GPS Challenge Team Report

- Purpose of the GPS Challenge Team
- Sponsors
- Scientific Based Ecosystem Investigation
  - Real Time Positioning
  - Multiple Occupations and Iterations
  - Landscape Characterization
- Supporting Agencies Pos/ Nav Requirements

USDA-DOI GPS Challenge Team

Observation Methodology

Gary Hallbauer, USDA-NRCS

Point Characterization

Wayne Dulaney, USDA-ARS

U.S Forest Service Findings

Gary Boyack, USFS–CO
Dick Karsky, USFS-MTDC

National Park Service Findings

Karl Brown, NPS
Tim Smith, NPS

Observation Methodology

The approach…

- Uniformity of procedures
- Consistency of applications
- Redundancy of equipment
- Availability of signal

Uniformity

Set protocols for:

- Data format: NMEA 0183
- Collection type: Static
- File naming:
  - Point designator, receiver & antenna model
  - Signal type (Autonomous, WAAS, NDGPS)
  - Collector

Uniformity

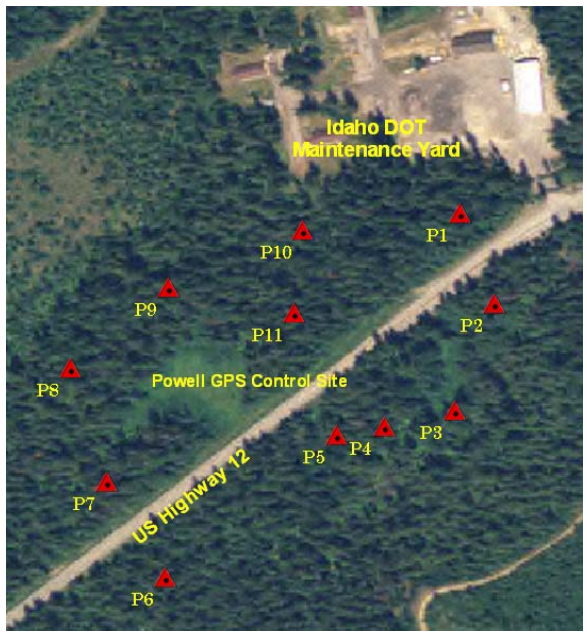
Additional protocols for:

- Collection duration:
  - 20 – 45 minutes at less challenged sites
  - 45 minutes to > 1 hour at more challenged sites
- Equipment placement:
  - Perpendicular to point and sky, level

Consistency

Protocols consistently applied:

- To each project location
- To each point
- To each file collected



Redundancy

- Duplicate equipment in some cases
- Multiple dates, multiple ecosystems
  - Acadia NP (2)
  - Bakerville, CO
  - Hoosier NF, IN (3)
  - Fort Worth, TX (Many)
  - Powell, ID and Lubrecht, MT (Many)
- Multiple archival sites

Availability of signal

Set survey controlled points in:

- Variety of canopy types
- Variety of slopes
- Variety of stand densities

Signal availability inferred from ability to resolve positions over time

- Autonomous
- WAAS

} With & without external antenna

Other considerations…

- Logistics of:
  - Shipping equipment to the locale
  - Transporting the equipment to site
  - Powering the equipment
  - Returning equipment
- Safety in the woods

GPS Site Characterization

Purpose:

- Provide data to assess impact of vegetation cover on GPS performance.

Tools:

- Hemispherical or “Fish-eye” photography
- LI-COR LAI-2000 Plant Canopy Analyzer

Digital Hemispherical Photography

- Two (2) different camera systems
- Fish-eye lens with 183^{O} field of view (FOV)
- Images georeferenced to magnetic north

Canopy Composition:

Species mix – Ecoregions (Domain/Division)

Canopy Architecture:

Obstruction or attenuation of GPS signals

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Arapaho NF, Colorado

Dry: Temperate Steppe

El Yunque NF, PR

Humid Tropical: Savanna

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Acadia NP, Maine
Humid Temperate:
Warm Continental

Hoosier NF, Indiana
Humid Temperate:
Hot Continental

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Tongass NF, Alaska
Humid Temperate: Marine

Redwood NP, California
Humid Temperate: Mediterranean

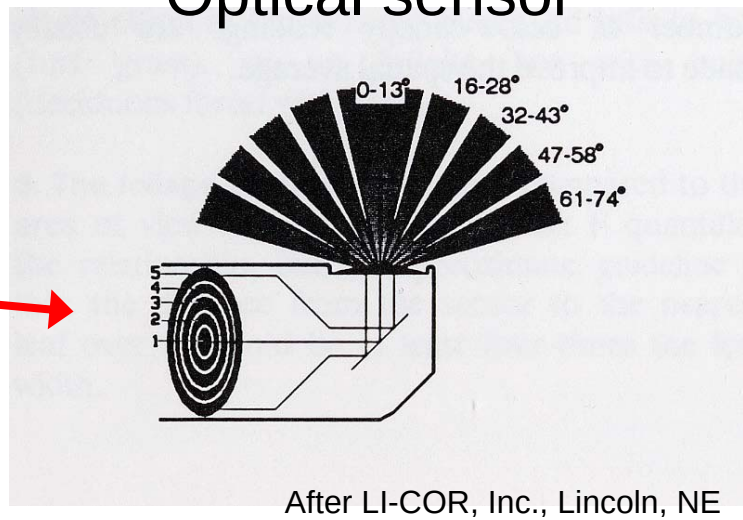
Leaf Area Index (LAI)

Definition: one-sided leaf area per unit ground area

In forest canopies, more accurately defined as a foliage area index -- area includes opaque canopy elements (e.g., trunks and branches)

LAI-2000 Plant Canopy Analyzer

Optical sensor



After LI-COR, Inc., Lincoln, NE

"Fish-eye" lens projects diffuse sky radiation at five (5) zenith angles onto corresponding concentric silicon detectors

LAI-2000 PCA Methodology

- Coincident, intercalibrated measurements acquired above and below the forest canopy
- “Above” sky measurements logged automatically in forest clearing
- Canopy light interception calculated at each zenith angle – BELOW / ABOVE
- Foliage amount determined from transmittances using a radiative transfer model

LAI-2000 PCA Data Quality

Previous research: LAI-2000 measurements are significantly and linearly correlated with direct LAI measurements

Spatial averaging: transect of six (6) below-canopy LAI-2000 measurements made at each GPS site

High degree of repeatability: provided confidence in usefulness of LAI-2000 data for characterization of GPS sites

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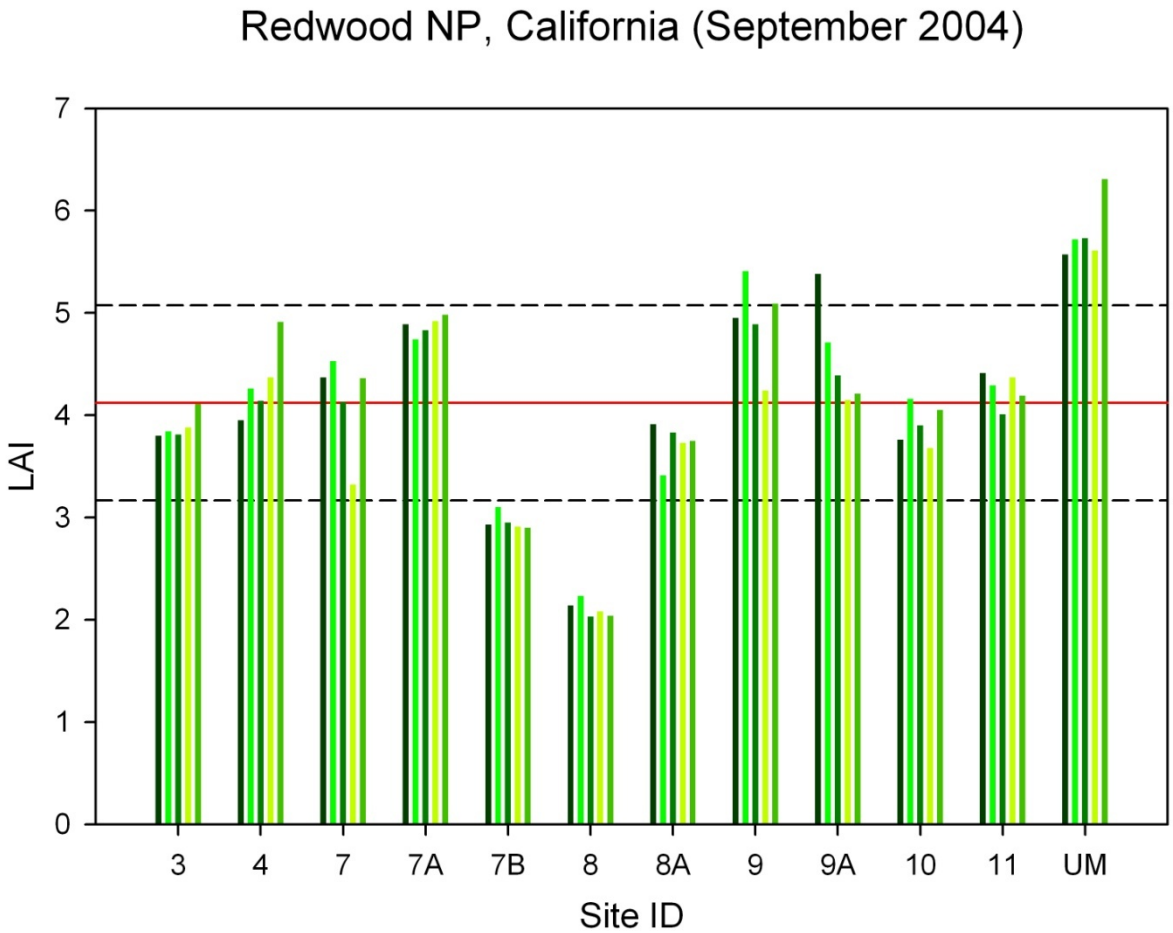

