Drones, a New Tool for Chemical Engineering Applications

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South Texas Section of the AIChE
(American Institute of Chemical Engineers)

Dinner Meeting
January 10, 2019
Presentation Outline

- Growth of the Drone Industry
- FAA Rules for Operating a sUAS
- Basic Components of a Drone System
- Types of Drones
- Drone Energy Sources
- Drone Sensors
- Software
- Ground Control Points (GCPs)
- Photogrammetry and Elevation Modelling
- Drone Aerial Survey Workflow
- Processing Imagery From Drones
- Examples of Aerial Survey Projects
- Inspection Drones
- Online Resources
Growth of the Drone Industry

**Drones in United States**

Number of Drones

Source: FAA's Unmanned Aircraft Systems Report

**Commercial Drones in United States**

Number of Drones

Source: FAA's Unmanned Aircraft Systems Report

**Commercial Drone Use**

Commercial drones are being used for a variety of purposes.

- Insurance: 3%
- Real Estate/Photography: 6.7%
- State/Local Governments: 10%
- Agricultural: 12%
- Industrial/Inspections: 38%

Source: FAA's Unmanned Aircraft Systems Report

**Fastest Growing Industries Using Drones**

- Construction
- Agriculture
- Mining

Source: DroneDeploy's Drone Deploy Report
FAA Rules for Operating a sUAS

Small UAS Rule (Part 107) Operating Rules

- Small Unmanned aircraft (sUAS) must weigh less than 55 pounds, including payload, at takeoff
- UAS must be registered with the FAA
- Operations in Class B, C, D and E (controlled) airspace are allowed with the required ATC permission. Operations in Class G airspace are allowed without ATC permission.*
- Keep the unmanned aircraft within visual line-of-sight (VLOS) ~ ½ mile*
- Fly at or below 400 feet above ground level (AGL) or, if higher than 400 feet AGL, remain within 400 feet of a structure*
- Fly during daylight or civil twilight with appropriate anti-collision lighting*
- Fly at or under 100 mph*
- Yield right of way to manned aircraft*
- Do not fly directly over people*
- Do not fly from a moving vehicle, unless in a sparsely populated area*
- FAA Reauthorization Act of 2018, became Public Law No. 115-254 on October 5, 2018
  - An aeronautical knowledge test and new requirements are in store for hobby flyers

*Exceptions may be approved by requesting a waiver
Basic Components of a Drone System

- **Drone with camera**
- **SD Card to store Images/Videos**
- **Rechargeable Batteries**
- **Phone/Tablet (Apps)**
- **Controller**
Quadcopter Drones

**DJI Phantom 4 Professional**
- Weight – 3.1 lbs (including battery and props)
- Diagonal Size – 14 inches
- Operating Frequency – 5.8 GHz
- Max Operating Distance – 4 miles
- Max Speed – 45 mph
- Max Flight Time – 30 min (20 min)
- Battery – LiPo 4S, 5870 mAh, 15.2V
- Camera – Fixed, 1” CMOS Sensor, 20 MP

**DJI Inspire 2**
- Weight – 7.58 lbs (including batteries and props)
- Diagonal Size – 23.8 inches
- Operating Frequency – 5.8 GHz
- Max Operating Distance – 3.1 miles
- Max Speed – 58 mph
- Max Flight Time – 27 min
- Battery – LiPo 6S, 4280 mAh, 22.8V
- Camera – Zenmuse X4S, X5S & Sentera Double-4K

**DJI Matrice 210**
- Weight – 11 lbs (including battery and props)
- Dimensions – 34.9×34.6×16.1 inch
- Operating Frequency – 2.4 GHz, 5.8 GHz
- Max Operating Distance – 2-3 miles
- Max Speed – 51 mph
- Max Flight Time – 27 min (25 min)
- Max Payload - ~3.5 lbs (1.6 kg) to 5 lbs (2.3 kg)
- Battery – LiPo 6S, 7660 mAh, 22.8V
- Camera – DJI Zenmuse X4S, X5S, Z30 and XTR
- Operating Temperature - -4° to 113° F
- IP Rating – IP43
DJI Wind 4

