California Real-Time Network (CRTN)

September 28th, 2012
Ontario, CA

October 5th, 2012
Sacramento, CA

Presenter: Art Andrew
CSRC Chairperson
CRTN Workshop Agenda

- 8:30 - 9:15 – History of CSRC and CRTN
  - Art Andrew

- 9:15 - 10:15 – Procedures/Guidelines for Static/RTK using CRTN
  - Dave Olander

- 10:15 - 10:30 – Break

- 10:30 - 11:15 – Connecting to CRTN; NTRIP Connections, IPs & Ports, RTCM versions
  - Richard Maher

- 11:15 - 12:00 – CSRN, CGPS, Usage, Advantages and Limitations
  - Yehuda Bock

- 12:00 - 1:00 – Lunch Break

- 1:00 - 3:00 – Understanding Datums, Epochs & California’s Unique Problems & Solutions
  - Michael McGee

- 3:00 - 3:15 – Break

- 3:15 - 4:30 – Geoid Models and the Future of Benchmarks
  - Greg Helmer
Handouts

- CSRC Handout
- CRTN Data Policy
- CRTN Backbone Map
- Current CRTN Map
- CSRN 2011.00 Epoch Map
3 Significant Driving Forces

► GPS
- Developed in 1973
- Fully operational in 1994
- Early 1990s was the beginning of the wave for the application of GPS to geodesy

► NGS
- Slow decline in resources
- Focus on maintaining the Federal Base Network (FBN)
- State sponsored survey campaigns

► Yehuda Bock
- First GPS network adjustment in 1984 with a limited constellation
- Principle Investigator for the creation of the first permanent GPS array in the US
- Director SOPAC & CSRC
- Research Geodesist/Senior Lecturer, IGPP
- UNAVCO, SCIGN, IGS
1990

Surveyors
- California Geodetic Reference Network

Scientists
- Permanent GPS Geodetic Array
California Geodetic Reference Network

- National Geodetic Reference System (NGRS)
  - 18,000 + horizontal control stations
  - NAD83(1986)
    - readjusted and redefined from NAD27 in 1986
  - Established from traditional survey methods
  - Served California well for many years
California Geodetic Reference Network

Problems with NGRS?

- Not accurate enough for future needs
- Limited use due to point locations and accessibility
- The **uproar about GPS** and its accuracy and ease in making observations almost anywhere
1990

Surveyors
► California Geodetic Reference Network

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In the late 1980’s, a core group of geodesists from MIT, Scripps, Caltech, UCLA and JPL believed in the potential of GPS for detecting minute “movements of the crust”.

JPL and Scripps collaborated on 4 sites being:

- **GOLD** - December 15, 1989
  GPS Antenna is mounted on top of a 25 meter Microwave tower.

- **PIN1** - February 9, 1990
- **PIN2, SI01** - March 3, 1990
  These 3 are deeply-anchored monuments out of which grew the SCIGN and PBO monuments.

1990
1991

Surveyors
- California Geodetic Reference Network
- High Precision Geodetic Network

Scientists
- Permanent GPS Geodetic Array
- Permanent GPS Geodetic Array

1990
High Precision Geodetic Network (HPGN)

- **Why?:**
  - Existing horizontal control were not adequate to obtain efficiencies and accuracies that were obtainable with the new GPS equipment and procedures that were becoming available.
  - Ongoing secular crustal motion (plate tectonics) and episodic motion (earthquakes) had distorted the network and made portions of the network virtually obsolete.

- Caltrans learned from NGS that a few other states were beginning to plan and develop High Precision Geodetic Networks.

- **Purpose:** provide an accurate and unified horizontal control network for California on NAD83 (1992)


- GPS based

- Caltrans provided the primary funding

- NGS assigned Don D’Onofrio to the new NGS Geodetic Advisor position for the state of California

- Observations made by Caltrans and NGS, with the assistance from local agencies
High Precision Geodetic Network (HPGN)

The network details:
- 245 stations (238 in California) approximately 40-mile spacing along transportation corridors
- 570 station occupations, 65 observing days, 23 GPS receivers

GPS Observations:
- One 6-hour session to be observed daily for 5-days

Computations:
- NGS provided computational expertise and performed computations in various Caltrans offices.

Adjustment:
- Final NGS adjustment accomplished May 1992
One unique requirement of the Caltrans/NGS agreement was that NGS requested an independent HPGN adjustment be performed by a third party outside NGS. This was due to complications of crustal motions that had occurred in California.

Caltrans initiated a contract with University of California, San Diego (UCSD) to perform this adjustment.

