URBAN AIR MOBILITY (UAM) MARKET STUDY

Presented to: *UAS Safety and Integration Task Force*

Presented by*: Dr. Colleen Reiche, Quantitative Scientific Solutions ("QS-2")*

APRIL 28, 2020

CONTENTS

EXECUTIVE SUMMARY

Recent analysis focused on three potential UAM markets: **Airport Shuttle, Air Taxi, and Air Ambulance** using **ten target urban areas**[1] to explore market size and barriers to a UAM market. Results suggest the following:

- Airport Shuttle and Air Taxi markets are **viable markets** with a significant total available market value of **$500B**[2] at the market entry price points in the best-case unconstrained scenario
- Air Ambulance market served by eVTOLs is **not a viable market** due to technology constraints, but utilization of hybrid VTOL aircraft would make the market potentially viable
- Significant legal/regulatory, certification, public perception, infrastructure, and weather constraints exist which reduce market potential in near term for UAM
- After applying operational constraints/barriers, **0.5% of the total** available market worth **$2.5B** can be captured in the near term
- Constraints can potentially be addressed through ongoing intragovernmental partnerships (i.e., NASA-FAA), government and industry collaboration, strong industry commitment, and existing legal and regulatory enablers

[1] New York, Washington DC, Miami, Houston, Dallas, Denver, Phoenix, Los Angeles, San Francisco, Honolulu
[2] US Domestic Airline industry has an annual market value of ~150B (Ibis, 2018)

EXECUTIVE SUMMARY - CONSTRAINTS

UAM MARKETS FACE SIGNIFICANT CHALLENGES AND CONSTRAINTS

	Near Term- Immature Market	*Longer Term- Mature Market*
Technology Challenges	**Economics:** High cost of service (partially driven by capital and battery costs) **Weather:** Adverse Weather can significantly affect aircraft operations and performance **Air Traffic Management:** High density operations will stress the current ATM system **Battery Technology:** Battery weight and recharging times detrimental to the use of eVTOLs for Air Ambulance market **Impacts:** Adverse energy and environmental impacts (particularly, noise) could affect community acceptance	**Impacts:** Energy and Environmental Impacts of large-scale operations **Cybersecurity** of Autonomous systems including vehicles and UTM **Weather**: Disruptions to operations during significant adverse conditions **New Entrants:** Large scale operations of new entrants like UAS, Commercial Space operations, private ownership of UAM vehicles could increase the complexity of airspace management and safety
Non-Technological Challenges	**Infrastructure:** Lack of existing infrastructure and low throughput **Competition:** Existing modes of transportation **Weather:** Conditions could influence non-technological aspects of operation **Public Perception:** Passengers concerned about safety and prefer security screening and preference UAM only for longer trips **Laws and regulations** for flying over people, BVLOS, and carrying passengers (among others) are needed **Certifications:** Gaps in the existing certification framework where UAM will experience challenges, particularly system redundancy and failure management	**Competition: E**merging technologies and concepts like shared Electric and Autonomous Cars, and fast trains **Weather:** Increase in some adverse conditions due to climate change may limit operations **Social Mobility:** New importance of travel time, increase in telecommuting, urbanization and de-congestion scenarios could reduce the viability of markets **Public Perception:** Passengers trust and apprehension with automation and pilot-less UAM and prefer to fly with others they know in an autonomous UAM

CONTENTS

LEGAL AND REGULATORY BARRIERS

Air Taxi, Ambulance, and Airport Shuttle UAM Markets share common Regulatory Barriers

*Remotely piloted and autonomous UAM markets **require the following aviation regulations (either modification of existing regulations, or new regulations)**, as the current regulatory structure does not fully allow for these activities to be performed:*

- Regulations for **beyond visual line of sight** (currently only with lengthy waiver process)
- Regulations for **operations over people, streets, etc**. (currently only with lengthy waiver process)
- Regulations for when **air cargo** is being carried commercially and across state lines
- Regulations for when a **passenger or patient** is being transported in a UAM either within visual line of sight or beyond
- Regulations for flight in **instrument conditions**
- Regulations for **airworthiness certification** of remotely piloted and autonomous aircraft
- **Training and knowledge** requirements for pilots and operators

Gaps in current certifications mean that new standards will need to be developed, especially in areas related to **system redundancy** and **failure management**.

A **legal framework for addressing privacy concerns** should be developed outside of the aviation regulatory framework.

State and **local** laws cover wide range of restrictions from no drones to protecting UAS in focus urban areas

Strategies moving forward: Enabling strategies can be employed to **accelerate the development** of a UAM legal framework:

- NASA – FAA cooperation, such as the Research Transition Teams
- FAA Aviation Rulemaking Committee
- FAA UAS Integration Pilot Program
- Leveraging strategies from automobile automation, such as voluntary standards may help UAM deployment

SOCIETAL BARRIERS

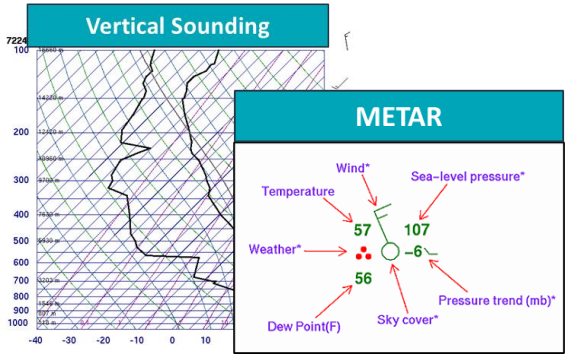
Key Concerns

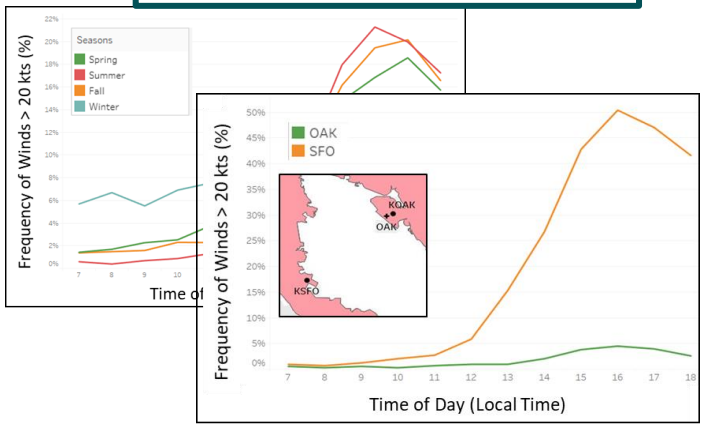
- Generally, ***neutral to positive reactions*** to the UAM concept
- ***Preference for longer inter-city flights*** (e.g., DC to Baltimore; LA to San Diego)
- Existing ***noise concerns*** focus on traffic noise during the night and early morning
- ***Cost*** is a primary consideration for public users when choosing a transportation mode
- Respondents ***most comfortable flying with passengers they know***; least comfortable flying with passengers they do not know
- ***Some willingness and apprehension about flying alone*** (particularly in an automated/remote piloted context)
- ***Preference for piloted operations***; may need to offer mixed fleets and/or a discount for remote piloted/automated operations to gain mainstream societal acceptance
- ***Safety***
  - Aircraft sabotage (by passengers or people on the ground)
  - Unruly and/or violent passengers
  - "Lasing"

GEOGRAPHIC LOCATION	Excited	Happy	Neutral	Confused	Concerned	Surprised	Skeptical	Amused
	Survey Results							
Houston, N = 344	32%	24%	27%	8%	9%	11%	19%	3%
San Francisco Bay Area, N = 337	33%	25%	27%	8%	9%	11%	20%	3%
Los Angeles, N = 345	32%	24%	27%	8%	9%	11%	19%	3%
Washington, D.C., N = 341	32%	24%	27%	8%	9%	11%	20%	3%
New York City, N = 344	32%	24%	27%	8%	9%	11%	19%	3%

WEATHER CHALLENGES

Historical Aviation Weather Observations → **Individual Adverse Condition Frequencies** → **Surface Observation Impact "Scores"**





