Integrating Spray Plane-Based Remote Sensing and Rapid Image Processing with Variable-Rate Aerial Application

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Outline

- Summarize our remote sensing systems for ag. aircraft
- Discuss variable rate aerial application system and evaluation of system accuracy
- Discuss how we might rapidly process remote sensing data in near real-time to support variable rate application

Components of Our Research in Automated Variable-Rate Aerial Application

1. Remote Sensing
   1. Image Analysis and Georectification
2. Variable-Rate Application System
   1. GPS-based guidance
   2. Automatic flow control
3. Rapid Image Processing for Applying RS Data to VRT

Remote Sensing

- The measurement or acquisition of information of an object or phenomenon, by a recording device that is not in physical or intimate contact with the object

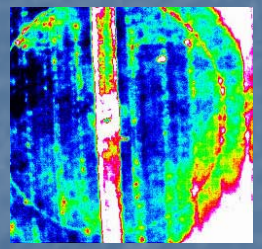
Remote Sensing Platforms

- Satellites
- General Aviation aircraft
- Helicopters
- Agricultural Aircraft (our platform)
- UAV (Unmanned Aerial Vehicles)

Remote Sensing Studies

- Weed detection
- Detection of insect habitat
- Insect and disease damage
- Nutrient status
- Plant vigor (for application of cotton defoliant and growth regulators)

- Determining the onset of plant water stress using thermal imagery

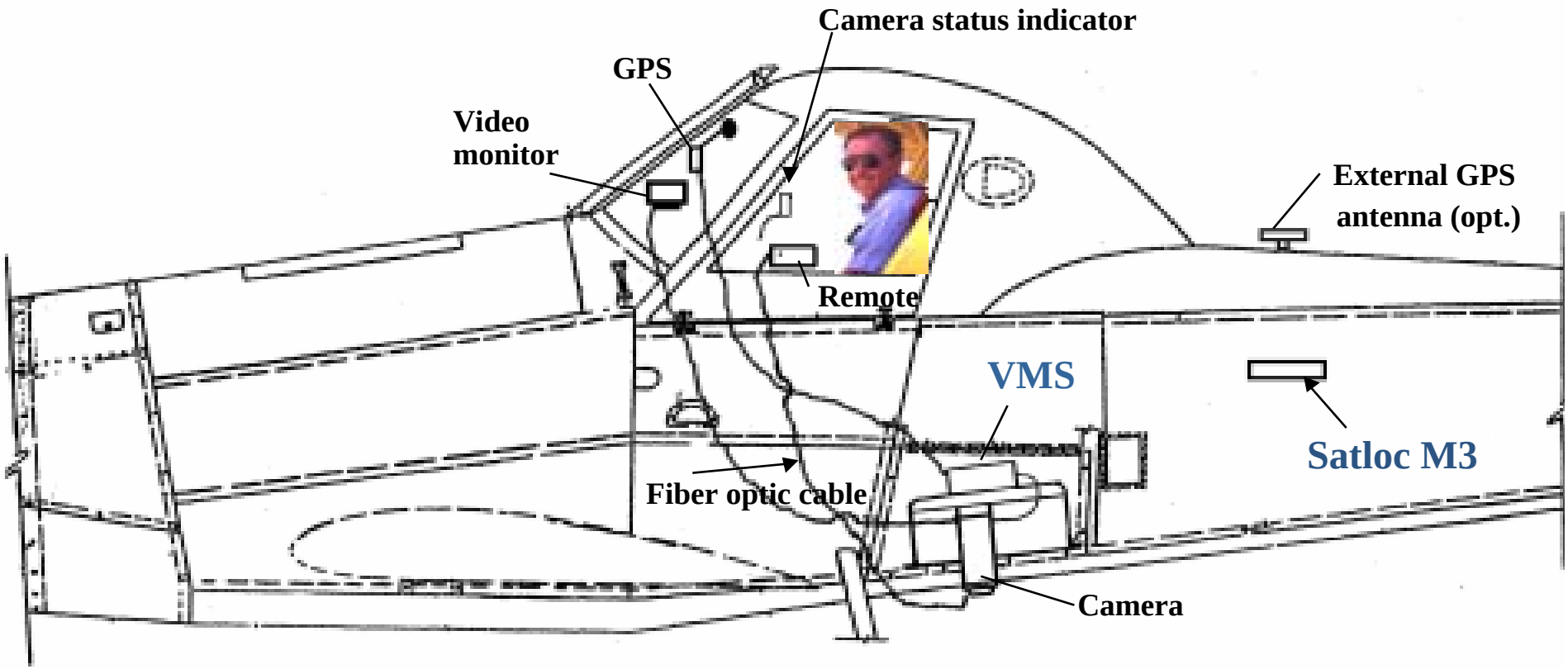


  - Also, system diagnostics: leaking or stopped up irrigation systems; leaking residential septic systems

Weed Detection - Examples

- Field Weeds
- Platform: Agricultural aircraft

- We were able to distinguish between spurge weeds, grass weeds and early cotton by analysis of digital video



Air Tractor 402B

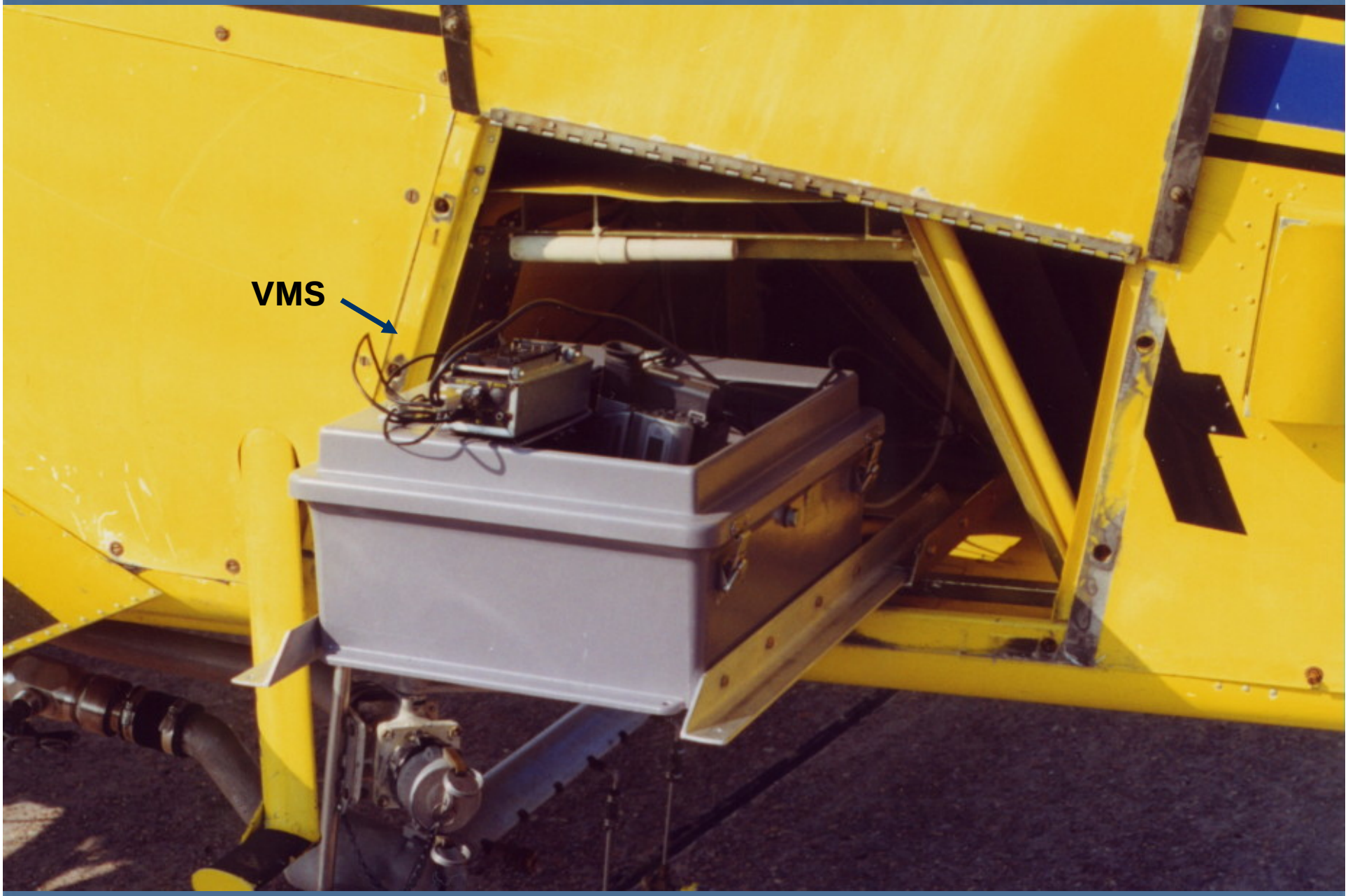
Agricultural Aircraft Instrumentation – Digital Video

