



A SunCam online continuing education course

Drones for Engineers

by

Peter Tavino, PE - Consulting Drone Engineer &
FAA Remote Pilot, Small Unmanned Aircraft Systems



New Costco under construction. Course reviewed by FAA representative before 2024 update.



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Introduction

An Unmanned Aerial System (UAS) or Vehicle (UAV) or Quadcopter, Multi Rotor Drone is an engineering marvel: a flying robot with firmware, onboard sensors and GPS capability. ASCE Past President, Mark Woodson, PE calls it a tool of the future. It will be referred to as a drone in this course. Two staples of engineering work are plan views and imaging. Drone technology has advanced to where many of these two engineering functions are best done this way. Imagine the data that is collected over a project site, if a lawn mower pattern was flown just above its entire geo-fenced area, to collect hundreds of high-definition photographs and or laser ray distances. Software translates these data into useful AutoCAD drawings. Volumes and payment fees are easily established. Higher elevation airplane or helicopter photogrammetry data cannot be collected as inexpensively as with a drone.

Bridge inspectors who might have to close or control traffic lanes can see steel and concrete detail through an eye in the sky at substantial cost and safety savings. The building featured in the SUNCAM building rebar inspection course 256 was monitored with a video recorder mounted to a telephone pole that showed construction progress, until its view was impeded. Future building construction can be monitored with preset repetitive drone waypoints, showing pictures or video inexpensively collected from overhead with a detail superior to that of a high flying google map image.

Each site engineer can envision the benefits to his or her work that can be achieved through greater use of aerial imaging. At a Massachusetts demonstration of 3DR drone capabilities and follow up question and answer session, the ramifications were obvious. Would many surveyors be put out of work by drones, which can replace field measurement personnel? After control point elevations are established by surveyors, a drone can measure topographical changes more efficiently. The usual technology and jobs answer is that people can be freed from standardized work to perform more complicated tasks, including processing and interpreting drone data. The same applies to small aircraft pilots and rope rappelling experts.

This SUNCAM course is only an introduction to drones, focusing on their cinematic ultra-high-definition video and photography functions, useful for engineering inspection. Non-engineering firm uses of drones like racing, specialized package delivery, light shows, surveillance, rescue work and other related topics are not addressed.

Engineering firms are encouraged to start or advance a drone program by having one or more employees become an FAA certified (small) sUAS pilot for \$175 as explained in this course and purchase a \$1000 drone for imaging purposes. For AutoCAD related work, a software license and an alternate drone should be purchased. And for more sophisticated missions, consider outsourcing to expert drone service providers. With the rapid advances in this technology, and reader support, we will endeavor to keep this important continuing education course up to date. The many website reference links are being kept current for future reference.



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Course Outline:

BRIDGE INSPECTION

Bridges per Minnesota DOT experience in *Civil Engineering* magazine.

INFRASTRUCTURE INSPECTION OVERVIEW

Inspection of Rooftop HVAC units, Chimneys, Gutters,
Dam and Water Resources Structures
Solar Panels, Wind Turbines, Antennae & Telecom Towers, Electric Transmission Wires,
Inside Commercial Boilers, Offshore Drill Rigs, Drone Sewer Inspection, Water Sample
Collection

INSURANCE ROOF DAMAGE ASSESSMENT

THERMAL IMAGING BELOW GROUND

CONSTRUCTION PROGRESS MONITORING

TRAFFIC

DRONE INSPECTION LESSONS

SURVEYING & ENGINEERING

Topography Image Processing with AutoCAD
-as outsourced or with license by a Developer
Volumes of excavation pits or soil/stone stockpiles – Calculating Cut and Fill

SIMPLE PLAN PRODUCTION FROM DRONE PHOTOGRAPHS

FEDERAL AVIATION ADMINISTRATION LICENSING OF UNMANNED AIRCRAFT
SYSTEMS (UAS)

FLIGHT BASICS

IMAGERY BASICS

CONCLUSION





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BRIDGE INSPECTION

Bridges have been inspected by drones and will be inspected more frequently by drones in the future. The leap frogging in firmware technology has already impacted quality U.S Bridge/Drone Studies such as those conducted by the Minnesota Department of Transportation. Where drones with cameras mounted above were not readily available for under bridge flight inspections, they are now. <https://mntransportationresearch.org/2022/03/15/drone-technology-enhances-bridge-inspections/> (Website links need not be viewed, and do not affect test results.)



*MN DOT headquarters in Roseville, MN as seen from the author's Mavic Pro.
Below: the clover leaf intersection of MN-36 & MN-51 taken from same drone position.*





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The Albris and the Matrice 210 for example allow camera gimbal as a top mount.

Matrice (right and below) inspecting a bridge courtesy of DJI website & use permission.

Different inspection needs may require different inspection drones as reviewed here:

<http://dronelife.com/2017/03/14/top-5-drones-inspections/>



(Left) DJI Matrice (200) on display at a Drone Show.

Besides prosumer drones, there are consumer off the shelf drones, like the Mavic Pro that the author's firm owns, shown below right, that can see 30 degrees above level. So all three examples can see above horizontal, useful for under bridge inspection. But top mount is best.



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Mavic Pro (below) camera and 3 axis mechanical gimbal face 30 degrees upward. Plastic propellers are shown, but quieter platinum props are available.



Below: Author's drone taking the Ultra High-Definition picture to the right of the bridge shown above.



Another issue impeding progress was loss of GPS under bridges. With multiple satellite links available with every flight in most locations, the signal might reach under certain bridges, or the drone can fly autonomously in ATTI (Attitude) mode without GPS or even human control as shown below. *Flying drones without GPS, human guidance:*

<https://www.youtube.com/watch?v=g1HqhCiNdQU>



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In 2015 and 2016, the Federal Aviation Administration (FAA) had not issued its 14 CFR part 107 rules for small UASs. Back then, before August 2016, non-participants had to be 500 feet away from the Minnesota bridge drone. Now drones must simply not fly over people or moving vehicles which allows safety judgment to be determined by the certified pilot. When documenting bridge or building construction job progress, workers used to be sheltered during flights, or flights only occurred at lunchtime. But post 2016, workers can be busy on one part of the job while drones fly above other parts. Following Part 107 safety protocols drone inspection work is easier.

Operating within 5 miles of an airport that can include a part-time landing strip or heliport, is revised under part 107 rules: with airports having traffic control towers being more restrictive. Other TFR (Temporary Flight Restrictions) often available as NOTAMs (Notice to Airmen {and Women}) limit drone work space, but allow reasonable use. More on Class A to G airspace will follow. Before Part 107, operators inspecting the Minnesota bridges were required to be certified pilots, and not simply drone pilots. While licensed pilots can transition to drone pilots easier than the public, passing the written test is not difficult, if the applicant is prepared. All these costs and inconveniences have been removed.

Note that bridge elements in poor condition, or fracture critical members must be inspected “hands-on”. Underwater components cannot be drone inspected either. But many routine bridge inspections are good candidates for drone technology.

Then as now, the drones flew alongside the fascia, above the deck and along the site vicinity including the stream banks. The images then and now are suitable for the Team Leader on site to review and decide on further investigation. If the Federal Highway Administration ever changes its rules that team leaders must be present, (per *Section 650.313 Inspection Procedures* <https://www.fhwa.dot.gov/bridge/nbis/index.cfm>) the importance of accurate high-resolution images will be more pertinent. Having a separate dedicated pilot and another person operating the camera will enhance this process. But having no on site Team Leader seems years off, even with drone capability to document bridge condition for most of its visible surface, available as a live stream to an offsite team leading inspector or multiple reviewing inspectors. PE’s would continue to be responsible for bridge load rating calculations.



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With larger bridge size, is an economy of scale for drone use. The author was PE Team Leader for bridge inspections in Manhattan, New York following the increased attention after the Mianus River bridge collapse in Greenwich Connecticut.

The elegant short span arch bridges in Central Park (above right) were and are more easily accessed without drone.



Wikimedia images

Facing southeast: The Willis Avenue Bridge inspected by the author (shown to the lower right) before it was replaced in 2010.



It is beyond the Third Avenue (foreground) bridge and closer than the old Tri-borough, now Robert F Kennedy Bridge towers shown.

All three bridges are conducive to drone inspection methods.

The economy of scale refers to inspection costs and benefits of fewer lane closures. MnDOT (Minnesota Department of Transportation) and its consultant Collins Engineers reported savings of 30% in a video a case study of inspecting the Robert Street Bridge here:

<https://airborne.skydio.com/public/videos/inspecting-the-robert-street-bridge-with-minnesota-dot-and-collins-engineers-2023-08-30>





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Snooper vehicles for a highway overpass (as shown) can cause lane closures from above, while bucket trucks cause lane closures below to inspect bridge undersides.



With allowable clearance, the bridges to the upper left and below could have a protective net placed under a drone or spherical cage around the drone that inspects without closing lanes. Or it closes lanes without netting for shorter periods of time. Wikimedia images.



Propeller guards are a must for close up work, as shown on the DJI Phantom 3.

