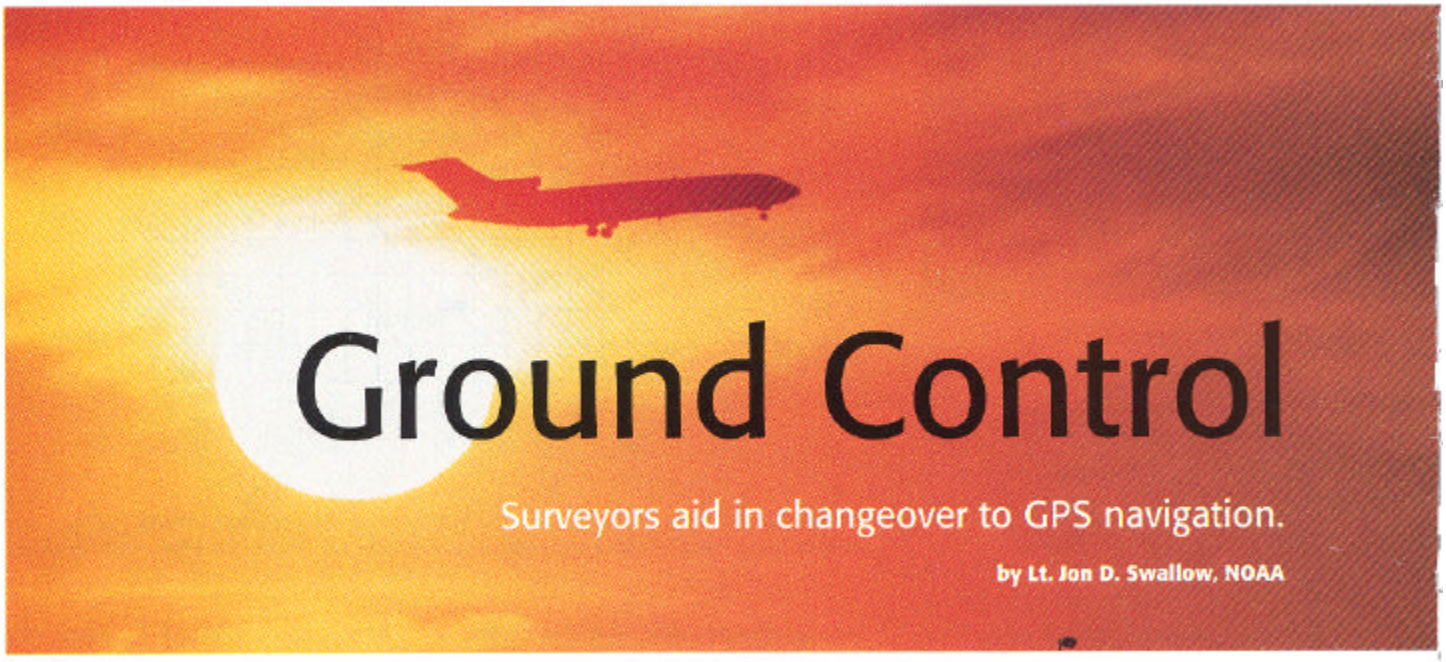
During the past year the National Geodetic Survey (NGS), Mountain Surveying and Mapping Inc. (MSM, Denver, Colo.), the Colorado Department of Transportation and the U.S. Army Corps of Engineers (USACE) worked together on a pilot project to establish Geodetic Control on 48 airports in Colorado for the Federal Aviation Administration (FAA). The project has become an example of how government agencies and private survey companies can work together to produce a high quality survey. It also provides a prototype for similar surveys to be performed throughout the United States.



Ground Control

Surveyors aid in changeover to GPS navigation.

by Lt. Jon D. Swallow, NOAA

CPS technology is revolutionizing the way aircraft navigate from airport to airport. Conventional air navigation is referenced to ground-based signals where geodetic coordinates are of secondary importance. Aircraft receive signals from an extensive array of ground-based equipment and navigate from one electronic aid to another.

