MIAASC
Michigan Advanced Aerial System Consortium

Welcome to the 2013 Michigan UAS Conference

October 28-30th, 2013

Sheraton, Ann Arbor, Michigan

MIAASC
Michigan Advanced Aerial System Consortium

AUVSI
ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS INTERNATIONAL
GREAT LAKES

ALPENA COUNTY 1857 2013 MICHIGAN

DAY 1 – October 29th 2013

Block 1 – Current & Future UAS Technologies Showcase

Block 2 – Integration of UASs in the NAS: Roadmap to 2015

Welcome Address

Valde Garcia

Manager & BD Aerospace Group /

MIAASC Board Member

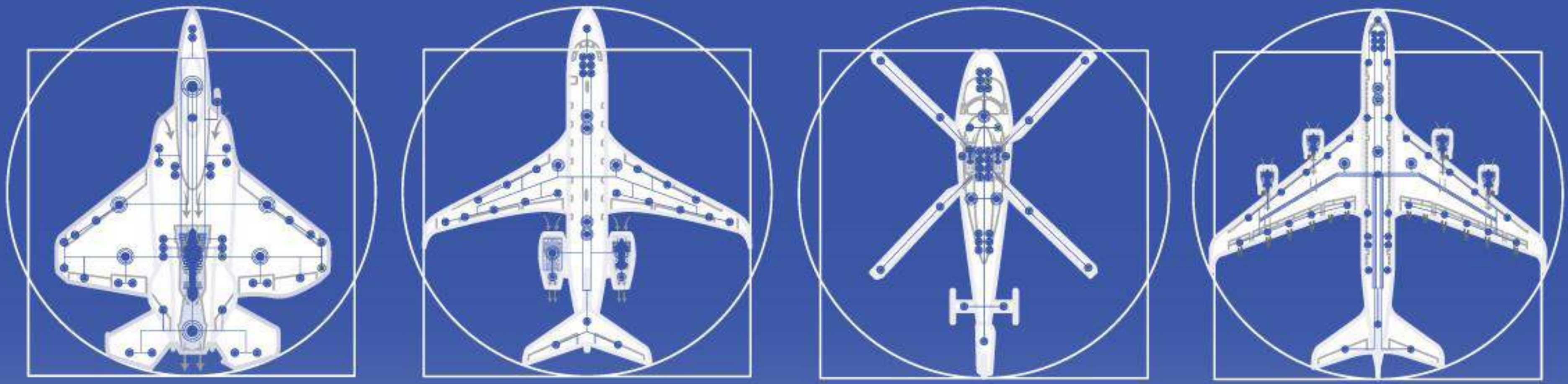
Wyle

Unmanned Aerial Systems Now and in the Future: GE Aviation Point of View

Hilary King

Product Area Director, Navigation & Guidance

GE Aviation



Unmanned aerial systems now and in the future

GE Aviation point of view

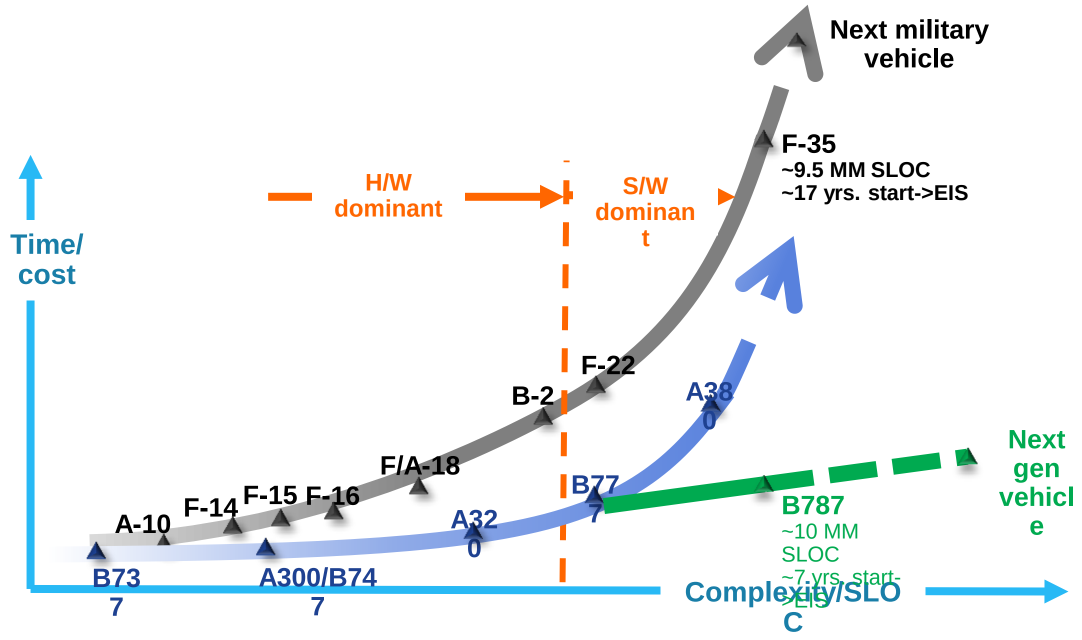
Hilary King – Director, Navigation & Guidance Systems

October 2013

imagination at work

Notional avionics cost/complexity

…breaking the unaffordable trend in modern systems



GE is investing in technology evolution to continue driving the trend

-
- Cost effective systems, software, hardware, integration
- Lower size, weight, power
- Improved reliability, availability

imagination at work

Improving efficiency, Reducing SWAP, Increasing affordability

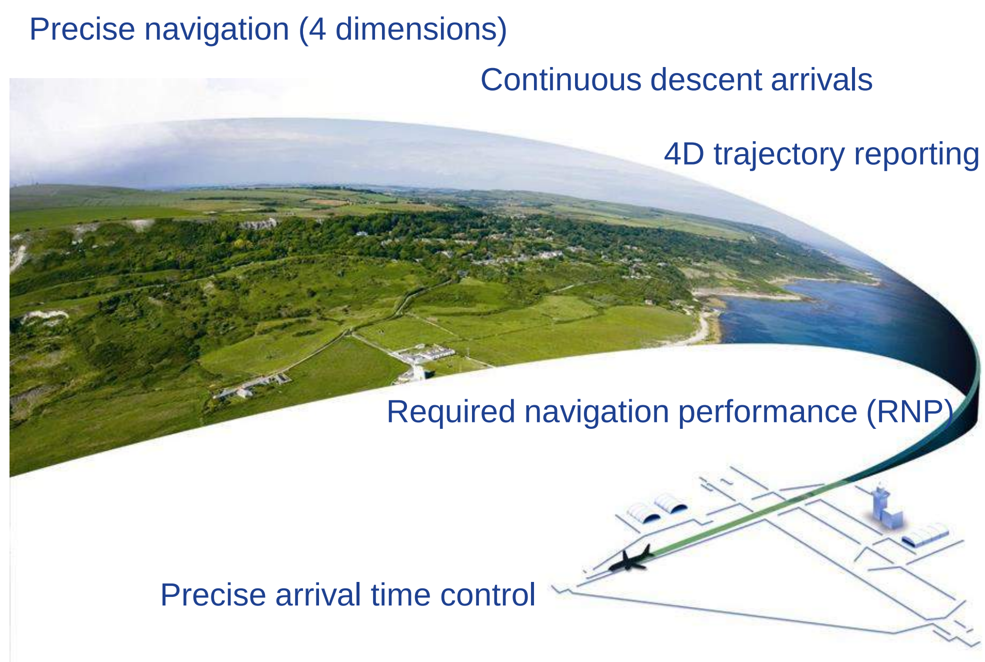
The Paradigm Shift…Trajectory Based Operations

Past

Procedural
- Estimate current, planned aircraft position

Radar
- Know current position
- Estimate planned position

4D TBO



FAA-certified flight management systems conduct trajectory ops today

Existing flight management technology

+ **Precise navigation (RNP 0.1)**
Time-based control

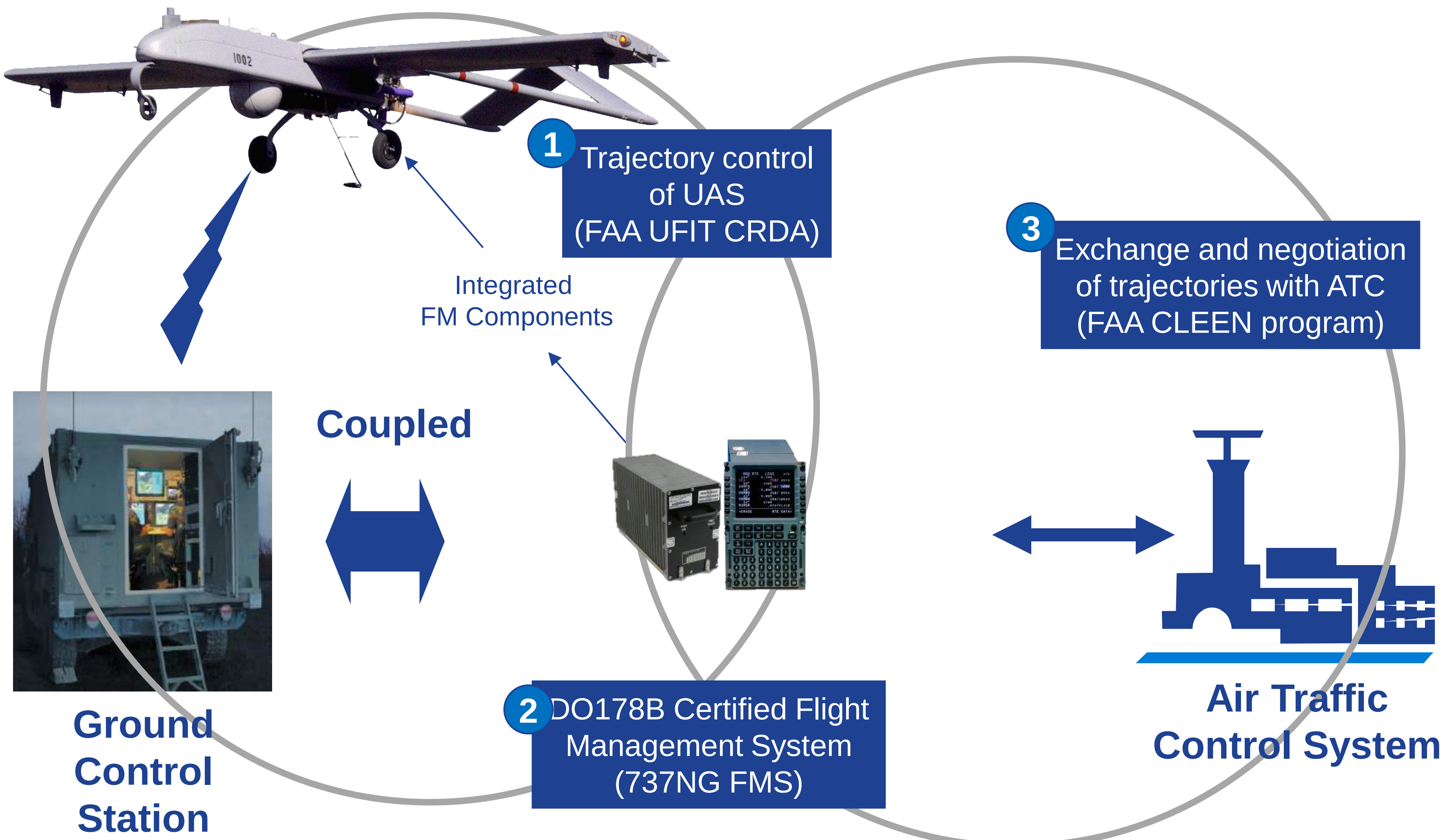
= **High degree of confidence in aircraft routing and timing**

Flight planning
Navigation database
Trajectory predictions
Optimized performance
Closed loop control
Performance advisories

Ability to scale, modularize for UAS applications

imagination at work

FAA-industry partnership demonstration



imagination at work

Extending beyond the NAS

…precision approach in remote operations

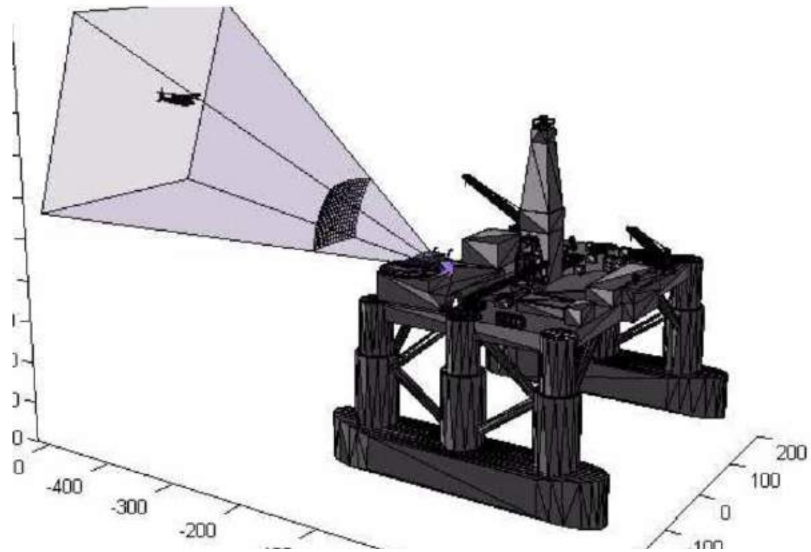
Electro optical grid reference system (EOGRS)

GPS-independent relative navigation system

RNP-compliant position to all aircraft via datalink

Motion compensated for platform movement

Operates in degraded visual environment



Other uses

- Ship station keeping
- UAV swarming
- Object positioning
- Surveying

Seamless Airspace Integration

Airspace is shifting to precision 4D trajectory-based operations

Commercial aircraft **already** trajectory-based

NextGen/SESAR further enable trajectory operations

Existing technology provides airspace access

Equip UAS to fly same as manned aircraft

Manned **certified** FMS systems can be adapted

New methods deal with contingencies (loss of link)

GE Aviation technology available for autonomous operations

Navigation R&D facilitating UAS airspace integration

Collaborating with FAA, industry partners

Seeking opportunities to advance research to application

imagination at work

imagination at work

Navigation and Control

Dr. Ella Atkins

Associate Professor – Department of Aerospace Engineering

University of Michigan

Research in…
UAS Navigation and Control

Ella M. Atkins
Director, Autonomous Aerospace System (A2SYS) Lab
Aerospace Engineering Department
University of Michigan
ematkins@umich.edu

A2Sys Research Program Goals

- Aerospace GNC (Guidance, Navigation, and Control) and Software Research to support Manned and Unmanned Aviation
  - Improved Safety, Mission Capabilities and Success
- Safety
  - Risk Assessment and Mitigation
  - Emergency Flight Management
- Mission Capabilities
  - Novel platforms: infinite-endurance, open-water, runway-independent
  - Novel sensing → Redefining the flight envelope, urban canyon ops
  - Unattended → AUTONOMOUS, not just automated, to IMPROVE safety and mission capabilities → Lost link not a factor

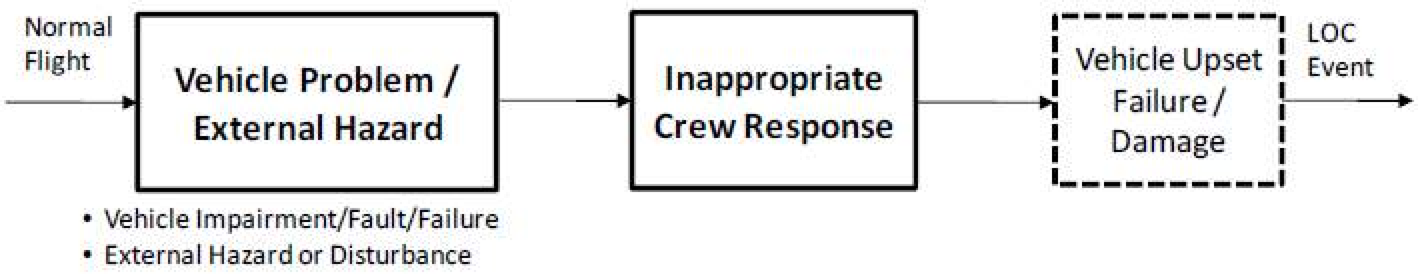
Ex: Flying Fish Unmanned Seaplane

Presentation Outline

- Overview of representative research projects
  - Flight Safety Assessment and Management to avoid Loss of Control (student: Swee Balachandran)
  - Quadrotor Risk Analysis and Mitigation (student: Isaac Olson, team: Michigan Autonomous Aerial Vehicles (MAAV))
  - Experimentally-Validated Aerodynamic Modeling for Post-Stall Flight (students: Derrick Yeo, Jerry Lin)
- Introduction to the Solar Sight Small UAS (on display!)

Loss of Control… A Challenge for Manned & Unmanned

* Loss of control (LOC) is the fundamental cause of aviation accidents.
* Loss of Control: Any uncommanded or inadvertent event with an abnormal aircraft attitude, rate of change of attitude, acceleration, airspeed, or flight trajectory.



* Despite the excellent safety records of the modern automation systems available on board, LOC events still occur!

* C. M. Belcastro and J. V. Foster, "Aircraft Loss-of-Control Accident Analysis," in *Proc. AIAA Guidance, Navigation, and Control Conference*, Toronto, Ontario, 2010.

LOC EVENTS

CONTINENTAL AIRLINES FL 1404

* Aircraft: BOEING 737-524
* Date: Dec 20, 2008
* Flight plan: Denver, CO to Houston, TX
* Phase: Takeoff
* Cause: Directional control loss
* LOC sequence:

Severe cross winds -> Inappropriate crew inputs -> LOC

AIR FRANCE FL 447

* Aircraft: AIRBUS A330-203
* Date: Jun 1, 2009
* Flight plan: Rio-de-Janeiro(Brazil) to Paris(France)
* Phase: Cruise
* Cause: Stall
* LOC sequence:

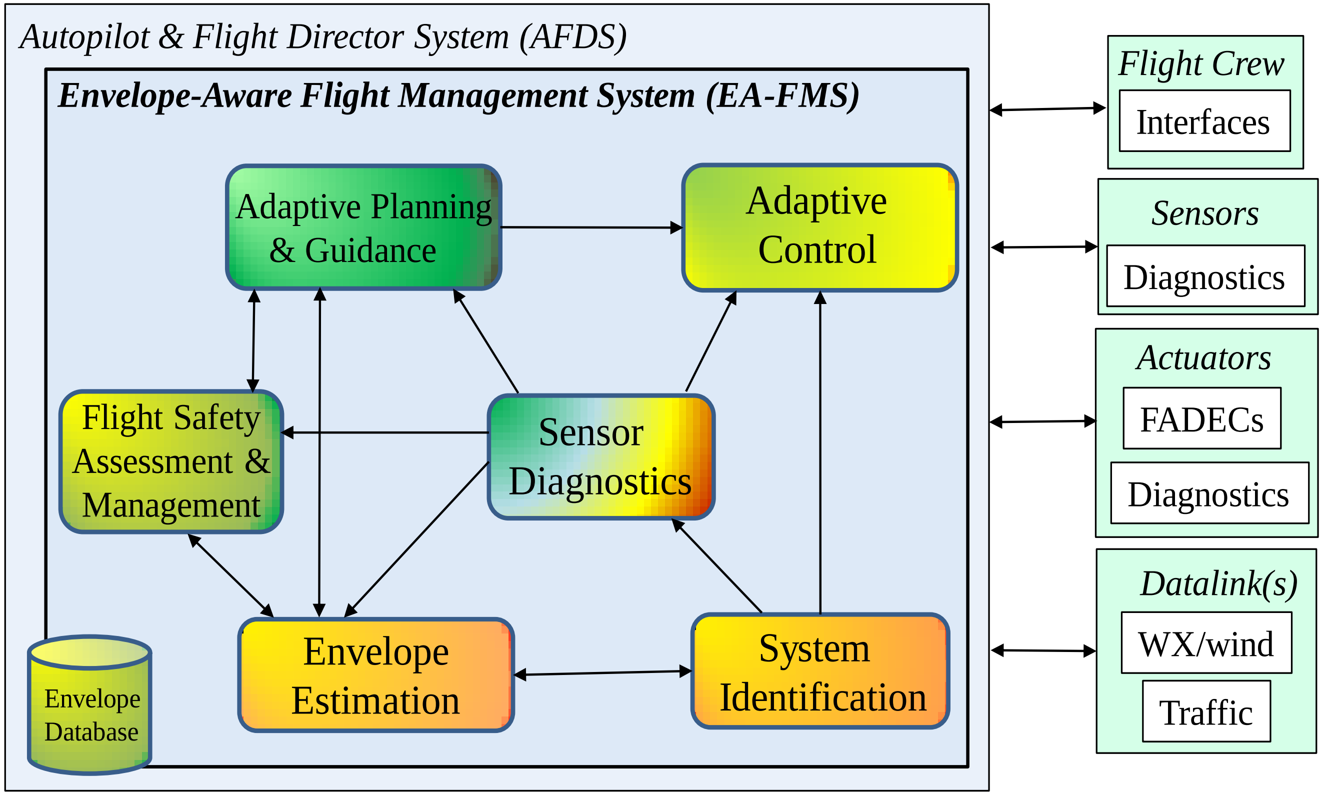
Pitot failure -> Inappropriate crew inputs -> LOC

*National Transportation Safety Board, "Runway side excursion during attempted takeoff in strong gusty crosswind conditions – Continental Airlines Flight 1404 , Boeing 737-500, N18611"

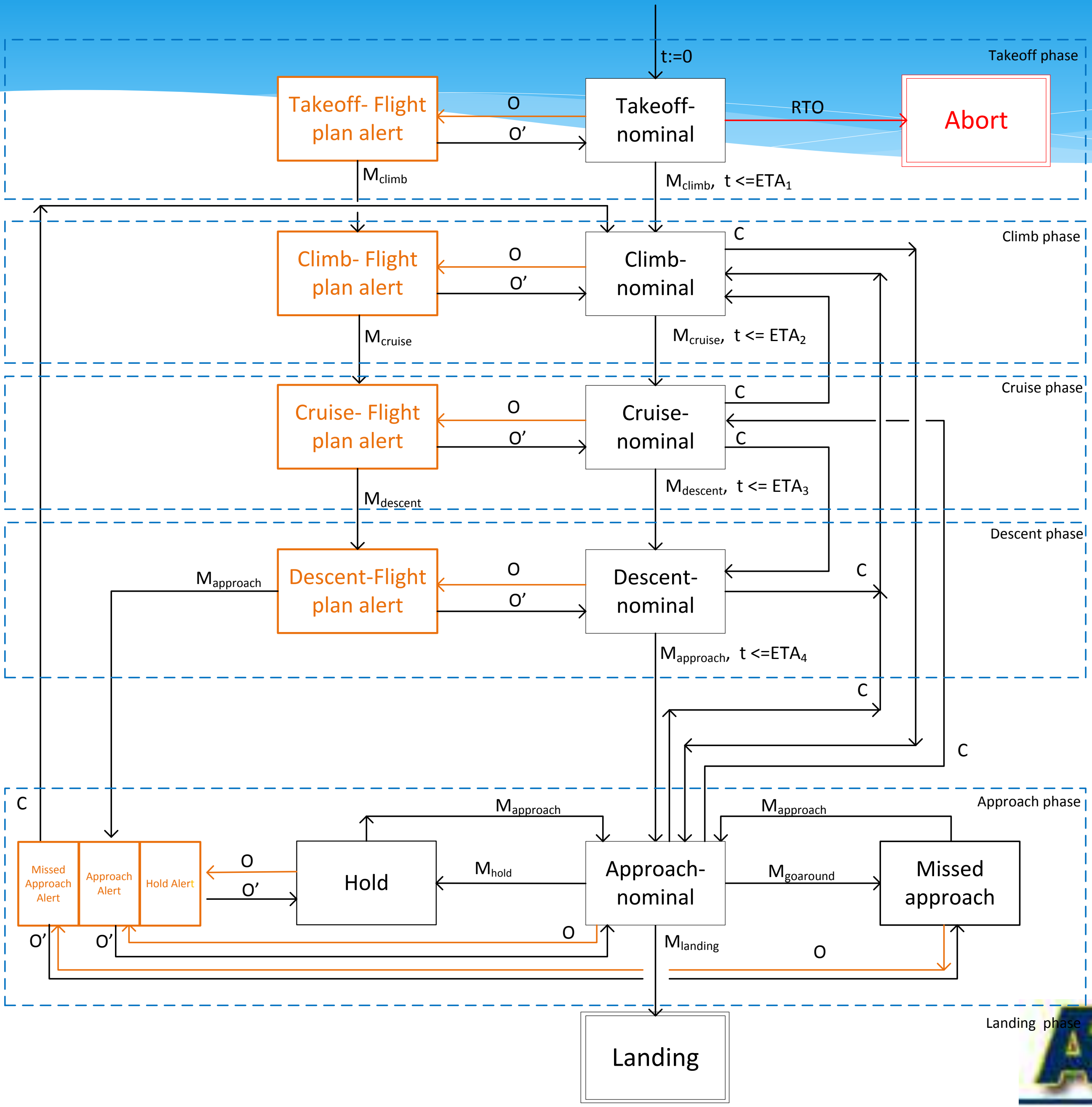
* Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA), Final Report on the accident on 1st June, 2009 to the Airbus A330-203 registered F-GZCP operated by Air France flight AF 447 Rio de Janeiro - Paris "

Envelope-Aware Flight Management System

* Extension of current FMS proposed to prevent LOC by improving capabilities in identifying/updating dynamics, envelope boundaries, and ultimately control authority switching.

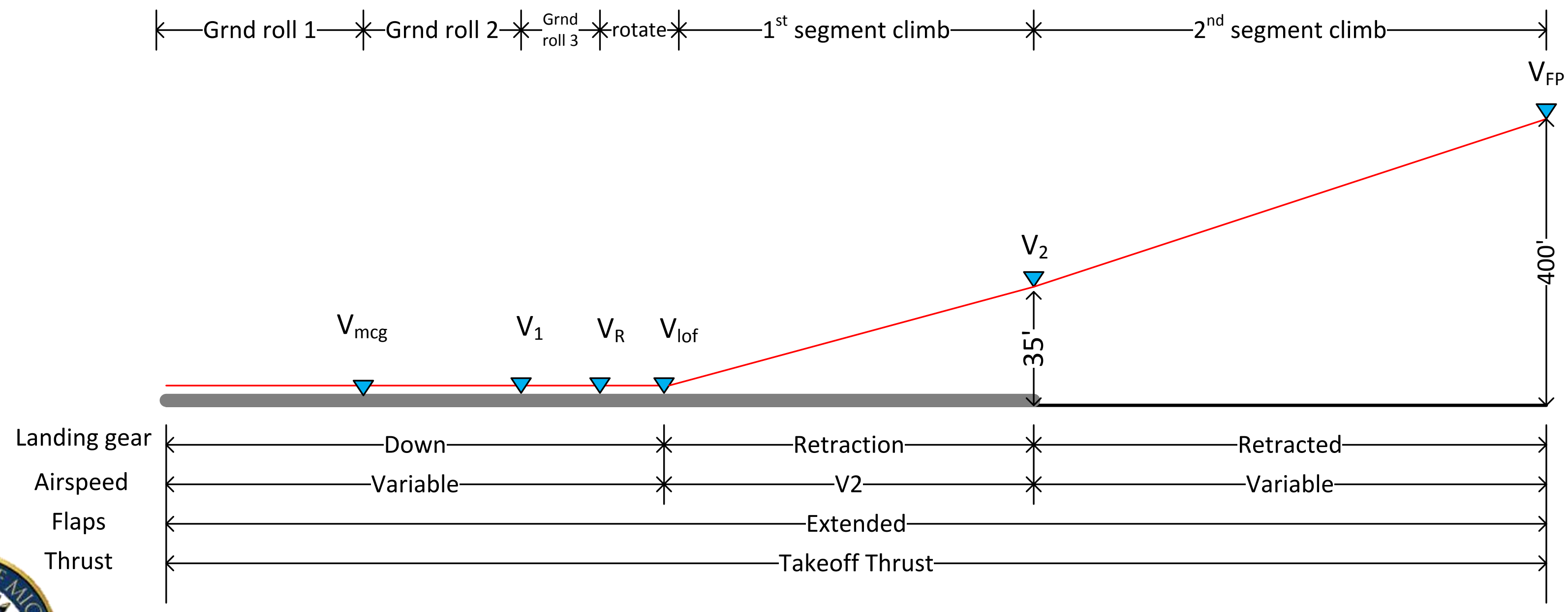


Hierarchical Timed Automaton Model



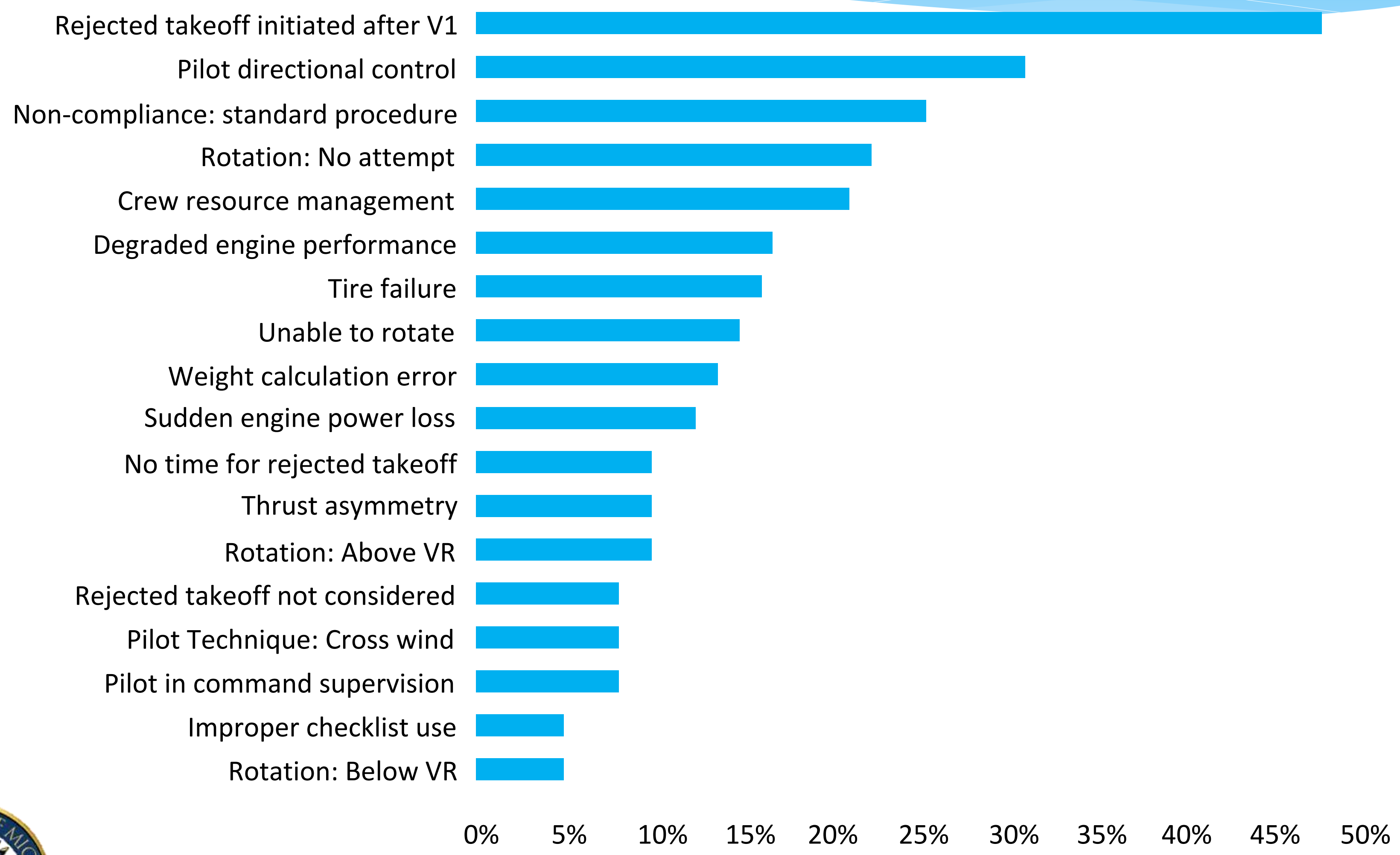
Takeoff Case Study

* Takeoff is one of the most safety-critical and difficult phases of flight, second to final approach and landing.
* Federal Aviation Regulations (FAR) defines several airspeed "checkpoints" (for fixed-wing operations) to guide a crew in the decision making process.



* Electronic Code of Federal Regulations, "Title 14: Aeronautics and Space," [online database] URL:

LOC contributing factors during takeoff



* Flight Safety Foundation, "Reducing the risk of runway excursions," May 2009

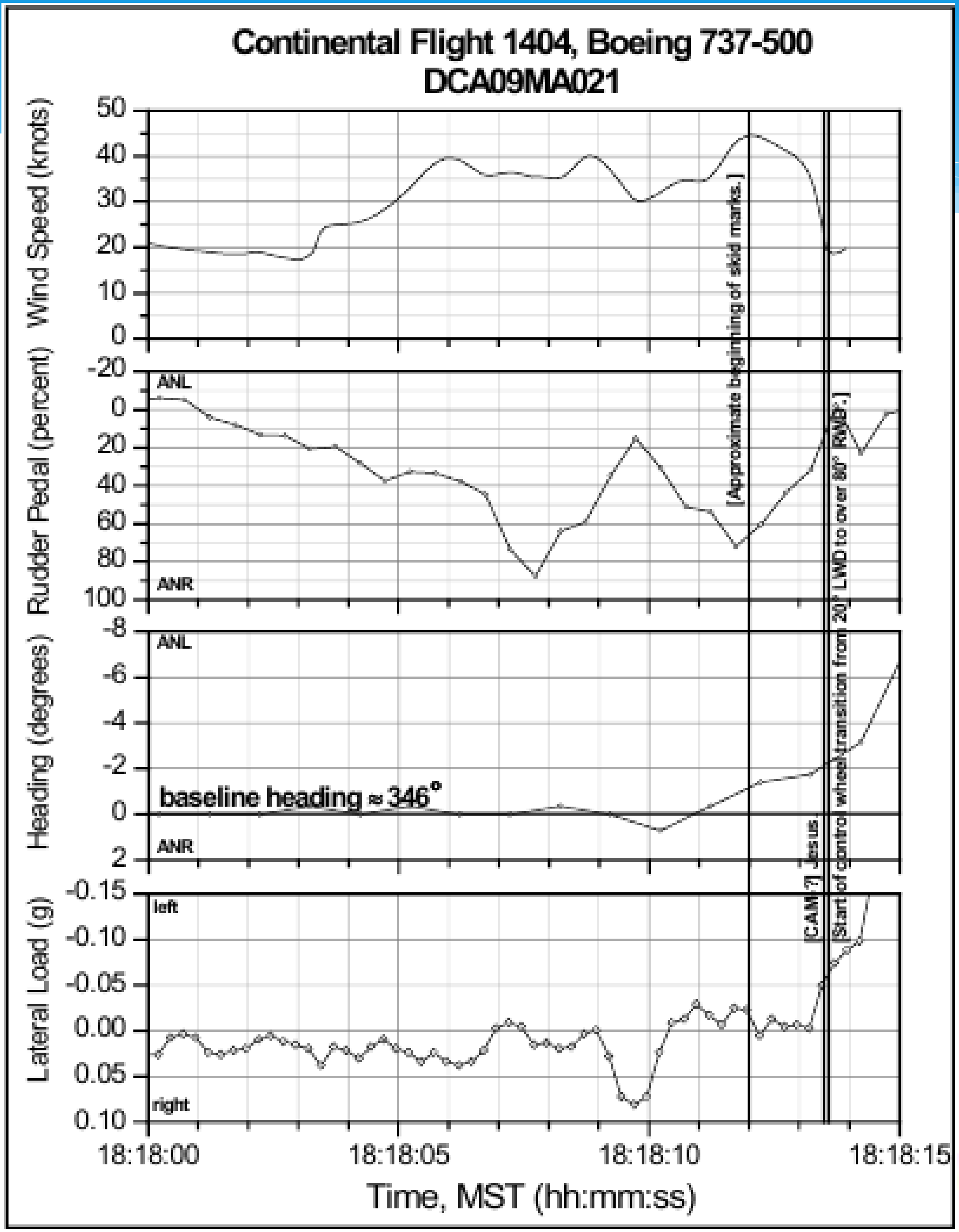
LOC metrics for takeoff

* V-speeds.
* Runway cross track position.
* Heading
* Roll attitude
* Lateral Acceleration
* Aircraft configuration for takeoff (C.G., flaps, slats, takeoff thrust, etc.)

CASE STUDY:
Continental Airways FL 1404

Figure 2. Aerial photograph (facing southeast) of the airplane wreckage. Ground scars are visible from the edge of runway 34R, across taxiway WC and the airport service road, and up to the wreckage. Fire station #4 is shown at the right edge of the photograph.

*National Transportation Safety Board, "Runway side excursion during attempted takeoff in strong gusty crosswind conditions – Continental Airlines Flight 1404 , Boeing 737-500, N18611"



*Source: NTSB FDR database

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  * Experimentally-Validated Aerodynamic Modeling for Post-Stall Flight (students: Derrick Yeo, Jerry Lin)
* Introduction to the Solar Sight Small UAS (on display!)