Weight – 24 lbs (including battery and props)
Dimensions – 42 inch diagonal length, 34 inches x 34 inches x 21 inches
Operating Frequency – 2.4 GHz, 5.8 GHz
Max Operating Distance – 2-3 miles
Max Speed – 40 mph
Max Payload – 22 lbs
Max Flight Time – 25 min with 9 lbs payload (with 2 DZ-12000mAh Batteries)
Battery – DZ-12000mAh
Operating Temperature 14° F to 122° F
IP Rating – IP56 Water and Dust Resistant
Other Types of Drones
Drone Energy Sources

Hybrid **Gas-Electric** Multicopter Drone

**THE PERIMETER DRONE**

<table>
<thead>
<tr>
<th>OPERATING SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Speed</td>
</tr>
<tr>
<td>Cruise Ground Speed</td>
</tr>
<tr>
<td>Maximum Endurance*</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Maximum Expected Range</td>
</tr>
<tr>
<td>(at cruise speed)</td>
</tr>
<tr>
<td>Maximum Tested Wind Speed</td>
</tr>
<tr>
<td>Maximum Payload Capacity</td>
</tr>
</tbody>
</table>

Gas-Powered VTOL Drone

Our V2 airframe can travel nearly 500 kilometers on 3.8 liters (1 us gallon) in optimal weather conditions. This opens up its coverage area to nearly 5 times that of typical electric powered planes, dramatically increasing the number of people and places we can reach.
Drone Energy Sources

Solar-Power Fix Wing UAV
Types of Cameras/Sensors

Zenmuse X4S  
Zenmuse X5S  
Zenmuse Z30  
Zenmuse XTR  
Sentera Double  
4K RGB/NDVI
Snoopy A-Series Scanner mounted on a DJI Matrice 200

- 100 meter max range (328 ft)
- 4-5 cm Accuracy
- Tactical grade L1/L2 IMU
- Weight: 1.63 kg (3.59 lbs)
Drone Sensors

Airborne (UAV) Ground Penetrating Radar (GPR)

Subsurface features and anomalies
Drone Sensors

UAV Aeromag Surveys

Figure 6: Color-scale magnetic map containing a strong monopole anomaly that denotes the location of an abandoned gas well. Yellow circles indicate locations where CH4 levels exceeded 100 ppm. Inset is a picture of the gas well casing excavated at this location.

NETL - Methods for Finding Legacy Wells in Residential and Commercial Areas
16 June 2016
Types of Sensors Used on Drones Today

- RGB (Photographic) Cameras of All Types and Sizes
- Multispectral and Hyperspectral Imaging
- Radiometric Thermal IR Imaging
- LIDAR
- Ground Penetrating Radar (GPR)
- Magnetometers
- Methane (Gas) Leak Detection and Gas Sniffing
- Air Sampling (Air Quality, Hazardous Sources, Flare Plumes, Chemical)
- Others
Software

- Google Earth Pro (Aerial Survey Planning)
- DroneDeploy (Mission Planning and Flight Automation)
- DJI GS Pro (Mission Planning and Flight Automation)
- DJI GO 4 (Drone Settings, Compass Calibration and Photography)
- DJI Pilot (Inspection)
- GPS Tracks/EOSToolsPro/ICMTGIS PRO (GCP Positioning)
- SimActive Correlator3D (Processing)*
- Blue Marble’s Global Mapper GIS (General Mapping)
- Virtual Surveyor (Visualization, 3D Measurements including Volumes)
- FLIR TOOLS (Thermal Imagery)
- Others –Microsoft Office Suite, Snagit, Camtasia, Zoom, TeamViewer

*Pix4D, Agisoft PhotoScan, Maps Made Easy, Datumate Suite …
Ground Control Points (GCPs)

• GCPs are large marked targets on the ground, spaced strategically throughout your area of interest.

• The GCPs and their coordinates are then used to help drone mapping software accurately position your map in relation to the real world around it.

• Recommend at least 5 GCPs located in the 4 corners and the center of your map.

