Development of an Underground Aerial Reconnaissance System Design to Assist in Mine Rescue

Steven A. Cotten - Subsurface Problem Solutions

Michael A. Trevits - Xtraction Science and Technology, Inc.

John E. Urosek - John Urosek Mine Consulting, LLC

Marlon Whoolery - Retired, United Mine Workers of America Career Centers, Inc.

This study was sponsored by the Alpha Foundation for the Improvement of Mine Safety and Health, Inc. (ALPHA FOUNDATION). The views, opinions and recommendations expressed herein are solely those of the authors and do not imply any endorsement by the ALPHA FOUNDATION, its Directors and staff.

Unmanned Aerial Vehicles (UAVs) or Drones

- The last century introduced us to an innovative technology, known as Unmanned Aerial Vehicles (UAVs) or Drones, that seems to have caught everyone's attention.
- This new industry is on the rise and has seemingly overnight became a billion-dollar industry.
- Drones were initially available for commercial customers but like all great trends has rippled out into all sorts of directions.
- Today, the civil uses of drones are countless.

Project Motivation

In response to a major underground mine emergency, mine rescue and recovery personnel require **timely, accurate, and reliable information** upon which to base their actions.

An Underground Aerial Reconnaissance (UAR) system would convey sensors and/or communication equipment into the mine ahead of mine rescue personnel to provide that information.

An aerial system approach potentially offers a faster, more agile, longer range, and more economical means of information collection than conventional ground-based reconnaissance options.

Vision and Project Objective

Long Term Vision

Deliver an effective Underground Aerial Reconnaissance (UAR) system to assist in mine rescue and recovery as well as normal mine operations

Immediate Project Objective

With guidance received from mine rescue team experts, design, assemble, and demonstrate a purpose-built aerial vehicle platform (AVP) capable of safely maneuvering through hazardous underground atmospheres

Technical Approach

Task 1: Develop a Concept of Operation (CONOP) and Define Requirements

- Background Information and Data Collection
- Define UAR system mission(s)
- Identify, quantify, and prioritize AVP performance requirements

Task 2: Investigate Candidate Technologies

- Identify any commercial IS AVP options
- Research AVP design, propulsion, and payload options
- Develop AVP integrated design concept

Task 3: System Engineering/Proof-of-Concept Construction

- Conduct AVP requirements engineering review
- Select AVP design
- Engineer integrated proof-of-concept design
- Assemble components; bench test vehicle
- Conduct field tests

Task 1 Background Information and Data Collection

Approach for CONOP and system requirements definition:

1. Review actions from actual mine emergency events
2. Discussions with mine rescue Subject Matter Experts (SMEs)
3. Conduct an online survey to engage additional SMEs
4. Evaluate MSHA Investigative Reports on mine disasters

Task 1.1 – Review actions from actual mine emergency events

- JWR No. 5 Mine Explosion, 2001 - 13 fatalities.
- Sago Mine Explosion, 2006 - 12 fatalities.
- Upper Big Branch Mine, 2010 - 29 fatalities.

Task 1.1 – Review of Mine Emergency Events

- An in-depth review of the events indicate that an unmanned aerial vehicle would be a useful tool following a mine disaster.
- Potential uses include:
  - Scout for advancing mine rescue teams,
  - Conducting mine exploration when it is too dangerous, and
  - Insertion through a shaft or borehole to obtain information.

Task 1.2 – Discussions with Subject Matter Experts

Series of Meetings Held

- MSHA Officials
- NIOSH Officials
- State Officials
- Mine Operators
- Mine Rescue Team Members
- Academia
- Vendors

Task 1.2 – Discussions with Subject Matter Experts

SOME OF THE GENERAL QUESTIONS

- Do you think an Unmanned Aerial Vehicle (UAV) could be a useful tool for rescuers in post-event operations?
- Step-by Step, what are your initial thoughts on how the UAV might operate? What specifically would you want the UAV to accomplish?
- What information would want the UAV to gather?
- Does the UAV have to be intrinsically safe/permissible?
- Are there any possible missions for a UAV that is not intrinsically safe/permissible?
- How many people should participate in the UAV mission?

Task 1.2 – Discussions with Subject Matter Experts

SOME SPECIFIC OPERATIONAL QUESTIONS

- Who should operate the UAV?
- If payload becomes an issue, can you prioritize the capabilities of the UAV?
- Should batteries be able to be changed out underground?
- How long should the UAV be able to operate for a mission?
- What is the optimal size for a UAV for underground use?
- What should the range of a UAV be?

Task 1.2 – Discussions with Subject Matter Experts

Results

The Experts:

- Indicated that the UAV could benefit and assist the rescuers.
- Felt there were several possible missions for a UAV.
  - In place of a mine rescue team when it is too dangerous
  - As a scout in front of advancing mine rescue teams
  - Through a borehole or shaft
- Agreed that the visual information the UAV could gather would help rescuers by providing a preliminary view of mine roof and rib conditions, possible explosion debris fields, water levels, ventilation and other mine information.
- All agreed that a UAV should be intrinsically safe or permissible. The experts felt that a UAV that is not intrinsically safe or permissible would have limited missions.

Task 1.2 – Discussions with Subject Matter Experts

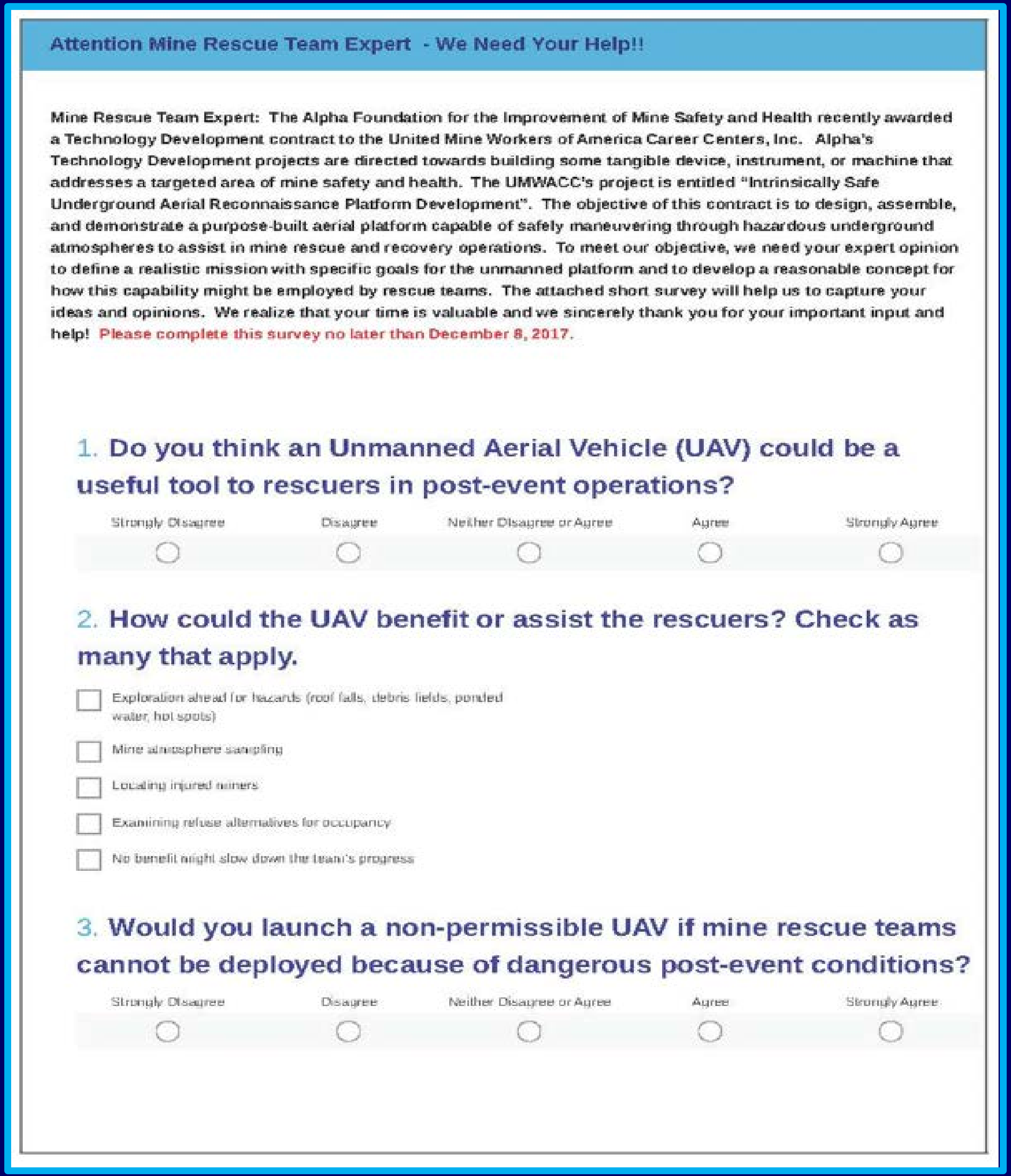
Results (Continued)

The Experts:

- Felt the UAV size would be dependent on the mission. A UAV that is deployed in the underground mine should be small enough to fit though a standard 30-inch man door.
- Have a variable opinion as to the ideal flight range. A mine rescue team typically advance in 1,000-foot increments, so some felt 1,000 feet would be a useful range. While others indicated that a shorter range of a few hundred feet would be useful.
- The experts agree the UAV should be easy to maneuver in a mine opening and would like the UAV to be able to make 90-degree turns into and through crosscuts.

Task 1.3 - Conduct an online survey to engage additional SMEs

Survey Monkey



Attention Mine Rescue Team Expert - We Need Your Help!!

