Drones in construction: Worker safety

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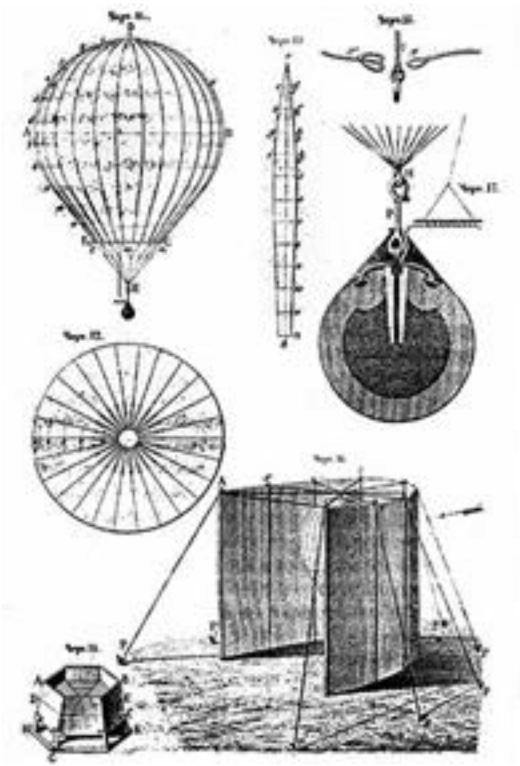
History of drones (UAVs)

1849: Pilotless balloons



1935: Queen Bee
(first fixed-wing)

1958: Lockheed CL-475
(first rotary-wing)

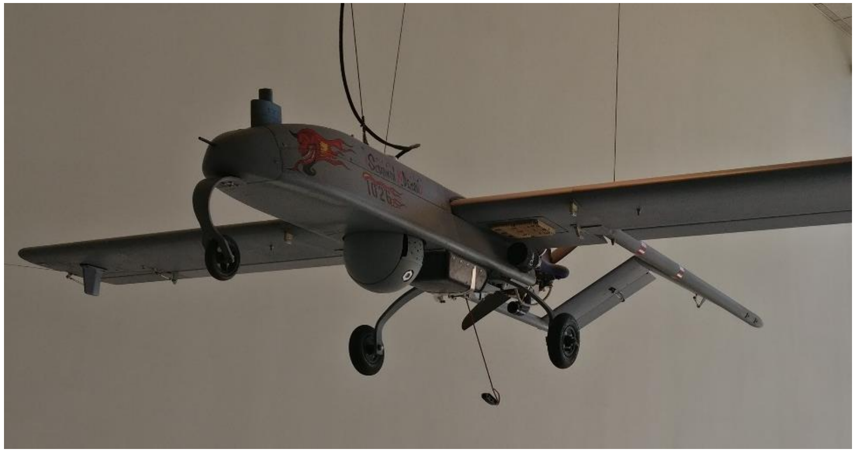
Definitions

- **UAV** - an unmanned aerial vehicle: an aircraft piloted by remote control or onboard computers; also referred to as “drone”

- **UAS** - an unmanned aircraft system; which include a UAV, a ground-based controller, and a system of communications between the two

- **Model aircraft** - an unmanned aircraft that is capable of sustained flight in the atmosphere, flown within visual line of sight of the person operating the aircraft and flown for hobby or recreational purposes

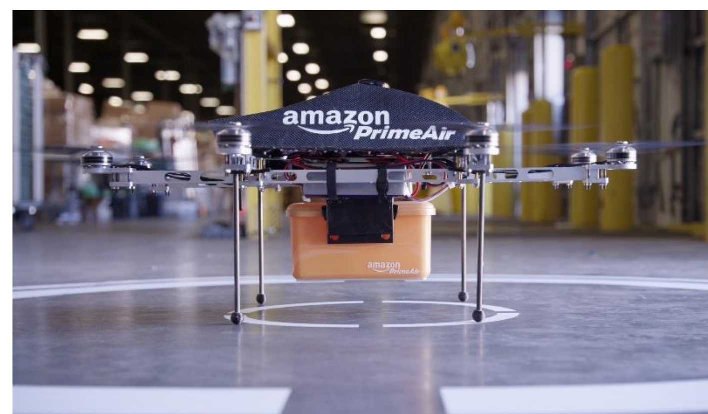
UAVs uses



Military

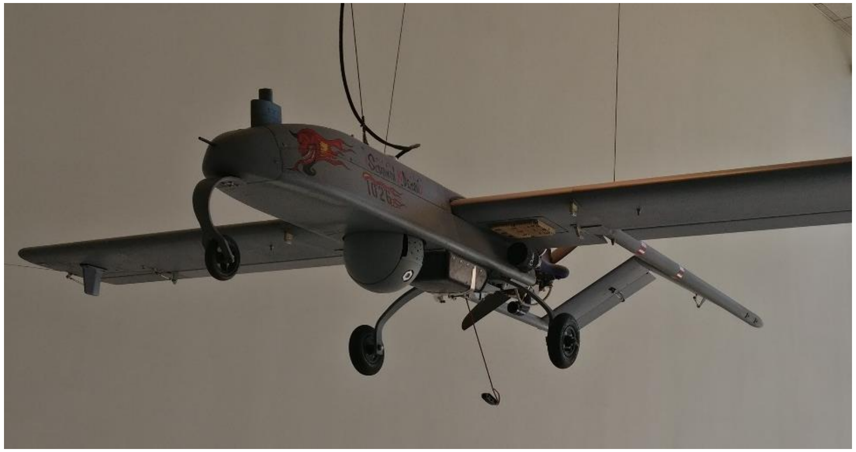
Recreational

Public



Commercial

UAVs uses



Military

- 24-hour eye in the sky
- equipped with weaponry for offensive capability
- missions that are too dangerous for a human-piloted aircraft
- controlled remotely by operators stationed anywhere in the world
- extended mission time

