Sensors and Data Collection

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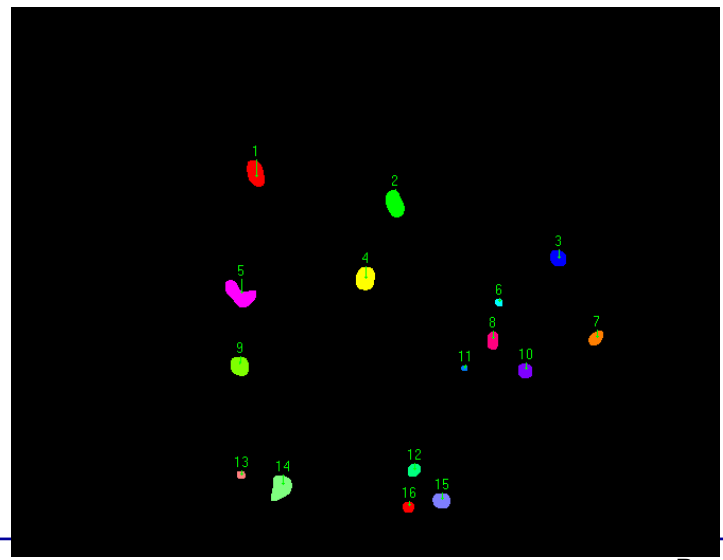
Introduction

- Link between Sensors/Data Collection to traceability is high
- Some sensors and data collection tools are available in agriculture, but are in the early phase of adoption on equipment.
- Evolution of sensors and automation are limiting factors.

Tracking individual fruits/vegetables

- Localized measurements
- Geometrically calibrated



Some Existing Traceability Systems

Cattle

AgInfoLink

Grain

efarm

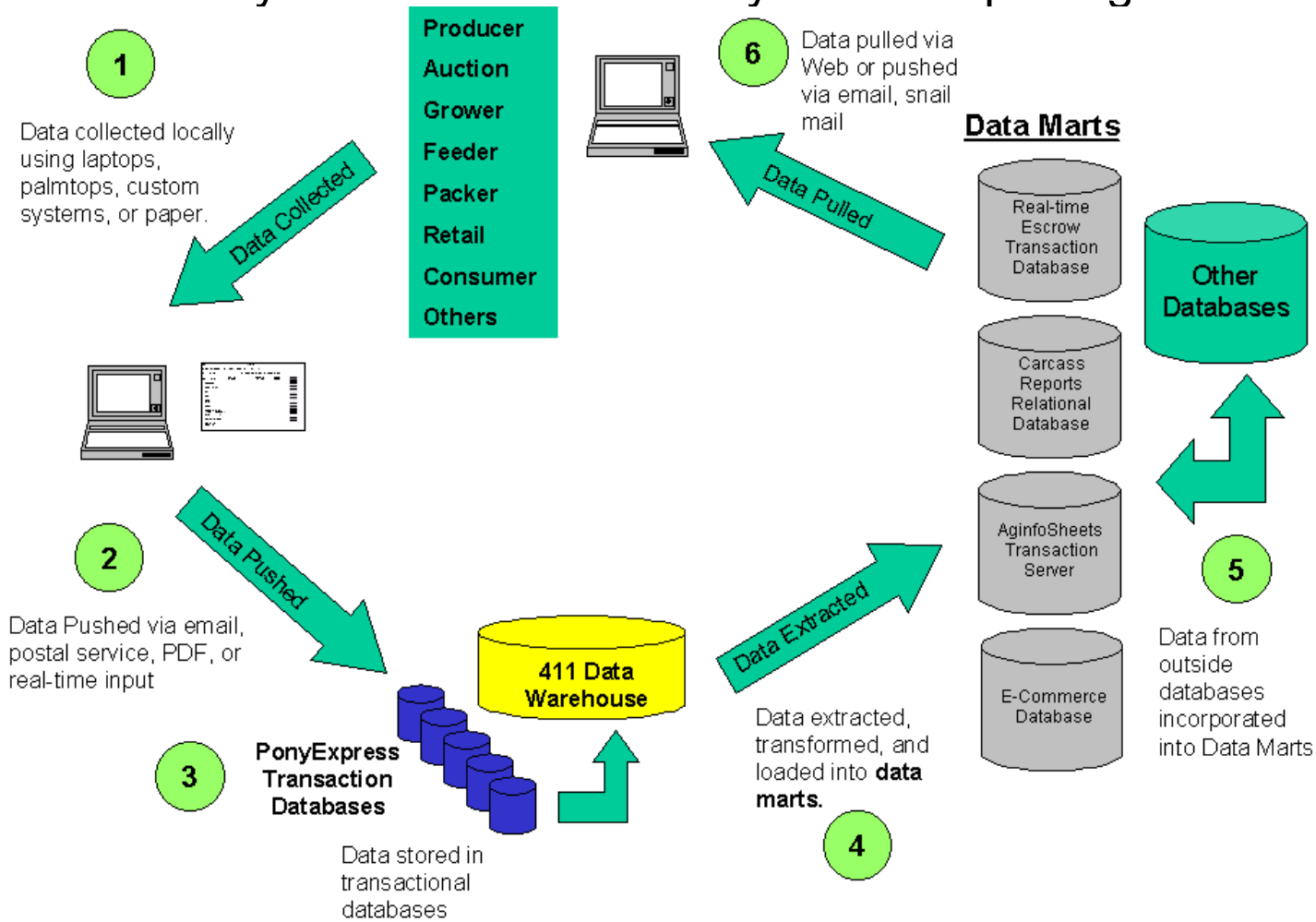
Fruits/Vegetables

AGRIS
A John Deere Company

THE INFRASTRUCTURE IS DEVELOPING FROM AN INFORMATION PERSPECTIVE

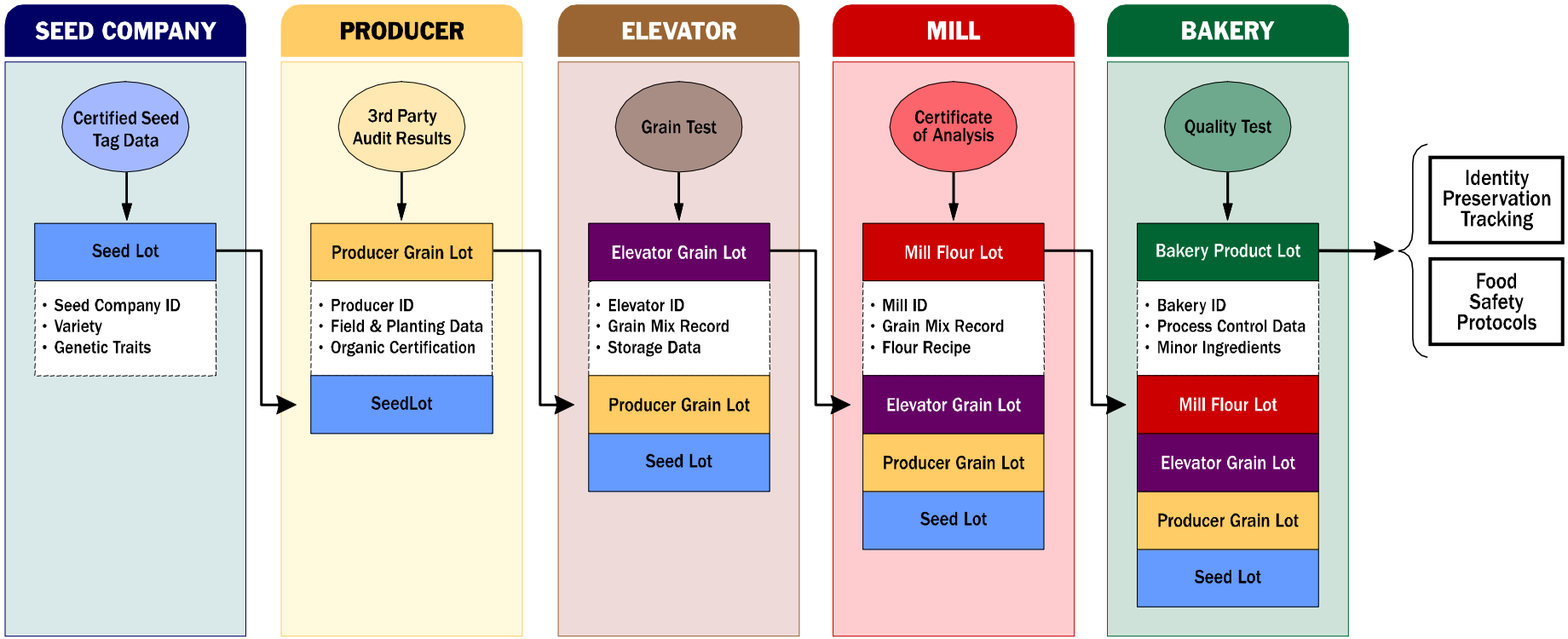
Existing Cattle Traceability System

AgInfoLink's "Pony Express" provides a technology backbone, supporting full food traceability with robust data analysis and reporting.



Existing Grain Traceability System

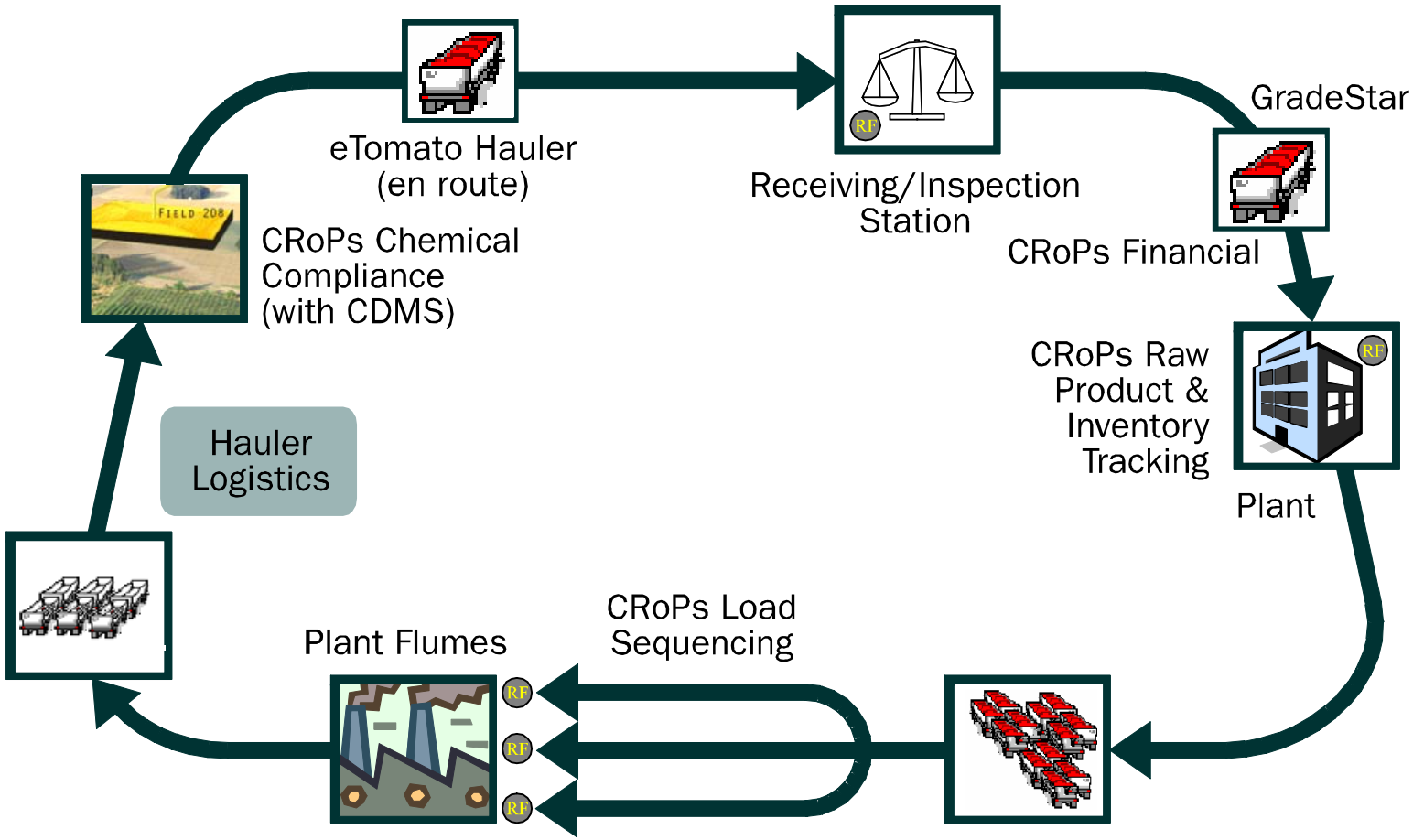
eFarm's private network delivers complete traceability from seed to final product, enabling efficiency, new revenue and food security.