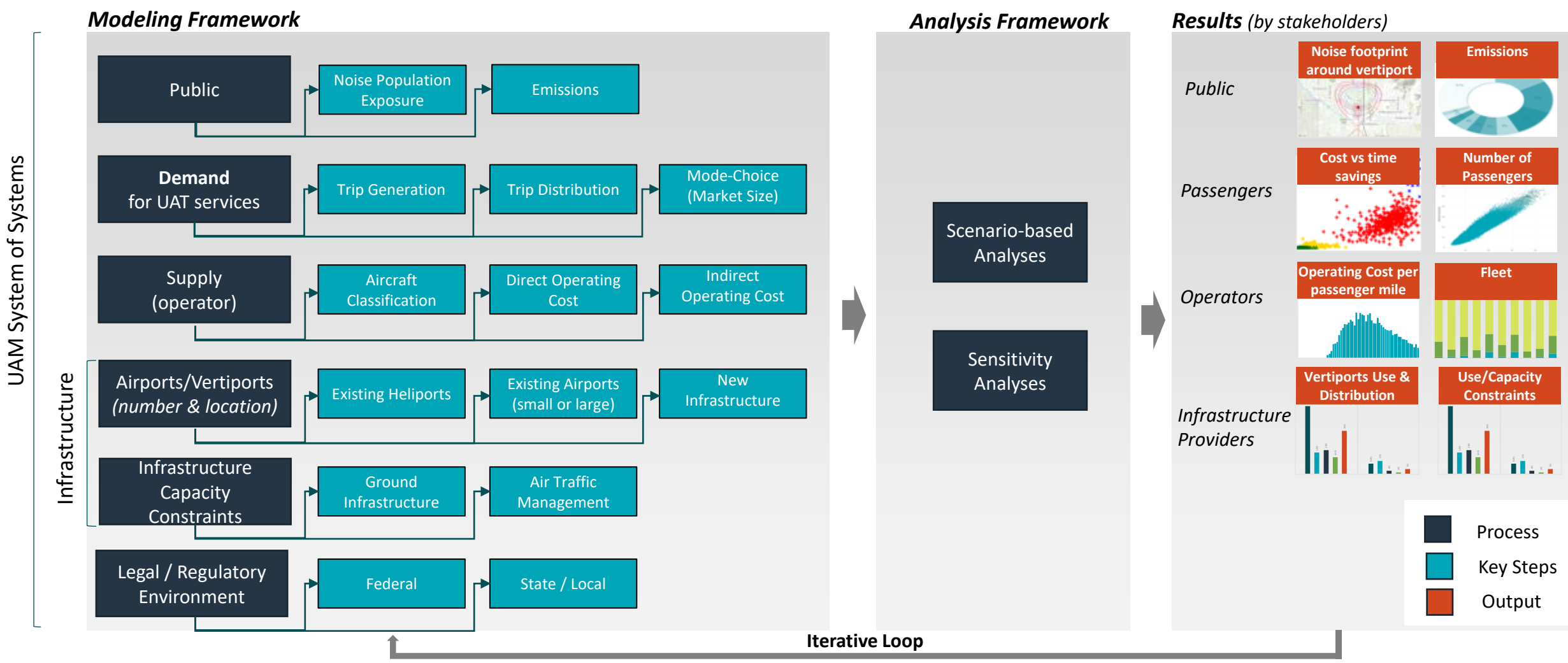
- Approximately half the UAM operational day potentially impacted by weather in several urban areas <u>on average across all seasons</u>
- High number of impacted hours in <u>winter and spring</u> in the Northeast, Texas, and Denver urban areas
- Conditions reported by aviation weather observations may not be fully representative of entire urban area

	Average Number of Impacted Hours (7am – 6pm Local)				
Urban Areas	**Winter**	**Spring**	**Summer**	**Fall**	**Average**
New York	12	12	0	8	8
Washington DC	12	12	0	0	6
Miami	0	0	0	0	0
Dallas	11	12	3	0	6.5
Houston	9	11	0	0	5
Denver	12	12	4	3	7.75
Phoenix	0	0	5	0	1.25
Los Angeles	2	1	2	1	1.5
San Francisco	3	6	6	4	4.75
Honolulu	0	7	9	6	5.5
Average	6.1	7.3	2.9	2.2	

CONTENTS

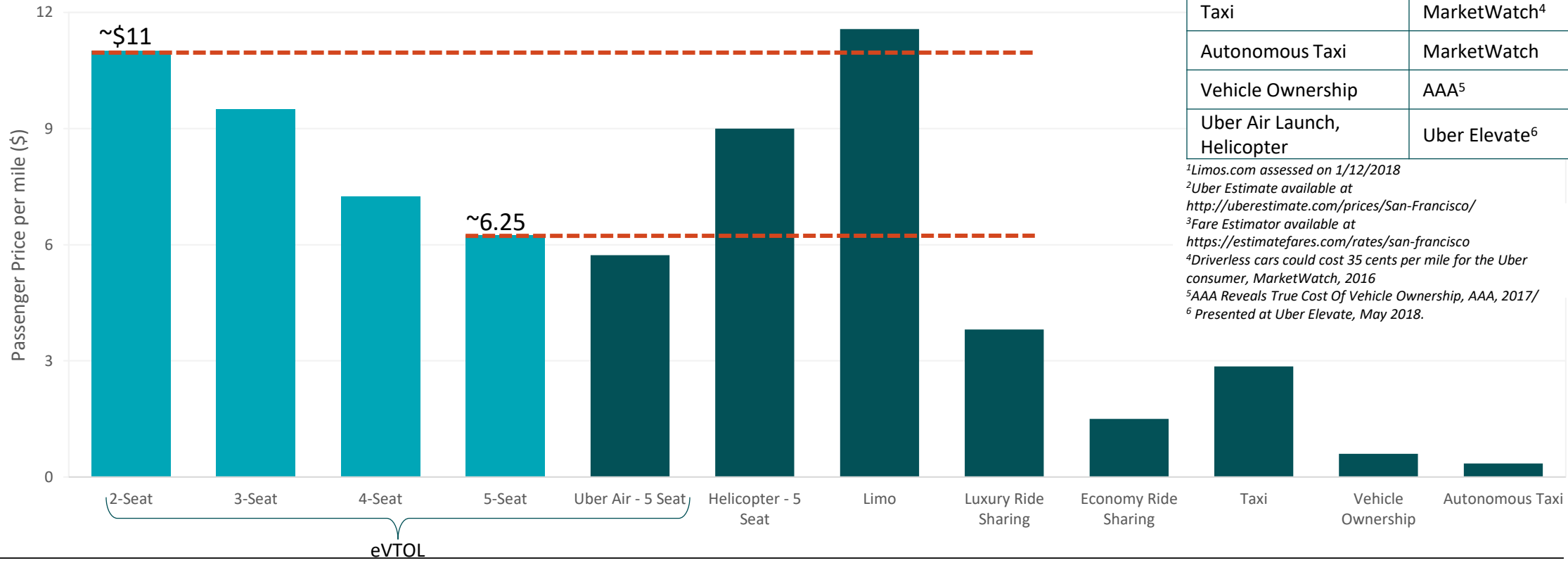
AIR TAXI - SYSTEM LEVEL FRAMEWORK

Analysis of urban Airport Shuttle and Air Taxi markets requires a system-level approach that comprise of various system level layers like supply, demand, infrastructure, legal/regulatory environment, public acceptance, safety and security. Each layer is investigated in a scenario and sensitivity-based analysis framework.



AIR TAXI - PRICE COMPARISON WITH OTHER MODES OF TRANSPORTATION

- 5-Seat eVTOL passenger price per mile is expected to be **more expensive than luxury ride sharing on the ground**
- 2-seat eVTOL aircraft is **comparable** to current limo type services. Operators like **Blade and Skyride charges ~$30** per passenger mile while **Voom charges ~$10** per passenger mile

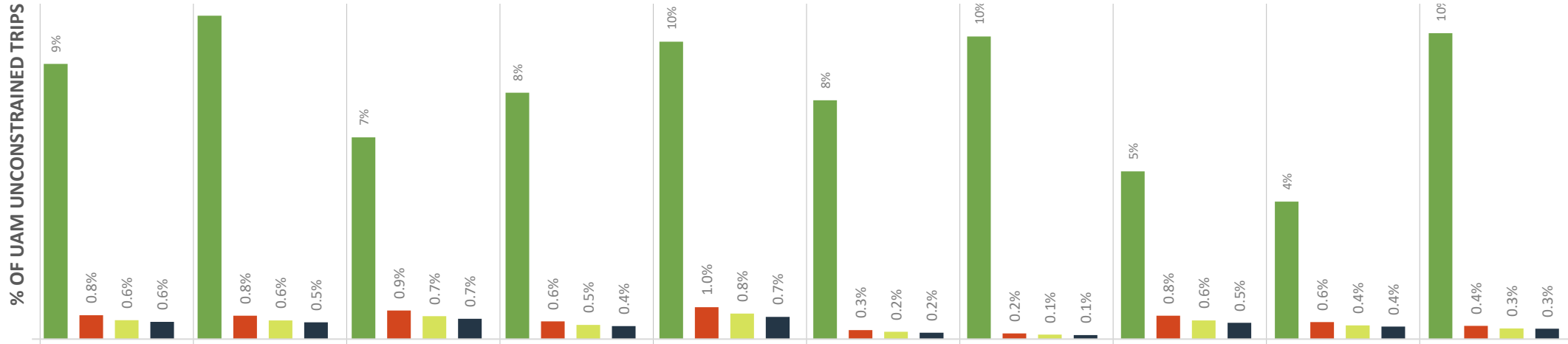


Mode of Transportation	Source
Limo	Limos[1]
Luxury Ride Sharing	Uber[2], Fare Estimator[3]
Economy Ride Sharing	Uber, Fare Estimator
Taxi	MarketWatch[4]
Autonomous Taxi	MarketWatch
Vehicle Ownership	AAA[5]
Uber Air Launch, Helicopter	Uber Elevate[6]

[1]Limos.com assessed on 1/12/2018
[2]Uber Estimate available at http://uberestimate.com/prices/San-Francisco/
[3]Fare Estimator available at https://estimatefares.com/rates/san-francisco
[4]Driverless cars could cost 35 cents per mile for the Uber consumer, MarketWatch, 2016
[5]AAA Reveals True Cost Of Vehicle Ownership, AAA, 2017/
[6] Presented at Uber Elevate, May 2018.

