SPACE-BASED POSITIONING
NAVIGATION & TIMING
NATIONAL EXECUTIVE COMMITTEE

Module 3B

Technologies of Interest to Surveyors in 2025

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For Space Based PNT
October 16, 2010

Single Point Jamming Events Since 2000

- Boston airport- 2000 – NGS unable to complete airport survey due to jamming. Had to use optical methods (Total Station) to complete survey.
  - Incident described in RTCA DO-235 publication, December 5, 2002.
- Monterey Bay – April 2001 – All of Moss Landing harbor jammed, reported by captain of research vessel PT SUR
  - Jamming source was a commercially available VHF/UHF television antenna with built-in preamplifier.
  - Three preamplifiers causing the jamming in Moss Harbor
  - Coordinated effort by Naval Postgraduate School (NPS) and FCC located two emitters in about 2 months, last emitter located by FCC 6 months later

Jamming Incidents (Continued)

- San Diego – January, 2007
  - Navy testing equipment in Port of San Diego caused interference to GPS for about 2 hours
  - Navy personnel suspected they were causing the unintentional GPS jamming and terminated the exercise
  - GPS and telcom outage reports to Coast Guard NAVCEN and GPS Operations Center (GPSOC) continued for about 4 hours
  - NAVCEN and supporting agencies 72 hours to pinpoint the jamming source
  - CORS reference station in San Diego lost GPS tracking

Jamming Events are Projected to Increase

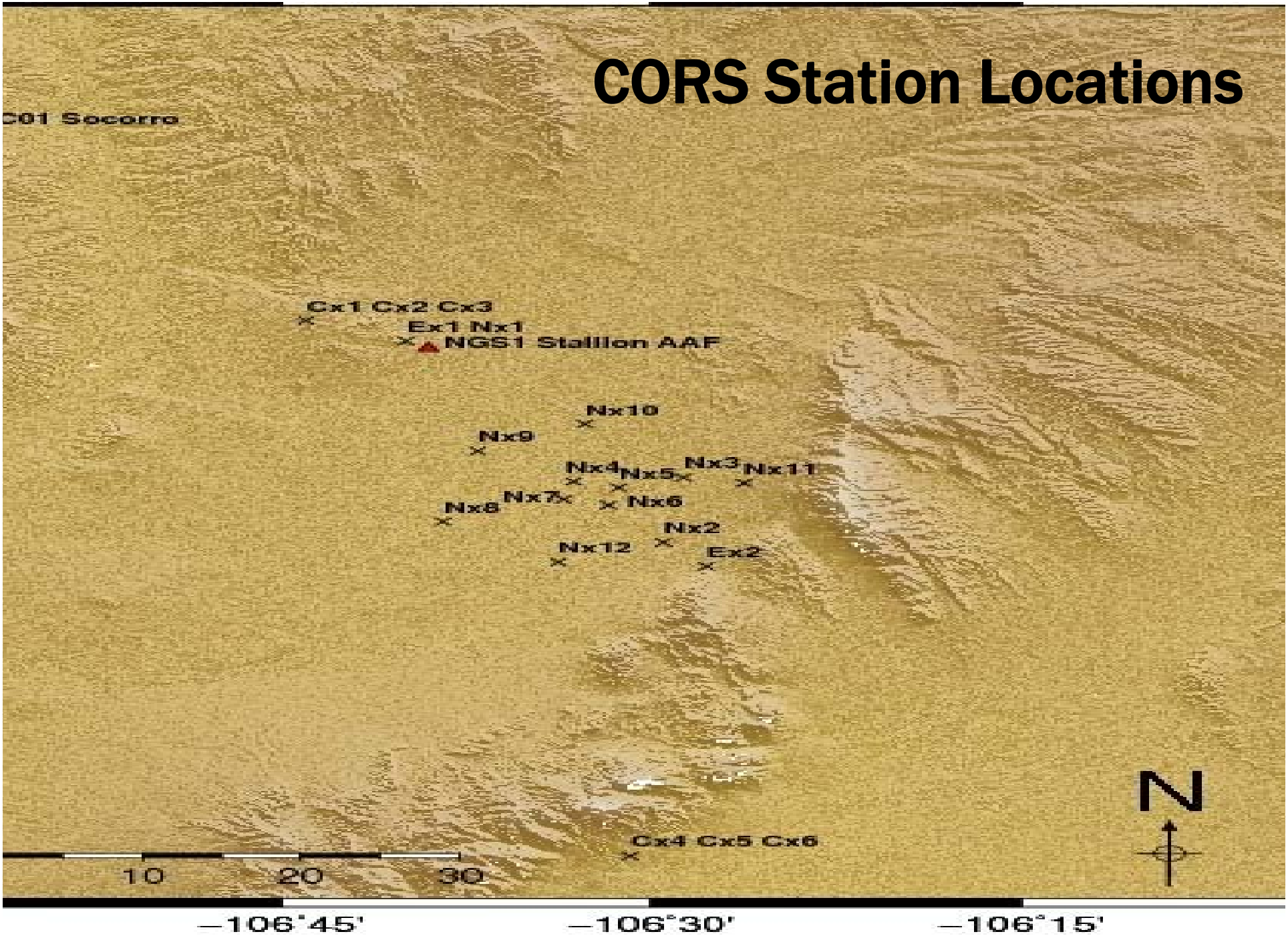
- GPS tracking technology increasingly available in the infrastructure
  - Transportation
  - Criminal Justice
  - Commercial Sector
- Employees may be reluctant to be tracked by GPS all the time
  - May use commercially available low power GPS jammers to avoid monitoring
- Increased use of these jammers may affect GPS surveying projects

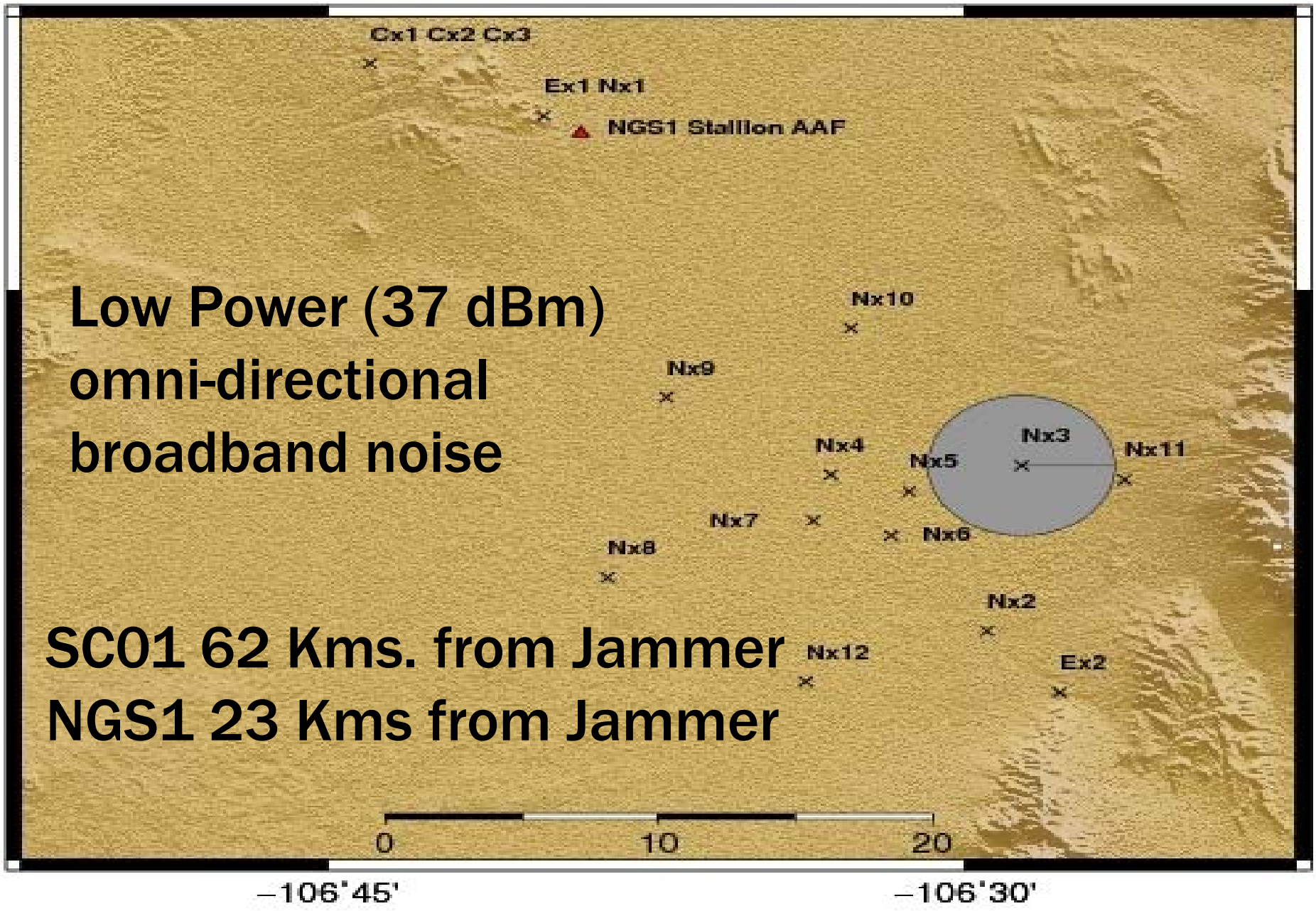
In November 2009 NGS Participated in Jamming Tests at Holloman AFB, New Mexico

- Objective was to determine if electronic interference could be detected by CORS stations.
  - Network CORS station Socorro (SC01) used
    - Collecting data @ 30 sec. rate
    - Approximately 62 Kms. from center of jammers
  - Temporary CORS station (NGS1) in close proximity to a number of jammers
    - Collecting data @5 sec. rate
    - NGS1 approximately 38 Kms. from SC1

