California Real-Time Network (CRTN)

September 28th, 2012
Ontario, CA

October 5th, 2012
Sacramento, CA

Presenter: Art Andrew

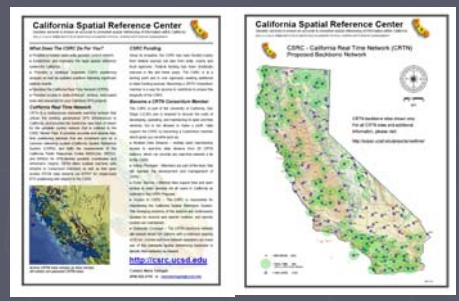
CSRC Chairperson

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



California Geodesy Timeline

Survey Community

Scientific Community

1990

2003

1991

2012

1998

1992

1997

1993

1996

1994

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

1990

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

1990

Surveyors

- California Geodetic Reference Network

Scientists

- Permanent GPS Geodetic Array

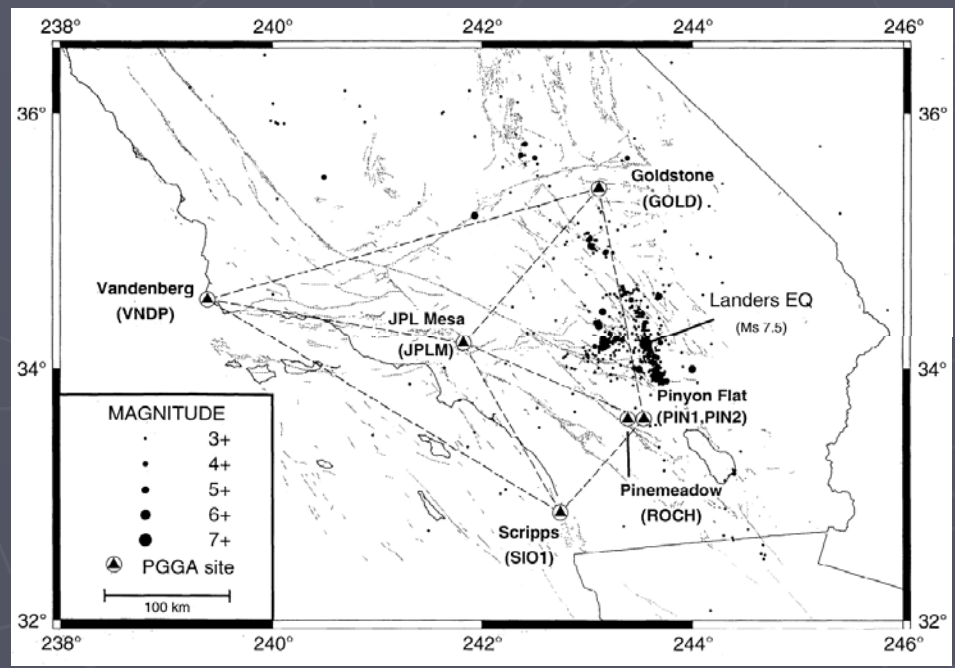
Permanent GPS Geodetic Array (PGGA)

- 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

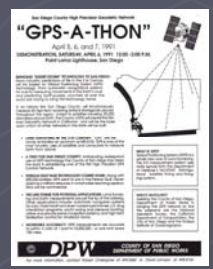
1990

Scientists

- Permanent GPS Geodetic Array
- Permanent GPS Geodetic Array

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)
- Completed in 1991 with a *birth date* of 1991.35 (May 8, 1991)
- 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



1991

The California High Precision Geodetic Network - A 20 Year Retrospective (California Surveyor Fall 2011)

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

High Precision Geodetic Network (HPGN)

- Unique Requirement!
  - 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.
- UCSD 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

Surveyors

- California Geodetic Reference Network
- High Precision Geodetic Network

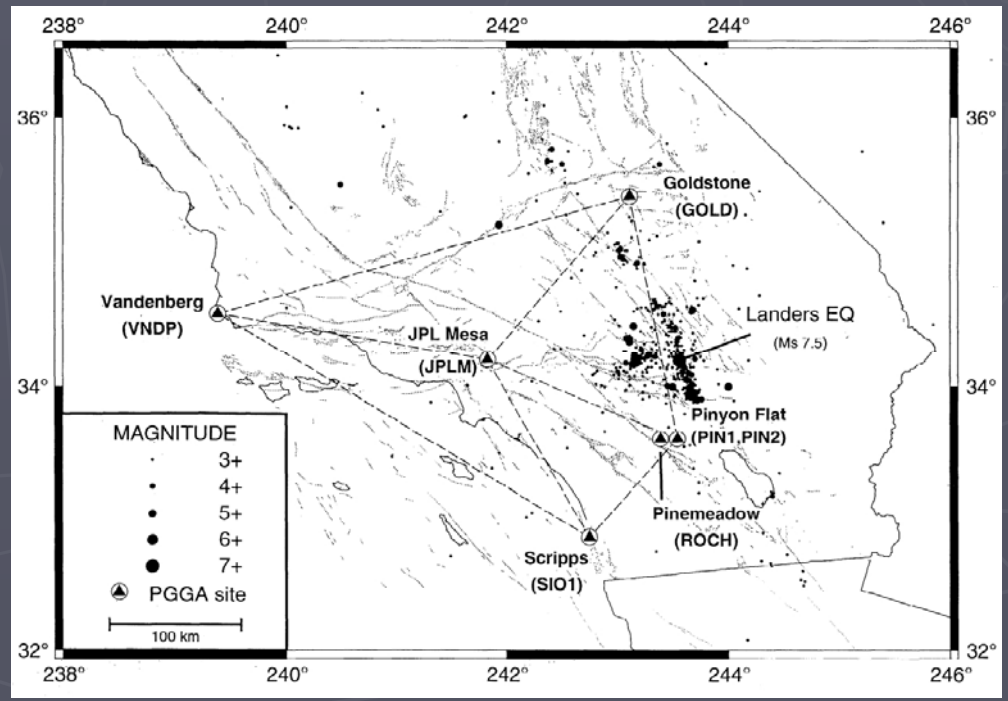
1990

Scientists

- Permanent GPS Geodetic Array
- Permanent GPS Geodetic Array

Permanent GPS Geodetic Array (PGGA)

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



1991

1992

Surveyors

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

1990

1991

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

Surveyors

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

1990

1991

Scientists

- Permanent GPS Geodetic Array
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- Scripps Orbit and Permanent Array Center

Scripps Orbit and Permanent Array Center (SOPAC)

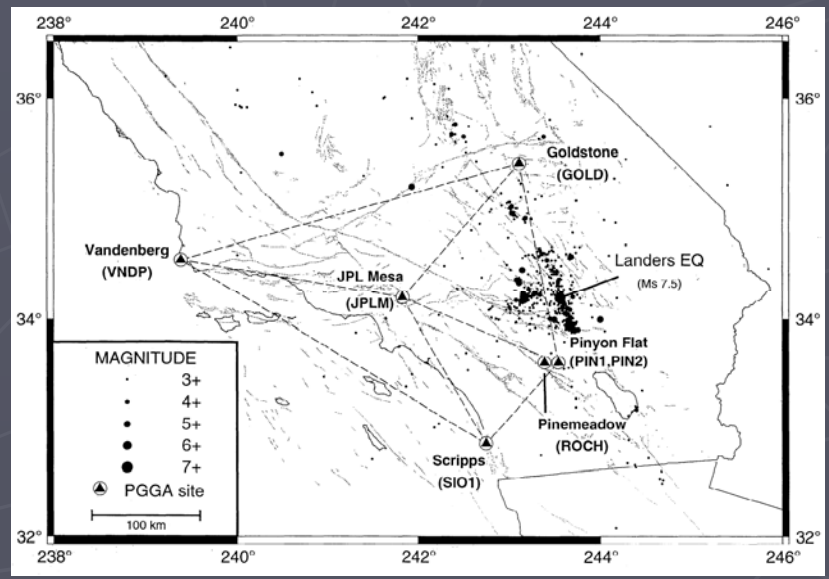
- SOPAC's primary scientific role is to **support high precision geodetic and geophysical measurements using GPS**, particularly for the study of earthquake hazards, tectonic plate motion, plate boundary deformation, and meteorological processes.
- SOPAC performs **research and provides operational support**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

