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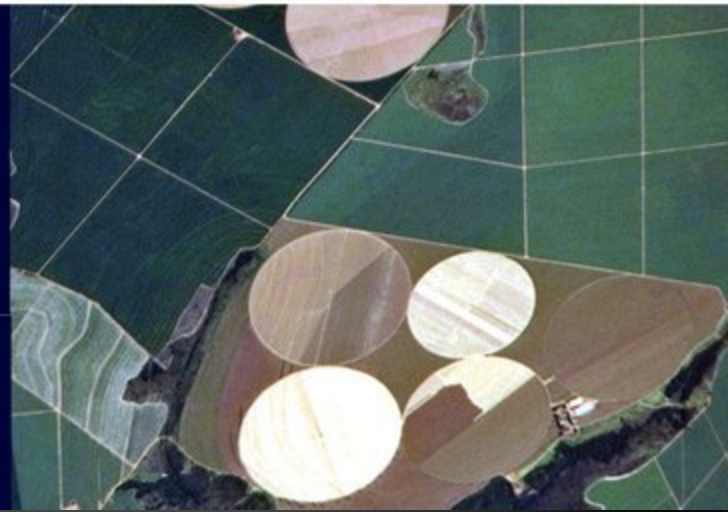
CUTTING-EDGE APPLICATIONS

OF UNMANNED SYSTEMS TECHNOLOGY

Tuesday, September 29, 2015



WELCOME TO
Cutting-Edge Applications of Unmanned Systems Technology

Dr. Ian MacRae
Professor of Entomology and Extension Entomologist
University of Minnesota
Northwest Research and Outreach Center

Dr. Steven Waslander
Asst. Professor, Department of Mechanical and Mechatronics Engineering
University of Waterloo

Co-Moderator: Lori Dearman, Sr. Webinar Producer

Who's In the Audience?

A diverse audience of over 400 professionals registered from 43 countries, 30 states and provinces representing the following industries:

- **23%** Professional User
- **23%** System Integrator
- **16%** Product/Application Designer
- **12%** GNSS Equipment Manufacturer
- **26%** Other

Welcome from *Inside GNSS*

Richard Fischer
Director of Business Development
Inside GNSS

Cutting-Edge Applications of Unmanned Systems Technology

Demoz Gebre-Egziabher
Aerospace Engineer and Mechanics Faculty
University of Minnesota

Poll #1

Currently, which of the following industry/operations has the most users of UAS? (Please select one)*

- *Agriculture*
- *Real estate and aerial surveying*
- *Utility inspection*
- *Emergency management*

** Based on the number of applications to the FAA for a Section 333 exemption*

Who is using UAS?

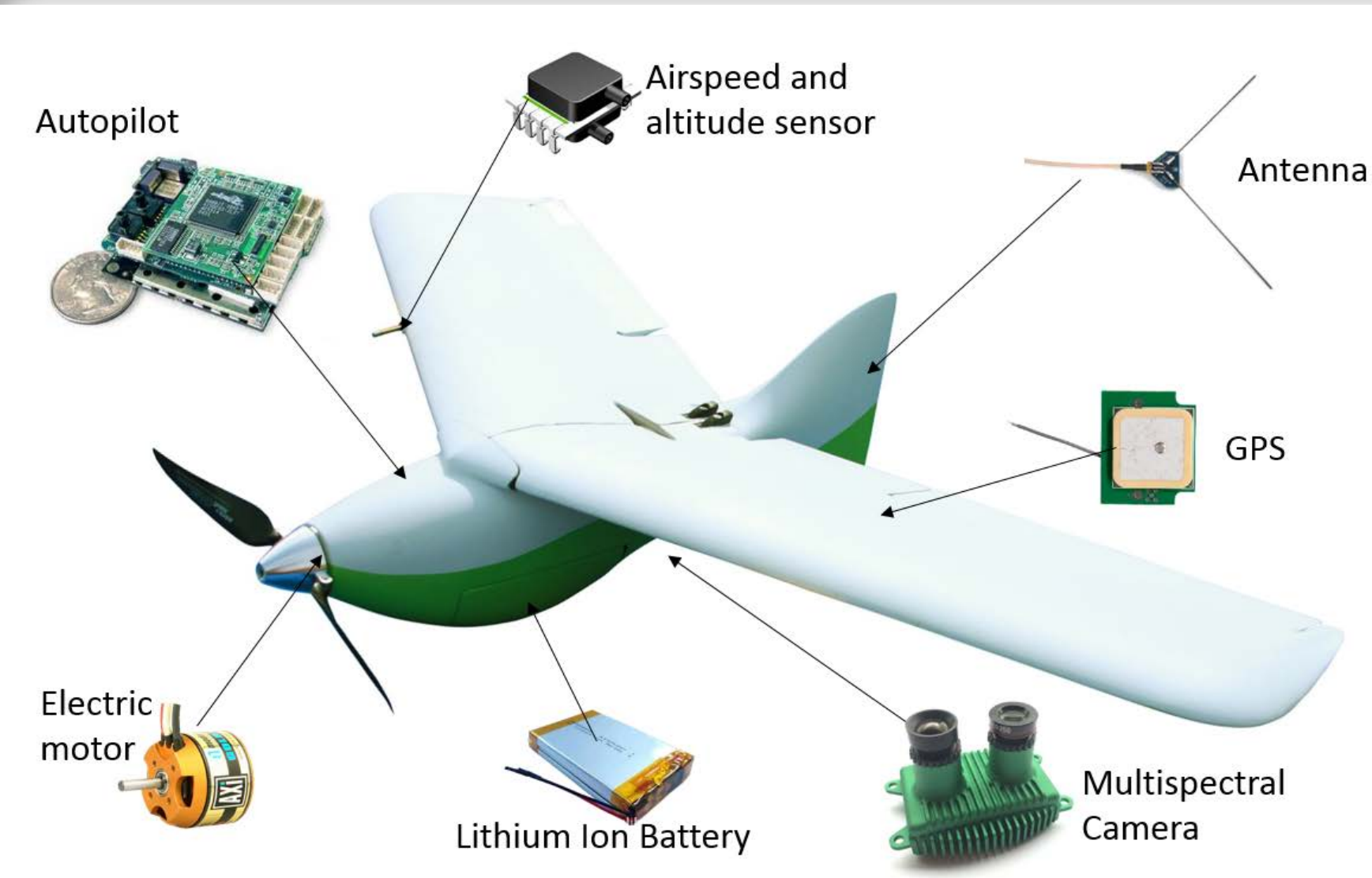
Dr. Demoz Gebre-Egziabher
Dept. of Aerospace Engineering & Mechanics
Univ. of Minnesota

UAS Use Cases – A Snapshot

Rank	Operation	# of Apps.
1	Aerial Photography	512
2	Real Estate	350
3	Aerial Survey	302
4	Aerial Inspection	242
5	Agriculture	164
6	Construction	134
7	Infrastructure Inspection	102
9	Utility Inspection	78
12	Search and Rescue	52
13	Research and Development	24
14	Emergency Management	38
16	Insurance	25
24	Education	8

- Data extracted from S. Kesselman and D Klein, "The First 1,000 Commercial UAS Exemptions, " AUVSI Report.
  - Data for US only
- Agriculture and aerial inspection applications expected to surge
  - Compelling use case.
- The majority of the applications were for multi-copters.
  - ~ 70% of applications

Precision Agriculture Platform



Road Map of Today's Discussion

- So what exactly is precision agriculture and why is it important?
- What role do UAS play in precision agriculture?
- What are some of the challenges (technological) that must be dealt with before we have a "turn key" UAS solution for precision agriculture and infrastructure inspection.

