HIGH ORDER GPS BASE STATION SUPPORT FOR RHODE ISLAND

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PREPARED FOR

UNIVERSITY OF RHODE ISLAND
TRANSPORTATION CENTER

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16. Abstract

With a grant from the URI Transportation Center, we have upgraded our GPS Base Station to provide round-the-clock Internet access to survey-grade (± 2 cm accuracy) reference files using a web-based data distribution system. In August 2000, we participated in the National Geodetic Survey/RI Department of Transportation GPS survey campaign to enhance the Federal Base Network (FBN) component of the National Spatial Reference System (NSRS) in the United States. During this effort, the URI Base Station served as a one of two Central Temporary Continuously Operating Reference Stations (CTCORS) in the State. The result will be a high-accuracy regional densification of the FBN with a goal of 2 cm horizontal and vertical accuracy at 16 control points in RI. This, in conjunction with the TC-funded Base Station upgrade, will significantly enhance the ease, speed, and accuracy of high-precision GPS-based surveys in the region. In June of 2001, we became part of the NGS Cooperative Continuously Operating Reference Station (CCORS) Network of National High Accuracy GPS base stations. In June 2000, our base station coordinates were readjusted by NGS Cooperative CORS geodesists using precise orbit data. Data are now available for station URIL 24/7 at http://edc.uri.edu/gps or http://www.ngs.noaa.gov/CORS/Coop/. Using nearby CORS sites, surveyors and scientists can now conduct single-receiver surveys eliminating the need to allocate additional personnel and receivers to occupy control points.

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Project Objective

The purpose of this project is to provide enhanced web-access to high-accuracy GPS base station reference files for the transportation planning, engineering, and emergency response communities in Rhode Island.

In August and September of 2000, we worked in close cooperation with Kathy Cheteyan, Programming Services Officer, RIDOT Survey Section to participate in a 2-week regional survey campaign to improve the Federal Base Network (FBN) in August and September, 2000. The purpose of the FBN Survey is to establish new FBN positions and to improve the horizontal and vertical accuracy of existing FBN points[1] along with a regional densification of the Cooperative Base Network. Another goal involves cooperation and technology transfer to state and local surveying agencies. During this effort, the URI GPS Base Station antenna mount was engineered, installed, and precisely surveyed. We received technical training in the setup and operation of a Trimble 4000 SSI survey-grade GPS receiver used to conduct this survey from Maine Technical Source of Woburn, MA and NGS.

Accomplishments

During the past six months we have achieved our goal of establishing a working high-order GPS base station and web distribution system that serves Rhode Island and the Northeast U.S. region. We received delivery of our dual-frequency L1/L2 Trimble model 4700 receiver and choke ring antenna on March 13, 2001. We mounted our new antenna on the secure antenna mount that we designed and manufactured in cooperation with the URI Equipment Development Laboratory at the Graduate School of Oceanography. This was the same mount that was used to establish our precise initial coordinate for our base station antenna reference point (ARP) during the Federal Base Network (FBN) and Cooperative Base Network (CBN) survey coordinated by our National Geodetic Survey and RI Department of Transportation partners in August and September of 2000. The purpose for our participation in this program was to obtain a precise coordinate for our reference station, establish our location in the CBN, and enhance the National Spatial Reference System (NSRS) in our region. Densification of the regional FBN will increase the precision and accuracy of survey applications as well as provide more convenience with respect to establishing regional and local control. Our precise coordinate was determined through a concurrent survey of 132 horizontal and/or vertical control points over a two-week period (see *Appendix A*). During this campaign we engaged research staff and graduate students to attend planning meetings, training workshops, install/configure loaned equipment, monitor the receiver/antenna, download daily reference files, develop station description information, and backup base survey data. Our coordinate results were provided to us on June 26, 2001. In May 2001 we purchased and installed an acrylic radome to protect our antenna from the elements -- mainly accumulating snow, ice, and particulates.

