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GNSS-Based Auto-Guidance Accuracy Testing

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Background

- Auto-guidance (auto-steering) systems provide numerous benefits
- Performance of different systems depends on internal and external factors
- Quality of auto-guidance performance must be quantified in repeatable manner
- ASABE has two active projects:
 - GPS Dynamic Test Standard (X578)
 - Auto-Guidance Test Standard (X605)



Outline

- Why do auto-guidance systems perform differently?
- What is “guidance error”?
- 2005 auto-guidance field day demo review
- 2006 pilot test of different systems using Nebraska Tractor Test Laboratory’s test track
- What discussion items should be addressed in the future?

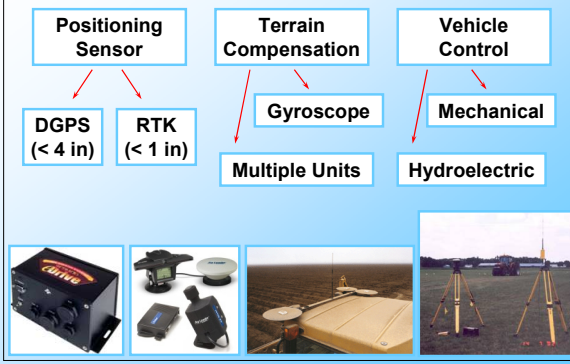


Agricultural Vehicle Guidance

- Reference method
 - Local triangulation
 - Crop-based methods
 - Mechanical feelers
 - Laser row tracking
 - Machine vision
 - GNSS-based guidance
- Level of assistance
 - Navigation aids
 - Lightbar parallel tracking
 - Auto-guidance
 - Auto-steering
 - Autonomous vehicles
 - Field robots

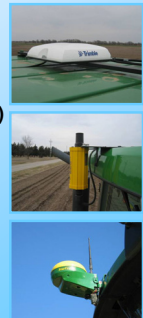


GNSS-Based Auto-Guidance



Popular GPS Solutions

- Single Frequency Receivers
 - WAAS, EGNOS, Beacon
 - OmniSTAR VBS, John Deere SF1
 - Subscription/Free (sub-meter accuracy)
- Dual Frequency Receivers
 - OmniSTAR HP/XP, John Deere SF2
 - Subscription (decimeter accuracy)
- RTK Receiver
 - Base Station (centimeter accuracy)



Auto-Guidance Applicability


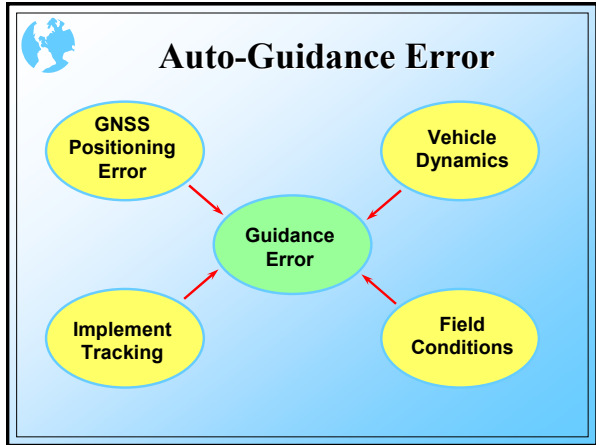
- **Sub-meter accuracy**
 - 2-4 ft year-to-year
 - 1 ft pass-to-pass
 - Mechanical steering
- **Decimeter accuracy**
 - 8 in year-to-year
 - 4 in pass-to-pass
 - Electro-hydraulic controls
- **Centimeter accuracy**
 - 1 in year-to-year
 - 1 in pass-to-pass
 - Base station

Tillage/Disking
 Spraying/Spreading
 Harvesting
 Seeding
 Mapping
 Planting
 Cultivating
 Bedding
 Strip Tilling
 Drip Tape Placement
 Land Leveling
 Topographic Mapping

What does “±” actually mean ?

