National Aeronautics and Space Administration

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NASA'S LANGLEY RESEARCH CENTER

System-Wide Safety Project

First Responder UAS Use in Post Disaster Environments

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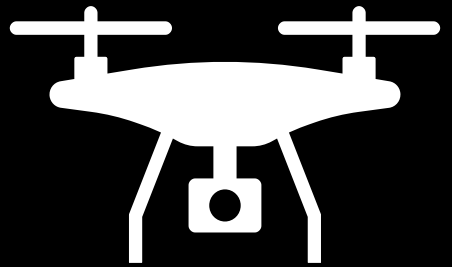
Drones and disaster management

- According to a scoping review by Mohd Daud *et al*. in 2022 [1]:
  - Uncrewed aircraft systems (UAS) are increasingly being used in disaster management
  - The number of studies on this topic is increasing
  - Main purposes of drones in disaster management:
    - Mapping
    - Search and Rescue
    - Transportation
    - Training
  - Regulations and policies vary widely by region
  - Experimental studies are difficult during real-world disasters
- We have a lack of knowledge about UAS use in real-world scenarios



[1] S. M. S. Mohd Daud *et al.*, "Applications of drone in disaster management: A scoping review," *Science & Justice*, vol. 62, no. 1, pp. 30–42, Jan. 2022, doi: 10.1016/j.scijus.2021.11.002.

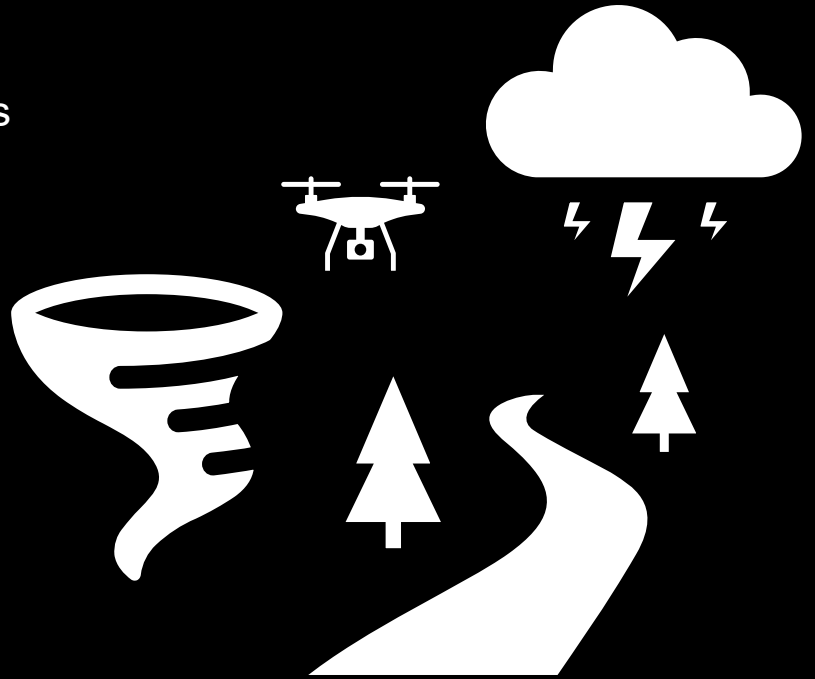
System-Wide Safety Project at NASA

- Goal of developing tools, technologies, and methods to make safe flight more efficient and accessible. [1]
- Drones are increasingly part of the national airspace
  - We wish to assist with drone operations in a post disaster environment
  - We need info on how drones are currently use in such environments

[1] www.nasa.gov/directorates/armd/aosp/sws/

Our goal: Interview emergency agencies

- We want to know how drones are currently used by:
  - Emergency management
  - Fire departments
  - Law enforcement
- Need to know current missions, current hazards



Agencies Contacted

- Reached out via email
- Agencies on the eastern seaboard
- Only received a few replies
  - Used those contacts to get more
- Ended up interviewing 7 people from 5 organizations.