Mine Rescue Team Expert: The Alpha Foundation for the Improvement of Mine Safety and Health recently awarded a Technology Development contract to the United Mine Workers of America Career Centers, Inc. Alpha's Technology Development projects are directed towards building some tangible device, instrument, or machine that addresses a targeted area of mine safety and health. The UMWACC's project is entitled "Intrinsically Safe Underground Aerial Reconnaissance Platform Development". The objective of this contract is to design, assemble, and demonstrate a purpose-built aerial platform capable of safely maneuvering through hazardous underground atmospheres to assist in mine rescue and recovery operations. To meet our objective, we need your expert opinion to define a realistic mission with specific goals for the unmanned platform and to develop a reasonable concept for how this capability might be employed by rescue teams. The attached short survey will help us to capture your ideas and opinions. We realize that your time is valuable and we sincerely thank you for your important input and help! Please complete this survey no later than December 8, 2017.

1. Do you think an Unmanned Aerial Vehicle (UAV) could be a useful tool to rescuers in post-event operations?

Strongly Disagree	Disagree	Neither Disagree or Agree	Agree	Strongly Agree
○	○	○	○	○

2. How could the UAV benefit or assist the rescuers? Check as many that apply.

- ☐ Exploration ahead for hazards (roof falls, debris fields, ponded water, hot spots)
- ☐ Mine atmosphere sampling
- ☐ Locating injured miners
- ☐ Examining refuse alternatives for occupancy
- ☐ No benefit might slow down the team's progress

3. Would you launch a non-permissible UAV if mine rescue teams cannot be deployed because of dangerous post-event conditions?

Strongly Disagree	Disagree	Neither Disagree or Agree	Agree	Strongly Agree
○	○	○	○	○

Task 1.3 - Online Survey

Sent to 102 Mine Rescue Team Members via Email

32 Responses
31.4% Response rate

4. Who should make the decision to launch the UAV?

Official in the Command Center	Mine Rescue Team Member	State Government Official	Federal Government Official (MSHA)	Other
○	○	○	○	○

5. What is the optimal mission flight time?

≤ 15 Minutes	16 to 30 Minutes	31 to 45 Minutes	46 to 60 Minutes	Flight time is dependent on the mission and tasks
○	○	○	○	○

6. What is the optimal flight range for a UAV for underground use?

≤ 250 Feet	251 to 500 Feet	501 to 750 Feet	751 to 1000 Feet	> 1000 Feet
○	○	○	○	○

7. What is the optimal size for a UAV for underground use?

≤ 12 Inches	13 to 18 Inches	19 to 24 Inches	25 to 30 Inches	> 30 Inches
○	○	○	○	○

8. Should the UAV fly back to takeoff point or should it land in the mine after the mission and be recovered later after safe power down?

Always Return to takeoff point	Always land after in the mine after the mission is completed	The decision is up to pilot depending on power and mission
○	○	○

9. Should the UAV have other underground uses in addition to mine rescue team assist?

Strongly Disagree	Disagree	Neither Disagree or Agree	Agree	Strongly Agree
○	○	○	○	○

10. Your ideas and opinions are important to us, please share them below.

Task 1.3 – Online Survey

Results

- 75% of the survey respondents agreed or strongly agreed that an UAV could be a useful tool to rescuers in post-event operations.
- Most respondents believed that the UAV could best benefit or assist rescuers by locating miners and the UAV could sample the mine atmosphere.
- 25% of the respondents would not launch a non-permissible UAV if mine rescue teams could not be deployed because of dangerous post-event conditions.

Task 1.3 – Online Survey

Results (Continued)

- A clear majority of the respondents believe that the optimal mission flight time should be dependent on the mission and tasks. Those who did respond to a specific flight duration selected between 16 to 45 minutes.
- When it comes to optimal flight range for a UAV for underground use, there were mainly two responses: 500 to 750 feet and >1,000 feet. The response >1,000 feet was clearly the most popular response.
- For the optimal size for an UAV, the most popular responses were evenly divided between 19 to 24 in and 25 to 30 in. Note that these size ranges, though popular, may preclude flight through open man doors.

Task 1.4 - Evaluate a number of MSHA's Investigative Reports on Mine Disasters

- JWR No. 5 Mine Disaster
  - The additional information provided to the Command Center could have helped their decision-making and increased the safety to mine rescue team members and any potential missing miners.
- Sago Mine Disaster
  - The additional information provided to the Command Center could have helped their decision-making and even the changed the eventual outcome of this disaster.

Task 1.4 - Evaluate a number of MSHA's Investigative Reports on Mine Disasters (Continued)

- Upper Big Branch Mine Disaster
  - The large area affected by the forces of the explosion made it difficult to explore all of the affected area quickly. The mine rescue teams could have used a UAV to more quickly reach each of the refuge alternatives to determine if they had been deployed and locate the missing miners.
  - UAV could have increased the advance rate of the mine rescue teams, especially with the delays encountered during exploration.

Task 1 - CONOP

- The UAV should have some of the following capabilities and characteristics:
  - Should be less than 36” wide and battery operated.
  - Must be intrinsically safe, at least as required by international standards.
  - Should be equipped with the minimum of a low-lux camera and an associated light source. An infrared camera, still camera, and microphone for the UAV is optional.

Task 1 – CONOP (Continued)

- The UAV should have the following capabilities and characteristics:
  - Should have an emergency shutdown system.
  - Must have a minimum operational flight time of 15 minutes.
  - There should be a battery life indicator on the pilot’s/navigator’s laptop computer.
  - The computers will record flight events, power consumption, gas readings and video images from each mission.

Task 1 Summary

Approach for CONOP and system requirements definition:

1. Review actions from actual mine emergency events
2. Discussion with mine rescue Subject Matter Experts (SMEs)
3. Conduct an online survey to engage additional SMEs
4. Evaluate MSHA Investigative Reports on mine disasters

Task 1 Summary

Approach for CONOP and system requirements definition:

1. Review actions from actual mine emergency events
2. Discussion with mine rescue Subject Matter Experts (SMEs)
3. Conduct an online survey to engage additional SMEs
4. Evaluate MSHA Investigative Reports on mine disasters

Possible CONOPs

- Scout for advancing mine rescue teams
- Conduct mine exploration when it is too dangerous to enter
- Insert through a shaft or borehole to obtain information

Task 1 Summary (Continued)

UAR requirements

1. Size: $\leq$30 inches
2. Highly maneuverable
3. Range: 1,000-foot minimum
4. Flight time or Endurance: 20-30 minutes
5. Intrinsically safe (at least by international standards)
6. Payload capacity: About 2.2 pounds
7. Mandatory payloads
   - Low-lux camera with supplemental LED light source(s)
8. Optional Payloads
   - Infrared camera
   - Gas sensors
   - Microphone
   - Communication system node

Task 2 Investigate Candidate Technologies: Class/Division/Group and Zone Classifications

- Locations with possible risks due to explosive atmospheres are called "**hazardous" or "classified" areas,**
- In North America (the United States and Canada), these areas are historically classified with the "**Class/Division/Group"** system. In Europe and the rest of the world, but now more commonly in North America, the "**Zone"** system is used.
- Both systems evolved over the past 100 years from efforts by several industrial safety organizations.
- These organizations needed to categorize both the risk level and required protection techniques and methods for each area to develop standards for electric and electronic equipment construction and protection to permit safe operation.
- International agreement and understanding have been reached regarding appropriate and effective means to achieve the EPL associated with the operating conditions associated with each zone.

Task 2 Investigate Candidate Technologies

General Intrinsic Safety Zone Classifications

Zone Grouping	Equipment Protection Level (EPL) (provided by techniques in this grouping)	Industrial Application Condition (frequency of occurrence of explosive atmosphere)
Zone 0	Highest	Continuous or nearly continuous explosive atmosphere
Zone 1	Moderate to High	Frequently occurring explosive atmosphere
Zone 2	Low	Infrequent presence of explosive atmosphere
No Requirements Zone (NRZ)	None	Negligible occurrence of an explosive atmosphere

Task 2 Investigate Candidate Technologies

General Intrinsic Safety Zone Classifications

Zone Grouping	Equipment Protection Level (EPL) (provided by techniques in this grouping)	Industrial Application Condition (frequency of occurrence of explosive atmosphere)
Zone 0	**Highest**	**Continuous or nearly continuous explosive atmosphere**
Zone 1	Moderate to High	Frequently occurring explosive atmosphere
Zone 2	Low	Infrequent presence of explosive atmosphere
No Requirements Zone (NRZ)	None	Negligible occurrence of an explosive atmosphere

Task 2 Investigate Candidate Technologies

Commercial IS UAV Market Survey

Manufacturer	Model	Type	Intended Use	IS Rating(s)	Physical Dimensions (LxWxH) (inches)	Air Frame Weight (lbs)	Payload Capacity (lbs.)	Payload(s)	Approximate Maximum Flight Duration (minutes)	Power Supply	12/31/17 Status
1	**A**	dual prop quad copter	monitoring and surveying hazardous industrial work facilities	Zone 1 Class I, Div. 1 & 2 Class II, Div. 1 & 2	66 x 60 x 30	21	12.3	infrared and/or visible cameras, data transmitters, gas monitors	22	LiPo batteries	available for purchase
2	**B**	quad copter	site inspections	Zone 1 Class I, Div. 2 (assumed)	15 x 15 x 3.5	1.1	TBD	fixed orientation visible light camera	25	LiPo batteries	not yet released
3	**C**	quad copter	inspection of enclosed vessels	ATEX Zone 0; IECEx Class 1 Div. 1 (anticipated)	12 x 12 x 4	TBD	TBD	fixed orientation visible light camera	unlimited	compressed air	under development
4	**D**	dual prop quad copter	chemical plant maintenance or diagnostic operations	ATEX Zone 2	48 x 48 x 12	9.25	2.6	visible light and infrared cameras, gas sensors	8 - 15	LiPo batteries	available for purchase

Task 2 Investigate Candidate Technologies

<u>Commercial IS AVP 1A</u>

- IS Zone 1 rated
- Dimensions: 60” x 60” x 30”
- Flight Duration: 22 min.
- Payloads:
  - Visible and IR cameras
  - Gas sensors
- Status: Purchase at $60k

