

HELICOPTER DRONES BECOMING A REALITY

- June 21, 2011, Libya state TV claimed Libyan armed forces had shot down a US helicopter. Showed it on TV. # "It's an Apache!" they said.
 - You can see why they said they shot down an Apache. # The wreckage looks just like it, what with it being a dark color and angular and...you know, it doesn't look like an Apache at all. Turned out it was one of these. # It's a Fire Scout, a UAV -- a drone helicopter. It's a Navy helicopter, as you can tell since it looks like a flying submarine. Was doing ISR (Intelligence, Surveillance, and Reconnaissance).
 - Why'd it crash? Weeeeell, the Command Center lost contact w/the Fire Scout and whoops! There it went.
- Wasn't the first time. Let's go back a year to # August 2, 2010. Flying a Fire Scout at Patuxent River (aka Pax River). 75 minutes into a routine test flight, operators lost control link to the Fire Scout. It wandered 23 miles north by northwest #. Lesse, where was it headed.... # Right, so you can see why that was a problem. The operators got to another ground control station and were able to regain control before the heli was shot down in DC restricted airspace. Instead # they re-directed it to land at Webster Field. As you can imagine, # this north-by-northwest jaunt caused quite a stir.
- The Fire Scout isn't the only full-sized robot helicopter. There's the # Boeing Hummingbird A160. Military is testing it for ISR and cargo. In September 2010, during a SOCOM two-week trial in Belize, one crashed.
 - In fact, Hummingbird has a history of crashes. # First flight was September 20, 2004. A year later in # August 2005 it crashed due to a mechanical failure. In # December 2007 it crashed because sensor data stopped being sent to the flight computer. Without that sensor feedback, it "departed controlled flight and impacted the ground at a near-vertical angle." # In July 2010 one crashed at a California airport, autorotating to the ground and rolling on its side, totalling it.
- # Why these stories?
 - Two important points. One: robot helicopters are *hard*. Two: robot helicopters are here and becoming more prevalent. #
- So why are we interested in robot helicopters?
 - First: helicopters let you do things like loiter, backtrack, go slow, and more, things that make missions like surveillance ones easier. # Imagine flying a Raven, a small fixed-wing UAV. You launch it and start looking through the controller. # Now imagine that, as you're flying it, you see something you want a closer look at. # Maybe there's something on the road you want to see. You can't just stop and watch it. # Now compare that to footage from the Fire Scout. This is from when the Fire Scout accidentally caught some drug smugglers. # If you look at the angle it's being taken from, you can see that Fire Scout isn't too high up, but it's a ways away from the action and just hanging out.
 - # Second: Robots let you do dull, dirty, or dangerous work. Want an eye in the sky? Why put a person up there when you could use a smaller robot-controlled

- helicopter so you use less fuel? Plus less trouble if it's shot down (pace the Fire Scout)
- Third: they're *cool*. # Who wouldn't want to have a hand in creating one of these babies? # Robots hunting down humans? Heck yeah! Besides, # as a scientist, I like doing cool things.
- Where have robot helicopters been? Why's it taken so long for them to show up?
 - # Here's the US's first production helicopter: the Sikorsky R-4. Any guess as to when it was created? Here's a hint. # The guy on the left is Igor Sikorsky. The guy on the right? That's Orville Wright. This picture was taken in 1942, right after the XR-4's first flight. It was the only helicopter to fly for the Allies in WW2.
 - # As a comparison, 1942 is the same year that the world's first jet fighter, the Messerschmitt Me 262, flew. Planes had gone from nonexistent to jet-powered before helicopters really ever got off the ground.
 - Okay, so helicopters developed later than airplanes, which means that their robot technology has been similarly delayed. Why did it take longer?
 - Helicopters have higher engine power density requirements b/c the rotors only generate aerodynamic lift when they're turning. The motor has to turn the rotors fast enough to lift the motor itself plus the rest of the helicopter.
 - # If you have a jet and you # lose your engines, # you can still glide. # If you have a helicopter and you # lose your engines, # you're in trouble. (I'm actually being a bit disingenuous: if you lose an engine you can autorotate down, but you've got to have the engine and engine power to get up there in the first place. You don't get the extra lift you get from an airplane moving forward.)
 - Helicopters also didn't have the benefit of a large commercial industry
 - Hands up if you've flown on a plane. Okay, now hands up if you've flown on a helicopter. Heck, I work with them and I've still never flown on one.
 - # Rotorcraft market (civil and military) is forecast to be \$184 billion over next 10 years. Sounds great, right? But # civil aviation alone is forecast to be \$1.8 TRILLION. # Military's another \$360 billion. (source: Forecast International)
 - The helicopter-versus-fixed-wing delay carried over to autonomous vehicles. Anyone know when the US flew its first fixed-wing UAV in operation?
 - People normally think about the # Predator -- sorry, # Predator in 1995. Try 1964.
 - # 20 August 1964: the Ryan 147B Lightning Bug. It was put together to replace the U2 spy plane after the Gary Powers incident. The CIA worked with the USAF via the National Reconnaissance Office, whose existence wasn't declassified until 1992! They put a film camera on it, launched it via a DC-130, flew it over China, and landed it via parachute.
 - Satellites eventually made that obsolete, but the USAF kept using the Lightning Bugs. In Vietnam they flew about one a day, where they imaged

