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Thursday, March 14, 2013

11 am – 12:30 pm PST
Noon – 1:30 pm MST
1 pm – 2:30 pm CST
2 pm – 3:30 pm EST

GNSS & UNMANNED AERIAL SYSTEMS: *The Road Ahead*

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WELCOME TO:

GNSS & Unmanned Aerial Systems:

The Road Ahead

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Josh Redding
Lockheed Martin Procerus Technologies
Research Lead, Embedded Systems

Kelly J. Hayhurst
NASA Langley Research Center
Safety Critical Avionics Systems Branch
Research Scientist

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Moderator: Demoz Gebre-Egziabher, Aerospace Engineer and Mechanics Faculty at University of Minnesota

Co-Moderator: Lori Dearman, Sr. Webinar Producer

Housekeeping Tips

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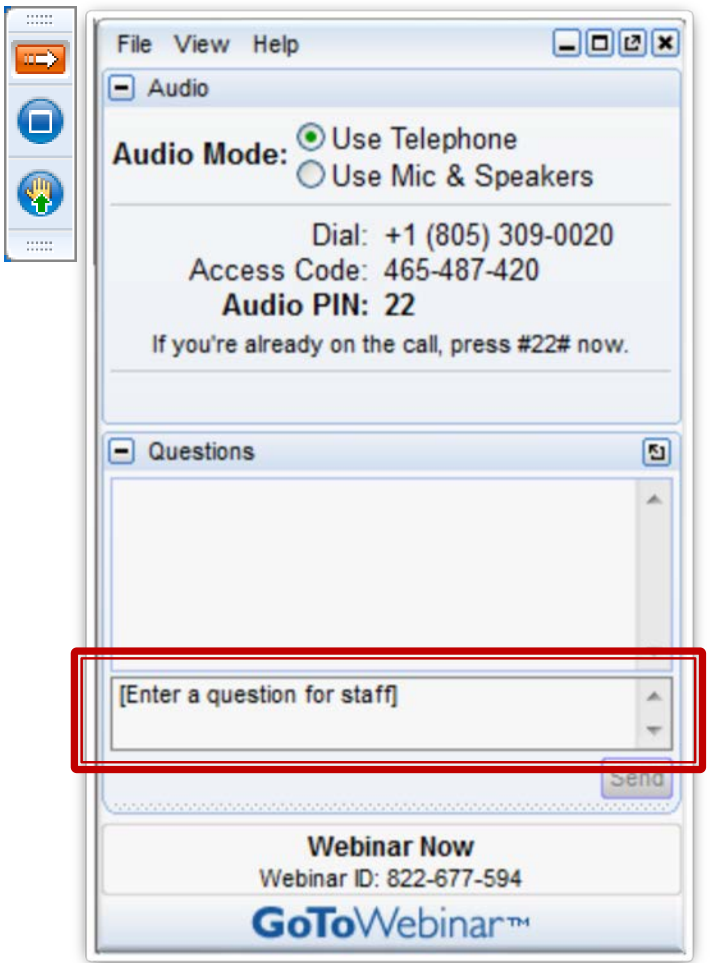
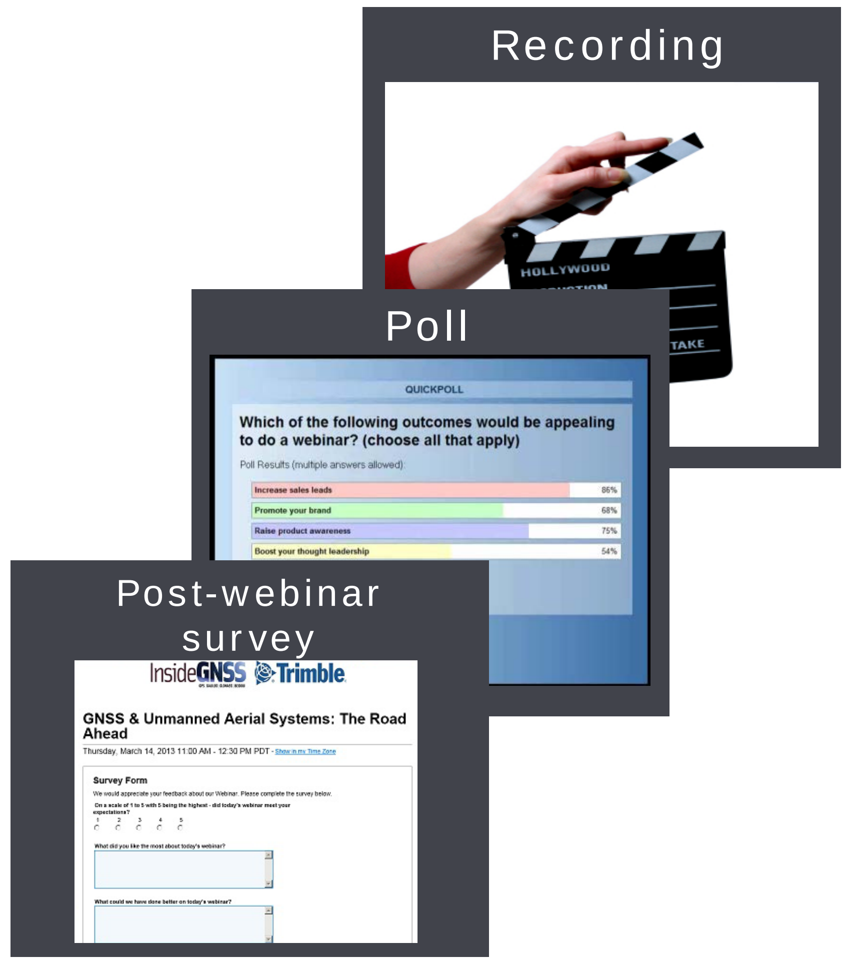
How to ask a question





Who's In the Audience?

A diverse audience of over 700 professionals registered from 59 countries, 42 states and provinces representing the following roles:

- **30%** GNSS End User
- **15%** GNSS Equipment Manufacturer
- **17%** Government/Policy Maker
- **19%** Product / Application Designer
- **19%** System Integrator

Welcome from *Inside GNSS*

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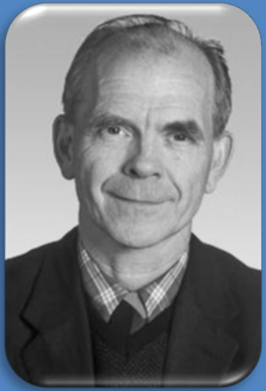

Glen Gibbons

Editor and Publisher
Inside GNSS

A word from the sponsor

Joe Hutton

**Director of
Inertial and Airborne Products
Applanix, a Trimble Company**

GNSS & Unmanned Aerial Systems:
The Road Ahead

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Demoz Gebre-Egziabher

Aerospace Engineer and Mechanics Faculty, University of Minnesota

Poll #1

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What do you see is the single biggest civilian application for Unmanned Aerial or Ground Vehicles? (please select one)

1. *Environmental monitoring and management* **21%**
2. *Agriculture (crop dusting, crop monitoring, etc)* **21%**
3. *Autonomous cargo shipments* **6%**
4. *Search and rescue/medivac operations* **6%**
5. *Mapping and survey* **46%**

UAVs and Applications

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Decreasing size, weight and power (SWaP)

- UAVs: Autonomously or remotely operated flying vehicles
- Envisioned for multitude of operations:
  - Environmental monitoring; Search and rescue; flight testing; surveillance;
- Challenge: How to share the same airspace with manned aircraft