LAI acquired two (2) days apart

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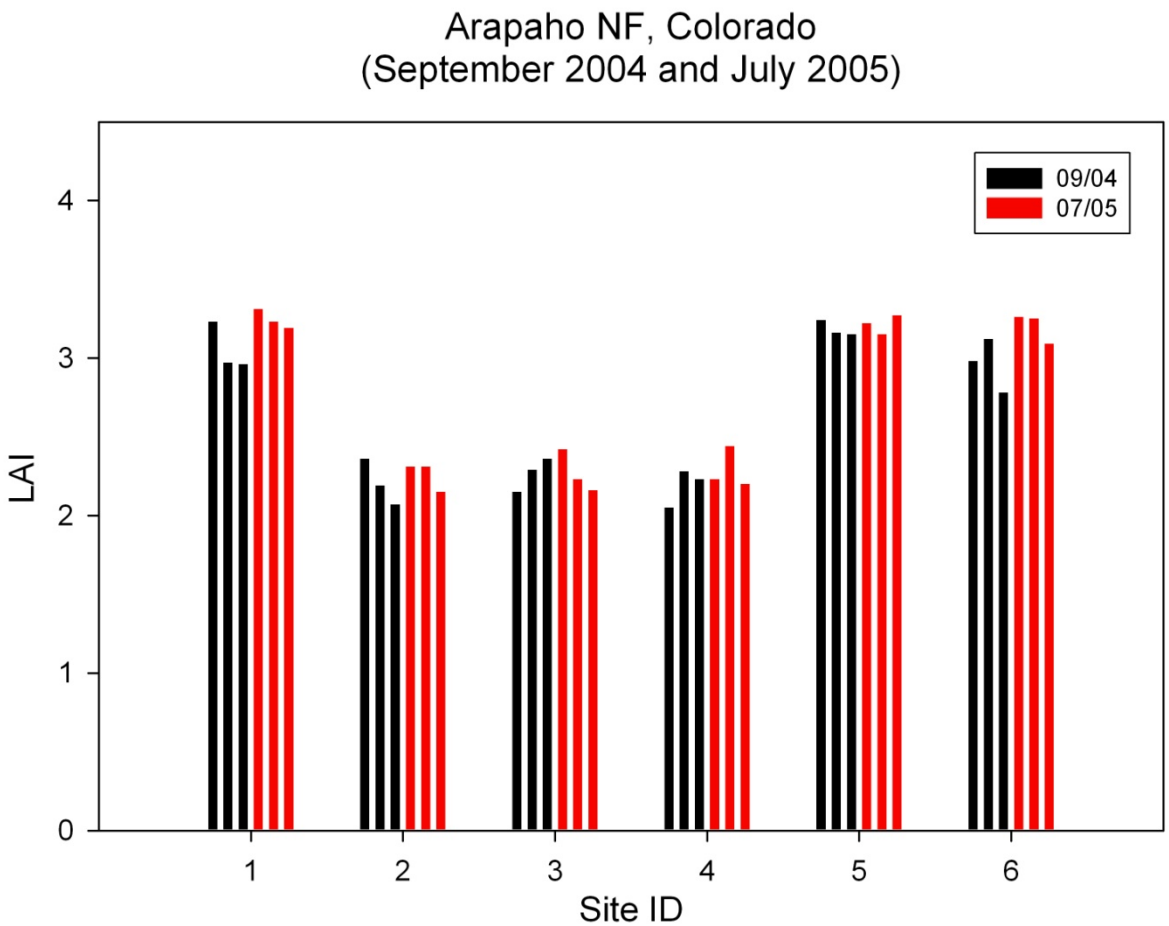

LAI acquired ten (10) months apart

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Forest	Domain	Division	LAI	SD
Lubrecht EF	Dry	Temperate Steppe	1.26	0.50
Arapaho NF (09/04)	Dry	Temperate Steppe	2.64	0.45
Arapaho NF (07/05)	Dry	Temperate Steppe	2.75	0.49
Acadia NP (06/05)	Humid Temperate	Warm Continental	2.91	0.56
Clearwater NF	Dry	Temperate Steppe	3.51	1.03
Acadia NP (06/08)	Humid Temperate	Warm Continental	3.52	0.70
Hoosier NF	Humid Temperate	Hot Continental	3.73	0.53
Chugach NF	Humid Temperate	Marine	3.75	0.55
Redwood NP	Humid Temperate	Mediterranean	4.12	0.95
Tongass NF	Humid Temperate	Marine	4.80	0.57
El Yunque NF	Humid Tropical	Savanna	5.11	0.62

Ascending order of LAI values

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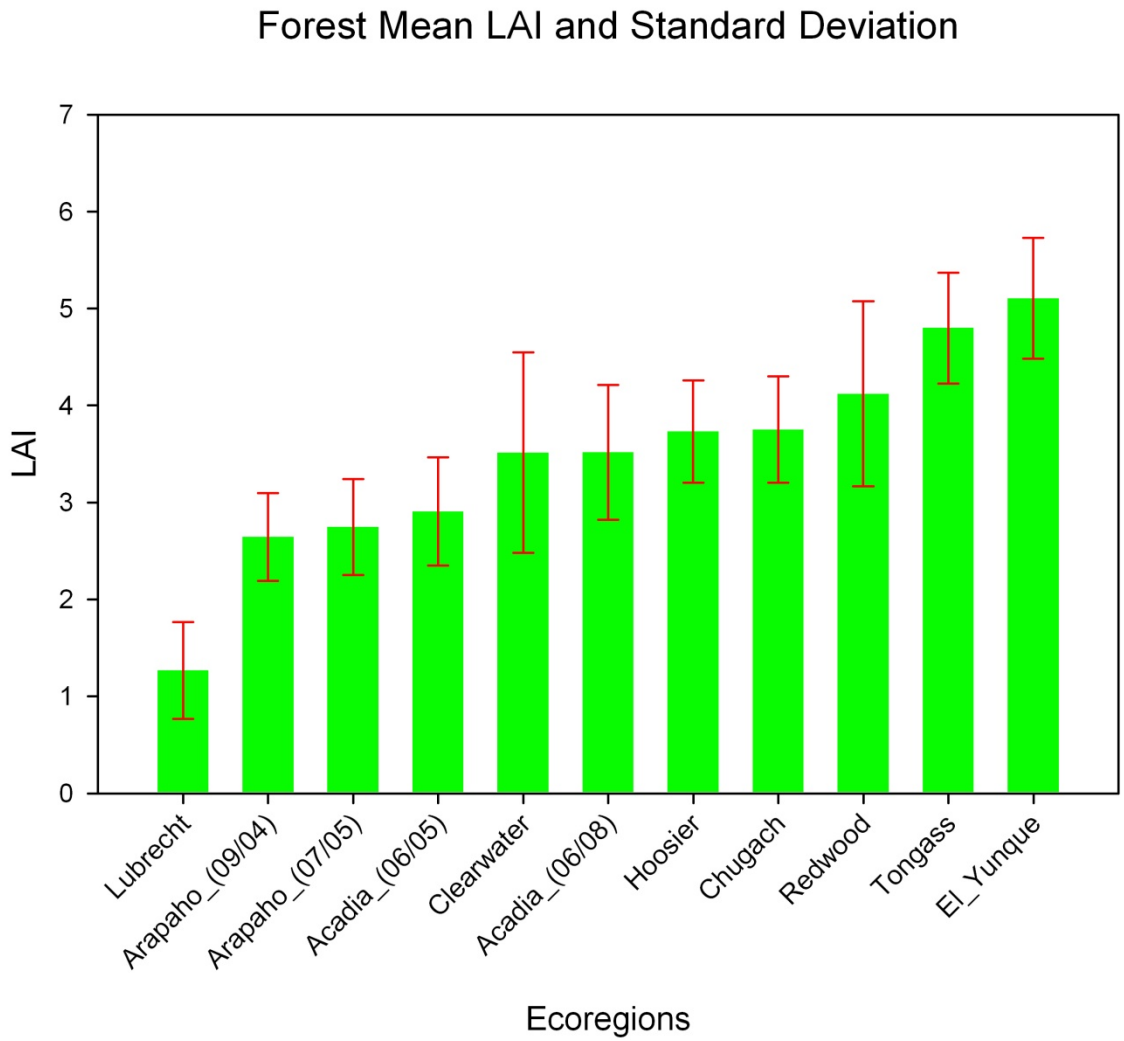


Conclusions

Forest mean LAI values follow expected trend suggested by ecoregion domain designations:
Dry → Humid Temperate → Humid Tropical

Quantitative information on forest canopy structure provides an analytical framework to better evaluate the impact of vegetation cover on GPS receiver and antenna performance.