AIR TAXI - BASE YEAR DEMAND COMPARISON FOR ALL URBAN AREAS

- On average **~0.5% of unconstrained trips are captured** after applying constraints[1]. **New York**, **Los Angeles, Houston and Dallas** are potential urban areas of high daily demand

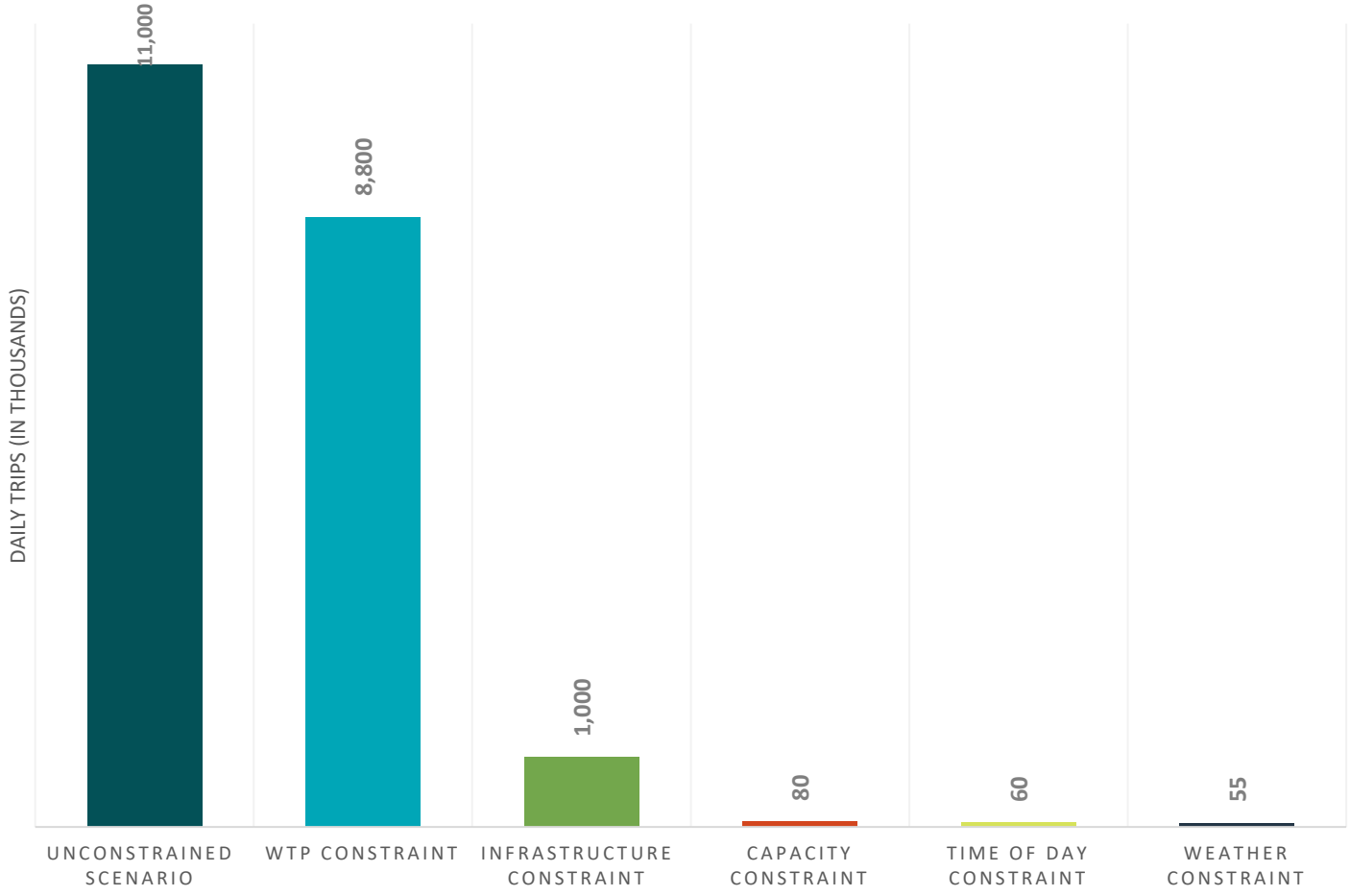


	NEW YORK	LOS ANGELES	DALLAS	MIAMI	HOUSTON	SAN FRANCISCO	WASHINGTON DC	PHOENIX	DENVER	HONOLULU
Un-constrained	1, 421, 000	1, 380, 000	717, 000	587, 000	673, 000	606, 000	600, 000	422, 000	358, 000	161, 000
Infrastructure Constrained	127, 000	145, 000	47, 000	47, 000	65, 000	47, 000	59, 000	23, 000	16, 000	16, 000
Capacity Constraint	11, 000	10, 500	6, 700	3, 400	7, 000	1, 800	1, 100	3, 200	2, 000	700
Time of Day Constraint	8, 800	8, 400	5, 360	2, 720	5, 600	1, 440	880	2, 560	1, 600	560
Weather Constraint	8, 000	7, 500	4, 750	2, 470	4, 890	1, 250	780	2, 230	1, 460	550

[1] WTP constraint not shown here but is applied

AIR TAXI - OVERALL MARKET SIZE AND VALUE

*Air Taxi market has a potential demand of **~55k daily trips** (or ~ **80k daily passengers**) across the US that can be served by **~4k aircraft.** Based on near term market entry assumptions, annual market value is projected to be **~$2.5 bn** for the first few years of operation. Longer term, high demand may be achieved by high network efficiency but autonomous cars are expected to provide strong competition.*



	Daily Trips	Daily Passengers	Total Number of Aircraft	Annual Market Value (in bn $)
Un-constrained	11,000,000	16, 000, 000	850, 000	500
WTP Constraint	8, 800, 000	13, 000, 000	680, 000	400
Infrastructure Constrained	1, 000, 000	1, 500, 000	80, 000	45
Capacity Constraint	80, 000	120, 000	6, 000	3.6
Time of Day Constraint	60, 000	90, 000	4, 500	2.75
Weather Constraint	55, 000	82, 000	4, 100	2.5

CONTACT INFORMATION

Dr. Colleen Reiche

Lead Scientist | Aviation and Weather

Quantitative Scientific Solutions (“QS-2”)

Arlington, VA

Colleen.Reiche@qs-2.com

Full UAM Market Study Report Available at: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20190001472.pdf

UAV Deployment in COVID-19 Response

Early lessons learned in the US through the disaster relief program

Romeo Durscher

Senior Director of Public Safety Integration

Wayne Baker

Director of Public Safety Integration

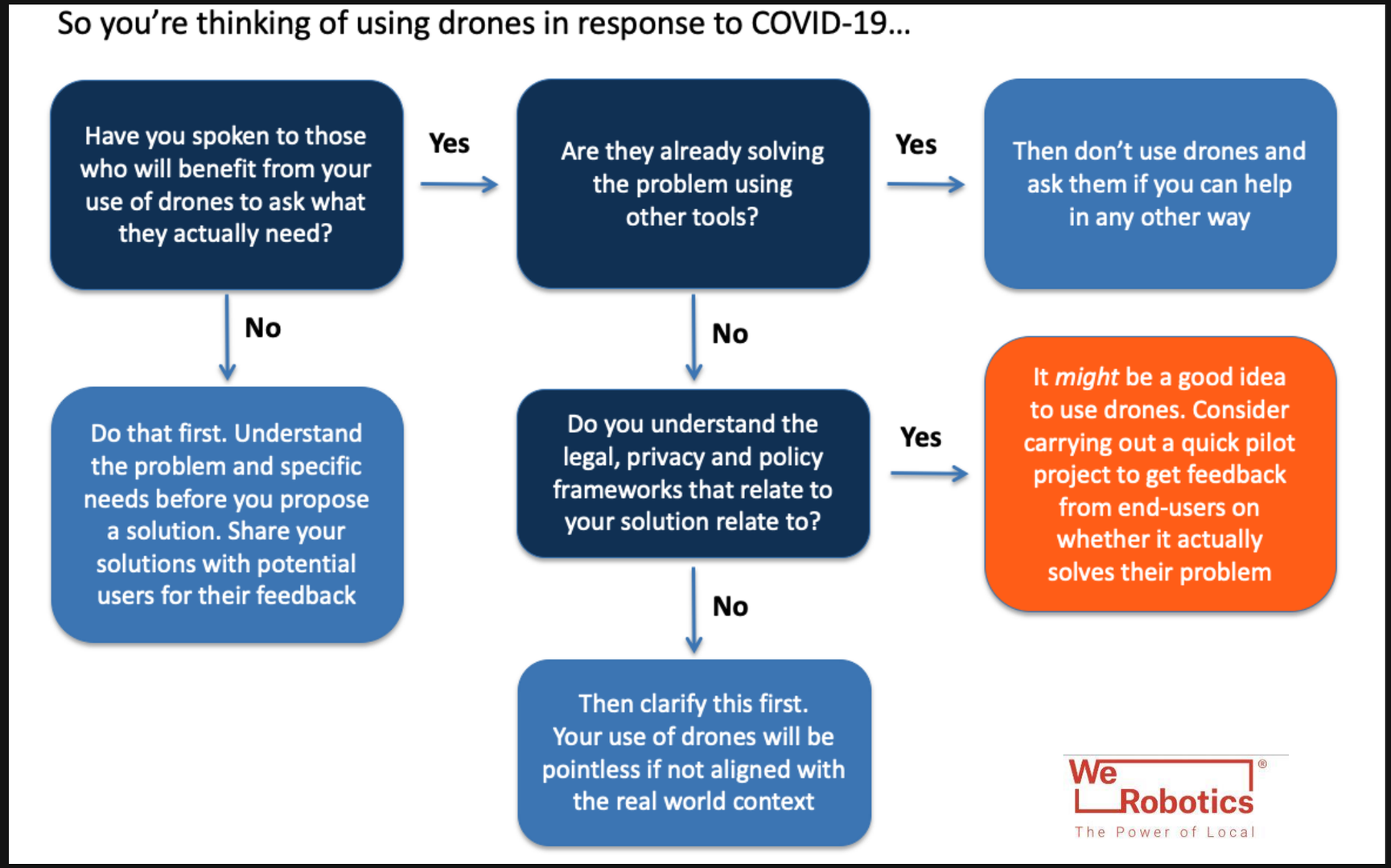
YOU ARE THINKING ABOUT A DISASTER DEPLOYMENT?