Apparatus in the cockpit

Monitor and camera status indicator

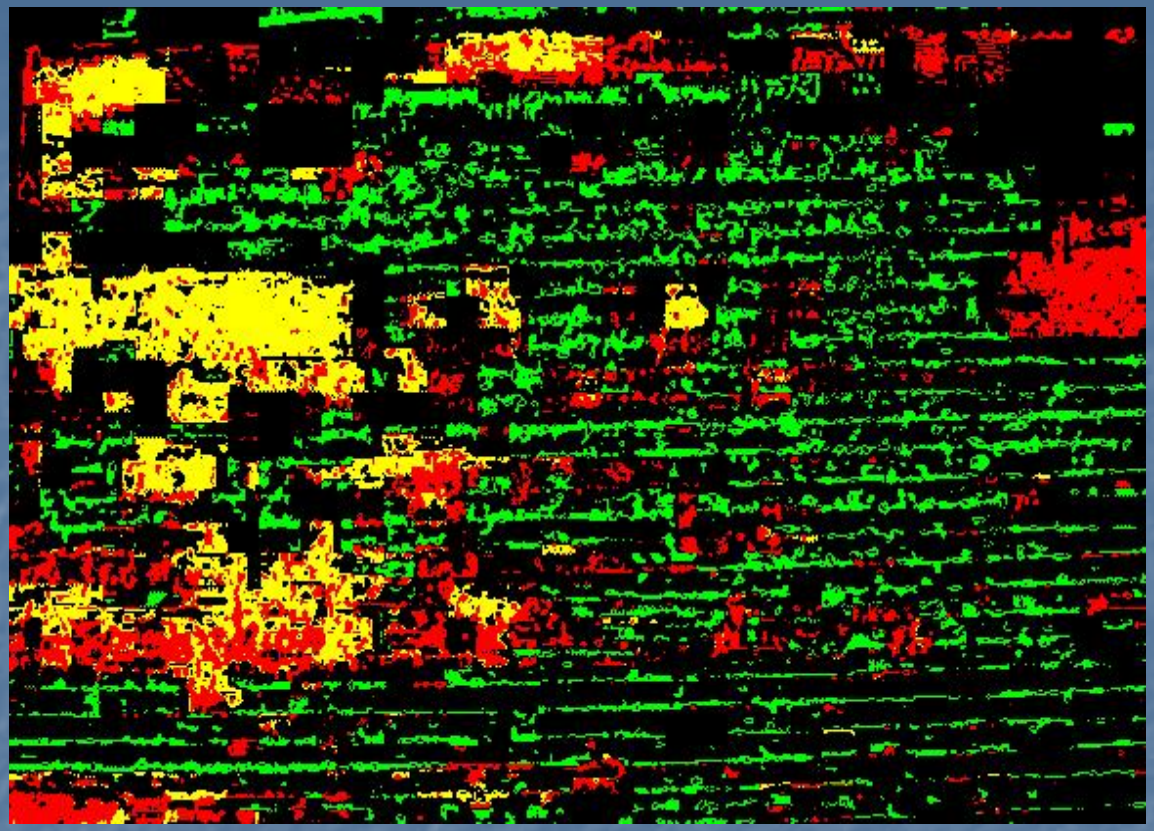
Lowrance Airmap 100 GPS

IR remote for DV camera


VMS

Original Image for Classification

Flight Direction: South to North
Ambient Conditions: Sunny
Altitude: 54-m (177’) 7.9 cm/pixel
Filter: None
Location: North Cumbaa Farm, Field #5
Crop: Cotton
Predominant weeds : Johnsongrass; spotted, prostrate, and hyssop spurge



Red = J-grass

Yellow = Spurge

Green = Cotton

Black = Unclassified

Resulting Image

Classified using Mahalanobis Distance Supervised Classification Method
Image analysis software used: ENVI 3.5

Digital numbers from image

Table 1. Average values for randomly selected digital numbers (DNs) corresponding to cotton, Johnsongrass, and spurges.

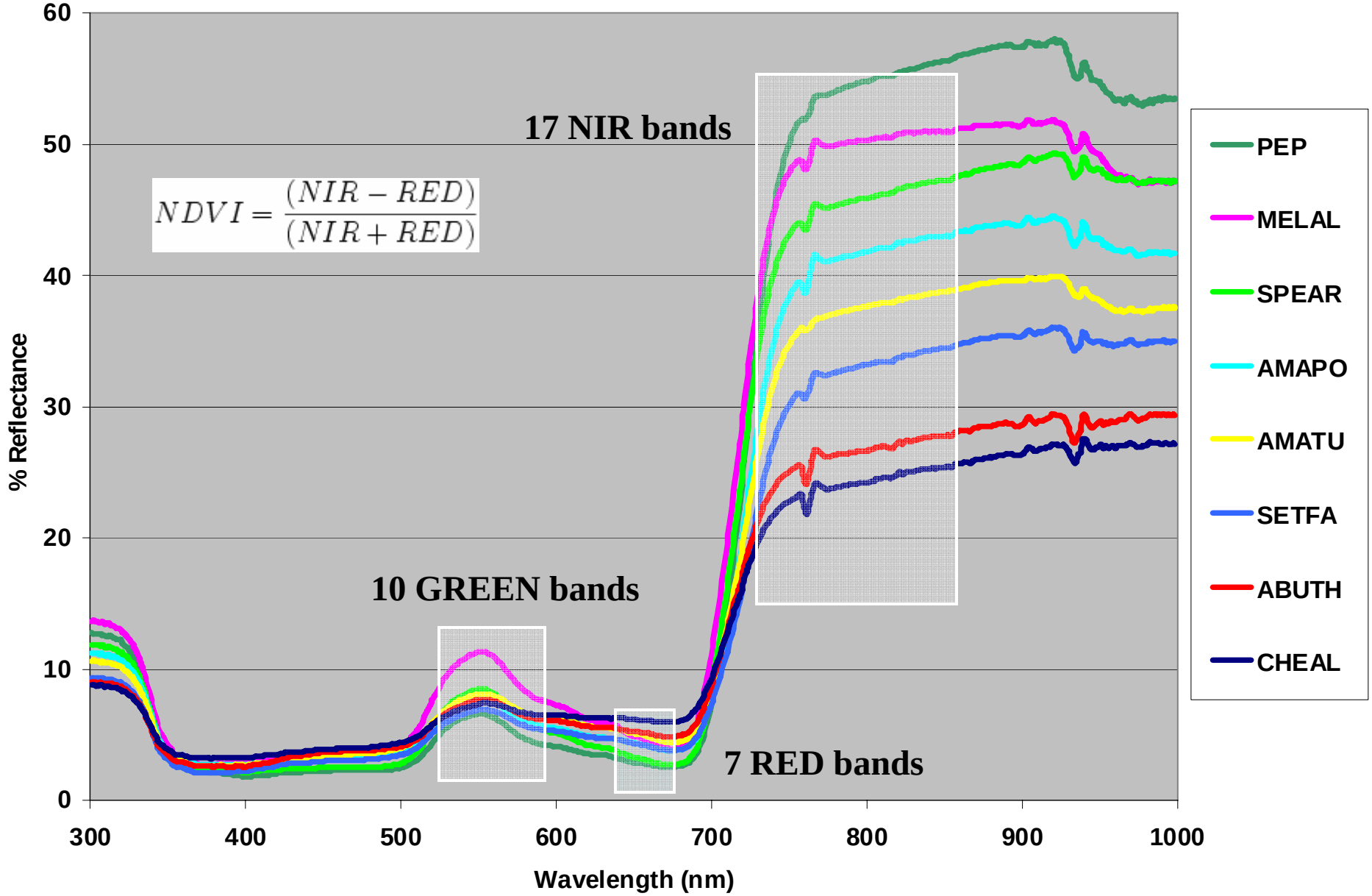
Cotton	Johnsongrass	Spurges	
93	60	104	
85	78	100	
90	75	94	
84	45	115	
89	56	106	
83	88	107	
83	76	106	
80	110	107	
88	68	105	
77	92	113	
85	75	106	Mean
4.8	18.9	5.9	Std. Deviation

Weed Detection - Examples

Use of specific band combinations for weed detection

- Gumz and Weller (2006) used spectral vegetation indices (SVI) that can differentiate between mint and weeds and weeds from each other.