Forest Service Concerns

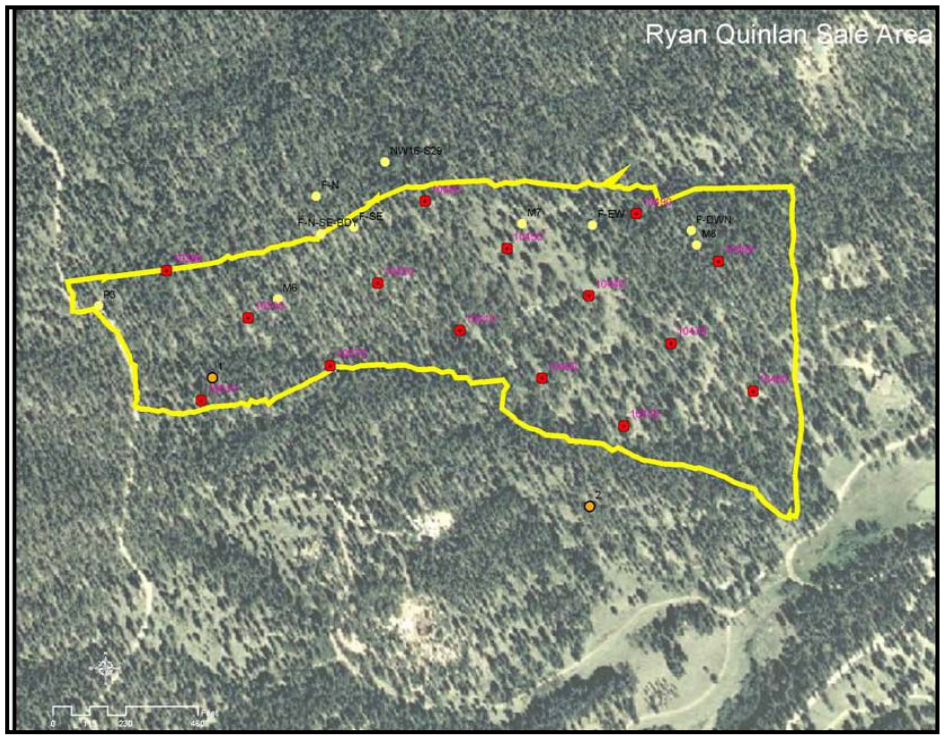
The Forest Service must conserve resources but still has to manage their lands.

– Overwhelming financial resources are going to fire activities

– Low cost materials are being harvested

– In spite of reduced funding, resource mapping still needs to done

Forest Service GPS Concerns



With data collected from this study and the software developed to query that data, a tool is available to help the USFS choose the correct receiver for the job and environment encountered.

This query tool also provides the user with a better understanding of the variables affecting accuracy such as canopy effect, signal differences, etc.

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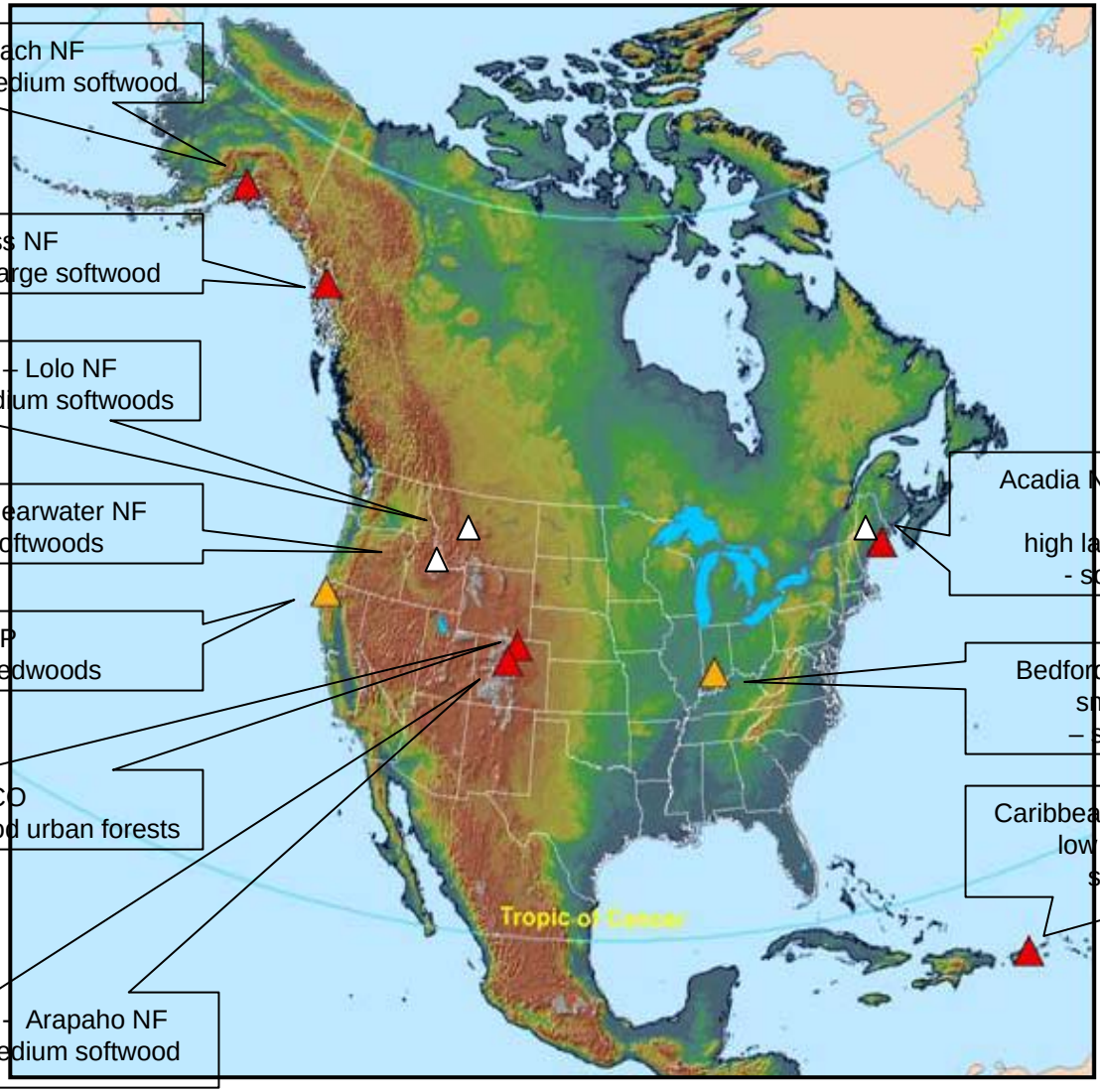


Anchorage – Chugach NF
High Latitude – typically medium softwood

Juneau– Tongass NF
High Latitude – typically large softwood

Lubrecht Test Course – Lolo NF
high latitude – small to medium softwoods

Powell Test Course – Clearwater NF
typically very large softwoods

Redwoods NP
typically very large redwoods

Fort Collins, CO
Mixed hardwood – softwood urban forests

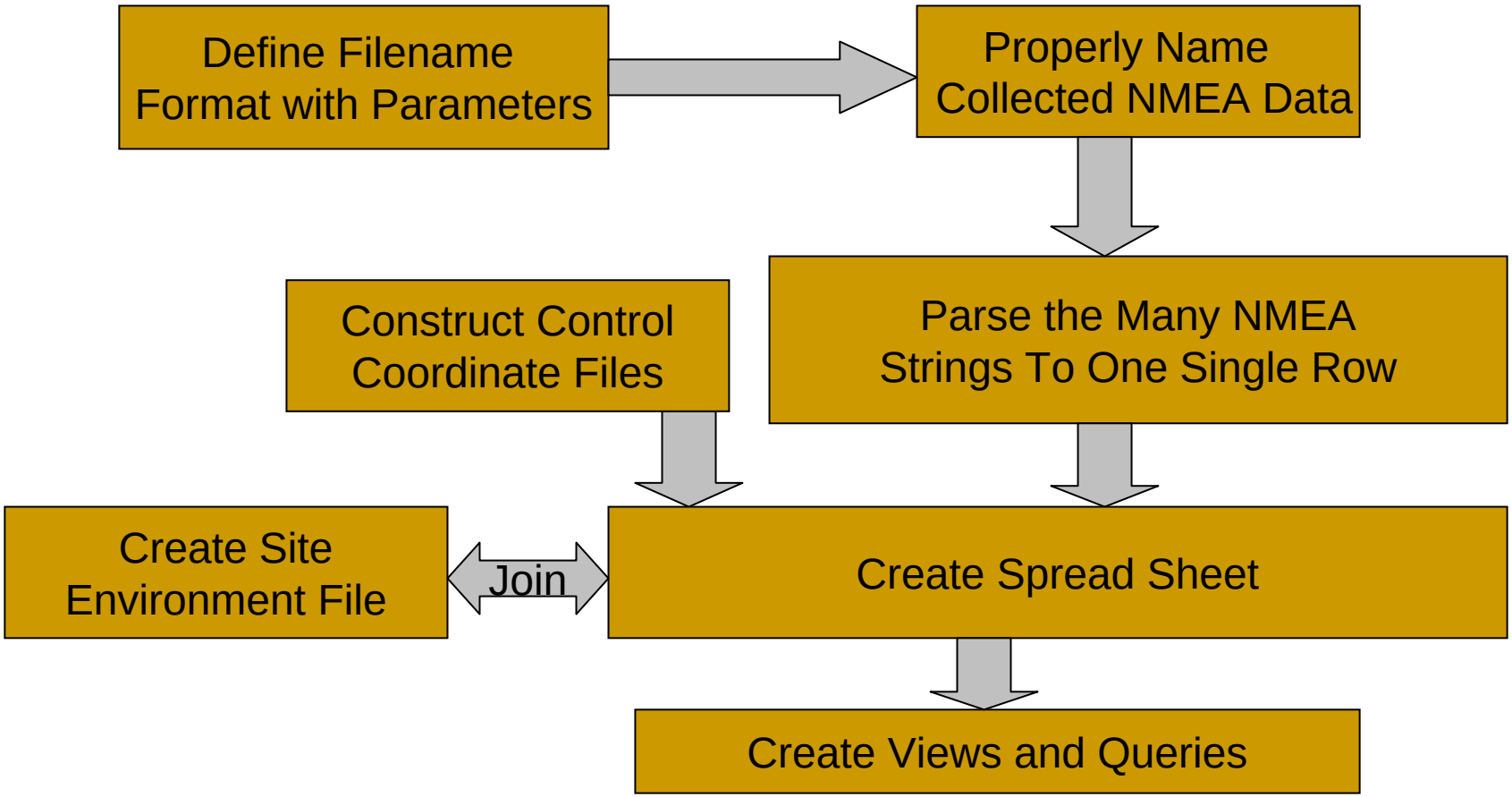
Bakerville Test Course - Arapaho NF
north slope – small to medium softwood

