GPS Workshop

NY GeoCon

Saratoga Springs, New York

Presented by:

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Waypoint Technology Group, LLC

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Topics

- Cosmic Day
- The B.Y.O.D. Revolution
- GPS Infrastructure Developments
- Show Us Your Stuff

Definitions

B.Y.O.D. – Bring Your Own Device

GPS - Global Positioning System

GLONASS – Russian “GPS”

GNSS - Global Navigation Satellite System

GNSS = GPS + GLONASS

SBAS = Satellite Based Augmentation System

RTN = Real-Time Network

Cosmic Day

Cosmic Day = 11-12-13

The B.Y.O.D. Revolution

B.Y.O.D – What Does It Mean?

Bring Your Own Device:

Companies leveraging employee-owned, connected, spatially-aware hardware devices for data collection, communication, analysis, and decision-making.

B.Y.O.D – What Does It Mean?

- “Non-professional” workers can contribute to spatial data collection
- Mixed “fleets” of hardware becoming increasingly common
- Variable accuracy
- Utilization of “on-demand” and/or “pay-as-you-go” solutions

B.Y.O.D – Pros

- Reduced Employer Hardware Costs
- Device-Agnostic (Typically)
- Immediate User Familiarity = Reduced Training Costs
- Access to a Vast “Army” of Contributors
- Software / App Distribution & Update Ease (via Cloud)
- Data Definition Distribution & Update Ease (via Cloud)

B.Y.O.D – Cons

- Data security
- Data integrity
- Data ownership
- Platform/hardware inconsistencies
- Software / App availability and compatibility
- Technical support responsibility
- Hardware replacement issues

Software / App Examples

- ArcGIS for Windows Mobile (ESRI)
- Collector for ArcGIS (ESRI)
- doForms
- Field2Base (Fulcrum)
- GeoJot (Geospatial Experts)
- GISRoam (Cogent3D)
- Myriad Private / Third Party Solutions
- Terra Flex (Trimble)

The TerraFlex Solution

- **Cloud: Data, Project, and User Management**
  - Form template definition and management
  - Project creation and assignment
  - User management
  - Data management and import/export
- **Mobile: Data Collection and Syncing**
  - Form fulfillment
  - Dynamic syncing

Terra Flex

Business Model

- Free Mobile App
- Back-end / Cloud Subscription
- On-line Help and Support

Trimble TerraFlex Basics

Cloud based solution for mobile field data collection

Subscription based web services as well as iOS and Android

Trimble TerraFlex Workflow

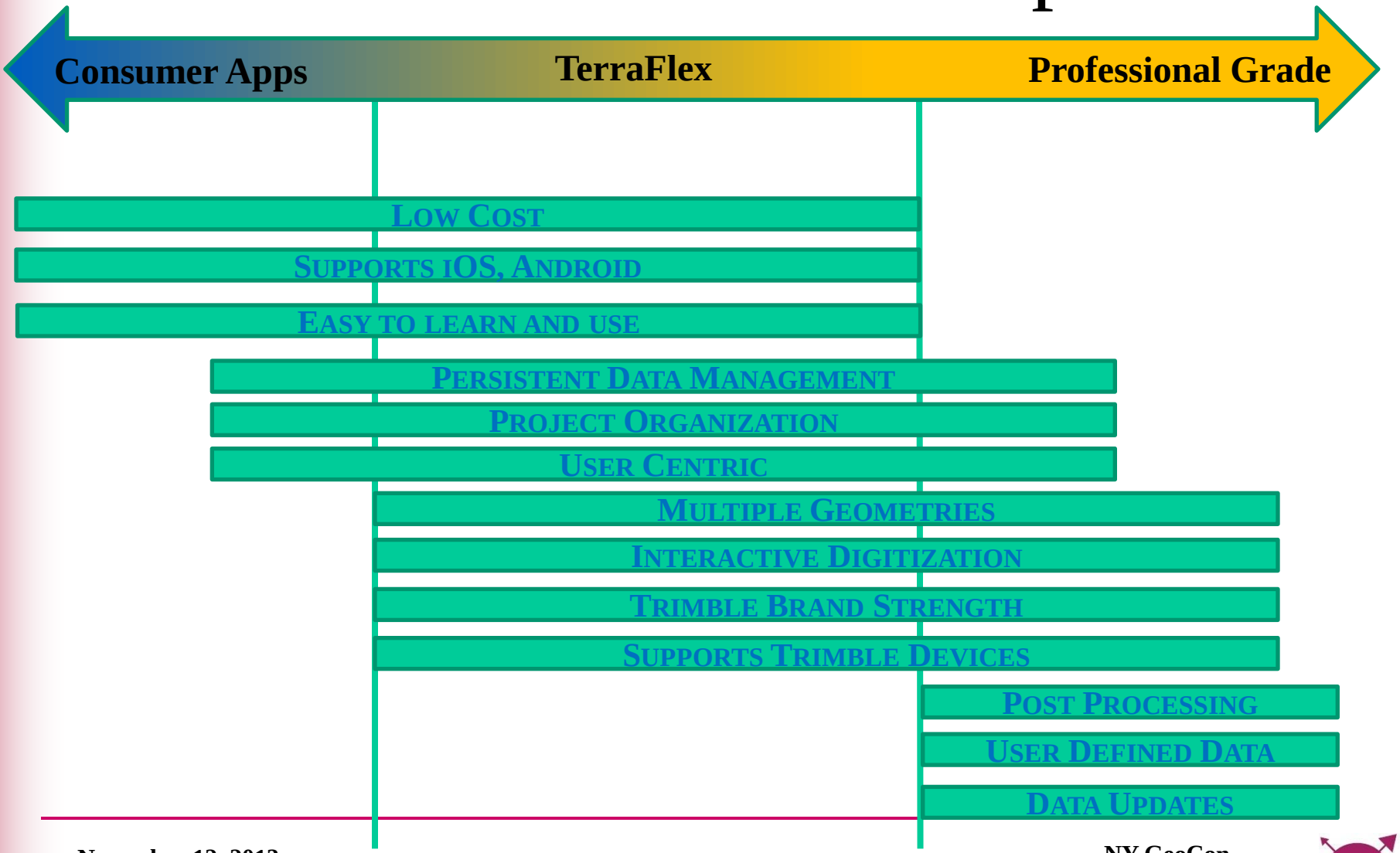
Terra Flex - Features/Benefits

Customer Need	Feature	Benefit / Value
Different data collection needs	Dynamic form template creator: • Text • Numeric • Multi-select • Single select	• Fast, easy, efficient
Field workers on a variety of devices, sometimes even their own	Supports iOS, Android, Windows Embedded Handheld	• Consistent, easy-to-use, confidence in the data
Different field workers work on different projects.	Projects: Manage your data and users	• Organized data • Focused crews

Terra Flex - Features/Benefits

Customer Need	Feature	Benefit / Value
Getting all of the field data back into the office and entered in	Field-Office syncing	Faster and more accurate
Field users need to work in remote areas	Offline capabilities	Uninterrupted productivity
Data portability	Import and export with common formats like Esri ArcGIS XML schema, CSV, and Google KML	Interoperability
Don’t have resources to manage another system	Managed, hosted services	Cost-efficient, immediate productivity

What Sets TerraFlex Apart?



How Do I Get It on My Mobile Device?

www.trimble-terraflex.com

Terra Flex

Supported Devices

- **iOS 5 and greater**
- **Android 4.x**
- **Windows Mobile/WEH 6.x**

GPS Infrastructure Developments

Differential Correction

Let's review…

What is it??

…….the process of correcting GPS data collected by a user, with data recorded simultaneously at a base station, in order to improve accuracy.

Differential Correction

Two methods:

- Post-processed
- Real-Time

We'll focus on Real-Time….

Real-time Differential GPS

Benefits of Real-time Functionality

- Navigation
- Eliminate post-processing
- Locate proposed features
- Relocate existing features
  - that are broken and need repair
  - update GIS attributes
  - prior to construction

Real-Time DGPS Sources

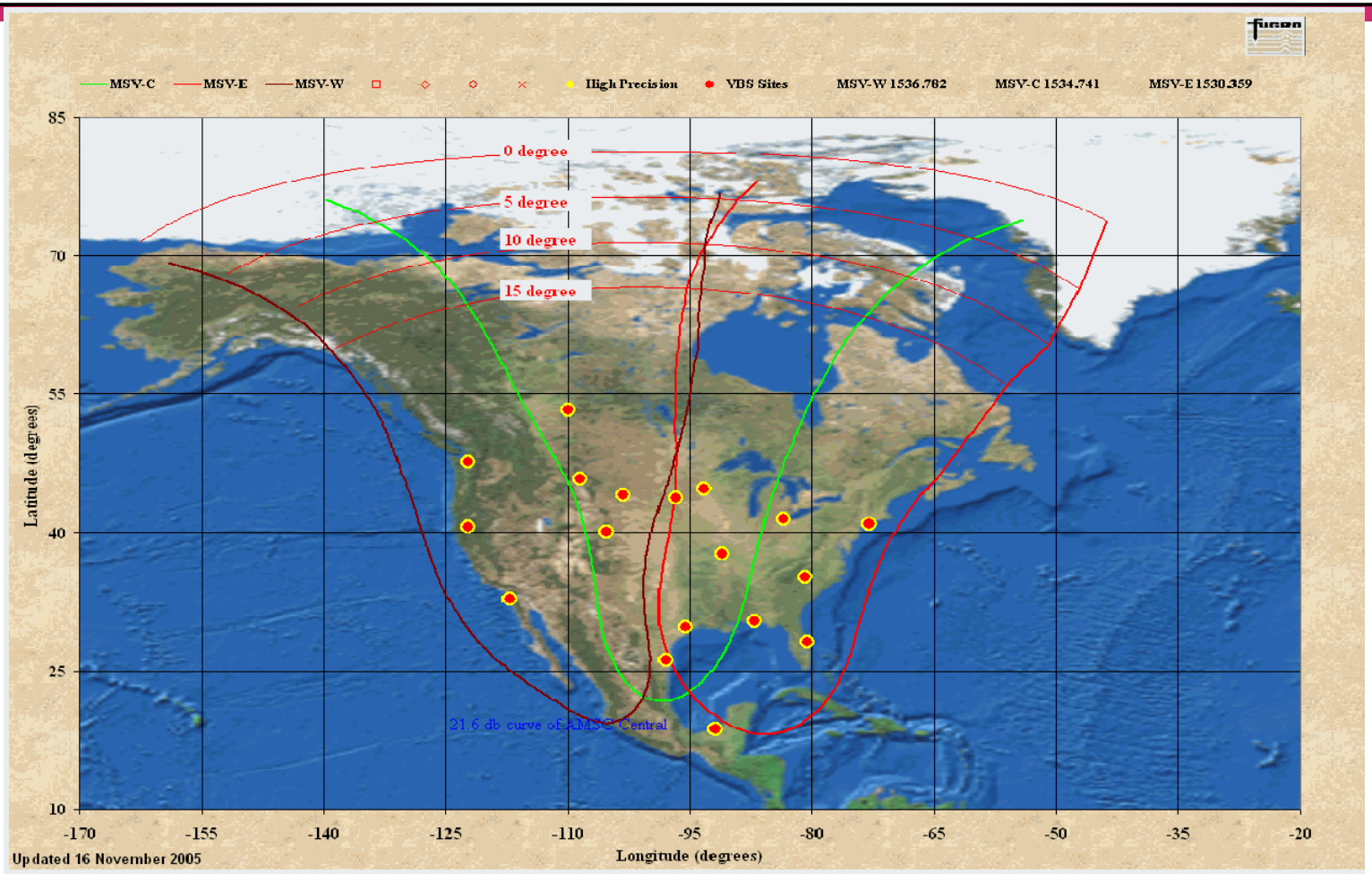
- Subscription Satellite-based Corrections
- Radio Beacon (Ground-based) Correction
- Satellite-Based Augmentation Systems (SBAS)
- Regional/Statewide RTN's