SVIs are more consistent than raw reflectance data


60
50
40
30
20
10
0
% Reflectance
300
400
500
600
700
800
900
1000
Wavelength (nm)
17 NIR bands
10 GREEN bands
7 RED bands
$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$
PEP
MELAL
SPEAR
AMAPO
AMATU
SETFA
ABUTH
CHEAL

SVI Separation of Mint and Weeds

NIR-GREEN

	SR 967/548	SR 975/540	SR 975/548	SR 982/540	SR 982/548
Peppermint	9.53a	9.94a	9.52a	9.96a	9.55a
PEP/ Giant Foxtail	7.84b	8.22b	7.87b	8.25b	7.90b
Thin Peppermint	6.74c	7.09c	6.83c	7.10c	6.83c
C. Lambsquarter	5.99d	6.26d	6.00d	6.29d	6.04d
Giant Foxtail	5.91d	6.17d	5.89d	6.20d	5.92d
Powell Amaranth	5.67d	5.93d	5.64d	5.95d	5.67d
Spearmint	5.61d	5.86d	5.59d	5.88d	5.60d
Waterhemp	4.33e	4.51e	4.32e	4.53e	4.34e
Velvetleaf	4.16e	4.35e	4.18e	4.37e	4.19e
White Cockle	3.90e	4.05e	3.88e	4.06e	3.88e

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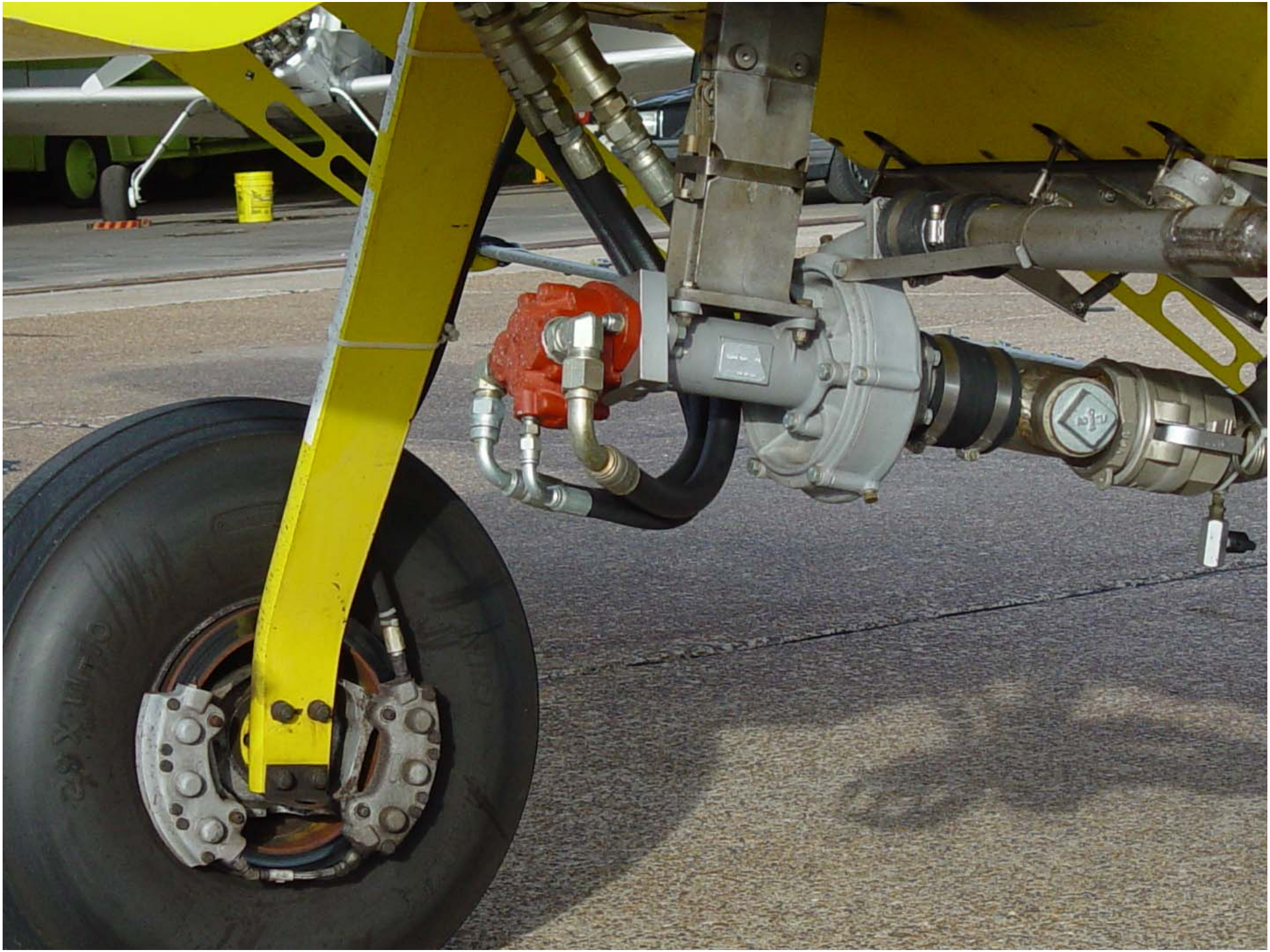
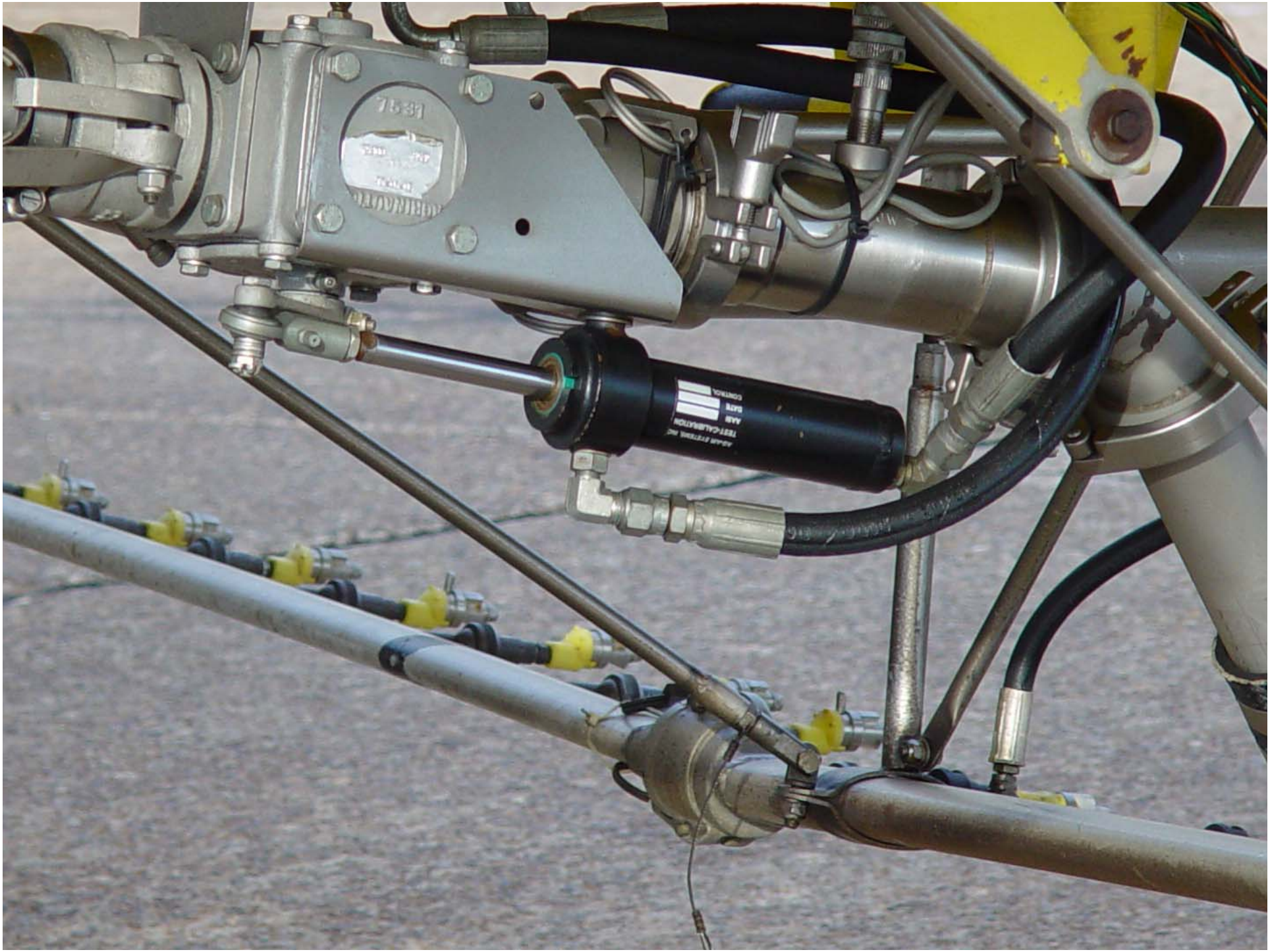
Variable-Rate Application –

