Future Transport - Potential of UAS and Hyperloop

New Ways to Move People and Parcels

embrv-riddle

September 19, 2018
PMI Memphis, TN
Dr. Sam Siewert

**Johnson Space Center**—Shuttle Ascent and Entry GN&C, Mission Control

**JPL AI Group, CU Space Grant and Ball Aerospace**

**CU Boulder Adjunct Professor** - CTO, Architect, Engineer in Local Start-ups and Intel Architecture / Labs

**U. of Alaska** - Assistant Professor, Computer Systems Engineering, Alaska Space Grant, DHS ADAC

**Embry Riddle Prescott** - Assistant Professor, Computer, Electrical and Software Engineering, ARI Drone Net

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What I presently teach - CS, SE, CE, ESE

CU Boulder Graduate ESE
ECEE 5623 - RT Systems
ECEE 5763 - EMVIA

Software Engineering (2018-2019 Catalog)

[Diagram of course structure]

- Please refer to catalog for official degree requirements.
- Course requisites are subject to change, as they are specific to the academic year, not to the catalog year.
R&D - A Tale of Two Cities

- Hawthorne CA - SpaceX, E. Musk, Student Leaders!
- Prescott AZ - ERAU, ICARUS, 2020 Shared Airspace
  - Common Goal to Revolutionize Parcel Transport
  - Eventually Move People Too! (Hyperloop, Air Mobility Taxis)
Challenges & Opportunity

**UAS Opportunity**
- Parcels, medical, SAR, Agriculture, Science, Mapping, Monitoring, Security, …

**UAS Challenges**
- Regulations
- **Traffic Management**
- Shared Airspace
- Social Acceptance
- Safety & Security

**Hyperloop Opportunity**
- Fast Freight
- High speed (rail) transportation
- City center to center

**Hyperloop Challenges**
- Maglev or Air Bearing
- Long Vacuum Tube
- Acceleration/Deceleration
- Social Acceptance
- Safety & Security
Drone Regulations

At ERAU Prescott - We have Dr. Sarah Nilsson

Sarah Nilsson
Assistant Professor of Unmanned Aircraft Systems
Applied Aviation Sciences Department
Ph.D., Northcentral University
J.D., Arizona Summit Law School
M.A.S., Embry-Riddle Aeronautical University

FAA guidelines - 3 Legal Ways to fly (must register)
- Part 101 (Section 336) - Hobby
- Part 107 Small UAS - 0.55 to 55 lbs, 400 AGL in Class G
- Public COA (Section 333), over 55 lbs
- Waivers are possible for some Part-107 restrictions

Primary Agency Research by NASA (UTM), FAA (ASSURE)
Project Team Management

**Drone Net**
- Faculty Led
  - PI, Co-I, Collaboration
- Student collaboration
  - MS, PhD
  - Undergraduate
- Outreach
  - H.S. summer camps
- R&D
  - Research focus
  - Theory - hypothesis
  - V&V - experiments

**AZloop - Hyperloop**
- Student Led
  - Student PM team
  - Subsystem leads
  - Faculty advisors
- r&D - ASU, ERAU (2018)
  - Engineering (all majors)
- ERAU URI and Corporate Sponsors
- SpaceX Competition
  - Design and Safety Reviews by SpaceX

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Genesis of the Hyperloop

Elon Musk - Hyperloop Alpha (2013), Boring (hates commuting)

ERAU Student Team went to Texas A&M for first ever Hyperloop Design and Build Competition

- They adopted me as club/URI advisor, They did everything
- We met Elon Mush and Anthony Foxx (Secretary of Transportation)
- Students had fun, but MIT, Delft, and other well-sponsored big universities won
- Then and there, Arizona students decided to band together

3 Types of Maglev

- Traditional Maglev - combination of permanent magnets and electromagnetic stabilization
- Induction of Eddy Currents in Metal by motion relative to magnet (video)
- 2 permanent magnets, but only if one is spin stabilized
Big Ambitious Projects …

Need Agile Development Methods

Overview and Simplified Version for
SE310 and SE420 Use
Workflow for a "V" using XP or Spiral

- Rather than Parallel Waterfall on Design/Dev Side and QA side, allow for Feedback or Evolution
- Task Level Workflow - E.g. Kanban (Github Project)