- **Nature of the test**
 - Static vs. dynamic
- **Duration of the test**
 - Pass-to-pass vs. year-to-year
- **Definition of the test**
 - Precision versus accuracy
- **Statistic used**
 - 68%/1σ vs. 95%/2σ PI
- **Guidance error versus GPS error**
 - Positioning vs. guidance error

Cross-track error





2005 Auto-Guidance Field Day


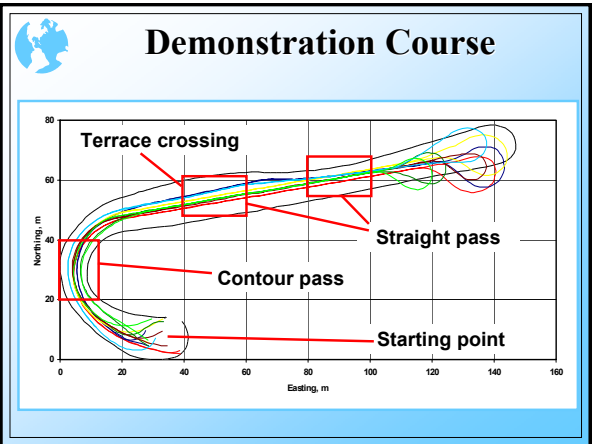


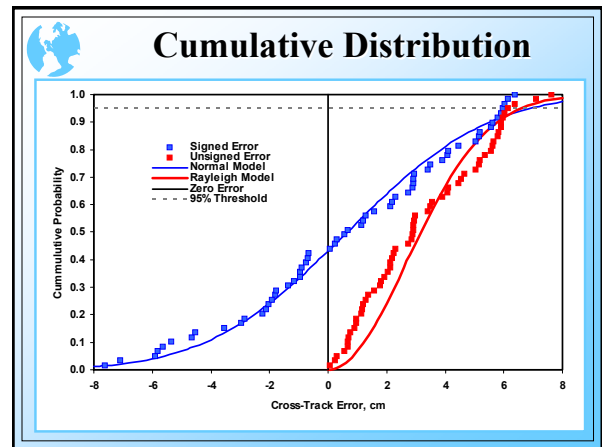
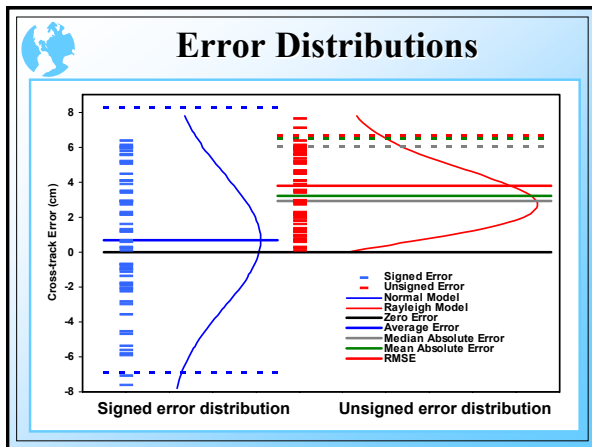
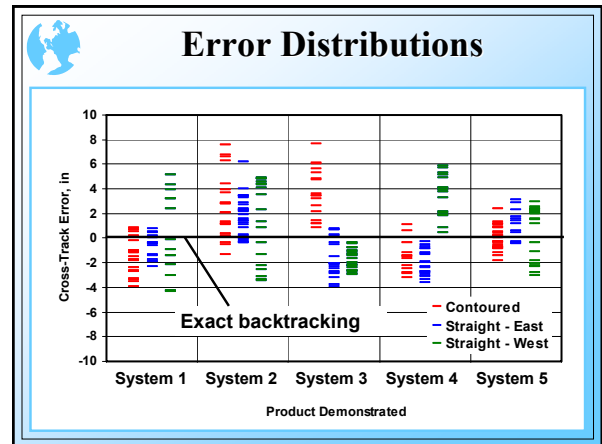
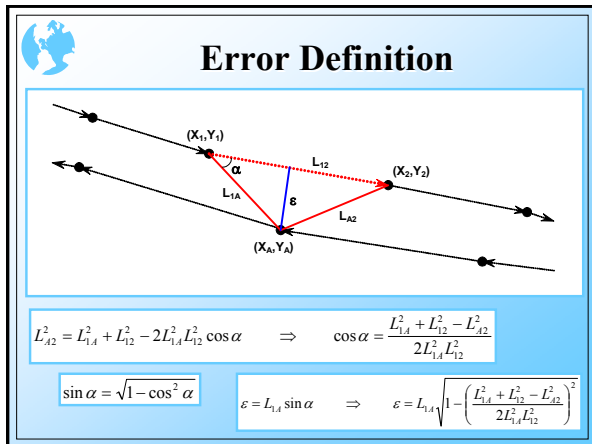