Existing Fruits/Vegetables Traceability System

AGRIS
A John Deere Company

AGRIS Extend Ag enables closed-loop traceability for perishable food products.



Role of Sensors and Data Collection

- Quantification of information
- Simplification of the process for chain management
- Important for food chain diagnostics/prognostics
- Essential element for automation of the food chain

2.0 Data Collection Systems

Mobile Processor and Information Display

Position Receiver

Solution Packages

Agronomic Management

Environmental Compliance

Identity Tracking

Fleet Management &Maintenance

Machine & Operator Productivity

Mobile Office

Parallel Tracking Display

- Uses the GreenStar display and audible tones
- Free downloadable enhancements
  - Contours
  - 5 hz WAAS and SF1
  - RowFinder

Other manufacturers:

-Operator interfaces

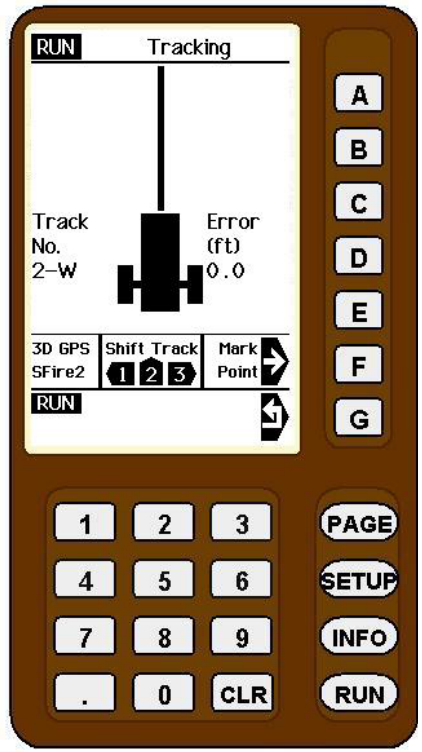
Lightbars

More graphical displays

Research need:

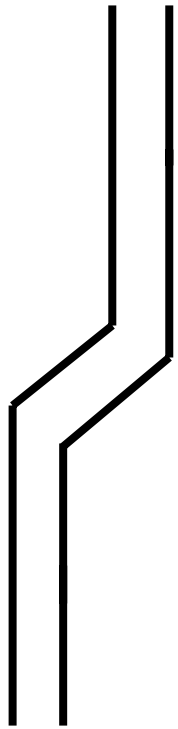
Man-machine interfaces.

Haptic devices



How Does it Work?

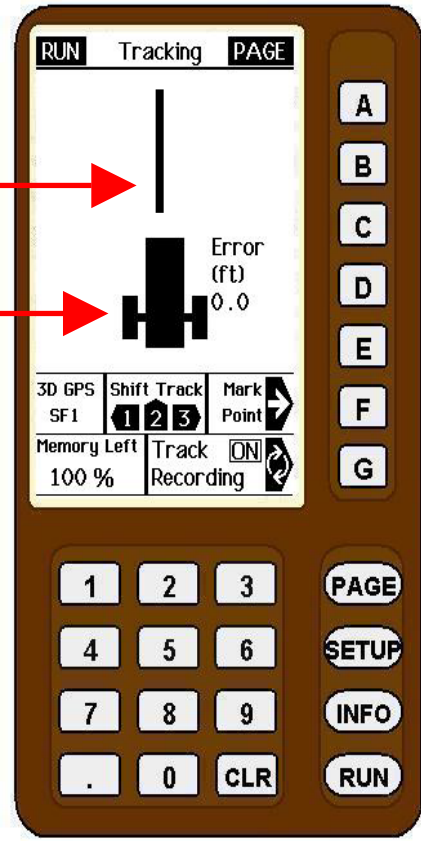
- System records passes in the GreenStar Display as a series of straight line segments
- 65,000 line segments can be stored
  - approx. 450 acres with 9.1-m (30-ft) implement
- % memory left on Run Page 1



What Does it Look Like?

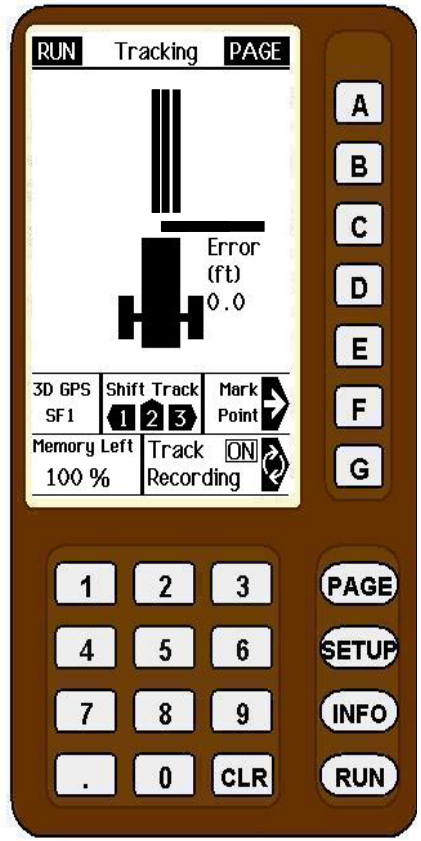
Navigation Bar

Vehicle Icon



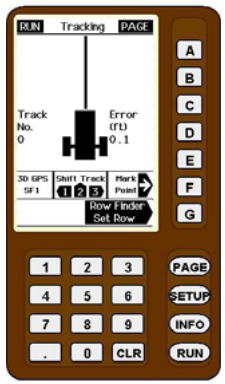
What Does it Look Like?

- **Steering Indicator**
  - Horizontal line located above vehicle icon
  - looks ahead six seconds
  - Points in the direction of the approaching turn
  - Length of indicator represents sharpness of the turn

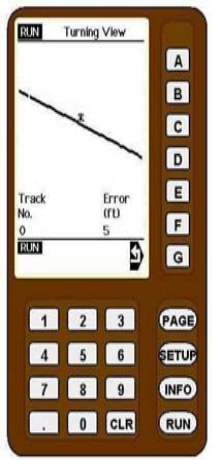


RowFinder

Field View

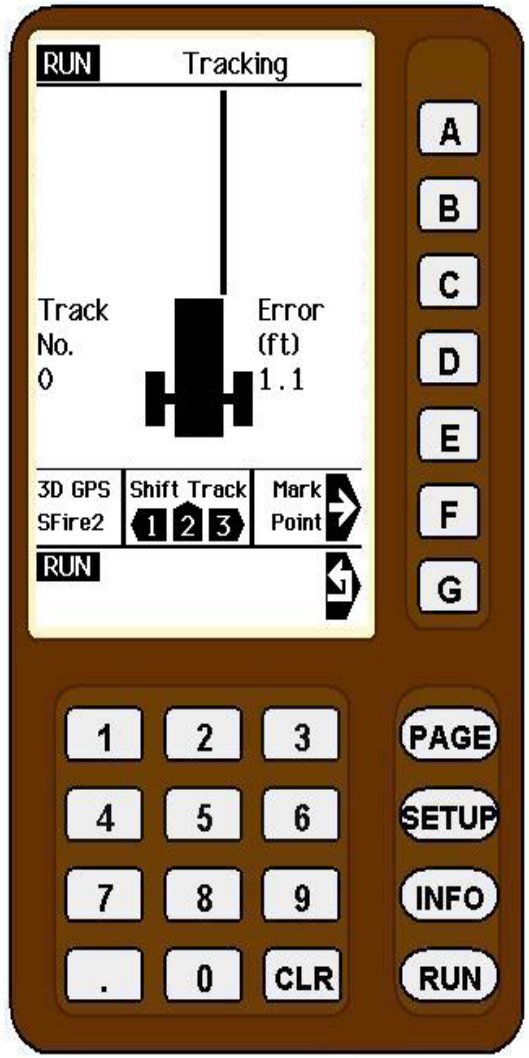


Turning View



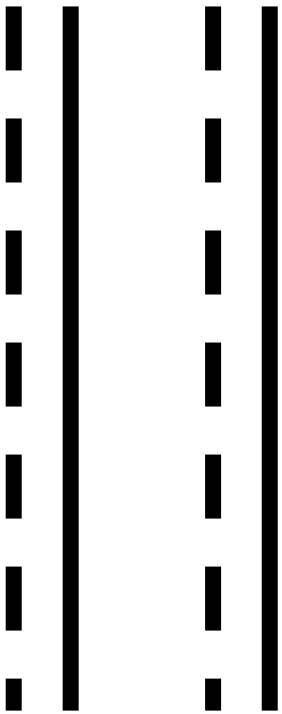
Shift Track

- Adjusts Track 0
  - Moves all subsequent tracks
- Moves in increments of 0.1 foot
  - 1 button moves left
  - 3 button moves right
  - 2 button centers track on vehicle's current position

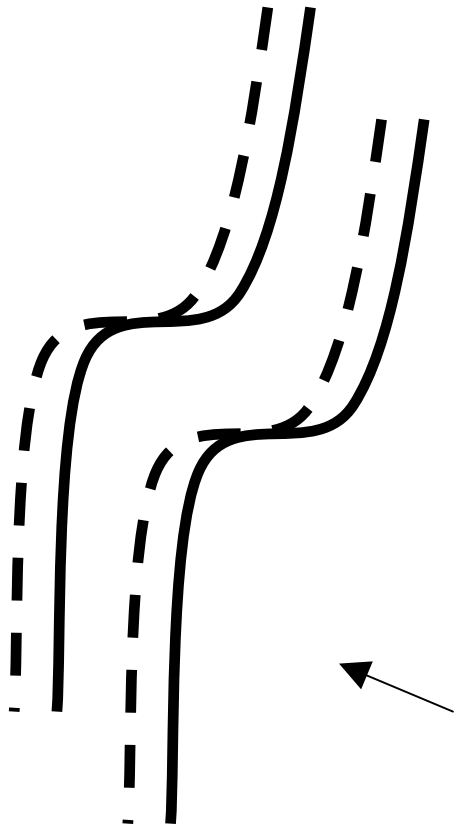


Shift Track Examples

Straight Track

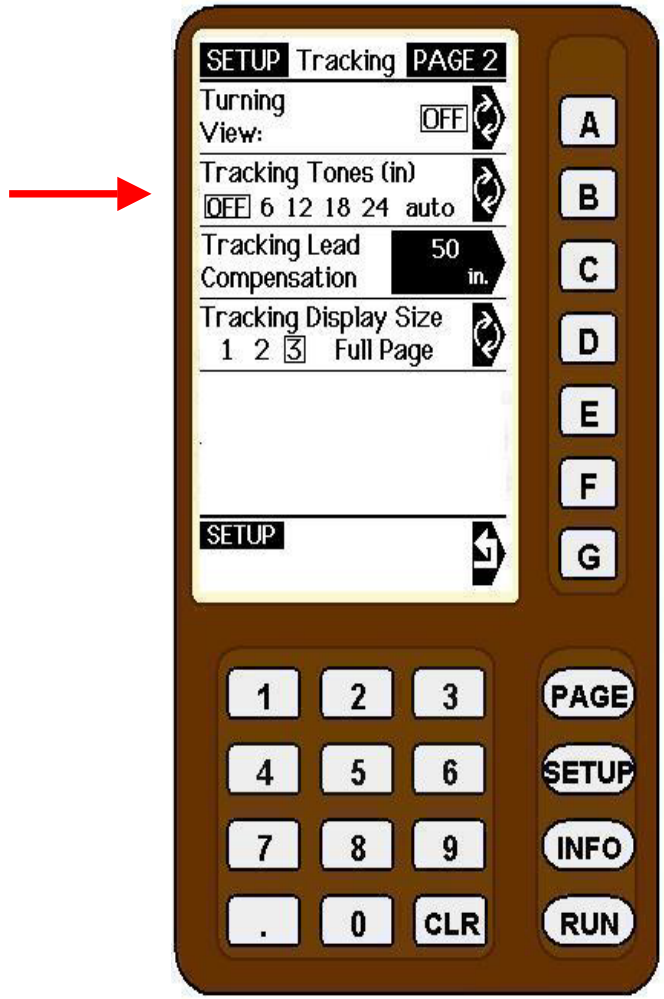


Contours



Adjustable Tracking Tones

- **User can set the off-track error that triggers tracking tones**



AutoTrac

GreenStar AutoTrac

- **Assisted steering system**
  - **Driver must takes control at the end of each pass**
- **Straight line guidance only**
- **Currently available for all John Deere Track Tractors**