An application made according to a “prescription” developed to optimize the utilization/performance of the material being applied.

APTRU Variable-Rate System

- Air Tractor 402B spray plane equipped with an engine-driven hydraulic power package (Kawak Aviation Technologies, Bend, OR)
- Satloc M3 with WAAS DGPS and 5 Hz position update interval using AirTrac software (Hemisphere GPS, Scottsdale, AZ)
- AutoCal II automatic flow control (Houma Avionics, Houma, LA)
- Hydraulically powered chemical pump and boom valve

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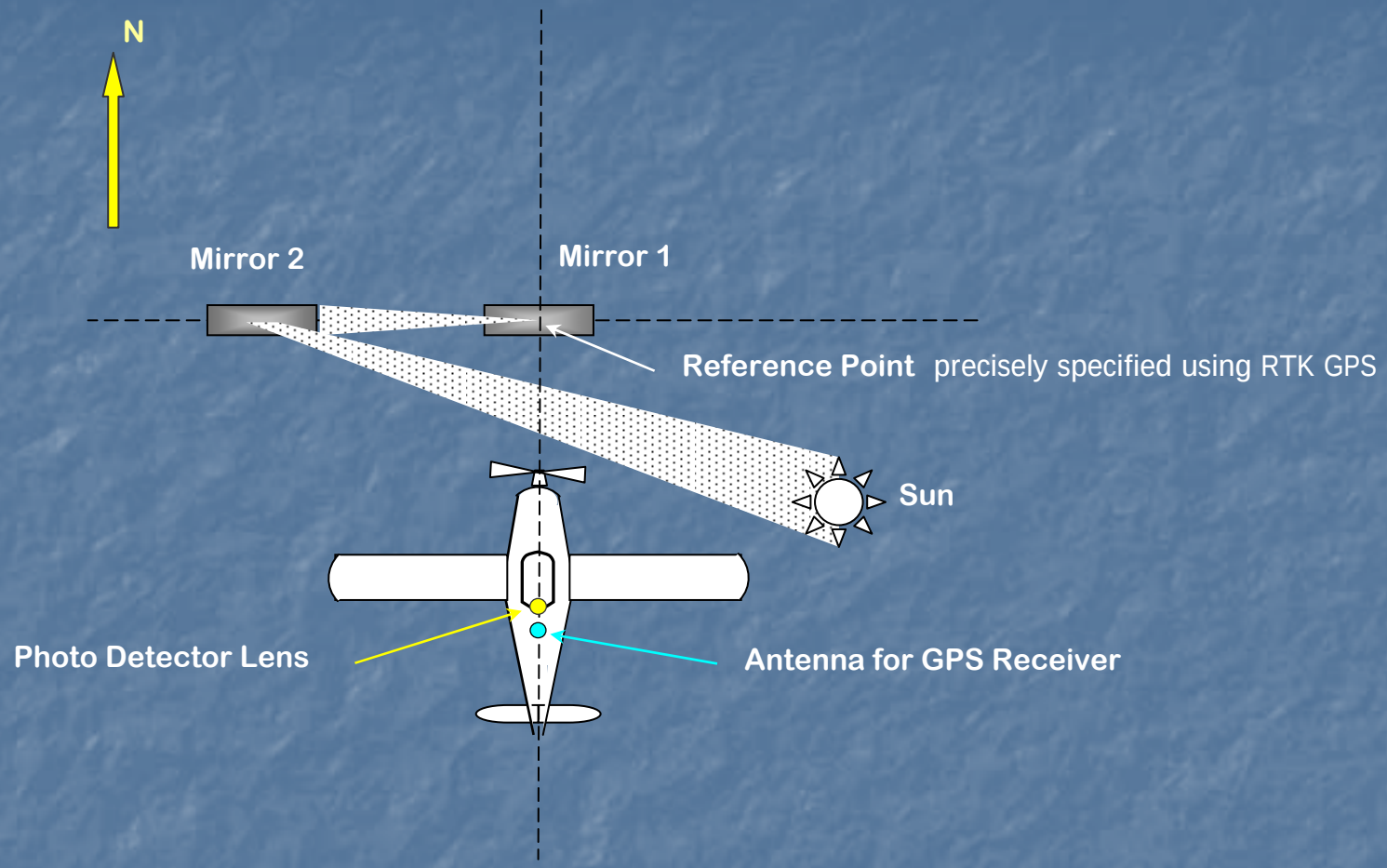
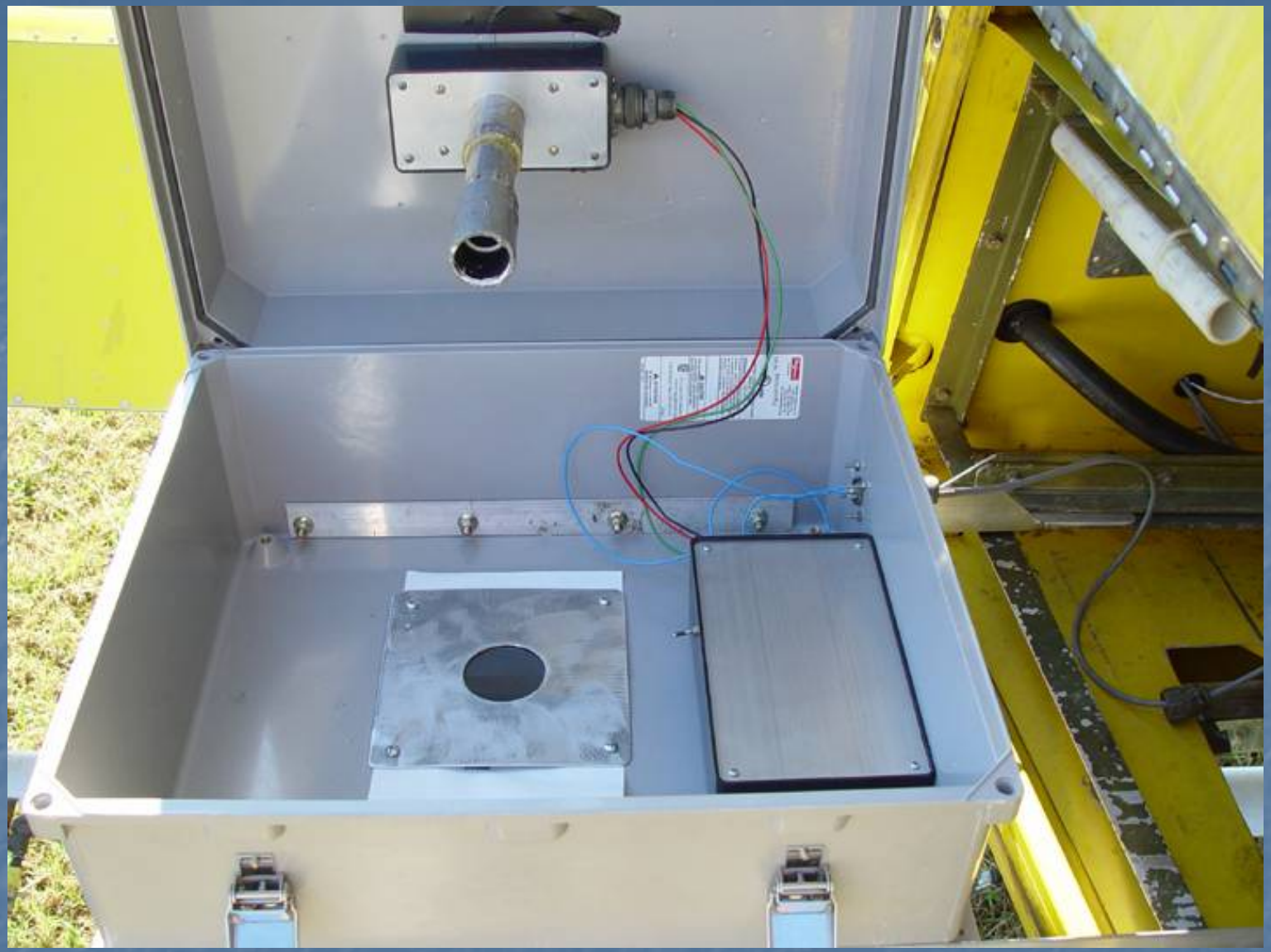
System Evaluations