Established Site in NGS Cooperative CORS Program

We worked in cooperation with NGS Geodesist, Julie Prusky, to establish our site as a Continuously Operating Reference Station (CORS) in the NGS Cooperative CORS Network. CORS provides Internet access to fixed-location GPS base stations generating carrier phase and code range measurements for 3-dimensional positioning applications, nationwide. Cooperative CORS stations supplement the rather sparse coverage of National CORS reference sites by providing densification of regional and local GPS reference

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stations. The Cooperative CORS systems must meet standards set by NGS and use positional coordinates consistent with the NSRS. For instance, the URI site must conform to minimum standards for antenna and receiver design as well as environmental operating conditions (e.g., unobstructed antenna view to horizon) and parameters (e.g., logging rate). The system must be networked in such a way as to support free FTP and www access to 30 days of archive data in Receiver Independent Exchange (RINEX) format and conform to standard file naming conventions. Our web site, http://edc.uri.edu/gps/cors.asp is linked to the National CORS website (see clickable station map), http://www.ngs.noaa.gov/CORS , and the Cooperative CORS website, http://www.ngs.noaa.gov/CORS/Coop , which in turns provides links to other CORS websites throughout the region and the country. As part of establishing our site on the Cooperative CORS network, NGS processed 120 hours of our GPS base data with precise orbital data through the Online Processing User Service (OPUS) to perform a consistency check on our coordinates that define our antenna reference position. NGS will process data collected from our site every 30 days with other CORS data to verify the integrity of our antenna reference position.

The Cooperative CORS network permits end users in the region to take advantage of the NSRS by making it possible to conduct single-person surveys without the added expense of concurrently occupying control points with field crews and additional GPS receivers.

Program Partnerships

In addition to partnering with NGS in the Cooperative CORS program, we have worked closely with the RI Department of Transportation (RIDOT) Survey Section who is establishing a similar system to cover positioning needs in northern RI. Kathy Cheteyan of RIDOT was our point of contact throughout the NGS FBN/CBN Survey campaign and was instrumental in making it possible for us participate in this program on short notice. We will continue to work with RIDOT as they develop and test their new system. Jim Bosworth of Maine Technical Source provided valuable support through equipment loan and training necessary for us to establish our antenna reference position. Curtis Crow of NGS also provided essential equipment, training, and counsel during the establishment of the base station.

Student Involvement

Graduate Student Greg Bonynge assisted with the initial FBN/CBN survey campaign when our initial coordinate position for the base station was established. Greg participated in the initial training workshops provided by NGS, RIDOT, and Maine Technical Source. He monitored our receiver over a two-week period and ensured that the system was running and that data were downloaded and backed up on a daily basis.

World Wide Web Distribution System

Our web interface consists of two links. http://www.edc.uri.edu/gps/cors.asp is designed to be the opening page for our Cooperative CORS users and has content that satisfies the requirements necessary for the Cooperative CORS Program. Our home page http://edc.uri.edu/gps handles general requests outside of the CORS program. Users obtain the same data from either page. The main menu contains hyperlinks for the submenus: Home, Download, Downtime, Links, Technical Specs, and News. Through the Download link, users are requested to provide their first/last name, email, affiliation, and comments on their application. After the form is filled out, base files can be obtained in Trimble .dat carrier phase, Trimble .ssf code range, and RINEX carrier phase formats. Detailed instructions are provided on file naming conventions. Data are maintained online for at least 30 days. The Downtime link provides status on system downtime, if any. The Links menu provides useful information about other GPS-related websites. Technical Specs provides operating parameters for the base station and digital pictures of the system. The News menu contains important information pertaining to the URI High-Order GPS Base Station.

Public Access Review

During the first week that our high-order base station has been up, running, and publicized, we've logged approximately 104 users accessing the system for reference files. We've had numerous land surveyors and engineering firms both corporate and private (e.g., DiPrete Engineering, Kilpatrick, Smith Surveyors, Stein Survey, Dicesare & Bentley Engineers, Hanlon Survey, Haley & Aldrich, Clough Harbor & Associates). For transportation-related applications, the Metropolitan Transit Authority Bridges and Tunnels Unit out of New York City has accessed the system to collect position of roadway features and ITS devices on bridge spans and to track positions of cameras located on their various facilities. J.F. Sato and Associates used the system to locate a helipad. R.E. Cameron and Associates uses the system for positioning cell towers for Verizon Wireless. We've had numerous mapping-related applications for building, trails, wellheads, forestry, wetlands, and wildlife habitat.