UAVs uses

Recreational

- advances in consumer electronics, mobile technology, and battery power
- can be outfitted with cameras
- capable of directional control by an on-the-ground operator
- do not require sophisticated training to operate

UAVs uses

- traffic management
- aerial viewing of crowds for riot control
- crime-scene photography
- search and rescue operations
- tracking fire personnel in dangerous settings
- mapping hazardous material spills

Public

UAVs uses

- construction
- agriculture and forestry
- mining
- warehousing
- motion picture production
- transportation

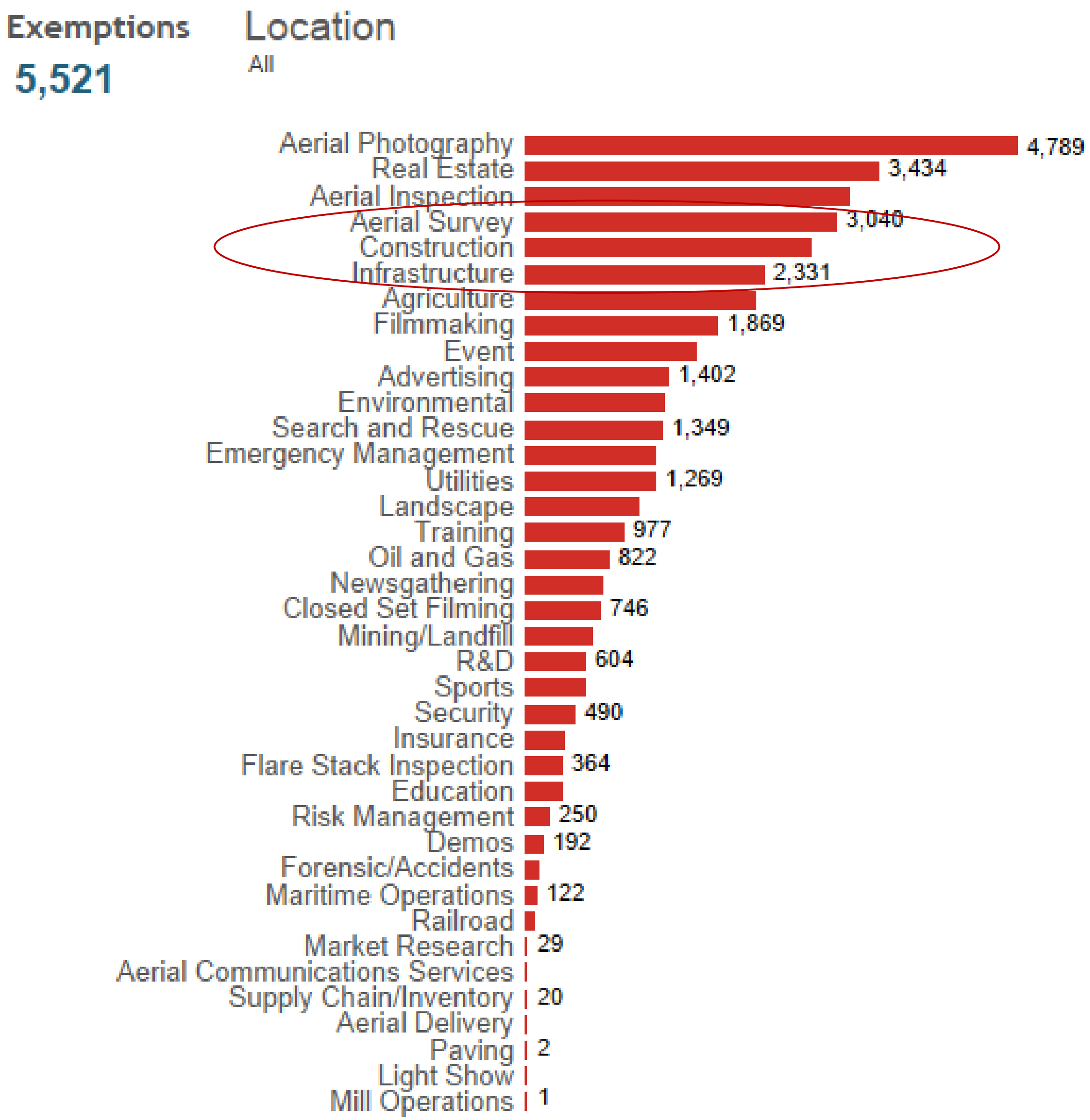
Commercial

FAA Regulations of commercial uses of UAVs

- FAA Modernization and Reform Act of 2012, Section 333: exemptions to airworthiness requirements were reviewed and granted by the FAA on a case-by-case basis
- 14 CFR Part 107 “the small UAS rule” (August 29, 2016) requirements:
  - weigh less than 55 pounds,
  - remain in visual line-of-sight of the remote pilot,
  - operate in daylight only,
  - stay away from bystanders, not operate over a human being unless the person is directly participating in the UAV operation,
  - fly at a maximum groundspeed of 100 miles per hour and at a maximum altitude of 400 feet above ground level, or if higher than 400 feet, remain within 400 feet radius of a structure
  - report within 10 days any serious injury to person and any property damage above $500