WeRobotics put together a flow chart, adapted from Sharon O'Dea's Diagram.

Key is to properly identify a solution and its outcome/benefits.

Humanitarian Drone Code of Conduct

Best Practices in Humanitarian Drone Missions



DJI DISASTER RELIEF PROGRAM
CURRENT SITUATION

Originally designed to support and help regional disasters; wildfire, hurricane, earthquake, flooding & tornado

Draw from first-hand experiences

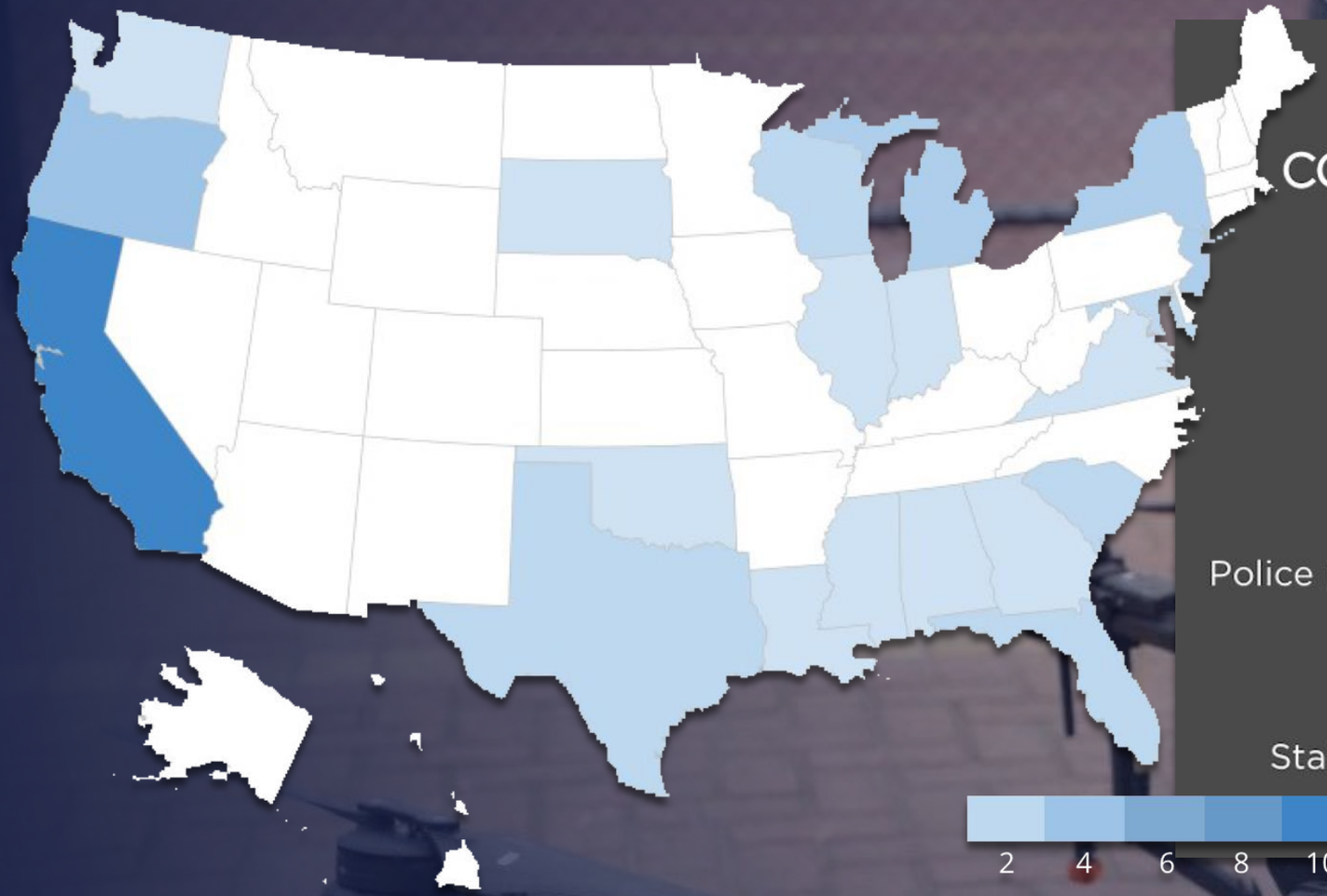
Announced at DJI AirWorks, September 2019