Cutting-Edge Applications of Unmanned Systems Technology

Site Specific Pest Management in Precision Agriculture

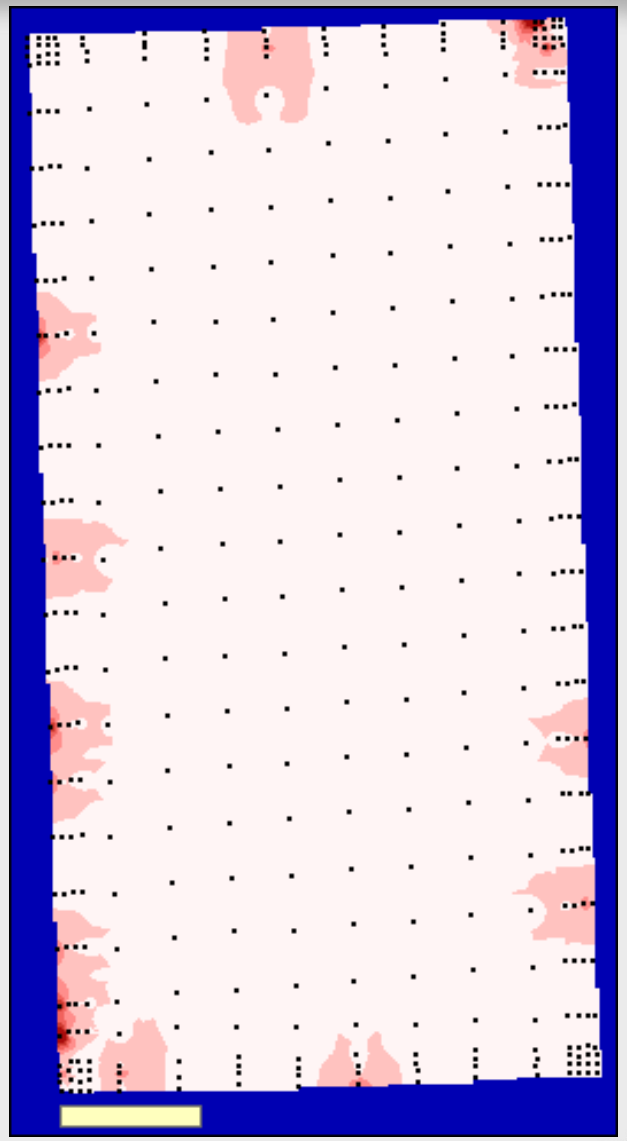
Dr. Ian MacRae
Department of Entomology
Univ. of Minnesota

More people, same land in production

- Population > 9B by 2050, food needs will grow
- Arable land limited, production increases must result from efficiencies
- Ecological sustainability will be increasingly necessary!

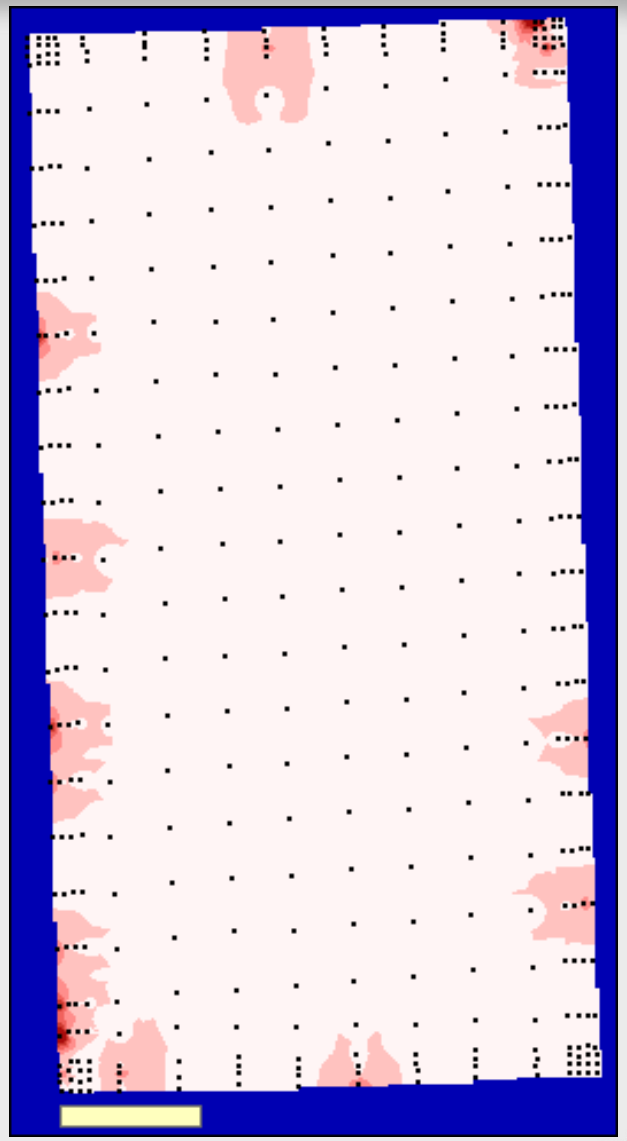
Site Specific Pest Management

- Integrated pest management
  - Environmentally & economically sustainable management
    - Pesticide use based on economic damage thresholds
  - Involves whole-field application
- Precision Agriculture/Site Specific Pest Management
  - Targeted application of agriculture chemicals when & *where* necessary!
  - Relies on high resolution mapping



Site Specific Pest Management

- Aphids first colonize edge of fields
- 14d period prior to redistribution into field
- Targeted application provides same control for 17% of the insecticide compared to whole field application
- MUST KNOW WHERE PESTS ARE!



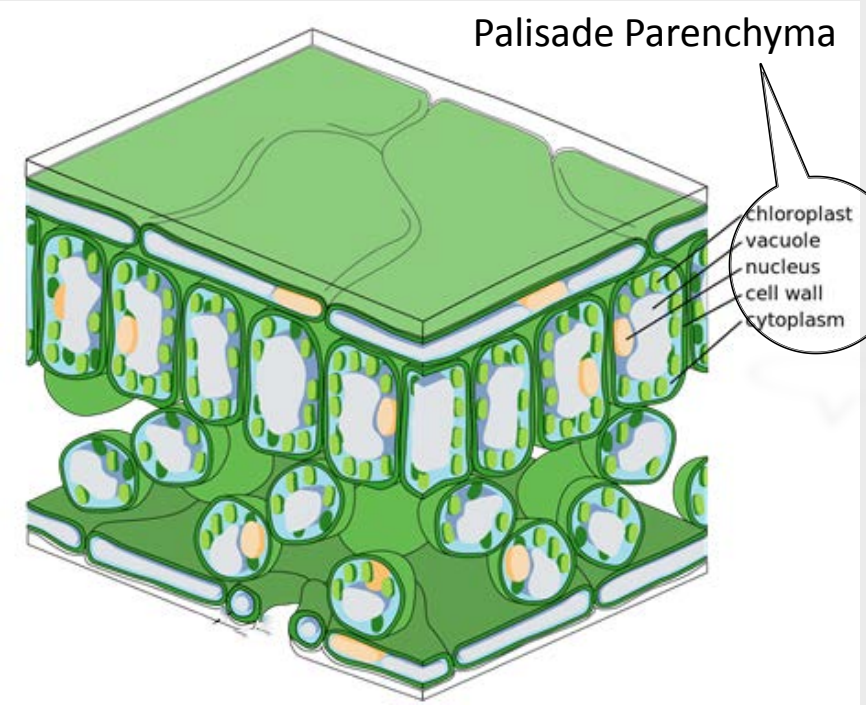
Temporal efficiency

- Mapping research field = ~16 man hrs
- Crop scouts >15K acres/day
- More rapid data acquisition required for real time decisions