- Cycle time for SE420 and SE310 should be 2 weeks (for a Scrum Sprint)
- Hold stand-up meetings in class (at least once a week - provide status and re-task once teams are formed)
Kanban on Whiteboard / Sticky Notes

- Kanban originally intended to be a physical workflow method

- Abstracted into software tools
  - Github - Development workflow, Project boards
  - Atlassian - Jira
  - Numerous other Agile and DevOps process management tools
  - Columns depend on project and phase of Analysis, Design, Development, Test, etc.
  - Facilitates stand-up status meetings

Backlog (deferred tasks)
  Analysis, design features, tests, …

Ready (start implementation)
  Code construction, test plan, design, …

Doing (coding, testing, designing, …)

On-hold (awaiting team decision)

Done (ready for next phase)
  Move up or down the “V”
  Spiral to next quadrant
  Pass to new XP cycle or Scrum sprint

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PMI-ACP

PMI - Software, Computer - R&D, R&d, r&D

PMI-ACP Agile Certified Professional
- While Agile Comes from Software World, it is Generally Useful
- Hardware, Firmware, Software -> Systems -> Products & Services

The Agile Project Management Philosophy

It is critical to note that agile is not a methodology, but an approach that can utilize a variety of methodologies.

Agile uses organizational models based on people, collaboration, and shared values. The Agile Manifesto outlines the primary tenets of the agile philosophy. It uses rolling wave planning, iterative and incremental delivery, rapid and flexible response to change, and open communication between teams, stakeholders, and customers.

Examples of agile methodologies include SCRUM, XP, Lean, and Test-Driven Development (TDD).

Universal Principles for SQA and SWE

Testing Throughout Process Life-cycle is Concurrent with Engineering (The Boehm “V”).

Testing Activity & Strategy Match Phase of Engineering
- Acceptance Testing – Requirements
- System & Integration Testing – System and Architecture Design
- Detailed Design and Coding – Design Execution, Unit Testing
- Iteration and Sustaining – Regression Testing at all Levels

Validation (Building Right Thing), Verification (Thing Built Right) are Continuous Activities, Equally Important

Avoid Rigid Long Phases and Silos, Solicit Requirements
Agile Manifesto

http://agilemanifesto.org/principles.html

1. Early and Continuous Software Delivery to Customer
2. Welcome Changing Requirements, Even Late in Process
3. Deliver Working Software Frequently
4. Sponsors and Developers Work Together Start to End
5. Build Project Around Motivated Developers, Empower
6. Face-to-Face Primary Method of Communication
7. Working Software Primary Success Metric
8. Process and Pace Must be Sustainable (No Burnout)
9. Continuous Attention to Design
10. Simplify and Maximize Work Not Done – Less is More
11. Best Requirements, Architecture, Design Come from Self-Organizing Teams
12. Regular Interval to Tune and Adjust Behavior
Agile Practices

Acceptance Test Driven Development (Requirements)

Inherently Evolutionary Principals (Extreme, Spiral, Risk Control, Adaptive)

- Imagine Boehm’s V as a Funnel with Spiral Inside it
  - Where Phases of Analysis, Design, Coding are Concurrent with Test, But Also Spiral for Early Deliveries
  - Acceptance Test is Focus, but Unit Tests, Integration tests, System Tests, Regression Required Along the Way
  - Executable Design (Simulation – State Machines)
  - Proof-of-Concept – Feasibility of Highest Risk Design Units
  - Evolutionary Prototypes – Solicit Early User Feed-back

- **Sprint** (Evolutionary Cycle in Spiral)
- **Scrum Meetings** (Quick, Stand-up Meetings, What is Done, What is to be Done, Blockers)
- **Sprint Retrospective**

Customers are Internal as Well-as External
Agile Advantages

- Does Not Dictate a Process
  - Fit Current Process to Agile Principals
  - Implies Evolutionary Process and Concurrent Engineering and Test
  - Works with Extreme Programming and Tight Spiral and V Models, Could Work with Feed-back Waterfall, but Awkward