DJI DISASTER RELIEF PROGRAM
CURRENT SITUATION

1st Activation: March 2-4, 2020; Nashville Tornado

2nd Activation: March 25, 2020; US COVID-19

Hardware Support Deployed by April 2, 2020

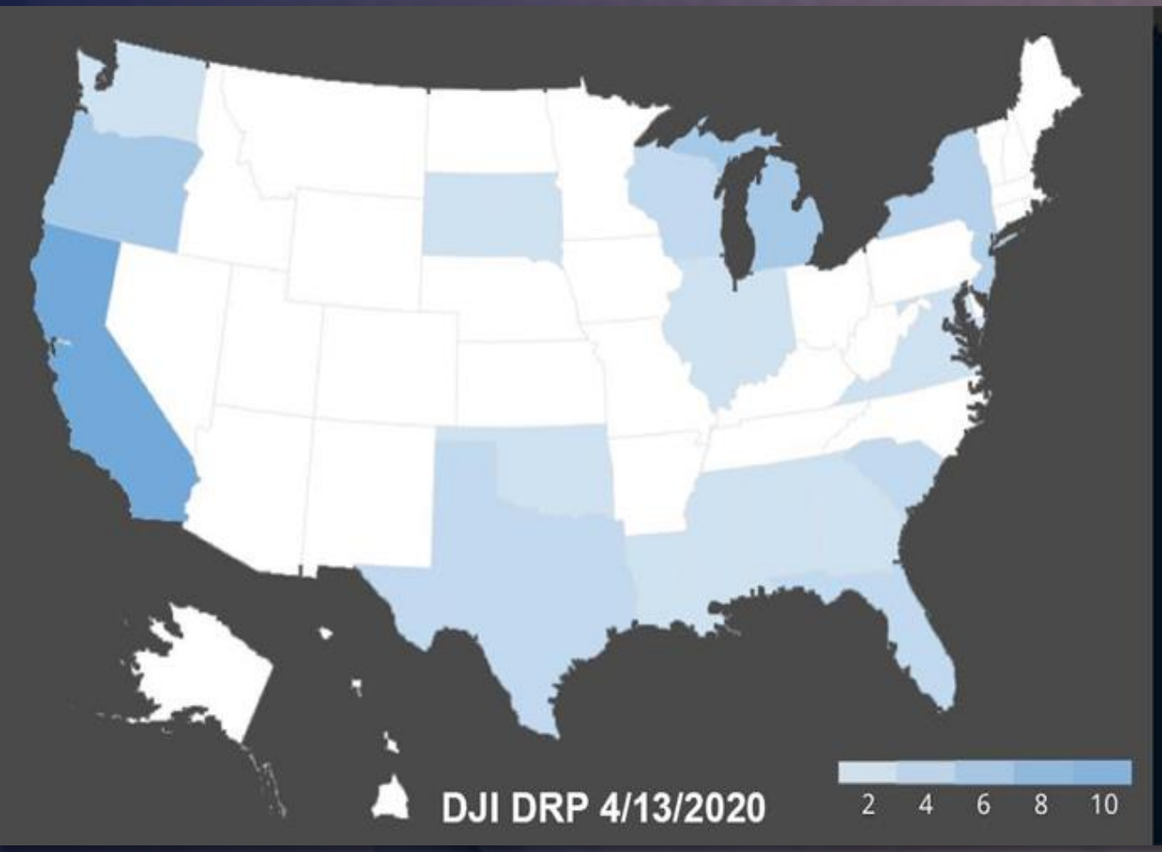


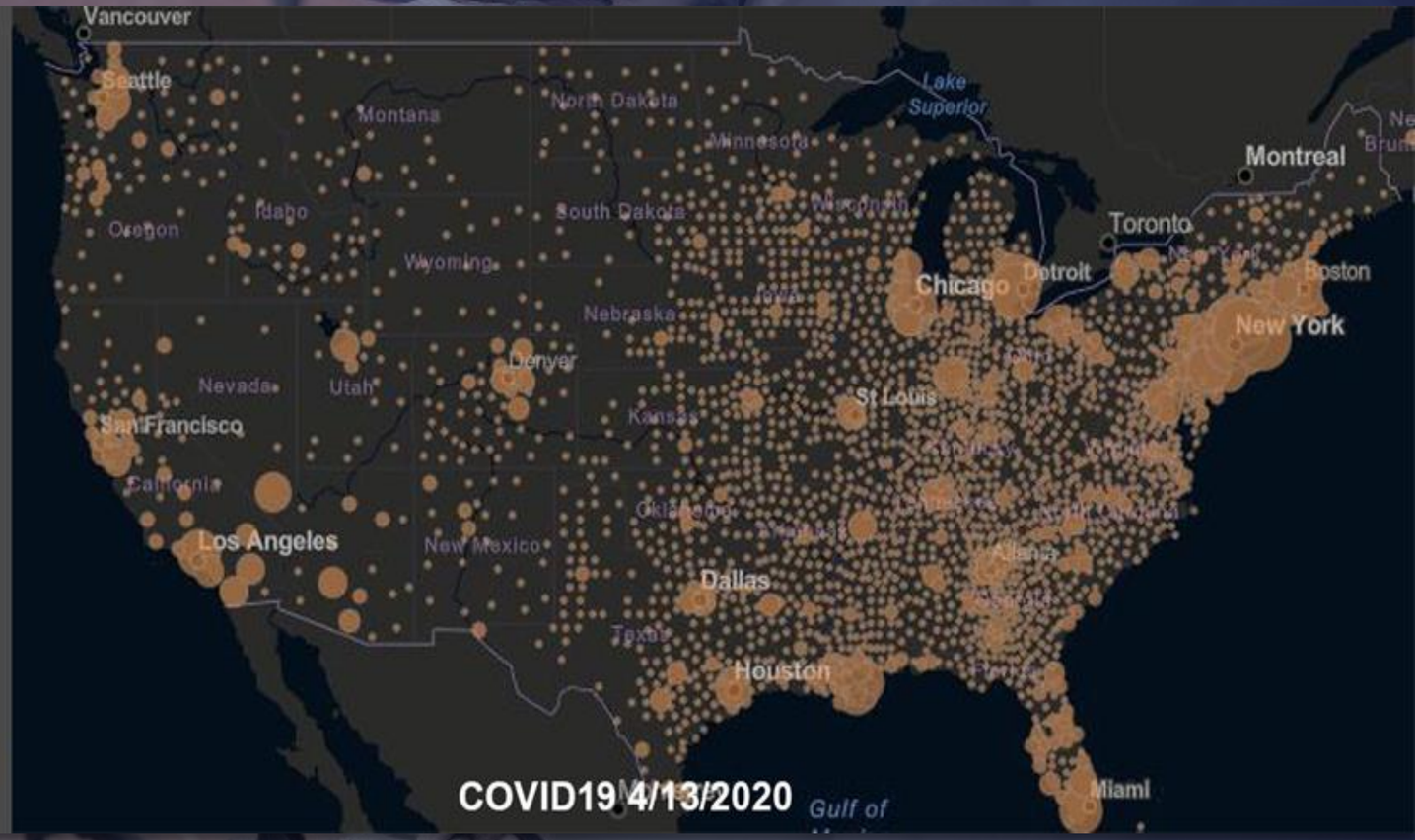
COVID-19 US DISASTER RELIEF PROGRAM BENEFICIARIES

As of April 20, 2020

By Department Type

22 Police Departments	**9** Fire Departments	**8** County Sheriff's Offices
3 State Patrols	**2** County Public Safety Agencies	**1** Hospital





