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THE FUTURE OF FARMING:

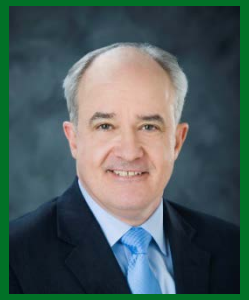
UNMANNED SYSTEMS IN AGRICULTURE—INNOVATIONS IN LAND AND AIR




Tuesday, March 7, 2017

WELCOME TO

The Future of Farming: Unmanned Systems in Agriculture - Innovations in Land and Air



James Poss, Maj Gen
(ret), USAF
CEO, ISR Ideas

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

Mel Torrie
Founder and CEO
Autonomous Solutions, Inc.

Benjamin Schilling
Director
NovAtel Inc

Co-Moderator: Lori Dearman, Sr. Webinar Producer

Who's In the Audience?

A diverse audience of over 350 professionals registered from 47 countries representing the following industries:

- **20%** Professional User
- **16%** GNSS equipment manufacturer
- **16%** Government
- **15%** Product/Application Designer
- **13%** System Integrator
- **20%** Other

Richard Fischer
Publisher
Inside GNSS and Inside Unmanned Systems

James Poss, Maj Gen (ret), USAF
CEO
ISR Ideas

Poll #1

Why would you invest in agricultural UAS?
(Please select one)

- *The market is about to explode; technology is ready!*
- *Right thing to do; precision ag is good for the environment*
- *The tech and policies might not be there yet, but I want in*
- *Are you kidding me? There's no market there*

Are Garden-Variety Drones for Real?

James Poss, Maj Gen (ret), USAF
CEO
ISR Ideas

Why Garden Drones?

Courtesy CNH Industrial

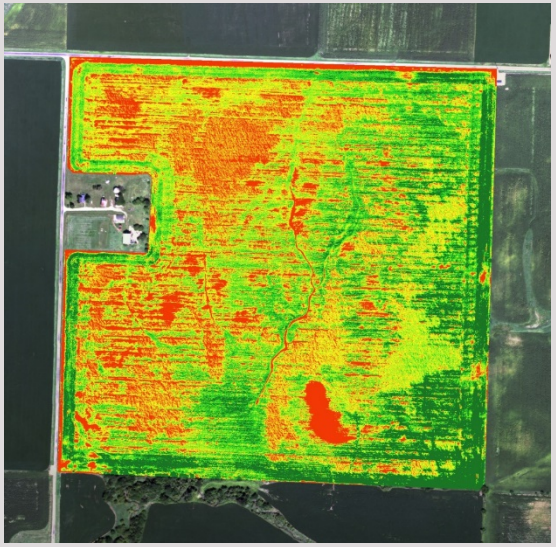
TO SAVE MONEY

- In an industry with razor thin cost margins in the most climatically and geographically divergent industry in the world

- The Theory behind agricultural UAS:
  - UAS can increase yields, cut costs by providing improved crop prescriptions based on frequent, highly accurate imagery
  - UAS can replace pilots for agricultural applications missions, cutting risk and saving materials

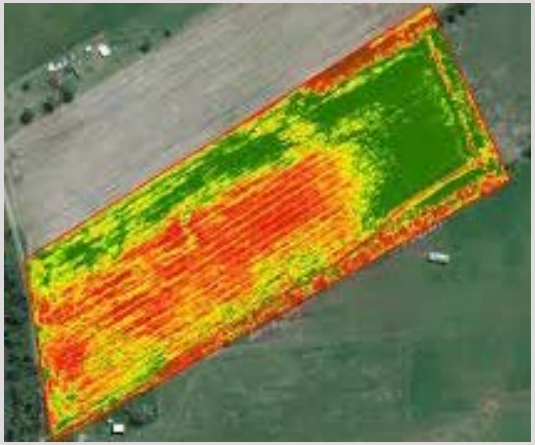
UAS: Improved yields

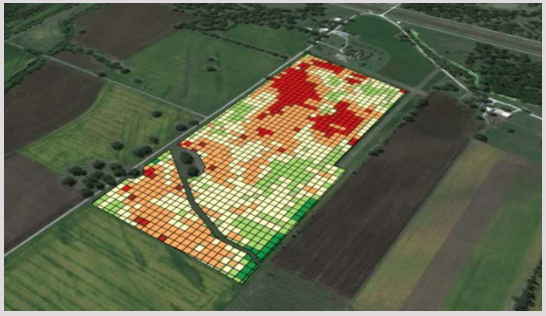
- Improving yields with imagery:
  - Electro optical: spots crop damage, equipment faults, etc.
  - IR: crop hydration, growth, insect infestation prediction
  - Hyperspectral: disease, insect activity, crop type
  - LIDAR: precision elevation, drainage, plant stand count, tree population



UAS: Improved yields

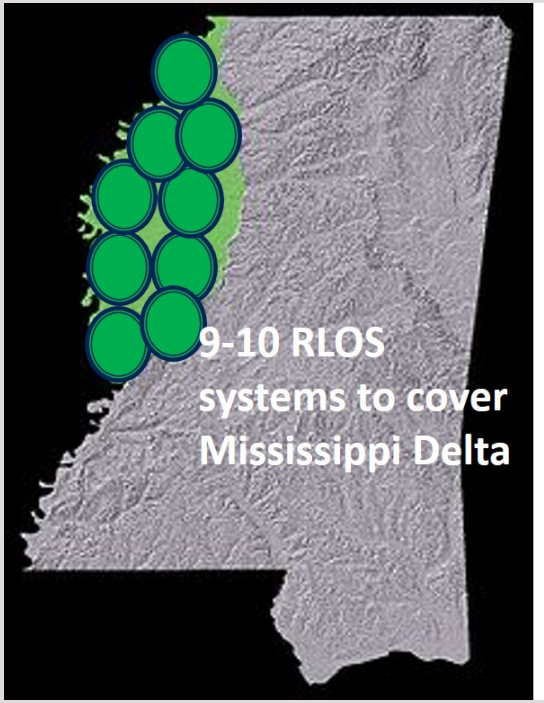
- Imagery MUST be processed:
  - Need rapid turn around (less than 24 hrs) from imagery to crop prescription
    - Prescription: georeferenced production inputs (seed, fertilizer, chemicals, etc.) for application only as needed and where needed for the most economic production.
  - Timelines less stringent for mapping, precision just as important

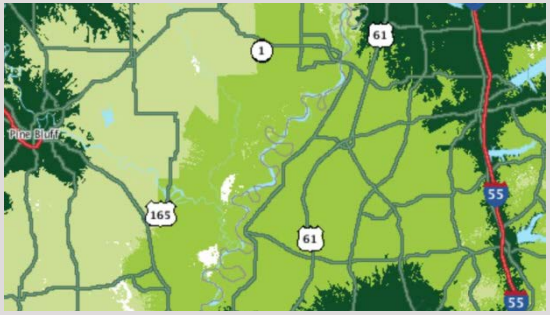




UAS: Precision Ag challenges

- Requires sophisticated, well equipped customers
  - Precision ag requires precision applicators, seeders harvesters; must be variable rate capable.
- Tough to make timelines with current sUAS rules; not BLOS, no enterprise solutions for processing
  - 2 nm drone coverage not efficient
  - Data link coverage spotty in agricultural areas



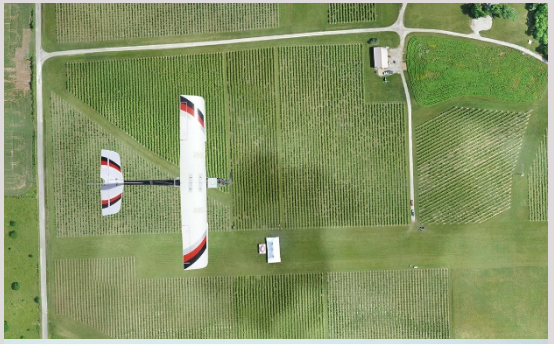


UAS: Precision Ag challenges

- Size matters
  - Crop dusters are sized for efficient application; Air Tractor 502-B carries 500 gallons
    - That's fifty sUAS in capacity alone
  - Small cameras = more pictures. More pictures = more passes (and more $)
- Manpower matters
  - Tough to make margins with one pilot per drone in VLOS
- Avg insecticide cost per acre:
  - $15-20
  - Whatever drones do, they have to be cheaper than this

UAS: Are there better markets?