Guards can be easily installed or removed.

The older Phantom 3 with gimbal stabilization accelerometers since 2013 has been upgraded to a larger Phantom 4.

Wikimedia image

Mavic Pro 2 with Optical Zoom camera and sideways obstacle avoidance.

With arms folded for transport. (Below)

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Author's Mavic Pro Propeller Guards



Mavic Pro sophisticated propeller guards

Beyond guards, an advancement in Switzerland mostly for industrial inspection that will have application for bridge inspection worldwide is the spherical cage enclosure by Flyability's Elios.

Such safety enclosures for the drone, people, occupied vehicles and objects could replace safety netting suggested above.

DJI Inspire (left) and Flyability protective cage (right)



2017: <https://www.youtube.com/watch?v=4aBVETefY6w>

2023: <https://www.youtube.com/watch?v=-37jFJx7tdY>



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More Bridge Inspection Footage is here:

<https://www.youtube.com/watch?v=0OVKcaTenTI&t=397s>

Infrared imaging of the deck:

The handy and portable Mavic Pro is not equipped with an interchangeable go pro type camera that can switch to infrared. (But infrared cameras have been Velcro mounted to it). A newer version does have it.

MnDOT showed that after dragging the deck with a chain to highlight delamination, a drone infrared worked as well as a hand-held FLIR (Forward Looking Infrared) camera. Indeed, the gimbal on a small drone can be used for steadier recording even if the drone were not to fly. And the digital images from a drone can be stitched into an AutoCAD drawing for a plan view of the entire bridge, approaches and where delamination is occurring. For more information on thermal imaging, see SUNCAM course 226 *Introduction to Thermal Imaging* by Joseph E. Osowski PE.

Following the Minnesota pioneering, bridge inspections by drones have occurred in many states, including one in the author's home state of Connecticut, where the Department of Transportation used a 6 rotor Align Drone by Exponent Technologies. The Hartford Courant newspaper reported that DOT successfully inspected the longest bridge in the state, the Gold Star Bridge, formerly the Groton – New London Bridge, spanning the Thames River.



Old Wikimedia Postcard image showing the multi-span bridge that was drone inspected in 2017.



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With large firms like Burns and McDonnell in the drone business, uniform standards for bridge inspections are not far off. www.youtube.com/watch?v=PQFNYIPEMNe

For railway bridges, HAZON Solutions in Virginia had inspected 64 complete bridges in the 18 months preceding mid-2017. This amounted to over 100,000 linear feet.

INFRASTRUCTURE INSPECTION OVERVIEW

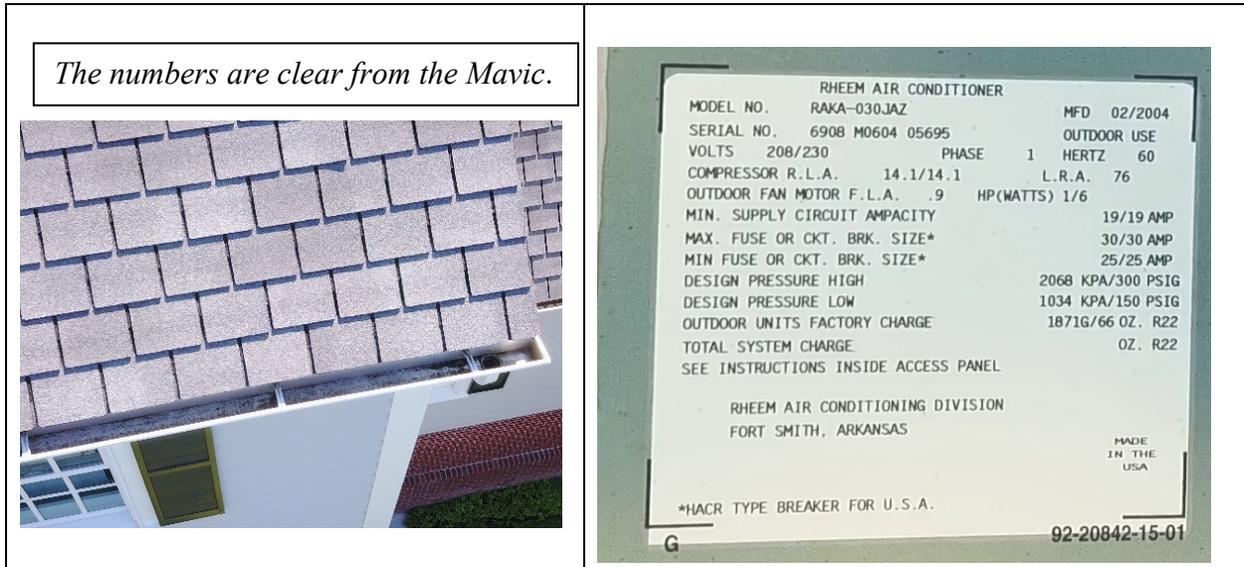
Inspection of Rooftop HVAC (Heating, Ventilating and Air-Conditioning) units, Chimneys, Gutters.

These photographs all show that ladder access is not always required to assess condition.





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By turning off forward sensors, and using propeller guards if necessary, drones can get quite close to target objects, and zoom magnify or video to see chimney flashing and masonry condition, or read model numbers off equipment metal tag plates, or see if downspouts or scuppers are clogged or not. A 28-foot ladder was not needed to see that the leader downspout drain to the left is clear. But Visual Line of Sight is needed for rooftop units.

Other easy drone inspections have involved flagpole pulley malfunction.

Dam and Water Resources Structures



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Reservoir workers can patrol for natural damage or vandalism less expensively than from a helicopter or fixed wing aircraft.



The reservoir outlet control tower with magnificent slate roof is best drone inspected with a Point of Interest rotating viewpoint.

<https://vimeo.com/210106114>



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These earth dams can be seen from many angles in all weather conditions. Drones fly over thin ice that is otherwise unnavigable.



This Cyclopean masonry dam (named for the only giant who could lift the stone blocks) was core drilled under the author's inspection years ago. Drones will enhance dam inspection in the future.



With the Army Corps of Engineers stating that over 5000 US dams are over a century old, rappelling work down vertical dam faces to inspect them can be greatly reduced. See *Electric Power Research Institute inside commercial boiler inspection reference*.

<http://eprijournal.com/the-power-industrys-new-birds/>



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Solar Panels, Wind Turbines, Antennae & Telecom Towers, Electric Transmission Wires, Inside Commercial Boilers, Offshore Drill Rigs, Drone Sewer Inspection, Water Sample Collection

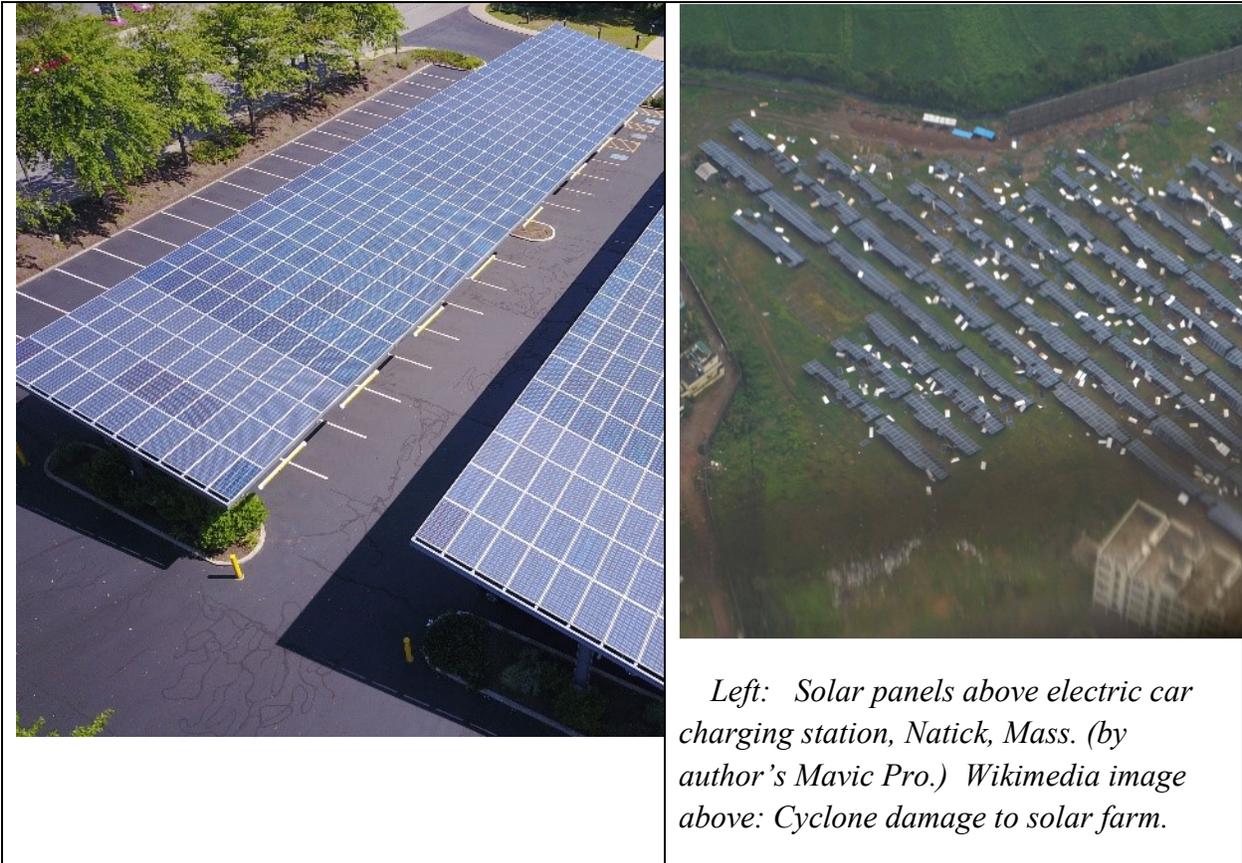
Introduction to uses only - to show feasible applications for Civil Engineering.

