Institutional Affiliate of American Congress on Surveying and Mapping.

The California Surveyor

SPRING 1995 The Voice of the Land Surveyors of California NO. 108

Why is the Trimble GPS Total Station today's hottest-selling new survey instrument?

Why? Because it delivers big benefits for everyday tasks. Benefits like major increases in productivity and dramatic cost savings. Ultra-quick job mobilization and exceptional accuracy and repeatability. Hundreds of organizations worldwide are already reaping these benefits.

Now, thanks to Trimble technology, surveyors can perform their everyday work with the logistical and productivity advantages of GPS. That means you can do topographic, boundary, detail, control, and even everyday stakeout work without pointing an instrument or needing line-of-sight. And you can do it with fewer setups and greater range, in any weather. The Trimble® GPS Total Station™ provides virtually instantaneous, 3-D, centimeter-level coordinates in the field as you survey the point. There's no more waiting for GPS post-processing!

Discover what the excitement's all about. For the location of your nearest dealer and a field-to-finish demonstration, call today.

Trimble
THE GPS SOLUTION

Surveying & Mapping Products
645 North Mary Avenue
Sunnyvale, CA 94088-3642
(408) 481-8940, North & South America
+44-1256-760-150, Europe
+61-7-262-8880, Australia
+65-296-2700, Singapore

The California Surveyor

is the quarterly publication of the California Land Surveyors Association, Inc. and is published as a service to the land surveying profession of California. It is mailed to all Licensed Land Surveyors in the State of California as well as to all members of California Land Surveyors Association, Inc. *The California Surveyor* is an open forum for all surveyors, with an editorial policy predicated on the preamble to the Articles of Incorporation of the California Land Surveyors Association, Inc. and its stated aims and objectives, which read:

"Recognizing that the true merit of a profession is determined by the value of its services to society, the 'California Land Surveyors Association' does hereby dedicate itself to the promotion and protection of the profession of land surveying as a social and economic influence vital to the welfare of society, community, and state."

"The purpose of this organization is to promote the common good and welfare of its members in their activities in the profession of land surveying, to promote and maintain the highest possible standards of professional ethics and practices, to promote professional uniformity, to promote public faith and dependence in the Land Surveyors and their work."

PERSONNEL
OWNER
California Land Surveyors Association, Inc.
CENTRAL OFFICE
P.O. Box 9098, Santa Rosa, CA 95405-9990
EDITOR
Tom B. Mastin, P.L.S.
ASSISTANT EDITORS
Michael McGee, P.L.S. • Linda Richardson, P.L.S.

ADVERTISING
Commercial advertising is accepted by *The California Surveyor*. Advertising rates and information can be obtained by contacting CLSA Central Office, P.O. Box 9098, Santa Rosa, CA 95405, (707) 578-6016, Fax (707) 578-4406. Circulation: 4,800.

SUSTAINING MEMBERSHIP
Membership in the California Land Surveyors Association, Inc. as a sustaining member is open to any individual, company, or corporation who, by their interest in the land surveying profession, is desirous of supporting the purposes and objectives of this association. For information regarding sustaining membership, contact CLSA Central Office, P.O. Box 9098, Santa Rosa, CA 95405, (707) 578-6016, Fax (707) 578-4406.

EDITORIAL MATERIAL
All articles, reports, letters, and contributions are accepted and will be considered for publication regardless of the author's affiliation with the California Land Surveyors Association, Inc. Contributions submitted on floppy diskette medium is encouraged. For compatibility, disks should be 5.25 or 3.5 inch, MSDOS (IBM compatible) format. We can accept ASCII text files or word processor files from the following programs: WordPerfect, Microsoft Word.

EDITOR'S ADDRESS
Tom Mastin, P.L.S.
1303 Garden Street, 2C, San Luis Obispo, CA 93401
The California Surveyor

DEADLINE DATES

Summer.......	April 10, 1995	Winter	October 10, 1995
Fall.............	July 10, 1995	Spring.........	January 10, 1996

Articles, reports, letters, etc., received after the above mentioned date will be considered for the next edition.

Opinions expressed by the editor or individual writers are not necessarily endorsed by the California Land Surveyors Association officers or its Board of Directors. Original articles may be reprinted with due credit given to the source and written notification to the California Land Surveyors Association.

Table of Contents

FEATURES

Mapping the Faces:
The Survey of Mount Rushmore
By Denise J. Smith. 8

A Few Things You Wanted to Know about
Least Squares But Were Afraid to Ask
By Marty D. Hartwig, PLS. 16

Four-Dimensional Surveying
The California Spatial Reference System and
Deformation Surveys
By Gregory A. Helmer, PLS. 19

From the Desk of
Rear Admiral J. Austin Yeager, NOAA
Director, Coast and Geodetic Survey 23

DEPARTMENTS

CLSA Officers and Board of Directors 4
Letters to the Editor 6
CLSA Application for Membership 6
Product News 24
CLSA Publication Order Form............... 26

Index to Advertisers

Association Administrators and Consultants .. 23
Cross Land Surveying, Inc.................. 13
Desert Engineering Group, Inc............... 4
Haselbach Surveying Instruments............ 5
Industrial Pipe and Steel 23
Lewis & Lewis Enterprises 15
McGee Surveying Consulting................ 24
Nikon Surveying Instruments 17
PafMap Consulting......................... 7
StarPlus Software 10
Surveyors Service Company (SERVCO) 27
Surv-Kap.................................. 25
Trimble Navigation 2
Carl Zeiss, Inc............................ 9

On the Cover:
Mt. Rushmore by Artist J. Grover.

LETTERS TO THE EDITOR

METRICATION IN SURVEYING

The letters by metrication proponents Harold B. Davis and Phillip A. Danskin in the Fall 1994 *California Surveyor* proposing the adoption of the SI (International System of Units) for our surveys both incorrectly deride our present system as a clumsy hodgepodge of unrelated measurement units and fail to consider the complexities of implementing a change to the metric system. First of all, we have but one measurement unit in California — the foot — to which the inch, link, yard, rod, chain, furlong, mile, and acre all bear an exact mathematical relationship, and second, real property in California has longsince been surveyed, sectionalized, subdivided, mapped and conveyed by such foot-units and those maps and deeds will remain in full legal force forever, requirement for metric surveys notwithstanding. Rather than simplifying our present survey system, metrication would only necessitate cumbersome double dimensioning that would continue to frustrate surveyors beyond the next millennium.

While metrication would be just one more bureaucratic headache for the private surveyor, it would mean welcome job security and many years of unchallenging make-work for those in the public sector. California's county surveyors could, of course, simply decree that all record map data must be shown metrically — as they've already dictated a series of costly and questionable high-tech ventures into Nintendoland — but they'd be well-advised to first consider the interests and wishes of their employer... the public. Californians have always used the foot to measure everything from 2 by 4's and shirt collars to football fields and the speed of sound and it's unlikely they'd embrace a strange new measurement system simply because foreign countries have done so. I know I'd check the area for pitchforks before informing Farmer Brown that his "South Forty", patented to his Grandaddy in the Spring of 98, must now be shown as 16.1875 hectares, more or less, to earn the respect of French exchange students.

The foot and the meter have peacefully coexisted for many years, each doing what it does best. Optics, pharmaceuticals, the sciences, certain firearms, anti-aircraft guns, goods for export, etc., are sized metrically while the foot is used by the general public for everything else. I am, frankly, appalled that a statewide organization of Professional Land Surveyors would actually have a "Metrication Committee" and suggest that a conversion to the SI at this late date in California's long existence would be ill-conceived, counter-productive and a shameful disservice to our clients and the public.

William J. McGee, Irate Citizen

IF YOU BUILD IT THEY WILL USE IT

In 1992, the State of California working with the National Geodetic Survey established the state's High Precision Geodetic Network (HPGN). Subsequently, Caltrans Districts and other government agencies have or are in the process of densifying this network. Upon completion there will exist a high precision reference system of monuments spaced about every 10-20 miles along most of the state's highways providing surveyors with local, accessible monuments which will provide the most reliable basis for NAD83 state plane coordinates.

As a GPS consultant who travels the state working with surveying and engineering firms on a multitude of projects I can attest to the benefits of this system. The new HPGN provides us with an opportunity to create a new California Spatial Reference System (CSRS) especially in view of the fact that the old NGRS (network of triangulation stations) will no longer be maintained. If the HPGN is both available and accessible then surveyors will utilize it more and more, tipping the economic scales toward long range benefits to the public. I urge surveyors to be in contact with local Caltrans Districts and government agencies to encourage and assist in their densification efforts.

Geographic Information Systems are here to stay and a common datum and reliable reference system is essential to the establishment and growth of a GIS. As we enter the 21st century and the use of GPS proliferates we should capitalize on this opportunity to encourage more survey activities be connected to the HPGN.

Michael R. McGee, PLS

A THOUGHT FOR CONTINUING EDUCATION

Knowledge gives you the ability to exclude from your thinking that which is not necessary, where ignorance renders you helpless to include that which may be essential.

Michael R. McGee, PLS

FEDS GIVE NOTICE ON METRIC CONSTRUCTION

Federal construction is converting to metric and the construction industry should prepare for the change, according to the leader of the government's construction metrication program.

"On Friday, September 16, we published a Special Notice in the Commerce Business Daily to formally announce the transition," said Thomas R. Rutherford, P.E. chairman of the Construction Subcommittee of the federal Interagency Council on Metric Policy.

The federal government, far and away the largest builder in the world with $40 to $50 billion in construction annually, has made major strides toward its goal of instituting metric in the design of federally funded facilities. Agencies with active metric construction programs include the Army Corps of Engineers; the Naval Facilities Engineering Command; the Air Force; the Federal Highway Administration; the General Services Administration; the National Aeronautics and Space Administration; the Bureau of Prisons; the Public Health Service; the Smithsonian Institution; the National Institute of Standards and Technology; and the Departments of Veterans Affairs, Energy, Interior, State, and Agriculture.

State and local construction tied to federal grant programs is converting as well. By 1997, total government metric work could amount to $50 billion annually and by the year 2000 to as much as $100 billion. "Now the focus is shifting to the private sector," Rutherford noted. "Any firm wishing to participate in federally funded construction work must do so in metric. Providers of architectural and engineering services will be expected to use metric units of measure in their work. Contractors and the trades will need to understand and bid on metric contract documents as well as prepare shop drawings and perform on-site work in metric. Product manufacturers are advised to include metric units in their product literature, catalogs, and advertising and they should design new products in rounded, rational metric sizes."

Rutherford pointed out that studies of completed federal metric projects have shown conversion to be neither difficult nor costly if participants in the process are properly prepared and take a positive approach to metrication. U.S. design, construction, and product suppliers that work or produce internationally routinely use metric.