Current Use of the System

We monitor use of the system through a web form that is filled out by the user each time the system is accessed. We also keep online logs of the number of files and size in bytes of files that are downloaded hourly, daily, and monthly at http://www.edc.uri.edu/stats/cors-gps During the period from July 14 through September 20, 2001 an additional 444 users accessed data from the system. A total of 5,955 hourly GPS files have been successfully obtained amounting to 1.2 Gb of GPS reference data. On average, 69 files totaling 14 Mb are downloaded on a daily basis. The average file size is 205 Kb. Recent transportation-related applications include establishing precise survey control for construction applications, survey control adjustments, long baseline testing, cadastral surveying, ship tracking, natural gas mapping, telecommunications, mapping hiking trails, wetland delineation, hazardous waste monitoring, water supply monitoring, vegetation mapping, and wildlife management.

Presentations/Meetings/Demos

August, P.V. and C.L. LaBash. 2000 High Accuracy GPS Base Station for Rhode Island. 13th Annual Rhode Island Transportation Center Forum, October 13, 2001, Kingston, RI (see Appendix B)

LaBash, C.L. and D. Chapman. 2000 NAVSTAR Global Positioning System. Lecture URI Civil Engineering 315 Surveying, November 21, 2000, Kingston, RI

LaBash, C.L. 2001. Roundtable Meeting with representatives of the USDOT Research and Special Programs Administration, January 23, 2001, Kingston, RI

LaBash, C.L. 2001. GIS Demonstration to representatives of the USDOT Research and Special Programs Administration, January 23, 2001, Kingston, RI

LaBash, C.L., P. August, D. Chapman, and R. Duhaime. 2002. High Accuracy Base Station for Rhode Island. URI Transportation Center Spring Seminar Series, March 2002, Kingston, RI

Appendix A

MA/CT/RI FBN/CBN Survey Campaign 2000

Table 1. GPS-occupied positions in the 2000 MA/CT/RI FBN/CBN Survey Campaign.

Permanent ID	H.V	Vert. Source	Approx. Lat.	Approx. Long.	Designation
OC2808	B .	88/GPS OBS.	N430211	W0711936	071 0300
MY5389	A .	88/GPS OBS.	N421718	W0711240	10002
MY6064	B .	88/GPS OBS.	N422537	W0714641	10488
LW5381	A .	88/GPS OBS.	N414426	W0711230	10936
MY5929	A .	88/GPS OBS.	N420216	W0715133	11369
MY5600	A .	88/GPS OBS.	N422726	W0713424	11387
MY5618	A .	88/GPS OBS.	N421717	W0713417	11406
MZ2781	A .	88/GPS OBS.	N423317	W0723714	186 U
MZ2996	B 2	88/ADJUSTED	N424911	W0723216	219 0090
MY5422	1 .	88/GPS OBS.	N425656	W0710330	243 0180
OC2782	1 .	88/GPS OBS.	N430858	W0705929	255 0180
MY5423	1 .	88/GPS OBS.	N425001	W0714126	303 0270
AJ4075	A .	88/GPS OBS.	N411616	W0700517	31 D
LW5817	B .	88/GPS OBS.	N413055	W0703920	31435
MY6362	B .	88/GPS OBS.	N424356	W0715740	387 0190
MZ2668	B .	88/GPS OBS.	N421748	W0731453	414 A
AJ4036	A .	88/GPS OBS.	N423119	W0705904	438 B
AJ4037	A .	88/GPS OBS.	N423731	W0704150	438 C
AJ4038	A .	88/GPS OBS.	N424335	W0711219	438 D
AJ4039	A .	88/GPS OBS.	N424807	W0710259	438 E
AJ4040	A .	88/GPS OBS.	N421146	W0705740	438 G
AJ4041	A .	88/GPS OBS.	N420634	W0704604	438 H
AJ4042	A .	88/GPS OBS.	N420626	W0710331	438 J
AJ4043	A .	88/GPS OBS.	N415622	W0710121	438 K
AJ4044	A .	88/GPS OBS.	N414541	W0703533	438 L
AJ4045	A .	88/GPS OBS.	N421752	W0712435	438 M
AJ4046	A .	88/GPS OBS.	N420718	W0712816	438 N
AJ4047	A .	88/GPS OBS.	N420221	W0711819	438 P
AJ4048	A .	88/GPS OBS.	N415608	W0703918	438 Q
AJ4049	A .	88/GPS OBS.	N413934	W0705240	438 R
AJ4050	A .	88/GPS OBS.	N415047	W0705107	438 S
AJ4051	A .	88/GPS OBS.	N420351	W0700849	438 T
AJ4052	A .	88/GPS OBS.	N423314	W0715504	438 V
AJ4053	A .	88/GPS OBS.	N420725	W0714222	438 X
AJ4054	A .	88/GPS OBS.	N422528	W0720733	438 Y
AJ4055	A .	88/GPS OBS.	N421527	W0714736	438 Z
AJ4056	A .	88/GPS OBS.	N422402	W0722414	448 A
AJ4057	A .	88/GPS OBS.	N422507	W0725527	448 B