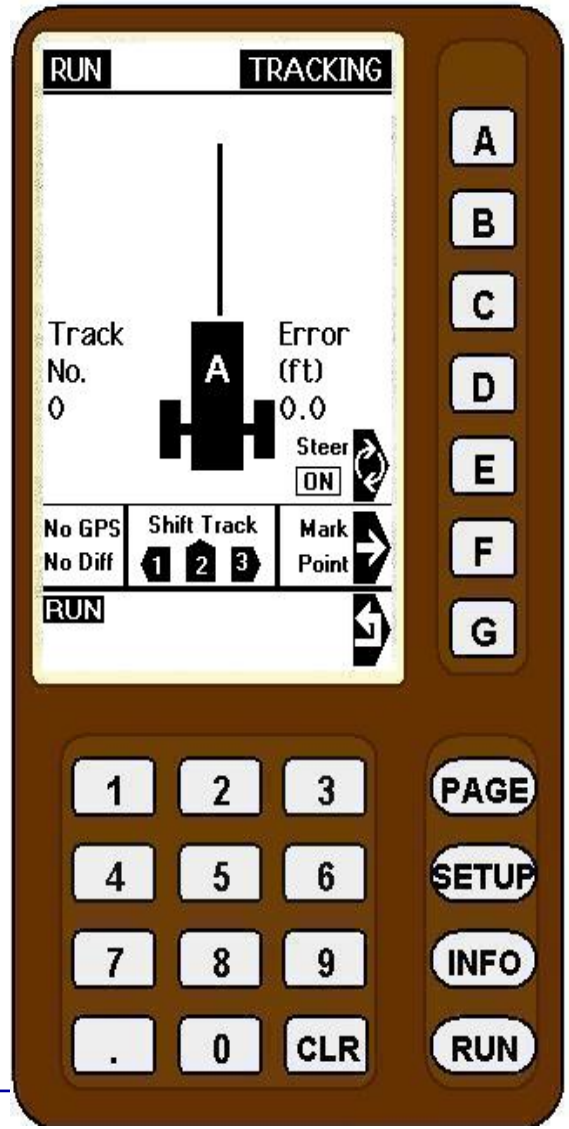
What is Needed for AutoTrac?

- Common Components for all AutoTrac Vehicles
  - GreenStar Display
  - Mobile Processor
  - StarFire Position Receiver
  - GreenStar Harness
  - Mounting Hardware
  - AutoTrac KeyCard
- Vehicle specific components
  - Some vehicles will require vehicle specific components

AutoTrac Operation

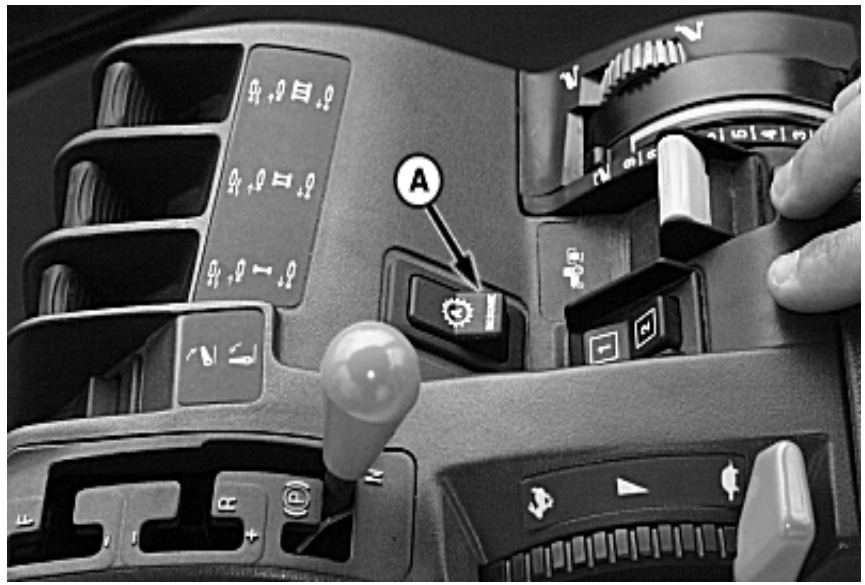
User interface of AutoTrac in the RUN screen.

1. Set track spacing
2. Define track 0 (A-B line)



AutoTrac Operation

- Auto Resume switch activates AutoTrac
- Auto Resume switch has dual functionality
- APS functionality is not affected



3.0 Sensors on Agricultural Equipment

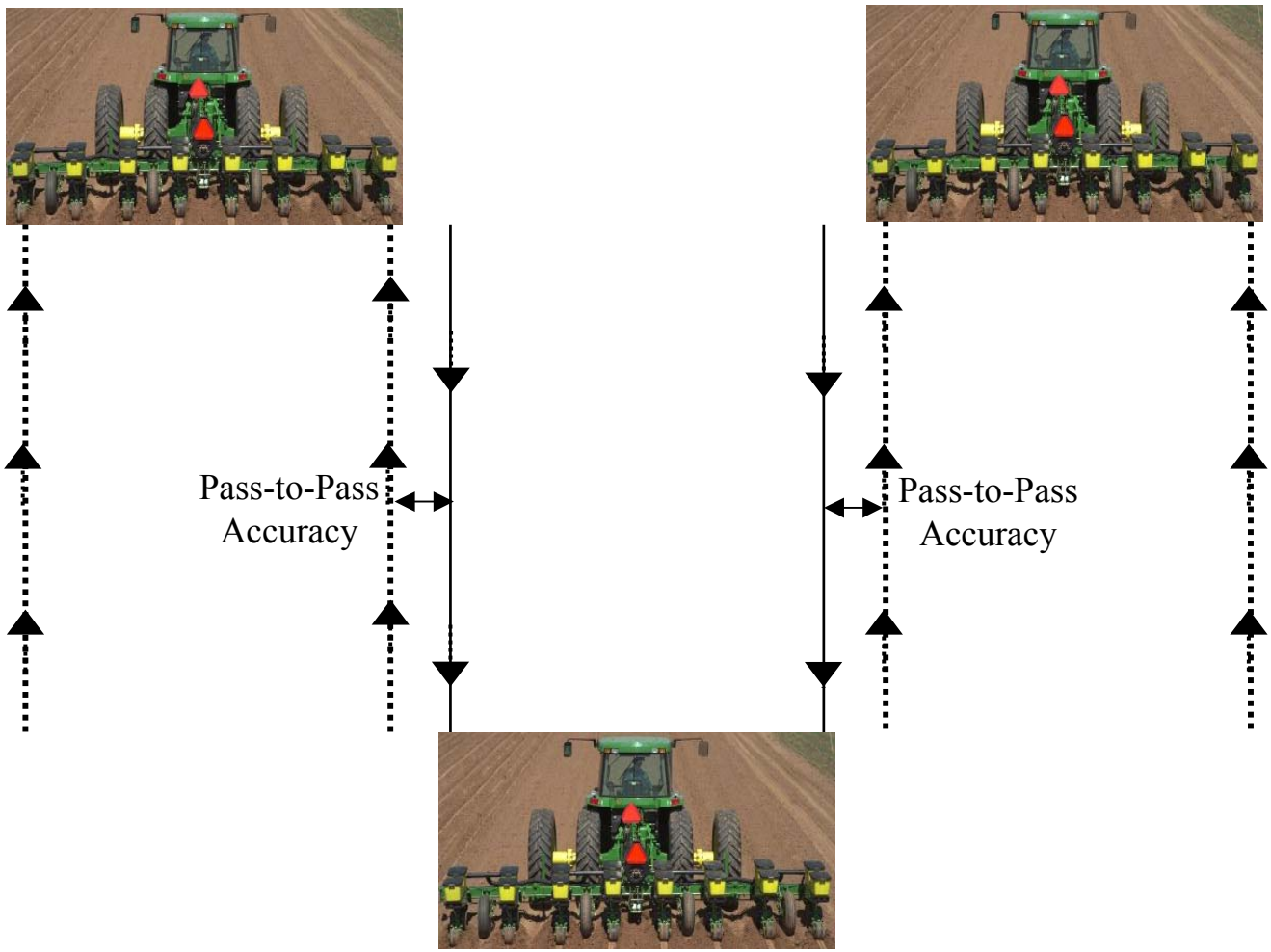
GPS Positioning Signal Options

- **Dual phase GPS receivers**
  - **Subscriptions are purchased to provide higher relative accuracy as needed**
    - **SF2 most accurate and reliable ($800/yr)**
    - **SF1 ($500/yr)**
    - **WAAS - still in test, less accurate (free)**
- **RTK GPS receiver**
  - **Requires a base station for corrections**
  - **High absolute accuracy (2 cm)**

