PSCR 2020:

THE DIGITAL EXPERIENCE

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INNOVATING ON DRONE TECHNOLOGY TO SUPPORT FIRST RESPONDER MISSIONS

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*** Please note, unless mentioned in reference to a NIST Publication, all information and data presented is preliminary/in-progress and subject to change**

Agenda

- Deployables Research
  - UAS and Broadband Communications
- First Responder Drones Usage Survey Results
- yet2 Market Research Results
- Open Innovation UAS Prize Challenges
- Q&A with UAS First Responder Expert Panel

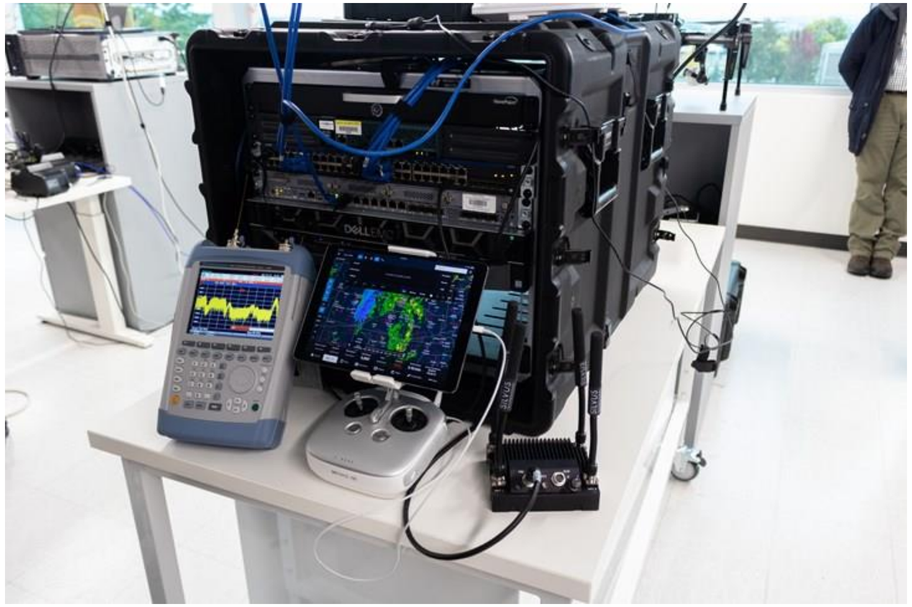
Deployables Research
UAS and Broadband Communications

Deployables Research

PSCR deployable broadband for public safety

Goal: maintain broadband services when the broadband network is not operational or users are outside of the network coverage area

- Maintain Push-to-Talk and Situational Awareness, no matter of the situation
- First responder-centric technology

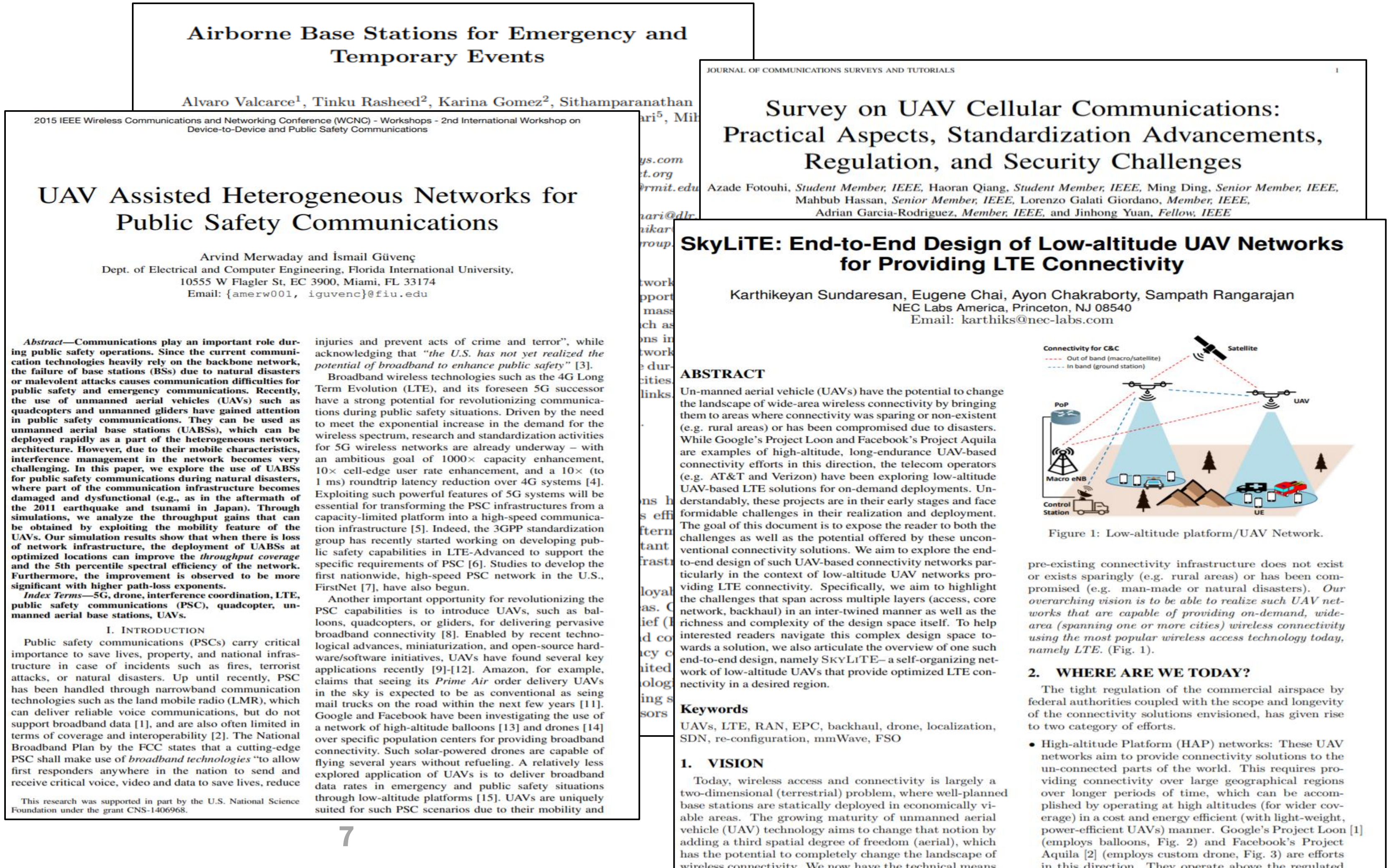


Deployables Research

Technical gap: Range of a wireless technology ↔ Solution: Utilizing Unmanned Aircraft Systems