August 18, 2005 – ARDC, Mead, NE

2005 Field Demonstration



- Pull-type cart
- J-type course
- Coulter marker
- RTK-level GPS position logging



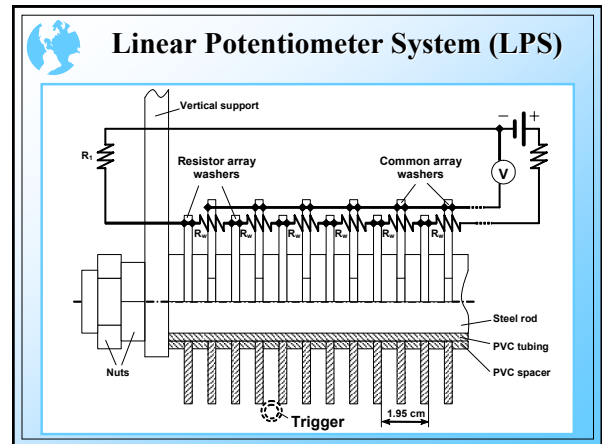
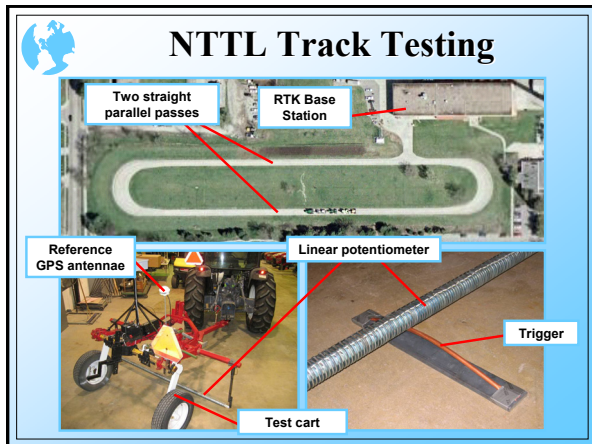
Field Day Results

Product	Points	Average	Standard Deviation	95% PI	p-value
RTK 1	52	-1.9	5.4	10.8	0.73
RTK 2	69	4.9	6.2	12.3	0.43
RTK 3	56	-0.1	7.4	14.8	0.99
RTK 4	48	-0.1	7.3	14.6	0.99
RTK 5	62	1.0	4.0	8.0	0.80
DGPS	48	-3.8	8.0	16.1	0.64
WAAS	66	24.3	15.1	30.2	0.11

Product	Maximum	Median		Average		RMSE	
		Value	95% PI	Value	95% PI	Value	95% PI
RTK 1	13.1	3.5	7.4	4.5	7.1	5.7	6.1
RTK 2	19.2	5.8	12.0	6.4	11.6	7.9	10.0
RTK 3	19.4	5.4	11.3	6.1	10.9	7.3	9.4
RTK 4	15.0	5.7	12.0	6.2	11.5	7.2	9.9
RTK 5	8.0	2.9	6.1	3.4	5.9	4.1	5.1
DGPS	19.5	7.3	15.2	7.5	14.7	8.8	12.7
WAAS	52.5	20.8	43.3	24.3	41.8	28.6	36.0

Error values are in cm

- ### Producer-Viewed Differences
- Interface and ease of use
 - Modes of operation
 - Installation time and options
 - Setup and calibration procedure
 - Cost and possible upgrades
 - Versatility and secondary use
 - Technical support
-