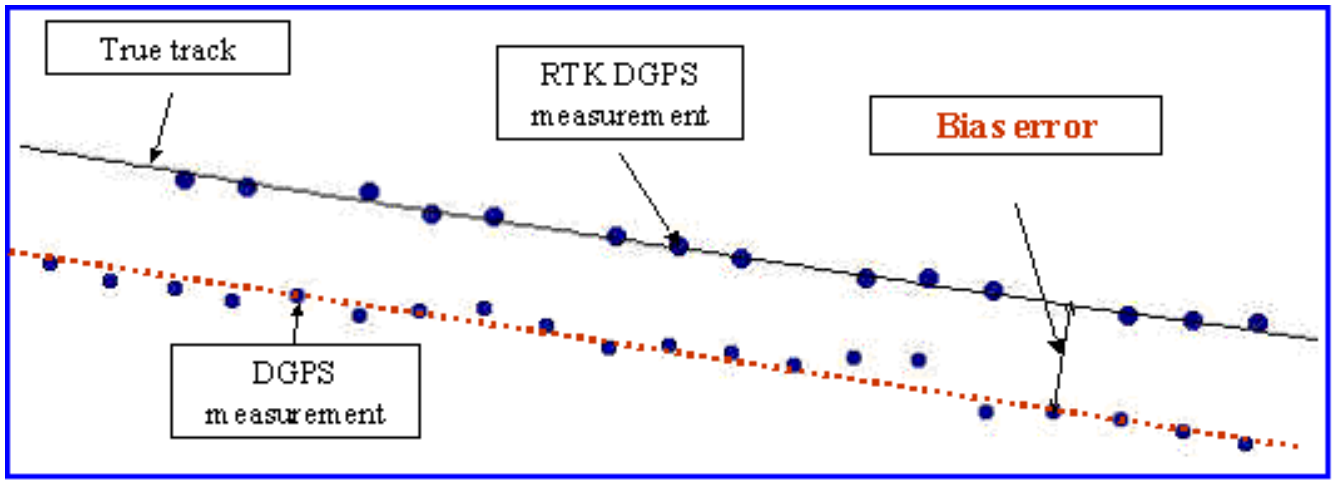
± 10 cm

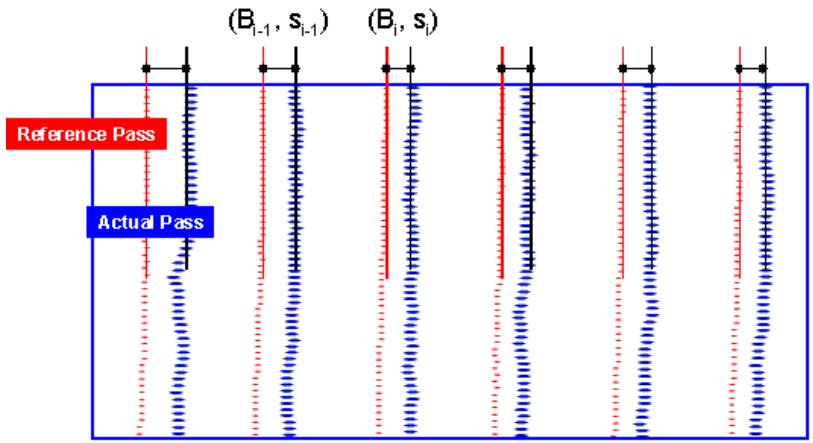
Pass-to-Pass Accuracy

Pass-to-Pass Accuracy

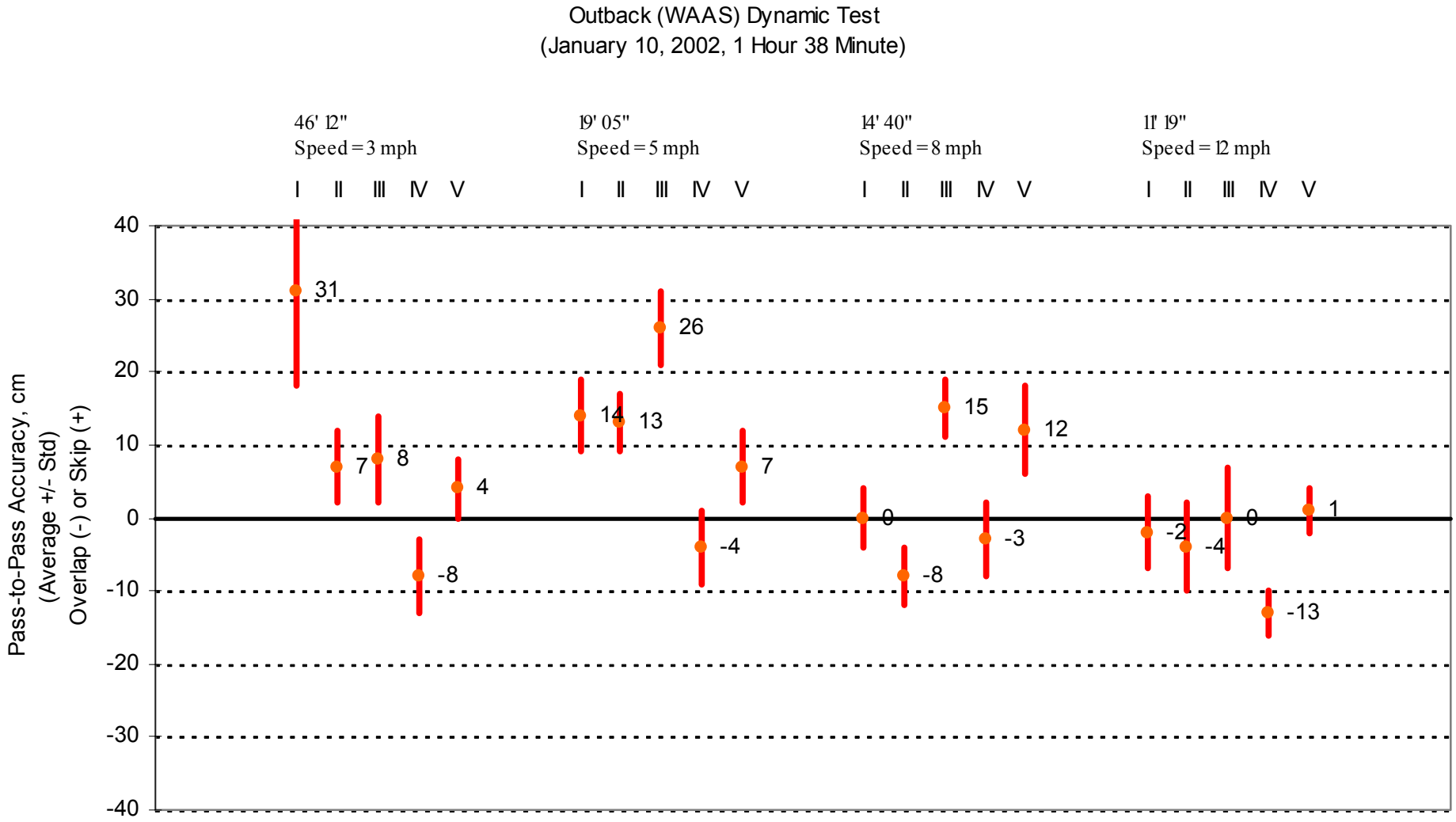


Dynamic Tests

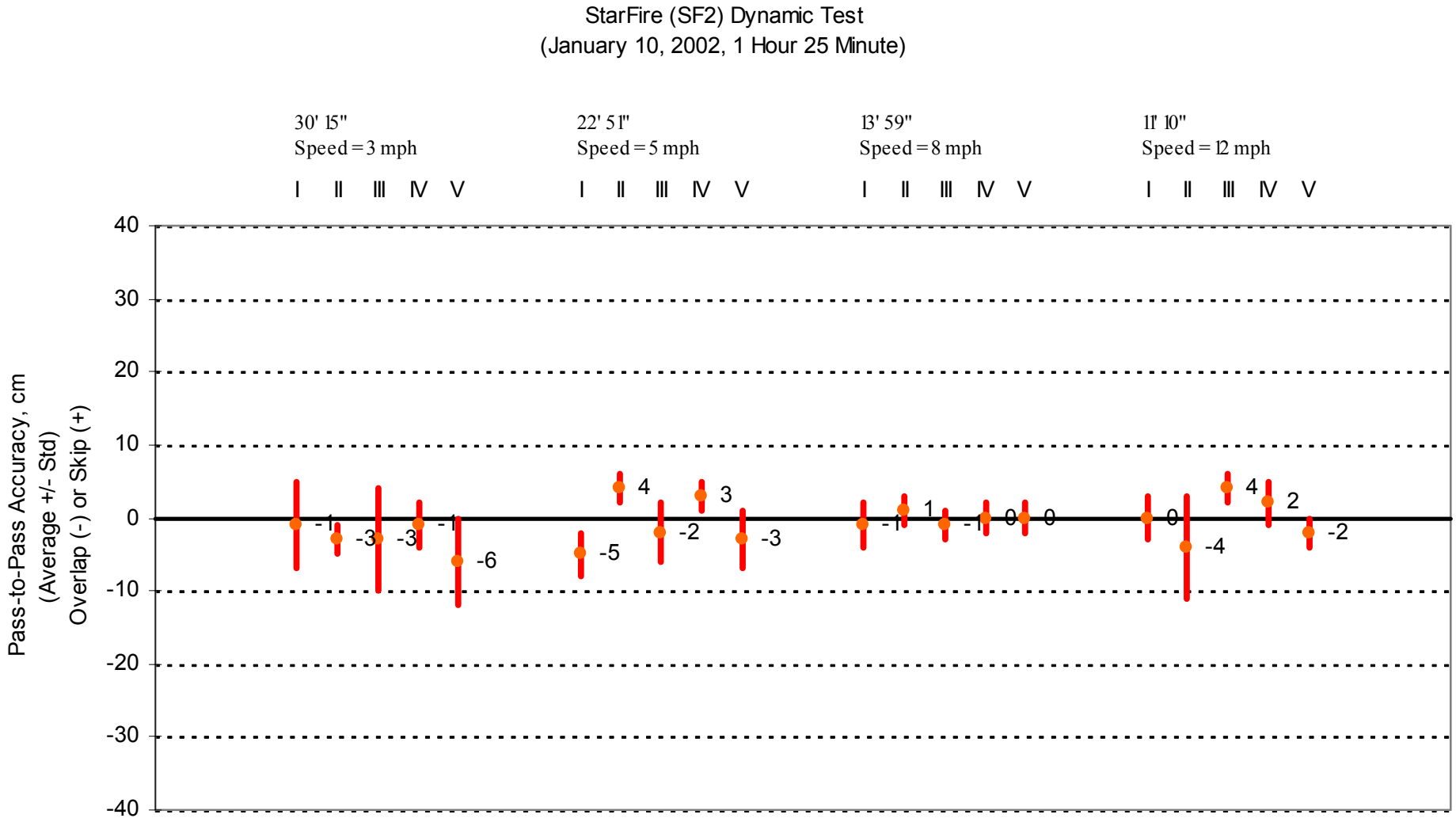




Dynamic Tests



Dynamic Tests

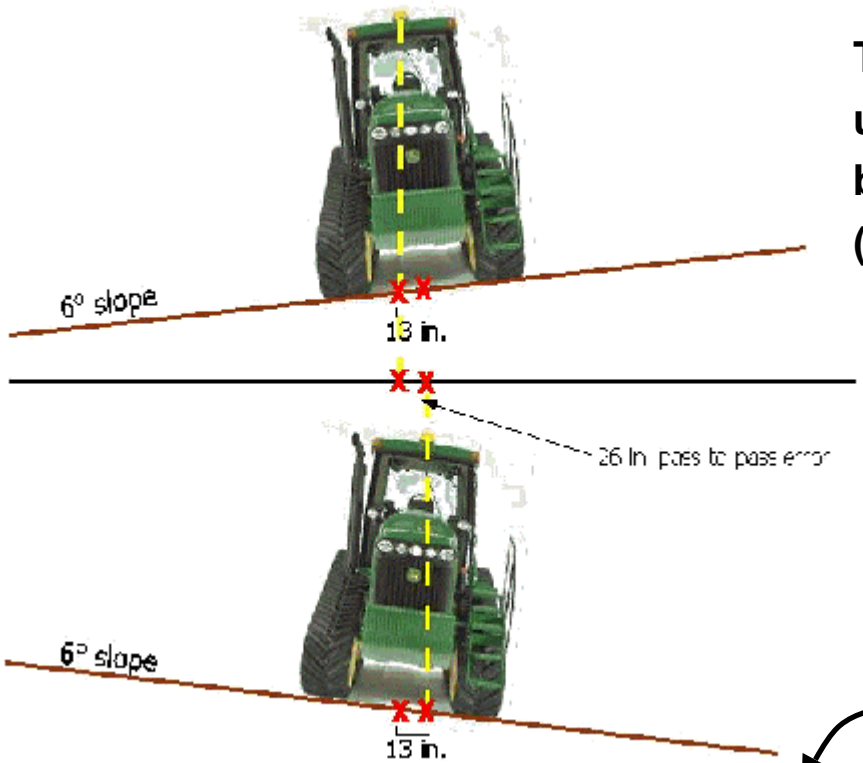


Localization Problems

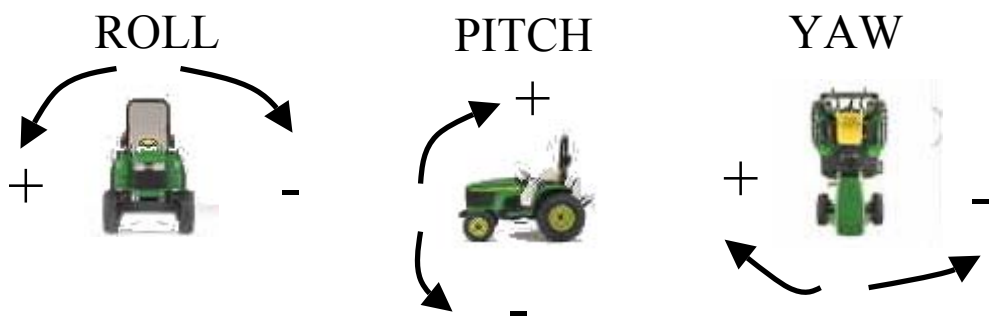
- **Unaided GPS navigation does not account for terrain variations.**
  - **Current product works well for fields with <3% slope**
  - **Customer workaround for constant slopes**
  - **Problems in moderate, variable, and steep terrain**

