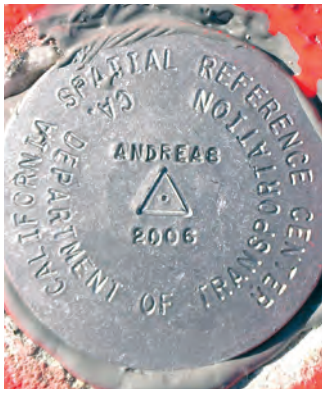
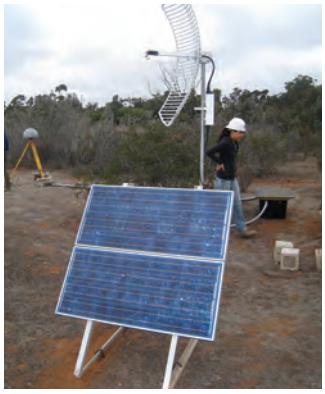


CALIFORNIA SPATIAL REFERENCE CENTER







STRATEGIC PLAN // DECADE THREE // AUGUST 30, 2021

SOPAC

CSRC

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GREETINGS FROM THE DIRECTOR

As we move into our third decade (2021-2031), I am proud to present this California Spatial Reference Center (CSRC) Strategic Plan. The CSRC, established as a Support Group of the University of California San Diego (UCSD), is recognized as an important community outreach program by the Director's Office at Scripps Institution of Oceanography (SIO) and by our hosts at the Institute of Geophysics and Planetary Physics (IGPP). We are grateful for their approval and encouragement over the last twenty years.

The CSRC is responsible for defining, maintaining, and publishing the California Spatial Reference System (CSRS) for our many stakeholders, including local and state organizations, academia, and the public and private sectors. Here we present to you our vision for modernizing and expanding the CSRC as we continue to meet the ever-evolving needs of the people of California to access accurate, timely, robust, and consistent geospatial information in the presence of significant crustal motions. We reaffirm our commitment to ensure the CSRS is aligned with the National Spatial Reference System (NSRS) in support of the National Oceanic and Atmospheric Administration (NOAA) and its National Geodetic Survey's (NGS) mission and with the backing of the California Department of Transportation (Caltrans).

The underlying CSRS framework is provided by the California Spatial Reference Network (CSRN), and consists of approximately 900 continuous Global Navigation Satellite System (GNSS) stations, 700 of which are providing real-time data through the California Real Time Network (CRTN). The CRTN serves as a clearinghouse of data contributed by our many partners at UNAVCO, University of California Berkeley, the U.S. Geological Survey (USGS), Caltrans, and San Diego and Orange Counties. Through the CSRS and CRTN, we are able to monitor and quickly restore the precise spatial fabric in areas disrupted by the devastating effects of geophysical, natural, and anthropogenic processes often experienced by the people of California.

From a historical vantage point, the CSRC was conceived by surveying and engineering community members as an outgrowth of a successful collaboration with academia and other research institutions. Our first effort was to establish the first continuous GNSS stations in California, which culminated in the 250-station Southern

California Integrated GPS Network (SCIGN). SCIGN was completed in 1999 as a collaboration with SIO, NASA's Jet Propulsion Laboratory (JPL) and the U.S. Geological Survey (USGS) under the umbrella of the Southern California Earthquake Center (SCEC). The CSRC, Headquarters Dedication was held on February 20, 2001, at SIO, with USGS' Ken Hudnut, the SCIGN Chairperson, remarking, "The CSRC is taking what otherwise might be a purely academic-type research and making the data available to a wide variety of applications."

Prominent in our founding was our first Chairperson, Bill Young, and the members of the CSRC Committee for developing the 2002 California Spatial Reference Network. Master Plan. Don D'Onofrio, NGS Geodetic Advisor, chaired the Master Plan effort with members from academia, state, and federal organizations, as well as the private sector.

To adequately maintain the CSRS into the future, the CSRC must continue to implement a dynamic datum (reference frame) to deal with the ever-changing California landscape and integrate GNSS and interferometric synthetic aperture radar (InSAR) methodologies to provide maps of surface deformation with high spatial and temporal resolution. Additional expansion areas include: improving our ability to measure sea level rise as part of ongoing climate research; near-real-time GNSS monitoring of extreme weather events; subsidence related to water and energy policies; structural health monitoring; reality capture through digital twins; and integration of multiple sensors such as light detection and ranging (lidar) and Unmanned Aerial Vehicles (UAVs).

I wish to express my sincere appreciation to our Strategic Plan Working Group (Dr. Dana J. Caccamise, Gregory Helmer, Steve Hennessee, Taleah Quemada, John Tosto), Executive Committee and Jennifer Matthews in preparing this Strategic Plan, Maria Turingan, Jennifer Matthews and Bobbi Simmons for technical support, and Steve Martin and Sharona Benami for their insight. We acknowledge with gratitude the support of Caltrans, NGS, the CRTN Consortium and its contributing members for their continued funding of the CSRC. The success of our endeavors is sustained by countless volunteers and the dedicated work of the staff at the Scripps Orbit and Permanent Array Center (SOPAC).

Finally, we have have greatly benefitted from the synergistic research at SOPAC, funded by NASA, U.S. National Science Foundation (NSF), NOAA, SCEC and USGS. However, we must strive for self-sufficiency in funding our myriad of activities, hence, a major motivation for producing this document; and having served as the California Spatial Reference Center's Director since our inception, it is my honor and pleasure to provide it to you.

EXECUTIVE SUMMARY

The California Spatial Reference Center (CSRC) has achieved two decades of success in developing and maintaining the California Spatial Reference System (CSRS) and its backbone, the California Spatial Reference Network (CSRN). Together they deliver a framework for users requiring precise geodetic and geospatial information in a dynamic landscape. With this Strategic Plan, we clarify and expand our vision for the next decade as we continue to meet the ever-evolving needs of our California stakeholders.

As a Support Group of the University of California San Diego (UCSD), we provide an important liaison between the scientific research and geospatial communities. Headquartered at Scripps Institution of Oceanography's Institute of Geophysics and Planetary Physics (SIO/IGPP), we play an important community outreach and education role by serving the professional community and our academic hosts.

The CSRC operates the California Real-Time Network (CRTN), initially established to support research into real-time earthquake and tsunami warning systems for disaster mitigation. The CRTN now supports a wide range of non-academic users who require precise real-time positioning and spatial referencing. We have established partnerships with federal, state, county, and university data providers to aid in this effort.

Moving forward, we recognize the need to modernize and expand our programs. The CSRS and CRTN provide the ability to monitor and quickly restore the geodetic fabric in areas disrupted by geophysical events. Agile responses to such events as earthquakes enable rapid assessment, help to inform decision makers and their stakeholders, and allow for faster restoration efforts. To this end, it is critical for us to implement a dynamic reference frame (geodetic datum). Related improvements include the integration of the Global Navigation Satellite System (GNSS) and interferometric synthetic aperture radar (InSAR) methodologies to provide the best maps of ground deformation with high spatial and temporal (time-based) resolution. Additional areas for expansion include: an improved ability for measuring rising sea levels as part of on-going climate research; near-real-time GNSS monitoring of extreme weather events, such as summer monsoons, atmospheric rivers, and drought; monitoring subsidence related to water and energy policy; structural health monitoring; supporting reality capture through digital twins and integration of multiple sensors such as light detection and ranging (lidar) and Unmanned Aerial Vehicles (UAVs).

The CSRC's spatial referencing expertise garnered through its demonstrated ability to bridge academic research and civilian applications has proven to be of significant value, serving society's increasing geospatial needs in infrastructure, industry, governance and public safety. Moving forward, we must actively seek the funding and support from new and diverse sources required to maintain and grow the Center into the next decade. In this way, we will bridge the geospatial information and knowledge gap to solve pressing societal issues.