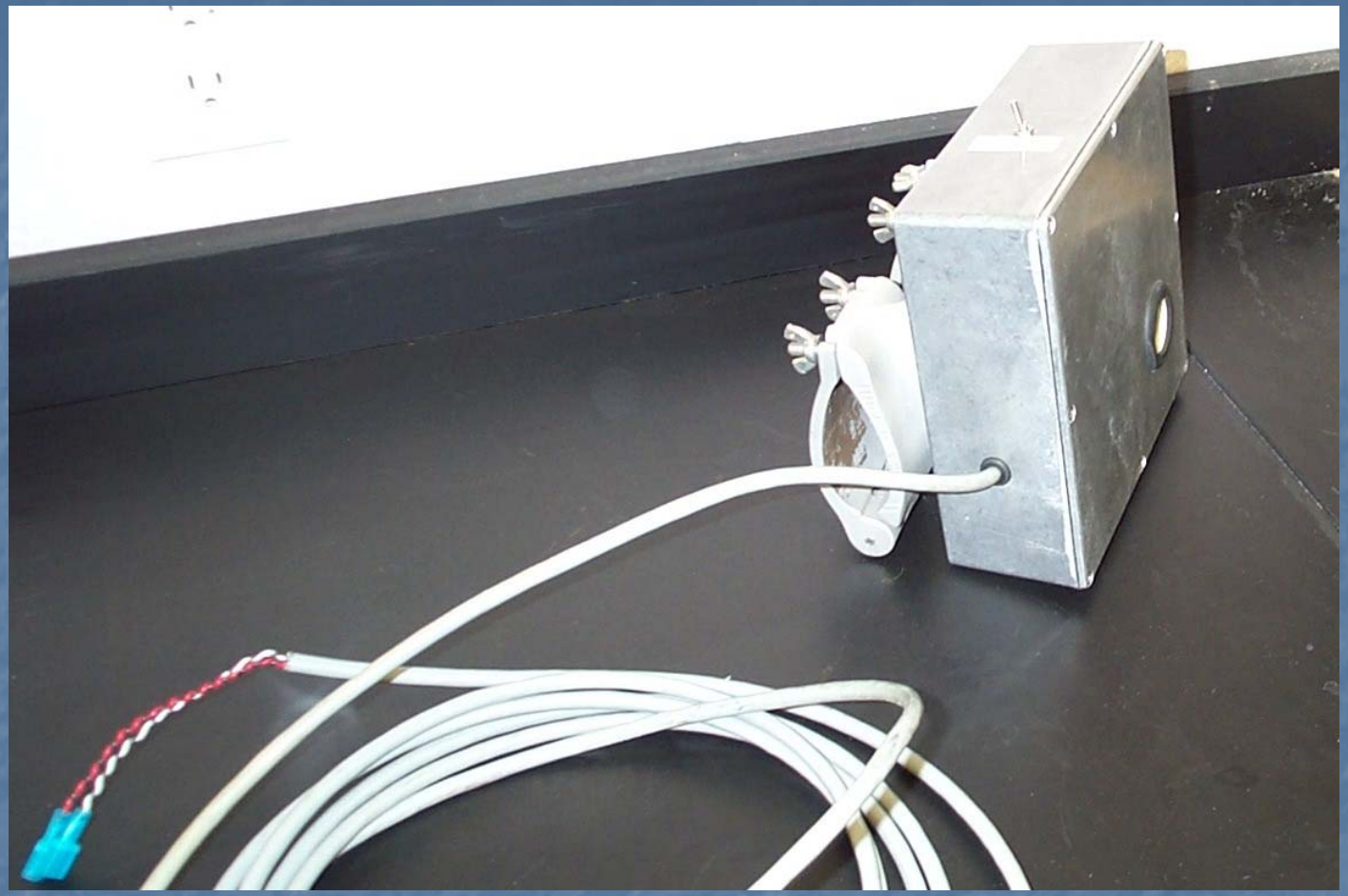
Determining Position Latency of the Satloc M3



Photodetector detects light beam and sends an “event” (via triggering circuitry) into the Satloc GPS log file to 1/100-s accuracy



Light detector and triggering circuit

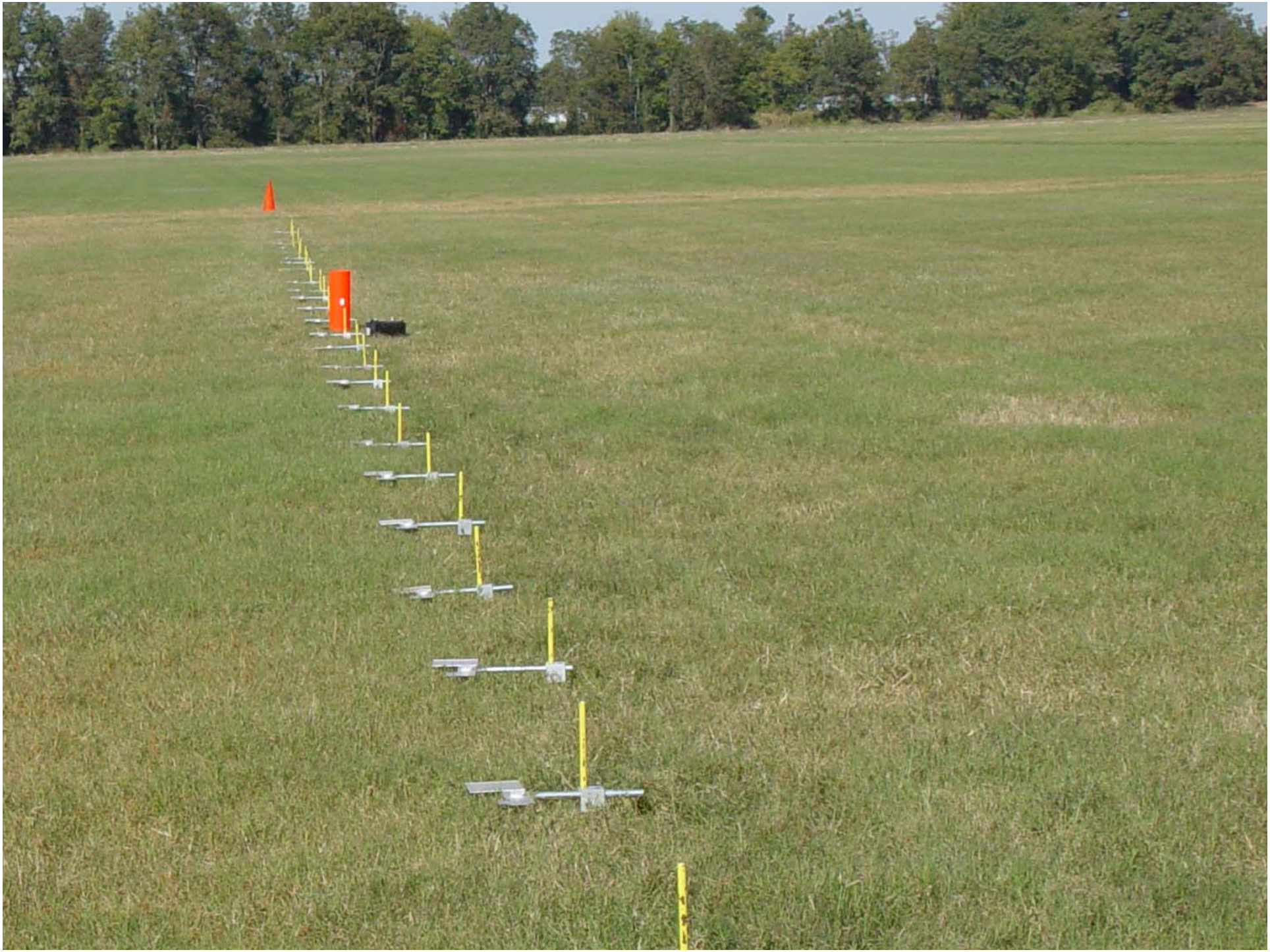


Portable light detector and triggering circuit

Some results of dynamic testing (Satloc Airstar M3)