- **Other Localization Problems**
  - **GPS is affected by location and topography effects**
  - **Vehicle posture is difficult to measure in stationary vehicles.**

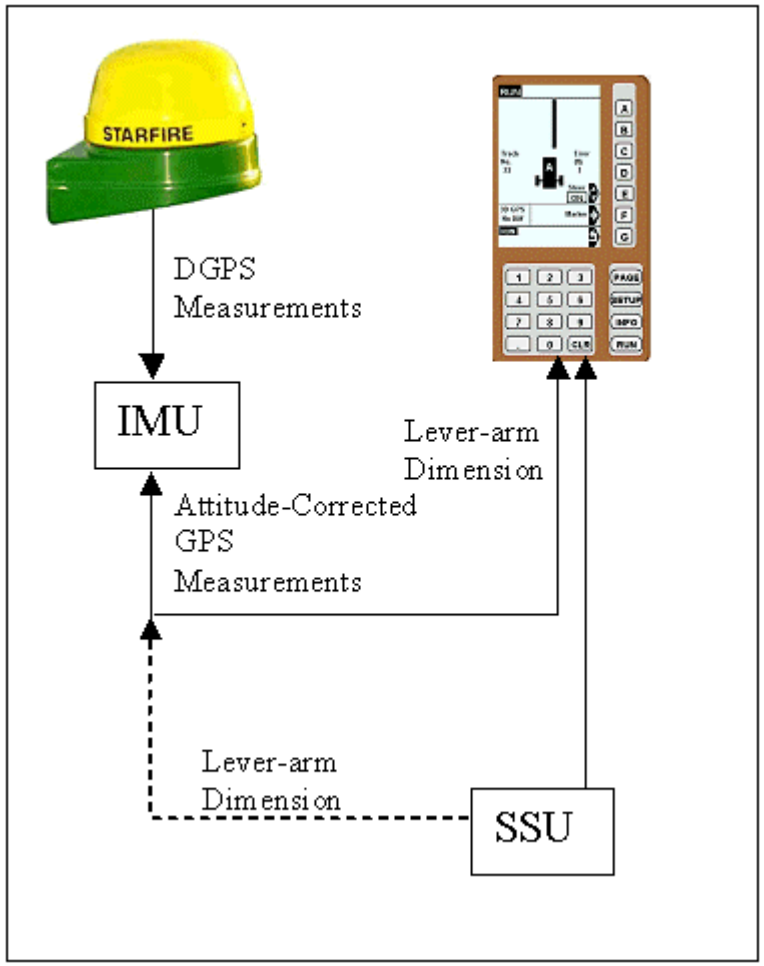
Attitude Compensation



To develop a low-cost solution for unaided GPS bias error created by antennae inclination (roll, pitch, yaw) on sloped terrain.



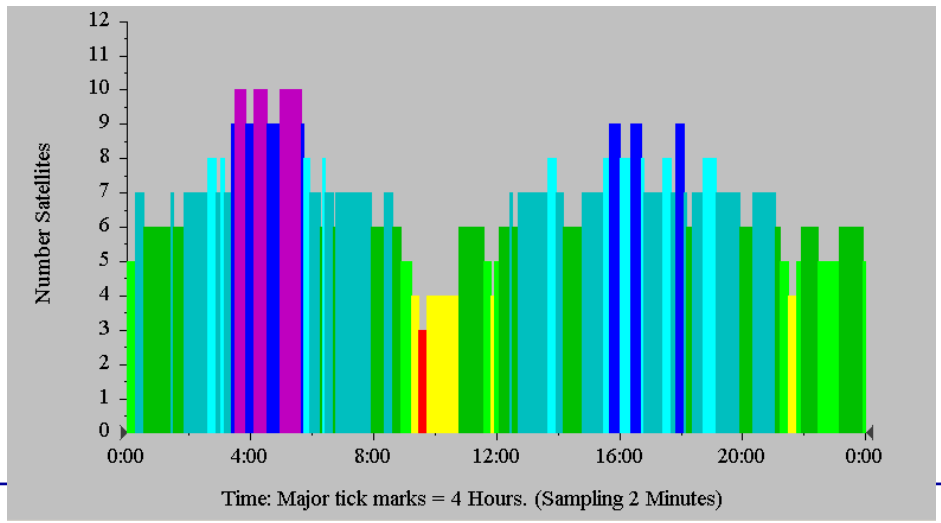
Attitude Compensation Solution

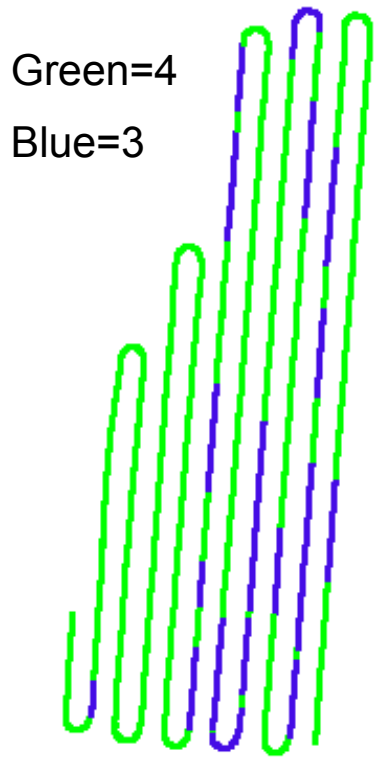


Localization in Orchard

Trimble RTK

- **Tree spacing .5m by 2m**
- **4-5m height**
- **Satellite availability: 4**





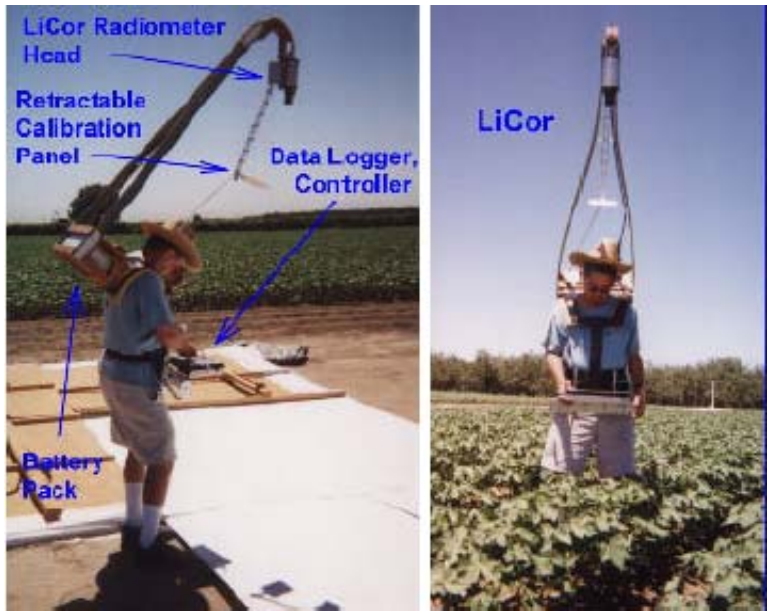
3.3 Optical Sensing of Plant/Soil Properties

Optical Sensing Characteristics

- Identification of the proper optical responses that relate to plant/soil characteristic.
- The methodology for compensation of illumination effects.
- The development of indices that remove plant, soil or environmental influences.
- Developing management strategies that relate the sensor response to meaningful influences on the plant, or soil, property.

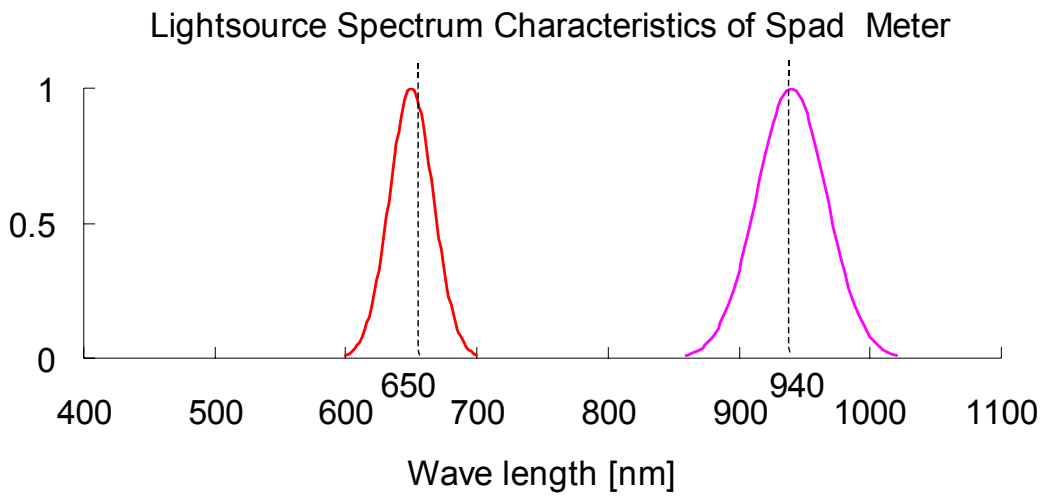
Handheld Units and Manual Measurements

- **Early development of technology requires a lot of inconvenient approaches to validate sensors performance and characterization of crop responses.**



SPAD meter

The meter calculates the SPAD value based on a ratio of transmittance of two Red and NIR illumination provided by LEDs; 650nm and 940nm.



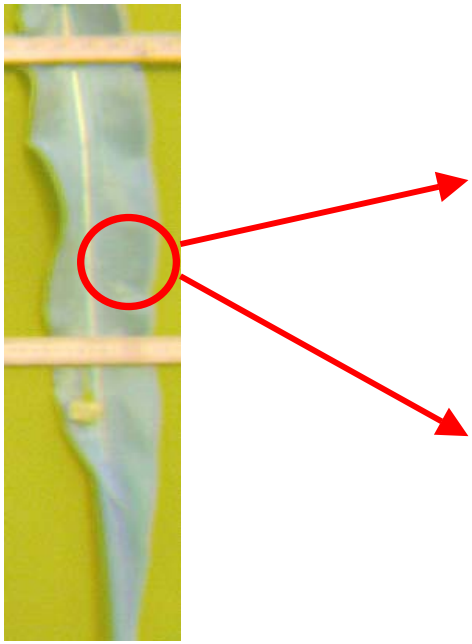
SPAD Value Calculation

$$SPAD = K \log_{10}\left[\frac{IR_t / IR_o}{R_t / R_o}\right]$$

$SPAD$	Spad value
K	Constant
IR_t	Transmittance of NIR (940 nm)
IR_o	Light power of NIR
R_t	Transmittance of R (650 nm)
IR_o	Light power of R

NIR light is used as a reference for compensating various leaf thickness, because a leaf does not absorb the NIR illumination.