"If the U.S. construction industry gets behind metric," Rutherford continued, "it can complete the conversion process in the next five to ten years and truly join the global marketplace. And metric usage, by increasing efficiency and improving quality control, will help the industry become a tougher international competitor." ⊕

MAPPING THE FACES:
THE SURVEY OF MOUNT RUSHMORE

By Denise J. Smith

Denise J. Smith is a freelance writer/photographer based in Rapid City, South Dakota. She is a geologist by education and has several years experience in the mapping industry.

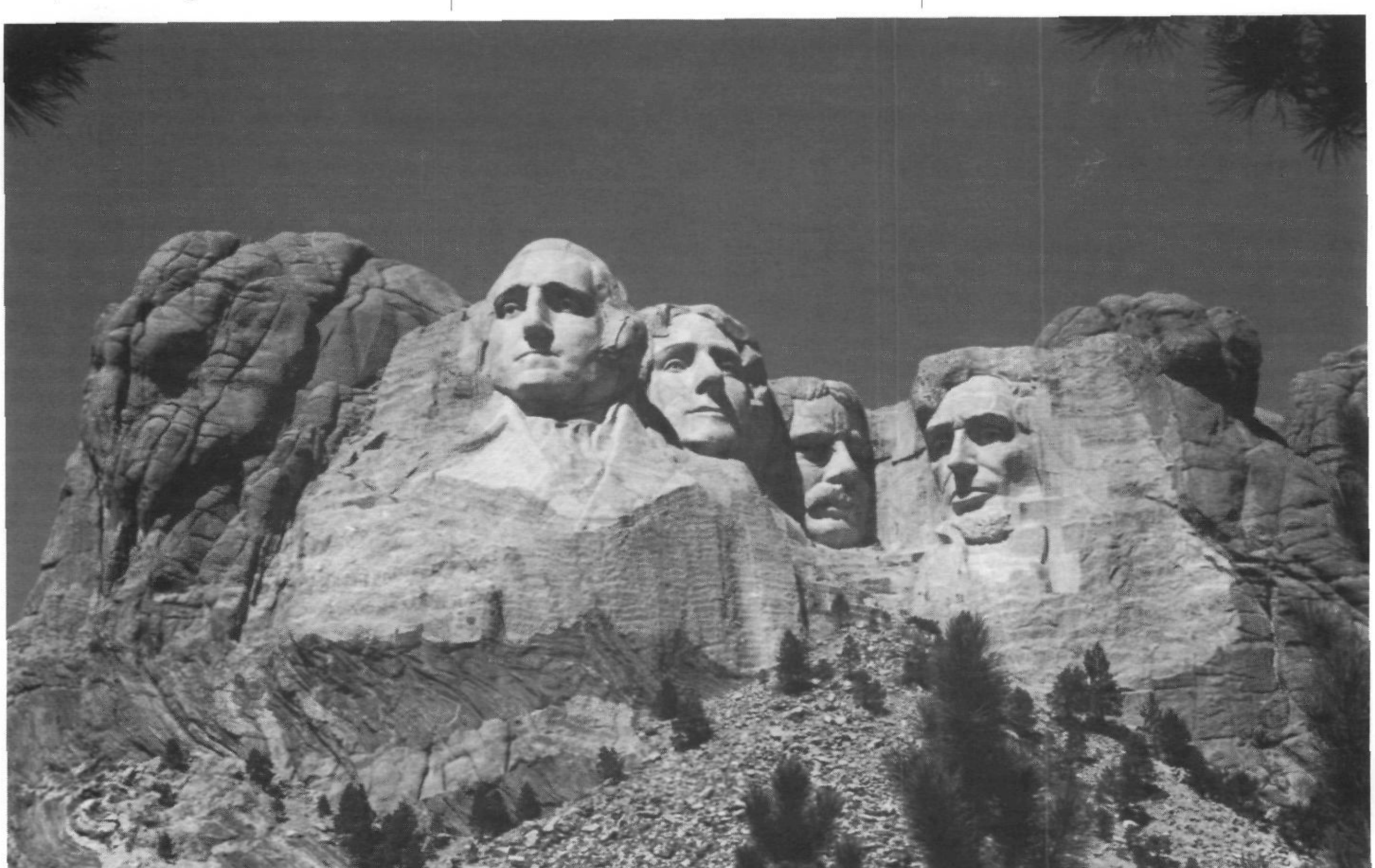
THE MEN OF MOUNT RUSHMORE, "three surveyors and one other guy," are beginning to show signs of age.

Despite their rugged exteriors, the likenesses of the four presidents, George Washington, Thomas Jefferson, Abraham Lincoln, and Theodore Roosevelt, have been ravaged by wind, rain, and temperature extremes. Lincoln, for example, has cracks spanning the bridge of his nose and Washington has a prominent crease across his forehead.

What is the life expectancy of such a monument? Some predicted it would endure a thousand years; its sculptor, Gutzon Borglum, contended that the presidential faces would last "until the wind and the rain shall wear them away." Now, as more than two million people per year view Mount Rushmore, which celebrated the 50th anniversary of the monument's completion in 1991, concern over the longevity of the memorial has been expressed by both the National Park Service and its civilian cohort, the Mount Rushmore National Memorial Society.

Just how long the sculpture will last is a question without an answer. But the question that can be asked and ultimately answered is, "What steps can be taken to protect the monument from further wear and tear?"

It was the search for this answer that brought us to where we now stood — nearly 500 feet up on top of the monu-



ment. Still breathing hard from the ascent, we stared wide-eyed and breathless at our surroundings. Paha Sapa, the Indian translation for "the hills that are black," stretched before us for miles and miles — a sea of dark pines and silvery granite pinnacles. There, off to the southwest, were the Cathedral Spires, and the city of Keystone to the northeast. On a clear day the South Dakota Badlands, 50 miles east of the Black Hills, can be seen.

Years before its completion in 1941, President Franklin D. Roosevelt nicknamed Mount Rushmore National Memorial the "Shrine of Democracy." It is perhaps the nation's best-known mega-sculpture, honoring four of our nation's presidents. The faces of these noble statesmen, carved during the Depression out of a granite mountain in the Black Hills of South Dakota, stand as a monument to America and an embodiment of its spirit and democratic ideals.

Borglum was intent on giving South Dakota a monument that would attract people from all over the world, enhance the tourist trade, and bolster economic opportunities in western South Dakota. However, South Dakotans of the era showed little gratitude for Borglum's endeavor. Early proposals had been considered little more than a "preposterous pipe dream."

Early environmentalists actively opposed the idea of a mountain carving. When the idea was first introduced in 1924, they accused its backers of promoting commercial rape of the Black Hills, as well as the ruination of the natural beauty of the Hills. "Why desecrate a noble work of nature with a puny work of man?" they asked.

The construction of the monument took place during the years between 1927 and 1941, and spawned many a controversy. From the environmentalists' desecration viewpoint to the local citizens' concerns of who would pay for it, the carving of Mount Rushmore was the topic of many lively editorials in newspapers statewide.

Structural Integrity

Now, many years later, Mount Rushmore is again in the news. This time, however, the question is not whether or not the monument should exist, but what steps can be taken to ensure its existence forever.

Today, the greatest threat to the memorial seems to be the many fissures crosscutting the mountain carving. From the beginning, Borglum recognized this problem and attempted to remove as much of the fissured rock as possible before fitting a face to a specific locale on the mountain.

The fissures form inlets in the sculpture through which water can enter, allowing the physical weathering process caused by freezing and thawing to occur. When water from rain or snowmelt enters a crack in the rock and freezes, the volume expands by nine percent, exerting a pressure of 2,000 pounds per square inch on the surrounding rock. Over time, smaller blocks are pried loose from the existing large block. Without question, the ramifications of a presidential nose or mustache slipping off the face of Mount Rushmore are cause for major concern.

Monthly measurements since 1980 of the crack on Washington's forehead indicate the potential instability of the fissure. According to National Park Service employee Bob Crisman, annual crack checks are performed. Using a chair and winch designed by Borglum, a five-day maintenance tour is executed each fall.

Borglum patched cracks on the faces and even on the mountaintop where direct contact with precipitation would be more likely (on top, runoff may actually pool over the cracks and then slowly drain into the sculpture). The sealant material is a mixture of granite dust, white lead, and linseed oil, formulated by the sculptor, and still used today by the National Park Service for maintenance on the monument.

An engineering study would enable the National Park Service to develop a comprehensive maintenance plan, as well as to identify and buttress unstable areas in advance.

Project Overview

In 1989, 48 years after the memorial was completed, Tim Vogt, a geologist with RE/SPEC, Inc., a geotechnical engineering and consulting firm based in Rapid City, South Dakota, was interested in creating a three-dimensional computer model of Mount Rushmore. He went to the National Park Service looking for survey data only to find that none existed. After talking with personnel at the monument, he discovered that there were a number of things they did not know, but wished they did, such as, "Just how stable is the monument?" RE/SPEC, Inc. responded to the concerns identified by the National Park Service and the Mount Rushmore National Memorial Society. Namely, they were seeking insight, as well as answers, concerning the longevity of the memorial. Was there more that could be done, from a maintenance standpoint, to assure the monument's well-being?

RE/SPEC, Inc presented a proposal, not to attempt to answer "How long will the memorial last?" but rather to define areas of concern based on an analysis of the geologic structure of the sculpture and surrounding mountain. Vogt, who would become the project coordinator, proposed that the mountain sculpture could be mapped photogrammetrically using both aerial and close-range photography. Then, using the digital data collected from the photography, a three-dimensional computer model could be generated. Pegmatite (large crystal) zones could be represented on the model, as well as the fissures crosscutting the sculpture. From this model, the mountain's crack systems can be studied, and specialists can determine which cracks to leave alone, which ones will need to be filled with a yet-undeveloped putty, and which ones will require fortification using steel pins.

To accomplish the proposed project, two other Rapid City firms joined with RE/SPEC, Inc. Horizons, Inc., a company specializing in aerial mapping, was brought in to provide the aerial photography and photogrammetry services. Warren Fisk, LS, PE, of Fisk Engineering, Inc. agreed to perform the ground-control survey for the aerial photography, and later the close-range photography.

JFK, Inc. of Indialantic, Florida, a company specializing in close-range photogrammetry, was responsible for the helicopter- and ground-based photography of the vertical portions of the sculpture. The close-range photography was to be used in conjunction with the aerial photography to define the spatial (three-dimensional) setting of the monument. The close-range photography provided data from the eyes, noses, and chins that was inaccessible from the aerial photography.

Field Work

The proposal for the study was accepted on October, 1989 by the National Park Service and the Mount Rushmore National Memorial Society (the society would actually fund the study). Due to a late-fall start, work was begun in earnest to complete the primary ground-control survey work, anticipating that the aerial and close-range photography could be completed before snow cover obscured features during the winter season.