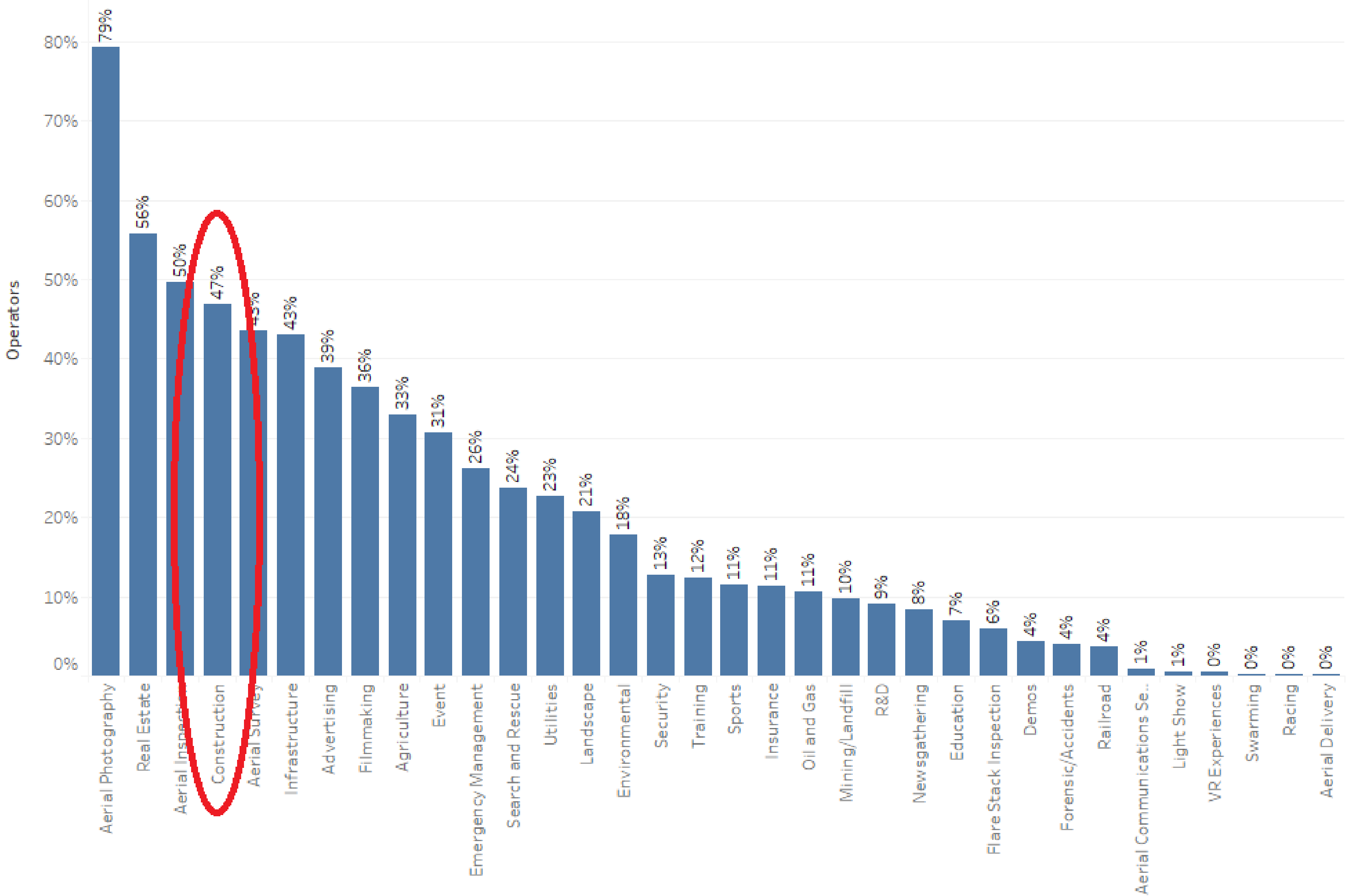
Drone Application Areas

(by Section 333 exemptions as of August 2016, before 14 CFR Part 107)