UAS: Generic System Architecture

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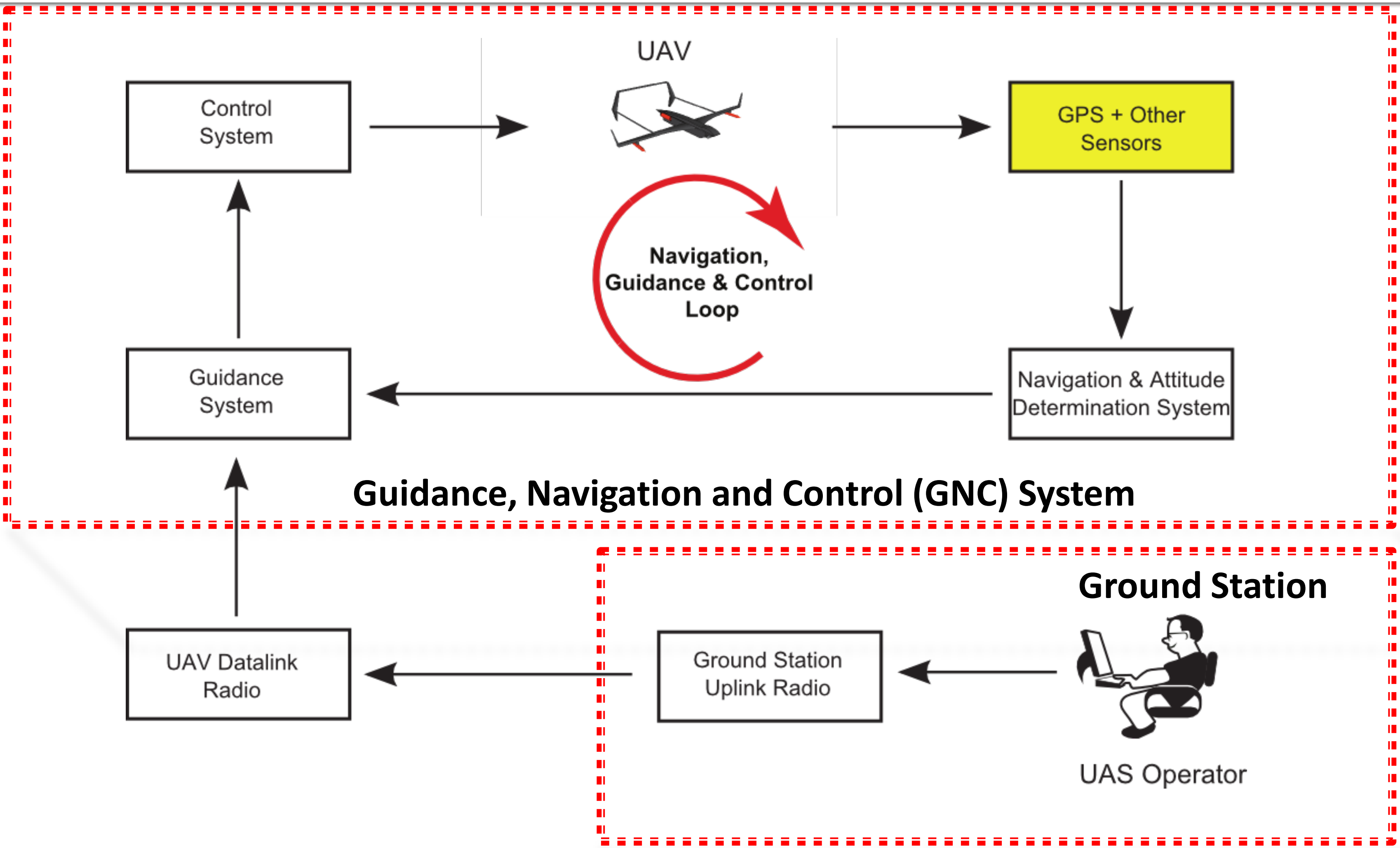
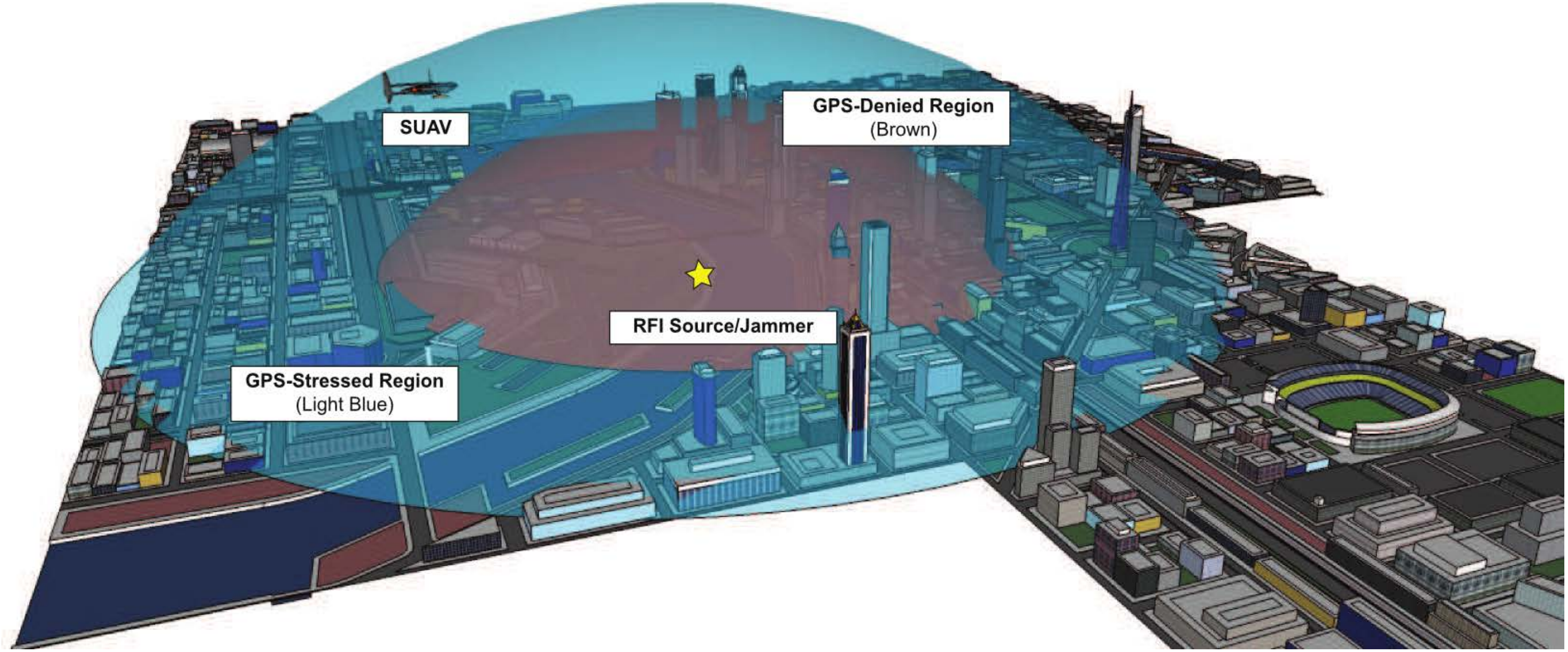


Unmanned Aerial System = UAV + Ground Station + Data Links

Challenge:
GNSS-Denied / Stressed Operations

GPS (GNSS): The KEY GNC sensor for small UAV.

