

GPS GLOBAL TRACKING NETWORK OPERATIONS AT JPL DURING THE 1992 IGS EXPERIMENT AND BEYOND

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The JPL GPS Network Operations center provides resource in personnel and equipment to support the activities of maintaining, collecting and sharing data from a global network of GPS receivers, this is done in cooperation with many agencies around the world with data being exchanged via networks. During the IGS campaign, from 21 June 1992 to 23 September 1992, JPL collected approximately 1000 station days of data from 10 globally distributed GPS sites. The average time of data acquisition from the receiver to final distribution of the data was 27 hours during the campaign. Currently data is collected, processed and distributed from a 15 globally distributed stations. It is our intention for the foreseeable future to support and keep up the operation of the GPS Global Tracking Network,

1 INTRODUCTION

The GPS Network Operations center at JPL provides resources for the collection, distribution and maintenance of GPS data from a global network of GPS receivers. This includes the ability to remotely diagnosis receiver problems, communicate with receivers and operators of receivers, to automatically collect, process and distribute data for 14 stations in the IGS network. This amounts to 35 megabyte.s of raw, finished data and products daily.

JPL GPS NETWORK OPERATIONS

Station Support

As part of our effort in the development, deployment and maintenance of the JPL JNN network and other NASA owned receivers a depot in operation has been created at JPL. The depot provides for receiver diagnostics and repair. This facility includes the ability to test, repair and calibrate the Rogue SNR-8, SNR-800 and SNR-8000 (Turbo Rogue) GPS receivers. The ability to provide working spares to keep the network up and running is also another requirement for maintaining a continuous data flow from each site. The depot also maintains a history on each receiver's performance and problems so that failure modes and trends can be identified and corrected either in hardware or for future releases of the firmware.

In addition to the hardware maintenance, software maintenance and diagnostics also continue at JPL. An example is on August 8 1992 Anti Spoofing was turned on for the

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first of many times to come. This serendipitously uncovered an anomaly in the Rogue receiver software. A team of was formed at JPL, to address the problem. The error was isolated, corrected and tested, Once. the. new code was validated firmware. (PROM's) were made and distributed to 28 Rogue sites within the GPS Global Network. A general network upgrade was planned for and implemented on 5 February 1993. Currently 27 of the 2.8 Rogue sites are known to have been upgraded to the new software (Menix 7.3),

Support by telephone for local operations or direct] y to remote. Rogue's are continuing for diagnosing receiver problems. This support of the global network is primarily for the NASA owned or operated receivers but is available to other users of the Rogue receivers. Rogue experts at JPL, with the. aid of local personnel can often resolve receiver problems at remote locations [ref 1]. This prevents the receiver from having to be returned for repair and keeps the site up time maximized. For NASA owned or operated sites (and other sites on request) the receivers periodically -called over telephone lines using modems for preventative maintenance. In addition telephone communication upload logs, when available, and data files are analyzed for indications of receiver or other site problems. in many cases a call to the local personnel will then allow for the confirmation and correction of the. problem and coordination for the receipt of replacement parts can be performed.

Site Catalog

A network of this complexity naturally produces a significant amount of site information. As a result we have cieve. loped a site catalog for the global network. The text portion of this catalog has five. tables similar to that of the Crustal Dynamics VI.BI