Task 2 Investigate Candidate Technologies

Commercial IS AVP 2B

- IS Zone 1 rated (anticipated)
- Dimensions: 15” x 15” x 3.5”
- Flight Duration: 25 min.
- Payloads:
  - Visible camera
- Status: Prototype remains under development since 2016

Task 2 Investigate Candidate Technologies

<u>Commercial IS AVP 3C</u>

- IS Zone 0 rated (anticipated)
- Dimensions: 12” x 12” x 4”
- Flight Duration: unlimited
- Payloads:
  - Visible camera
- Status: prototype still under development (employs compressed air supplied through a ~100-foot tether to power propeller motors)

Task 2 Investigate Candidate Technologies

Commercial IS AVP 4D

- IS Rating: Zone 2
- Dimensions: 48” x 48” x 12”
- Flight Duration: 15 min.
- Payloads:
  - Visible and IR cameras
  - Gas sensors
- Status: Purchase at ~$100k

Task 2 Investigate Candidate Technologies

Flyability Elios drone and control unit

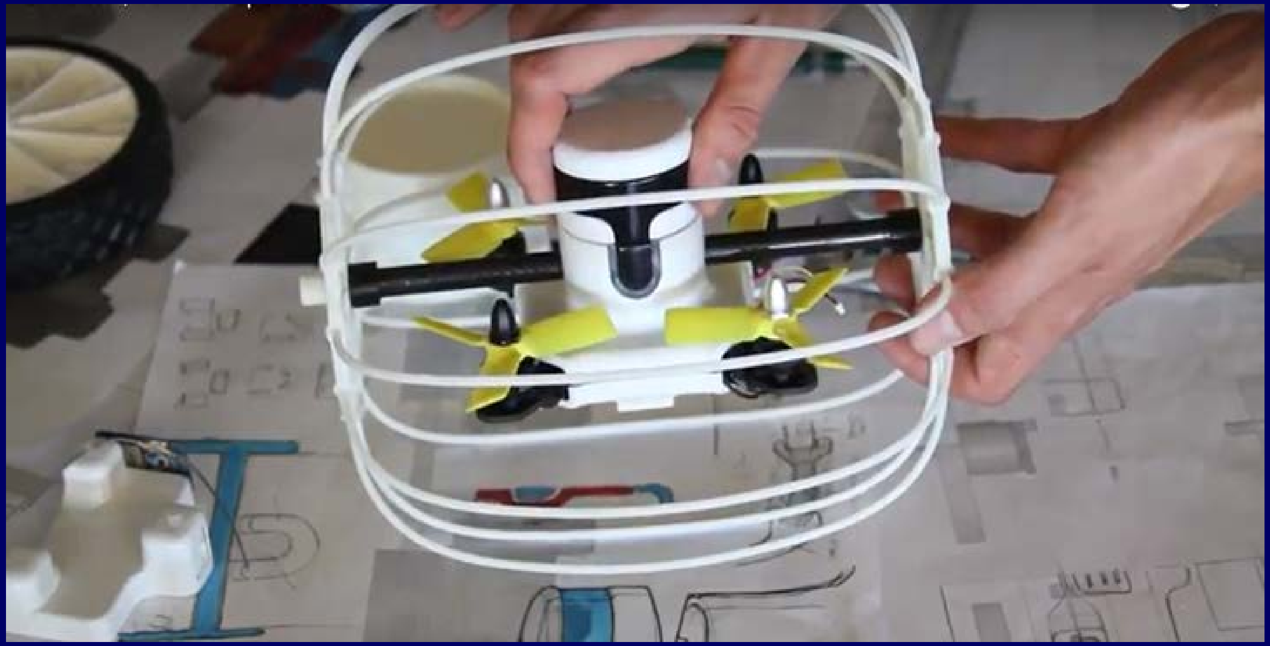
Flyability is a Swiss company founded in 2014 concentrating on building safe drones for operating indoors, in complex and confined spaces, and in contact with people   The Flyability Elios is claimed to be the first collision-tolerant drone, designed for the inspection and exploration of inaccessible places.

Task 2 Investigate Candidate Technologies

Skypersonic Skycopter™

Skypersonic™ is a metro Detroit-based research and design engineering company providing autonomous systems and vehicle technology services as well as real-time location systems for various industries. The Skycopter™ drone was designed for indoor applications and for commercial, industrial, agricultural and civil purposes.

Task 2 Investigate Candidate Technologies



ASU/Honeywell CANARY drone with interchangeable sensor module

The CANARY Tunnel Inspection Drone is a joint development of Honeywell and Arizona State University (ASU) to enable interior inspection of pipes, large conduits, utility passages, and other long enclosed confined spaces. It is also designed to permit easy inter-changeability of different sensor modules (visible light camera, infrared camera, lidar scanner and communications node).

Task 2 - Investigate Candidate Technologies

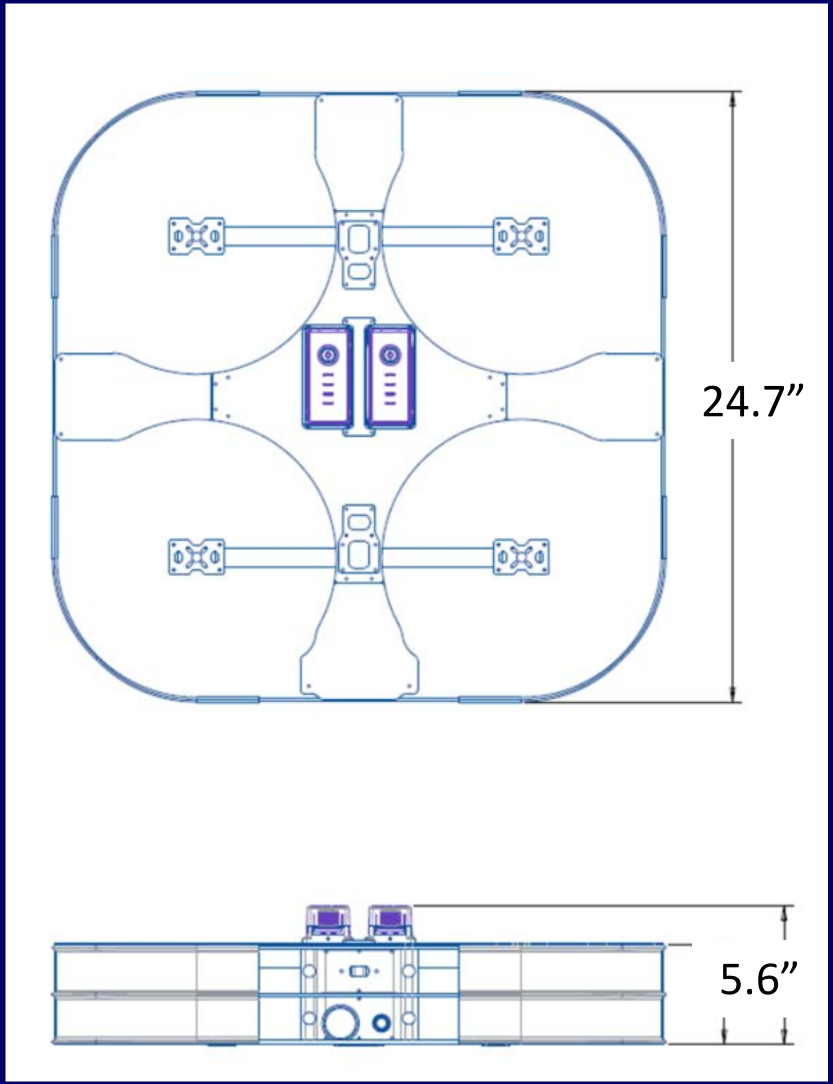
- In summary, only two of the four identified “hazardous atmosphere” UAVs have acceptable physical dimensions for underground application.
- Unfortunately, neither of these is currently offered as a commercial product nor do they have documented IS ratings.
- The development status of the one of the two remains unknown

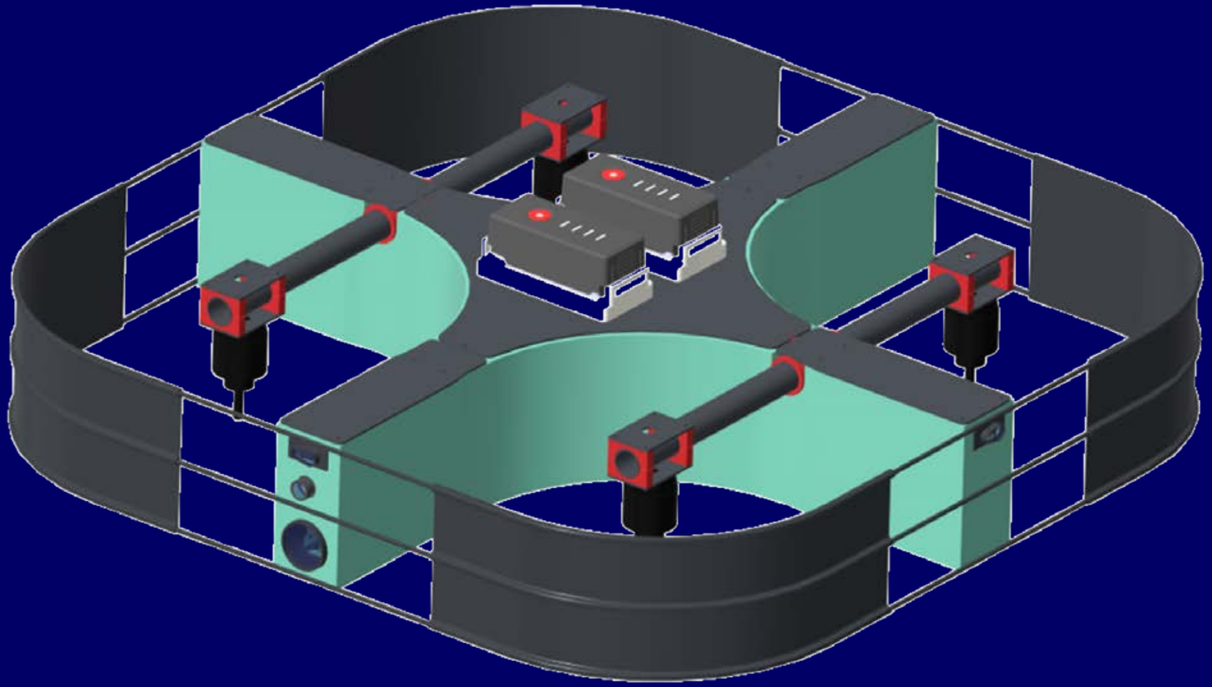
Task 3 - System Engineering/Proof-of-Concept Construction