AJ4058	A .	88/GPS OBS.	N420640	W0730824	448 C
AJ4059	A .	88/GPS OBS.	N420651	W0720450	448 D
AJ4061	A .	88/GPS OBS.	N423116	W0714205	448 F
AJ4062	A .	88/GPS OBS.	N423328	W0721801	448 G
AJ4063	A .	88/GPS OBS.	N422144	W0723817	448 H
AJ4064	A .	88/GPS OBS.	N423822	W0725445	448 J
AJ4065	A .	88/GPS OBS.	N420514	W0732042	448 K
AJ4066	A .	88/GPS OBS.	N424200	W0730954	448 L
AJ4030	A .	88/GPS OBS.	N422140	W0710302	844 3970 D TIDAL
AJ4031	A .	88/GPS OBS.	N413129	W0704020	844 7930 B TIDAL
AJ4032	A .	88/GPS OBS.	N411721	W0700533	844 9130 K TIDAL
LW0493	A 2	88/ADJUSTED	N413024	W0711936	845 2660 TIDAL 6
AJ4033	A .	88/GPS OBS.	N414827	W0712411	845 4000 L TIDAL
LX3418	A 1	88/ADJUSTED	N412142	W0720541	846 1490 K TIDAL
AJ4034	A .	88/GPS OBS.	N411038	W0731047	846 7150 D TIDAL
LX2948	A 1	88/ADJUSTED	N414929	W0722953	A 3829
MZ1405	A 1	88/ADJUSTED	N420614	W0723755	A 51
AA3508	A 1	88/ADJUSTED	N424055	W0712628	A 56
AJ4067	A .	88/GPS OBS.	N421049	W0725546	AB 45
LX3556	A .	88/GPS OBS.	N413250	W0730143	ABROGATOR
LX7571	B .	88/GPS OBS.	N411344	W0730901	ARMORY
LX3247	A 1	88/ADJUSTED	N413459	W0722148	B 2763
MZ2640	A 2	88/ADJUSTED	N425321	W0731424	BENPORT AZ MK
LW5523	A .	88/GPS OBS.	N414114	W0711701	BR 001
LW0418	B 2	88/ADJUSTED	N415508	W0712916	CENTRAL
AF9494	A .	88/GPS OBS.	N414016	W0695700	CHATHAM 1 CORS ARP
AB2629	A 1	88/ADJUSTED	N414018	W0695656	CHATHAM LIGHT USCG
AJ4070	A .	88/GPS OBS.	N415428	W0713950	CHEPACHET ECC
AJ4035	A .	88/GPS OBS.	N415607	W0712842	CHETEYAN
AJ4073	A .	88/GPS OBS.	N420953	W0705314	COLER COLANTONIO NE BASE
OC0429	A 2	88/ADJUSTED	N430413	W0704239	CONSTITUTION 147 RM 1
LX3066	1 1	88/ADJUSTED	N413408	W0723723	D 92
LX7346	A .	88/GPS OBS.	N415654	W0731155	DENNIS HILL
AH8858	B .	88/GPS OBS.	N425542	W0725156	DOVER2
LW0235	A 2	88/ADJUSTED	N413547	W0711547	E 28
LW5304	A 2	88/ADJUSTED	N414709	W0712001	EP 013
LX1955	A 1	88/ADJUSTED	N414717	W0732421	G 59
LW5587	A .	88/GPS OBS.	N412250	W0713023	GALILEE CBL ZERO
AJ4069	A .	88/GPS OBS.	N414523	W0721051	HOLLOW DAM