SOPAC

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”



1992

1993

Surveyors

- California Geodetic Reference Network
- High Precision Geodetic Network
- High Precision Geodetic Network Densification
- California Geodetic Control Committee

1990

1991

1992

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- Permanent GPS Geodetic Array
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- Permanent GPS Geodetic Array

California Geodetic Control Committee (CGCC)

- 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

Surveyors

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1991

1992

Scientists

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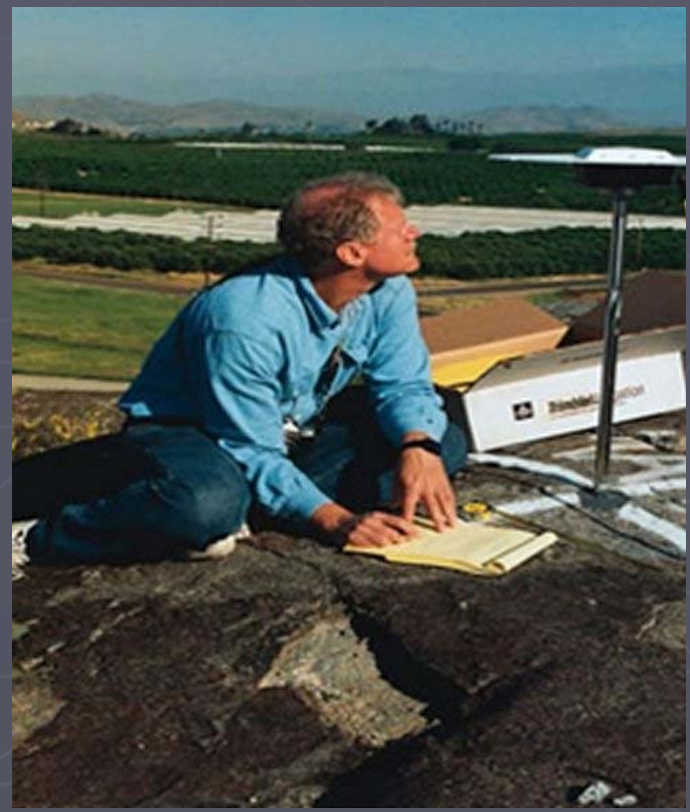
- Permanent GPS Geodetic Array

Permanent GPS Geodetic Array (PGGA)

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

MATH installed April 14, 1993



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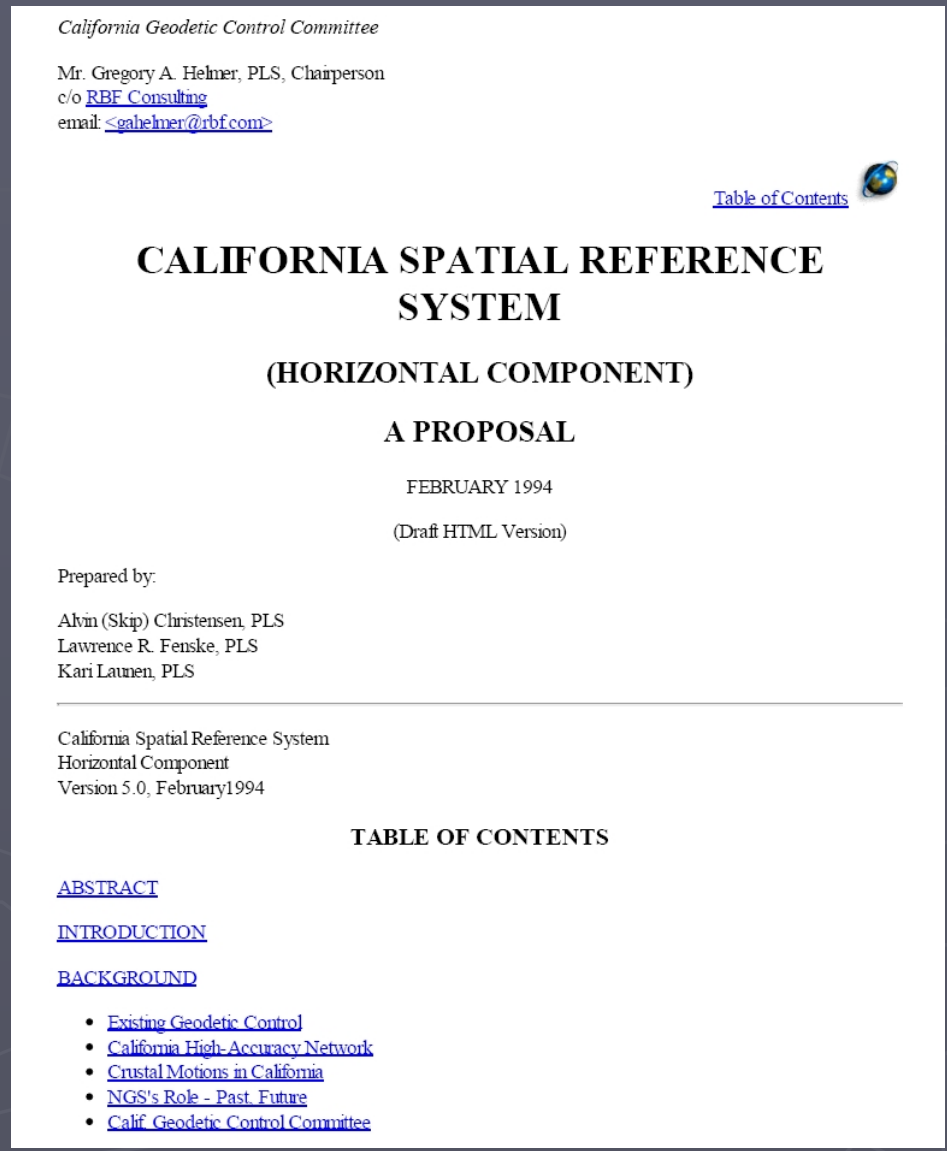
Scientists

- Permanent GPS Geodetic Array
- Permanent GPS Geodetic Array
- Scripps Orbit and Permanent Array Center
- 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”.



California Geodetic Control Committee

Mr. Gregory A. Helmer, PLS, Chairperson
c/o RBF Consulting
email: <gahelmer@rbf.com>

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CALIFORNIA SPATIAL REFERENCE SYSTEM

(HORIZONTAL COMPONENT)

A PROPOSAL

FEBRUARY 1994

(Draft HTML Version)

Prepared by:

Alvin (Skip) Christensen, PLS
Lawrence R. Fenske, PLS
Kari Launen, PLS

California Spatial Reference System
Horizontal Component
Version 5.0, February1994

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ABSTRACT

INTRODUCTION

BACKGROUND

- Existing Geodetic Control
- California High-Accuracy Network
- Crustal Motions in California
- NGS's Role - Past, Future
- Calif. Geodetic Control Committee

1994

1994

Surveyors

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Scientists

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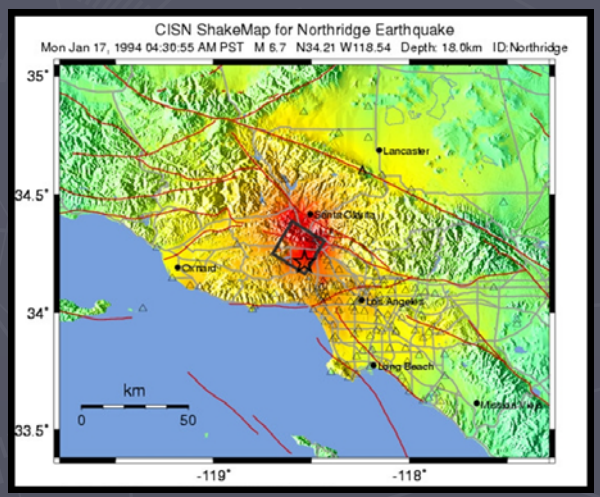
- Permanent GPS Geodetic Array
- Scripps Orbit and Permanent Array Center
- Permanent GPS Geodetic Array
- Northridge Earthquake Jan 17, 1994 (6.7 mag)