Agency	Description	Pilots
A	Rural county Emergency Management Agency	2
B	National drone organization	0
C	State Patrol Department	30-50
D	State Patrol Department	320-370
E	City Fire Department	50-80

Table 2 Details of interviewed organizations

Location	Agency
National	AIRT and DRONERESPONDERS
Maine	ME Emergency Management Agency
New Hampshire	NH Homeland Security and Emergency Management
Massachusetts	MA Emergency Management Agency
Rhode Island	RI Emergency Management Agency
Connecticut	CT Division of Emergency Management and Homeland Security
New York (state)	NY Division of Homeland Security and Emergency Services
New York (city)	Fire Department of New York City
New Jersey	NJ State Police (Emergency Management Section)
Pennsylvania	PA Emergency Management Agency
Delaware	DE Emergency Management Agency
Maryland	MD Department of Emergency Management
Washington DC	DC Homeland Security and Emergency Management Agency
Virginia	VA Department of Emergency Management
	VA State Police
North Carolina	NC Department of Public Safety
South Carolina	SC Emergency Management Division
Georgia	GA Emergency Management and Homeland Security Agency
Florida	FL Division of Emergency Management
Alabama	AL Emergency Management Agency
Mississippi	MS Emergency Management Agency
Louisiana	LA Governor's Office of Homeland Security and Emergency Preparedness
Texas	TX Division of Emergency Management
	TX Department of Public Safety
Puerto Rico	Puerto Rico Emergency Management
US Virgin Islands	VI Territorial Emergency Management Agency

Table 1 Contacted agencies

Interview Topics

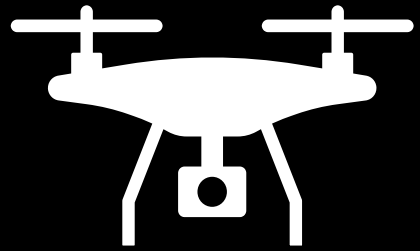
Logistics
- Pilot Training
- Types of UAS being flown
- Maintenance

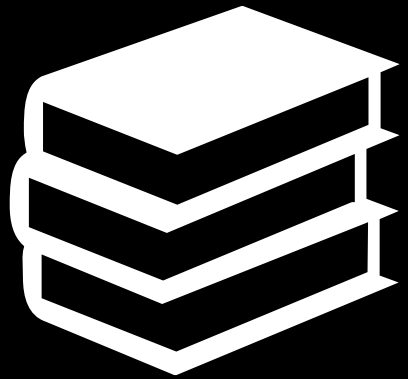
Missions
- Current disaster relief missions
- Other emergency response missions
- Drone deliveries

Laws and Regulations
- Airspace authorizations
- Pilot knowledge of regulations
- Chinese drone bans

Pilot Training

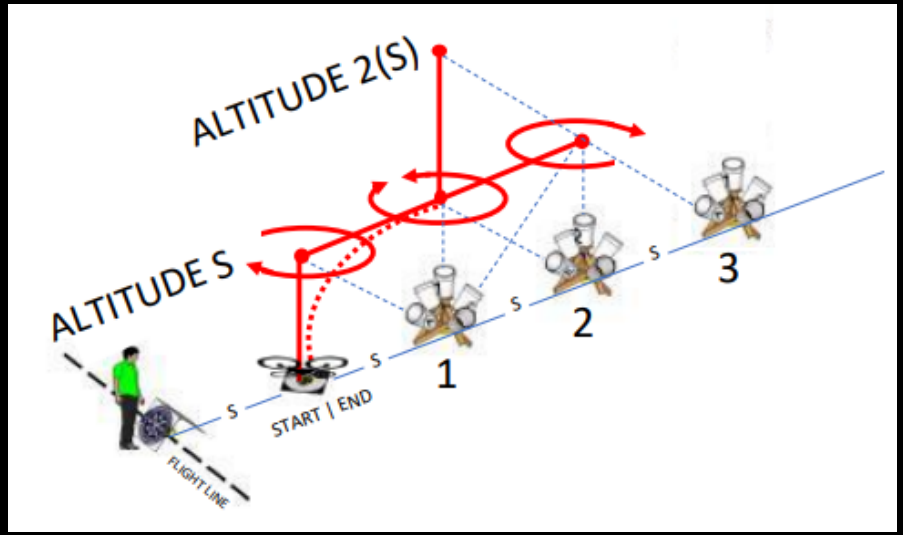
- Each agency had different pilot training standards
- All required Part 107 Certification before training starts
  - Part 107 is a Remote Pilot Certification from the FAA
  - Requires a test over:
    - Regulations, loading, weather, radio communications...
  - Requires a background check
  - Does not require flight time
- Each agency had created their own training program
  - Includes both knowledge tests and flying tests
  - Various companies also provide this sort of training
- Most pilots fly UASs in addition to their existing work
  - Some larger agencies have dedicated pilots for things like border patrol