• Use an RTK GPS system for the most accurate reading.
Ground Control Points (GCPs)
Photogrammetry and Elevation Modelling

The process of photogrammetry requires a series of overlapping photographs to be captured. It relies on a concept called relief displacement - elevation can be calculated based on where an object actually appears on an image (its apparent location), compared to where it would appear on a planimetric (i.e. flat) surface. Other factors which must be considered include camera altitude, tilt and lens characteristics.
Understanding Elevation Data

• Elevation maps are created using standard geo-referenced information embedded in your drone imagery.
• By applying some advanced math, you can figure out the elevations by looking at differences in perspective between two or more overlapping images.
• By default, maps show elevation data relative to your drone’s take-off location.
• If you want to view elevation data expressed in height above average mean sea level (MSL) or relative to your project coordinate system, you can either add Ground Control Points (GCPs) to your map or you can use the elevation calibration tool to easily adjust the elevations in your map in just a few clicks.
Drone Aerial Survey Workflow

- Pre-Flight Meeting (Survey Objectives)
- Flight Planning (Google Earth, GIS and Customized Maps)
- Laying Out and Positioning of GCPs
- Drone Aerial Survey Data Acquisition (< 1 Hour – Days)
- Process Images (Desktop or Cloud Computing)
- Generation of Orthomosaic, Elevation Models, 3D Model
- Ancillary Products – Contours, Profiles/Cross Sections, Volumes
- Large Format Hardcopies
Mission Planning & Piloting

DroneDeploy Web App Main Mission Planning Screen

DroneDeploy iOS App Main Mission Pilot Screen

Other Mission Planning Apps - Pix4DCapture, Maps Made Easy, DJI Ground Station Pro
Cloud vs Desktop Processing

• Cloud Processing (DroneDeploy, Pix4D, Maps Made Easy, Datumate Suite)
  • Pros
    • More simplified process
    • Lower learning curve
    • Less expensive subscription service
    • Less powerful personal desktop computer/laptop required (processing performed on the servers)
    • Fairly responsive support
  • Cons
    • Less options available (fewer parameters to choose)
    • Requires high speed internet connection to upload images

• Desktop Processing (Correlator3D, Pix4D, Agisoft PhotoScan)
  • Pros
    • More options available (more parameters to select)
    • Generates better overall results
    • High speed internet connection less important (no uploading images)
  • Cons
    • Higher learning curve
    • A more powerful desktop computer/laptop required (Dell XPS 8920 w/ 64GB RAM)
    • More expensive subscription service
Summary of Actionable Data Products from Drones

- High Resolution Aerial Photos and Videos
- 2D Orthophotomosaics (Photo Maps)
- Digital Surface Elevation Models
- Digital Elevation Models (DEM) - less structures and vegetation
- 3D Point Clouds
- 3D Surface Models
- Surface Contours and Topographic Maps
- Length, Area and Volume Measurements
- Surface Profiles and Cross Sections
- Multispectral and Thermal IR Maps
- Geophysical Surveys (Magnetic, Gravity, GPR, etc.)
- Methane (Gas) leak detection and gas sniffing
- Air sampling (hazardous sources, flare plumes, chemical)
Example of Aerial Survey Project
Select Sands Corp
Ozark Operations, Arkansas
2 Passes, Perpendicular Grid Pattern
Sandtown Quarry (30 Acres)

Orthomosaic Photo  Digital Surface Elevation Model  3D Model
Construction Site Monitoring (e.g., Well Pad, Production Facility)
# Quarterly Stockpile Volumes Report

