Game of Drones
Medical Application

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Disclosures

Advisory Boards (Paid):

Facebook B8, Biogen, AtomicRx, DNARx, NED Biosystems

Caivis Fund, Camden Partners, Heritage Fund

Advisory Board (volunteer):

NIH-NCATS, VA NRAC, NFL Health Foundation, NFLPA Health

Co-Founder/Co-Owner:

On Demand Pharmaceuticals (COO), Mind-X/Know Limits, Host Response, SunQ, Ling&Assoc

Can Technology Help?

http://filmonic.com/wp-content/uploads/2011/10/

DARPA and UAVs

- 1960s: QH-50 Drone Anti-Submarine Helicopter carried torpedoes

  Reported to have picked up a downed aviator

- 1970s: improved UAV design led to the first small battlefield drone, MQM-105 Aquila

- 1980s: Amber long-endurance UAV led to the Gnat renamed Predator and Reaper

- 1990s: RQ-4 Global Hawk (high-altitude, long-endurance) and T-Hawk (micro air vehicle)

- 2000s: Wasp III (first micro air vehicle used in combat), X-47B (UAV for aircraft carriers) and A-160 Hummingbird (world UAV record for endurance – 18.7 hours)

- 2016: Gremlin UAV swarm

Commercial Drones

2013, Domino's introduces DomiCopter
2014, DHL ParcelCopter
2016, Amazon Prime Air
2017, UPS drone

Humanitarian
2005, Hurricane Katrina damage assessment
2010, Haiti earthquake
2011, Fukishima nuclear power plant tsunami
2013, Canadian search and rescue

Drones for Casualty Evacuation

vs Medical Evacuation

UAVs for CASEVAC

UAVs built for materiel transport will likely be used as transport of convenience for military CASEVAC

- issues: temp, light, comms (pt), O2 if >10K ft alt

Developing a dedicated UAV platform for CASEVAC

- MEDEVAC with manned assets places additional lives at risk
- MEDEVAC with robot provider has not yet been developed
- First CASEVAC drone will be remotely piloted

First UAV unlikely to provide care en route

- will provide a time-critical response
- enables meeting the CPG time to treatment mandates
- eliminate aircraft crew threat

NATO HFN-184 (2012)

Automated En Route Care
Lost Opportunity: DARPA Trauma POD 2

Continuation of DARPA Trauma POD 1 program by Dr. Satava

Demonstrate resuscitation and damage control surgery on live animal:

- Robot establishes airway and starts ventilation
- Robot places an IV and delivers resuscitation fluids/drugs
- Robot diagnoses and treats tension pneumothorax
- Robot diagnoses and controls non-compressible internal bleeding

Funded at $49M in 2007, Cancelled due to USAMRMC "not wanting" it

Cormorant (formerly the AirMule) Ambulance Drone

Developed by Urban Aeronautics (Israel)

Transport only, no en route treatment

Payload of 500 kg (1,100 lbs), room for 2 litters

Internal rotors , can reach 185 kms/hr (115 miles/hour)

Can be remotely piloted or fly autonomously

1st solo flight in November 2016

Company working to meet FAA safety and other standards

- Would open up global markets

Cal Tech Personal Rescue System

- California Institute of Technology developing autonomous ambulance
- Goal is to specifically transport patients
- Sensors to monitor vital signs during flight
  - No treatment capability
- Currently, have built test 1/5th scale model
  - actual drone will be the size of a small car and piloted by artificial intelligence system

https://wtkr.com/2018/04/30/drone-ambulances-how-this-rescue-drone-could-save-lives/

Drones for Blood Delivery

Transfusion Challenges in War

Medical need for large quantities of blood products, including platelets

Logistic challenges associated with blood products

cold chain storage, shelf life, etc

Risks and benefits associated with collecting blood products

in the theater of operations

US Military Blood Delivery Drones (2018)

US DIUx is developing drone to carry a 5-pound blood package over 100 kilometers in "austere environments"