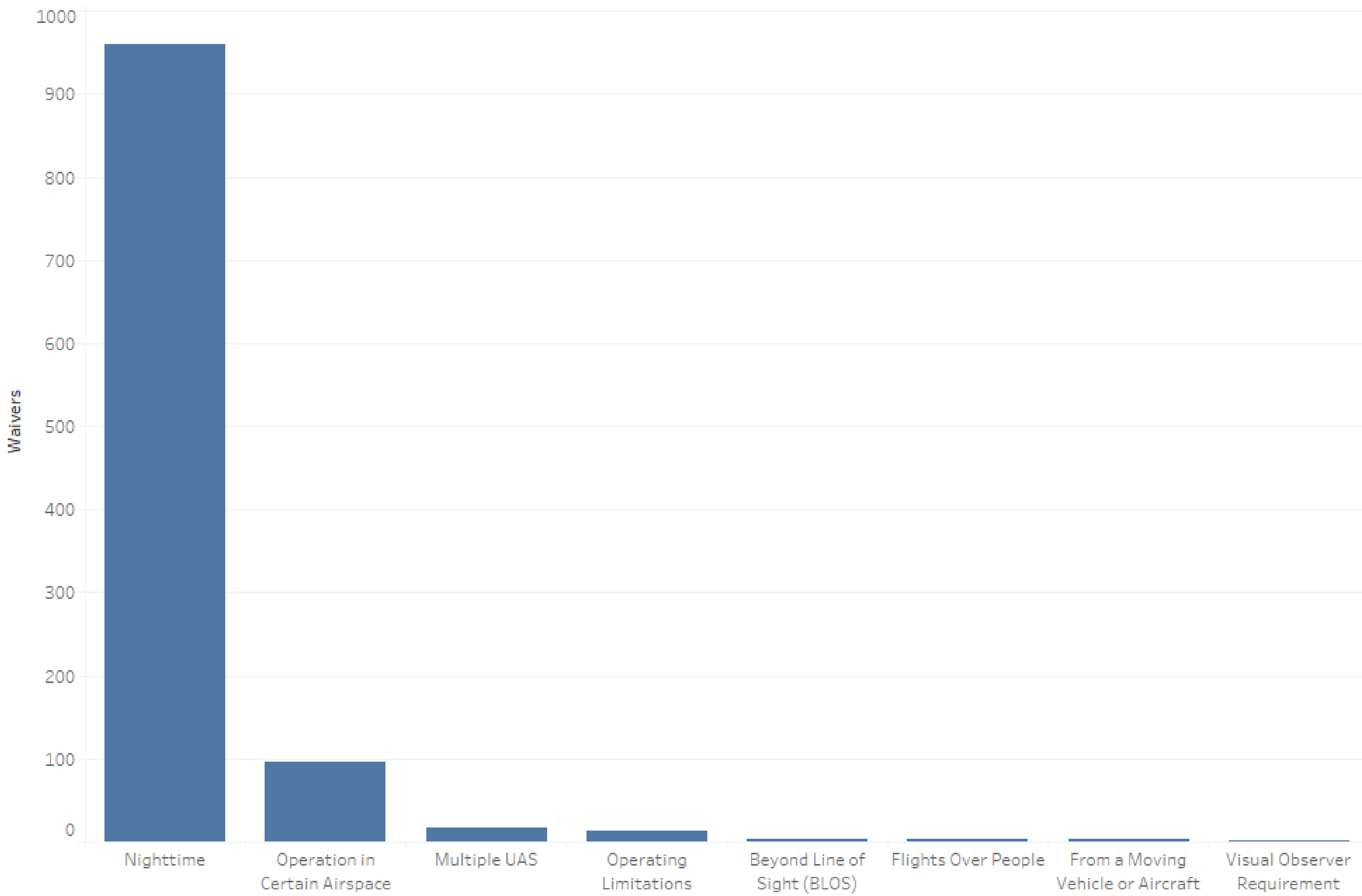
AUVSI

Part 107 waivers as of July 31, 2017: application areas



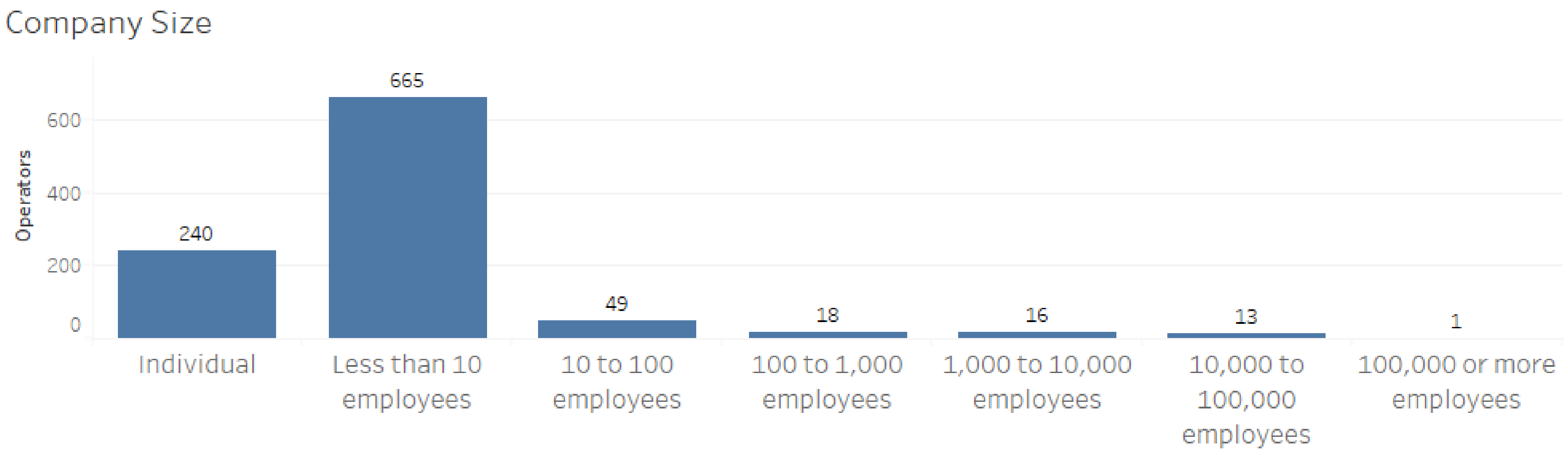
AUVSI

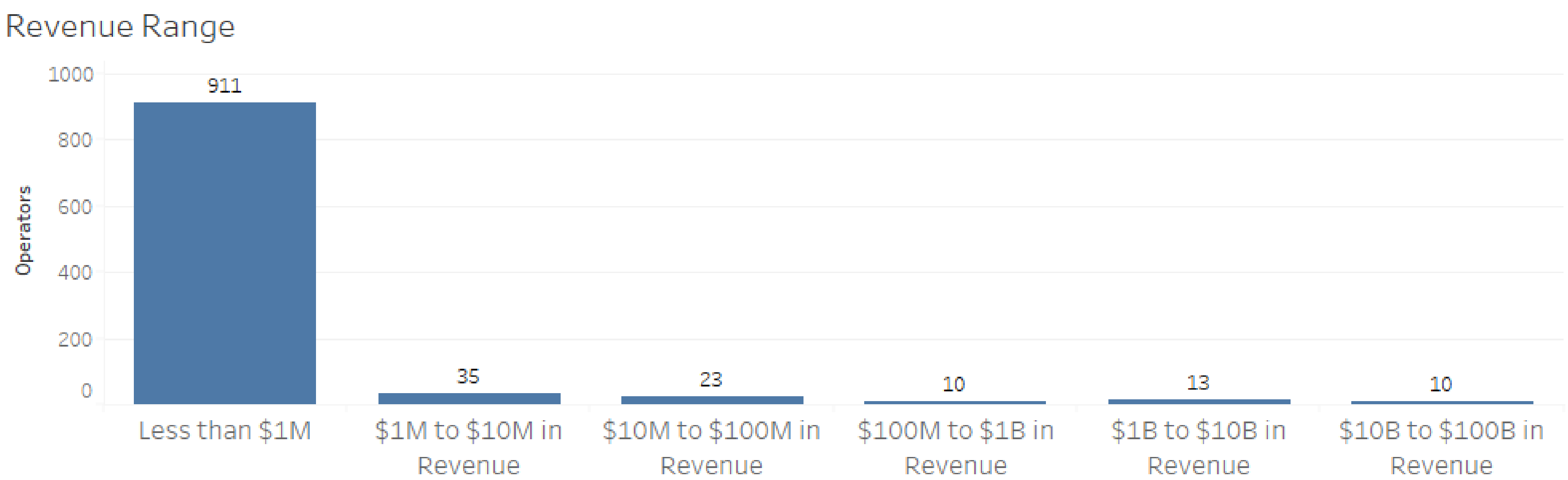
Part 107 waivers as of July 31, 2017: waiver types



AUVSI

Part 107 waivers as of July 31, 2017: company size





AUVSI

Forecast

- The Federal Aviation Administration (FAA) Aerospace Forecast for fiscal years 2016 to 2036 predicts that the sales of small UAVs will increase from 2.5 to 7 million by 2020.