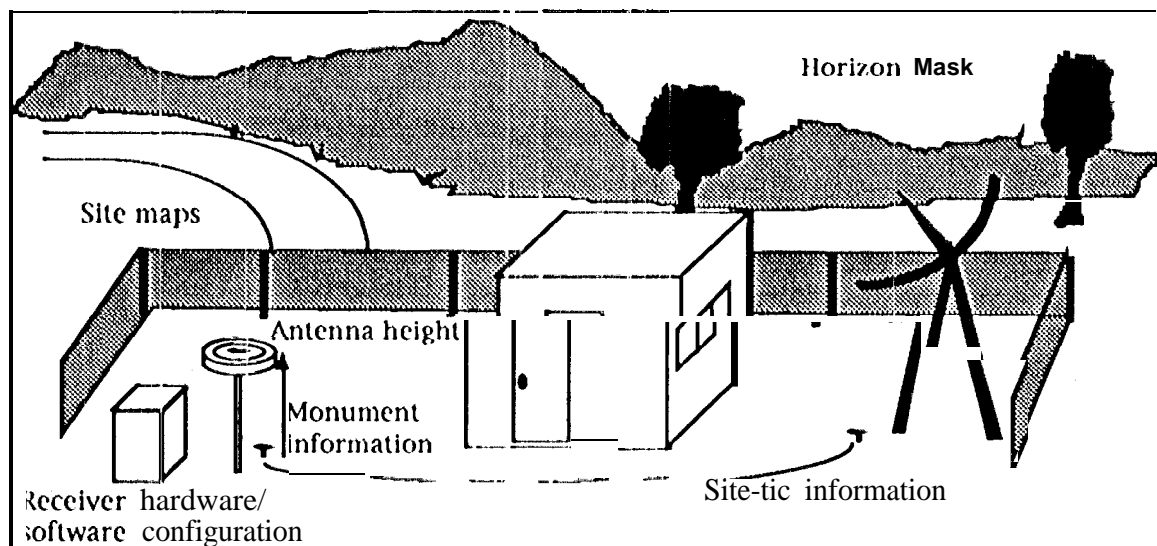


Fig.1 Types of information in the site catalog

catalog. Information in the text portion of the catalog contains site names, locations, contacts, coordinates both geodetic and geocentric, monument information, site tie information and contacts, as well as receiver information (hardware type), and antenna height. Other information soon to be added in a database includes site occupation history, software and hardware configuration, communications paths and survey information. Much of this information wit] be put on-line the. near future. Currently it resides on hard copy only.

Communications

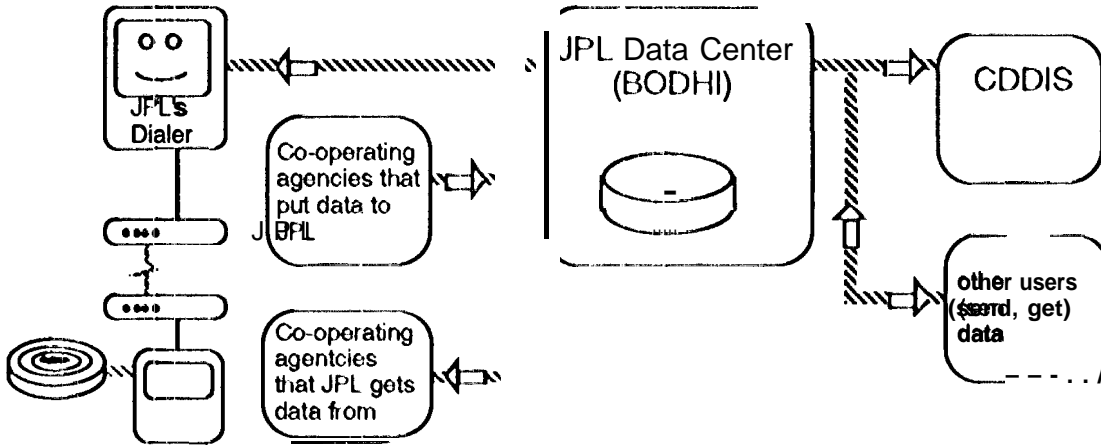


Fig 2. The JPL Data Handling Facility has 3 basic parts; data acquisition, data processing and storage, anti data distribution.

As of this writing JPL, is obtaining data from 35 Rogue receivers globally of which JPL/NASA provides data from 15. The remaining 20 receivers are operated by various other agencies around the world in which data sharing is common place., The volume of data that flows in and out of the data center is approximately 70 megabytes of raw and

finished data daily. The data arrives via the phone system and computer networks. The data leaves via computer networks to other users. Agencies with which we share data are CDDIS, CNES, DLR, EMR, ESOC, GFZ, IFAG, NGS, OSO, SIO and SK. These agencies either allow us to retrieve data from their computers or place data onto our computers in a timely manner. And in turn we place data onto other computers or allow others to retrieve data from our systems.