Many YouTube and Vimeo videos are available showing these facilities as inspected and monitored from the air. A brief overview is given and interesting follow-up websites are recommended for more in depth knowledge. (No test questions from websites.)

Solar Panels

Solar panels can be inspected for damage and debris with video or stills. Some light snow removal by propeller wash may also be feasible.

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For operation and monitoring in addition to installed sensors, thermographic inspection benefits are described here: https://www.youtube.com/watch?v=LY_SOwu4TzA

From that video, the user states that there are five steps to a successful solar panel visual inspection. Instead of walking through an array if feasible, a drone, can inspect it much faster. And a 4000-panel rooftop photovoltaic site was inspected with thermal photographs from above that can identify “hotspots” in only 5 minutes of flight time.

<https://www.youtube.com/watch?v=s04ngPFXo94>

Wind turbines - well described by the Office of Energy and Renewable Energy
<https://www.energy.gov/energysaver/articles/energy-101-video-wind-turbines>



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Wikimedia photo



From the author's drone

Drone inspection of wind turbines: <https://www.youtube.com/watch?v=RaSo9uPUUzY>

<https://www.youtube.com/watch?v=gGZK4cIzMq0> Pro-drone wind turbine blade inspection.

Note that larger drones than can support piping hoses and such are being used for Wind Turbine cleaning (and firefighting) <http://www.startupselfie.net/2018/03/29/aerones-super-sized-drone-firefighting-human-rescue/>

Antennae & Telecom Towers



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Gunn Photo Services

A simple example of a Mavic Pro close to a radio tower inspecting a 2000-watt antenna array near Cleveland, Ohio. Signal was not lost because the remote controller frequency was greater than the antennae, but be cautious when attempting to duplicate. Magnetic fields will affect yaw first, because the internal compass calibrates yaw.

Cell tower climbers' safety is improved or their dangerous work is reduced. ATT and Verizon wireless use of drone vendors is described here: <http://www.rcwireless.com/20170221/cell-tower-news/drones-telecommunications-tower-inspection-tag23-tag99>

AT&T is also using Artificial Intelligence to perform drone inspections of its towers:

Electric Transmission Wires

If wire insulation is frayed, it will show heat loss that can be detected by infrared isotherms. Temperatures over 200°F could indicate damage. Another application is to detect telephone pole rot from above.

https://www.youtube.com/watch?v=i4J2U7_0U7Q

Power line helicopter inspection crash danger:

<https://www.youtube.com/watch?v=ZxX7OITuMhA>

Inside Commercial Boilers



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This informative article by the Electric Power Research Institute (EPRI) discusses Fukushima, concrete inspection and boiler inspection.
<http://eprijournal.com/the-power-industrys-new-birds/>

Working inside the boiler requires the drone to supply its own flood lights to allow camera work. And the drones can attach to walls and climb them with rollers to conserve electric power. Conservation of power is also addressed by the advancement of batteries beyond the twenty or so useful minutes for a Mavic pro. At police patrols and at the Boston Marathon, (after the earlier terrorist attack) security drone energy was conserved with tethered wires to the ground. Such advances for increased flight time are applicable to many engineering applications. And police department drones that can be secured in their docking bays within five seconds of landing, to allow emergency response, will also have engineering application where remote docking is necessary.

This Fluor Company (described below) uses drones in the boiler inspection business. There are savings in boiler cooling down costs, scaffolding required only for repair work of internal flaws, (not to see everything) and time saving with turnaround time reduced. Only actual repair work needed must occur. <https://www.stork.com/en/industries/references/internal-vessel-drone-uav-inspection>

Make contact with Fluor/Stork if further info is required.

Con Edison in NY boiler inspection video: <https://www.youtube.com/watch?v=b5eHwqpDilc>

Offshore Drill Rigs

Other facilities for drone inspection are oil and gas offshore drilling platforms.



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Sky-Futures describes the process here:

<https://www.youtube.com/watch?v=TLa1NrBEeE>

The video interview shows that drones can obtain data that is unavailable without them.

Wikimedia image

By using drones before an expensive platform shutdown, the inspectors and Oil and Gas companies knew what to expect. In the North Sea, five days of drone data collection was the same as eight weeks of people climbing. That saves on overnight accommodation costs for helicoptered workers on board. They share company data from one platform to another with the structural engineers.

Drone Sewer Inspection:

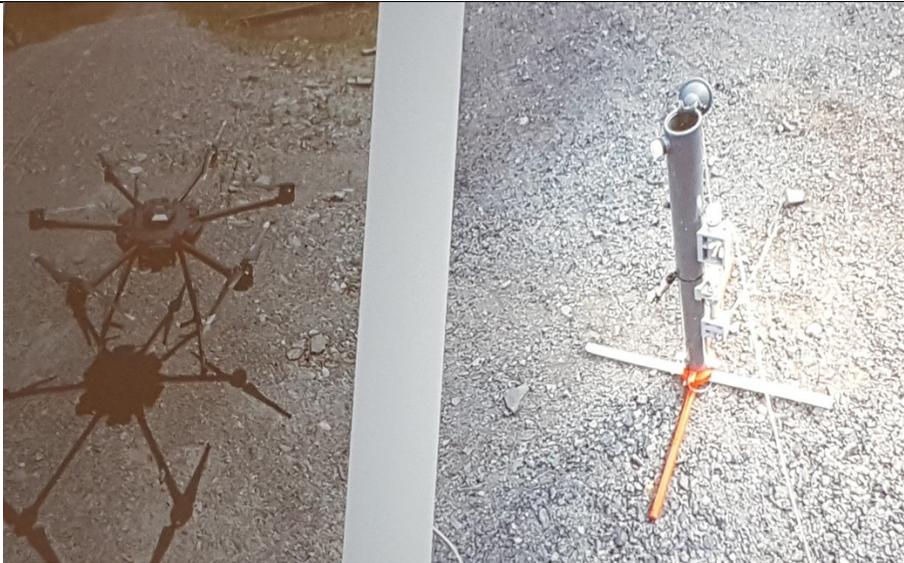
In Minneapolis, Minnesota, the sanitary sewer pipes are inspected by introducing pressurized inert smoke into them. Inspectors watch the exhaust vents on rooftops of residential dwellings for the streaming smoke. If smoke does not emerge, or if it leaks out through a storm sewer, they investigate the problematic issue.

https://www.mswmag.com/online_exclusives/2017/08/drowatsonnes_deployed_to_aid_in_sewer_system_smoke_testing

Note the similar inspection for **oil pipelines, air emissions, & gas leaks**, available by photography or thermal imaging.

Water Sample Collection:

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Where toxic pools discourage people from sampling by conventional boats, Hatch Engineering of Canada, has successfully used the drone and tube sampler shown to not only photograph, but physically collect water samples at the required depths below the surface.

<http://enterprise.dji.com/news/detail/water-sampling-with-drones>

INSURANCE ROOF DAMAGE ASSESSMENT

https://www.youtube.com/watch?v=u_ORwYQ9mPM shows property insurance inspection methods by Airware. More video here: <https://www.youtube.com/user/AirwareUAS/videos> After an insured customer submits a claim for roof damage, a flight mission is planned in the office, and a pilot drives to the house with the preprogrammed drone ready to fly overhead and photo survey it. Following the preflight safety checklist completion, the drone flies autonomously to collect the data. It is uploaded to the cloud securely, and an orthomosaic image is available to **permitted viewers only**. Security of private information is managed, as the rich data set collected is extracted efficiently and stitched into a seamless data set. Individual high-resolution images can be seen so that roof damage can be assessed. Measurements are taken and reports are generated.

Disaster damage to an entire community can be similarly assessed. Drones should not interfere with emergency aircraft, unless contracted (such as searching for residents standing on rooftops; some drones can fly in light rain and snow.) Afterwards, imagery is useful. Volunteer groups (like DroneUp -to which the author belonged as a volunteer) coordinate flights. While privately operated by some insurance companies, the methods lend themselves to outsourcing to engineering firms who can also provide this level of drone service.