Adjustment was accomplished by Dr. Yehuda Bock of Scripps Institution of Oceanography (SIO), for which he and his staff had extensive knowledge of California’s unique crustal motions, GPS technology, and related adjustment processes. This proved to be valuable rationale as there was a minor disagreement in one area of the state between the NGS and Scripps adjustment. Dr. Bock’s adjustment was proven correct in this area and was incorporated into the NGS adjustment.
1991

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1990
Permanent GPS Geodetic Array (PGGA)

- ROCH – April 14, 1991
- Unsuccessful proposal for increasing PGGA network to 12 stations by 1995
1992

Surveyors
- California Geodetic Reference Network
- High Precision Geodetic Network
- High Precision Geodetic Network Densification

Scientists
- Permanent GPS Geodetic Array
- Permanent GPS Geodetic Array
- Scripps Orbit and Permanent Array Center
High Precision Geodetic Network Densification (HPGN-D)

- Densification of the HPGN to about 15 km throughout the state
- Originated by Caltrans
- 850 stations
- Observations made by Caltrans and many local agencies

1992
1992

**Surveyors**
- California Geodetic Reference Network
- High Precision Geodetic Network
- High Precision Geodetic Network Densification

**Scientists**
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1990

1991
Scripps Orbit and Permanent Array Center (SOPAC)

- SOPAC's primary scientific role is to support high precision geodetic and geophysical measurements using GPS, particularly for the study of earthquake hazards, tectonic plate motion, plate boundary deformation, and meteorological processes.

- SOPAC performs research and provides operational support for NOAA's Forecast Applications Branch (FAB) real-time GPS meteorology project for short-term weather forecasting.

- SOPAC provides essential infrastructure support and helps maintain the operational center for the CSRC.

- SOPAC provides precise, rapid, ultra-rapid, and hourly orbits for the International GPS Service (IGS) and NOAA's Forecast Systems Laboratory (FSL).

- SOPAC archives 24-hour RINEX data from about 800 continuous GPS sites from more than 20 scientific networks around the world.

- SOPAC collects and archives high-rate (1 Hz), low latency (1-2 seconds) GPS data from stations in California.

- SOPAC is a major participant in the International GPS Service (IGS), serving as a Global Data Center and a Global Analysis Center.

1992
Permanent GPS Geodetic Array (PGGA)

- VNDP – May 25, 1992
- HARV June 7, 1992

Various proposals to increase stations where unsuccessful
  - “lesser precision”
  - “not appropriate for looking at very small signals”
  - “Costly proposal relative to expected return”
1993

Surveyors
- California Geodetic Reference Network 1990
- High Precision Geodetic Network 1991
- High Precision Geodetic Network Densification 1992
- California Geodetic Control Committee

Scientists
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- Permanent GPS Geodetic Array
In 1992, members of CLSA Advanced Technologies Subcommittee began to discuss the need to develop standards and specifications for high-production-type GPS surveys.

2 meetings later, the CGCC was established in March 1993

Included 17 members from various public and private organizations

Horizontal Spatial Referencing Issues:

- Inadequate Network Accuracy - horizontal control stations (except HPGN) are of insufficient accuracy for current GPS survey methods
- GPS survey methods detect errors in networks that could not be discovered prior to GPS
- Existing control stations may be unsuited for GPS surveys; poor location, poor visibility
- Limited Network Maintenance - NGS budget constraints have eliminated maintenance efforts

1993
1993

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Permanent GPS Geodetic Array (PGGA)

First site installed in collaboration with the survey community (Riverside Flood Control District)

MATH installed April 14, 1993
1994

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- Permanent GPS Geodetic Array
- Northridge Earthquake Jan 17, 1994 (6.7 mag)
California Geodetic Control Committee

DEFINITION:

► CSRS will be part of the NGRS; NGS is responsible for integrity, publication and distribution of CSRS data in the same manner as other NGS data.

► 1,100 B Order or better stations including:
  - HPGN (240+/-)
  - HPGN-D (850+/-)
  - Others that meet or exceed outlined requirements

► Official Horizontal Spatial Reference System for California

► Reference Control Network – HPGN

► GPS Only

► Includes section on CORS and encourages owners of CORS to make their stations CSRS stations. At this time, 10 PGGA are running with data available via “PC Bulletin Board”.

1994
1994

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Northridge Earthquake Jan 17, 1994
6.7 magnitude

- Northridge gave the impetus to increase the number of stations
- Increased interest in and funding for research in the hidden faults below Los Angeles
1996

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► Southern California Integrated GPS Network
Specifications for “High-Production” GPS Surveying

Supplement FGCS standards and Specifications

Why Needed?
Advancements in GPS technology and methodology

Proliferation of CORS

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1996

SPECIFICATIONS FOR GEODETiC CONTROL NETWORKS USING HIGH-PRODUCTION GPS SURVEYING TECHNIQUES

Version 1.0, July 1996

(HTML Version)

Prepared by:

Michael Anderson, PLS
Don D’Orocho
Gregory A. Helmer, PLS
Wayne Wheeler, Jr., PLS

Specifications for Geodetic Control Networks Using High-Production GPS Surveying Techniques
Version 2.0, July 1995

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► California Geodetic Control Committee 1993
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► Permanent GPS Geodetic Array
► Northridge Earthquake Jan 17, 1994 (6.7 mag)
► Southern California Integrated GPS Network
Southern California Integrated GPS Network (SCIGN)

- SCIGN was a collaborative effort by NASA/JPL, USGS, and SIO, under the umbrella of SCEC
- SCIGN became official in 1996
- Interest and funding for the SCIGN 250 station proposal occurred due to the Northridge Earthquake on January 17, 1994
- Network completed on July 6, 2001
1997-2001