Quadrotor Risk Analysis & Mitigation

* Unmanned Aircraft Systems (UAS) are becoming increasingly popular as research platforms and are beginning to enter the commercial market
  * Proper regulations are necessary before UAS may be integrated into the National Airspace System (NAS)
  * UAS have higher average number of failures per flight hour than manned aircraft
* Small UAS (SUAS) are typically unable to meet the stringent regulatory requirements meant for larger craft
  * Mass, size, and cost limits prohibit triple redundancy
  * Impact of failures on surroundings are typically much less
* Failure mode analysis and risk identification are very important
  * Classify risks posed by these craft
  * Increase level of safety before flying in open environment

Project Goals

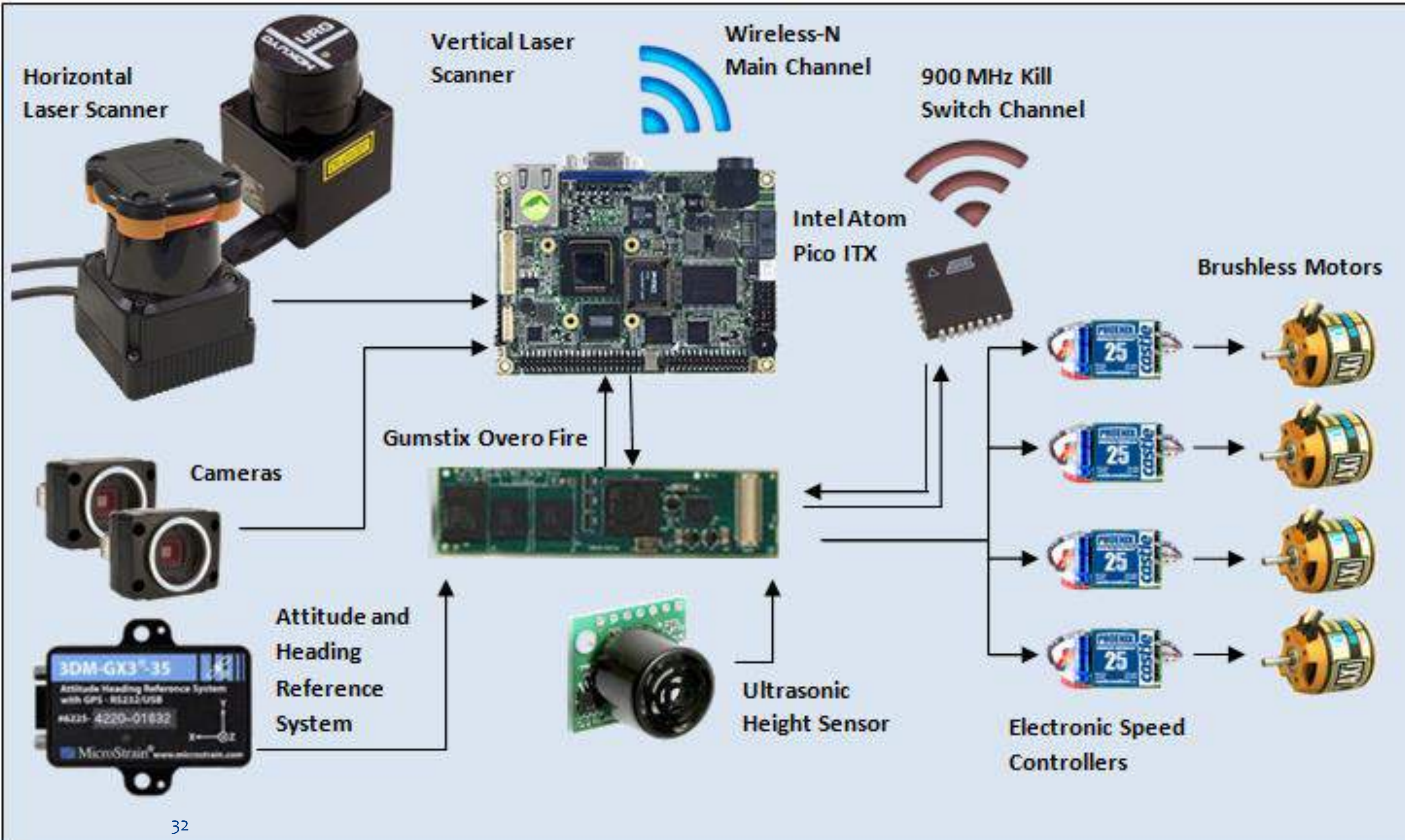
* Analyze failure modes of the Michigan Autonomous Aerial Vehicles (MAAV) team's quadrotor
* Construct causality networks from failure modes
* Determine risk mitigation methods to improve system performance and safety
* Identify risks to surroundings posed by failures

International Aerial Robotics Competition: Mission 6

- Mission Objectives
  - Enter and explore an unknown building
  - Follow signs to locate a designated room
  - Retrieve a flash-drive and deploy a decoy
  - Exit building
- Mission Requirements
  - Mass limit: 1.5 kg
  - Size limit: 1.0 m diameter
  - Time limit: 10 min
  - Complete autonomy
- *2013: MAAV won 1st place in the US competition, but didn't complete the mission; a team from China did complete the mission*

Retrieving Flash-Drive

MAAV Quadrotor: System Architecture



Failure Mode Frequencies

* Data collected over 1000+ indoor test flights during 2012
* System under rapid development over course of testing
  * Data cannot be used to accurately represent the probability of future failures
  * It does indicate what aspects of the system need the most improvement
* *Of all the quadrotors out there, this is the only such statistical data known to have been collected and processed*

Failure Mode	Crash	Unstable Control	Height data failure	Motor Seizing	Low Battery Voltage
Frequency (Failures/Flights)	0.7%	2.4%	6.9%	1.2%	4.5%

Identified Failure Scenarios

* Sensor Failures
  * Ultrasonic height sensor failure
  * *AHRS failure*
* Actuator Failures
  * *Motor or ESC failure*
* Software and Communications Failures
  * Navigation software failure
  * Ground station link failure (lost link)

Height Sensor Failure Modes

Failure Mode	Causes	Results	Mitigation Methods
Measurement noise	Vibration from airframe	Reduces controller accuracy and stability	Damping material, Kalman filters
Loss of return from ground	High roll or pitch, flying above sensor range	Possible loss of control	Height measurement from downward facing laser
Return from object other than ground	Improper filtering, obstacles in flight path	Induces sudden motion in z axis, possible loss of control	Height measurement from downward facing laser
Cease to function	Power surges from circuit board	Loss of control	Height measurement from downward facing laser, open loop control with Kalman filter until safe landing

Navigation Failure Modes

Failure Mode	Causes	Results	Mitigation Methods
Controlled Flight into Obstacle	Failed to detect obstacle, noisy control, recirculation currents	Loss of control	Maintain greater distance from obstacles, use a full 3D detection system, prop guards
Bad map association	Featureless rooms or hallways	Incorrect global map, incorrect position estimates	Integrate visual markers into navigation
Inefficient navigation	Poorly tuned exploration algorithms	Excess time spent, Jittery waypoint following	Test and tune navigation algorithms

Communication Failure Modes

Failure Mode	Causes	Results	Mitigation Methods
Loss of WiFi	Router problems, loss of signal due to interference	Navigation disabled, runaway vehicle	Disable with kill switch, return to base
Data latency and loss	Router problems, high network traffic	Data processing on ground is not real time, navigation delayed	Safe hover
Delay receiving commands	Router problems, high network traffic	Unresponsive to pilot input	Safe hover

Loss of Control: Risk to Surroundings

* Low altitude and enclosed environments mean loss of control almost always results in a crash.
* Kinetic impact poses minimal risk due to low mass and velocity.
* Primary hazard: propellers
  * Injury to any person that contacts them
  * Snap on hard impacts: minimal risk to other objects
* Secondary hazard: Lithium polymer battery pack
  * Can ignite under rare circumstances
  * Common in modern electronics, tested technology with minimal risk

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Experimentally-Validated Aerodynamic Modeling for Post-Stall Flight

High Angle of Attack Flight Benefits

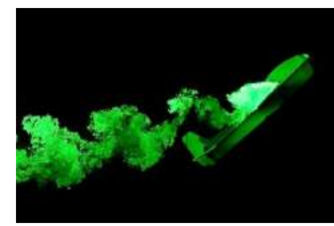
•Fixed wing operations below the low speed range of most envelopes.

•Precursor to perching capabilities.

Challenges

•Non-linear aerodynamics

•Flow fields are difficult to predict

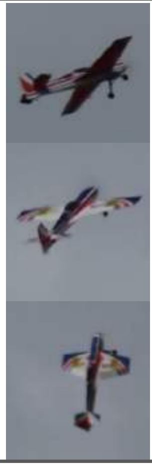


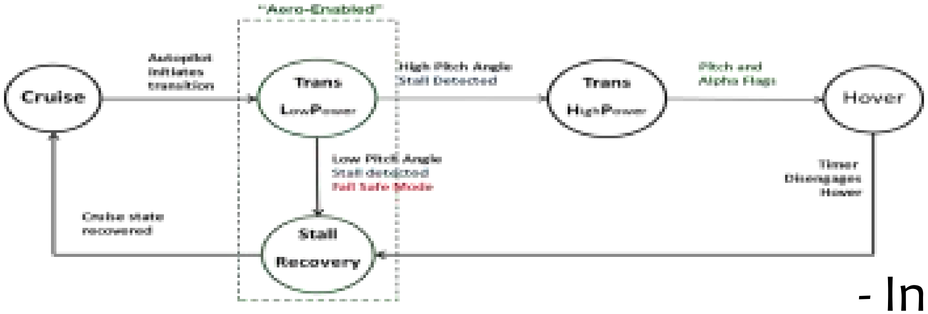
Onboard flow sensing capabilities can aid in modeling post-stall flight & in the development of advanced flight controllers applicable with slow to no free-stream flow

THE UNIVERSITY OF MICHIGAN 1817

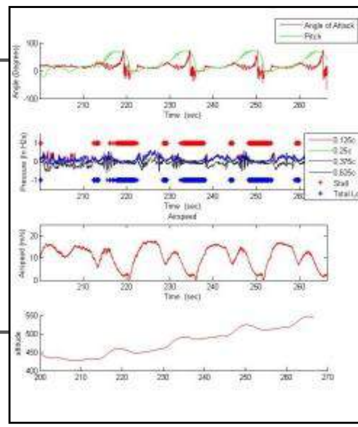
A2 SYS LAB

Direct Measurement of Aero Forces & Moments





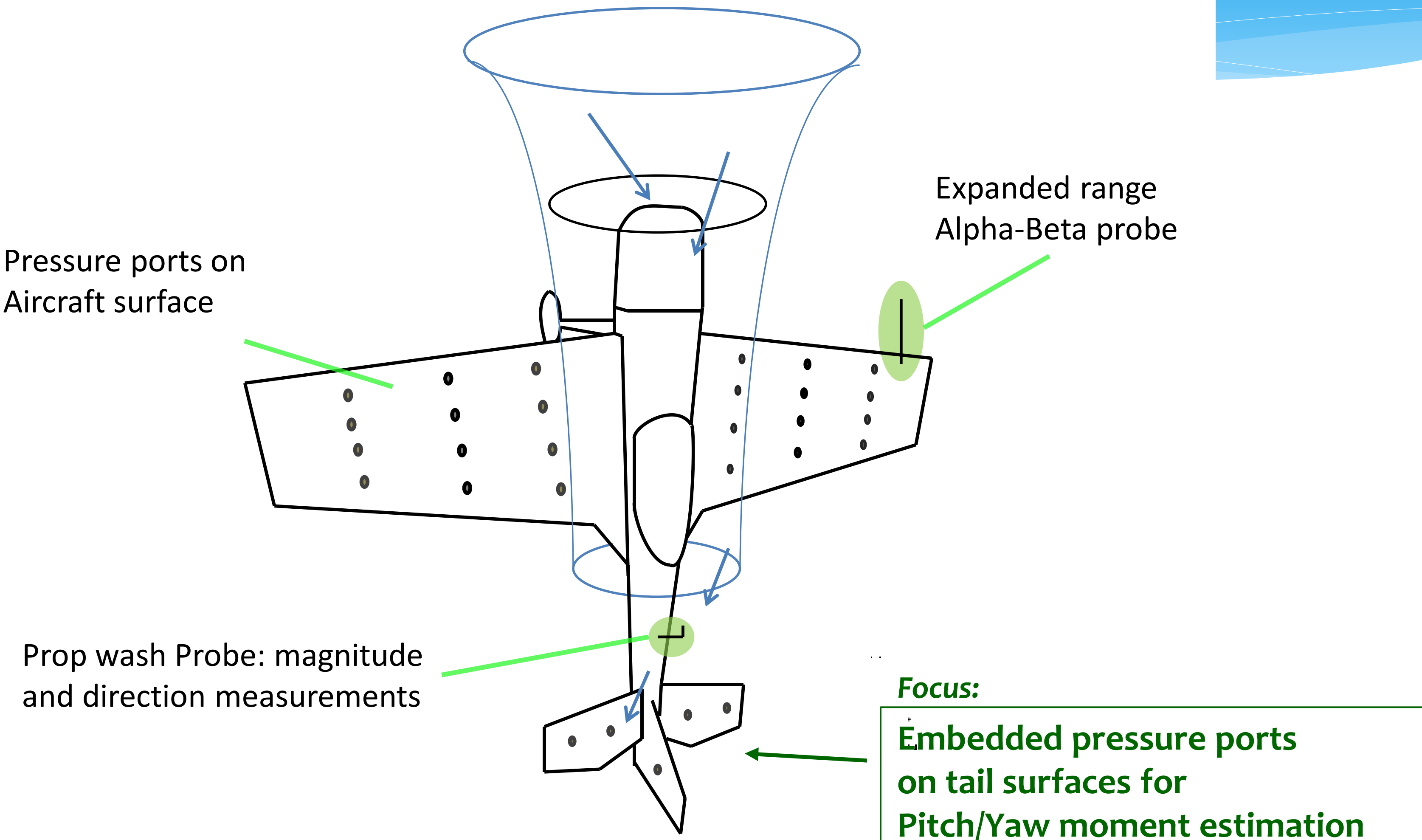
- Instrumentation design
-Wing 'Stall-detect' algorithm



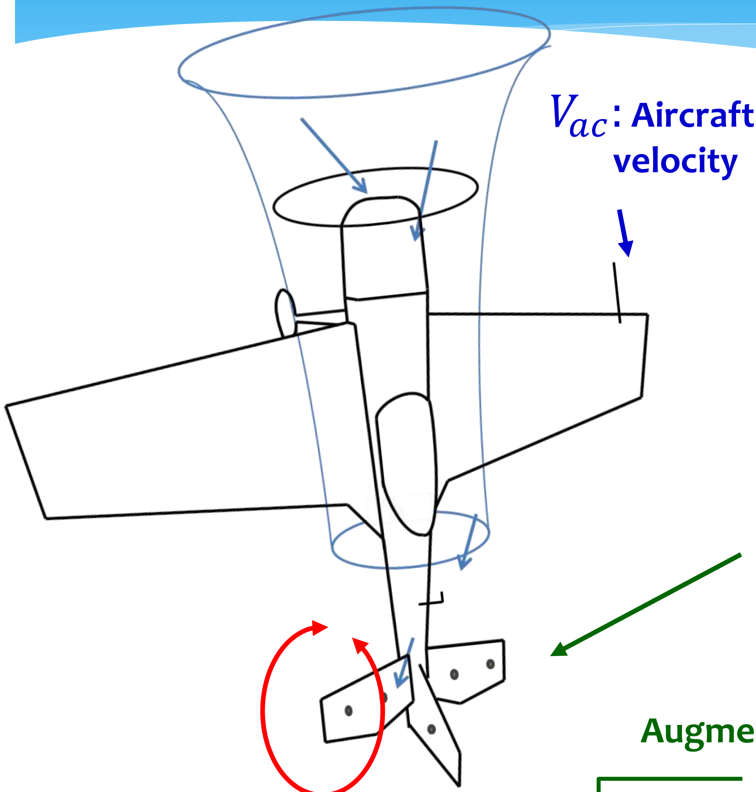
- Autopilot transitions between forward and hover flight

- Wind tunnel testing with slow/hover flight
- "Steady Flight" Pitch/Yaw Model Developed

Instrumentation Scheme



Augmented Pitch Moment Equations



Original Steady Flight Equation, Pitch

$$M = \frac{1}{2}\rho \boldsymbol{V_{ac}}^2 S c C_M$$

$$C_M = C_{M_0} + C_{M_\alpha}\alpha + \boldsymbol{C_{M_{\delta_e}}\delta_e}$$

Distributed Sensing

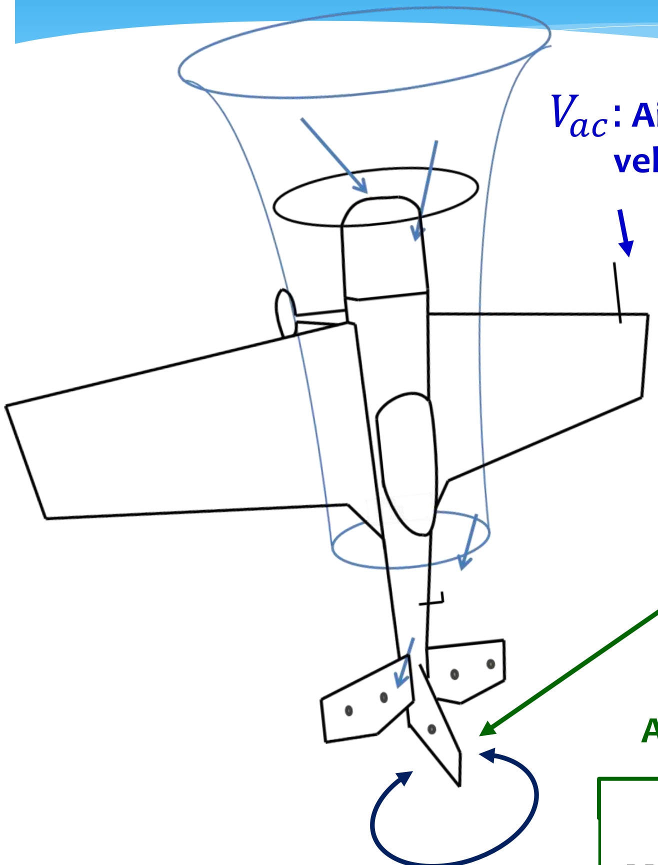
Augmented Pitch Moment

$$M = \frac{1}{2}\rho \boldsymbol{V_{ac}}^2 S b C_{M_{ac}} + \sum_{i=1}^{n_{htail}} \cos\theta_i \cdot \boldsymbol{P_{diff-i}} \cdot S_{htail_i} \cdot l$$

Distributed pressure measurements

$$C_{M_{ac}} = C_{M_{ac_0}} + C_{M_{ac_\alpha}}\alpha$$

Augmented Yaw Moment Equations



V_{ac}: **Aircraft velocity**

Original Steady Flight Equation, Yaw

$$N = \frac{1}{2}\rho \boldsymbol{V_{ac}}^2 SbC_N$$

$$C_N = C_{N_\beta}\beta + C_{N_{\delta_a}}\delta_a + \boldsymbol{C_{N_{\delta_r}}\delta_r}$$

Distributed Sensing

Augmented Yaw Moment

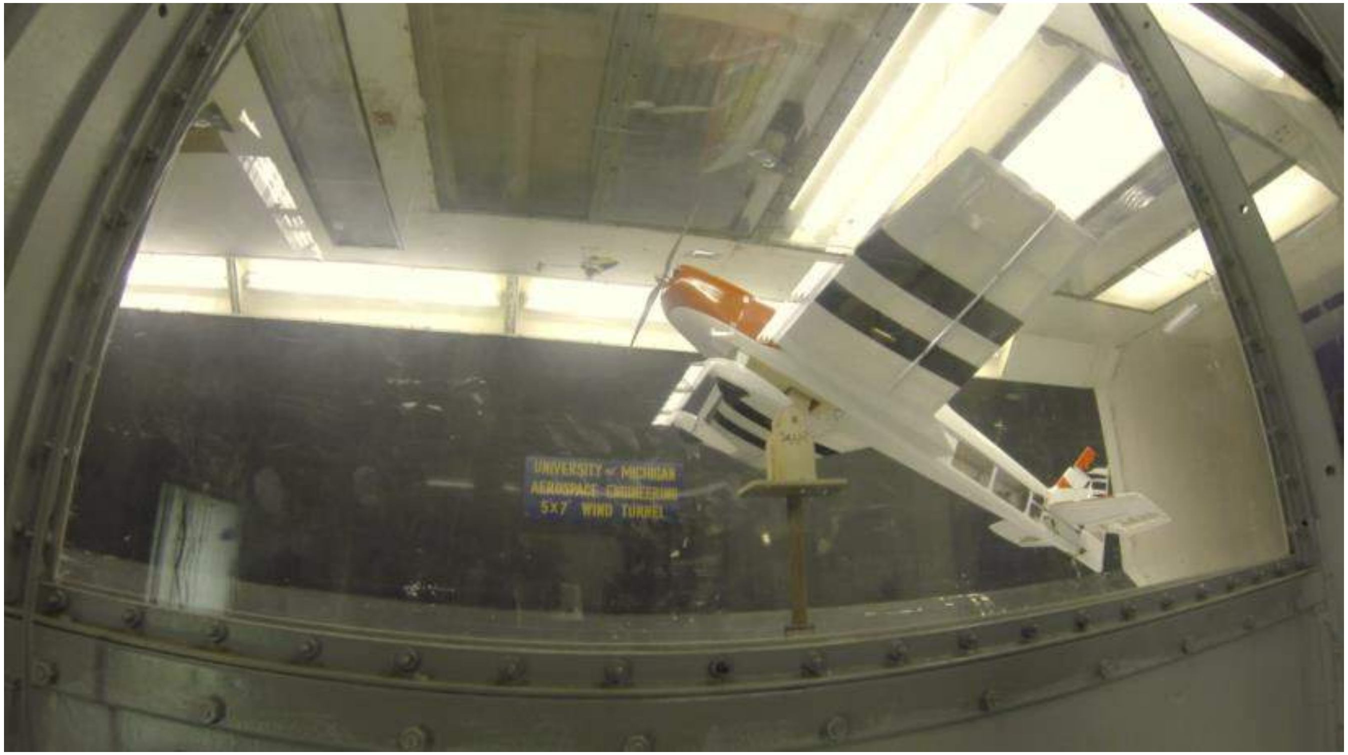
$$N = \frac{1}{2}\rho \boldsymbol{V_{ac}}^2 SbC_{N_{ac}} + \sum_{i=1}^{n_{vtail}} \cos\theta_i \cdot \boldsymbol{P_{diff-i}} \cdot S_{vtail_i} \cdot l_i$$

Distributed pressure measurements

$$C_{N_{ac}} = C_{N_{ac_0}} + C_{N_{ac_\beta}}\beta$$

Experimental Procedure

- **UMich Aero 5x7 Wind tunnel**
- **Moments measured using FT sensor and pressure instrumentation**
- **Simulated hover , and high-alpha conditions**

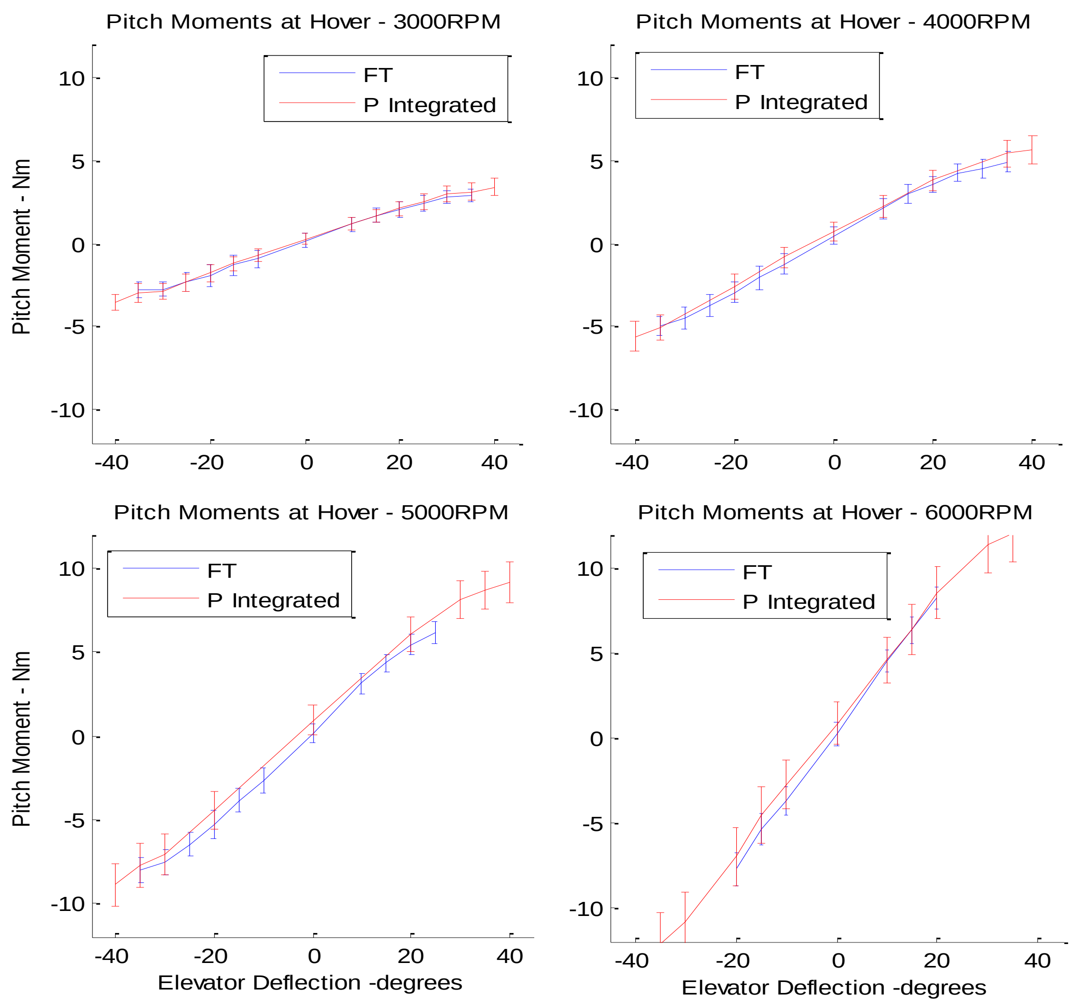


Test Results – Hover (Pitch Data Shown)

$$M = \frac{1}{2}\rho V_{ac}^{2} S b C_{M_{ac}} + A_M \sum_{i=1}^{n_{htail}} \cos\theta_i \cdot P_{diff-i} \cdot S_{htail_i} \cdot l_i$$

$V_{ac} = 0$

Calibrated pressure-based measurements show good agreement with FT pitch and yaw data at hover

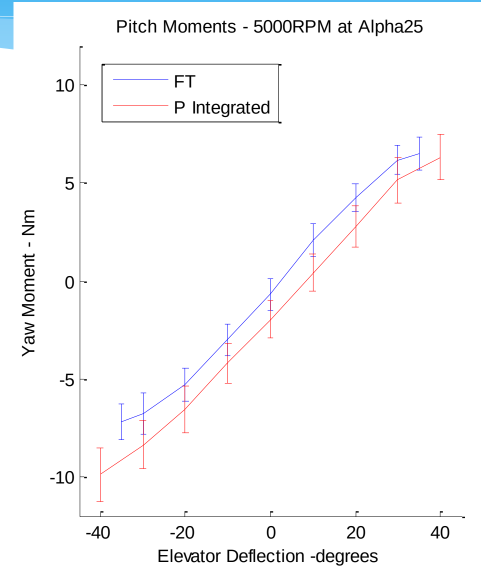


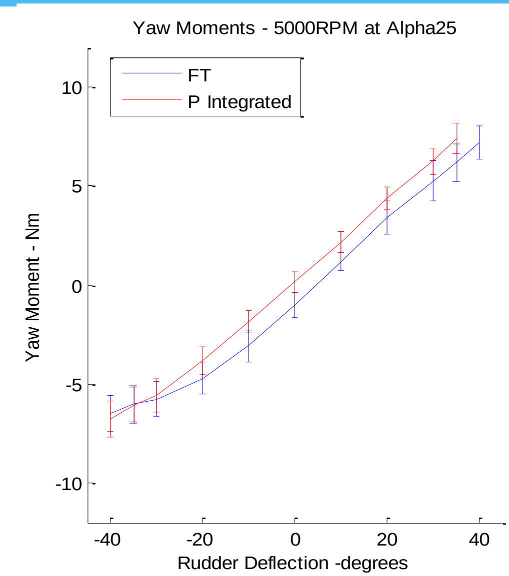
Distributed Sensing – General Test Cases

High-alpha off-hover

-Model mounted at +25° alpha
-2-3m/s free-stream

-Slopes show good agreement
-***Calibration factors are valid near hover***

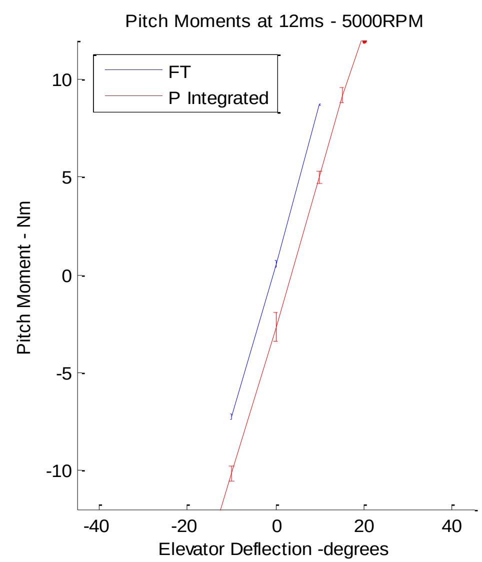


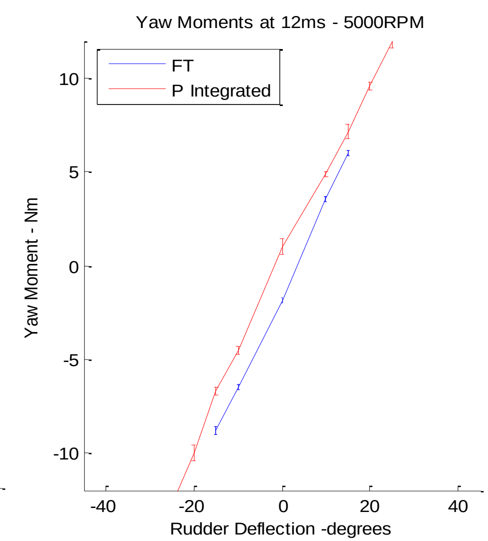


Powered cruise

- Aircraft level, 5000RPM
-12-13m/s free-stream

-Slopes show good agreement
-***Calibration factors are valid at cruise***





Solar Sight

* Developed through a collaboration between the University of Michigan and MIT Lincoln Laboratory
* Accomplished by the Solardrones student team with support from MITLL, A2SYS lab, and Peter Baumeler (R/C enthusiast)
* On display here (presented by Brian Boomgaard, Peter Baumeler)

Break

Command and Control Technologies

John Moore
System Principal Engineer
Rockwell Collins

Progress in Certifiable UAS Command & Control Links

John R. Moore
Principal Investigator, UAS CNPC System, Rockwell Collins
Co-Chair, RTCA SC-228 UAS C2 Working Group

Michigan UAS Conference, 29 October 2013

Agenda

- Background
- NASA UAS in NAS Project, Overview
- Rockwell Collins / NASA UAS Control & Non-Payload Communication (CNPC) System Cooperative Agreement
- RTCA Special Committee 228, C2 Working Group

Background

Motivation for UAS C2 Standards

- Many current and potential Unmanned Aircraft System (UAS) users are seeking routine access to the U.S. National Airspace System (NAS)
  - Military – Training, system development and deployment, and current military restricted airspace is not sufficient.
  - Public Use – Homeland security, law enforcement, science & research, emergency management, land management, others.
  - Commercial Use – Photography, package delivery, agriculture, others.
- At World Radiocommunications Conference (WRC) 2012 a new AM(R)S spectrum allocation (agenda item 1.3) was approved for terrestrial UAS Control & Non-Payload Communication (CNPC) in two frequency bands
  - L- band: 960-1164 MHz
  - C-Band: 5030-5091 MHz
- No civil certification basis exists for UAS, and there are critical technology gaps that must be bridged, most notably
  - Detect and Avoid (DAA) – Replacing the function of human vision onboard the aircraft
  - Command and control (C2) – Providing robust, reliable connection from pilot to aircraft

NASA UAS in the NAS Project

Overview of NASA UAS Integration in the NAS Project

There is an increasing need to fly UAS in the NAS to perform missions of vital importance to National Security and Defense, Emergency Management, Science. There is also an emerging need to enable commercial applications such as cargo transport (e.g. FedEx)

Capitalizing on NASA's unique capabilities, the project will utilize integrated system level tests in a relevant environment to eliminate or reduce critical technical barriers of integrating UAS into the NAS

The project will develop a body of evidence (validated data, algorithms, analysis, and recommendations) to support key decision makers establish policies, procedures, standards, and regulations to enable routine UAS access to the NAS.

The project will also provide a methodology for developing airworthiness requirements for UAS, and data to support development of certification standards and regulatory guidance for civil UAS

The project will support the development of a national UAS access roadmap

Overview of NASA UAS Integration in the NAS Project

Develop validated data, algorithms, analysis, and recommendations to support key decision makers, establish policies, procedures, standards, and regulations to enable routine UAS access to the NAS

Sub-Projects:

Separation Assurance/Sense and Avoid Interoperability (ARC, LaRC)
- Assess NextGen separation assurance systems for UAS in mixed operations, and in flight tests with realistic latencies and trajectory uncertainty

Human Systems Integration (ARC)
- Develop a research test-bed and database for GCS operations in the NAS
- Coordinate with standards organizations to develop human factors guidelines

Certification (LaRC)
- Define a UAS classification scheme and approach to determining airworthiness requirements (.1309) applicable to all UAS avionics
- Provide hazard and risk-related data

Communications (GRC)
- Develop data and rationale to obtain CNPC frequency spectrum allocations
- Develop and validate candidate UAS secure safety critical CNPC concepts that enable completion/validation of CNPC requirements and standards

Integrated Tests and Evaluation (ARC, DFRC)
- Integrate and test mature concepts from the technical disciplines (separation assurance, communications, and human systems integration) to demonstrate and test viability

7

Communications Sub-Project

The Communications subproject will seek to address barriers regarding lack of frequency spectrum and data links for civil UAS control communication.

Objectives

The Communications subproject technical challenge will be met through 4 primary objectives:

1. Develop data and rationale to obtain appropriate frequency spectrum allocations to enable the safe and efficient operation of UAS in the NAS
2. Develop and validate candidate UAS control and non-payload communication (CNPC) system prototype which complies with proposed international/national regulations, standards, and practices
3. Perform analysis and propose CNPC security recommendations for civil UAS operations
4. Perform analysis to support recommendations for integration of CNPC and ATC communications to ensure safe and efficient operation of UAS in the NAS

Rockwell Collins / NASA UAS CNPC Cooperative Agreement

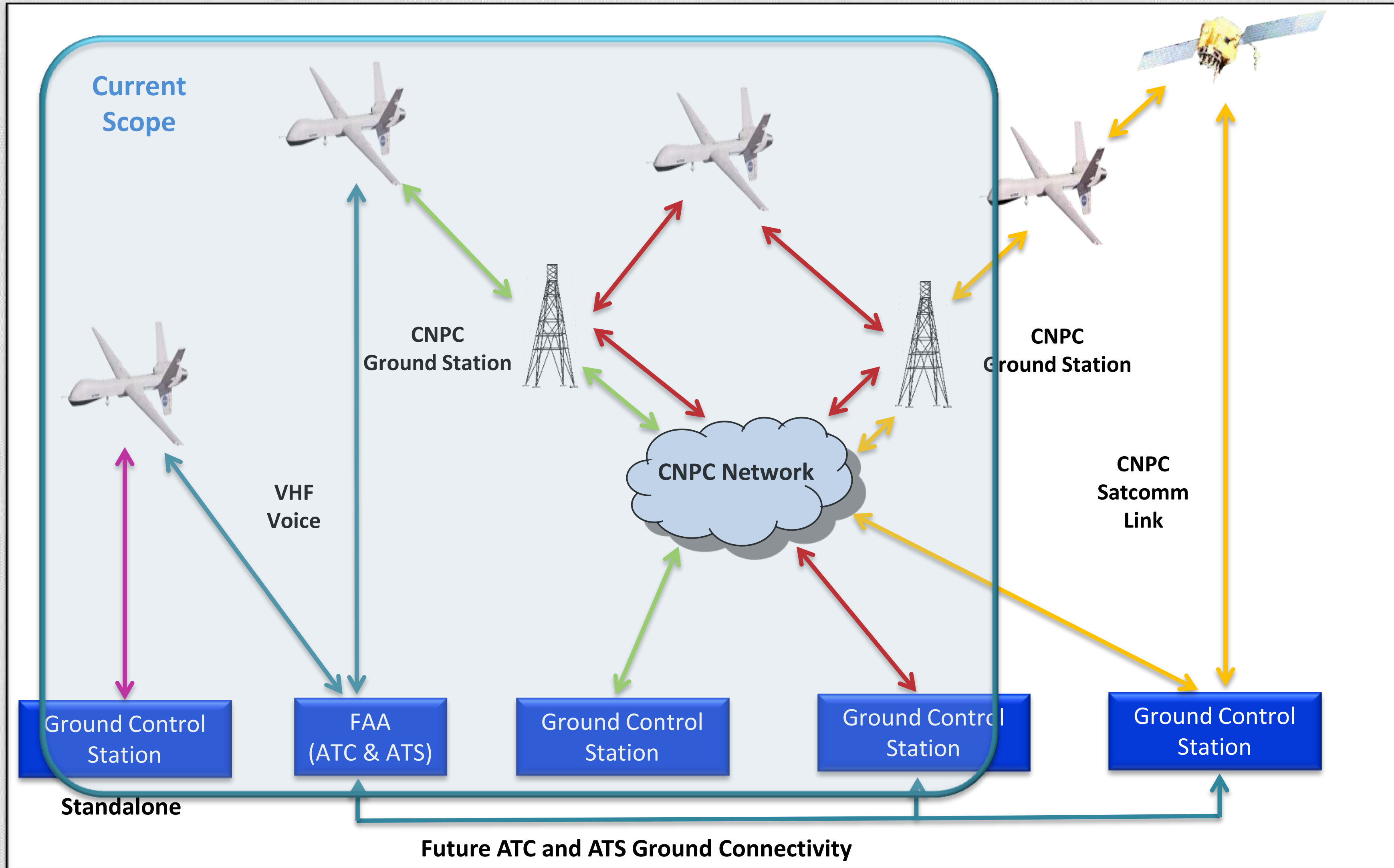
Prototype CNPC Radio Cooperative Agreement

- On Nov 1, 2011, NASA initiated a three-year shared resource cooperative agreement with Rockwell Collins to demonstrate and support the further development of a UAS CNPC System.
  - Develop a prototype CNPC system to provide a basis for validating and verifying proposed system performance requirements.
- Specific tasks include:
  - Identify signal waveforms and access techniques appropriate to meet CNPC requirements within the potential UAS CNPC frequency bands.
  - Develop prototype radios capable of enabling CNPC waveform testing and validation.
  - Perform relevant testing and validation activities.
- The radios must operate in proposed UAS radio frequency spectrum
  - 960 MHz – 977 MHz (L band)
  - 5030 MHz – 5091 MHz (C band)
- Multiple ground stations and multiple aircraft must be supported.

Cooperative Agreement - Status

- Major Deliverables to date:
  - CNPC Waveform Trade Study, March 2012
  - CNPC System Requirements Review, May 2012
  - CNPC Preliminary Design Review, August 2012
  - CNPC Critical Design Review, October 2012
  - CNPC Gen 1 Radio Delivery (L-Band), February 2013
  - CNPC Design Revision #1, June 19, 2013
  - CNPC Gen 2 Radio Delivery (L&C-Band), September 2013
- Upcoming Deliverables:
  - CNPC Design Revision #2, March 2014
  - CNPC Final Radio Delivery (L&C-Band), July 2014

UAS Communication Architecture – Use Cases



Key High Level Attributes Needed in C2 Solution

- **Availability, Integrity, and Continuity of Function**
  - The CNPC is a safety of life system which will enable UAS to share congested airspace with manned aviation, and above populated areas.
  - System availability, integrity and continuity of function capabilities need to be sufficient for this intended application.

- **Capacity / Scalability**
  - Current frequency management approaches, with many using dedicated point-to-point communication architectures, is not scalable to the capacities anticipated for fully fielded UAS.
  - The spectrum allocations are limited, and the actual demand for UAS may exceed anticipated loading levels.
  - Strategies more easily supporting potential expanded demand in the future are required so that the network is not obsolete by the time it is fielded.

- **Reduced Complexity**
  - Increased complexity of either airborne or ground components will lead to both higher acquisition cost (more components, more lines of code, more combinations and variations, etc.) and higher life cycle costs (such as potentially higher component count, and higher retesting / recertification costs for software changes).

Specific Challenges for Airborne Equipment

- **Size, Weight, and Power (SWAP)**
  - There will be numerous UAS that weigh as little as 55 pounds that will require CNPC.
  - SWAP is a critical consideration for application to this class of aircraft. Airborne radio transmitter power and required linearity are considerations of primary importance.

- **Cost**
  - CNPC airborne systems will have significant cost pressures for the smaller sized vehicles, reflective of their generally lower costs.
  - This implies reductions in both hardware complexity and size of software implementation.
  - Qualification of the software will be performed using DO-178 processes, which can become quite expensive.
  - Reducing the total number of lines of code and isolating higher criticality functions can help reduce the cost.

- **Certification Risk**
  - The CNPC will be a safety of life system that will require high levels of availability, integrity and continuity of function.
  - In general, it is desirable to implement solutions that are relatively straightforward to build and test, even if they are not the most absolutely efficient.
  - Determinism, repeatability and predictability are important characteristics that help mitigate certification risk and the associated costs.