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Flood and Tornado Damage aftermath (Wikimedia)

For hail damage using data wing and IBM's Bluemix, 4000 x 3000-pixel images are broken into 300 x 300 tiles and analyzed by IBM's Watson Visual Recognition Service for hail damage. More on Watson here:

<https://www.ibm.com/blog/sharpen-watson-visual-recognition-results/>



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Photogrammetry develops a 3D model, used to determine repair costs.

All with cloud object storage. Laptop application that would take 3 hours takes 10 minutes on the server.

Shingle hail damage image by author's drone.



For flat roofs, thermal imaging allows inspection to detect moisture problems from above. Camera cost can approach \$10,000. <https://www.youtube.com/watch?v=cN32-na-X-Q>
And thermal imaging is in use for Industrial Processes.

THERMAL IMAGING BELOW GROUND

Ground penetrating thermal imaging also has engineering/archaeological applications in discovering buried objects that emit heat differently than the surrounding soil. A 1000-year-old ancient Native American Settlement in New Mexico was discovered by drone years ago, and more searches are planned. A circular village gathering place structure appeared on the infrared image. The author is following a local effort to use LIDAR (Light Detection and Ranging laser reflection) and forward-looking infrared camera drones to discover buried stone walls of importance to land developing civil engineers. Depending on moisture content of soil or leaves above, the stones can be detected by either method. Appropriate drones and imaging systems can be rented from quarry expert Caterpillar, Inc. (and Redbird) etc.

<https://www.livescience.com/44679-drone-images-reveal-buried-archaeological-ruins.html>

PBS Engineering in the Pacific Northwest, working with Skyward.io, also used a drone to video record cliff sides above a highway, so that archaeologists could view them for possible human activity there in the past.



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Enhanced thermal imaging - seeing through walls:

<http://interestingengineering.com/drones-scan-inside-buildings-3d-wi-fi-signals/>

CONSTRUCTION PROGRESS MONITORING

As mentioned in the SUNCAM Rebar Inspection course 256, a new science center featured an all-weather camera affixed to a telephone pole, providing the view from a single direction. That view by drone is shown below.

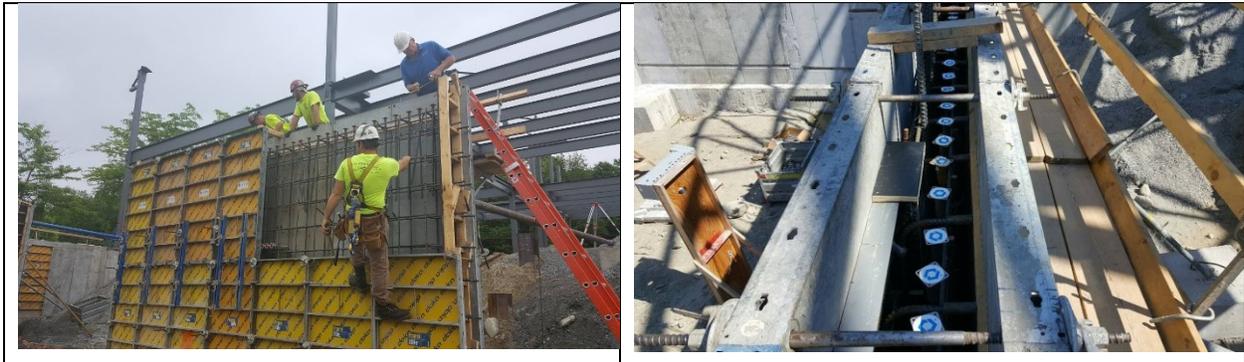


Winsted. CT Science Center droned by author

During construction, the engineering and construction management teams could go to their laptops or mobile devices at any time and see the continuous cam stream live. But as the front building walls were erected, the view became obscured. While not a substitute for 24/7 coverage like many fixed web cams, an occasional 5-minute flyover mission would give the off-site managers and design architects a better depiction of progress. Being able to see steel rebar in full time-stamped site plan before a concrete pour in one **high definition** (HD) picture (1920 x

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1080 pixels) or 4k **ultra** high definition (UHD) at 3840 pixels horizontally and 2160 pixels resolution vertically for 4 times the resolution of HD can lead to better management decisions. These pictures below were not taken by drone but could have been.



Another eventual use might be for inspectors, not able to watch full time rebar assembly and wood form covering, to confirm that no changes were made to the approved mats by peering down into forms from above high walls with an overhead drone. There might be no need for the inspector to climb a tall ladder to access the railed walkways to see what his or her drone could see, and climb only if warranted, after seeing the instantaneous footage or image off the tablet or mobile cell phone device.

Marine Pile Bent inspection by drone rather than boat is a similar inspection task keeping inspectors and management personnel safer. Inspectors of many types of construction projects take multiple pictures to document what they have seen. Managing these image files is time consuming. Inspecting without worrying about taking extra camera pictures can also be accelerated, if a follow up drone imaging process takes bird's eye view pictures where appropriate.

The owner of a new condominium project being built in New England lives in the South. A drone services firm with engineering experience is taking overhead pictures every few weeks and sending them to the owner, at fair fee for the value provided.

And beyond inspection, this 2021 drone is tying reinforcing steel bars together in a horizontal slab concrete application:

https://techcrunch.com/2021/03/02/_trashed-12/



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A residential construction job in Torrington, CT

By author

Another example of a construction progress photo is shown in the school image below.



Gunn photo services Cleveland, Ohio.

For more information, read this Case study by Skyward.io

How a Major General Contractor Built and Scaled Drone Operations:

https://www.contentree.com/caseStudy/how-a-major-construction-management-company-used-skyward-to-launch-safe-successful-drone-operations_353959

Another industry leader is www.Kespry.com

TRAFFIC



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The author's Mavic Pro shows that gridlock congestion at the intersection to the right is not backing up traffic on the exit ramp. With 4 batteries, 40 minutes of morning and then 40 minutes of late afternoon (half an hour past sunset) rush hour traffic can be easily recorded and presented to the client in one day. Latitude and Longitude stamp shows location off Interstate 91.



DRONE INSPECTION LESSONS More excellent articles:



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<https://www.nytimes.com/2018/08/14/business/drones-real-estate-construction.html>

Drone Operations Software

https://prismic-io.s3.amazonaws.com/dronedeploy-www%2Fd29a6dda-d266-4c53-9382-33b9a496582e_preparing_to_takeoff_f.pdf

SURVEYING & ENGINEERING

Implementing a drone program in a civil engineering company can often make sense by starting with the surveying department. This will have a worthwhile investment to beneficial return ratio. It is one of the safer uses of drones to minimize liability and risk, if company skeptics complain about more innovative uses. Aerial photo/video use and traffic monitoring or other department uses can follow. Records on projects and data should be managed. Surveyors do not have to work in dangerous locations (near hazardous materials, roof tops, unnavigable waters, rattlesnake country, areas of steep or slippery embankment) if a drone can obtain the same data. Working with the surveying photogrammetry professional is the first step.

Topography Image Processing with AutoCAD -as outsourced or with license by a Developer

See the list of 12 major drone software developers in the construction hubspot reference above.

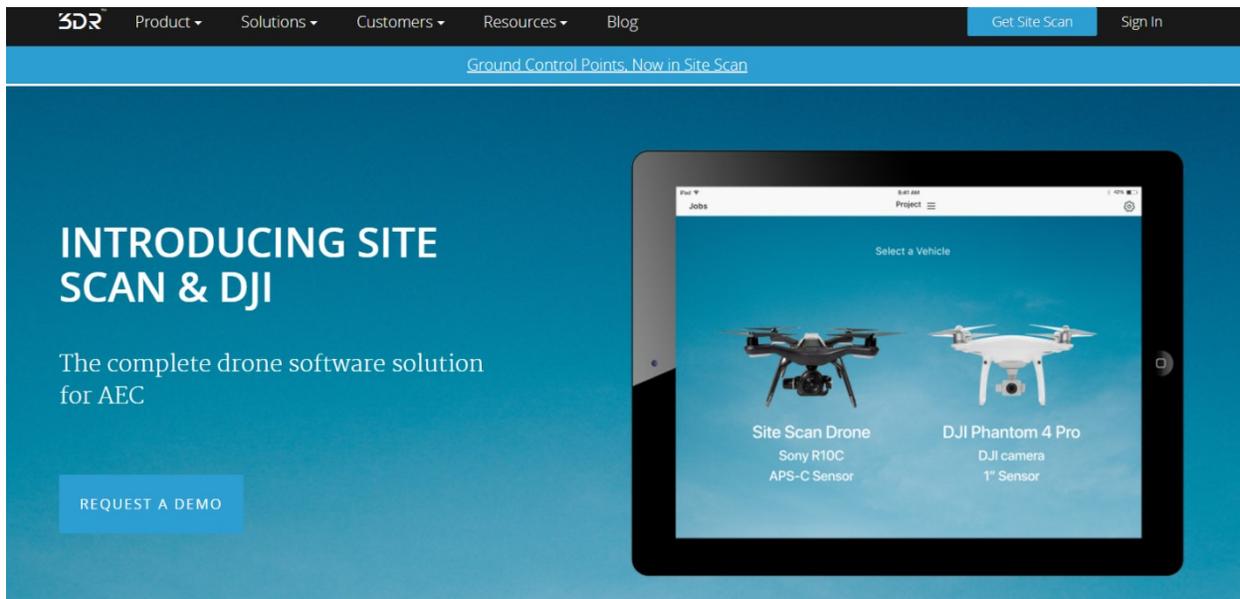
A precious metals mining site case study showed beneficial drone use. The drones assist in cut and fill cost calculations, monitor leach pad solution process, ensure environmental compliance for acreage disturbed and help in new exploration.