Subscription Satellite-based Corrections

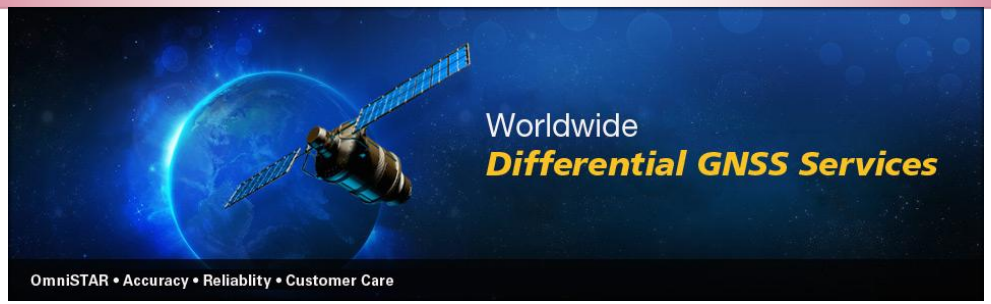
Operated by Private Enterprise (Omnistar)

- Space-based service
- Line-of-sight required
- Fee-based business model
- Significant service area (i.e. continental)
- Variable accuracy, and priced accordingly

OmniStar Coverage



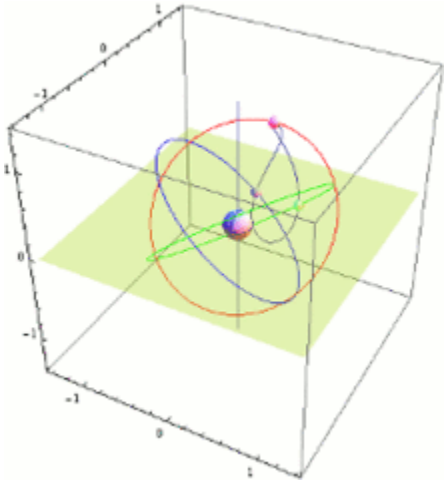
OmniStar Services



Service	Horizontal Accuracy
VBS	+/- 1-meter
XP	+/- 15 cm
HP	+/- 10 cm
G2	+/- 15 cm

Satellite-Based Augmentation Systems (SBAS)

- Wide Area Augmentation System (WAAS) – FAA
- European Geostationary Navigation Overlay Service (EGNOS)
- Quasi-Zenith Satellite System (QZSS) - Japan

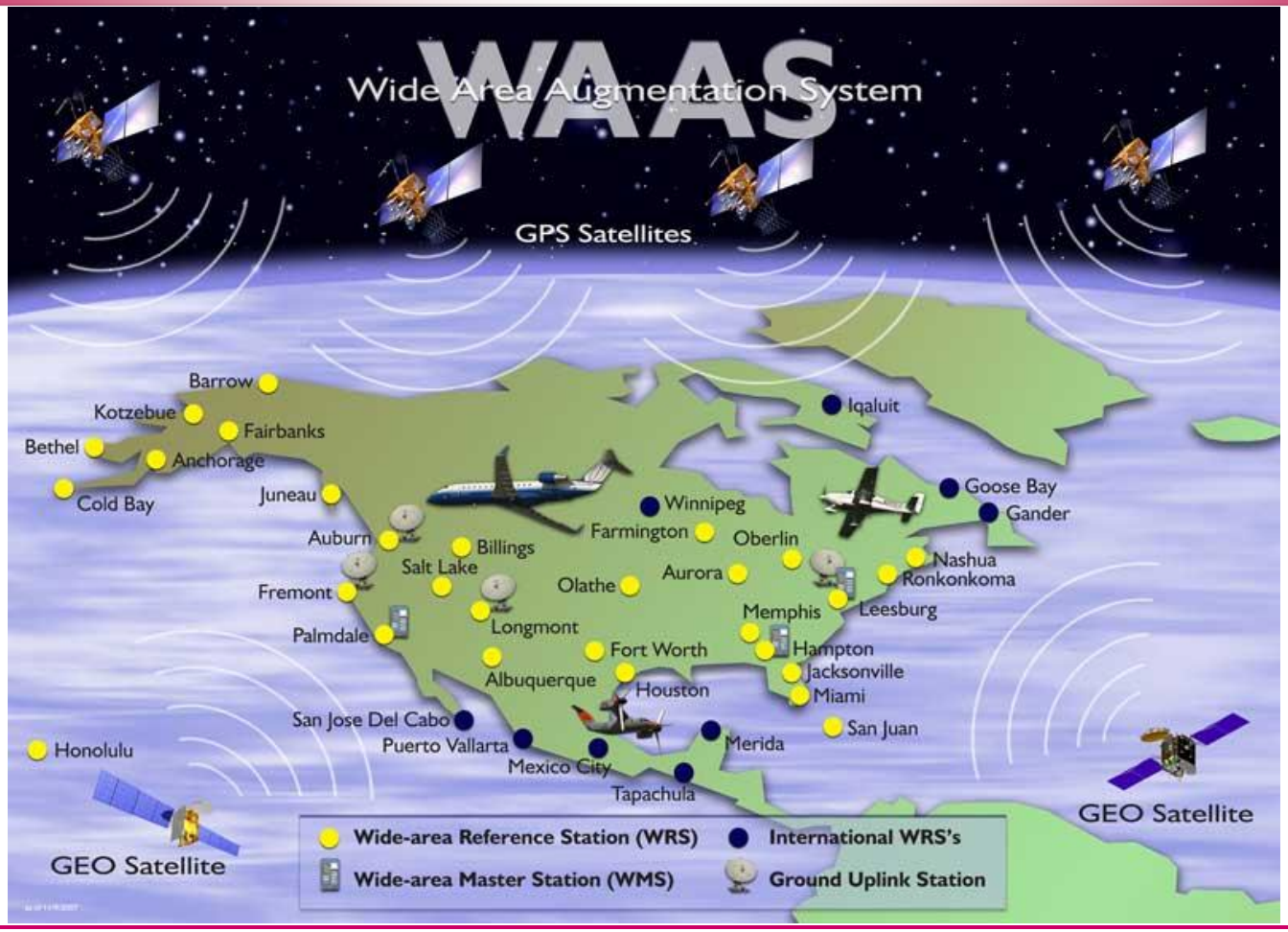


Satellite-Based Augmentation Systems (SBAS)

Operated by Federal Aviation Administration

- Space-based service
- Line-of-sight required
- Geostationary
- Free service
- Significant service area (i.e. continental U.S.)
- Limited to sub-meter accuracy
- Future not in doubt

WAAS Network

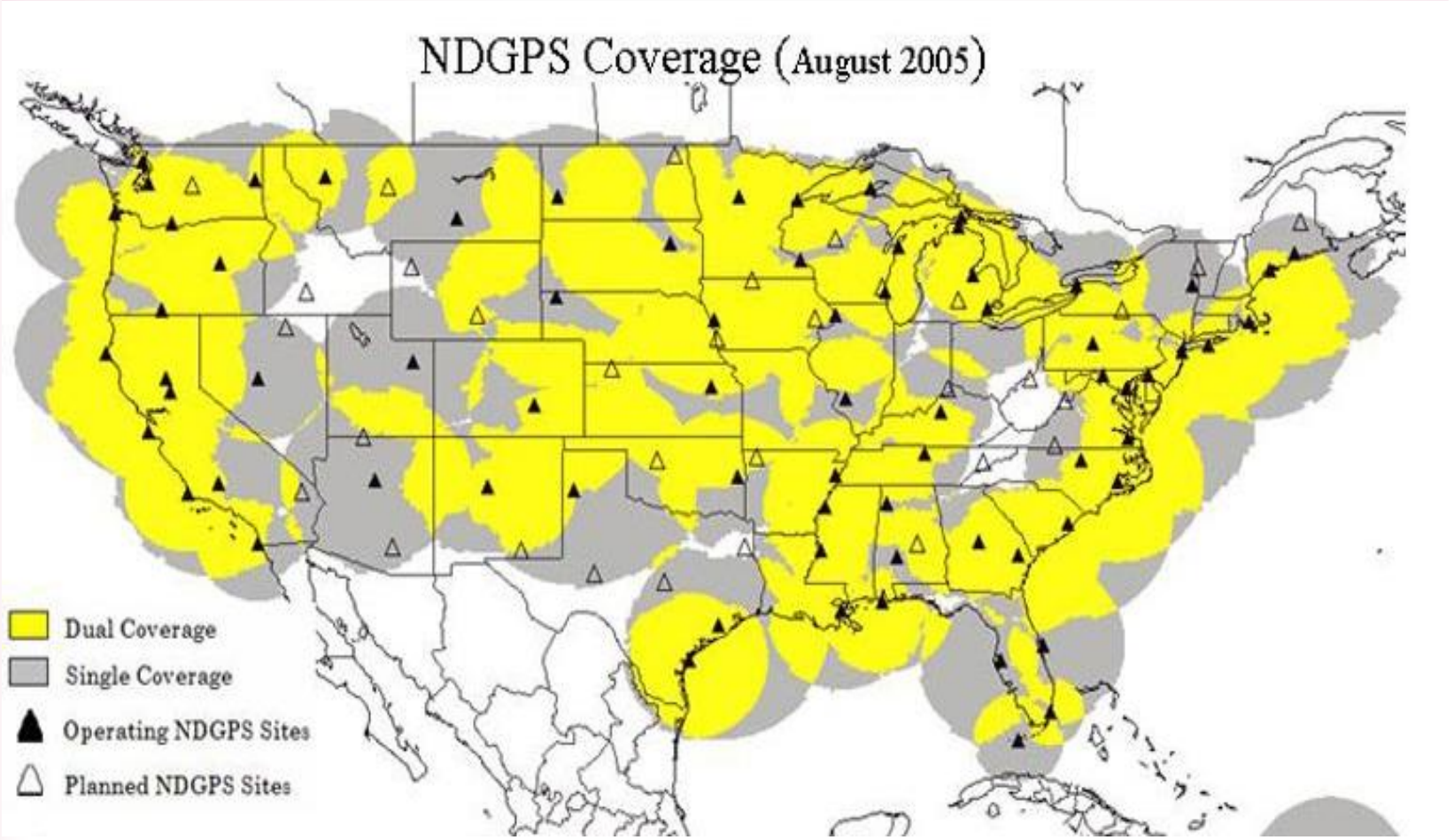


Radio Beacon

Operated by U.S. Coast Guard

- Ground-based service
- Line-of-sight NOT required
- Free service
- Limited service area
- Limited to sub-meter accuracy
- Additional hardware required
- Future is bleak

National USCG Beacon Coverage



Real-Time Networks

- Networks of reference (base) stations
- Public or private (free/subscription)
- Regional or state-wide (national in Europe)
- Serve post-processing and real-time DGPS purposes
- Often serve dual-frequency survey-grade (RTK) and mapping-grade (code) corrections

NYSNet Spatial Reference Network

- Operated by New York State DOT
- Reference stations available via NGS CORS website for post-processed DGPS (5-second data)
- Internal data available at 1-second epoch rate
- Streaming broadcast via TCP/IP (cell phone/modem) of RTK (real-time kinematic) corrections

NYSNet Spatial Reference Network

Summer ‘13 Status:

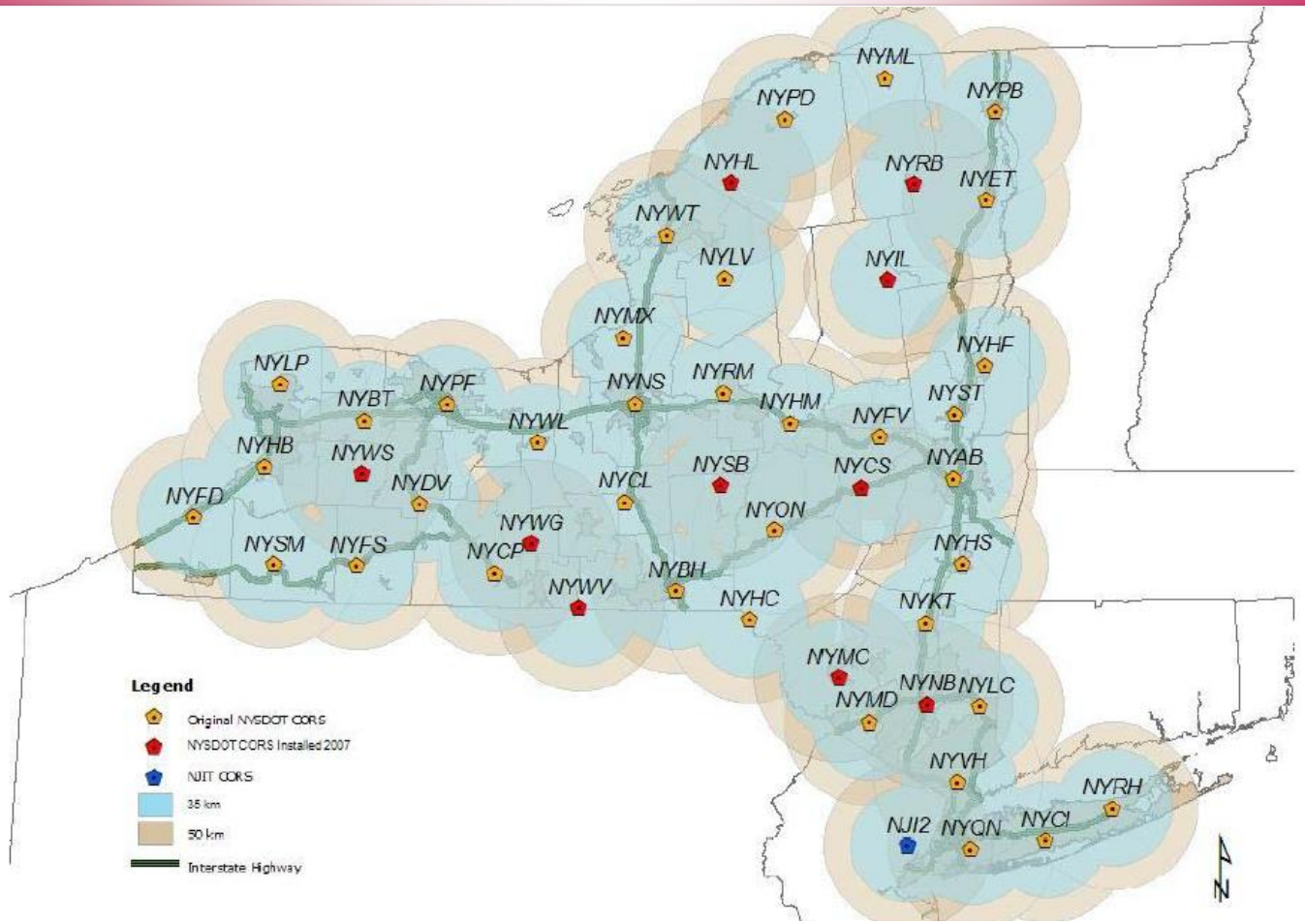
- 46 dual-frequency RTK corrections yield 1 – 2 cm horizontal positions, state-wide
- Also broadcasting code phase DGPS stream for Mapping/GIS users (sub-meter)
- Service is free & available in areas w/cell phone coverage

NYSNet Spatial Reference Network

- User must sign data use agreement
- NYSDOT provides user name and password
- NYSDOT monitoring of usage (e.g. duration, location)

Waverly, New York

Base Stations Serving New York State GPS Users

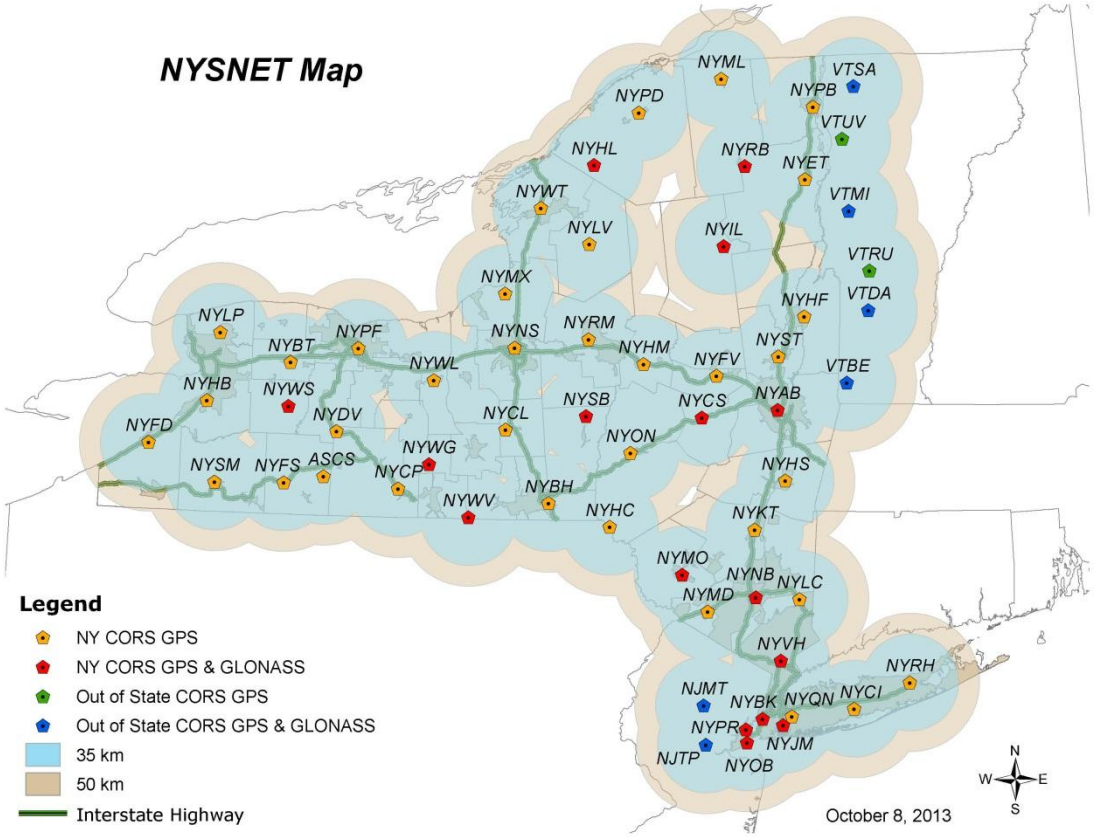


NYSNet Spatial Reference Network

Fall '13 Update:

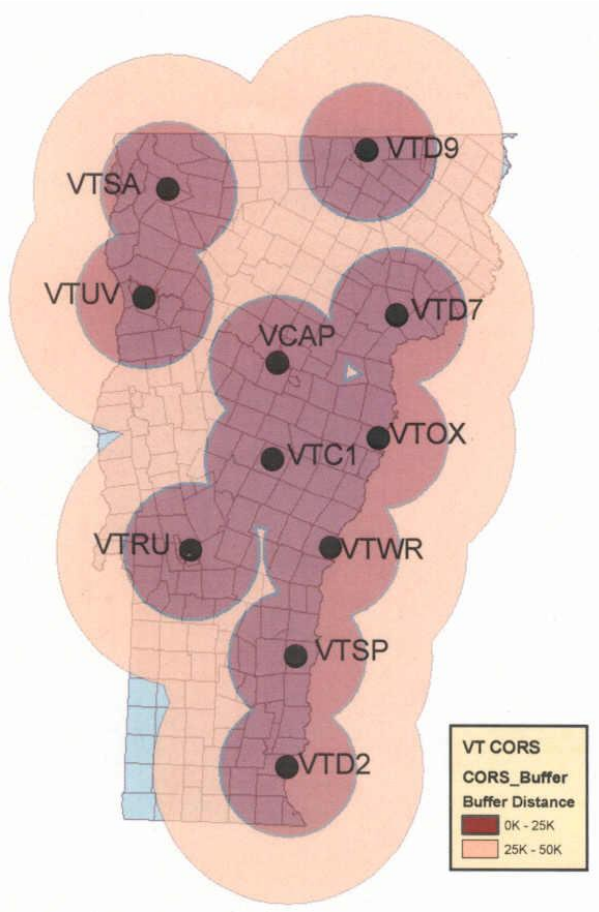
- GLONASS corrections added at 15 reference stations
- GLONASS corrections currently availability only via RTN
- Complemented by out-of-state (VT, NJ) reference stations