Waveform Trade Study

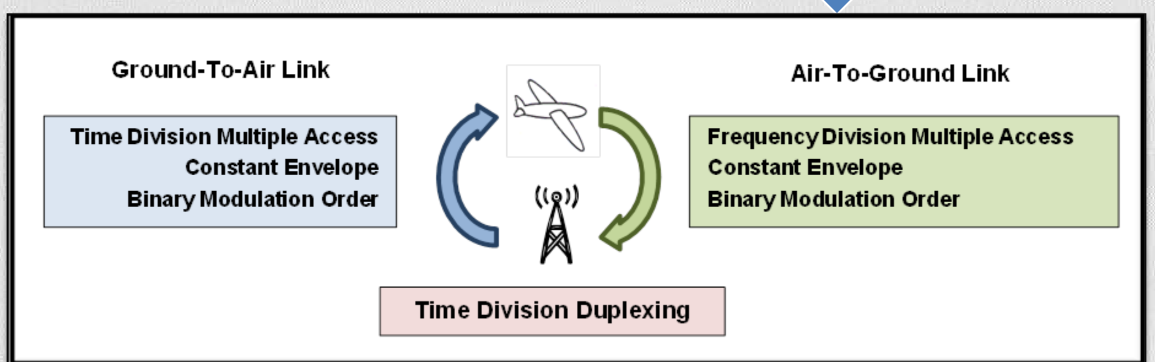
Seed Requirements (RTCA SC-203)

Requirement (PARTIAL LIST)	Source
Aircraft density assumptions Small UAs = 0.000802212 UA/ km^2 Medium UAs = 0.000194327 UA/ km^2 Large UAs = 0.00004375 UA/ km^2	ITU-R M.2171 P.54
Cell Service Volume Radius = 75 miles (L-Band)	RTCA SC-203 CC016
Maximum number of UAs supported per cell = 20 (basic services) Maximum number of UAs supported per cell = 4 (weather radar) Maximum number of UAs supported per cell = 4 (video)	RTCA SC-203 CC016
Uplink Information Rates (Ground-to-Air) Small UAs = 2424 bps Medium and Large UAs = 6,925 bps	ITU-R M.2171 Table 13
Downlink Information Rates (Air-to-Ground) Small UAs (basic services only) = 4,008 bps Medium and Large UAs (basic services only) = 13,573 bps Medium and Large UAs (basic and weather radar) = 34,133 bps Medium and Large UAs (basic, weather radar and video) = 234,134 bps	ITU-R M.2171 Table 13
Airborne radio transmit power = 10 W	RTCA SC-203 CC016

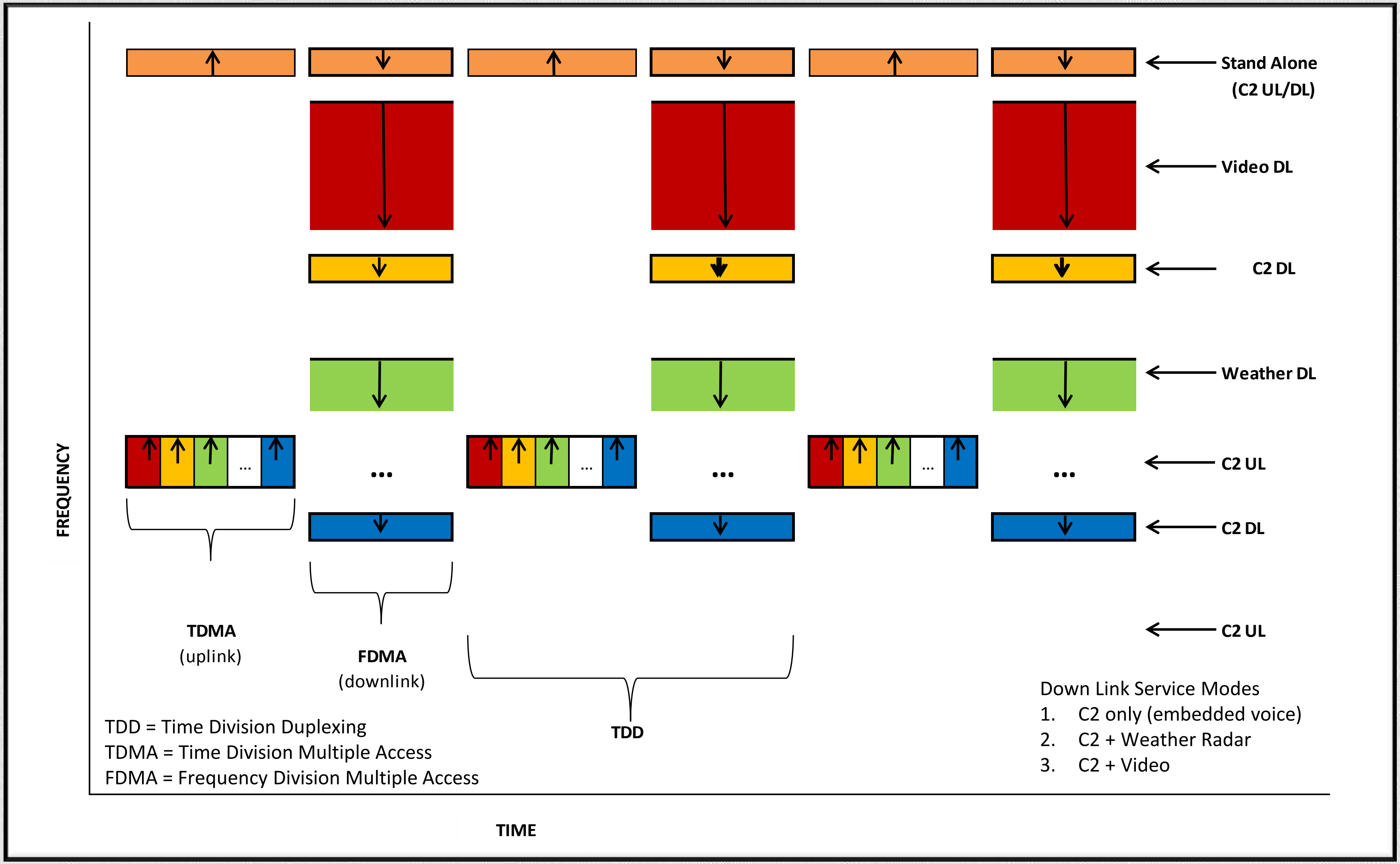
Technology Candidates, Criteria, & Scoring

Evaluation Criteria	System Level Factors Addressed	Downlink Multiple Access Candidates		
		CDMA	FDMA	TDMA
Link Margin at Full Capacity	Availability	Unacceptable	Reference	-13 dB for identical PA
Airborne Transmitter Power	SWAP, Cost, Complexity	10 Watts peak	10 Watts peak	200 Watts peak
Multipath Mitigation	Availability, Cost, Complexity	Link margin, spreading, RAKE processing	Link margin	Link margin, adaptive equalization
Synchronization Required	Cost, Complexity	None beyond that required for TDD	None beyond that required for TDD	Tight synchronization for low guard time overhead
Power Control Required	Cost, Complexity	Tight control mitigates near-far problem, 10-20% added complexity	Gross control mitigates near-far problem	Gross control beneficial but not required
Ground Signal Processing Complexity	SWAP, Cost, Complexity	10-20% added complexity	10-20% added complexity	Reference

Results

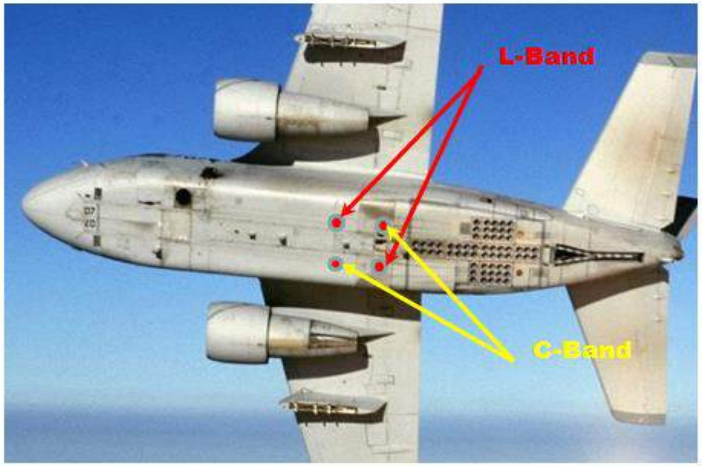


Multiple Access Design – In Frequency and Time



First Prototype Testing – Van Tests (Feb 2013)

Aircraft & Ground Station



First CNPC Radio Prototype Delivered and Flight-tested

Gen 1 CNPC Prototype Radio Flight Tests

Ten flight tests were conducted from May 10 to June 24, 2013, collecting >25 hours of flight data on the performance of the Gen 1 and pre-Gen 2 CNPC Dual-Band Prototype Radios.

- Altitudes ranged from the surface up to 9,000 feet, speeds up to 250 knots.
- Radios were operated in various data flow configurations and frequencies, successfully demonstrating 100% bi-directional L-band communications between aircraft and ground.
- Flight profiles included range testing and "real-world" airport approaches and landings.
- The Gen-1 radios performed at or above design requirements - reception range of 140 nautical miles at 9,000-ft, exceeding the 69 nautical mile range preliminary requirements.
- Additionally, two flight tests of preliminary Gen-2 radios were conducted on June 18, 2013 to demonstrate C-band radio operation, well ahead of the planned schedule.

Test flight tracks for 23 May 2013 testing at Plum Brook Station (Sandusky OH)

CNPC Prototype Radio Installed on the GRC S3-B

Test flight tracks for 18 June 2013 testing at Cedar Rapids, IA

RTCA Special Committee 228 – Minimum Performance Standards for Unmanned Aircraft Systems

RTCA

THE GOLD STANDARD FOR AVIATION SINCE 1935

Initial Terms of Reference (20 May 2013)

- The FAA UAS Integration Office and major UAS Stakeholders are working closely with the UAS community to develop the ***Minimum Operational Performance Standards (MOPS) for Detect and Avoid (DAA) equipment***, with emphasis in an initial phase of standards development on civil UAS equipped to ***operate into Class A airspace under IFR flight rules***.
  - The Operational Environment for the MOPS is the transitioning of a UAS to and from Class A or special use airspace, ***traversing Class D and E, and perhaps Class G airspace***.
  - A second phase of MOPS development is envisaged to specify DAA equipment to support extended UAS operations in Class D, E, and perhaps G, airspace.

- The UAS Integration Office is working closely to with the UAS community to develop the ***MOPS for the Command and Control (C2) Data Link***.
  - An initial phase of standards development will provide standards for the C2 Data Link using ***L-Band Terrestrial and C-Band Terrestrial data links***.
  - A second phase of MOPS development is envisaged to provide standards for the use of SATCOM in multiple bands as a C2 Data Link to support UAS.

SC-228 Leadership

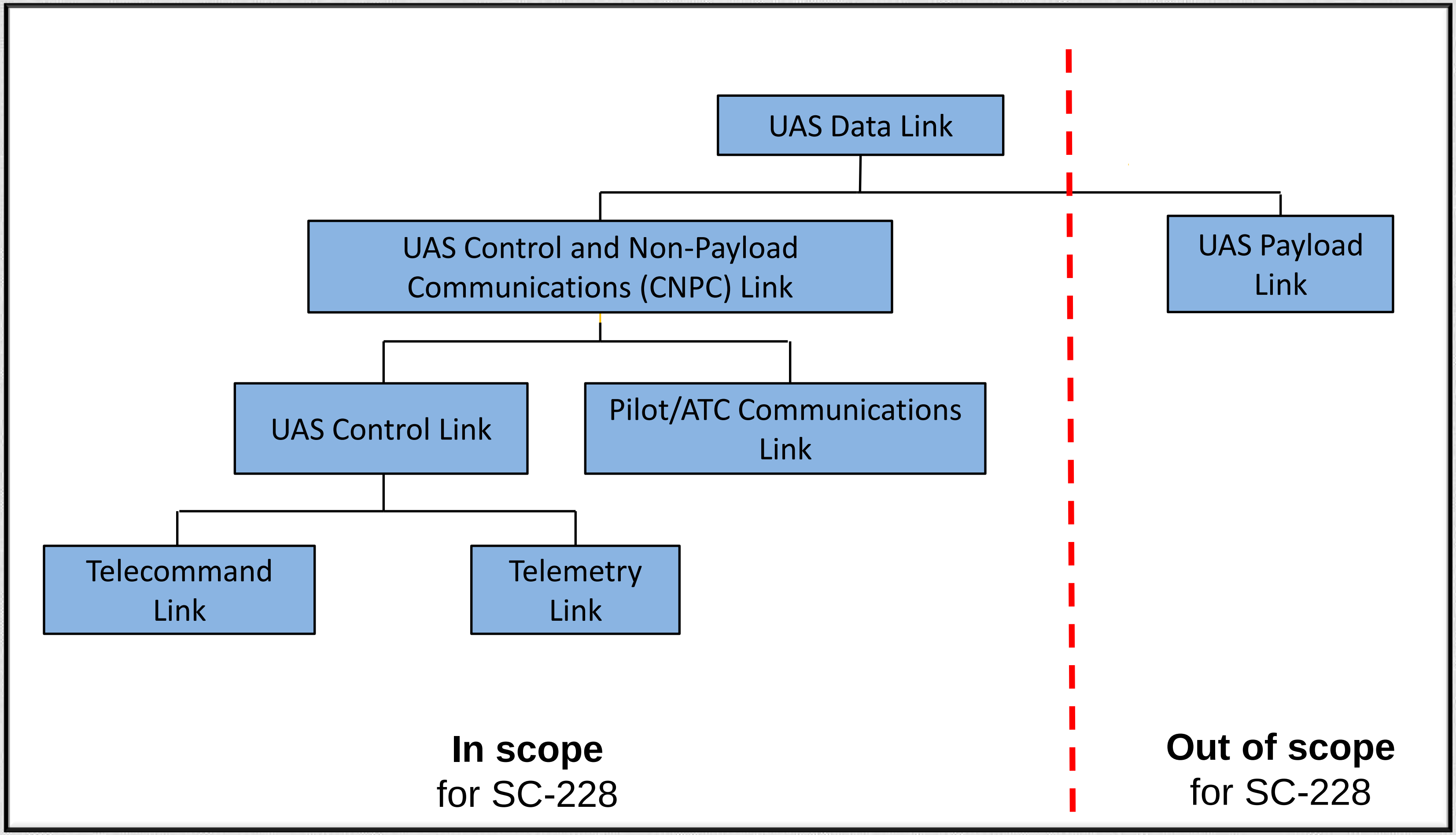
- Plenary
  - Co-Chairs
    - George Ligler, Consultant to Project Management Enterprises, Inc. (PMEI)
    - Paul McDuffee, Insitu Inc.
  - Designated Federal Official
    - Steve Van Trees, FAA, Aircraft Certification
  - Secretary
    - Gary Furr, Engility Corporation
- Working Groups
  - Detect and Avoid (DAA) Co-Leads
    - Paul Schaeffer, Air Force Life Cycle Management Center
    - Don Walker, FAA, Aircraft Certification
  - Command and Control (C2) Co-Leads
    - John R. Moore, Rockwell Collins
    - Steve Van Trees, FAA, Aircraft Certification

Working Groups – Method & Timeline

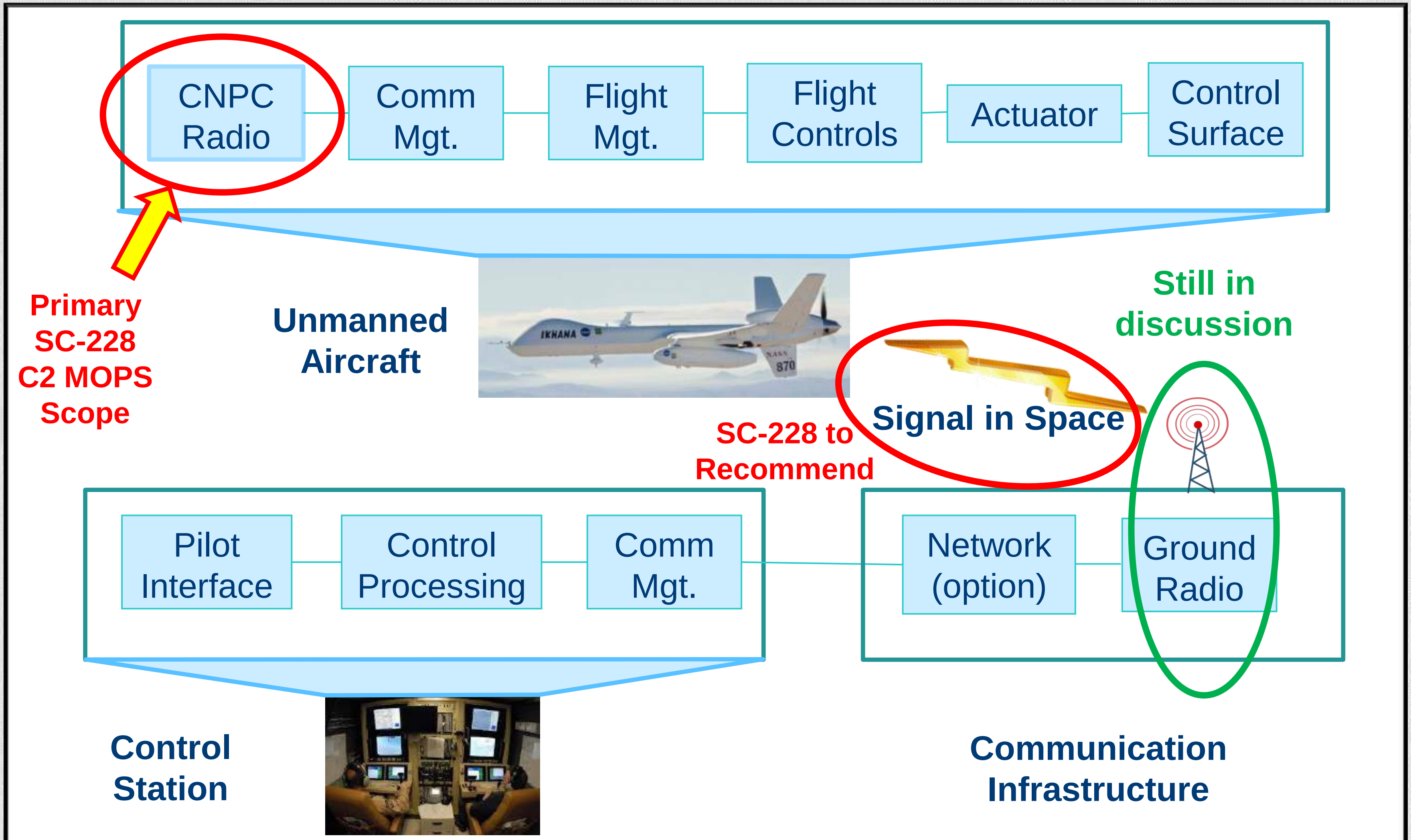
- White Papers
  - Defines assumptions, envisioned approach, initial requirements, and method for developing additional requirements
- Initial MOPS for Verification and Validation (V&V)
  - Develop preliminary MOPS and V&V Testing Program
- Final MOPS
  - Deliverable based on results of V&V activities

Phases / Steps	Phase One		Phase Two	
	DAA	C2	DAA	C2
White Papers	Dec 2013	Dec 2013	TBD	TBD
MOPS for Verification & Validation	July 2015	July 2015	TBD	TBD
Final MOPS	July 2016	July 2016	TBD	TBD

C2 Data Link Taxonomy

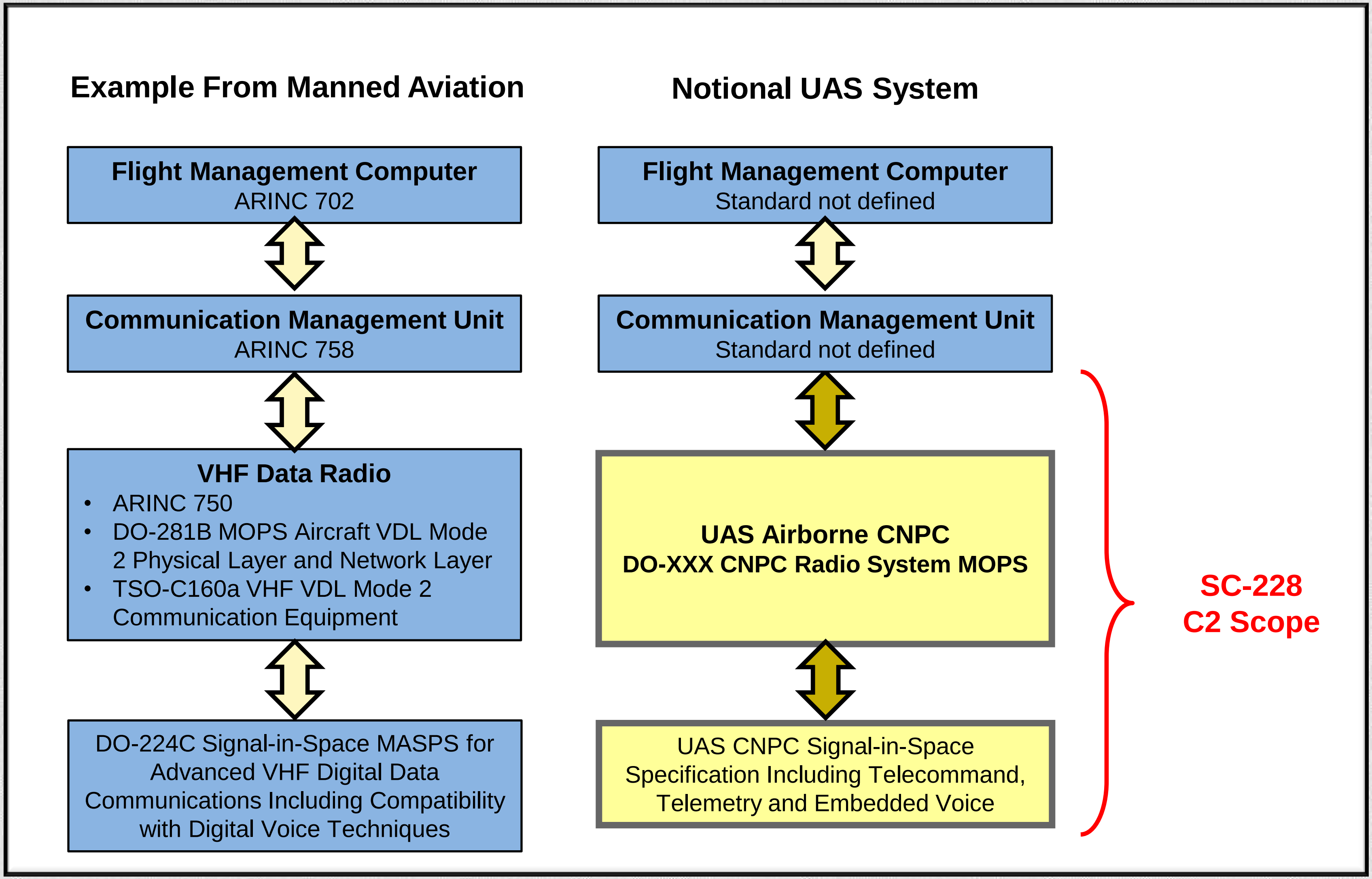


What is Addressed in the C2 MOPS?

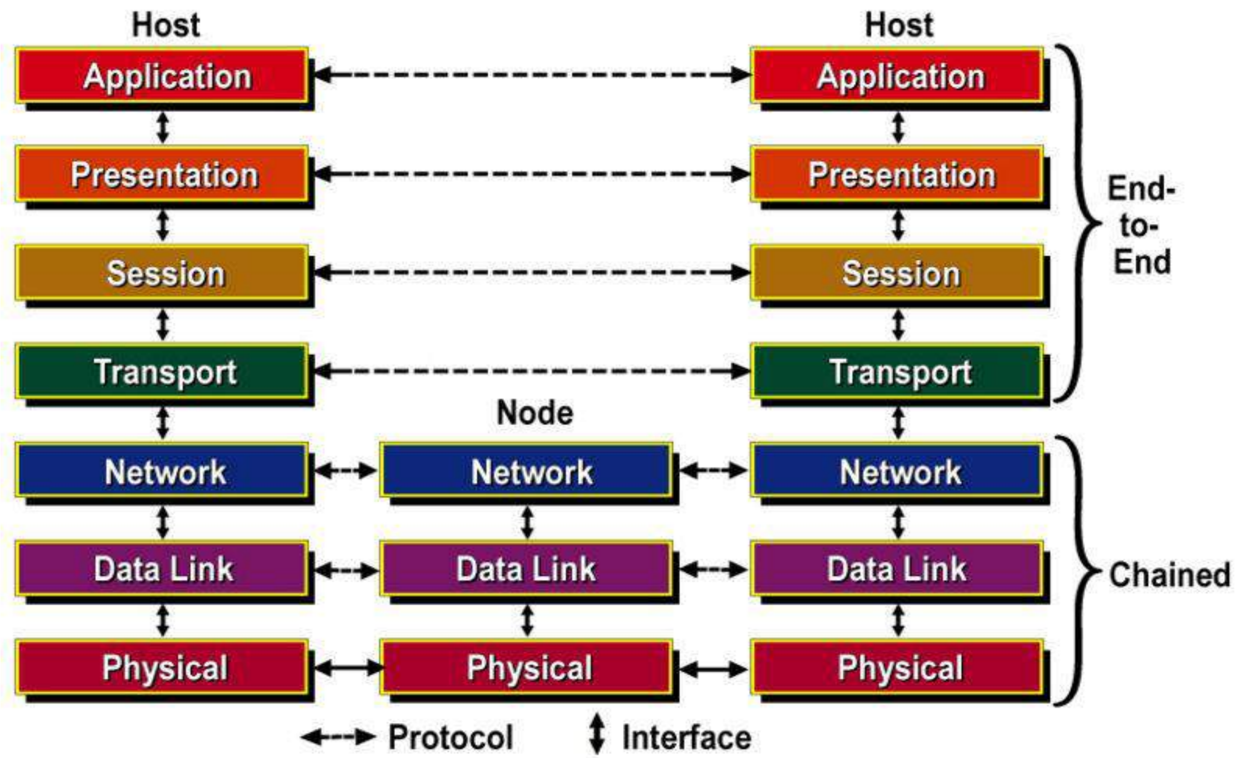


The Control Chain – Pilot to Control Surface

C2 Working Group Products



Communication Protocol Stack Architecture



Provided by each applicant, unique to each application.

SC-228 MOPS provides one means of compliance. Applicants may bring forward alternatives.

Control Station

Network Infrastructure

Unmanned Aircraft

Some Challenges in C2 Standards Development

- Spectrum Considerations
  - A national plan is needed for frequency reuse to ensure responsive assignments that is flexible and scalable to UAS densities that are envisaged.
  - UAS C2 waveforms must be compatible with existing aeronautical systems.

- Small UAS
  - Spectrum allocation request at WRC 2012 assumed all UAS operated under the proposed Small UAS rule would not use CNPC aviation protected spectrum.
  - There is growing interest in small UAS community now to use that spectrum.
  - The shear number of small UAS will impact the system design if significant numbers are to be accommodated by CNPC.

- Air-to-air
  - Current UAS C2 spectrum and standards work has assumed two basic architectures: 1) terrestrial based, and 2) satellite based.
  - Some military systems today use airborne control stations or air-to-air relay for control of UAS for tactical missions, particularly at low altitudes.
  - It remains to be validated if there is a commercial case for this type of operation, which would impact system designs that could be considered.

Concluding Thoughts

- A broad set of UAS users from military to state aircraft to commercial applications are all seeking routine access and interoperability in the US National Airspace System (NAS).
- A robust C2 data link suitable for safety of life operation in aviation protected spectrum is one of the key technologies that is needed to enable this expanded access to the NAS.
- Development of standards for civil certified UAS C2 data links is well underway, with broad participation of UAS OEMs, avionics manufacturers, UAS operators and other key stakeholders.
- Prototype equipment is currently in early development and in testing in relevant test environments to provide validation of system design concepts to mature and accelerate completion of these civil certification standards.
- The task is large and all interested parties are encouraged to participate to bring this capability to the field in a timely manner.

Questions???

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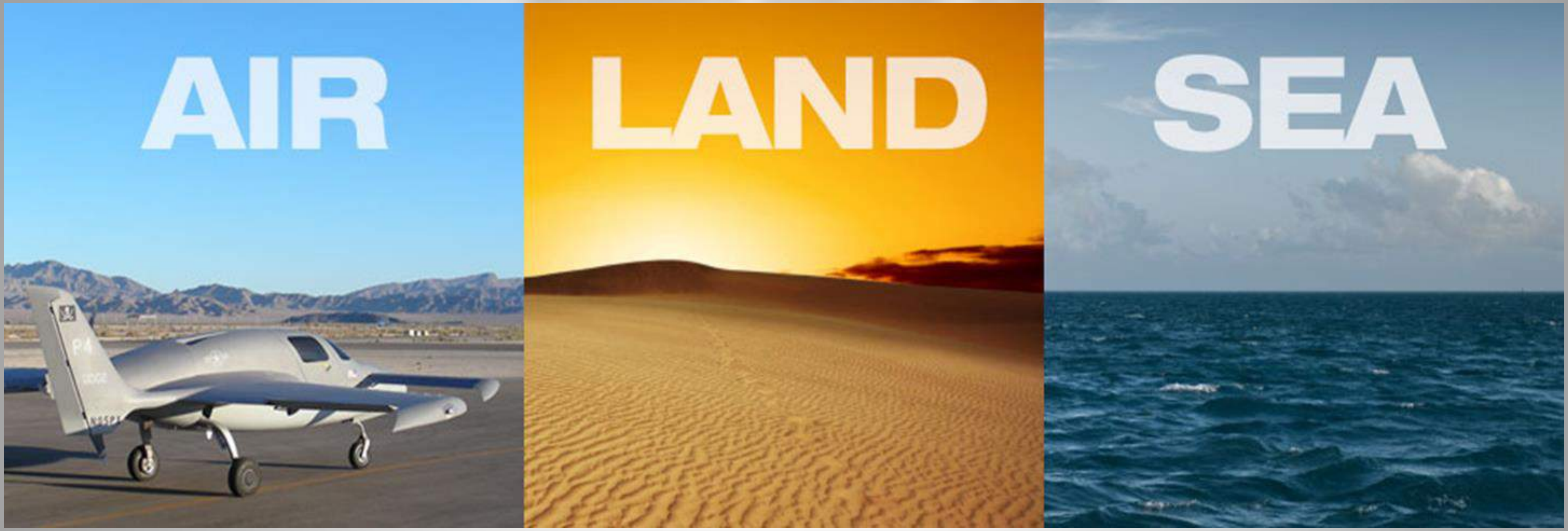
Cooperative Flight / Multiple Vehicles Control

Robert F. Davis
CEO
Proxy Technologies Inc.

Proxy Technologies
Robert Davis, CEO



Cooperative Flight / Multiple Vehicle Control for ISR Applications

Current State of the Art

- UAVs today are primarily Remotely Piloted Vehicles
- Sensor operators have very limited control of vehicle navigation
- Multiple sensors and platforms are not well integrated to operate together
- Pre-Flight Mission planning is very time consuming and a cumbersome process
- Dynamic mission re-tasking is difficult if not impossible during flight
- Aircraft today are primarily designed to be either manned or unmanned

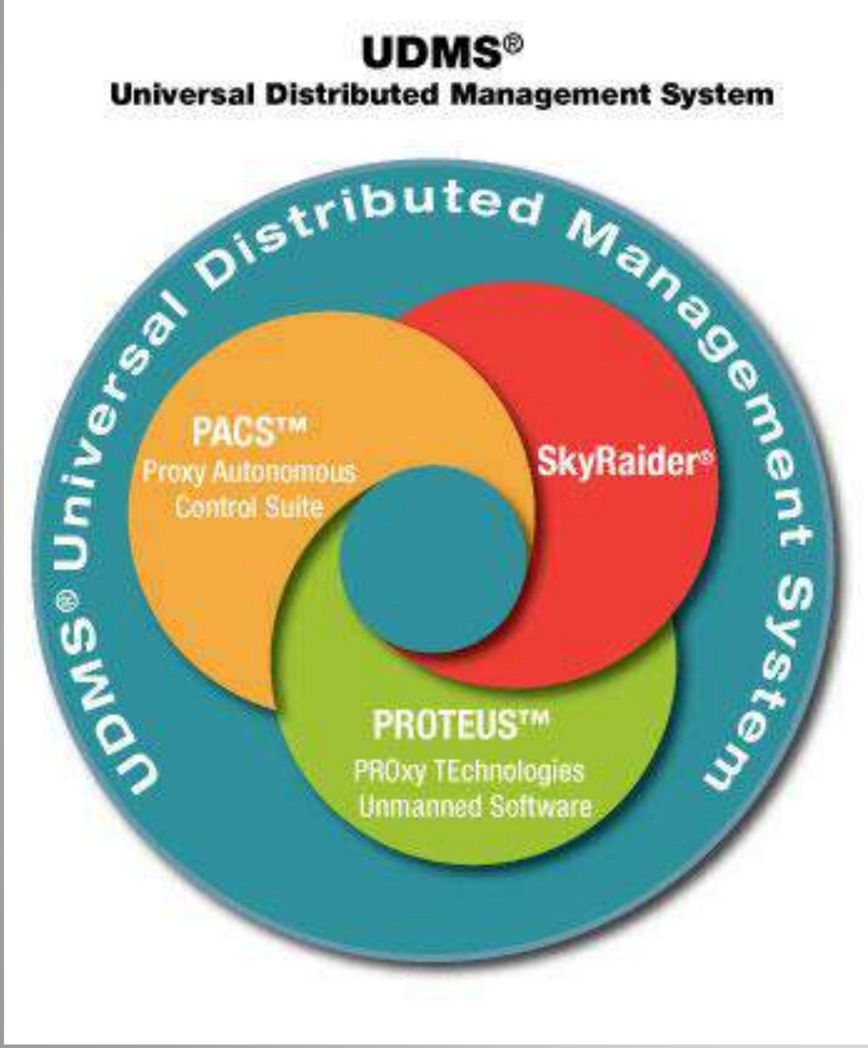
Expanding Beyond State of the Art

- UAVs today are primarily Remotely Piloted Vehicles…
  - Moving decisions to the platform through the use of autonomy
- Sensor operators have very limited control of the vehicle navigation…
  - Vehicle navigation is linked directly to sensor activity
- Multiple sensors and platforms are not well integrated to operate together…
  - All sensors and manned/unmanned platforms are networked together to share data
- Pre-Flight Mission planning is very time consuming and a cumbersome process…
  - An easy and intuitive way to plan missions
- Dynamic mission re-tasking is difficult if not impossible during flight…
  - Re-tasking built into the operator control station
- Aircraft today are primarily designed to be either manned or unmanned…
  - Future aircraft programs will include an Optionally Piloted Capability

Solutions Available Today via Proxy's UDMS®

- Moving decisions to the platform through the use of autonomy…
  - Provides an expert system onboard the platform
- Vehicle navigation is linked directly to sensor activity…
  - UDMS® automatically navigates vehicle to optimize sensor view
- All sensors are networked together to share data…
  - Mesh communication scheme allows all vehicles and sensors to share data
- An easy and intuitive way to plan missions…
  - Graphical mission planning with drag and drop objects from a library
- Re-tasking built into the operator control station…
  - Intuitive route planning which can be uploaded immediately to the vehicle
- Future aircraft programs will include an Optionally Piloted Capability…
  - UDMS® product currently can convert any aircraft into an OPV

Proxy's Autonomy Approach using UDMS®



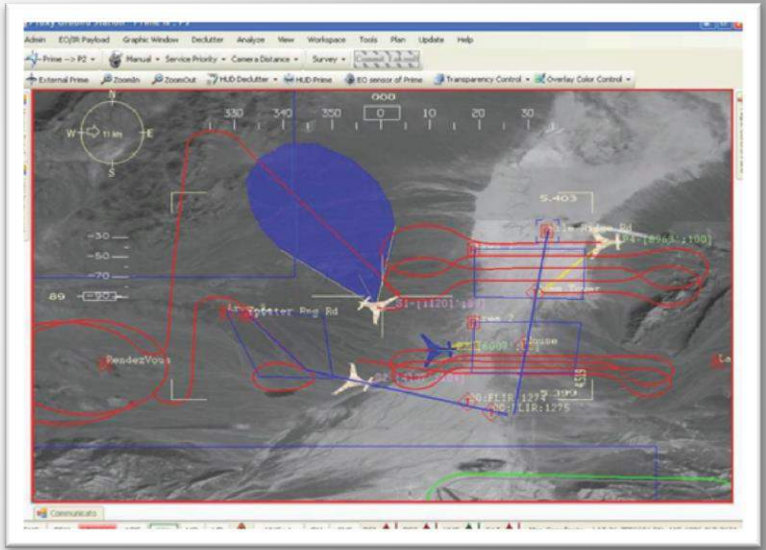
- Users control sensors & payloads and vehicles can fly autonomously
- Operators act as Managers of tactical groups of UAVs
- Management by Exception
- Multiple UAV missions are preplanned
- Enables dynamic re-tasking of platforms during a mission
- Vehicles share their future path plan and cooperate with all network participants

Proxy Technologies Offerings

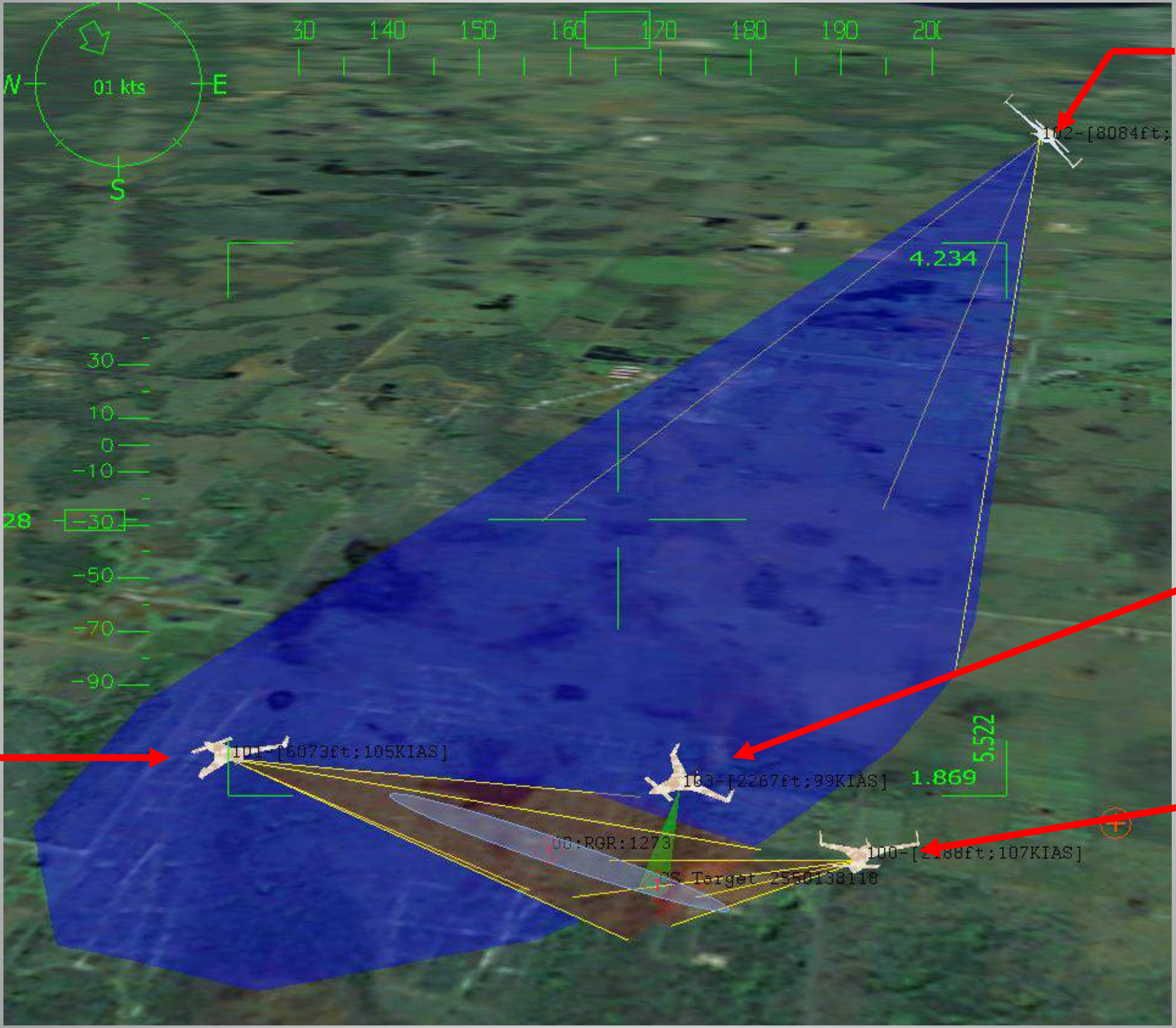
- UDMS® Products
  - PROTEUS™, the UDMS software application
  - Proxy Autonomous Control Suite (PACS™)
  - SkyRaider®
- Services
  - Flight testing services
  - UDMS® Software product support
  - Intelligence, Surveillance and Reconnaissance (ISR) and Incident Analysis & Awareness Services
  - System Integration
  - Conversion of commercial fixed wing to autonomous operation and Optionally Piloted Vehicles (OPV)
  - Software Maintenance

PROTEUS™

- PROTEUS™ is the software portion of UDMS® and includes:
  - Ground Control Station
  - User Payload Station
  - Virtual Pilot (on-board 'brain')
  - Junction (communication control)
  - Firmware (Pilot box, PDU, APC)
  - Graphics Mission Editor (Mission planning)
  - STANAG 4586 Vehicle Specific Module and support
  - Mission Debrief
  - Cursor on Target support
  - SIM (simulator)
  - Test tools (e.g. hardware emulators, event logging, event analysis, Database Editor)



Mesh Network Cooperative Vehicles & Sensors



UAV with Wide Area Sensor, 10,000 ft.