Contrary to conventional air navigation, geodetic coordinates are of primary importance when using CPS navigation because aircraft navigate by waypoint coordinates input into the CPS system. A precise, consistent coordinate system is required to ensure all critical airport features, such as runway ends and ground obstructions, are on the same reference frame as the coordinate readout in the aircraft.

The FAA plans to establish CPS Area Navigation Approach (ANA) procedures for approximately 3,000 airports in the United States. In order to establish accurate, integrated approach and departure procedures for runways, the FAA needs precisely positioned airport geodetic control, runway, navigation aid and obstruction features. The responsibility for positioning airport feature data resides with the NGS, a part of the National Oceanic and Atmospheric Administration (NOAA).

NGS is establishing a program to contract a significant amount of the ANA survey work to the private sector. Under the plan, private companies perform the survey work, NGS performs the technical oversight and quality monitoring, and the USACE performs the contract negotiation and administration of the surveys. State aviation and department of transportation offices provide local knowledge to the surveyors and actively involve airport managers to support the survey.

The goal of the control survey is to establish one B-order, Primary Airport Control Station (PACS) and two first-order Secondary Airport Control Stations (SACS) at each airport. The monuments must meet specific siting, construc-

tion and accuracy requirements and will provide the basis for positioning all critical features on an airport. The control is positioned and tied to the National Spatial Reference System (NSRS) through specific GPS observation procedures. Each PACS is positioned to the nearest National Continuously Operating Reference Station (CORS) and is tied to a nearby A- or B-order High Accuracy Reference Network (HARN) station and two first or second-order NAVD 88 bench marks. The entire project will be adjusted as a whole, and the resulting coordinates and data sheets for each station will be loaded into the NGS database. The control will be used for subsequent precision surveys of runways, navigation aids and obstructions at the airports.

The final list of airports to be surveyed was narrowed down to 34 FAA funded and 14 state funded airports. A meeting was held in Denver, Colo., to discuss the specifications, expectations, timeline and survey plan in detail. The survey encompassed three phases: Reconnaissance, Mark Setting and Observations.

Kevin Hoffman, PLS, vice president of MSM, led the survey effort for the company. The NGS state advisor for Colorado, Richard Cohen, provided valuable insight on the existing benchmarks and HARN stations in Colorado and ensured quality construction of the new marks set on the airports. Cohen also represented the Colorado DOT for the project. Technical oversight and quality assurance for the project were performed by Lt. Jon Swallow, NOAA of NGS. Mike Nettles performed the contract administration function for the USACE.

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Reconnaissance

The reconnaissance phase of an ANA survey consists of interviewing airport managers for pertinent information, recovering existing control at the airport and selecting control or new locations for the PACS and SACS stations. Input from the airport managers is vital to selecting locations that are clear of future construction, accessible to survey crews and meet the intervisibility and siting requirements in the specifications. The reconnaissance information gathered at each airport, which consisted of airport information, updated descriptions and photographs of control stations, visibility diagrams and control sketches, was sent to NGS for evaluation and approval.

Two teams, one led by Hoffman and one led by Cohen, performed the reconnaissance phase of the Colorado project. The team leaders scheduled appointments with airport managers to ensure their availability to provide insight during the reconnaissance and to arrange access onto the airfields.

Existing control on each airport was recovered, maintained, photographed, redescribed if necessary, and analyzed to determine if it would meet the criteria for a PACS or a SACS station. Guidelines considered included the stability rating of the monument, intervisibility with other control, obstructions and airport features, accessibility and survivability of the monument, and suitability for the extended use of the monument without interfering with airport opera-