Date	Time of Day (HHMMSS.SS)	Dir.	Easting (m)	Northing (m)	**Position Latency (m)**
	Reference Point		-698043.0	3706900.0	
10/15/03	113509.0	E	-698048.5	3706899.3	**-4.02**
10/15/03	120159.9	S	-698042.6	3706893.4	**8.00**
10/15/03	113922.9	W	-698036.8	3706899.1	**-4.83**
10/15/03	115425.3	N	-698042.6	3706905.4	**6.79**

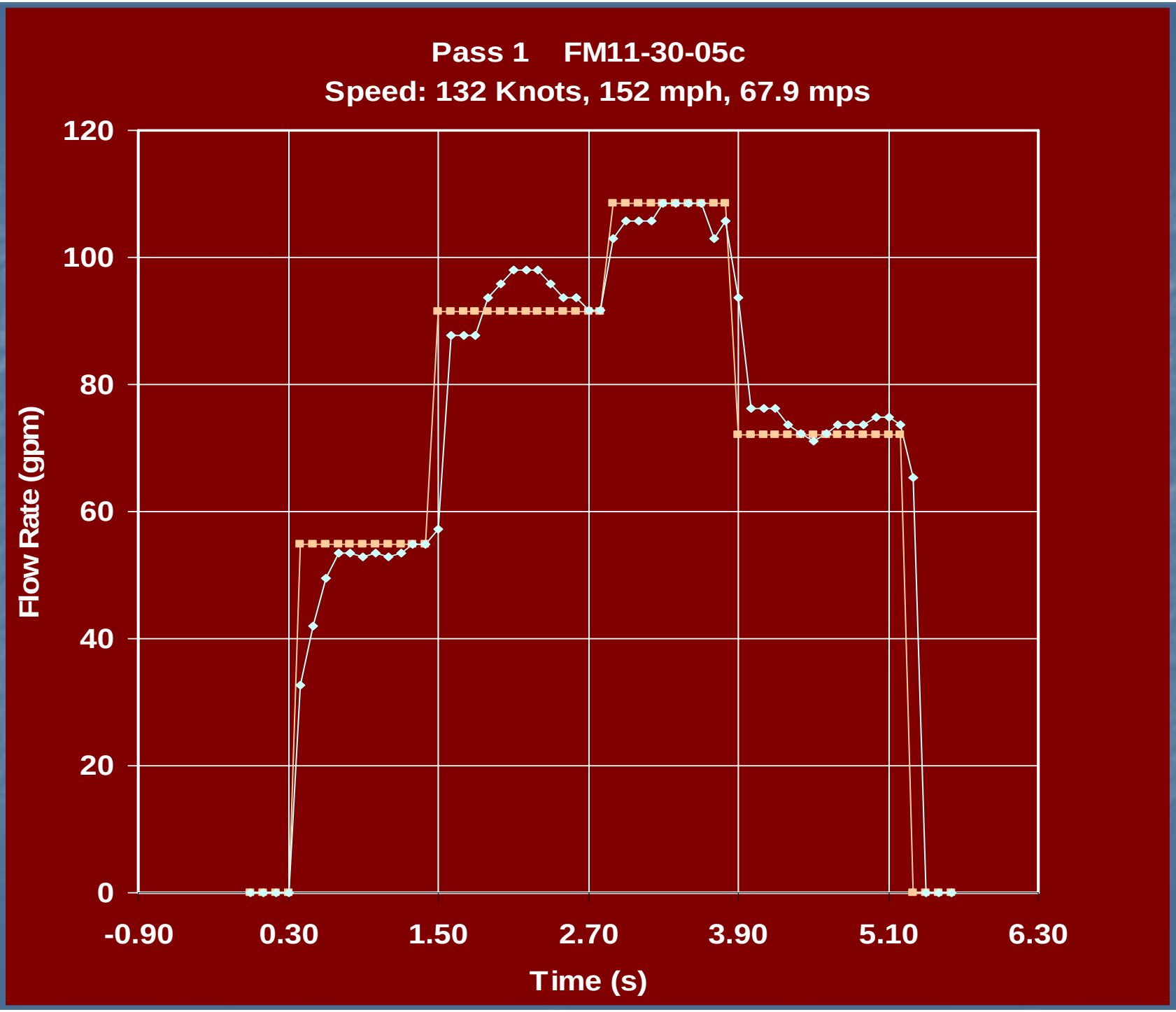
Testing Variable-Rate System Performance

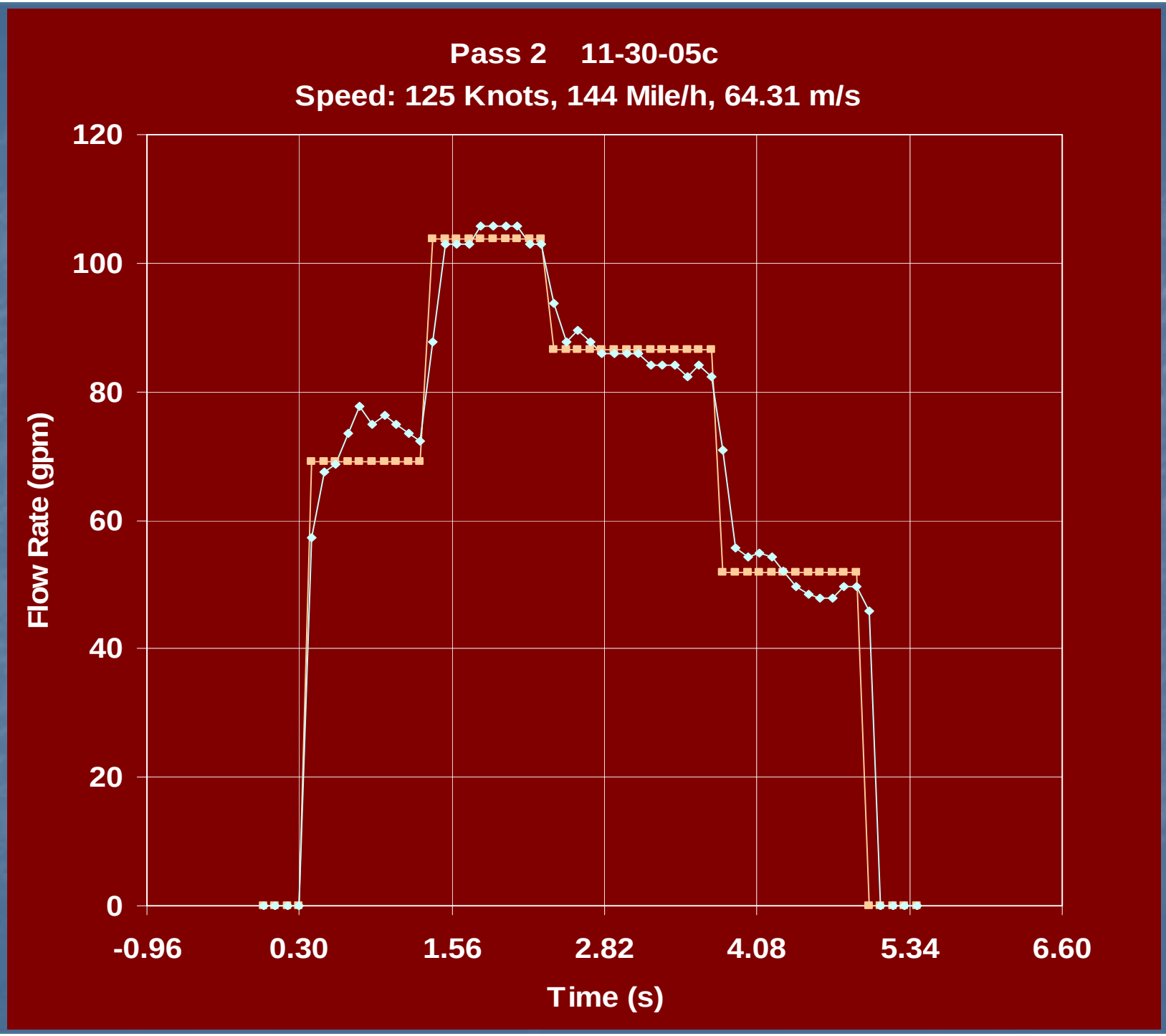


Data – Response Time

- Captured data stream generated by AutoCal II
- Captured flow meter data with an electronic circuit designed to read the flow meter at regular intervals