UAV with GPR 3,000 ft

UAV with EO/IR Sensor 6,000 ft.

UAV with Direction Finder Sensor 2,000 ft

- PACS™ is the hardware suite installed in a manned aircraft to convert to a UAV or OPV
- The major Proxy developed or modified subsystems in PACS™:
  - Power Distribution Unit [PDU] provides remote switching and dual 100A 28VDC buses
  - Autopilot Controller [APC] provides redundancy logic
  - Virtual Pilot/ Operator [VP/O] Air Controller [VAC] acts as the operator of the vehicle
  - Power Switching Box [PDU] expansion for large payloads
  - Servos for control of flight surfaces
  - Electronic engine control & monitoring
  - Local Area Network

Proxy Test Platforms

- Turnkey optionally piloted aircraft systems based on the SkyRaider® airframe
  - Portable Ground Control System (Vehicle or portable rack mounted)
  - Aircraft can be disassembled and reassembled by 3 technicians
  - Transportable by military cargo aircraft

- SkyRaider® high lift capacity, low operating cost aircraft
  - Capacity for 20+ hours of endurance
  - 1700 lb lift capacity
  - Speed range 80 – 150 kts
  - Allows simultaneous deployment of multiple sensor systems
  - Interoperable payloads

Autonomous Taxiing Capability

- Autonomous Taxiing
  - Capability added in 2012 under Proxy IR&D program
  - Allows for autonomous ability to taxi aircraft from hangar to the hold short line and then to commit for take-off once authorized (similar capabilities after landing)
  - Minimizes the potential for off-taxiway/runway excursions.
  - The ground station operator has total control of the operation and the option to stop the aircraft's movement instantaneously

Proxy Technologies – Summary

- **PROXY TECHNOLOGIES IS A SOFTWARE, SPECIALIZED SERVICES, AND SYSTEMS INTEGRATION COMPANY**
- Proxy's Universal Distributed Management System (UDMS®) is key intellectual property which provides:
  - Cost Savings: high level of autonomous vehicle control currently allows 32 nodes to be managed by a single operator
  - Multiple vehicle cooperative flight
  - Autonomous taxiing capability
- Proxy's FAA experimental certificate permits Proxy to fly in the National Air Space under autonomous control (with a Safety Pilot on-board)
  - Over seven hundred hours of flying an OPV in the national airspace.
    - Instantaneous engagement of autonomous operation from piloted mode

Conclusions

- Cooperative flight services that can be added to existing infrastructure - **TODAY**
- Cooperating autonomous vehicles that permit intelligent networked sensors and vehicles - **TODAY**
- Enhances current ISR capabilities and reduces resource requirements - **TODAY**
- Proxy is flying these technologies -**TODAY**

Questions?

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www.ProxyTechnologiesInc.com

(703)485-1035

Lunch

Michigan Room I

UAS Integration in the NAS: History and Future Perspectives

Ted Wierzbanowski

Retired USAF Colonel, Chairman F-38 UAS Committee ASTM

UASs in the National Airspace System (NAS)

Past – Present – Future

Ted Wierzbanowski, Chairman ASTM F-38 UAS Standards Committee

Michigan UAS Conference

Oct 2013

Agenda

- Prelude – A Historical Perspective
- UASs in the NAS
  - Differences/Definitions
  - Past
    - Small UAS flown in Visual Line of Sight (VLOS)
    - Other UAS
  - Present
    - Small UAS flown in VLOS
    - Other UAS
    - FAA UAS organization changes
    - FAA Modernization & Reform Act of 2012
  - Graphical Views
- Spectrum
- The Future ala W+12?

Historical Perspective

- Aircraft showed great promise in WW I
  - Initially adopted and found success in small niches
  - Rapidly employed in other missions
- After the war, they became curiosities
- “Golden age of the barnstormers”
- Commercial roles were slow to develop

Can you see parallels to UAS today?

Historical Perspective

- Air Mail Act of Feb 2, 1925 -Provided for transportation of mail on the basis of contracts between the Post Office Department and individual air carriers
  - April 15, 1926: Charles Lindbergh flew a bag of mail from Chicago to St. Louis
- Air Commerce Act of May 20, 1926, required
  - Licensed pilots
  - Airworthiness certificates
  - Investigation of accidents
- July 1, 1927 - Boeing Air Transport started commercial air service between Chicago and San Francisco

1926, Colonial Air Transport begins first airmail flight between Boston and New York. Juan Trippe, far right, receives an airmail package

Historical Perspective

- The Air Mail Act of 1925 created a profitable commercial airline ***business case***
- Airline Companies were born
  - Pan American Airways
  - Western Air Express
  - Ford Air Transport Service
- Mar 29, 1927- Aircraft Type Certificate No. 1 issued
- By the end of 1927, nine total aircraft type certificates had been issued

- The rate of type certification then increased. By the end of 1928, the total had reached 47; by the end of 1929, 170; by 1930, 287

A profitable aviation business case led to people going out and doing commercial aviation.

Historical Perspective

- Oct 1927 - The International Radio Convention
  - Secured international agreements on the use of frequencies by aircraft and airway control stations
  - Reassigned frequencies to the Airways Division of the Aeronautics Branch and to other U.S. Government agencies
- Airlines were required to apply for certificates by Aug 15, 1930
  - Certificate required if engaging in interstate passenger service
  - To get certificated an airline had to
    - Demonstrate aircraft that were properly equipped and maintained
    - Have a sufficient number of qualified airmen
    - Have an adequate ground organization for the services provided

Commercial aviation and the regulations governing it grew up together. Not the case today for UAS!!

UAS in the NAS

Differences/Definitions

- Differences
  - Commercial/general aviation well established
  - Regulations are in place and flying in the NAS is very safe
  - UAS capabilities/technology “exploding” and threatening the safety of the NAS including persons/property
    - In the air (mid-air collisions)
    - On the ground (many recent examples of “careless/reckless” UAS flights)
- Definitions
  - Public
    - Military
    - Non-military government (non-public safety applications)
    - Public safety (special non-military government case)
  - Civil
    - Pure commercial (real estate, news, etc)
    - Support of non-military government (environmental cleanup, pipeline, etc)

Past

Small UAS

- Small UAS (sUAS) civil operations in the U.S. were “shut down” in Feb 2007
  - Prior to this, sUAS were operated under AC 91-57 (model aircraft “rules”)
  - FAA issued “Clarification of Existing Policy” (Docket No. FAA-2006-25714) on 6 Feb 07 that said that operating civil sUAS under AC 91-57 was not allowed
- Once that happened there were only two ways to fly sUAS in the NAS outside of restricted airspace
  - Public entities could obtain a Certificate of Waiver or Authorization (COA) with many operational and location restrictions
  - Civil entities could obtain an Experimental Certificate for R&D, training, and marketing (with significant restrictions and no ability to perform missions for compensation and/or hire).
- To help develop rules to allow more sUAS access to the NAS for civil applications, the FAA chartered a sUAS Aviation Rulemaking Committee (ARC) in Apr 2008
  - sUAS ARC recommendations were provided to the FAA in Apr 2009
- Since then, the FAA has used the ARC recommendations to develop the sUAS rule that will be published for public comment “soon”
  - Rule is currently in final coordination within OST/OMB
  - Even if it is published for public comment in 2013 the rule won’t be effective for civil applications until late 2014 or 2015 depending on comments received

Other UAS

- Beginning in 2001 UAV National Industry Team (UNITE) members began work on all issues involved with flying High Altitude Long Endurance (HALE) UAS in the NAS for civil applications.
  - These efforts eventually resulted in the funded NASA Access 5 program that continued this work.
- Approval of Certificates of Authorization (COAs) for civil UAS operations in the U.S. were no longer approved after Sep 05
  - Prior to this, some U.S. companies were "inappropriately" issued COAs by the FAA without public entity sponsorship
  - FAA issued AFS-400 UAS Policy 05-01 "Unmanned Aircraft Systems Operations in the U.S. National Airspace System – Interim Operational Approval Guidance" on 16 Sep 05 to rectify this situation
- After the NASA Access 5 program was cancelled, the FAA chartered RTCA to develop Minimum Aviation Performance Standards (MASPS) for larger (not just HALE) UASs in the NAS for two specific topics:
  - Command and control
  - Sense and avoid
  - This work continues but has been restructured to be more focused (details were recently announced)

Present

Small UAS

- The small UAS rule will reference "consensus standards" for detailed requirements for civil operations (as recommended by the sUAS ARC)
- ASTM has been chartered by the FAA to develop the consensus standards required to implement the rule
  - Design, Construction, and Test
  - Production Acceptance
  - Quality Assurance
  - Maintenance and Instructions for Continued Airworthiness
  - Aircraft Flight Manual
  - Additional Requirements for Operations over People
- All required standards (except Operations over People) are now drafted and being reviewed/modified by ASTM international membership and the FAA to ensure they meet both ASTM and FAA needs
- Goal is to have the first set of ASTM final standards available early fall of 2013 so they can be "beta tested" and modified for public and civil operations over the next several years while the sUAS rule for civil operations is being finalized
- Expect that these will also have to be modified once the rule is published for public comment (only government persons have seen the actual draft rule)
  - Will most likely also have to be modified again once the final rule is published

Other UAS

- Currently there are only four ways other UASs can fly in the NAS
  - Fly in restricted airspace sponsored by the government "owner" of that restricted airspace
  - Fly under a COA (outside of restricted airspace) sponsored by the government entity that "owns/leases" the UAS and accepts the liability
  - Fly a company/privately owned UAS under an experimental certificate granted by the FAA for research and development, training, and marketing
  - Fly a company/privately owned UAS under a COA for civil applications - provided the UAS is certified either through a "restricted" or a "special class" certification (recent option!!)
- The FAA recently chartered a new UAS Aviation Rulemaking Committee (ARC)
  - "This committee will provide a forum for the U.S. aviation community to discuss, prioritize, and resolve issues, provide direction for U.S. UAS operational criteria, support the NextGen Implementation Plan, and produce U.S. consensus positions for global harmonization." – full charter is on the FAA web site.
- EUROCAE Working Group 73/93 are also preparing rules/recommendations for the EU for UAS
  - Being done collaboratively with the FAA, RTCA, and ASTM efforts
- However, lots of work left to do (CFRs, standards, policies, training, etc) to safely integrate UASs into the NAS

FAA UAS Organization Changes

- Reorganization of two organizations into a single, unified UAS integration office (UAIO) now official
  - Unmanned Aircraft Program Office (UAPO) [Aviation Safety], and
  - Unmanned Aircraft Systems Group (UASG) [Air Traffic Org]

- Organization reporting structure:
  - The **old** (current) UAPO is under the Flight Technologies and Procedures Division which falls under Flight Standards Service
  - The **new** UAIO will reside directly under Flight Standards Service Director for Policy

- Implications
  - FAA recognizing UAS are here to stay
  - “Much” more focus and attention to UAS
  - The new lead for the UAIO (Jim Williams) is very proactive and is pushing really hard to get things done and comply with Congressional direction
    - **<u>PRIVACY</u>** issue has negatively affected FAA ability to comply

FAA Modernization and Reform Act of 2012

- Enacted into law on February 14, 2012 after ~24 extensions to previous authorization act
- Subtitle B – Unmanned Aircraft Systems
  - Contains 16 pages
  - Sections, 331-336
- Many UAS integration tasks with timelines included

Major Reauthorization Timelines/Status

- May 14, 2012
  - Enter into agreement to simplify the process of issuing COAs for public operators – completed for public safety entities and in process for others

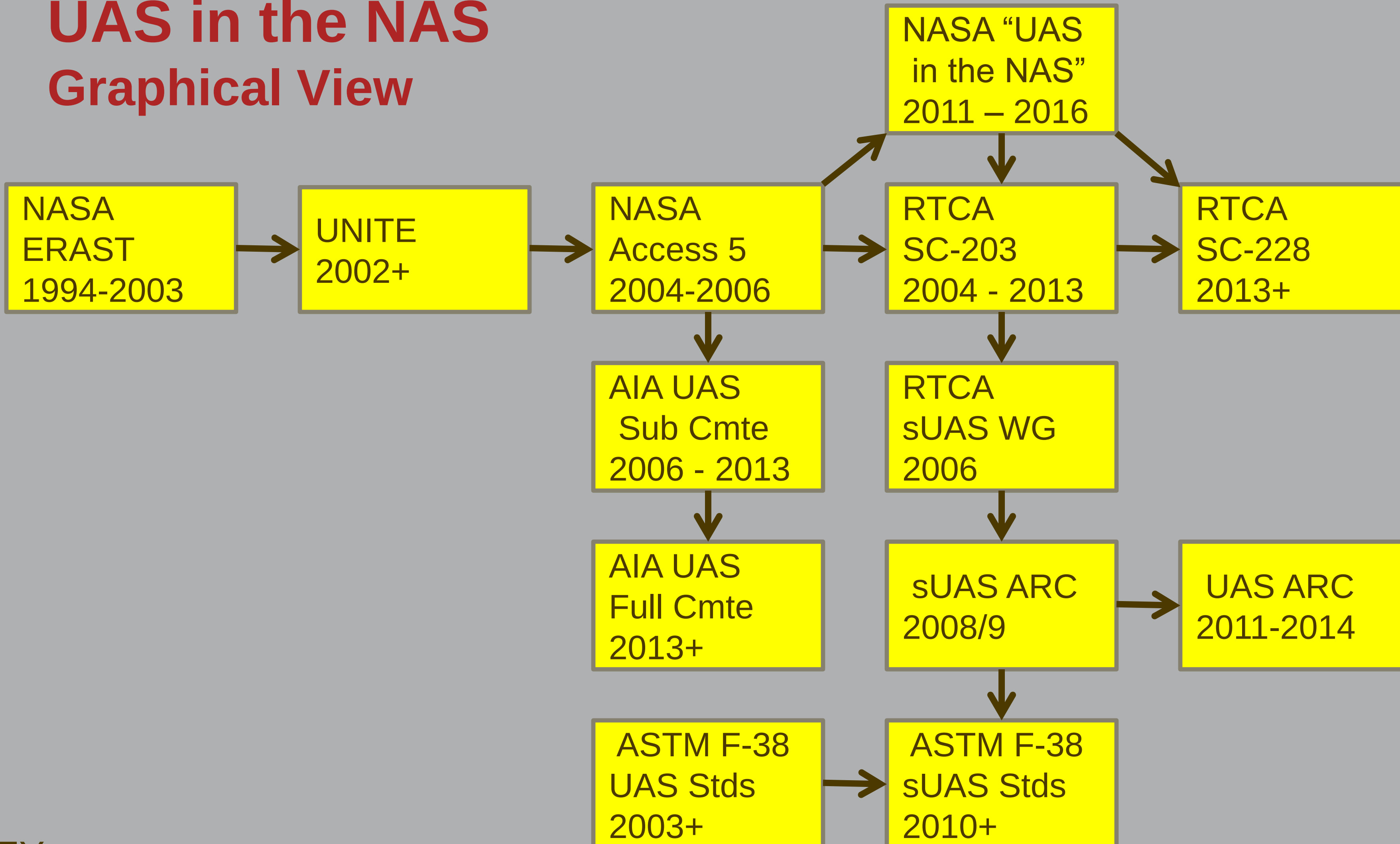
- August 12, 2012
  - Establish a program to integrate UAS into the NAS at 6 test ranges – selection process underway
  - Develop plan and initiate process for designating permanent areas in the Arctic where small UAS can operate 24 hours a day for research and commercial purposes – plan completed and effort is underway
  - Determine if certain UAS may be operated safely in the NAS before completion of the plan and rulemaking – in process

- November 10, 2012
  - Comprehensive Plan to safely accelerate the integration of civil UAS into the NAS – in process with support from UAS ARC
  - Issue guidance regarding expanding operation of public UAS –in process

Major Reauthorization Timelines/Status (cont)

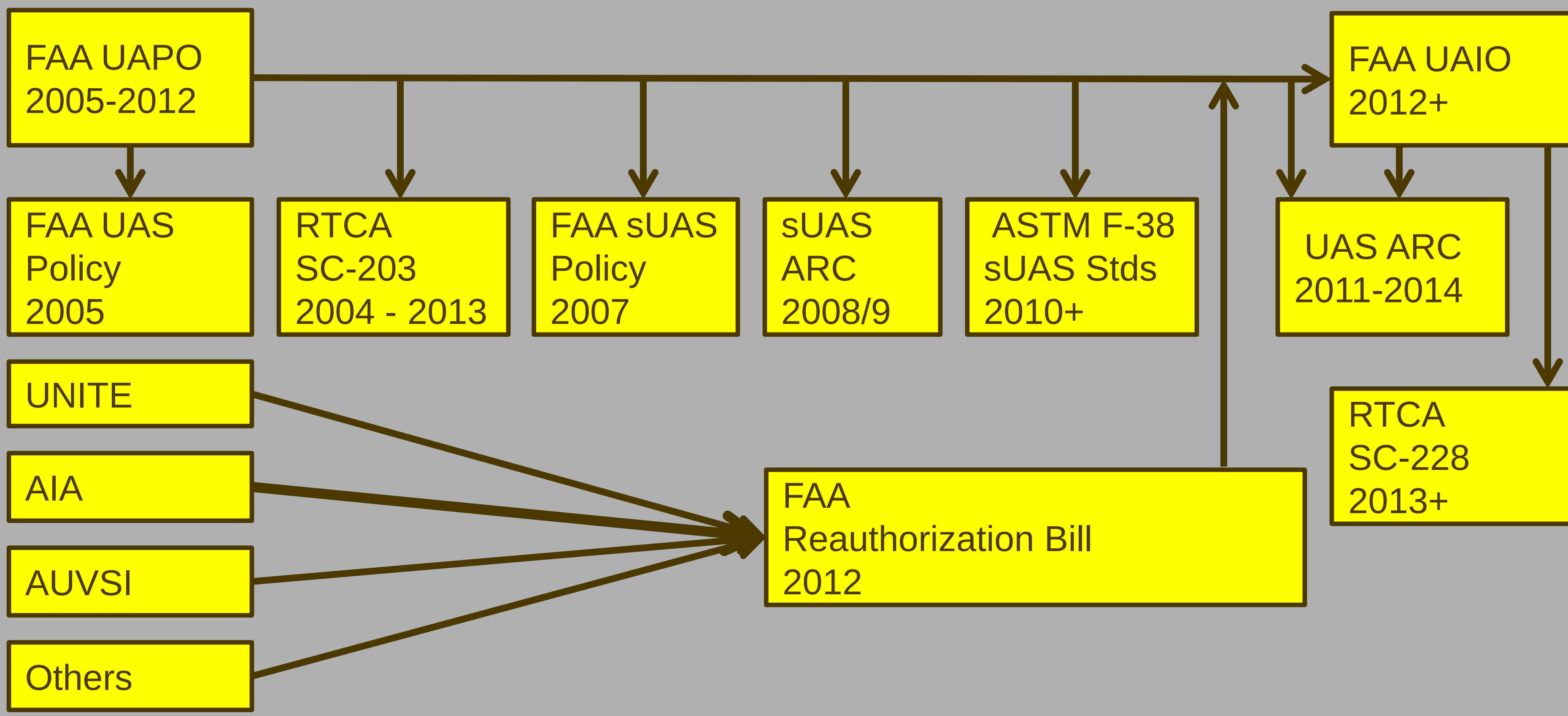
- February 14, 2013
  - Provide copy of comprehensive plan to Congress – completed but will be refined next year
  - 5 year roadmap for introduction of civil UAS into the NAS posted on web site and updated annually – in process
- August 14, 2014
  - Publish a final rule on small UAS – Notice of Proposed Rulemaking (NPRM) delayed by **PRIVACY** issue so this date will probably **NOT** be met
  - Publish an NPRM to implement the recommendations of the comprehensive plan – may also be delayed
  - Update policy statement in Docket No. FAA-2006-25714 – in process
- September 30, 2015 (hard date)
  - "No later than" date for "safe" integration of civil UAS into the NAS
  - Success criteria not well defined or understood

UAS in the NAS
Graphical View



KEY
- Environmental Research Aircraft and Sensor Technology (ERAST)
- UAV National Industry Team (UNITE)
- Access to the National Airspace in 5 Years (Access 5)
- Small UAS (sUAS)
- Aviation Rulemaking Committee (ARC)

UAS in the NAS
Another Graphical View



KEY
- Unmanned Aircraft Program Office (UAPO)
- Unmanned Aircraft Integration Office (UAIO)

Spectrum

Spectrum

- Spectrum for UASs is quickly becoming (or already is) the most critical issue for future UAS applications (other than the **PRIVACY** issue)
  - Public
    - Non-military government (law enforcement, first responders, etc)
    - Military
  - Civil (pure commercial, support of non-military government, etc)

- Significance of issue not universally understood
  - Availability of spectrum for other than US military applications
  - Process and extended timeline to get spectrum allocated

- Opportunities exist to ensure spectrum is available for UASs in the future but this requires:
  - Long-term commitment
  - Near-term support

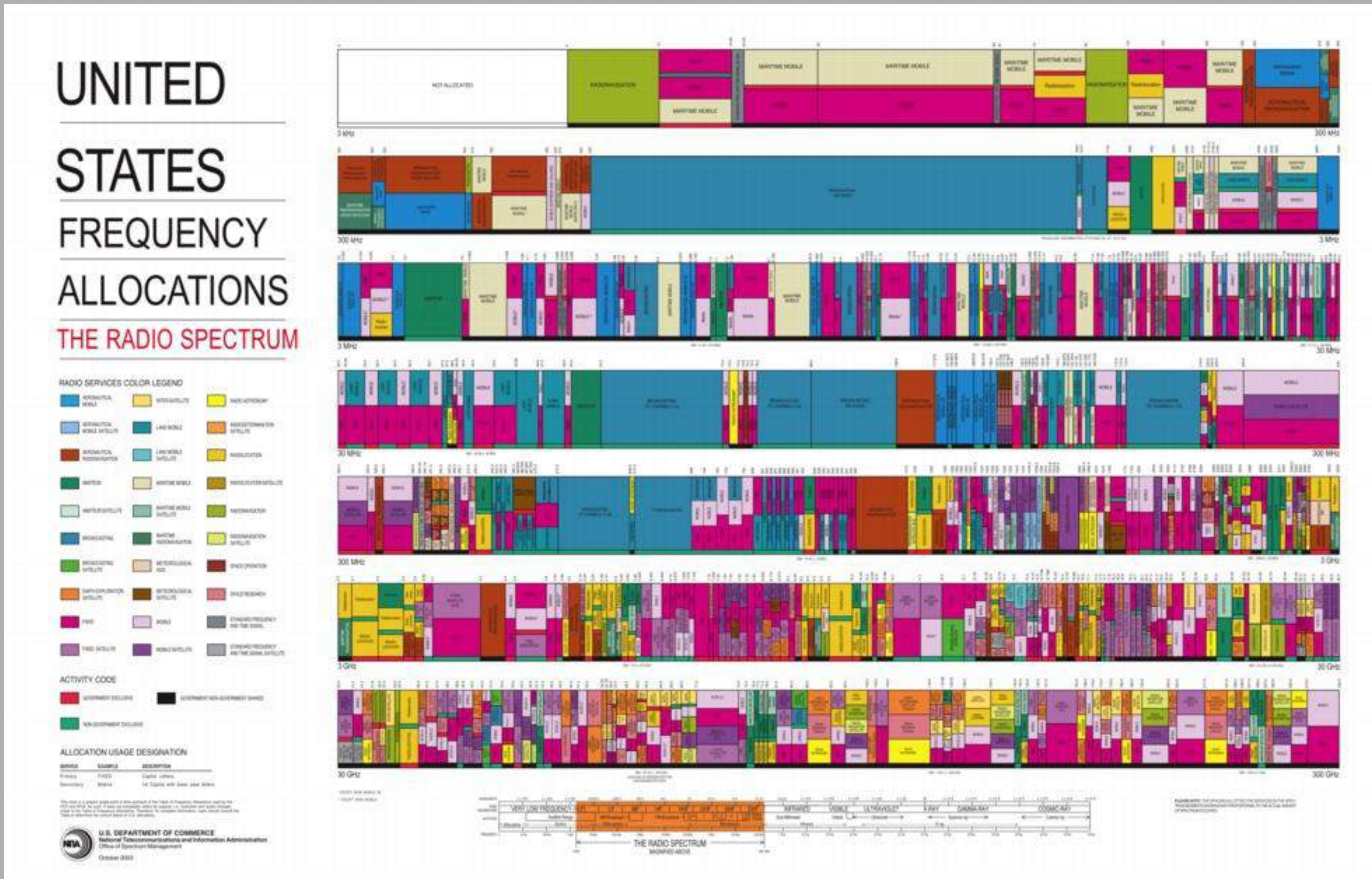
Spectrum (cont)

- Spectrum allocation determined by World Radiocommunication Conference (WRC)
  - International forum for world agreement
  - Reviews and revises radio regulations
  - Meetings previously held every 2 - 3 years, now extended to 4 years
  - Operates by consensus, voting on occasion
  - Sets the world stage for future technological development
  - Greater emphasis on consolidated regional positions and proposals
  - Last meeting was in Geneva in Jan/Feb 2012
  - Won’t meet again until 2015/2016 so……………

- Process is time consuming and very “political” (like the UN)
  - Each of the regional spectrum organizations (see next charts) have a WRC preparatory function
  - Administrations/nations submit draft proposals
  - The regional organization, in accordance with their own procedures, adopt common proposals before the WRC
  - The regional proposals are submitted to the WRC on behalf of all of their members
  - The U.S. is part of CITEL (Inter-American Telecommunication Commission)

Spectrum (cont)

Spectrum (cont)



Spectrum (cont)

- Various industry organizations worked with the US delegation to the WRC 12 to obtain spectrum for UASs
  - RTCA
  - UNITE (supported an event at CITEL meeting in Puerto Rico and a booth at the WRC 12 meeting Geneva explaining value of UAS for non-military applications)
  - AIA
  - AUVSI
- Results of WRC 12
  - Line of Sight (LOS) spectrum allocated
  - Beyond Line of Sight (BLOS) put on agenda for WRC 15/16
  - Spectrum allocated for Gateway links for High Altitude Platform Stations in certain countries
- Current activities
  - RTCA and ASTM working to develop standards to use LOS spectrum allocation
  - RTCA and others working on technical justification to use existing satellite spectrum for BLOS rather than aviation protected spectrum

The Future?

The Future (ala W+12)

- Small UAS flown in VLOS (largest near/mid term market)
  - The NPRM for the sUAS rule for civil operations will be published “soon”
  - ASTM standards required for the sUAS rule will be completed this year and “beta tested” for public and civil operations over the next several years
  - The actual sUAS rule for civil operations will not be finalized for several years
  - In the meantime,
    - Civil sUAS operations will flourish in other countries but **<u>NOT</u>** in the US unless alternatives to the sUAS rule can be implemented
    - Public sUAS operations will flourish in both the US and in other countries

- Other UAS
  - Public UAS operations will continue to grow in both the US and in other countries
  - Civil UAS operations are going to be difficult (at best) until:
    - The sense and avoid and command/control issues are resolved
    - Civil Aviation Authorities (including the FAA) develop and implement a comprehensive plan to integrate civil UASs into their airspace
    - HALE UAS will be easier than “tweenies”

- Spectrum availability will continue to be an issue (not just for UASs)

- **<u>EVERYONE</u>** here will volunteer to help RTCA, ASTM, and other UAS standards organization develop and refine **<u>ALL</u>** the standards that will be required to safely integrate UASs into the NAS

Questions/Discussion

Contact info: Wierzbanowski@UASintheNAS.com

Integrating Civil UAS in Class B Airspace: The Miskam Experience

Marc Moffatt
R&D Director
UAS Centre of Excellence (CED Alma, Qc)

Integrating Civil UAS in Class B airspace

UAS Centre of Excellence

Alma (QC)

www.cedalma.com

CED UASCE

Agenda

- UAS Centre of Excellence
- Primary services
- Alma airport
- Secure environment
- UAS Ops in Canada
- UAS Regulation
- Miskam program
- Canadian Domestic Airspace
- From theory to reality
- Challenges
- Operating the MISKAM
- Question period

UAS Centre of Excellence

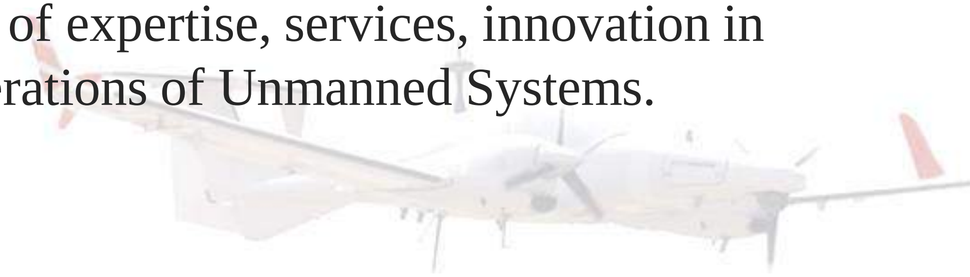
The UAS CE is an NPO established in June 2011. It is composed of private and institutional members contributing to the centre's development through an annual membership and by their implication in diverse services and projects offered by the UAS CE. Our services are offered nationally and internationally

OUR VISION

To be the Canadian reference for civil and commercial Unmanned Systems and a leader on the international stage.

OUR MISSION

Develop an international centre of expertise, services, innovation in conception, application and operations of Unmanned Systems.



Primary Services

Services & supports of UASCE:

- Knowledge of market, competencies in the business sector
- Scientific and technical knowledge
- National & International Networking
- Access to vast training areas
- Support in obtaining Special Flight Operation Certificate (SFOC)
- Access to platforms and airborne systems
- Research & Development Centres (Scientific committee)
- Training for UAS Pilot (Training Centre)
- MRO Services
  - Support & Services through partnership

Location & Airspace

Alma airport

Alma Airport					
IATA: CYTF – ICAO: YTF – TCLID – None					
Summary					
Airport type	Public				
Operator	City of Alma				
Localisation	Alma, Quebec				
Elevation	449 feet / 137 meters				
Coordinates	48°30′31″N 71°38′29″O				
Runway					
Direction	Length		Width		Surface
	Ft	Mr	Ft	Mr	
13 / 31	5 000	1 524	100	30,5	Asphalt
Source: Canada flight supplement					

Secure Environment

- Collaboration from 3 WING Bagotville (Tower, Radar, training areas)
- Meet Transport Canada regulations and standards / civil aviation (licensed pilot, medical, communications, etc.)
- Experienced pilots
- Use of corridors and restricted airspace
- Urban areas avoidance
- Emergency plans in place – l’Aéroport et de la Ville d’Alma
- Trained & experienced personnel
- Operating under Special Flight Operations Certificate (SFOC)

UAS Operations in Canada

- Canada offers a unique environment to develop a global leadership in civil/commercial UAS capability
- In 2009 CARAC approved the UAV Program Design Working Group, consisting of interested stakeholders and co-chaired by TC and Unmanned Systems Canada to develop regulations for UAS operation in Canada
- The Working Group is a 4 phased project; Phase 1 has been completed and recommended regulations approved by TC CARAC
- Canadian industry interest in using UAS for commercial purposes has grown rapidly and has now overwhelmed the capacity of Transport Canada regional inspectors to approve the deluge of SFOC applications
- Canada’s potential to be the global leader in developing civil and commercial UAS technology, applications and markets is in jeopardy due to delays in response from Transport Canada

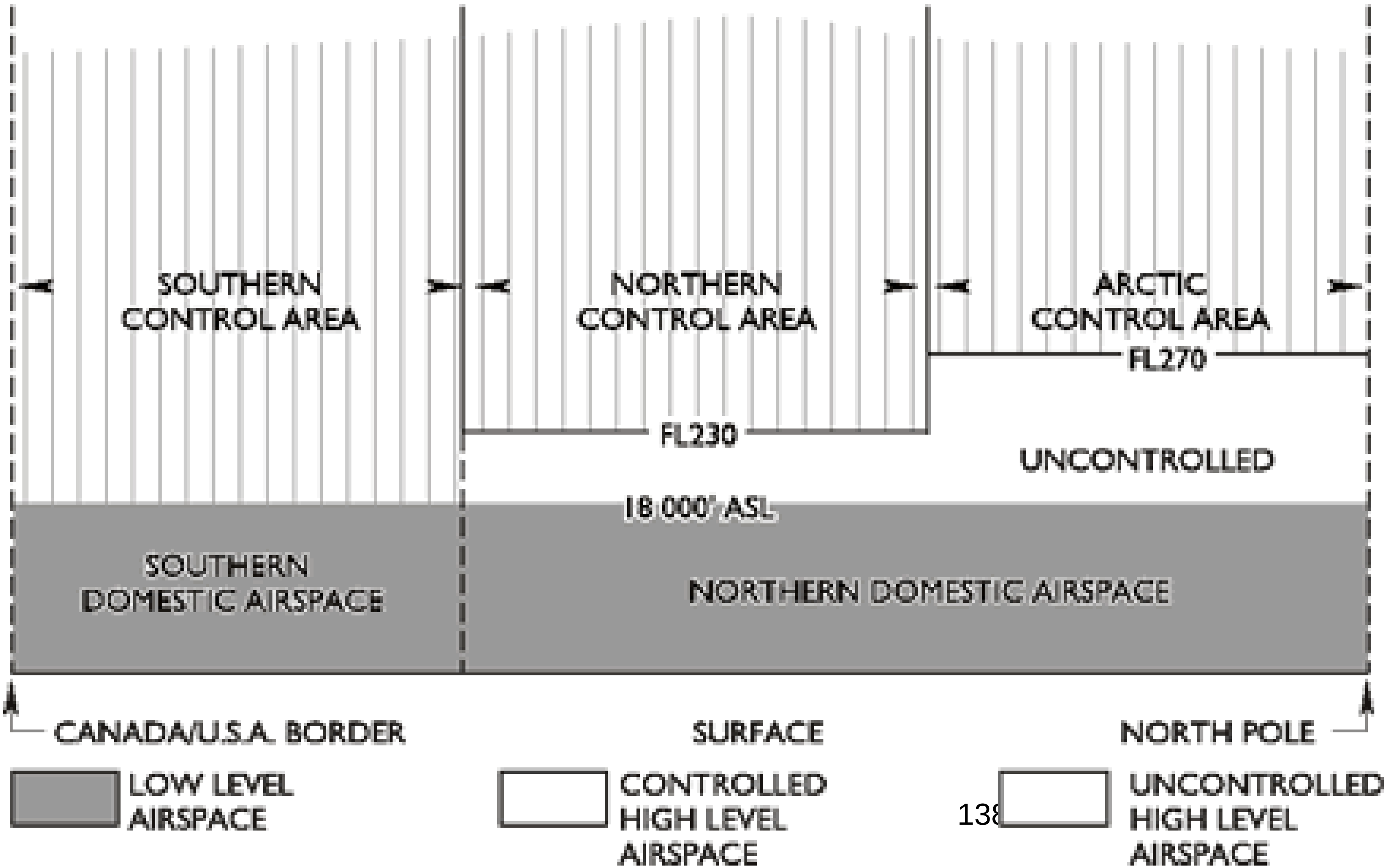
UAS Regulations

- Unmanned Systems Canada represents the Canadian unmanned systems sector; Over 500 members spanning Canada: industry and academia
- Partnered with TC from the beginning in the development of the necessary regulatory environment
- Prudent approach taken throughout the industry in Canada to ensure the highest standards of safety and behaviour
- Excellent support from all levels of Transport Canada, and excellent and thorough assessments undertaken by the regional inspectors in approving SFOCs. However, the throughput is unacceptably slow

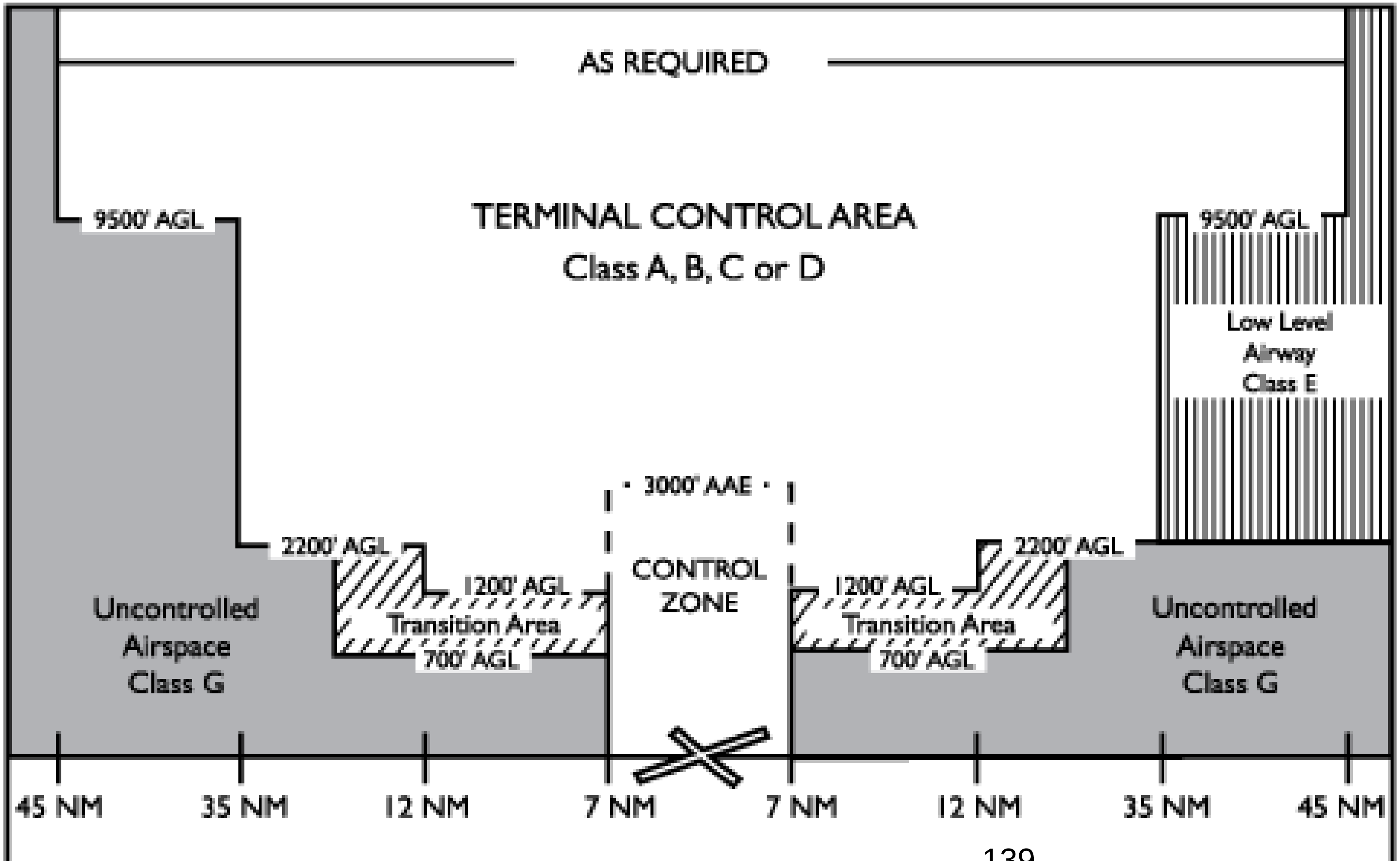
MISKAM Program

- Based on Diamond DA-42
- Beyond visual line of sight (150 km from airport)
- Night VFR flights
- Intergration in non-restricted airspace (Class B)
- Installation of modified sensors (MAD system)