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



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- Northridge Earthquake Jan 17, 1994 (6.7 mag)
- Southern California Integrated GPS Network

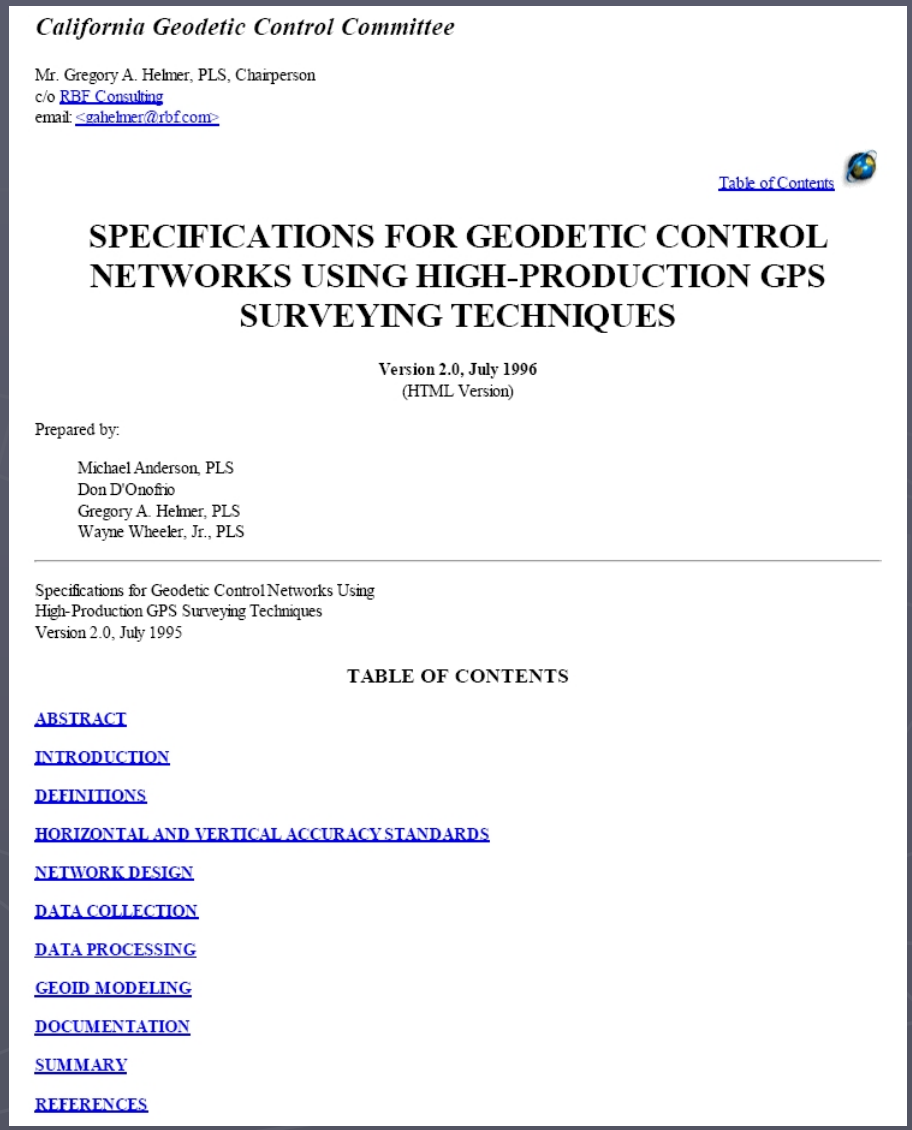
California Geodetic Control Committee

Specifications for “High-Production” GPS Surveying

Supplement FGCS standards and Specifications

Why Needed?

- Advancements in GPS technology and methodology
- Proliferation of CORS



California Geodetic Control Committee

Mr. Gregory A. Helmer, PLS, Chairperson
c/o RBF Consulting
email: <gahelmer@rbf.com>

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

Version 2.0, July 1996
(HTML Version)

Prepared by:

Michael Anderson, PLS
Don D'Onofrio
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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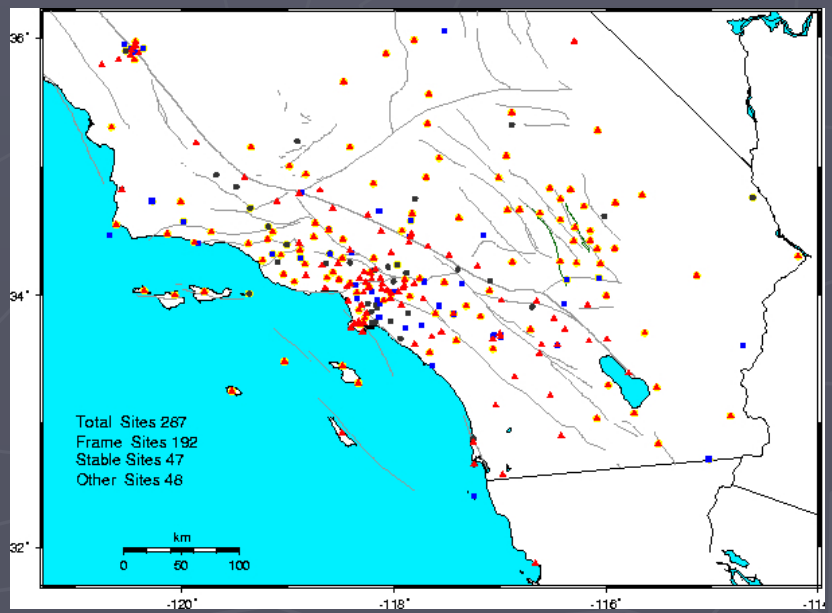
- Scripps Orbit and Permanent Array Center
- Permanent GPS Geodetic Array
- Northridge Earthquake Jan 17, 1994 (6.7 mag)
- Southern California Integrated GPS Network