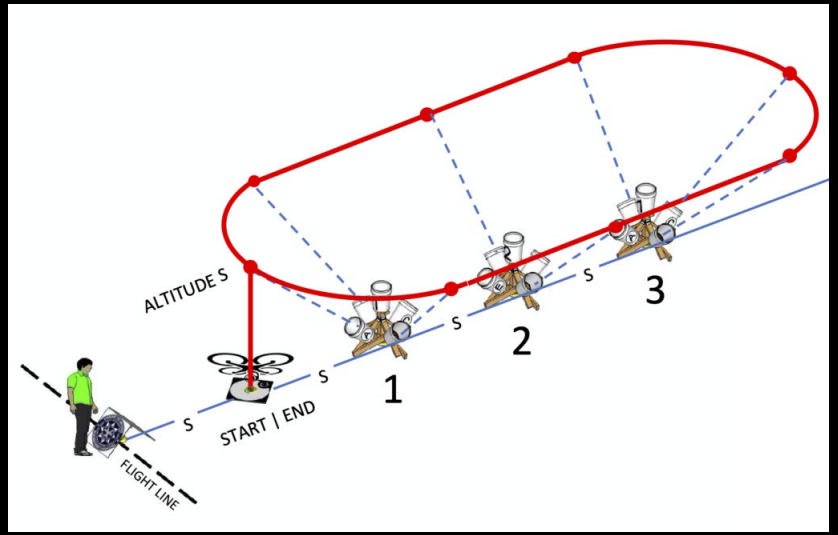




Pilot Training with NIST Aerial Drone Tests

Some agencies implement the NIST flight training standards into their training. Others do not.





Example flight tests from:
NIST, “Standard Test Methods for Small Unmanned Aircraft Systems,” 2019.

Training from the NFPA Standards

- Some agencies referred to NFPA 2400:
  - Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations
- Comprehensive, but difficult to implement as a training guide.

Kind of Broad

5.3.2 Flight.

5.3.2.1 Perform take-off under the regulatory requirements as determined by the AHJ given a specific sUAS and confirmed state of readiness, so that the sUAS takes off after having completed system checks and flight is initiated and maintained in a manner compliant with regulatory requirements.

(A) Requisite Knowledge. Knowledge of aircraft, systems, payload, and changes in environmental conditions, weather, and regulatory requirements relating to the use and operation of sUAS.

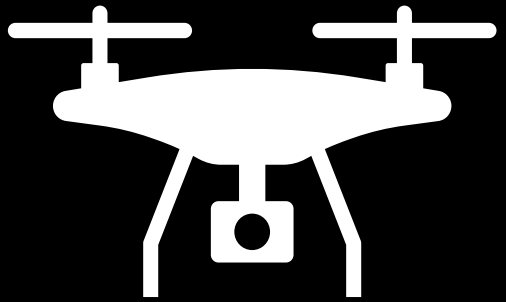
(B) Requisite Skills. The ability to operate the specific sUAS and maintain control in a safe manner during this phase of flight.

