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GNSS-Based Auto-Guidance Test Program Development

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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)

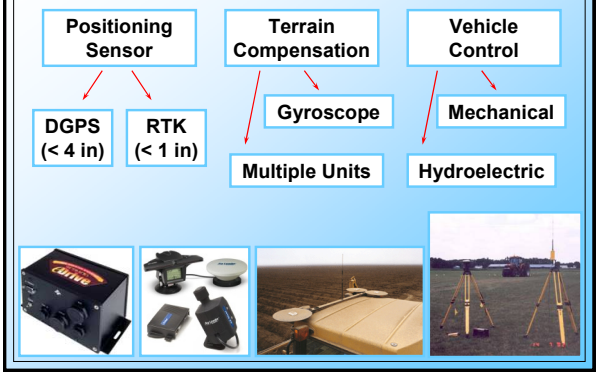
Outline

- 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
- 2007 instrument development and future plans

Agricultural Vehicle Guidance

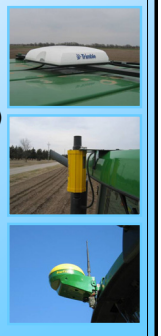
- Reference method
  - Local triangulation
  - Crop-based methods
    - Mechanical feelers
    - Laser row tracking
    - Machine vision
  - GNSS-based guidance
- Level of assistance
  - Navigation aids
    - Lightbar parallel tracking
  - Auto-guidance
    - Auto-steering
  - Autonomous vehicles
  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

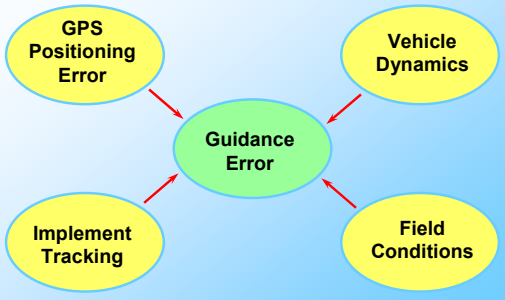
- Sub-meter accuracy
  - 2-4 ft year-to-year
  - 1 ft pass-to-pass
  - Mechanical steering
- Decimeter accuracy
  - 8 in year-to-year
  - 4 in pass-to-pass
  - Electro-hydraulic controls
- Centimeter accuracy
  - 1 in year-to-year
  - 1 in pass-to-pass
  - Base station

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. long-term
- Definition of the test
  - Precision versus accuracy
- Statistic used
  - 68% (1σ) vs. 95% (2σ) prediction
- Type of error
  - Positioning vs. guidance error

Auto-Guidance Error



2005 Auto-Guidance Field Day

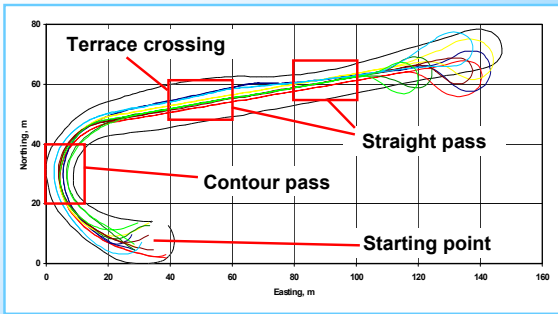
BEELINE TECHNOLOGIES
AUTOFARM GPS Precision Farming
OUTBACK eDrive Just Let Go™
Ag Leader Technology
JOHN DEERE
Trimble