- Cost margins are tough for agricultural production
- Crop Insurance market?
  - 2016 Farm bill starts switch from subsidies to crop insurance
  - Crop insurance requires verification throughout growing season to cut false claims
  - Every American farm will need multiple images per year
- Commodities market?
  - Cheap drone imagery + improved weather forecasting = Market cornered
- No one makes money without BLOS, larger UAV, enterprise imagery storage/interpretation



Unmanned Ground Systems

- Similar disadvantages to UAS:
  - Requires sophisticated, well equipped customers
  - Highly reliant on accurate location & geospatial data
  - Cost margins are TOUGH
- Advantages over UAS
  - Ground robotics well established in US agriculture (Eli Whitney?)
    - Driving tractor the “easy part” compared to modern seeders/applicators
  - No FAA to deal with

UAVs and Precision Agriculture: The PNT Challenge

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

Precision Agriculture

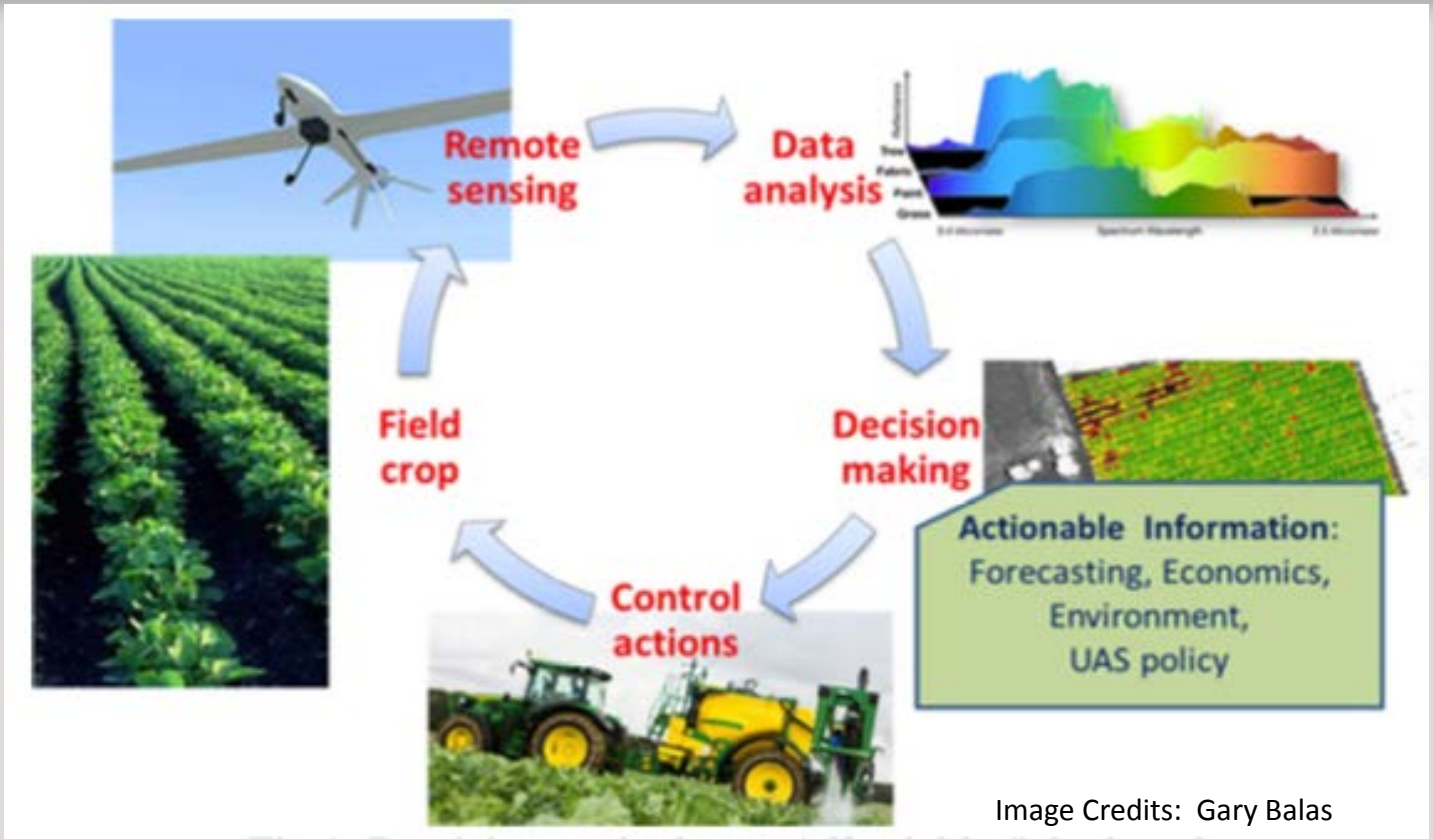


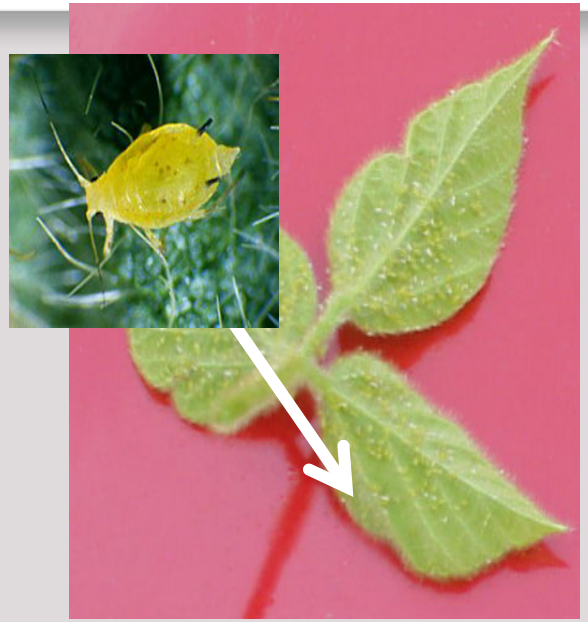
Image Credits: Gary Balas

- Close the data-decision-action loop more efficiently
  - Allow more **economic** use of resources.
- PNT accuracy and integrity will be key metrics