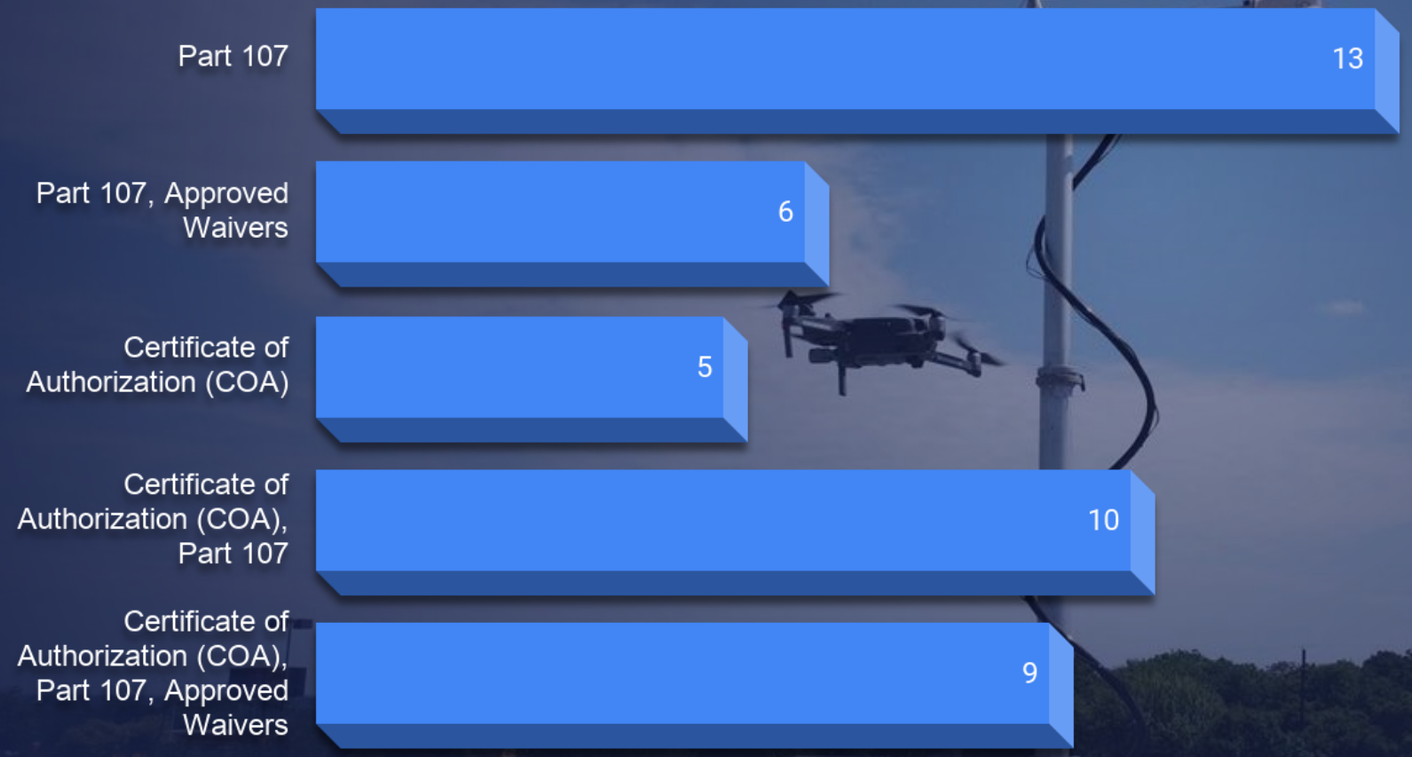
COVID19 4/13/2020

281

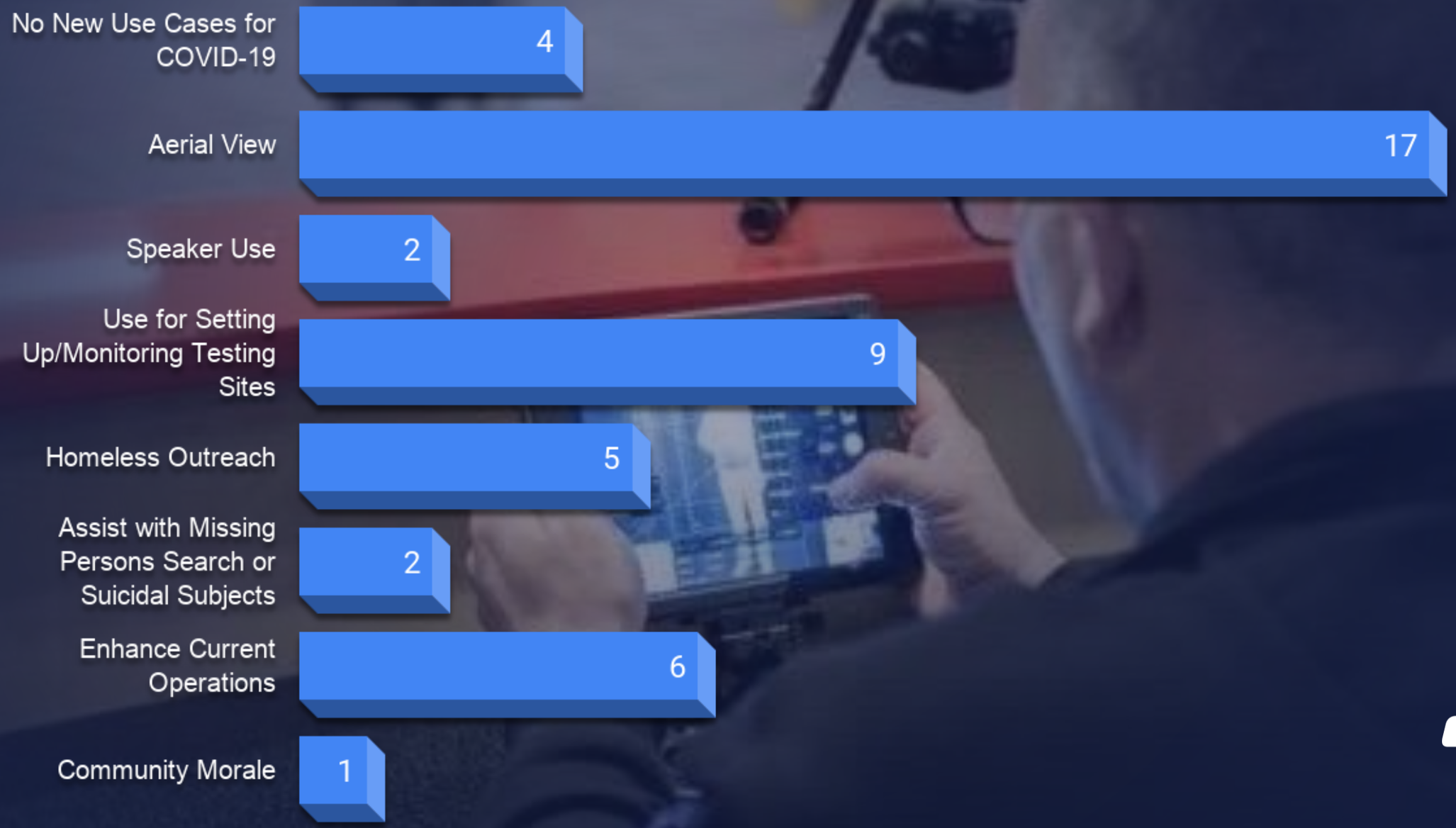
COVID-19 Related Flights

DRP COVID-19 STATS

Does your agency operate under:



What benefits have UAVs provided your department in its COVID-19 response?



PUBLIC SAFETY UAV DEPLOYMENTS OVERVIEW

FIRE RESCUE

PRE-PLANNING FUTURE TESTING AND FIELD HOSPITAL SITES.

STATIONARY MATRICE 210 with DJI/FLIR XT2 THERMAL CAMERA AS SECONDARY CHECK

TRAFFIC FLOW MONITORING AT TEST SITES

PUBLIC SAFETY UAV DEPLOYMENTS OVERVIEW

LAW ENFORCEMENT

INFORM THE POPULATION ON HOW EACH INDIVIDUAL CAN PROTECT THEMSELVES.

ADVISE THE POPULATION ON SOCIAL DISTANCING, CLOSED PARKS, BEACHES ETC.

HOMELESS POPULATION OUTREACH.

CHULA VISTA POLICE, CA
HOMELESS OUTREACH EFFORTS

Pockets of homeless community in hard to reach terrain

Staged service locations at canyon exists

UAV with speaker to share public health messages in English & Spanish

Informed of staging area for services; food, personal hygiene kit, faces masks, medical screening.

CHULA VISTA POLICE, CA
HOMELESS OUTREACH EFFORTS

Square miles covered by drone = 8

Encampments reached = 26

People offered services via speaker = 16

Persons personally served = 3

Time to provide outreach and service = 3 hours

Time to provide same service without drone support = 2 days

SCAN ME

FREMONT FIRE, CA
TESTING SIDE PLANNING

Setting up two COVID-19 testing sites

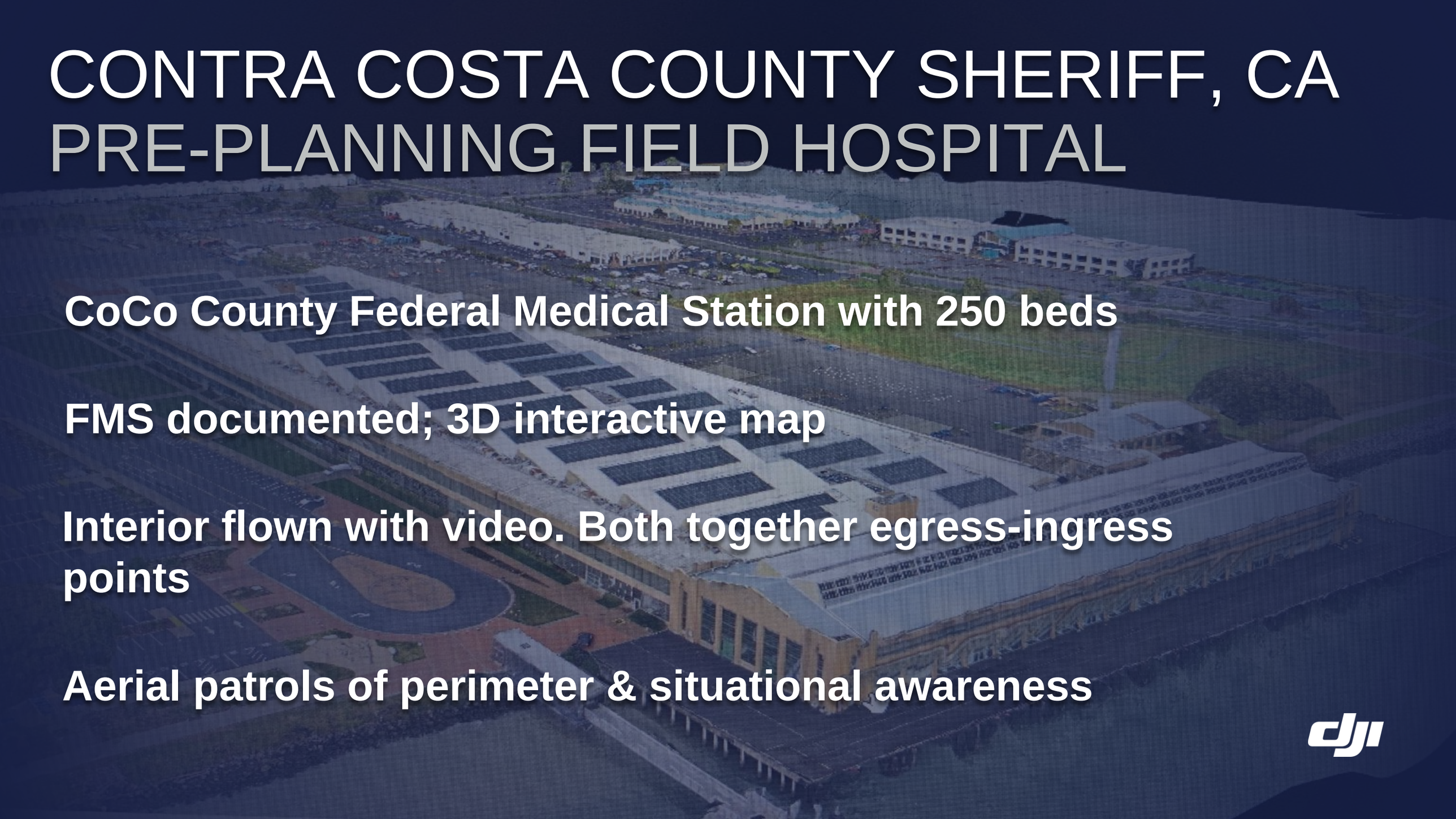
Concern was long vehicle & walk-up lines

UAV monitored line of traffic, get vehicle count, document activity for future needs

UAV speaker used to give estimated wait time & other information.