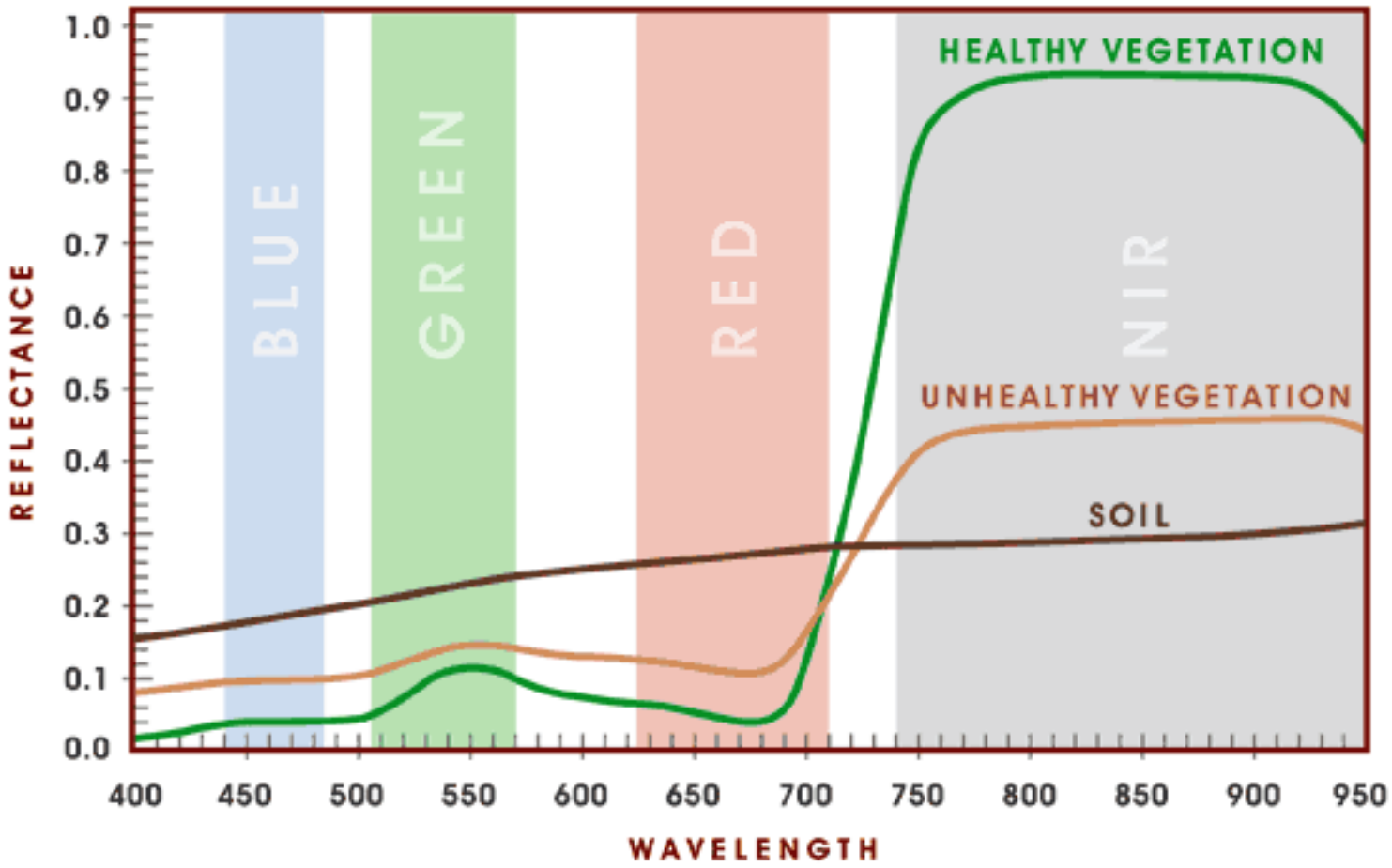
Remote sensing using canopy reflectance can provide real-time data

Plant (Crop) reflectance

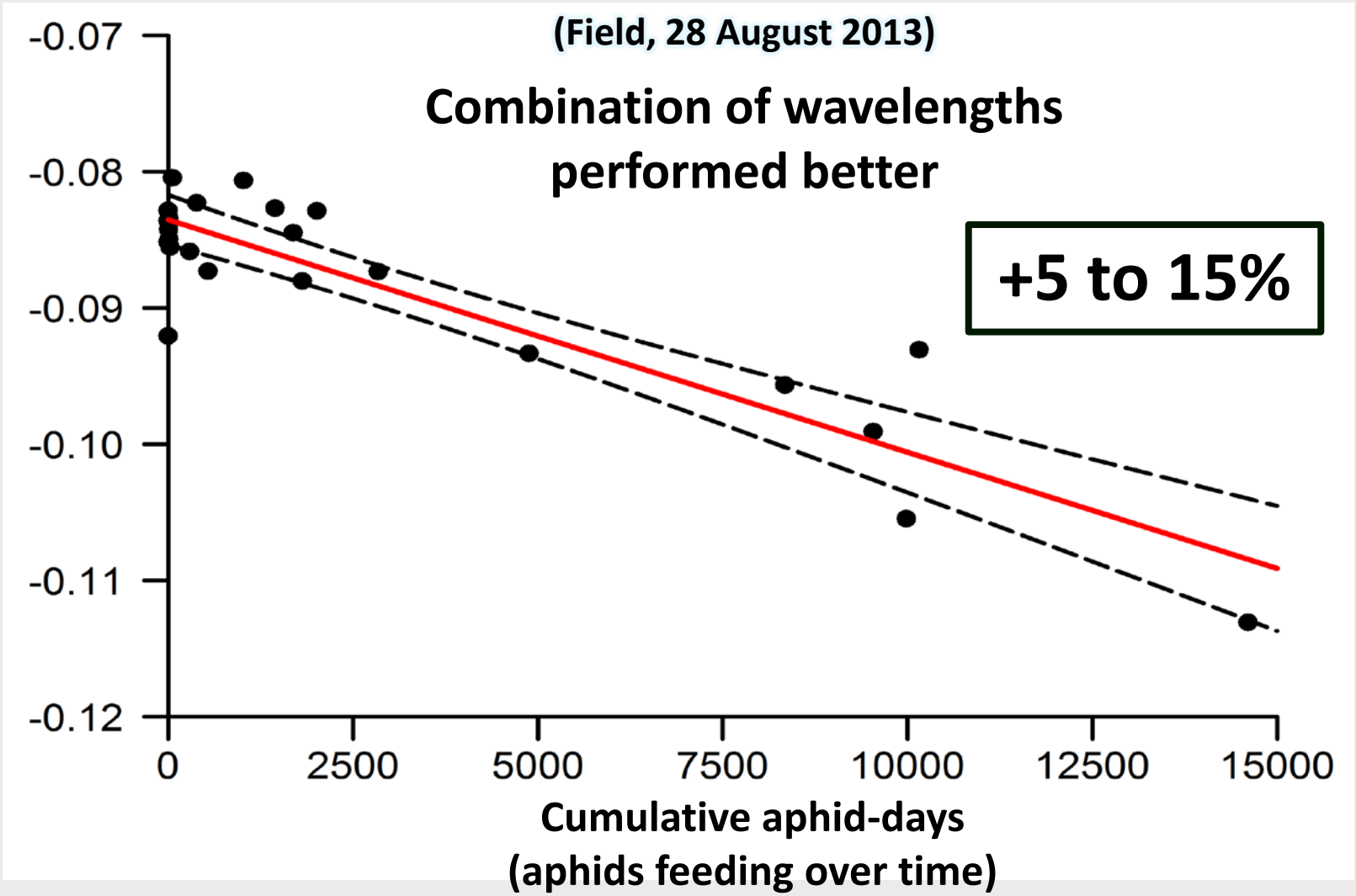
- Leaf reflectance
  - Pigments
  - Internal leaf structure
  - Water content
- Canopy reflectance
  - Leaf reflectance
  - Plant geometry
    - Orientation & distribution



Slide courtesy of Dr. Robert Koch


REFLECTANCE
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
BLUE
GREEN
RED
NIR
HEALTHY VEGETATION
UNHEALTHY VEGETATION
SOIL
400
450
500
550
600
650
700
750
800
850
900
950
WAVELENGTH

Soybean Aphid Affects Canopy Reflectance



Sugarbeet Root Maggot

- Sugarbeet Root Maggot (SBRM) feeds on root sof sugarbeet
  - Difficult to scout (underground)
  - Stresses plant within season
- Researching ability to remotely scout for SBRM

UAS fills a platform gap, provide more options/tradeoffs for resolution, speed, & immediacy

Higher resolution than a satellite or plane, more immediate/convenient, but covers smaller footprint. Less detailed info than a person/ATV, but covers a bigger footprint. Economics depend on what's being sensed & how

3-D Robotics Iris

GoPro Hero3

VIS/NIR cameras

Sony NEX-T5

Others (thermal, radiometry, hyper vs mutlispec, etc)

Spatial resolution

- UAS - GPS geo-coordinates
  - SNR optimized to ~1-1.5m res
- Sensors
  - cm to sub-cm accuracy depending on res of sensor and altitude