<https://www.identifiedtech.com/wp-content/uploads/2017/08/Identified-Technologies-SSR-Mining-Case-Study.pdf>

A company actively making licensing available to engineering and surveying firms is 3DR. Licensees may purchase a 3DR drone or use Site Scan software for their DJI Phantom 4 Pro. <https://3dr.com/> 3DR with its Site Scan product will be described more fully.



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Originally a manufacturer of drones including the Solo, 3 DR now offers drone software, leaving most consumer and prosumer hardware production to world leader DJI (Dà-Jiāng Innovations Science and Technology Co., Ltd) of Shenzhen, China, just north of Hong Kong. Yuneec, with offices in Hong Kong, Shanghai, Los Angeles and Hamburg is one manufacturing competitor; Autel Robotics is another. DJI first developed on board gyro / accelerometers to stabilize gimbal cameras, and took the lead in the drone manufacturing business, as *Forbes* magazine reports. DJI's Phantom in 2013 was a success.

3DR responded with new emphasis on software development for drones. 3DR products run on their own drones with Sony R10C camera or the DJI Phantom 4 Pro with 20-megapixel camera, -and with others planned for future support. The DJI Spark (which only shoots at 1080 pixels) is not compatible with Site Scan. The 4k Ultra High-Definition Mavic Pro, (but with 20-megapixel raw .jpg images) is also incompatible. The DJI Air 2S and Air 3 feature 5k video.

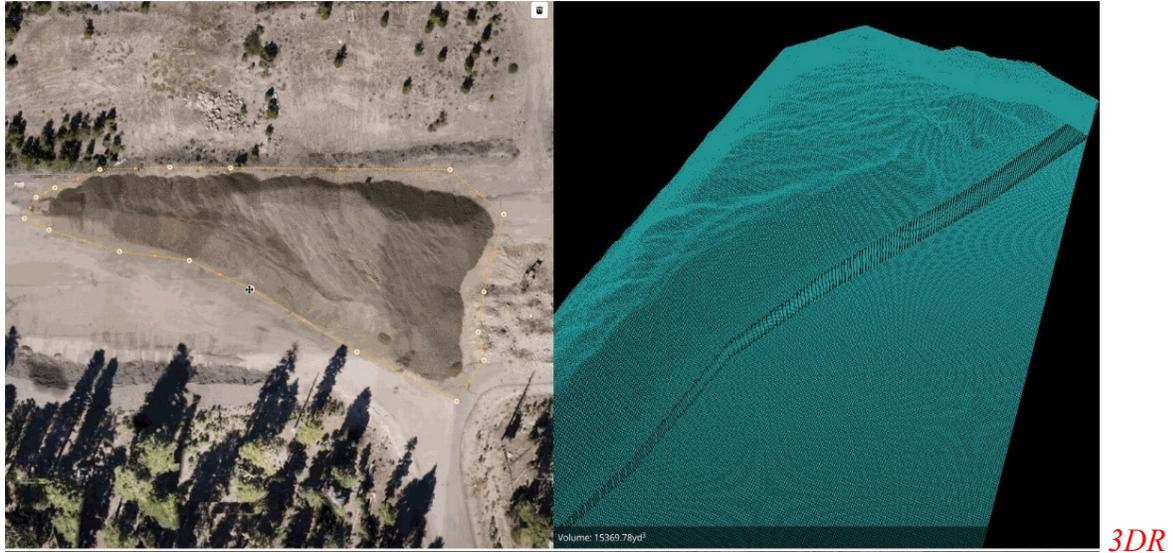
3DR offers both Site Scan and Enterprise Atlas management for engineers and surveyors. Data is shared on the cloud, only as authorized by the licensee. The 5 flight modes to capture ground data are: Area Survey, Crosshatch, Perimeter, Re-Fly Previous and Inspect mode (manually).

The pilot chooses the area for flyover off a Map satellite image, and the desired height above ground. The Site Scan App then calculates the flight path, and at the swipe of a button, the drone autonomously flies the route and lands. If batteries run low, the flight can be interrupted and resumed. Once data is uploaded to Site Scan Manager, it is processed by Pix4D or Autodesk



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ReCap. Elevation models are analyzed with cut and fill calculations, and file overlays are available to compare existing As Built to Design, etc. Contours can be prepared with interval down to 5 inches. Orthomosaic base maps, point clouds and 3D models are all easily made. One of the many uses demonstrated is stockpile volume measurement for payment:



Once control points are established, the same flight plan can determine volume shown as 15,369.78 cubic yards within the yellow polygon area. And the polygon can be reshaped to give the new volume. For fixed polygon on level surface the changing volume of the stockpile can easily be determined for payment according to material amounts processed. New control point features allow continuous triangular checking.

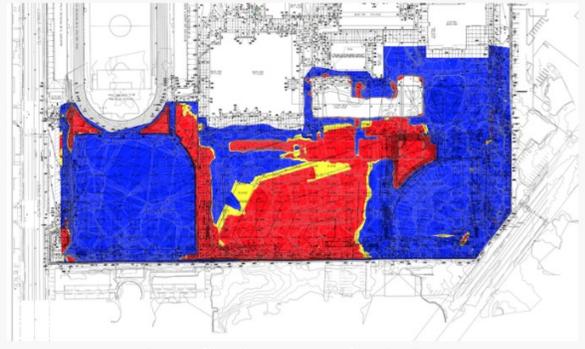


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Color elevation model imaging for cuts and fills is available for many products; but 3DR integrates with AutoCAD for complete analysis.



Aerial image of the site



Cut-and-fill analysis using data from Site Scan

For aerial topography purposes, drones can have cameras or use lasers or both. Depending on trees and other obstacles, the pros and cons of the alternative photogrammetry versus LIDAR (Light Detection and Ranging) are shown here: <https://www.spar3d.com/news/lidar/drone-lidar-vs-photogrammetry-technical-guide/> LIDAR measures distance by measuring the reflection of a laser light pulse off the ground target with on-board sensors.

Author's overhead stockpile image.

Sloped existing ground surface below the trap rock is defined and accounted for by 3DR.





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The Topcon instrument is familiar to surveyors. Here is their drone:



Landfill volume application:



The demonstration of a typical topographical mapping flight in Massachusetts is available to engineering and surveying firms interested in purchasing a license to use 3DR products. Autodesk users as shown here have already been notified.

In this December picture, the UAV pilot explains procedure before the drone to the right lifted off. This was integrated with classroom presentations and Q & A.

Engineers considering this product are encouraged to attend a future 3DR webinar and subscribe to the newsletter. License and Support pricing is available upon request.

The 22-page Surveyor's eBook is here:

<https://www.scribd.com/document/364712713/3DR-Surveying-eBook>

www.DroneDeploy.com is another source, as is www.pix4D.com



From Drone Deploy (available for licensing) project by the Author: a 3D model and plant health. Taken by autonomous lawn mower pattern of still shots from overhead, uploaded and automatically processed online. The foreground Building shown has volume of 458 cubic yards.

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Plants in the clay infield do not exist. An elevation map showing the ballfield to the right is at a higher level is also available.



How Robots (and Drones) Helped Out After the Surfside Condo Collapse August 2021

<https://spectrum.ieee.org/building-collapse-surfside-robots>

SIMPLE PLAN PRODUCTION FROM DRONE PHOTOGRAPHS

Since a plan view is from directly above, a drone image from there can be used to make engineering drawings without sophisticated software for surveying accuracy, nor for a total station crew to be present. Where engineering measurements are all that are needed without accuracy to the nearest one tenth of a foot, drones can save time. In many cases Civil Engineers can decide how exact they need to be. An As-Built measurement of septic tank manholes from two corners of the house is usually sufficient with tape measure to the nearest half foot.

Drones can be used overhead with caution to determine shapes and important areas. Just as a picture of an expensive oriental carpet is better from a drone than a photographer on a step ladder, a drone with GPS calibrated gimbal pointing straight down can produce sufficient data in a photograph. Four simple examples are shown.

1. Where zoning regulations restrict the area of impervious surface for rain to a certain percentage of the lot area, odd shapes can be photographed by overhead drone and the 5 MB picture can be downloaded and inserted into an AutoCAD drawing. The engineer can verify that the As Built condition is as designed, or within acceptable deviation. The area can be determined quickly and accepted if not close to the limit. The raster image is simply traced and sized for one or two known dimensions. Five examples I, II, II, IV & V are shown next.