2006 Pilot Test

- System A – Centimeter-level accuracy
- System B – Decimeter-level accuracy
- LPS – based analysis
- GPS – based analysis
- Straight passes
- Three 15-min runs
- Two consecutive days
- Urban environment
- Concrete pavement

Test Sequence

North – 9 triggers

South – 11 triggers

Spacing – 50 ft

Swath – 125 ft

Test Run 1

Test Run 2

Test Run 3

Test Run 4

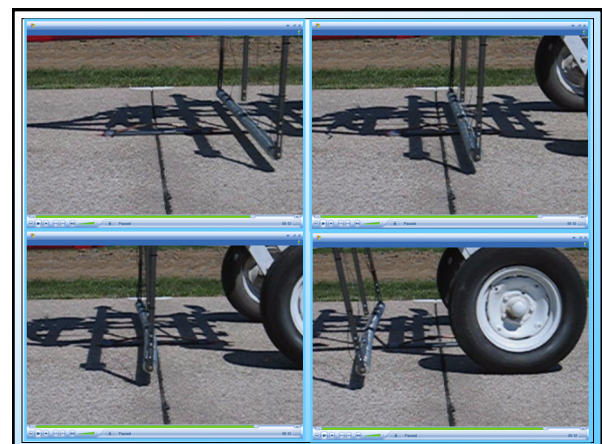
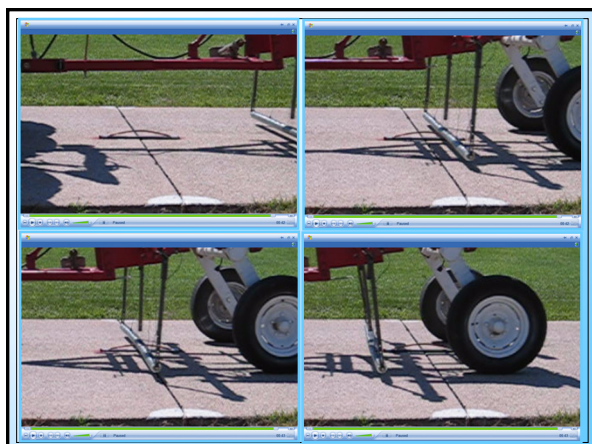
A-B line