Comparison of SPAD with Spectral Reflectance



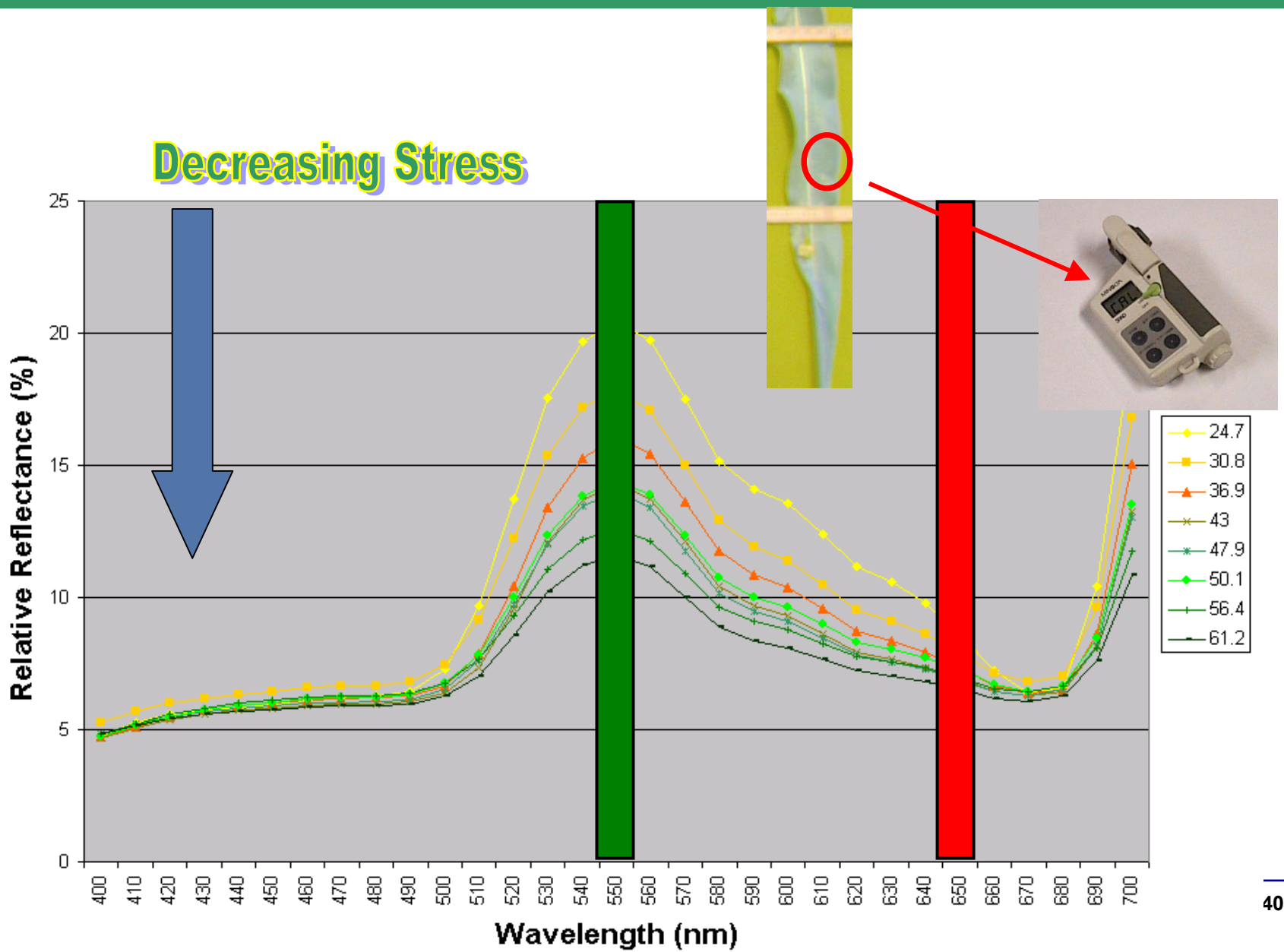
SPAD meter

Spectral radiometer

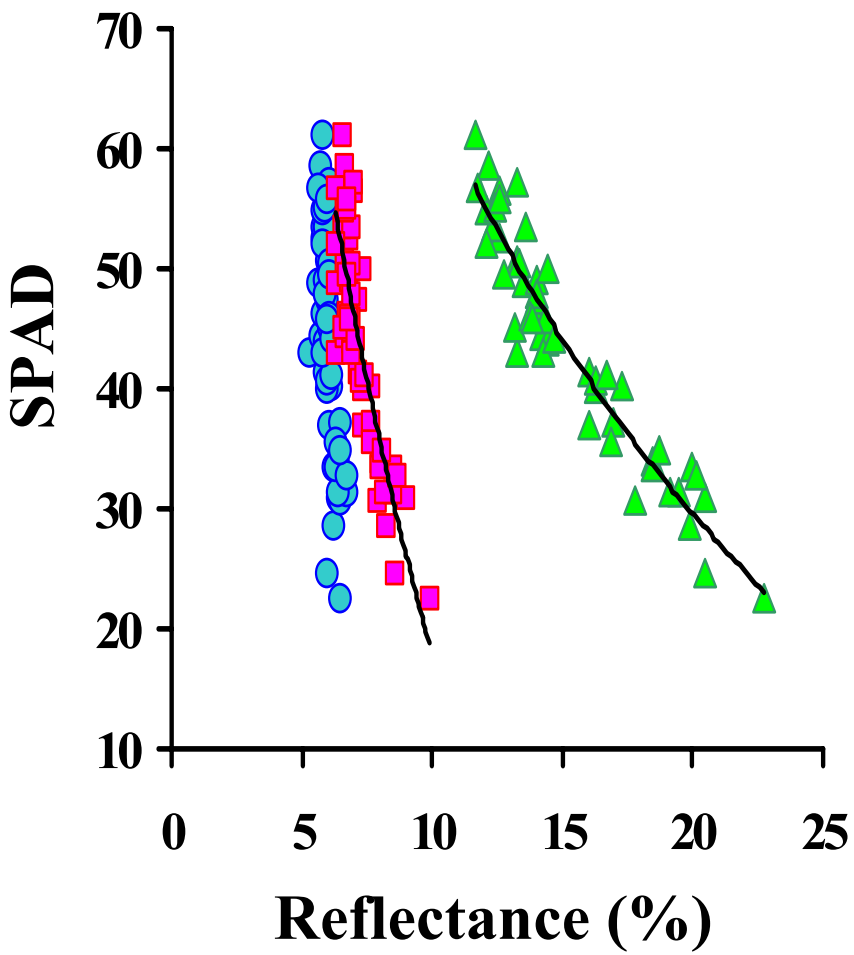
Fifty leaf samples covered SPAD value from 20 to 60.

- 20 - high stress
- 60 - no stress

Spectral Reflectance of Corn Leaves in the Visible Spectrum



Results using a radiometer and a SPAD meter



- **Red Response**
  - **reflectance - 6-10%**
  - **SPAD - 60-20**
- **Green Response**
  - **reflectance - 12-23%**
  - **SPAD - 60-20**

x_1….G-*Reflectance - 550 nm*

x_2….R-*Reflectance - 650 nm*

Photodiode Systems

- Patchen
- Multiple row units with zones of detection
- Applications:
  - Weed control
  - Nitrogen application systems on large sprayers