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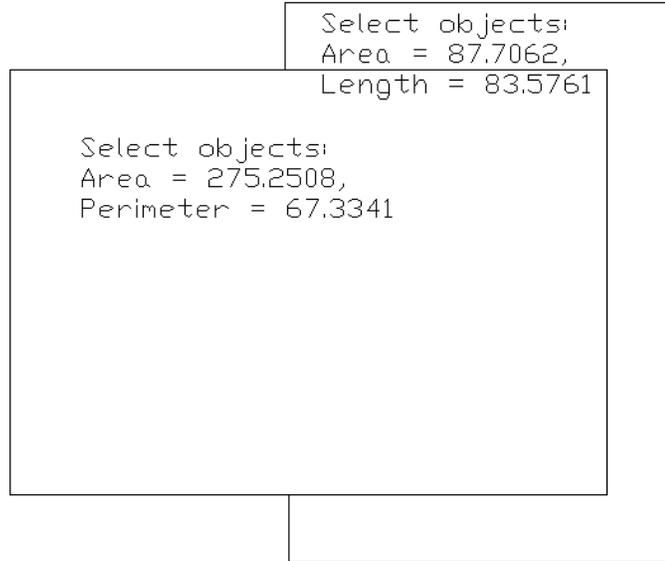
I. In the first example, a small bluestone floor and seating area pavilion is being built as part of the landscaping enhancement to museum grounds. One dimension of 14 feet was field measured by the drone pilot. The other was at 19.8' scaled to 19'-8" in AutoCAD for only slight warping and within acceptable tolerance. Considering the one inch \pm overhang of the bluestone seating, the area is very close. For more exact measuring, advanced software licensing or measurement by a ground crew is necessary. The certifying professional engineer must decide.

The picture shown allowed easy tracing of the two object shapes below it with a closed P line command. After tracing, the objects are moved away from the photo raster image. Next, the Area command showed the pavilion to have a floor area of 275.25 square feet with a perimeter of 67.33 feet, correct for the actual 14' x 19'-8". The "C" shaped seating area was 87.7 square feet with reasonable perimeter of 83.58 feet. The engineer certifying impervious area at 363 square feet is correct.





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Total impervious surface area for Zoning:
14' x 19'-8" plus seating = 363 sq feet

II. In winter, with snow clearly distinguishing remnant stone wall foundations, an overhead drone image and three tape measured distances allowed mapping of the Holiday House Hotel for working young ladies in New York City who traveled to the country. The curved retaining wall is separate.



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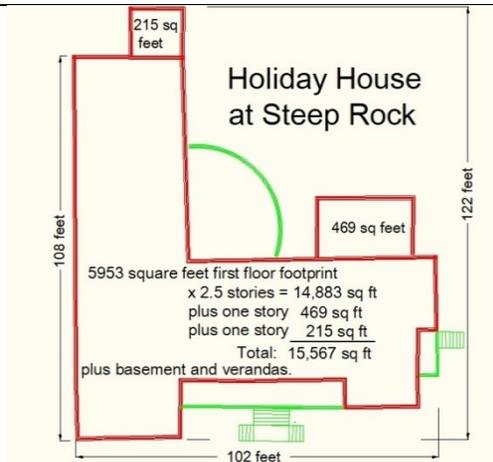
1. Surveying and measuring from the ground is challenged by trees.



2 Drone takes photo looking down.



3. In AutoCAD or simple photo editing software, walls are traced, and then moved to a separate scaled drawing.

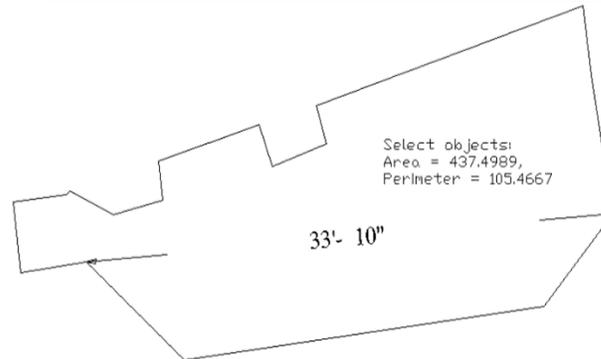


4. From historic front view photo, square footage is determined for Historians.

III. A concrete patio with odd shape against a house limited by zoning rear yard setback is proposed to be tiled. The brick and concrete raised deck will remain unchanged. The tile will not extend into the sidewalk area on the left, nor will it cover the historical stepping-stone nor the air conditioning condenser pad. One dimension of 33'-10" was field measured after the flight. A check of the longest corner to corner width of 17'-11" was close. Area of 438 square feet allows ordering of sufficient tile without waste. This is also suitable impervious area information.



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Total concrete surface area for tiling:
= 438 sq feet

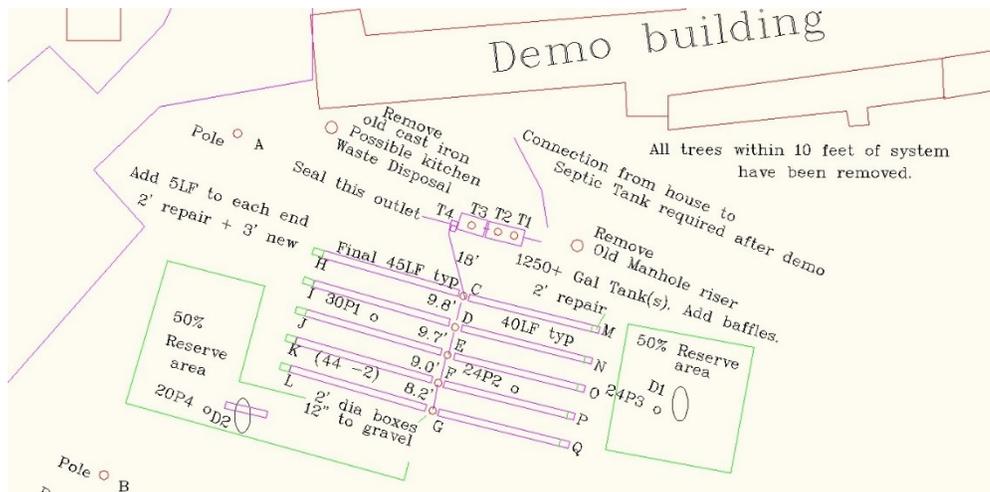
IV. An old septic system with clay hexagon tiles is being certified for conversion use as a dwelling, instead of the campsite dormitories and mess hall it served in the past. The Health Department required the Professional Engineer to perform perc tests and deep test holes in the existing system area and in the 100% reserve area. The results showed that the 400 feet of trench at 30-minute per inch perc rate could support a 3-bedroom house.

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Having an overhead image after mapping onto the AutoCAD, shows the proper circular D boxes. But while the septic tank manhole positions are correct, the tanks need to be redrawn at proper angle. The trench ends could have been red flagged to show up on the photograph as well. The right side could not be photographed from above because tree branches interfered.



Note that the fifth circular distribution box and concrete cover are slightly to the right of linear as shown.



V. The zoning office questioned a new outbuilding construction because the steep driveway had deviated from the design plan. They could not be sure the accessory structure was within the allowable setbacks. The owner flew his drone and photographed straight down, instead of paying a surveyor, and showed the subdivision map property line overlain on the GPS coordinates. The center white building is properly located and the zoning permit under open public record availability was issued.



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**FEDERAL AVIATION ADMINISTRATION LICENSING
OF UNMANNED AIRCRAFT SYSTEMS (UAS)**

Drone pilots (men and women) must meet certain standards to operate the controls of a drone, if it is used commercially to make money. The person at the controls must be UAS certified when the aircraft is being used for business or must be under the direct supervision of a certified UAS remote pilot. Certification is not necessary for recreational or hobby flying. Drones used for engineering businesses must operate under these rules as well. Making a youtube video of an aerial scene can be considered commercial business use, if the video has advertisements that make money for the moviemaker. The FAA enforces improper and illegal remote pilots, competing against legitimate pilots or not. Few cases have been brought in the initial program months, but civil lawsuit actions are possible. Case law for many aspects of drone flying is yet to be established. Obviously, drug or alcohol impaired pilots are prohibited from flying. Showing off is discouraged. Professional Engineers understand the importance of adherence to proper qualifications of personnel performing their assigned tasks.

This 14 CFR (Code of Federal Regulations) part 107 small Unmanned Aircraft Rule began on August 29, 2016. By January 2021, over 203,000 pilots 16 years of age or older were qualified. By 2024, 330,000. Each had to be properly vetted by the Transportation Safety Administration, show physical and mental fitness and understand English. The test is administered for a \$175 fee at Knowledge Testing Centers, usually at local airport flight schools. The pass rate has been 88% of individuals scoring over 70% on the 60-question two hour written test. Sometimes extra questions are included for research purposes that might not count in the final score. The test is not uniform, as the FAA draws from a pool of approved questions. Each



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test taker is given a paper copy of the 82-page *Airman Knowledge Testing Supplement Book*, available online for study before the test. It is otherwise a closed book test.