1.3MP

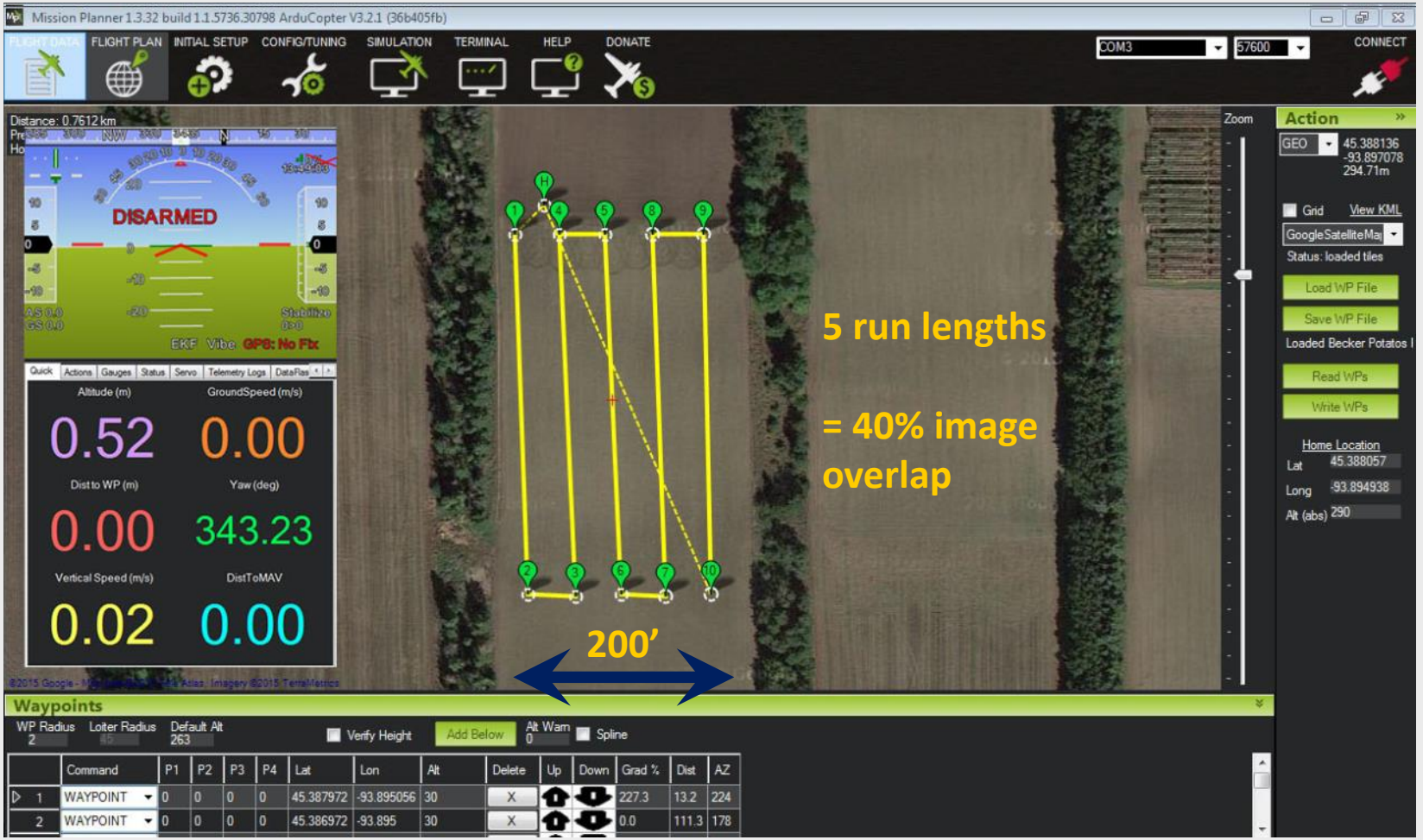
GoPro Hero4

16MP

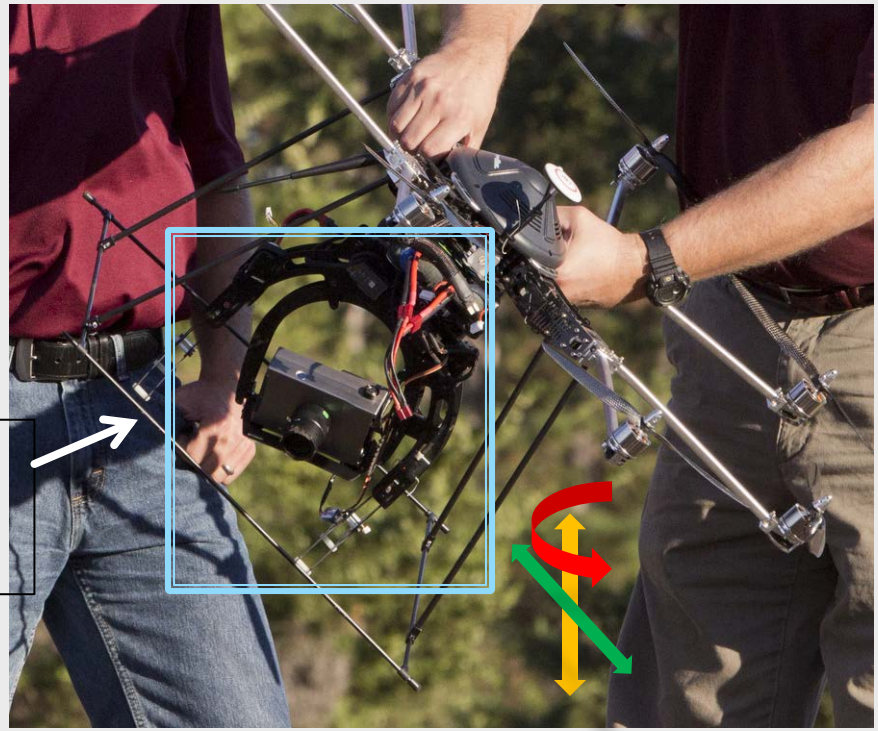
True Ultra HD

Sony NEX-T5

Flight planning

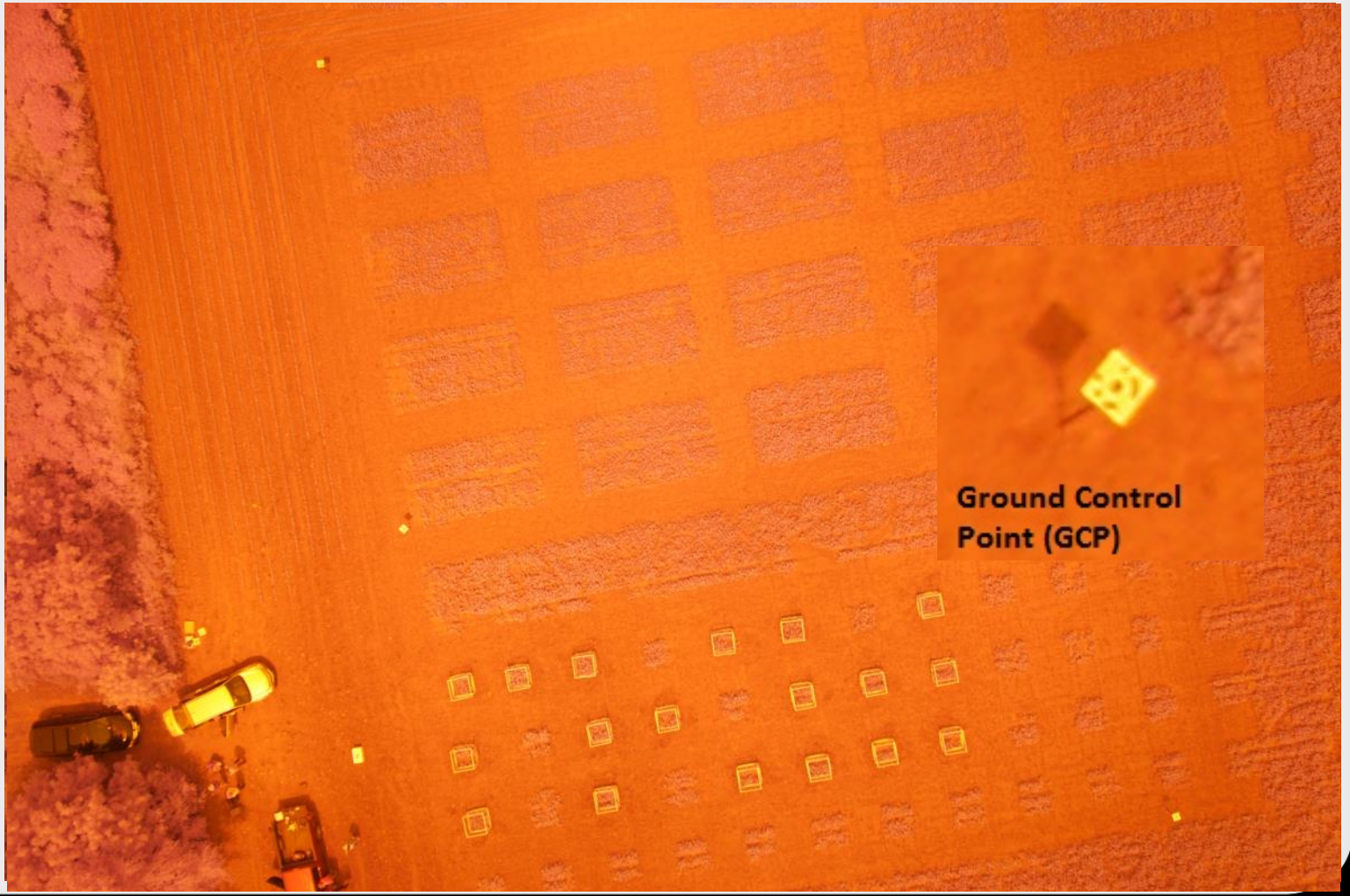


Sensor orientation

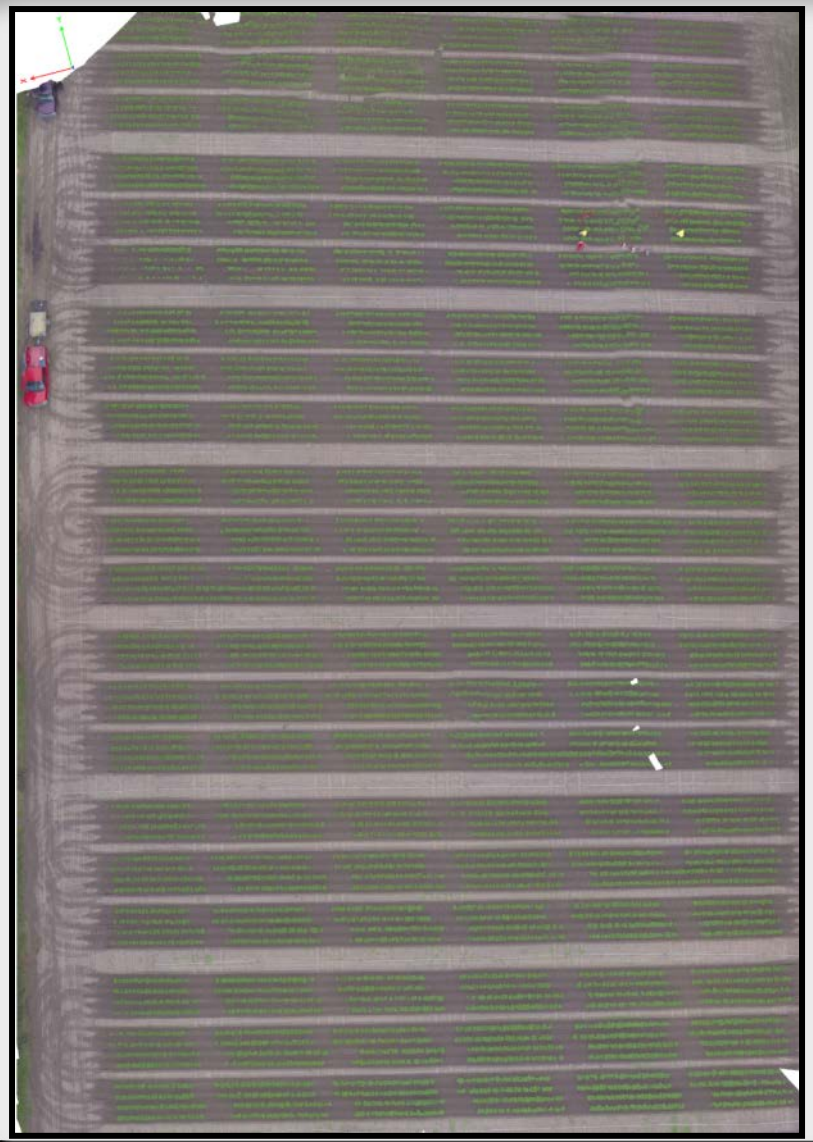


Stabilized gimbal compensates but image may be taken when not true 90° down, vehicle telemetry may not match. Require alternate pitch/yaw/roll meters (and maybe GPS).

Stitching imagery

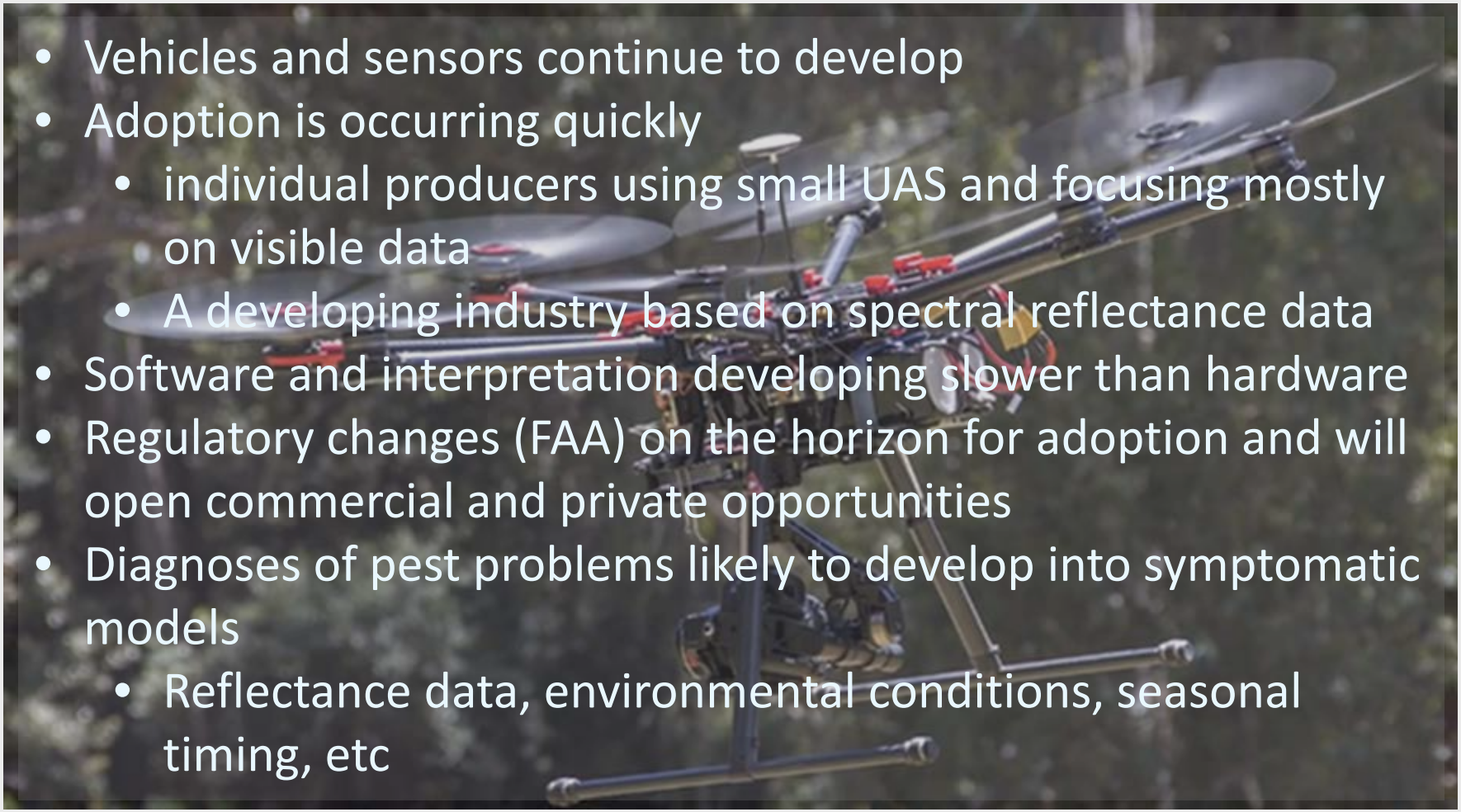


Stitching the mosaic



- Facilitates Image/Data Analysis
- Altitude decreases no. of images
  - Economics (fuel/time/post-processing)
  - ***BUT*** Regulatory issues (FAA operational ceilings)

UAS in Pest Population Mapping



- Vehicles and sensors continue to develop
- Adoption is occurring quickly
  - individual producers using small UAS and focusing mostly on visible data
  - A developing industry based on spectral reflectance data
- Software and interpretation developing slower than hardware
- Regulatory changes (FAA) on the horizon for adoption and will open commercial and private opportunities
- Diagnoses of pest problems likely to develop into symptomatic models
  - Reflectance data, environmental conditions, seasonal timing, etc

Ask the Experts – Part 1

Dr. Ian MacRae
Professor of Entomology and Extension Entomologist
University of Minnesota
Northwest Research and Outreach Center