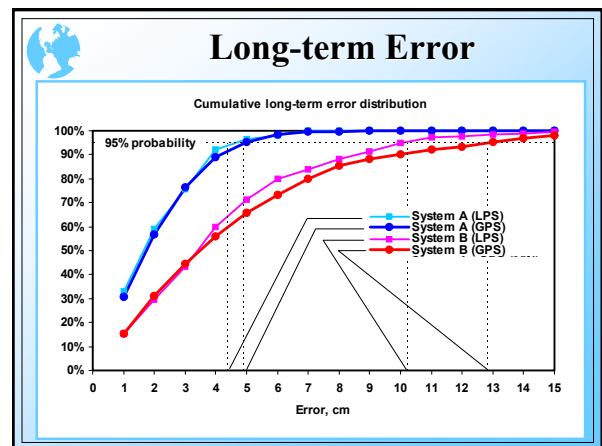
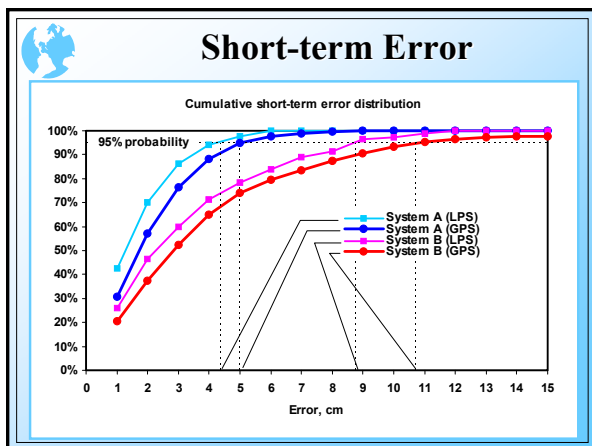
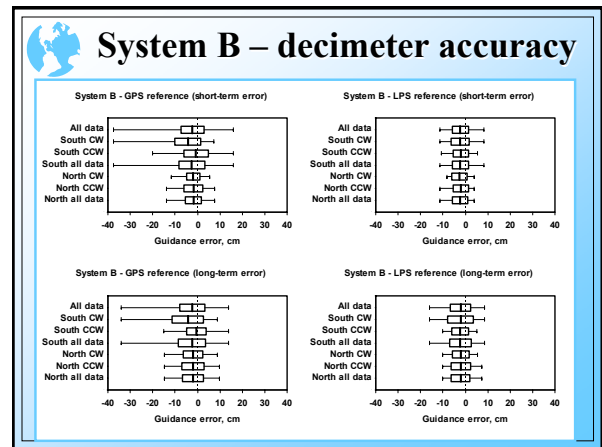
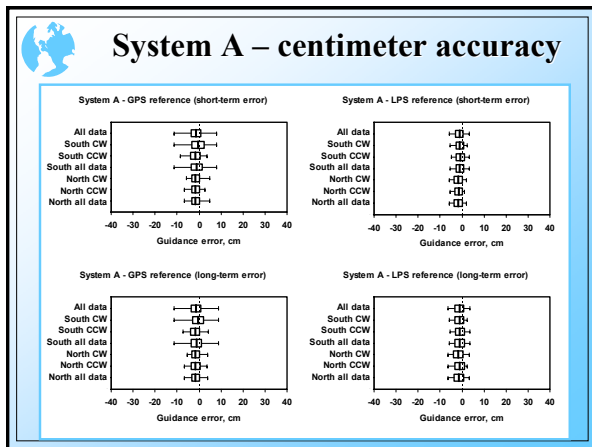
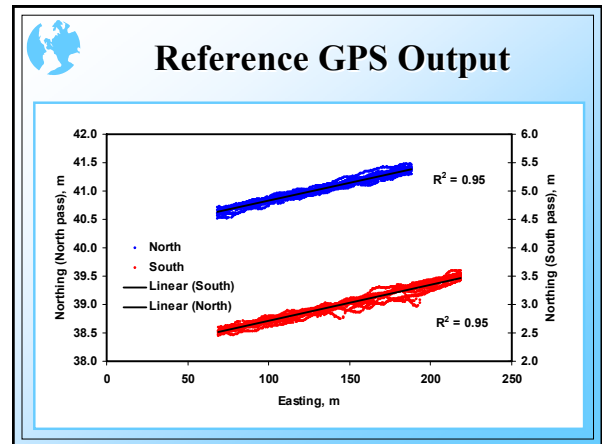
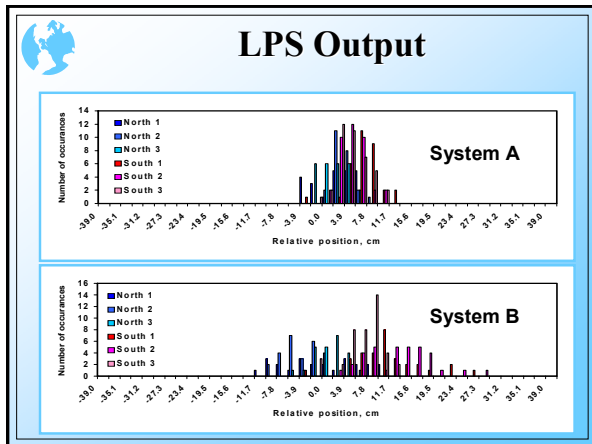
Northing, m

0 25 50 75 100 125 150 175 200 225 250

0 25 50 75 100 125 150 175 200 225 250

Easting, m







Discussion Items

- **Test location**
 - Surface conditions
 - Clarity of sky
 - Test course segments
- **Point of measurement**
 - Reference receiver
 - Total station
 - Mechanical (contact) sensor
 - Optical (non-contact) sensor
- **Test sequence**
 - PDOP requirements
 - Pass-to-pass test
 - Year-to-year test
- **Error terms**
 - Dealing with bias
 - Parametric and non-parametric estimates
- **Machinery selection**
 - Tractors
 - Sprayers



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