MY6363	A .	88/GPS OBS.	N422815	W0711442	KELLY
LW5147	A .	88/GPS OBS.	N415951	W0711132	MANSFIELD
LW5552	A .	88/GPS OBS.	N413136	W0711632	MI 001
MY2204	A 1	88/ADJUSTED	N423703	W0712929	MILL
AI5589	B .	88/GPS OBS.	N413046	W0724955	MMK A
AH5048	A .	.....	N404722	W0724446	MORICHES 1 CORS ARP
AJ4068	A .	88/GPS OBS.	N424057	W0705828	MORONEY
MZ1654	B .	88/GPS OBS.	N421801	W0723516	MOUNT HOLYOKE RESET
AJ4072	A .	88/GPS OBS.	N422900	W0710928	MTS WOBURN GPS BASE STA ARP
MZ1345	A 1	88/ADJUSTED	N422816	W0731122	N 53
AI3285	A .	88/GPS OBS.	N413035	W0711939	NAVAL STATION NEW CORS ARP
AH5052	A .	.....	N404429	W0741039	NJ INST OF TECH CORS ARP
LW5671	A 2	88/ADJUSTED	N413453	W0713012	NK 004
AI9509	A 2	88/ADJUSTED	N413023	W0711931	NPRI A
AI9510	A 2	88/ADJUSTED	N413033	W0711937	NPRI B
LW5677	A 2	88/ADJUSTED	N415924	W0713312	NS 015
LX0452	A 1	88/ADJUSTED	N411609	W0723557	P 36
LX2892	A 1	88/ADJUSTED	N414759	W0723704	P 85
AD9919	A .	88/GPS OBS.	N414024	W0724252	PAQUETTE
LX6301	A .	88/GPS OBS.	N412648	W0724024	PISGAH
LX5210	A .	88/GPS OBS.	N411857	W0720358	PLANT
LW5727	A .	88/GPS OBS.	N412931	W0713306	PLEASANT
AI1408	A .	88/GPS OBS.	N430415	W0704234	PORTSMOUTH 4 CORS ARP
AJ4071	A .	88/GPS OBS.	N414955	W0712452	PROVIDENCE GPS BASE STA ARP
LX7656	B .	88/GPS OBS.	N414033	W0724249	PUGLISI
LW1891	A 2	88/ADJUSTED	N412944	W0714255	RI 006
LX3599	A .	88/GPS OBS.	N413302	W0731531	ROXBURY
LX4876	A .	88/GPS OBS.	N413159	W0721745	SALEM
MY5214	B .	88/GPS OBS.	N425218	W0704912	SALISBURY MARSH MONUMENT
AF9509	A .	88/GPS OBS.	N402817	W0740041	SANDY HOOK 1 CORS ARP
MY2936	A .	88/GPS OBS.	N421839	W0710258	SAVIN HILL RESET
LW5573	A .	88/GPS OBS.	N414953	W0713620	SC 007
LW3984	A .	88/GPS OBS.	N414107	W0702047	SHOOTFLYING