Dr. Steven Waslander
Asst. Professor, Department of Mechanical and Mechatronics Engineering
University of Waterloo

Poll #2

From a guidance, navigation and control perspective, which are key challenges for small UAS avionics? (Please select your top two)

- *Reliability*
- *Size*
- *Power requirements*
- *Ubiquitous operation*
- *Cost*

Using Small Rotorcraft UAVs for Inspection Tasks

Localization, Mapping , Collision Avoidance and UAV/UGV Teams as Enablers for the Next Wave of UAV applications

Steven L. Waslander
Associate Professor
University of Waterloo

Civilian Drone Applications

- Three dominant civilian applications are agriculture , real estate and cinematography
- Most operation within line of sight and in open space for safety
  - Collision and obstacle avoidance not yet integrated
  - Positioning too imprecise for online mapping
- Next wave of applications require more precise UAV motion estimation and flight near obstacles
  - Inspection, tracking, mapping can all benefit from Computer Vision based solutions

Open Problems for Aerial Inspection

Perception

- Accurate multirotor modeling
- Universal state estimation
- Dense onboard mapping
- Detection of other aerial vehicles

Planning and Execution

- Precise control in wind
- Motion planning on evolving maps
- Collision avoidance of aerial vehicles
- Range Extension

Today's Subset of Open Problems

Perception

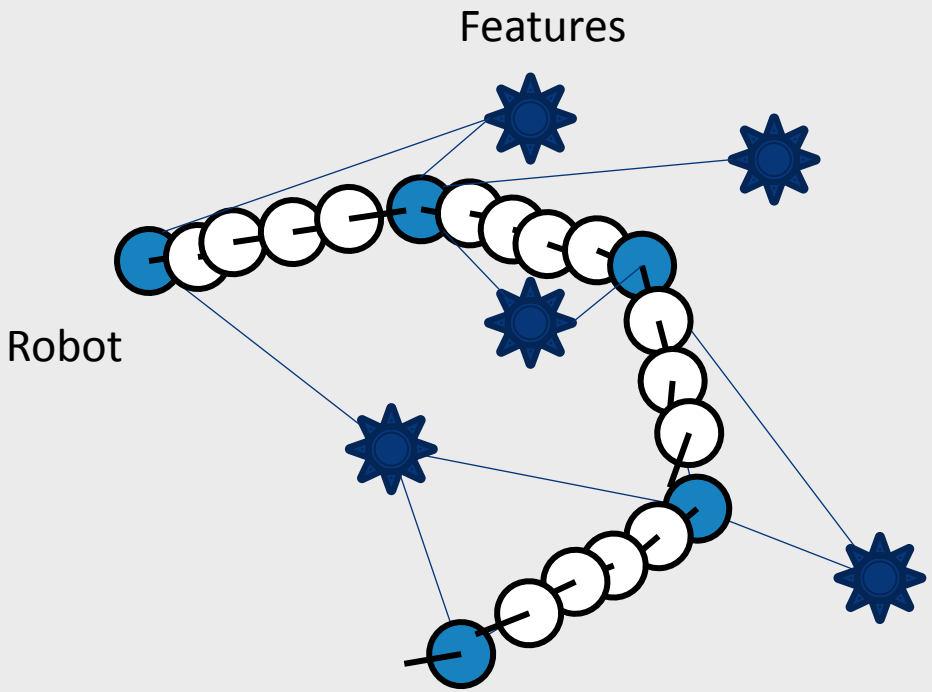
- Accurate multirotor modeling
- Universal state estimation
- Dense onboard mapping
- Detection of other aerial vehicles

Planning and Execution

- Precise control in wind
- Motion planning on evolving maps
- Collision avoidance of aerial vehicles
- Range Extension

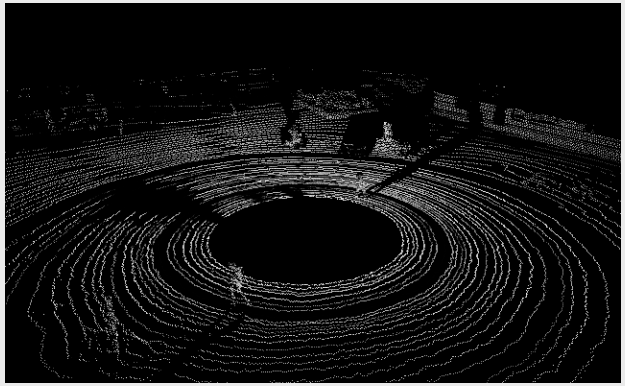
- Localization and Mapping are at odds computationally
  - Localization – fast, lightweight
  - Mapping – slow, detailed

- Parallel Tracking and Mapping (PTAM) [Klein and Murray, 2007]