Highly trained airplane and helicopter part 61 pilots have an expedited way to become Part 107 pilots. They need not take and pass the written test, but complete an online training course in sUAS, and apply using IACRA for the additional certification.

The test is much more difficult than a driver’s license test. It requires knowledge of the rules, of weather events, how to communicate with airport traffic control towers, airspace classes and sectional aeronautical charts, such as a portion shown below. The blue wallet sized card issued after passing that Remote Pilots carry is also shown.



Portion of a Sectional Chart showing Airspace Classes (left)

Wallet sized Remote Pilot Certification Card



The magenta shading (above left) is Class E with floor at 700 feet above ground level, so drones below 400 feet are allowed there, but not in areas close to the airport with restriction to SFC = down to the surface (Class B, C & D), unless a waiver is issued. Class A is prohibited too. (faasafety.gov)

Note that many urban areas featuring large civil engineering projects are also close to traffic control tower airports. These airspace classifications prohibit flight. Washington DC or the Presidents current location as well as military bases are no fly zones. More info is at www.airmap.com The FAA has also issued a more specific map for Drones here: <https://faa.maps.arcgis.com/apps/webappviewer/index.html?id=9c2e4406710048e19806ebf6a06754ad>



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Click on the grid to see allowable drone height. Massachusetts Institute of Technology students in Cambridge, Mass should not be flying drones on campus within the Class B airspace of Logan Airport. MIT is just north of Fenway Park, shown as a stadium (just west of the runways) with restrictive rules about no flying during games, even if distant from an airport. But they can fly as high as 100 feet. For a part 107 waiver to the rules, air traffic control towers should not be called. Use the online FAA portal for either airspace waiver requests or non-airspace (see list below) waiver requests. **Apply using IACRA.** The LAANC (Low Altitude Authorization and Notification Capability) system with maps allowing approval to operate near 500 airports was implemented in 2018. LAANC allows approval by test in 20 seconds. A sample waiver to an engineering company that is public record shows allowable nighttime flying under certain conditions:

U.S. DEPARTMENT OF TRANSPORTATION FEDERAL AVIATION ADMINISTRATION CERTIFICATE OF WAIVER OR AUTHORIZATION	
ISSUED TO	Michael Baker International Responsible Person: Jim Duguay Waiver Number: 107W-2017-03634
ADDRESS -	420 Technology Parkway, Suite 150 Norcross, GA 30080
This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.	
OPERATIONS AUTHORIZED	Night small unmanned aircraft system (sUAS) operations at Hartsfield-Jackson Atlanta International Airport (KATL) for "The Mayor's 5K On The 5th Runway" event.
LIST OF WAIVED REGULATIONS BY SECTION AND TITLE	14 CFR § 107.29 Daylight operation
STANDARD PROVISIONS	
1. A copy of the application made for this certificate shall be attached to and become a part hereof.	

Study guides for FAA tests are available from multiple sources, some for free and others at cost. Classroom instruction is also available. Two convenient sources for free sample questions and answers are the FAA and 3DR. RemotePilot101 has had favorable reviews on the drone forums. Every two years, pilots must recertify online or at a test facility. As of January 13, 2020, the FAA requires all part 107 pilots and other pilots to register an IACRA (Integrated Airman Certification and Rating Application). This will lead to an FNT (FAA Tracking Number). An FTN will be required before taking any initial or recurrent knowledge test. <https://iacra.faa.gov/IACRA/Default.aspx> The FAA now has a free recurrent test with training for night flying is required. Plus Remote ID is implemented. Call 844 FLY MYUA.

A public Inquiry Registry is available on the FAA website of certified remote pilots that can be checked just as engineering licenses can be checked. The FAA website answers



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Frequently Asked Questions and published the reasons why it drafted the rules as it did after studying considerable public comment. Among the most important rules subject to waiver are:

Regulation Description:	Comments:
Do not fly above 400 feet	- Set altitude limit on controller to 120 meters
Drone must be in visual line of sight (VLOS)	- Visual Observer(s) (VO) can help. No binoc's.
Daylight flying only (1/2 hour past sunset)	- (1/2 hr before sunrise) Or drone lights & test.
No flying over people (*)	- Except Pilot and VO. Use common sense.
No flying over 100 mph	- Drones have Positioning and fast Sport Mode
Fly in Class G space only	- Check < 5 miles of a traffic control tower, etc.
No flying from a moving vehicle or aircraft	- Limits distance to VLOS (sparsely populated)
Three-mile visibility	- Drone flies in snow, but visibility restricts
Aircraft carrying people has Right of Way	- They should not be below 500', but yield if so.
Preflight check that drone is air ready	- Remove gimbal clamp. Check propellers.
Communication procedures with helpers	- Emergency contingency plans prepared.
Report accidents costing >\$500 to the FAA	- FAA may inspect or test your drone.
<i>*There are almost no drones approved for flying over people or moving vehicles without a waiver</i>	

Regulations: https://www.faa.gov/newsroom/fact_sheets

A common rule concerns privacy and what would a judge rule. Although property owners own the ground beneath them, they do not own the airspace and cannot prohibit an airplane from flying overhead; how far off the ground is not settled. An engineer seeking a specific angle over a facility has the right to enter a neighboring airspace for the data or image collecting activity. The FAA controls the air, so ordinances focus on takeoff and landing property law. New Hampshire tried to prohibit drone flights below 250 feet, to allow delivery package drones to fly between 250 feet and 400 feet. They do regulate hunting & fishing with drones. Most states have not passed laws; local municipalities or private landowners that have, might need state or FAA approval for such regulations. The 2017 Newton, Massachusetts case shows that localities cannot infringe on FAA jurisdiction. Orlando, Florida has very restrictive drone flying laws. But operators standing outside restricted areas who can see their drones, can fly there. Drones have been gun shot from the sky and the drone industry awaits favorable court case precedents. More local information here: <http://statedronelaw.com/>

Active Florida Pilot and Attorney Jonathan Rupprecht keeps 107 pilots up to date on legal news and issues. <https://jrupprechtlaw.com>



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<https://dronelife.com/2020/03/20/attorney-launches-drone-legal-database/>

A notable case drone pilots cite is from 1946 where airplanes (not drones) flying at 83 feet altitude impacted farmer Thomas Lee Causby’s chicken farming operation. A Remote Pilot should not “interfere with a property owner’s right to light, air, view, or the safe and peaceful occupation and enjoyment of his (or her) land.” All fliers are encouraged to follow the UAS Privacy Best Practices voluntarily. Professional Engineers who adhere to a higher ethical standard than most people, understand if they are “crossing a line” for intrusion into someone else’s rights or privacy.

Drones are to be registered online by the FAA for a \$5.00 fee. A 2017 court case (Taylor vs FAA) overturned this requirement, but the FAA website had not changed policy. Recreational drones must register as well, even if not flown by a part 107 Remote Pilot. Public Law 112-95 Section 336 applies. Hobbyists must receive air space authorization for airports within 5 miles as seen on the FAA’s B4UFLY app. Hobbyists are subjected to more stringent rules through the FAA Reauthorization Act of 2018. Part 107 Pilots and hobbyists must abide by Class airspace restrictions.

	<p><i>Drones affected weigh between 0.55 pounds and 55 pounds. The Mavic Pro weighs 1.62 pounds.</i></p> <p><i>Hobbyists can be insured through membership in the Academy of Model Aeronautics, which does not insure Part 107 flights. For that, 3DR supplies insurance as do private carriers, or for \$10 an hour, use Verifly.com</i></p> <p><i>Also: DroneInsurance.com</i></p>
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FLIGHT BASICS

For work subcontracted out to a drone company, these basics need not be totally understood. But for in-house drones, no matter the brand, characteristics are similar. Drone systems include the aircraft, the remote controller and the tablet. They fly by pilot manipulation



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of the controller sticks, or autonomously with built in computer processing. Press Lift Off button in the App and swipe to have the bird rise 4 feet and hover, recording its GPS home point and awaiting further instructions.

Propellers are not installed and removed each time on this Mavic Pro example model shown. A spare battery, 3 polar filters (sunglasses for over the camera lens) and carrying case are shown with the controller and tablet.

Note the decals meant to look like bird eyes. This is to discourage bird of prey attacks. Remote controller or just "Controller" with two antenna ears and two sticks attached to an iPad tablet (or mobile phone).



If an eagle circles, pilots know to increase altitude rapidly, because raptors can dive, but not ascend as fast. Some eagles are trained to take down unauthorized drones trespassing near military bases, etc.

(Forums show DJI seems to work better with Apple than some Samsung products.) Tablet displays what the camera sees, and it has touch screen buttons for the firmware App.



Read the manufacturer's and software manuals for further information.



Folded drone with sun filter removed. Round Downward sensors are visible. Transparent plastic gimbal clamp & camera cover are off in the picture to the right.