UAV Initial Design Work

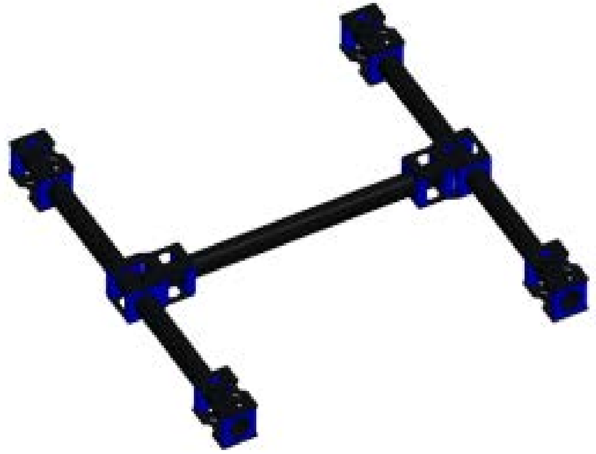
Requirement Number	Requirement Title	Shall statement	Verification Method Summary	Verification Method
AVP-1	Manuverability	The aircraft shall be capable of manuvering in all 3 dimensions when operated by a highly trained pilot.	Flight manuverability will be shown during demonstration flights.	Demonstration
AVP-2	Maximum dimension	The airframe shall not exceed 30 inches in any dimension when in flight configuration.	The airframe will be inspected and measured to ensure that no dimension exceeds 30 inches.	Inspection
AVP-3	Useful Payload	The aircraft shall have a payload capacity between 1.1 and 2.2 pounds (500 and 1000 grams).	The aircraft will be flown with a 2.2 pound payload.	Demonstration
AVP-4	Operational Range	The aircraft shall be able to maintain positive control link for at least 1000 feet when flown within visual line of sight.	The aircraft will be flown to a distance of 1000 feet.	Demonstration
AVP-5	Flight Duration	The aircraft shall be capable of maintaing a hover between 20 and 30 minutes.	The aircraft will be hovered in place with a payload of 1.1 and 2.2 lbs.	Demonstration
AVP-6	Rotor Enclosure	The aircraft shall have a protective enclosure around the rotors.	The airframe will be inspected to verify that the rotors have a protective enclosure.	Inspection
AVP-7	Crash Resistance	The aircraft shall be of rugged construction with an emergency landing/collision/crash-tolerant physical configuration.	The aircraft shall be subjected to an unpowered drop from a height of 6 feet (TBR) to a concrete floor without (1) suffering any structural damage to its primary airframe and (2) exposing any of its electronic components (including batteries and motors) either to damage or the ambient atmosphere, if originally isolated from that atmosphere.	Demonstration
AVP-8	Hazardous Area Operation	The aircraft shall be constructed to allow its safe operation in hazardous atmospheres	The aircraft and its material parts list shall be inspected to verify construction either (1) with electronic components that possess an intrinsic safety certification, or (2) in a manner isolating electronic components from contact with any explosive atmosphere, or (3) some combination of (1) and (2).	Inspection
AVP-9	Obstacle Sensing	The aircraft shall be equipped with sensors that allow it to sense obstacles on all six sides (Front, Back, Left, Right, Top, and Bottom).	The design will be inspected and verified for inclusion of the appropriate sensoors prior to build.	Inspection
AVP-10	Centering Flight Mode	The aircraft shall have a flight mode where it attempts to center itself within its environment for operation in an enclosed environment.	The aircraft will be flown in an environment demonstrating the centering capability.	Demonstration

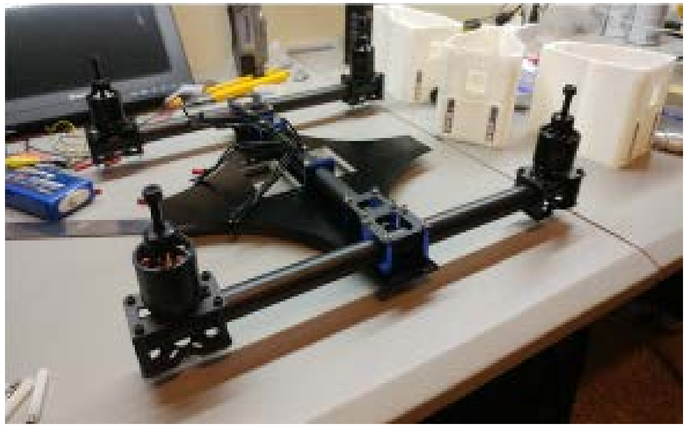
Task 3: Proof-of-Concept: AVP Design





Task 3 - System Engineering/Proof-of-Concept Construction: Designed, Custom Built Aerial Vehicle Platform



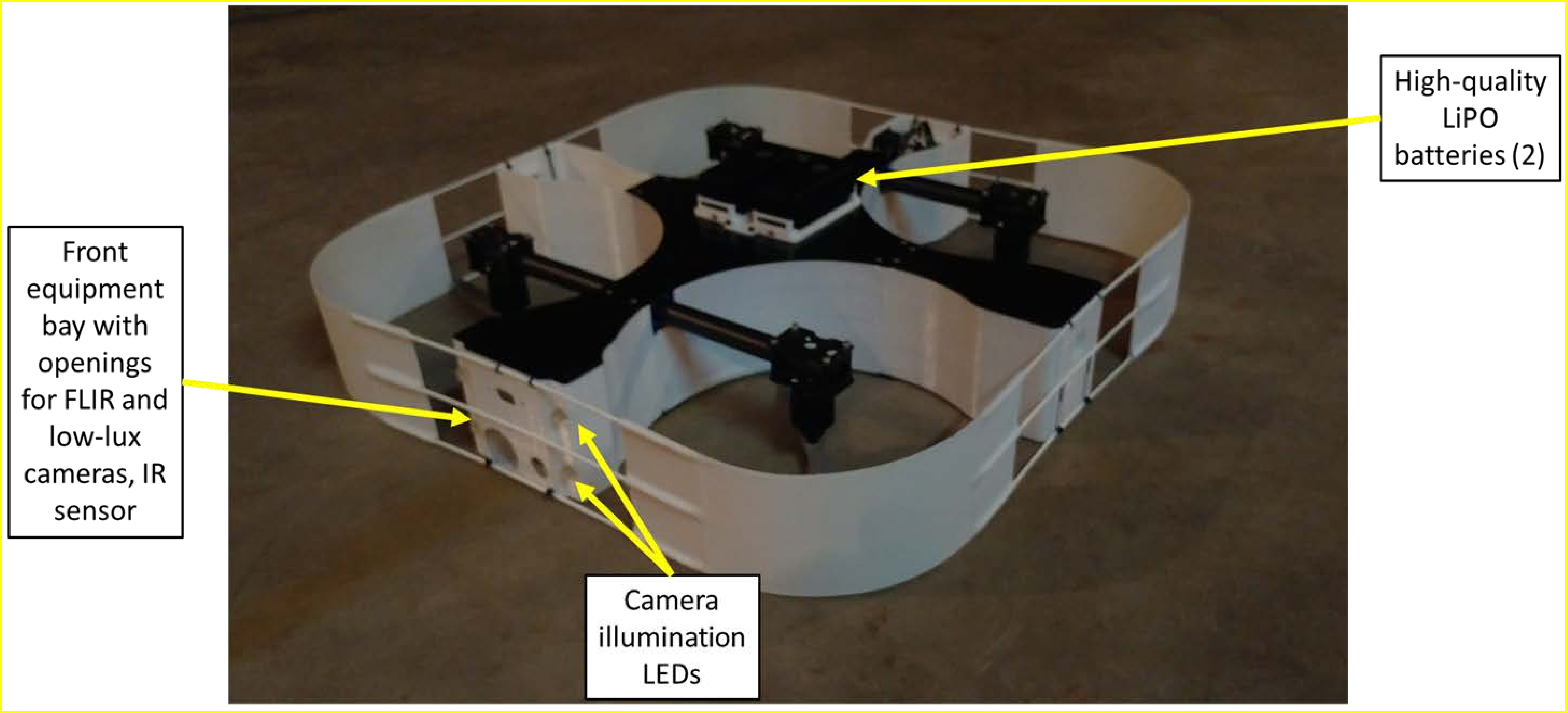


Hollow tube structure "skeleton" construction:

- 0.75-inch carbon tubes
- Carbon plates
- Aluminum tube clamps

UAV Construction

Task 3 - System Engineering/Proof-of-Concept Construction: Designed, Custom Built Aerial Vehicle Platform