Preplan

The field work would have to be completed in two phases. Phase I would entail a conventional ground-control survey for the aerial mapping operation. Once the ground-control targets were in place and located, the aerial photography could be performed.

Phase II of the operation would involve more time and effort. A total of 99 targets would have to be placed on the vertical portions of the monument on both the front and the backsides. Of these 99 targets, 53 would be precisely located by surveying methods and related to the local coordinate system, while the remaining 46 would be used as general reference points on the photographs when the actual mapping was begun.

Phase II also included acquisition of the close-range photography. JFK, Inc. had determined ahead of time the vantage points for both the helicopter- and ground-based photography. Since the study required that the mountain be mapped in as great a detail as possible to ultimately provide the most accurate model, the photographs had to be taken from many angles, both laterally and vertically, to provide enough views of the monument to accomplish such three-dimensional accuracy.

Three sets of "flight-lines" were determined for the aerial photography. For the terrestrial photography, several photographs were to be taken from a helicopter at the monument's eye level; along three lines traversing the scree slope below the monument faces, ranging from just below the chins to the lower portion of the slope; and at the backside of the monument, from the canyon floor below and the outcrop just above and west of the sculpture. (The scree slope, a steep mass of small particles, had been formed when 400,000 tons of excess rock were dynamited off the mountain during the carving process.) Some fill-in photographs from on top of the sculpture, looking down between the heads, were also to be taken.

Two important survey-planning decisions had to be made early. First, it had been hoped that this project could be tied into the State plane coordinate grid system. However, it was soon discovered that the nearest National Geodetic Survey (NGS) control point was four miles away and over difficult mountainous terrain. Budgetary constraints forced the establishment of a local ground-based grid system. Second, any hope of using Global Positioning System technology also had to be abandoned due to the cost of bringing in crews and equipment just to set a few points, in addition to scheduling considerations.

Phase I

Phase I required a conventional ground-control survey for the aerial mapping project. Fisk, however, will be the first to point out that there seemed to be nothing conventional about surveying a solid granite mountain that offered 500 feet of relief and four presidential faces. Special safety considerations would have to be given to navigating the mountainous terrain and surveying this national monument. No paint or markers that might scar the monument would be allowed.

Tuesday, October 24, 1989, was an Indian summer day, with clear blue skies and temperatures near 70°F. Our group included Jack Dozzi, vice president of Horizons, Inc. (He would have the last word on target locations); project manager Vogt; park ranger Leo Zwetzig (a 20-plus year veteran of Mount Rushmore National Memorial, he was there to make sure we did not damage his mountain in any way, shape, or form); surveyor Fisk, his crew members Ben Lamke and Randy Tuffs; and myself. I was invited to tag along as a freelancer to document the field work on film and to later write the technical report when the project was completed. Since Fisk and his crew were actually there to perform a survey, the remaining participants pitched in to help wherever they could. The survey crew's purpose was to provide the ground-control survey for aerial mapping of approximately nine acres of the Mount Rushmore National Memorial.

Due to extreme relief and heavy forest cover on all but the high rock outcrops within the target area, Horizons, Inc. had taken a reconnaissance photograph of the area to plan the target layout. From this one vertical shot, Dozzi and Fisk planned the target layout to solve the problems presented by the terrain. Both the extreme relief and heavy forest cover hampered line-of-sight to such a degree that several intermediary shots had to be taken.

A trip to the top of Mount Rushmore is by invitation only. With all the surveying equipment in tow, we reached the top in under an hour. The route took us along a valley that lay to the north side of the scree slope below the sculpture. The entrance into the canyon directly behind the sculpture is heavily fortified with chain-link and barbed-wire fencing. (The National Park Service is serious in its attempt to keep the top of Mount Rushmore secure.) We were fortunate because the park ranger had a key for the gate.

We ascended a 60° slope on a steel staircase that brought us into the canyon behind the sculpture. From here, another 50 vertical feet were gained by climbing stairs, which put us on top of the "heads."

Even though it was my second trip to the top, I found the view just as breathtaking as the first time. Being on top of Mount Rushmore was pretty heady stuff for all of us, except for Zwetzig, who could no longer remember the number of times he had been on top. It was obvious, however, that he never really tired of making the trip. Soon we were chatting quite amiably about George, Tom, Teddy, and Abe; as though we had known them for years. However, there was work to be done.

From the center of the mountain, four panel targets were placed radially at horizontal distances of approximately 500 feet. Two ground-mounted winches, formerly used for the actual carving of the mountain, had been located. These two points could be used as "picture points" in the photographic analysis. Finally, a seventh target was placed at the bottom of the small north-south canyon (30 feet wide, 100 feet long, and 50 feet deep) directly behind the sculpture. Now all that remained was to survey the seven targets, determining both horizontal and vertical positions.

Not wanting the final computer model of Mount Rushmore to take on a new shape because of an error in his surveying technique, Fisk had given serious thought to the integrity of the survey. The most reliable means of relating the seven targets would have been to include all targets in a closed traverse system. However, this area did not lend itself to that practice, because of the very irregular terrain (some of which would require professional climbing gear to negotiate) and the dense cover of ponderosa pine everywhere except on the rock outcrop. Since most of the targets would be visible from the top of the mountain, we decided to resort to radial ties, using extra caution to minimize the obvious hazards. A careful check of equipment, including a trip to the calibration base line, and a thorough review of the methodology would reduce the amount of field time measurably.

Since the entire survey crew was perched on top of the sculpture at the day's beginning, the more accessible targets from that location would be placed and located first. However, the first order of business was to establish true north. To accomplish this, a solar observation was taken from the first point. Then the target on the canyon floor was set and shot, while Lamke and Vogt went to the other side of the canyon to place the target to the northwest of the heads. The angles and distances were measured to the target, and then to the two winches. Additionally, on top of Washington's head was a raised block of granite, about six inches high, with a drill hole in the center. That point was measured and later assigned as 10,000E, 10,000N for the local coordinate system.

Lamke stayed on top with the instrument (a Lietz SDM3E total station), while Dozzi, Tuffs, Fisk, and I headed down to set the other three targets. Since line-of-sight was a deciding factor in target locations, we were in continual radio contact with Lamke, who directed the minor adjustments in target locations to allow a reading on each one. Even though all of the targets are visible from the top, none can be seen from a common point, thus requiring several control points along the top edge of the sculpture.

Lamke's special talents must be noted. With the surefootedness of a mountain goat, he moved over the steep, rocky terrain with confidence and ease, carrying his equipment with him. On more than one occasion I watched Lamke's boss hold his breath and cover his eyes. Lamke's abilities certainly helped reduce the field time.

On Wednesday, October 25, the stable weather continued, allowing Horizons, Inc. to send up a flight team to complete the aerial photography portion of Phase I. The aerial photography work was performed with a Cessna

210 aircraft and a Zeiss RMK-A 15/23 aerial camera. Two flight-lines were flown with 60-percent overlapping coverage at an altitude of 1,000 feet above mean terrain.

This concluded Phase I of the field work. While project participants will remember weather conditions as "near perfect" for the first phase, they will certainly remember the weather conditions for the second phase as "testy" at best.

Phase II

Scheduling considerations for all of the participants to be involved in Phase II pushed the start date back to Monday, November 27. However, Monday morning did not dawn bright, clear, or calm. Rather, we were greeted with howling winds, blowing snow, and a wind chill factor of -11°F. In effect, an early-winter snowstorm dashed all hopes of starting that day.

While the National Park Service assessed weather and snow conditions on top of Mount Rushmore, the weather forecast was calling for the storm to end on Monday, and a warming trend to develop toward the middle of the week. Since the National Park Service would be responsible for all activities and people on top of Mount Rushmore, they determined that Thursday, November 30, would be the first day we would be allowed to go up. All of the vertical work involved with placing the targets on the faces would be handled by National Park Service employees Crisman and Jim Chambers. This is the same team that operates the chair, cable, and winch each fall for the annual maintenance on the sculpture.

Fortunately, November 30 did dawn bright, clear, and calm. In spite of occasional high wind gusts, the day was sunny with a high temperature of 46°F. The purpose for today's work would be to place targets on the front of the faces in preparation for the helicopter-based photography mission scheduled for the following morning.

The targets designed for Phase II were 15-inch-diameter circles of an adhesive sign material called Fascal, from Avery International, painted black with a three-inch-diameter white circle in the middle. Due to the cold air temperature, and especially the cold rock temperature, Dozzi and Vogt recognized that the targets' adhesive properties might be reduced. A second adhesive material, supplied by the Panduit Corporation, and rated for applications in temperatures down to -10°F, was quickly shipped in as a backup.

The group that went up that day consisted of many of the same people involved in Phase I. New members included Fisk's son, Ron, and Dennis Laughlin and Russ Tiensvold (volunteer winch operators from RE/SPEC and Horizons, respectively). Fisk set up his instrument on the viewing terrace at the Visitor Center to shoot some of the targets placed on the faces.

Beginning on the south side of Washington, the National Park Service team rigged the bosun's chair and began the task of lowering Crisman in front of the faces to place each target. The bosun's chair was designed by Borglum for the mountain carvers to be lowered over the faces for drilling and rock removal. Each chair was suspended from a single 3/8" cable and operated by its own winch. Commands between the winch operator and the occupant of the bosun's chair were relayed by an intermediary "call boy." Shouts and whistles were resorted to when the low-frequency radios were out of range. Throughout the course of the 14 years of carving on the mountain, only a few minor injuries associated with use of the bosun's chair were reported.

With radio contact between Vogt on top and Dozzi and Fisk on the viewing terrace, the optimal location of each target was determined. Vogt then directed Crisman to the desired location. For the targets that required coordinates, Crisman carried a retroprism on a string around his neck. He held it in place over the target long enough for Fisk to gather his data. Crisman made a total of about 15 trips in the chair to set 44 targets on the faces. The volunteer winch operators certainly got their exercise for the day., but all agreed that it beat spending a day in the office.

Crisman learned early that the targets adhered better to rock that was exposed to sunlight. Also, resting his hands for several seconds over the target allowed his body heat to soften the adhesive, making it more effective.

As the angle of the sun changed and the temperature dropped, the Fascal adhesive became even less effective. At noon, Dozzi made a quick trip to town to get the Panduit material. He quickly prepared targets by cutting rectangular sheets, approximately 8" x 10", and painting the yellow material black. A 1.5-inch-diameter opening of yellow was left in the center of each target. By 2 p.m., he had the new targets on top of Mount Rushmore, ready for use. Several were used on Roosevelt and Lincoln. It became quickly apparent that the adhesive qualities of the second product were superior to those of the first.