Satellite
4000CDT

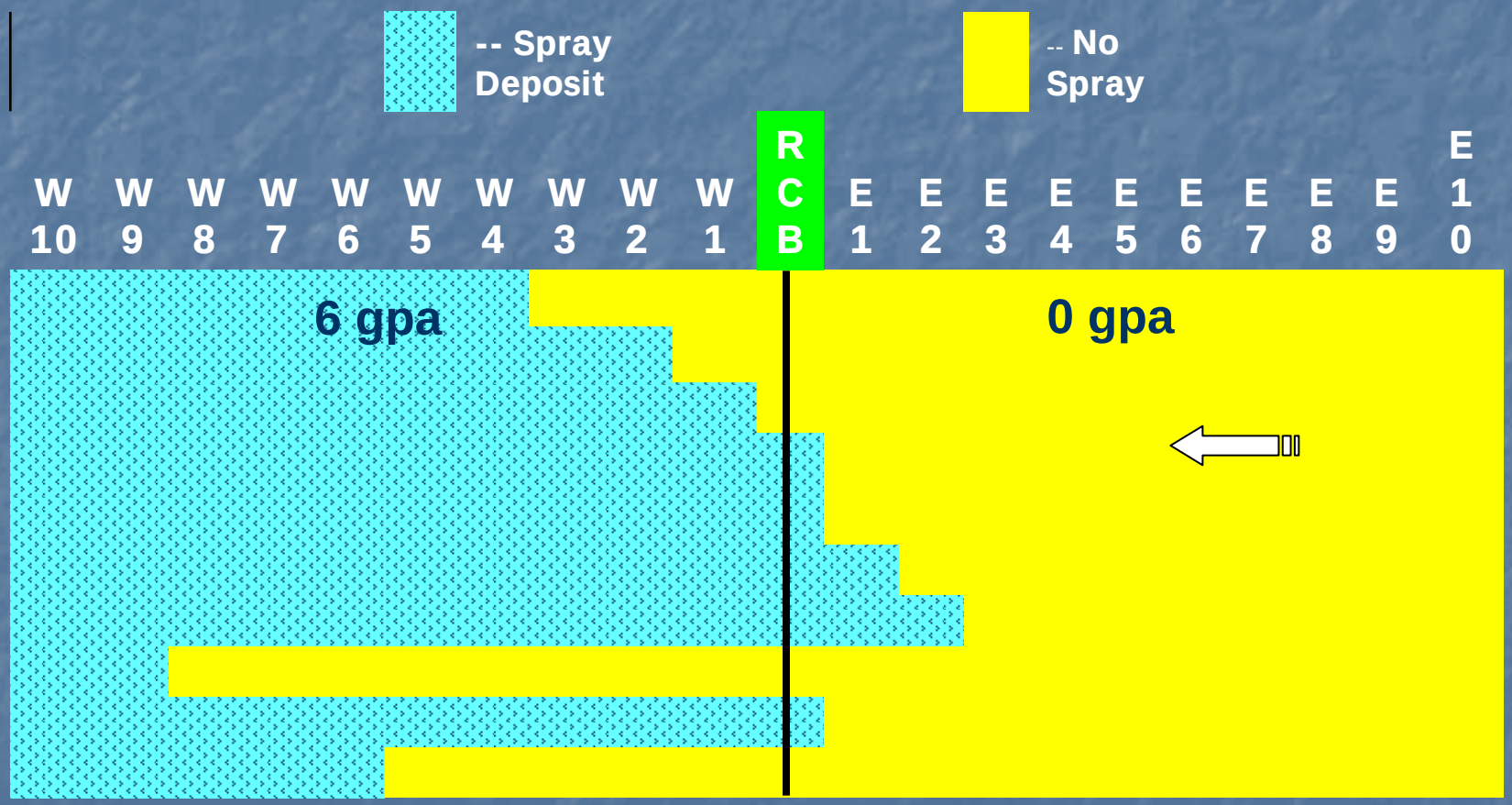

Pass 1 FM11-30-05c
Speed: 132 Knots, 152 mph, 67.9 mps
Flow Rate (gpm)
120
100
80
60
40
20
0
-0.90
0.30
1.50
2.70
3.90
5.10
6.30
Time (s)


Pass 2 11-30-05c
Speed: 125 Knots, 144 Mile/h, 64.31 m/s
120
100
80
60
40
20
0
Flow Rate (gpm)
-0.96
0.30
1.56
2.82
4.08
5.34
6.60
Time (s)

Data – Flow Control Error

Pass	Actual (gal)	Required (gal)	Average Error (%)
1	6.63	6.57	0.83
2	6.01	5.90	1.87
3	6.39	6.23	2.57
4	6.14	6.19	-0.84
5	6.49	6.42	1.10
6	6.48	6.45	0.40
Average			0.99

Data – Spray Deposits



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Steps Required to Process Images for use in Variable-Rate Application

1. Image analysis and georectification
2. Convert GIS shapefile to prescription format
3. Application of prescription

- Georectification – Imagery are represented with accurate geographic coordinates using ground control points and airplane attitude data (pitch, roll)

We are looking for a rapid, near real-time method for *image analysis*, *georectification*, and *conversion.*

- The idea is to remotely sense the field variable on one pass and apply the prescription on the next pass
- Field scouting ?

Present Methods for Prescription Generation

- Aerial crop management solutions:
  - In-Time
  - John Deere

Rapid turnaround of images, prescriptions

Good success with variable defoliant and growth regulator applications as a function of crop vigor indices (NDVI)

Prescription generation done by user based on segmented imagery (In-Time)

Objective

- Develop and test a system that will automatically transform a Color-Infrared (CIR) image into a georegistered NDVI map for the purpose of prescription map generation.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

Airplane

- GA 200 spray plane (Gippsland Aeronautics Pty Ltd., Australia)

Hardware

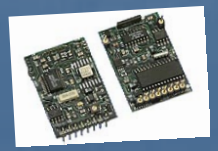
- CIR camera (Redlake/Duncantech MS-3100)

- Computer (Model SK41G, AMD 1800 processor, Shuttle Corp.)

- PCI frame grabber card (Model PCI-1428 with Camera Link®, National Instruments Corp.)

- Camera control software - DT Control - FG software (Version 1.04.63, DuncanTech Inc., Auburn, California).
- GPS (Magellan Meridian; Garmin 16 HVS)

- Attitude sensor (Honeywell HMR3300)

