SAFE INTEGRATION OF UAS INTO THE NATIONAL AIRSPACE SYSTEM

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NSF CPS PI MEETING
CPS Challenges for Unmanned and Autonomous Systems Workshop
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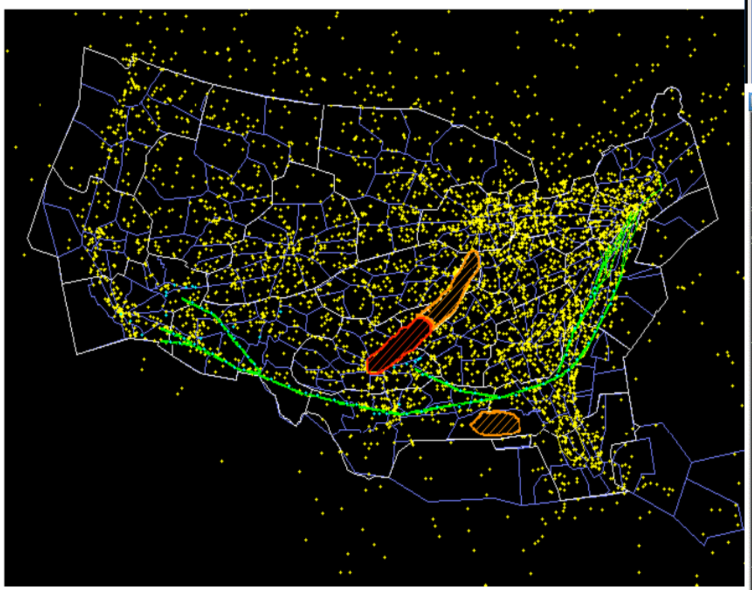
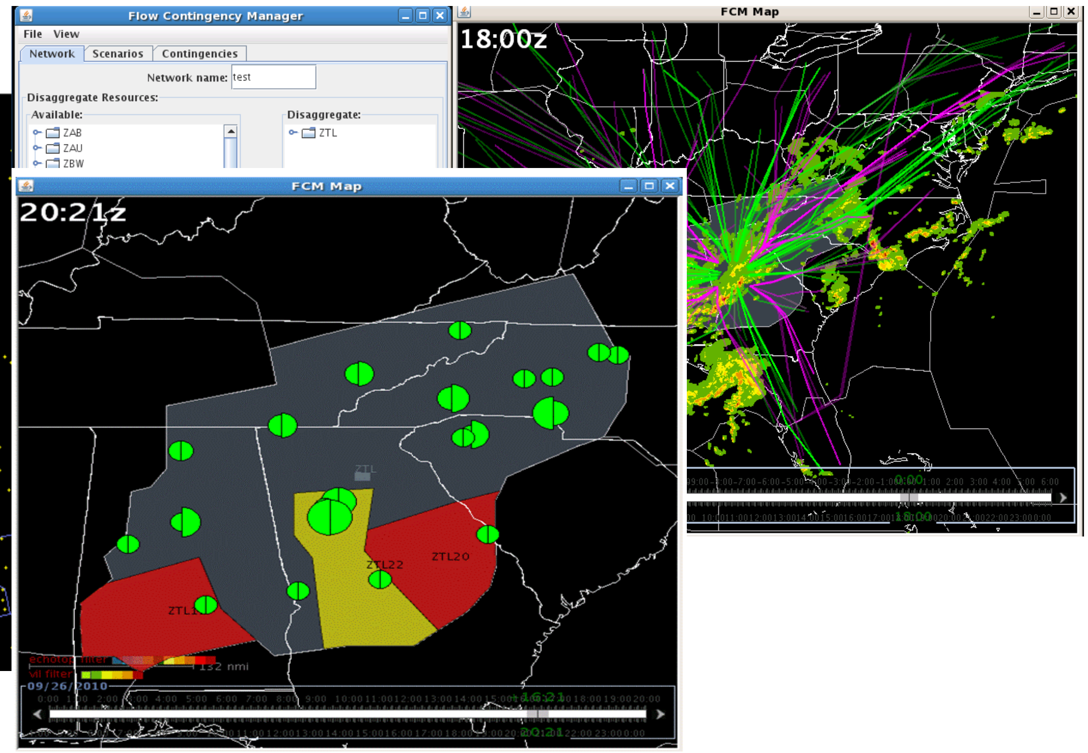
AIRSPACE INTEGRATION