LX7615	A .	88/GPS OBS.	N411153	W0730359	SILVER
LW5637	A 2	88/ADJUSTED	N412340	W0713426	SK 004
LX3109	A 1	88/ADJUSTED	N414021	W0722032	SKYLINE RM 4
LX2363	A 1	88/ADJUSTED	N412452	W0732248	T 74
LX0900	A 1	88/ADJUSTED	N411238	W0730248	TIDAL 3 STA 26
MZ0318	B 2	88/ADJUSTED	N424944	W0725913	TT 40=1785
AJ4074	**A .**	**88/GPS OBS.**	**N412920**	**W0713139**	**UNIV OF RHODE IS GPS BASE ARP**
AF9563	A .	88/GPS OBS.	N441543	W0723456	VERMONT CAPITAL CORS ARP
LX3226	A 1	88/ADJUSTED	N413126	W0720446	W 90
LX3162	A 1	88/ADJUSTED	N414034	W0724249	W 91
MY2749	A .	88/GPS OBS.	N422600	W0710356	WAYTES MAGS 1934
LW5273	A 2	88/ADJUSTED	N412107	W0714550	WE 002
AI9590	A 1	88/ADJUSTED	N423630	W0712938	WES2 A
AF9520	A .	88/GPS OBS.	N423647	W0712935	WESTFORD CORS ARP
LW1894	A 2	88/ADJUSTED	N413648	W0713907	WG 003
LW5179	A 2	88/ADJUSTED	N414000	W0712956	WK 001
LW5194	A 2	88/ADJUSTED	N414453	W0712636	WK 015
MY0497	1 1	88/ADJUSTED	N421113	W0711035	Y 30
LX3030	A 1	88/ADJUSTED	N414844	W0721502	Y 88
MZ1129	A 1	88/ADJUSTED	N420947	W0722036	Z 39
AA3501	A 1	88/ADJUSTED	N424412	W0712851	ZBW B
LX2642	1 1	88/ADJUSTED	N412307	W0723024	ZIEMBA

Table Column Definitions:

Permanent ID - Permanent Identifier
H - Horizontal Order (A,B,1,2,3)
V - Vertical Order (1,2,3,m,p)
Vert_Source - Datum and Source of the Vertical Control where the various Sources are explained in the NGS DSDATA format specifications file.
Approx. **Lat** - Approximate NAD27 Latitude (deg-min-sec)
Approx. **Long**. - Approximate NAD27 Longitude (deg-min-sec)
Designation - Station Name

Appendix B

13th Annual RITC Forum October 13, 2000

Abstract from presentation

Title: High Accuracy GPS Base Station for Rhode Island

Authors:
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Since January 1995, the Environmental Data Center in the URI Department of Natural Resources has been providing Base Station support through the Internet to the GPS user community of the northeastern United States. GPS Base Station files allow a user to remove the effects of Selective Availability (currently disabled by the government) and atmospheric degradation on positional data collected in the field. The result is an improvement in accuracy from $\pm$ 15-100 m before correction to < 3 m after differential correction using the data obtained from the URI Base Station. In the past 7 years, over 3,000 users from all over the eastern United States have obtained in excess of 20,000 correction files to support their GPS applications.

With a grant from the URI Transportation Center, we are upgrading the Base Station to provide round-the-clock Internet access to survey-grade ($\pm$ cm accuracy) reference files. In August 2000, we participated in the National Geodetic Survey/RI Department of Transportation GPS survey campaign to enhance the Federal Base Network (FBN) component of the National Spatial Reference System (NSRS) in the United States. During this effort, the URI Base Station served as a one of two Central Temporary Continuously Operating Reference Stations (CTCORS) in the State. The result will be a high-accuracy regional densification of the FBN with a goal of 2 cm horizontal and vertical accuracy at 16 control points in RI. This, in conjunction with the TC-funded Base Station upgrade, will significantly enhance the ease, speed, and accuracy of high-precision GPS-based surveys in the region.