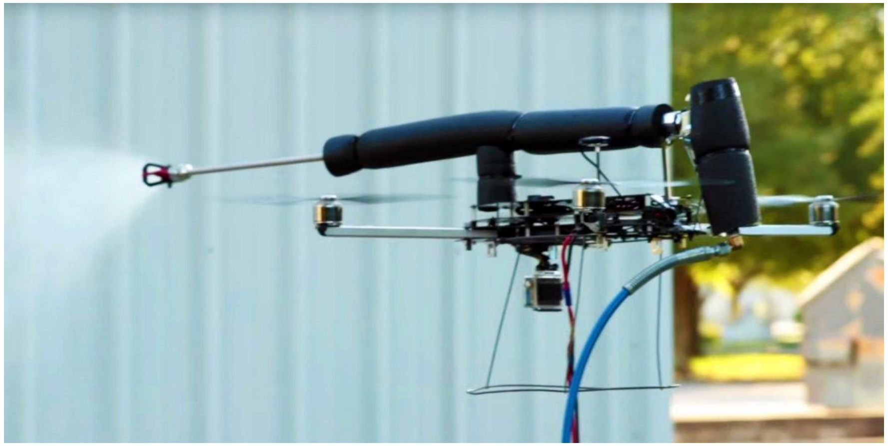
- The Association for Unmanned Vehicle Systems International (AUVSI) expects 100,000 jobs to be created by 2025 from the expanding market for small UAVs. Spending on all categories of UAVs is likely to total $100 billion by 2020. The commercial segment is predicted to be the fastest growing with the construction industry accounting for the largest share of the growth.

UAVs uses in construction

Monitoring

Inspection

Maintenance



Transporting/applying materials

UAVs uses in construction

Monitoring

- collect images, which are converted into 3D picture of the site and compared to computerized architectural plans to monitor progress
- track moving objects on construction sites such as people, equipment, and material
- map indoor construction environments

UAVs uses in construction

Inspection

- detect hazardous conditions, materials and dangerous structures to aid in construction site hazard identification
- identify potential violations through aerial imaging, which are then investigated by inspectors

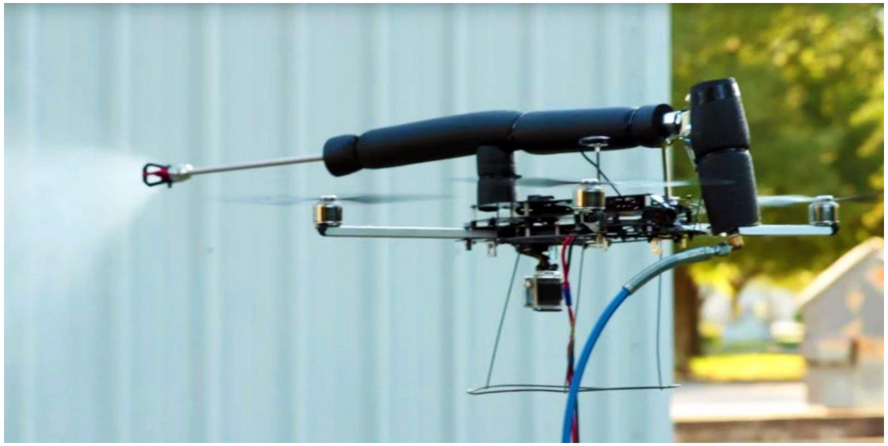
UAVs uses in construction

- carry out planned or reactive maintenance inspections of tall structures, such as skyscrapers, bridges and towers where access can be costly and pose a risk to workers

Maintenance

UAVs uses in construction

- material handling vehicles, transporting tools, equipment and materials at construction sites
- spray-paint or waterproof a structural component



Transporting/applying materials

Improvements in workplace safety by drone usage area in construction sites

- *Monitoring*: important source of data about the safety of UAVs to workers at construction sites

- *Inspection*: remote site inspections and violation detection at construction sites may be more efficient, safer and less costly; inspection of awkward locations on and under bridges and along highway can reduce the risk of working along busy highway or erecting equipment close to the flow of traffic

- *Maintenance*: inspections of tall structures, such as skyscrapers, bridges and towers where access can be costly and pose risk to workers of falling from height

- *Transporting/applying materials*: spray-painting or waterproofing a structural component at heights can reduce risk to workers

Applications of drones to improve workplace safety in construction sites

- Using drones in hazardous operations:
    - Risk of falls, e.g. activities at heights
    - Musculoskeletal disorders, e.g. above-head activities
    - Chemical hazards, e.g. enclosed and contaminated spaces
    - Traumatic injuries resulting from collisions with heavy equipment