August 18, 2005 – ARDC, Mead, Nebraska

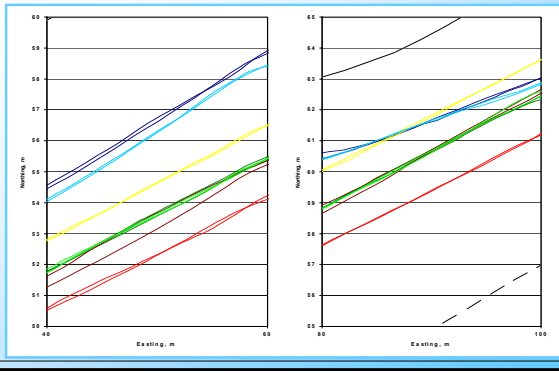
2005 Field Demonstration

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

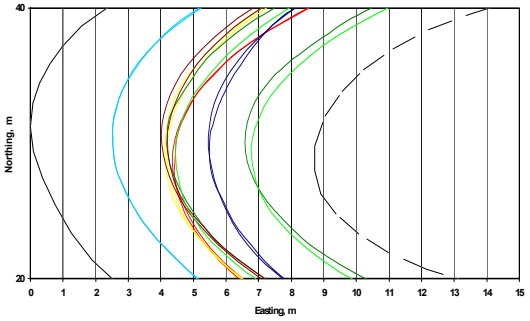
Demonstration Course



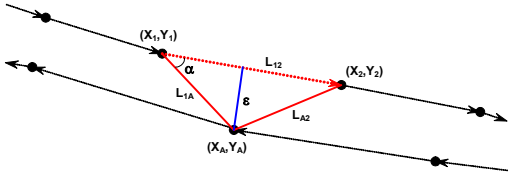
Straight Pass



Contour Pass



Error Definition

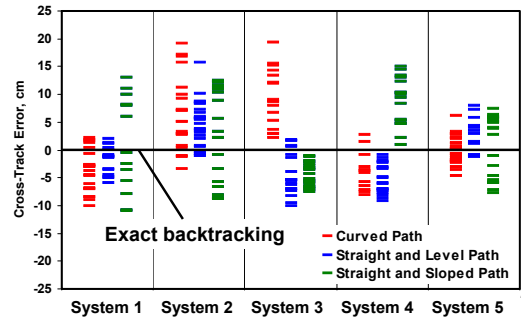


$$L_{A2}^2 = L_{1A}^2 + L_{12}^2 - 2L_{1A}L_{12}^2\cos\alpha \quad \Rightarrow \quad \cos\alpha = \frac{L_{1A}^2 + L_{12}^2 - L_{A2}^2}{2L_{1A}^2 L_{12}^2}$$

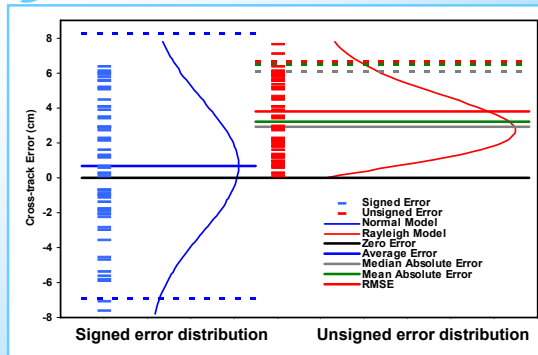
$$\sin\alpha = \sqrt{1-\cos^2\alpha}$$

$$\varepsilon = L_{1A}\sin\alpha \quad \Rightarrow \quad \varepsilon = L_{1A}\sqrt{1-\left(\frac{L_{1A}^2 + L_{12}^2 - L_{A2}^2}{2L_{1A}^2 L_{12}^2}\right)^2}$$

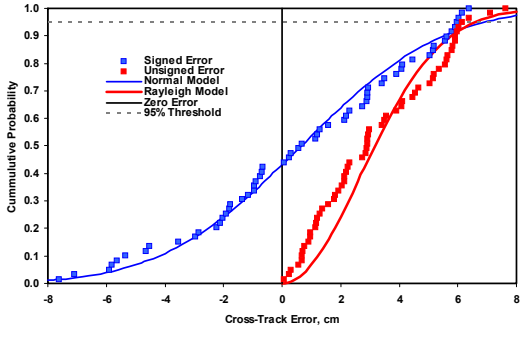
Error Distributions



Error Distributions



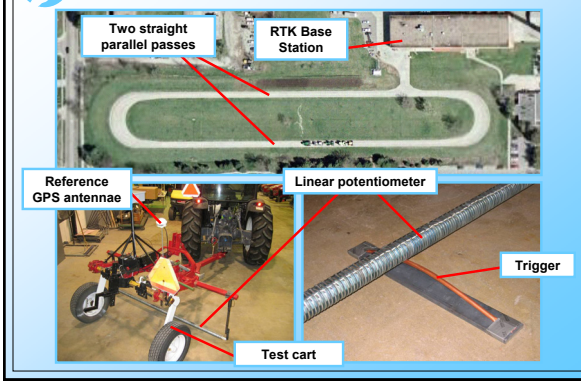
Cumulative Distribution



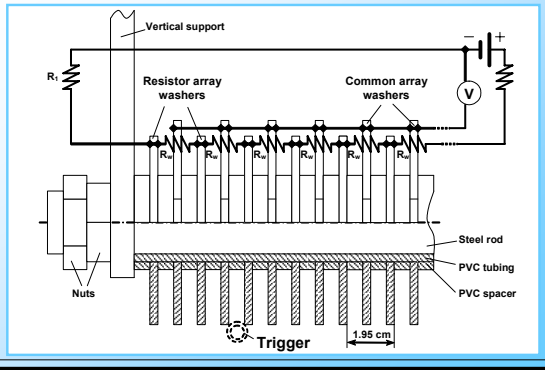
Producer-Viewed Differences

- 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 NTTL Track Testing



Linear Potentiometer System (LPS)