- Sustainable

- Focus on Team Behavior

- Works Well in Rapidly Evolving Markets

Extreme Programming Process
1. Faster Iteration of Spiral
2. Iterate Release Plan to Code Process
3. Acceptance Test Driven
4. Program in Pairs (Walk-through)
5. Design Refinement Throughout Process
6. Define Requirements with Communication
7. Code in Small Increments
8. Revisit Requirements & Design Often

http://en.wikipedia.org/wiki/Extreme_programming
Misinterpretations of Agile

- Process and Rigor is No Longer Needed
- Steps Can Be Skipped (Instead, Moved Up in Time & Iterated)
- Code First, Figure out Requirements and Design Later
- Requirements and Acceptance Testing De-emphasized
- Shortens Overall Development Time

Drone Net - Challenge & Significance

Watch Drone Net video

Motivation – Growth of sUAS
- Droneii, FAA, Sandia, ASSURE
- Counter UAS, NASA UTM (UAS Traffic Mgt.)

Problem – Sharing Airspace
- Part 107, Restrictions, ADS-B Rx
- Ground RADAR, LIDAR high cost
- sUAS ADS-B Tx/Rx insufficient
- Flight LIDAR & Vision (last 50 feet)
- Public Opportunity & Concern
- Safe Urban UAS Operations

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ERAU and CESE Motivation

- Fits ERAU Aviation Safety & Security heritage & mission

- Aligned with student interest and Undergrad Research
  - Drone (Aerial Robotics) Summer Camp 2018 - Ryzer Robotics Tello
  - Selected by student groups for several projects (HCI, SE Design)
  - Student authors (SGP), co-authors (AIAA, SPIE, IEEE, AUVSI)
  - CUR, ERAU URI, ASEE Ugrad research, ERAU Ugrad research FLC

- Range of opportunity for student involvement
  - Fundamentals and hands-on experiments
  - Applied and basic research (accelerated MS program)

- Example multi-disciplinary design (EE, CE/SE, ME Robotics)

- Aligned with National Security (3rd Offset aspects), Homeland Security, NASA and FAA agency interests & challenges

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Method – Information Fusion

- **EO/IR** Multi-spectral camera system
  - Visible, NIR, LWIR pixel-level fusion, narrow FoV

- **All-sky camera** - hemispherical, high resolution (2-20 MP)
  - Azimuth and Elevation (Cue to slew EO/IR)

- **Acoustic cameras** & Microphone arrays
  - Beam-forming microphone array (Azimuth & Elevation)

- **Purpose Built RADAR**
  - Echodyne MESA, Fortem - sUAS tracking to 1 Km +

- **Link Drone Net Nodes**
  - Detect and Track Compliant and Non-compliant sUAS
  - Wireless to Acoustic arrays, wired All-sky and EO/IR

- **ADS-B** aggregation and improvement
  - Comparing ADS-B to OEM and Custom IMU+GPS (e.g. ping2020)

- **Flight LIDAR** and EO/IR - last 50 foot navigation
Drone Net - UAS Traffic Management Test System

Compliant Flight Configuration

Air-column Test Range
[Drone Net Node Sensor Network]

UAS LIDAR
For Proximity Operations

1 Km

ADS-B
[Ping 2020i]

sUAS

ADS-B truth

Navigation Log truth

MAVlink

Detect, Track, Classify, Identify, Localize

Performance

ROC, PR, F-measure, new metrics

Cluster & GP-GPU

NAS Database

Machine Vision & Learning
[Real-Time and Simulation]

Passive Sensing Net

EO/IR Narrow Field

Acoustic Array

All-sky Hemispherical

Active Sensing

S or X-band RADAR

Ground LIDAR
Limited Range

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Method – Machine Vision & Learning

Machine Vision using SoC Linux
- Salient Object Detection
  - Shape, Behavior and Contrast/Color/Texture in Multiple Bands
  - Performance [ROC, PR, F-measure, confusion matrices]
- Real-Time Detection, Segmentation, Tracking, Classification, Identification

Machine Learning (Traditional, ANN)
- Expert systems
- Bayesian inference, Deep Belief Net
- PCA [Principal Component Analysis]
- SVM [Support Vector Machines]
- Clustering [e.g. K-means]
- GPU Accelerated DNN (cuDNN)
- Supervised, Unsupervised learning

Leverage Open Source: ROS, OpenCV, PyBrain, PyML, MLpack, cuDNN, Caffe, Tensorflow

University “Open Research” – Goal for replication similar to early Internet
Drone Net - Feasibility Test Range