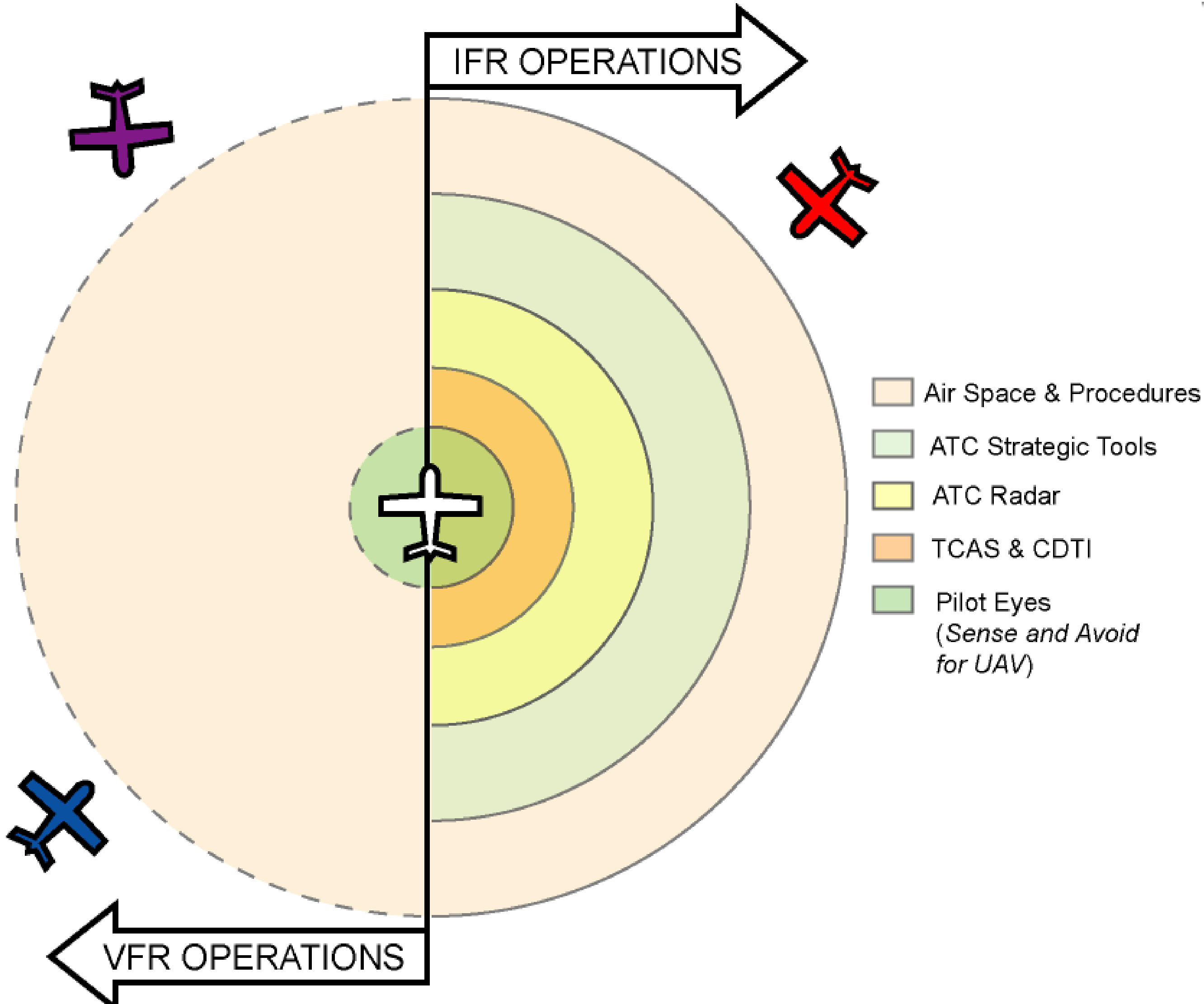
How do we deal with its unavailability of degradation?



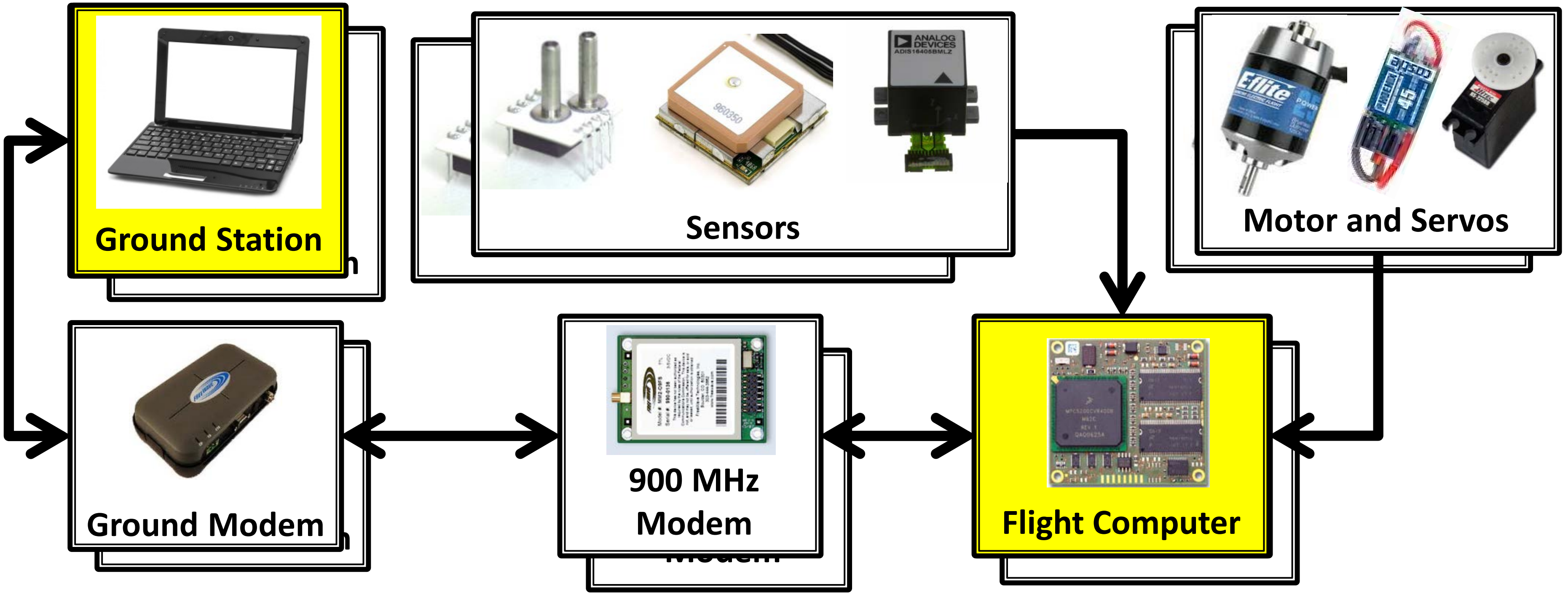
- FAA's Alternate Position Navigation and Time (APNT) effort:
  - √ for large UAVs. For small UAVs (SUAV) = ???

Challenge: Sense and Avoid

- What technologies are equivalent to (or can replace) the pilots eyes?



Challenge: Certifiable (Provable) Reliability



- Consequence of system malfunction (GNC, sense and avoid, etc) can be severe.
- Risk minimization: Procedural; Hardware Redundancy (large UAVs); Analytical Redundancy (small UAVs).
- How to prove hardware/software system always performs as intended?