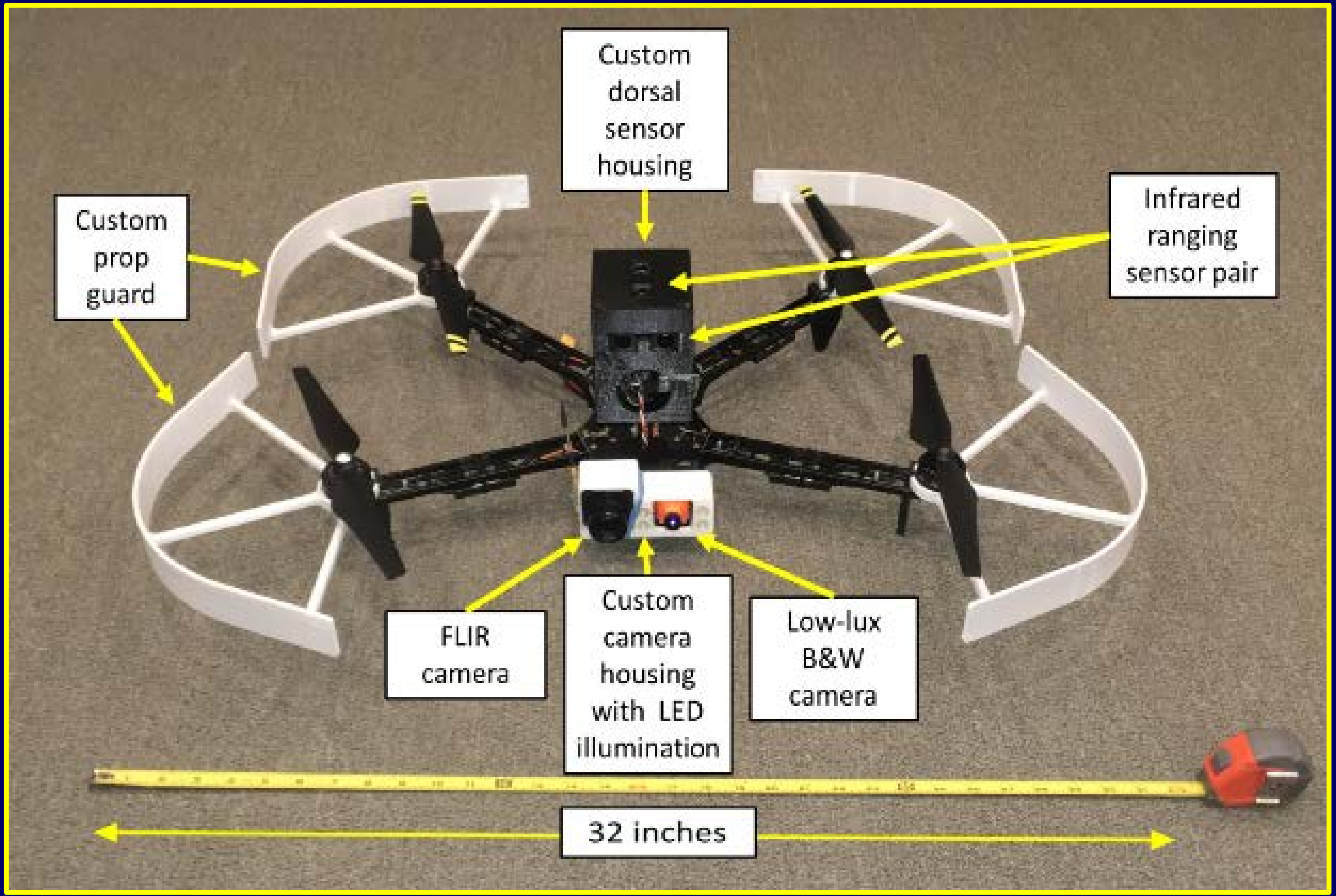


Task 3: System Engineering/Proof-of-Concept Construction: Designed, Custom Built Aerial Vehicle Platform: AVP Bench Tests

Issues

- Non-linear motor behavior
  - Flight instability
- MSHA – Intrinsic Safety
  - System power
  - Motor protection
  - Confidentiality of commercial component designs

Task 3 - System Engineering/Proof-of-Concept Construction: Designed, Custom Built Aerial Vehicle Platform

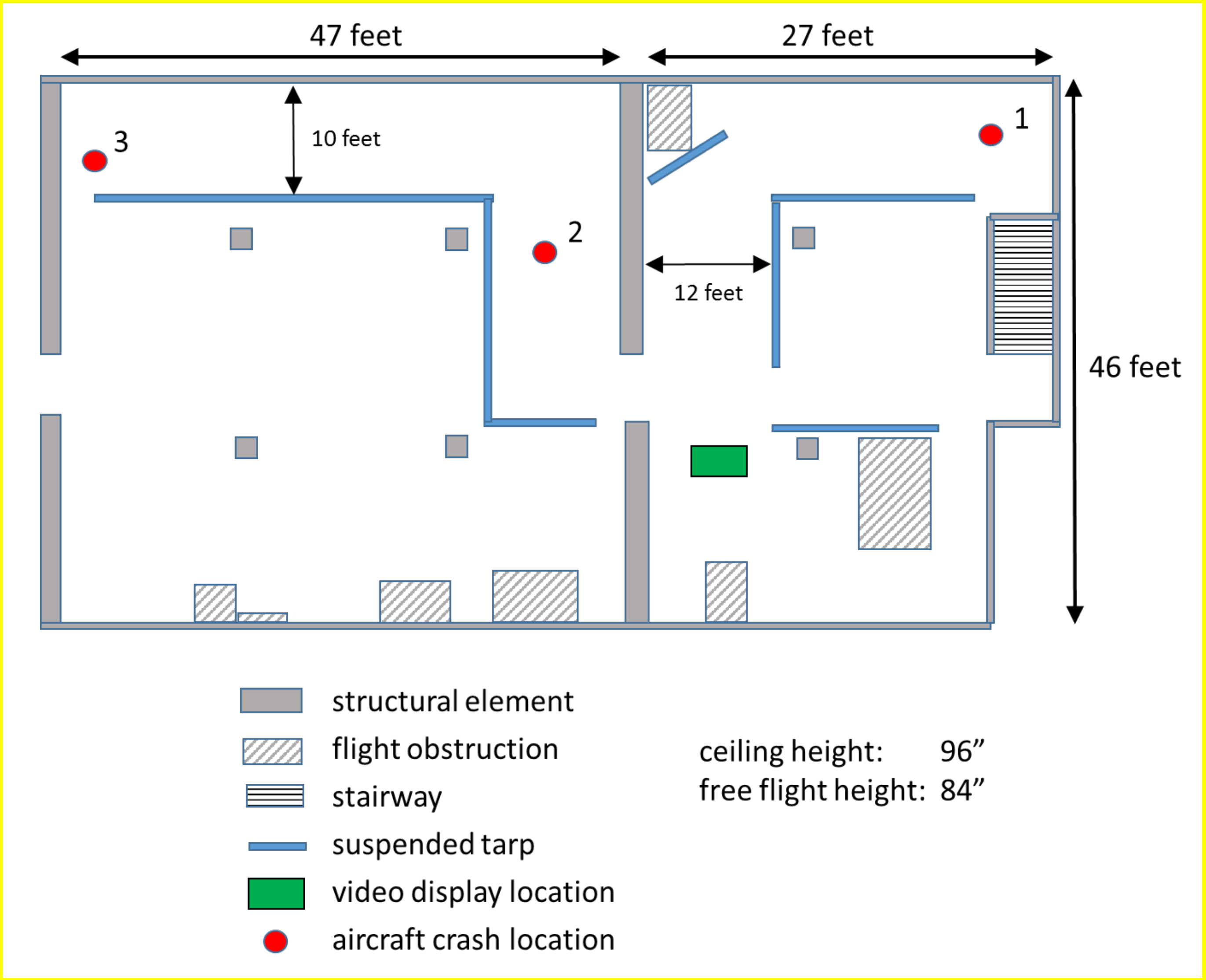


Customized TBS Discovery Airframe

Task 3 - System Engineering/Proof-of-Concept Construction: Designed, Custom Built Aerial Vehicle Platform: TBS Discovery Flight Tests

Flight Test Observations

- Ground effect turbulence can adversely affect flight stability
- Obstacle detection / collision avoidance system must be robust and fault-tolerant
- Large UAV operation in tightly confined spaces may encounter unexpected problems due to non-uniform air flow