FREMONT FIRE, CA
TESTING SIDE PLANNING

CONTRA COSTA COUNTY SHERIFF, CA
PRE-PLANNING FIELD HOSPITAL



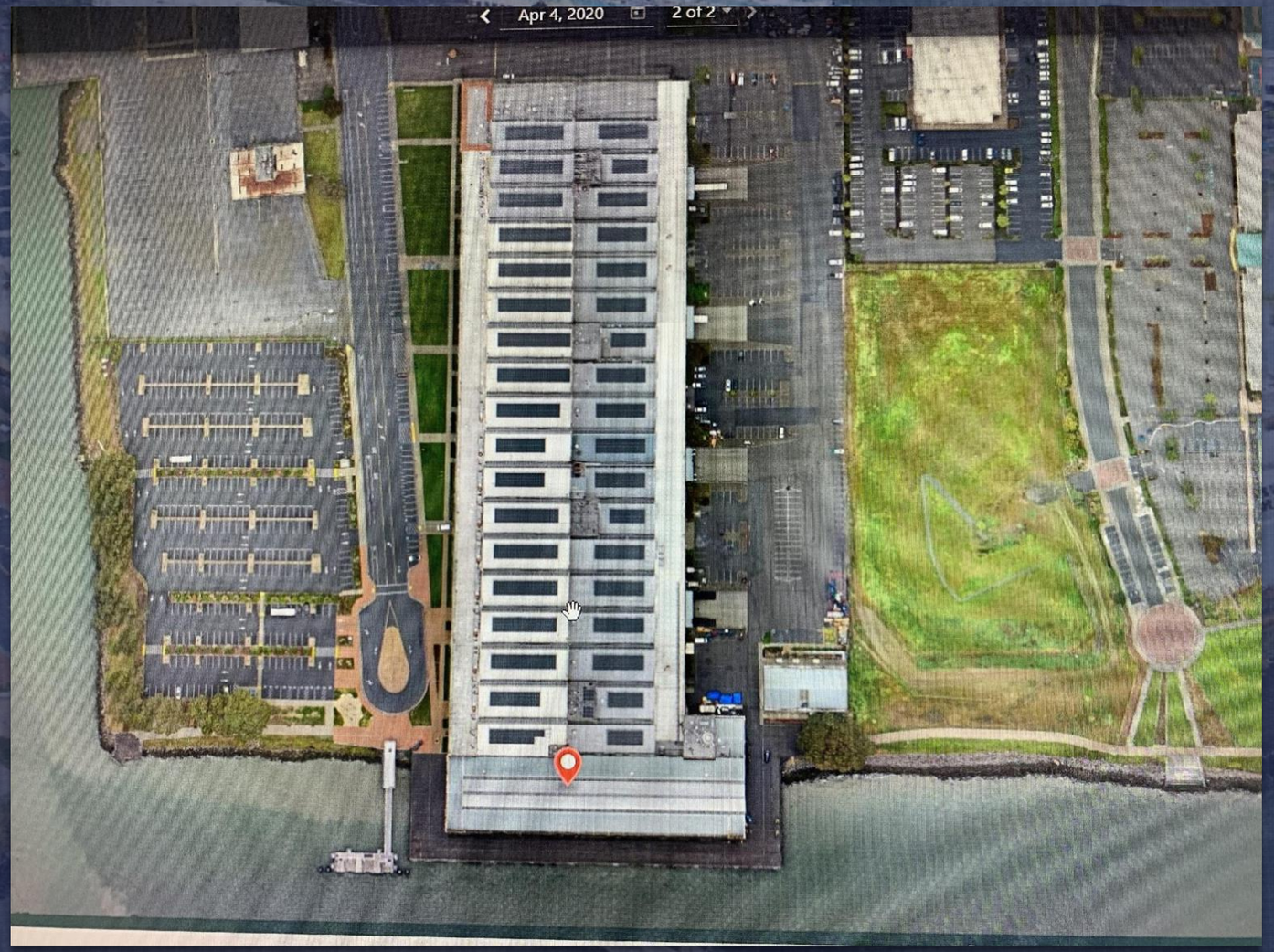
CoCo County Federal Medical Station with 250 beds

FMS documented; 3D interactive map

Interior flown with video. Both together egress-ingress points

Aerial patrols of perimeter & situational awareness

CONTRA COSTA COUNTY SHERIFF, CA
PRE-PLANNING FIELD HOSPITAL



EARLY LESSONS LEARNED

1) IDENTIFY OBJECTIVE & BENEFITS
2) THINK ABOUT PUBLIC & MEDIA PERCEPTION
3) STANDARDIZATION
4) SHARING BEST PRACTICES
5) PROPER DATA ANALYSIS TOOLS & PERSONNEL
6) DATA STORAGE AND SECURITY MEASURES

RESOURCES

Humanitarian Code of Conduct &
Best Practices in Humanitarian
Missions

QEP GEO Unlock

FAA COVID19 SGI

DJI COVID-19 Response Use-Cases

DJI COVID19 Deployment Survey

HUMANITARIAN CODE OF CONDUCT

”Thinking of Drone Use to COVID-19 Response” diagram, including:

- - Humanitarian Drone Code of Conduct
- - Best Practices in Humanitarian Drone Missions
- - Data Protection and Privacy

Qualified Entities Program

Qualified Entities Program (QEP) is a program that unlocks DJI’s GEO system for authorized Federal, State and Local public safety agencies. QEP requires the following information to be provided:

- - COA/107 or similar flight authorization
- - Signed Terms & Conditions
- - Authorization letter on official entity letterhead
- - F/C Serial Numbers & DJI Accounts

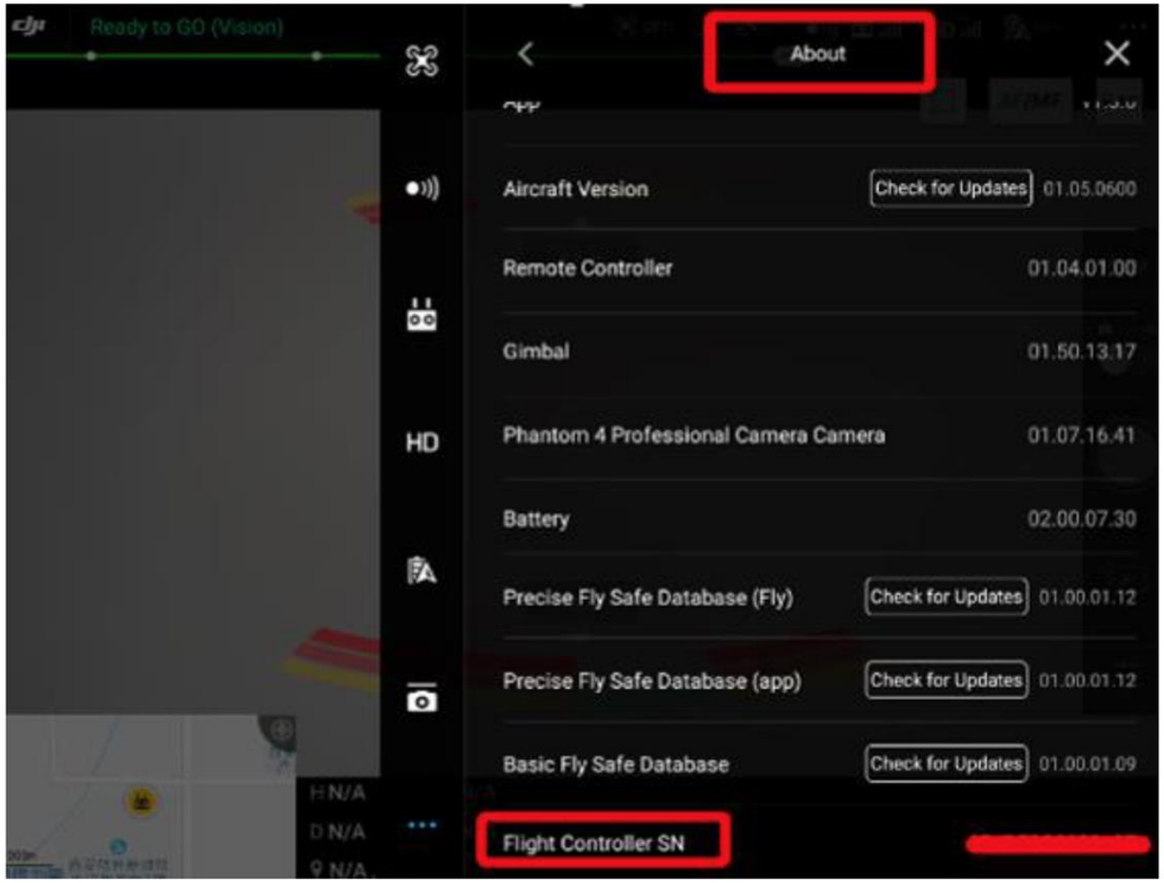
QEP - F/C SN

The F/C Serial Number can be found in the DJI Pilot and the DJI Go/Go4 app.

- Turn on drone, radio controller and connect smart device.
- Select top right ...
- Select bottom center ...