Featured Presenter

Josh Redding
Lockheed Martin Procerus Technologies
Research Lead

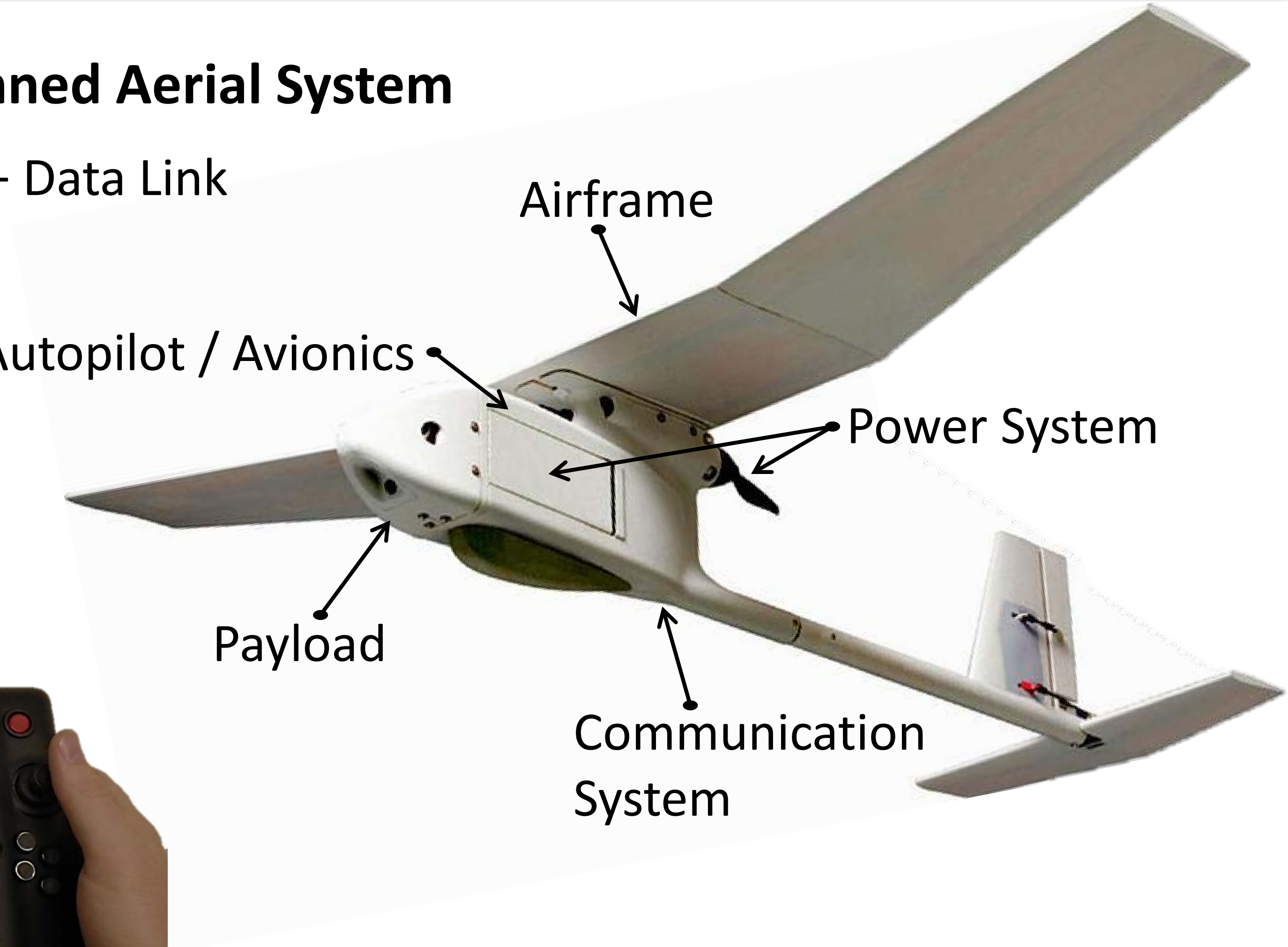
Small Unmanned Aerial Systems

An overview

Josh Redding
Lockheed Martin
Procerus Technologies

Basic SUAS Architecture

- **Small Unmanned Aerial System**
  - UAV + GCS + Data Link



Basic SUAS Architecture

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- **Airframe & Power System**
  - One- or two-man packable
  - Battery-powered
  - Hand-launched
  - < ~20 lbs

Basic SUAS Architecture

- **Communication System & GCS**
  - Command and control
  - Data downlink & datalogging
  - Streaming video & exploitation

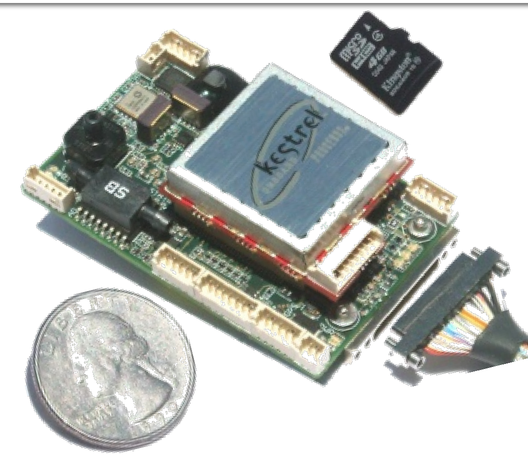
- Small, lightweight
- Low power (range)

Basic SUAS Architecture

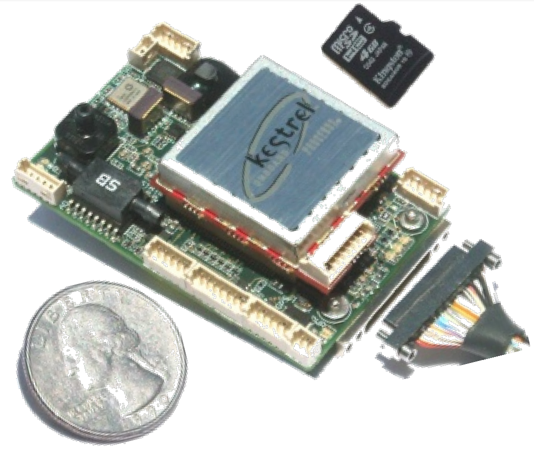
- **Payloads**
  - Camera systems
    - Electro-Optical, Infrared
    - Multi/Hyper-spectral
  - Gimbaled camera systems
  - Pollution/Weather sensors
  - Chemical sniffers
  - Synthetic aperture radar

Basic SUAS Architecture

- **Autopilot Hardware**
  - CPU or microcontroller
    - Connects w/ GPS, IMU, Airframe, Data link
    - Control loops (position, attitude, flight mode, etc.)
  - Inertial Measurement Unit (IMU)
    - Body-axis accelerations & angular rates
  - GPS (GNSS)
    - **Key** absolute position & velocity sensor



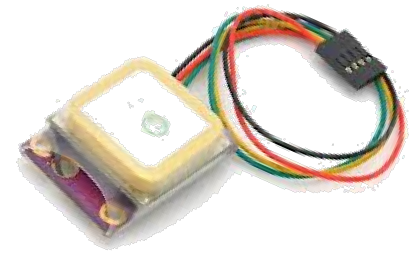
Basic SUAS Architecture

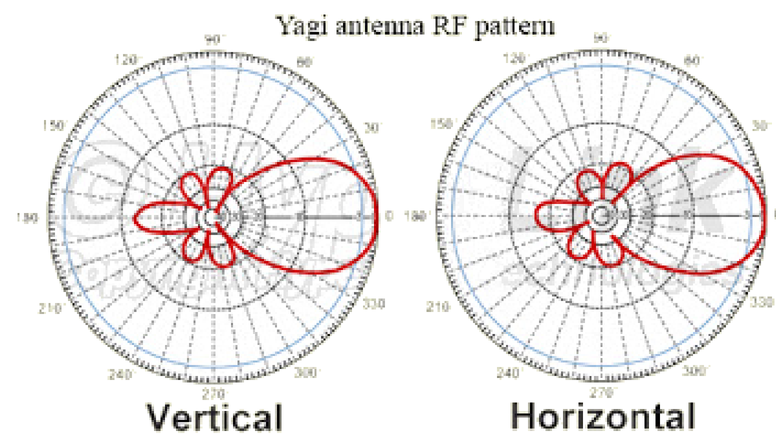


- **Autopilot Firmware**
  - Navigation, Guidance & Control
    - Determine navigation solution & goal location/orientation
    - Generate desired trajectory
    - Determine actuation commands to generate forces/moments
  - Payload interaction/control
    - Trigger snapshot, collect data, etc.
    - Influence navigation/guidance (e.g. vision-aided nav)
  - Communication
    - Receive/process command, control and flight mode changes
    - Telemetry downlink

SUAS: Complex System of Systems

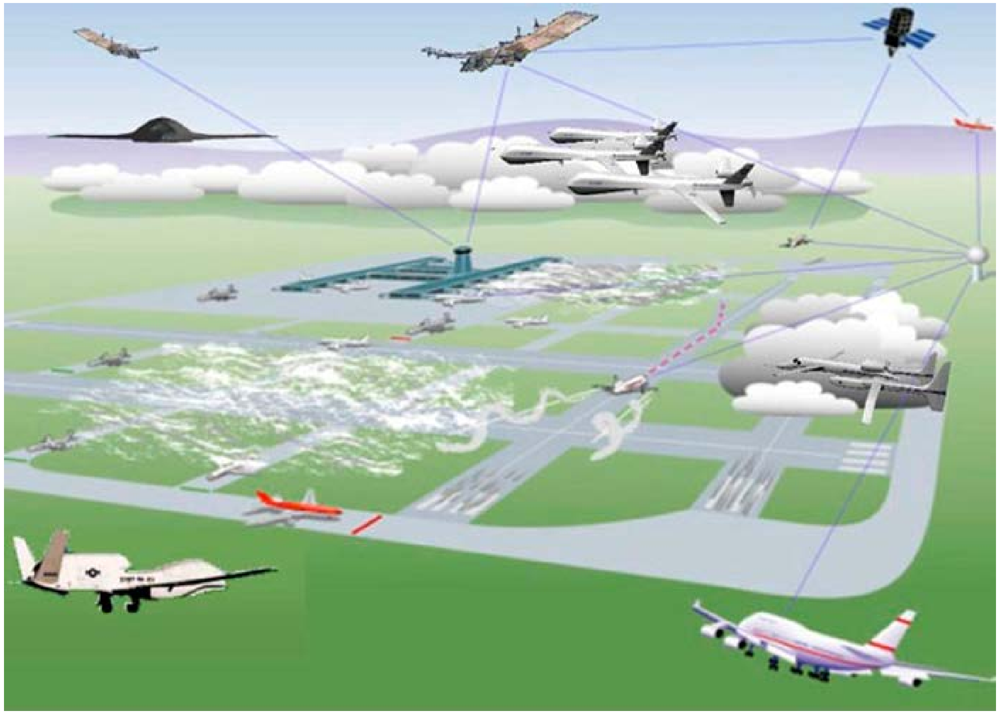
- Size/weight/power restrictions
  - Lead to hobby-grade hardware
  - No space/weight budget for redundancy
- Fly-by-wire airframes
- Microcontrollers for nearly each subsystem (firmware, configuration)
- Noisy/compacted RF environment onboard