Survey Community

Scientific Community
California Spatial Reference Center

First Formulation Meeting, San Clemente – August 22, 1997

First Chairperson – Bill Young

Draft Bylaws – August 12, 1998

First General Coordinating Council Meeting, Sacramento – July 8, 1999

Bylaws accepted – July 24, 2001

(Left to right) Charlie Challstrom - NGS Director; Yehuda Bock, Bill Young, Charles Kennel - SIO Director

1997-2001
California Spatial Reference Center

The CSRC’s mandates include:

- Establish and maintain the CSRS.
- Provide the necessary geodetic services to ensure the availability of accurate, consistent, and timely spatial referencing data.
- Monitor temporal changes in geodetic coordinates due to tectonic motion, earthquakes, volcanic deformation and land subsidence.
- Establish the legal spatial reference system for California.

1997-2001
California Spatial Reference Center

- In partnership with surveyors, engineers, GIS professionals, NGS, Caltrans, and the geophysics community;

- CSRC has developed a plan to establish and maintain an accurate state-of-the-art network of GPS control stations necessary to meet the demands of government and private businesses for a reliable spatial reference system in California.

1997-2001
In 1998, the U.S. Congress directed NGS to determine the effectiveness of using GPS techniques to establish accurate heights in California and North Carolina.

National Height Modernization Study officially documented the needs and benefits of accurate heights.

Since 1999, NGS and the CSRC have joined in partnership for the purpose of researching precise spatial referencing and height modernization in California.

1997-2001
Objective: to specify in detail a modern statewide geodetic control network

One component of a “complete” spatial reference system

Other component; “Real-Time positioning infrastructure”
CSRC Height Modernization Projects
Orange County Real Time Network

- Concept began in 2000

- **CSRC pilot project** with Orange County Survey Division

- Determine if real-time networks would be beneficial and apply the results to future networks in California

- OCRTN became publicly available February 20, 2003.
Plate Boundary Observatory (PBO)

- Geodetic component of EarthScope, operated by UNAVCO
- 1100+ CGPS
- Funded by the National Science Foundation
  - 2003-2009
    - Installed 891 CGPS
  - 259 CGPS in California
- Currently streaming 340 +/- sites in real-time
Statewide California Real Time Network

Elements of statewide infrastructure
Describes CRTN and its components
Defines users
Management and Governance
Cost Recovery

Describes CRTN Consortium
Data Availability
CRTN support and providers
Cost Recovery
Estimated Budget
2012

Where are we today?
CSRC Epochs

- Epoch 2011.00 (830 stations)
- Epoch 2009.00 (766 stations)
- Epoch 2007.00 (551 stations)

Referenced to ITRF2005 and NAD83(NSRS2007)
CRTN
2011.00 Epoch

Coordinates, velocities, and uncertainties

830 CGPS

ITRF2005 & NAD 83(NSRS2007)
EPOCH - 2011.00

2012
CRTN
Backbone

163+/- CGPS to achieve 50 km grid state wide coverage

93 CGPS real-time

57% complete

95% NGS CORS
NAD 83(2011)
EPOCH - 2010.00
CRTN

303 RT sites

All available via NTRIP

2012
CSRC Funding
July 1, 1998 through June 30, 2012

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CRTN Consortium

- CRTN Consortium members are those who contribute funds to recovering the costs of operating CRTN. The general goals of the CRTN Consortium membership are to support and provide the following:

  - **Public Service** - Member fees support free and open access to basic services for all users in California as outlined in the CRTN Proposal.

  - **Supporting the Maintenance of the California Spatial Reference System (CSRS)**

  - **Densification** - CRTN backbone network will include about 200 stations with a minimum spacing of 50 km. Current real time network operators can make use of this statewide spatial referencing network backbone to densify their networks as needed.

- In addition to this, CRTN Consortium members will also provide governance and oversight/management of the network.
CRTN Consortium Membership Tiers

► Contributing Members: donate $1,000 annually, which provides access to a second NTRIP account for real-time access to RTCM 3.0 data (all users have free access to a single account). Additional access increases by $1,000 per account. Please note that contributing members do not participate in oversight/management of the network.

► CRTN Consortium Members: contribute $15,000 annually, which provides access to any 20 real-time CGPS sites 24/7 (multiple NTRIP accounts). This membership has voting privileges on the CRTN Consortium, which oversees the development and management of the network. If a Consortium member needed more than 20 sites, they can add additional sites at $1000 each.

► Statewide CRTN Consortium Members: contributes $150,000 annually to fund CRTN and has access to all real-time CGPS sites 24/7. This membership has voting privileges but is limited to three voting members, and also includes being part of the team that will oversee the development and management of the network.

► Donations for any amount are welcome. All donations are used towards operating and maintaining CRTN and our data services. If you or your organization would like to donate or contribute membership dues, please go to the following link: https://www-er.ucsd.edu/givetoucsd/secure/paymenttran/onlinegiving.asp?sk=367
Questions?