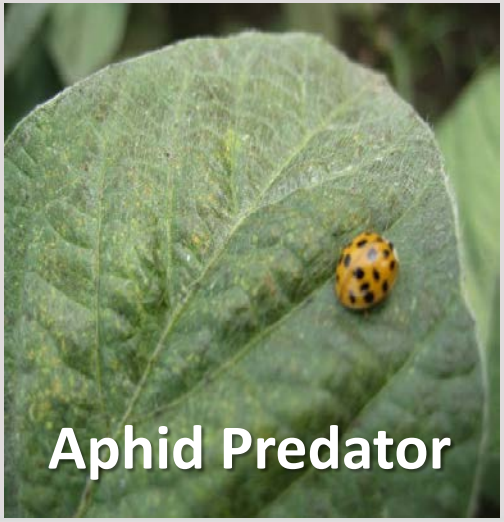
Example: Soybean Aphid Management

Example: Soybean Aphid Management

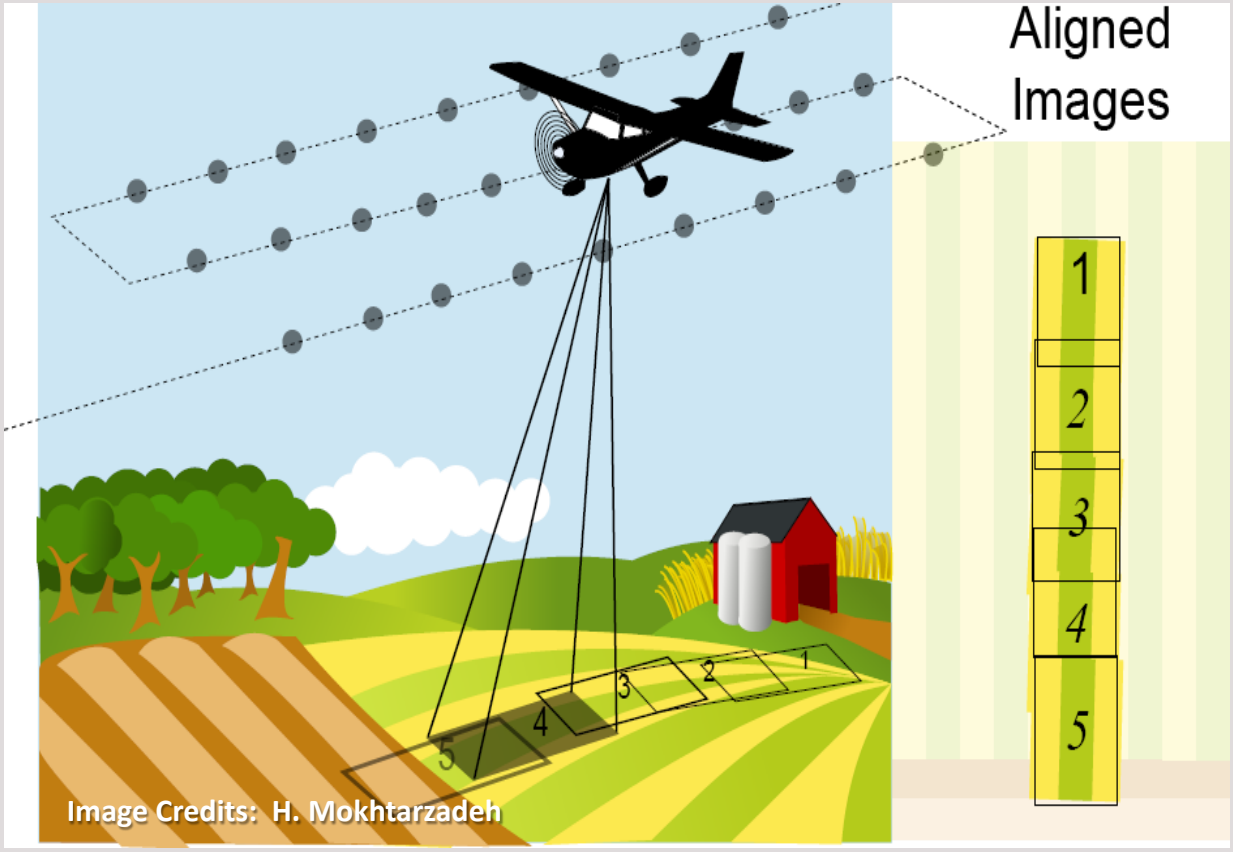
- Soybean aphid (Aphidis Glycines) causes up to 40% loss in yield.



- Uniform pesticide application inefficient.
  - Non-uniform Infestation
  - Unnecessary runoff
  - Kills off natural predators
- Solution: **Targeted** pesticide application.
  - Right time.
  - Only where needed.
- Image crops in a band which shows plant damage due to infestation.

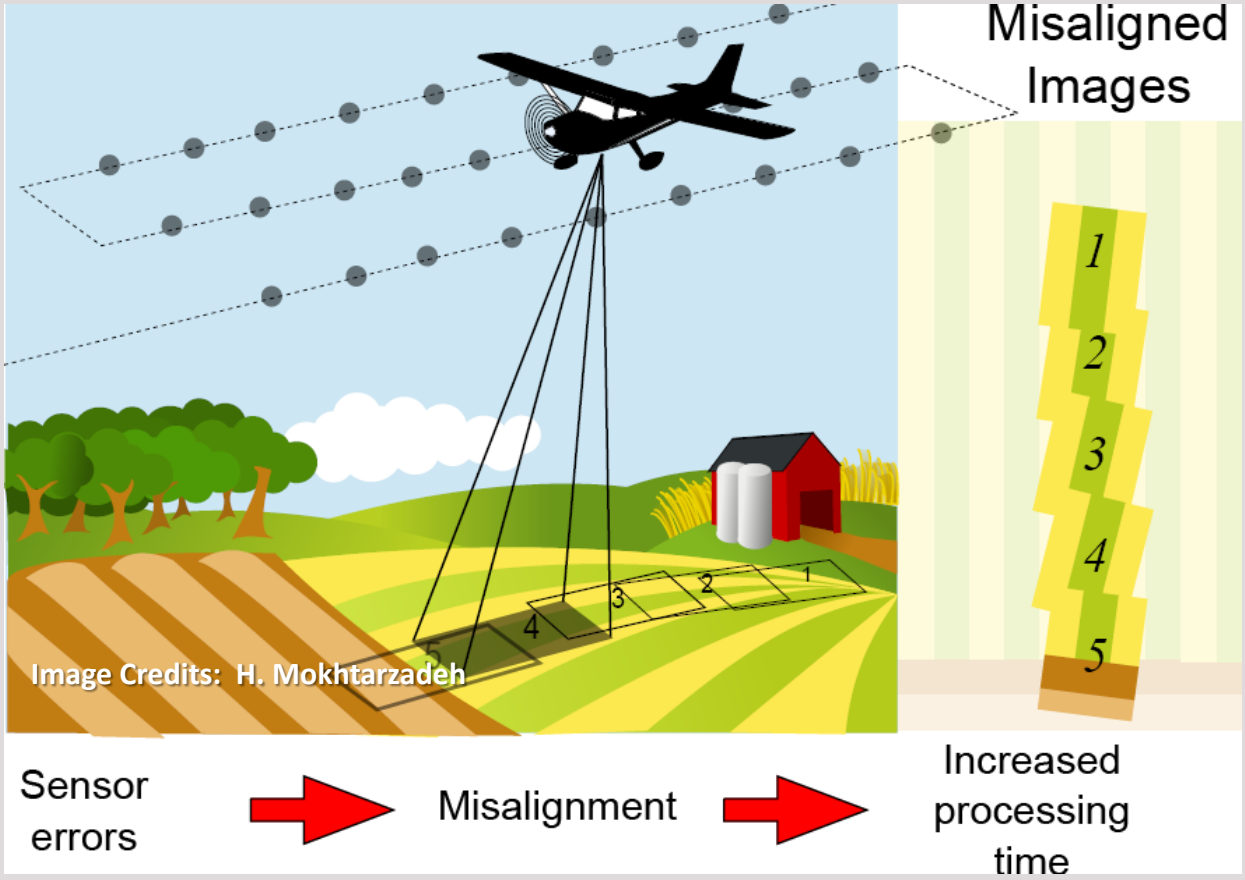


Direct Geo-referencing



- **Geo-referencing** = Assigning position coordinates to objects in an image.
- **Direct Geo-referencing** = Geo-referencing only by using observers pose and a terrain database.