SUAS: Reliable Behavior

- SUAS in the NAS must be reliable & predictable
- Reliable/predictable behavior depends on **many** subsystems
- Failsafe behaviors
  - Mechanical/firmware issues
  - Loss of communication link
  - Loss of GPS signal lock
    - SUAS can maintain attitude
    - **Drift** in absolute position



Featured Presenter

Kelly J. Hayhurst
NASA Langley Research Center
Safety Critical Avionics Systems Branch
Research Scientist

Outlook on Integration

Kelly Hayhurst
NASA Langley Research Center

FAA Perspective on Integration

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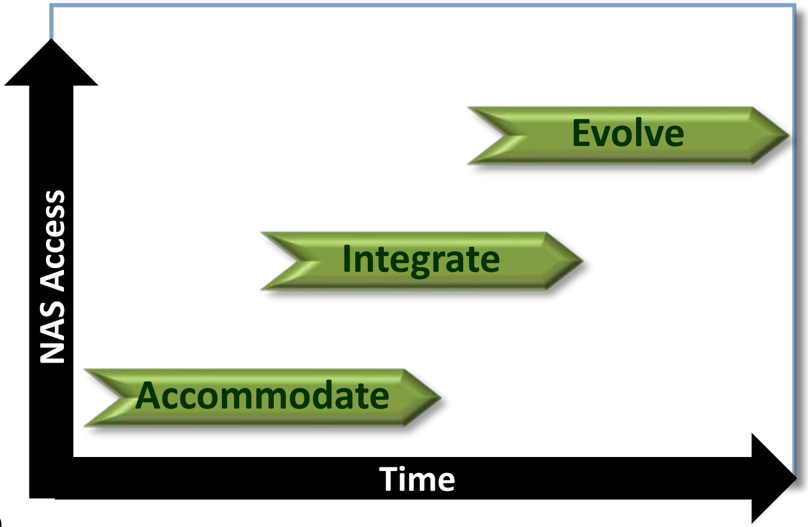
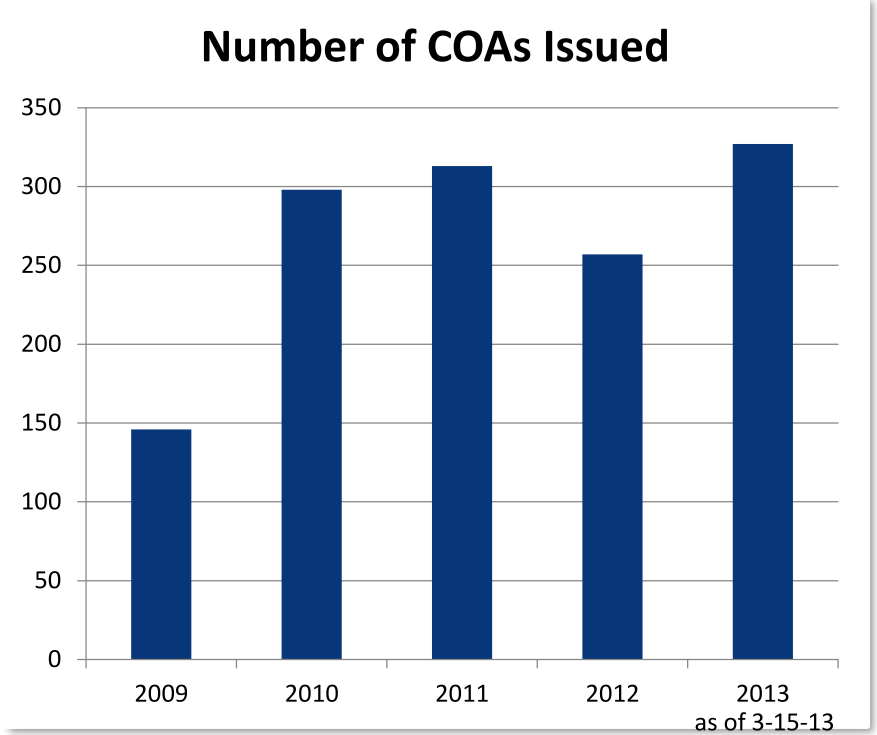
- Accommodate
  - case-by-case
  - special mitigations
- Integration into the NAS
  - establish UAS certification criteria
  - performance standards
- Evolution
  - integration into the Next Generation airspace (NextGen) environment



UAS Operations Today

- Limited access to the NAS
  - Public use operation under a COA
    - Certificate of Authorization or Waiver
  - Civil operation under an experimental airworthiness certificate
- No commercial use



FAA Mandate

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- FAA Modernization and Reform Act of 2012
  - comprehensive plan to safely accelerate integration
  - rule on operation of small UAS
  - 6 test ranges
  - small UAS operations in the Arctic beyond line of sight
  - expedite access for public aircraft

One Hundred Twelfth Congress
of the
United States of America

AT THE SECOND SESSION

Begun and held at the City of Washington on Tuesday, the third day of January, two thousand and twelve

An Act

To amend title 49, United States Code, to authorize appropriations for the Federal Aviation Administration for fiscal years 2011 through 2014, to streamline programs, create efficiencies, reduce waste, and improve aviation safety and capacity, to provide stable funding for the national aviation system, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

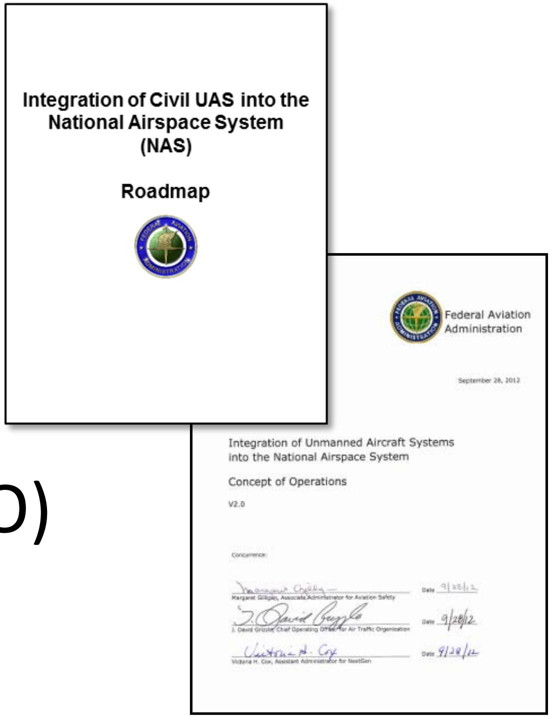
SECTION 1. SHORT TITLE; TABLE OF CONTENTS.

(a) SHORT TITLE.—This Act may be cited as the "FAA Modernization and Reform Act of 2012".

(b) TABLE OF CONTENTS.—The table of contents for this Act is as follows:

Current Activities

- FAA
  - Improving COA process
  - ConOps & Roadmap
- UAS Aviation Rulemaking Committee
- Joint Program Development Office (JPDO) UAS National Plan
- RTCA Special Committee 203 on UAS
- Lots of research
  - FAA, NASA, Dept. of Defense, Universities, ….


Integration of Civil UAS into the National Airspace System (NAS)

Roadmap

Federal Aviation Administration

September 28, 2012

Integration of Unmanned Aircraft Systems into the National Airspace System

Concept of Operations

V2.0

Integration Issues

People

- Pilot qualification standards

Aircraft and systems

- reliability
- certification standards
- control station layout/certification
- dedicated, protected spectrum
- sense and avoid capability