- Multiple levels:
  - Individual aircraft->air traffic control-> air traffic flow management -> airspace management



Snapshot of FACET, NASA



MITRE's FCM Decision Support Tool

AIRSPACE INTEGRATION

- Future Airspace?

https://gcn.com/Articles/2014/10/21/NASA-drone-air-traffic-control.aspx

AIRSPACE INTEGRATION

- Future Airspace?
  - Heterogeneous missions

AIRSPACE INTEGRATION

- Future Airspace?
  - Infrastructure support

04.25.17 | MOST INNOVATIVE COMPANIES

Uber's Flying Taxis Will First Take To The Skies In Dallas-Fort Worth And Dubai

The ride-hailing giant exclusively shared details of its ambitious program to start testing sky cabs by 2020 and putting them into service as soon as 2023.

CHALLENGES

- Safety is difficult to achieve in a dense airspace of aerial vehicles
  - Constrained payload for UAS platforms
  - Limited capability of sensors to reach out for sense-and-avoid
  - Complicated environment: powerlines, people and properties on the ground
  - A dense airspace of UAS
  - Instable communication and control links
- Heterogeneity
  - Aerial vehicle types: types (weight, maneuvering), environment (urban, rural), missions, users
- Levels of responsibilities
  - On-board pilot, drone operator, traffic management, etc.
- Stakeholder roles: Profit-driven industries vs. the safety of NAS
  - Should the market self-adapt or should organization be provided?
- Security
- Societal Acceptance
  - Environmental impact, e.g., noise and pollution
  - Privacy

ADVANCES

- FAA 107
  - UAS less than 55 lbs
  - Remote pilot certificate
  - Visual line of sight, daylight or civil wrilight operations
  - Yield right-of-way to manned aircraft
  - One UAS per remote pilot
  - No operations over people
  - 400 feet or below
  - Waivable provisions
- NASA Technology Capability Levels (TCL) https://utm.arc.nasa.gov/
  - TCL1 (August 2015): geofencing, altitude "rules of the road" and scheduling of vehicle trajectories
  - TCL 2 (October 2016): beyond visual line-of-sight operations in sparsely populated areas
  - TCL 3 (January 2018): maintain safe spacing between cooperative (responsive) and non-cooperative (non-responsive) UAS over moderately populated areas
  - TCL 4: UAS operations in higher-density urban areas for tasks such as news gathering and package delivery. It will also test technologies that could be used to manage large-scale contingencies

GAPS, RESEARCH AND OPERATIONAL BARRIERS

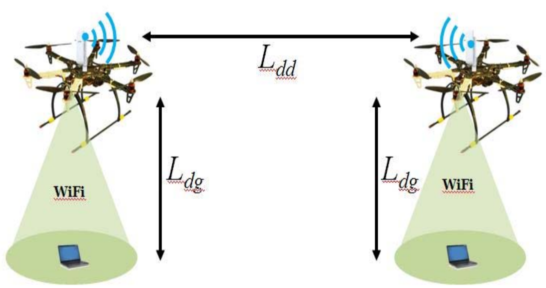
- Lack of requirements on the categories of vehicles and circumstances to be safe, e.g., to achieve predictable behaviors by using the rules.
  - Diversity of vehicles makes it difficult to set requirements
- Lack of sense-and-avoid protocols
  - Complicated environment (e.g., powerline): restriction on going down unless it is safe
  - Sensors that meet the requirement of drone platforms
  - Mission/vehicle category based
  - Classification is needed
- Lack of certifications
  - Levels of certifications, certification of components
  - Need and risk-based certifications
- Lack of security and safety solutions
  - Lost communication link
  - Lost GPS and navigation data
  - Robustness to prevent jam and take-over
  - Secure communication link with respect to spectrum and performance requirement