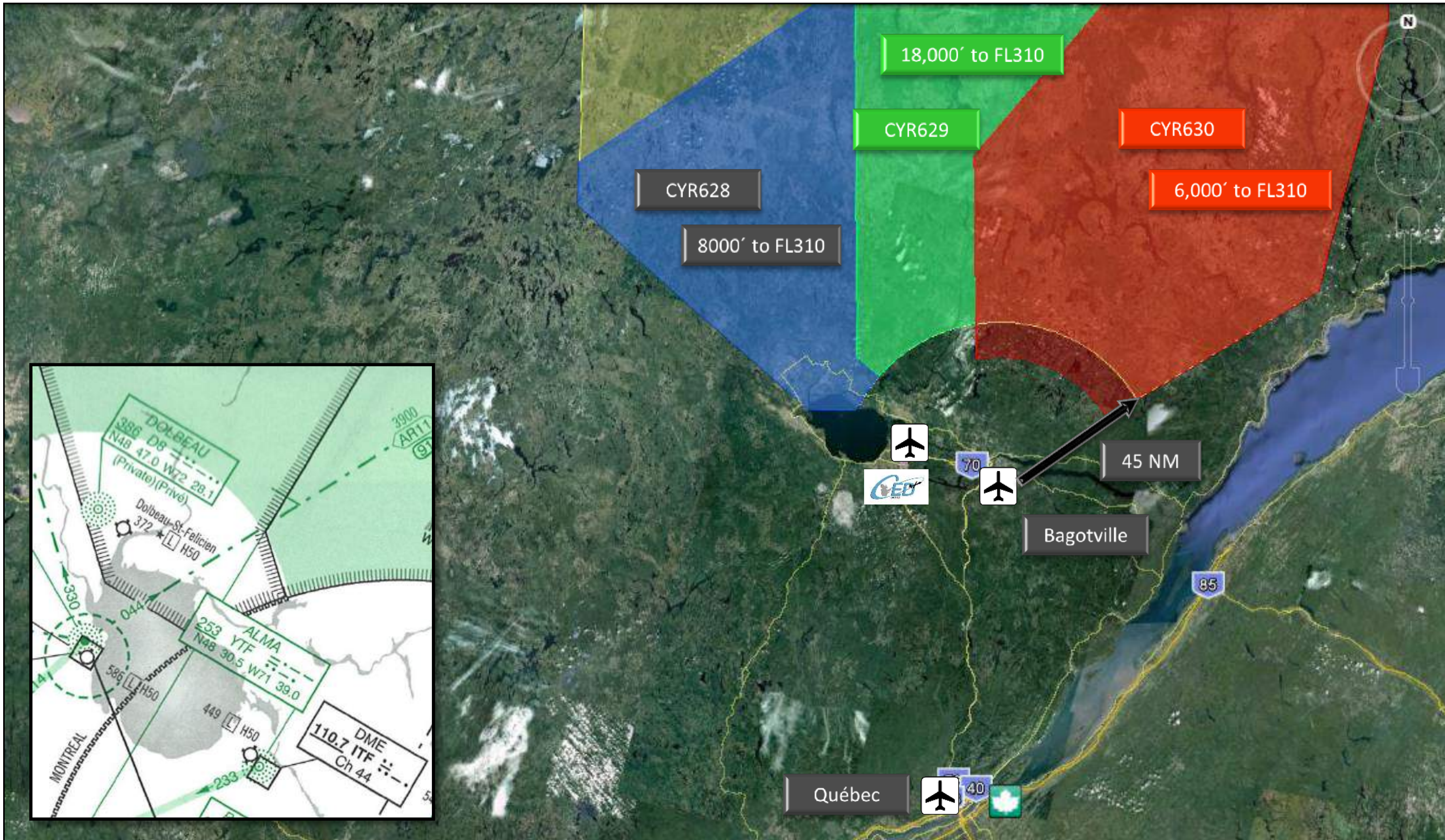
Canadian Domestic Airspace (CDA)



Canadian Domestic Airspace (CDA)



From the theory to reality



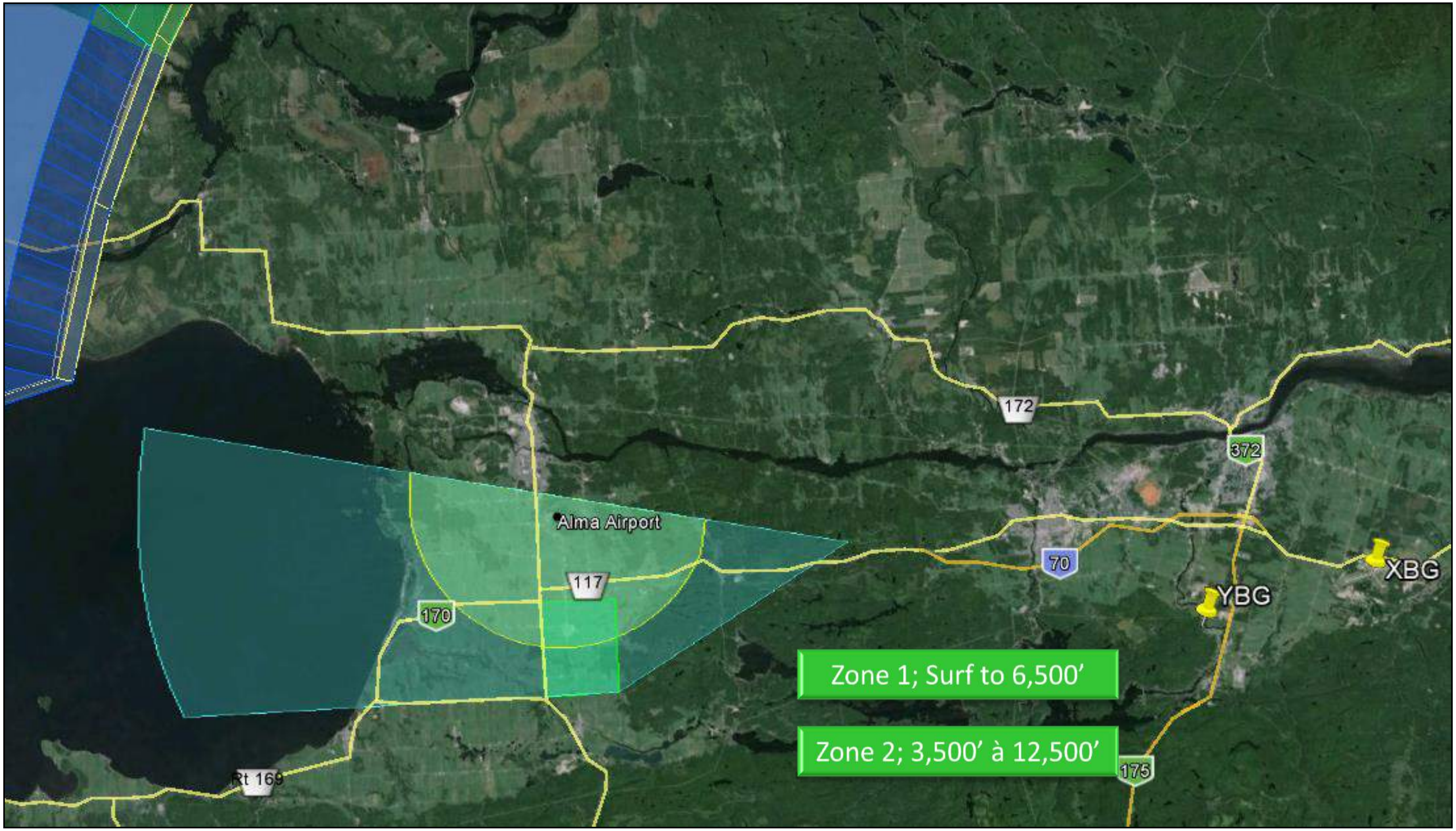
Challenges

- Min weather for a VFR flight plan:
  - Ceiling 3000' and visibility 3 miles
- Miskam BLOS minimum VFR weather requirements:
  - Ceiling 14,000' and visibility 25 miles
- Limited to Bagotville Class F airspace for flights BLOS
- No flights through clouds at any altitudes
- Not authorized in Class A airspace (no IFR)
- Transport Canada regulations for RPAS
- Sense & Avoid system

Operating MISKAM in CDA

- 1st SFOC approved on 7 Nov 2011
  - VLOS only (Day VFR)
  - Implementation of a MF frequency at CYTF
  - NOTAM for RPAS activity at CYTF surface to 6500’
  - NOTAM for RWY closure at CYTF
- 2nd SFOC approved on 12 May 2012
  - BLOS (Day VFR)
  - NOTAM for RPAS activity at CYTF surface to 6500’
  - NOTAM for RWY closure at CYTF
  - NOTAM required for new restricted airspace created under section 5.1 of the Aeronautics Act (see AIP Canada 56/12)
  - VFR route in Class B (CVFR) airspace to Bagotville Class F airspace

Shuttle Climd Area



Operating MISKAM in CDA

- 3rd SFOC approved on 28 Aug 2012
  - BLOS (Day & Night VFR)
  - NOTAM for RPAS activity at CYTF surface to 6500’
  - NOTAM for RWY closure at CYTF
  - Restricted airspace created under section 5.1 of the Aeronautics Act is now published in AIP Canada (56/12) with new effective hours
  - VFR route in Class B (CVFR) airspace to Bagotville Class F airspace

Future Steps

UAS CE Development Plan

- Demonstrate the commercial potential of the UAS sector
- Modification of systems; Sense & Avoid, High-res camera (Multi spectral), Deicing projet
- Develop sUAS market
- Establish, on location, services from private companies to include manufacturing and modifications of UAS
- Offer directly or through our partners, a wide range of services related to the UAS sector (training centre, R&D, MRO)
- Controlled Goods/ITAR handling services
- Recruting campaign on-going

Future Hangar (fall delivery)

- 9600 sqft – Hangar
- 4800 sqft – office space
- Labs
- Secure environment

Question Period

Centre d’excellence sur les drones
(CED)
www.cedalma.com

Alma, Lac-Saint-Jean
Québec - Canada

MIAASC
Michigan Advanced Aerial System Consortium

Integration of Small UASs in the NAS: Potential Issues & New Developments

Panelists:

- Stephen Morris, CEO, MLB Company
- Craig Witte, General Manager, Merrill Technologies Group
- Paul McDuffee, VP Government Relations & Strategy, Insitu

Break

Michigan UAS Potential

Gavin Brown

President, Michigan Aerospace Manufacturing Association (MAMA)

Michigan's UAS Potential

MICHIGAN AEROSPACE MANUFACTURERS ASSOCIATION

Gavin Brown, Executive Director

October 29, 2013

Sense and Avoidance

- Create new system - at least three to seven years out
- Air Force competition in Indiana next April 2014
- For use by both UAS and Commercial/General Aviation.
- Before UAS is in mass use in commercial air space sense and avoidance systems must be implemented- $1 billion market

Air frame & Composites

- Air frame manufacturers design from under 1 pound to large air carriers for fire fighting, cargo carrying and ultimately passenger transportation.
- Composites will be the main material used for air frame, structures, and any other parts that can replace metals for weight gain. Composite manufacturing will increase as well as composite repair technology.
- Graphene technology will be used for all components within 3 years to give flexibility, strength and aero dynamic advancements needed for small, large aero structures.

Precision Machining-

- Aerospace machining will demand high tech machinery and new advancements.
- Friction Stir welding will replace currents rivet systems
- 8+ axis CNC machines for complex, small components

Tooling and Final Assembly Systems

- Tooling will be needed for the build out of many different platforms.
- Lay up for composite and metal components.
- Final Assembly will also be done in many new locations than the existing sites where both commercial and defense are currently located.

The Future

- UAS systems will be regulated by size, weight, altitude and power.
- 55 pounds and under- first to be deployed (model airplane)
- Electric powered propulsion
- Above 18,000 feet
- Below 400 feet- line of sight

Military/Commercial Use

- Military is in use: Global Hawk, Predator.
- Technology from these will transfer to commercial use, where applicable… not giving away military secrets.
- Commercial use will be in agricultural, police, cargo, traffic observation, aerial mapping, power line system checks, fisheries, and many more uses where it is currently done by helicopter or light aircraft.
- Michigan institutions and businesses have knowledge, produce materials and engineering expertise for components and systems that are already in use for both defense and commercial UAS systems.

MAMA

Michigan's Differentiators

- Michigan is the center of the automotive universe.
  - Research and development of autonomous vehicle technologies can be directly applied to UAS sense and avoidance systems.
  - Automotive research and development of light weight technologies for auto fuel efficiency is technology applicable to UAS designs.
- Precision machining capabilities in Michigan can serve the UAS market.
- Assembly systems, fixtures, jigs and tooling capabilities in Michigan can serve the UAS market.
- The growth in UAS's is creating a demand for more pilots, a demand Michigan's Universities can fill.

Michigan National Guard and UAS: An Effective Collaboration

Brig Gen Michael A. Stone
Assistant Adjutant General Installations
Michigan National Guard

2013 Michigan UAS Conference

Brigadier General Mike Stone
Assistant Adjutant General—Installations
Michigan National Guard

29 October 2013

What we use…

SHADOW 200 TACTICAL UNMANNED AIRCRAFT SYSTEM (TUAS)

MQ-9 Reaper

Michigan National Guard

“A World Class, comprehensive, all season, full spectrum , interagency & combined arms training experience..”

MG VADNAIS

THE

CAMP GRAYLING

JOINT MANEUVER TRAINING CENTER

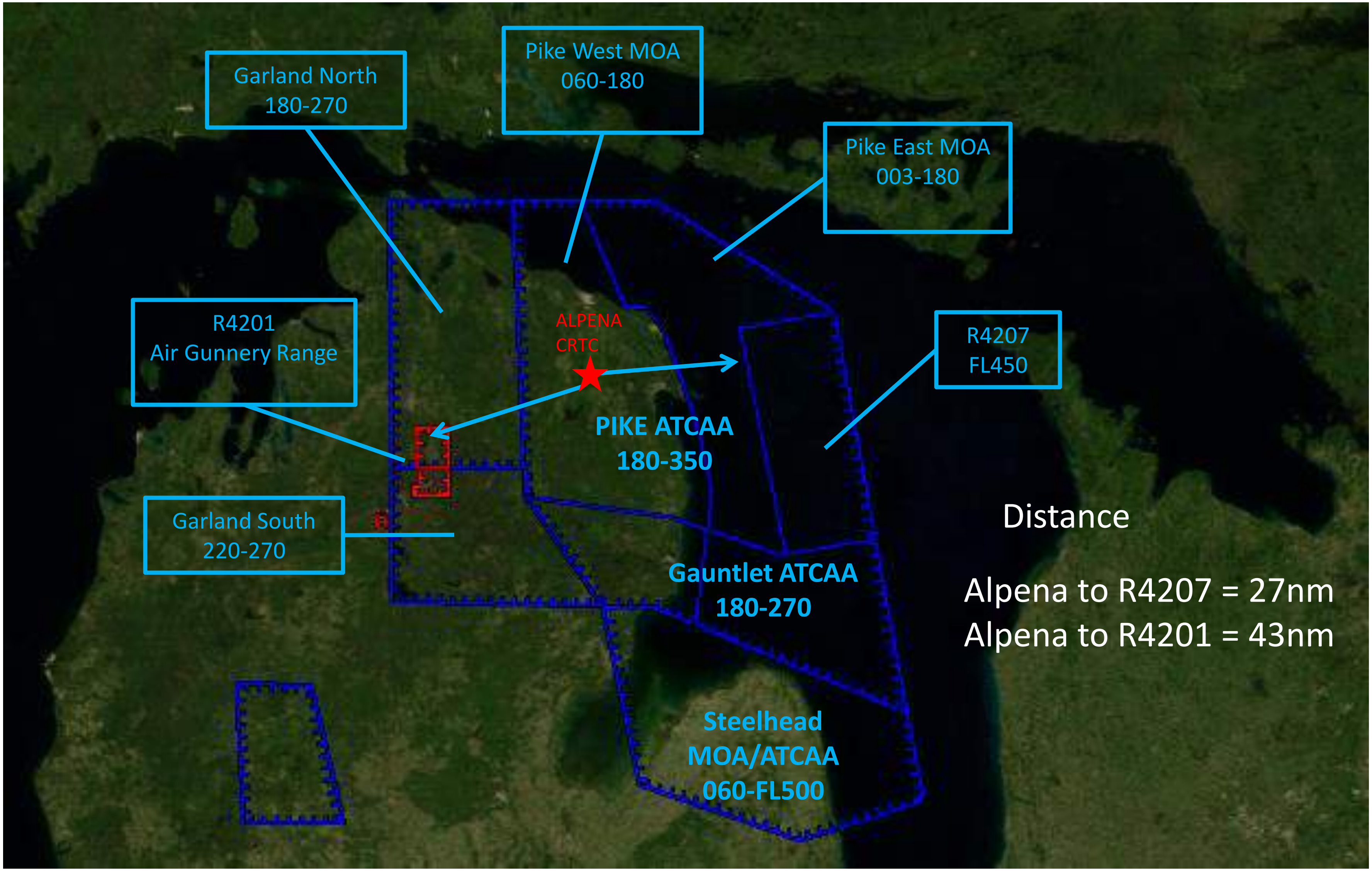
&

ALPENA COMBAT READINESS TRAINING CENTER

JOINT TRAINING COMPLEX

THE ALPENA COMBAT READINESS TRAINING CENTER

AIRSPACE


Garland North
180-270
Pike West MOA
060-180
Pike East MOA
003-180
R4201
Air Gunnery Range
ALPENA
CRTC
R4207
FL450
PIKE ATCAA
180-350
Garland South
220-270
Gauntlet ATCAA
180-270
Steelhead
MOA/ATCAA
060-FL500
Distance
Alpena to R4207 = 27nm
Alpena to R4201 = 43nm

CAMP GRAYLING JOINT MANEUVER TRAINING CENTER

Robotics


Space
Cyberspace
Air
Five Domains of Warfare
Land
Sea

“You only have to look at the distributed denial-of-service attacks that we’ve seen on Wall Street, the destructive attacks we’ve seen against Saudi Aramco and RasGas, to see what’s coming at our nation.”

General Keith B. Alexander

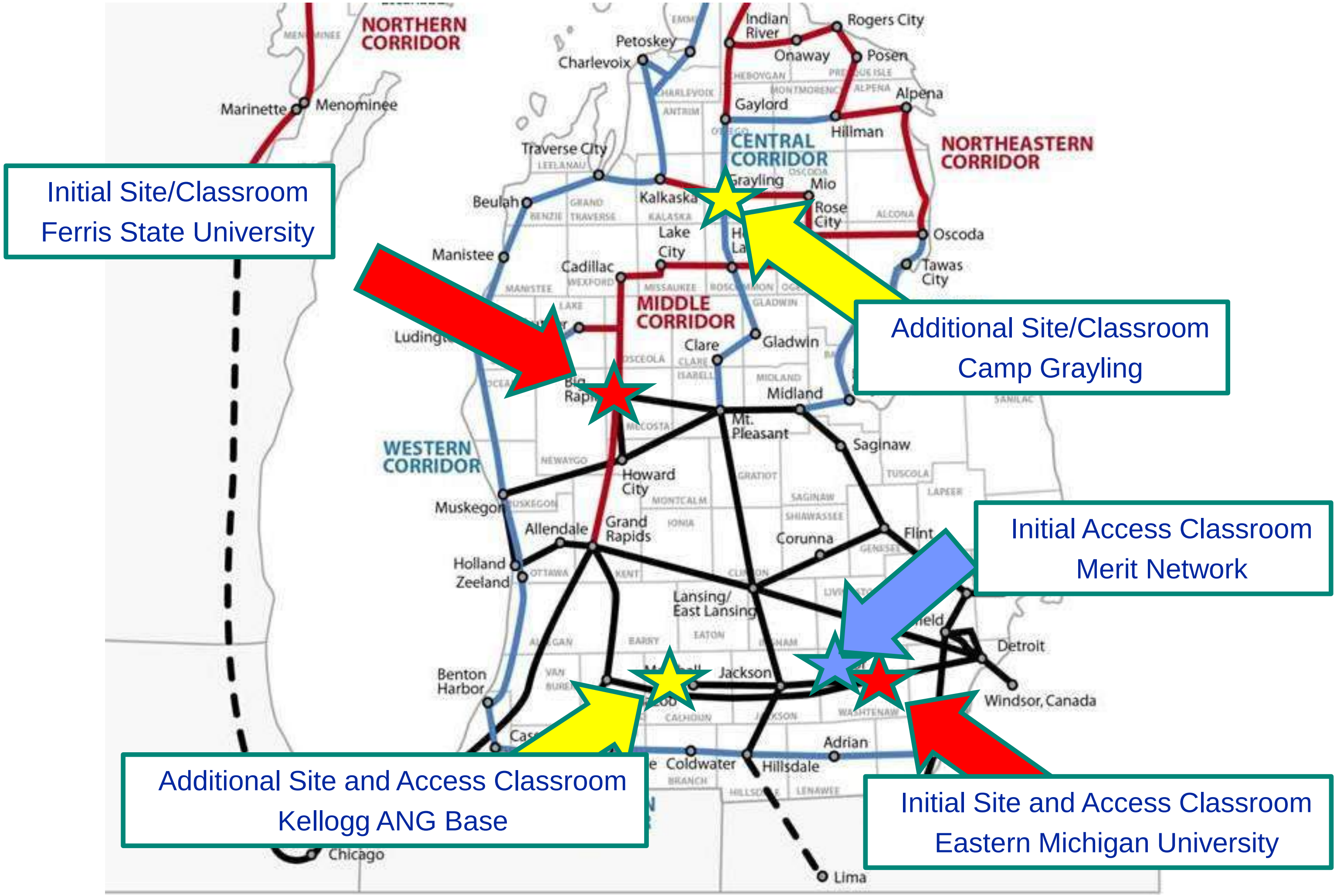
Commander U.S. Cyber Command

Cyber Attack on Saudi Aramco

Cyber Range

- Test large-scale cybersecurity solutions without impacting operations
- Emulate any host domain and an infinite variety of endpoints
- Subject virtual elements to simulated internal or external cyber exploits
- Practical and controlled setting
- Attack scenarios and security responses can be evaluated in real-world conditions and recorded, analyzed, and employed

Range Map



Initial Site/Classroom
Ferris State University
Additional Site/Classroom
Camp Grayling
Initial Access Classroom
Merit Network
Additional Site and Access Classroom
Kellogg ANG Base
Initial Site and Access Classroom
Eastern Michigan University
NORTHERN CORRIDOR
CENTRAL CORRIDOR
NORTHEASTERN CORRIDOR
MIDDLE CORRIDOR
WESTERN CORRIDOR
Marinette
Menominee
Petoskey
Charlevoix
Indian River
Rogers City
Onaway
Posen
Alpena
Gaylord
Hillman
Traverse City
Grayling
Mio
Kalkaska
Rose City
Beulah
Lake City
Oscoda
Manistee
Cadillac
Tawas City
Clare
Gladwin
Midland
Mt. Pleasant
Saginaw
Howard City
Muskegon
Allendale
Grand Rapids
Corunna
Flint
Holland
Zeeland
Lansing/
East Lansing
Detroit
Benton Harbor
Jackson
Windsor, Canada
Adrian
Coldwater
Hillsdale
Chicago
Lima

Networking Cocktail

Michigan I Prefunction

Dinner Event

Michigan Advanced Aerial System Consortium (MIAASC) : An Integrated UAS Test Center & Cluster

Day 2 – October 30th 2013

Block 3 – Commercial & Civil Applications: Business Cases and Future Opportunities

How UASs Can Help your Organization

Mario Mairena
Government Relations Manager
Association for Unmanned Vehicle Systems International (AUVSI)

Unmanned Aircraft Systems Roadmap to the Future

Mario Mairena

Government Relations Manager

AUVSI

AUVSI

ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS INTERNATIONAL

Discussion Topics

- About AUVSI

- UAS Industry Outlook

- Current Legislative Landscape

About AUVSI

AUVSI's mission is to advance the unmanned systems and robotics community through education, advocacy and leadership.

AUVSI's vision is to improve humanity by enabling the global use of robotic technology in everyday lives.

- In its 41st year, AUVSI is the ***world's largest non-profit association*** devoted exclusively to unmanned systems and robotics
  - Air, Ground and Maritime
  - Defense, Civil and Commercial
- AUVSI represents more than ***7,500 members,*** including ***more than 600 corporate members*** from more than ***60 allied countries***
  - We add a new corporate member every 3.2 days
- ***Diverse membership*** from industry, government and academia

AUVSI
ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS INTERNATIONAL

AUVSI Events

- **AUVSI's Unmanned Systems Symposium and Exhibition (Orlando, FL, 12-15 May 2014)**
  - The World's Largest Unmanned Systems and Robotics Event
  - 8,000 Delegates and 600 Exhibitors from more than 40 Countries
  - Renowned keynote speakers from industry and government
  - 100+ other presentations, panels, workshops and posters
  - Air, Ground and Maritime system demos
  - International pavilions

- **AUVSI's Unmanned Systems Program Review (Washington, DC, 4-6 November 2014)**
  - Military and Civilian Government Agency Updates on Unmanned Systems Programs

AUVSI
ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS INTERNATIONAL

AUVSI Events Cont.

- **AUVSI Hill Day: National Robotics Week (Capitol Hill, 2nd Week April)**
  - Meetings and Reception with Members of Congress and Staff
- **AUVSI's Driverless Car Summit**
  - Dedicated to understanding and working to solve the core challenges impacting driverless vehicle integration onto tomorrow's roadways.
- **AUVSI's Unmanned Systems Europe Conference (Köln, Germany, 15-16 October)**
  - Brings international UAS leaders from Europe together to address the most important trends, advancements and information impacting the UAS industry in Europe.
- **Global Reach and Participation in Events** in Australia, Canada, Europe, Asia, South America, the Middle East and the United States
- **Webinars, Roundtables, Workshops and more**


AUVSI
ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS INTERNATIONAL

AUVSI Advocacy

- AUVSI advocates for the interests of the entire unmanned systems community with Members of Congress, the FAA, and other stakeholders
- **House Unmanned Systems Caucus**, Co-chaired by Reps. McKeon (R-CA) and Cuellar (D-TX) which has more than 50 members.
- **Senate Unmanned Aerial System Caucus**, Co-chaired by Senators Inhofe (R-OK) and Manchin (D-WV), which already has 7 members.
- Testifying at Congressional hearings
- AUVSI hold numerous events on Capitol Hill every year to educate Members of Congress and their staff
- AUVSI works with other US federal agencies (DHS, DOJ, DOD, NASA, USGS…)

AUVSI
ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS INTERNATIONAL

AUVSI Products and Services

- Publications
  - *Unmanned Systems* Magazine – readership of 18,000
  - *Mission Critical* – more than 250,000 individual page views
  - eBrief – distributed to more than 40,000 individuals
- Communications
  - Media Outreach
  - Public Awareness and Education Campaign
    - www.increasinghumanpotential.org
  - Social Media
    - LinkedIn Group – 8,600 members
    - Twitter – more than 3,800 followers
    - Facebook – 2,300 followers
- Knowledge Resources
  - Knowledge Vault
  - Market Reports
    - US Jobs Report
  - Unmanned Systems & Robotics Directory
    - More than 3,800 platforms

UAS Industry Outlook

What is an Unmanned Aircraft System (UAS)

- **There is nothing unmanned about an unmanned system!**
- What are they called:
  - Unmanned Aircraft System (UAS)
    - FAA and Congress
  - Unmanned Aerial Vehicle (UAV)
  - Remotely Piloted Aircraft Sys (RPAS)
    - ICAO and Air Force

- Public perception is somewhat skewed:
  - Drones
  - Military
  - Hostile
  - Weaponized
  - Autonomy

Unmanned Systems Potential Applications

Border Security	Industrial Logistics	Search & Rescue
Arctic Research	Pollution Monitoring	Volcanic Research
Firefighting	Storm Research	Pipeline Monitoring
Flood Monitoring	HAZMAT Detection	Filmmaking
Crop Dusting	Asset Monitoring	Crowd Control
Mining	Event Security	Aerial News Coverage
Farming	Port Security	Wildlife Monitoring
Aerial Photography	Construction	Forensic Photography
Real-estate	Cargo	Power line Surveying
Communications	Broadcasting	Damage Assessment

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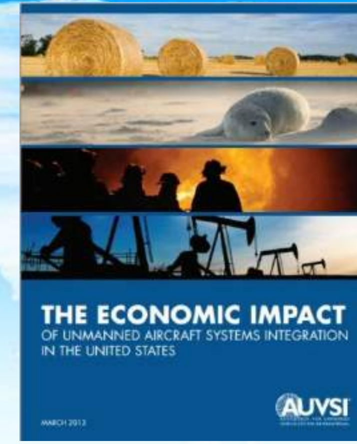
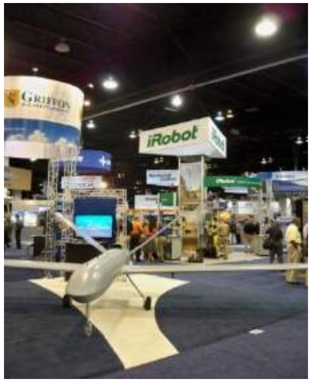
UAS Economic Potential



- **AUVSI's 2013 Economic Report:**
  - www.auvsi.org/econreport
  - The UAS global market is currently **$11.3 billion**
  - Over the next 10 years, the UAS global market will total **$140 billion**
  - The economic impact of US airspace integration will total over **$13.6 billion** in the first three years and will grow sustainably for the foreseeable future, cumulating to more than **$82.1 billion** between 2015 and 2025
  - Every year that airspace integration is delayed will cost the U.S. over **$10 billion** in lost potential economic impact, which translates to **$27 million** per day



UAS Industry on the Rise

AUVSI Economic Impact Study of UAS Integration

- **Nationally:**
  - >70,000 jobs in the first three years following integration
  - >100,000 jobs after 11 years

- **Michigan**
  - First three years following integration:
    - 965 jobs
    - $188 million in economic impact
  - In the 11 years following integration:
    - 1,426 jobs
    - $1.3 billion in economic impact

Additional economic benefit will be seen through tax revenue to Michigan, which will total more than $8.26 million in the first decade following the integration.

UAS Job Potential

- US airspace integration will create **more than 34,000 manufacturing jobs** and **more than 70,000 new jobs** in the first three years
- By 2025, total job creation is estimated at **103,000**.
- The manufacturing jobs created will be high paying and require technical degrees.

UAS Job Salary Information	
Position	Annual Salary Range
UAS Pilot	\$85,000–\$115,000
Systems Engineer	\$72,350–\$127,000
Instructor/Training Specialist	\$74,500–\$93,000
Intel/Imagery Analyst	\$57,350–\$84,600
Maintenance Specialist	\$59,500–\$67,500
Sensor/Payload Operator	\$69,300–\$89,450
Manufacturing	\$45,700–\$67,890
Consultant	\$70,500–\$145,000

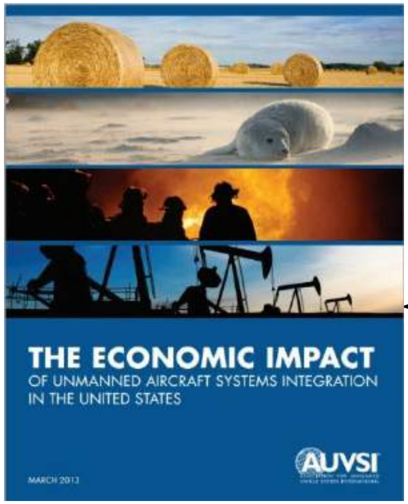
AUVSI
ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS INTERNATIONAL

UAS Industry on the Rise

Precision agriculture totals approximately **80%** of the potential commercial market for UAS

- Drought management
- Disease detection
- Watering
- Spraying pesticides

UAS in agriculture has the potential to have an **$11 billion** economic impact in the first three years following integration. Almost **$66 billion** over 11 years.



www.auvsi.org

"Precision application, a practice especially useful for crop farmers and horticulturists, utilizes effective and efficient spray techniques to more selectively cover plants and fields. This allows farmers to provide only the needed pesticide or nutrient to each plant, reducing the total amount sprayed, and thus saving money and reducing environmental impacts."