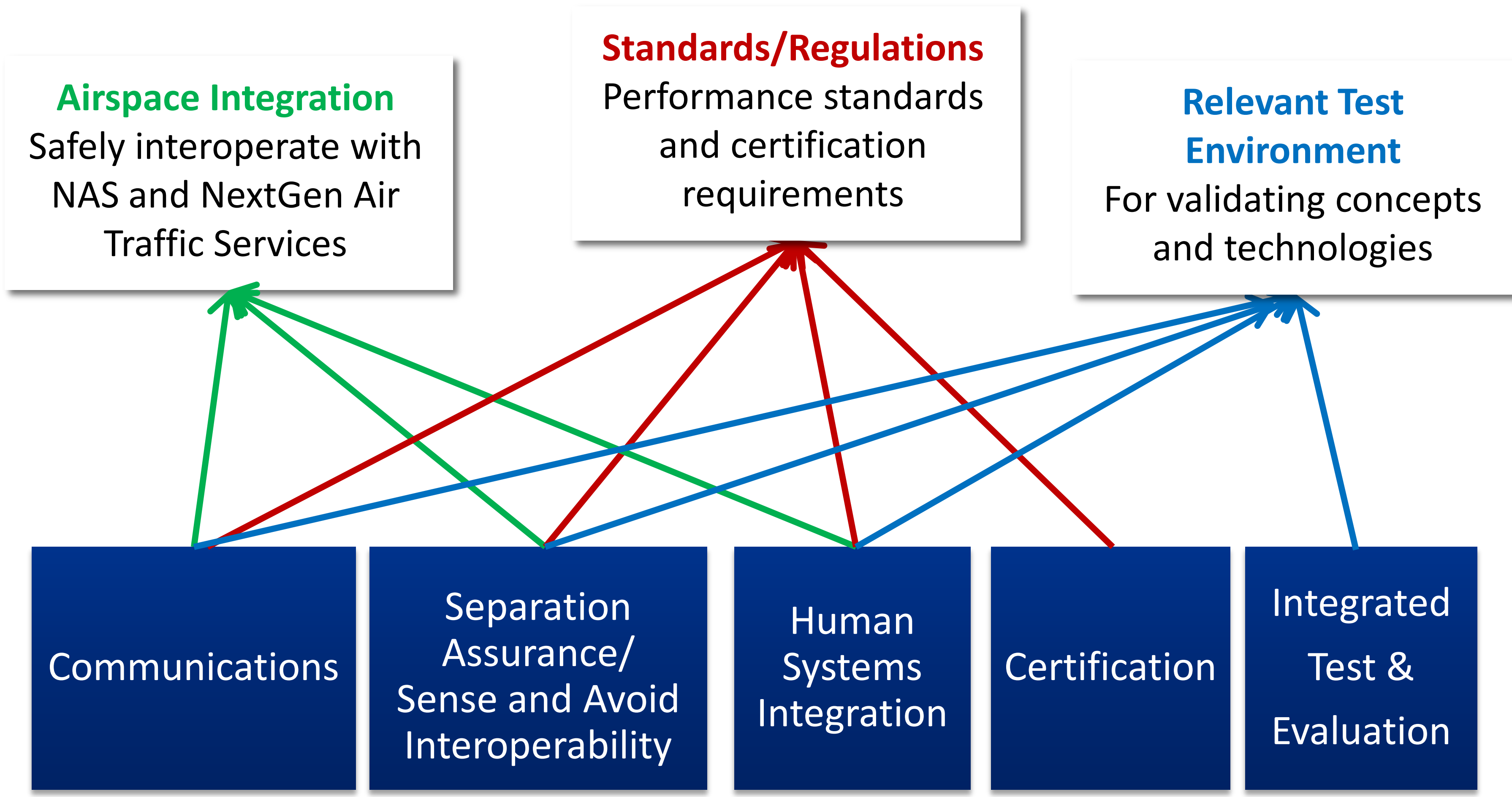
Operations

- NextGen ground systems design
- ATC interoperability

NASA's UAS in the NAS Project

- Goal: eliminate/reduce technical barriers to UAS integration
  - using integrated system level tests in a relevant environment
- Evaluate promising concepts & technologies
- Led by NASA Dryden
  - May 2011 - September 2016

Subprojects & Challenges



Technology Subprojects

Communications

- Communications
  - frequency spectrum
  - data links for control communication

Separation Assurance/ Sense and Avoid Interoperability

- SSI
  - interoperability of sense-and avoid systems
  - separation roles & responsibilities

Human Systems Integration

- HSI
  - human factors
  - ground control station guidelines

Integrated Events

System level tests to evaluate these technologies

Certification Research

- FAA is responsible for certifying many things
  - aircraft are airworthy
    - production, maintenance, and continued airworthiness
  - compliance with operational requirements in different airspace
  - people involved

- Certification subproject is focused on research supporting airworthiness certification for UAS

Ask the Experts – Part 1

Josh Redding
Lockheed Martin Procerus Technologies
Research Lead, Embedded Systems

Kelly J. Hayhurst
NASA Langley Research Center
Safety Critical Avionics Systems Branch
Research Scientist

Joe Hutton
Director of
Inertial and Airborne Products
Applanix, a Trimble Company

Ed Norse
GNSS Portfolio Manager
Integrated Technologies,
Trimble Navigation Ltd

Poll #2

Other than regulations, what is the top technical issue currently limiting the use of Unmanned Vehicles for commercial applications? (Select one)

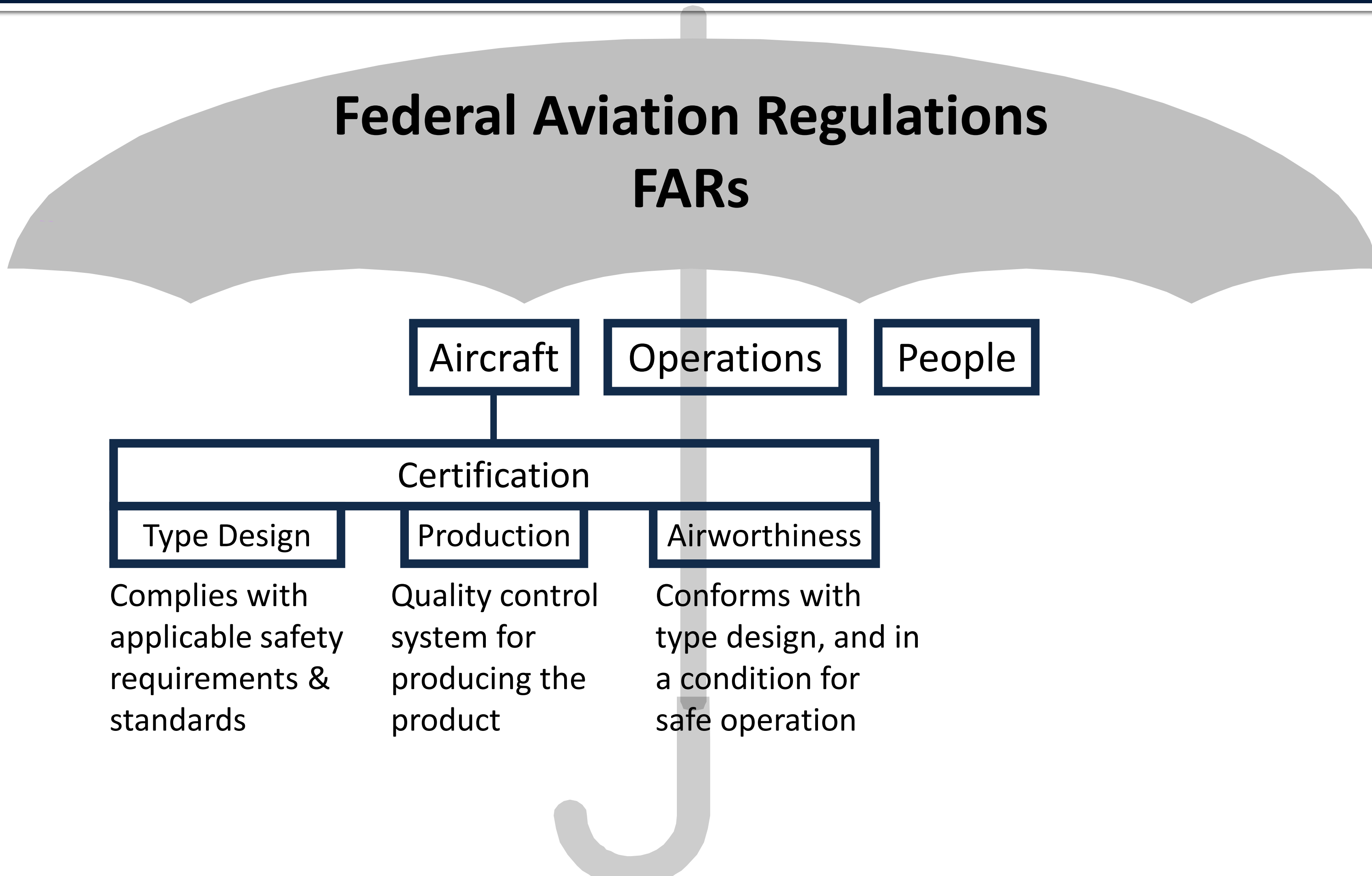
1) *Endurance of battery and power plants* ***21%***
2) *Reliability and safety of systems* ***33%***
3) *GNC system performance* ***8%***
4) *Sense and avoid capability* ***33%***
5) *Others* ***5%***