Later in the day, while the winch and chair crew continued to lower Crisman in front of the faces, Vogt and Lamke left the top of the heads and hiked around the front of the sculpture in the area of Roosevelt's and Lincoln's chins. Scrambling over the rock, they were able to set targets from below. Knowing that darkness came at approximately 4:30 p.m., this was seen as a necessary time-saving measure.

By the time complete darkness had settled in, everyone was off the mountain, Fisk had managed to obtain readings on 25 of the facial targets — a sufficient number of points to provide a solid network of data for photogrammetric needs. Once on the ground, the group gathered one last time to formulate a work plan for the following day.

Readings of all of the critical targets were complete, but Lincoln still needed about six more targets before the photography mission could be flown. The plan was to take the helicopter up at first light (approximately 7 a.m.) to photograph Washington and Jefferson before heavy shadows obscured some of the features. In the meantime, the winch and chair crew would complete the task of placing the final targets on Lincoln. Then, the helicopter could go up again and obtain the remaining photographs, while the crew continued placing targets on the backside of the monument.

Hanging in There

By 6 a.m. on Friday, December 1, everyone had gathered in the Visitor Center parking lot. While we waited in the predawn darkness, we only half-jokingly speculated about the chances that the targets had remained on the faces through the night. The overnight low had been 36 F and the winds had been gusting at 50 miles per hour. High winds were already threatening the helicopter flight and a heavy cloud layer on the horizon made it appear that the sunrise would not provide enough light for the photography. In the early light, Vogt, using binoculars, discovered that all but three targets on the sculpture had survived the night temperatures and wind. Those three targets were not considered critical, so the plan to fly was still intact.

Helicopter services were contracted by HP Aviation Services of Greybull, Wyoming. Pilot Bob Hawkins brought over a BELL L-3 Longranger to fly the Mount Rushmore mission.

In spite of high winds and poor light, the helicopter went up with Dozzi, photographer Roger Pannabecker from JFK, Inc., and Tiensvold of Horizons, Inc., who was responsible for supplying Pannabecker with glass film plates for a Wild P-31 terrestrial camera.

Those of us remaining on the ground knew the ride had to be rough. The helicopter was buffeted by the high winds, and even more so by a wind wave created at the top of Mount Rushmore. The helicopter was only able to get within 600 feet of the monument on this pass. Pannabecker took his measurements, but upon immediate processing in the darkroom at the Visitor Center, learned that there was too much image motion — the mission would have to be flown once more. The problem of losing some detail in the shadows between Washington and Jefferson would have to be overcome with fill — in photography taken of the area from other angles.

Two operations would be executed simultaneously on December 1. The helicopter-based, close-range photography mission would be flown as soon as the few remaining targets had been placed on Lincoln. In the meantime, the National Park Service and survey crews would continue placing targets on the backside of the monument in preparation for some of the ground-based photography scheduled for the following day.

While Hawkins checked wind and weather conditions for later in the morning, the rest of the group was on top of the monument placing the remaining targets on Lincoln. The last of the targets were in place by 8 a.m. Fisk had set up the total station on the viewing terrace just long enough to double-check his work from the previous day. By 8:30 a.m. he had hiked to the top of Mount Rushmore and established the total station in the canyon behind the monument.

The crew continued placing targets on the backside of the sculpture. Due to the cold, they were still using the heavy-duty adhesive material. Many targets were placed in easily accessible locations; however, Crisman spent much of the morning in a harness, rappelling down the steep canyon wall to set the other targets.

Due to the low angle of the sun, the canyon was completely enveloped in shadows. It was cold and the wind racing through the canyon made for bracing wind chill factors. Everyone was glad when all 55 targets had been placed and 28 of them recorded by 1 p.m. To protect himself from the wind, Fisk had set up the total station inside the unfinished Hall of Records. (According to original construction plans, an opening 20 feet high, 12 feet wide, and nearly 70 feet deep was to be cut into the canyon wall, where a record of the history of our civilization would be stored. Due to the lack of funds, it was never completed.)

While the field survey was being completed, the close-range photography mission was being threatened by bad weather. When Hawkins checked with the flight service for weather conditions, he learned that the forecast called for heavy winds to remain throughout the day. Postponing the flight until the next day was becoming a possibility.

However, by 9:30 a.m., the weather was showing signs of improvement, which says something about the unpredictability of Black Hills weather. The winds had let up and the clouds had disappeared, thus allowing another opportunity for the helicopter mission. The same crew went up and made several passes in front of the monument, this time getting within 400 feet of the faces.

Once Pannabecker completed the photography work, the helicopter returned to the Visitor Center parking lot. The glass plates were quickly developed, and it became immediately evident that it truly had been a successful mission. All that remained of Phase II was to get the ground-based close-range photography from the scree slope below the faces and from the canyon behind.

On Friday afternoon, December 1, using the terrestrial camera, Pannabecker and company traversed the scree slope at two different levels below the sculpture. Every 40 feet, the tripod and camera were assembled and two exposures made. Tiensvold carried a backpack with three leather cases of glass film plates, each holding about a dozen plates. Each plate was a negative. When each exposure was complete, the camera, which weighted approximately 25 pounds, was disconnected from the tripod and slung around Pannabecker's neck. When I asked Pannabecker how he felt about scrambling over granite boulders with the equivalent of a year's salary hanging around his neck, he only grinned.

As daylight faded, this portion of the ground-based photography was completed. Plans were made to meet the following morning to obtain the remaining photography. The canyon wall directly behind the sculpture was yet to be photographed from two locations, as well as the sculpture from below the faces, just below chin level.

Final Touches

On Saturday, December 2, Pannabecker, Dozzi, Vogt, and Laughlin were hard at work photographing the backside of the sculpture when I joined them at 9 a.m. The weather was the nicest of any we had during Phase II — clear, sunny skies, calm winds, and a high of 36 F. The photography was going well, and it appeared that a short day of work would have Phase II all wrapped up.

Pannabecker's camera of choice today was the Rolleiflex 70mm metric camera. Its small size and light weight allowed for greater mobility on the steep, rocky terrain. Photographs were taken from the canyon floor of the wall behind the sculpture and then from the high outcrop above the canyon to the west.

Laughlin's role was to assist Pannabecker as he worked his way over the rock. An avid rock climber, Laughlin was right at home traversing across the rock. In reviewing the photographs taken that day, one can see that he took his job very seriously. In every photo he was right next to Pannabecker offering support or a steady hand. In several cases, Pannabecker just gave the camera to Laughlin and let him waltz right up to the edge and take the required photographs. Although it had been considered, no supporting ropes or devices were used.

The final photographs from the monument were taken from directly on top of the heads. These were fill-in photographs of the top of the sculpture oriented downward between the faces.

The work on top was complete. Since none of us were quite ready to have this fabulous experience end, we wandered around a bit longer soaking in the view and the setting. We finally headed off the top and down the stairs for the last time. The gate was locked behind us, and we stepped out onto the scree slope. The photographs from below the chins were obtained, and by early afternoon Phase II was complete.

However, while Vogt and Dozzi may have thought that Phase II was complete, the National Park Service was thinking otherwise. "What about all of those black spots still sticking to the faces?" they wondered. So Vogt, with two more volunteer winch operators from RE/SPEC, and Crisman spent Monday, December 4, on the sculpture removing all of the targets. Now, Vogt could truly say Phase II was complete. Winter could come again.

What's Next?

With the completion of Phase II, the field data acquisition is finished. Project progress is now in the capable hands of Dozzi and Horizons, Inc. All of the film has been processed and prints developed. Aerotriangulation for the aerial photography has been completed by Horizons, Inc., while JFK, Inc. is responsible for the aerotriangulation of targets on the front and backsides of the faces. A photogrammetric adjustment system (aerotriangulation) uses the close-range photography to create a network of digital data that fits the local coordinate grid system.

The next stage involves photogrammetrically mapping the topography of Mount Rushmore by digitizing points to define the sculpture's surface, as well as points to delineate cracks and other geologic features. From this, a structural model of the monument will be developed that will show the location of cracks in the rock surface and the transitions from one type of structure to another. The digital data will be gathered by placing stereo pairs of photographs into an analytical stereoplotter and referencing them to the local grid coordinate system. Each digitized point will have an X, Y, and Z coordinate that fits into the local coordinate system. The digital data will be gathered into general ASCII-format file at the stereoplotter. Later, the data will be used to generate a wireframe model for use with AutoCAD.

Horizons, Inc. is still in the digitizing process. It is estimated that more than 100,000 points will be digitized by the time this stage of the project is completed.

Vogt speculates that interpreting the data for the structural analysis of Mount Rushmore will require about six additional months. He is anxious for Horizon, Inc. to finish gathering the digital data so he can get started on determining the structural integrity of the sculpture.

Certainly, no one anticipated the flurry of media coverage produced by this project. For several days the survey crews worked amidst television cameras and reporters. Stories of what we were attempting to do traveled nationwide. As project manager, Vogt found himself being interviewed on numerous occasions.

As for the rest of us, we had known all along that the topic of our study was very special. To be part of the history and the future of Mount Rushmore is, to all of us, a privilege beyond expression.

A FEW THINGS YOU WANTED TO KNOW ABOUT LEAST SQUARES

BUT WERE AFRAID TO ASK

By Marty D. Hartwig, PLS

Introduction

THE FOLLOWING IS INTENDED as a basic introduction to a few of the fundamental concepts of least squares adjustments as they apply to survey measurements. An effort is made to minimize mathematics and define some of the most common terms. It should not be considered to be comprehensive, but rather should be treated as a starting point for exploring the complexities of the subject.

What is Least Squares

You've probably been using least squares most of your life, whether you knew it or not. A simple average problem is a "special case" of least squares. Consider the average of the following values:

	10.19
	10.24
	10.17
total:	30.60 / 3 = 10.20

The idea here is that we have more information (three values) than we really need (one value). By calculating the average, we arrive at the most likely value. But why is the average the most likely value ? Statistically speaking, the most likely value is the one that **minimizes the sum of the** squares of the residuals. The residual value is equal to the observed value minus the adjusted value. Therefore, the values as shown in Table 1 will apply:

Observations	Adj. Value	Residual	Residual ^{2}
10.19	10.20	-0.01	0.0001
10.24	10.20	0.04	0.0016
10.17	10.20	-0.03	0.0009
			0.0026

Table 1

If you substitute another value for the adjusted value (say 10.21) and compute as above, you will find that the sum of the squares of the residuals is higher (0.0029 in this case). As you can see, least squares does not necessarily have anything to do with surveying. Least squares is a statistical analysis tool that may be applied to surveying adjustments.