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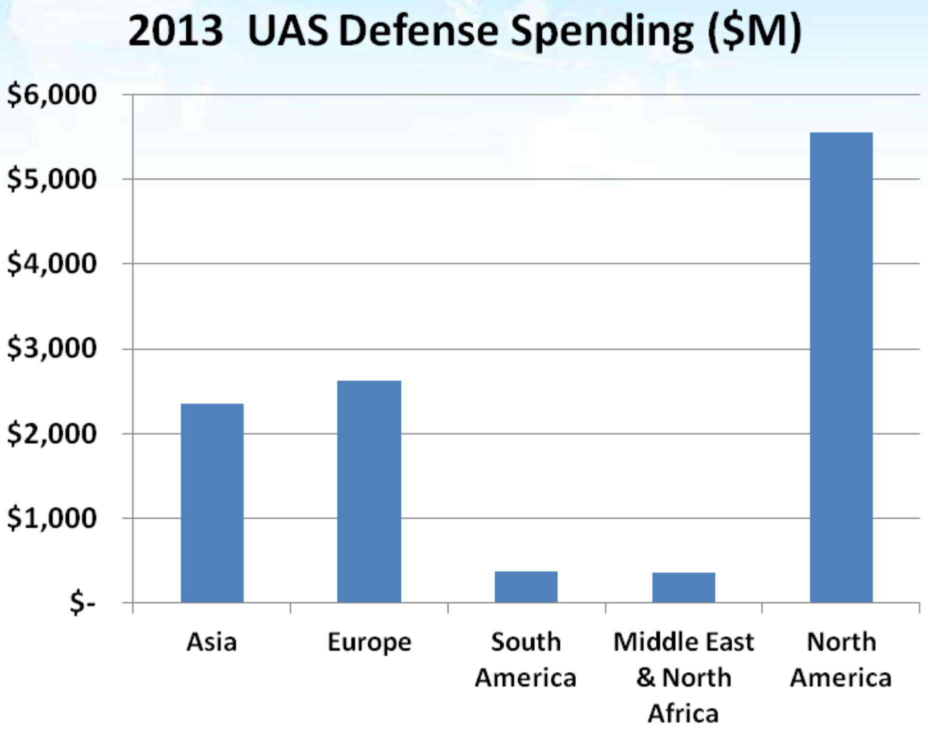
AUVSI UAS 2013 Forecast

- **UAS global defense spending** is expected to be **$11.3 billion** in 2013
- Defense spending will not grow as it has in the last 10 years
  - Likely to stagnate over next several years
  - Defense spending will increase in 5-10 years as commercial systems drive capability, reliability, and price points
- As legislation barriers lessen over next several years, commercial spending will exceed defense spending
  - Current commercial UAS use vary greatly between countries, limited by legislation
  - Countries that delay airspace integration will lag in technology development and manufacturing, relying on imports to gain UAS benefits
- Over the next 10 years**, total UAS spending will reach $140 billion**



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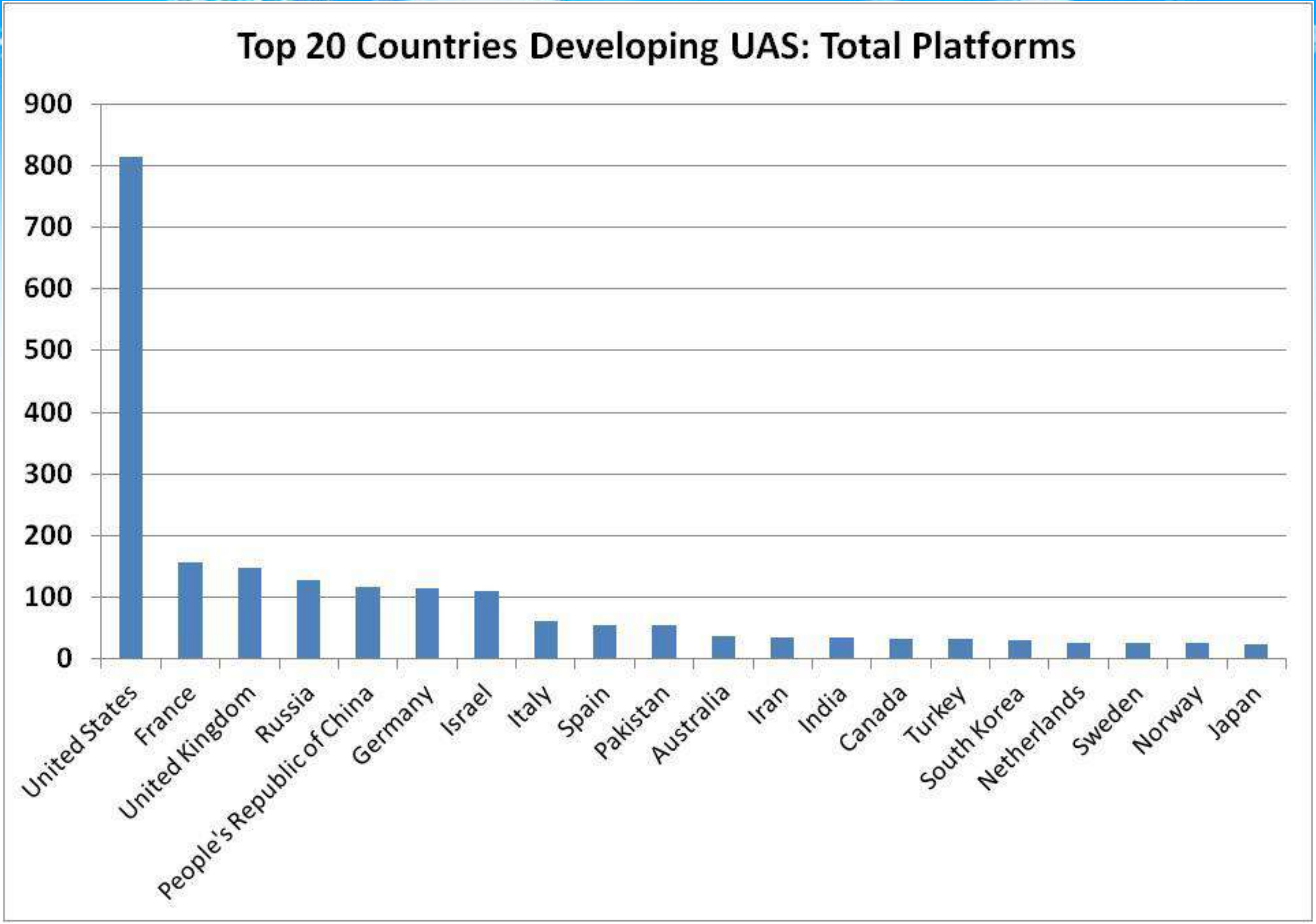
Unmanned Air Platforms – Geographic Distribution



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Recent Examples of UAS Use

- UAS credited with first live save in **vehicle rollover** in **Canada**
- **Japan** is using unmanned helicopters for **spraying crops** for pest control
- Predator B aircraft provided aerial surveillance for **Yosemite National Park** wildfire
- Predator surveyed **flood waters** in the upper Midwest
- **USGS** used small UAS to monitor Sandhill cranes, Pygmy rabbits and several other **wildlife species**
- **NOAA** using UAS to **monitor ice** and **weather conditions** in the U.S. Arctic, in addition to **wildlife monitoring**
- **Police** using small UAS for **public safety**






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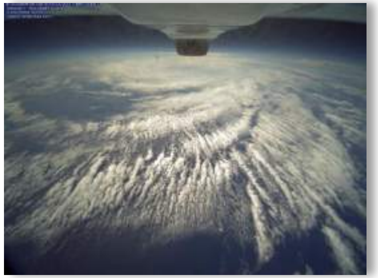
Recent Examples of UAS Use

- Aurora Flight Sciences is using the Skate UAS to study **archeological sites** in **Peru**
- **Nepal, Russia, South Africa, Thailand** testing UAS to save **endangered animals from poachers**
- **Nicholls State University** testing UAS to **map coastline**
- **Colorado State University, Univ. of Oklahoma** testing UAS to fly into **tornados**
- **NASA** launched three UAS into smoke plume of Turrialba volcano in Costa Rica
- **Kansas State University, Virginia Tech University** using UAS for **agriculture research**
- **New Caledonia** using UAS for nickel ore **mine mapping surveys**



Emerging Commercial UAV Uses

Agriculture

- UAV use for crop-dusting minimizes possibility of fatalities
- Manned crop-dusting costs up to $8.00 per acre, compared to UAV crop-dusting for just $2.00 per acre

News Media

- Over $200 million spent in media helicopter gasoline every year
- 2007: two news helicopters collide in Phoenix, Arizona; four passengers killed

Wildlife Monitoring

- 2011: 25-year veteran pilot dies in crash while conducting wildlife survey
- Flights can cost upwards of $200,000 every year
- UAVs well equipped to monitor wildlife

Federal Legislation in 2013

H.R.972: Preserving Freedom from Unwarranted Surveillance Act of 2013
Sponsor: **Rep Scott, Austin [GA-8]** (introduced 3/5/2013) Cosponsors (None)

H.R.637: Preserving American Privacy Act of 2013
Sponsor: **Rep Poe, Ted [Texas-2]** (introduced 2/13/2013) Cosponsors (11)

H.R.1083: No Armed Drones Act (NADA) of 2013
Sponsor: **Rep Burgess, Michael C. [Texas-26]** (introduced 3/12/2013) Cosponsors (1)

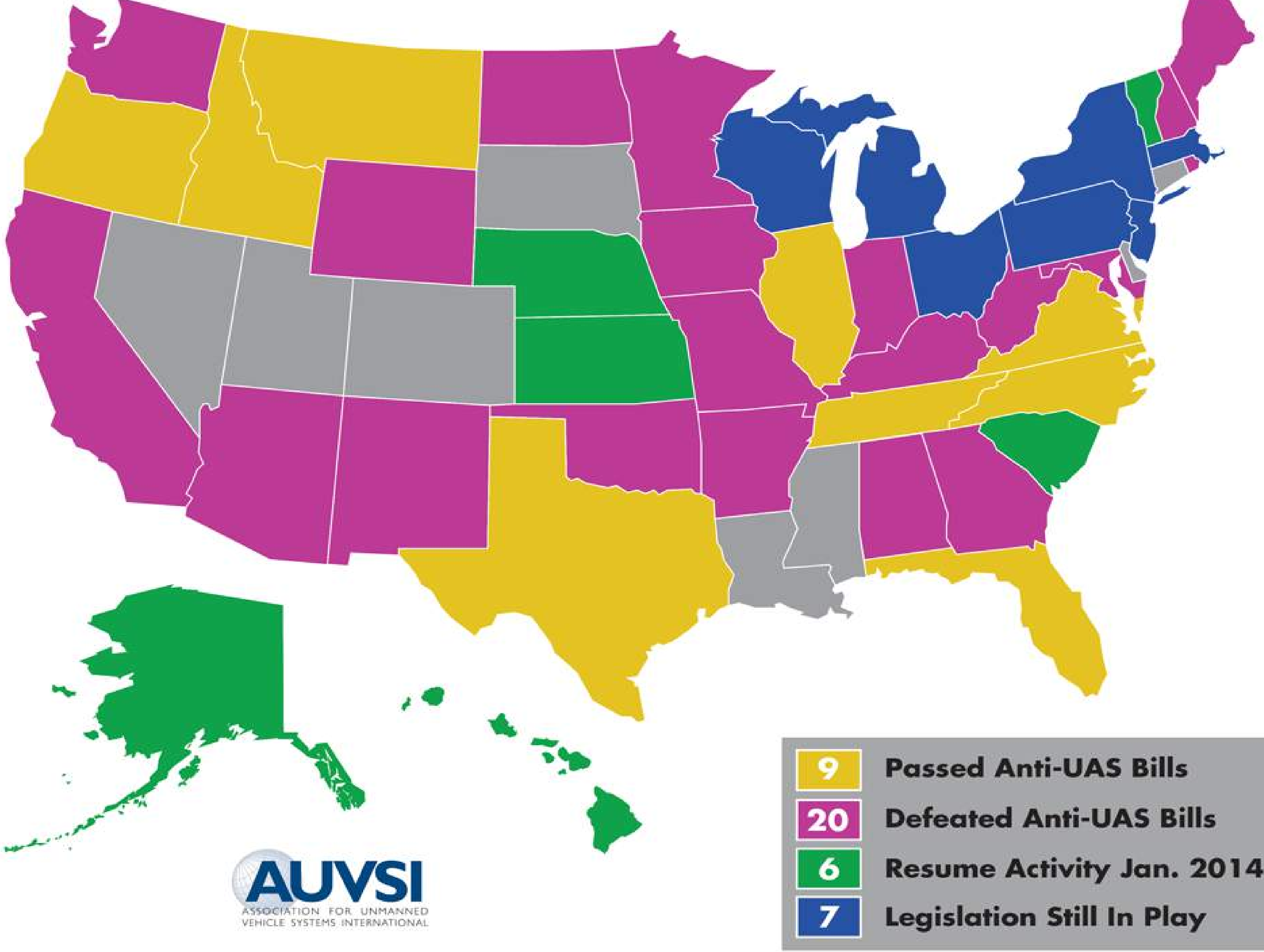
H.R.1242: To prohibit the use of drones to kill citizens of the United States within the United States.
Sponsor: **Rep Ribble, Reid J. [Wis.-8]** (introduced 3/18/2013) Cosponsors (2)

S.505: A bill to prohibit the use of drones to kill citizens of the United States within the United States.
Sponsor: **Sen Cruz, Ted [Texas]** (introduced 3/7/2013) Cosponsors (3)

H.R.1262: To amend the FAA Modernization and Reform Act of 2012 to provide guidance and limitations regarding the integration of unmanned aircraft systems into United States airspace, and for other purposes.
Sponsor: **Rep Markey, Edward J. [Mass.-5]** (introduced 3/19/2013) Cosponsors (None)

H.R.637: Preserving American Privacy Act of 2013
Sponsor: **Rep Poe, Ted [Texas-2]** (introduced 2/13/2013) Cosponsors (11)

STATES AND UAS LEGISLATION



UAS Test Sites

- Establish a program for **Six UAS test sites**
  - On 14 Feb (the one year anniversary of the FAA bill) the FAA released it's Request for Proposals
- **25** Applicants from **24** Different States
- Each applicant must file seven (7) documents on different deadlines, which will be scored, outlining:
  - Safety Plan
  - Experience
  - Risk Mitigation
  - Existing ground infrastructure
  - Airspace design
  - Economic impact assessment
  - Privacy plan

- The FAA is expected to pick the winners by December 31, 2013
- The FAA will lower scores for states that have passed restrictive UAS legislation

AUVSI's Position on UAS Privacy

All stakeholders can work together to advance UAS technology, while protecting Americans' safety, as well as their rights. AUVSI supports:

- **Transparency Measures**
  - Register unmanned aircraft and pilots with the Federal Aviation Administration (FAA)
- **Prohibiting Weaponization**
  - The FAA already prohibits the deployment of weapons on civil aircraft
- **Data Retention Policies**
  - Governing the collection, use, storage, sharing, and deletion of data
  - Policies should be available for public review and comment
  - Policies should outline strict accountability
  - AUVSI supports the International Association of Chiefs of Police model guidelines
- **Accountability**
  - The Fourth Amendment already protects against unreasonable searches
  - People should be prosecuted for violating privacy laws
- **Technology Neutral Laws**
  - Any new laws or regulations should focus on whether the government can collect and use data, not how it is collected

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Questions?

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Case Study: Chemical Industry
Monitoring the Heat

Aaron Cook
Director of Aviation
Northwestern Michigan College (NMC)

UAS and Infrastructure

Aaron Cook, Director of Aviation

Northwestern Michigan College

Northwestern Michigan College

AVIATION

DIVISION

The Project

- Validate the use of UAS in a Petroleum/Chemical/Manufacturing environment.

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Requirements To Operate

- FAA COA
- DHS regulated area
- Coast Guard Regulated area
- DEQ regulated area
- Electrically Classified Areas
- Company and plant specific safety training/requirements

UAS to be Evaluated
Aeryon Scout

Dragan Flyer X6

Sensors

- Day Video and Photo
- Infrared
- Lidar

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Equipment to Inspect

- Flares
- Tanks
- Piping
- Bridges
- Power distribution
- Cooling towers
- Steam stacks

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Current Methods

Current Methods

Current Methods

Areas To Be Addressed

- General concern over new technology
- Perception of what a UAS is
- Not intrinsically safe
- Many structures around that interfere with GPS and Magnetic Compass
- Line of sight with large structures (CC/COA)
- Heat from open flame

Areas To Be Addressed

- Pilot fatigue
- Consistency with image quality
- Current aircraft not designed for commercial applications(daily ops)
- Ensuring UAS inspections can meet regulatory requirements.
- Data management
- Uncertain performance in weather

Initial Conclusions

- Project is ongoing
- Benefits
  - More timely
  - Safer for inspectors
  - More Data
- Building more questions than answers
  - Lack of data on component reliability
- Barriers to use are extensive

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Initial Conclusions cont.

- Many lessons still to be learned
- Many, many regulators
- No immediate need, nice to have technology
- UAS technology has focused on military not commercial activity, creating the need to adapt. (cost, features)

Radio/Cell Towers

Short Term Options

Wind Turbines

Thermal Imaging

Agriculture Infrastructure

Emergency Response

Overall Thoughts

Development is still needed and applications with lower barriers to entry exist.

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Case Study: Agricultural Business Ag Applications & the Michigan Potential

Benjamin Heumann

Professor, Remote Sensing and Geo Information Center for Geo Information Science

Central Michigan University

AGRICULTURAL BUSINESS APPLICATIONS: THE MICHIGAN POTENTIAL

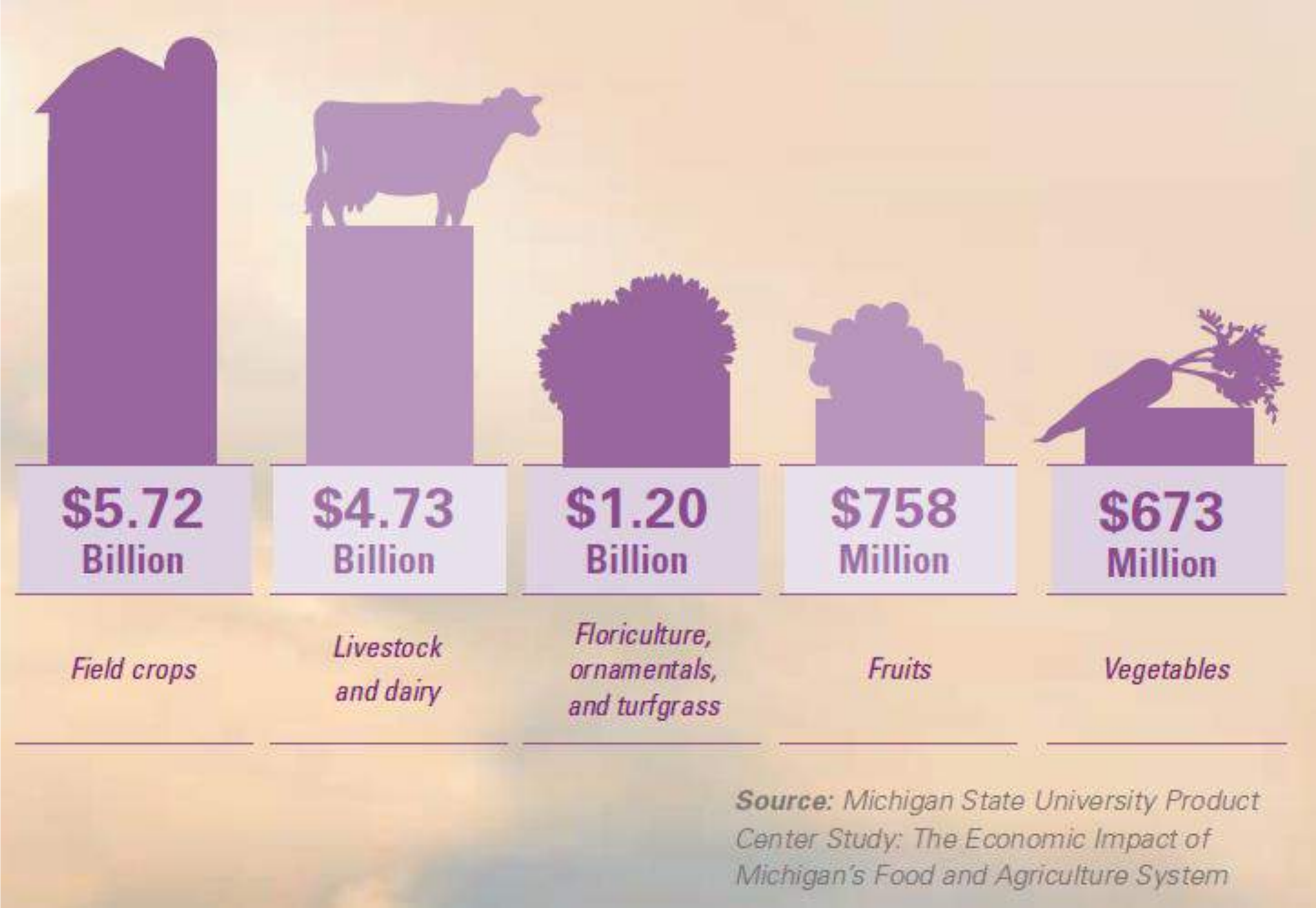
2013 MICHIGAN UAS CONFERENCE

Dr. Benjamin W. Heumann, Central Michigan University

Outline

- Background:
  - Michigan Agriculture
  - Precision Agriculture
- Applications of UAS in Precision Agriculture
  - Monitoring
  - Differential Application
- The Michigan Potential

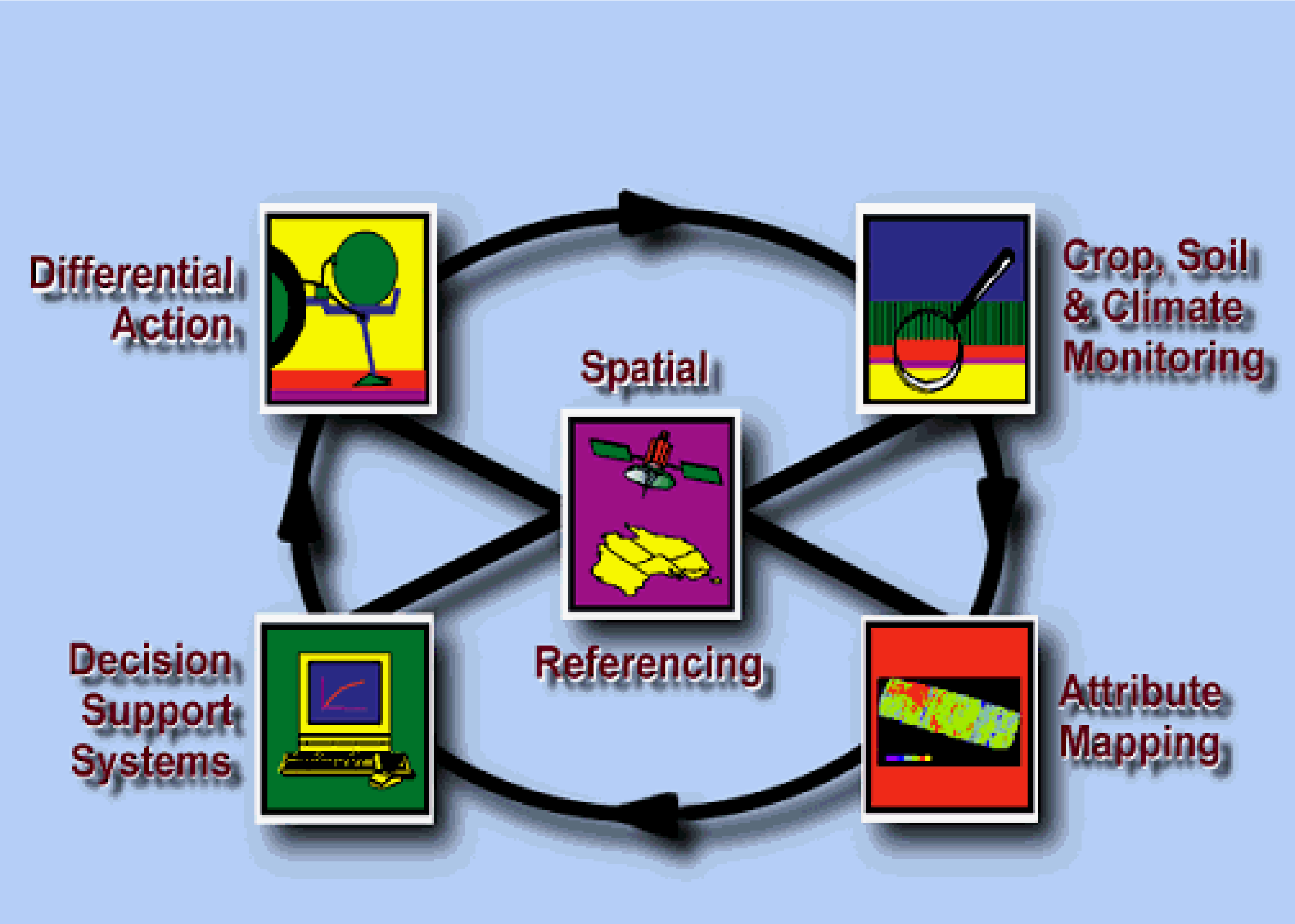
Michigan Agriculture



Michigan: an Agricultural Leader

- **#1!**
  - Blueberries
  - Tart Cherries
  - Cucumbers (for pickles)
- **#2**
  - Dry Beans (all)
  - Carrots and Celery
  - Squash
- **#3**
  - Apples
  - Asparagus
- **#4**
  - Grapes
  - Cucumbers (Fresh)
  - Sugar Beets
  - Sweet Cherries
- **#5**
  - Plums
  - Pumpkins

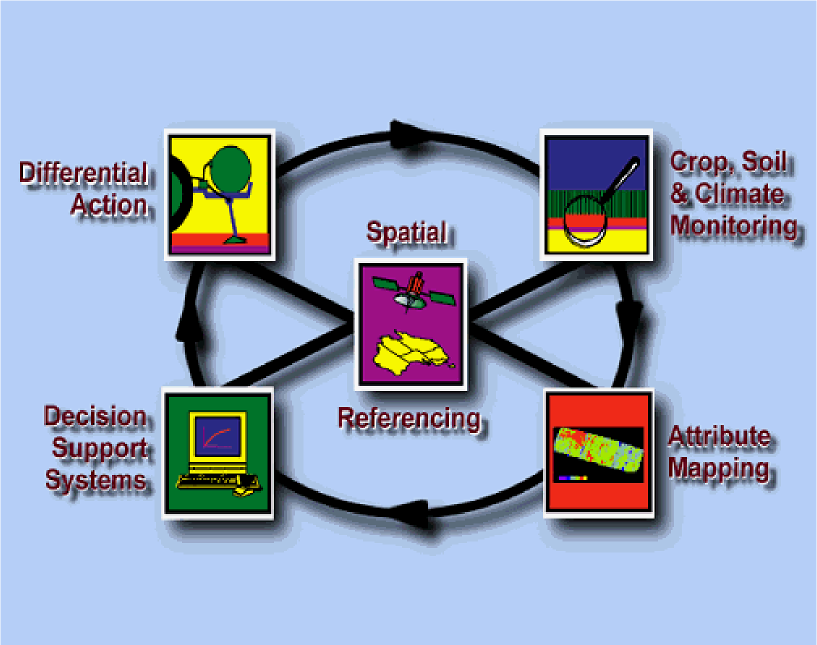
What is Precision Agriculture (PA)?



Source: McBratney and Whelan, 2001

The UAS Potential

- **<u>Attribute Mapping:</u>**
  Detailed and Timely Geographic Data
  - Climate
  - Soils
  - Plant Stress
  - Disease
  - Weeds
  - Pests
- **<u>Differential Action:</u>**
  Targeted Applications of Inputs
  - Pesticide
  - Herbicide
  - Fungicide
  - Fertilizer



UAS and Attribute Mapping

- Precision Ag. Attribute Mapping
  → Application of Remote Sensing

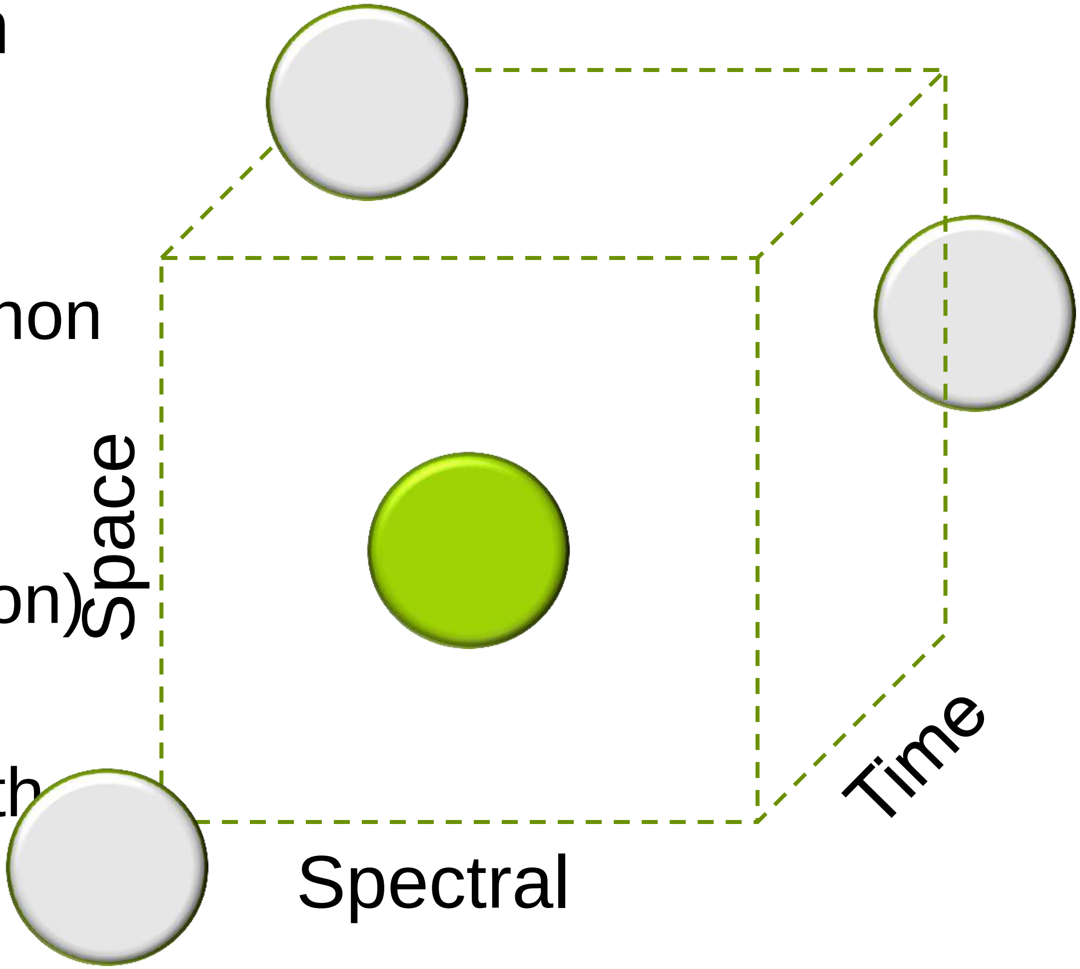
- Types of Remote Sensing
  - Photogrammetry
  - Multispectral
  - Hyperspectral
  - Thermal
  - Other

Source: Leptron Industrial Robotic Helicopte

Monitoring Issues

Scales of Detection:
Extent and Resolution

- Temporal Scale
  - Revisit Time
  - Timing of Phenomenon
- Spatial Scale
  - Areal Extent
  - Pixel Size (Resolution)
- Spectral Scale
  - Color vs. Wavelength



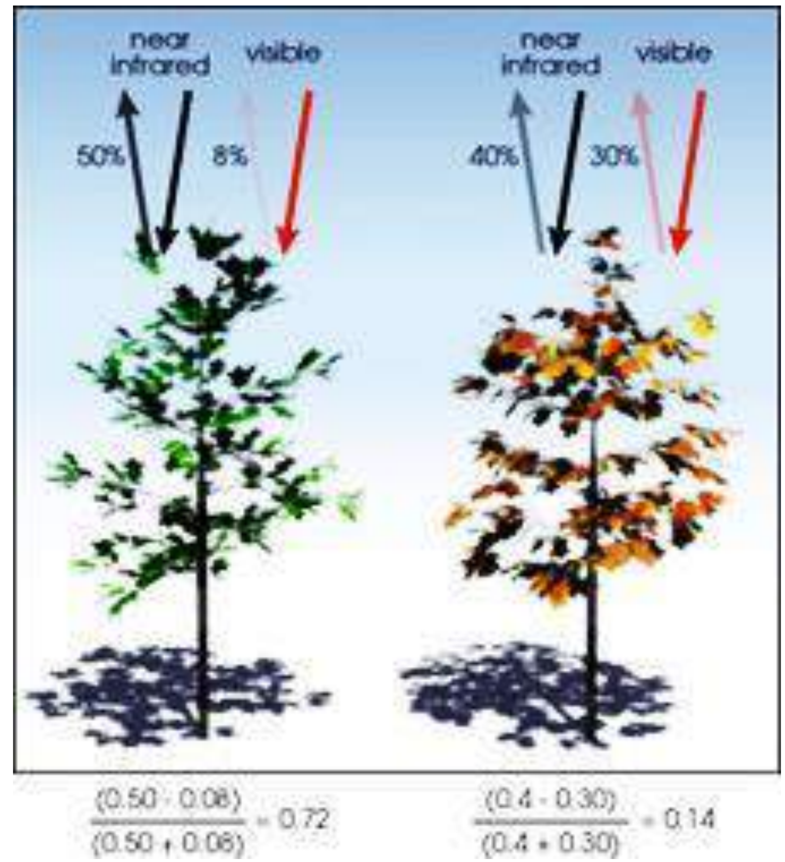
Monitoring – Photogrammetry (Air Photos)

- "Bird's Eye View"
- Photographs as Geographic Information
- Visual Interpretation of Crop Health
- Digital Photogrammetry
  - 3D Surface Modeling
- Low Cost

Source: Leptron Industrial Robotic Helicopte

Monitoring – Multispectral

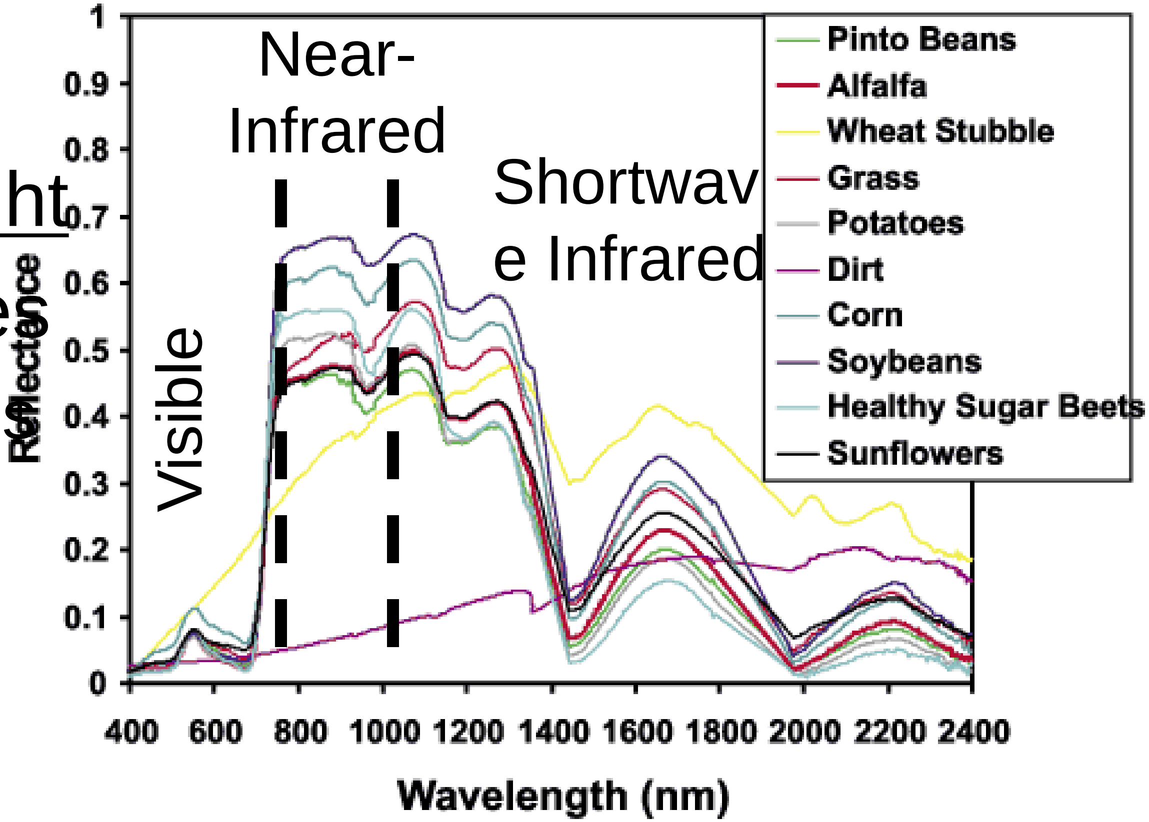
- Precise Measurement Reflected Light (watts/sq. m)
- Multispectral: Broadband "Colors" into Infrared
  - Chlorophyll absorbs Red
  - Red and NIR → NDVI
  - General Vegetation Health / Density
- Cost / Processing



Credit: Robert Simmon, NASA

Monitoring – Hyperspectral

- Measurement of Continuous Wavelengths of light
- Spectral Signatures
  - Narrowband Ratios
  - Slope
  - Shape

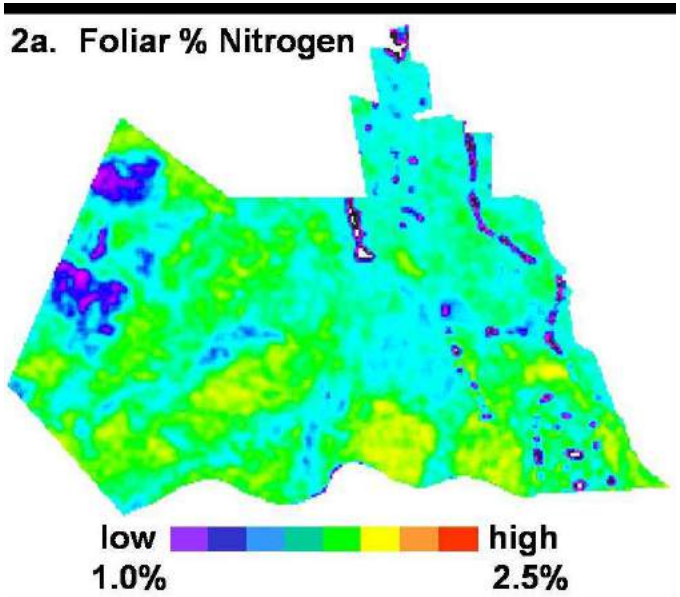


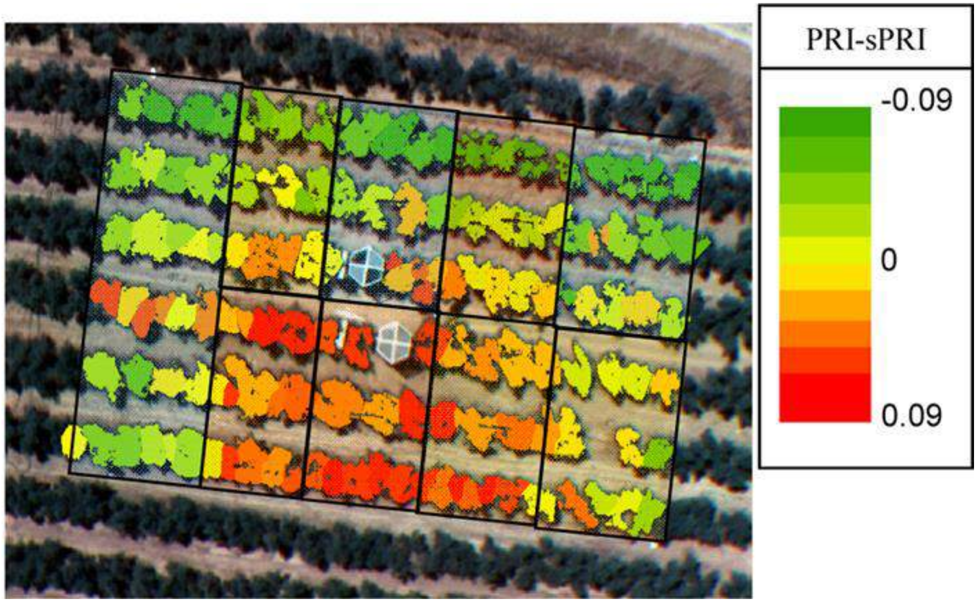
Source: Kyllo, 2003

Monitoring - Hyperspectral

<u>Applications</u>

- Water Stress
- Leaf Pigments
- Disease
- Weed Detection





Zarco-Tejada et al. 2008

Smith et al. 2003

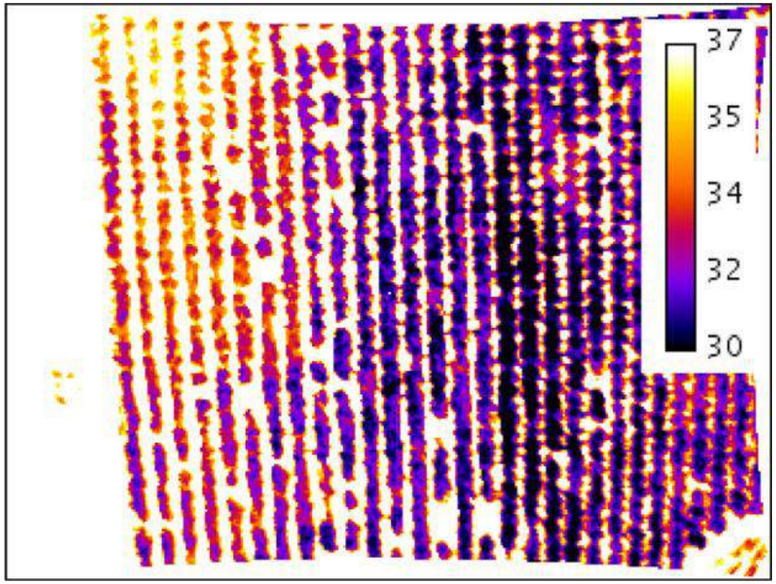
- Expensive sensors and requires stringent procedures

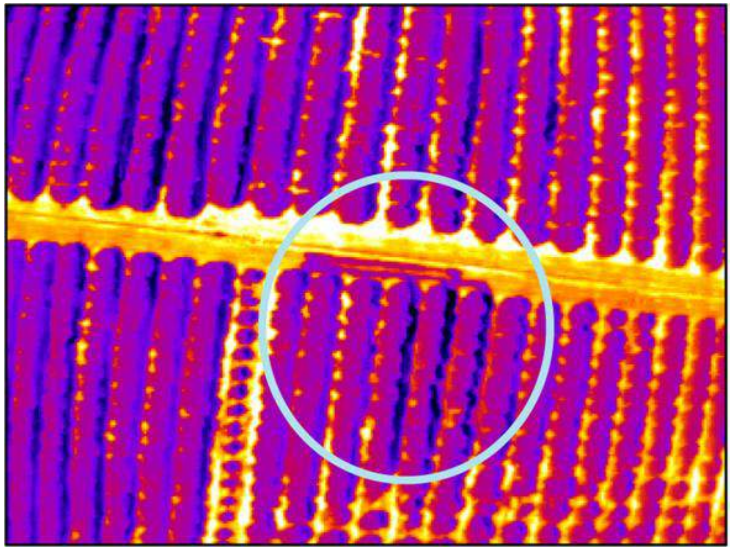
Monitoring - Thermal

Surface Temperature Imaging

Applications

- Water Stress
- Water Use / Waste





Zarco-Tejada et al. 2008

Monitoring - Summary

<u>Types of Remote Sensing</u>

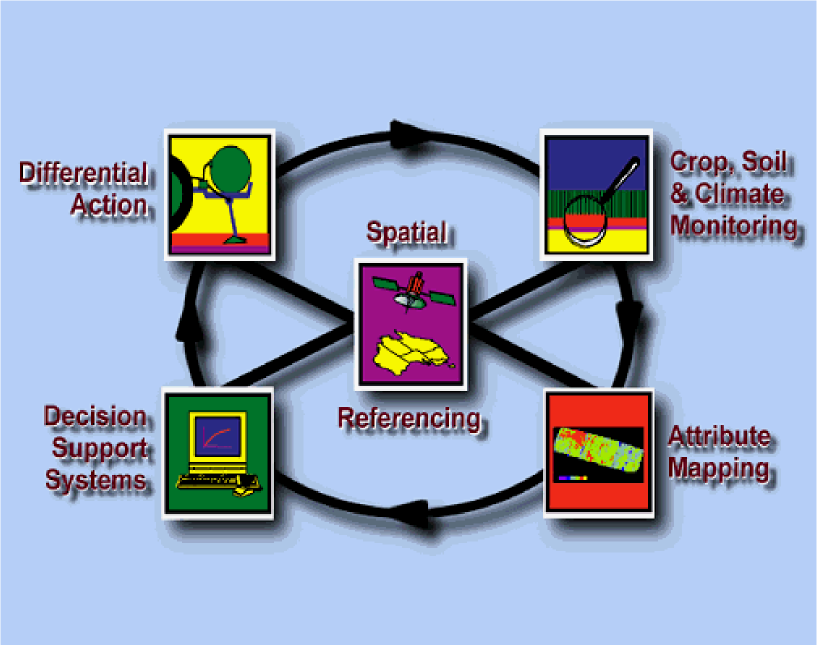
- Photogrammetry
- Multi/Hyperspectral
- Thermal
- Others
  - LIght Range And Detection (LIDAR)
  - Synthetic Aperture Radar (SAR)
  - Air Sampling