Image-Based Sensors

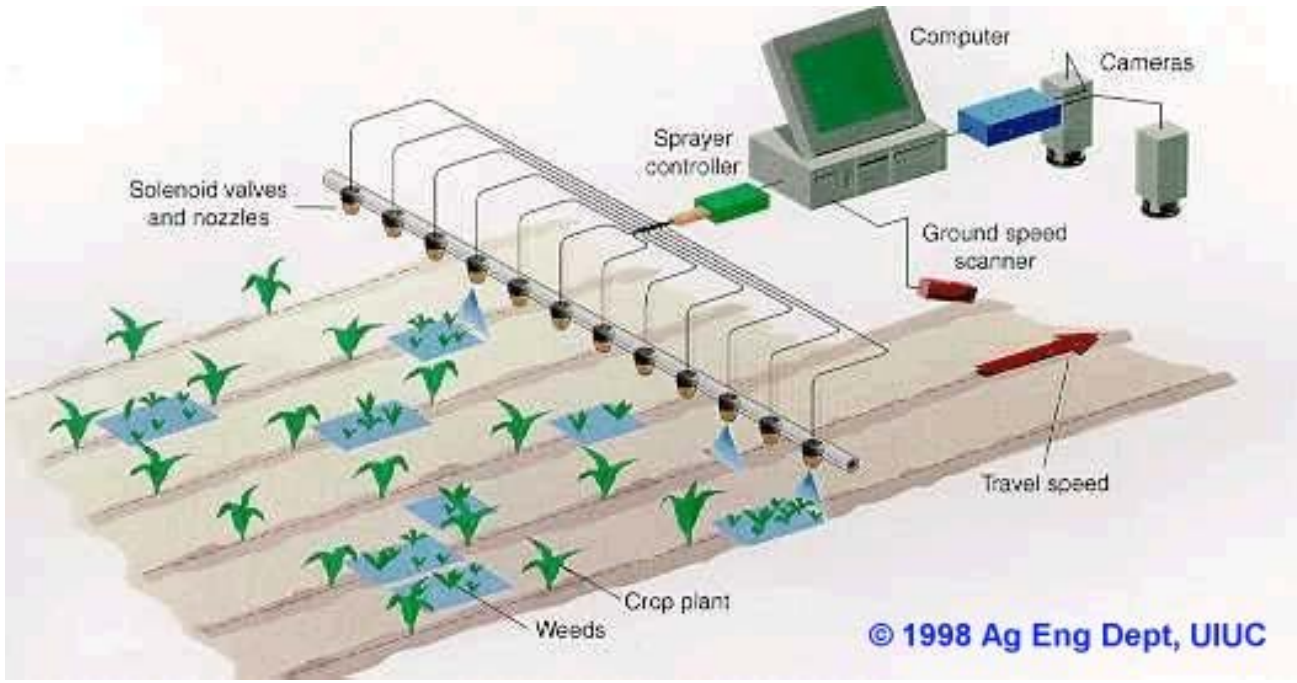
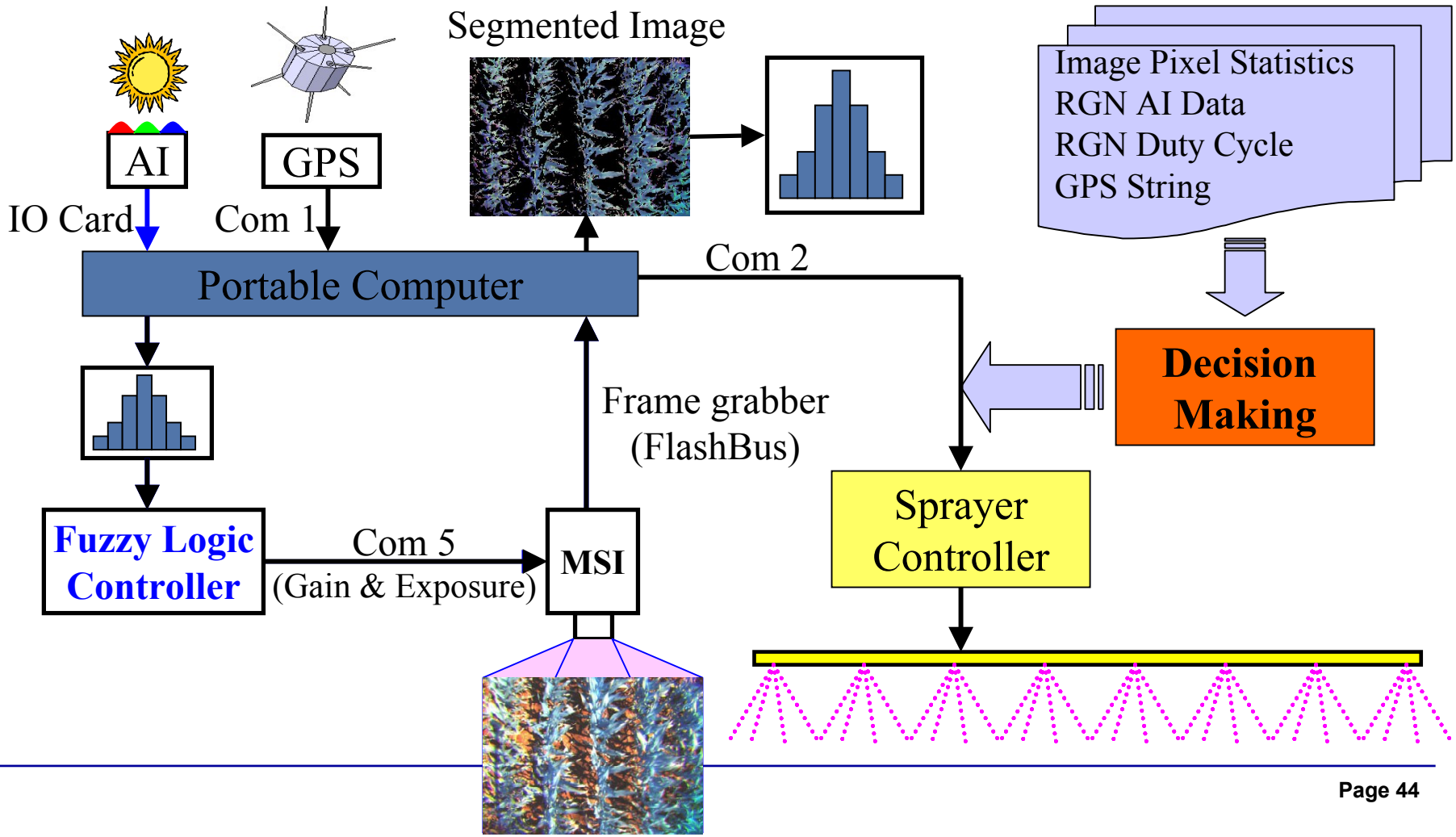
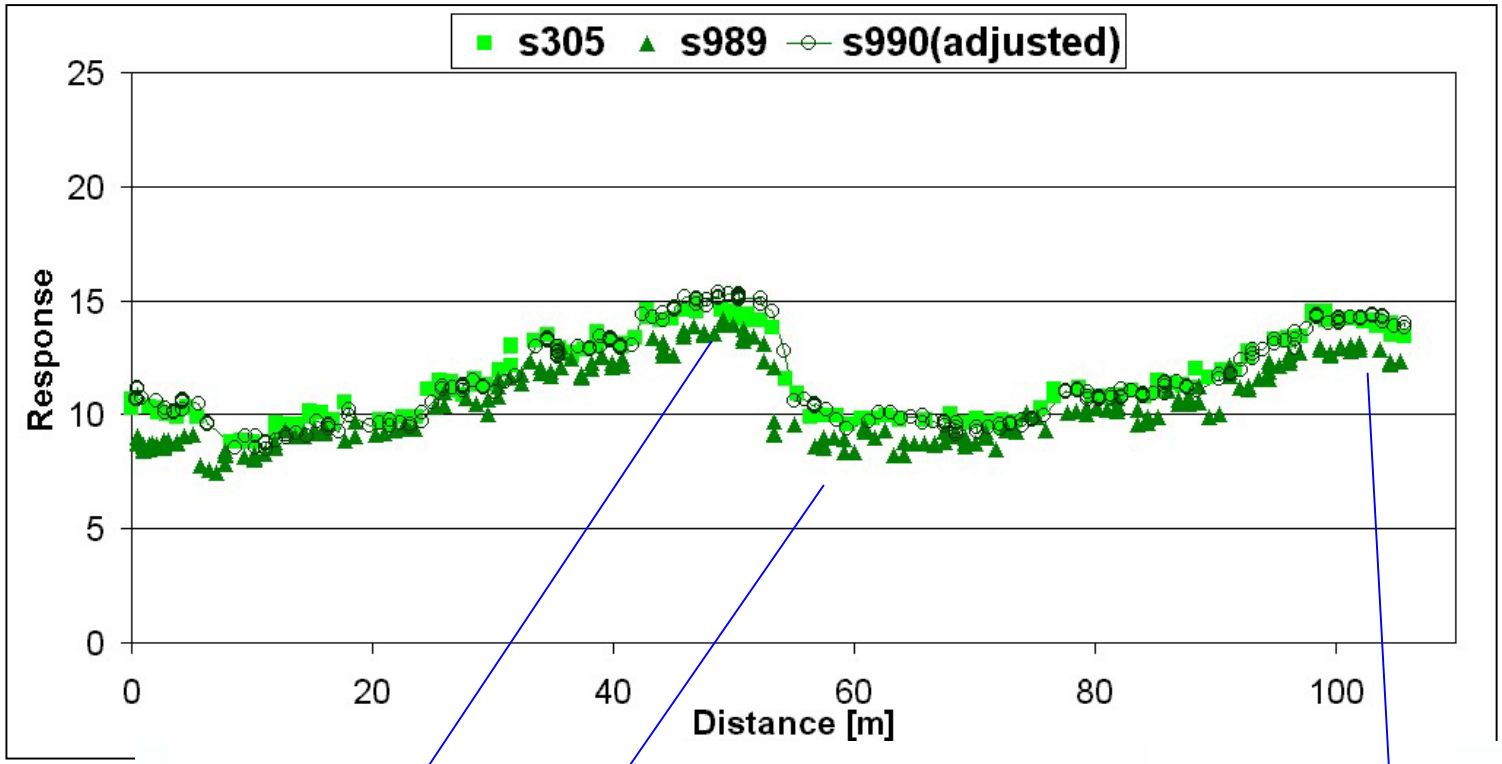
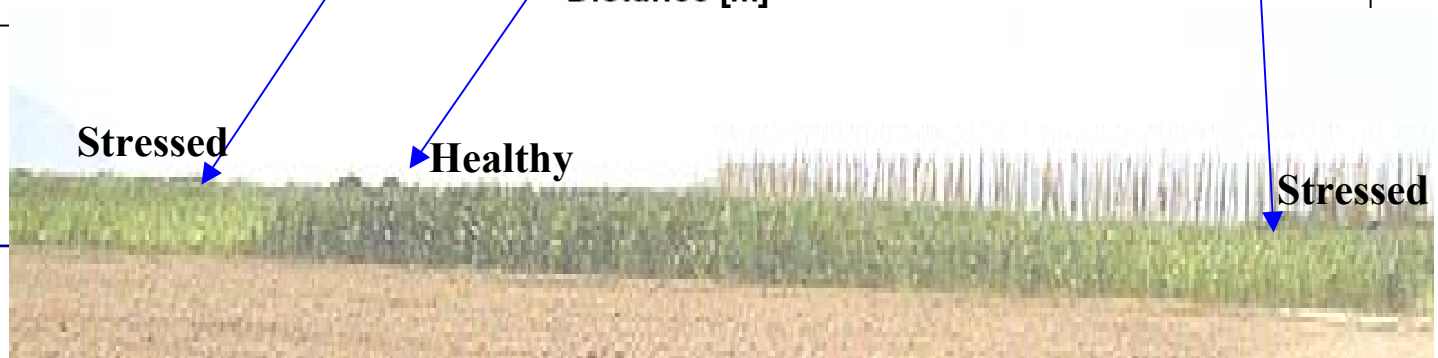