Now let's consider something a little more complex. In high school, I learned to solve for two unknowns with two equations, and I was pretty proud of myself. Then I learned to solve for three unknowns with three equations and I was really proud. Least squares gives us the ability to solve for the most likely solution when we have more equations (observations) than we do unknowns. If you have an equal number of equations and unknowns, you have a **unique solution**. As conscientious professionals, we all understand the need to "close" our surveys. When we close that survey, we are taking "extra" measurements that are not required to provide a solution. These extra measurements are known as redundant measurements. The number of equations minus the number of unknowns is equal to the **degrees of freedom.**

Terrestrial Survey Adjustments

Least squares adjustments of survey data have become feasible with the advent of relatively inexpensive computers. Hand calculation of a least squares adjustment is a tedious process. The following presents a few basic concepts of ground survey networks, although most of the concepts apply to other types of observations (such as GPS) as well.

There are actually different types of least squares adjustments. We will consider a least squares by variation of the coordinates adjustment, which is the most commonly used adjustment. The mathematical model for this type of adjustment is:

$$V + B(\text{delta}) = X$$

or:

residuals + observations(corrections) = coordinates

All the variables in the equation represent matrices. Let's forget about the V for the time being. The "B" is a matrix containing the observations. The "delta" is what we are solving for, which are corrections to be applied to the coordinates. The "X" represents approximate values for the coordinates. Since "B" and "X" are known values, we solve the above equation for delta using matrix algebra and apply the corrections to the initial coordinates. However, we probably are not finished yet. Due to the nature of the mathematical functions (trigonometric) involved in the mathematical model, we must use an iterative process. One iteration consists of the process described above.

If there are no blunders in the data, the corrections will get smaller with each successive iteration. When the corrections get too small to be significant, the adjustment is considered to be complete. In most software, this limit can be set by the user, since what is significant may vary depending on the type of survey involved.

If there are blunders in the data, the solution may **diverge**. That is, the corrections become larger instead of smaller. If this condition is allowed to continue unchecked, numbers will eventually become too large and a computer error will occur, causing the program to "crash". To avoid this possibility, software generally is set to perform some maximum number of iterations (usually the user can change this value). Assuming the absence of blunders in the data, the number of iterations required for convergence is usually a function of how close the initial approximations of the coordinates are to the actual value. It is important to note that the adjustment may converge even with blunders present if the blunders are small in magnitude. The mere fact that an adjustment converges does not indicate that the adjustment is valid.

So what happened to the "V" in our equation ? The "V" represents residual values. Once the network has converged, and we have "final" coordinates, we can calculate values for all observations used in the adjustment. Just as in the averaging example above, the difference between the observed value and the adjusted value is the residual, and each successive iteration attempts to minimize the sum of the squares of the residuals.

It is important to note that all the observations are considered simultaneously, not individually, in the adjustment. this is important to understand because one blunder will have an affect on the residual values of many, and potentially all of the observations in the network. It is often the case that if the network does not converge the observations with the highest residual values are a good place to start looking for blunders.

Weights

Not shown in the above equation is the ability to weight individual observations in the adjustment. Weighting allows you to control how much individual observations affect the adjustment, or how much weight they carry in the adjustment. This process allows the mixture of different types of data, or data collected using instruments of different qualities. The value used to weight the observations in an adjustment is the standard error. The standard error is anticipated precision of the instrument used to make the measurements. The weight is calculated as:

$$\text{weight} = 1/\text{standard error}^2$$

Because the weight is inversely proportional to the square of the standard error, measurements with small standard errors will be weighted higher in the adjustment, as you would expect.

Most software also computes a value that is usually known as the **standard deviation of unit weight**. Let's say you measure the distance between two points with a steel chain, and expect the standard error to be 0.01 feet. You make multiple measurements of the line, and calculate a standard error of 0.02 feet. The standard deviation of unit weight for this system would be 2.0.

If you think of the standard deviation of unit weight as a summation of the comparison of all standard errors to the associated residual value, the optimum value for the standard deviation of unit weight would be 1. Practically speaking, a value near one (between 0.8 and 1.2 is a popular range) is sufficient to ensure a valid adjustment. Note, however, that a standard deviation of unit weight that is near 1 does not ensure that the adjusted values are suitable. Because the standard deviation of unit weight is dependant on the weights used in the adjustment, it is possible to achieve a standard deviation of unit weight that is near a value of 1 even with blunders in the observations if inappropriate weights are applied. Therefore, it is imperative to look at individual residual values for all of the measurements to ensure that the adjusted coordinates will not be erroneously affected by the applied weights.

Types of Errors

Regardless of the type of adjustment used, consideration must be given to the nature of errors that should be adjusted. **Systematic** errors are errors in the measuring system itself (an uncalibrated EDM, for example) that need to be removed **prior** to any adjustment. Systematic errors can be removed because they can be modeled by some mathematical equation. **Blunders** are mistakes that also must be eliminated prior to determining final adjusted values. The only errors that should be adjusted are **random** errors such as the personal limitations of centering during instrument and target setup and pointing errors during actual observations.

Real World Applications

In a purely statistical sense, the more degrees of freedom you have the more valid your final solution will be. It makes sense that if you were to take a poll, the results will be more representative of the truth if you ask more people. Therefore, theoretically speaking, the more observations the better (leading to what associates of mine refer to in the field as the "If you can see it, shoot it" method. Practically speaking, time is money and there is never enough budget to use this method, so the goal is to provide sufficient redundancy to validate our work to the required precision.

Is a least squares adjustment better than more traditional adjustment methods (such as compass rule) for ground survey applications ? I believe that the greatest advantage of using least squares adjustments is not that the adjustment is better, but that you can do your work in a less traditional manner. Provided that a sufficient number of observations have been taken, least squares adjustments provide the ability to adjust triangulation, trilateration, resection and hybrid network adjustments in addition to traverses. If you think creatively while designing control networks for large projects, you can often achieve a stronger control net with fewer setups if you think about the capabilities of least squares rather than a traditional traverse. For example, turning angles from multiple positions to a remote object, such as a tower, can help to strengthen control networks with little additional time required since it is not necessary to set additional targets.

Consider a simple example that rarely occurs in the real world, a four point, square network with open visibility between all points. In a traditional traverse, you would occupy each of the four points, measure the length of the four sides and each of the four angles. Let's say that we are considering only the horizontal positions, that one point is fixed and that we have a known backsight azimuth. The number of unknown values is then 2 (unknowns for each point) X 3 points = 6 unknown values. We have measured four angles and four distances, so we have eight equations and a redundancy of two.

Now consider the same four points, but instead of occupying all four points we will occupy only three. We will, however, measure angles and distances at all setups to the diagonal points as well as ahead to the next point. A conservative count (assuming distances measured in one direction only) gives us twelve observations and a redundancy of six with one less point occupied. As long as the geometry is sound, you will have a better opportunity to find and isolate blunders. With enough redundant measurements, you may be able to avoid a return trip to the field when a blunder does occur.

Conclusion

The use of least squares for the adjustment of survey data is an excellent tool for surveyors to begin using in 1995. As with all tools, an effort must be made on the part of the individual to learn its proper use. Least squares is a tool that provides great advantages to surveyors. The concepts presented here apply to other types surveys as well. Although the mathematical models are different, extensive use is made of least squares in GPS processing. ⊕

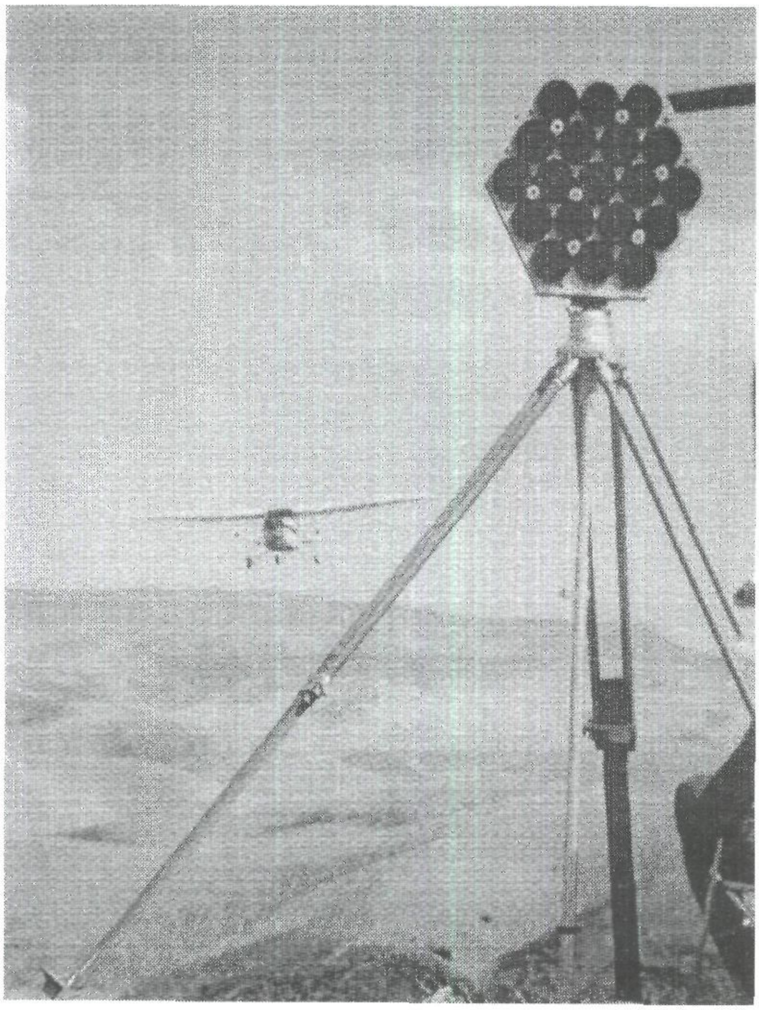
FOUR-DIMENSIONAL SURVEYING THE CALIFORNIA SPATIAL REFERENCE SYSTEM AND DEFORMATION SURVEYS

By Gregory A. Helmer, PLS

A remarkable sequence of events has transpired to place California at a unique focus of attention and opportunity relative to geodetic surveying and geophysical science. May of 1992 saw public distribution of the California HPGN coordinates. One month later the Landers and Big Bear earthquakes decimated the geodetic control system over a 5,000 square mile area. Less than two years later the Northridge Quake, in January of 1994, has again disrupted the geodetic reference system for the region. Some of the worlds foremost experts in geodesy and geophysical science, in efforts related to their particular pursuits, as well as a sincere interest to benefit surveying and geodesy, have formed an alliance to address issues of crustal motion in California. The California Spatial Reference System proposal is one result of these efforts and stands as evidence of the vision of California's Surveyors.