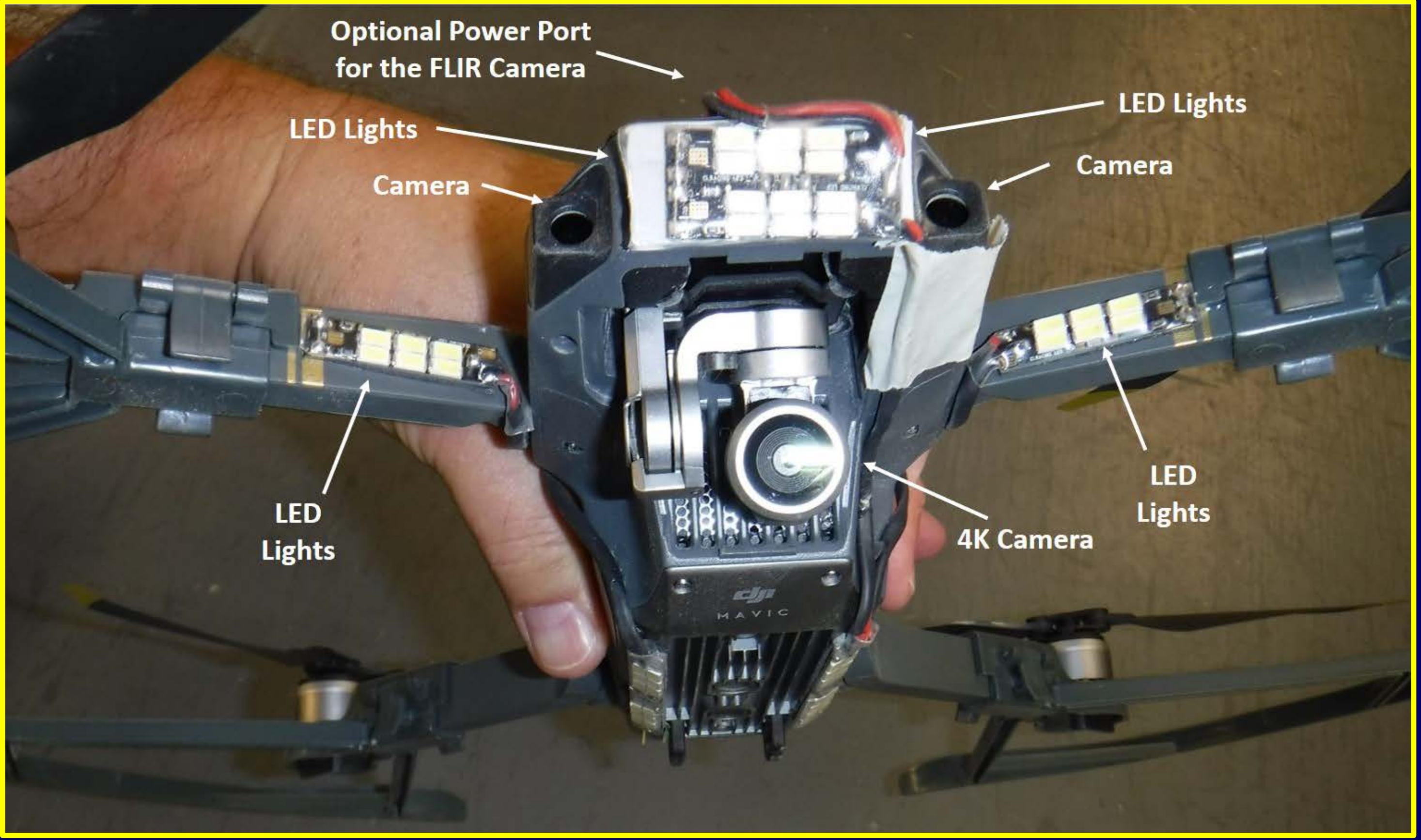
Task 3 - System Engineering/Proof-of-Concept Construction: Simultaneous Operational Developments

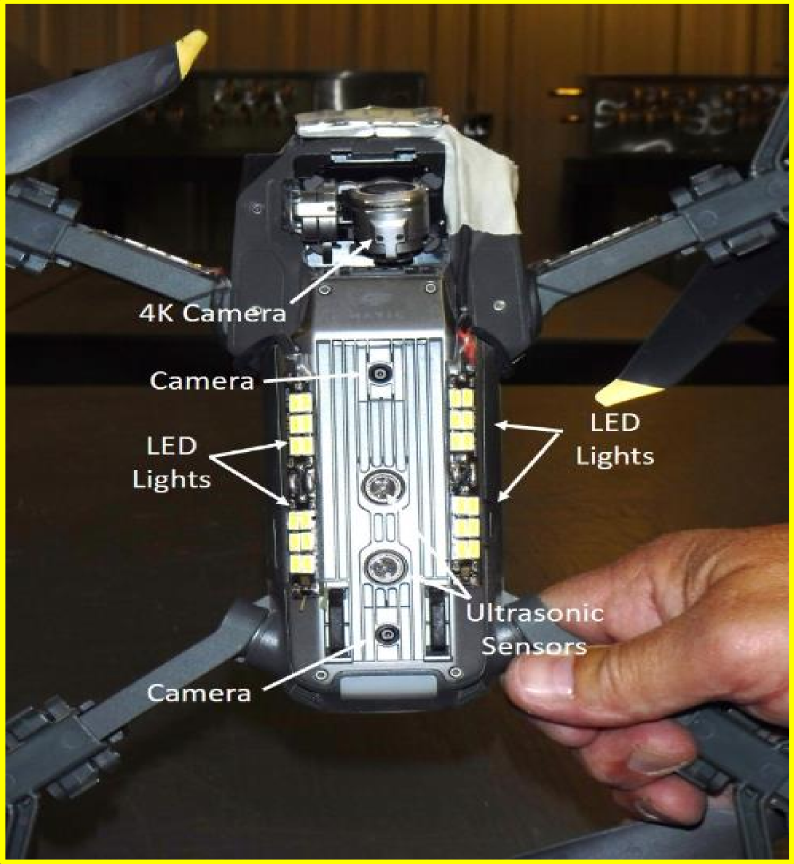
Parrot Bebop 2 Quadcopter

Task 3 - System Engineering/Proof-of-Concept Construction: Simultaneous Operational Developments

DJI Mavic Pro Quadcopter

Task 3 - System Engineering/Proof-of-Concept Construction: Simultaneous Operational Developments