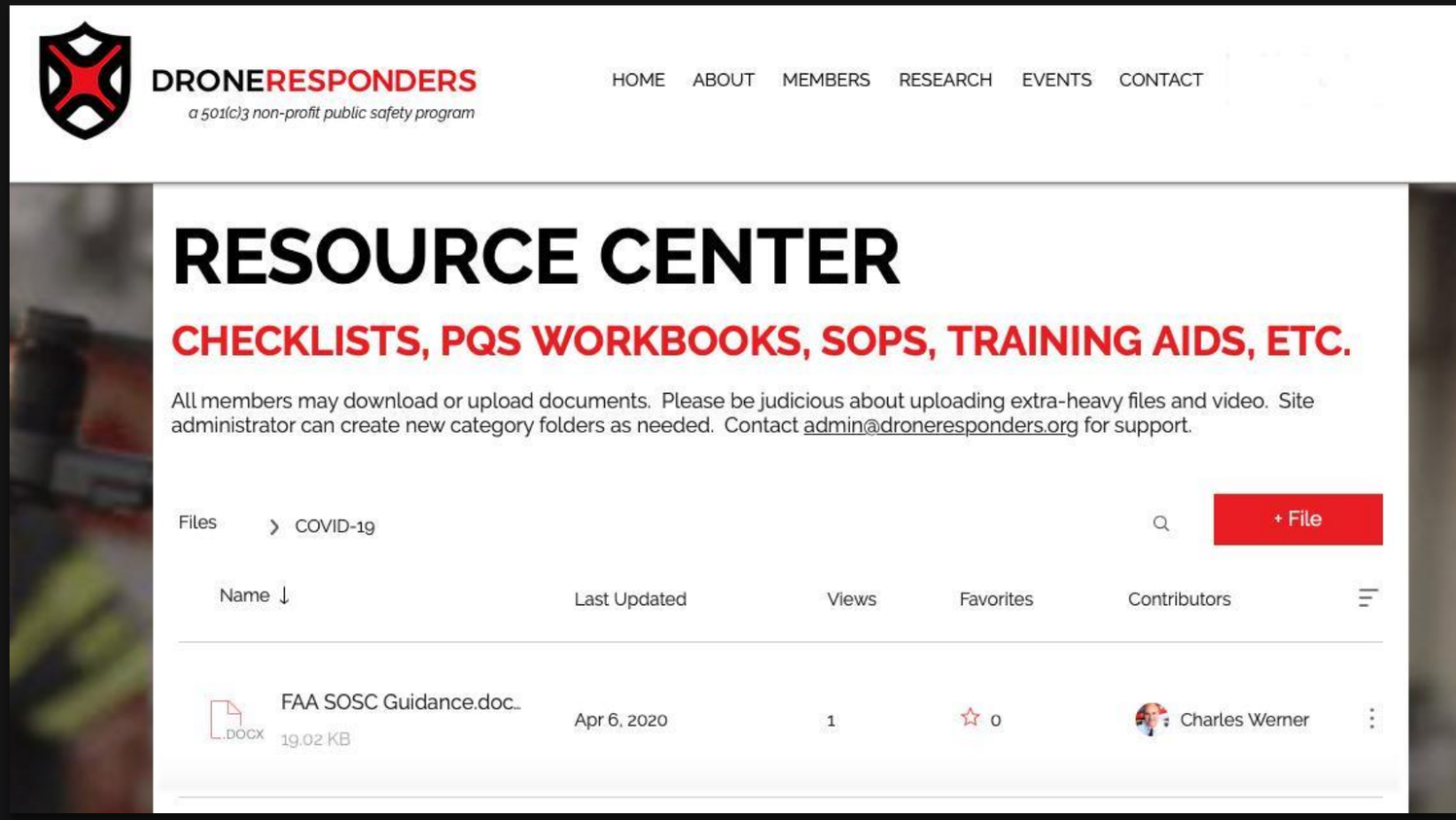
DJI Pilot app

Please connect the drone with the app, go to DJI PILOT APP-General Settings > About >Flight Controller SN to check the number.



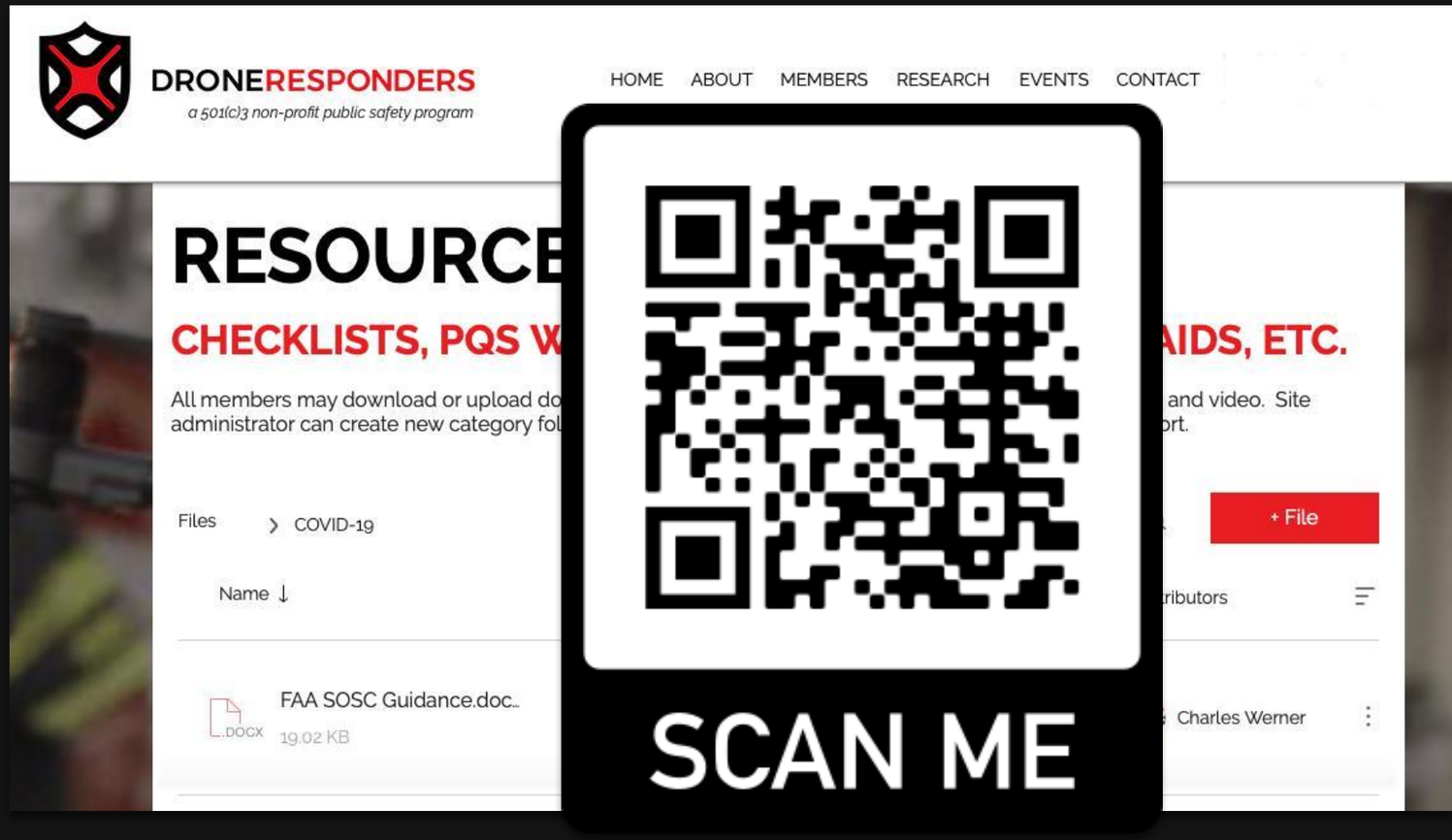
FAA COVID19 SGI

- Expedite allowable operations in NAS for COVID-19 responses
- Firefighting, SAR, Law Enforcement, Utility and Other Critical Infrastructure, Incident Awareness and Analysis, Damage Assessments Supporting Disaster Recovery, Media crucial information.
- Resource on DRONERESPODERS



FAA COVID19 CLOSE PROXIMITY LOW ALTITUDE (CPLA) BVLOS Waiver

- Define a compelling need in response COVID19
- Define the threshold - local, state or national declaration of emergency
- Identify the specific mission(s)
- Define the specific area(s) and complete flight path(s)
- Identify all aircraft to be flown in the waiver request
- Declare that all included aircraft are reliable and airworthy



DJI COVID-19 RESPONSE USE-CASES

SCAN ME

DJI COVID-19 OPERATIONS SURVEY

SCAN ME

COVID-19 OPERATIONS SURVEY

* Required

Agency Information

Agency Name: *

Your answer

Your Title and Name: *

Your answer

What country does your agency operate in (type in below): *

Your answer

QUESTIONS


MAVIC 2 ENTERPRISE
USA
Not connected
No Camera
PHANTOM 4 PRO
Enter Device

THANK YOU!