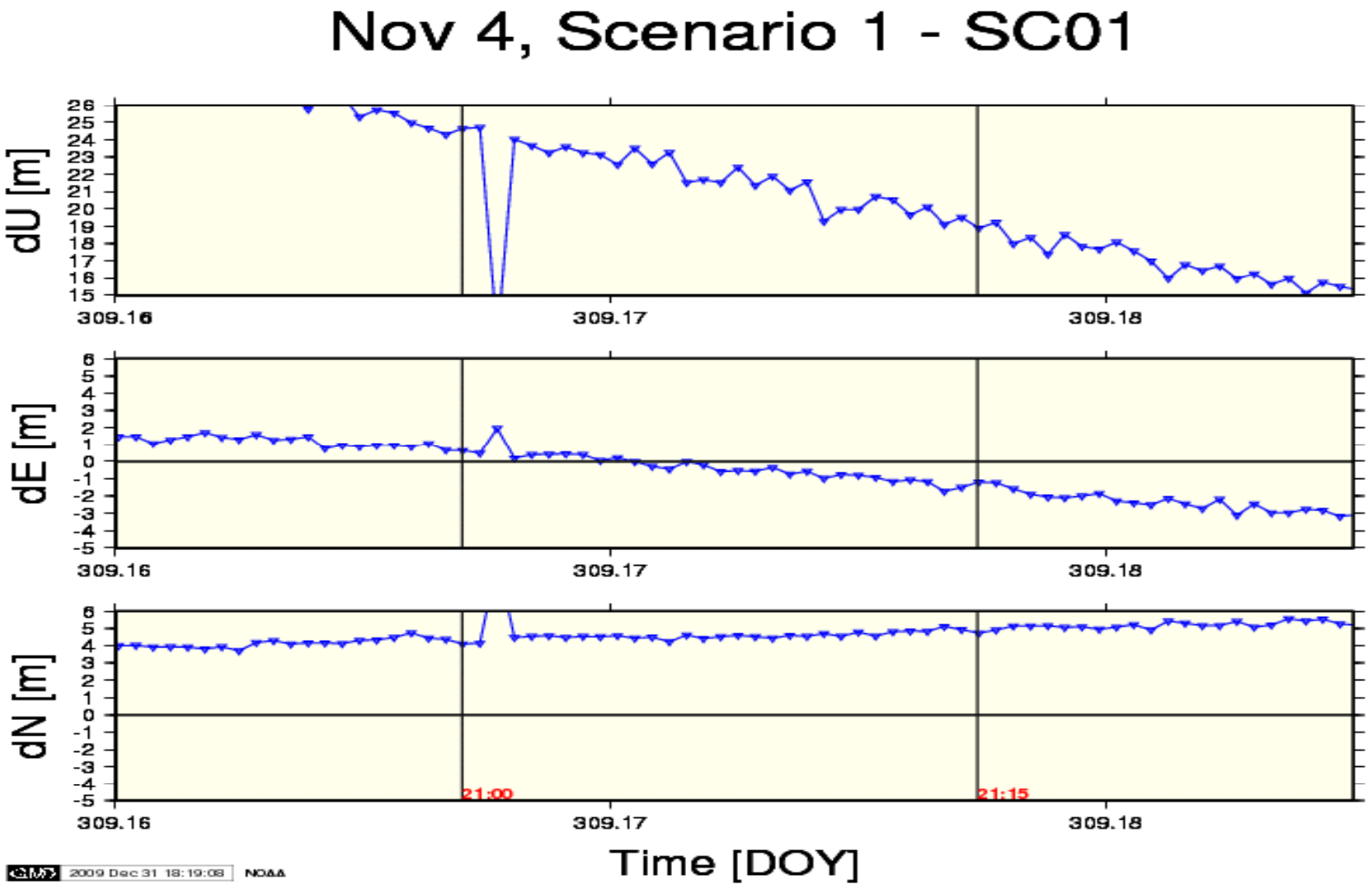
Weston, Neil; et al, *A Near Real-time GPS Interference Detection System in the United States Using the CORS Network*, FIG Congress 2010, Sydney , Australia, April 11-16, 2010.

CORS Station Locations

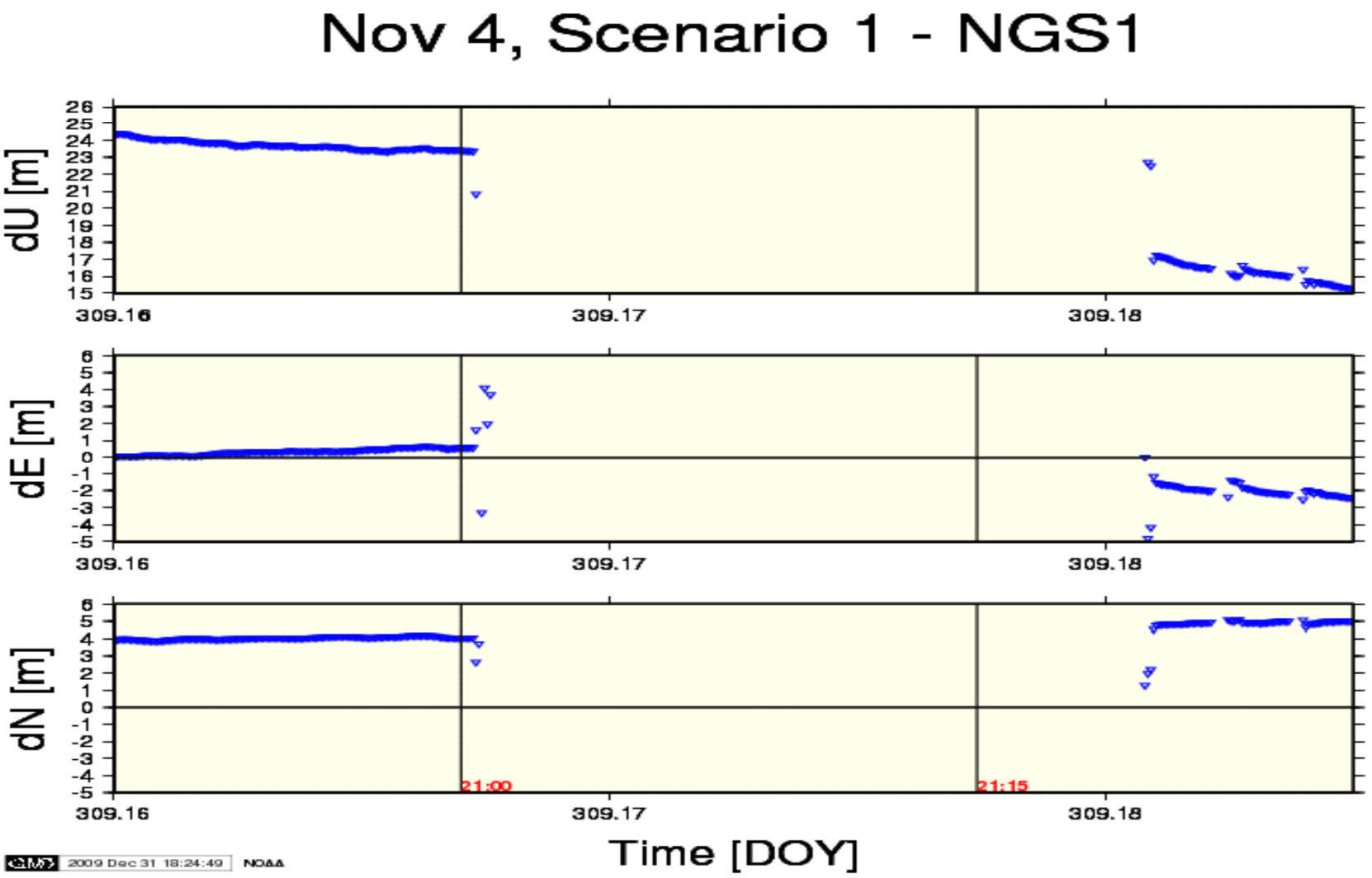


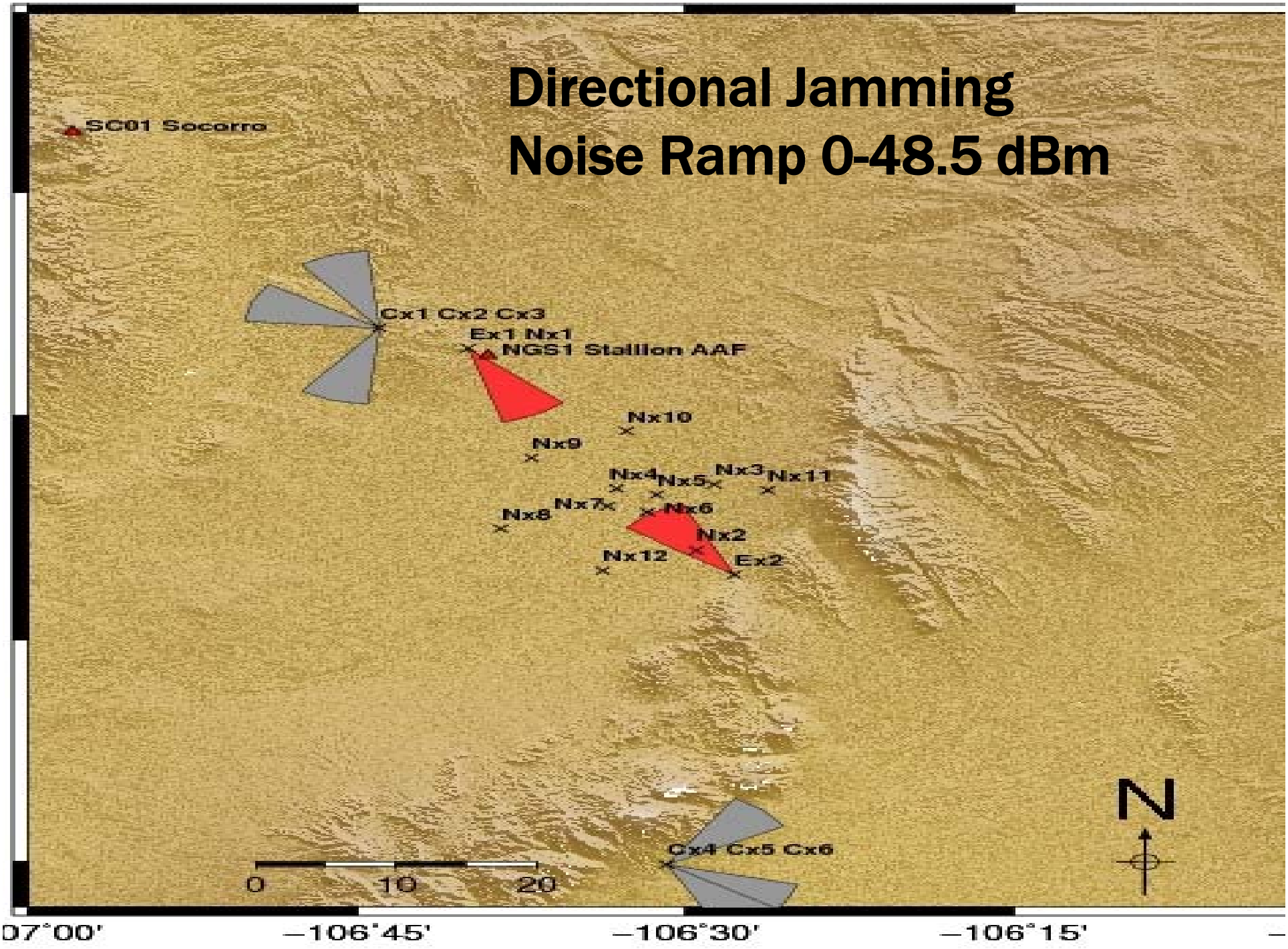

Cx1 Cx2 Cx3
Ex1 Nx1
NGS1 Stallion AAF
Low Power (37 dBm)
omni-directional
broadband noise
Nx10
Nx9
Nx4
Nx3
Nx11
Nx5
Nx7
Nx6
Nx8
Nx2
SC01 62 Kms. from Jammer
Nx12
Ex2
NGS1 23 Kms from Jammer
0
10
20
−106°45'
−106°30'
Dec 31 12:54:45
NGS/NOAA