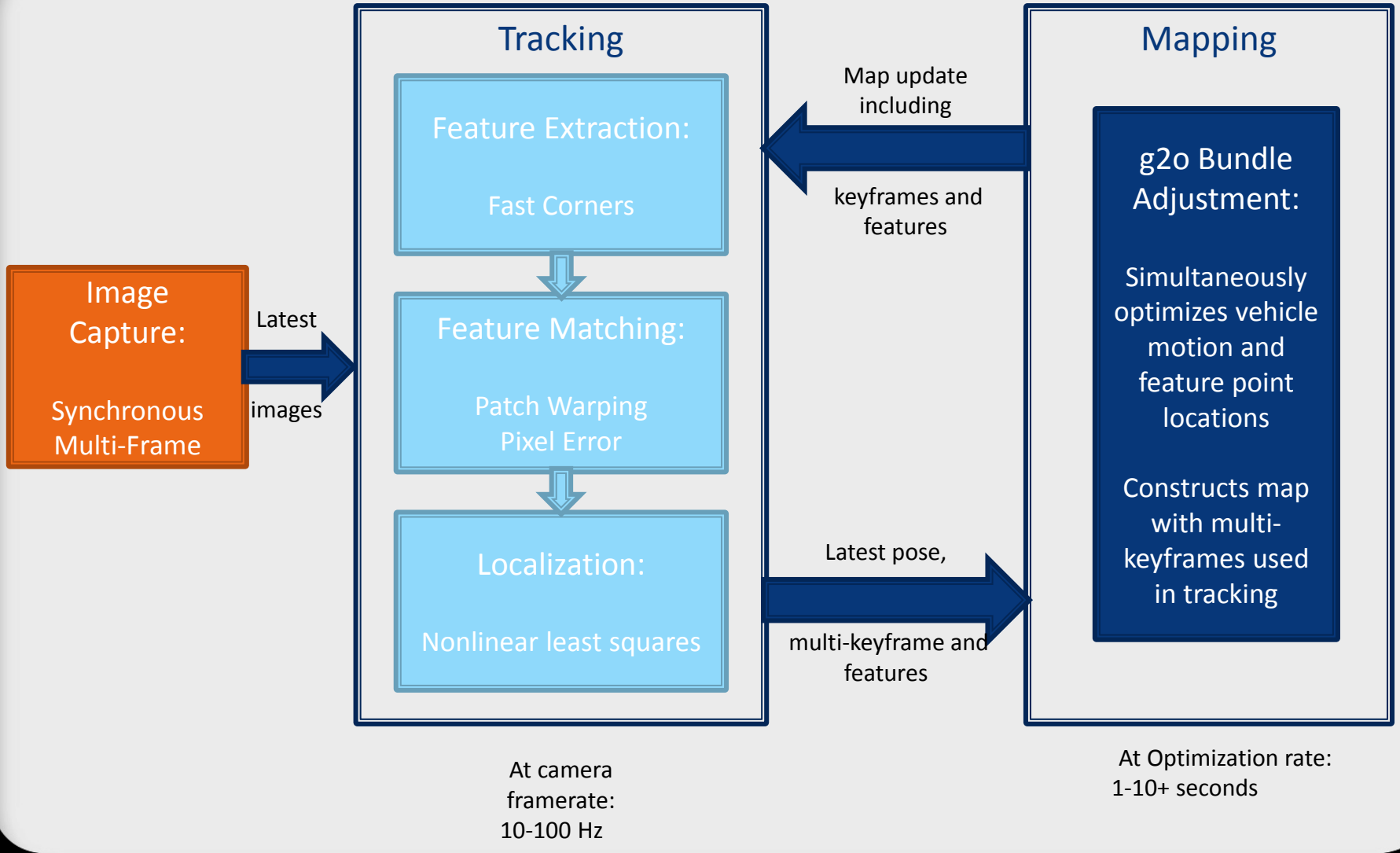


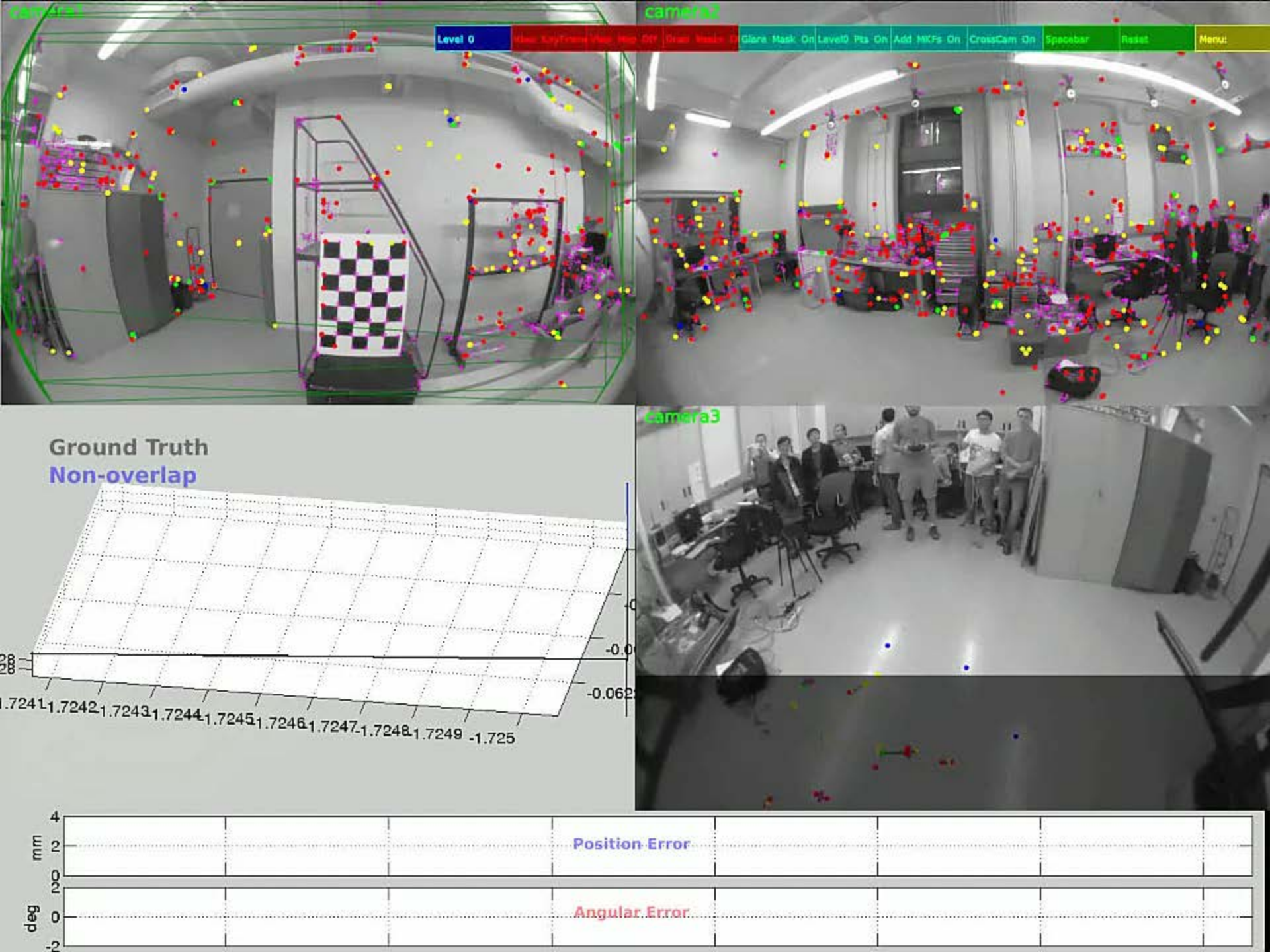
Move to Multiple Wide FOV Cameras

- Relative to monocular cameras
  - Can resolve scale
  - Better visibility
  - Robustness to partial occlusions
- Relative to lasers
  - Cheaper and lighter but still offer large visibility
  - More resolution, more data channels
  - Colours useful for scene understanding, segmentation, target detection
  - Cameras often already required as payload
- Drawbacks
  - Very large data acquisition rate
  - Still subject to illumination, motion blur, feature correspondence challenges



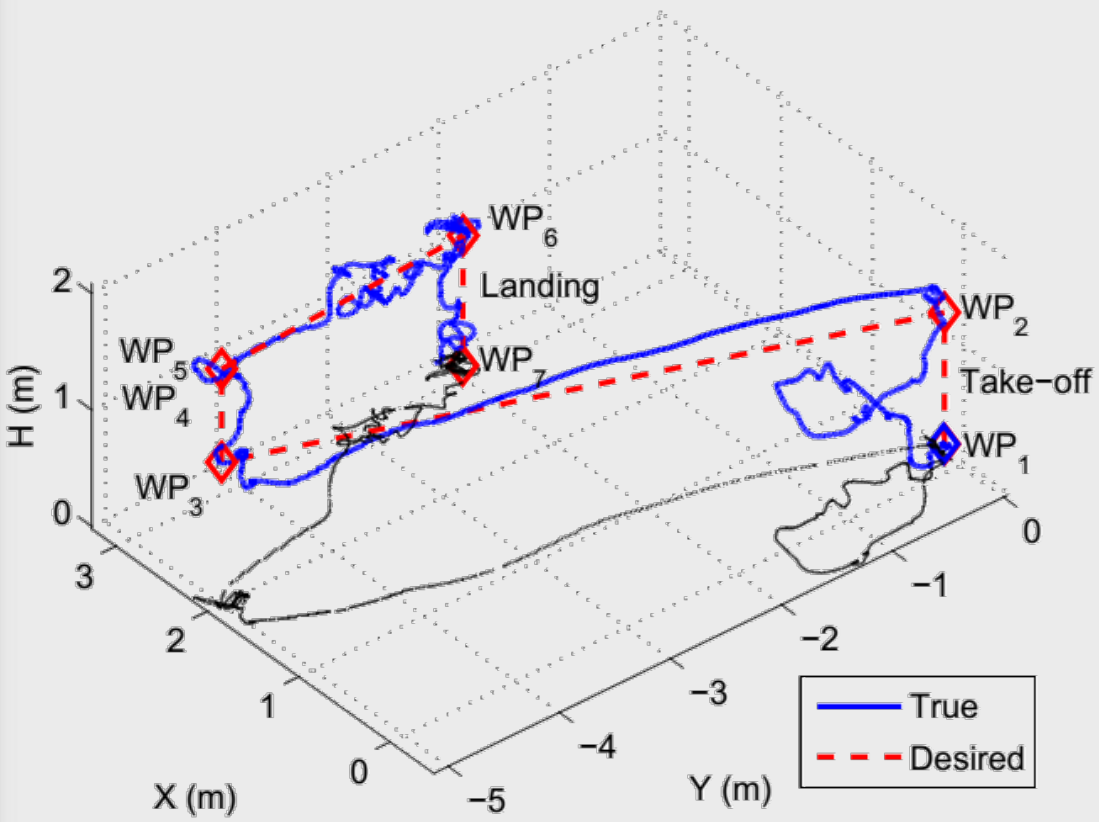
Multi-Camera PTAM Architecture

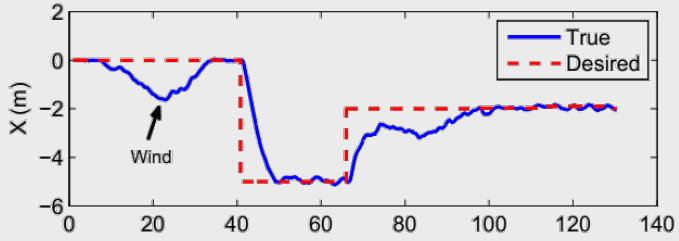


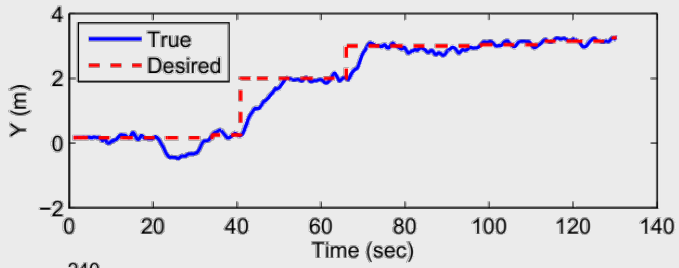

camera1
camera2
Level 0
Glare Mask On
Level0 Pts On
Add MKFs On
CrossCam On
Spacebar
Reset
Menu:
Ground Truth
Non-overlap
camera3
1.7241
1.7242
1.7243
1.7244
1.7245
1.7246
1.7247
1.7248
1.7249
-1.725
-0.062
Position Error
Angular Error
mm
deg
4
2
0
-2