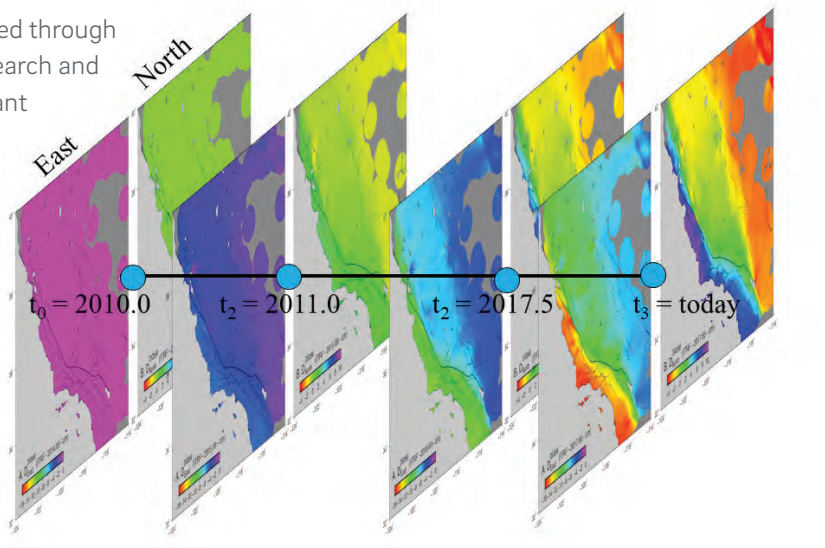

Figure 1. Dynamic datum concept. The CSRC produces weekly surface displacement grids in North and East components that allow users to calculate horizontal coordinates at any epoch of time with respect to the CSRS. The grids include the effects of tectonic motions, earthquakes and transients such as postseismic deformation and irregular subsidence and uplift. The CSRC also provides weekly vertical grids. We are working to integrate GNSS and InSAR to increase spatial resolution. Source: Klein et al. (2019).

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PURPOSE AND VISION

The **California Spatial Reference Center's (CSRC)** primary mission is to establish, maintain, and deliver the **California Spatial Reference System (CSRS)**. It is the CSRS that defines the geodetic datum for precise geospatial positioning for the State of California. Underlying the CSRS is the **California Spatial Reference Network (CSRN),** a state-of-the-art network of approximately 900 geodetic-quality **Continuous Global Navigation Satellite System (cGNSS[1])** reference stations established within the state and its immediate surroundings (Figure 2). The CSRN, state-of-the-art geophysical models and modern digital distribution infrastructure provide a reliable multi-purpose spatial reference system for the people of California. We ensure that the CSRS is aligned with the **National Spatial Reference System (NSRS)** and the missions of both the **National Oceanic and Atmospheric Administration (NOAA)** and the **National Geodetic Survey (NGS)**. In this regard, the **California Department of Transportation (Caltrans)**, a leading contributor to the CSRC, strengthens and reinforces our NGS partnership.

Maintaining the CSRS requires accurate accounting for changes in CSRN coordinates due to crustal motions from plate tectonics, earthquakes, and volcanoes, as well as California's physical environment, including natural (e.g., extreme weather, hydrology, drought, volcanism) and anthropogenic processes, (e.g., rising sea level, subsidence due to groundwater extraction, geothermal energy mining). The CSRC's mission is to rapidly restore the geodetic control in areas disrupted by these crustal motions within the framework of the CSRS. This restoration is accomplished by posting a new set of coordinates for the affected stations but also by transmitting them to real-time users through the **California Real Time Network (CRTN)**. The dynamic datum (Figure 1), once integrated into CRTN, will further enhance our capabilities to respond quickly to and recover from natural disasters. This utility will serve a diverse group of users, including land surveyors, scientific and academic researchers, geographic information system (GIS) professionals, state and local governments, and the navigation and positioning industries.

Organizations and individual volunteers assist us in our mission by providing expertise and experience, assuming roles and responsibilities, and contributing to public outreach and fundraising endeavors. However, the key to continued success in delivering the geodetic and the broader geospatial framework for the people of California is the modernization and expansion of the CSRC programs and products. Our growth must align with technological advancements and changing initiatives. Adding scope and value to the CSRC will allow us to expand our constituent community in emerging areas of geospatial science, industry, academics, and governance.

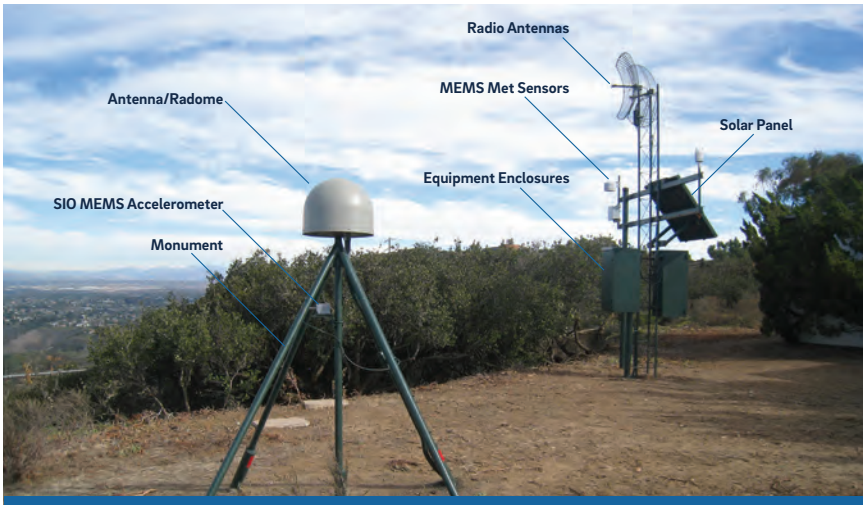


Figure 2. Typical GNSS station. Components of real-time GNSS station ("SIO5") maintained by the CSRC and located on Mt. Soledad in La Jolla. To ensure site stability, the geodetic monument consists of four oblique and one vertical stainless-steel rods driven to 10-meter depth and isolated from the soil to a depth of a few meters. The antenna cover (radome) and special antenna adaptor were designed by the Southern California Integrated GPS Network (SCIGN). The station operates on solar power and dedicated radio communications through UCSD's High Performance Wireless Research and Education Network (HPWREN). A collocated SIO MEMS accelerometer mounted on the monument's vertical leg is used for earthquake early warning research. The SIO MEMS meteorological sensors can track extreme weather events such as summer monsoons and atmospheric rivers. Photo credit – D. Glen Offield.

[1] *In conformance with the emerging international convention, the term cGNSS is used in this document to connotate all continuous tracking position and timing satellite receiver installations whether single or multi constellation (GPS, GLONASS, Galileo, etc.) and inclusive of NOAA's Continuously Operating Reference Stations (CORS), cGPS, and other similar acronyms.*

Education, outreach, diversity, and advocacy are the means to reach these goals and innovate for the dynamic changes in the geospatially-reliant 21st century. As a Support Group of the Regents of the University of California (*supportgroups.ucsd.edu*) and our affiliation with UCSD's Scripps Institution of Oceanography we are committed to the university's dedication to diversity: "Diversity is a defining feature of the State of California and is a source of innovative ideas, creative accomplishments, and a variety of values and worldviews that arise from differences of culture and life experiences. The University of California strives to reflect this diversity in its students, faculty and staff. Achieving such diversity is a high institutional priority, and is integral to UC San Diego's achievement of academic excellence" (*https://academicaffairs.ucsd.edu/about/diversity.html*).

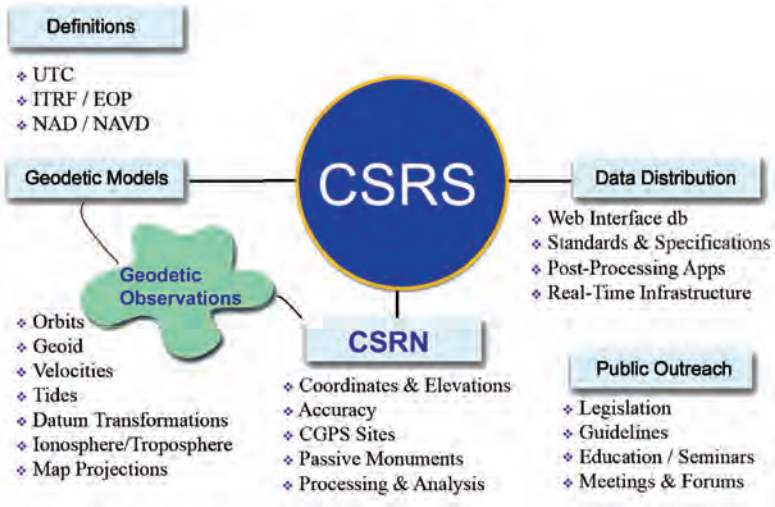


Figure 3. Elements of the California Spatial Reference System (CSRS) maintained by the CSRC. Source: Greg Helmer

To remain operational, the CSRC must generate continuous, long-term, independent sources of funding. Without permanent financing, we have depended on contracts, grants and private donations through our relationships with the university and federal, state, and local partners. This document presents well-defined priorities and specific CSRC offerings within a three-tier structure of continued support, modernization, and expansion.