617.5 meters [diagonal measure of cell that is 437m²]

Mavic Pro
[335mm diagonal size]

FreeFly ALTA6
[1.126 m diameter]
Drone Net - RADAR Comparison

**EO/IR Cost estimate - $33K**
1. Qty 5, $5K EO/IR = $25K
2. Qty 4, $2K All-sky = $8K

**Ground RADAR comparison - $120K to $610K**
1. EEC Ranger X5 dual-polarization X-band - est. $610K
2. Echodyne - MESA-DAA - est. $120K for 4 panels, (750m)
3. SRC Gryphon R1400 - unknown cost, (8.5Km)

**Aviation Weather RADAR**
1. Garmin X-band **GWX-70** - $33K+ (Weather only)

---

**Target Feature**

<table>
<thead>
<tr>
<th>Feature</th>
<th>EO / IR</th>
<th>Acoustic</th>
<th>Spectrum Analyzer</th>
<th>RADAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>X</td>
<td></td>
<td></td>
<td>X (dual-polar)</td>
</tr>
<tr>
<td>Track</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Texture, color</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acoustic Spectrum</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-mag signature</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Range</td>
<td>&lt;1Km</td>
<td>&lt;100m</td>
<td>&lt;5Km</td>
<td>&lt;10Km</td>
</tr>
</tbody>
</table>

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ERAU ICARUS, 2018 - Drone Net
Cover ERAU Campus

5 EO/IR Nodes
4 All-sky Cameras
Acoustic (TBD)

874m x 874m

Approximately 1Km Grid
Imagined for ATC

VLOS from Physics to DLC Parking lot

VLOS from AXFAB to DLC Parking lot

Part-107 Compliant
\[ G = B \times \frac{(g - f')}{f'} \]
\[ AR = \frac{H_{\text{pixels}}}{V_{\text{pixels}}} \]
\[ H_{\text{pixels}} = \frac{D_{H_{\text{section}}}}{G} \times R_{H_{\text{fov}}} \]
\[ V_{\text{pixels}} = \frac{D_{V_{\text{section}}}}{G} \times R_{V_{\text{fov}}} \]

**AR** is aspect ratio, **B** is the object image size on the detector, **f’** is the focal length **g** is the working distance, and **G** is the physical extent of an observable object.

E.g. ALTA6 sUAS has \( H_{\text{section}} = 1126 \text{ mm} \), at \( g = 617.5 \text{ meters} \) using an LWIR 6.0 degree Hfov \( G = 64.96 \text{ meters} \), so horizontal pixel extents for **640 line-scan resolution would be 11 pixels**.

Figure 1, shows a **test image** from 55mm focal length visible camera with a 24mm detector, such that \( G = 269.43 \text{ meters} \), 6K line-scan resolution, and therefore **25 pixels** for \( H_{\text{section}} \) of 1126mm.
MV/ML Flight EO/IR Frames
[OEM Snapshot for prototype, MV/ML future enhancement]

MV/ML Ground EO/IR Frames
[Detection, Classification and Identification Subset of frames from Continuous 10Hz baseline]

OEM Navigation Log Data
ADS-B Log Data
[SUAS, GA compliant identification]
HF Navigation Log Data
[future enhancement]

MATLAB Geometric Analysis & Re-Simulation

Optical Navigation truth

Time Correlated Frame Retrieval

Simulated HFOV, VFOV And Cross Section of Tracked sUAS

Localization Error & ADS-B Identification, Detection {TP, FP, TN, FN}

Detected, Classification, and Identification {TP, FP, TN, FN}

Human Review

Frame Compare

Localization Error & ADS-B Identification, Detection {TP, FP, TN, FN}

HRV ROC, PR, F-measure

<table>
<thead>
<tr>
<th>Actual</th>
<th>Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>sUAS</td>
<td>250 TP</td>
</tr>
<tr>
<td>Not sUAS</td>
<td>0 FN</td>
</tr>
</tbody>
</table>

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Acoustic Detection/Localization
Research Topic #1

Dr. Mehran Andalibi, Steve Rizor, Omkar Prabhu, and Dr. Siewert

- Goal - Perimeter Detection (all conditions)
- Elevation/Azimuth Estimate for EO/IR
- General Localization to narrow EO/IR tilt/pan search for re-detection
- Characterization of Drone acoustic signatures in progress with ANSYS