ROLES OF CPS TECHNIQUES FOR THE INTEGRATION

- Human-Systems
  - Reduce the probability of human commanding errors
  - Improve the situation awareness of the operator
  - Increase automation on the vehicle such that the operators tasks are a manage-by-exception
  - Enable decision support tools for emergency situations and contingency management
  - Enable a single operator to command and control multiple vehicles
- UAS vehicle and ground support automation
  - Provide onboard and/or ground-based separation assurance from other airborne traffic, terrain and natural obstacles, man-made obstacles, and people on the ground.
  - Fault tolerant systems to reduce the risk in emergency situations (lost-link, hardware failure, etc.)
  - Path planning in complex environments (GPS-denied environments, variable weather conditions and obstructions, man-made structure and terrain avoidance, etc.)
  - vehicle health monitoring and diagnostics.
- Capacity and Airspace Management
  - Spectrum allocation and management
  - Airspace management system health monitoring
  - Flight monitoring and conformance monitoring
  - Flight planning, scheduling and demand management and separation assurance
  - Contingency Management
  - Providing information to various communities that are connected to the airspace (other ATM systems, UAS operators, general aviation community, public, law enforcement, etc.)
- Mission planning and contingency management
  - Risk-based operational planning and contingency management
  - Using vehicle performance modeling to determine operation feasibility and contingencies

WHAT IS "SAFE" AND HOW TO MEASURE?

- Short-range communication
- Jammer/cyber-security
- Sensors on board/where does the computing take place
- Marginal operational requirement
- Intelligent crash
- All disciplines to work together
- Rules have gaps



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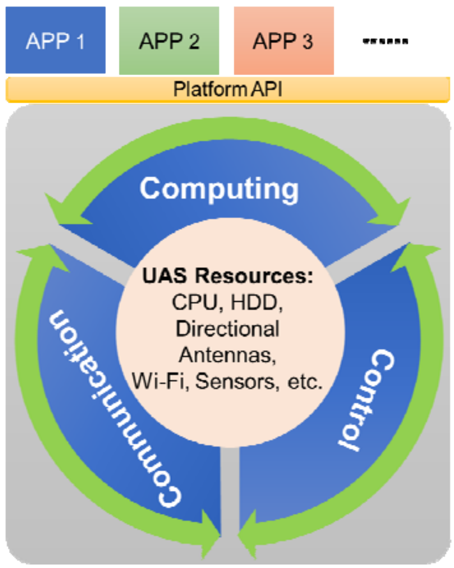
Demo 28



CRI 1730675
http://www.uta.edu/utari/research/robotics/airborne/index.php

WHAT ARE THE APPROPRIATE FUTURE AIRSPACE STRUCTURE AND SCHEDULING SCHEMES FOR FUTURE UAS TRAFFIC?

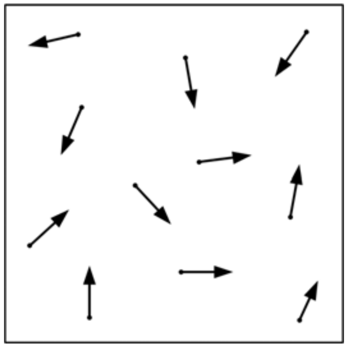
- Organized traffic or not?
- Is it centralized or decentralized
- A comprehensive capacity study is critical

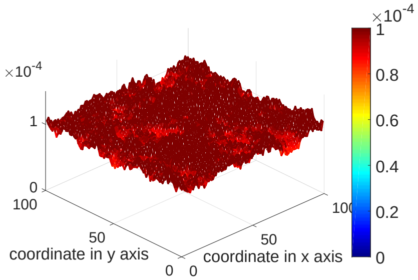
https://sites.google.com/site/degond/Home/scientific-interests/pedestrians-and-crowds

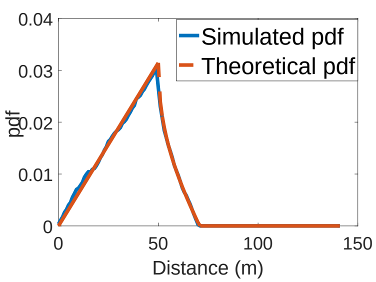
WHAT ARE THE CRITICAL TECHNIQUES/RULES FOR UAS AUTOMATION, SENSE AND AVOIDANCE?