<p>JPL/NASA Dialed Sites - phone line transfer</p> <p>Pair banks, Harvest, JPL Mesa, Kokee, North Liberty, Pie Town, Quincy, Santiago, Usuda, Vandenberg, Yaragadee</p>
<p>JPL/NASA DSN Sites - network transfer</p> <p>Goldstone, Madrid, Tidbinbilla</p>
<p>JPL/NASA Contracted Sites - network transfer</p> <p>McMurdo</p>
<p>Sites Provided by Other Agencies - network transfer</p> <p>Kootwick, Onsala, Graz, Metsahovi, NyAlison, Tromso, MasPalomas, Kouru, Hartebestok, Pamati, Hersmoncueax, Materia, Taiwan, Westford, Hobart, Alberthead, Algonquin, Penticton, St. John, Yellowknife</p>

Fig 3. How station data arrives at JPL.

Of the 15 sites that we provide data from 11 of the sites are called up over the phone, 3 are associated with the Deep Space Network and 1 is operated under contract and the data is delivered to JPL. A

typical daily phone call to one of the 11 sites for data off-loading takes approximately 12 minutes and transfers about 350 kilobytes of CONAN binary format data (the data spans 24 hours at a 30 second sample rate) . At 6 hour intervals the data is off loaded from the dialing computer to the processing computers. What is happening here is shown in figure 4. The remaining 4 sites arrive via a combination of networks that are part of JPL, or contracted out. Some of the sites for which we provide data is provided as a courtesy of other ongoing projects that use GPS data (such as the Topex/Poseidon Experiment). Data from the remaining 20 sites is provided by other agencies and the raw data arrives at JPL, via global computer networks.

Data Handling

The goal of the JPL GPS Data Handling Facility is to provide a consistently handled set of data and products to its customers in a timely manner. The GPS data collected and processed by JPL, is used by many projects both within and outside of JPL, of which the IGS community is one significant customer,