GLONASS Support

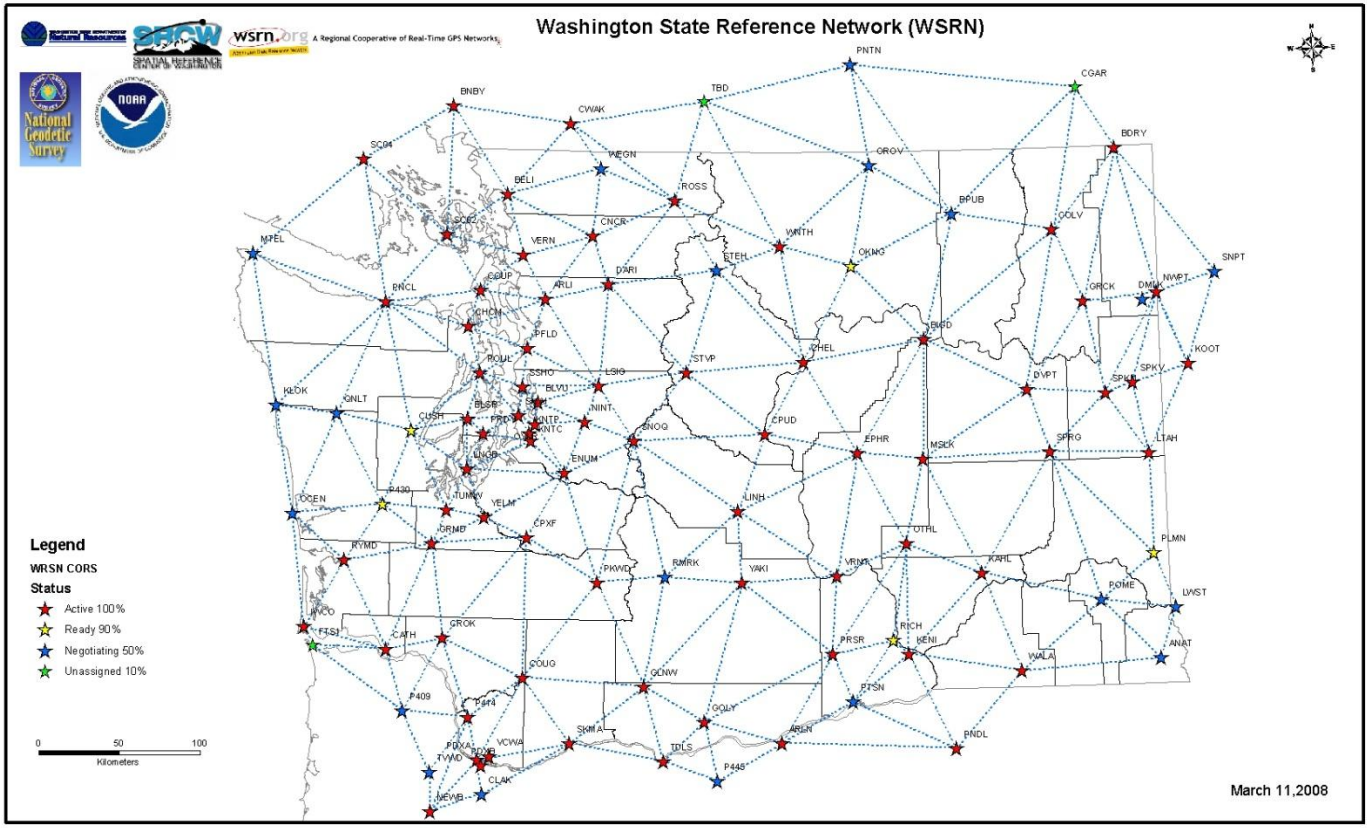


Vermont AOT

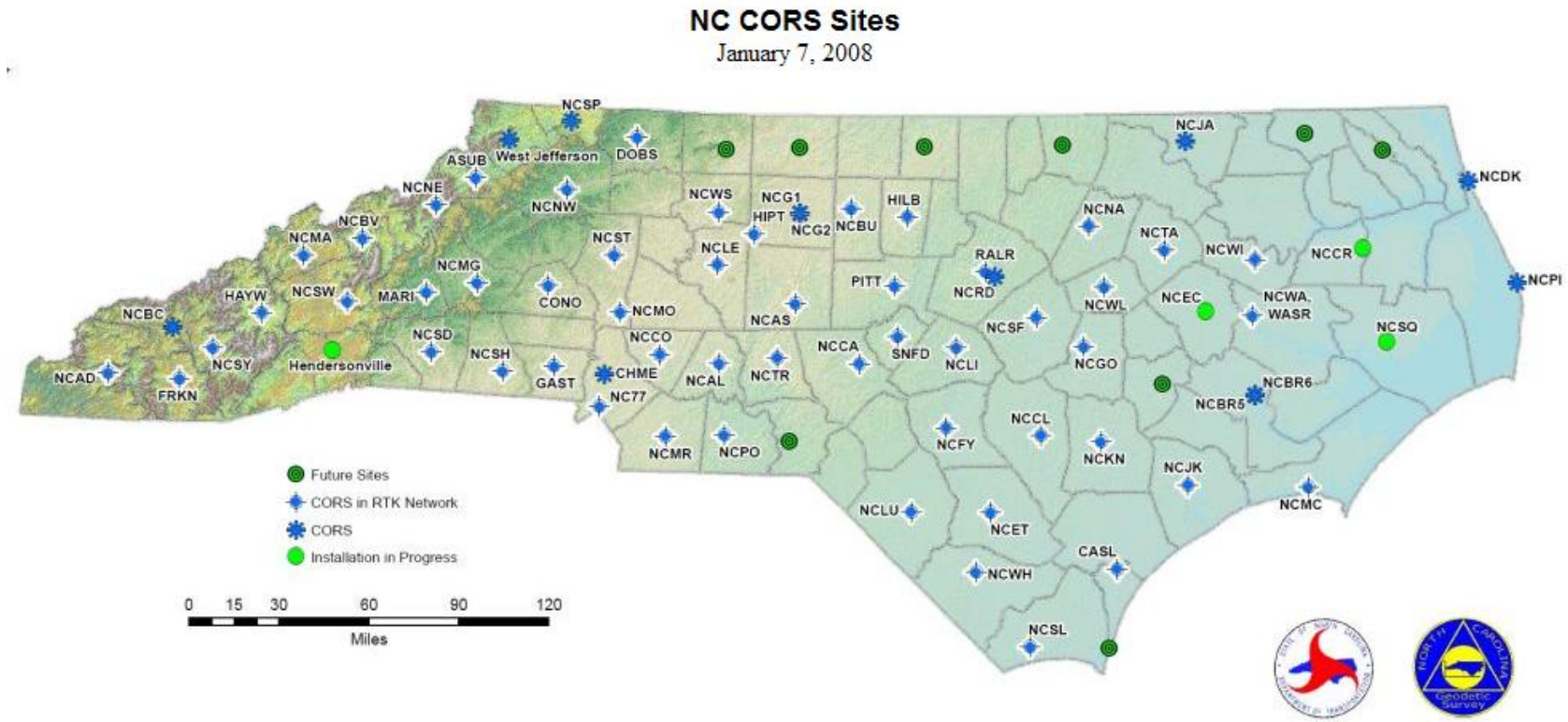
- 11 (13) reference stations
- GPS and GLONASS
- 45-day file storage
- Free



Washington State Reference Network



North Carolina Dept. of Environment & NR



Other GPS Reference Networks

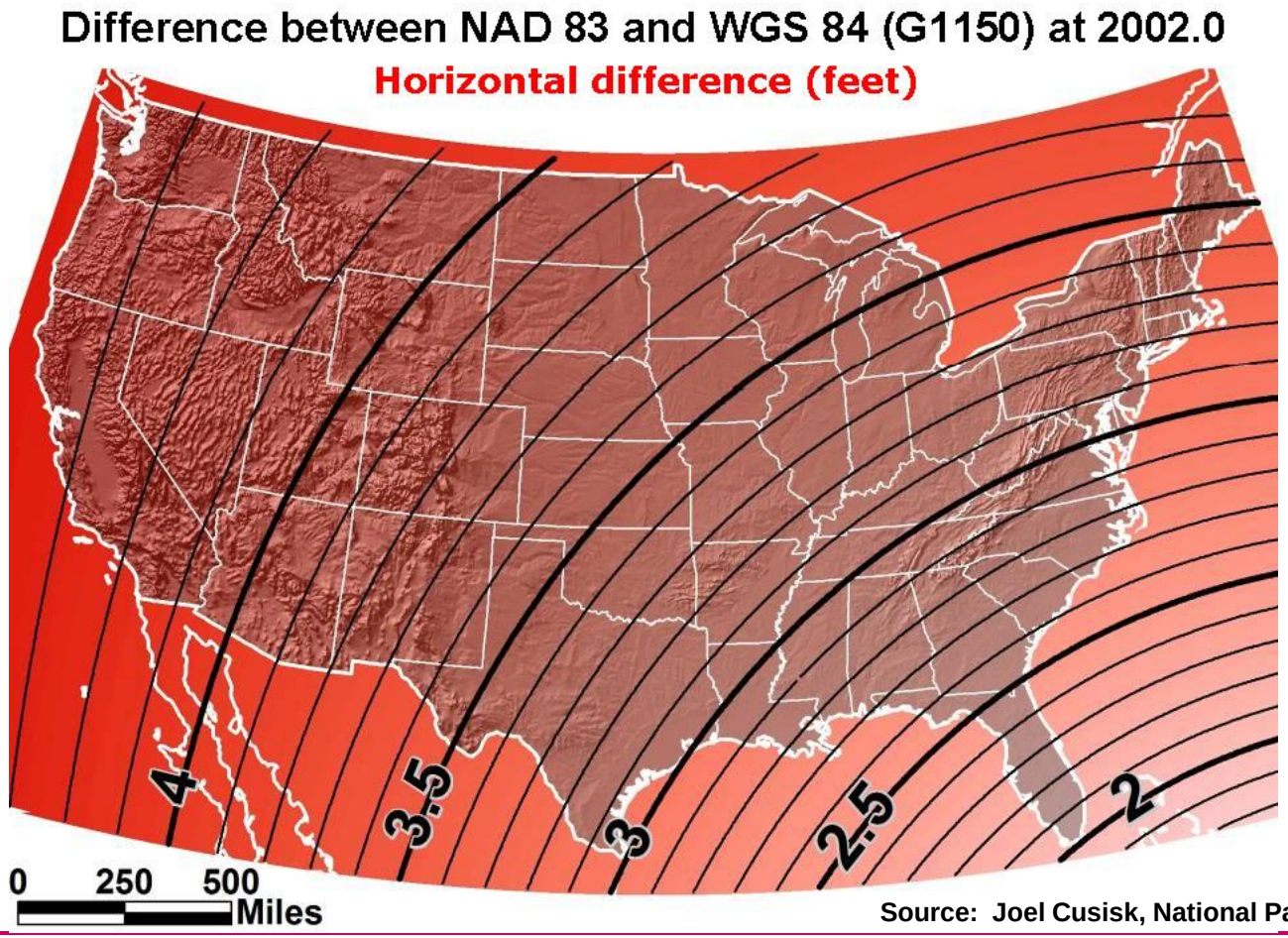
- Ohio
- Michigan
- South Carolina
- Texas
- Louisiana
- California Central Valley
- Minnesota
- Georgia
- Florida
- Boston Metro
- Norfolk, VA
- Washington DC Metro

Datum References

- GPS: WGS 84
- OmniStar VBS (North America): NAD 1983
- OmniStar XP & HP: ITRF 2000
- WAAS: ITRF 2000
- USCG Beacon Network: NAD 1983
- NYSNet: NAD 1983

- What datum is your GIS data referenced to?

Why Should I Care?



Source: Joel Cusisk, National Park Service

Image Reference

Summary

Summary

- Make Something Cosmic Happen Today
- The B.Y.O.D. Revolution is Real – Embrace It!
- Differential Correction (DGPS) Infrastructure Networks are Proliferating – You Have Options

Thank You!

What's New?

GeoExplorer 7X

- Image

GeoExplorer 7X

- New Features

GeoExplorer 7X

- Benefits

Connections and Convergence: New Products

- GeoExplorer 6000/Floodlight
- Trimble Municipal Reporter
- Trimble Assistant

GeoExplorer 6000/Floodlight

GPS Data Collection for GIS

- Issue Focus: Heavily Canopied and Urbanized Areas
- Historic Approaches/"Remedies"
- Meeting the Challenge Using "Floodlight"

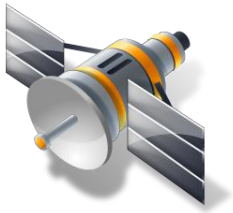
Heavy Canopy and Urban Areas

In what types of environments do GIS professionals operate?

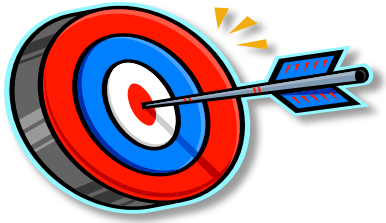
Heavy Canopy and Urban Areas

What, specifically, is the problem with GPS data collection in "hostile" environments?

Limited GPS Satellite Availability



PDOP



Historic Approaches/Remedies

- Wait..... and wait..... and wait..... and wait.....