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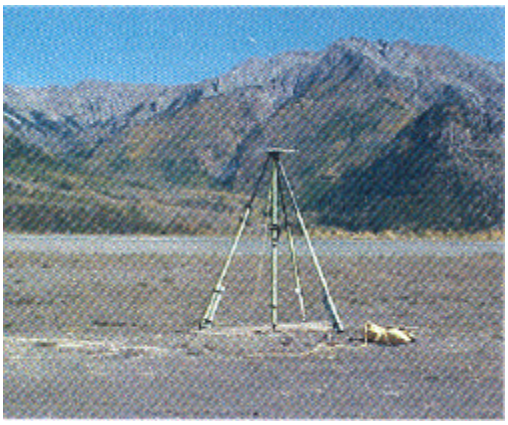


GPS observations were performed during a five-week span in the fall of 1999.

tions. Team leaders recovered 237 existing control points and determined 47 sites for new control stations.

Mark Setting

Sites for 15 new PACS and 32 SACS were determined during the reconnaissance phase. The specifications for a new PACS call for a disk set in sound bedrock or a NGS 3-D stainless steel rod mark driven to refusal (embedded in bedrock). The upper 3' of the rod is encased in a grease-filled sleeve to mitigate the effects of frost heave. The monument is centered in a 20"-Iength of 5"-PVC pipe covered by an aluminum logo cap surrounded by a concrete collar. New SACS called for a 12'-diameter, 4'- deep, bell-bottomed, poured-in-place concrete monument. Each SACS contained 400 to 450 lbs. of concrete.

Cohen worked with Hoffman's crew during the mark setting at each airport. MSM rigged a 12' trailer with a generator, concrete mixer, 50-gallon water tank with electric pump, gas-powered easy-auger with 6" and 12" bits, and numerous digging tools for mark set- ting. Cohen's truck was outfitted with a Pionjar reciprocating hammer and tools for setting the stainless steel rod marks.

Monument sites were checked for underground utilities before holes were dug. Various soil conditions were found when setting the marks. The reciprocating hammer was used often to break through stubborn clay layers, and many rocks encumbered the hole-digging process. Care was taken to ensure the marks were set cleanly and according to specifications. Airport personnel assisted with special equipment if avail- able and often purchased the concrete for the monuments. Photographs were taken of the new marks and will eventually be accessible via the data sheet program on the NGS web site.

Positioning

GPS observations were performed for five weeks during September and October 1999. Forty-eight PACS and 96 SACS were established on the airports. Additionally, GPS positions and elevations were established on 82 existing first- or second-order benchmarks throughout the state. MSM performed the GPS observations using seven GPS receivers and four observers. One Trimble 4000 SSE, and four Trimble 4000 SSI receivers, each matched with a Trimble Compact Geodetic LI/L2 antenna with ground plane (Trimble Navigation Ltd., Sunnyvale, Calif.), were used to observe the PACS, HARN and benchmark stations. The SACS stations were observed using two Trimble 4700 receivers, each matched with a Trimble micro-centered LI/L2 antenna with ground plane. To ensure reliable power, each receiver was powered by at least a 6-amp hour battery using standard camcorder batteries as a backup. Fixed-height, two-meter tripods were used for all occupations.

The GPS requirements, summarized in Figure I on page 30, call for two four-hour sessions between the PACS and the nearest National CORS station; one four-hour session between the PACS and a nearby HARN station; and one four-hour session with two first- or second-order NAVD 88 benchmarks. The SACS require two one-and-a-half-hour sessions with their respective PACS.

Observations began at airports in the mountain region before winter weather set in. The schedule was

designed to complete all the required observations at two airports each day. The observer at each airport ran one receiver on the PACS and a second on each of the SACS. The other observers were responsible for observing the required HARN and benchmark ties simultaneously with the PACS sessions. Airports near each other were observed together to share HARN and benchmark ties if possible. Data was downloaded, quality-checked and backed up each evening before the crew traveled to the next site.

The survey data will be post-processed by MSM using NGS's OMNI or PAGE-NT software. NGS CORS data and precise ephemeris will be down loaded via the Internet. The project will be adjusted using the NGS ADJUST software package. The data will be quality-reviewed by NGS for accuracy, completeness and conformance to the contract specifications. The final coordinates and data sheets for the stations will be made available on the NGS web site and published on the next edition NGS data sheet CD-ROM.