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

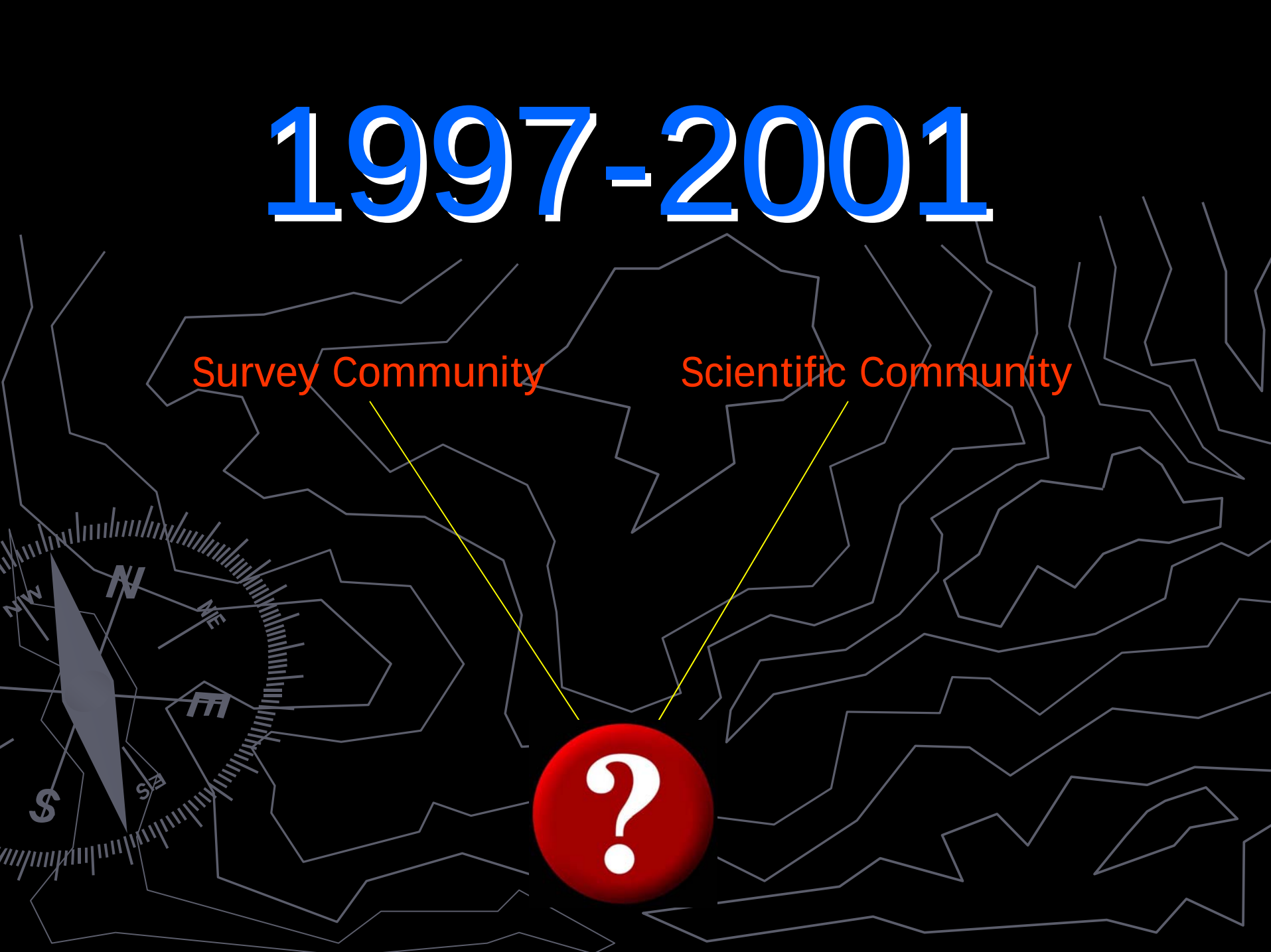


1996

1997-2001

Survey Community

Scientific Community



California Spatial Reference Center

First Formulation Meeting, San Cle[illegible] – August 22, [illegible]

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

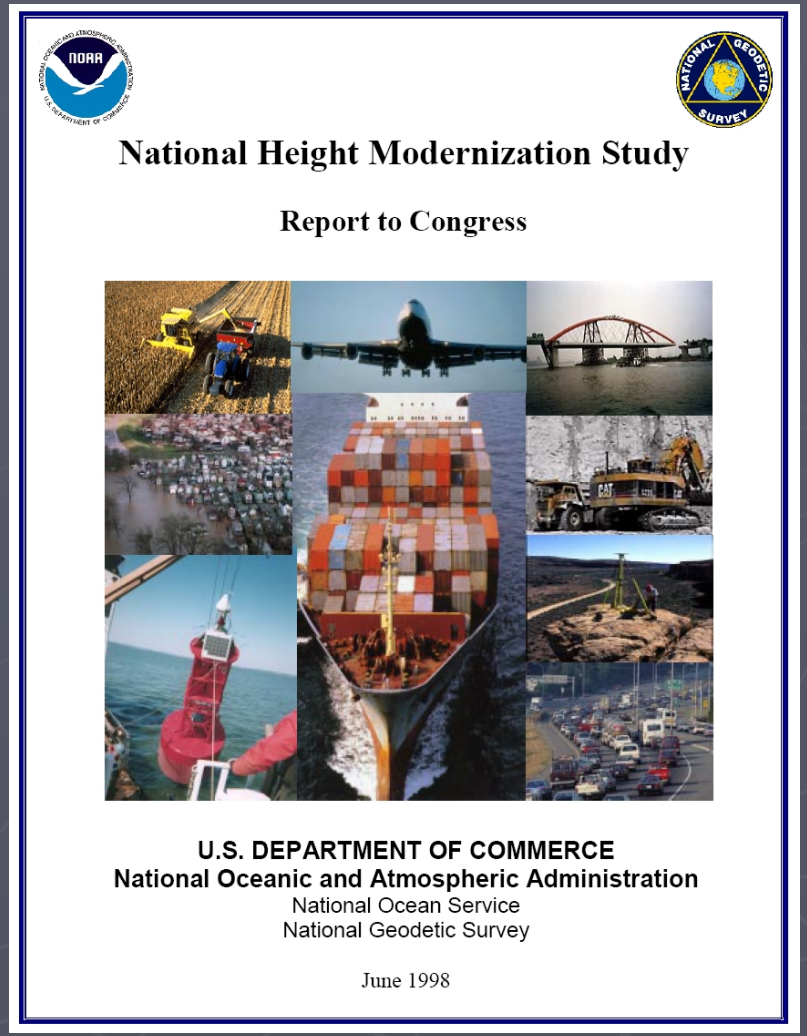
California Spatial Reference Center

- 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

National Height Modernization Program

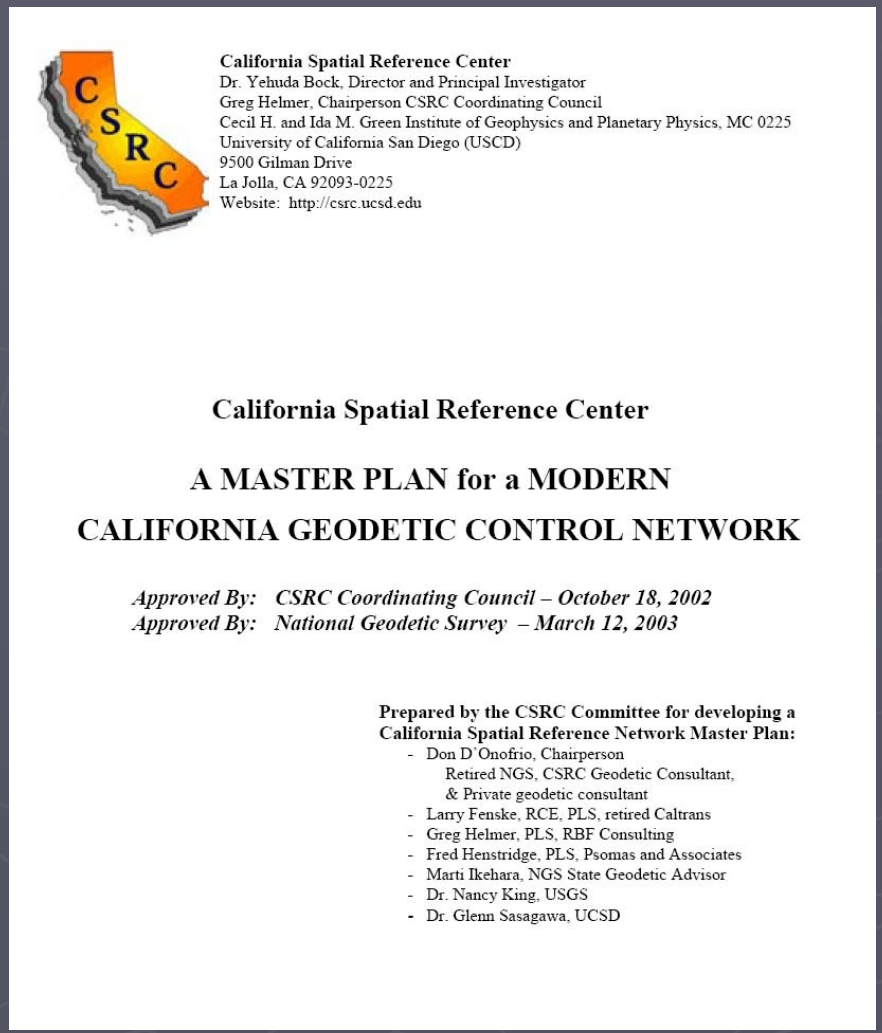
- In 1998, the U.S. Congress directed NGS to determine the effectiveness of using GPS techniques to establish accurate heights in California and North Carolina.
- National Height Modernization Study officially documented the needs and benefits of accurate heights.
- Since 1999, **NGS and the CSRC have joined in partnership** for the purpose of researching precise spatial referencing and height modernization in California.