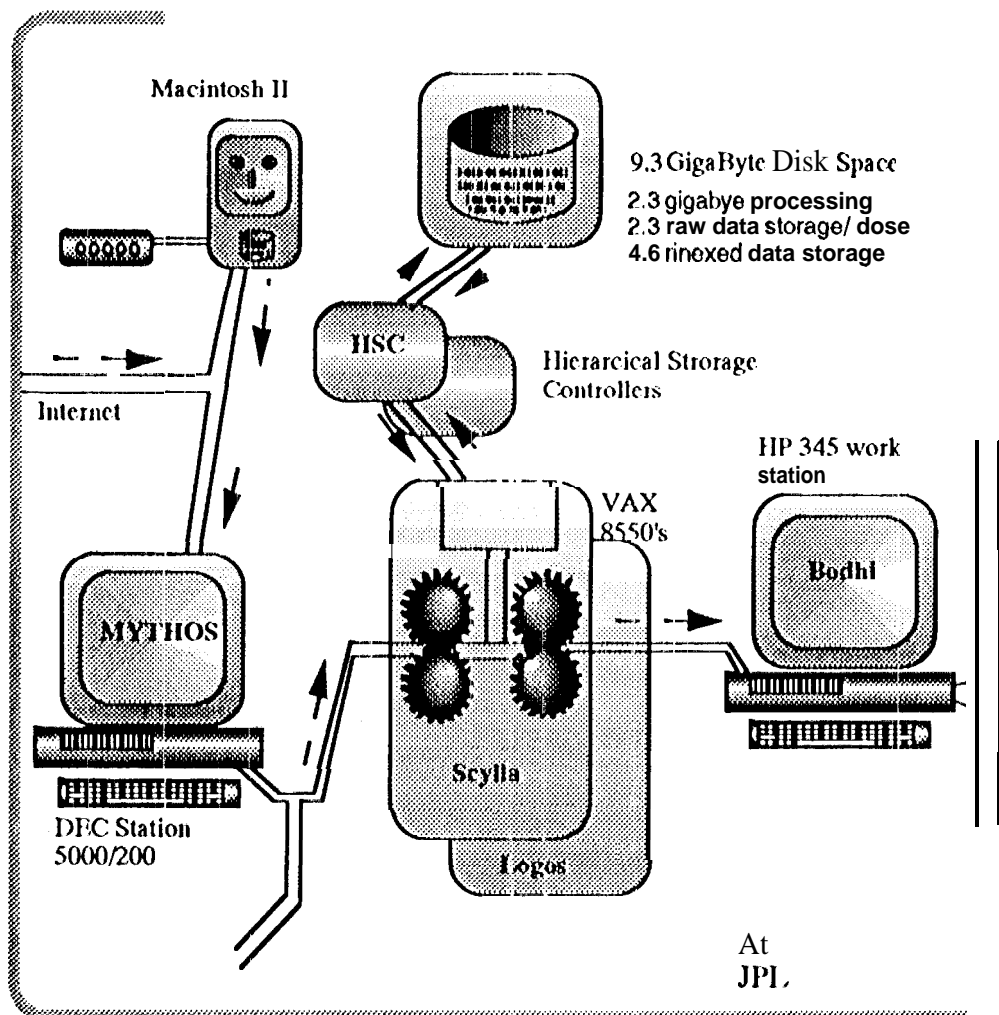


Fig 4. Current hardware configuration of BODHI.

The data processing at JPL is performed on a VAX cluster using the VMS 5.5 operating system. The data communications is handled by one node using TGV Multinet Software. The data being deposited into the import area by any of several agencies is scanned once an hour at 35 minutes past the hour. If new data has arrived during the previous hour, all the relative information for each site-day is collected together and scheduled for execution on one of the batch queues. The impact on the computer resources for the conversion is minimal owing to coincidental fact the UT midnight time tag occurs as the staff at JPL is finishing for the day. The conversion process from raw data to RINEX format starts shortly after zero UT when the first data files arrives from some of the cooperating agencies. By 16:00 UT most of the data that is going to arrive for the previous day has arrived and has been processed into the RINEX format [ref 2],

The transmission of data from JPL to the CDDIS (the GPS archive at Goddard Space Flight Center) occurs during the night, and is so timed as to cause minimal network impact at both JPL and at CDDIS. This distribution process is fully automated and sends a UNIX compressed version of the RINEX formatted daily data files plus a listing of what files were made available for a given day and the size of the data files. The transmission of 15 stations of compressed RINEX data to CDDIS prior to the 1st of March 1993 used to take about 50 minutes of clock time. On the 28th of February we connected to the JPL fiber optic network (FFDI) ring which allows a 100 megabit per second data transfer out of the data center. Data transmission now requires about 15 minutes of clock time for a normal days worth of data. The overall performance of our network is such that RINEX files for 12 of the sites arrive at CDDIS within 12 hours of being collected. The other 4 sites are delayed to when the data is being collected. The average data turn around time for the entire 35 station network is on average a little over 26 hours at JPL.

At the Data Handling Facility the data flows from the import directories to a processing directory to the finished products area, and to the data transmission area. The processing of the data from raw to compressed RINEX takes approximately 12 minutes of CPU time on a VAX 8S50 and about 22 minutes of clock time per 24 hour station file. The processing sequence first decompresses the raw data then scans the data for start and stop times, and finally renames the file to an internal format. The data for this site is then merged with data from the previous day to generate the RINEX file. This merging of the data allowed us to account for any overlap of midnight if the data file has multiple parts or is not terminated on the midnight UT boundary. The data files are then compressed using a VMS version of the UNIX compression routine.