Acadia NP – before and after WAAS change
high latitude --- small to medium
- softwood and hardwood

Bedford Test Course - Hoosier NF
small, medium and large
– softwood and hardwood

Caribbean Test Course - El Yunque NF
low latitude – small to large –
softwood and hardwood

NMEA: Raw Data to Final Information



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NMEA Data to Information

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2	1	1010		1	70807	170515	10504.95	4033.648	493014.118	4490006.673		1536.9	-20.9	1	none	0	none	3	2.2	1.3	1.8	10.6	7	01^14^16^20^23^30^31
3	1	1010		1	70807	170517	10504.95	4033.648	493014.118	4490006.673		1536	-20.9	1	none	0	none	3	2.2	1.3	1.8	10.6	7	01^14^16^20^23^30^31
4	1	1010		1	70807	170519	10504.95	4033.648	493014.118	4490006.673		1535.8	-20.9	1	none	0	none	3	2.1	1.2	1.7	10.6	7	01^16^20^23^30^31
5	1	1010		1	70807	170521	10504.95	4033.648	493014.118	4490006.673		1535.6	-20.9	1	none	0	none	3	2	1.2	1.6	10.6	6	01^14^16^20^23^30^31
6	1	1010		1	70807	170523	10504.95	4033.648	493014.118	4490006.673		1535.3	-20.9	1	none	0	none	3	2	1.2	1.6	10.6	7	01^14^16^20^23^30^31
7	1	1010		1	70807	170525	10504.95	4033.648	493014.118	4490006.673		1535.5	-20.9	1	none	0	none	3	2	1.2	1.6	10.6	7	01^14^16^20^23^30^31
8	1	1010		1	70807	170527	10504.95	4033.648	493014.118	4490006.673		1535.9	-20.9	1	none	0	none	3	2	1.2	1.6	10.6	7	01^14^16^20^23^30^31
9	1	1010		1	70807	170529	10504.95	4033.648	493014.118	4490006.673		1536.5	-20.9	1	none	0	none	3	2	1.2	1.6	10.6	7	01^14^16^20^23^30^31
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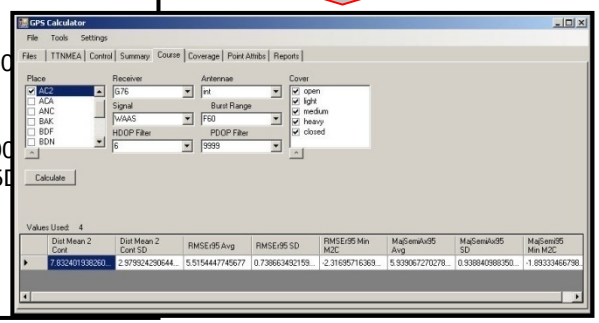
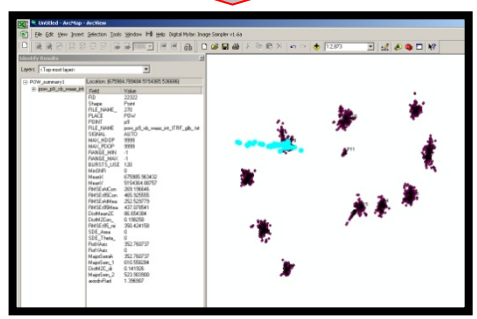
11	1	1010		1	70807	170533	10504.95	4033.647	493014.116	4490004.98		1537.5	-20.9	1	none	0	none	3	2	1.2	1.6	10.6	7	01^14^16^20^23^30^31

	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	SIGNAL	MAX_HDOP	MAX_PDOP	RANGE_MI	RANGE_MA	BURSTS_U	MinSNR	MeanX	MeanY	RMSErAtControl	RMSEr95Control	RMSErAtMean	RMSEr95Mean	DistMean2Control	DistM2Con_	RMSEr95_r
40	AUTO	9999	10	-1	-1	30	0	313891.732	5196436.16	1.527685742	2.644118483	0.121014955	0.209452683	0.075071659	0.3584182	0.134381
41	NDGPS	9999	4	-1	-1	1	0	313847.322	5196281.42	0.339024199	0.586783083	0	0	0.076896827	-1	-0.0769
42	WAAS	10	9999	-1	-1	120	0	313961.086	5196430.01	1.4501147	2.509858523	1.013978262	1.754993575	0.078788865	0.0448941	1.676205
43	NDGPS	9999	4	-1	-1	30	0	314008.936	5196363.97	1.453719469	2.516097657	0.711559023	1.231566356	0.079058082	0.0641931	1.152508
44	NDGPS	6	9999	-1	-1	120	0	313945.132	5196273.91	2.071948487	3.586128441	1.512295214	2.617480557	0.087336834	0.0333668	2.530144
45	WAAS	4	9999	-1	-1	60	0	313961.051	5196430.15	1.397641477	2.419037868	0.846902051	1.46581807	0.088348487	0.0602725	1.37747
46	NDGPS	9999	10	-1	-1	60	0	313945.179	5196274.03	2.224067399	3.849415855	1.375623192	2.38092862	0.089550876	0.0376117	2.291378
47	WAAS	9999	10	-1	-1	120	0	313961.11	5196429.99	1.52827704	2.645141901	1.081854974	1.872474589	0.093285465	0.0498193	1.779189
48	NDGPS	4	9999	-1	-1	30	0	314008.926	5196364.07	1.375220522	2.380231679	0.657053338	1.13722791	0.093992083	0.0826502	1.043236
49	WAAS	9999	10	-1	-1	30	0	313961.105	5196429.99	1.409434535	2.439449293	0.618143948	1.069883544	0.0941224	0.0879744	0.975761
50	NDGPS	9999	9999	-1	-1	120	0	313945.15	5196273.91	2.845848235	4.925594124	2.366319795	4.095626301	0.098094991	0.0239512	3.997531
51	NDGPS	9999	6	-1	-1	1	0	313945.162	5196273.92	1.392849034	2.410743107	0	0	0.098538503	-1	-0.09854





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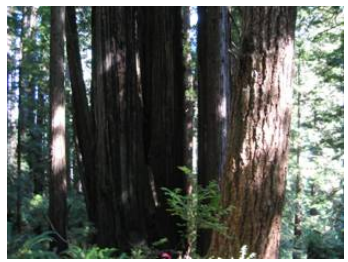
North