Introduction

EVENTS SUCH AS LANDERS and Northridge have occurred with regularity throughout the state's history. Episodic movement however, is only one portion of the domain for dynamic surveying. The frequency and magnitude of movement is of great concern to many interests groups. Oil companies need to know the level of subsidence in areas influenced by their pumping activities. Water districts have similar concern over natural and influenced subsidence which could effect hydraulic balances. Geologists are interested in the horizontal and vertical movement of slopes and other improvements relative to grading and construction. Others are interested in the subtle movement of dams, bridges and similar constructed works. The surveying required for this type of work involves some of the most exacting measurements and analysis known. For several decades, geophysicists have been collecting precise surveying measurements to analyze the movement of the earth's crust. This work, together with other scientific studies, has contributed to some well understood relationships between the tectonic plates. Detailed investigations have filled in some of the details regarding the dynamics in certain areas of interest. For obvious reasons, California has been the focus of much of this interest.



For most work, the surveying profession has been fortunate to ignore this phenomenon. Disregarding dynamics greatly simplifies positioning problems since the fourth dimension, time, is considered fixed. The increased demand and capability for precise spatially referenced data however, has presented geodynamics as a significant challenge for surveyors in California. The High Precision Geodetic Network (HPGN), the State's primary horizontal reference system, is very quickly approaching its practical life expectancy. In the nearly four years since its completion, the stations of the HPGN have experienced an average displacement of 9.5 cm (0.31 ft) relative to the North American plate (mean = 9.5 cm, sigma = 13.6 cm). Figure 1 shows a plot of the HPGN stations with their relative displacement represented (at exaggerated scale) by different symbols. While the majority of this displacement is uniform when looked at within any particular local area, relative distortions exist and are becoming more significant with time. Even excluding the Landers and Northridge earthquakes, average relative distortions between the HPGN stations at epoch 1995.0 are estimated at 0.75 ppm. This represents over half of the original error budget for the network and places the B-Order accuracy in question after 1997. Clearly provisions must be made to accommodate crustal motion in our geodetic reference system if we wish to participate in the advances in GPS and GIS technologies.

The Nature of Crustal Motions in California

Geologic and geodetic investigations have revealed a fairly clear picture of how crustal motions manifest themselves in California. The infamous San Andreas fault is the dominant geophysical feature in California and is generally recognized as the approximate boundary between the Pacific and North American tectonic plates. This boundary accommodates 48 mm per year of right lateral slip — meaning the Pacific plate moves northwest (to the right) relative to the North American plate. This continuous motion is known as secular movement and is well known and virtually invariant. The actual deformation zone between the plates is not even close to a unique boundary. The zone extends from well offshore through several significant fault systems, across the San Andreas, into Arizona and Nevada and diminishing to the east. The secular motion is distributed throughout this zone under greatly varying conditions. Recent events in Nevada and Colorado are obvious testaments to the distribution of this deformation.

In the area around San Francisco, the San Andreas accommodates approximately 19 mm per year of slip. Much of the remaining movement is accommodated by the Calaveras and Hayward faults. In the Cholame Hills and Carizzo Plain area, a long segment of the San Andreas is very nearly parallel with the direction of the Pacific plate. This segment extending from Parkfield to Carrizo experiences approximately 34 mm per year of slip. The continuum of motion experienced in this area makes it one of the most studied earthquake zones in the world. In the area around Taft and Tejon, known as the "Big Bend", the San Andreas changes direction by about 30 degrees. This creates increased friction between the blocks, diverting the accumulated strain into congigate fault systems, among these are the White Wolf and Garlock faults. Congigate faults run nearly perpendicular to the primary fault. Strike slip along these congigate faults is left lateral, reverse from the primary system due to the rotational forces imposed upon these blocks. The southern section of the state is characterized by a series of parallel fault systems. Deformation south of the Tehachapi mountains is spread across a shear zone encompassing the western two-thirds of the state. Very long baseline interferometry (VLBI) measurements reveal velocities in this area from 40 mm per year at Monument Peak in central San Diego County, to 23 mm per year at Pinyon Flats south of Palm Springs, to 6 mm per year at Black Butte north of the Salton Sea. The northwestern corner of the state experiences an entirely different deformation. The Gorda plate, immediately offshore of Washington and Oregon, is wedged between the Pacific and North American plates. The Gorda plate is being forced beneath the North American plate. This subduction is largely responsible for the volcanic activity in the Cascade range and influences deformation throughout the Pacific Northwest, including Northern California. Geodetic evidence indicates northwestern velocities of approximately 15 mm per year in Humboldt County.

Secular movement is virtually constant over any historical time period. The crustal blocks move past each other continually but friction along the fault restricts that movement. This action causes the crust to bend under the force of the accumulated strain. As strain increases, the west side of the fault bends southerly and the east side bends northerly. In theory this bending approximates a tangent function. At some point the force overcomes the friction releasing the strain in the form of an earthquake. The elasticity of the crust allows it to return to its zero-strain shape with an offset occurring along the fracture zone. Dislocation theory has been verified using historical geodetic measurements and geologic investigations along fracture zones. Precise GPS obser-

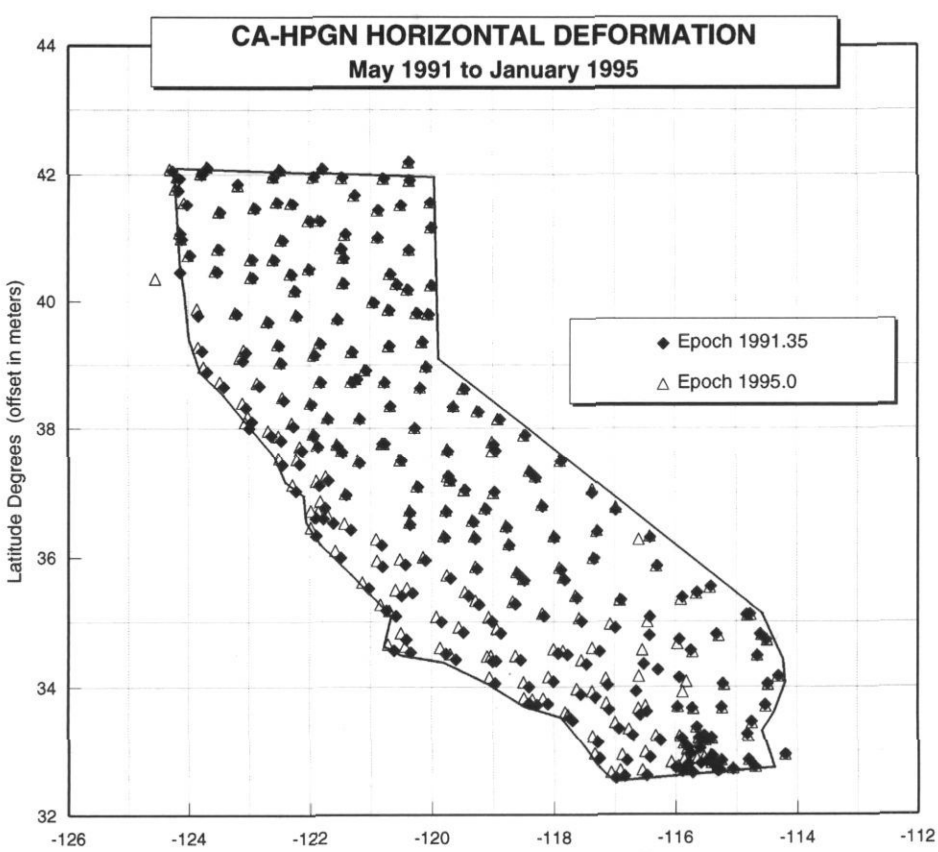


Figure 1

vations before and after the Landers event revealed displacements of over 2 meters near the epicenter. Offsets in stream courses found imbedded in geologic strata show regular 300 to 700 year displacements of 2 to 20 meters in the Salton Trough area.

Vertical Deformation

Vertical deformation is found in many areas of North America. Some of the numerous causes include fluid withdrawal, post glacial uplift, seismic deformation, sedimentary loading and magma intrusion. While vertical deformation is not unusual, California is again unique having regions of deformation from at least three different causes. Subsidence resulting from fluid withdrawal is found in the Sacramento, San Joaquin and Imperial Valleys. Seismic deformation is found to varying degrees throughout the San Andreas fracture zone and uplift due to magma intrusion is known to occur in the Mammoth Lakes area. Vertical deformation does not lend its self to simple modeling. The forces influencing vertical deformation are neither time dependent nor predictable. The amount of ground water removed, or replaced, in any given area can vary dramatically, and the removal may not produce the same magnitude of subsidence throughout the effected area. Seismic and volcanic activity, as we are so acutely aware, is essentially unpredictable. Further complicating the situation is the lack of studies to monitor vertical deformation on a regional scale. The high cost of precise leveling has limited the ability to investigate vertical deformation. What is clear is that California represents a unique challenge in the definition of a vertical reference system due to the described vertical deformation.

The California Spatial Reference System

A proposed set of definitions for a state-wide spatial reference system has been prepared by the California Geodetic Control Committee (CGCC). This proposal consists of two components. The horizontal and vertical components are treated independently in their own publications since each is faced with its own types of uses and users and its own unique challenges. Fundamental in the proposals is acceptance of NAD83 and NAVD88 as the official horizontal and vertical datum for the State. Beyond the datum definition however, the proposals provide guidelines to bring together state-of-the-art GPS surveying with continuous operating reference stations (CORS) into a unified four-dimensional spatial reference system providing a foundation for both position and velocity.

California's crustal motions require that surveyors become accustomed to some unfamiliar concepts. Foremost among these, geodetic quality coordinates must be published with an associated epoch date. The date, expressed in decimal years, is the computed survey date (the date for which the coordinates are valid) for the general adjustment which fixes the project to NAD83 (i.e., North American Plate). The California HPGN was observed on an average date of May 8, 1991. Hence, all the observations and computations were adjusted to that date, and the epoch is therefore termed NAD83(1991.35). Following the June 1992 Landers earthquake, a resurvey was conducted which established updated coordinates for several stations in Los Angeles, Orange, Riverside, and San Bernardino counties. The updated coordinates, dated 1992.9, contain not only the episodic deformation from the Landers and Big Bear events, but also the secular movement which occurred between 1991.35 and 1992.9. Surveyors using published coordinates in this area must be extremely careful that the correct date is used since values are commonly available for 1984.0, 1991.35, and 1992.9 as well as countless project-specific coordinates which are not clearly related to a particular epoch (Note: The original NAD83 adjustment was performed to epoch 1984.0, but is typically referred to as NAD83(1986).) No particular difficulty is encountered when a project is conducted wholly within a given epoch, providing the date is clearly identified. The most complicated of conditions arises when a project spans regions with primary control of differing epoches. GPS and geophysical science has given us the ability to easily detect this deformation, but has also presented a dilemma over how to accommodate it.