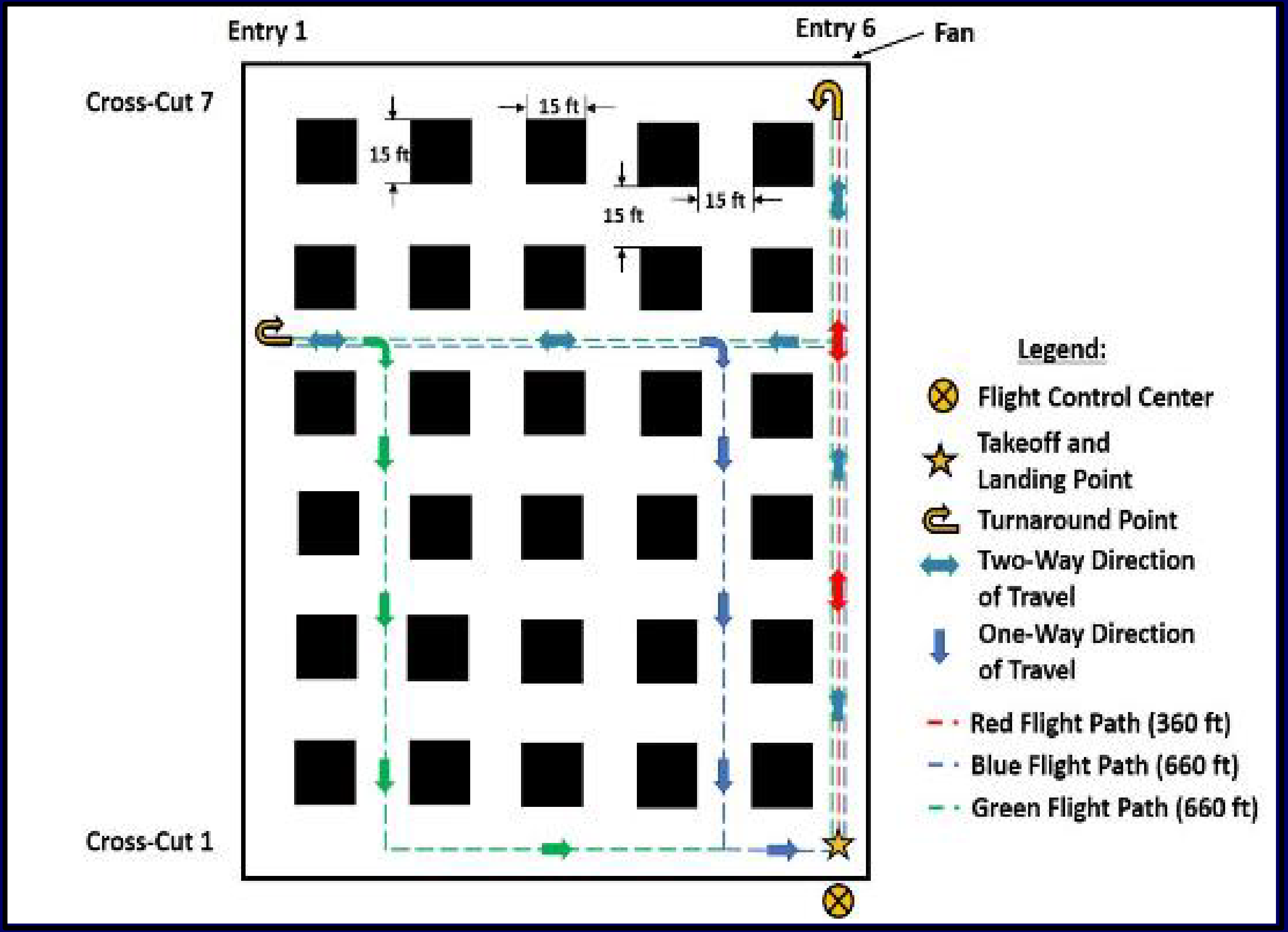




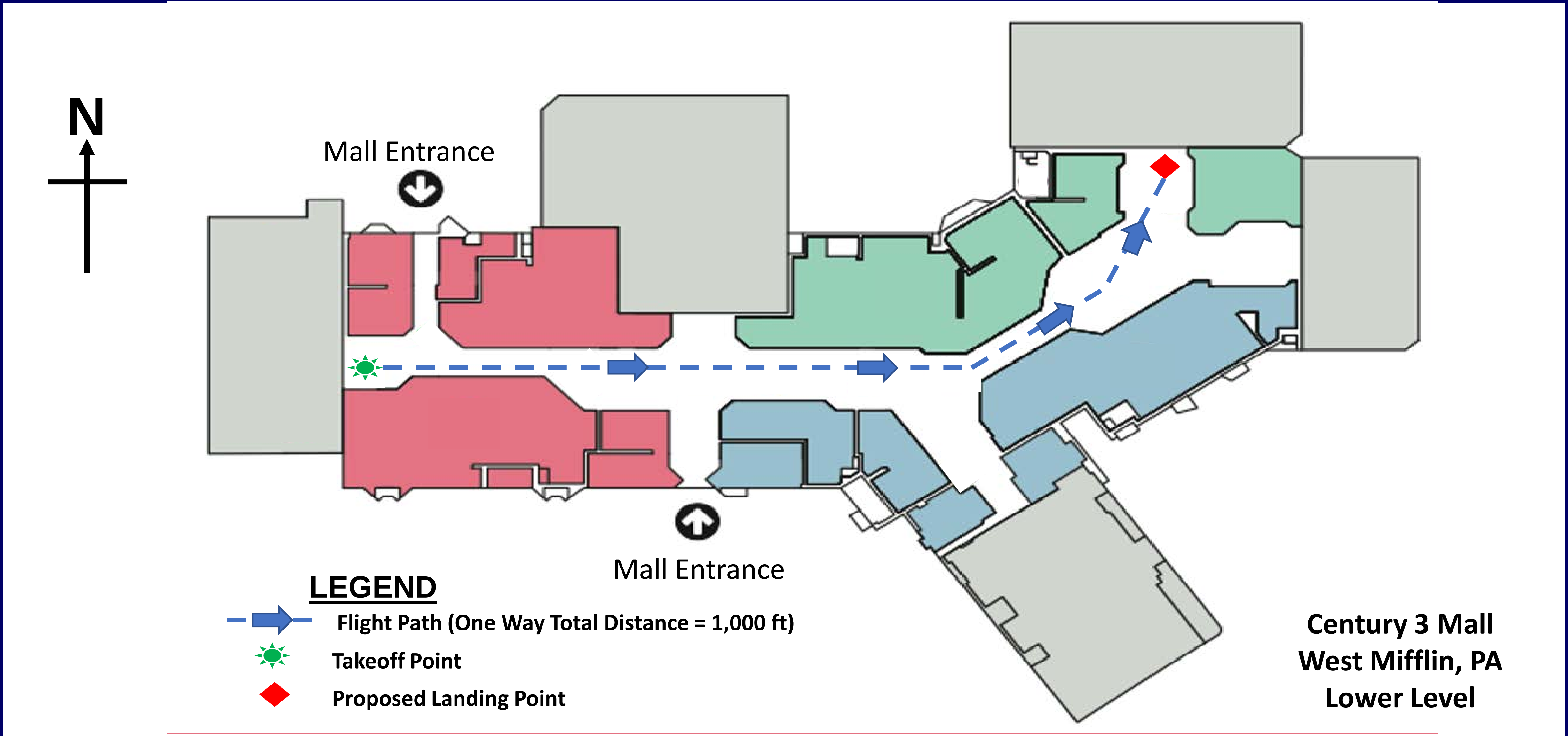
DJI Mavic Pro Quadcopter Modified with LED Lighting

Task 3 - System Engineering/Proof-of-Concept Construction: Simultaneous Operational Developments

Successful Flights inside UMWACC Simulated Mine With the DJI Mavic Pro Quadcopter Modified with LED Lighting



Long distance test flights at the Century 3 Mall, West Mifflin, PA: Proposed Flight Path

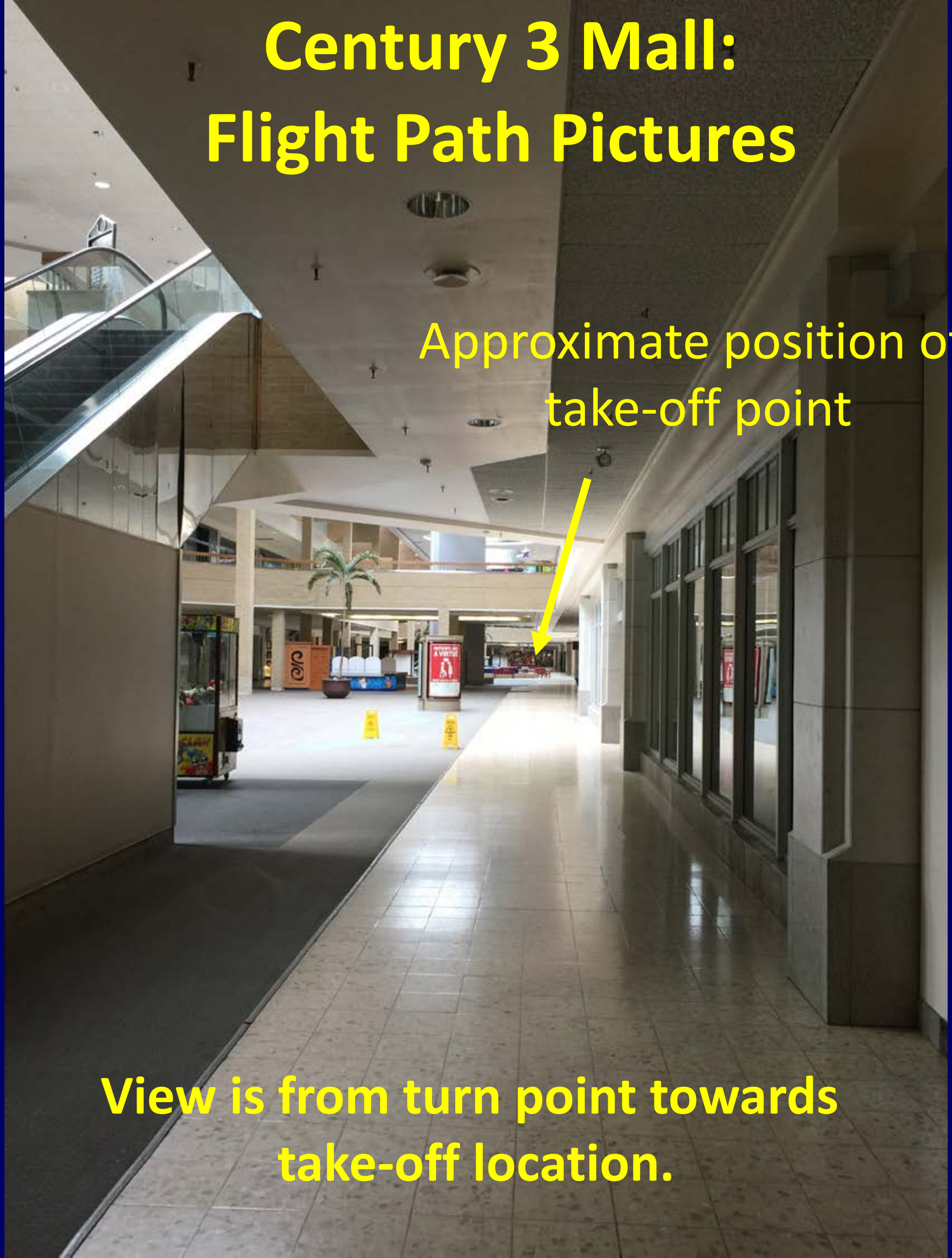


Century 3 Mall: Flight Path Pictures

Note: The lighting in this picture is correct

View is from take-off location towards the turn point.

Century 3 Mall:
Flight Path Pictures



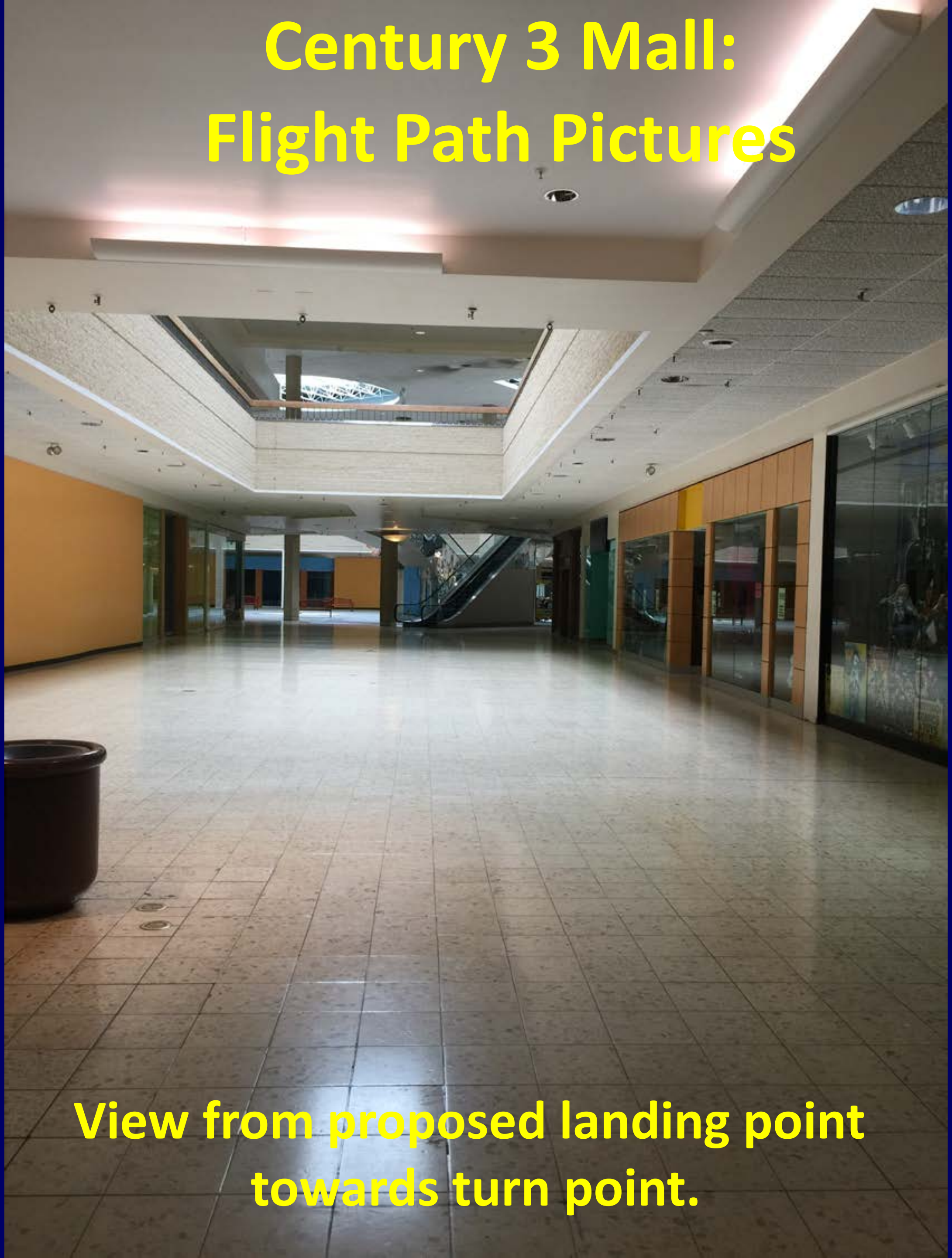
Note: The lighting in this picture is correct

Century 3 Mall: Flight Path Pictures

Note: The lighting in this picture is correct

View from turn point to proposed landing point.