- Hosting radios on UAS provides line of sight to a much larger area

- Lots of information exists on aerial communication systems



Deployables Research

Technical gap: **Range of a wireless technology** **↔ Solution:** **Utilizing Unmanned Aircraft Systems**

- Not as widespread for public safety themselves to deploy
- This is done today, but PSCR looks ahead when drones are untethered and independent of a backhaul connection

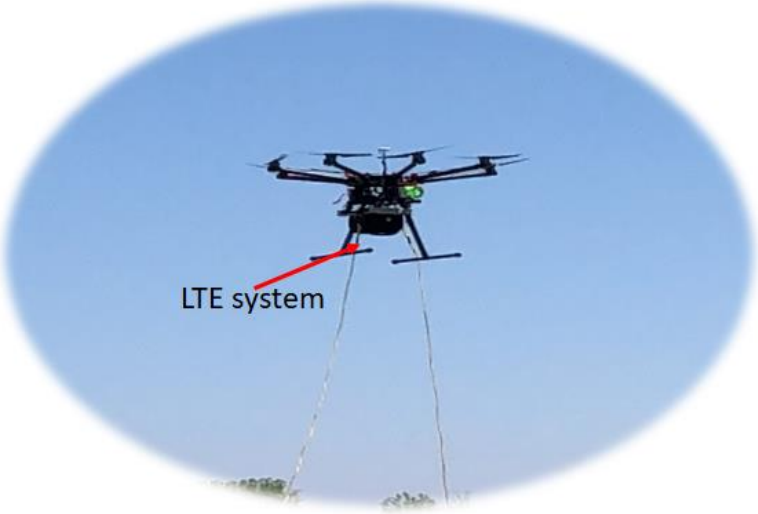
Source: AT&T

Deployables Research

- Live aerial tests by PSCR conducted last year showed the complications and opportunities of the concept

- Low cost multi-rotors solutions are limited in duration for heavy deployable equipment, which leads to another technical gap for the deployables use case

Technical gap: Length of UAS flight times



Deployables Research

- Industry continues to deploy tethered solutions while innovating into completely new designs like blimps and fixed wing systems
- The goal of the research is to document the issues and write best practices for public safety stakeholders
- Enabling aerial deployable systems is key in supporting first responders

Source: Yet2

First Responder Drones Usage
Survey Results

The Reason for the Survey

The survey asked, **‘would a deployable unit, such as a drone or UAS, enhance their mission if they had wireless communications on the ground with a network communications system in the air?’**

- First Responders are deploying Unmanned Aircraft Systems (UAS) on missions in hard-to-reach areas or otherwise challenging conditions.
- PSCR published a survey to understand the current and potential uses of drones by first responders.

NIST IR 8305 Publication – Survey of Drone Usage in Public Safety Agencies https://doi.org/10.6028/NIST.IR.8305

The Focus of the Survey

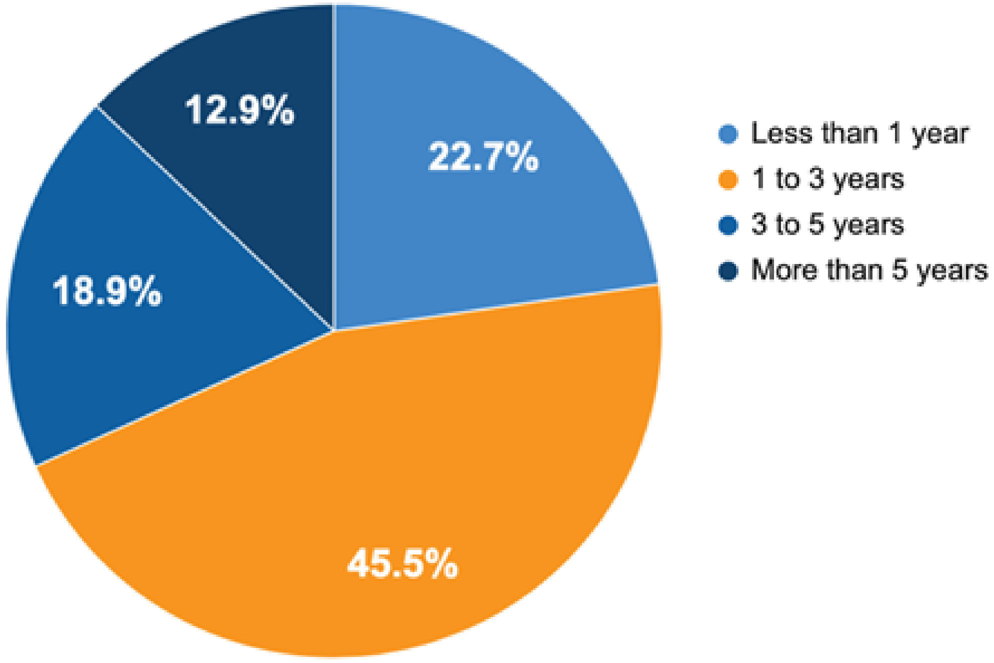
- The 2019 survey asked America’s first responders:
  - How they use drones in their operations
  - The benefits of using drones to support wireless communications during an incident
  - Describe their missions
- The survey was sent to ~900 first responders with a 20% response rate

Demographics & Experience Survey Results

Respondents were first responders in *law enforcement, fire fighting, EMS, rescue services, emergency management*

Supporting missions in various geographic environments:

- Rural (68%)
- Suburban (68%)
- Urban (61%)
- Wildland (43%)
- Mountains (25%)
- Desert (13%)



Years of experience using drones

Wireless Communications Survey Results

Most first responders want wireless communications on missions where wireless communications are not available

Some examples of those missions:

- Border Enforcement
- Commercial building fire recon
- Crime scene documentation
- Earthquake/Flood Response
- Fire fighting in rural areas
- Hurricane/Tornado Recovery
- Search & Rescue/Missing person
- National disasters
- Train derailment
- Wildland fire

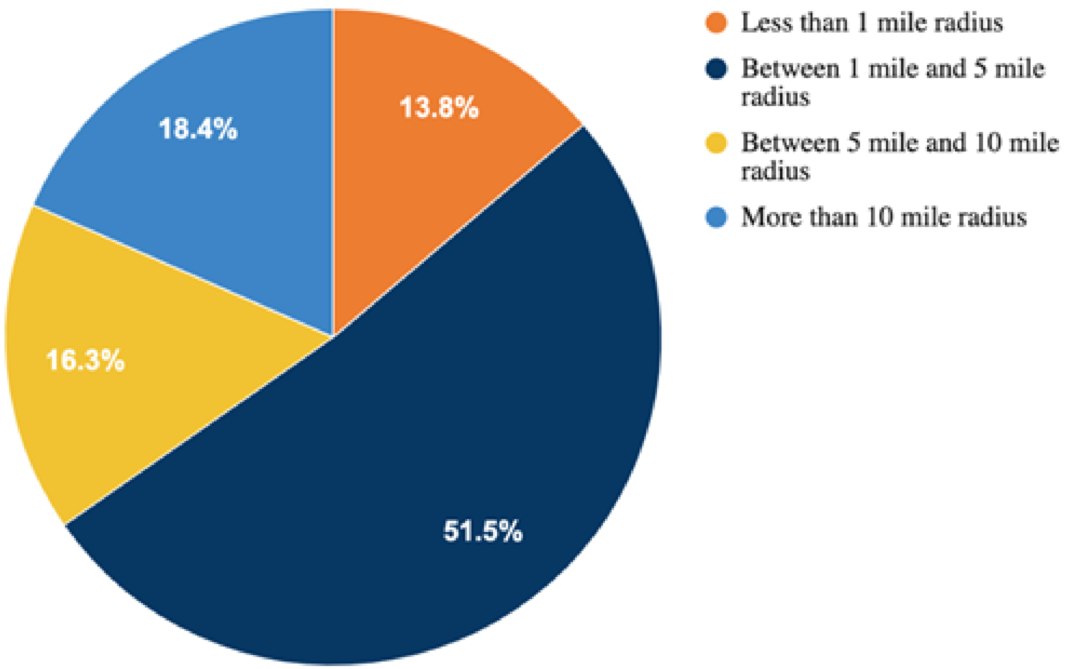
Wireless Communications Survey Results

Benefits using wireless communications on a mission

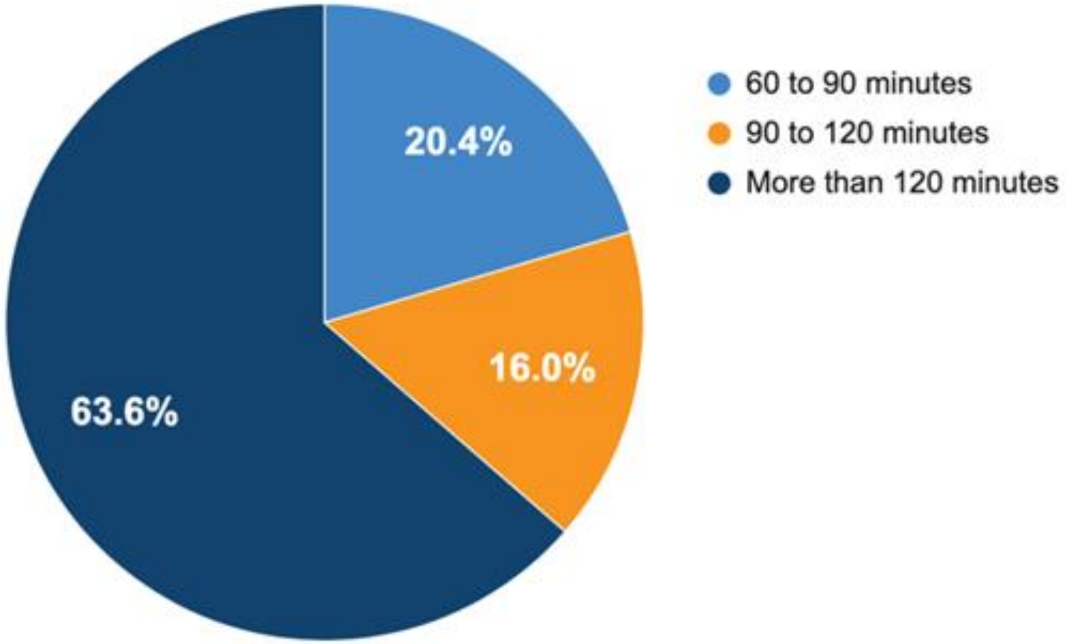
- Ability to download maps, access online databases
- Ability to transmit back to command
- Ability to transmit video and photos
- Without cellular communications there can be safety issues, time delays, and a lack of mobile data when needed the most
- Increased situational awareness
- Location services
- Live streaming of data and video to command post
- Enhance operations
- Communication is mission critical

Wireless Coverage Survey Results

Estimated distance for cellular broadband coverage needed to effectively perform their work