UAS Airworthiness Considerations

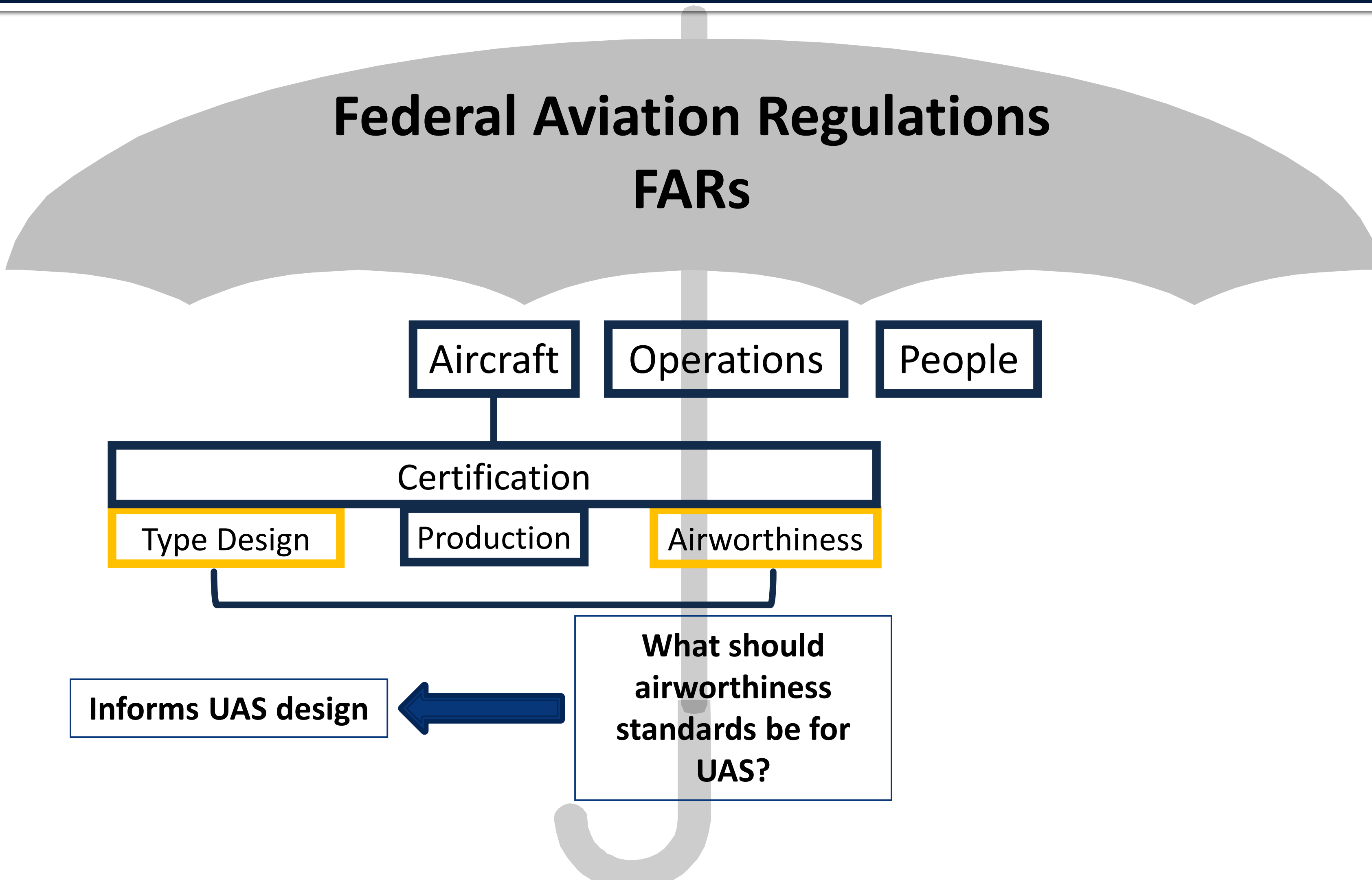
Not to worry – this won't hurt

Kelly Hayhurst
NASA Langley Research Center

In Context


Federal Aviation Regulations
FARs
Aircraft
Operations
People
Certification
Type Design
Production
Airworthiness
Complies with applicable safety requirements & standards
Quality control system for producing the product
Conforms with type design, and in a condition for safe operation

In Context


Federal Aviation Regulations
FARs
Aircraft
Operations
People
Certification
Type Design
Production
Airworthiness
What should airworthiness standards be for UAS?
Informs UAS design

Current Airworthiness Standards

- No person may operate an aircraft unless it is airworthy
- FARs have airworthiness standards for
  - Part 23 Airplanes
  - Part 25 Airplanes
  - Part 27 Rotorcraft
  - Part 29 Rotorcraft
  - Part 31 Manned Free Balloons

Part 25: Airworthiness Standards: Transport Category Aircraft

1. Subpart A – General
2. Subpart B – Flight
3. Subpart C – Structure
4. Subpart D – Design & Construction
5. Subpart E – Powerplant
6. Subpart F – Equipment
7. Subpart G – Operating Limitations & Information
8. Subpart H – Electrical Wiring

Applicability of Current Standards

- Do existing standards apply to UAS?
  - in whole or in part?
  - to all UAS or just some?
- What about UAS-unique parts?
  - communication links
  - sense and avoid systems
  - ground control stations
- How do you know what applies?

XX.1309

- Avionics considerations are in FAR Parts xx.1309
  - intended functions must be performed under any foreseeable operating condition
  - unintended functions must be improbable
    - failure conditions preventing safe flight and landing must be *extremely* improbable
- FAA Advisory Circulars provide guidance (e.g., AC 23.1309)
  - reliability and design assurance requirements

Reliability and Design Assurance

Probabilities for single component failure causing a system failure condition of the given severity

Classification of Failure Conditions	No Safety Effect	Minor	Major	Hazardous	Catastrophic
Part 25 Transport	No Requirement	$<10^{-5}$ Level D	$<10^{-5}$ Level C/D	$<10^{-7}$ Level B/C	$<10^{-9}$ Level A/B

Reliability requirement

Design Assurance Levels for Software and Complex Electronic Hardware

Would avionics on a large UAS need to comply with this?

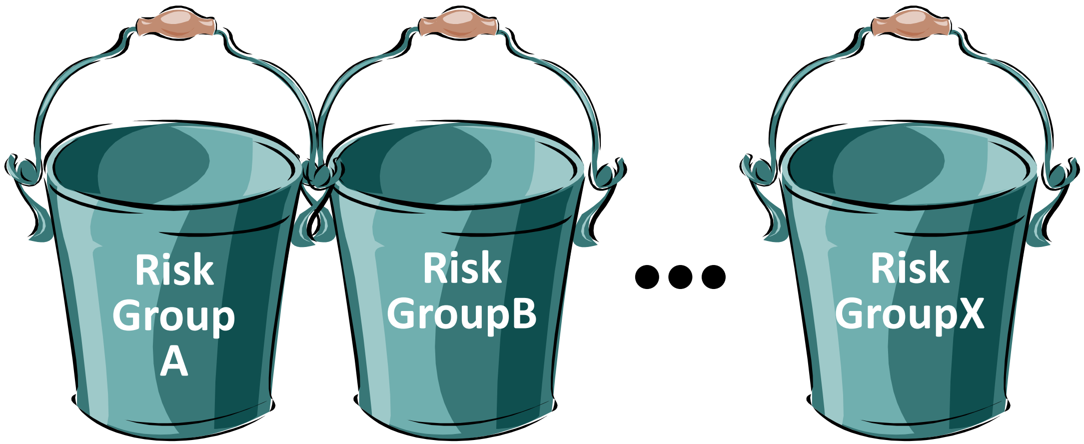
Categories

Type of Aircraft	Weight Ranges (lbs)	Reliability & Design Assurance Level Source
Part 23 Airplane (1 reciprocating engine)	< 6000	Part 23, Class 1
Part 23 Airplane (2 reciprocating or 1 turbine engine)	< 6000	Part 23, Class 2
Part 23 Airplane	[6000 - 12, 500]	Part 23, Class 3
Commuter Airplane	[12, 500 – 19,000]	Part 23, Class 4
Transport Airplane	> 19,000	Part 25
Normal Rotorcraft	< 7000	Part 27
Transport Rotorcraft	> 7000	Part 29

What if those are imposed on UAS?