- their targets about 50% of the time, mainly because of navigation errors.
- Right now the US DoD flies a lot of fixed-wing UAVs: the # Predator, # Grey Eagle, # Global Hawk, # Shadow, # Reaper, # Raven, # Sentinel, and # Scan Eagle. They've got thousands of these things.
 - You know how many types of rotorcraft UAVs the DoD are flying? # Just this one. (It looks like it wants to joust.) It's the only helicopter UAV that's a program of record. Only now being used, and the Navy only has eight # ... er, seven.
 - Overall, helicopters are where airplanes were thirty years ago. That means there's lots of cool stuff to be done! So let's make a helicopter drone.
 - So, okay, how do you make a helicopter drone?
 - (Get someone from the audience and walk them through this.)
 - First, let's learn how to pilot a helicopter
 - # Airplane: You can go forward, up, down, bank left, bank right-5 dirs
 - # Helicopter: Now add backwards, plus turning/heading. 7 directions!
 - # Standard helicopter: collective (all blades' pitch changes together i.e. collectively) stick with throttle (since you have to increase throttle as you change the blades' pitch to climb), cyclic joystick (changes blades' pitch at a specific point in the cycle, tilting the rotor disc and moving the helicopter), rudder pedals (changes helicopter pointing direction by varying tail rotor pitch). It's like playing an organ that can KILL YOU.
 - That's for a standard helicopter. You could do a # quadrotor instead. With four rotors you don't have to change blade pitch. Instead you vary motor speed for control. This makes them easier to maintain and less complex to build -- don't need weird swashplate linkages.
 - Except it's tough to control four motors together accurately enough to keep the thing stable and workable. Got better as inertial sensors got better and computer processors got more powerful. First RC quadrotor didn't show up until 1996, haven't become really common until recently.
 - # Usually helicopter controls are via direct mechanical linkages, but that's no good for a computer. # So let's make the helicopter be fly-by-wire
 - Instead of tilting the cyclic to push mechanical rods around, your input goes to a computer that sends signals to move actuators. (F'r instance, this is how you get an RC helicopter! (fly my helicopter)) Once you've done that, you can just have the computer control everything!
 - This is a new development: the DoD still has no fly-by-wire helicopter. The Black Hawk was supposed to get it in the Mike-upgrade, but only two Mus were built and then the program was put on hold.
 - Have a computer measure what's going on:
 - # What's the helicopter's settings? Collective/cyclic/throttle/rudder
 - # Where are you? GPS
 - # How's the helicopter moving? IMU
 - (now let the volunteer go)
 - Create a controller

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- Knowing how helicopters fly and what the helicopter's doing, you can create something that controls the helicopter.
- This involves # MATH. I'll just handwave and pretend we've put a controller together.
- Tah dah! Robot helicopter!

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- So what are people doing with drones?
 - Military
 - ISR
 - # Fire Scout
 - Cargo
 - # K-MAX
 - # A-160
 - In the future: high-level autonomous helicopters
 - Black Hawk! Formation flying (already partially demonstrated!), cargo, more.
 - Commercial
 - Police drones
 - # Merseyside Police (includes Liverpool) in the UK had a Microdrone UAV quadcopter with visible and infrared cameras on it as of 2007. Funny story: in 2010 they used it to track a man running from a stolen car. Then it turned out that as of 1 Jan 2010 the UK's Civil Aviation Authority had changed the rules about unmanned aircraft. Originally anything weighing less than 15kg didn't have to be licensed, but they changed it so all UAVs had to be licensed. The police hadn't noticed the rule change, so when they trumpeted how awesome their drone was, the CAA shut them down. To add insult to injury, the guy running away from the car wasn't convinced b/c of insufficient evidence. (MENTION FAA)
 - # Canadian firm Draganfly has sold their quadroters to several CA towns for police work including Saskatoon and Regina, as well as Mesa County on the west side of Colorado.
 - Draganfly is selling drones in general for camerawork
 - # Games (Parrot drone)
- What's next?
 - # Sense and avoid. Here's an example from UC Berkeley.
 - # Working in tandem to build stuff. Here's the GRASP lab, which has done some spiffy quadcopter stuff.
 - # Better flying (GRASP lab)
- Build your own!
 - # DIYDrones

SOURCES

- # Airplane: You can go forward, up, down, bank left, bank right (<http://science.howstuffworks.com/transport/flight/modern/helicopter1.htm>) So 5 directions
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the rule change, so when they trumpeted how awesome their drone was, the CAA shut them down. (src: http://news.bbc.co.uk/2/hi/uk_news/england/merseyside/8517726.stm)

To add insult to injury, the guy running away from the car wasn't convinced b/c of insufficient evidence (<http://www.clickliverpool.com/news/national-news/128901-merseyside-police-drone-fails-to-convict-car-thief.html>)

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- # Working in tandem to build stuff. Here's the GRASP lab, which has done some spiffy quadcopter stuff. (<http://www.botjunkie.com/2011/01/14/autonomous-quadrotor-teams-may-build-your-next-house/>)
- Better flying (GRASP lab: https://www.grasp.upenn.edu/success_story/aggressive_maneuvers_autonomous_quadrotor_flight)