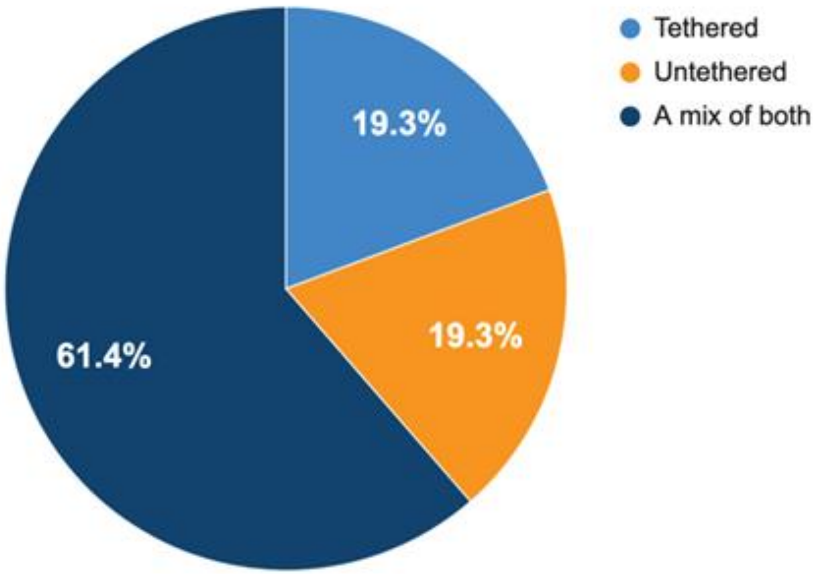


Estimated time a drone is needed in the air for a mission



Tethered vs Untethered Survey Results

Is there a preference for tethered vs untethered drones?



Reasons

Tethered

- Additional flying time
- Provides long term communications support
- Another operator and observer is not needed
- Increase flying time and payload capacity

Untethered

- More flexibility
- Area wide observation
- Concern about flying a drone in areas with trees
- Power is always an issue
- A more versatile platform

Frame Options Survey Results

First Responders preference for multi-rotor, fixed wing or hybrid

- 29% multi-rotor
- 14% hybrid
- 1% fixed wing
- 46% no preference
- 11% indicated VTOL was critical

Reasons for their answer

- Flight time
- Multiple missions & longer flight time
- Total manpower
- Cost and reliability
- Distance to cover & length of time aloft
- Battery consumption
- Operating endurance
- Amount of space for launch & recovery
- Ease of use and implementation
- High quality and efficient
- Skill of the flight pilot

Power Sources Survey Results

First responders would consider alternatives to traditional power sources
- These are preferred for a drone providing cellular communications -

- Electric (50%)
- Hybrid (24%)
- No preference or not relevant (17%)
- Mission dependent (5%)
- Liquid fuel (2%)
- Whatever power source is most available (2%)

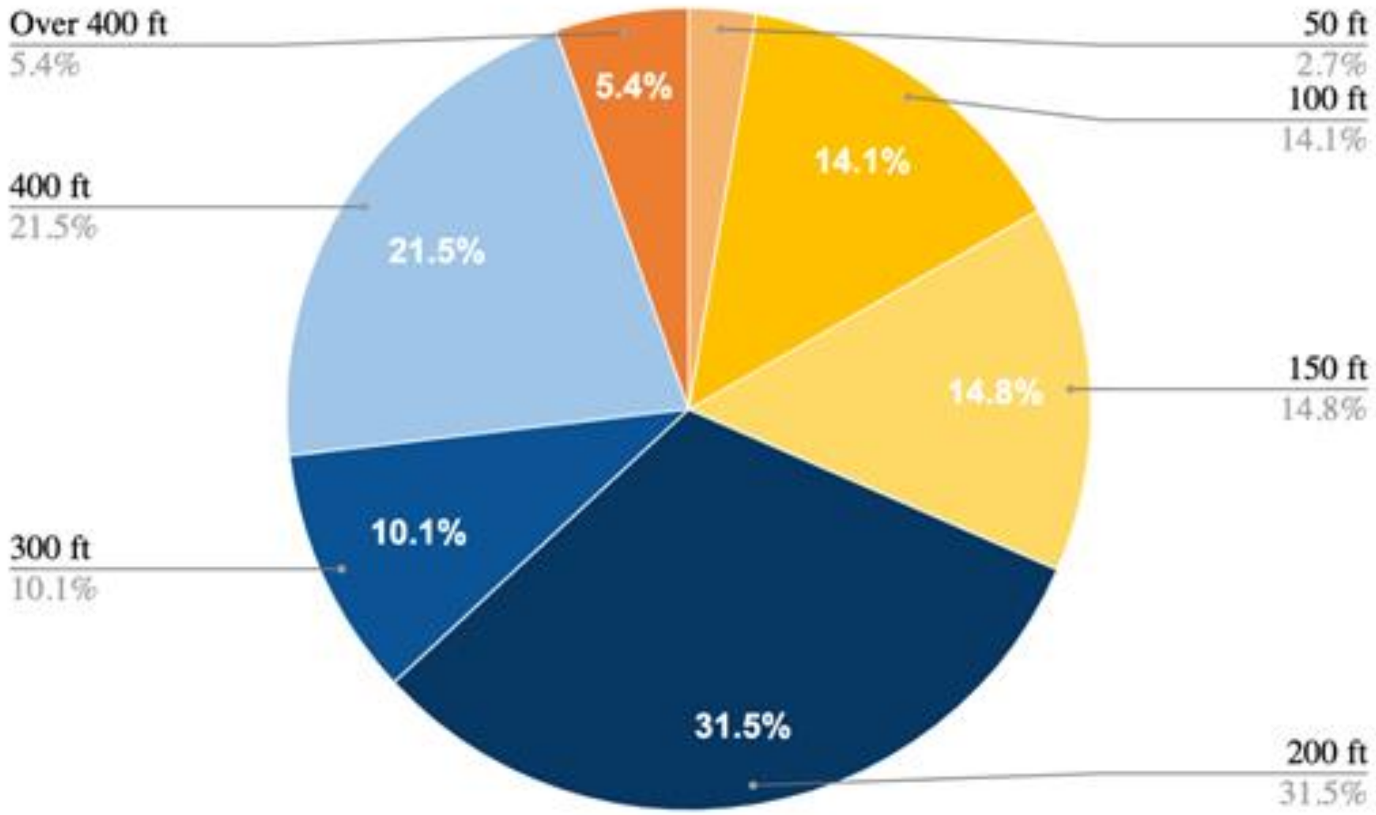
Flight Time & Payload Survey Results

Considering the trade-off between flight time and payload capacity
- Larger drones >55 lbs can carry more energy and stay in the air longer -