Be Safe!

From: NFPA 2400-2019.

Drone Models Being Flown

- These drones were mentioned
  - Many using DJI
- Mainly quadcopters
- .25 kg to almost 10 kg



Drone	Dims. ($l \times w \times h$ (mm))	Wt. (kg)
Quadcopters		
Skydio X2	660 × 560 × 200	1.3
Skydio X10	790 × 650 × 145	2.2
DJI Mavic Mini	245 × 289 × 55	0.25
DJI Mavic 2 Enterprise Dual	322 × 242 × 84	1.0
DJI Matrice 200 V2	883 × 886 × 398	5.0
DJI Matrice 30T	470 × 585 × 215	3.8
PDW C-100	1625 × 1651 × 279	9.7
VTOL Aircraft		
Autel Dragonfish (std)	1290 × 2300 × 460	7.5

Drone models mentioned in our interviews

DJI Drone Model Examples

DJI Mavic 3 Pro

File:2024-10- DJI Mavic 3 Pro - 09.jpg - Wikimedia Commons
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DJI Mavic 2 and Mavic Mini

File:DJI Mavic Mini in front of DJI Mavic 2 Pro.jpg - Wikimedia Commons
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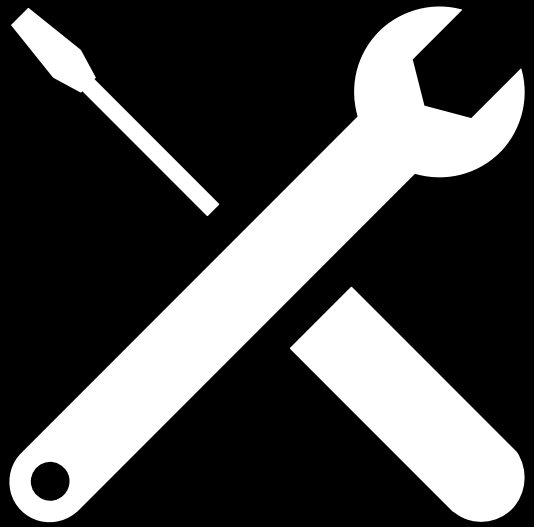
Maintenance

- Pilots handle routine inspections of drones
- Small agencies outsource maintenance and repair to outside companies
- Larger agencies have in-house maintenance personnel.



Types of Missions Currently Being Flown

Mapping and photography for:

- Navigation
- Detecting changes or damage
- Planning future operations
- Keeping track of the progress of fire or flooding
- Automotive crash reconstruction
- Crime scene reconstruction
- Research purposes, such as environmental assessments

Damage in Buncombe County North Carolina after Hurricane Helene
NCDOT Photo via Wikimedia Commons
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Types of Missions Currently Being Flown

Intelligence, surveillance and reconnaissance (ISR) for:

- Crime scenes
- Warrant service
- Large public events and protests
- Search and rescue
- Searching for wanted suspects
- Border patrol
- Inside of buildings
- Infrastructure inspections such as powerlines, bridges, above-ground pipes, etc.
- Crop inspections (post-disaster for public safety organizations)