The permanent GPS geodetic array (PGGA), operated by the Institute of Geophysics and Planetary Physics at Scripps Institution of Oceanography, has been computing near real time coordinates for CORS in their network since 1991. The PGGA operates on a different datum from both GRS80 and NAD83, but could be transformed to be useable by surveyors, and could easily include other CORS networks such as those operated by USGS in the Bay area and the continental-wide network being installed by the US Coast Guard. PGGA coordinates are computed on the International Terrestrial Reference Frame (ITRF). The ITRF datum is only slightly different from NAD83 (approximately one part in 107). The absolute coordinates in ITRF change constantly with respect to NAD83. A real-time reference system, fixed to a global monitoring network is the most elegant of solutions. Conceptually however, it may be very difficult for users to get accustomed to the transformation process necessary to bring projects to a common datum and epoch. Further, NAD83 is firmly entrenched in legislation, so that a scientifically pure reference system may not be realized any time soon.

A second option involves utilization of the Horizontal Time Dependent Positioning model (HTDP) developed by NGS. The HTDP provides velocities including secular and episodic motion backward in time, and secular motion forward in time. Using the program, a coordinate is entered together with a beginning and ending date, and updated (or back dated) coordinates, velocity and offsets are output. Reliability of the HTDP has been estimated at $7.5+0.018L$ mm/yr (one sigma error, L = separation in km). Theoretically, control coordinates and observations can be transformed to a common epoch prior to a project adjustment. This in fact is how both the original NAD83 and HPGN were adjusted. Using HTDP, survey observations would be corrected for the changes in position differences which occur between the observation date(s) and the control coordinate epoch. These "corrected" vectors would be the observations entered into the least squares adjustment where the published control coordinates are held fixed. Alternately the observations could be entered as measured and the control coordinates "corrected" to match the survey date. After adjustment on the current epoch, HTDP would be used to bring the adjusted coordinates back to the chosen epoch date. The general concept is that HTDP provides a tool to bring all components of a network together at a common point in time.

The default option of course is to do nothing. Providing that practitioners are diligent in documenting geodetic control projects and in epoch dating coordinates, this may not be the worst solution. The reality is that the magnitude of deformation is tolerable for many applications. It would be extremely poor practice to fix coordinates and observations on different epoches, but the method used to bring the data to a common date makes very little difference. A carefully documented project clearly qualifies its conclusions and can be reconstructed for future analysis as needed. So the critical component comes down to education and professionalism.

The Futurist's Perspective

The County Engineers Association of California voted to support the horizontal and vertical components of the CSRS at its November 1994 meeting. Revisions to the Professional Land Surveyors Act and Public Resources Code have been drafted and are being reviewed by the CLSA Legislative Committee. The Federal Register notice filed on June 23, 1994 reports that NGVD29 is to be replaced by NAVD88 as the official height reference in the United States. It is clear that California occupies a particularly unique position in geodetic surveying and geophysical science. The procedures formulated and implemented here will be as useable elsewhere, and the attention focused upon the region provides many interesting opportunities.

California's surveyors are poised to accept a significant roll in the societal transition to the information age. Just as visionaries in the eighteenth century lead a transition - ironically with an information-based public land survey system - of the agrarian age to the manufacturing age, today's professionals have an opportunity to provide equally important participation. The CSRS represents one supporting component of the information age. ⊕

Who is the California Geodetic Control Committee?

During the last two years an ad hoc group of land surveyors and geodetic scientists has worked together in meetings, public forums and research endeavors to help provide guidance and communication regarding California's unique concerns relative to geodetic control. Collectively, the California Geodetic Control Committee (CGCC) has prepared reports and proposed legislation which defines an official horizontal and vertical spatial reference system for the state. They have published proposed specifications for high-production GPS surveying techniques and several members have presented seminars, written articles and participated in national forums where these issues have been particularly relevant. The eighteen members of the CGCC were selected from various public agencies, private businesses and educational institutions in California. They have been assisted by numerous corresponding members including professionals from throughout the local community, to interested individuals and groups at the National Geodetic Survey, US Geological Survey, and the Wisconsin State Cartographer, to such far reaching places as The University of Calgary, The University of New South Wales, and The National Geodetic Survey of Sweden.

The CGCC is continuing in its participation in state and national efforts relative to geodesy and geodetic surveying and willingly contributes resources and expertise toward education and communication for related programs. The following dedicated professionals are contributing their time and knowledge as members of the CGCC:

Michael Anderson, PLS The May Group San Diego	Yehuda Bock UCSD La Jolla	Alvin Christensen, PLS Greiner, Inc. Santa Ana
Earl Cross, PLS Cross Land Surveying San Jose	Ron Dodds, PLS City of San Diego San Diego	Don D'Onofrio NGS Sacramento
Michael B. Emmons, PLS County of Orange Santa Ana	Lawrence Fenske, PLS CALTRANS Sacramento	William Finfrock, PLS CDS Engineering San Luis Obispo
Frank Fitzpatrick, PLS Manitoo Engineering Escondido	Roger Frank, PLS Johnson Frank & Assoc. Anaheim	Gregory Helmer, PLS Robert Bein & Frost Irvine
David Johnson, PLS Trimble Navigation Sunnyvale	John Langan, PLS Towill, Inc. Concord	Robert T. Macomber Control / Photo Ramona
Don Marcott, PLS County of Santa Clara San Jose	Michael McGee, PLS McGee Surveying Santa Barbara	Wayne Wheeler, PLS GPS/GIS Land Surveying Escondido

The CGCC may be contacted through its Chairperson:

Gregory A. Helmer, PLS
c/o Robert Bein, William Frost & Associates, Inc.
P.O. Box 57057
Irvine, CA 92619-7057

Fax No: (714) 472-8373
email: RBFGAH@aol.com

⊕

From the Desk of

Rear Admiral J. Austin Yeager, NOAA
Director, Coast and Geodetic Survey

FEDERAL AGENCIES spent a great deal of time watching the actions of Congress as budgets for 1995 were being determined. After a decade of eroded budget authority given to the providers of mapping, charting, and geodesy information, we in the Coast and Geodetic Survey (C&GS) are particularly concerned that further erosion will critically affect our ability to support you, our customer.

In recent years, we have already discontinued geodetic survey mark maintenance, proposed discontinuation of our World Aeronautical Chart series (a move we ultimately did not have to make) and, most recently, reviewed our nautical chart suite in order to identify charts where low sales volume or duplicate coverage would permit withdrawal. (Happily we were not forced to take such action in 1994, but the fact that this was a serious consideration merits ongoing concern.) Fewer new nautical editions are requiring mariners to apply large numbers of corrections from the Coast Guard's *Notice to Mariners* releases in order to keep their charts current. We are not satisfied with the services we are presently providing and have a deep concern for our future capabilities. You, our customer, deserve better.

For the past 3 years, C&GS has submitted an initiative through the Federal budget process, which would modernize our navigation and positioning services. Our proposed increase for 1996 is now being considered. Failure of this initiative to receive funding will not only bring closer those cuts, which have been previously considered, but will also prevent timely conversion of our operations to the digital product environment.

There may be a light at the end of the tunnel, however. At the time of this writing, the Senate is recommending an increase for mapping and charting funding to "enhance NOAA's efforts to modernize nautical chart technologies." The House of Representatives has also recommended an increase in this program. The next step is for these two bodies to resolve their differences and approve an authorization. Although these proposed increases are far short of what is needed, they could be the first real step in the right direction during this decade.

As those most affected by our products and services, we strongly encourage you to take a more active role in determining the level of service we provide to you. For our part, we commit to providing the best possible response within the constraints of our resources. However, without an increased operating budget, we will be unable to provide the flexibility and timeliness of high quality digital data and products in the foreseeable future. The future of mapping, charting, and geodesy as practiced by C&GS is, to a great extent, in your hands! ⊕

Product News

Updated Nikon Field Station Software Offers Ease of Use, Increased Flexibility, and Field Productivity

Users of Nikon Field Stations can now benefit from the latest release of software for the systems, which combine a total station, personal computer, on-board data recorder, and software into a single piece of equipment. The Nikon AP-700 version 1.2 user-configurable software significantly enhances field efficiency with powerful new functions for Control and Traverse Adjustment, Stakeout, Multiple Point Resection, Remote Benchmark, On-screen Mapping, and a full range of COGO functions. All new functions are designed to be consistent with current software, ensuring that the AP-700 maintains its logical, intuitive and easy mode of operation.

For more information on Nikon's AP-700 Version 1.2 software, contact: Nikon Inquiry Response Center, 101 Cleveland Avenue, Bayshore, NY 11706

Nikon Laser Level Gives Simultaneous Grade Checks Throughout Job Site; Offers Long Life "Hard Hat" Warranty

The new AL-50 laser level from Nikon creates a fast, accurate one-person leveling crew for increased speed and profitability on the job. Its consistent, 360-degree automatic level reference permits instantaneous, simultaneous grade checks throughout the job site. The easy-to-use level combines superb optics and a specially-designed precision compensator for accuracy over a long life. It is so durable that it comes with Nikon's exclusive "Hard Hat" warranty.

For more information on the AL-50 electronic level from Nikon contact: Nikon Inquiry Response Center, 101 Cleveland Avenue, Bayshore, NY 11706

New Theodolite and Total Station Especially Designed for Routine Surveying

The new ETh 50 theodolite and Elta 50 total station from Carl Zeiss are lightweight, compact instruments with a distinctive design. They are intended for all-round surveying and especially work on construction sites.

The Elta 50 total station contains integrated application-oriented programs for fast surveying, verification and setting out in cadastral, construction and utility-line surveys, as well as in forestry, landscaping and horticulture surveys. These programs offer a huge potential for solving the most varied surveying tasks.

For complete details and pricing, contact: Carl Zeiss, Inc., Surveying Division, One Zeiss Drive, Thornwood, NY 10594, (914) 681-7305, Fax (914) 681-7472

Software Programs and GPS Data Available Free on Internet

Approximately 30 NGSD-developed software programs are now available on the Internet World Wide Web (WWW). These programs were developed to compute, verify, or adjust field surveying operations; convert coordinates from one geodetic datum to another, or to assist in other specialized tasks utilizing geodetic data. In addition, Global Positioning System (GPS) data from Continuously Operating Reference Stations (CORS) are also available through NGSD's Internet home page. The home page is available only by using a WWW software browsing tool such as Mosaic.