Low Power Omni-directional Jammer

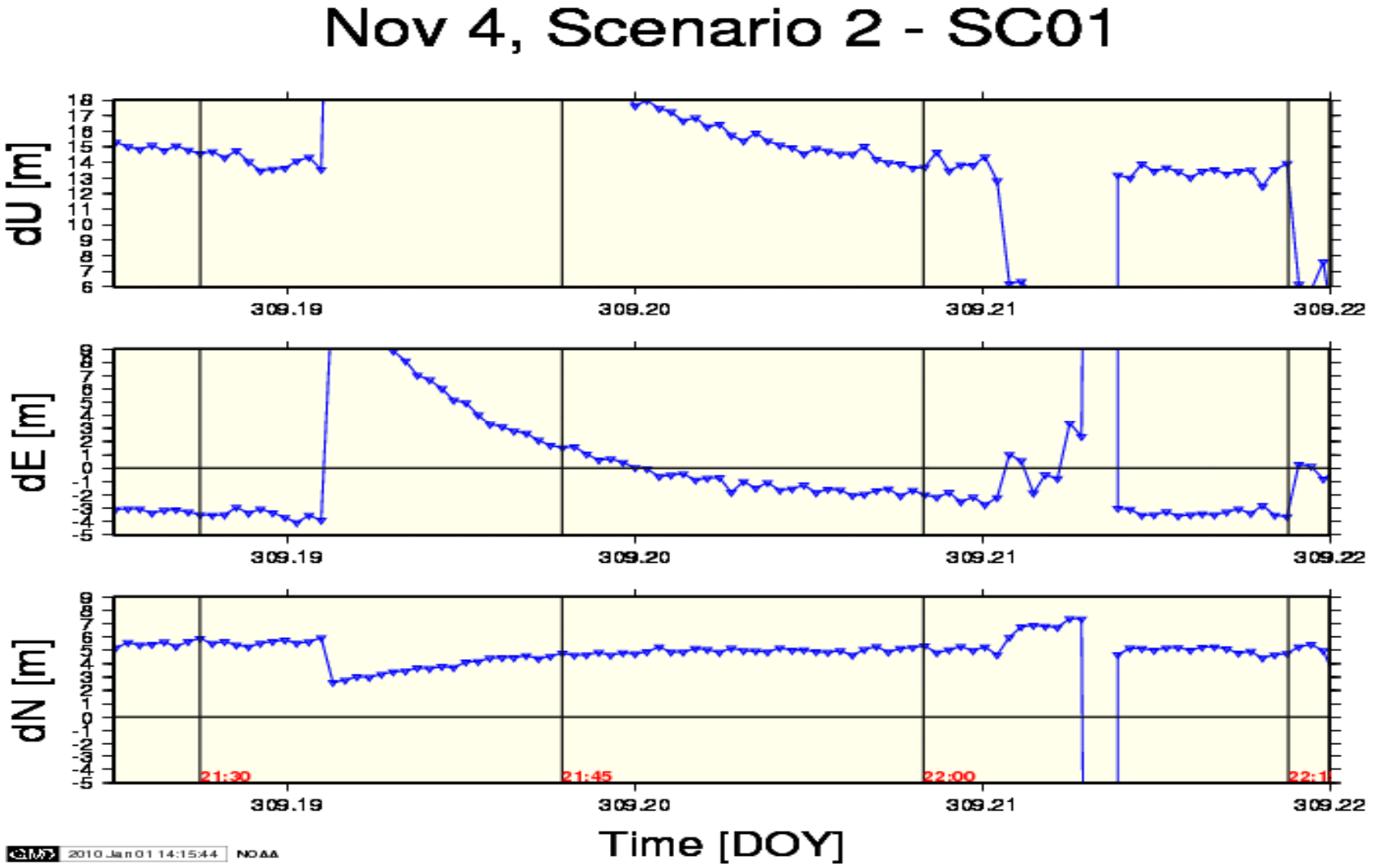


Low Power Jamming Results @ 23 Kms.

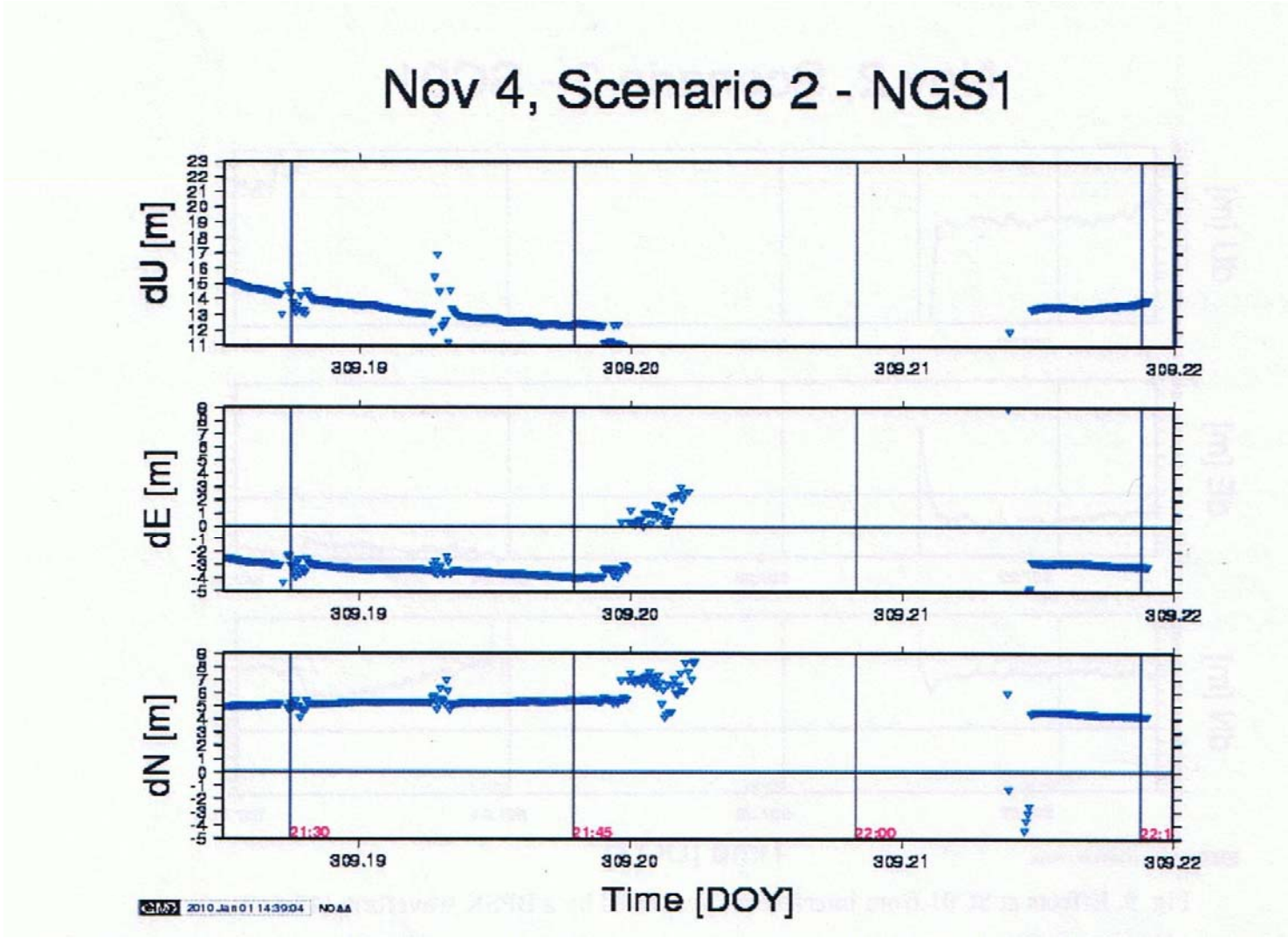



Directional Jamming
Noise Ramp 0-48.5 dBm
SC01 Socorro
Cx1 Cx2 Cx3
Ex1 Nx1
NGS1 Stallion AAF
Nx10
Nx9
Nx4
Nx5
Nx3
Nx11
Nx7
Nx6
Nx8
Nx2
Nx12
Ex2
Cx4 Cx5 Cx6
0
10
20
N
07°00'
−106°45'
−106°30'
−106°15'

Noise Ramp – Significant Position Changes and Tracking Loss Near End of Scenario – 32 Kms from Jammer



Noise Ramp – NGS1 Tracking Initially, but Lost Track 15 Min. Later



Existing/Emerging Global Threats

GPS and GSM Jammer

U.K. £150

1 Watt Jammer

Links between Criminal & Terrorist activity are indisputable

GPS Navigation Devices Can Be Duped

Just like flat-screen televisions, cell phones and computers, global positioning system (GPS) technology is becoming something people can't imagine living without. So if such a ubiquitous system were to come under attack, would we be ready?

It's an uncomfortable question, but one that a group of Cornell researchers have considered with their research into "spoofing" GPS receivers.

GPS is a U.S. navigation system of more than 30 satellites circling Earth twice a day in specific orbits, transmitting signals to receivers on land, sea and in air to calculate their exact locations. "Spoofing," a not-quite-technical term first coined in the radar community, is the transmission of fake GPS signals that receivers accept as authentic ones.

Todd Humphreys, right, discusses with Paul Kintner, left, and Mark Psiaki how a GPS receiver can be "spoofed," based on the research at work at Cornell. Robert Barker/University Photography

The Washington

Gunmen Used Technology as A Tactical Tool

Haste Could Make Waste

Obama Teams Are Scrutinizing

Coaxing!

Aug 08, FCC cites Colorado business for selling GPS jammers to counter GPS vehicle trackers

WA Post Aug 08

Police Turn to Secret Weapon: GPS Device

By Ellen Nakashima
Washington Post Staff Writer

Someone was attacking women in Fairfax County and Alexandria, grabbing them from behind and sometimes punching and molesting them before running away. After logging 11 cases in six months, police finally identified a suspect.

David Lee Boltz Jr., who had served 17 years in prison for rape, lived near the crime scenes. To figure out if Boltz was the assailant, police pulled out their secret weapon: They put a Global Positioning System device on Boltz's van, which allowed them to track his movements.

Police said they soon caught Boltz dragging a woman into a wooded area in Falls Church. After his arrest on Feb. 6, the string of assaults suddenly stopped. The leads in the case reflect largely on a crime-fighting tool they would rather not discuss.

