and anomalous results.

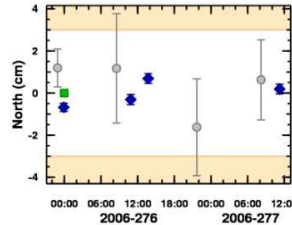
■ NETWORK SOLUTION			EPOCH	EAST (cm)
network-final			2006-275T23:59:45GPST	0.0 ±0.0
◆ SESSION SOLUTION			EPOCH	EAST (cm)
2006-275-B			2006-275T23:54:51GPST	0.4 ±0.0
2006-276-A			2006-276T10:53:00GPST	-0.1 ±0.0
2006-276-B			2006-276T13:44:12GPST	0.1 ±0.1
2006-277-A			2006-277T11:14:01GPST	-0.2 ±0.0
● OPUS SOLUTION			EPOCH	EAST (cm)
2123275u 06s			2006-275T22:54:28GPST	-0.8 ±2.0
2123276g 06s			2006-276T08:32:38GPST	-2.6 ±1.6
2123276a 06s			2006-276T21:41:02GPST	0.2 ±2.3
2123277g 06s			2006-277T08:11:45GPST	-0.5 ±2.5

The EAST 0 point represents W090:29:12.73738.



■ NETWORK SOLUTION			EPOCH	NORTH (cm)
network-final			2006-275T23:59:45GPST	0.0 ±0.1
◆ SESSION SOLUTION			EPOCH	NORTH (cm)
2006-275-B			2006-275T23:54:51GPST	-0.7 ±0.2
2006-276-A			2006-276T10:53:00GPST	-0.3 ±0.2
2006-276-B			2006-276T13:44:12GPST	0.7 ±0.2
2006-277-A			2006-277T11:14:01GPST	0.2 ±0.2
● OPUS SOLUTION			EPOCH	NORTH (cm)
2123275u 06s			2006-275T22:54:28GPST	1.2 ±0.9
2123276g 06s			2006-276T08:32:38GPST	1.2 ±2.6
2123276a 06s			2006-276T21:41:02GPST	-1.6 ±2.3
2123277g 06s			2006-277T08:11:45GPST	0.6 ±1.9

The NORTH 0 point represents N30:38:23.69935.



as the origin for the remaining plots. The plots of the vertical, east and north as a function of time are very useful for identifying any problem with this mark in a particular session.

Page Plots.

OPUS-Projects is still undergoing development but is nonetheless operating during this beta-test phase. Approximately 200 Project Managers have been trained as of this writing and several hundred projects have been loaded and processed providing NGS with valuable feedback on its performance. Reaction to OPUS-Projects has been very positive and NGS expects that this and the other OPUS capabilities will become the primary means by which users may tie their data to the NSRS.

Figure 10. The OPUS-Projects Station Plots.