Air Self-Defense Force drone search operation at Wajima Asaichi
Japan Air Self-Defense Force via Wikimedia Commons
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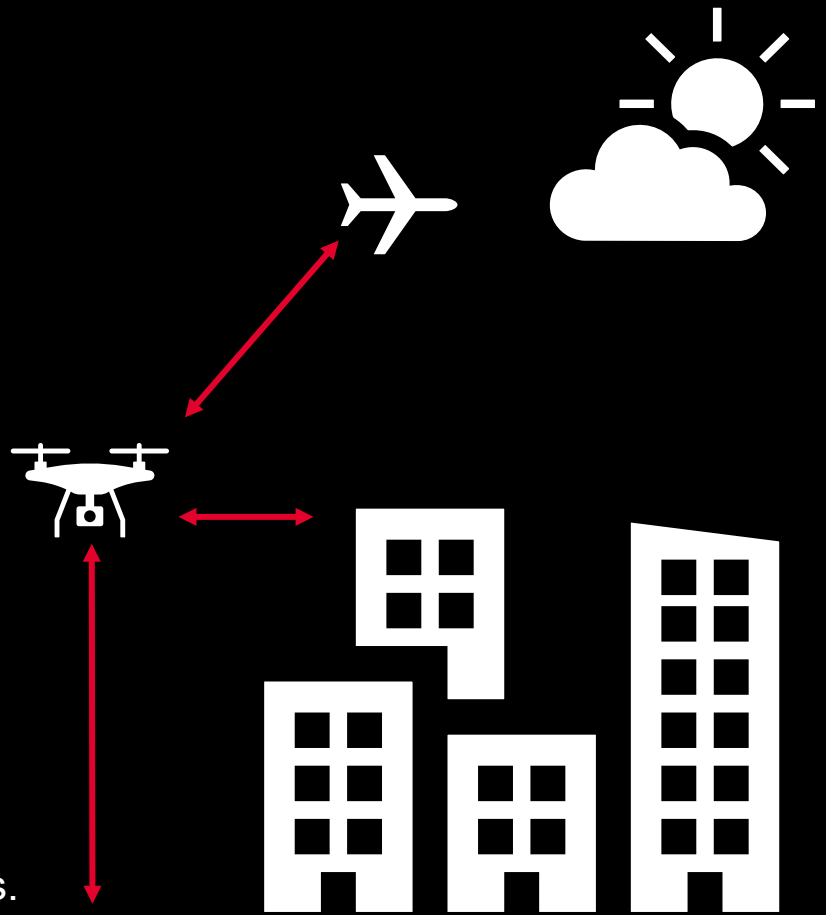
Common UAS Hazards

- These are common hazards met during normal operations
- We discuss disaster-specific hazards later

Failure or Error	Possible Causes	Possible Failure Effects
Battery Disconnection	Battery vibrates loose	LOS from Ground
Battery Low Charge	Battery failure due to age/cycles	Early flight termination
	Insufficient charge for given flight	
	Battery outside temperature limits	
Camera blocked	Fog/smoke/smog blocks camera	Deviation from flight plan
Control system failure	Malfunction of control system	Deviation from flight plan
Communication failure	RFI interference	Deviation from flight plan
Electronics system failure	Malfunction of electronics	Deviation from flight plan
	Water penetration of electronics	
	RFI interference	
Ground control sys. failure	Malfunction of GCS	Deviation from flight plan
GPS connection issue	Blockage of GPS signals	Deviation from flight plan
	Lack of sufficient GPS satellites	
Insufficient thrust	Steady wind	Deviation from flight plan
	Wind gusts	LOS from ground
	Wind shear	LOS from air traffic
	Wind around terrain/structures	Early flight termination
	Precipitation outside specs	
Navigation system failure	Malfunction of nav system	Deviation from flight plan
	Bad sensor or sensor input	
Navigation failure	Fog/smoke/smog prevents navigation	Deviation from flight plan
Motor failure	Exceeding design thresholds	Early flight termination
	Malfunction of motors	LOS from ground
	Water penetration of motor	
Rotor failure	Damage to rotors over time	LOS from ground
Detect and Avoid failure	Radar uncertainty	LOS from air traffic
Software configuration error	Software configured incorrectly	Deviation from flight plan
	Previous incorrect configuration	
Structural failure	Structural damage from age/usage	LOS from ground
Programming error	Software violates safety limits	Deviation from flight plan
User Error	Autopilot not started correctly	Deviation from flight plan

Laws and Regulations

- Part 107 flight restrictions (abbreviated):
  - Avoid manned aircraft.
  - Keep your drone within sight.
  - One drone at a time.
  - Do not fly over people.
  - Do not fly off moving vehicles
  - Do not fly under covered structures
  - Fly during daylight.
  - Minimum weather visibility is three miles.
  - Max altitude is 400 feet AGL, or within 400 feet of a structure.
  - Maximum speed is 100 mph (87 knots).
  - Maximum weight is 55 lbs.
- Agencies can and do get waivers for these rules.