1997-2001

California Spatial Reference Center

- 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"



California Spatial Reference Center
Dr. Yehuda Bock, Director and Principal Investigator
Greg Helmer, Chairperson CSRC Coordinating Council
Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics, MC 0225
University of California San Diego (USCD)
9500 Gilman Drive
La Jolla, CA 92093-0225
Website: http://csrc.ucsd.edu

California Spatial Reference Center

A MASTER PLAN for a MODERN

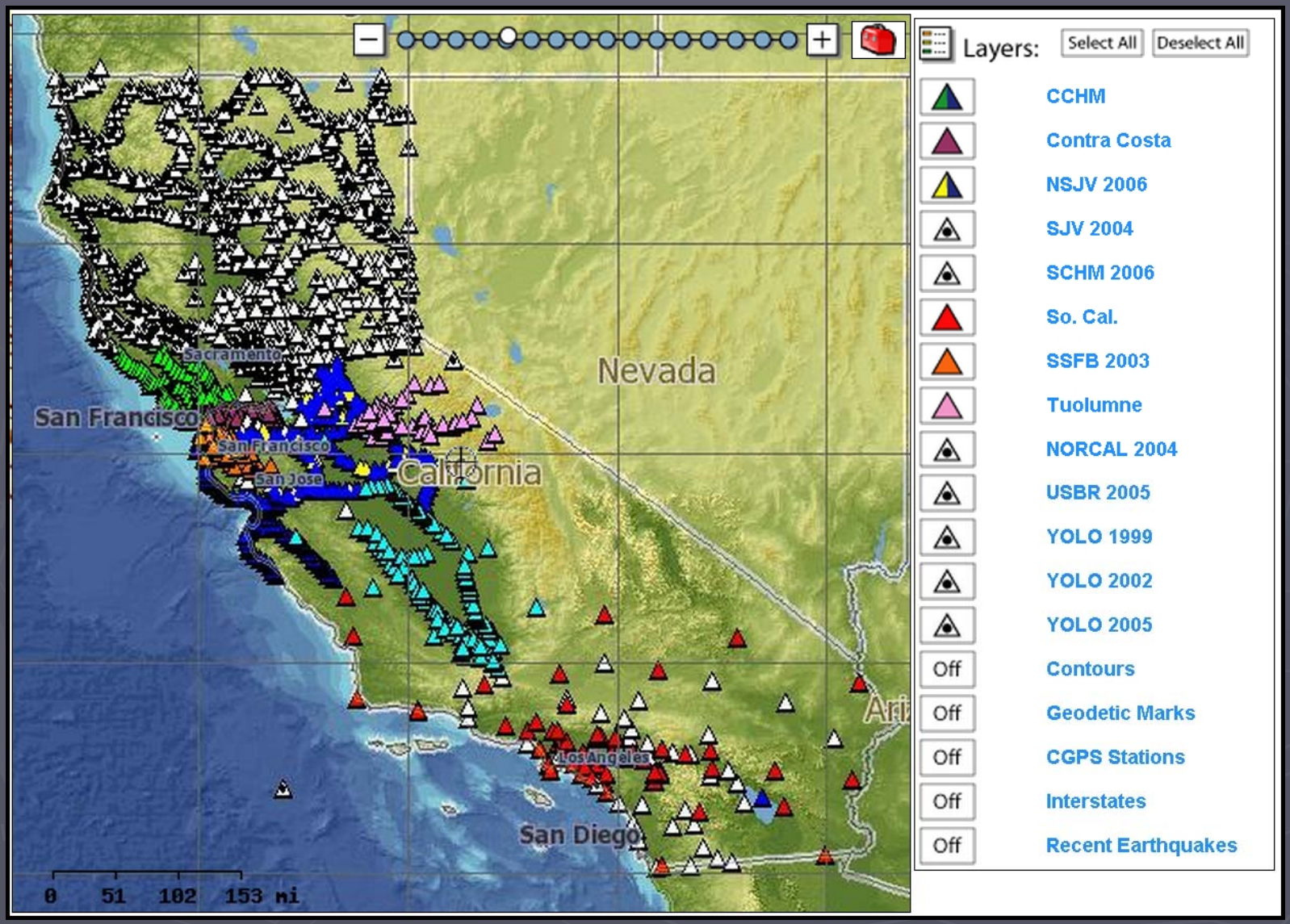
CALIFORNIA GEODETIC CONTROL NETWORK

Approved By: CSRC Coordinating Council – October 18, 2002
Approved By: National Geodetic Survey – March 12, 2003

Prepared by the CSRC Committee for developing a California Spatial Reference Network Master Plan:
- Don D'Onofrio, Chairperson
  Retired NGS, CSRC Geodetic Consultant,
  & Private geodetic consultant
- Larry Fenske, RCE, PLS, retired Caltrans
- Greg Helmer, PLS, RBF Consulting
- Fred Henstridge, PLS, Psomas and Associates
- Marti Ikehara, NGS State Geodetic Advisor
- Dr. Nancy King, USGS
- Dr. Glenn Sasagawa, UCSD

2003

CSRC Height Modernization Projects



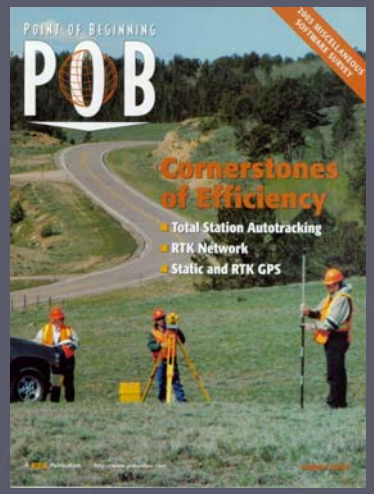
2003

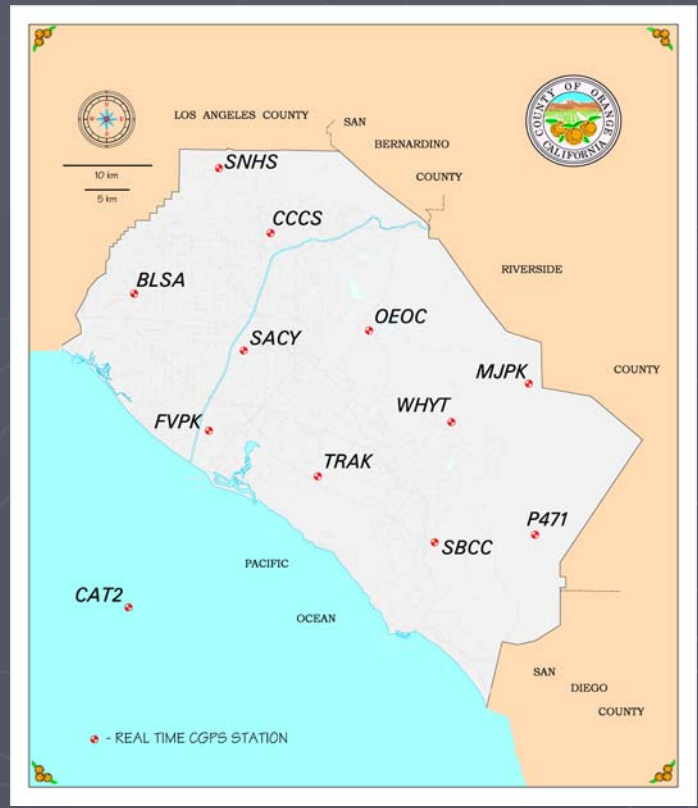
Orange County Real Time Network

- 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 publically available February 20, 2003.