Push the Left stick forward and the drone will rise. Toward pilot and drone descends. Push Left or Right to rotate (yaw turn) the drone. Right stick forward and drone advances forward. Toward pilot and drone backs up. Left or Right for drone to fly left or right.



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Once airborne, if sticks are not touched, the drone hovers in place for manual flights. Besides the stick controls, modern drone platforms have automatic takeoff after GPS position is recorded, to allow Return to Home if pilot commands, or if signal is lost, or battery gets too low (after about 20 minutes) (55 minutes for an Atlas Dynamics). Tethered wiring can be used too. Return to Home uses forward sensors so that the drone will stop if an obstacle is in front of it (including a person). The Mavic Pro has forward and downward sensors. The downward sensors use a sound frequency that might be recognized by dogs. But it has no side or backup sensors. It is easy for a pilot to back the drone into a tree or building that would not happen if it were going forward or down. Phantom 4s are equipped with side obstacle avoidance sensor systems that help in tree and wired places. Home points should have no wires or branches above to allow a vertical descent. Landing is automatic as the ground is detected. Repair insurance is popular. Hand catching is done if grass or rocks that would break propellers are present. A Location Map window is also available, plus directional arrow showing which way the drone is flying relative to the pilot. Some calibrations are required for compass, camera and IMU (Inertial Measurement Unit).

Typically, there will be 10 to 20 satellite GPS connections to the modern drone. These give location and altitude. The number of satellites connected is displayed on the controller screen. This second signaling system is weaker than the remote controller's antennae system, but essential in most cases. Both US GPS and Russian GLONASS satellites provide free service to private users. Many country systems are being collected into the new GNSS (Global Navigation Satellite System). But buildings and trees can interfere with the controller signal.

Beyond pilot flying, there are autonomous intelligent flight functions. The most important to engineers is Waypoints, where a pilot programs or flies the drone to each location desired and records that position into memory for a flight path. Once a dozen or so waypoints are input, the pilot launches the waypoints mission function, sets desired flying velocity and watches as the drone takes control and flies the exact same pattern. The drone records the repetitive video. These missions can be saved so that the same flight can be repeated. Besides Beginner Mode for practicing, (P) Positioning (S) Sport and Fixed Wing Mode (soars like a plane), certain drone platforms can also be set for specific intelligent flight modes. This table gives an overview of firmware capabilities:

Tripod	Slow flying and turning
Follow Terrain	Adjusts altitude up and down hills
Tap Fly	Pilot sets direction & speed without sticks
Cinematic Mode	Slows turning yaw speed & stops smoother
Point of Interest	Drone circles object at set radius and speed



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Follow Me	Follows a moving vehicle or person with GPS
Active Track	Follows a moving vehicle or person with camera
Gestures	Recognizes people to be recorded
Course Lock	Sets course for stick control regardless of orientation
Home Lock	Navigates home with stick no matter the location
Waypoints	Repeats a pre-programmed course autonomously.

IMAGERY BASICS

Engineers use drones for their picture taking and video recording capabilities. Thermal imaging and LIDAR are separate. The floating, stable gimbal allows the camera to capture images while the propellers spin to stabilize in the wind. Although automatic imaging exposure settings are available, better quality is available through manual settings. The downloaded App allows adjustment of ISO (International Standards Organization) for sensitivity of a digital image sensor. For bright sunshine, set the ISO to 100. Set to over 1000 for indoor poorly lit space. As the light changes with clouds, etc. the ISO can be changed too.

Shutter speed (like 1/50th of a second) can also be controlled manually, to adjust brightness easily on the controller wheel. Focus to the center of the screen is by tap or autofocus. Focus is important, because recording at 50 feet altitude will require a different focus than on the same target at 400 feet. For better depth of field quality, consider focal length F-stop for lens aperture.

Pictures of the scene on the tablet are taken by pushing the camera button or the video button on the controller or tablet to start and stop. Video duration in seconds is shown on the screen. Each photo or video is saved to an SD card within the drone and can be transmitted back to the tablet. The images can be reviewed before leaving the site with caching onto the tablet. After landing, the pictures and videos can be downloaded from the removable SD (Secure Digital) card or micro-USB cable onto a laptop for processing, or directly for editing through the tablet or mobile device.

(Because the images are available digitally, there has been concern about privacy and whether manufacturers like DJI can view classified military or government data. After a prohibition, DJI took steps to ensure the Army of security of its images and flight paths, etc. <https://dronedj.com/2024/03/02/dji-response-drone-ban-us/>

Engineering companies will also wish to secure their drone flight and imagery data.) According to www.Digitaltrends.com, DJI alternatives are: Parrot Anafi USA with a 32 x zoom

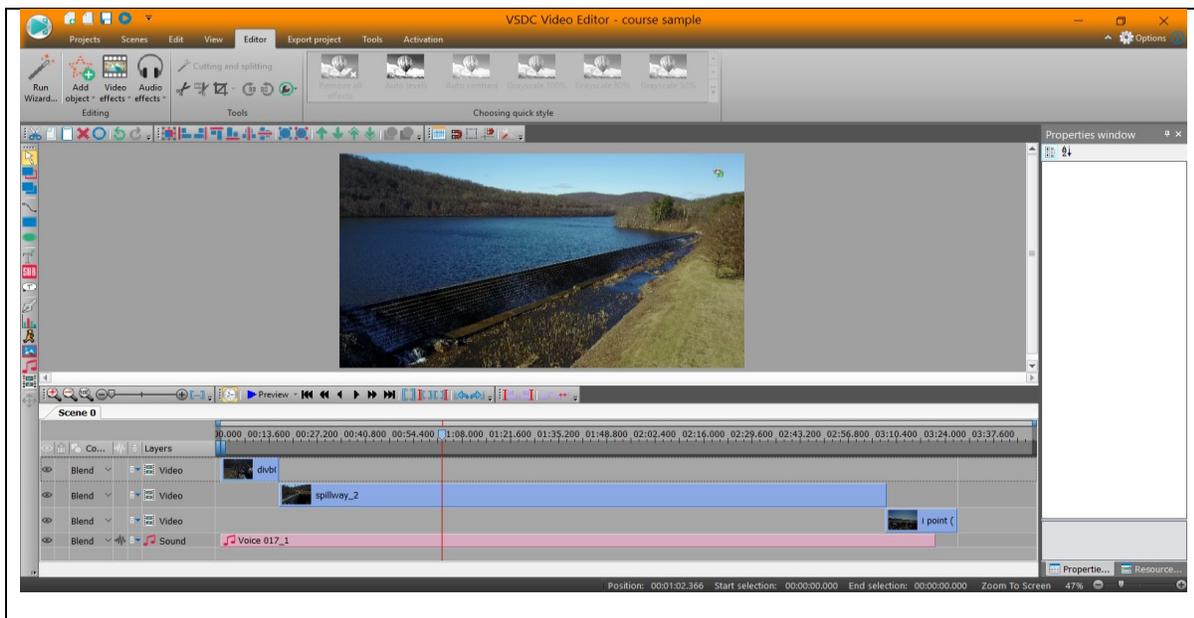


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and thermal imagery. The Yuneec H250E is a commercial hexacopter. And the Autel Robotics EVOII Pro has a 6k camera.

After downloading, the images on the SD card should be deleted to make room for future videos. 16, 32, 64 and 128 Gigabyte SD cards can be filled quickly with 4k video using about a **GB for every two minutes of video**. They can be sequentially numbered so that file 001 does not overwrite file 001 from an earlier mission. Images that are cached to the tablet allow checking for completeness from the tablet, instead of wire downloading or removing the SD Card before leaving the job.

Here is a typical video editor. Each of three separate video clips shown in blue is inserted in its timeline. Audio voice narration shown in pink can be added as shown. The preview (spillway picture) is the image associated with the cursor on the 3 ½ minute timeline shown. An example of a documentary project is for a drill rig crew preparing and conducting a thermal conductivity test. The final video showed work activity from the ground and the sky with narration as an audio Voice file and text added where relevant. A spillway editing screen is shown below:



After editing, mostly cutting out unwanted portions or changing speed, the project is exported all together, such as an .MOV file compatible with Apple products. The processed



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video file can be uploaded to YouTube, Vimeo, etc. or used as its own file, for embedment on an engineering company website for instance.



CONCLUSION

Drones are here to stay. From the Skylogic Research article above, Moore's Law and DJI technology are advancing drones at as rapid a pace as computers and mobile devices, making them better and less expensive.

Drones fill the altitude void people have sought for ages between 20 feet and 400 feet. Images taken from the ground have been around for a century and a half. Images taken from airplanes or satellites that mostly point down, are too far away to capture the detail needed by engineers, now available by drone.

As with much technology, a robotic whirly bird's ability to physically access previously denied airspace should be harvested by engineers interested in the data that can be obtained from the new perspective. Drones can cut inspection costs to pay for themselves. They are a new device in the engineer's toolbox that can improve the quality of service performed and be beneficial to our clients. So, go out and "spend some time on the sticks".

Engineers who use drones should be proud to help both their own profession and the drone industry by taking advantage of the features most suitable to their operations.

End