- More paperwork/special permit required
- Only if "Time in the Air" provided a benefit
- Additional cost may be an issue
- Too big and heavy
- Would consider if it provides better coverage for an operation
- A larger drone makes it difficult to coordinate in FAA airspace
- Too big and heavy for fast deployment
- More training and upkeep is required

Other Considerations Survey Results

When asked for a safe minimum flight elevation above ground (AGL)
- 90% of the respondents would want to fly between 100-400 feet -

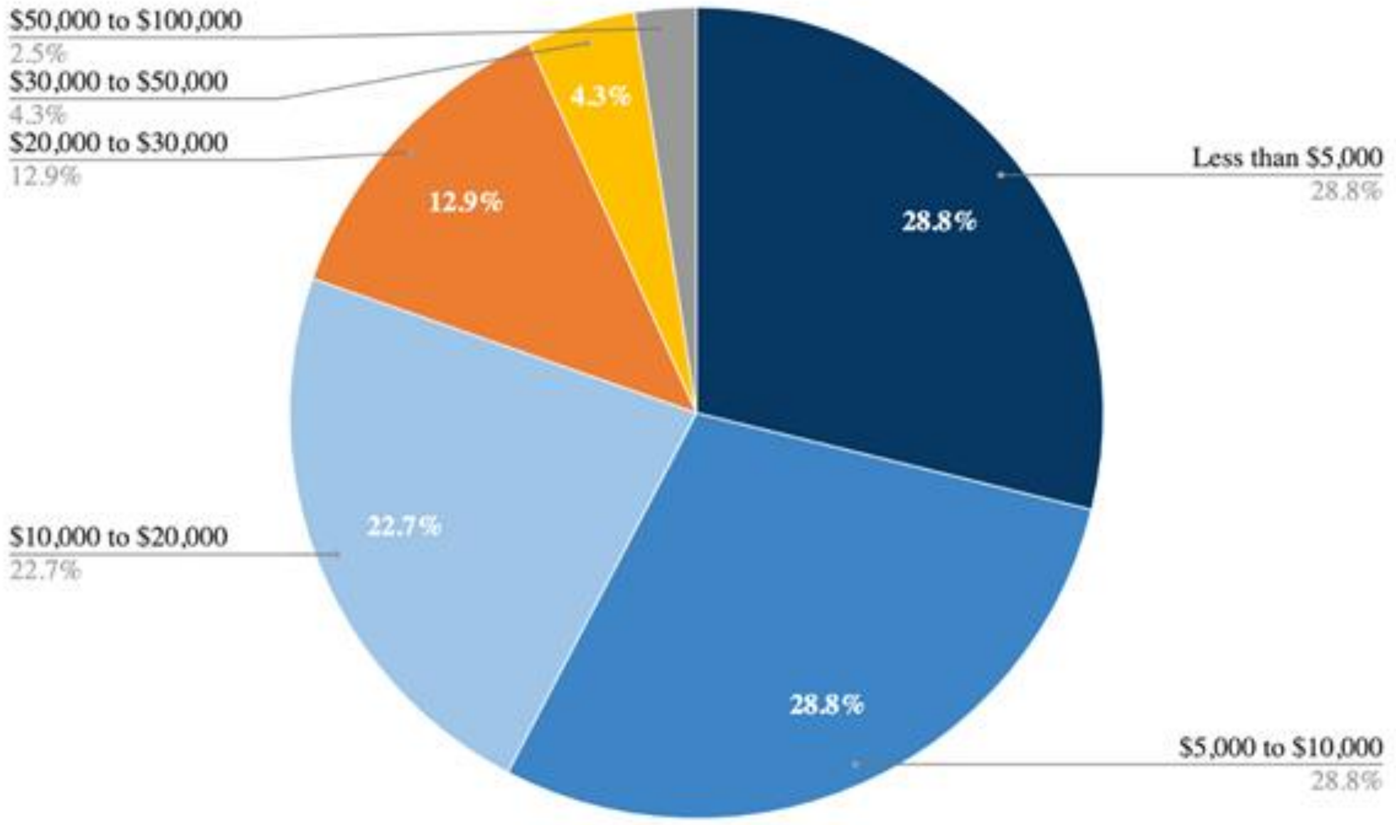


Other Considerations Survey Results

When asked the environmental conditions that a drone would operate in, the following examples were given:

Other Considerations Survey Results

Based on the value that a public safety agency would give to a drone used to carry a communications device
- 81% said they would consider spending $20k or less -



yet2 Market Research Results

Objective of Market Research

- Identify existing UAS technologies that meet NIST's minimum requirements:

payload ≥ 15 lb **endurance ≥ 30 minute**

weight < 55 lbs **volume ≤ 6'x 4'x 3'**

- Identified drones *close to meeting* or *could already meet* the requirements
- Other considerations:
  - hovering precision
  - cost
  - maximum altitude
  - optional tether
  - fixed-wing flight radius
  - innovative solutions

Heavier Aircraft Market Research

NIST also considered heavier UAS between 55 lbs and 100 lbs

- Aircraft > 55 lbs require additional FAA approval
- Although heavier aircraft are designed to carry large loads, little noticeable increases in endurance were observed

Source: yet2

One exception was a drone that could carry 15 lbs for 60 minutes at slightly > 55 lbs (or 12 lbs for 63 minutes at < 55 lbs)

Industries Market Research

Identified 41 Companies with UAS designed for:

- Industrial applications (wind turbine inspection, agriculture, mapping, surveying, cleaning)
- Government (law enforcement, fire, security)
- Photography/cinematography
- Commercial payload delivery