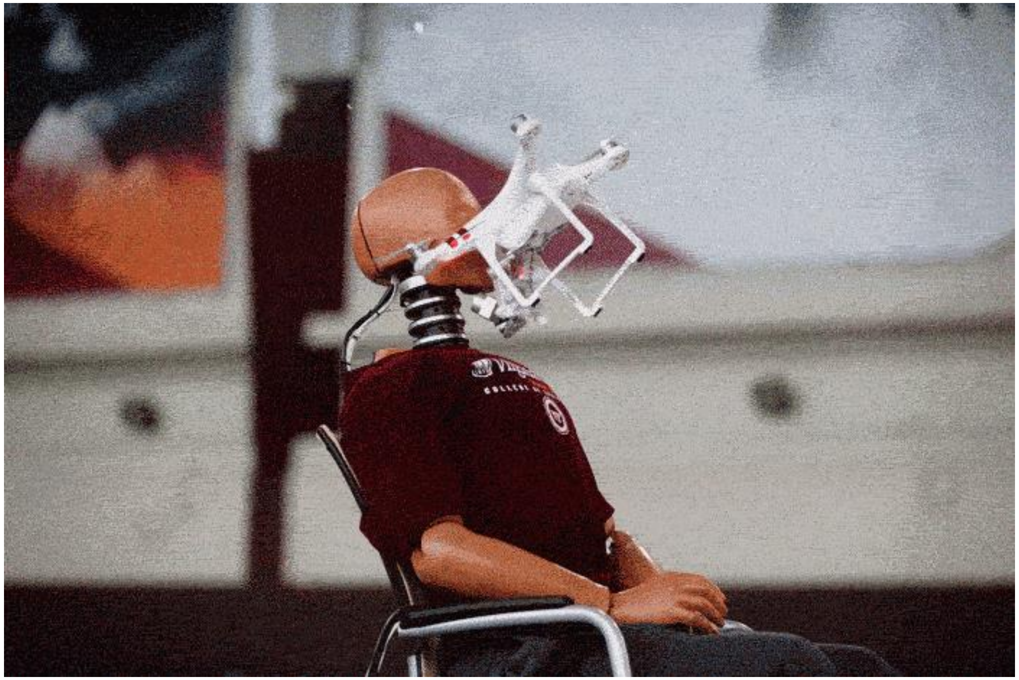
Drones and Occupational Safety

- **The Motivation**
  - Thousands of drones are being deployed at construction sites.
  - Drones can improve workplace safety by taking on dangerous tasks and by making safety inspections and monitoring more effective.

- **The Challenge**
  - Presence of UAVs flying in close proximity to human workers can create new hazards at construction sites.
  - Data supporting the hazard potential of UAVs for workers are scarce.
  - Safety professionals need to be aware of these new hazards, assess the risks arising from them, and apply controls to reduce the risks.

Hazards

- Mechanical hazards such as collisions, cuts with rotor blades

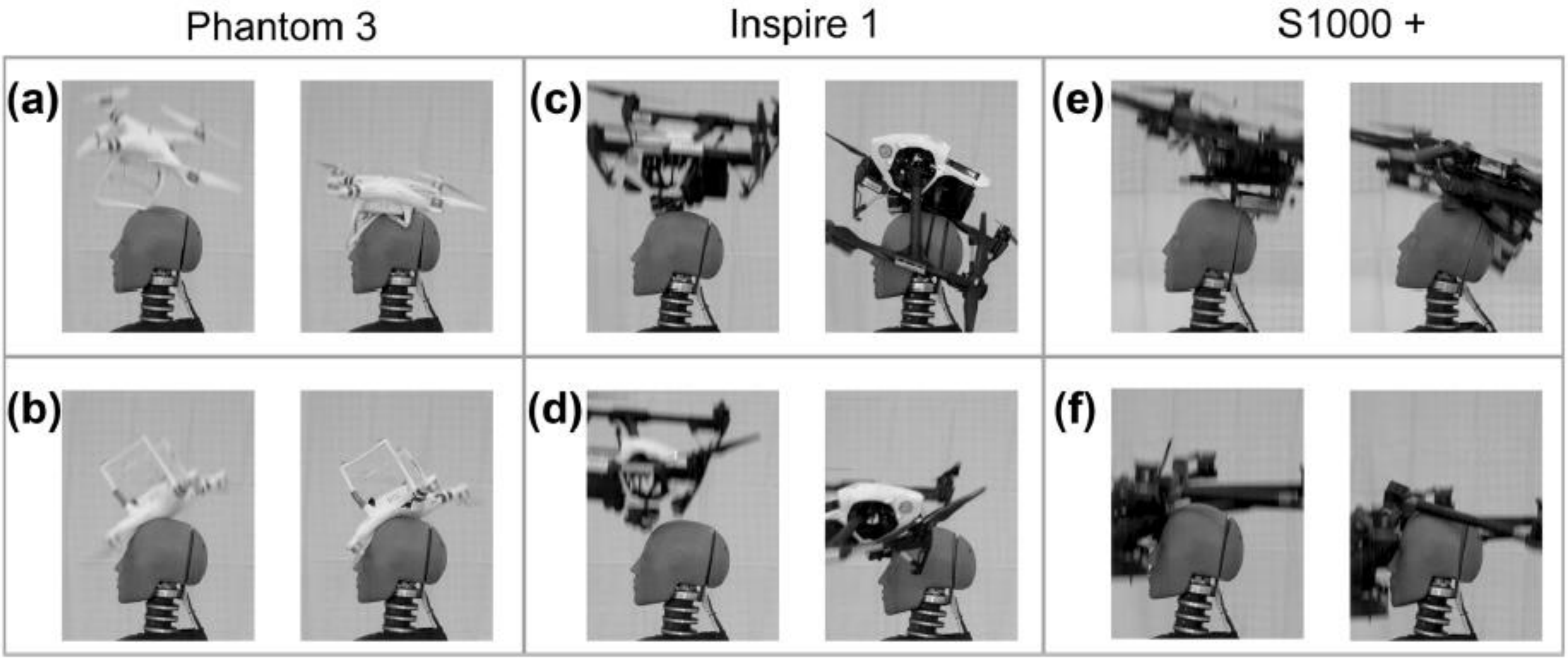


- Burn hazards due to batteries catching fire

Injuries due to drone impact

- Campolettano et al. Ann. Biomed. Eng., 2017, 45(12), 2733-2741
- Collision and fall (18 feet) impact injuries with Hybrid III test dummy
- Three UAS models
  - DJI phantom 3: mass 2.6 lb, speed 36 mph
  - DJI inspire 1: mass 6.8 lb, speed 49 mph
  - DJI S1000+: mass 24 lb, speed 40 mph
- Variations in impact orientation and mass distribution in live flights affect severity of collision impact injuries