Historic Approaches/Remedies

- Deferral/Come Back Later

Historic Approaches/Remedies

- Contortionism

Historic Approaches/Remedies

- Digitize

Historic Approaches/Remedies

- Offset

Floodlight Shadow Reduction Technology

- More positions and better accuracy in obstructed GNSS conditions

Floodlight Shadow Reduction Technology

Floodlight - Meeting the Challenge

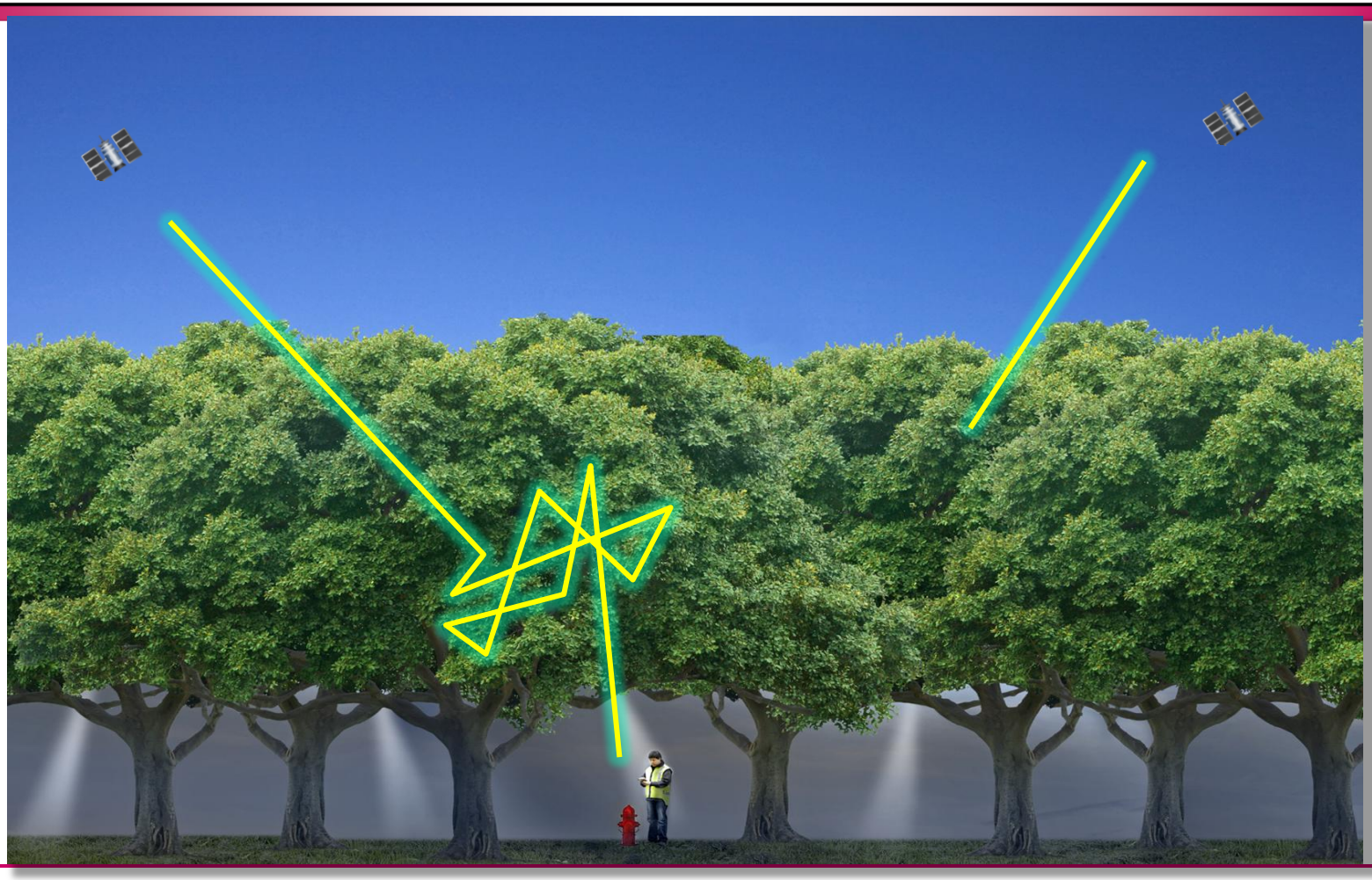
- Increase satellite availability
- Stable satellite tracking
- Improve accuracy and prevent position outages in hostile GNSS conditions

Floodlight Shadow Reduction Technology

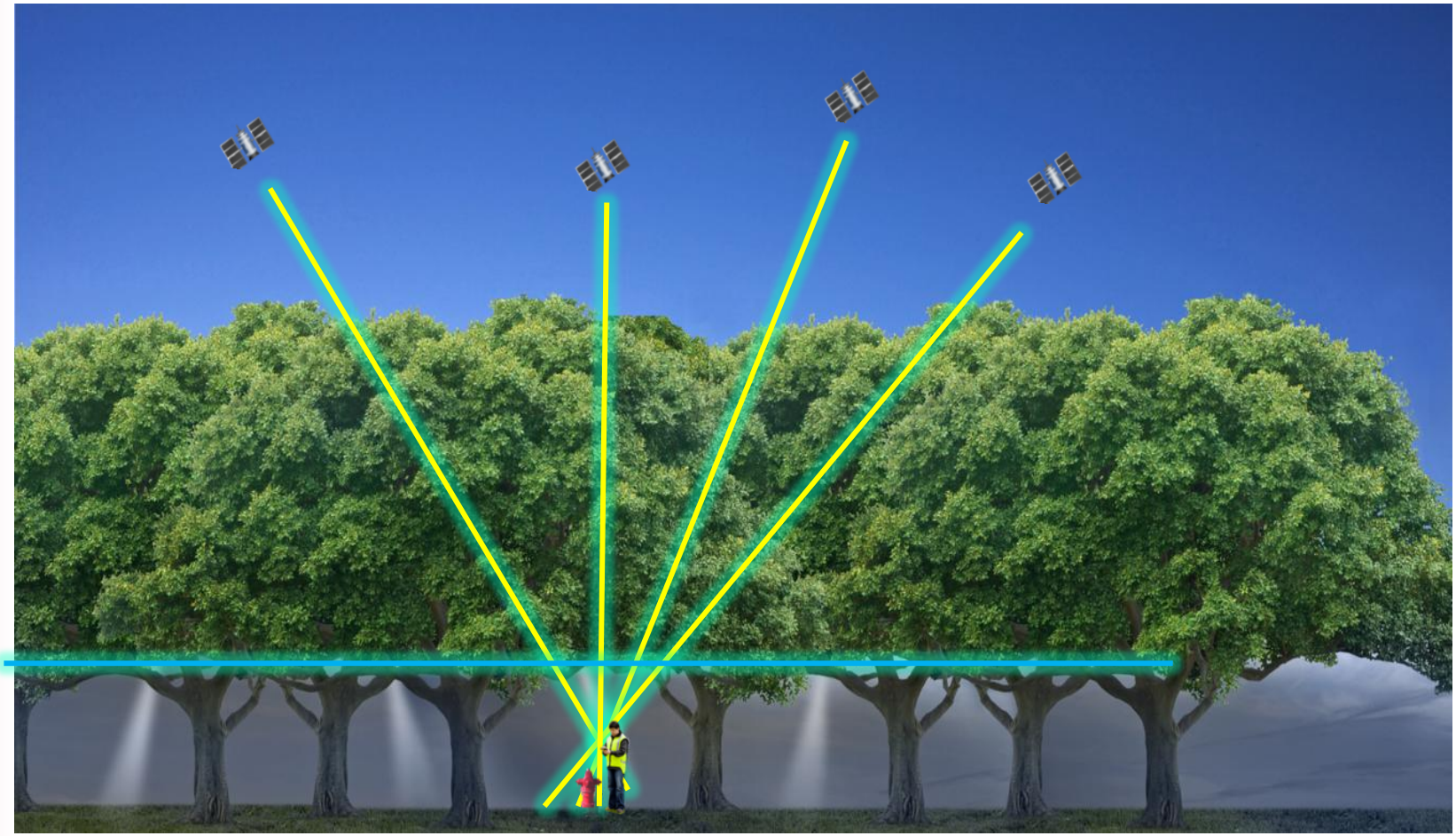
Floodlight - Meeting the Challenge

- Multi-constellation (GPS + GLONASS)
- Advanced tracking algorithms and filters
- Altitude-constrained positioning

GPS + GLONASS



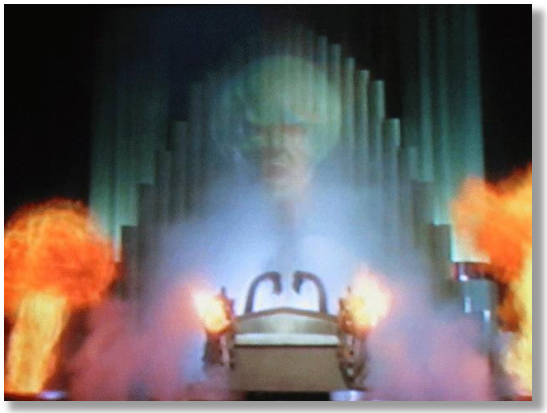
GPS + GLONASS



Tracking and Algorithms

Tracking and Algorithms

$$x = \sqrt[3]{\left(\frac{-b^3}{27a^3}+\frac{bc}{6a^2}-\frac{d}{2a}\right)+\sqrt{\left(\frac{-b^3}{27a^3}+\frac{bc}{6a^2}-\frac{d}{2a}\right)^2+\left(\frac{c}{3a}-\frac{b^2}{9a^2}\right)^3}} + \sqrt[3]{\left(\frac{-b^3}{27a^3}+\frac{bc}{6a^2}-\frac{d}{2a}\right)-\sqrt{\left(\frac{-b^3}{27a^3}+\frac{bc}{6a^2}-\frac{d}{2a}\right)^2+\left(\frac{c}{3a}-\frac{b^2}{9a^2}\right)^3}} - \frac{b}{3a}.$$



???

Altitude-constrained Positioning

GPS Pseudorange Navigation Example - Peter H. Dana - 4/24/96

Satellite (SV) coordinates in ECEF XYZ from Ephemeris Parameters and SV Time

$SVx_0 := 15524471.175$ $SVy_0 := -16649826.222$ $SVz_0 := 13512272.387$ SV 15

$SVx_1 := -2304058.534$ $SVy_1 := -23287906.465$ $SVz_1 := 11917038.105$ SV 27

$SVx_2 := 16680243.357$ $SVy_2 := -3069625.561$ $SVz_2 := 20378551.047$ SV 31

$SVx_3 := -14799931.395$ $SVy_3 := -21425358.24$ $SVz_3 := 6069947.224$ SV 7

Satellite Pseudoranges in meters (from C/A code epochs in milliseconds)

$P_0 := 89491.971$ $P_1 := 133930.500$ $P_2 := 283098.754$ $P_3 := 205961.742$ Range + Receiver Clock Bias

Receiver Position Estimate in ECEF XYZ

$Rx := -730000$ $Ry := -5440000$ $Rz := 3230000$

For Each of 4 SVs $i := 0..3$

Ranges from Receiver Position Estimate to SVs (R) and Array of Observed - Predicted Ranges

$$R_i := \sqrt{(SVx_i - Rx)^2 + (SVy_i - Ry)^2 + (SVz_i - Rz)^2} \qquad L_i := \mathrm{mod}\left[\left(R_i\right), 299792.458\right] - P_i$$

Compute Directional Derivatives for XYZ and Time

$$Dx_i := \frac{SVx_i - Rx}{R_i} \qquad Dy_i := \frac{SVy_i - Ry}{R_i} \qquad Dz_i := \frac{SVz_i - Rz}{R_i} \qquad Dt_i := -1$$