<u>Why UAS?</u>

- <u>Temporal Scale</u>
  - Quick Deployment
  - Flexible Timing
- <u>Spatial Scale</u>
  - High Resolution
- <u>Spectral Scale</u>
  - Flexible Sensor Options

The UAS Potential

- **Attribute Mapping:**
  Detailed and Timely Geographic Data
  - Climate
  - Soils
  - Plant Stress
  - Disease
  - Weeds
  - Pests
- **Differential Action:**
  Targeted Applications of Inputs
  - Pesticide
  - Herbicide
  - Fungicide
  - Fertilizer



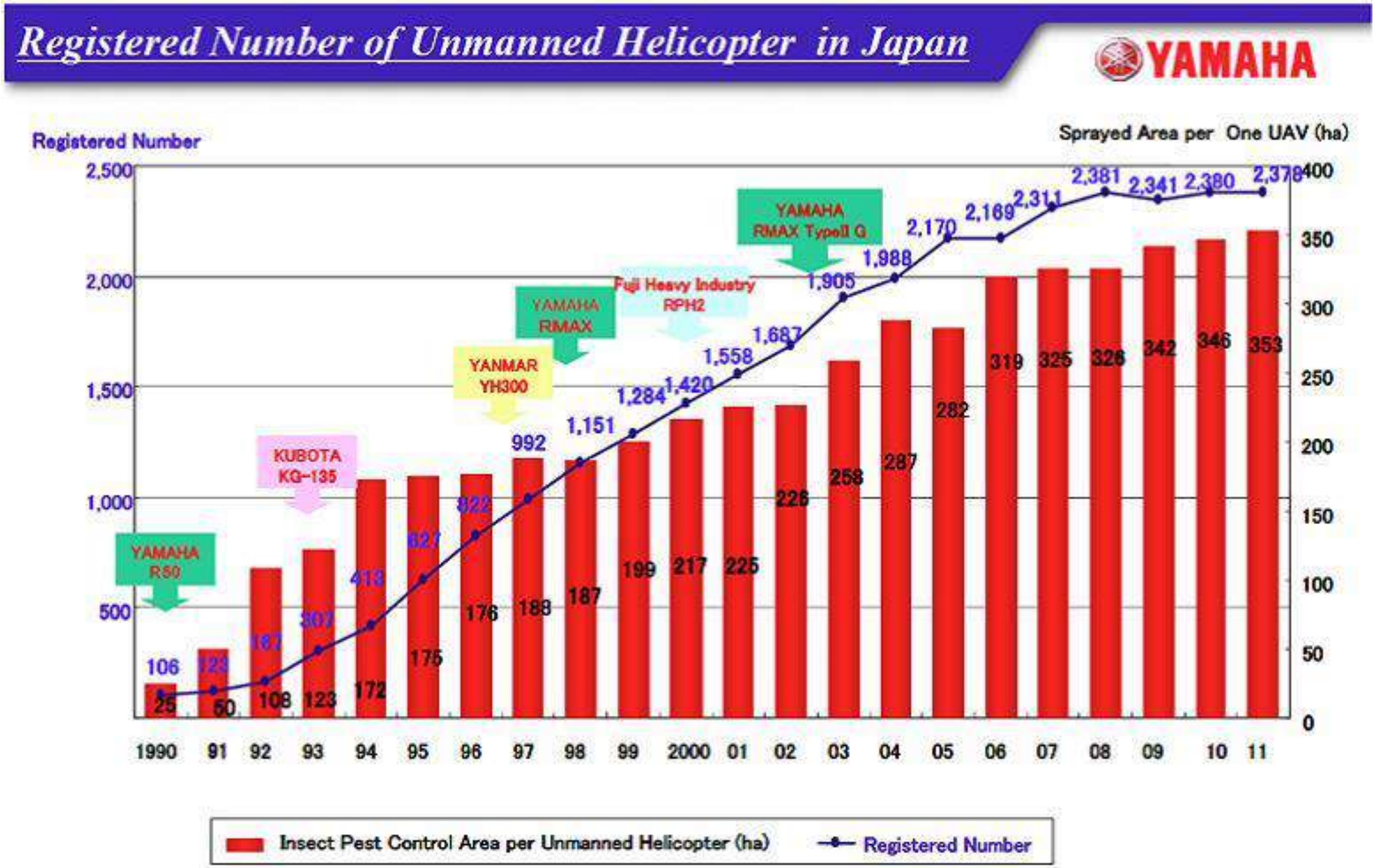
UAS and Differential Applications

Differential Applications

- Targeted Pesticide / Herbicide / Fungicide
  - Reduced financial cost
  - Reduced human health hazard
  - Reduced environmental pollution
- UAS use in small areas
  - Family Farms and Orchards
  - Mosaicked Landscape
- UAS at low altitude
  - Less Drift / Loss / Exposure

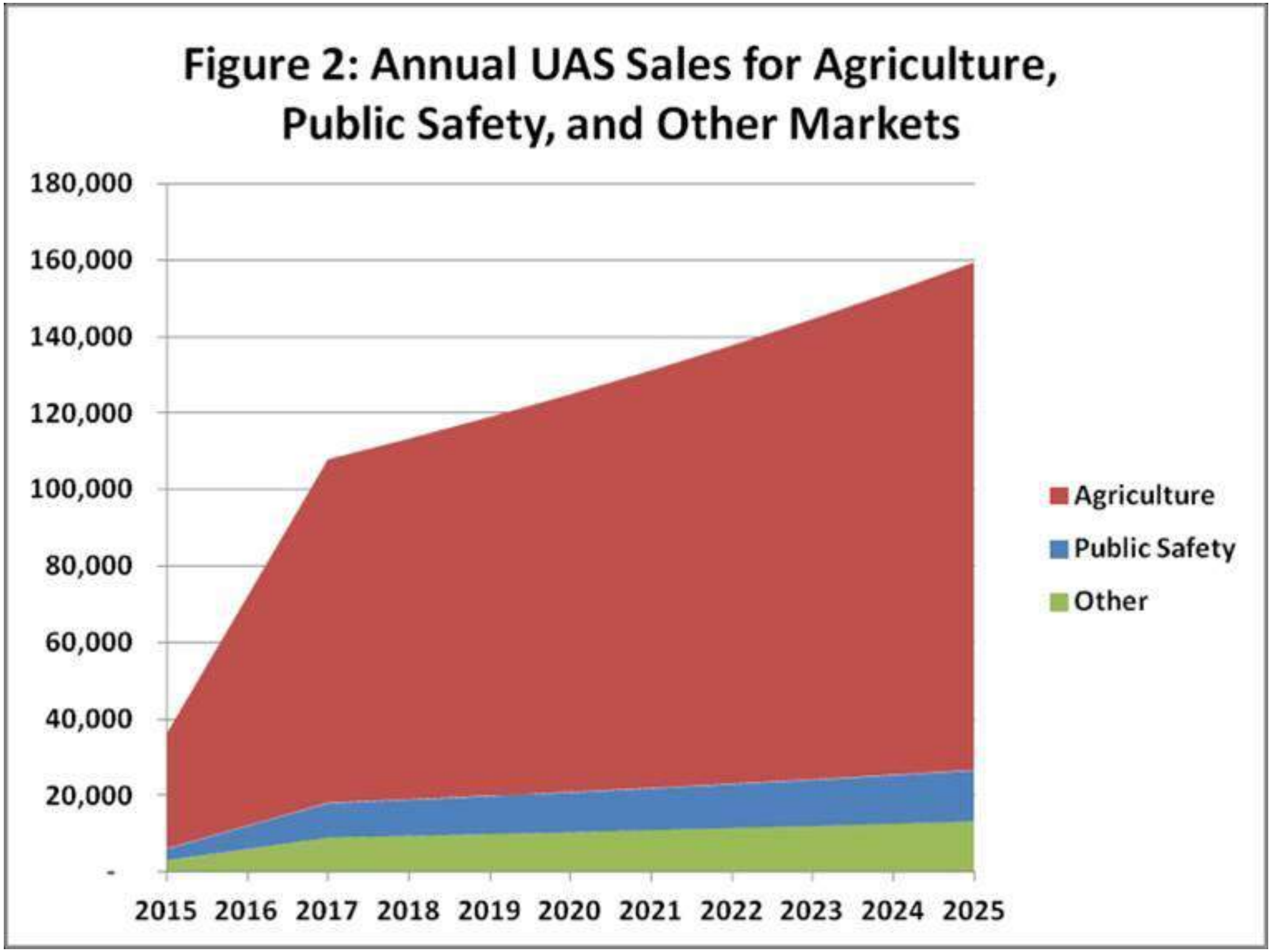
Source: Joe Proudman/UC Davis

UAS and Differential Applications:
Is there really demand for this situation?



Sato, Akira (2011, October) printed in AUVSI Economic Report 20

The UAS Potential



AUVSI Economic Report 2013

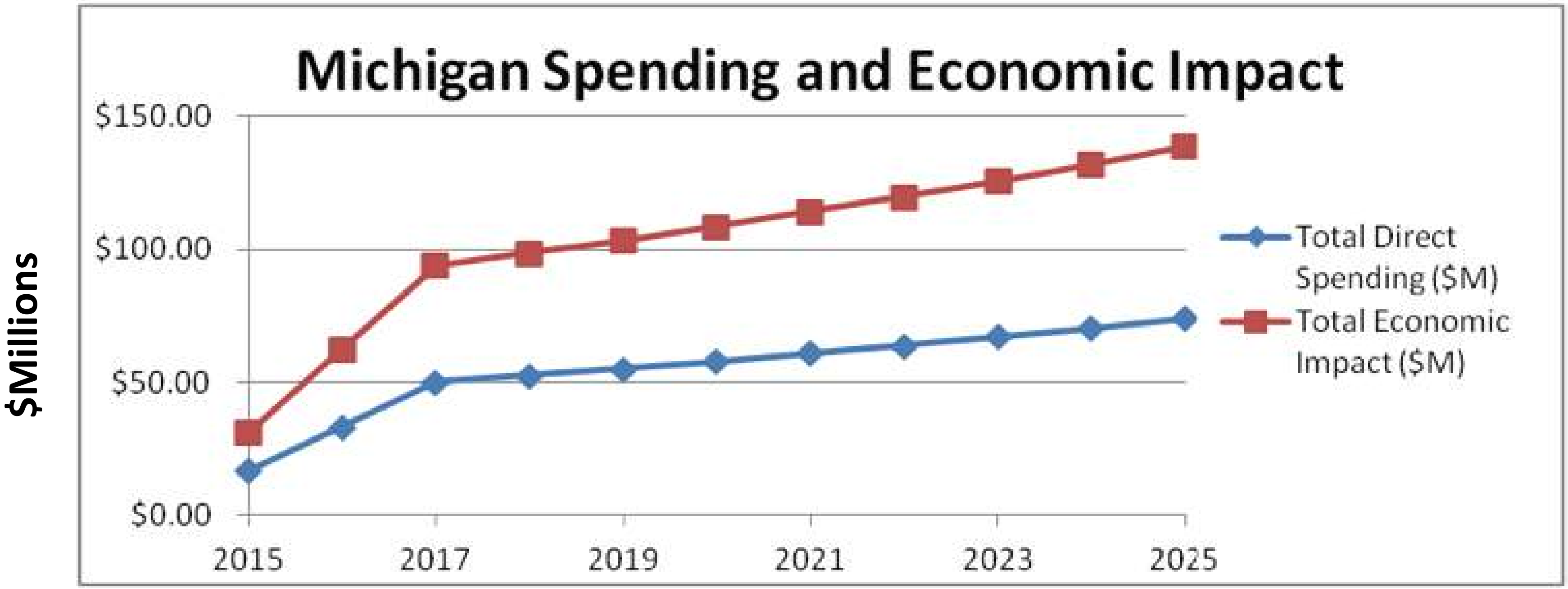
The Michigan Potential - 2015

- **Major MI Crops**
  - Cherries
  - Grapes
  - Apples
  - Cucumbers
  - Blueberries
  - Beans
- **Applications**
  - Monitoring
  - Differential Application

- **Total Economic & Employment Impacts of Ag. Spending**
  - Payroll: $6,050,323
  - Parts: $9,090,485
  - Taxes: $210,899
  - Employment: 296 jobs

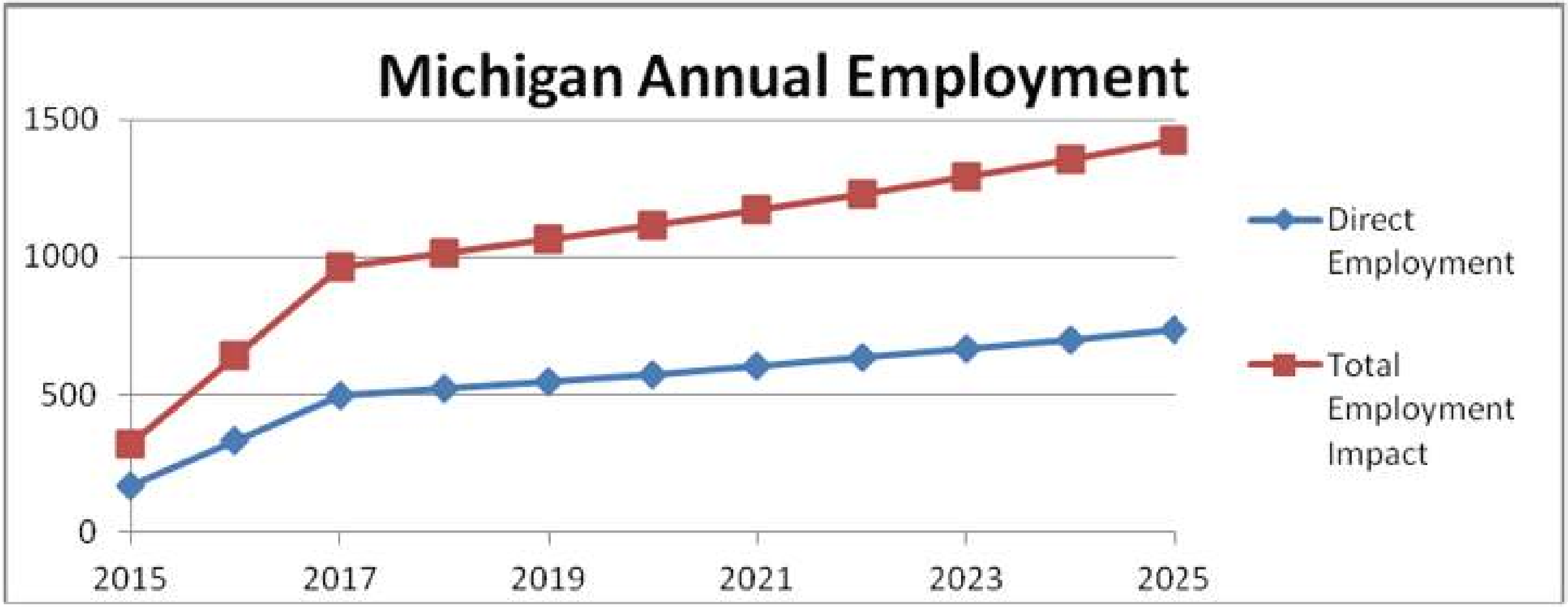
AUVSI Economic Report 2013

The Michigan Potential – 2015 and Beyond



AUVSI Economic Report 2013

The Michigan Potential – 2015 and Beyond



AUVSI Economic Report 2013

Summary

Precision Ag Needs	UAS Solutions

Precision Ag Needs

- Timely Geographic Data
  - Pests
  - Weeds
  - Disease
  - Plant Stress
- Differential Action
  - Pesticides/Herbicides
  - Fertilizer

UAS Solutions

- Lower-cost
- Quick and Flexible Deployment
- Low Altitude
- Well-suited to size of MI farms and major crops

Thanks You, Questions?

CMU's Chippewa Hyperspectral Imaging Platform

Break

The Future of Training & Simulation

Gilles Laflamme
Director, Mission Solutions
CAE

Applying Remote Sensing Technologies for Transportation Infrastructure Assessment in Michigan

Chris Roussy and Rick Dobson
Research Scientists
Michigan Technological Research Institute (MTRI)

MichiganTech Research Institute

Applying remote sensing technologies for transportation infrastructure assessment in Michigan

Colin Brooks, Rick Dobson, Chris Roussi, Tim Colling,Thomas Oommen, Timothy C. Havens, Theresa M. Ahlborn, Dave Dean, Melanie Kueber.

Center for Technology & Training

U.S. Department of Transportation
Research and Innovative Technology Administration

MichiganTech Research Institute
www.mtri.org

MichiganTech Transportation Institute

MichiganTech
Michigan Technological University
Department of Civil & Environmental Engineering

MichiganTech
Michigan Technological University
Department of Electrical and Computer Engineering

MichiganTech
Michigan Technological University
Department of Geological/Mining Engineering & Sciences

Previous MTRI Work: USDOT-RITA Project

- **Characterization of Unpaved Road Conditions through the Use of Remote Sensing -** http://www.mtri.org/unpaved/
- Bergen RC helicopter & multi-rotor used to collect overlapping imagery from about 75ft above the road surface

Bergen Tazer 800 ready for deployment

Nikon D800 mounted to the bottom of the helicopter

Bergen Hexacopter: more stable, more reliable, safer to operate

- Weight: 4kg unloaded
- Max flight time: 20 min w/ small payloads
- Max Payload: 5kg
- GPS IMU: Autopilot system capable of holding position and altitude; waypoint system available
- Stabilized mount that allows for the sensors to be pointed in various directions, independent of platform movement
- Flies back to and lands at the spot at which it was turned on if it loses radio contact
- Able to deploy within minutes
- First person viewer system with heads up display that provides a readout of altitude, speed, rate of ascent and battery life.

Unpaved Road Characteristics

- Unpaved roads have common characteristics (Army URCI manual)
  - Cross Section (Loss of Crown)
    - Facilitates drainage, typically 2% - 4% (up to 6%) vertical change
    - Sloping away from the centerline to the edge
    - Measure the profile every 10' along the road direction
    - Able to detect a 1% change across a 9'-wide lane
  - Potholes
    - <1', 1'-2', 2'-3', >3‘ width bins
    - <2”, 2”-4”, >4” depth bins
  - Ruts
    - Detect features >5”, >10' in length, precision +/-2”
  - Corrugations (washboarding)
    - Classify by depth to a precision of +/-1”
    - <1”, 1”-3”, >3”
  - Report total area of the reporting segment affected
  - Roadside Drainage
    - System should be able to measure ditch bottom
    - Relative to road surface within +/-2”, if >6”
    - Detect the presence of water, elevation +/-2”, width +/-4”
  - Float aggregate (berms)
  - Surface type
  - Surface width
    - Collected every 10', with a precision of +/- 4”








TM 5-626
TECHNICAL MANUAL
UNSURFACED ROAD MAINTENANCE MANAGEMENT
HEADQUARTERS, DEPARTMENT OF THE ARMY

Unpaved Roads Demonstration

- http://www.youtube.com/watch?v=KBNQzM7xGQo

Performance – Collected Imagery

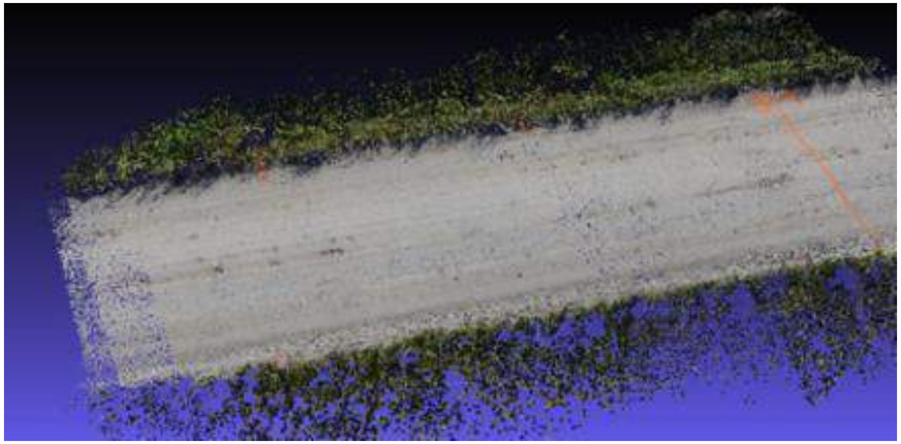
Performance – Collected Imagery

MichiganTech Research Institute

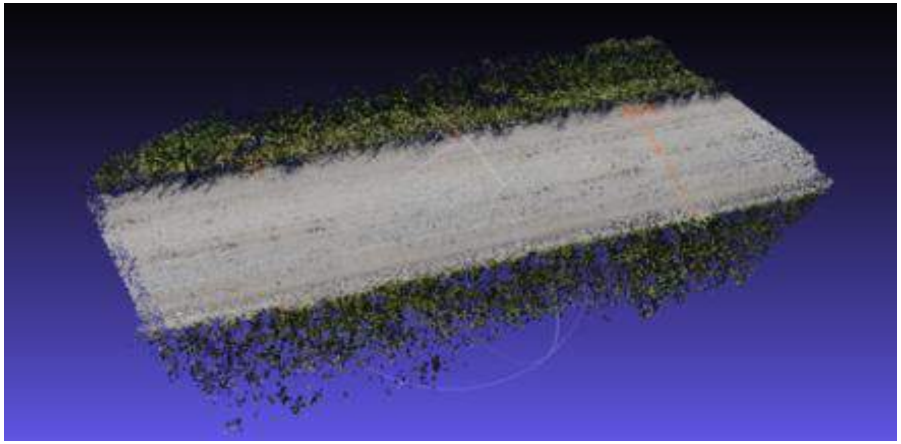
Processing Overview

- Generate a 3D point cloud from multiple overlapping photographs (more images -> better 3D resolution)
- Densify point cloud using patch-based multi-view stereo
- Fit a “water-tight” surface to the point cloud
- Reorient the surface to a standard orientation
- Find distresses from surface characteristics
- Format the distresses using standard metrics (e.g. unsurfaced road condition index (URCI)) and output in a standard format (XML)
- NOTE! None of the outputs you are about to see are actually displayed for the user

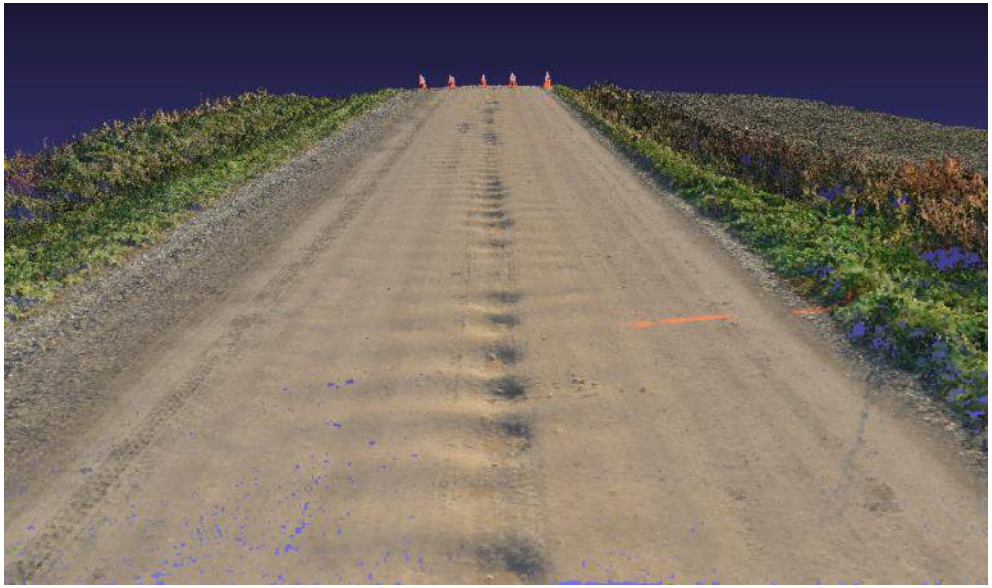
3D Reconstruction (Helicopter)



Initial point cloud

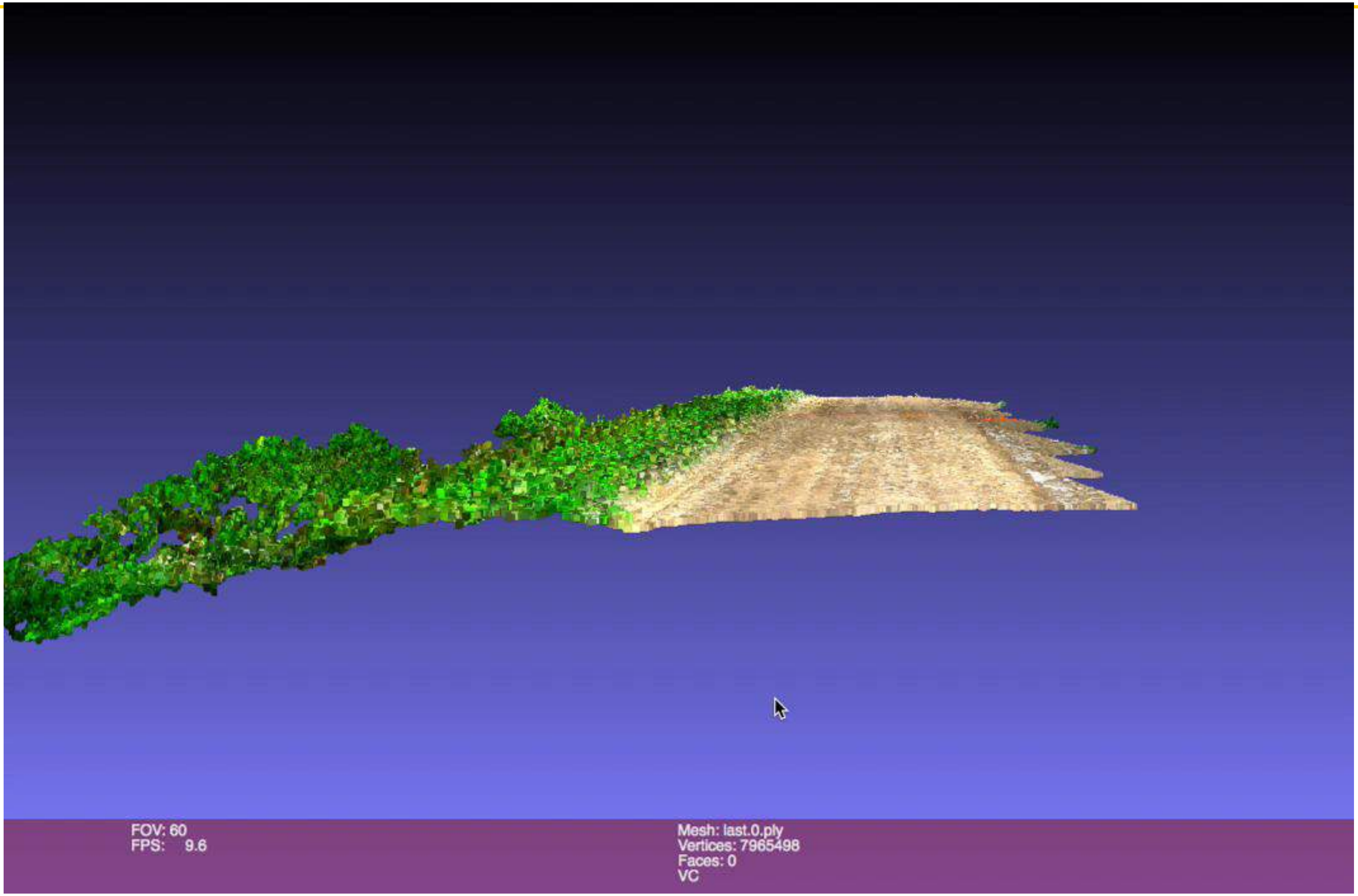


Densified point cloud

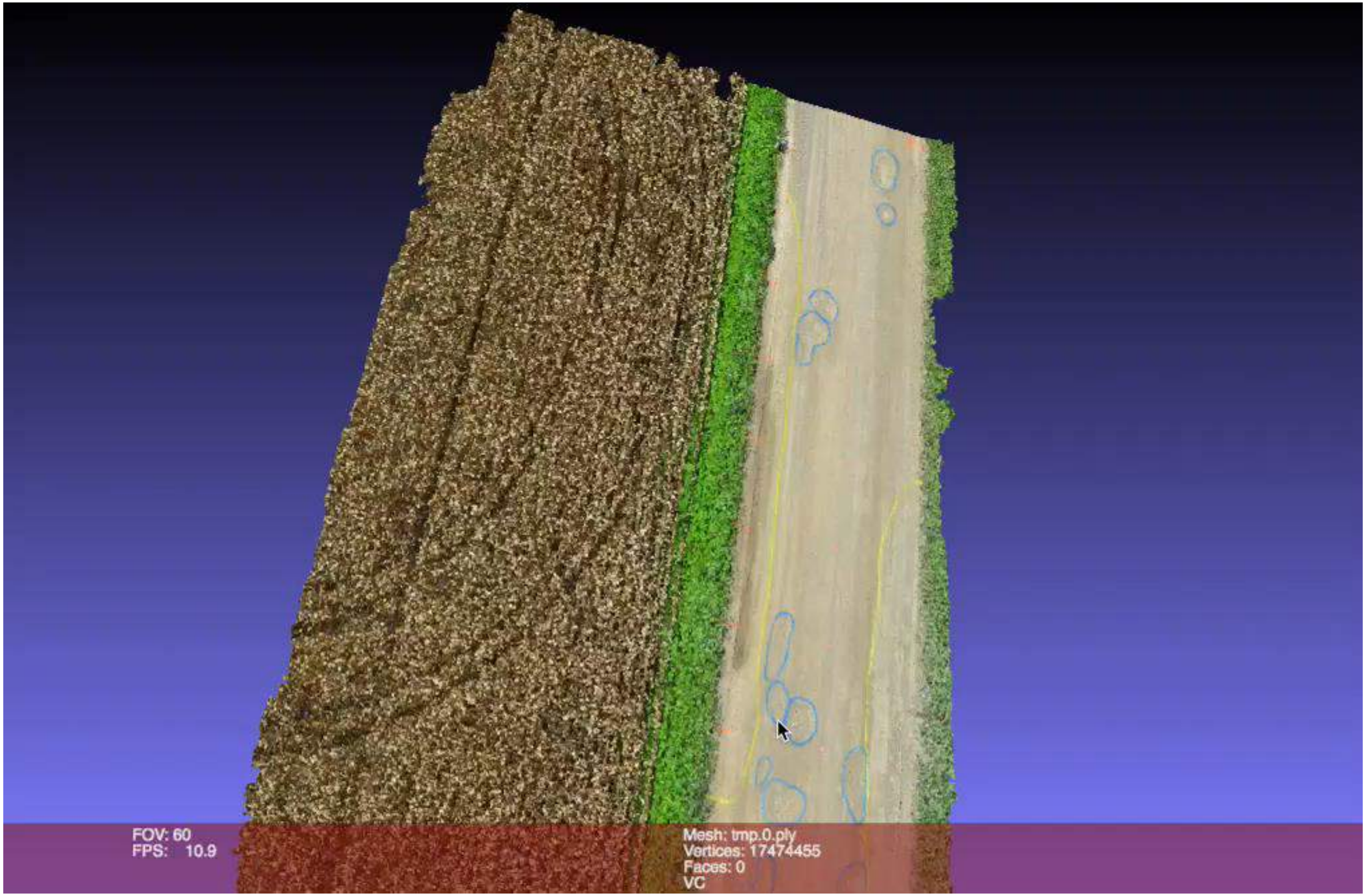


3D surface from point cloud

3D of Palmer Hwy (Hexacopter, 5 images)

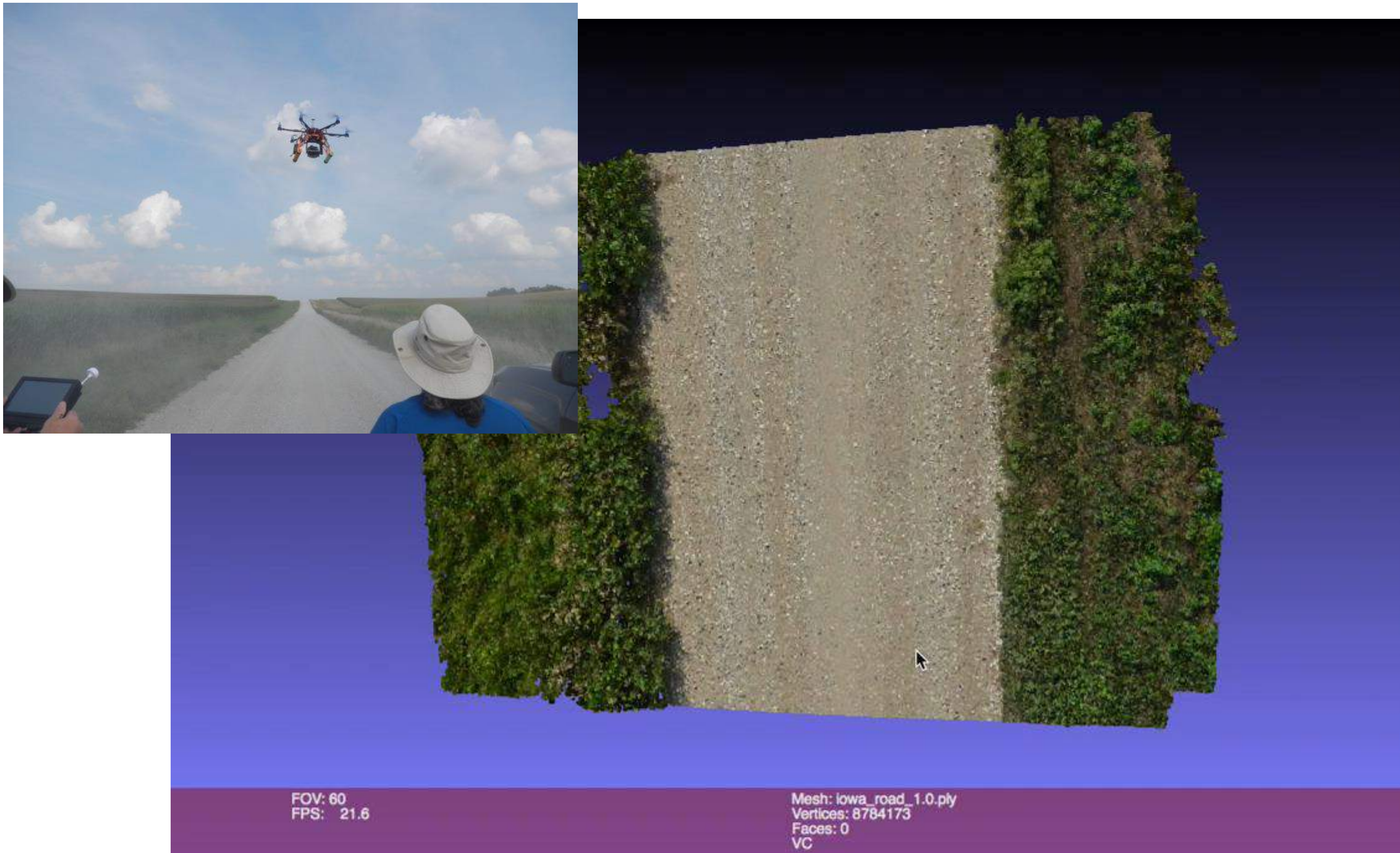


3D of Piotter Rd (Hexacopter, 27 images)



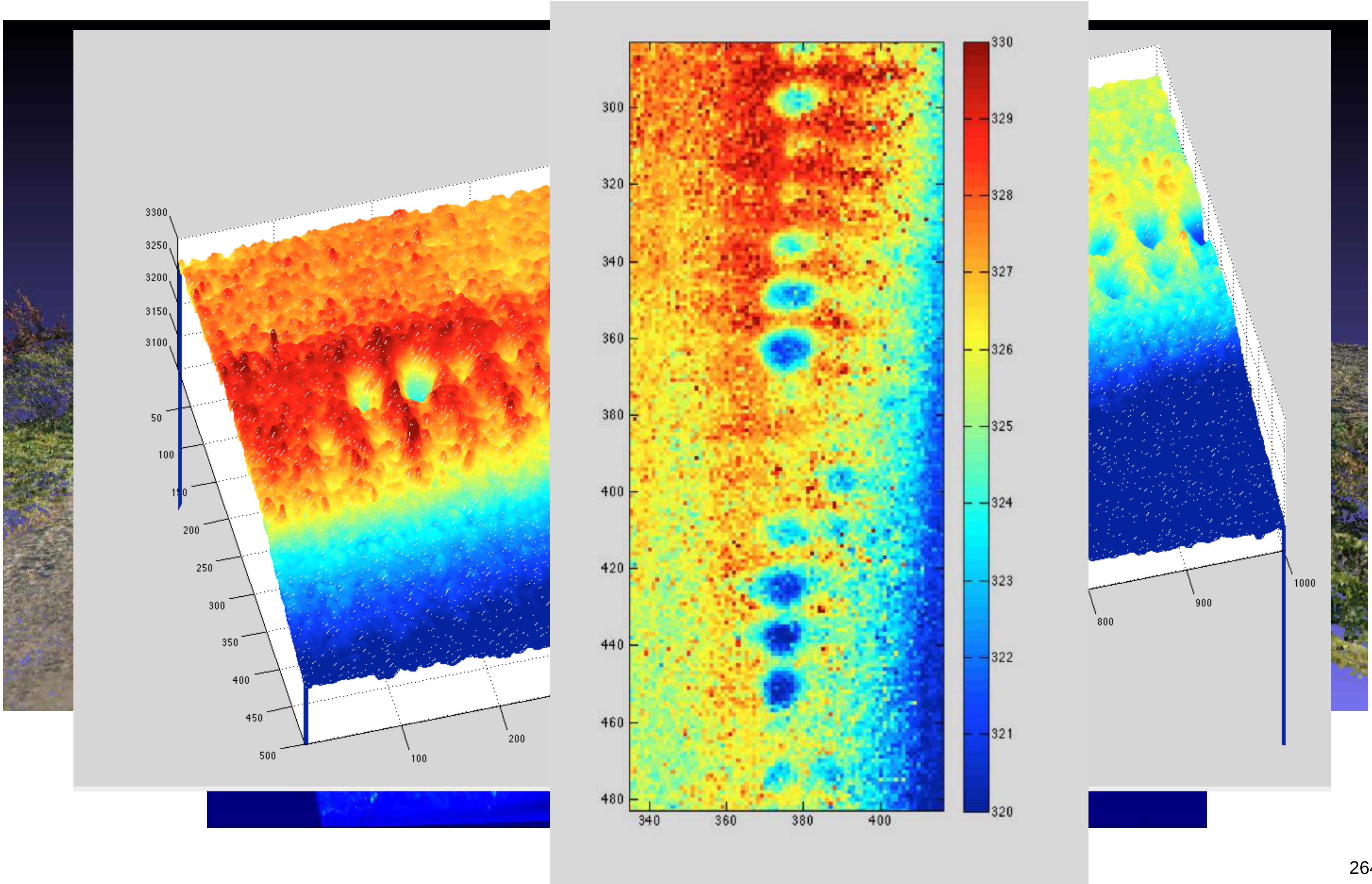
Michigan Tech Research Institute

3D of an Iowa Road (Hexacopter, 18 images)