Impact of Sensor Error



- IMU + single freq. GNSS code phase is not accurate enough.
- Real Time Kinematic (RTK) can provide the requisite accuracy.

Direct vs. Post Process

Direct Geo-referencing
(IMU + Code Phase GNSS)

Bundle Adjustment
(Optimization in post-process)

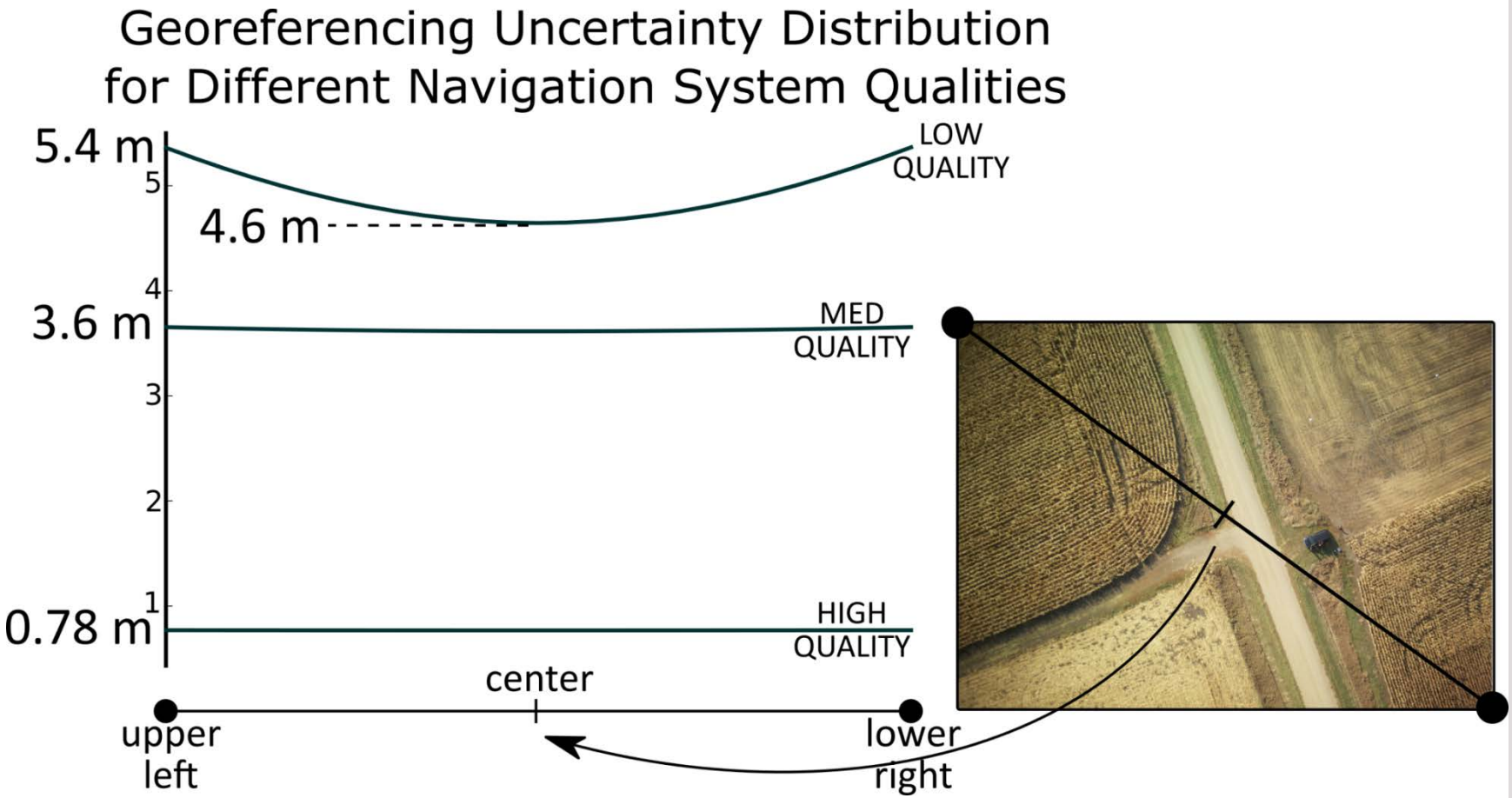
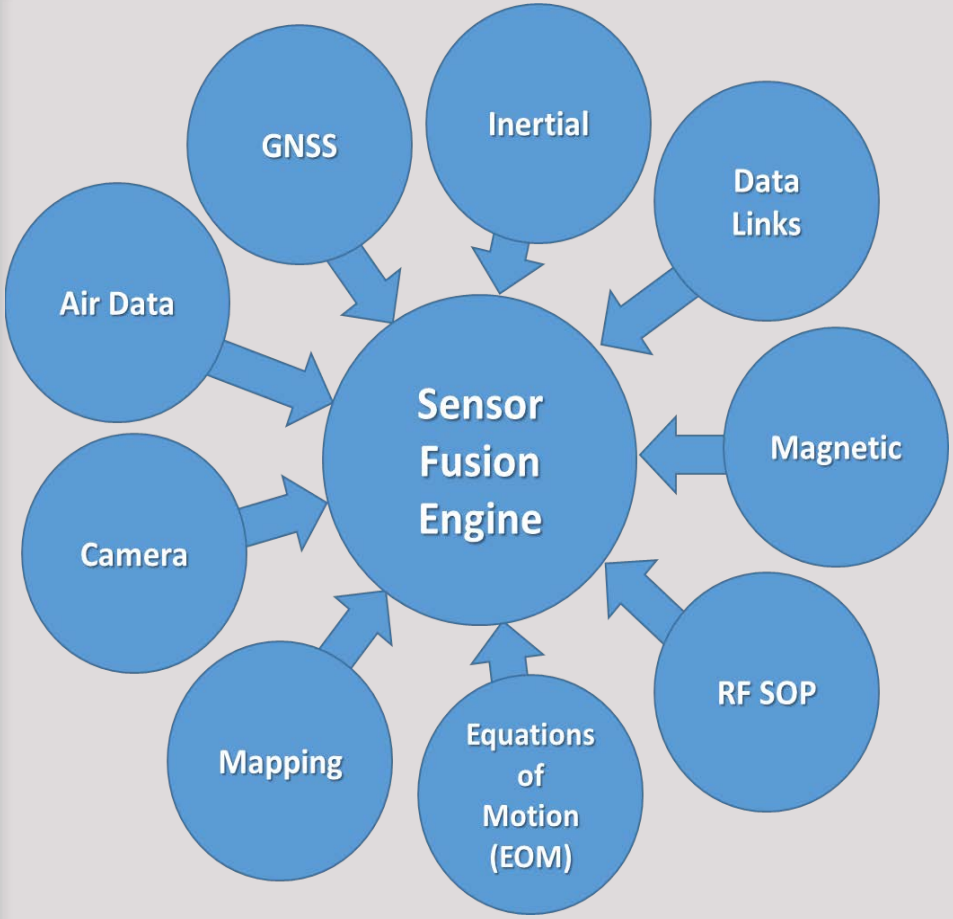