Solve for Correction to Receiver Position Estimate

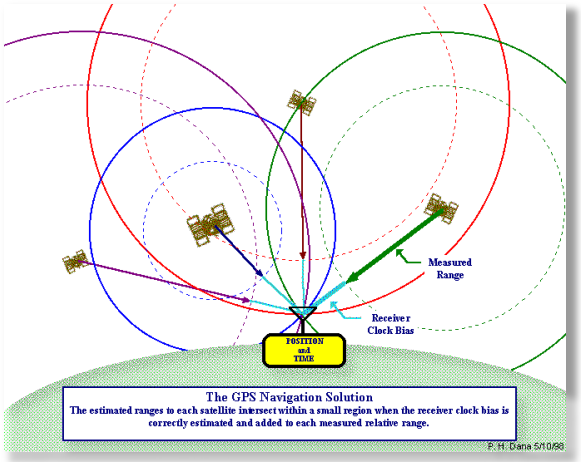
$$A := \begin{bmatrix} Dx_0 & Dy_0 & Dz_0 & Dt_0 \\ Dx_1 & Dy_1 & Dz_1 & Dt_1 \\ Dx_2 & Dy_2 & Dz_2 & Dt_2 \\ Dx_3 & Dy_3 & Dz_3 & Dt_3 \end{bmatrix} \qquad dR := \left(A^T \cdot A\right)^{-1} \cdot A^T \cdot L \qquad dR = \begin{bmatrix} -3186.496 \\ -3791.932 \\ 1193.286 \\ 12345.997 \end{bmatrix}$$

Apply Corrections to Receiver XYZ and Compute Receiver Clock Bias Estimate

$Rx := Rx + dR_0$ $Ry := Ry + dR_1$ $Rz := Rz + dR_2$ $Time := dR_3$

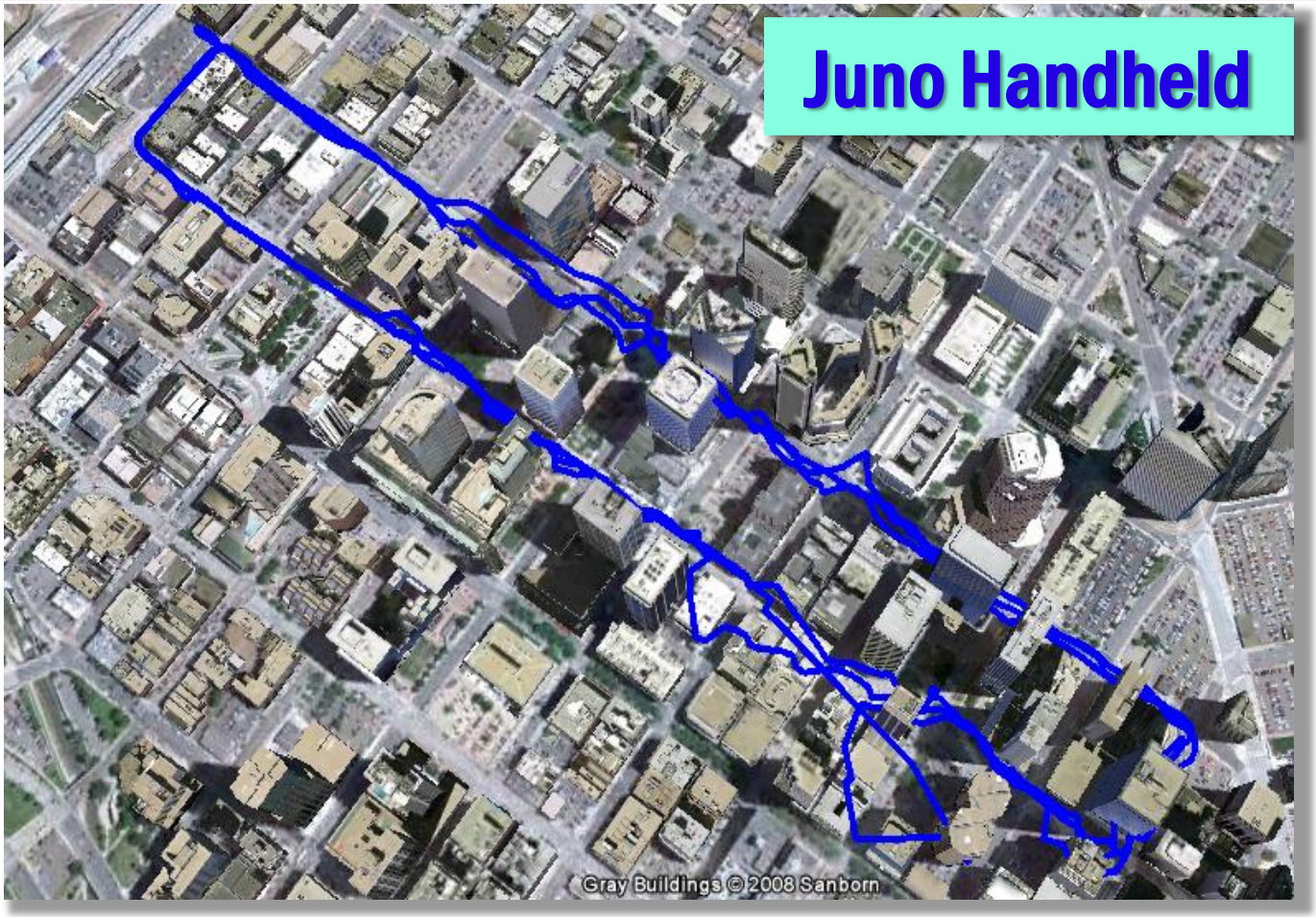
$Rx = -733186.496$ $Ry = -5443791.932$ $Rz = 3231193.286$ $Time = 12345.997$