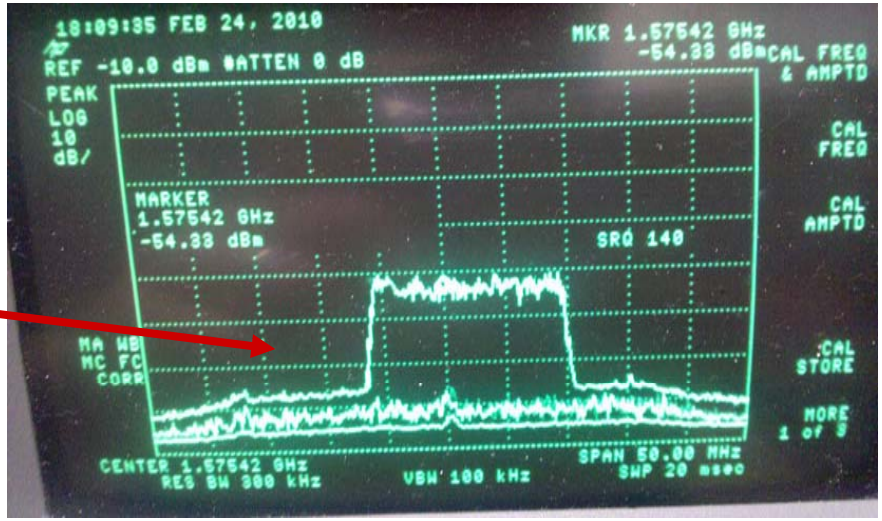
"We don't really want to give our info on how we use it as an investigative tool to help the bad guys," said Officer Shelley Brodeur, a Fairfax police spokeswoman. "It is an investigative tool for us, and it is a very narrowed investigative tool."

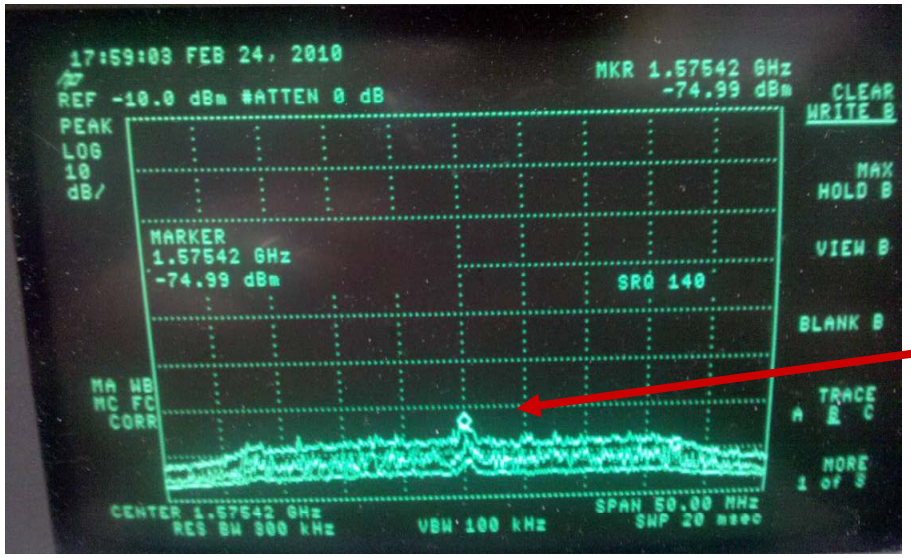
Across the country, police are using GPS devices to snare thieves, drug dealers, sexual predators and killers, often without a warrant or court order. Privacy advocates said tracking suspects electronically ex-

See GPS DEVICES, A12, Col. 1

US Government Measurements

Wideband RFI Source measured occupying approximately 20 MHz – 5 MHz below L1 and 15 MHz above L1.

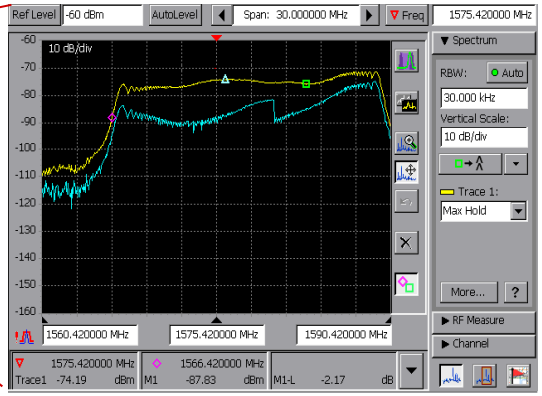




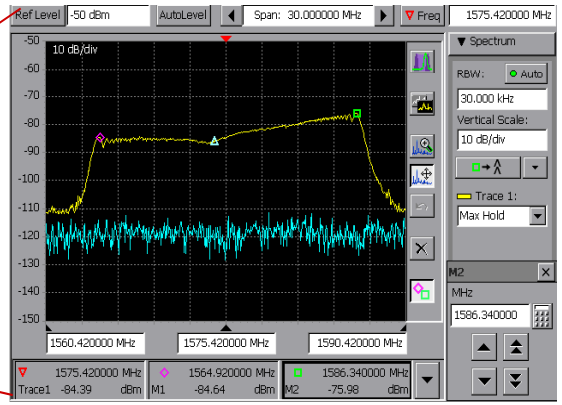
Normal L1 passband Spectrum when RFI Source is not present.

UNCLASSIFIED

US Government Finding



RFI source "Locked-on" and pursued.



On Site ON-OFF tests confirms GPS RFI source.

The GPS Triad

Joint GPS User Support Service

USAF GPSOC
(military)

FCC

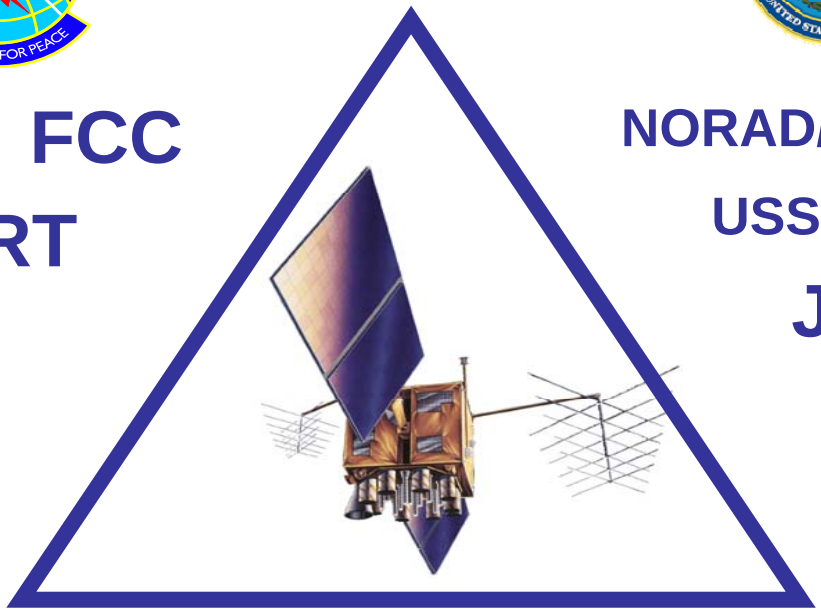
PIRT

NTIA

NORAD/NORTHCOM

USSTRATCOM

JSC



USCG NAVCEN
(surface)

FAA NOCC
(airspace)

Patriot Watch Customer Base/Users

Reporting a GPS RFI Incident

NAVIGATION CENTER

The Navigation Center of Excellence

U.S. Department of Homeland Security

UNITED STATES COAST GUARD

Home | Consolidated Nav Info | DGPS Advisories | GPS Advisories / NANUs | GPS Testing Notices | LNMs | Almanacs | Nav Rules | AIS | Contact Us | Search

Primary Mission Areas:

- Global Positioning System
- Differential GPS
- Nationwide DGPS
- LORAN C
- Inland River Vessel Movement Center
- Long Range Identification and Tracking
- Civil GPS Service Interface Committee
- Automatic Identification System
- Nationwide AIS (NAIS)
- Electronic Navigation & Charting
- Maritime Telecommunications

Services & Reporting:

- Receive Free LNM Updates
- Receive Free GPS Status Messages
- Receive NANU Updates
- Join CGSIC (free)
- Report an ATON Discrepancy or Outage
- Report a GPS Problem
- Report a DGPS Problem
- Ask a Question or Report an AIS Problem
- Contact Us

October 6, 2010

NAVIGATION CENTER POINTS OF INTEREST

Current Operational / Safety Information

- Consolidated Nav Info
- DGPS Site Status
- GPS Ops Advisories & NANUs
- GPS Almanacs
- GPS Interference Notices
- Local Notice to Mariners
- Light List and Corrections
- Navigation Rules
- Navigation Regulations
- Navigation Safety Alerts

Maritime Information

- USCG "Homeport" Website
- Long Range Identification and Tracking
- Global Maritime Distress and Safety System
- CG Nat'l Distress System
- Digital Selective Calling
- Vessel Traffic Services
- VHF Channels & Freqs
- MF & HF Channels
- Nav Pubs and Documents
- Radio Watch Requirements
- Marine Safety Information Broadcasts
- Ports and Waterways Safety System

More About NAVCEN

- Mission Statement
- Contact Us
- Directions to NAVCEN
- Search Our Site
- Site Map
- Website Privacy Policy

News and Notices:

- RSS Feeds (LNMs, LL Corrections)
- Mariners are advised that over the course of the next several weeks, the Air Force will conduct an integration assessment of the current GPS Software Baseline. Please read the entire notice here...
- USCG cautions Mid-Atlantic (VA, MD, DE, PA, NJ, NY) AIS users that they may be operating on improper channels. Read the Safety Alert here...
- Online registration is now closed for the 50th meeting of the Civil GPS Service Interface Committee (USSLS/CGSIC), to be held Sept 20-21, 2010 at the Portland, Oregon, Convention Center in conjunction with the ION GNSS 2010 meeting. You may still register in person at the meeting. Read more...
- You may view the Joint Statement on cooperation and release of the recently-concluded documents for the combined use of GPS & Galileo and WAAS & EGNOS.
- The GPS Systems Wing announced the public release of On Orbit Testing of the first GPS Block IIF Satellite. Read the announcement for details and watch this site for release of the test schedule.
- Coast Guard encourages prudent use of AIS messaging. Please review USCG Safety Alert 05-10 and our AIS Frequently Asked Questions and AIS Notices Section

Outage Report

- Long Range Identification and Tracking
- Civil GPS Service Interface Committee
- Automatic Identification System
- Nationwide AIS (NAIS)
- Electronic Navigation & Charting
- Maritime Telecommunications

Services & Reporting:

- Receive Free LNM Updates
- Receive Free GPS Status Messages
- Receive NANU Updates
- Join CGSIC (free)
- Report an ATON Discrepancy or Outage
- Report a GPS Problem
- Report a DGPS Problem
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Maritime Information:

- USCG 'Homeport' Website
- Vessel Traffic Services
- Global Maritime Distress and Safety System
- CG Nat'l Distress System
- Digital Selective Calling
- Marine Safety Information Broadcasts
- VHF Channels & Freqs
- MF & HF Channels
- Digital Selective Calling
- Nav Pubs and Documents
- Radio Watch Requirements

1) * Your Name:

2) * Email Address:

3) * Telephone number: [ie. - (703) 313-5900]

4)Preferred method and time to be contacted if additional information is necessary: Click Here For Choices / Click Here For Choices

5) *What was the start time and date of the GPS outage? Date: 10/06/2010 Time: Select Time Zone

6) * Is the GPS outage ongoing? Select

7) * Where did the outage occur? (LAT/LONG; Nearest City or landmark) Lat | Long | City/Landmarks

8) GPS user equipment make and model (receiver manufacturer and model, antenna type, etc...)?