Image Credits: H. Mokhtarzadeh

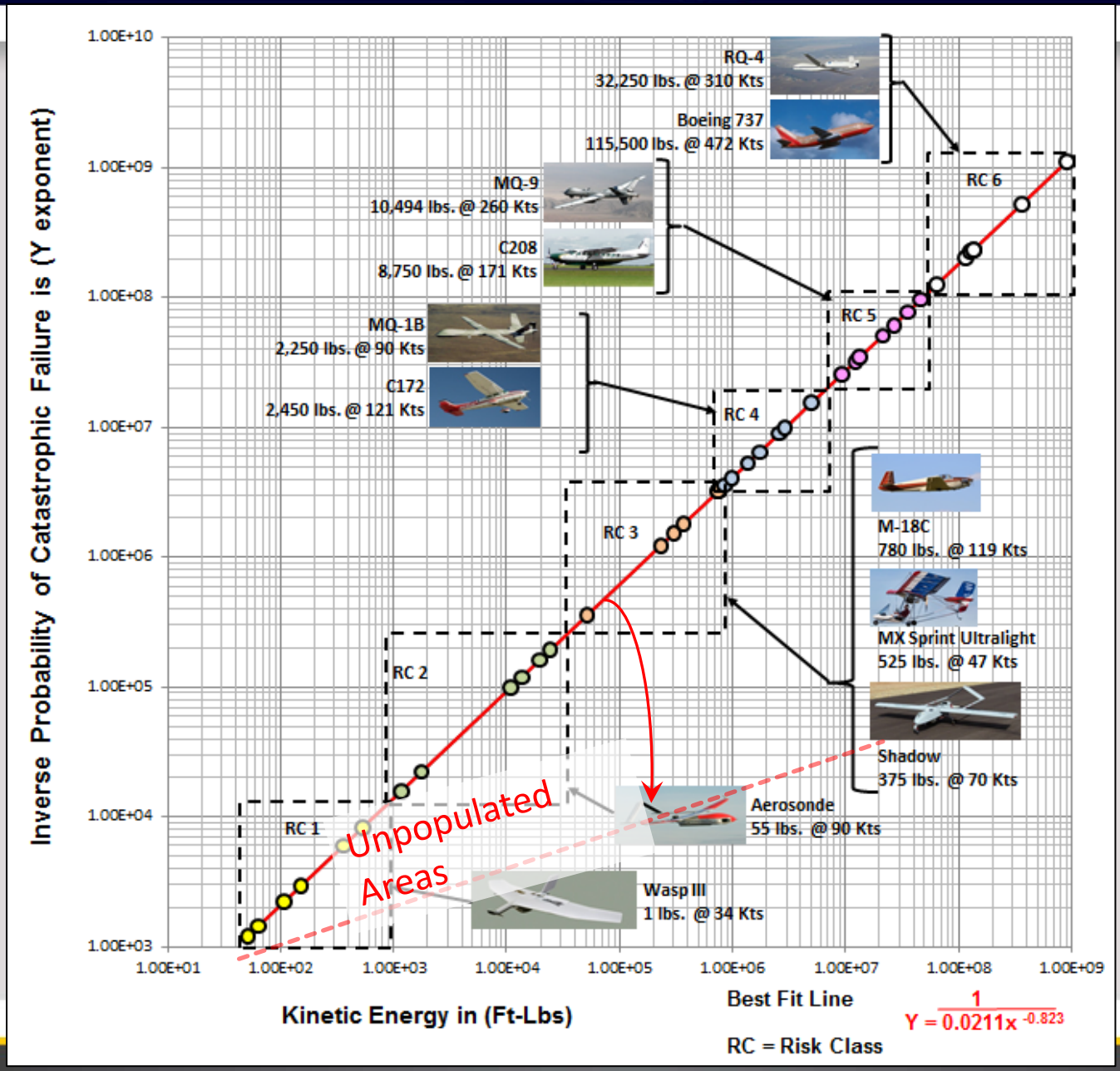
The Integrity Challenge



- Vehicle states estimated using traditional sensor integration schemes
  - Kalman Filter & variants
  - Crucial for safe control
- Future integration schemes will use
  - Non-traditional integration schemes (e.g., deep learning)
  - Non-traditional sensors.
- How do you prove integrity on with such sensor fusion schemes?
- Proving safety is a key requirement for Beyond Line of Sight (BLOS) operations.

See P. Groves, "The PNT Boom," InsideGNSS, March/April 2013, pp. 44-49

Risk-Based Certification

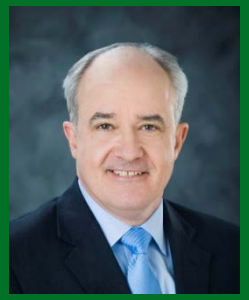


Credit: Wes Ryan, Manager Advanced Technology Programs & Procedures, FAA

Conclusions

- UAS can potentially increase the efficiency of agriculture operations.
- Accurate and reliable PNT is a key enabler.
- Provable level of safety and robustness of PNT solution is a key challenge moving forward.

Ask the Experts – Part 1



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Benjamin Schilling
Director
NovAtel Inc

Poll #2

What's stopping you from investing in agricultural UAS?
(Please select all that apply)

- The FAA rules are too restrictive
- Technology just isn't there yet
- There's no market; cost margins are too tight
- Are you kidding me? I'm investing now
- Other

Autonomous Farm Vehicles

Mel Torrie
CEO
Autonomous Solutions Inc. (ASI)

Autonomous Solution Inc. (ASI)

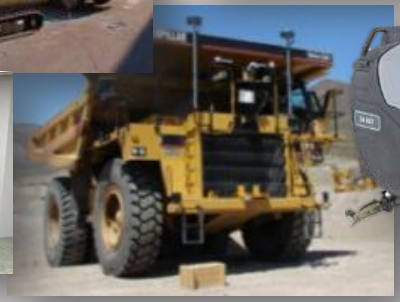
- Founded 17 years ago
- Field robotic ground vehicle solutions leveraging common platform building blocks





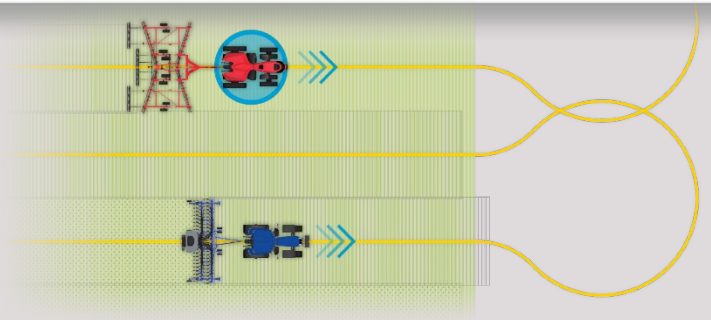





Our Autonomous Farming 1995-2017

Current Drivers for Automation



1. Step change in Labor Costs
   - Minimum wage hikes
2. Availability of labor and the right skill levels
   - Children not staying on the farm
   - Immigration reform, pending wall, etc.
3. Maintenance savings
   - Mining example -> 3X tire life in an autonomous mine
4. Productivity – deterministically optimize how crop is covered, the size of the equipment, and the number of units given choice of priorities (time, compaction, fuel, cost, etc.)