Integrated Barometric Altimeter

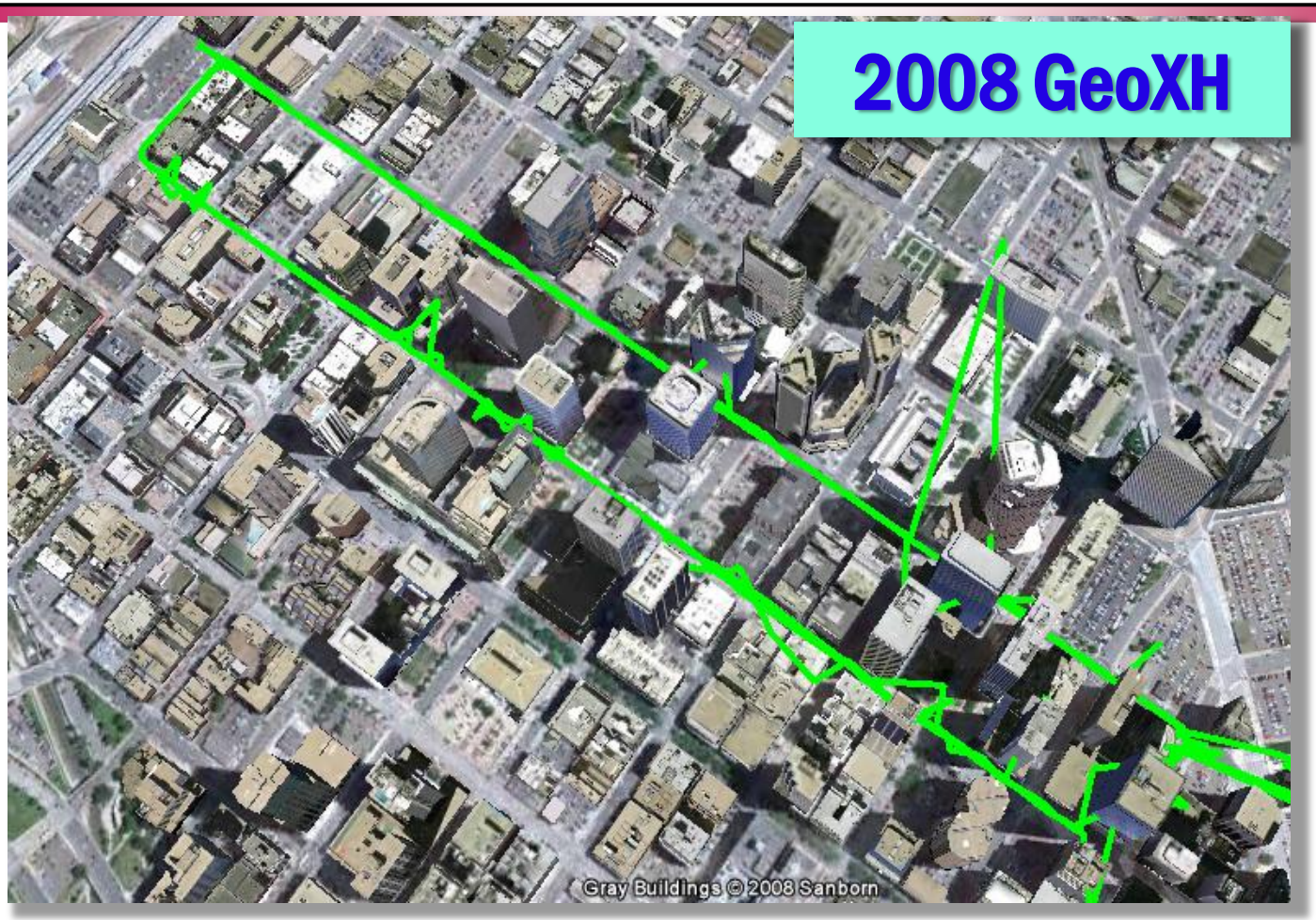


Credit: Peter Dana

Floodlight - Meeting the Challenge

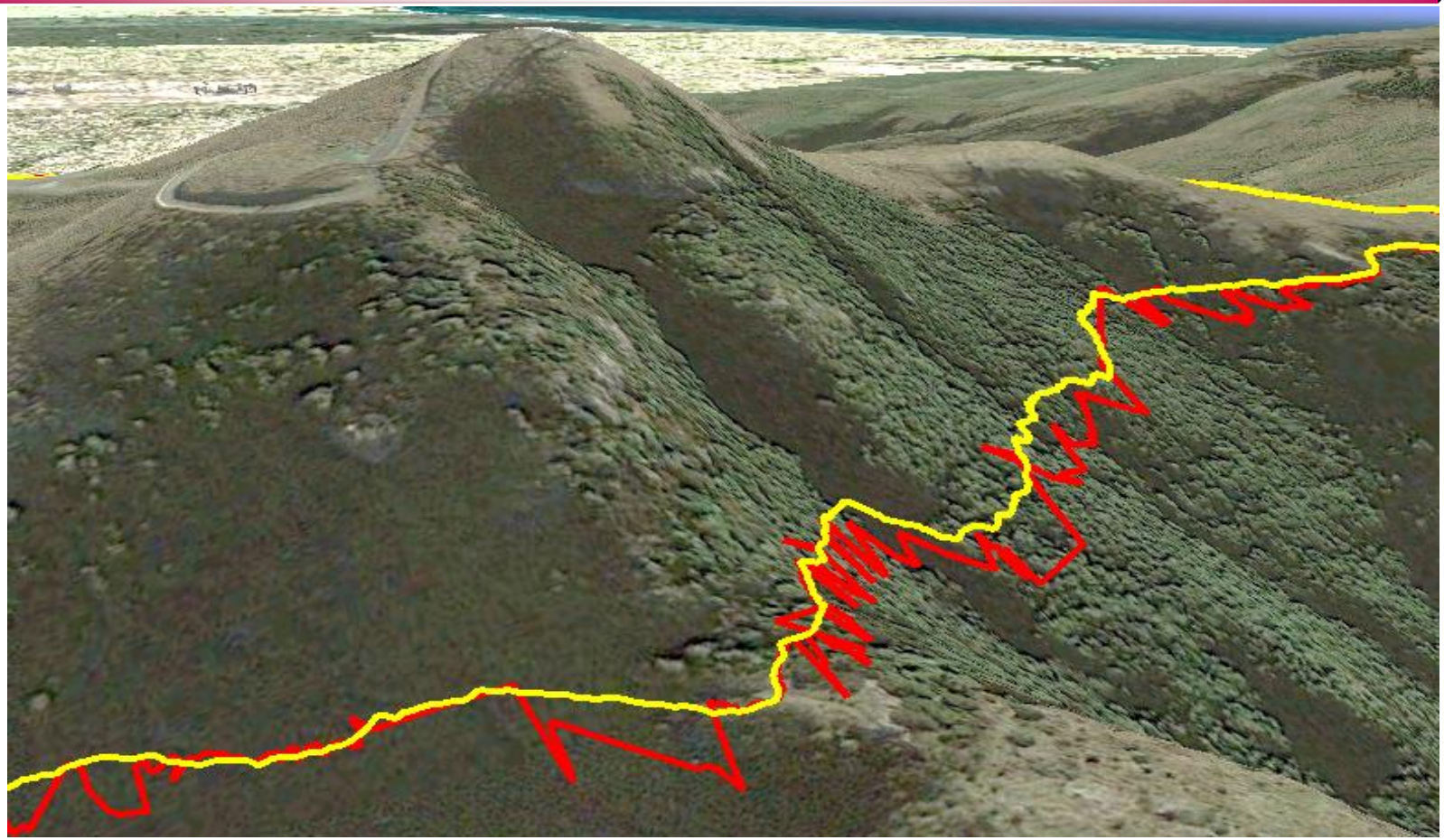


Floodlight - Meeting the Challenge

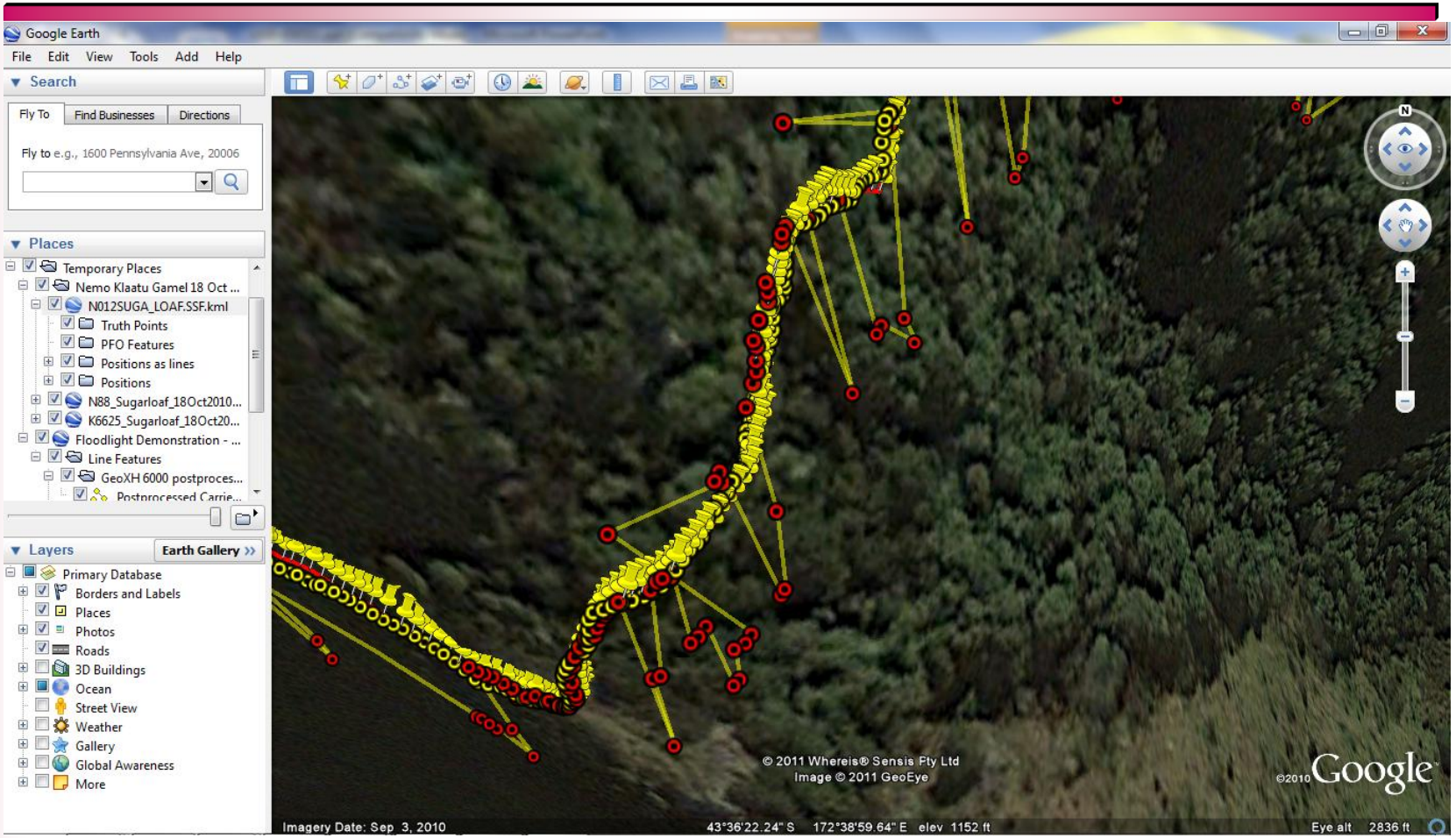


Floodlight - Meeting the Challenge

Floodlight



New Zealand


Google Earth
File Edit View Tools Add Help
Search
Fly To
Find Businesses
Directions
Fly to e.g., 1600 Pennsylvania Ave, 20006
Places
Temporary Places
Nemo Klaatu Gamel 18 Oct ...
N012SUGA_LOAF.SSF.kml
Truth Points
PFO Features
Positions as lines
Positions
N88_Sugarloaf_18Oct2010...
K6625_Sugarloaf_18Oct20...
Floodlight Demonstration - ...
Line Features
GeoXH 6000 postproces...
Layers
Earth Gallery
Primary Database
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Street View
Weather
Gallery
Global Awareness
More
© 2011 Whereis® Sensis Pty Ltd
Image © 2011 GeoEye
©2010 Google
Imagery Date: Sep 3, 2010
43°36'22.24" S 172°38'59.64" E elev 1152 ft
Eye alt 2836 ft

Floodlight Examples

- New Zealand

MGIS Support Docs\6000 GeoExplorer\Floodlight Demonstration - Christchurch.kmz

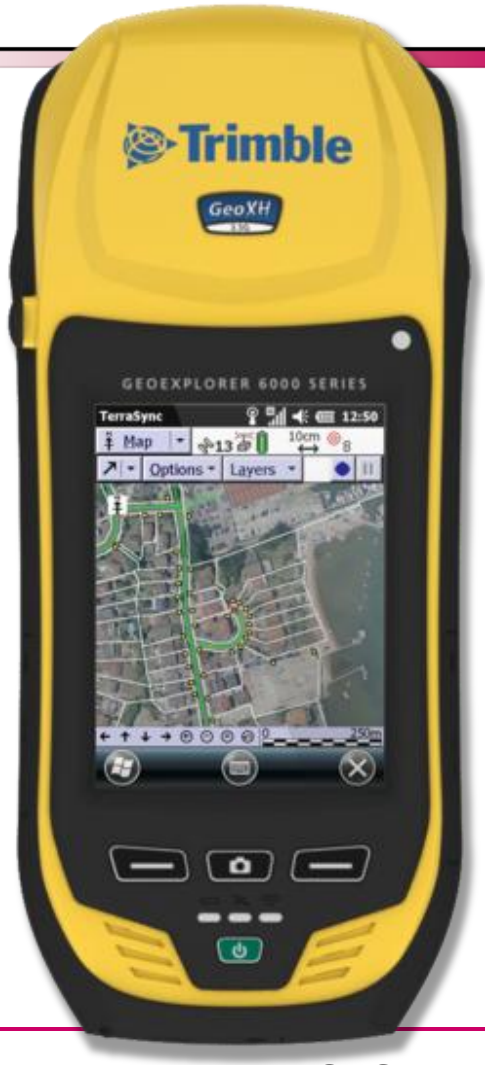
- Denver

MGIS Support Docs\6000 GeoExplorer\Floodlight Demonstration - Denver.kmz

Floodlight - Meeting the Challenge

GeoExplorer XH 6000

- Floodlight Enabled
- Integrated Digital Camera
- Integrated 3G Modem (optional)
- “Field-swappable” Battery



Floodlight - Meeting the Challenge

Benefits

- Speed
- Accuracy
- Simplicity
- Frustration Reduction/Elimination

Floodlight - Meeting the Challenge

Limitations

- GPS Base/Reference Station Infrastructure
  - WAAS – GPS only
  - US Coast Guard Beacons – GPS only
  - Legacy reference station networks - GPS only

Trimble® GeoExplorer® 6000 series

- Handheld computer with integrated high accuracy GNSS
- Exceptional GNSS performance in difficult environments
- A completely integrated data capture solution
- Optimized for mapping and GIS data collection activities
- Windows Mobile® versatility

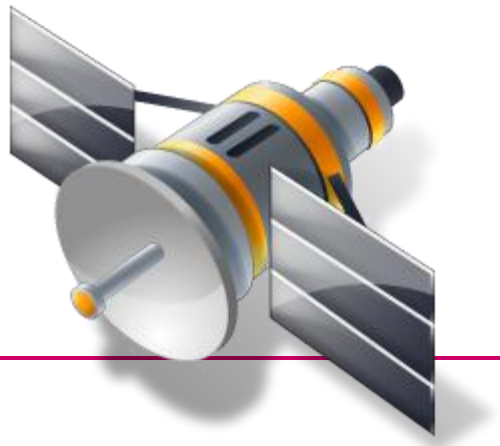
Configurations & Receiver Options

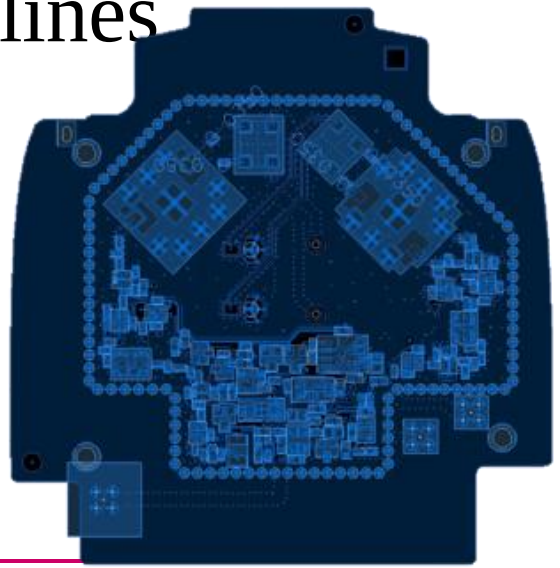
GeoXH™ standard edition	GeoXT™ standard edition
GeoXH 3.5G edition (adds cellular modem)	**GeoXT 3.5G edition** (adds cellular modem)

GeoXH receiver options	GeoXT receiver options
NMEA output upgrade	NMEA output upgrade
	Floodlight Technology upgrade