Remaining Characters 3000

9) GPS installation type (aviation, marine, surveying, agriculture, transportation, timing)? Click Here For Choices Other:

10) What was the elevation of the GPS antenna? Click Here For Choices — Above Ground Level / Above Sea Level

11) What GPS frequency are you using? L1 (1227.6 MHz) L2 (1575.42 MHz)

12) How many satellites were being tracked at the time of the outage? Click Here For Choices

13) Which satellites were being tracked at the time of the outage? Don't Know SVN23/PRN32 SVN24/PRN24

14) What was the GPS receiver being used for at the time of occurrence?

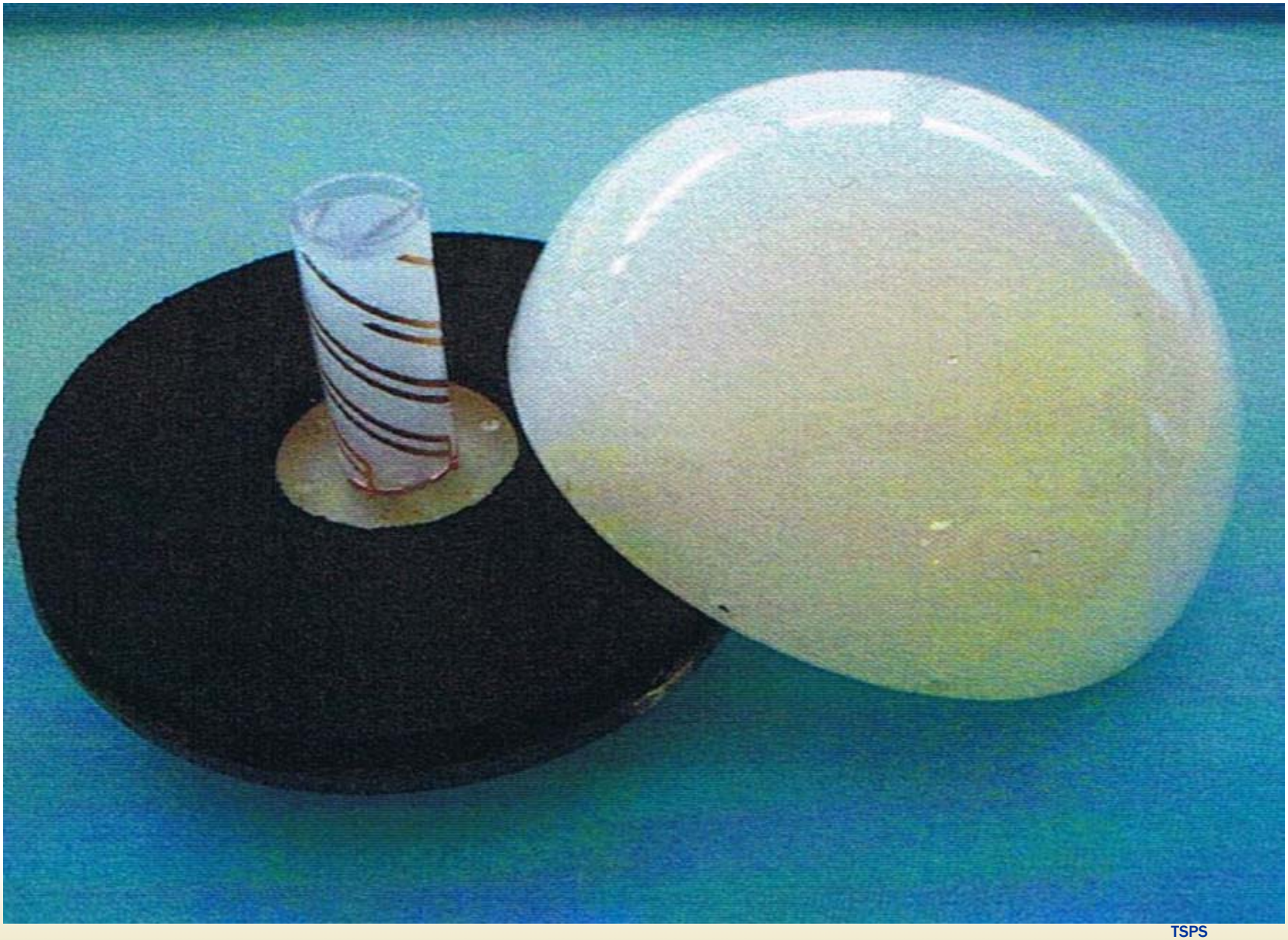
15) Summary (Please provide any additional information, unusual screen display indicating a problem and/or operator intervention that may have helped)?

Remaining Characters 3000

Multipath Mitigation Antenna Research

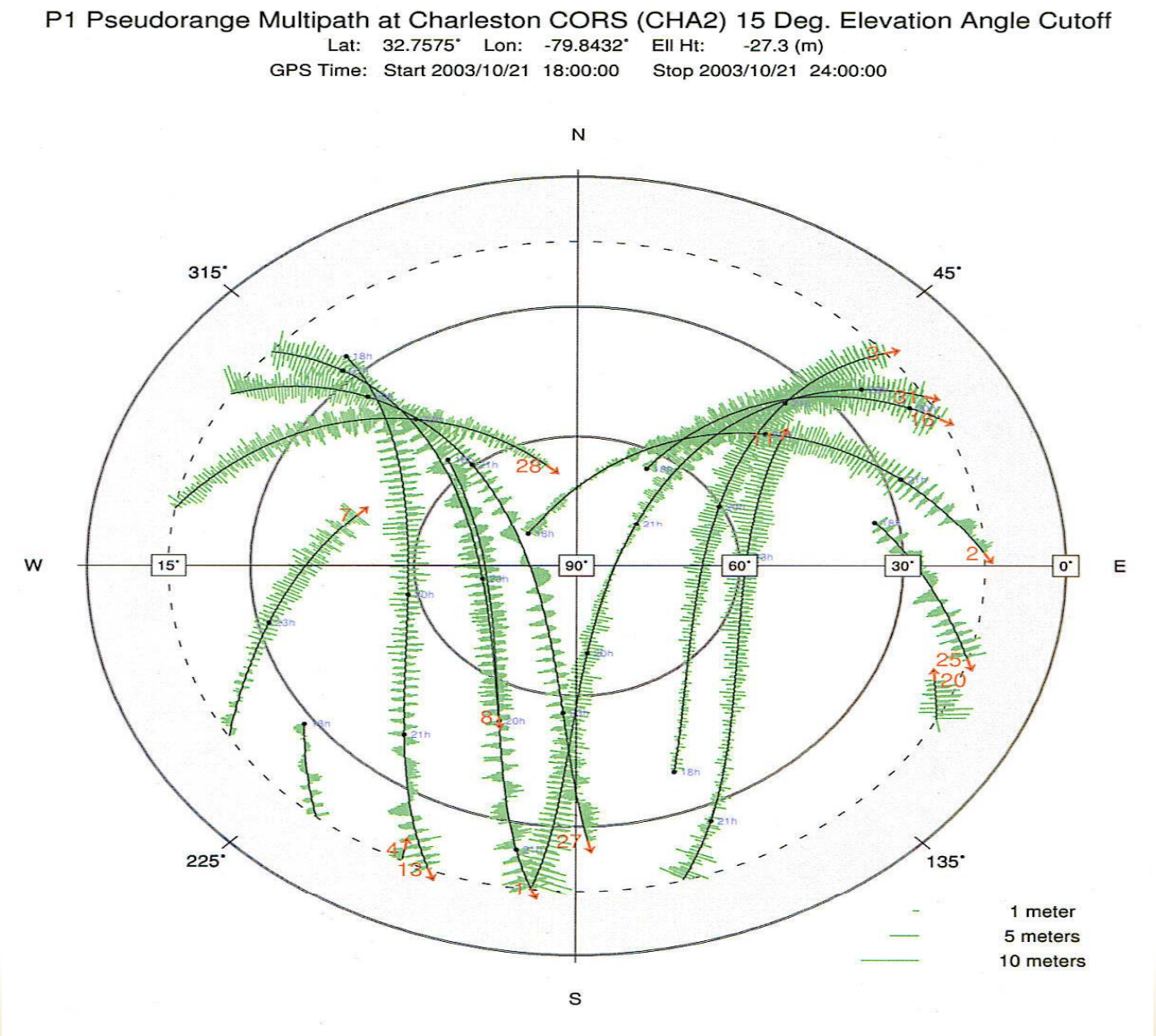
- Small Business Innovation Research (SBIR) Grants awarded to Toyon Research Corporation
  - Phase I and Phase II Grants
- Prototype Antenna delivered to NGS in August 2008
  - Tests conducted near a lighthouse in South Carolina
  - Objective is to evaluate multipath mitigation at high elevation angles
  - Compare results with choke ring antenna

Toyon L1 / L2 Antenna with Radome & Radar Absorbent Material (RAM)