Size – The New Math

LESS COMPACTION, FUEL, SERVICE, DOWNTIME IMPACT, TRANSPORT COSTS

Smaller machines, less service, and fewer total units, pending disruption attempts by small tractor OEMs

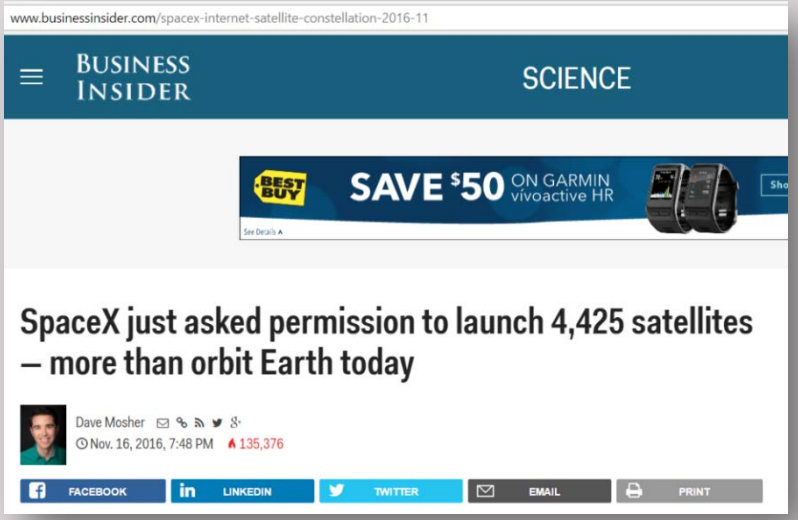
Challenges for Automation

1. Vehicle Automation
2. Communications Limitations
3. Perception
   - Cost, Weather, Dust, Foliage Penetration
4. Positioning blockage and consistency
5. Serviceability
6. Liability

- Larger tractors are making great inroads towards full drive by wire actuation
- Progress in centralized / distributed electronics via CAN bus standards
  - "**ISBUS Class 3** is currently the highest interface level and allows the implement to take control of certain tractor functions (e.g hydraulic remotes, PTO, 3-point hitch, steering, ground speed, etc.)."

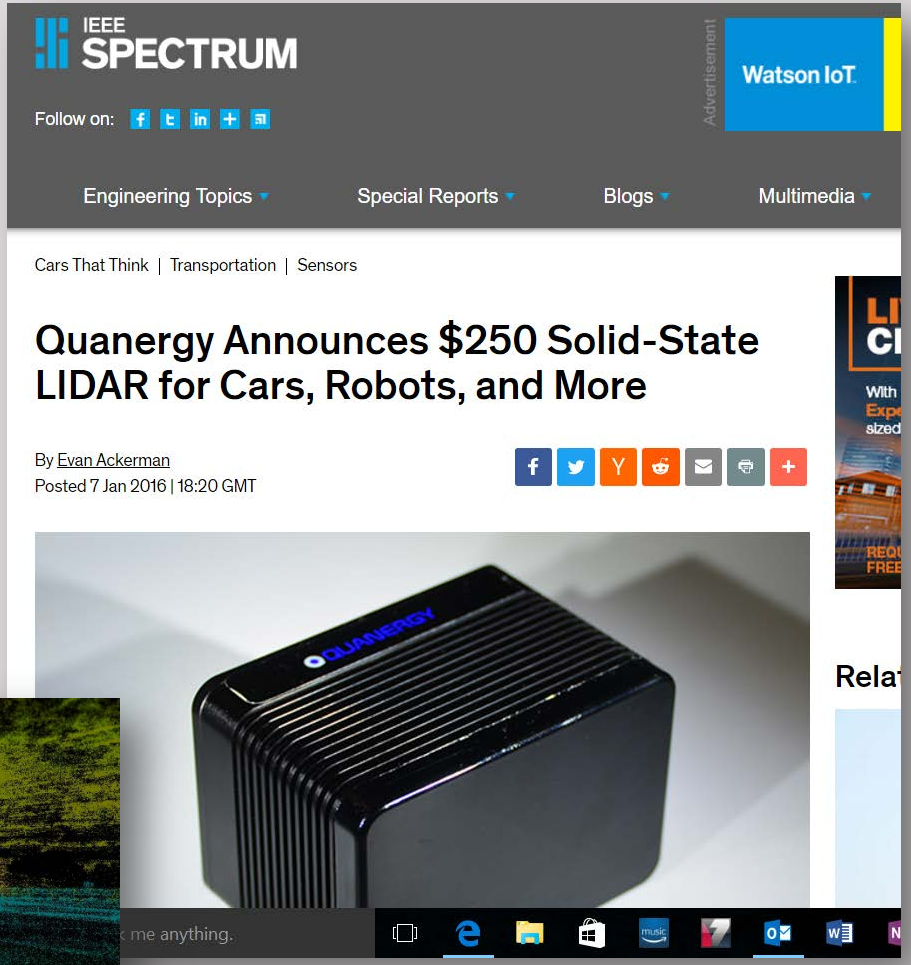
Communications Advances

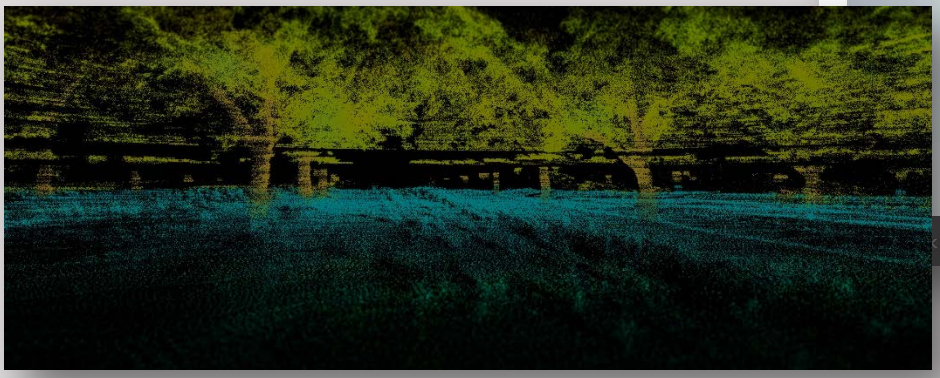
- Meshing multi-frequency radio solutions for better foliage penetration and range
- Telematics connectivity getting better
- 1Gbps coming:
  - 5G (2018)
  - Low Earth Orbit Satellites (2019)



Sensor Cost

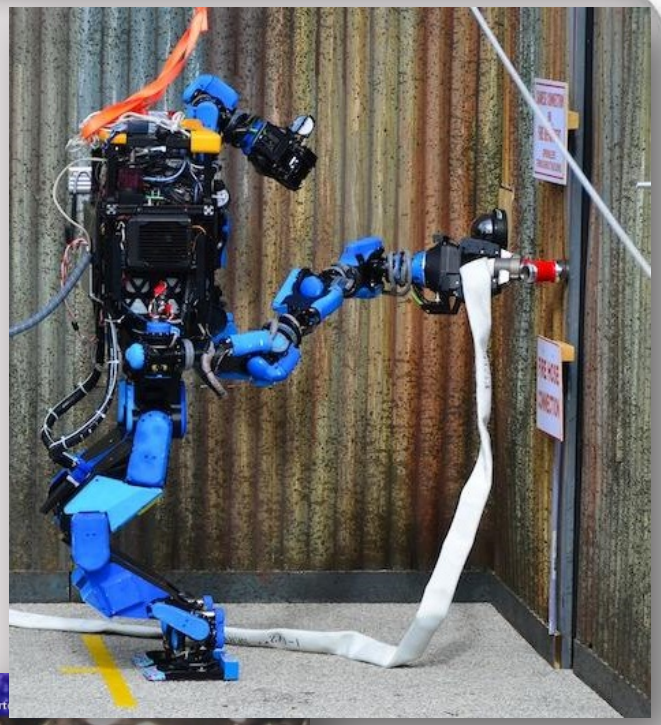
- Automotive driving down costs and advancing technology maturity
  - Lidar -> Solid State
  - Lower cost and higher accuracy Radar
  - Parallel GPU Image processing