- Simple rules to separate
- How does this impact capacity management
  - Sense and stop is not effective for highly variable UAV traffic

- Without S&A

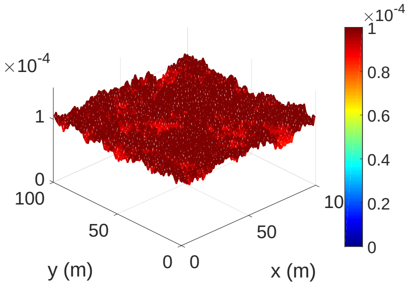


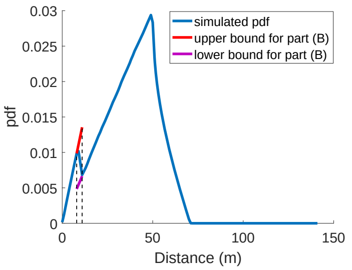




- With S&A

$$\begin{cases} \frac{1}{2}\pi d p_{1min} < f_D(d) < \frac{1}{2}\pi d p_{1max}, & 0 \leqslant d \leqslant d_o - V \\ \frac{1}{4}\pi d p_{1max} < f_D(d) < \frac{1}{2}\pi d p_{1min}, & d_o - V < d \leqslant d_o + V \\ \frac{1}{4}\pi d p_{1min} < f_D(d) < \frac{1}{4}\pi r p_{1max}, & d_o + V < d \leqslant \frac{B}{2} \\ \frac{1}{2}\left(\frac{\pi}{2} - 2arccos\left(\frac{B}{d}\right)\right) d p_{1\,\mathrm{min}} < f_D(d) & \\ < \frac{1}{2}\left(\frac{\pi}{2} - 2arccos\left(\frac{B}{d}\right)\right) d p_{1\,\mathrm{max}}, & \frac{B}{2} < d \leqslant \frac{\sqrt{2}B}{2} \end{cases}$$





HOW TO INTEGRATE WITH AIR/GROUND INFRASTRUCTURE?

- Design of communication and power infrastructures
- Integration with ground transportation systems
- Limitation of capacity on the vertiports

QUESTIONS (CONTINUED)?

- What regulations/procedures are critical to the future of flying on-demand UAS in U2C environment?
  - Should report to FAA, state government, or travel agencies?
  - How about approval timeline?
- What do you foresee the future business on urban air transportation?
  - Federal oversights?
  - It is easy to lean the focus toward specific business…
- What are the critical contingencies to manage and how to accomplish them?
  - How to achieve performance guarantees

QUESTIONS (CONTINUED)?

- What technologies From ATM/ATC can/cannot be used for the airspace integration?
- What are the human roles in the airspace integration?
- What are the challenges and solutions for training and education?
- …

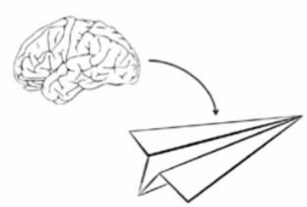
https://info.aiaa.org/tac/isg/ISTC/Shared%20Documents/Roadmap%20for%20Intelligent%20Systems%20in%20Aerospace/AIAA_Roadmap_for_Intelligent_Systems-v1.0_14Jun2016.pdf

AIAA Intelligent Systems Technical Committee

American Institute of Aeronautics and Astronautics (AIAA)

Intelligent systems technical committee (ISTC)

ROADMAP FOR INTELLIGENT SYSTEMS IN AEROSPACE



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