Laws and Regulations

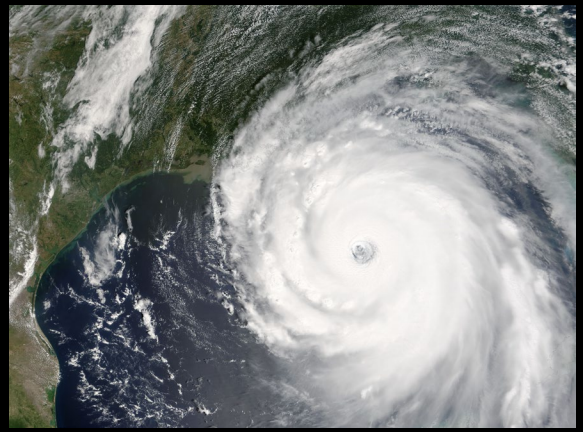
- There have been recent attempts to ban drones from China
  - Including DJI and Autel
- DJI is by far the most popular drone manufacturer on the market with over 70% of global drone market share [1]
  - Florida has passed a ban for police and public safety agencies [2]
  - Federal agencies likewise cannot purchase or operate DJI drones [3]
  - The 2025 National Defense Authorization Act will effectively ban all drones made by DJI and Autel if those drones fail a security review by a federal agency, or *if one is not performed within 1 year*. [4]

[1] Drone Industry Insights, The Chinese Drone Market Report 2019-2024, Drone Industry Insights, 2024.
[2] Mower, L., “How Florida lawmakers are grappling with DeSantis’ Chinese drone ban,” Tampa Bay Times, 2023.
[3] Daleo, J., “Defense Policy BillWould Ban Chinese, Russian Drone Tech in U.S.” Flying Magazine, 2024.
[4] United States Congress, “Servicemember Quality of Life Improvement and National Defense Authorization Act for Fiscal Year 2025,” PUBLIC LAW 118–159, 2025.

Hurricane Katrina Damage

To create a realistic post-disaster scenario, we used Hurricane Katrina as an example.

- Large initial evacuation
- Extensive wind damage
- Widespread flooding
- Many people trapped and in need of rescue
- Unstable structures
- Difficulty navigating