Relationship of Risks to Standards

- Aircraft with similar risk should be held to similar standard
  - greater risk ⟷ higher standard
  - lower risk should not be unduly burdened



- How do different UAS fit?

Research Thrust

Determine appropriate criteria for allocating airworthiness standards
- especially for avionics

Objective 1

UAS Classification

(To determine factors important to grouping UAS)

Objective 2

UAS hazard and risk-related data

(To facilitate comprehensive understanding of UAS risks)

Concluding Thoughts

- Airworthiness standards for UAS are still in formulation
- Understanding risk is essential to appropriate standards
- NASA's UAS research aims to provide data to help

SUAS in the NAS

How to fit in

Josh Redding
Lockheed Martin
Procerus Technologies

FAA Certification

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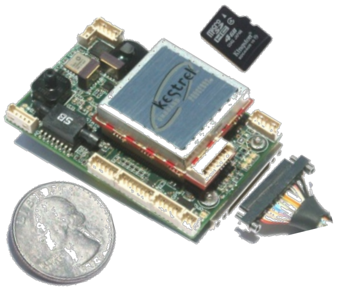
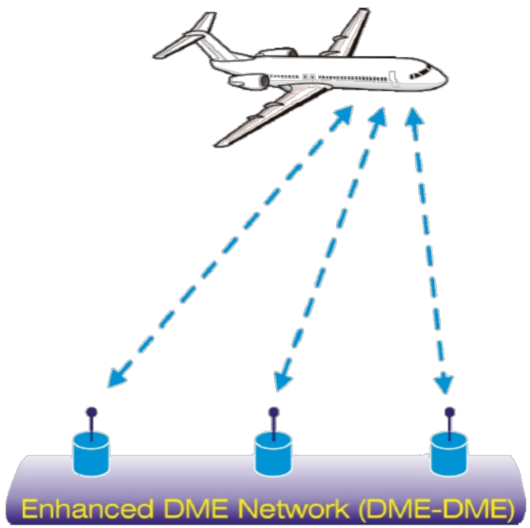
- FAA certification requires **reliability** and **predictability**
- SUAS can meet these requirements in many areas:
  - Loss of communication link behavior
  - Software/Firmware assurance (e.g. DO-178b/c)

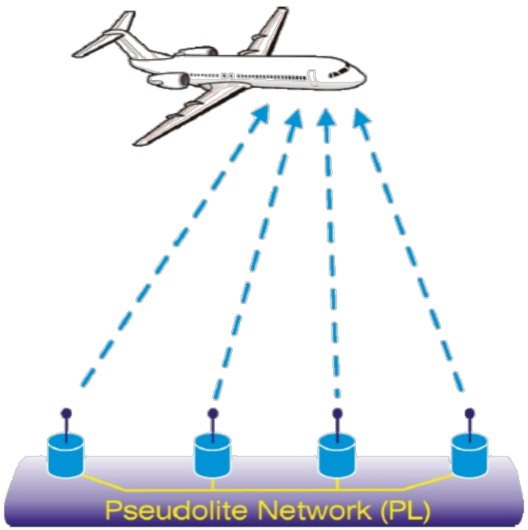


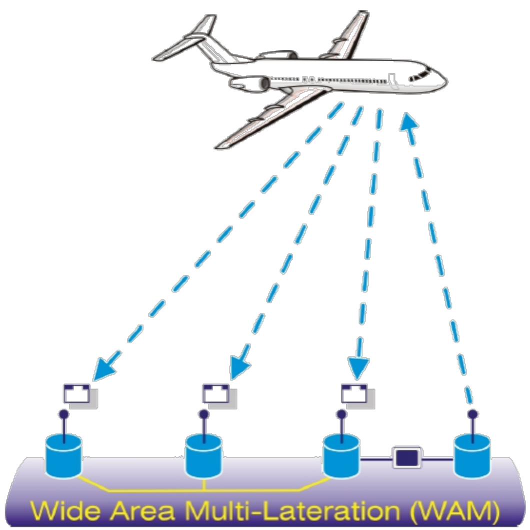
- Kestrel autopilot
  - ~15,000 flight hrs
- Insitu ScanEagle
  - ~600,000 flight hrs

GNSS Degradation

- Dealing with GNSS degradation is a **major** issue
- Slow, positional drift is **undetectable** by IMU
  - SUAS location is therefore not predictable
- FAA's Alternate Position Navigation and Time (APNT)
  - Some equipment likely too large/heavy for SUAS
  - Proposes pseudolites





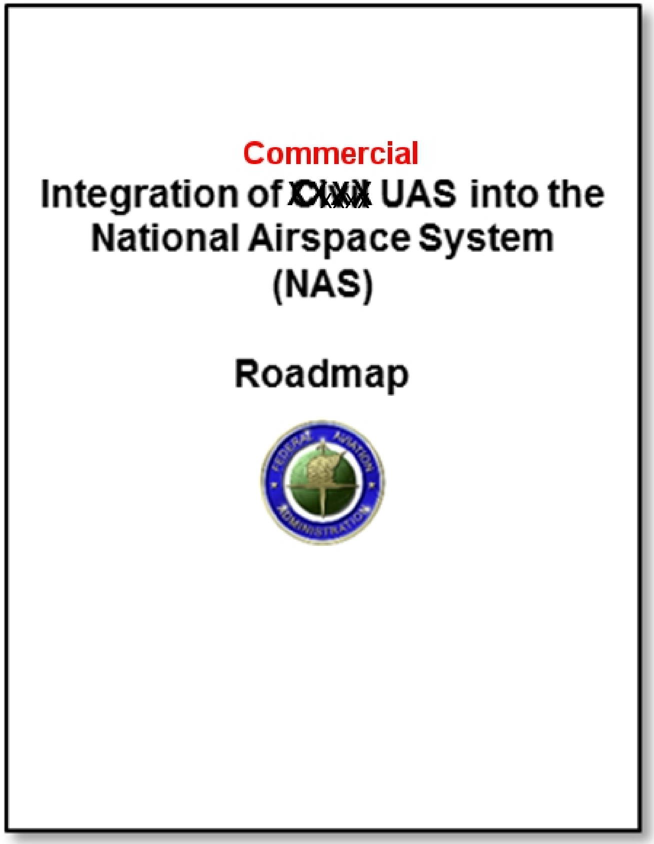


Sense and Avoid

- Are sense and avoid capabilities necessary for SUAS?
- Vision sensors effectively provide **relative** navigation
  - E.g. vision-aided landing
- With GNSS
  - ADS-B In/Out & computer vision
- Without GNSS
  - Onboard radar/vision, relative navigation
  - Ground-based radar (Mode C transponder)

Implications for SUAS Developers

- SUAS developers are pushing **commercial** acceptance
- Obtain airworthiness certificate(s)
- Assist customers in obtaining proper authorization
- Participate in FAA feeder panels and workgroups toward defining the certification process


Commercial
Integration of ~~Civil~~ UAS into the National Airspace System (NAS)

Roadmap

Implications for SUAS Developers

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- SUAS must be behave reliably/predictably
  - Transponder support, TCAS, ADS-B
  - Sense and Avoid
- SUAS behavior well-defined
  - Software assurance: DO-178b/c
- **Simulation** increasingly important
  - Statistically verify 10^{-5} failure rate
- Accurate/complete documentation

Poll #3

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Considering the implications of FAA's NextGen policy on UAS integration, how likely are you to opt for an FAA certifiable avionics-rated GNSS receiver in your navigation/payload design? (Please select one)

1) *Currently using an avionics-rated GNSS receiver* **4%**
2) *Considering an avionics-rated GNSS receiver* **4%**
3) *Considering both commercial and avionics-rated GNSS receivers* **17%**
4) *Use and will continue to use commercial positioning technology* **23%**
5) *Unsure and will wait for further clarifications from the FAA* **52%**

Next Steps

Contact Info:

- For more information on Trimble Unmanned Systems visit www.trimble.com/unmanned
- Email specific questions to unmanned@trimble.com

For more information:

- **Visit www.insidegnss.com/webinars for:**
  - PDF of Presentation
  - List of resources provided

Ask the Experts – Part 2

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A word from the sponsor

Joe Hutton

Director of Inertial and Airborne Products Applanix, a Trimble Company

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