Injuries due to drone falls



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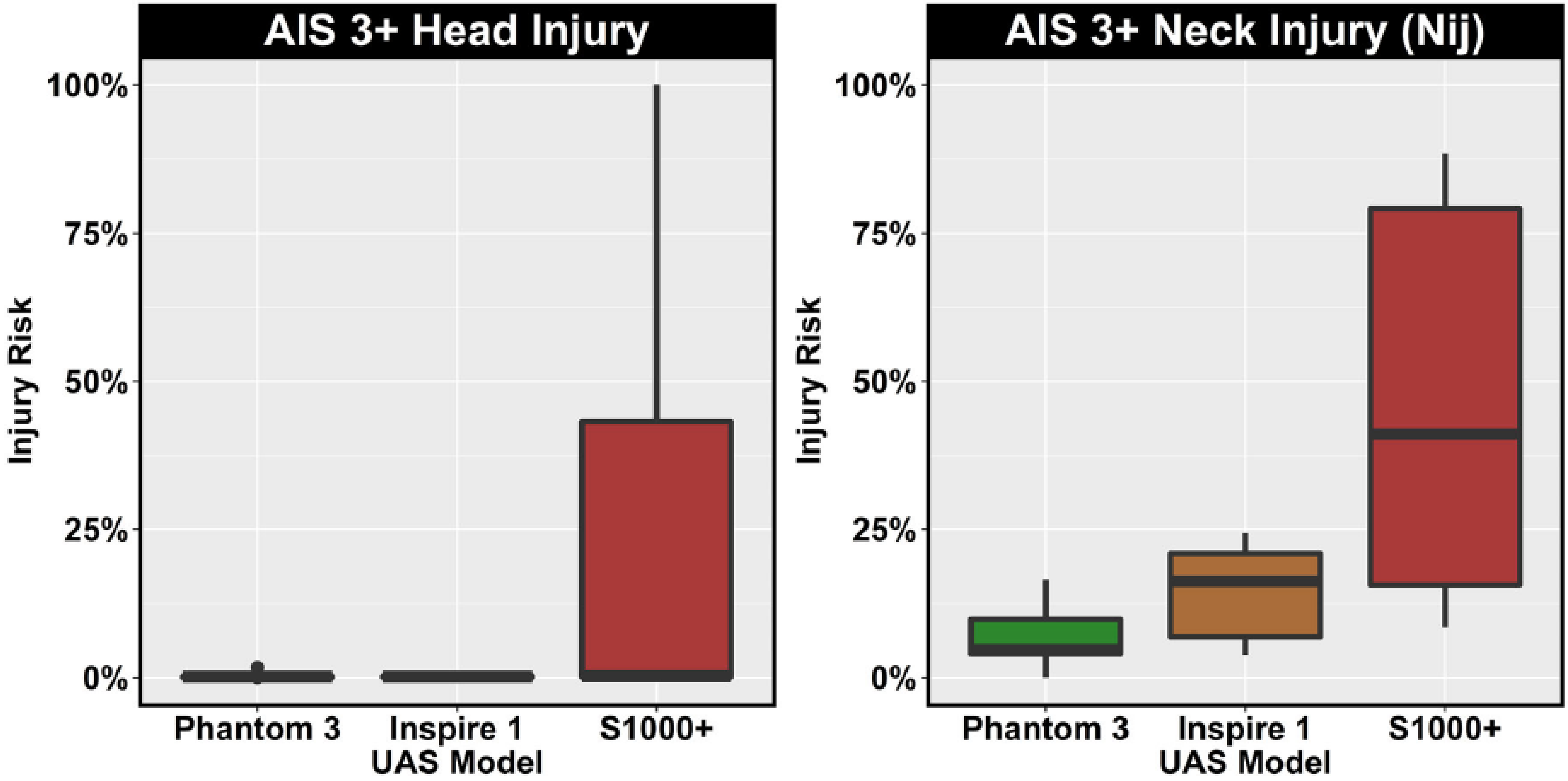
Injuries due to drone falls