RELATIONSHIP TO NATIONAL SPATIAL REFERENCE FRAME

The California GIS (Geographic Information System) Council on December 14, 2017, in regards to a state-wide reference system, declared that: *"Failure to maintain the system will compromise the state's ability to support high-precision calculations of locations used across a wide variety of technologies and standards..."* [From letter preceding "Maintaining California's Geodetic Control System Strategic Assessment Version 1.0."]. The CSRC fulfills this role through the CSRS (Figure 3). For more than two decades, the CSRC has been a proven expert, partner, collaborator, and trusted support organization to the California geospatial community by serving a wide range of public and private entities. Figure 4 illustrates the value of CRTN to the private sector in terms of cost savings. The CSRC is poised to meet the spatial referencing challenges of an increasingly location-oriented society.

The CSRC's long-standing partnership with the NGS, the agency responsible for providing geodetic control for the Nation, further demonstrates our societal benefit. In addition to NGS, the CSRC has the authority to establish and publish California's official geodetic coordinates according to the state's **Public Resources Code (PRC)** §§8850-8902. The CSRN has many more stations (and coordinates) than the NGS CORS network in California, thereby providing added value to our users. Our commitment is to continue to ensure the CSRS is aligned with the NSRS in support of NOAA's and NGS' missions, facilitated through our relationship with Caltrans.

Looking to the future, the NGS "Blueprint for 2022, Part 3: Working in the Modernized NSRS" describes the implementation and application of geodetic networks. The Blueprint states that "NGS is committed to providing an **Intra-Frame Velocity Model (IFVM)...** The exact nature of the IFVM is under development, but its use within a modernized NSRS is already clear." The CSRC is poised to deliver an IFVM through the dynamic datum utility, **SOPAC Coordinate Interpolator**

Prompt (SCIP). Tied to the CSRS, SCIP corrects for the crustal motions that complicate positioning and precise spatial referencing. SCIP is an excellent example of how modern advances in research and science partnerships are a benefit that can translate into a reliable production service for the public.

ACCOMPLISHMENTS

We have delivered on the goals listed in our 2002 Master Plan (*http://sopac-csrc.ucsd.edu/wp-content/uploads/2017/09/csrcMasterPlan.pdf*). We highlight here some significant achievements (see Glossary and References for corresponding links and publications).

1. **Transition from passive-monument to cGNSS-based datums for California.** A series of Height Modernization projects (primarily funded by NGS) linked monument coordinates to the CSRS/NSRS.

2. **Publication of several Epoch-date datums to define and maintain the CSRS.** These and future datums take into account California's physical movements due to, for example, plate tectonics, significant earthquakes, and subsidence.

3. **Publication of the most recent, 2017.5 Epoch-date adjustment based on 830 cGNSS stations,** including geodetic NAD83 (2011) coordinates and orthometric heights with respect to the NGS-published geoid model, GEOID18 (funded by Caltrans).

4. **Publication of special Epoch 2019.55** for the more than 100 stations displaced by the July 2019 Ridgecrest, California earthquakes (Figure 5).

5. **Publication in 2018 of a conceptual plan "Investigations into a Dynamic Datum for California"** to replace the Epoch-date datum approach and to allow a seamless and continuous tie to the upcoming National Terrestrial Reference Frame (NTRF) (funded by Caltrans).

6. **Delivery of a 2019 report to NGS, "Scoping Study for Intra-Frame Velocity Model for the United States"** on the applicability of the dynamic datum concept to an NSRS Intra-Frame Velocity Model for the western United States, Alaska, and the Caribbean (funded by NGS).

Figure 4. CRTN contributes to cost savings for the public and private sectors. "One such example that was a benefit to a particular client, and their constituents, was a project for the Metropolitan Water District, their Structure Positioning Program throughout Los Angeles and Orange Counties, as well as touching into San Bernardino, Riverside, and San Diego. This project utilized the CRTN throughout this area to accurately position, to the centimeter level, 4,912 structures throughout the region. A project of this magnitude would have been exponentially more costly without the CRTN infrastructure being in place and readily available. MWD would have either done without, or would have had to pass that cost on to their subscribers, which would have translated into higher residential water rates throughout the region This is just one such example, but as stated, we, and I believe the overall surveying community as a whole, put the CSRC resources to use on a daily basis, to the benefit of our clients, both public and private." Alan Frank, Johnson-Frank & Assoc., Inc., June 25, 2021

7. Ongoing development of a **web-based dynamic datum interface (SCIP) to provide the transformation of coordinates between epochs and multiple reference frames** for any location in the state (funded by Caltrans).

8. Publication and maintenance of a **modern web interface** to access cGNSS data, metadata, and guidance in using CSRS and CRTN, among other tools we offer.

9. Delivery of **real-time cGNSS data streams embedded with Epoch-date coordinates**. The CRTN supports precise positioning applications for static and moving platforms (funded by CRTN Consortium and users).

We in Caltrans Surveys are excited about SCIP. The possibilities of SCIP are not limited to the concept of point movement through time. SCIP opens the door to the consideration of "area" movement through time. The future development of SCIP may allow for the input of large integrated data sets (for example mobile scan data of road surfaces). SCIP could be utilized to manipulate these large data sets over time. For the surveying world, the implications are at least fourfold.

1. **Engineering design field data can be used multiple times.**
2. **Risk assessment can be performed, on the movement of design field data to determine project life cycles.**
3. **Historical monument data movement can be predicted. This can change how surveyors "search" for monuments.**
4. **The use of SCIP will save money.**

Bryan Banister, Caltrans, District 6, July 29, 2021

GOVERNANCE

The CSRC follows the guidelines of a University of California Support Group (*https://regents.universityofcalifornia.edu/governance/policies/5203.html*). The CSRC Coordinating Council (*http://sopac-csrc.ucsd.edu/index.php/coordinating-council*) fosters cooperation and partnerships between agencies, research entities, and other organizations. The Council consists of approximately 60 members from different constituent community sectors within California. We hold a Coordinating Council meeting twice a year, alternating locations between northern and southern California.

The **CSRC Executive Committee (EC)** (*http://sopac-csrc.ucsd.edu/index.php/executive-committee/*) includes elected officials drawn from the Council's membership and university representatives and serves as a board to steer the CSRC. The Executive Manager serves as the liaison between funding agencies and the communities we support and is an EC appointee. The EC hosts the NGS Regional Geodetic Advisor and California Geodetic Coordinator as non-voting members.

The EC furthers outreach, educational goals, and fundraising for us. The EC is authorized to conduct the Council's operations, approve expense disbursements, plan programs, and set fees for programs as applicable. It maintains a roster of current Council membership, including names and contact information. The EC develops and adopts policies and procedures consistent with the Council membership's direction and the CSRC Bylaws, (*http://sopac-csrc.ucsd.edu/wp-content/uploads/2020/01/CSRC_Bylaws.pdf*) which describe the roles and responsibilities for each of its elected officers. The EC conducts its business through monthly teleconferences. Ad hoc committees are assigned specific tasks. For example, our Strategic Plan Working Group assisted in preparation of this document.

The CRTN Consortium provides overall direction for CRTN and suggests ways to improve real-time coverage and services. The members' institutions direct funding support to CSRC to operate and maintain the two CRTN servers based at SOPAC. The Consortium underwrites our policy of free access to real-time data streams – a single account is provided per user.

OUTREACH

Our first collaborative effort began in the 1990s when we assisted the academic community in creating the Southern California Integrated GPS Network (SCIGN) (*http://scecinfo.usc.edu/instanet/01news/spot010828.html*) and its **Permanent GPS Geodetic Array (PGGA)** predecessor. The original collaborations and partnerships continue today and are described in Appendix A.1, CSRC History.