Northwest

Northeast

West

East



Southwest

South

Southeast

Hemisphere (Fisheye) Information

ARS Information --- LAI is also available

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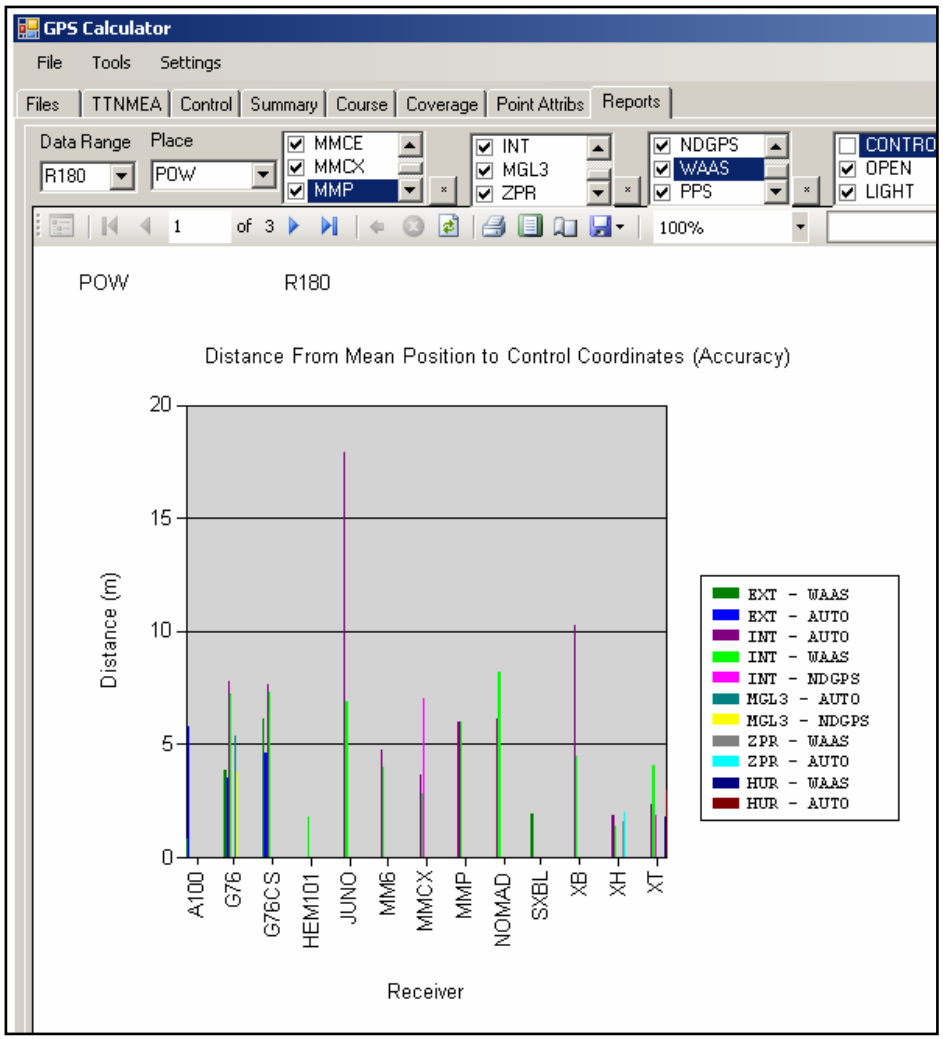
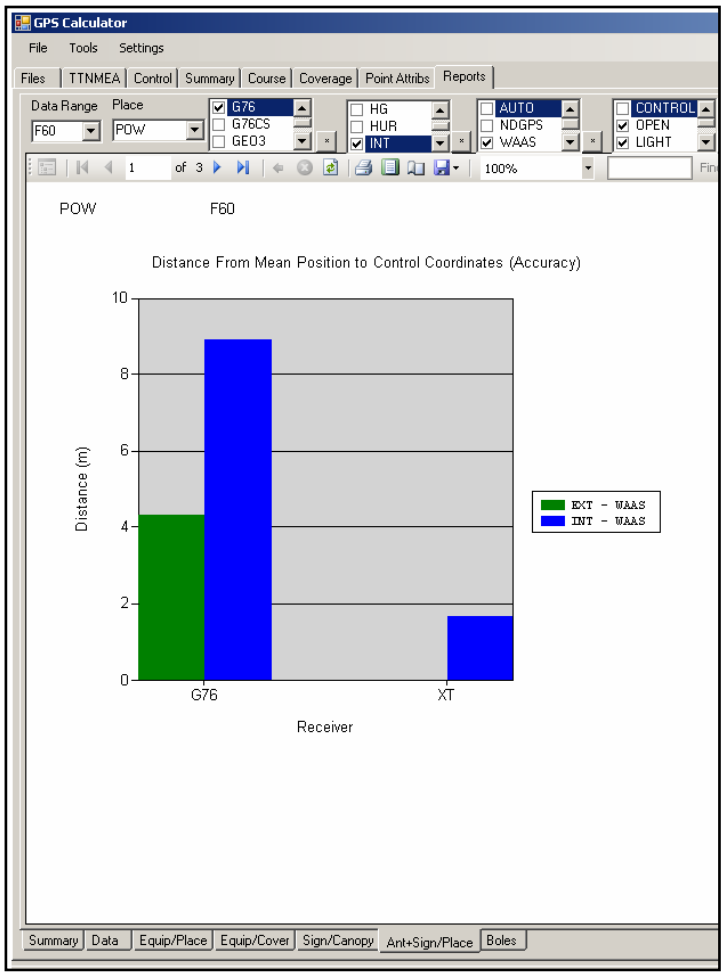


Receiver Comparison under various forest canopies.

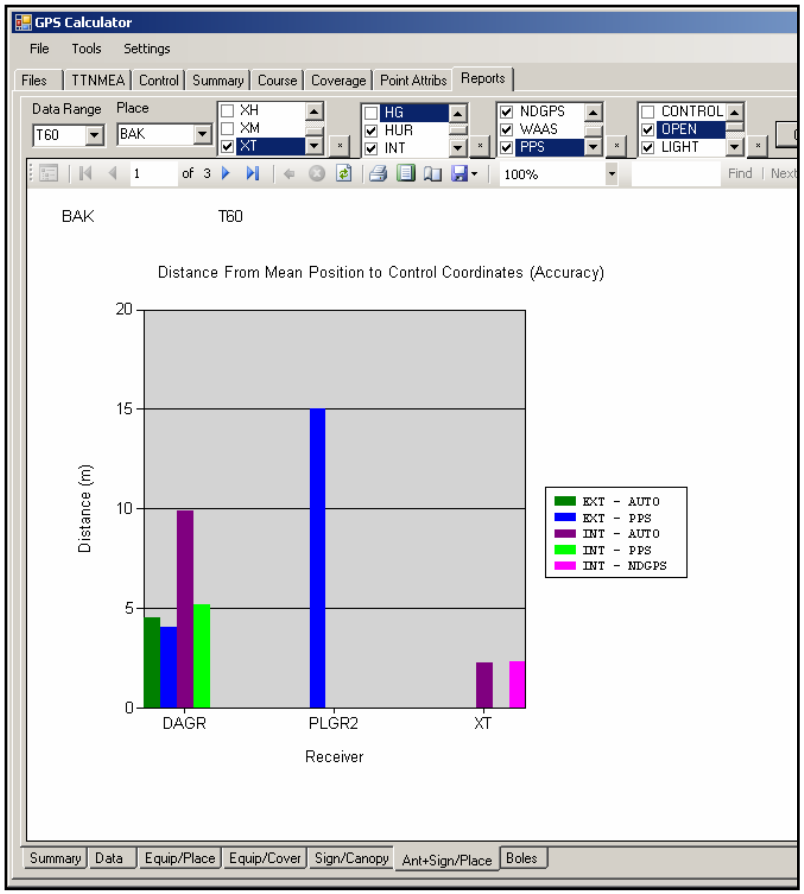
Query tool helps Forest Service personnel determine which receiver configuration will meet a specified need.

Mapping versus Recreation Receivers



- The query tool can be used to determine which GPS receivers and procedures are suitable for various positioning and navigation operations such as:
  - timber cruising (high accuracy)
  - sample plot location
  - fire boundary
  - noxious weed, pest damage location, etc. (low accuracy)
- At the same time, these measurements can be quantified

Military Equipment



- PLGRs and DAGRs were also observed as there are some being used within the agency.

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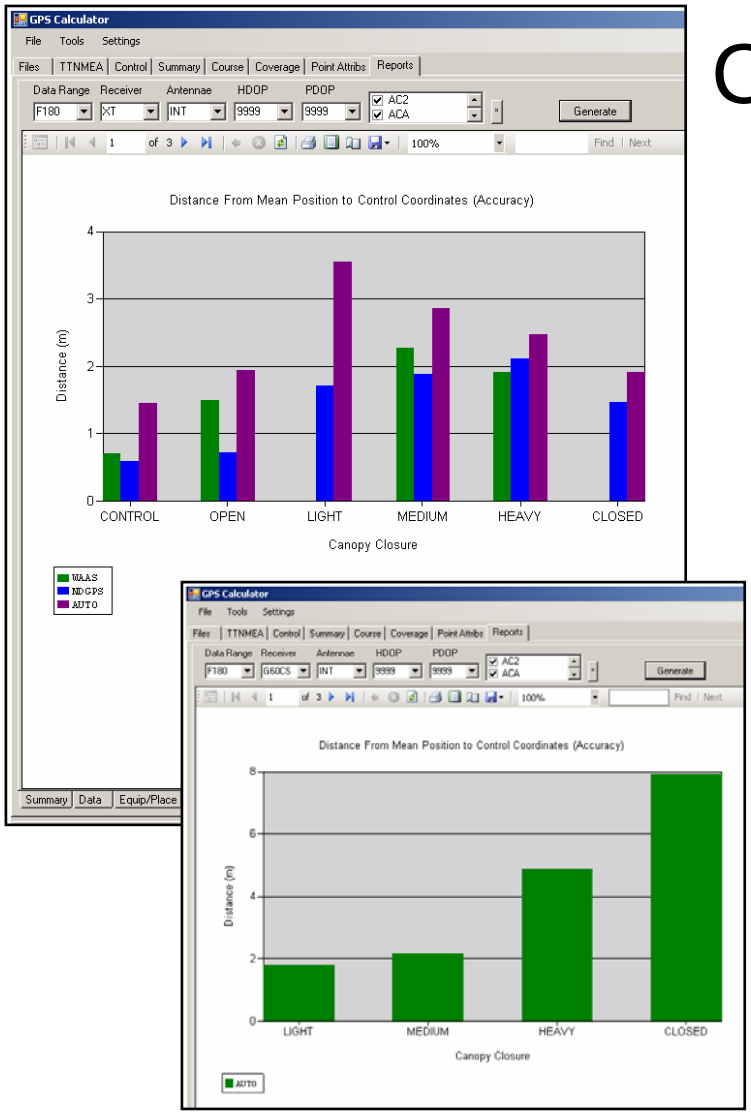

Canopy Cover Considerations

- What are the observed influences of canopy cover?
- What are affects of boles, stems, foliage?