Source: yet2

In addition to the minimum core requirements,

NIST focused on innovative drone designs and energy sources

Most Promising Market Research

- 13 companies showed the most promise in meeting NIST requirements
- Additional factors considered:
  - Cutting edge technologies that will move the field forward
  - Technology solutions (such as energy harvesting) designed to allow longer UAS flight endurance

Source: yet2

Source: yet2

Power Sources Market Research

Different power sources offer different advantages, depending on the use case of the drone. yet2 explored seven (7) different power source categories at varying stages of development

1. Battery

- the most common in consumer drones; charged anywhere; transported with ease; lower cost

2. Gasoline

- longer flight times; high energy density; UAVs lose weight over time; refueling is typically quick; gas is easy to obtain
- combustion engines are noisy, may have efficiency/fuel-injection issues at higher altitudes, and tend to be heavier and bigger

Source: yet2

Power Sources Market Research

3. **Hybrid Electric-Gas**
    - allows a gasoline engine to charge the battery or provide power to the electric motors directly; can be more efficient than direct power-train; onboard batteries don’t need to be re-charged
4. **Hydrogen Fuel Cell**
    - clean energy source with high energy density; potential instability near heat and lack of infrastructure for refueling; early stage technology, currently available for smaller drones with less capacity to carry heavier payloads

Source: yet2

Source: yet2

5. **Solar-Powered**
    - solar cells are evolving with increase in efficiency; harvests energy from the sun, even in cloudy or smoky conditions; night missions require energy storage; most commonly seen on fixed-wing drones

Power Sources Market Research

6. **Tethered/Untethered**
    - an option to keep drones in the air longer with a continuous power supply; use in areas with no power outlets, an external battery source must also be carried along with the tether
7. **Wireless charging**
    - could allow untethered drones to stay in the air indefinitely; becoming more technically feasible and commercially viable; this area of technology is likely to continue to grow and be of high interest in coming years

Source: yet2

Airframe Types Market Research

- **Multi-rotor**
  - most common design in consumer drones; greater maneuverability such as vertical takeoff and landing (VTOL); can hover in mid-air; usually lower priced than fixed wing; more compact; can carry a variety of payload sizes; shorter ranges and typically less stable in the wind
- **Fixed Wing**
  - very long ranges; great stability in high winds; longer flight durations due to gliding capability; require runways or a catapult to launch, less compact than multi-rotors, can't hover in place
- **Hybrid Fixed Wing/Multi-rotor**
  - uses rotors for VTOL and wings for optimizing flight times; designs aren't prolific in the marketplace