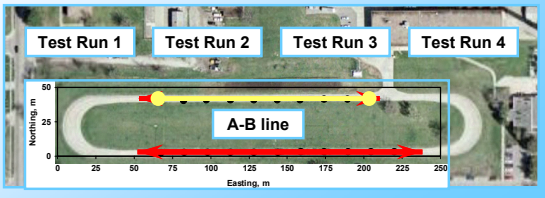


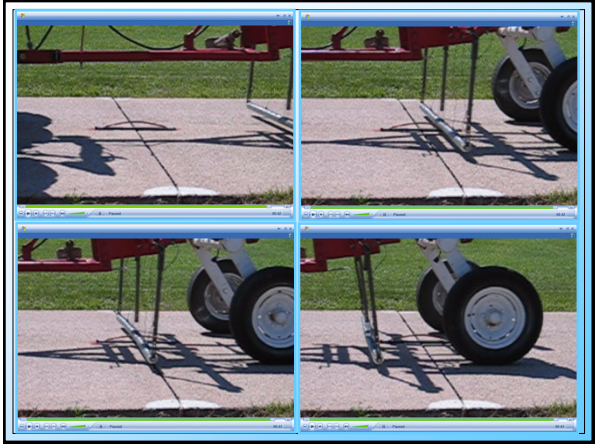
2006 Pilot Test

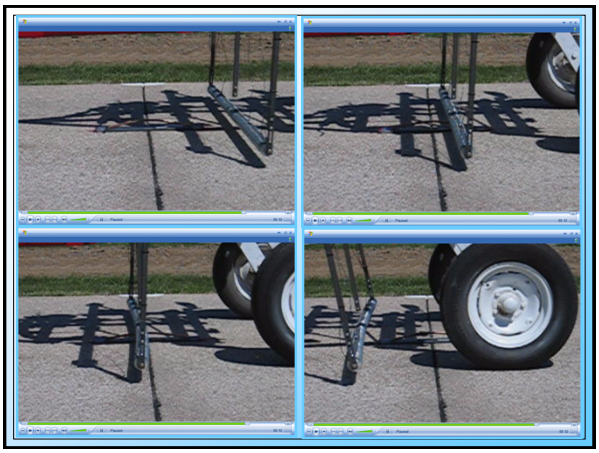
- System A – Centimeter-level accuracy
- System B – Decimeter-level accuracy
- LPS – based analysis
- GPS – based analysis
- Straight passes
- Three 15-min runs
- Two consecutive days
- Urban environment
- Concrete pavement

Test Sequence

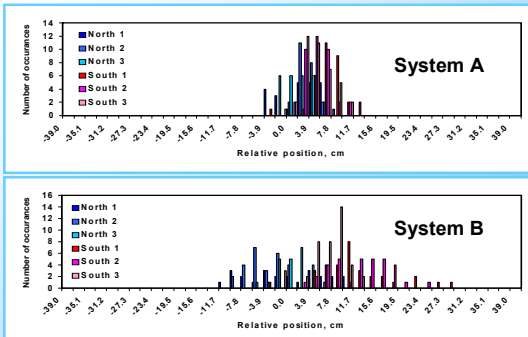
North – 9 triggers
South – 11 triggers
Spacing – 15.2 m
Swath – 38.1 m