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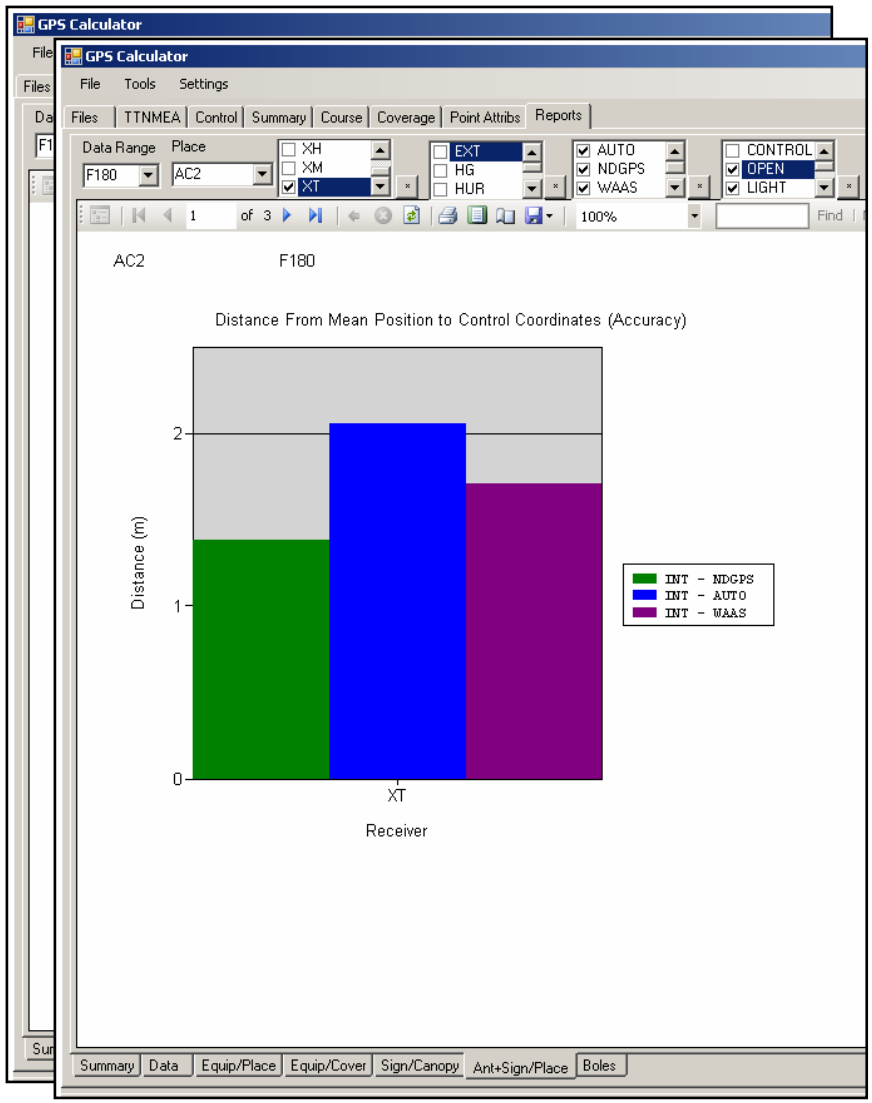

Signal Difference

- Augmentation signal helps improve measurement accuracy, but by how much?

- NDGPS can be received under canopy but the WAAS signal is sometimes blocked.

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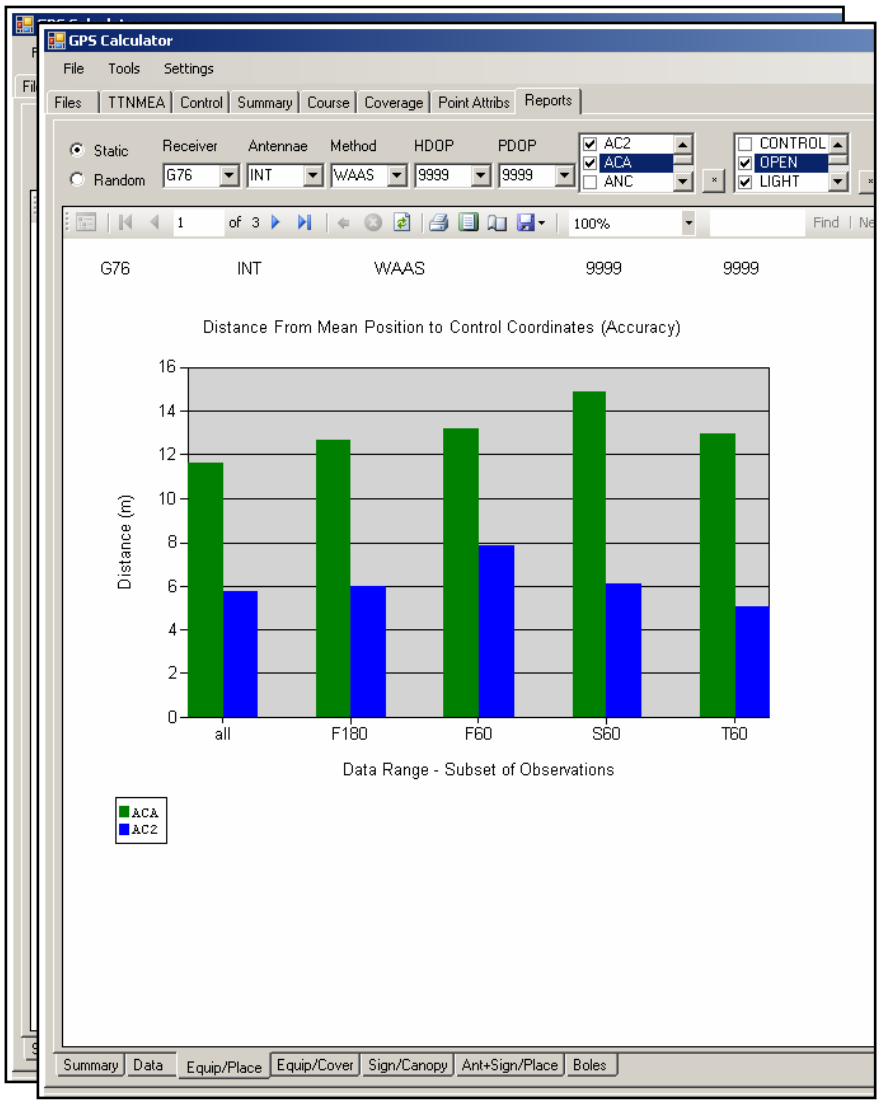
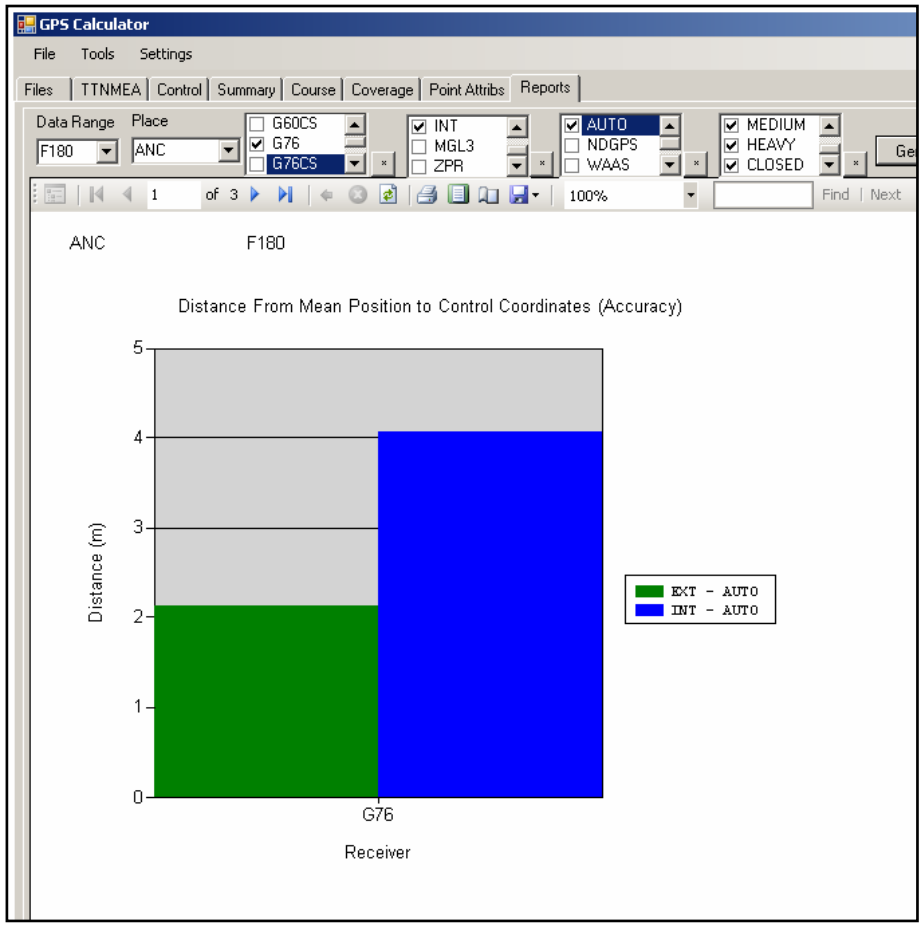


Measurements Improved by WAAS Change

- WAAS is becoming more available for use in lighter canopy by the Forest Service.
- There were observed improvements at Bar Harbor relative to the WAAS satellite change.