<table>
<thead>
<tr>
<th>Stockpile</th>
<th>Area (sq. ft.)</th>
<th>Volume (cu. ft.)</th>
<th>Volume (cu. yd.)</th>
<th>Tons</th>
<th>Reference</th>
<th>Totals</th>
</tr>
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<tbody>
<tr>
<td>100 Mesh #1</td>
<td>8,048.00</td>
<td>39,898.00</td>
<td>1,218.64</td>
<td>2,439.61</td>
<td>Flat 204</td>
<td>2,439.61</td>
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<td>100 Mesh #2</td>
<td>4,859.00</td>
<td>38,488.00</td>
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<td>1,824.47</td>
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<td>100 Mesh #3</td>
<td>28,385.00</td>
<td>190,798.00</td>
<td>11,140.66</td>
<td>14,260.04</td>
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<td>14,260.04</td>
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<td>100 Mesh #4</td>
<td>26,584.00</td>
<td>209,555.00</td>
<td>7,701.29</td>
<td>9,934.65</td>
<td>3D Polygon</td>
<td>9,934.65</td>
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<tr>
<td>100 Mesh #5</td>
<td>18,725.00</td>
<td>102,143.00</td>
<td>3,783.26</td>
<td>4,842.57</td>
<td>3D Polygon</td>
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<tr>
<td>100 Mesh #6</td>
<td>8,654.00</td>
<td>55,926.00</td>
<td>1,670.22</td>
<td>1,229.68</td>
<td>Flat Minimum</td>
<td>1,229.68</td>
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<tr>
<td>100 Mesh #7</td>
<td>9,042.00</td>
<td>10,824.00</td>
<td>400.89</td>
<td>513.14</td>
<td>3D Polygon</td>
<td>513.14</td>
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<tr>
<td>40-70</td>
<td>18,812.00</td>
<td>228,076.00</td>
<td>8,447.25</td>
<td>10,812.48</td>
<td>3D Polygon</td>
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<tr>
<td>Drums Waste</td>
<td>9,386.00</td>
<td>63,490.00</td>
<td>2,283.89</td>
<td>2,925.37</td>
<td>3D Polygon</td>
<td>2,925.37</td>
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<tr>
<td>Raw Feed #1</td>
<td>22,197.00</td>
<td>175,569.00</td>
<td>5,169.69</td>
<td>8,341.75</td>
<td>3D Polygon</td>
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<tr>
<td>Raw Feed #2</td>
<td>3,175.00</td>
<td>16,190.00</td>
<td>599.63</td>
<td>767.53</td>
<td>3D Polygon</td>
<td>767.53</td>
</tr>
</tbody>
</table>

### Total Volumes
- **Total Tons**: 10,109.28
- **Total Volumes (cu. yd.)**: 45,443.35
Traditional Stockpile Inventory Method

- Performed Annually
- Time Consuming and Labor Intensive Resulting in Higher Costs
- 1-2 Weeks Turnaround from Start to Finish
- Safety Risks with Survey Team Climbing on Stockpiles
- Summarized Final Report for Each Site
Drone Stockpile Inventory Method

• Performed Quarterly
• 7 Days or Less Turnaround from Start to Finish
• Digital Data delivered via Dropbox including Georeferenced Orthomosaic Photo, Digital Surface Elevation Model and 3D Model for Each Site
• Stockpile Polygons for Each Site Visually Confirmed Collaboratively
• Detailed Final Report
• 34”x44” (ANSI E) Scaled Hardcopy Plots Provided for Each Site
Inspection Drones
DJI M210 – External Inspection Drone
Close-up Inspection Work
SKY - FUTURES
Unmanned System Solutions

Single Man UAV Team
Live Flare Inspection
35km/h Winds
Thermal Inspection
Radiometric Thermal Imagery

Gray Palette

Rainbow Palette
Flyability Elios – Internal Inspection Drone

INTEGRATED PAYLOAD
Simultaneous full HD and thermal imagery recording, and adjustable tilt angle.

LIVE 2.4 GHZ VIDEO FEEDBACK
Robust digital video downlink for beyond line of sight operation, even in metallic environments.

ON BOARD LIGHTING
Powerful LEDs for navigation and inspection in dark places.

PROTECTIVE FRAME
Carbon fiber structure, collision-tolerant up to 15 km/h. Modular design for easy maintenance.

CONTINUOUS OPERATION
Batteries can be changed in seconds.