Summary

The geodetic control established during this project and in ANA surveys in other states provide a valuable foundation for performing surveys of runways, navigation aids and obstructions. The control provides secondary benefits to the surveying community by substantially increasing the number of data points used to calculate the GEOID model, and by providing local surveyors with horizontal B-order monumentation on the airports.

The PACS monument should be used as the reference point for any survey work performed on an airport. Data sheets for the control points are accessible via the NGS web site, www.ngs.noaa.gov. To determine if there is a PACS or SACS station at an airport, use the web site to perform a radial search based on the airport latitude and longitude, and limit the search to PACS and SACS using the drop-down menu.

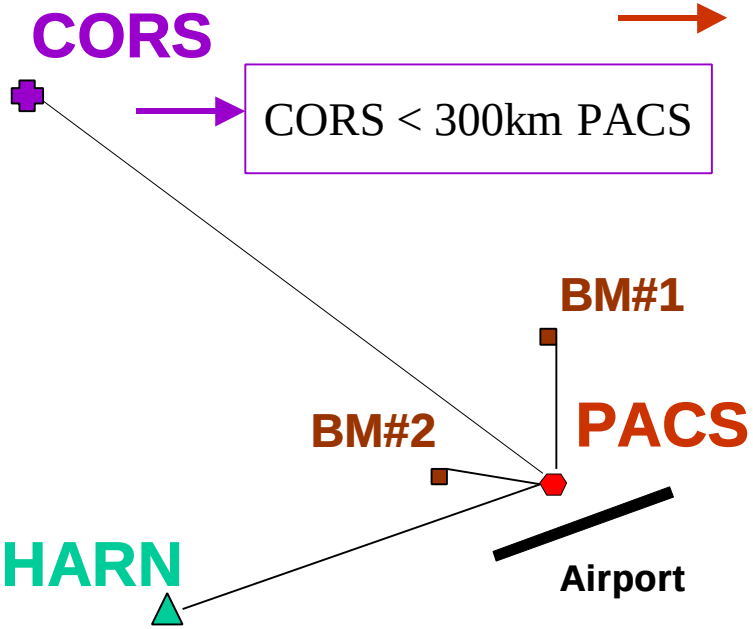
Similar ANA surveys are currently being performed in New England and Tennessee and will expand to other states as FAA funding for the program becomes available. For more information on the NGS Aeronautical Survey Prograrn, visit the NGS home page and click on the "Aeronautical Data" hot link.

Jon Swallow is an officer in NOAA's commissioned corps. He is currently assigned to the NGS as a GeodesistIContract Specialist.

GPS Positioning Procedures

PACS Ties-

- **2, >4hr Sessions PACS - CORS**
- **1, >4hr Session PACS - HARN**
- **1, >4hr Session PACS - BM#1**
- **1, >4hr Session PACS - BM#2**



CORS < 300km PACS

Bench Marks-
BM's > 1km Apart
BM's < 50km PACS

Co-observe BM's if < 20km Apart

HARN > 50km CORS
HARN < 100km PACS

NOTE: Final processed sessions must consist of at least 4 hours of continuous, simultaneous observations between points.