POB

August, 2003

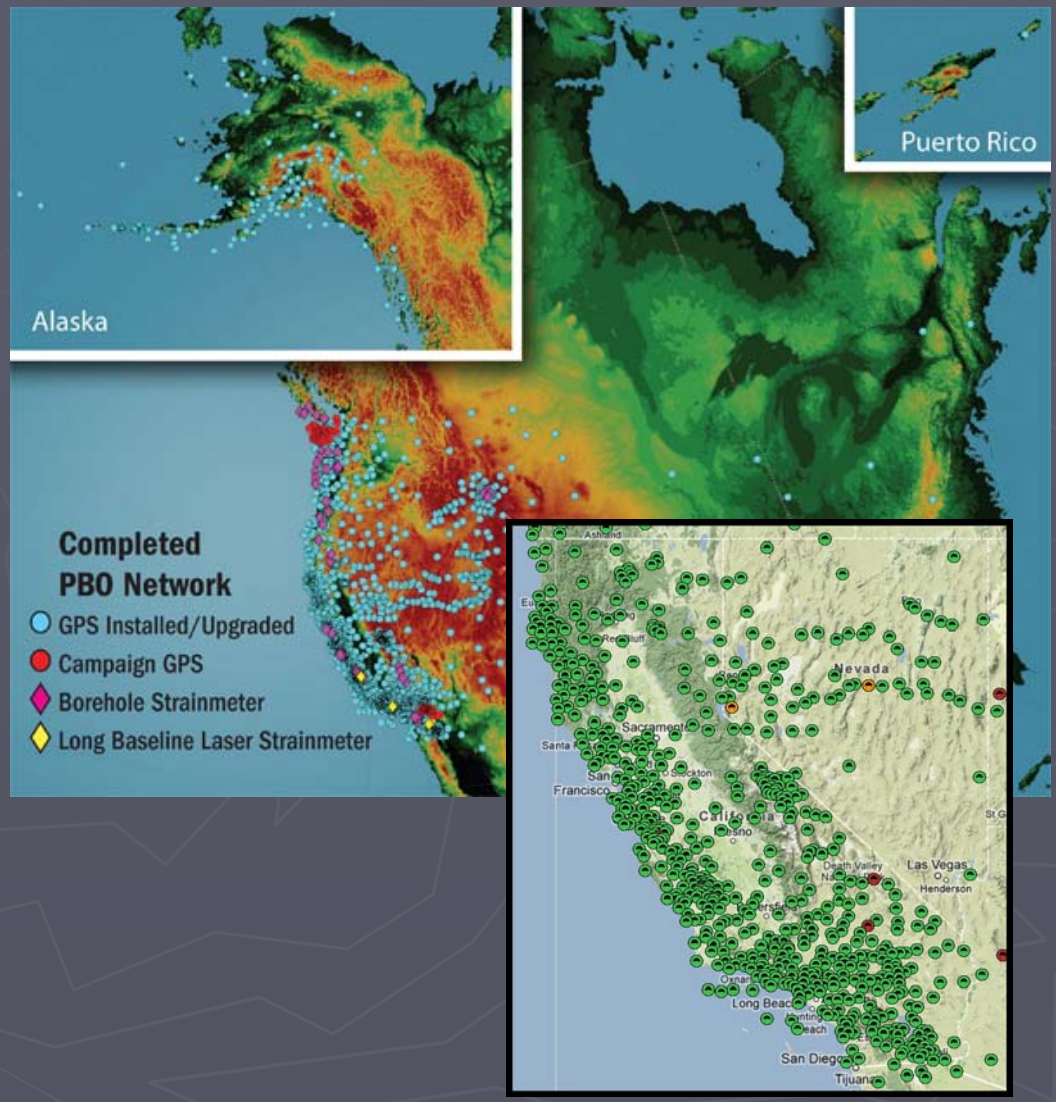




2003

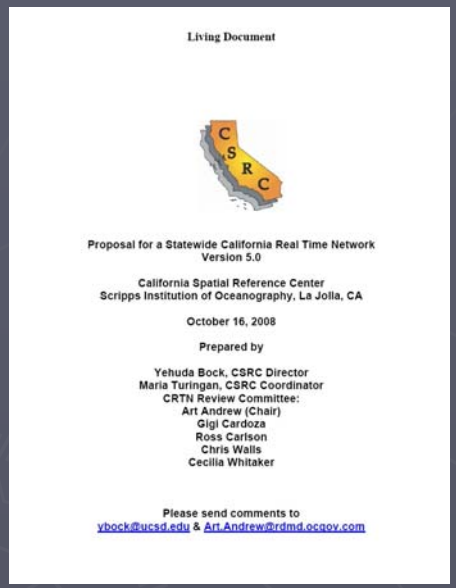
Plate Boundary Observatory (PBO)

- 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



2003

Statewide California Real Time Network



Living Document

Proposal for a Statewide California Real Time Network
Version 5.0

California Spatial Reference Center
Scripps Institution of Oceanography, La Jolla, CA

October 16, 2008

Prepared by

Yehuda Bock, CSRC Director
Maria Turingan, CSRC Coordinator
CRTN Review Committee:
Art Andrew (Chair)
Gigi Cardoza
Ross Carlson
Chris Walls
Cecilia Whitaker

Please send comments to
ybock@ucsd.edu & Art.Andrew@rdmd.ocgov.com

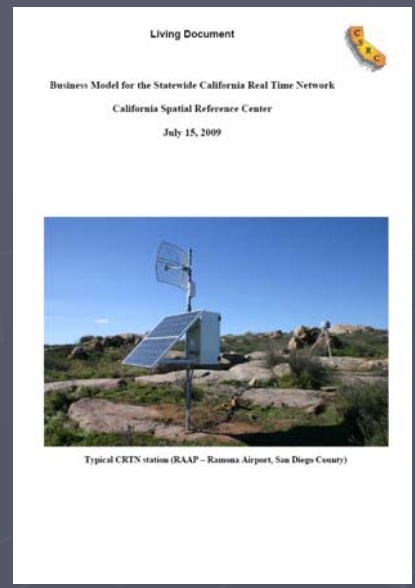
Elements of statewide infrastructure

Describes CRTN and its components

Defines users

Management and Governance

Cost Recovery



Living Document

Business Model for the Statewide California Real Time Network

California Spatial Reference Center

July 15, 2009

Typical CRTN station (RAAP – Ramona Airport, San Diego County)

Describes CRTN Consortium

Data Availability

CRTN support and providers

Cost Recovery

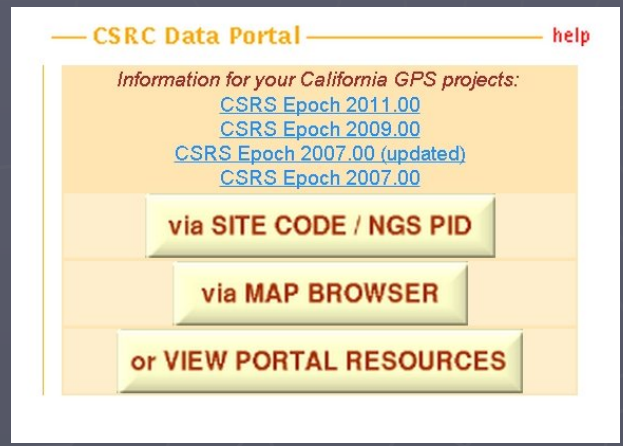
Estimated Budget

2012

Where are we today?