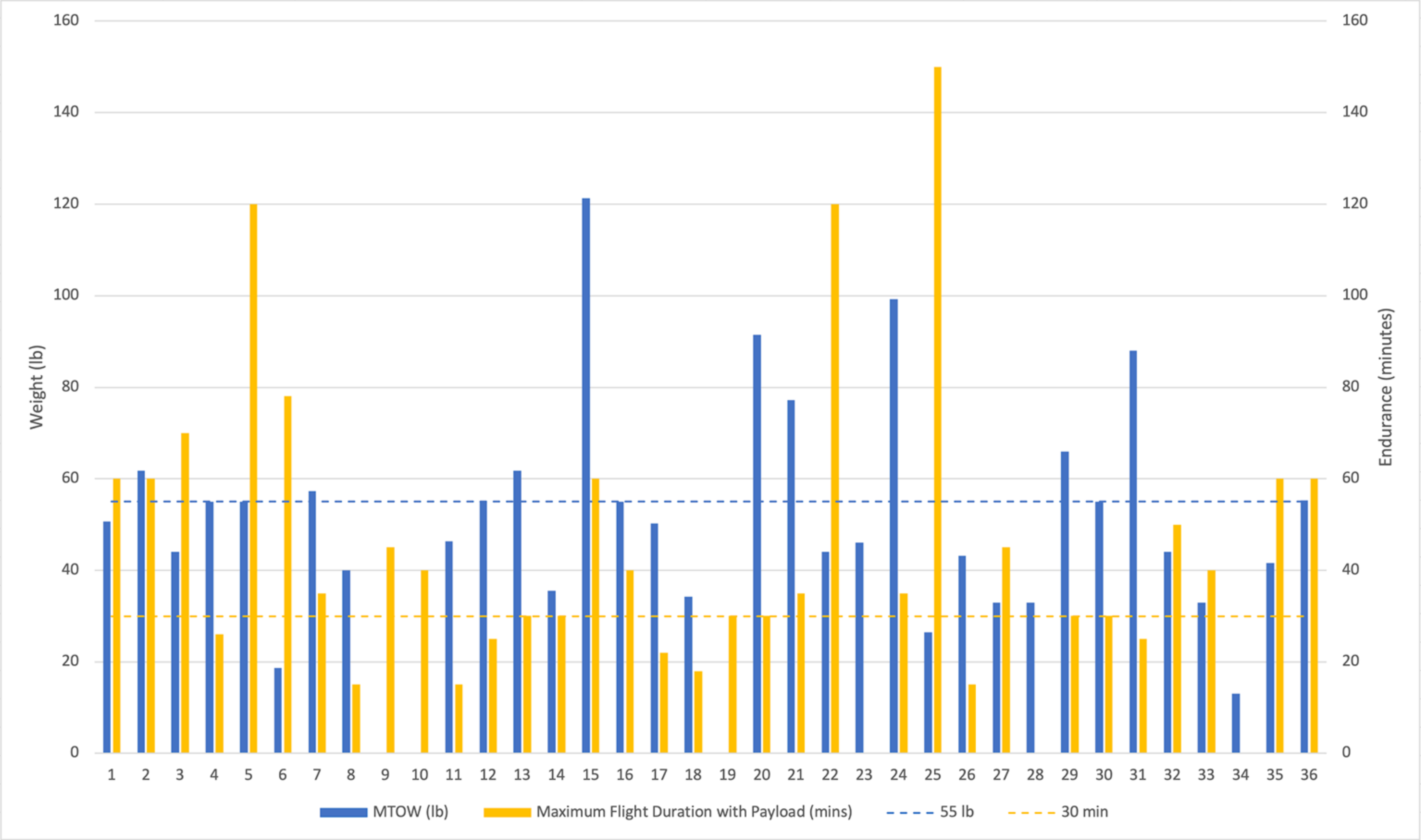
Source: yet2

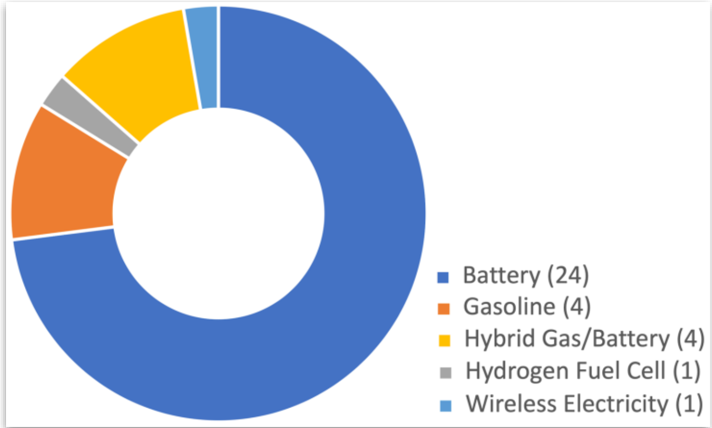
Frame Types Market Research

- **Intermeshing Rotors**
  - used on helicopters with two rotors at a slight angle; intermesh without colliding; notable for improved payload capacity; eliminates the need for a tail rotor
- **Helicopter**
  - better empty weight-to-payload and payload-to-endurance ratios; tend to be large; best fit would include a foldable tail rotor and removable rotor blades
- **Modifying the body of the drone**
  - Instead of incremental improvements in payload vs endurance, some companies are making more transformative changes to improve drone performance

Source: yet2

Results Market Research





Out of 36 VTOL drones:

- 19 drones < 55 lbs
- 19 drones > 30 min

MTOW = maximum takeoff weight

Open Innovation UAS Prize Challenges

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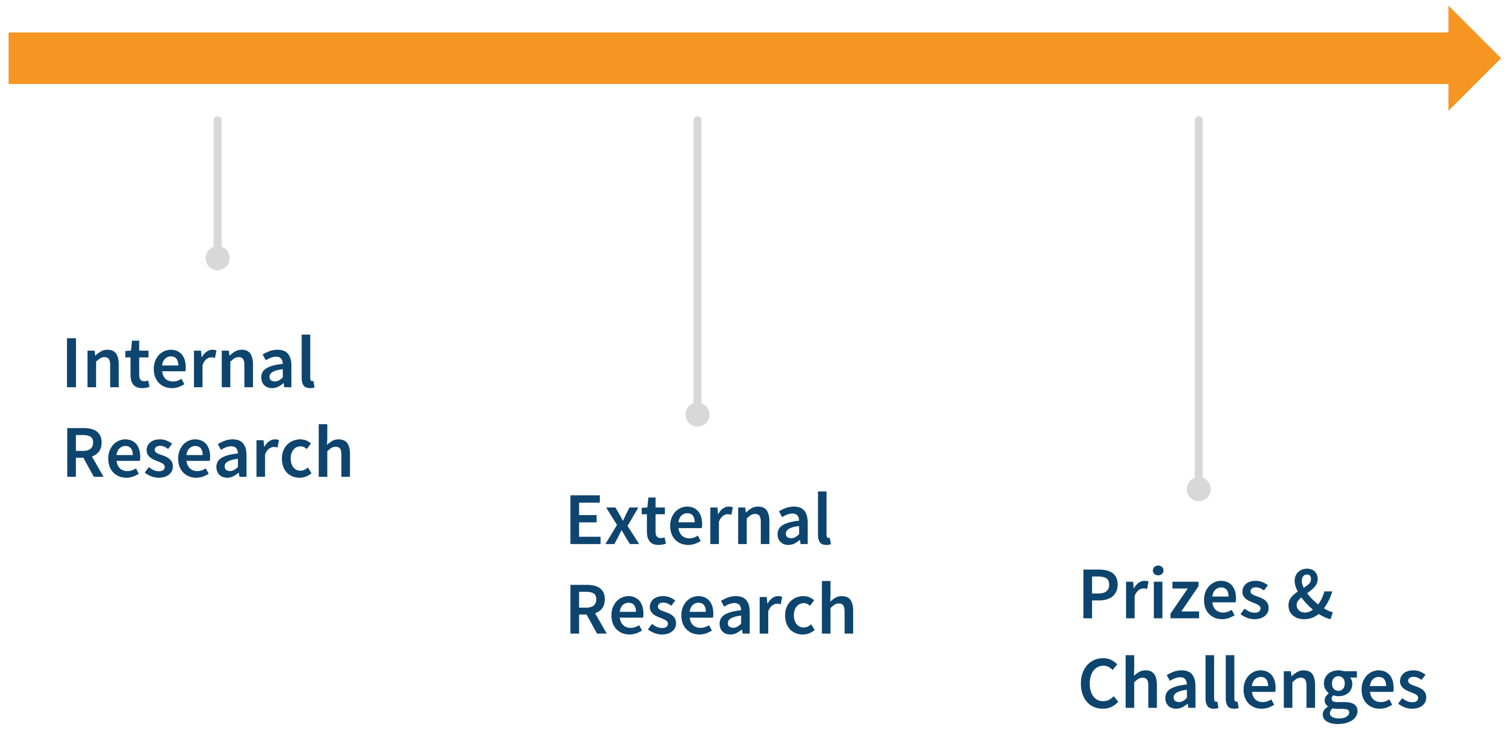
How does PSCR achieve their mission?