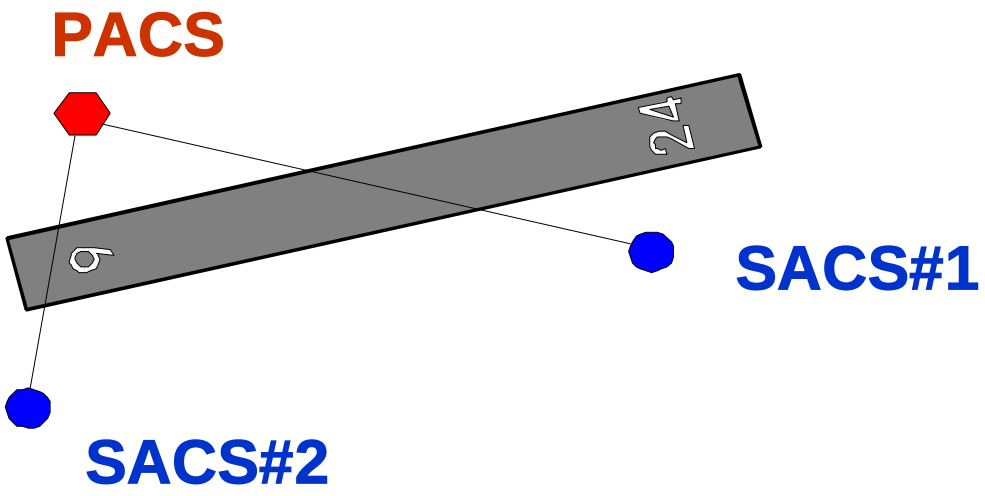
Simplified Schematic, See detailed requirements in the Supplemental Instructions for Airport ANA Surveys
http://www.ngs.noaa.gov/AERO/aero.html

GPS Positioning Procedures

SACS Ties-

→ **2 >1.5 hr Sessions SACS - PACS**

→ **Separate Sessions by 2.5 Hours**



Simplified Schematic, See detailed requirements in the Supplemental Instructions for Airport ANA Surveys http://www.ngs.noaa.gov/AERO/aero.html

Protect the Airspace of ANA Geodetic Control Stations!

Supplemental Instructions for Airport ANA Surveys
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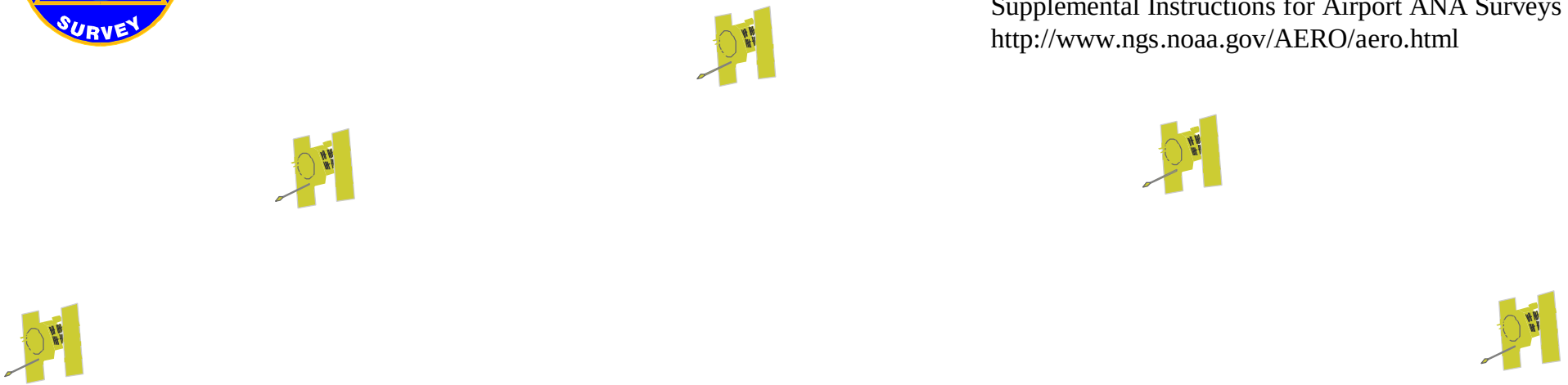

➡ GPS Survey equipment requires a 15 degree minimally obstructed view of the horizon to collect signals from GPS satellites.

15 degree horizon

➡ Keep the area surrounding the survey mark free of large reflective items such as chain-link fences, structures, and buildings.

➡ Potential sources of electrical interference such as radio repeaters and high voltage power lines should not be placed near the survey marks.

GPS Equipment set up over Survey Mark

National Oceanic and Atmospheric Administration