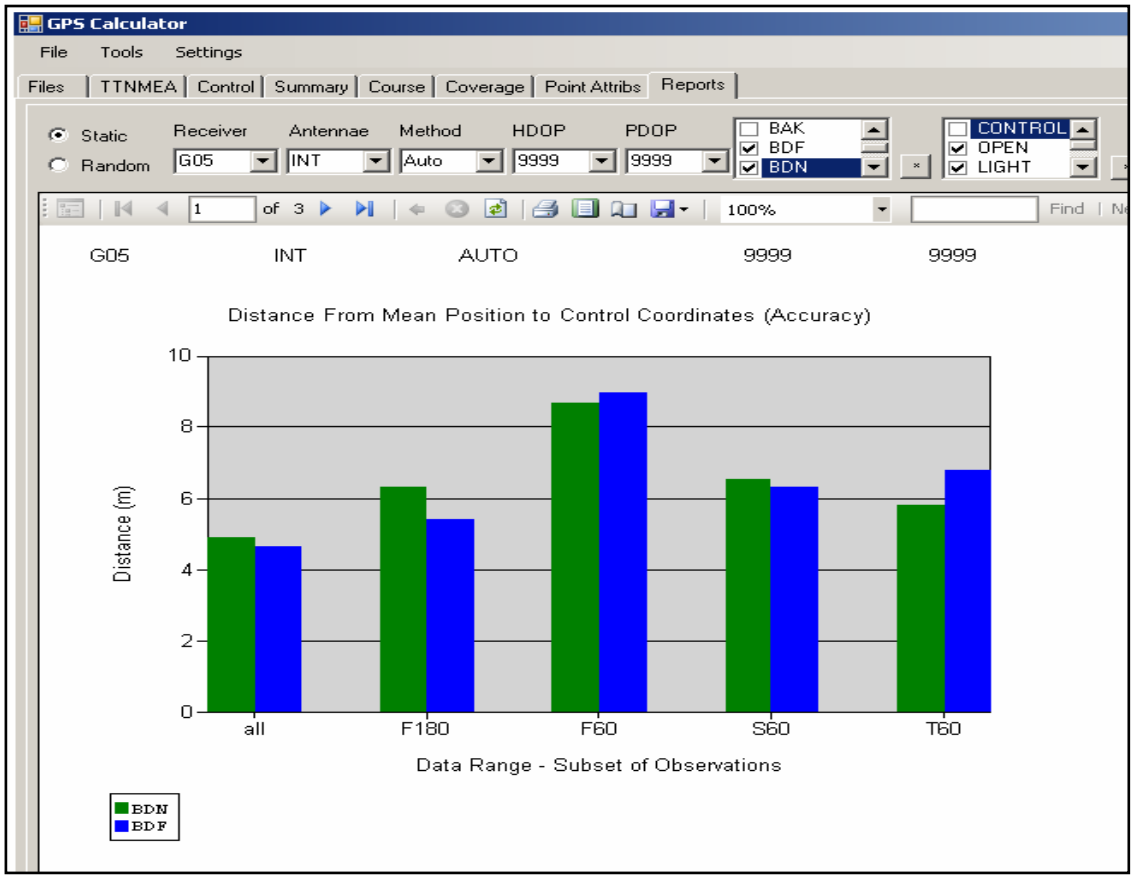
Antenna Influence



How much does an antenna improve the measurement?

External antenna usually speeds up data collection under canopy.

Leaf On versus Leaf Off



Hoosier Natl. Forest experience shows little difference in accuracy between leaf on / leaf off conditions but collection efficiency improved significantly with leaf off.

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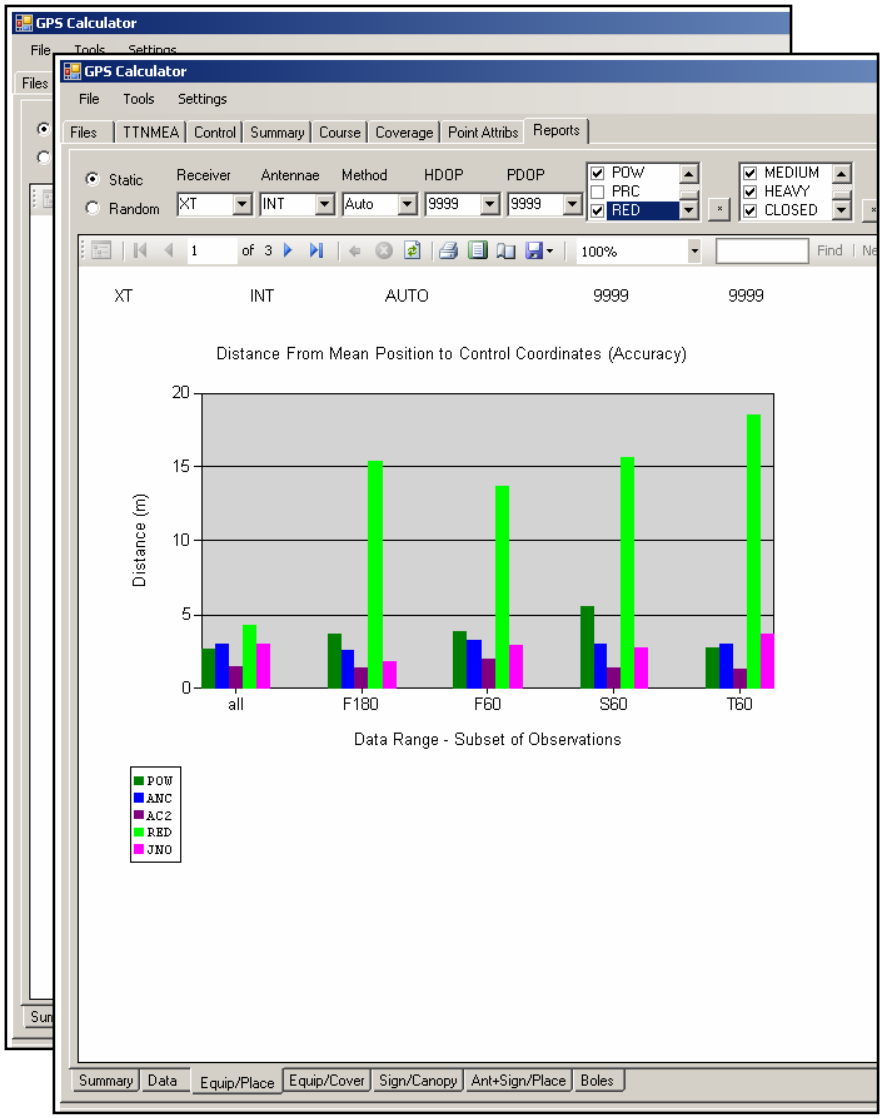

Tree Bole Influence

With the limited data collected, it appears that accuracy may be influenced more by the bole density than the foliage density.

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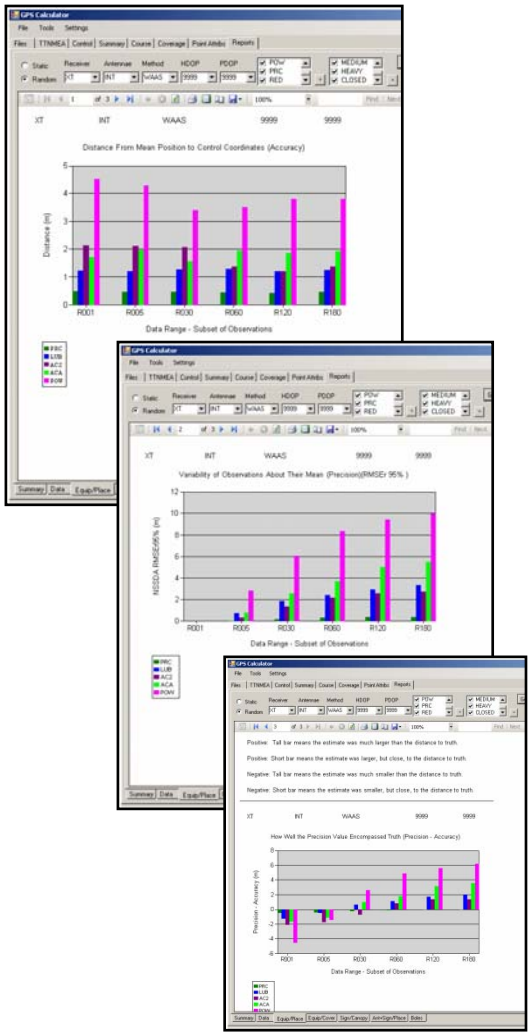
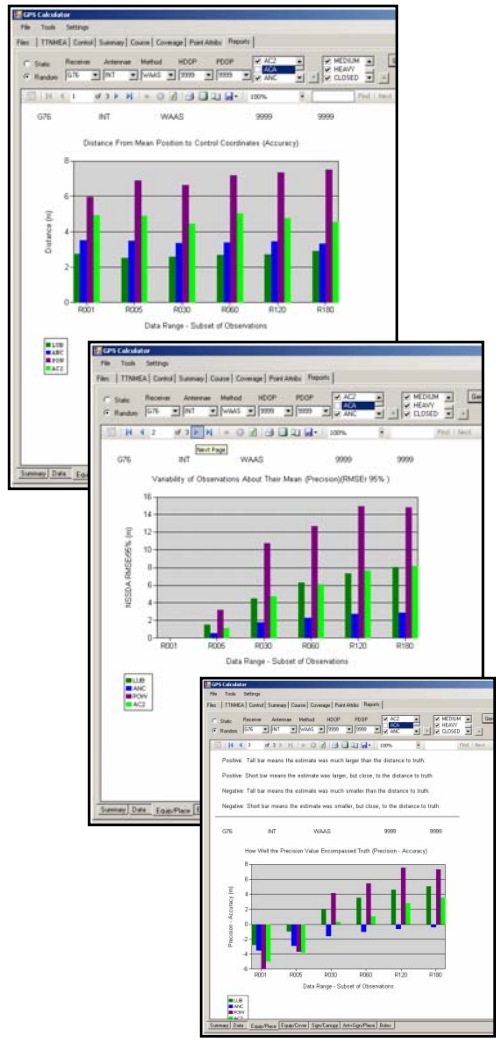
Field Procedure Improvement