Integrated High-Accuracy GNSS System

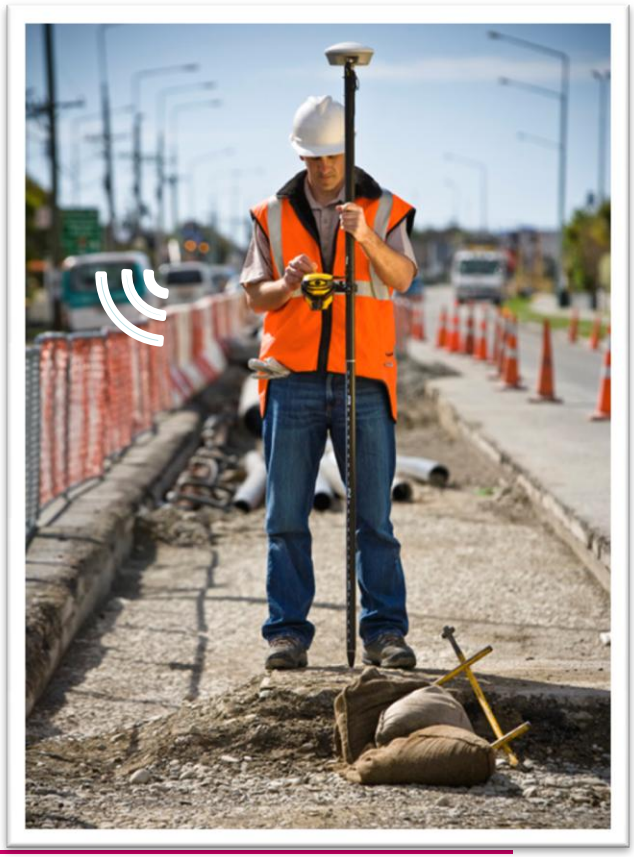
- Decimeter H-Star™ accuracy in the hand
- Available in real time and after postprocessing
- Fast accuracy and at longer baselines
- Better precision estimates





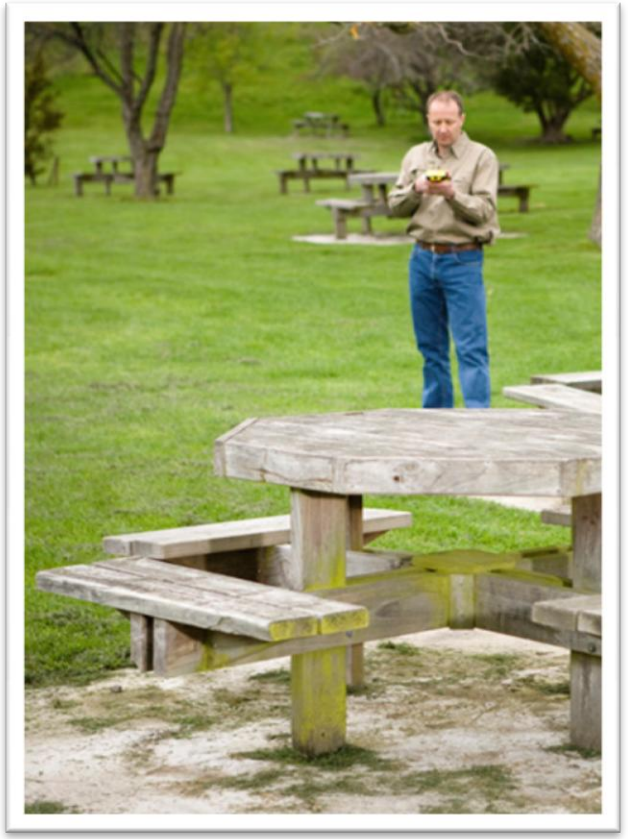
Integrated 3.5G cellular data modem

- Internet connectivity in the field



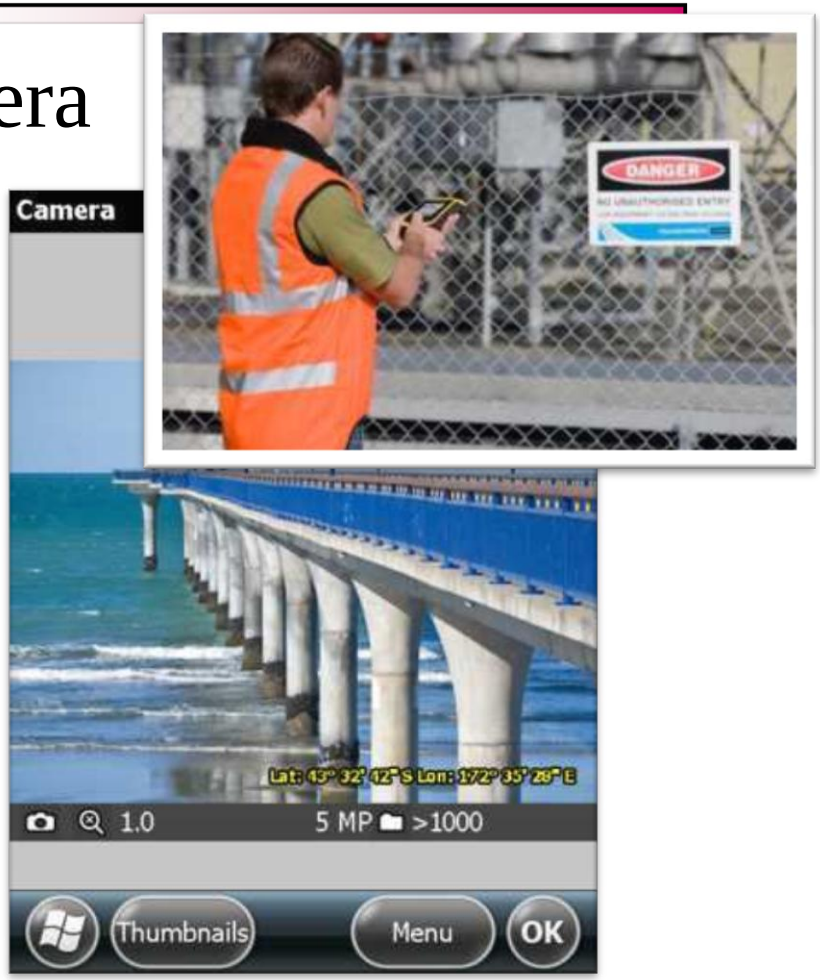
Integrated 5 megapixel autofocus camera

- Capture photo attributes directly in the field without additional equipment



Camera specifications

- 5 megapixel autofocus camera
  - 7-stop exposure adjustment
  - 6 resolution options
  - 3 JPEG quality modes
  - Macro mode (20 cm)
  - Geotagging capable
  - VGA video with audio

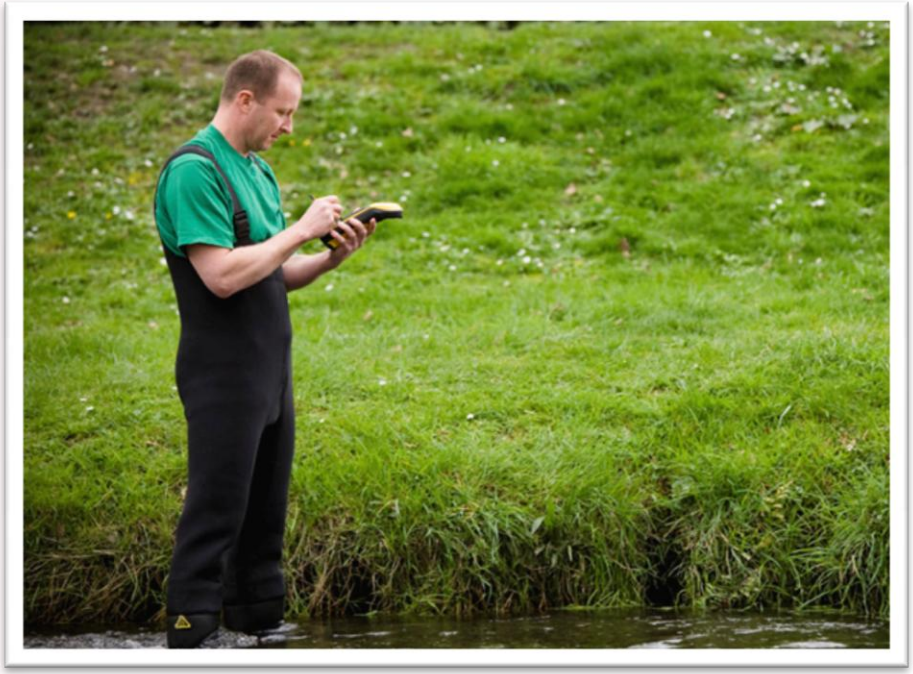


4.2 inch sunlight readable display

- Crystal clear maps and forms

Long-life field-swappable battery

- Up to 11 hours operation on a single charge
- Field swappable without shutting down



Powerful computing and rugged hardware

- Efficient operation in all conditions

GNSS receiver specifications

Receiver	Trimble Maxwell™ 6 GNSS chipset
Antenna	GeoXT models: L1, GeoXH models: L1/L2
Channels	220 channels
Systems	GPS, GLONASS*, SBAS
GPS	L1C/A, L2C, L2E
GLONASS	L1C/A, L1P, L2C/A, L2P
SBAS	WAAS/MSAS/EGNOS
Update rate	1 Hz
Time to first fix	45 s (typical)
NMEA-0183 output	Optional
RTCM support	RTCM2.x/RTCM3.x
CMR support	CMR/CMRx/CMR+

GNSS accuracy specifications

Real Time	
H-Star (GeoXH only)	10 cm + 1 ppm
DGNSS Code	75 cm + 1 ppm
SBAS (WAAS/EGNOS/MSAS)	Submeter

Postprocessed	
H-Star (GeoXH only)	10 cm + 1 ppm
GeoXT Postprocessed Carrier	after 20 minutes: 10 cm + 2 ppm after 10 minutes: 20 cm + 2 ppm
GeoXT/GeoXH Postprocessed Carrier	after 45 minutes: 1 cm + 2 ppm
Code/SBAS (WAAS/EGNOS/MSAS)	50 cm + 1 ppm

Floodlight Satellite Shadow Reduction Technology

Increase satellite availability

Multi-constellation Positioning (GNSS)

Stabilize acquisition and tracking

Advanced tracking algorithms and filters

Improve accuracy and yield

Altitude-constrained positioning

Cellular, Wi-Fi, and Bluetooth

Cellular (optional)

- Siemens HC25 HSDPA cellular modem
- Quad band GPRS/EDGE
  - 850/900/1800/1900 MHz
- Tri-band UMTS/HSDPA
  - 850/900/2100 MHz

Wi-Fi

- 802.11b/g

Bluetooth

- Version 2.0 + EDR
- Supports SPP, DUN, PAN, OPP,

Trimble Assistant

Trimble Assistant

- Remote support technology
- Supports multiple operating systems – Windows CE/Pocket PC, Windows Mobile 5/6, Linux, Windows Desktop, Mac
- Drag and drop file transfer
- VOIP
- Session Recording/Playback
- Secure/Encrypted

Trimble Assistant

- Applications
  - Technical support/trouble shooting
  - Training
  - Software/firmware upgrades
  - Sales demonstrations

Trimble Assistant

- Candidates
  - Government agencies
  - Construction contractors / land surveyors
  - Utilities
- Benefits
  - Reduce technical support costs
  - Save time / improve productivity
  - Record and replay for distribution

Summary

Leveraging Public Data Sources for Mobile GIS - Benefits

- Minimize pre-field prep time - no need to identify correct ortho tiles in advance
- Improved GPS accuracy (closest base station)
- Built-in DGPS redundancy (USCG and WAAS still available)
- “Instant” gratification/validation
- Potential to migrate to bi-directional, real-time, data flows

Leveraging Public Data Sources for Mobile GIS - Limitations

- Connectivity (e.g. cell phone signal)
- Bandwidth
- Technological complexity (i.e. integrating multiple hardware and software components)
- Over-reliance

Summary

- Technological Convergence, including:
  - Cell Phone Service
  - Bluetooth
  - GPS
  - DGPS
  - Web Services
  - Internet
- Data feeds are free (generally)
- Web Map Services Expanding
- Differential Correction (DGPS) Infrastructure Networks Growing Rapidly

Questions?

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