IGS 92 SUPPORT

The JPL Data Handling Facility has been on-line since late 1991 and is capable of processing all Rogue receiver data to RINEX received at JPL. During the 1992 campaigns starting with the extended IGS campaign on June 21st and the intensive 2 week Epoch 92 campaign starting on July 28 we processed into RINEX all Rogue GPS data received. This allowed the center to serve as a backup site for other centers that may have experienced difficulty during the campaigns. However only a subset of this data was provided to CDDIS during this time frame as requested. Data from the following sites was provided during the campaign: Goldstone California, Madrid Spain, Tidbinbilla Australia, Fairbanks Alaska, JPL, Mesa California, Kokee Hawaii, McMurdo Antarctica, Santiago Chile, Usuda Japan, and Yarragadee Australia. For the 105 day period starting with 21 June 1992, Figure 5 shows the number of available days, all of which was delivered to the CDDIS. The average data turnaround was less than 27 hours during EPOCH 92.

In addition to providing data to the IGS community, technicians support was provided

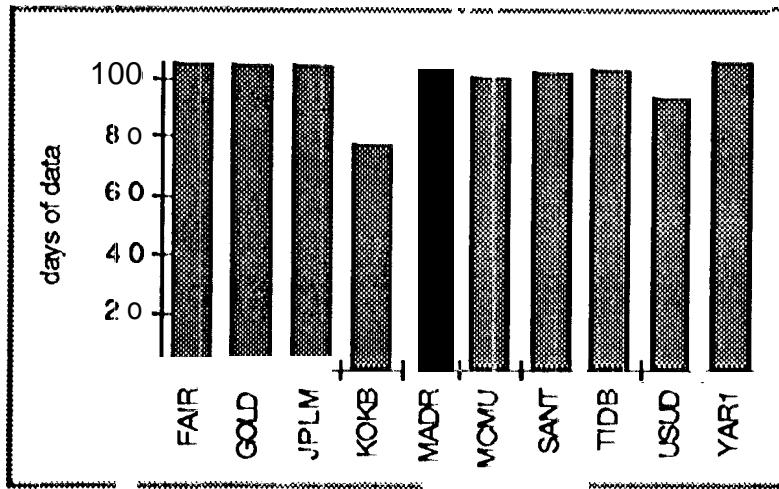


Fig 5 Days of data per site delivered to CDDIS

during the entire IGS campaign (and beyond) to help keep the receivers up and running. This proved to be a substantial amount of work as Anti Spoofing (AS) was turned on and an error was discovered in the Rogue code. A work around was found by off loading the receiver every four hours which bypassed the erroneous software loop. The software for the Rogue

portion of the global network has now been corrected and upgraded to new software.

BEYOND TOMORROW

As the clock rolls into the future, we will continue to operate a viable and expanding network of GPS receivers. At the network currently exist with a number of stations being owned and or operated by JPL/NASA and others being owned and operated by other agencies so it will be in the future, Sharing of the resulting data will improve the robustness of the solutions and products. JPL envisions a network of nearly 200 stations globally, being operated and maintained much as the current network is using cooperation with other agencies, We have recently installed Turbo Rogues at North Liberty Iowa and Pie Town New Mexico (part of the North American Fiducial network), At Easter Island another installation is currently underway (in cooperation with the Chilean University Centro de Estudios Espaciales). Other global sites to be installed in the future may include Kwajalein, Seychelles, Arequipa and Bogota as well as continued expansion in the North American Fiducial Network [ref 3].

As the data continues to be received from around the globe we will continue to process the data into RINEX for redistribution, continue to provide precise orbits and other products that are currently being produced as well as adding more Earth platform products. One of the products we hope to add in the near future is precision baselines between stations. In addition to the work currently being done for the geodetic community we are supporting a number of other efforts that will require faster data turnaround, which the geodetic community will benefit from, This includes the acquisition of more powerful computer-s and additional disk space. at our processing center.