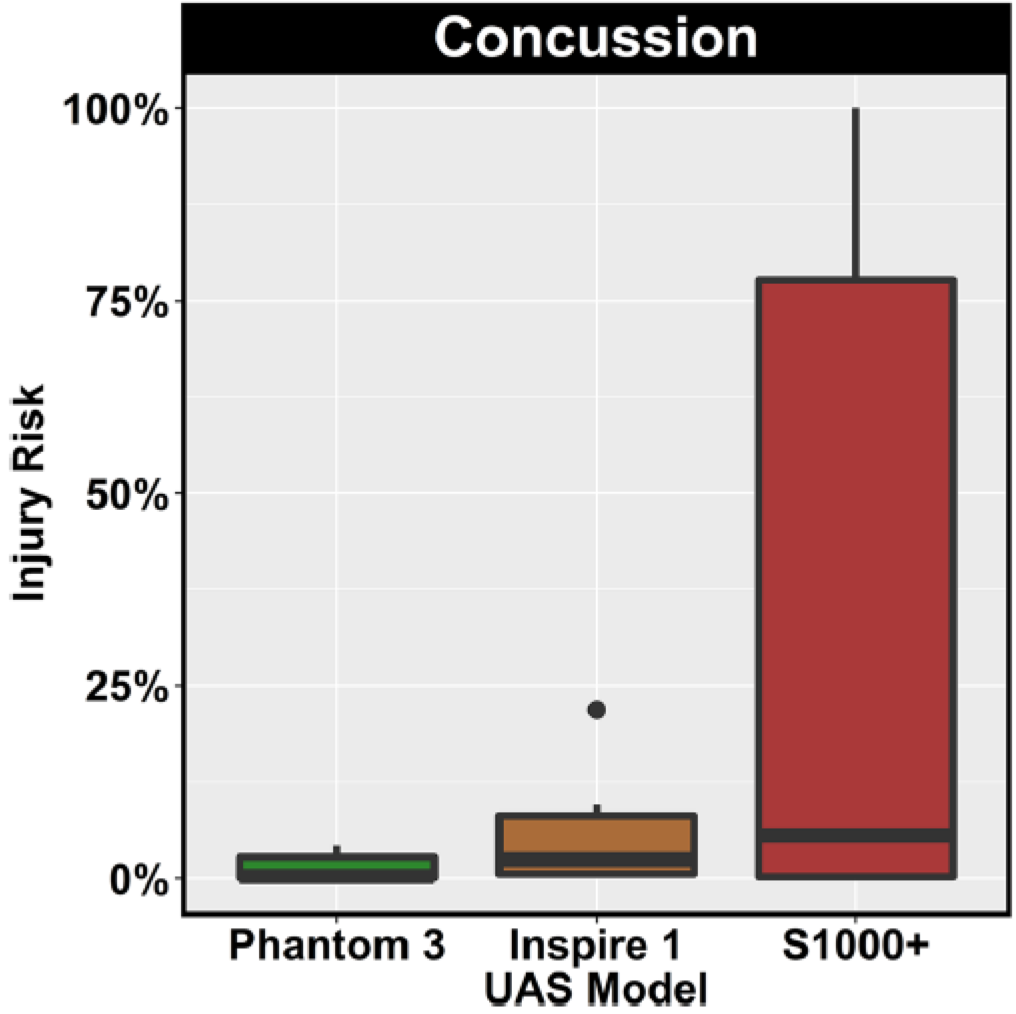


Campolettano et al. Ann. Biomed. Eng., 2017, 45(12), 2733-2741

Injuries due to drone falls

Injury risk:

- Phantom 3 – < 5%
- Inspire 1 - < 10%
- S1000+ - sometimes 100%



Campoletta no et al. Ann. Biomed. Eng., 2017, 45(12), 2733-2741

Hazards (cont.)

- Psychological hazards of autonomous drones:
  - Unpredictable nature of robot motion causing unpleasant reactions like fear, shock, or surprise;
  - Attributing non-existent “reasoning” or “recognition” capabilities.

Sources of worker injuries

- Engineering errors include
  - errors in the drone's mechanics (e.g., loose connections across parts, faulty electronics and sensors).
- Human sources of injuries include
  - errors in programming, interfacing peripheral equipment, and connecting input/output sensors resulting in unpredicted movement or action by the drone;
  - errors in judgment resulting from "over-attributing" to autonomous robots more human-like qualities and capabilities;
  - errors in remote operating.
- Environmental factors include
  - Unstable flying conditions, extreme temperature, poor sensing in difficult weather or lightning conditions leading to incorrect response

Safety approaches

- Construction sites represent unstructured and highly unpredictable environments where complete worker isolation from drones might not be an option as the main safety approach.

- Collision detection and avoidance systems; reduction of drone weight, size, operating speeds and forces; software tools and controls.

- Adequate training of operators.

Workplace safety of drones: Needs

1. Occupational safety and health professionals should be directly involved in the development of national and international standards aimed at ensuring safety of UAVs.

2. Objective data about injuries to workers caused by UAVs should be collected and analyzed.

3. Safety professionals, organizations and government should adopt a proactive approach to the integration of UAV technology and work.

Additional information

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COMMENTARY

WILEY AMERICAN JOURNAL OF INDUSTRIAL MEDICINE

Unmanned aerial vehicles in construction and worker safety

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Applications of unmanned aerial vehicles (UAVs) for military, recreational, public, and commercial uses have expanded significantly in recent years. In the construction industry, UAVs are used primarily for monitoring of construction workflow and job site logistics, inspecting construction sites to assess structural integrity, and for maintenance assessments. As is the case with other emerging technologies, occupational safety assessments of UAVs lag behind technological advancements. UAVs may create new workplace hazards that need to be evaluated and managed to ensure their safe operation around human workers. At the same time, UAVs can perform dangerous tasks, thereby improving workplace safety. This paper describes the four major uses of UAVs, including their use in construction, the potential risks of their use to workers, approaches for risk mitigation, and the important role that safety and health professionals can play in ensuring safe approaches to the their use in the workplace.

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Can Drones Make Construction Safer?

Posted on October 23, 2017 by John Howard, MD; Vladimir Murashov, PhD; and Christine Branche, PhD, FACE

Unmanned aerial vehicles (UAVs) often called drones are increasingly used for military, recreational, public, and commercial purposes. UAVs have the potential to prevent injury and death in the construction industry where nearly 1,000 workers died in 2015. Advancements in UAV technology could help reduce construction-related injury and death from falls, toxic chemical exposures, electrical hazards, or traumatic injury from vehicle and equipment collisions.

As is the case with other emerging technologies, occupational safety assessments of UAVs lag behind technological advancements. UAVs may create new workplace hazards that need to be evaluated and managed to ensure their safe operation around human workers. A recent paper from the National Institute for Occupational Safety and Health (NIOSH) in the American Journal of Industrial Medicine "*Unmanned Aerial Vehicles in Construction and Worker Safety*" describes the four major uses of UAVs, including their use in construction, the potential risks of their use to workers, approaches for risk mitigation, and the important role that safety and health professionals can play in ensuring safe approaches to their use in the workplace.

Thank you!