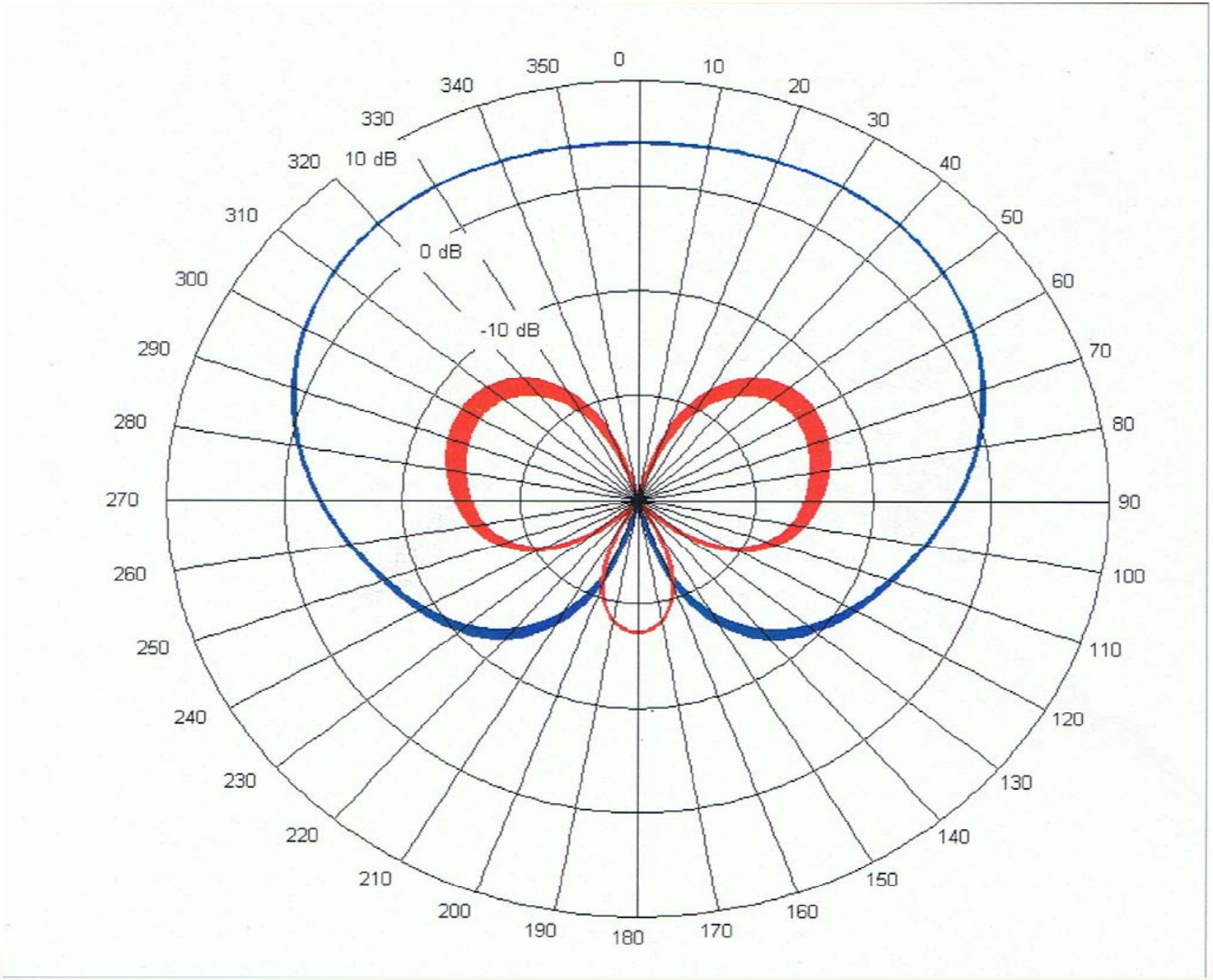


High Elevation Multipath Test Site Charleston, SC

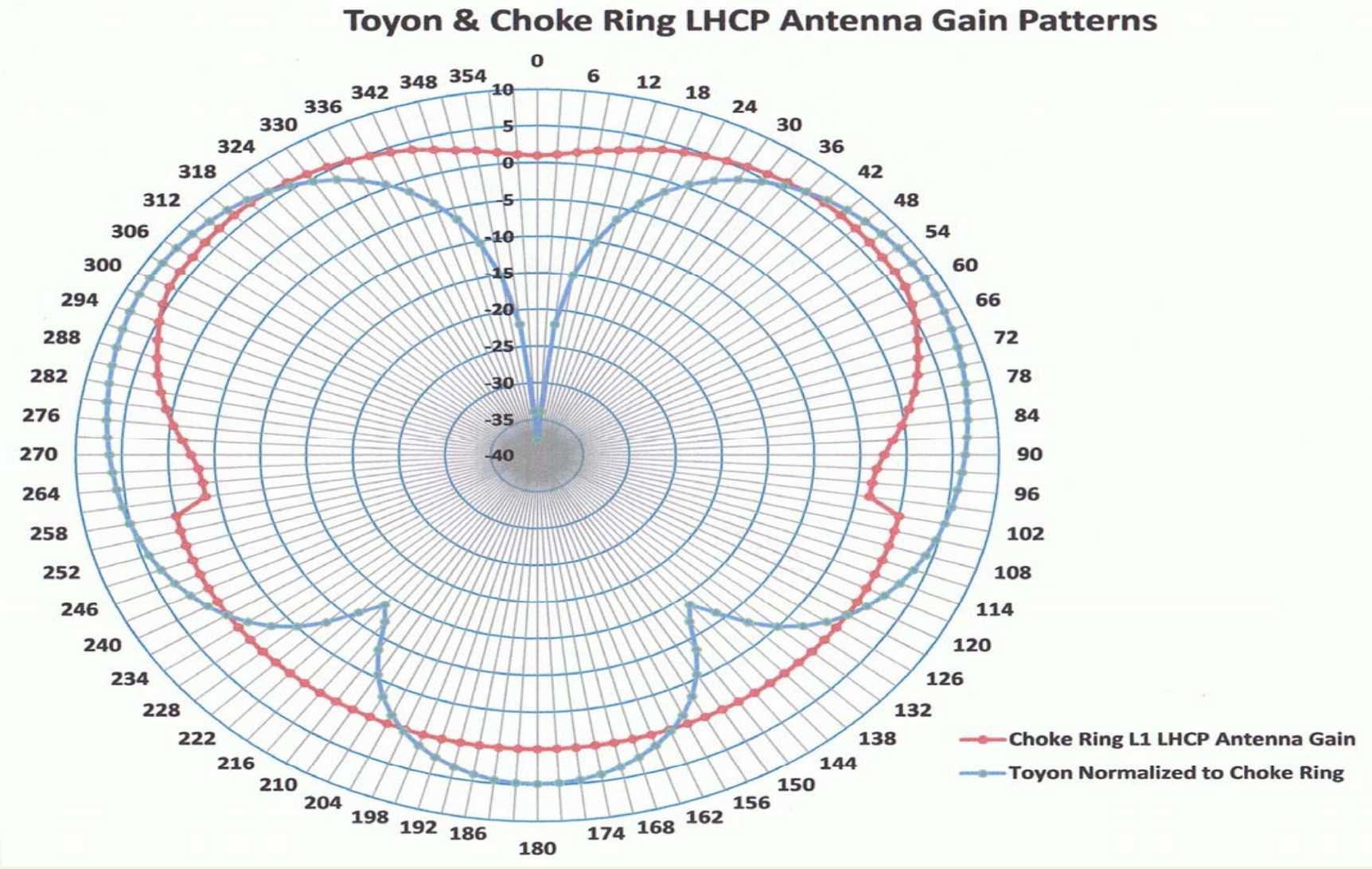
Multipath at Sullivan's Lighthouse Charleston, SC



Toyon Antenna Patterns (RHCP & LHCP)



LHCP Patterns



The Last Topic for This Morning!

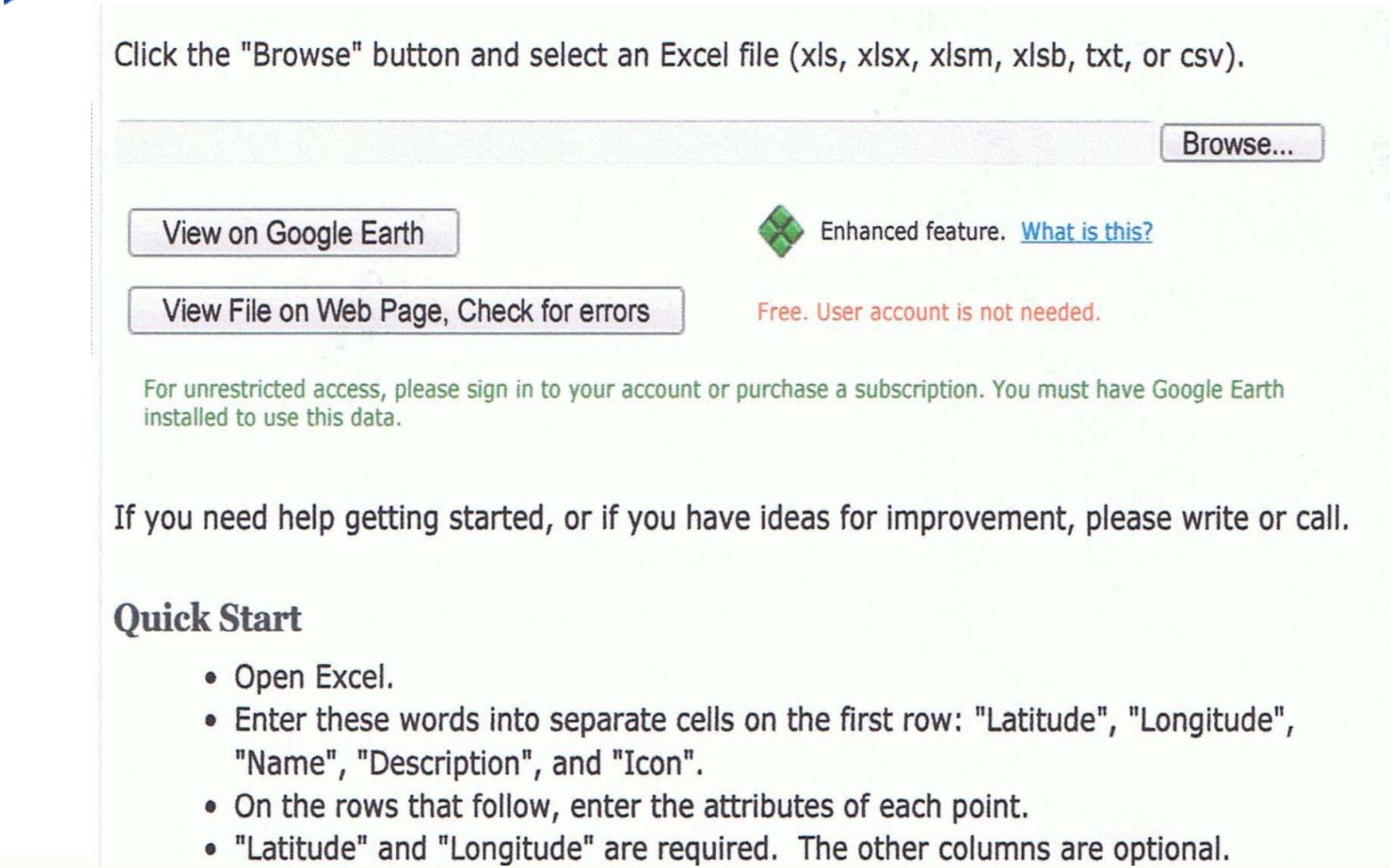
- **How to display large data sets on Google Imagery without becoming an GIS expert !**

California Tracklines Near Fault Line

A Useful Link to Rapidly Plot Large Data Sets on Google Earth

- http://www.earthpoint.us/ExcelToKml.aspx
- Application processes an excel spreadsheet of lat/long coordinates and displays the coordinates in Google Earth.
- State Plane coordinates for the United States are supported.
- Initially no cost to display large data sets; now a nominal charge for up to 10,000 data points for a single run.