All-sky acoustic evaluation kit for beam-forming DOA

Angle Estimation Compared to Actual in Feasibility Testing

<table>
<thead>
<tr>
<th>Frequency [KHz]</th>
<th>5 meters from source</th>
<th>10 meters from source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detected angle</td>
<td>Actual Angle</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>22.5</td>
<td>22.5</td>
</tr>
<tr>
<td>2.5</td>
<td>22.5</td>
<td>22.5</td>
</tr>
<tr>
<td>3.5</td>
<td>22.5</td>
<td>22.5</td>
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<tr>
<td>35</td>
<td>67.5</td>
<td>67.5</td>
</tr>
<tr>
<td>70</td>
<td>202.5</td>
<td>202.5</td>
</tr>
<tr>
<td>230</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on MATLAB code adapted from: Edaboard MUSIC, Labbook Beamforming
MV/ML Classification/ID
Research Topic #2

- Dr. Siewert, Soumyatha Gavvala (CU MS ESE)
  - Tensorflow R-CNN and Single Shot Detector
  - ROC comparison to Motion-Detect Baseline

- Goal - Outperform Motion-Detect with filters, train on workstation, deploy to Tegra TX2 for real-time operations

Results from R-CNN MV/ML Classification with Drone Net Detection Images

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All-Sky Detection/Localization Research Topic #3

Dr. Siewert, Aasheesh Dandupally (CU MS ESE)
- Simple Salient Object / Motion Detect in Hemisphere (all-sky)
- 6 Cameras with overlapping FoV

Goal - detect and estimate aerial object elevation and azimuth to notify EO/IR for re-detection and tilt/pan tracking

Eliminate simple false alarms (birds, bugs, clouds)

6 x 2 Mpixel MPTS
Scale up to 6 x 20 Mpixel
EO/IR RT Detect, Classify, Track and Localize
Research Topic #4

Dr. Siewert, Garrison Bybee (ERAU SE)
- Notification from All-sky or Acoustic provides coarse Elevation, Azimuth
- Re-detect and classify as sUAS (CNN, DBN, SVM, …)
- Tilt/pan tracking of sUAS targets of interest and UTM disposition (on-flight plan, off-flight-plan, no-flight-plan)

Goal - Track, shape, texture, color (multi-spectral) for all sUAS of interest, logged to Aerial Catalog

DSRC protocol between EO/IR nodes and Overly-Compliant EO/IR/LIDAR nodes

Support UTM 2020+ Urban ConOps

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Over-Compliant Aerial Node
Research Topic #5

Dr. Bruder, Gentilini, Siewert, Jonathan Buchholz (ERAU MS UASE)
- HF Navigation compared to ADS-B (Bruder)
- LIDAR + LWIR Fusion (Gentilini, Siewert, Buchholz)
- Last 50 foot Urban Navigation (Buchholz)

Goal - Determine safe urban operation, GPS-denied, for parcel delivery scenarios with Sense-and-Avoid

NASA UTM Challenge (2020)
Data Management and Analytics
Research Topic #6

Dr. Siewert, Prof. Perry, Prof. Young

MV/ML on Workstation ground nodes (Lambda DevBox, 20TB RAID)
- R-DBMS for Aerial Catalog
- Blockchain research for Drone catalog and tracking events (shared in Drone Net network)
- File management of raw images
- Automated human review (Auto-it)
- Real-Time ATC NOTAMs
- Forensic browsing

Goal - Human Review Truth model and Secure sharing of aerial catalog for registered and non-compliant sUAS