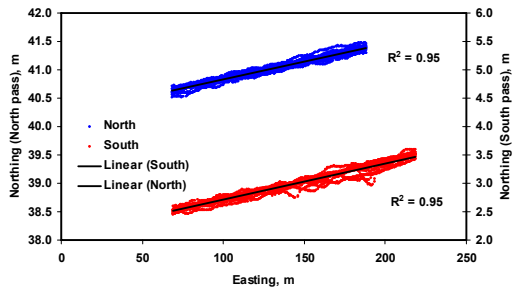




LPS Output



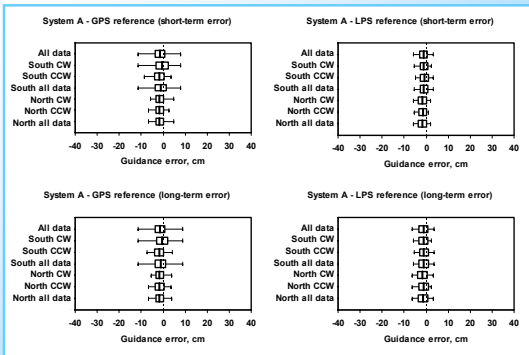
Reference GPS Output



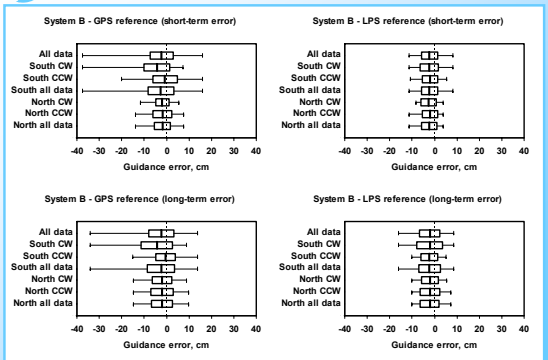
Error Definition

- **Standard error**
  - Difference between each trigger hit position and an average (balanced in terms of direction of travel) of all relevant hit positions calculated for each trigger separately (within 15 min for short-term error and all test data for long-term error)
  - Standard error of a simple linear regression for the GPS data
- **Cross-track error**
  - Expected difference between two tracks randomly selected from either a short-term or long-term pools of data
  - Theoretically, cross-track error equals to standard error multiplied by square root of 2

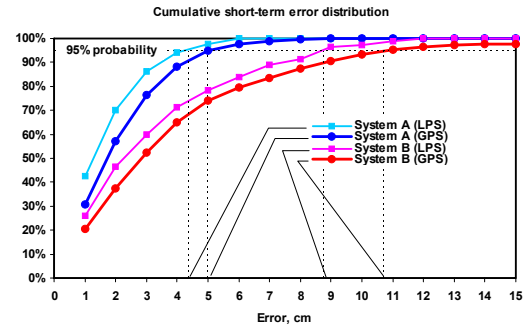
System A – centimeter accuracy



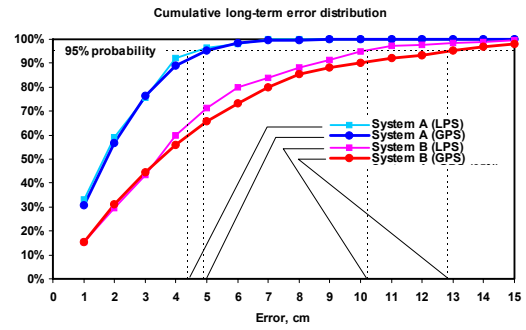
System B – decimeter accuracy



Short-term Error (Pass-to-Pass)



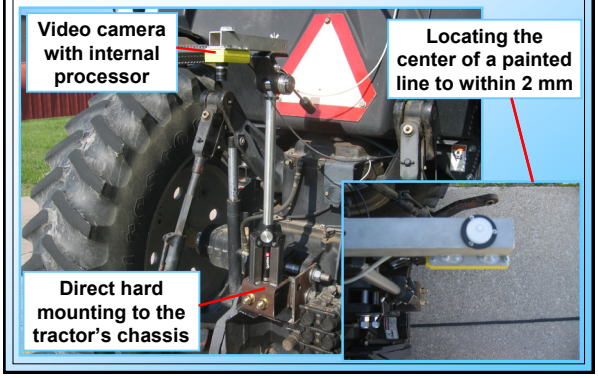
Long-term Error (Day-to-Day)



Standard Related Discussion Items

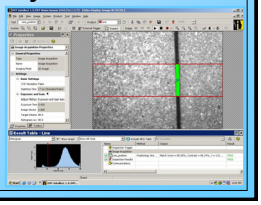
- Test location
  - Surface conditions
  - Clarity of sky
  - Test course segments
- Method of measurement
  - Reference receiver
  - Total station
  - Mechanical (contact) sensor
  - Optical (non-contact) sensor
- Test sequence
  - PDOP requirements
  - Pass-to-pass test
  - Day-to-day test
- Error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

Optical Sensor Development



2007 Test Plans

- Measurement close to the drawbar pivoting point
- Three 15-min test run sequences repeated three times
- Actual cross-track error calculation
- Non-parametric statistics only
- Three test segments
  - Linear flat
  - Curved flat
  - Curved sloped
- Line acquisition test trial



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