CSRC Epochs

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

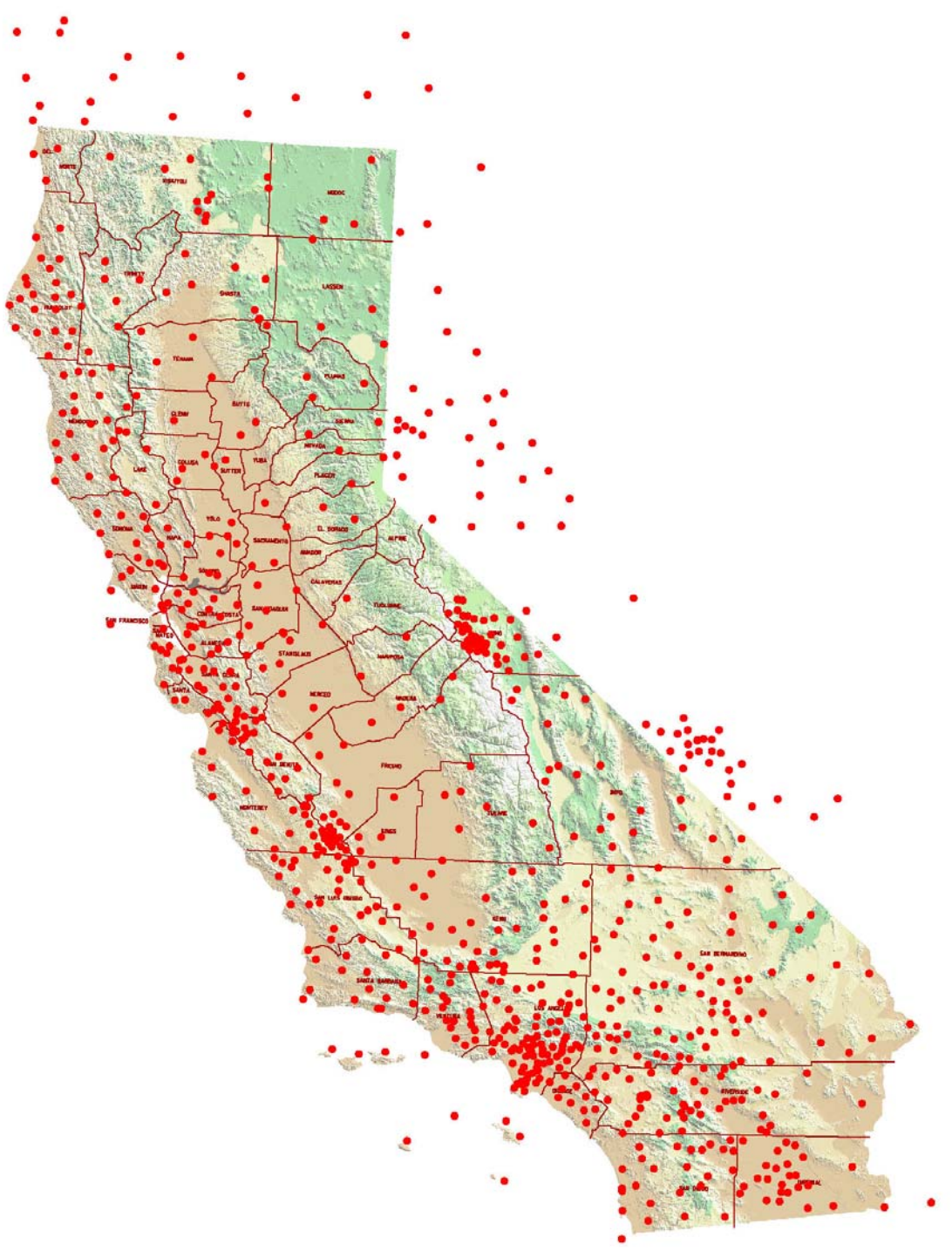


Referenced to ITRF2005 and NAD83(NSRS2007)

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

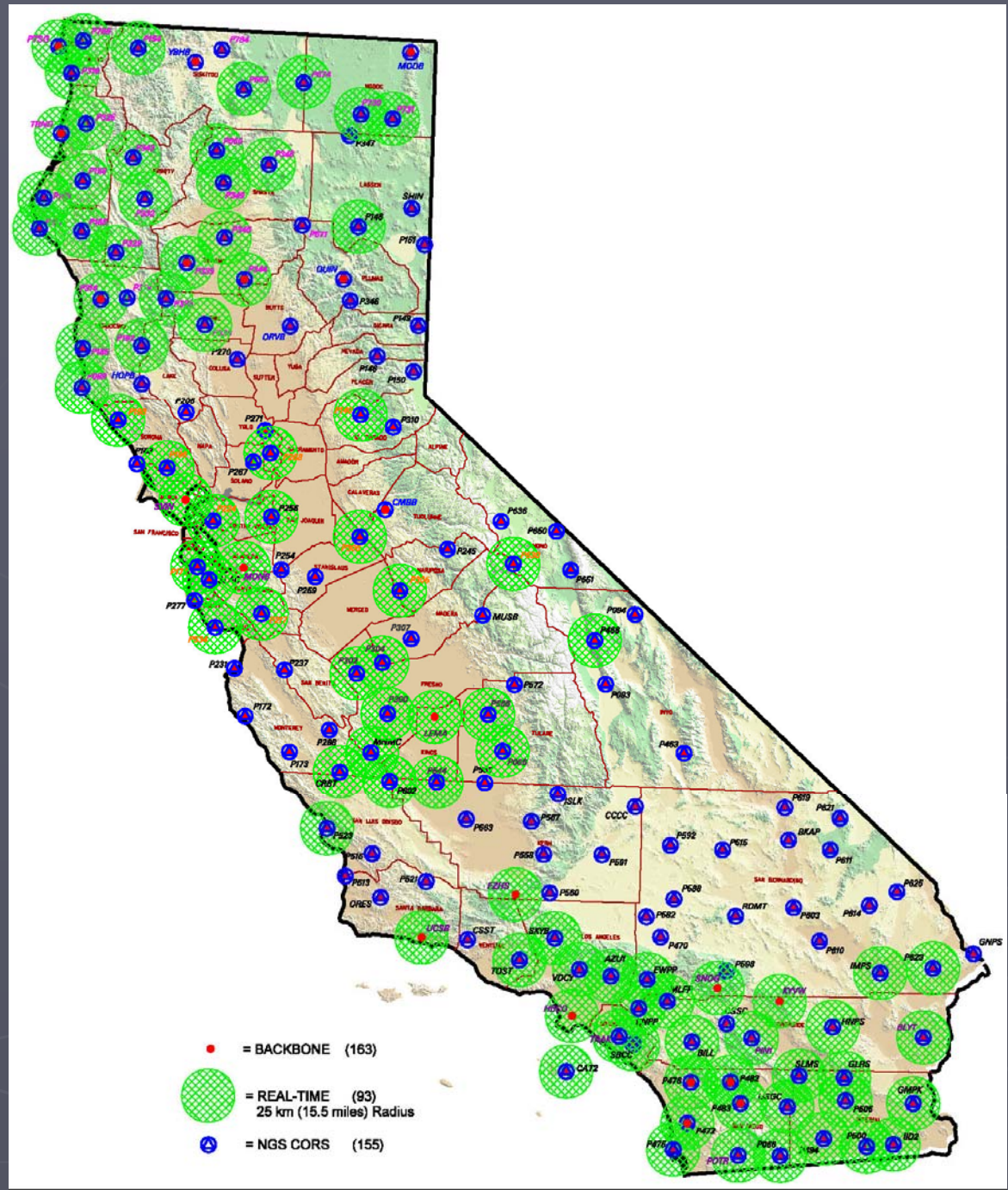
93 CGPS real-time

57% complete

95% NGS CORS

NAD 83(2011)