Image-sensors for Crop Health Response



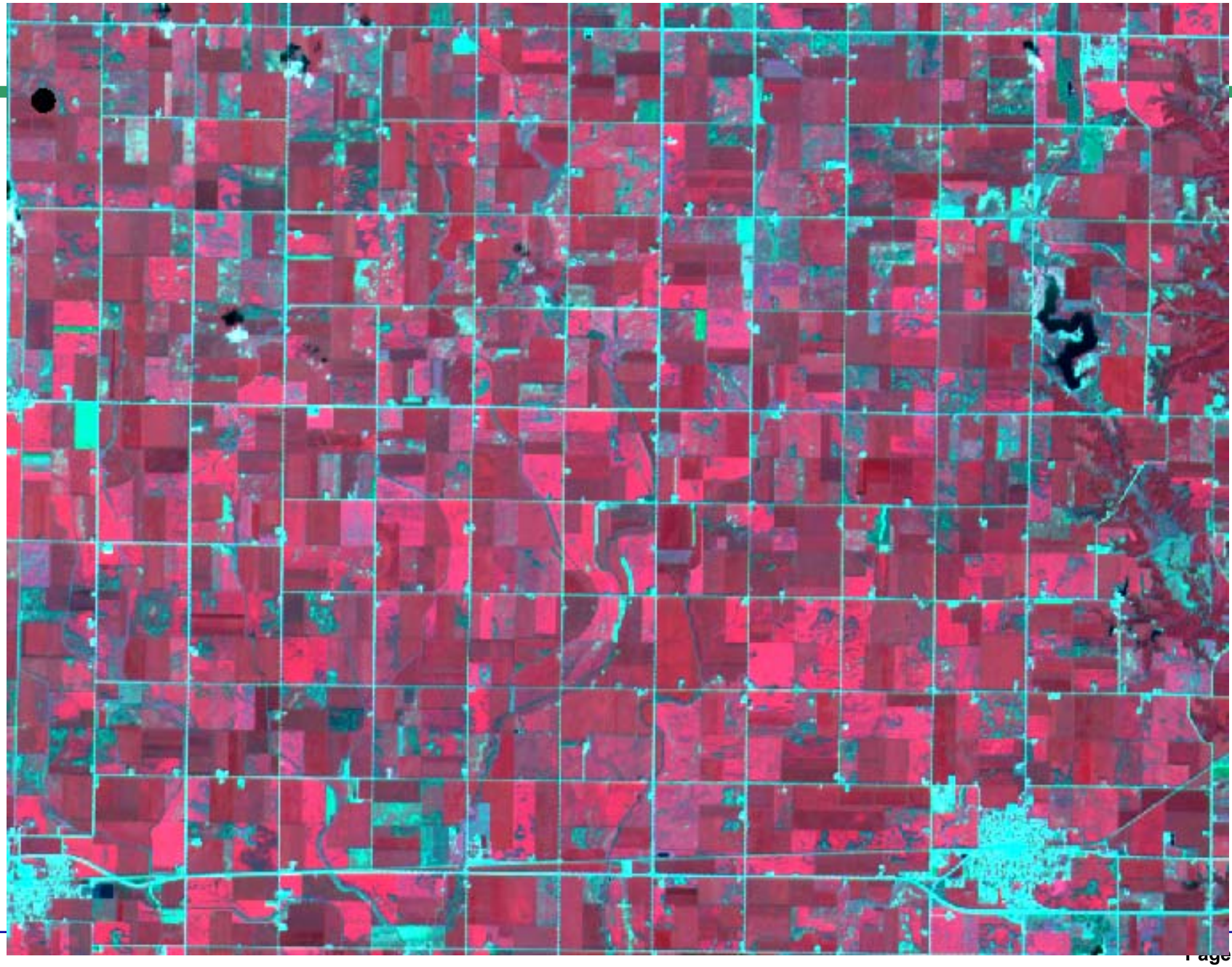
Crop Sensing Performance

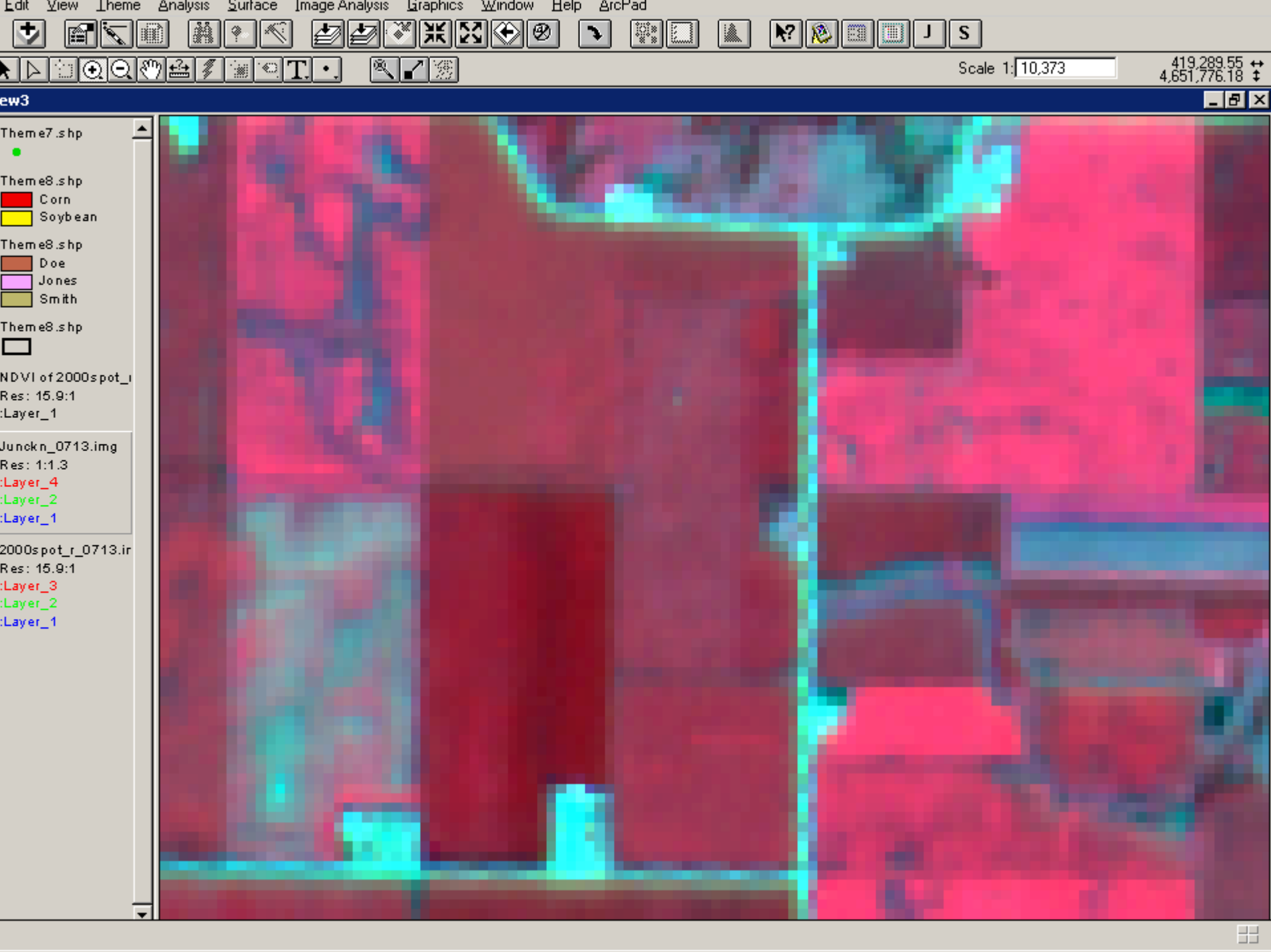




Remote Sensing System

- Somewhat redundant with ground-based sensor systems
- Greatest advantage is its capability as a triage tool for in-season crop management

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Res: 1:1.3
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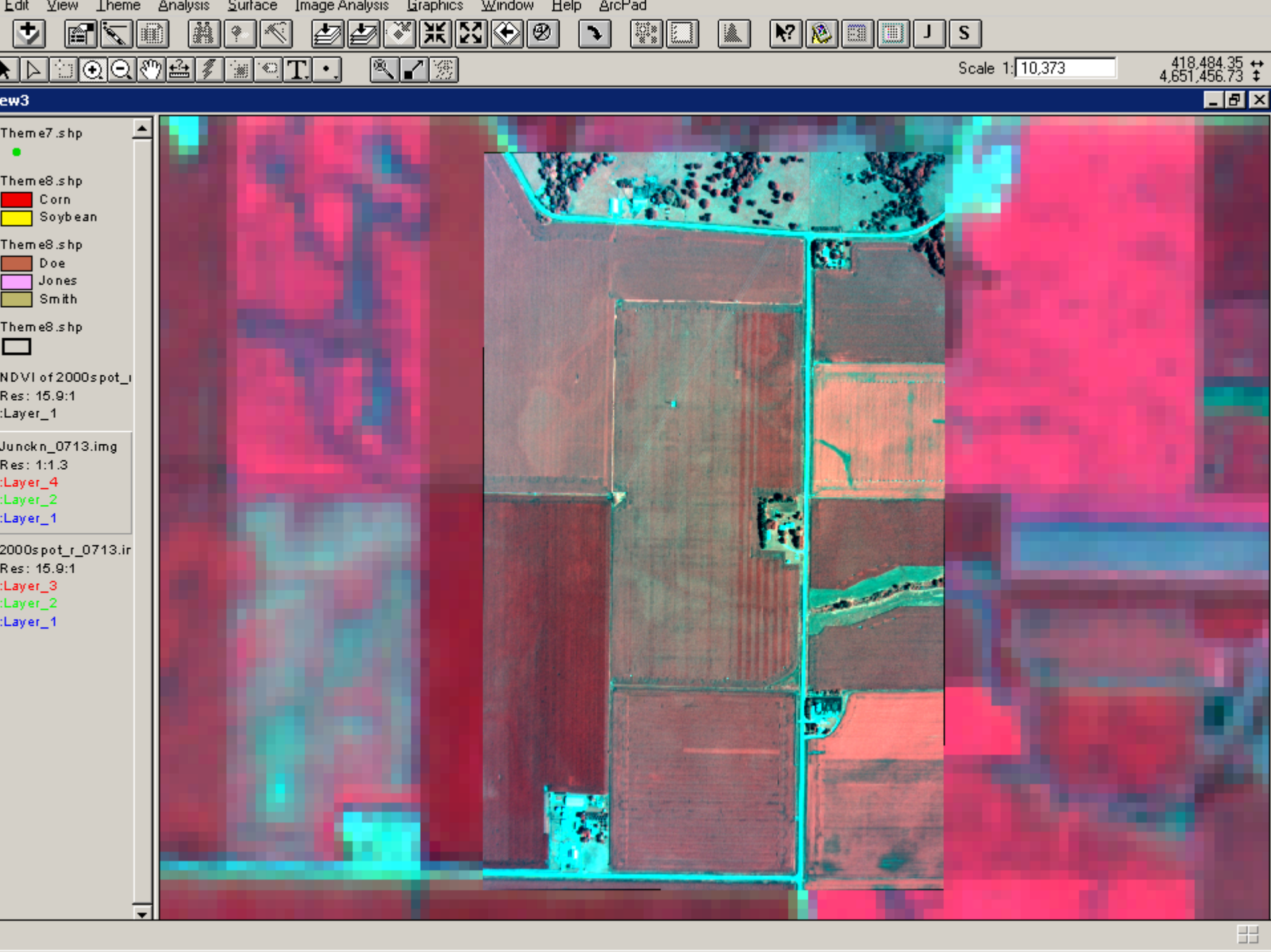
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:Layer_2
:Layer_1
2000spot_r_0713.ir
Res: 15.9:1
:Layer_3
:Layer_2
:Layer_1

Remote Sensing System

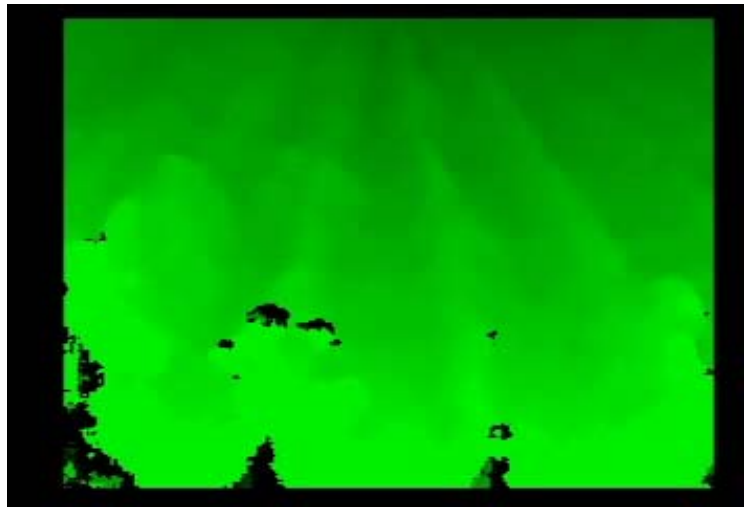
- Aerial systems offer greater control than satellite systems, but will require greater management of data acquisition process
- Prototype sensors and software processes available, but will require considerable development and optimization
- Can easily be converted to desired maps with high spatial resolution

Stereo Images

- **Stereo image is formed by a sensor that determines a range image from a left-right stereo pair.**

Left Image Right Image

Row Crop Guidance

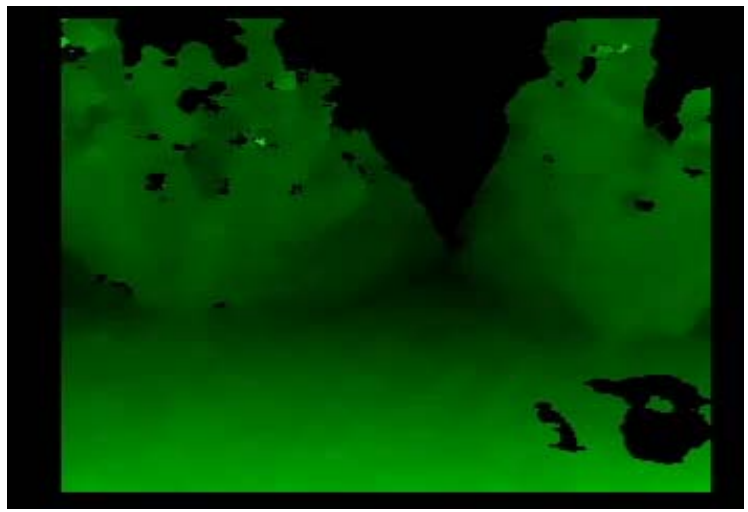


Soybean canopy near harvest

- **Perception of crop height, shape, row spacing, objects within row**

Mapping Crop Information

- **The 3-D nature allows for perception of**
  - **Path for guidance down row of trees**
  - **Estimation of tree height and volume, spacing, shape**



Soil Characterization System

- **Soil Color**
  - Soil color can be related to soil organic matter, soil moisture, and several other soil nutrients
  - No commercial soil color sensors yet available, but radiometer technology can be adapted for sensor platform
  - Ground-based system avoids crop residue
- **Electrical Conductivity**
  - Recent acceptance as useful information layer
  - Veris uses coulter-based system
  - EM-38 induces electric field and doesn't require soil penetration, but must be electrically isolated

Soil Physical Properties

- **Immediate need for sensors for application on equipment**
  - **Precision-depth control**
  - **IVT tractor**
  - **GPS/GIS technology**

Soil Physical Properties

- Machine-soil interactions are critical for the future of offroad vehicles
  - High speed operation
  - Autonomous vehicle performance
- The work expertise has been on a decline.

Conclusions

- The sensors and data collection systems that are available today provide a low-level foundation for the development of traceability systems.
- Data collection systems will need to expand to match the level of data needed for the traceability systems. Automated data transfer between elements of the systems will increase the effectiveness of traceability.
- Permanent storage methods are needed to provide a record of the responses measured by traceability.
- Additional sensors will be needed to facilitate the measurement of responses and to provide automated data transfer. Increased funding will be required to lead to the development of these innovative technologies.