- FS requires averaging fixes to help determine measurement quality
- From this work it appears we might have a procedure that allows reducing field time by half
- *This still needs to be studied more thoroughly.*



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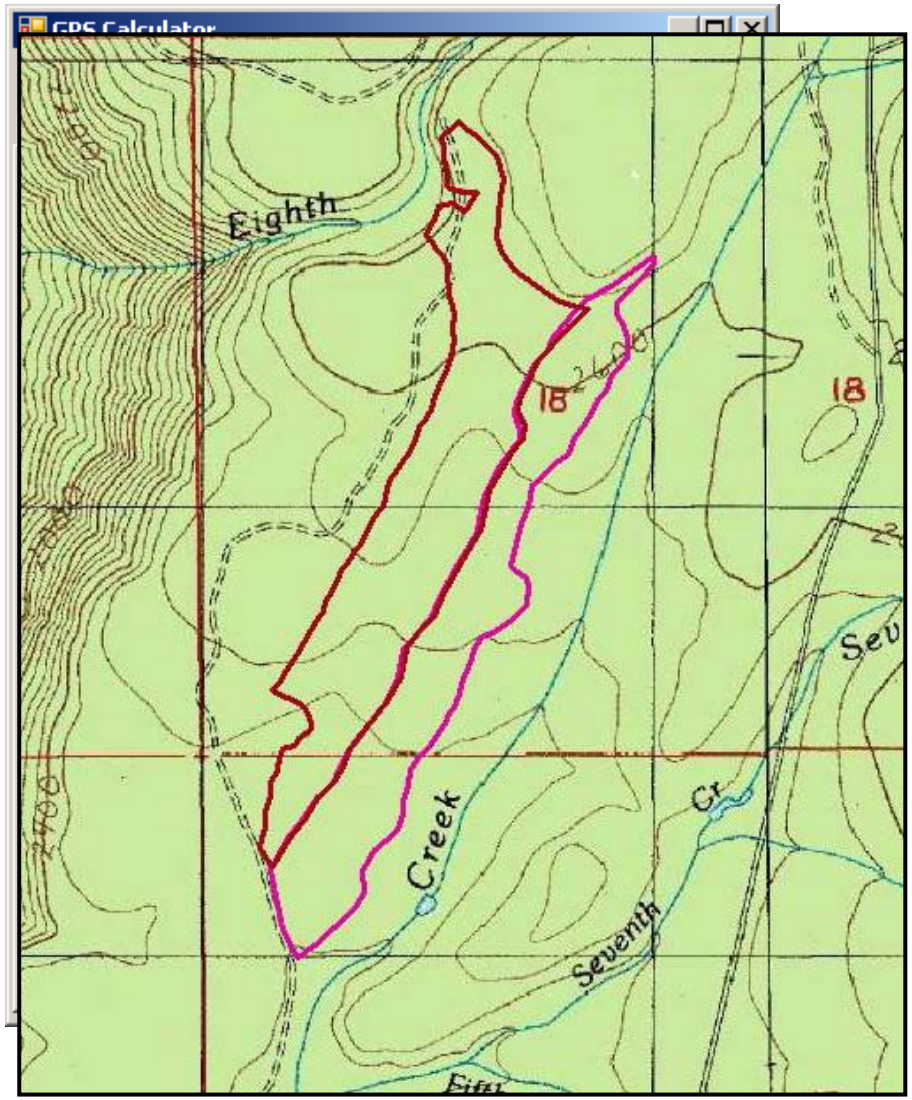

Forest Unit Area Expanded Volumes

- Timber cruising needs to know the area accuracy for an entire unit that is being measured with a specific GPS configuration.
- This is done by comparing the timber unit being measured to similar control courses.
- Area based sampling methods can then be used to better quantify timber, biomass, carbon sequestration or similar volumes.
- The information from this project is invaluable.

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Forest Service Gratitude

The USDA Forest Service has come a long way in positioning and navigation to manage our nations timber and range resources ---

We express our thanks to the Defense Department and those associated with making GPS available to the civilian community.

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GPS Use In The DOI

"Soup to nuts"

- Safety-of-Life operations – Search-and-Rescue, Fire, Homeland Security, Transportation, etc. Law Enforcement
- Natural and Cultural Resource data collection and monitoring
- Facilities management
- Navigation for many other activities

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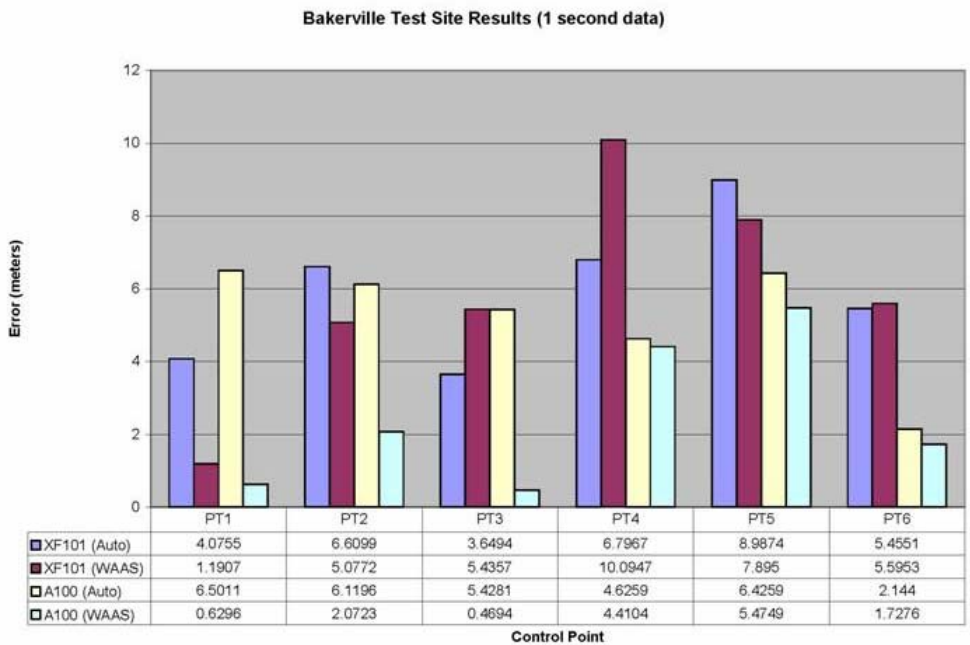
Why Do This?

- Saves the government money
- Provides accurate receiver specifications information under actual field conditions
- Helps develop efficient workflows based on real world field conditions



	PT1	PT2	PT3	PT4	PT5	PT6
XF101 (Auto)	4.0755	6.6099	3.6494	6.7967	8.9874	5.4551
XF101 (WAAS)	1.1907	5.0772	5.4357	10.0947	7.895	5.5953
A100 (Auto)	6.5011	6.1196	5.4281	4.6259	6.4259	2.144
A100 (WAAS)	0.6296	2.0723	0.4694	4.4104	5.4749	1.7276

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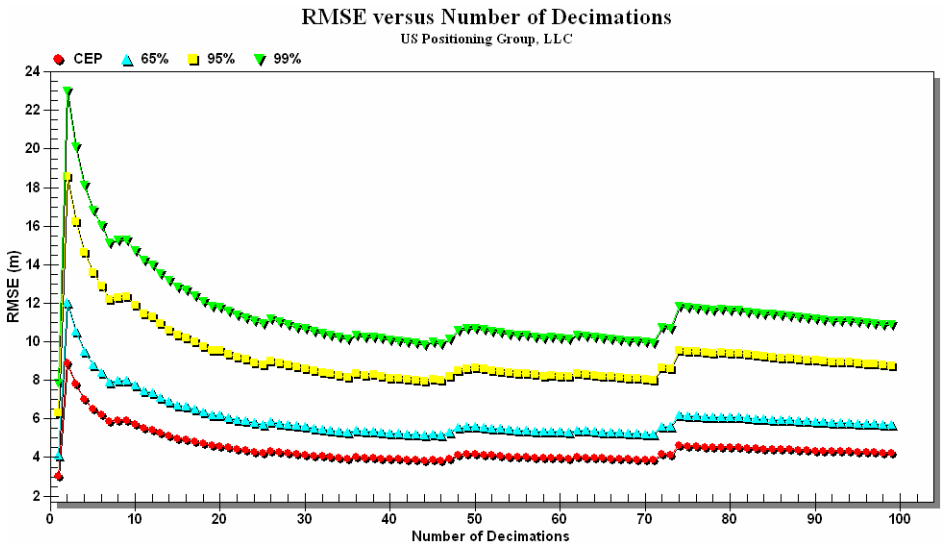
Which tool?

- Provides information to users on the right tools to meet their requirements
- Helps to validate manufacturers performance specifications



Requirement: "*I need a hammer.*"