We perform outreach through personal communications, workshops, biannual meetings rotating between northern and southern California venues, virtual meetings, workgroups, guest lectures, user forums, and through the products and services available on our website. One such outreach effort is exemplified by our collaboration with the **California Land Surveyors Association (CLSA)** (*http://sopac-csrc.ucsd.edu/wp-content/uploads/2018/06/CLSA_CSRC_GNSS_Standards_and_Specifications_v1.1.pdf*) to modernize GNSS standards and specifications. Another is consideration of 2022 State Plane Coordinate Systems and Proposed LA & SF Bay Area Low Distortion Projections, by EC member John Tosto, Los Angeles Department of Water and Power, who has taken the lead for California with the support of Dana Caccamise, NGS Pacific Southwest Regional Advisor (CA, NV) and EC member, with the goal to create low-distortion projections for mapping.

Additional outreach opportunities involve hosting student interns and graduate students and providing educational opportunities to both public agencies and private enterprises. We also take pride in awarding and recognizing individuals who have been instrumental in advancing our goals.

The CRTN Consortium fosters cooperation and partnerships within the affiliated agencies. We add value to the rebroadcast data streams by embedding the latest CSRS Epoch-date coordinates (currently 2017.5). The CRTN's nearly 2000 registered user base consists of federal, state, county, local agencies, private companies, and non-profit organizations.

The CSRC's outreach capabilities are enhanced by its association with Scripps Institution of Oceanography and UCSD. SIO is recognized as one of the most reputable institutions for global earth science, oceanographic research, and education since 1903. The SIO Director's Office has helped strengthen collaborations and bridge new industry and legislative connections.

SIO's **Institute of Geophysics and Planetary Physics (IGPP)** houses the CSRC and supports outreach efforts. Facilities provided for us include staff offices, laboratories, and space for collaborative events such as the Coordinating Council meetings. Computer network support and infrastructure are also provided, as well as business and financial services, and offices for procurement and contracting, human resource services, and government relations.

The CSRC's operations are the responsibility of SOPAC. We are privileged to work with the SOPAC team members who provide valuable scientific and research expertise and service to the national and international community since 1991, including the **International GNSS Service (IGS)**. The CSRC's outreach efforts have benefitted from SOPAC's assistance in the coordination of scientific projects and community education and outreach and access to extensive GNSS infrastructure, including real-time cGNSS stations, Oracle database management system, GPS/GNSS software and hardware, communications equipment, archive of data and data products and web-based applications. Each month, approximately 10,000 distinct users access SOPAC web services, and 4,000-plus separate users download data from the SOPAC archive, with an approximate 23.5 million data products and files transferred monthly. The synergy and overlap between SOPAC and CSRC are exemplified by their common web interface (*http://sopac-csrc.ucsd.edu*).

THE NEXT DECADE: INNOVATION AND IMPROVEMENT

The CSRC plays a vital role in delivering and maintaining a spatial reference system for California and in supporting the geospatial and geophysical research communities. Education, outreach, the SOPAC geodetic database and website, the **Scripps Epoch Coordinate Tool and Online Resource (SECTOR)**, and CRTN contribute to science and industry. We continue to innovate the sciences of geodesy and geophysics. We are currently developing and implementing the **SOPAC Coordinate Interpolator Prompt (SCIP)** utility to access a state-of-the-art dynamic datum Model. These ongoing contributions have proven their value during our more than two-decade history.

Looking to the future, we must reflect upon our proven successful programs and evaluate how we can improve and innovate within advancing technologies to enable us to best serve an ever-growing number of geospatial users. Our commitment to provide value and enhance the recognition of that value can be stated as follows:

SUPPORT those programs our users have come to rely upon, and focus on ways we can both advance and highlight them;

MODERNIZE by investing in emerging technologies so as to grow our spatial referencing expertise in science and industry;

EXPAND by delivering enhanced geospatial information and knowledge to help solve pressing societal issues.

SUPPORT

Perhaps the most significant challenge to maintaining a modernized spatial reference system lies in our ability to span across the vast intra-plate velocity zone between the North American and Pacific plates and tie this region into the NSRS and the global reference frame. Large areas of subsidence and rebound also pose a challenge to infrastructure.

Over the last two decades, we at the CSRC have demonstrated the ability to offer practical solutions to pressing geospatial challenges in this shifting landscape as technology has evolved in computing, instrumentation, communications and infrastructure. An example is the publication of Epoch-date coordinates for the evolving CSRN and the transmission of this information through CRTN and user applications. We continue to serve as a legislative authority and contribute essential guidance to traditional geodetic control users and need to maintain this role. Testimonials lauding the value of our services to the surveying and broader geospatial community are provided throughout this document and in Appendix A.2.

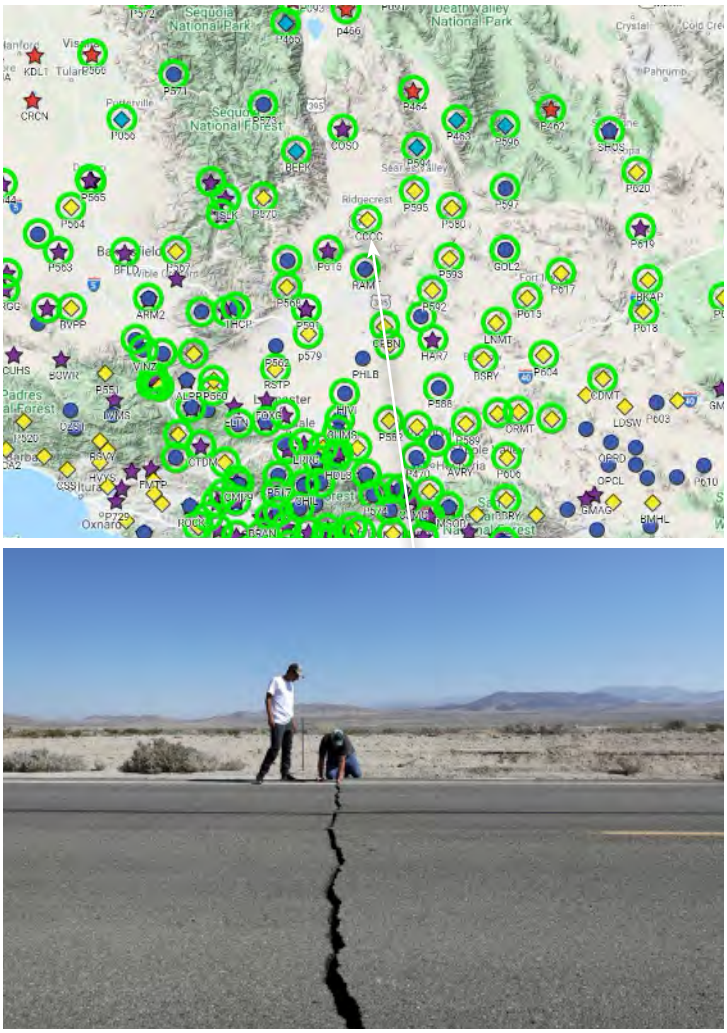


Figure 5. The CSRC published a special Epoch date after the July, 2019 Ridgecrest earthquakes (magnitudes 6.4 and 7.1), the largest event to strike California in two decades. One month after the event, the CSRC published coordinates at Epoch 2019.55 for the more than 100 stations (green circles) that suffered significant permanent displacements. Photo of surface rupture courtesy Greg Helmer.

Through our university connections, we have been able to innovate in the geodetic and geophysical sciences and transition this knowledge to support the CSRC. Recently, SOPAC performed a study and published our findings on transient deformation in California and neighboring states (Klein et al., 2019). Consequently, Caltrans contracted with the CSRC to develop a dynamic datum to replace the Epoch-date approach. Our efforts will have greater importance as we approach the anticipated release of the modernized NSRS of horizontal and vertical datums (*https://www.ngs.noaa.gov/datums/newdatums/delayed-release.shtml*). The NSRS requires an Intra-frame Velocity Model for the North American, Pacific, and Caribbean plates to account for significant crustal motions such as those experienced in the Western U.S. The CSRC is poised to deliver such a model through the dynamic datum utility and has provided a report to NGS to this effect.

However, we must find the resources to maintain current CSRS Epoch dates, to continue this service, and to transition to the dynamic datum; there are no other viable alternatives. The CSRC is uniquely positioned to fulfill these roles. We must now direct our efforts to maximize the value of our expertise and authority through continued collaboration with science, government, academia, and industry, while developing informative solutions for our different constituent groups.