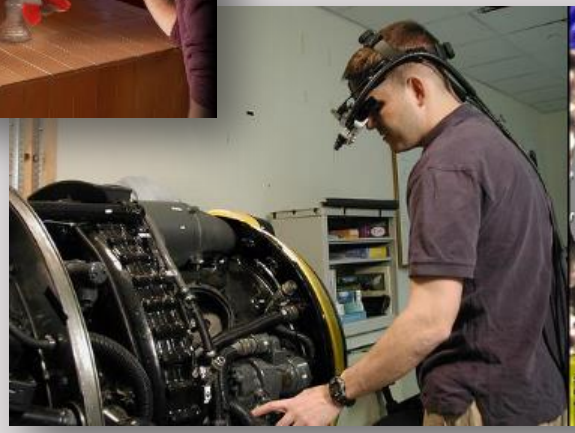




Service and Support

- Telematics connectivity is continuing to get more functional and better coverage
- Future: Robots will resupply and service equipment
  - …While it is moving





People disable safety systems and win lawsuits in every industry

- Design tamper proof systems
- Get good insurance
- Support best practice standards establishment

Functional Safety

- An accident sets us all back
- Find the relevant safety standards and get educated and if possible contribute
  - ISO 25119 Agriculture Machine Safety
  - ISO 18497 Highly Automated Agriculture Machines (HAAM)

OEMs starting to take risk

- OEM's usually wait to be pushed by small companies
- Large companies are showing willingness to lead the way and tolerating more risk
- Triggers competitors to do the same

Lessons in the Field

Slippery Slope!

1. Ignore them
2. Stop monitoring them
3. Taunt them!

Where Are We Really At?

- Technology maturity and costs are finally to the point where we can start fielding systems!
- “Hands Off” field trials this year with early adopter farms doing “low hanging fruit” applications

Poll #3

What incremental cost would you expect to pay for a fully autonomous piece of Ag equipment? (per unit)
(Please select one)

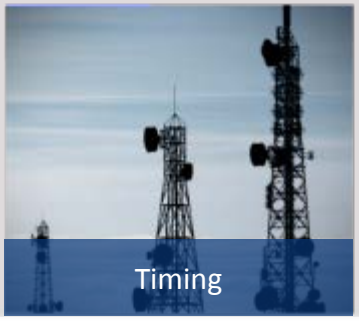
- 10K
- 35k
- 65K
- 100k plus

Unmanned systems in Agriculture Innovations in Land and Air

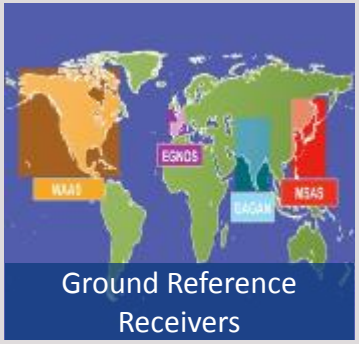
Ben Schilling
Director of Sales
Global Business Manager - Ag
NovAtel Inc

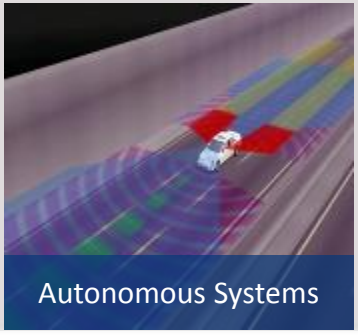
NovAtel Market Segments

Measuring (Sensing)

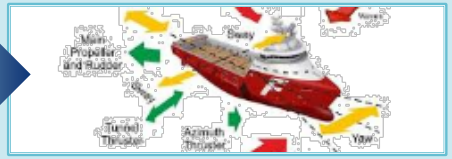


Guiding (Controlling)





OEM Strategy

Technology	Customer	End User
 GNSS Positioning Engine	 Autopilot System	 Autonomous Aircraft
 GNSS Smart Antenna, Corrections	 Ag Guidance System	 Farmer
 GNSS Positioning Engine & Antenna, Corrections	 Dynamic Positioning System	 Offshore Vessel Operator

Trends in GNSS Positioning

InsideGNSS | NovAtel | inside unmanned systems

90s and early 2000s: Accuracy

- Positioning techniques
- DGPS, RTK
- Multipath mitigation

Now: Availability

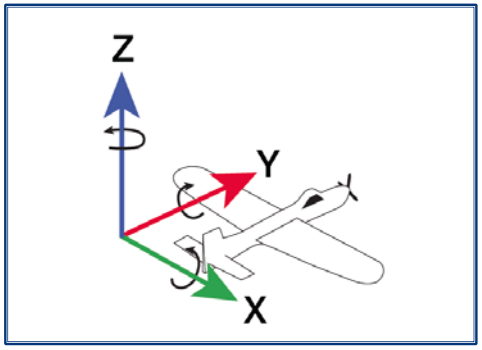
- Multi-constellation: GPS, GLONASS, Galileo, Beidou
- Sensor fusion
- Position + orientation

Future: Safety & Reliability

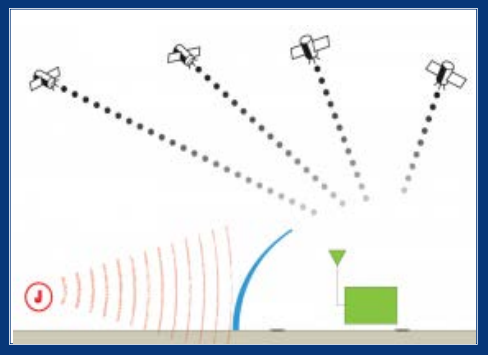
- Safety of Life applications
- Functional safety
- Protection from spoofing/jamming

Our Competitive Advantage

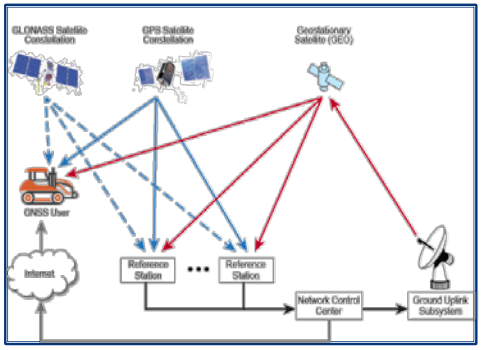
Unlocking Precision and Reliability in Positioning by Mitigating GNSS limitations