Photos from commons.wikimedia.org

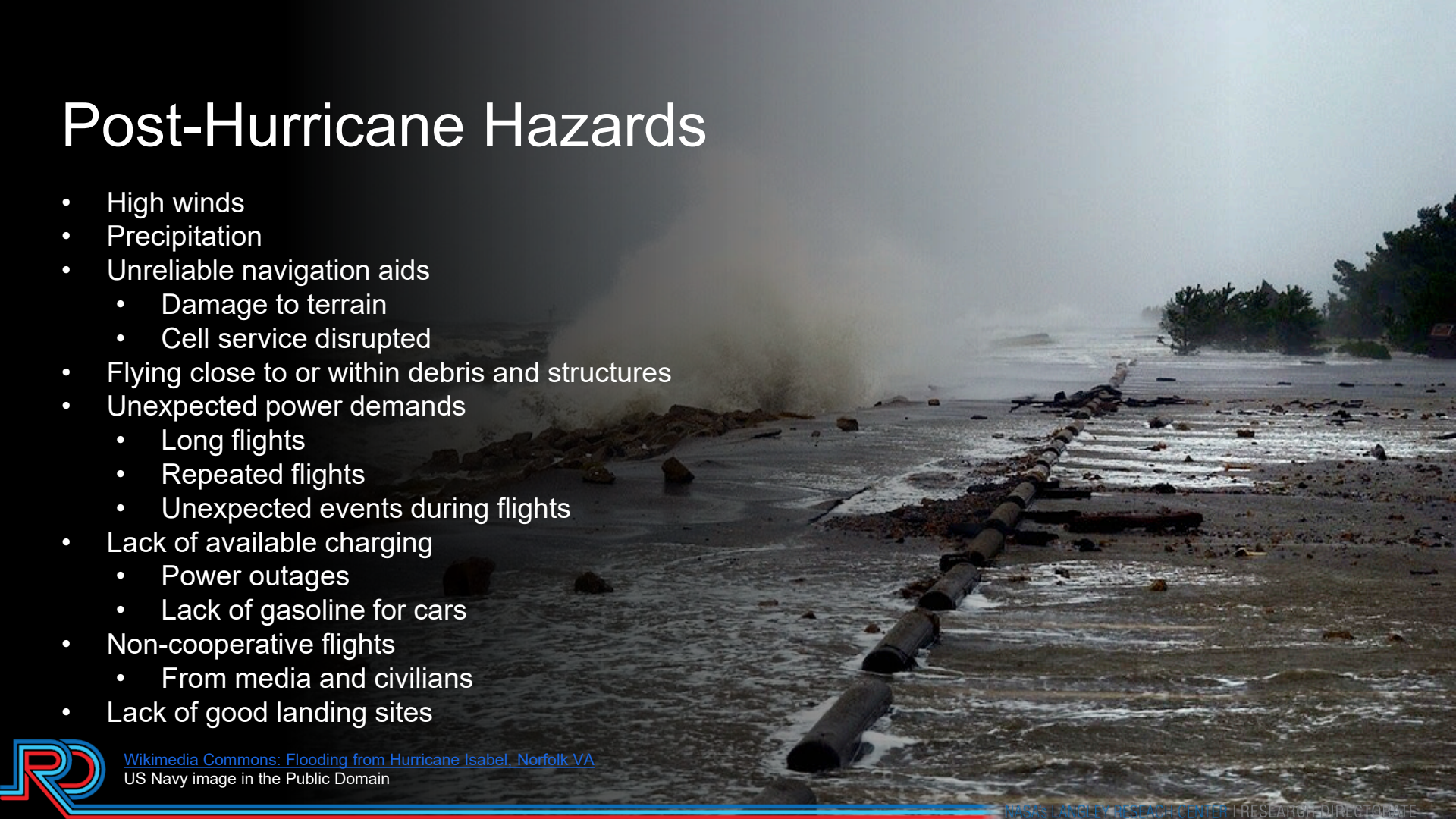
Post-Hurricane Missions

- Traffic oversight and management
- General mapping
- Reconnaissance for mission planning
- Search and rescue
- ISR for other emergency workers
- Damage inspections
- Inspections inside buildings
- Drone delivery

Wikimedia Commons: Hurricane Helene Damage in Southwest Virginia
United States Congress image in the Public Domain

Post-Hurricane Hazards

- High winds
- Precipitation
- Unreliable navigation aids
  - Damage to terrain
  - Cell service disrupted
- Flying close to or within debris and structures
- Unexpected power demands
  - Long flights
  - Repeated flights
  - Unexpected events during flights
- Lack of available charging
  - Power outages
  - Lack of gasoline for cars
- Non-cooperative flights
  - From media and civilians
- Lack of good landing sites



Wikimedia Commons: Flooding from Hurricane Isabel, Norfolk VA
US Navy image in the Public Domain

Discussion

- Agencies agreed on the importance of pilot training
  - Pilots are a vital risk mitigation factor
  - Continue to work sharing training plans
- Drone delivery will likely increase
  - Companies, individuals, and public safety agencies
  - Delivering items is necessarily higher risk than other flights
- Urban air mobility
  - Moving passengers and cargo around urban areas
  - Will create more points of conflict
  - More delivery and emergency management opportunities

System-Wide Safety Project

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