The CRTN is mature and has a significant user base. Today, users see the CRTN as a vital CSRS component due to its proven dependability and value. But, the CRTN program lacks financial self-sufficiency. We must maintain and improve our ability to distribute real-time GNSS base station data to users and corrections for transforming coordinates between arbitrary locations and points in time.

Dependable geodetic control is also necessary for a wide range of coordinated emergency response programs. At the CSRC, we must continue to meet this critical need to rebuild the geodetic infrastructure following catastrophic events, and provide for the rapid acquisition of required emergency response resources. To ensure this level of readiness occurs, engagement with state partners and educators and other outreach and advocacy efforts must happen.

The California Spatial Reference Center (CSRC) has been an integral piece to the production of nearly all infrastructure produced by the Riverside County Flood Control and Water Conservation District since its dedication in 2001. **The District has completed roughly 875 separate capital improvement projects during that time frame, with an estimated asset value of over $485 million. This does not include thousands of other mapping products produced by the District over the last 20 years which were derived using CSRC curated datums. These other data products were in turn used to support work such as landfill monitoring, flood basin and channel maintenance, floodplain mapping and right of way engineering. Jim McNeill, Chief of Surveying and Mapping Division, June 7, 2021**

In the section on Budget and Financial Strategy, we provide the costs of continuing to operate the CSRC in support of our constituents at the current level of effort and estimate what is required for modernization and expansion.

Current support areas include:

- Education and outreach (seminars, presentations, webinars, social media);
- Coordination of Coordinating Council activities (semiannual meetings);
- CRTN stakeholder engagement (e.g., state agencies, counties, utility districts, private sector, academia);
- Geodetic and geophysical science efforts, including earthquake monitoring;
- Publication and maintenance of CSRS Epoch-Date coordinates tied to the NSRS;
- Intra-plate velocity zone contributions, with respect to the North America plate;
- Consultation relating to California Public Resources Code.

MODERNIZE

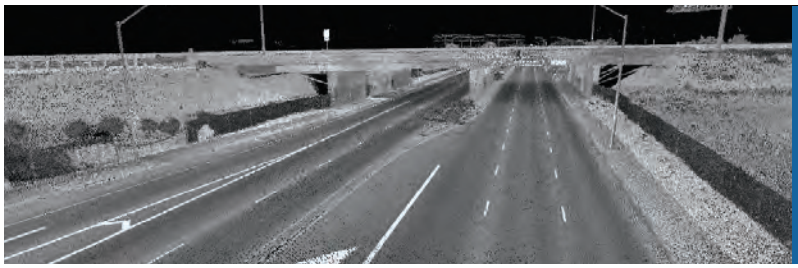


Figure 6. Reality capture of California's highway infrastructure with Lidar and GNSS. The CSRS/CRTN provides a precise and consistent dynamic reference frame for construction, autonomous navigation and geospatial mapping.

The CSRC in its role in defining and maintaining the CSRS is uniquely positioned to maintain a common reference frame for Reality Capture and Digital Twin models, which are catchphrases in today's commercial geospatial services (Figure 6). These concepts prioritize the digitizing of all positioning and remote sensing technologies for existing conditions into three-dimensional, high-resolution models. Data capture and data models can be cataloged in timetagged versioning for asset management and forecasts. We can do this by leveraging the CSRS to incorporate these dynamic conditions. Natural resources, infrastructure, and deformation monitoring, for example, require precise real-time geospatial knowledge. Continuously-operating sensors, such as the cGNSS networks underlie the CSRN, add datum consistency (space) and the fourth dimension (time), to Reality Capture and Digital Twin models. An example currently funded by the U.S. Corps of Engineers is a collaboration of UCSD's Jacobs School of Engineering and SIO and SOPAC to develop digital twins for structural monitoring. The project uses a combination of GNSS, seismic instruments, UAVs and lidar imaging systems.

Reality Capture sensor networks initially must process positioning within the global International Terrestrial Reference Frame (ITRF)—the frame used by GNSS providers— before transforming to target regional control systems. Regional control systems may include national datums or local mapping efforts, such as California's State Plane Coordinate System. At the CSRC, we possess the expertise and data to enable technology transfer and assist developers and users with global-to-local transformations.

In today's digital society, education and outreach are increasingly broadcast and consumed over social media feeds. The CSRC, too, must adopt modernized practices for our education and outreach. Training programs for the SOPAC archive and user applications, the SCIP dynamic datum application, and the connection and use of CRTN on a CSRC YouTube channel would be valuable resources to offer existing and potential user communities. Regular updates posted to media developed for us on Twitter, LinkedIn, and other online venues would educate and attract today's digitally engaged professionals. Social media requires a commitment to provide meaningful and current content, and the CSRC must embrace that commitment.

Target Modernization Activities:

- Update the geodetic reference frame (a dynamic datum);
- Integrate InSAR and GNSS (Figure 7);
- Focus on hydrology (drought conditions) (Figure 8);
- Create strong links to the geospatial community through education. Conduct outreach to industry and technology disrupters (e.g., AutoDesk, Tesla Mapping, Augmented Reality);
- Disseminate geodetic topics via social media;
- Share expertise through capacity building;
- Update our web interface with improved ease-of-use, accessibility, content, graphics, and presentations;
- Provide education on the importance of the geodetic framework and the need to rapidly rebuild following a disaster (e.g., to federal, state, county, and city agencies; utility districts; the U.S. Department of Defense; the private sector; and academia).

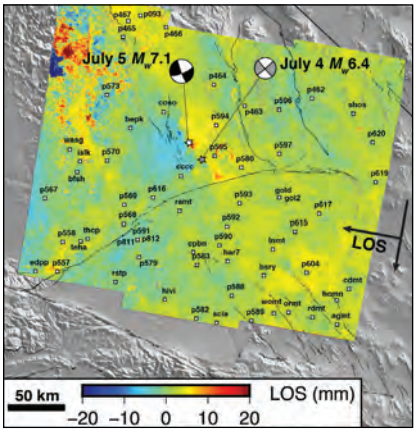


Figure 7. Cumulative 48-day Line of Sight postseismic displacements estimated pixel-by-pixel from a GNSS-corrected InSAR time series spanning the July, 2019 Ridgecrest earthquake sequence. Source: Katherine Guns

EXPAND

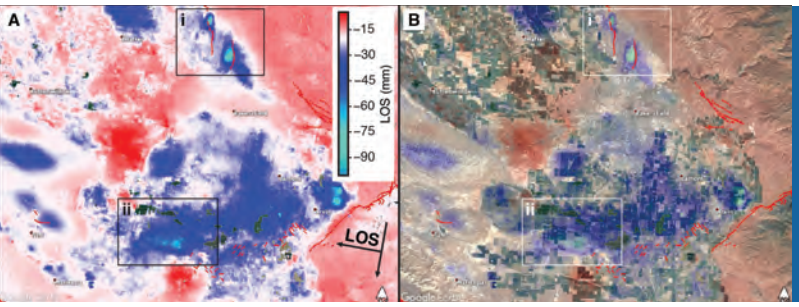


Figure 8. InSAR/GNSS-derived Line of Sight velocities showing subsidence in the southern San Joaquin Valley; (A) shows the velocity map covering the period 2014 - 2019, where the entire Valley is subsiding (note scale); (B) shows the same transparent velocity field overlying Landsat satellite imagery. Box (i) shows an area of subsidence due to oil and gas extraction processes, while box (ii) shows an area of groundwater pumping for agriculture. Source: Xiaohua Xu

The CSRC, with our geospatial expertise and intimate proximity to a world-leading marine and Earth sciences institution, will forge partnerships with ongoing sea level research. We will seek organizations outside of SIO to jointly pursue research grants. The value of California's coastal resources cannot be overstated. As it is known, sea-level rise presents a severe risk that, at a minimum, demands reasoned study for the design and protection of our valuable coastal infrastructure and our improved understanding of the earth's geophysical processes. The CSRS provides a reliable reference frame rigorously tied to the ITRF. It is only reasonable to utilize the CSRS and our rigorous geodetic foundation to unify what may otherwise be disparate studies and monitoring networks.