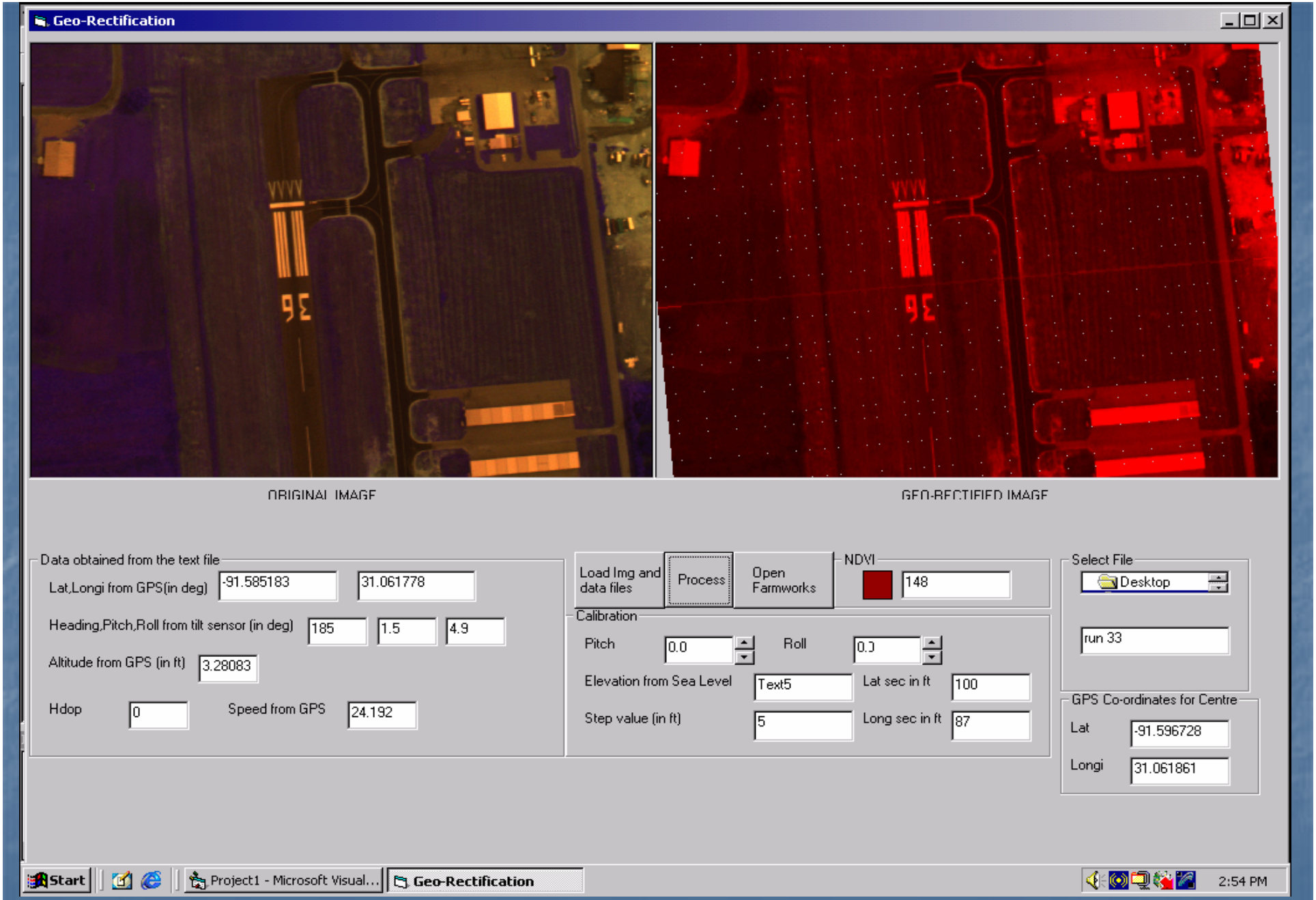


Data Acquisition

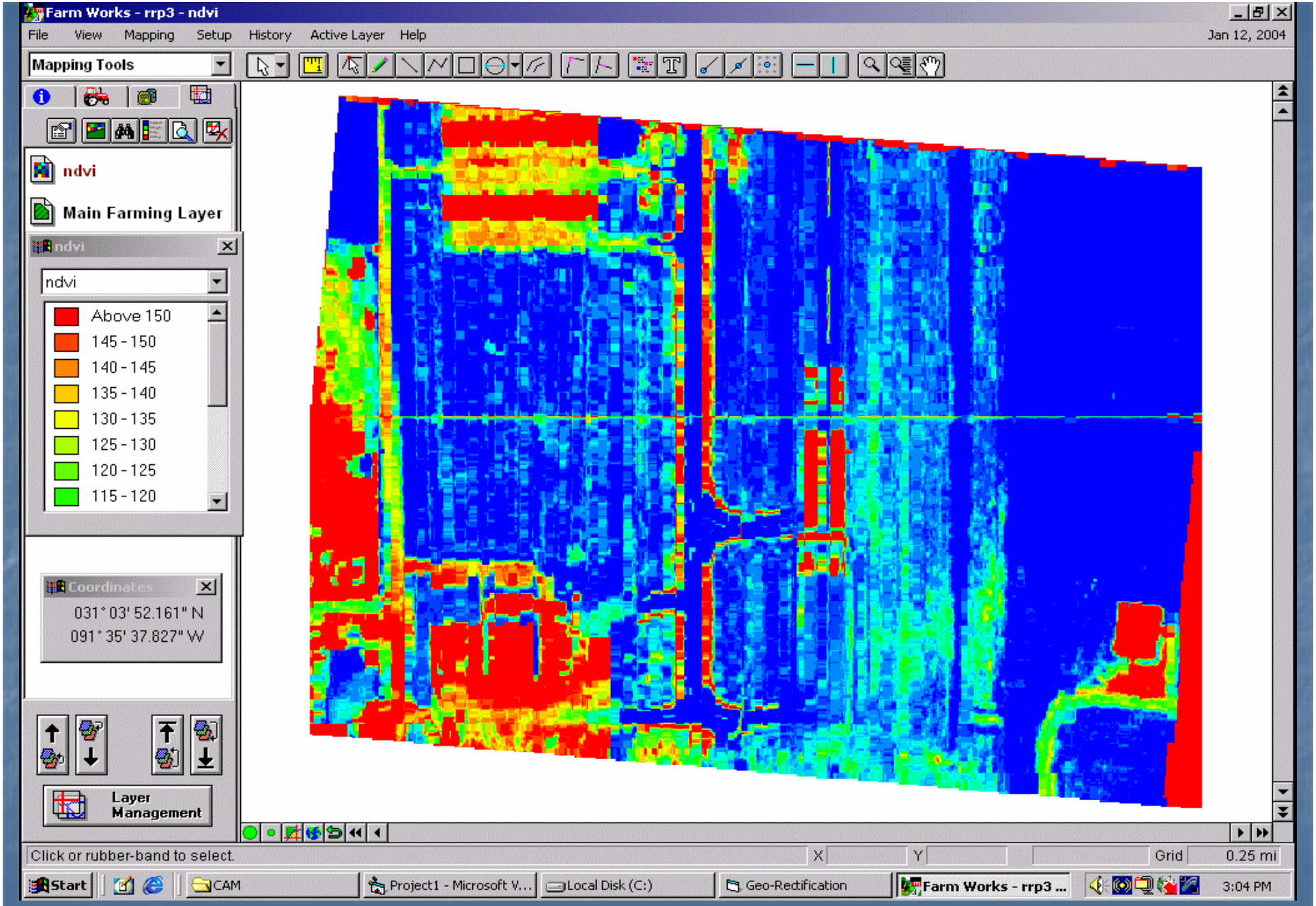
- Single board computer (BasicAtom pro) controlled image acquisition and acquisition of data from sensors.
- Pilot could control image and data acquisition
- Software determined the correct time between photos, and to produce a percent overlap in the images (20% in this case).

Image Analysis and Georegistration

- A conversion program used standard trigonometry and plane attitude data to determine a center coordinate in the image (assuming a flat field).
- The program then stepped across the image using a moving box that determined an average NDVI value and GPS coordinate for each box. This box could be any size selected, or desired, by the user (i.e., 1.5, 3, 6 m., etc.).
- The average NDVI value and GPS coordinates were saved into a separate text file. This file format was used since it can be imported into virtually any software available.
- The process was repeated until the entire image had been transformed.



Program to convert CIR images into georectified NDVI data and store in text file.



Farmworks® NDVI output from text file data

- Using this procedure, image data could be converted into point data with geospatial coordinates, and reduced for easy mapping in site specific farming programs.

- Since the text file format was used, multiple images could be appended in one file to create a mosaic easily.

Preliminary Results – Georeferencing Accuracy

- Average RMS error for all images was 56 meters. This value was <u>not</u> acceptable for prescription map generation.

Errors influencing results

1. GPS errors caused by
   - Latencies in direction of flight
   - Time required by software to calculate correct GPS coordinate

When consistent GPS errors were accounted for, about half the RMS error was removed leaving 27m error

Errors influencing results

2. a. Synchronization problems between GPS data arriving from the satellite and camera triggering.

   b. Attitude data were not synchronized

Partial Solution: PPS line from Garmin GPS was used to allow triggering the camera from the GPS time clock.

RMS errors were reduced to 10-m when using the GPS only (no attitude adjustment) with PPS synchronization, under 1600 ft altitude.

- System accuracy could be improved by connecting to the airplane’s guidance GPS.

General Observation

- Level of involvement of field scouting data needs to be addressed

Thank you!