Quick Start Instructions (Page 1)



Click the "Browse" button and select an Excel file (xls, xlsx, xlsm, xlsb, txt, or csv).

Browse...

View on Google Earth

Enhanced feature. What is this?

View File on Web Page, Check for errors

Free. User account is not needed.

For unrestricted access, please sign in to your account or purchase a subscription. You must have Google Earth installed to use this data.

If you need help getting started, or if you have ideas for improvement, please write or call.

Quick Start

- Open Excel.
- Enter these words into separate cells on the first row: "Latitude", "Longitude", "Name", "Description", and "Icon".
- On the rows that follow, enter the attributes of each point.
- "Latitude" and "Longitude" are required. The other columns are optional.

Quick Start Instructions (Page 2)

Required Columns

Column Heading	Default Value	Description
Latitude	None	Latitude of point. Google Earth uses the WGS84 geodetic datum. Valid formats include: N43°38'19.39" 43°38'19.39"N 43 38 19.39 43.63871944444445 If expressed in decimal form, northern latitudes are positive, southern latitudes are negative. If blank or invalid, item is not displayed on Google Earth.

Quick Start Instructions (Page 3)

Basic Optional Columns

Column Heading	Default Value	Description
Name	None	The text displayed next to the icon on Google Earth. If blank, no text is displayed.
Description	None	The text displayed in the Google Earth pop-up balloon. An Excel formula can be used to combine text from several columns. For example, to display data from columns D, E, and F, with each of D, E, and F on its own line, and supposing we are on row 6, the Description column formula is =D6 & " " & E6 & " " & F6 where is the html tag for a new line. HTML tags are allowed. Note to HTML authors: Except for specifying font color, the HTML "style" attribute is ignored by Google Earth. Earlier formatting methods must be used, as illustrated in the sample data ExcelToKmlDemo.zip. If blank, no balloon is displayed.
Icon		Either: 1) A integer between 1 to 279, which designates an icon selected from the table below; or 2) The URL of an icon stored on a web site; or 3) the word "none". If the file cannot be found, Google displays  . If "none", no icon is displayed. If blank,  is displayed.

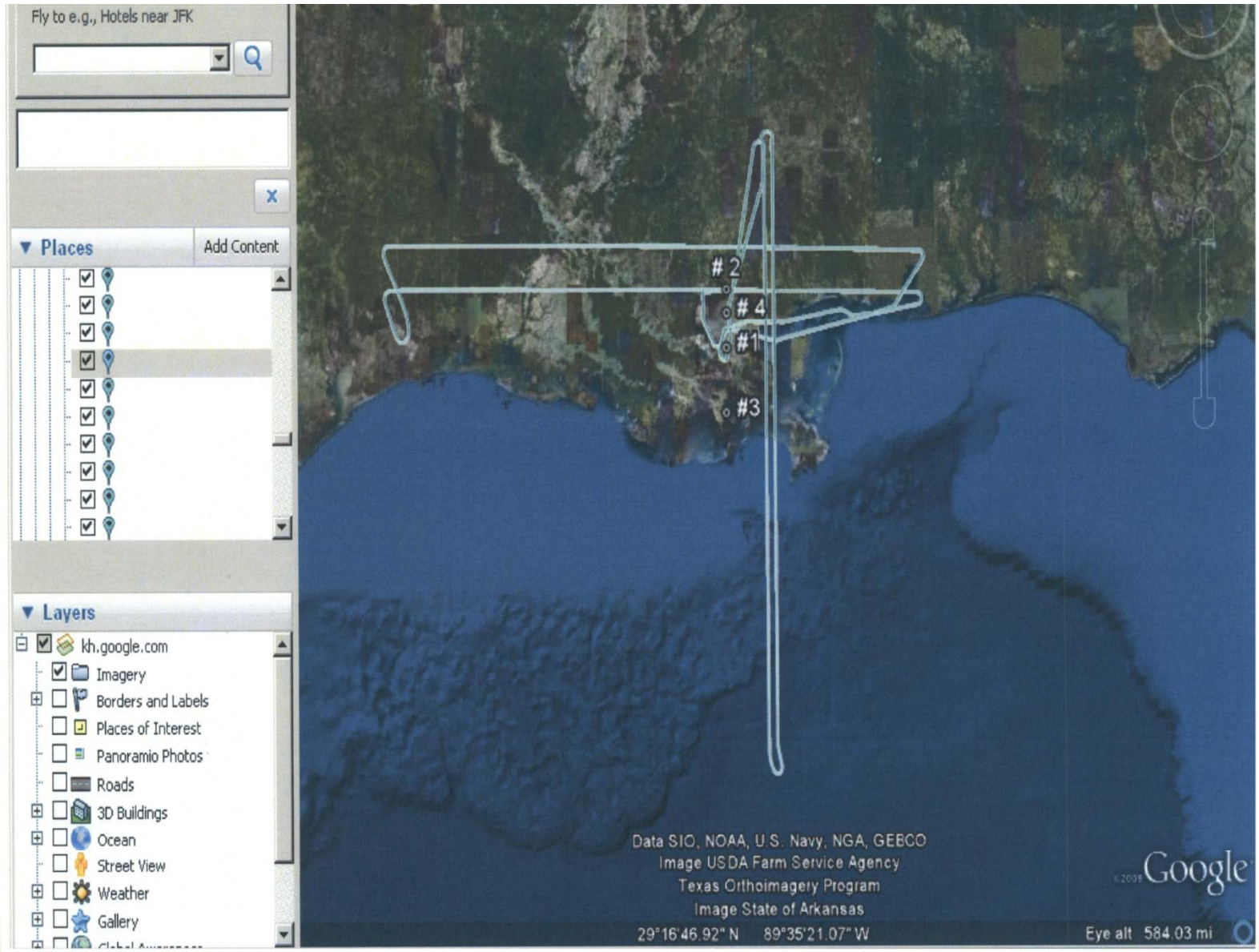
Quick Start Instructions (Page 4)

IconScale	1	A decimal number that increases or decreases the display size of the icon. Typical values are in the range of .5 to 1. No matter how big or small an image actually is, Google Earth displays it according to the scale. For example,  Scale=1 Scale=.7 Scale=1.5 If blank, scale is 1.

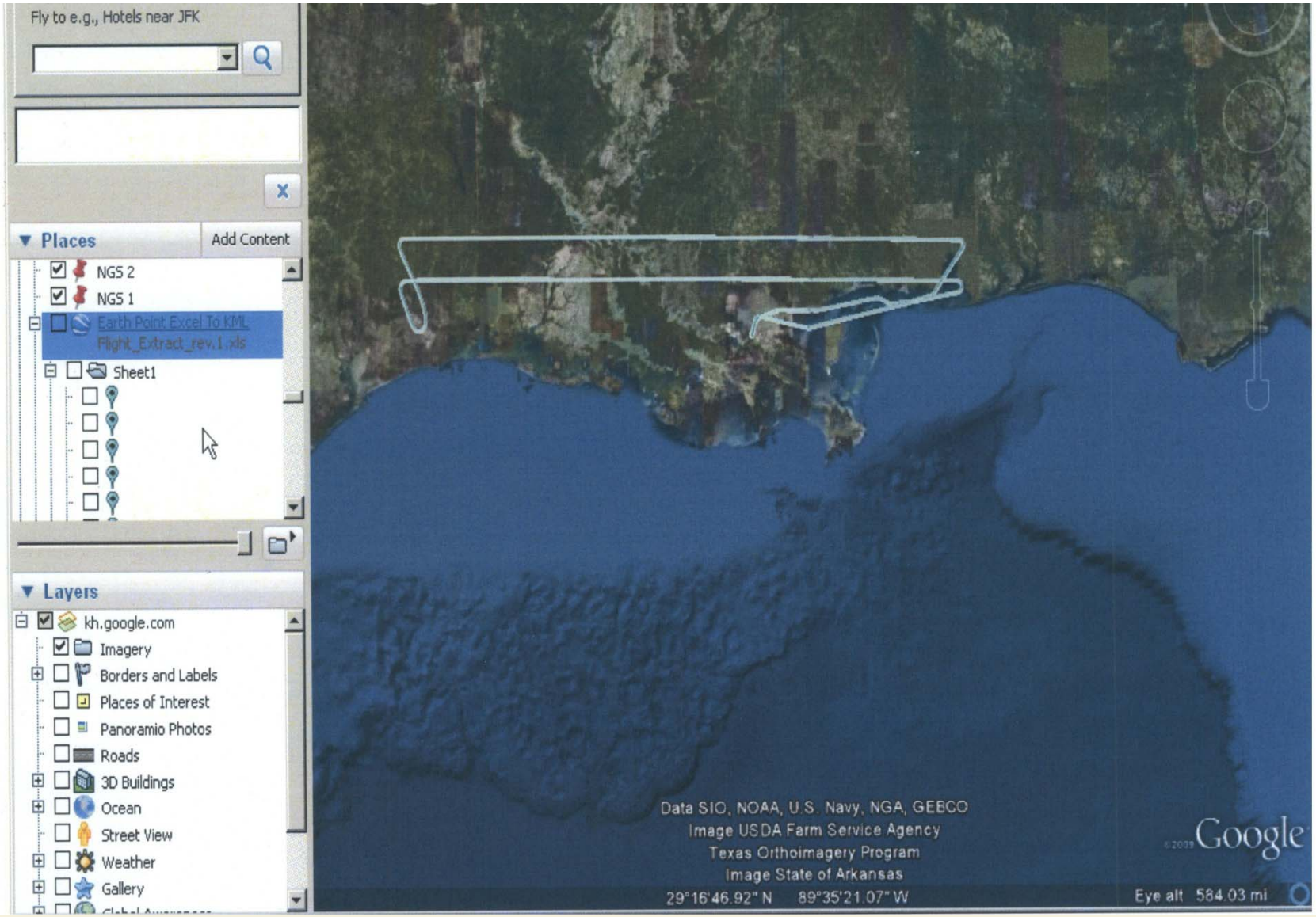
Louisiana Tracklines Excel Spreadsheet

Latitude	Longitude	Name	Description	Icon	AppendLatLonToDescription	Folder	HideNameUntilMouseOver	IconScale
29.99756961	-90.26522301							0.1
29.99756963	-90.26522299							0.1
29.99756964	-90.26522299							0.1
29.99756948	-90.26522295	***Basic Optional Columns***						0.1
29.99756963	-90.26522301							0.1
29.9975697	-90.26522302				***Advanced Optional Columns----------->***			0.1
29.99756967	-90.26522293							0.1
29.9975696	-90.26522293							0.1
29.99756963	-90.26522298							0.1
29.99756962	-90.26522302							0.1
29.99756962	-90.26522296							0.1
29.99756957	-90.265223							0.1
29.99756958	-90.26522299							0.1
29.99756961	-90.26522296							0.1
29.99756963	-90.26522302							0.1
29.99756965	-90.26522299							0.1
29.99756958	-90.26522294							0.1
29.99756954	-90.2652229							0.1
29.99756958	-90.26522294							0.1
29.99756959	-90.26522297							0.1
29.99756958	-90.26522301							0.1
29.99756964	-90.26522298							0.1