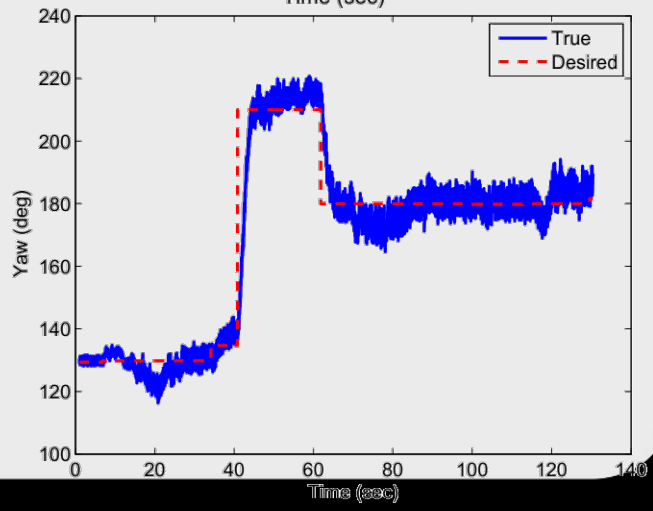
Vehicle Control Using MCPTAM at 7 Hz

- Closed loop outdoor control using MCPTAM on Draganflyer X8



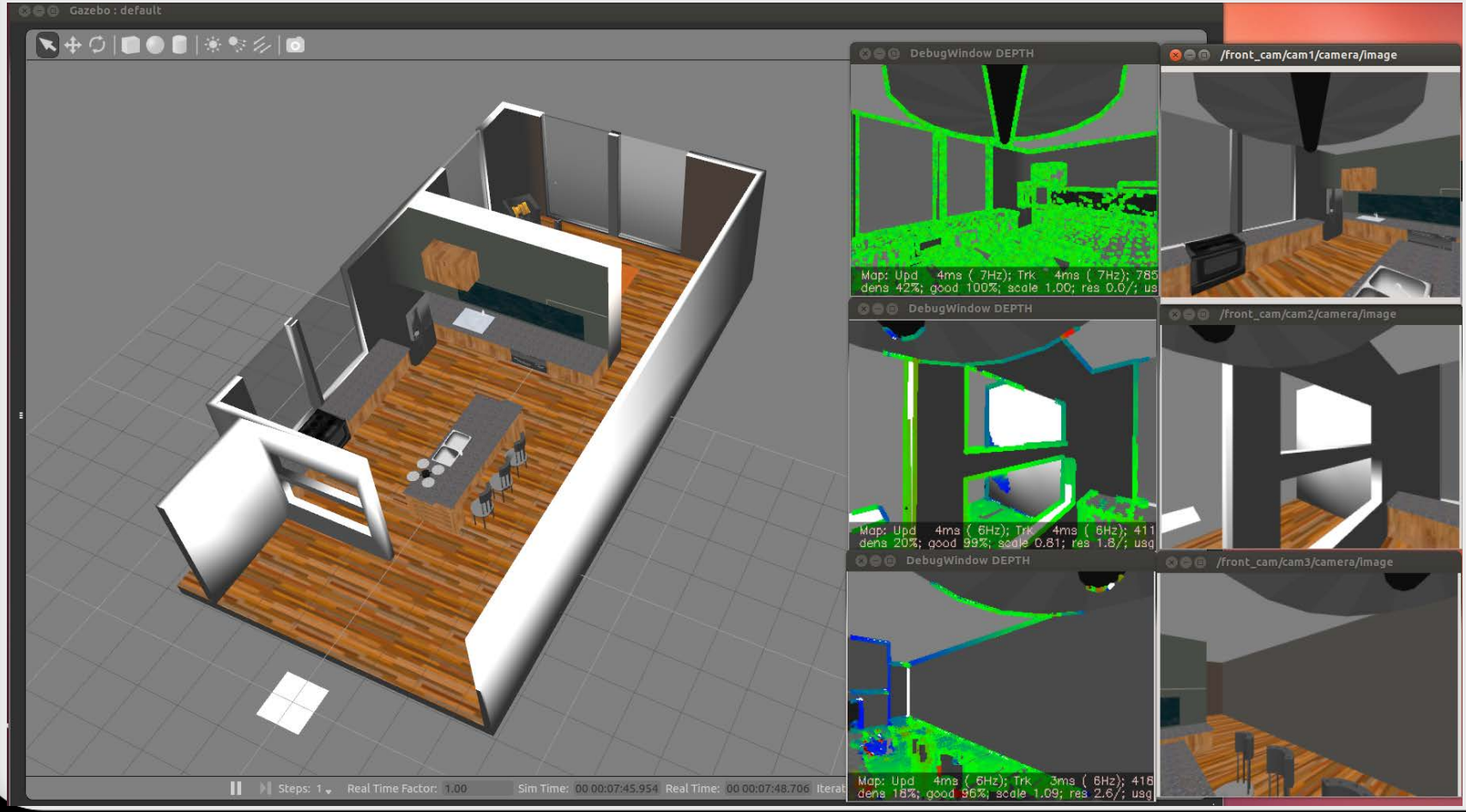






Dense Mapping with MCPTAM

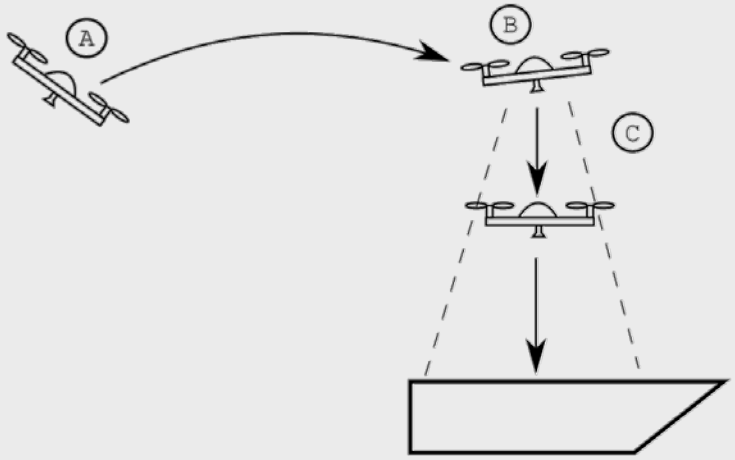
- Multi-camera clusters now functional in simulation
  - Real-time dense mapping still under development, preliminary results



Range Extension Through Autonomous Docking

- Extend UAV range and mission types with support ground vehicle
  - Wheeled, surface vessel etc.
- Fully independent docking requires minimal infrastructure on support vehicle
  - Target, GPS position broadcast
- Enables many new applications:
  - Long term field management
  - Autonomous pipeline, transmission line inspections
  - Remote exploration
  - Iceberg tracking, wildlife monitoring

- Three phase system : Rendezvous, Acquisition, Landing
  - Rendezvous – GPS only
  - Acquisition – GPS control, visual target detection
  - Landing – Vision only
- Control design avoids unreliable low-cost sensors when necessary
  - GPS/Magnetometer ignored during critical landing phase, only relative pose from camera estimation is used



Quadrotor Landing on a Moving Vehicle Using Vision

Summary

- Onboard motion estimation and map construction will open the door to more detailed inspection based applications
- Multi-camera configurations can improve accuracy near obstacles over GPS/INS alone
  - Sub-cm and sub-degree at close range
- Extended missions are possible through autonomous ground support vehicles and coordinated operations

Next Steps

- **Visit www.insidegnss.com/webinars** for a PDF of the presentations and a list of resources.
- Review the recorded version of today's webinar

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  - **Ian Mac Rae** imacrae@crk.umn.edu
  - **Steven Waslander** stevenw@uwaterloo.ca

Poll #3

In which of the following unmanned system operating domains are the PNT requirements most stringent?

- *Air*
- *Land*
- *Marine*
- *It depends on the operation*

Ask the Experts – Part 2

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