3D data examples

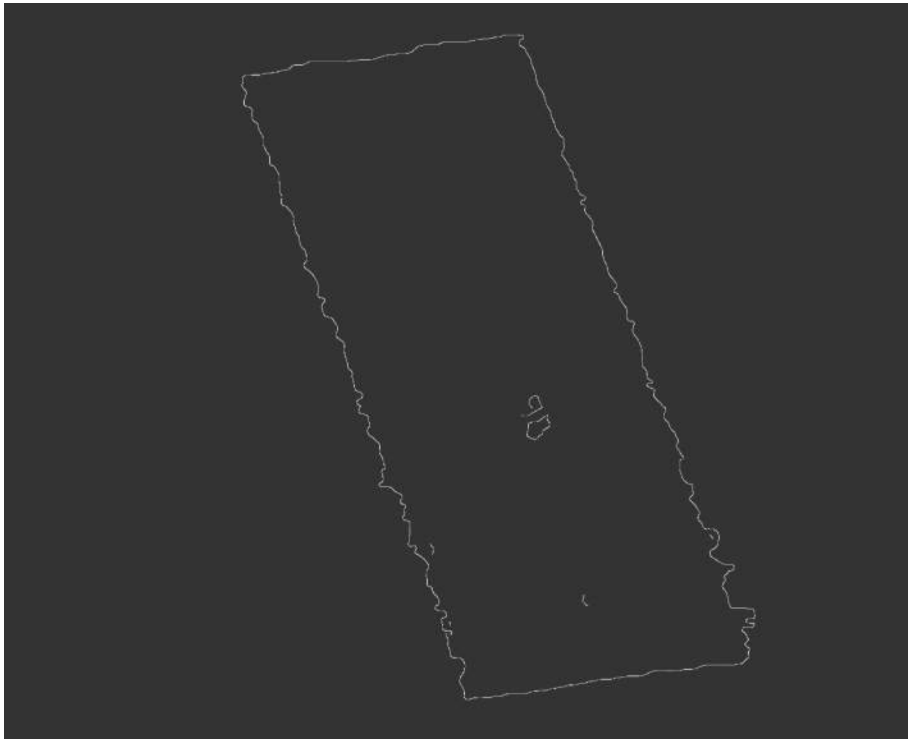
Important to categorizing distresses by severity
Obtaining 0.9 cm ground sample distance



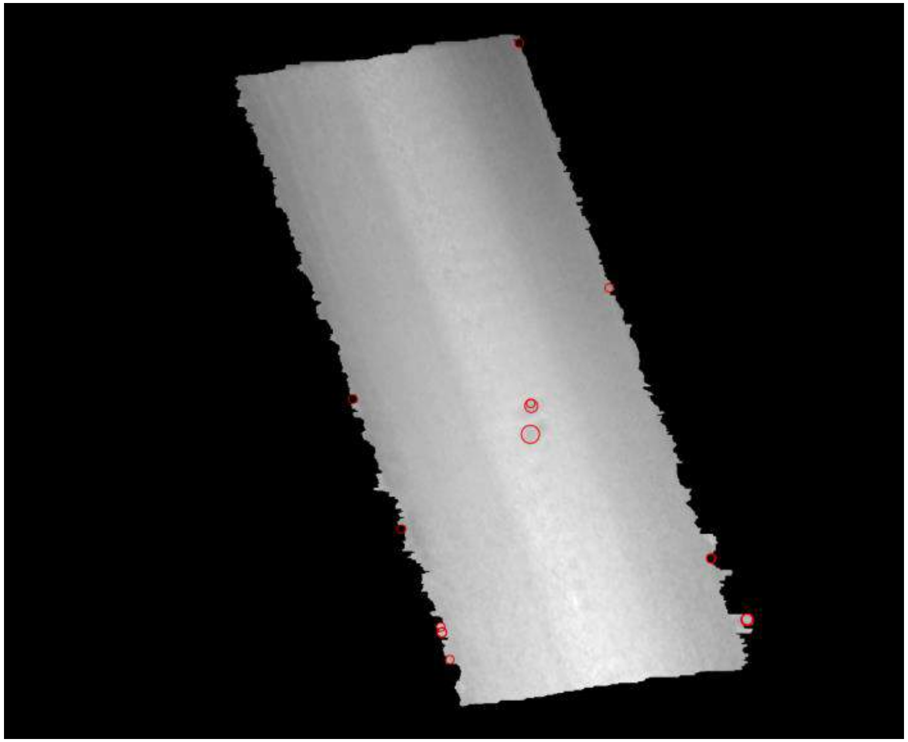
Distress Detection – Potholes

- Canny Edge detection used to locate edges
- Hough Circle Transform is used to locate potholes

Edge Detection

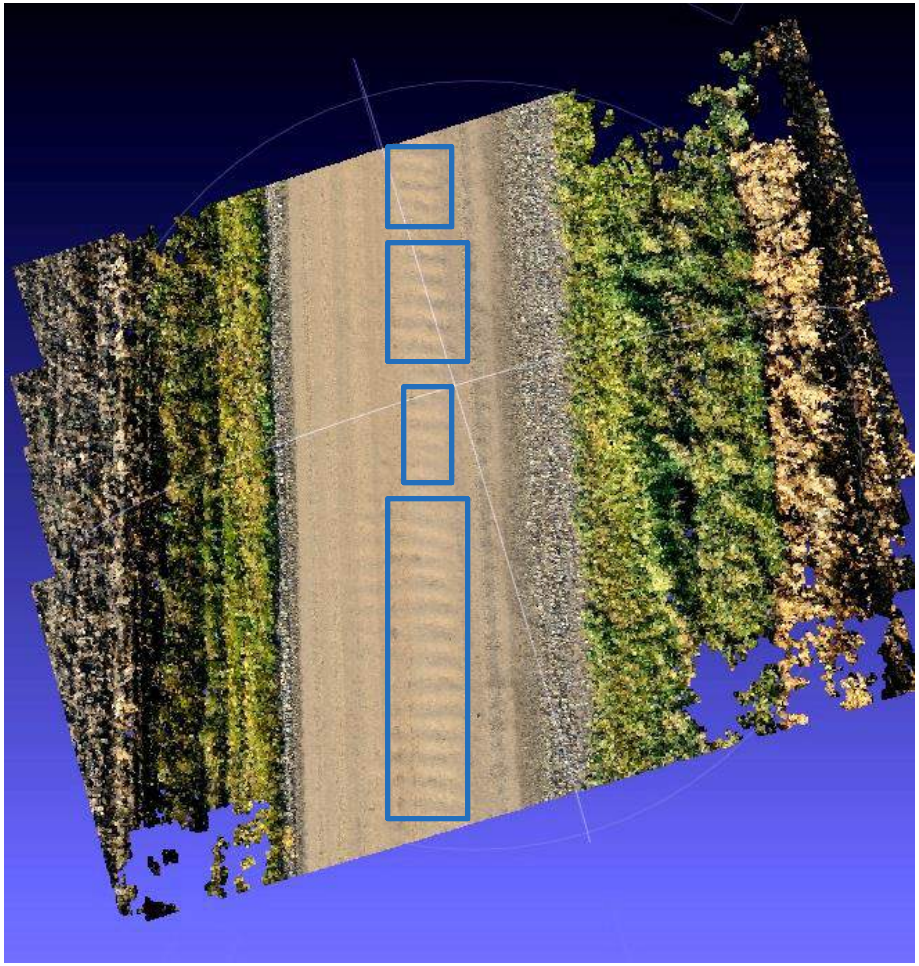


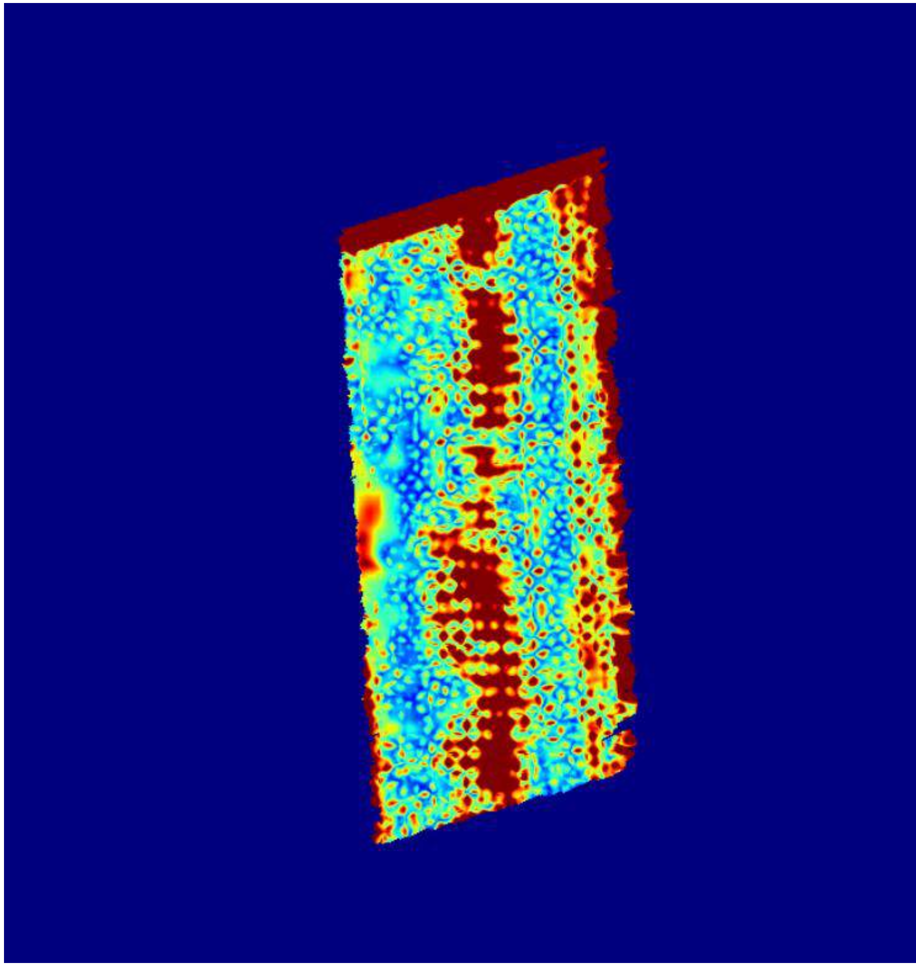
Identified circles



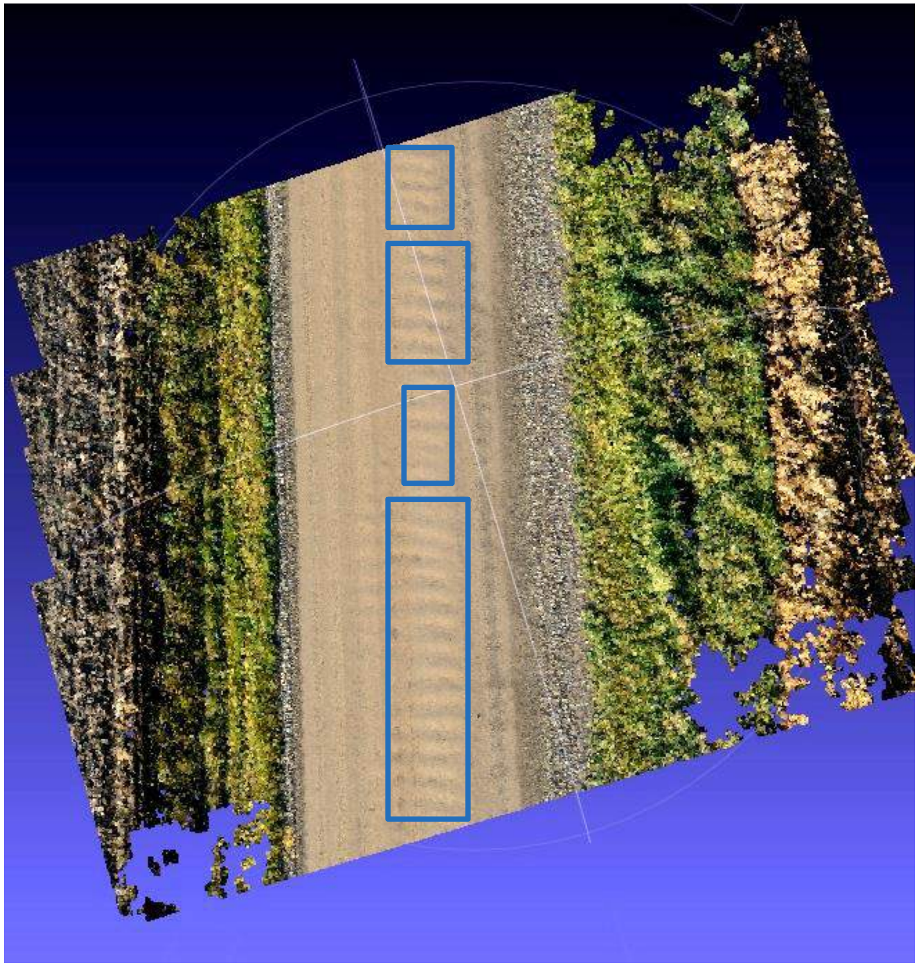
Note: Circles near edges ignored.

Distress Detection – Washboarding

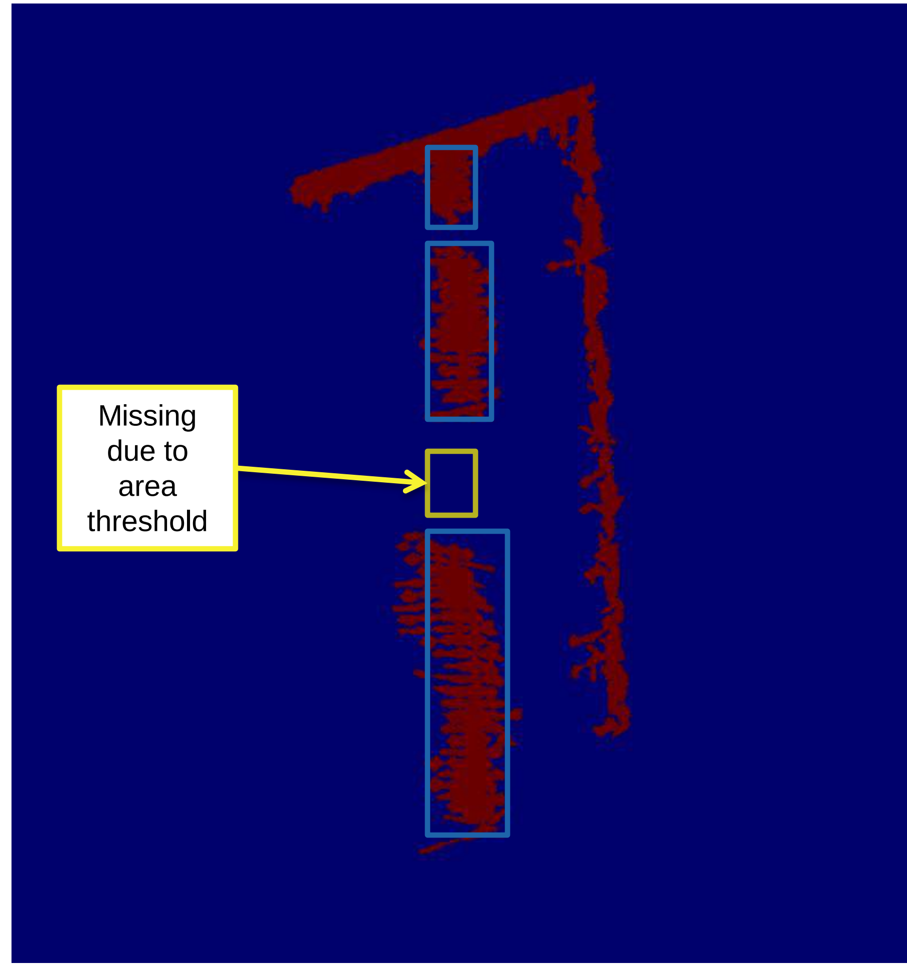




Distress Detection – Washboarding

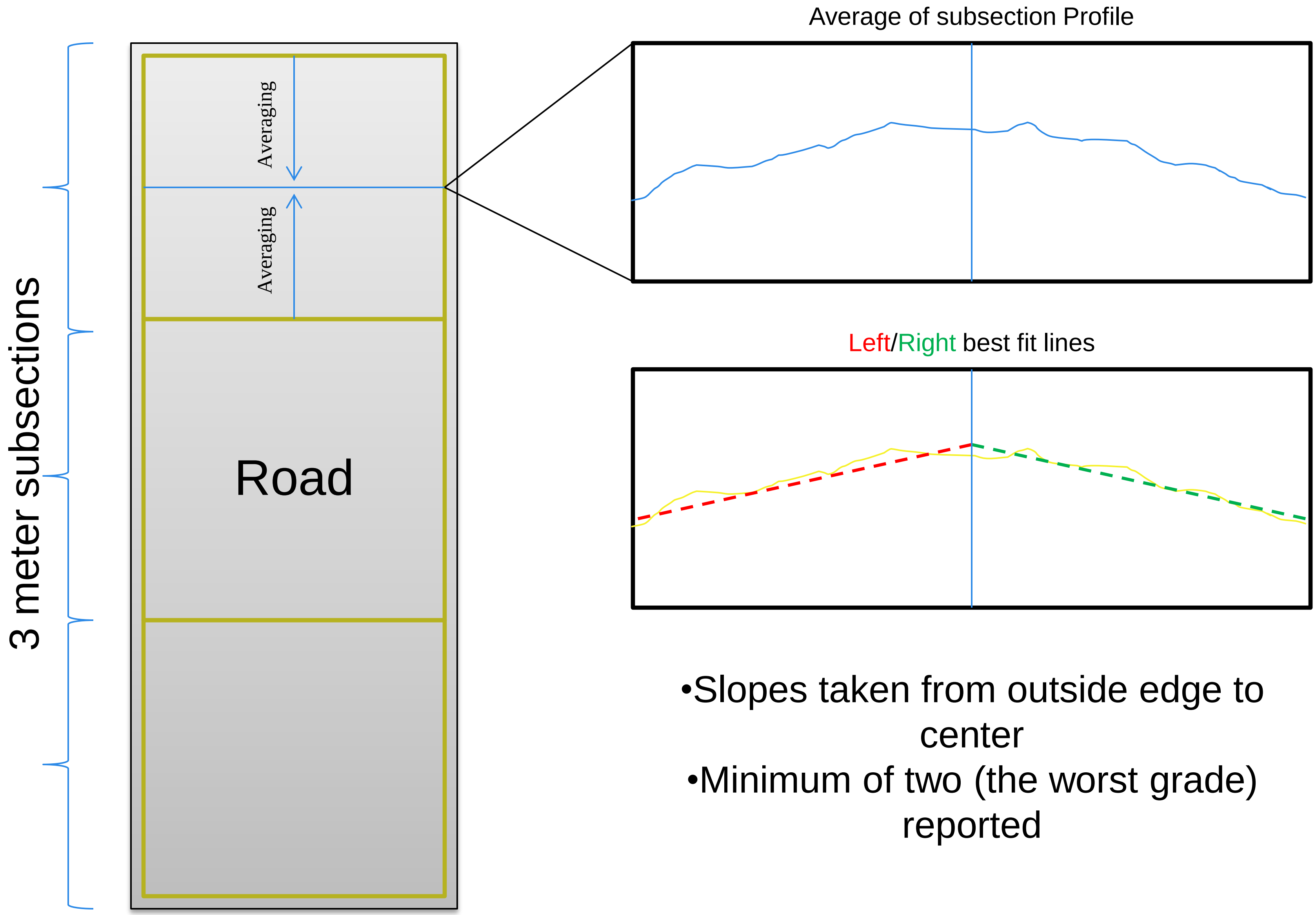


Ground Truth Corrugation Area:
19.6 sq. m



Computed Corrugation Area:
17.2 sq. m

Distress Detection – Crown



•Slopes taken from outside edge to center
•Minimum of two (the worst grade) reported

Michigan Tech Research Institute

MDOT UAV Technologies project

- **"Evaluating Unmanned Aerial Vehicles for Transportation Purposes"**
- Michigan Department of Transportation (MDOT) sponsored 21-month project, ongoing

MDOT

Objectives of MDOT Study

- Develop, test, and demonstrate how UAV technology can help provide visual inspections from above for a variety of structures and locations of interest to MDOT, to enhance and support current data collection systems & visual inspections for a DOT's operations, maintenance, and Asset Management Programs.
  - Roadway Assets
    - Lighting, signs etc.
  - Confined spaces
    - Pump Stations
    - Entrances to Sewers and Culverts
  - Bridge assets & condition
- Demonstrate how a UAV system can be deployed to monitor traffic operations
- Investigate how UAV based optical and thermal IR technologies can be used to evaluate surface and structural integrity of bridge elements
- Demonstrate how a LiDAR sensor could be used to rapidly assess and inspect transportation infrastructure

Task 1: Develop, Test and Demonstrate How UAV Technology Can Help Provide Visual Inspections

- Multiple Platforms are proposed based upon space and sensor size restrictions
- Appropriate UAV Sensors
  - Digital Cameras
  - Thermal Infrared Sensors
  - LiDAR
- Demonstration Locations & Possible Platforms
  - Overhead Infrastructure: Bergen Hexacopter
  - Bridge Elements: Medium UAV
  - Pump Stations and Culverts: Micro-UAV

UAV Sensors

- Optical
  - Able to characterize surface defects and generate a photo inventory. Higher-res can also be used to generate 3D models of surfaces.
- LiDAR
  - Used to create 3D point clouds of surfaces
- Forward Looking IR
  - Used for the detection of subsurface defects such as delaminations on bridges.

Nikon D800

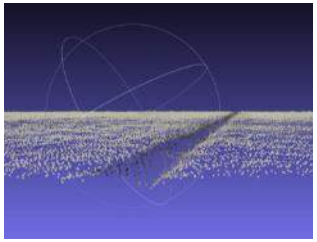
GoPro Hero 3 – for small UAVs

Hokuyo UTM-30LX-EW
Scanning Sensor

Tau 2 Thermal Imaging Camera

Potential UAV-capable remote controlled devices

- Bergen Helicopters - Hexacopter
  - 4 kg payload
  - 20 minute flight time
  - Easy to fly
  - Overhead infrastructure assessment, unpaved roads
- Mid-sized UAV with “sense & avoid” – Skyspecs or similar
  - Close-up infrastructure imagery
- Small UAV – DJI Phantom
  - Underside infrastructure photography, quick aerial imagery
  - 8 minute flight time
- Micro UAV
  - 3.5 in wide and weighs 0.67 oz
  - 7 minute flight time
  - 0.35 oz payload
  - Confined space inspection
- Blimp / aerostat
  - 16 ft long blimp can carry a 2 lbs payload
  - Able to remain on station for long periods of time.
  - Traffic monitoring

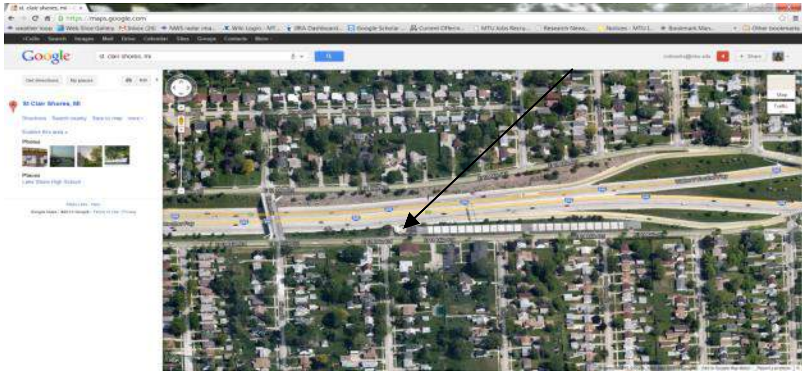


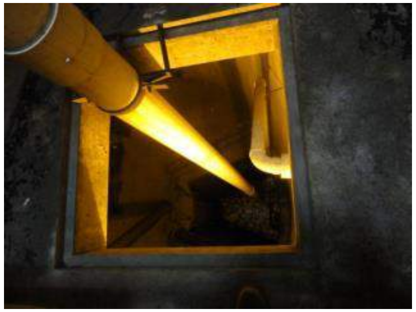
MTRI aerial platforms in-house: a wide range of capabilities

MichiganTech Research Institute

Confined space inspection

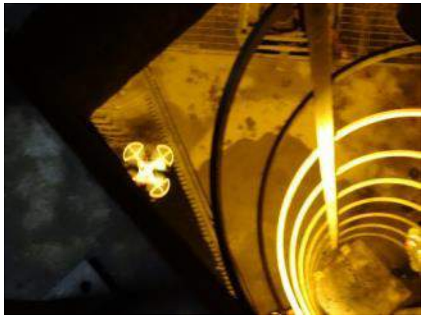
- Is it safe to send in a person? Look around first – live video via micro UAV
- MDOT pump stations, culverts

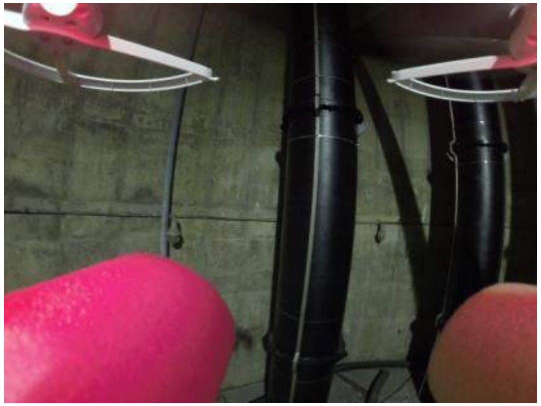




Confined space inspection – initial flights

- Initial flights – understand capability to fly in confined spaces.
  - MDOT Pump Station.
- Is it safe to send a person in there?
  - Eventually: unlit, retrieve through opening
- Successful testing of DJI Phantom with HD Go Pro camera & live video, micro UAV with keychain camera
  - Operation with confined space
  - useful optical captures – stills, video
- Next: system between these units in size



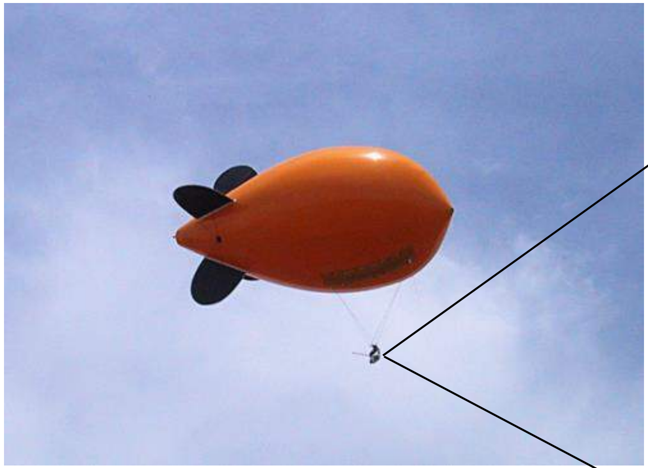


Task 2: Provide a Demonstration of UAV Based Traffic Monitoring

- Extended Flight Time Required
  - Battery powered helicopter UAVs have max flight times of about 10 – 30 minutes (for <$20k ones) depending on payloads and flying conditions
  - Nitro powered helicopters have longer flight times but produce smoke and can leave an oil residue on equipment inc. cameras
- Imagery will be collected through HD video or pictures taken with camera (DSLR, etc.)
  - Goal: Live video feed to a Traffic Operations Center
  - Help with situations where MDOT wants to monitor traffic but doesn’t want to install permanent infrastructure.

Traffic Monitoring

- A tethered blimp is proposed for long term traffic monitoring
  - Able to stay aloft for extended periods of time
  - Able to carry a variety of cameras
- Provides near-real time imagery of traffic conditions
  - Imagery to be transmitted to ground based receiver



http://academic.emporia.edu/aberjame/airphoto/blimp/blimp.htm

M-59 and North Ave. in Macomb Township

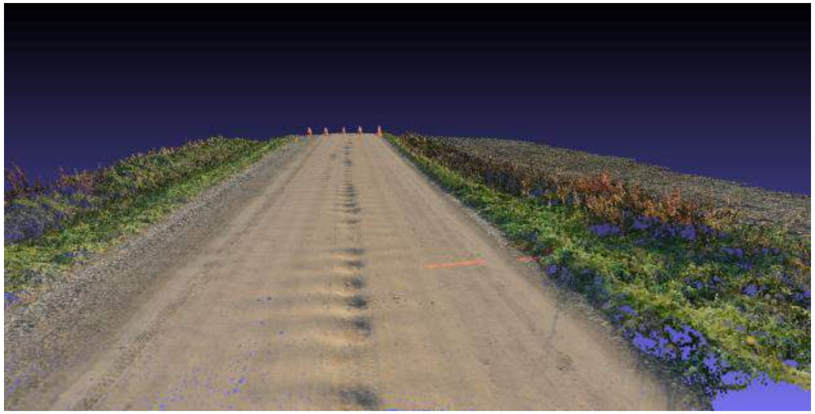
Bing Maps 2013

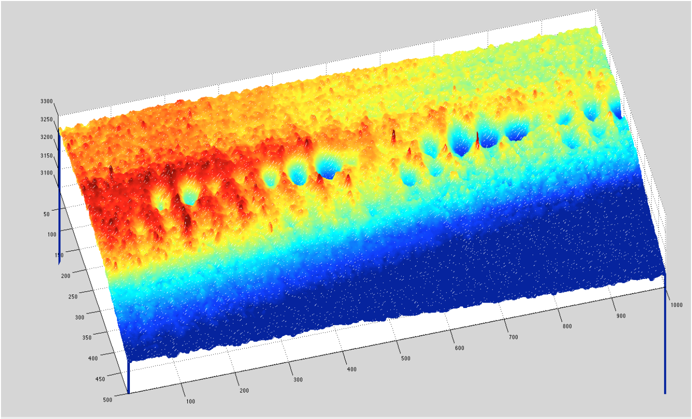
Task 3: Investigate Non-Destructive Evaluation (NDE) of Bridge Elements

- Goals:
  - Develop technology to obtain bridge condition data from UAV platform to supplement routine inspections
  - Surficial condition
  - Non-destructive structural evaluation of bridge element integrity
- Optical and Thermal Sensors will be flown
  - Optical imagery will capture surface defects such as spalls
  - Thermal imagery will capture sub-surface defects such as delaminations
- 3D reconstructions from optical imagery will be used for automated detections of spalls
  - Similar to previous work done with vehicle based data collected and processed under the USDOT Bridge Condition Project (Ahlborn et al.)
- Optical and thermal data will be fused for a complete surface and sub-surface characterization of the bridge elements

NDE Techniques: Optical

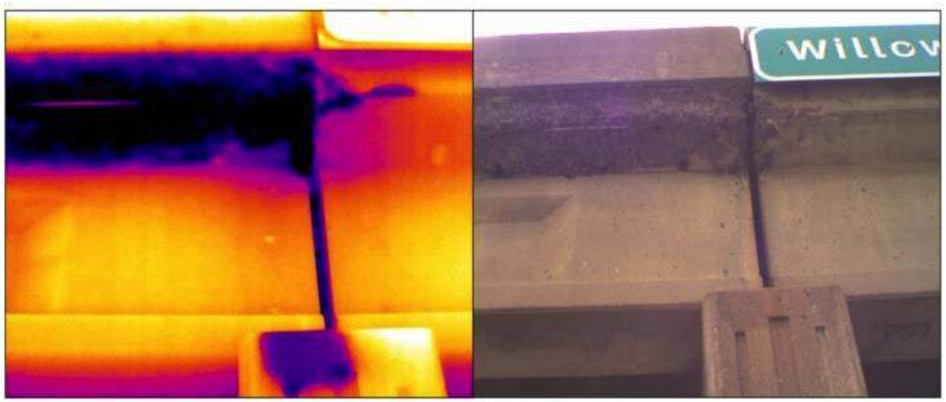
- Used to detect surface conditions
  - Spalling/potholes, cracks, etc.
- Overlapping imagery can be used to generate 3D models to characterized condition
  - Close-range photogrammetry
  - Structure from Motion (SfM)


3D point cloud of an unpaved road generated using SfM techniques

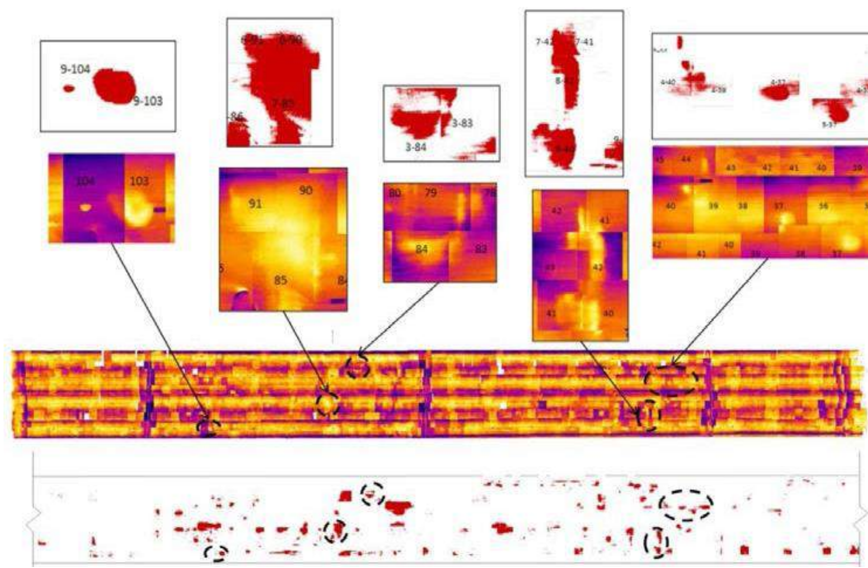

3D height field showing potholes on an unpaved road

NDE Techniques: thermal IR

- Used for the detection of subsurface condition
  - Delaminations
- To be deployed to same areas as optical to form a complete surface and subsurface understanding



Thermal IR imagery taken from Willow Rd. bridge over US-23 near Milan, Michigan. A handheld thermal camera detects a delamination on the bridge fascia (above) and a composite image of delaminations locations on the bridge deck (right).



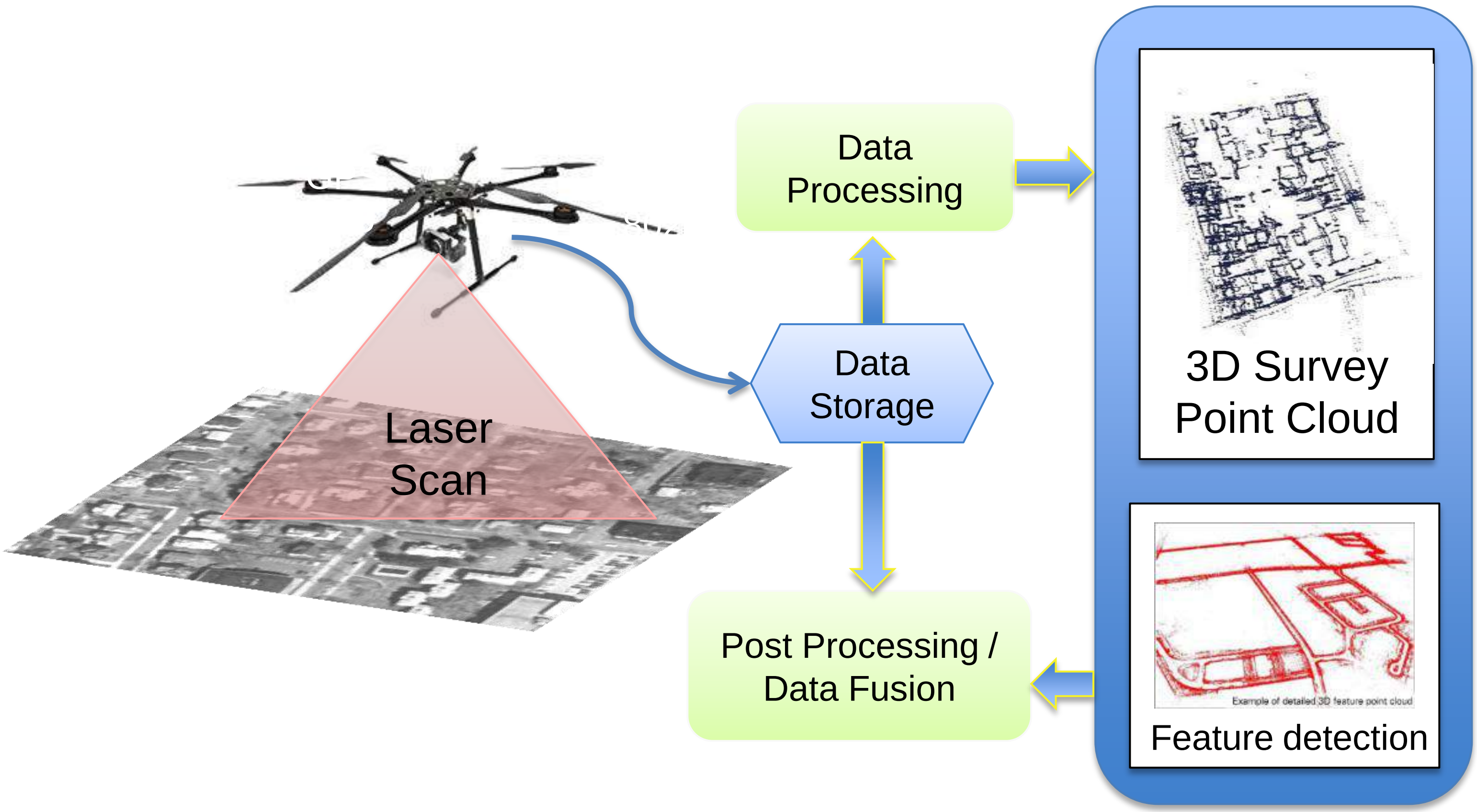
Task 4: Demonstrate UAV Based LiDAR Inspection of Transportation Infrastructure

- Goals:
  - Measurement of transportation infrastructure at 10cm resolution.
  - Autonomous Detection of transportation infrastructure such as signs and roadway lighting.
  - Autonomous and dynamic path planning for systematic and accurate data collection

P.R.I.M.E. Lab Research

- Projects:
  - Autonomous navigation of human-engineered environments
  - Transportation infrastructure inspection using micro-UAVs
  - Explosive hazard detection using sensor fusion
  - Algorithms and methods for social network data mining
  - Unsupervised learning in Big Data
- Research Areas:
  - Pattern recognition
  - Big Data
  - Mobile robotics
  - Cloud robotics
  - Remote Sensing
  - Sensor Fusion

Airborne Laser Scanning of Transportation Infrastructure



Task 5: State-of-the-Practice

- State-of-the-Practice report on how UAVs are currently being used for a variety of transportation purposes
- Detailed literature review
  - NDE techniques with remote sensors
  - Relevance and application of these sensors from a UAV platform
  - Data collection and deployment on a UAV platform
- Analyze the merit of sensors in terms of capability to identify infrastructure defects
- Will include MDOT's measurement and assessment requirements - apply these to current practical deployable UAV systems

Task 6: Provide Recommendations and an Implementation Plan

- Technical training for each technology and technique
  - Generation of a “How To” manual
  - Training sessions for select MDOT personal
- Technical training will show accuracy and reliability of measurements made by the tested sensors compared to standard measures made by inspectors
- Future of technology: a possible a cost-effective, high-resolution aerial imaging service provided to transportation agencies by the private sector?

Contact Information, Project Info

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- MDOT research project number OR13-008.
  - Program Manager: Steven Cook, P.E., Operations/Maintenance Field Services Engineer, 517-636-4094.
- Unpaved Roads Assessment project funded by US Department of Transportation Research & Innovative Technology Administration - RITARS-11-H-MTU1.
  - The views, opinions, findings and conclusions reflected in this presentation are the responsibility of the authors only and do not represent the official policy or position of the USDOT\RITA, or any State or other entity.

Michigan and UAS: A Partnership for the Future

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Manager & BD Aerospace Group /
MIAASC Board Member
Wyle

Lunch

Michigan I