Hive Final Mile Project

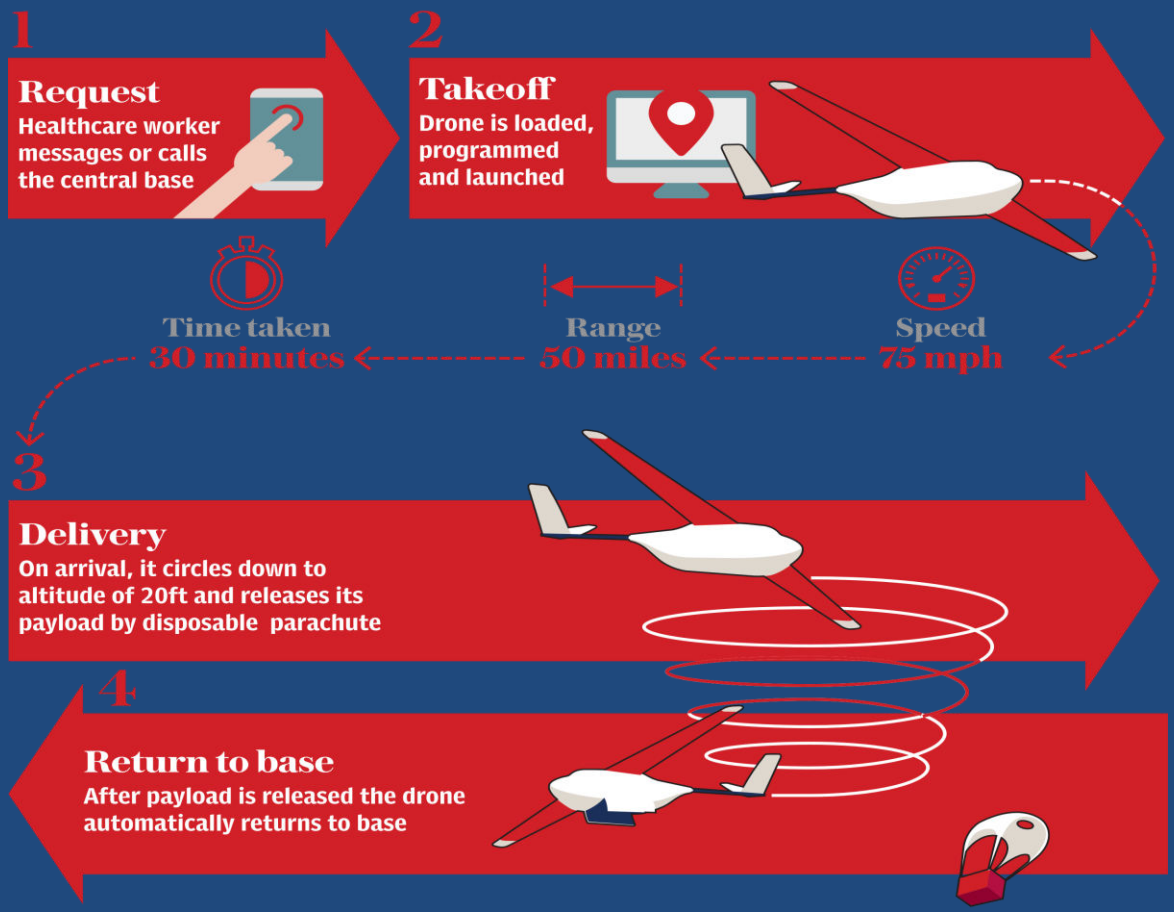
- USMC NexLog and DOD Rapid Reaction Technology Office
- Goal: resupply troops on the battlefield Key elements:
  1. mobile app for placing orders to drones
  2. automated drone launcher , up to 32 drones simultaneously (hive), 500m, 36Kph/22mph
  3. software for managing flight operations
  4. cloud based data storage

Uber for Blood

- 2016, US company, Zipline, launched drone delivery services in Rwanda in 2016

  Funded by Paul Allen, add'l support World Bank
- 25-pound "Zip" drones
  - Range: 150 kilometers per charge
  - Payload: 1.5 kg (3.3 lbs) of blood
- Reduces the delivery time from 4 Hrs to 0.5hrs
- Flown > 200,000 miles, delivering > 7,000 U RBC
- Delivering blood to 12 regional medical treatment facilities (MTF)

Zip Drones Saving Lives in Africa



https://www.telegraph.co.uk/news/0/pointing-way-medical-drones-saving-lives-africa/

Blood Delivery in Rwanda

Clinical Goals

- Reduce maternal deaths
  - 50% of hemorrhage deaths are the result of blood loss during childbirth
- Reduce malaria-induced anemia
  - 25% of hemorrhage deaths, mostly children

Zipline Expansion

- Expanding to Tanzania in 2018
- Four bases
  - Each by with 30 drones
  - 500 flights per day
- Expanding mission to include:
  - Blood, vaccines, HIV meds, other meds
  - Consumables: IV tubing, sutures
  - Therapeutics: Snake antivenom and rabies drug
    - In Tanzania, both account for 2000 deaths per year, mainly children

Drones Delivering AED

Study compared drone vs ambulance response time in delivering AED (automated external defibrillator)

- The median time from dispatch to drone launch was 3 seconds
  - Median time from dispatch to arrival of the drone was 5:21 minutes
- EMS median time was 22:00 minutes

**JAMA.* 2017;317(22):2332-2334. doi:10.1001/jama.2017.3957
www.tudelft.com

Drones for Lab Tests

Latitude Engineering, Johns Hopkins University and Uganda's Makerere University HQ-40 drone transports biospecimens

Up to 5 hour flight

Refrigerated payload at 68° F

VTOL launch and lands in a 25-foot radius

One button activation

Remote provider just hits the "ready" button, launching the aircraft for return to its origin

- Reduce ship time from days to hours

https://latitudeengineering.com/case-study/johns-hopkins/

Effect of Drone Transport on Biofluid Sample Integrity

- Johns Hopkins studied the impact of drone flight on the chemical, hematological, and microbial makeup of drone-flown blood samples

  none were negatively affected

- Successful blood transport >161 miles of desert
- Temperature controlled chamber maintains 68°F