EPOCH - 2010.00

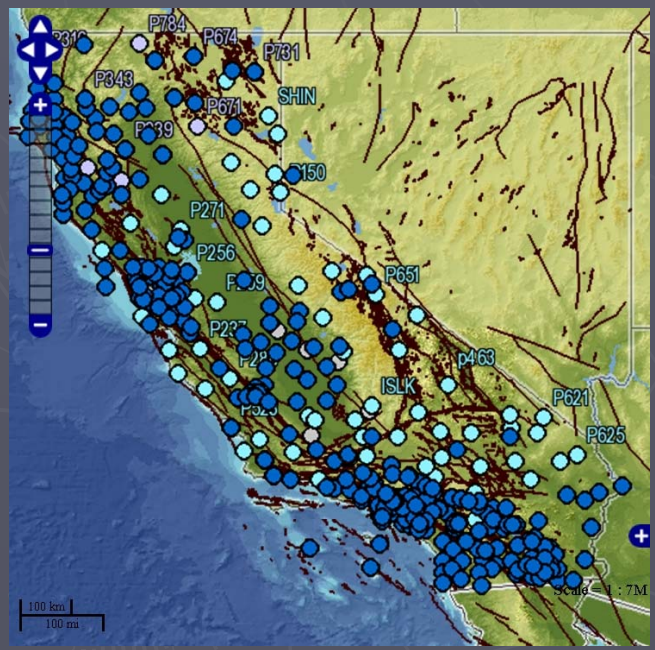


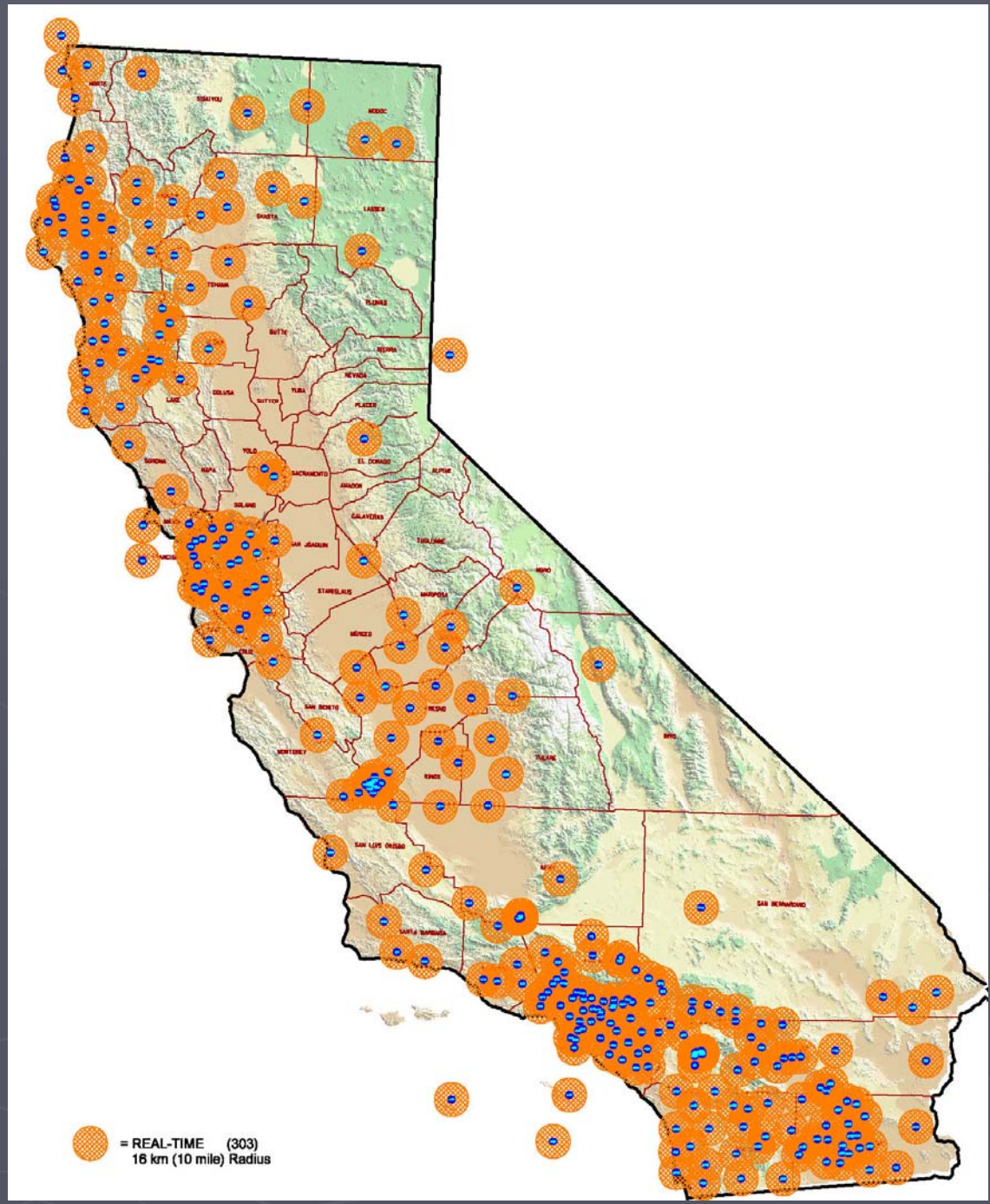
2012

CRTN

303 RT sites

All available via NTRIP



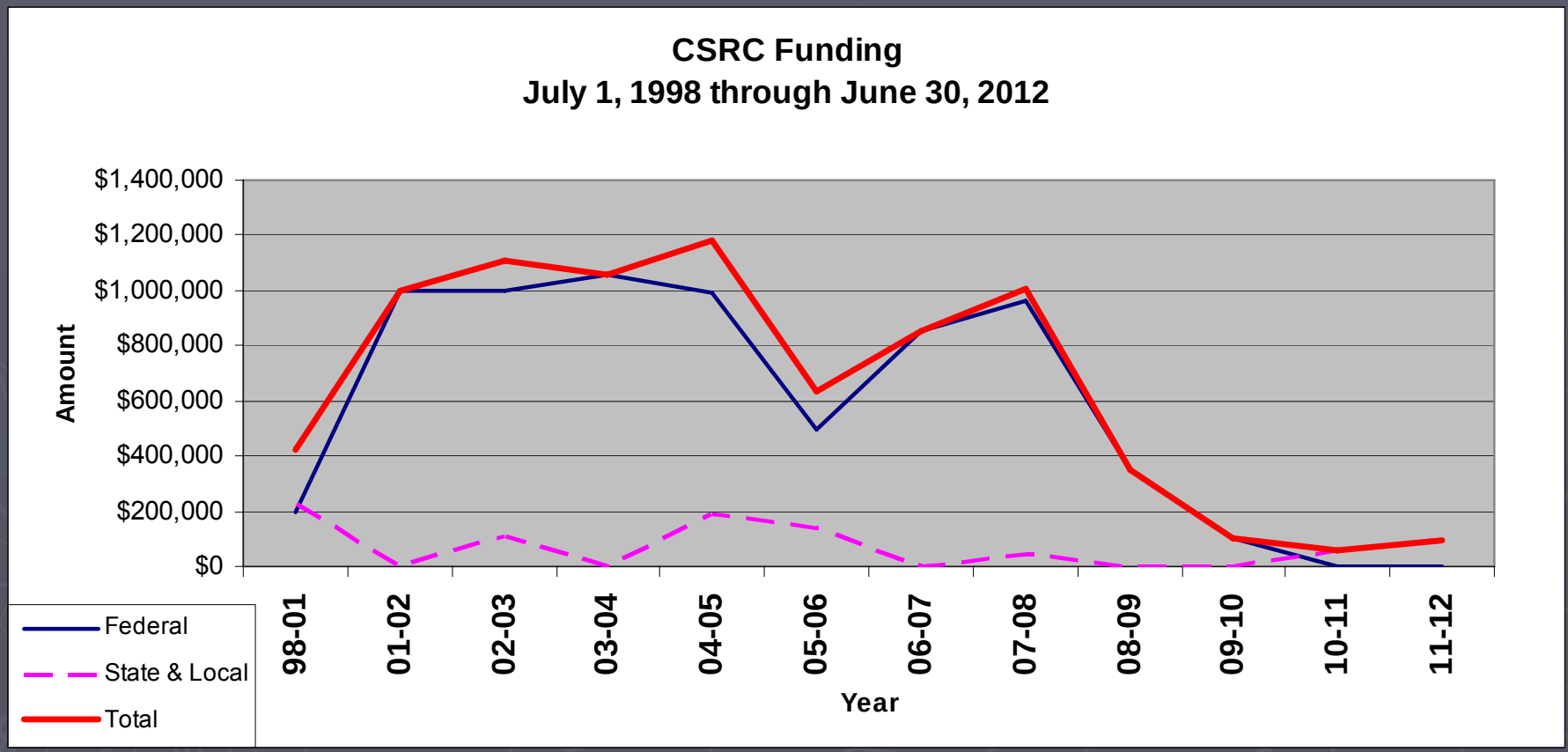


2012

FUNDING

Where are we today?

CSRC Funding



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 addition 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?


C
S
R
C
California Spatial Reference Center
IGPP - SIO
Providing California's geodetic framework for scientific,
surveying, engineering, and geographic information systems