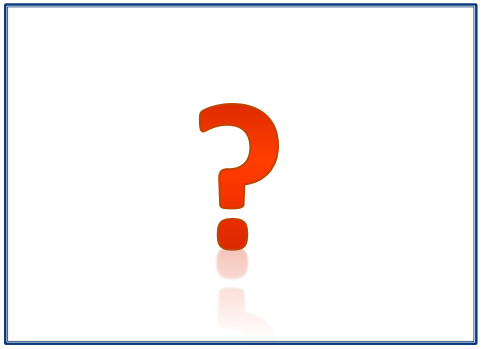
GNSS Sensor Fusion



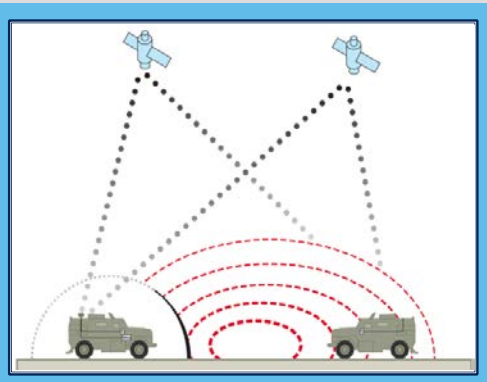
Anti-Jamming (GAJT)

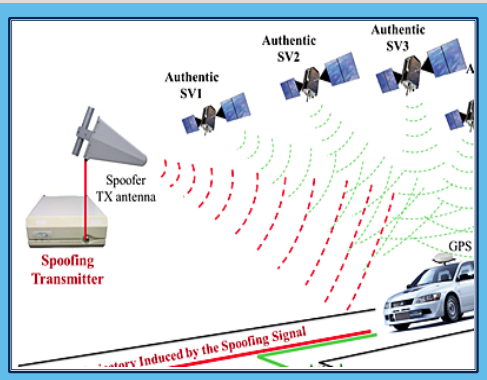


Authentication



Solving Limitations





Jamming

Availability

Spoofing

A Long History in OEM Precision Agriculture

1999

2007

2008

2013

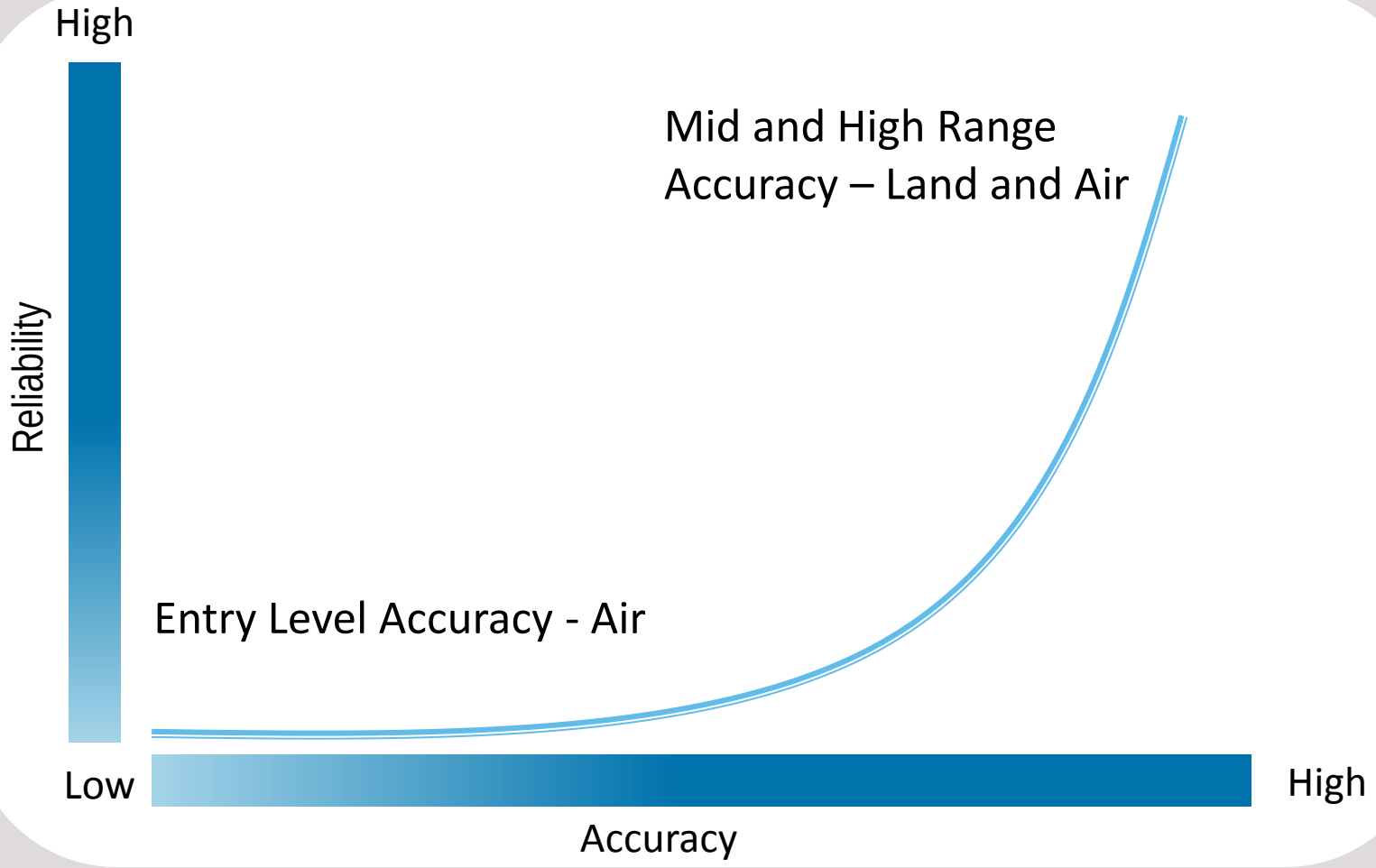
TERRASTAR C

2015

2016 TERRASTAR L

Trend to higher accuracy

The focus is reducing size, weight, and cost of a GNSS position solution while increasing accuracy and robustness.



Achieving Reliability & Accuracy with GNSS

GNSS Signals
Multi-constellation and multi-frequency GNSS drive solution accuracy and availability

Receivers
Optimization of cost/weight/size/ performance

Antenna
Critical to accuracy and often neglected

Corrections
Augmentation of GNSS to improve accuracy and reliability

Sensor Fusion
Motion and environmental sensing offsets GNSS limitations

Smaller receivers—Tightly Coupled INS - Smaller antenna's
Safety of life applications
Multiple and redundant corrections services
Multi-sensor integration
Supporting the expansion of constellations
Waypoint post processing

Assured Positioning—Anywhere.

In our ideal view of the future, position, velocity and attitude are solved in every application, in every environment, all the time—to an appropriate level of accuracy, and with a high level of integrity.

Next Steps

Visit www.insidegnss.com/webinars for:

- PDF of Presentations

Contact Info:

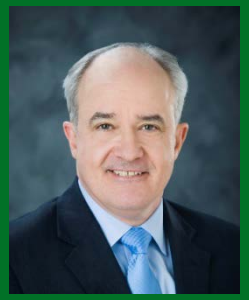
- **Major General James Poss**
  james@isr-ideas.com
- **Demoz Gebre-Egziabher**
  gebre@umn.edu
- **Mel Torrie**
  Mel.Torrie@asirobots.com
- **Ben Schilling**
  Ben.Schilling@novatel.com

Poll #4

What are the big obstacles with agricultural UAS?:
(Please select all that apply)

- Can't fly BLOS yet; no money in VLOS
- Technology isn't there yet to provide timely ag data
- Cost margins are too tight
- 55 lbs is too small for an ag UAS
- Other

Ask the Experts – Part 2



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Benjamin Schilling
Director
NovAtel Inc

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