Our intimate relationship with UCSD and SIO/IGPP presents an opportunity for the CSRC to promote valuable outreach and professional development, and a graduate level degree program to educate future professionals in geodesy and spatial reference systems could find no better home. The CSRC, with our constituents who broadly span public and private geospatial practices, will identify prospective pools of degree candidates and curriculum topics and work with the university to promote a graduate degree program.

Current CRTN users include researchers and developers of precision navigation and autonomous vehicles. Outreach efforts to better understand the needs of these groups could guide future CRTN improvements and help us build new partnerships. Precise navigation systems for autonomous vehicle networks and other forms of transportation demand increasingly high levels of validation and risk management. The CRTN provides a consistent reference frame through the CSRS to meet increasingly stringent accuracy requirements.

It may be possible to split out specialized sets of high-end data streams from CRTN for precise navigation or value-added resale. Creating partnerships for providing data streams, dynamic datum grid parameters, or real-time meteorology for tracking extreme weather events is an option worthy of exploration.

Expansion areas:

- To facilitate modernization and with support from SIO, CSRC EC and others, pursue new funding opportunities and collaborations, for example, at Department of Water Resources, Department of Defense and the private sector.
- Lobby state, county, and federal (i.e., NOAA and Department of Defense) partners for retainer agreements to rebuild the geodetic framework following a disaster;
- Engage CRTN users and promote activities to expand membership (i.e., state agencies, counties, utility districts);
- Promote CRTN expansion to specialized high-end data streams (large engineered structures);
- Ensure 'QA/QC' of geodetic networks;
- Support precision navigation and autonomous vehicles;
- Develop a graduate program in geodesy (reference frames, measurements);
- Promote diversity and expertise of the CSRC Executive Committee, staff and within outreach to constituent communities and activities.

BUDGET AND FINANCIAL STRATEGY

We will use this Strategic Plan as a guide moving forward to ensure our goals, responsibilities, and assignments are being met and are financially secured over the next decade. The basic costs for maintaining current CSRC operations at SIO/IGPP are on the order of $1,100,000 (Appendix A.3), assuming we retain the same level of volunteerism (e.g., the Executive Manager and Executive Committee, and CRTN consultations with licensed land surveyors). However, the CSRC must secure an overall operating budget that reflects well-defined priorities and specific CSRC offerings within the three-tier structure of continued support, modernization and expansion outlined in this document. Our strategic vision for the next decade must consider new investments in resources (human, computing, space) and technology (data science, cloud computing, security, telemetry, social media, etc.). A funding level of $3.5 million per year will accommodate the goals laid out in this document. This level of funding is warranted in exchange for the unique value-added services we plan to provide.

We assimilated rapid changes in resources and technology in our first two decades while integrating relevant scientific advances. The CSRC is poised to do the same in the upcoming decade, but creating new partnerships, growing our user base, and augmenting our expertise is critical. Until now, the CSRC has benefited from SOPAC research activities that overlap in scope with our own functions; an example is the multi-purpose CRTN effort that supports academic and other CSRC constituents. Going forward, we expect that these overlapping projects will be limited and insufficient to support base-level operations. The CSRC must generate continuous, long-term, independent funding sources that clearly distinguish themselves from fundamental university academic research. Currently, we have only penned new collaborative proposals totaling about $500,000, short of our base operating budget of $1,100,000 (Appendix A.3).

The CSRC is unique in maintaining the CSRS, providing a public utility spanning federal, state, local, public, and private sectors, with the ability to operate more effectively than any other entity in the service of our stated mission. Although our current user base covers these various sectors, we must expand our pool of resources to ensure the longevity and financial health of the CSRC over the next decade and beyond. Ours is a public mission, as exemplified by our connection to the University of California, with its strong commitment to research, education, outreach, entrepreneurship, diversity, and societal relevance. Our successful management and maintenance of the CSRS and CRTN over our first two decades must now be leveraged for additional new financial resources.

We welcome comments regarding the CSRC's priorities and look forward to guidance on how to sustain the CSRC into the next decade. The future of CSRC and CSRS depends on feedback and contributions from our many stakeholders, including local and state organizations, academia, and the public and private sectors who rely on our expertise and dedication to the success of the CSRC mission.

CONCLUSIONS

Through the CSRC's maintenance of the CSRS, we have long been the recognized guardian of California's geodetic control. Our role is particularly significant in consideration of the complications arising from the active tectonic setting and large areas of subsidence found throughout the state of California.

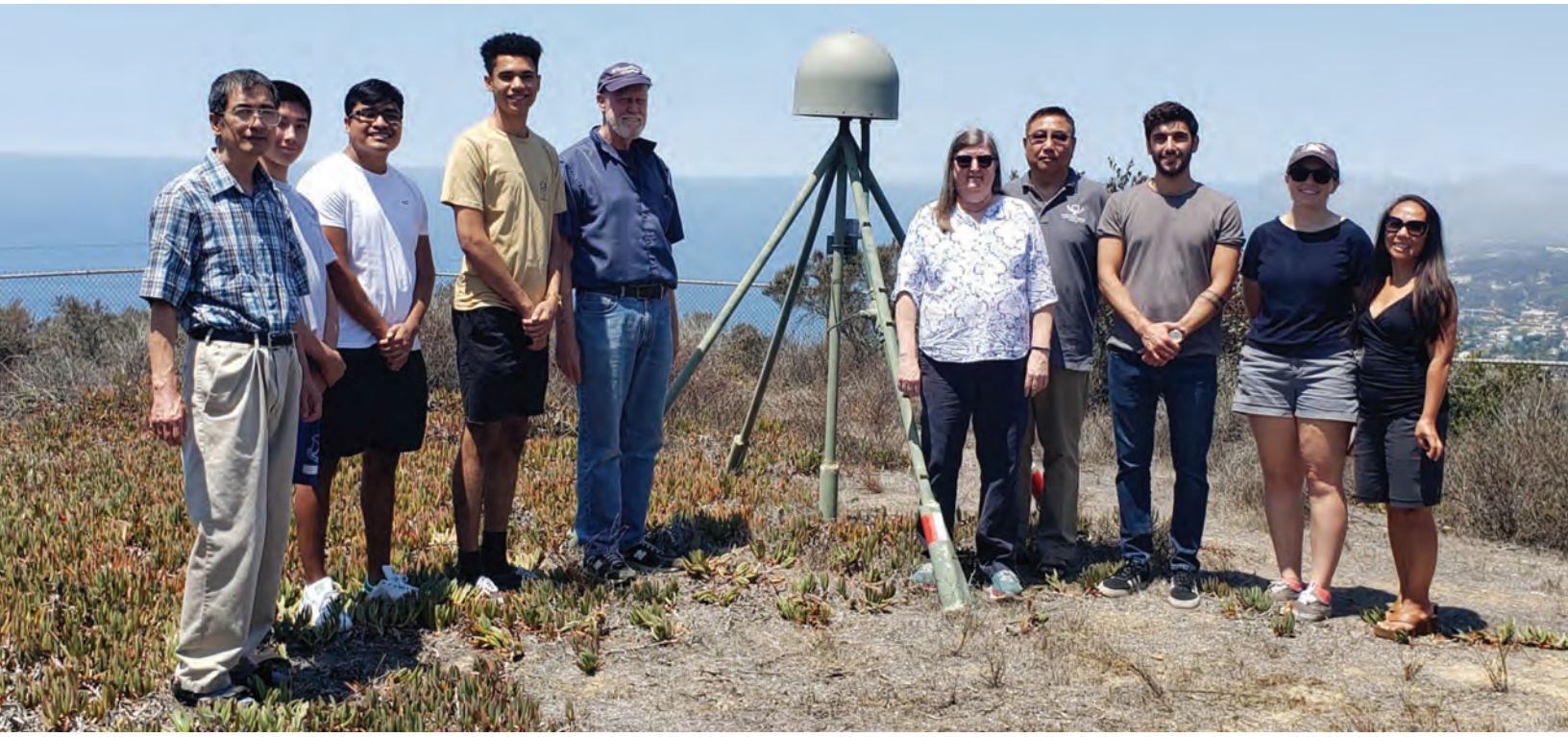
We must redouble our efforts to promote the value of our services and to bridge funding gaps. We must continue to develop value-added products through our projects and services, such as the CRTN, precise positioning standards, reference frameworks and dynamic datum development, and the validation of third-party networks. Forging partnerships with users, manufacturers, and distributors is essential to realizing our organization's full potential.