  Cool samples in hot weather

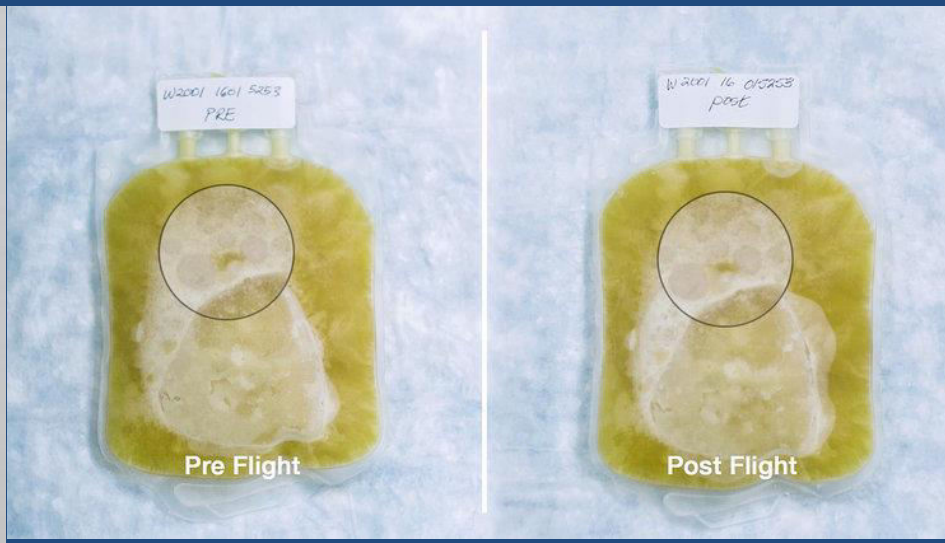
  lighter than an equivalent amount of ice

  warm samples in cold weather

http://www.medicaldrones.org/publication-long-distance-chemistry

Flight Effect on RBC and Plasma

Red blood cells before flight (left) and after flight (right) show no difference in hemolysis.



Bubble patterns in frozen plasma before flight (left) and after flight (right) show no difference, indicating no thawing occurred during flight

Johns Hopkins

Cost / Time Savings Examples

For vaccine delivery, drones increase availability and reduce costs by much as $0.21 per dose vs. traditional delivery

In rural southwest Virginia drones delivered prescription drugs in 3 min vs. 90 minutes by car along a winding bumpy road

Matternet's drones deliver blood samples for HIV/AIDS testing in Lesotho in 15 minutes for a delivery cost of $0.24

Vaccine 2016 Jul 25; 34(34): 4062–4067
https://pdfs.semanticscholar.org/622a/d97506e882bf30ba4dab9c0748ce540ecee3.pdf
https://www.flexport.com/blog/drone-delivery-economics/

Small Unmanned Aircraft Regulations (Part 107)

Commercial uses for drones weighing less than 55 pounds:

- Must keep drone within sight
- Fly during daylight or in twilight
- Minimum weather visibility is three miles from control station
- Maximum allowable altitude is 400 feet above the ground; higher if drone remains within 400 feet of a structure
- Maximum speed is 100 mph
- Remote pilot airman certificate with a small UAS rating

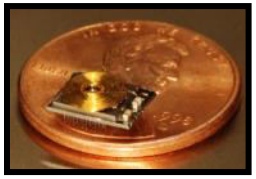
Following hurricanes and tropical storms in Texas, Florida and Puerto Rico last fall, the FAA granted drones a special exemption to survey wrecked roads, bridges and rail lines, identify oil and gas leaks, inspect damaged cell towers, check insurance claims

US Drone Pilot Program

- In May 2018, the FAA announced 10 projects selected from 149 applications for the Unmanned Aircraft Systems Integration Pilot Program
- City of Reno, Nevada was the only medical focused award
- Reno will be testing the delivery of medical supplies and will build up infrastructure including radar and weather data to help facilitate these operations

https://gcn.com/articles/2018/05/10/uas-integration-pilot-program-winners.aspx

Use Brain to Control a Robotic Device

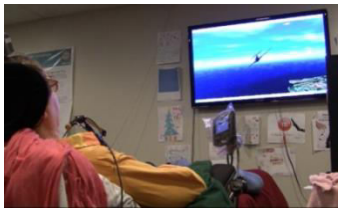


60 Minutes (2012)

Boninger & Schwartz, U Pitt

McLoughlin, APL

Use Brain to Control Aircraft



Brain-machine symbiosis

VIE Flight Simulator

4-29-14

JHU Applied Physics Laboratory
University of Pittsburgh

Boninger & Schwartz, U Pitt

McLoughlin, APL

Other Industry Use

Use of drones in industries such as delivery, film, mining, and agriculture is expanding rapidly

US use regulated by FAA regulations

Wider use means economy of scale = cheaper and better