Louisiana Tracklines



Louisiana East - West Trackline



References

- [1] National Positioning, Navigation, and Timing Architecture Study Final Report, September 2008 http://www.acq.osd.mil/nsso/pnt/PNT Architecture Final Report_PublicRelease%20Signed%20Version_Sep%2008.pdf

SPACE-BASED POSITIONING
NAVIGATION & TIMING

NATIONAL COORDINATION OFFICE

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Washington, D.C. 20230

Tel: +1 (202) 482-5809
Email: **PNT.office@PNT.gov**

Backup Slides

Gravity for the Redefinition of the American Vertical Datum (GRAV-D)

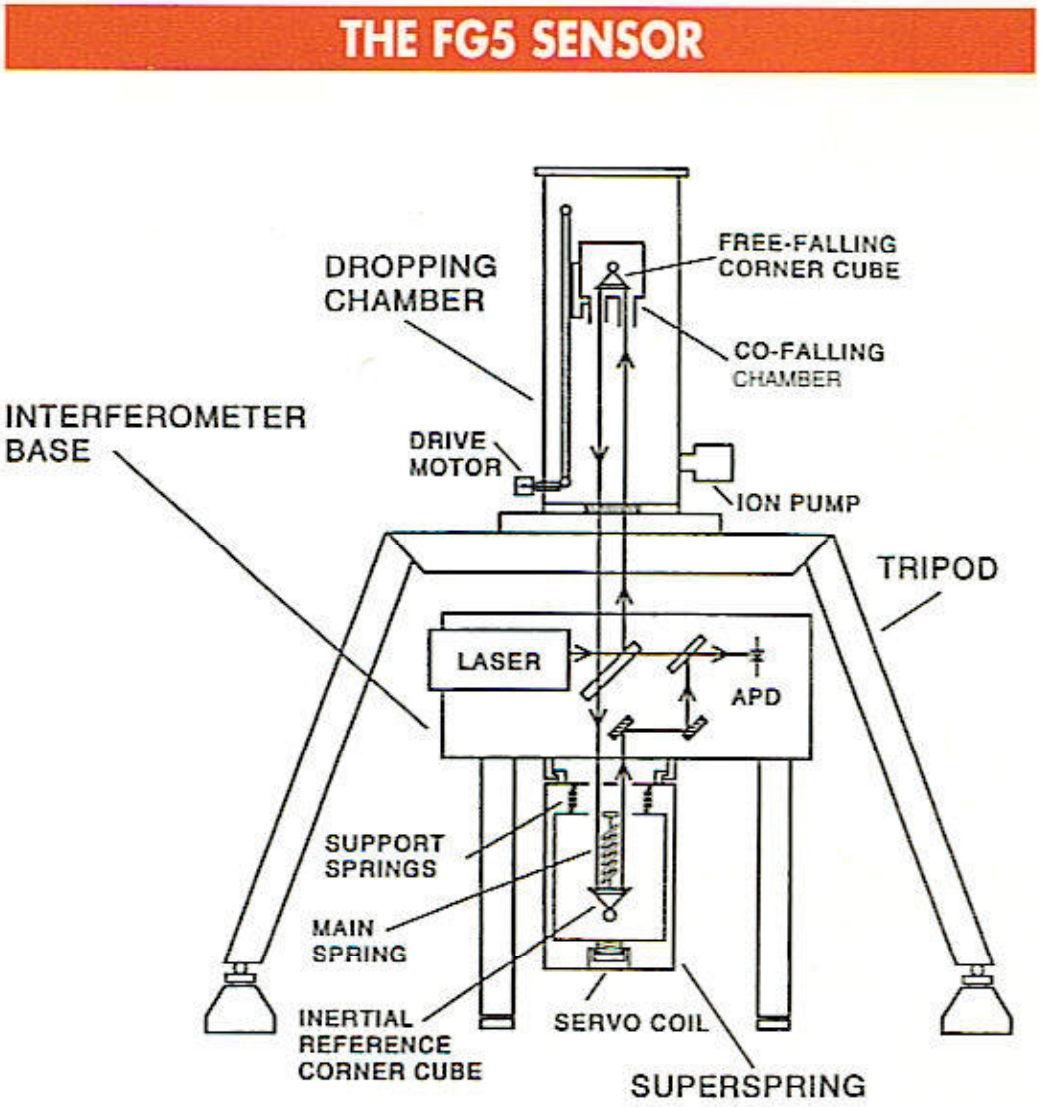
- **GRAV-D is a proposal by the National Geodetic Survey to re-define the vertical datum of the US by 2021.**
  - The gravity-based vertical datum resulting from this project will be accurate at the 2 cm level for much of the country.
- **The GRAV-D project consists of three major campaigns:**
  - 1. A high-resolution "snapshot" of gravity in the US:
    - This is a predominantly airborne campaign with The highest priority targets are: Alaska, Puerto Rico and the Virgin Islands, the Gulf Coast, the Great Lakes, and Hawaii.

Gravity for the Redefinition of the American Vertical Datum (GRAV-D)

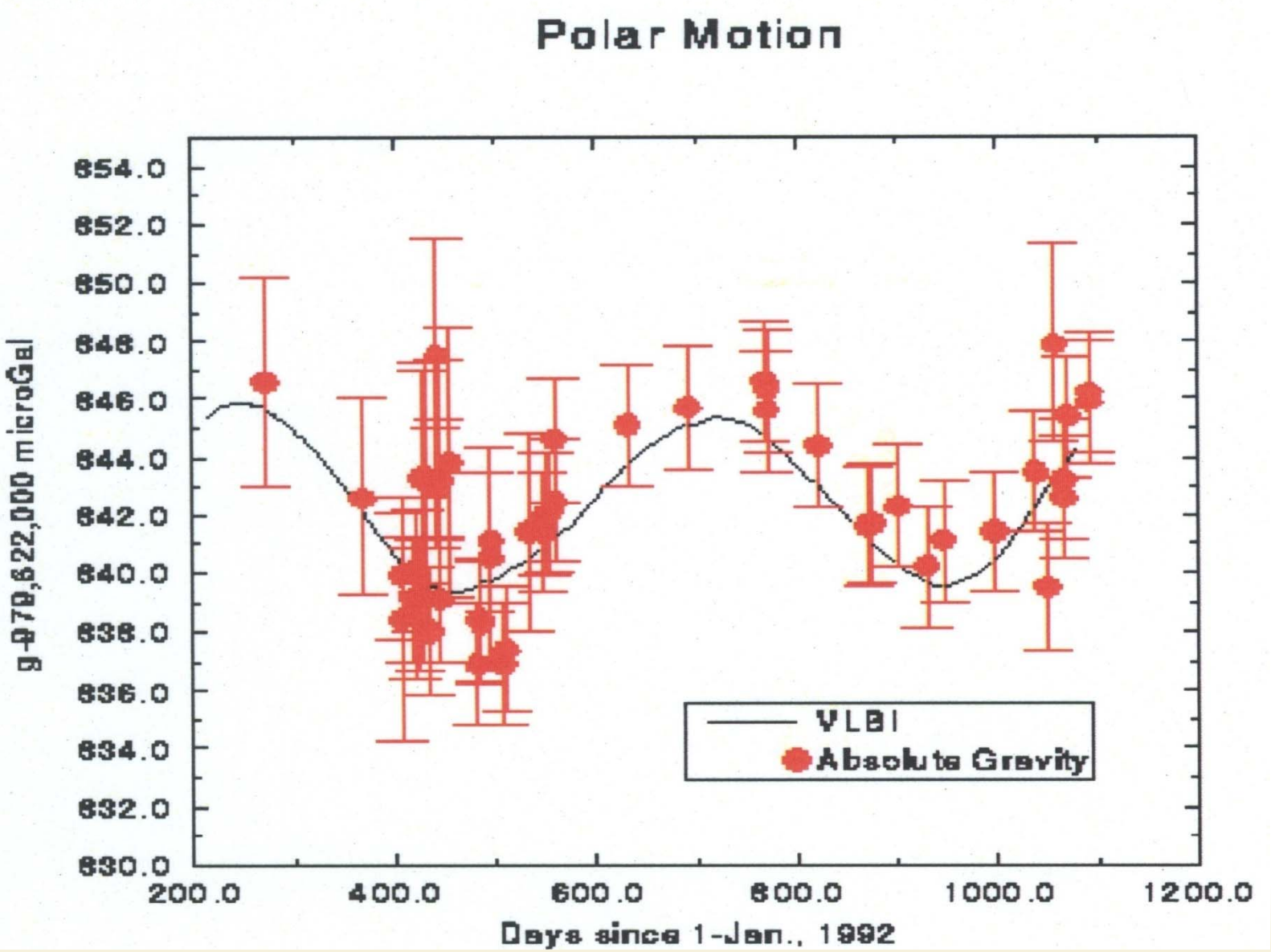
- 2. A low-resolution "movie" of gravity changes:
  - This is primarily a terrestrial campaign and will mostly encompass episodic re-visits of absolute gravity sites, attempting to monitor geographically dependent changes to gravity over time.
- 3. Regional partnership surveys:
  - NGS seeks to collaborate with local (governmental, commercial, and academic) partners throughout the GRAV-D project. Partners that are willing to support airborne or terrestrial surveys or to monitor local variations in the gravity field are a critical component of GRAV-D.

Absolute Gravimeters

FG-5 Sensor Diagram



Absolute Gravimeter Data



NGS Phase I and Phase II SBIR

NOAA Mobile Absolute Gravimeter
A prototype small absolute gravimeter was developed by Micro-g Solutions Inc. for NOAA under Phase II SBIR contract #50-DKNA-6-90138. Delivery of the prototype was taken in June 1998 and first tests were conducted on the Rocky Mountain Calibration Line near Idaho Springs, CO in mid November.

Micro-g Solutions Mobile Absolute Gravimeter Prototype A-10

A10 Instrument Deployed During Winter Field Survey in Colorado

A-10 deployed near Tucker Snocat in Prudhoe Bay, Alaska, 2002.

The tent will be used as a wind block. (-20C)

Deployment in Alice Springs, Australia

A-10 deployed in Alice Springs, Australia, 2003. (+30C)