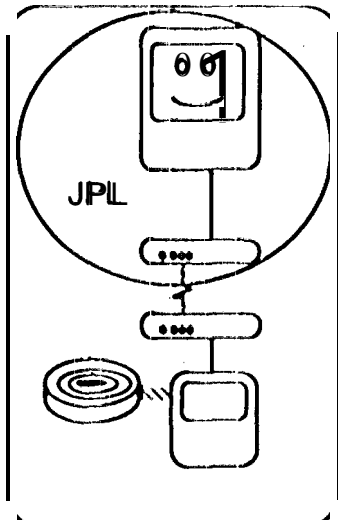


Fig 6 Current data retrieval methods.

The ability to get this much data in and out of anywhere requires a sophisticated network. Data arriving via the telephone lines does not only tax the telephone network but also has become expensive. Although the telephone network is reliable, in many parts of the world, it is not as reliable or of the quality required for data transmission in other parts of the globe. Even though computer networks are becoming more prevalent globally they are not everywhere we would like to place a receiver. As a result a combination of solutions will be required to return GPS data in a timely manner and at reasonable cost from the more remote areas of the world. In some cases an unusual solution may have to be found. There are a number of ways to off load receiver data, The phone network usually involves a modem and expensive overseas phone calls. In many cases a local area network such as InterNet is available nearby, hence all that is required is a local phone call to bring the data to the nearest InterNet node., The data would then be retrieved from the remote node

via the networks for processing at the center.

As the Rogue and Turbo Rogue receivers are not currently capable of interfacing to a network an intermediary is required. This intermediary may be a terminal server which speaks the appropriate protocols for the network it is attached to, or another computer that has data gathering capabilities. The computer allows for a number of different options such as local storage of the data if the communications network (phone, or other) goes out for extended periods of time, The retrieving data from other collocated instruments may require periodic or even continuous off loads of the data). Or the computers may operate as a regional dialer, where network connections are not practical at each site in an area of the world. Lefty over seas phone charges could be avoided by installing a computer at a site with network access in the desired region, and then using the local telephone lines to access the rest of the sites. The data for the entire region would then be off loaded over the network from one computer and take just a few minutes as opposed to several hours of phone calls.

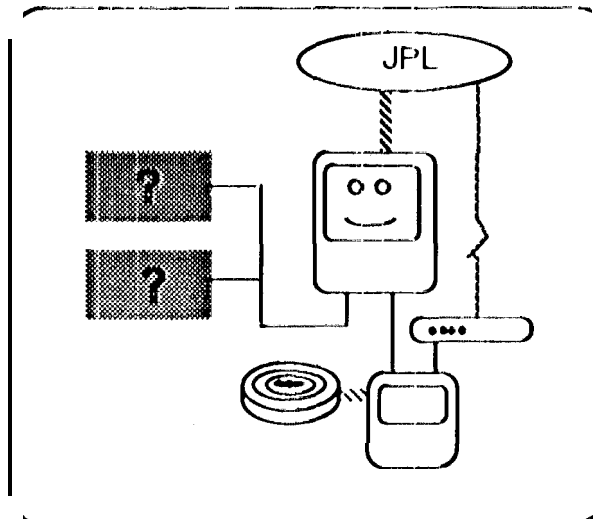


Fig 7. Future connection for data retrieval

Once this data is in house, there is a significant amount of other data that is required to make use of the GPS data, This other data called Mets data consists of some of the information in the site catalog and on other bulletin boards. In the not so distant future we hope to have available an on-line database with most if not all of the required information

not only for the geodetic community but for all of the other tasks we currently and in the future will be supporting.

ACKNOWLEDGMENT:

We would like to thank the various agencies for their contributions of data and information to the many different tasks and projects being developed or underway at JPL. These agencies include CD DIS, CNES, DEL FT, EMR, ESOC, GFZ, IFAG, NGS, OSO, SIO and SK.. In addition we extend our thanks to the many individuals who without their efforts this experiment and program would not have succeeded. The work described in this paper was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautical and Space Administration.

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