The CSRC will continue to assist and expand our outreach, research, collaborations, interactions, and presentations to our communities and constituents. The marketplace of geospatial products is rapidly changing, consequently the CSRC and California must remain at the forefront of this growth.

We will remain mindful of the interests of our UCSD academic hosts as part of their public mandate for research and education, including the promotion of a professional Master's program in Geodesy and Spatial Referencing at the Institute of Geophysics and Planetary Physics.

We are extremely proud to have the opportunity to continue our legacy of excellence over the next decade and to serve California and its communities. We are fully committed to a policy of reliable and freely available geodetic control. We look forward to continuing to serve as a public resource to benefit society with an increasing dependency on precise georeferencing.

This CSRC Strategic Plan is a living document, and it will be reviewed and updated as priorities, technologies, and associated costs change in the coming years.



GLOSSARY AND REFERENCES

CSRC – California Spatial Reference Center: *http://sopac-csrc.ucsd.edu*

CSRC Executive Committee: *http://sopac-csrc.ucsd.edu/index.php/executive-committee/*

CSRC Coordinating Council: *http://sopac-csrc.ucsd.edu/index.php/coordinating-council/*

CSRC Bylaws: *http://sopac-csrc.ucsd.edu/wp-content/uploads/2020/01/CSRC_Bylaws.pdf*

UC San Diego – University of California San Diego: *ucsd.edu*

Support Groups: *https://supportgroups.ucsd.edu*; *https://regents.universityofcalifornia.edu/governance/policies/5203.html*

Commitment to Diversity: *http://academicaffairs.ucsd.edu/about/diversity.html*

SIO – Scripps Institution of Oceanography: *http://sio.ucsd.edu*

IGPP – Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics: *https://igpp.ucsd.edu*

SOPAC – Scripps Orbit and Permanent Array Center: *http://sopac-csrc.ucsd.edu*

CSRS/CSRN – California Spatial Reference System/California Spatial Reference Network

CRTN – California Real Time Network: *http://sopac-csrc.ucsd.edu*

SECTOR – Scripps Epoch Coordinate Tool and Online Resource: *http://sopac-old.ucsd.edu/sector.shtml*

Current CSRS Epoch-date datum: *http://sopac-csrc.ucsd.edu/index.php/epoch2017*

CSRS Epoch 2019.55 after the July 2019 Ridgecrest earthquakes: *http://sopac-csrc.ucsd.edu/wp-content/uploads/2019/08/PostRidgecrestCoordinatesEpoch_2019.55.txt*

Legacy CSRS Epoch-date datums: *http://sopac-csrc.ucsd.edu/index.php/previous-datums*

Publication of "GNSS Surveying Standards and Specifications, 1.1": *http://sopac-csrc.ucsd.edu/wp-content/uploads/2018/06/CLSA_CSRC_GNSS_Standards_and_Specifications_v1.1.pdf*

CSRS Master Plan 2002: *http://sopac-csrc.ucsd.edu/wp-content/uploads/2017/09/csrcMasterPlan.pdf*

Height Modernization Projects: *http://sopac-csrc.ucsd.edu/index.php/csrc-height-modernization-projects/*

PRC – California Public Resources Code: *https://leginfo.legislature.ca.gov/faces/codesTOCSelected.xhtml?tocCode=PRC&tocTitle=+Public+Resources+Code+-+PRC*

Dynamic Datum

Klein, K., Y. Bock, X. Xu, D. Sandwell, D. Golriz, P. Fang, L. Su (2019), Transient deformation in California from two decades of GPS displacements: Implications for a three-dimensional kinematic reference frame, J. Geophys. Res., 124(11), 12189-12223. *doi.org/10.1029/2018JB017201*

"Investigations into a Dynamic Datum for California": *http://sopac-csrc.ucsd.edu/wp-content/uploads/2019/12/SIOTask4Report_final.pdf*

SCIP – SOPAC Coordinate Interpolator Prompt (SCIP)

NSRS – National Spatial Reference System

NGS – National Geodetic Survey: *https://geodesy.noaa.gov*

Modernized NSRS: *https://www.ngs.noaa.gov/datums/newdatums/delayed-release.shtml*

"Scoping Study for Intra-Frame Velocity Model for the United States": *http://sopac-csrc.ucsd.edu/wp-content/uploads/2021/08/BockSandwell_IFVM_Scoping_Study.pdf*

GNSS Networks

SCIGN – Southern California Integrated GPS Network: *http://scecinfo.usc.edu/instanet/01news/spot010828.html*

IGS – International GNSS Service: *https://igs.org*

PBO – Plate Boundary Observatory (renamed NOTA)

NOTA – Network of the Americas: *https://www.unavco.org/highlights/2019/nota.html*

BARD – Bay Area Regional Deformation Array: *http://seismo.berkeley.edu/bard/*

RTN's – Caltrans Real Time GPS Networks: *https://dot.ca.gov/caltrans-near-me/district-6/district-6-programs/d6-land-surveys/d6-rtn-gps*

General

GNSS – Global Navigation Satellite System

cGNSS – Continuous Global Navigation Satellite System (reference stations)

InSAR – Interferometric synthetic aperture radar

Lidar – light detection and ranging

UAV – Unmanned Aerial Vehicle

IFVM – Intra-Frame Velocity Model

APPENDICES

A.1 CSRC HISTORY

Prior to the formation of the CSRC in 1999, SOPAC had a long history of collaboration with the National Geodetic Survey (NGS) and survey organizations within California. The most significant example of this was the California High Precision Geodetic Network (HPGN) project in 1990/91, which was spearheaded by Caltrans, with guidance and support from NGS. NGS provided a Geodetic Advisor to Caltrans for the survey and beyond. SOPAC processed the static GPS data and submitted it to NGS for publishing. This project was the genesis of ongoing relationships with NGS, Caltrans, and some of California's counties and other agencies involved; in subsequent years, interactions with these and other agencies such as Metropolitan Water District (MWD), Riverside County Flood and Water Conservation District (RCFWCD), and the California Land Surveyors Association (CLSA) increased. Eventually a few visionaries such as Bill Young of RCFWCD, Greg Helmer with CLSA, Don D'Onofrio and Marti Ikehara for NGS, Larry Fenske of Caltrans and Michael Duffy and Cecilia Whitaker of MWD, along with the SOPAC Director, acted to formalize the relationship with geodetic and geophysical researchers studying crustal deformation and associated seismic hazards, and form the CSRC to fulfill common geodetic needs in California.

The unique challenges encountered during the early projects, and indeed one of the primary motivations for the CSRC, was the location of California in a plate boundary zone of active tectonic deformation and large earthquakes with volcanic deformation and land subsidence. The main challenge for us and our constituents was to maintain up-to-date control values by monitoring temporal changes in geodetic positions (coordinates).

The dynamic nature of California's tectonic setting led to the CSRC's primary roles in establishing and maintaining Epoch-date coordinates and velocities (datums) for the cGNSS stations within the CSRS, tied to the **National Spatial Reference System (NSRS)** defined by NGS. The early datums were tied to passive geodetic monuments published as the **"High Precision Geodetic Network (HPGN)."** The first Epoch date replacing HPGN 1998.00 was published by the CSRC as 2000.35 and was necessitated by the 1999 M7.1 Hector Mine earthquake. That earthquake displaced nearly all the monuments and the few cGNSS stations in southern California. Epoch-dates 2004.00, 2007.00, 2009.00, 2011.00 (*sopac-csrc.ucsd.edu/index.php/previous-datums*) were solely based on cGNSS stations. Epoch 2017.50 is the latest realization of the CSRS (*sopac-csrc.ucsd.edu/index.php/epoch2017*).

The CSRC facilitated public support for developing cGNSS networks in California, beginning with the 250-stations **Southern California Integrated GPS Network (SCIGN)** in the late 1990s to early 2000s. The tragic loss of life and severe damage to infrastructure due to the 1994 magnitude 6.7 Northridge earthquake motivated action and support for the networks. The development of cGNSS networks in the state was heavily weighted to southern California until the late 2000s, with the exception of the UC Berkeley's 30-station **Bay Area Regional Deformation Array (BARD)**. Full statewide coverage was achieved with UNAVCO's **Plate Boundary Observatory (PBO)**, renamed the **Network of the Americas (NOTA)**, and with other networks established by Orange and San Diego Counties, the **Metropolitan Water District (MWD)**, and Caltrans in the Central Valley.