Century 3 Mall:
Flight Path Pictures



View from proposed landing point towards turn point.

Note: The lighting in this picture is correct

Long distance test flights at the Century 3 Mall, West Mifflin, PA

Pilot (John Urosek) flew the quadcopters using FPV (First Person View)

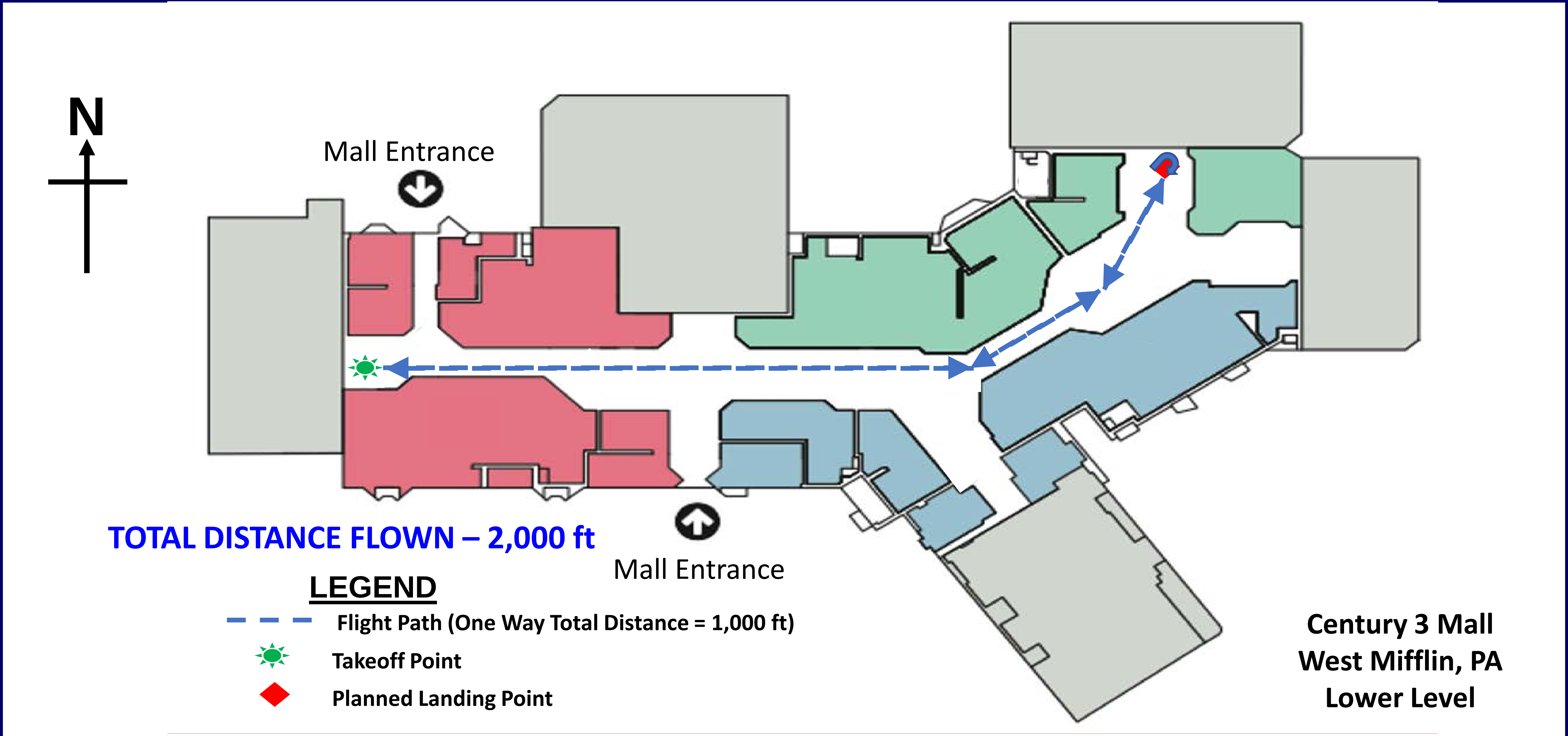
Long distance test flights at the Century 3 Mall, West Mifflin, PA: Quadcopters Used

Parrot Bebop 2

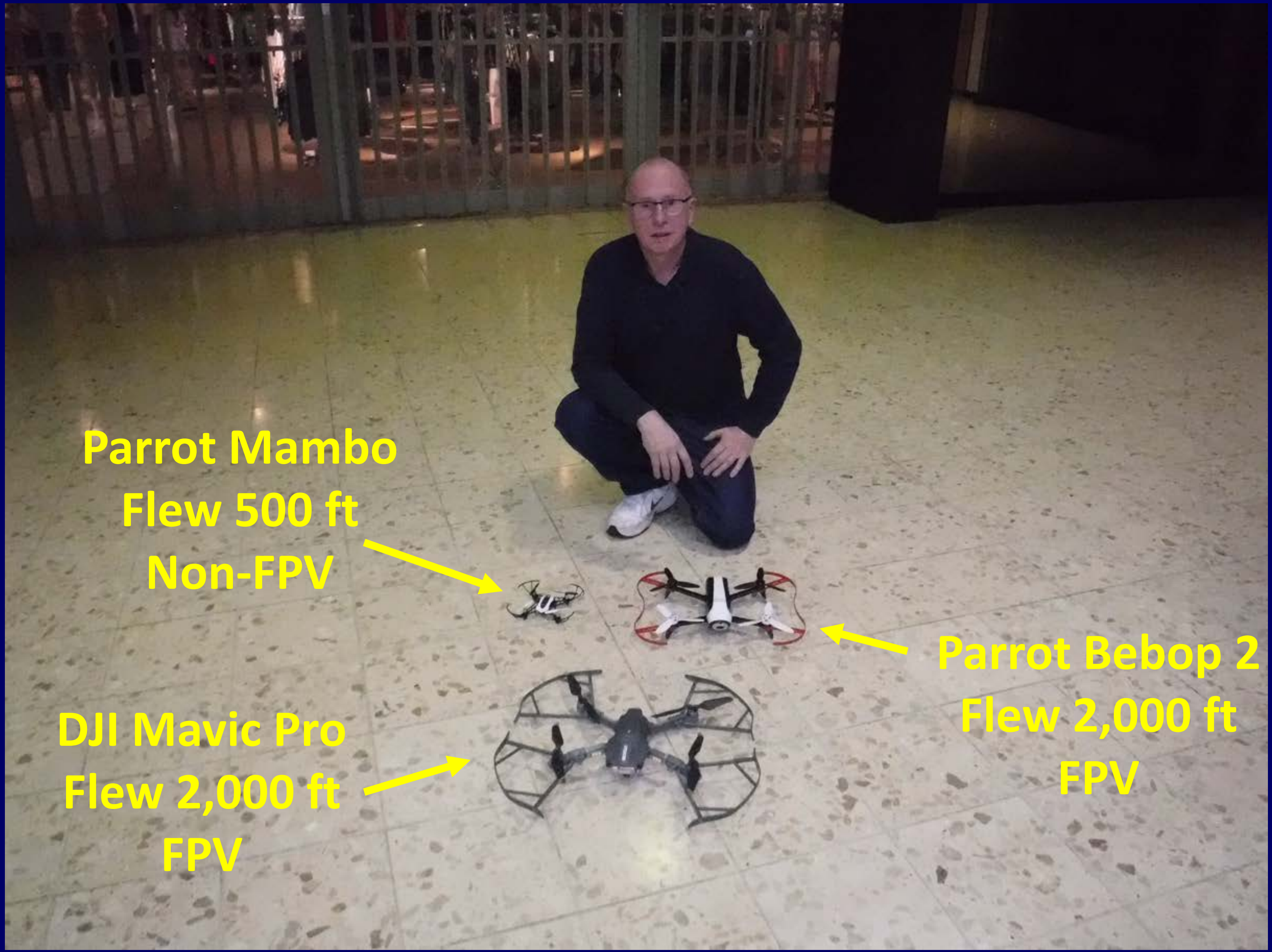
Parrot Mambo

DJI Mavic Pro

Successful long distance test flights at the Century 3 Mall, West Mifflin, PA



Long distance test flights at the Century 3 Mall, West Mifflin, PA: Results



Lessons Learned

AVP Re-design

- Initiate the design process with a first focus on IS requirements
- Smaller airframes function better in confined spaces
- Propellers must be adequately and fully protected

Aircraft Guidance and Navigation

- Robust on-board imaging is critical for successful in-mine flight
- Visible, fixed landmarks or reference points are necessary to perceive drone movement.
- Effective auto hover, height control, and collision avoidance systems did mitigate some demands of remote piloting

Flight Operations

- Both a pilot and a navigator observing the same video feed are essential for successful underground flight operation

NOTICE

This study, AFC519-23, was sponsored by the Alpha Foundation for the Improvement of Mine Safety and Health, Inc. (ALPHA FOUNDATION). The views, opinions and recommendations expressed herein are solely those of the authors and do not imply any endorsement by the ALPHA FOUNDATION, its Directors and staff.

Questions

Speaker Contact Information: Michael A. Trevits
Phone: 412-874-6556 Email: mat412@verizon.net