The Uniform Resource Locator (URL) address for NGSD's home page is:

http://www.ngs.noaa.gov

For those who do not have access to Internet browsing software, these software programs and CORS data may be obtained through Internet using anonymous file transfer protocol (ftp). To access software files, type:

ftp ftp.ngs.noaa.gov

Then change the directory to pub/pcsoft. To access the CORS files, type:

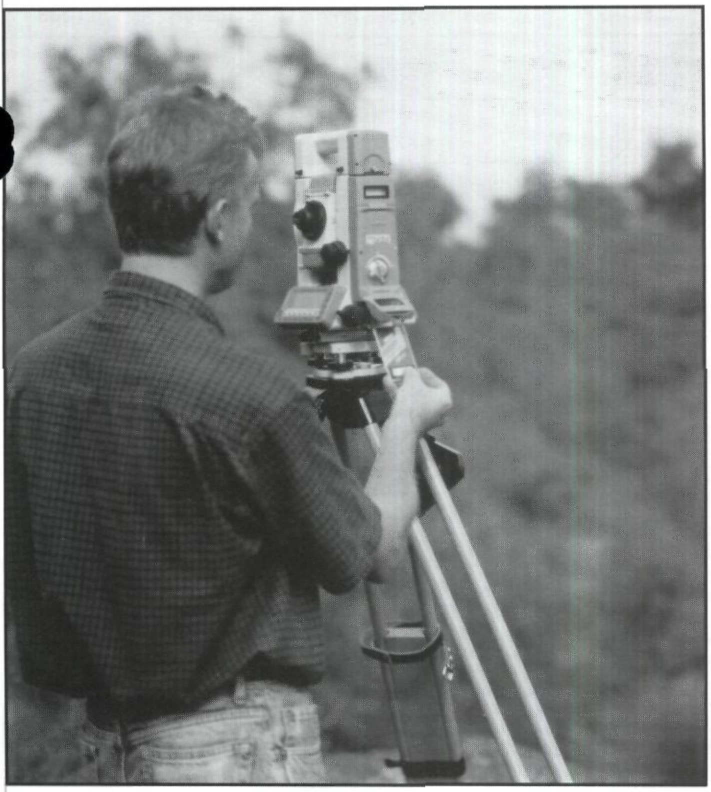
ftp cors.grdl.noaa.gov

Then change the directory to dist/corsl/rinex.

The following information is also available on Internet using NGSD's home page: NGSD's Catalog of Products and Services; Mission, Vision, and Strategic Goals of NGSD; the NGSD telephone directory; a geiod height model and a deflection of the vertical model; NGSD's organization structure diagram; and general information about NGSD's products, services, and program activities.

Inquiries: George Frank, Phone: (301) 713-3251
E-mail: george@galaxy.ngs.noaa.gov ⊕

New Elta 50 Total Station and Theodolite for all round surveying.



Nikon's new AP-700 Version 1.2 software for 700 Series Field Stations greatly enhances flexibility and field efficiency with powerful new functions.

The easy-to-use AL-50 laser level from Nikon allows simultaneous grade checks throughout the job site.

CLSA PUBLICATION ORDER FORM	Member Price	Non-Member Price	Quantity	Total
1995 Complete Package including PLS Roster, Pre-'82 CE Numerical Listing, PE & PLS Act with Board Rules, Subdivision Map Act, & Binder	$ 24.00	$ 38.00		
1995 Complete Package (as above) plus disk with PE & PLS Act with Board Rules, and Subdivision Map Act	$ 34.00	$ 54.00		
1995 Refill Package including PLS Roster, PE & PLS Act with Board Rules, and Subdivision Map Act	$ 18.00	$ 28.00		
1995 Refill Package (as above) plus disk	$ 28.00	$ 44.00		
PE Act & PLS Act with Board Rules – 1995 publication (5½" x 8½")	$ 6.00	$ 12.00		
Subdivision Map Act – 1995 publication (5½" x 8½")	$ 6.00	$ 12.00		
California Coordinate Projection Tables – NAD '83 by Ira H. Alexander, C.E., P.L.S., and Robert J. Alexander, P.E.	$ 6.00	$ 12.00		
Right of Entry Cards *(minimum order is two)*	2 / $ 3.00	2 / $ 6.00		
Corner Records Forms – FORM PWA-102 (8/88) *(minimum order is 25)*	$ 10.00 (25)	$ 15.00 (25)		
Land Surveying Brochures *(minimum order is 100)*	$ 15.00 (100)	$ 30.00 (100)		
Standard Contract Forms – Agreement for Professional Services	$ 6.00 / pad of 25	$ 12.00 / pad of 25		
Land Surveying for the Land Owner and Real Estate Professional by Daniel E. Beardslee, P.L.S.	$ 6.00	$ 12.00		
Easements and Related Land Use Law in California – 2nd Edition by Donald E. Bender, J.D., L.S.	$ 20.00	$ 30.00		
CLSA 25th Anniversary Commerative Belt Buckle – Bronze	$ 20.00	$ 20.00		
CLSA 25th Anniversary Commerative Belt Buckle – Sterling Silver	$ 80.00	$ 80.00		
COMPUTER SOFTWARE				
Cadastral Survey Measurement Management System Three-ring binder documentation and three disks	$ 50.00 / set	$ 75.00 /set		
GEOID93 – Calculates estimated geoid heights	$ 20.00	$ 30.00		
VERTCON – Calculates estimated difference between NGVD29 and NAVD88	$ 20.00	$ 30.00		
CORPSCON – Calculates geodetic and SPC transformations in NGVD27 and NAD83 *(includes NADCON)*	$ 20.00	$ 30.00		

- *Member prices are only available to members of the State California Land Surveyors Association*
- *Minimum order for Mastercard or Visa is $20.00*
- *Fax orders accepted with Mastercard or Visa only at (707) 578-4406 between 9:00 a.m. and 5:00 p.m., Monday through Friday*
- *Mail your order form and payment to:*
  CLSA Central Office
  P.O. Box 9098
  Santa Rosa, CA 95405-9990
  Phone: (707) 578-6016
  Fax: (707) 578-4406

Subtotal of all items	
Shipping – UPS Ground Service Up to $20.00 add $2.75 $20.01 to $40.00 add $4.50 $40.10 to $60.00 add $6.00 Over $60.00 add 10% (up to maximum of $10.00)	
Next Day Air Shipping (if placed by 3:00 p.m.) Add additional $15.00	
Subtotal including shipping	
7½% California Sales Tax on above	
TOTAL	

Make check or money order payable to California Land Surveyors Association (CLSA)

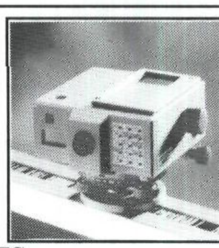
NAME	PAYMENT ENCLOSED: ☐ CHECK ☐ MASTERCARD ☐ VISA
COMPANY *(if company is mailing address below)*	ACCOUNT NUMBER
STREET ADDRESS *(we cannot ship to P.O. Box)*	EXPIRATION DATE
CITY / STATE / ZIP	NAME ON CARD
DAYTIME TELEPHONE	AUTHORIZED SIGNATURE

Surveyors Service Company

QUALITY SERVICE SINCE 1926

Leica RENTAL EQUIPMENT

Servco features Quality Leica products. "If you're going to rent,why not rent the best?"

GPS SYSTEMS	ACCURACY	DAILY	WEEKLY	MONTHLY
				
DUAL FREQUENCY SYSTEM 200 W/ SR299 SENSOR	STATIC............................10mm+1ppm RAPID STATIC...........5-10mm+1ppm REOCCUPATION.......5-10mm+1ppm KINEMATIC..............10-15mm+1ppm AROF KINMATIC......10-15mm+1ppm STOP AND GO.........10-15mm+1ppm DIFFER.CODE.................0.5m+1ppm RTDGPS...........................0.5m+1ppm	$180.00	$875.00	$3000.00
DUAL FREQUENCY SKI SOFTWARE (L1/L2)		60.00	385.00	1200.00
SINGLE FREQUENCY SYSTEM 200 W/ SR-261 SENSOR	STATIC...........................10mm+2ppm REOCCUPATION..........10mm+2ppm KINEMATIC............. 15-20mm+2ppm STOP AND GO........ 15-20mm+2ppm DIFFER.CODE................1-2m+2ppm RTDGPS...........................1-2m+2ppm	80.00	490.00	1590.00
SINGLE FREQUENCY SKI SOFTWARE (L1 ONLY)		30.00	175.00	600.00
TOTAL STATIONS	ANGLE #PRISMS RANGE			
				
TC-1610 VIP TOTAL STATION	1.5" 1 1.6 MILES 3 2.2	110.00	630.00	2100.00
TC-1010 VIP TOTAL STATION	3" 1 1.2 MILES 3 2.2	75.00	455.00	1500.00
TC-500 TOTAL STATION	6" 1 .43 MILES 3 .68	40.00	245.00	810.00
DATA COLLECTION				
				
GIF10 INTERFACE	N/A	10.00	56.00	150.00
RECORD MODULE	64K	5.00	28.00	75.00
LEVELING EQUIPMENT				
				
NA-3000 DIGITAL LEVEL	0.4MM INVAR ROD 1.2MM DUAL FACE ROD	45.00	245.00	800.00
NA-2002 DIGITAL LEVEL	0.9MM INVAR ROD 1.5MM DUAL FACE ROD	30.00	154.00	500.00
INVAR BAR CODE ROD /STRUTS	N/A	40.00	20.00	600.00

GPS RECEIVERS
INCLUDE BATTERIES, CHARGERS, CABLES, TRIBRACH AND TRIPOD.
TOTAL STATIONS
INCLUDE TRIPOD, PLUMB POLE AND SINGLE PRISM ASSEMBLY.
DIGITAL LEVELS
INCLUDE FIBERGLASS BAR CODE ROD AND TRIPOD.

WE ALSO RENT:
THEODOLITES, EDM'S, TRANSITS, DATA COLLECTORS INTERIOR/EXTERIOR LASERS, AUTOMATIC LEVELS, MAGNETIC LOCATORS, TWO-WAY RADIOS, PRISM ASSEMBLIES, TRIPODS, AND RODS. CALL US TODAY !

CALIFORNIA
[illegible]942 CENTURY PLACE
COSTA MESA, CA 92626
800-938-0606 714-546-0606
714-546-9724 (FAX)

ARIZONA
4317 NORTH 16TH ST.
PHOENIX, AZ 85016
800-938-0608 602-274-2052
602-274-3740 (FAX)

SURVEYORS SERVICE COMPANY

SPECIALISTS TO THE SURVEYING INDUSTRY FOR OVER 65 YEARS.

Sustaining Members

The California Surveyor
Published Quarterly by the
CALIFORNIA LAND SURVEYORS
ASSOCIATION
Post Office Box 9098
Santa Rosa, Ca 95405-9990

ADDRESS CORRECTION REQUESTED

BULK RATE
U.S. POSTAGE
PAID
Permit No. 635
Santa Rosa, CA