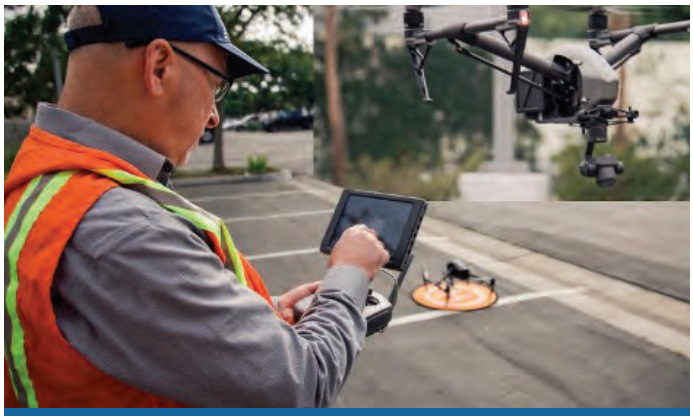


Figure 9. UAV Survey. Photo Credit: Greg Helmer

In the early 2000s, SOPAC began to upgrade SCIGN stations to real-time high-rate operations to support earthquake and tsunami early warning systems research and through the CSRC to support real-time kinematic (RTK) surveying and navigation. This upgrade effort morphed into CSRC's CRTN (*sopac-csrc.ucsd.edu/index.php/crtn*). CRTN transcended its research roots and is now an integral part of California's geospatial infrastructure.

A.2 TESTIMONIALS

Los Angeles County Public Works. ***Our field surveyors have recently successfully started using CRTN in their GNSS surveys. Further, we have moved to using to Epoch 2017.50 (NAD83) in lieu of Epoch 2007 (NAD83) for our GNSS surveys…***

The current procedures include use of a receiver in conjunction with the CRTN (in lieu of 3 receivers) and 5-minute measurements are taken 3 times at different times of the day. The cost savings is quantified in using 2 fewer GNSS receivers and spending a third of the time occupying points. Steve M. Hennessee, Principal Engineer, October 15, 2020

California Land Surveying Organization (CLSA). **CLSA acting through the Advanced Technologies Committee, seeded the California Geodetic Control Committee in the early 1990s, which evolved into the present CSRC organization. With the rapidly changing technologies, CLSA 's members foresaw the need and benefits for supporting such an organization that could develop geodetic standards, tools, and the science to take California into the 21st Century. CLSA is invested in the continuing partnership with CSRC promoting land surveying as an essential profession based in the law, science, and technology critical to protecting private and public interests in California, which directly benefits its membership. CSRC is critical to the future of geodetic surveying and maintaining the positional integrity and alignment of California's geodetic infrastructure with the National Spatial Reference System. Working together, CLSA and CSRC can ensure orderly development and land use for housing, commercial, industrial and infrastructure projects in California. CLSA was there in the beginning, is here now and will be in the future for CSRC. Michael McGee for CLSA, August 13, 2021.**

Orange County Public Works. **Kevin Hills, County Surveyor, Deputy Director, June 11, 2021**

- **We save time by not having to set up a base station**
- **Less potential of equipment being stolen (Cost savings-$30K per Receiver)**
- **Eliminates needing a third person to monitor the base station (Cost savings- $879/day)**
- **We hold the CGPS stations on our maps as our Basis of Bearings Projects are time stamped with an Epoch that we can always refer back to**
- **Base stations are dependent on radio signal and limit the distance that you can travel. This would require more setups. (Cost Savings- Two-person crew-30 minutes per setup- 3 setups a day= $375/day)**

McGee Surveying Consultants, **In 2011, a QAQC Survey of 927 miles of California coastline (Mexico to Oregon) was undertaken to establish 275 ground truthing check points every 3 miles including 34 benchmarks and 71 CGPS Stations to validate lidar and orthophotography for a NOAA Sea-Level Rise Study. The CSRC California Spatial Reference Network of 71 continuous GPS stations along the coast alleviated the need to establish a primary control network leading to very substantial cost saving, reduction in delivery time and validating that the survey met the required accuracies. August 13, 2021**

Johnson-Frank & Assoc., Inc. I wanted to write you a quick note to stress the value and necessity of the CSRC not only to the Surveying community, but to the state and region as a whole. The CSRC has stepped in to fill the hole where the NGS no longer has the resources to support the geodetic needs of the State. We at Johnson-Frank, and the surveying community as a whole, use products from the CSRC on a daily basis. These services range from positional values on California Public Resources Code sanctioned passive and active (CGPS) control, to additional GNSS hubs for various projects through use of CGPS sites, to use of the California Real Time Network (CRTN). One such example that was a benefit to a particular client, and their constituents, was a project for the Metropolitan Water District, their Structure Positioning Program throughout Los Angeles and Orange Counties, as well as touching into San Bernardino, Riverside, and San Diego. This project utilized the CRTN throughout this area to accurately position, to the centimeter level, 4,912 structures throughout the region. A project of this magnitude would have been exponentially more costly without the CRTN infrastructure being in place and readily available. MWD would have either done without, or would have had to pass that cost on to their subscribers, which would have translated into higher residential water rates throughout the region. This is just one such example, but as stated, we, and I believe the overall surveying community as a whole, put the CSRC resources to use on a daily basis, to the benefit of our clients, both public and private. Alan Frank, Johnson-Frank & Assoc., Inc., June 25, 2021

On behalf of Towill Inc. [and] as an ambassador-at-large for the broader community of Geomatics Engineering stakeholders in California.

CSRC product and service benefits include time and cost savings to our customers in the $100Ks and consistent traceability by other surveyors or contractors…This level of value reasonably extends to our other three branches in CA. Our Colorado Springs office also uses SOPAC and CSRC resources and information for large-scale LiDAR and mapping project support.

In addition, the U.S. Bureau of Economic Analysis (BEA) confirms California's gross domestic product (GDP) as the top-ranked state and fifth in the World! By contrast, the 2021 American Society of Civil Engineers (ASCE) report card assigns California a grade point average (GPA) of C-, equal to the Nation's average for seventeen individual (system of systems) infrastructure categories. Overall, the grades vary from C+ to D-. Sadly, for example, based on ASCE's metrics, *USNews.com* ranks California's Transportation Infrastructure at 45th out of the 50 States evaluated. In addition to post-COVID stimulus imperatives, such statistics are clearly behind current Federal-level nationwide infrastructure plans and are a significant force driving the initiatives of California's 2021/2022 5-Year Infrastructure Plan. The CA Geomatics Engineering community will play a substantial role in infrastructure systems with geospatial components. The CSRC will need to maintain and extend its products, services, and knowledge transfer in these areas, filling an important, perhaps critical, support function.

Towill being a full-service surveying, mapping, and GIS company, works on a wide range of public infrastructure projects. We draw heavily on the CSRC's products and services and will continue to do so in the future. Public infrastructure includes wastewater, freshwater, transit tunnels, pipelines, wide-area land subsidence monitoring, light and heavy rail, highways, energy (gas and electric), and levee rehabilitation. We are very appreciative of the CSRC as you are the anchor for most of these activities. Trevor Greening, Principal, June 28, 2021

A.3 ANNUAL CSRC OPERATING BUDGET

Salaries and Benefits Full-Time Employees (FTEs)	
Director (0.5 FTE)	
Communications and Outreach Coordinator (1.0 FTE)	
System Administrator (0.5 FTE)	
Database Manager (0.5 FTE)	
Archivist (0.5 FTE)	
Data Analyst (0.5 FTE)	
Applications Programmer (1.0 FTE)	
CRTN Administrator (0.5 FTE)	
Subtotal Salaries	**$507,000**
Subtotal Benefits	**$209,000**
Other Costs	
Software Licenses and Maintenance	$5,000
Computer/Network, Station Supplies	$5,000
Meeting Costs	$2,000
Travel	$3,000
Department Network and Computing Support	$15,000
University Communication Charges	$6,000
Subtotal Other Costs	**$36,000**
Total Direct Costs	**$752,000**
Indirect Cost (48%)	**$361,000**
Total Costs	**$1,113,000**