<table>
<thead>
<tr>
<th>Compliance Description</th>
<th>Flight Plan</th>
<th>ADS-B</th>
<th>Compliance</th>
<th>ATC notification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registered sUAS, flight plan filed, following flight plan, ADS-B, safe navigation.</td>
<td>X</td>
<td>X</td>
<td>Full</td>
<td>None</td>
</tr>
<tr>
<td>No ADS-B, unknown navigation equipment, standing waiver with Part 101 registered drone (e.g. hobby)</td>
<td>X</td>
<td></td>
<td>Full</td>
<td>None</td>
</tr>
<tr>
<td>Registered sUAS, ADS-B, but not on filed flight plan.</td>
<td></td>
<td>X</td>
<td>Partial</td>
<td>Warning</td>
</tr>
<tr>
<td>No ADS-B, unknown navigation equipment, no standing waiver or filed flight plan</td>
<td></td>
<td></td>
<td>Partial</td>
<td>Warning</td>
</tr>
<tr>
<td>No ADS-B, large visual size, no standing waiver or filed flight plan, not classified or identified as hobby drone, unexpected track, shape, texture, and color in visible and LWIR.</td>
<td></td>
<td></td>
<td>None</td>
<td>Safety Alert</td>
</tr>
</tbody>
</table>

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Verification with Re-simulation

Research Topic #7

- Dr. Andalibi, Bruder
  - MATLAB simulation to verify detection in HFOV, VFOV
  - Track history and geometric observability
  - Add virtual cameras to explore potential improvements

Goal - Geometric Truth model for compliant HF Nav, OEM Nav, ADS-B tracked drone
2018-19 Drone Net Team, ERAU Sponsor

**ERAU – Drone Net**
- Dr. Sam Siewert, PI, Assistant Prof.
- Dr. Stephen Bruder, Co-I, ICARUS Director
- Dr. Mehran Andalibi, Co-I, Assistant Prof.
- Dr. Iacopo Gentilini, Co-I, Advisor
- Jonathan Buchholz - ME Robotics (graduate), MS UASE
- Robert Noble - EE Student
- Garrison Bybee - SE Student
- Thomas Rapp - SE Student
- Jacqueline Abendaroth-Smith - ME Robotics
- Evan Atlas - AE Student
- Dakota Burklund - AE Student (graduated)
- Demi Matthew Vis – AE/SE Student (graduated)
- Ryan Claus – SE Student (graduated)

**CU Boulder – Embedded Systems Engineering**
- Steve Rizor (Engineering Management Candidate)
- Aasheesh Dandupally – MS, ESE
- Omkar Prabhu – MS, ESE
- Soumyatha Gavvala – MS, ESE (graduated)

**Industry Advising & Collaboration Participants**
- Randall Myers, Mentor Graphics (PCB, CAD, Systems)
Drone Net Summary

Drone Net Architecture Defined and Shown Feasible
- 2 Rural Tests Completed [IEEE Aerospace data]
- 2 Urban Tests Completed [2/25/18, 3/25/18]
- Summer Experiment Planning in progress

Promise to match or enhance RADAR at low cost

Forms Reference Design for UTM collaboration research

Next Steps …
- Further develop research topics, analyze, replicate and scale
- Enable simulation of larger systems [MATLAB]
- RADAR simulation compare
- Work with partner with ground RADAR
- Test UTM Last 50 Foot Scenario (Parcel Delivery)

Questions?
ERAU Hyperloop History

2016 - Team Adopts Me, We go to Texas A&M Design Competition
- Founding Student Team, I was an Advisor and Design Judge
- Team not Selected for Build and Test
- Joins forces with ASU, NAU and Thunderbird

2017 - Bigger Team Storms, Norms and Performs
- New Student Leadership
- Goes to SpaceX with our Lab Tech

2018 - Smaller Team, Gets More Focus
- New Student Leadership, Gets Further at SpaceX, still no Run

2019 - All New Team, First Meeting on 9/20/18
Research References
References


[flightradar24.com](http://flightradar24.com), ADS-B, primary/secondary RADAR flight localization and aggregation services.

Drone Detection and Neutralization Companies

Leading Drone Detection Companies

• Rohde & Schwarz Ardronis - Ardronis I
• https://www.blacksagetech.com/
• https://www.droneshield.com/
• http://www.dedrone.com/en/
• https://www.kongsberggeospatial.com/applications/argus-cuas
• https://fortemtech.com/ - DroneHunter

List of Drone Detection and Counter UAS Products and Experiments

• DJI Aeroscope
• Drone Capture with Nets
• Test at JFK by FBI
• Dynetics - Counter UAS
• SRC Gryphon Sensors Counter UAS
• SPI Infrared Drone Detection
• Industrial Camera Drone Detection
• HGH Infrared Drone Detection
• http://www.cerbair.com
• Israel Defense Counter UAS
• AARONIA Drone Detection