Overview Challenge 1.0

- Up to $432k in Prize awards
- Ten (10) teams & designs
- Three (3) stages: concept, prototype, live event
- Test & evaluation included:
  - 10lbs, 15lbs, 20lbs payloads
  - Vertical take-off and landing with ability to hover in place
  - Autonomous and human controlled flight capability
  - In flight accuracy to within +/-5 ft
- UAV Design Parameters
  - Weight < 55lbs
  - Transport Size < 6ft x 4ft x 3ft
  - Hardware Cost < $20k

Lessons Learned Challenge 1.0

- **Flight Time**

  Hybrid design explored practical solutions
- **Payload**

  Tradeoffs were made to support various payload weights
- **Accuracy/Versatility**

  Maintaining accurate location in flight was a significant challenge
- **Cost**

  More funds spent on hardware vs software; advanced software may add stability, accuracy and autonomous functions

1st Place

Finalists

As these approaches are refined and improved, in-flight battery charging has the potential to expand the possibilities for use by First Responders

Overview Challenge 2.0

Goal

Advance UAS technologies by **designing, building and flying drone prototypes** that are safe and stable to support first responders.

Context

The Public safety community requires enhanced drone features and capabilities to **fly for 90+ minutes** while carrying a heavy payload to support the mission.

Scenario

A 'lost person in a desert area' initiates a search & rescue operation; An aerial vehicle/**UAS carrying a 10 pound network device is deployed to provide broadband network coverage.**

Objective

To **fly a UAS and its payload airborne for the longest time possible** to support first responders' communication technology.

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Requirements & Objectives Challenge 2.0

Requirement	Objective
Endurance	> 60 minutes
All Up Weight	< 100 lbs
Vertical Take-off and Landing	Demonstrate ability
Loiter	+Points for a defined airspace
Level of Autonomy	Achieve Levels 0,1, 2
Total System Weight	< 120 lbs
System Volume	6’x4’x3’
Payload	10 lbs (provided by NIST)
Payload Mount	Equipped (provided by NIST)
Component Weight	< 50 lbs

Refer to the official challenge rules, Table B: Drone Design Specification
(https://firstresponderuaschallenge.org/rules.php)

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Requirements & Objectives Challenge 2.0

Requirement	Objective
Set Up Time	< 20 minutes
Video, Camera, GPS, RTK-GPS	Equipped
No Tethers	No tethers
Radio Controller (FHSS)	Use FHSS
System Cost	< $30k
FAA	Comply with FAA regulations/laws
Pilot (Part 107 certified)	One (1) FAA certified pilot
Drone Insurance	Minimum coverage $1M
FCC Compliance	Comply with FCC regulations/laws

Refer to the official challenge rules, Table B: Drone Design Specification (https://firstresponderuaschallenge.org/rules.php)

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Summary Challenge 2.0

Stage 1 — 01

Up to 10 Contestants invited with prize awards
Up to 10 additional Contestants invited

Stage 2 — 02

M1: Preliminary Design Review
Up to 15 prize winners
M2: Critical Design Review
Up to 15 prize winners

Stage 3 — 03

Walk-on Contestants evaluated

Up to 15 Winners (from Stage 2 winners & Walk-ons) invited to compete in Stage 4

Stage 4 — 04

Up to 11 Winners completing minimum standards at the finals
Last Drone Standing

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Timeline/Roadmap Challenge 2.0

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Prize Awards Challenge 2.0

STAGE 1

Up to 10

$10K each team,
Up to $100K total
(Up to 20 teams will advance to Stage 2)

STAGE 2

Up to 15 x 2

Achieving Milestone 1:
$5K each team,
Up to $75K total

Achieving Milestone 2:
$5K each team,
Up to $75K total

STAGE 3

Up to 15

$6K each team,
Up to $90K total
Travel prize awards to compete in Stage 4

STAGE 4

x 1
First Place
$100K

x 1
Second Place
$40K

x 1
Third Place
$20K

Up to 6
Best-In-Class Award
$5K each team,
Up to $30K total

Up to 2
First Responder's Choice Award
$5K each team,
Up to $10K total

Up to 3
Travel Funds
$4K each team,
Up to $12K total
Travel prize awards for top 3 teams to attend 2021 PSCR Conference

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Stage 1 Winners Challenge 2.0

Just Announced!

- Concept Paper Contest
- Teams were evaluated on:
    - Knowledge, Skills, and Team ability to build a UAS prototype
    - Strategic and Technical Ability, including their innovative approach
- The Top 20 teams were invited to compete in Stage 2

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Stage 1 Winners Challenge 2.0

Ranked 1-10

- Team Tempus
- Team GB40
- Mobile Recon Systems
- Alfred Gessow Rotorcraft Center
- Pharos
- Endure Air
- Therecraft
- Autonomous Robotics Competition Club
- SummitView
- UAV Master Lab

Stage 1 Finalists Challenge 2.0

Ranked 11-20

Advanced Aircraft Company

Team Maverick MN State University

SPIN

RMD Systems

Applied Cybernetics Research Group

Ptero Dynamics

MarutSpace

AirGO.Ai

Mothership Aeronautics

UAS@UCLA

Stage 1 Designs Challenge 2.0

Frame Type	Power Source
Helicopter	Battery
Multi-rotor	Gasoline engine
Fixed-wing (FW) airplane	Hybrid gasoline / battery
Tandem rotor (front / back) helicopter	Hybrid diesel / battery
Tandem rotor (top / bottom) helicopter	Hybrid AvGas / battery
Intermeshing rotor (side by side) helicopter	Hydrogen fuel cell
Hybrid FW/multi-rotor	On-demand hydrogen production
Aerostat	Helium Gas
Tiltrotor	Heavy fuel engine

Cost estimates range from $8k to $28k

Endurance estimates range from 77 minutes to 390 minutes

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Q&A with First Responder Expert Panel

Panel Speakers

Captain Philip Hall

Director, NOAA UAS Program
National Oceanic and Atmospheric Research

Christopher Stockhowe

Master Firefighter, EMT, UAS Team Trainer
Virginia Beach Fire Department

Michael O'Shea

Program Manager, Public Unmanned Aircraft Operations
Federal Aviation Administration (FAA) Aviation Safety (AVS)

Raymond Sheh

Professor, Georgetown University
& NIST Associate

THANK YOU

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