POST-MISSION REVIEW
After finishing the inspection flight, our software presents mission data for future reference.
Drone Inspection Resource Efficiencies

Table 1: Case Study Resource Efficiencies

<table>
<thead>
<tr>
<th>Activity</th>
<th>Resource Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flare Inspection (unplanned)</td>
<td>60%</td>
</tr>
<tr>
<td>Flare Inspections (2)</td>
<td>80%</td>
</tr>
<tr>
<td>Electrical Substation Thermal Imagery</td>
<td>90%</td>
</tr>
<tr>
<td>Confined Space Inspection</td>
<td>80%</td>
</tr>
<tr>
<td>Unit Transformer Inspection</td>
<td>90%</td>
</tr>
<tr>
<td>Two-dimensional top-down photos of units and</td>
<td>80%</td>
</tr>
<tr>
<td>oblique angles</td>
<td></td>
</tr>
</tbody>
</table>

“Unmanned Aircraft Systems (UAS): Case Study that Highlights Challenges and Opportunities”


Figure 6. Case Study Confined Space and Flare Mission Pictures
Drone Inspection Cost Savings

- **Onshore Oil and Gas Drone Inspection Saves Client $4m in Egypt**
- **North Sea offshore structural drone inspections saved Oil & Gas client 80% cost**
Using of Drones To Investigate Major Industrial Accidents

• Assessing damage to ensure investigation team safe access to the incident site;
• More accurate recording of the incident site via aerial stills and videos; and
• Easier-and-earlier assessment of the extent of damage for the purpose of recovery and business resumption.
Drone Inspection Advantages and Disadvantages (Offshore Oil Platform)

**Advantages:**

- **Safety** – UltraHD 4K quality up close image without a man’s presence onto the inspected objects,
- **Cost saving** – Drone inspection is cheaper than using a helicopter while also maintaining the same image quality,
- **Time saving** – The system’s mobility and its ability to rapidly analyse gathered data reduces the time of defect detection and repair to a minimum,
- **High productivity** – Low costs and short time of taking photos make for the most effective way of the offshore oil platform’s inspection,
- **High quality inspection** – our trained pilots are able to fly very close to the inspected object. Together with our engineers’ knowledge we are able to rapidly locate and diagnose even a thermal related problem.
- **The best thermal imaging equipment** – using highest quality thermal imaging cameras we are able to detect, among others, corrosion, consumption and breakage of the inspected objects.

**Disadvantages:**

- **Short flying time** – short flying time due to low battery durability requires coming back to the starting point every 15-25 minutes. However, we have a lot of batteries as well as a mobile recharging station to ensure the consistency of inspections,
- **Weather restrictions** – considering relatively low weight of the drone and considerable amount of electronic elements we must not fly when the wind’s speed exceeds 18 m/s, when it’s raining or snowing.
Online Resources

• FAA/UAS – http://www.faa.gov/uas
• FAA Federal Drone Registration - https://registermyuas.faa.gov/
• Know Before You Fly - http://knowbeforeyoufly.org/
• UAS Pilot Knowledge Test Prep - https://www.faa.gov/uas/getting_started/fly_for_work_business/becoming_a_pilot/
• Remote Pilot 101 - https://remotepilot101.com/
• UAV Coach - https://uavcoach.com/
• Dronedpedia - https://dronedpedia.xyz/
Over 700 industry leaders attended the 2018 Summit, from companies including:

"The Energy Drone Coalition Summit is an intensive course in meeting the energy industry's best minds. With the high quality of attendees at EDC, we felt as though we had a direct line to share valuable information with key decision-makers in this evolving industry." — Pat Lohman, Vice President, Energy, PrecisionHawk
Q&A

Any additional questions or comments?
Thank you!!

Thanks To The AIChE South Texas Section for the Opportunity To Provide You an Overview of Drones, a New Tool for Chemical Engineering Applications
Bio

- B.S and M.S in Geology
- 34 Years Working in Oil & Gas – Gulf, Chevron, Halliburton, Devon Energy, Fieldwood Energy
- Various Geology and IT Leadership Positions
- Purchased 1st Drone in 2015
- Started Raptor Aerial Services LLC in February, 2017
- FAA Part 107 sUAS (Drone) Exam/License in March, 2017
- >450 flights logged in several different States
- Attended Drone-related Conferences and Workshops
- Networking and Business Development
- Technical Presentations and Courses on Drones
Mike Allison
Raptor Aerial Services LLC
www.raptoraerialservices.com
mike@raptoraerialservices.com
832-242-4406
Backup Slides
LAANC is the Low Altitude Authorization and Notification Capability, a collaboration between FAA and Industry. It directly supports UAS integration into the airspace.

It provides access to controlled airspace near airports through near real-time processing of airspace authorizations below approved altitudes in controlled airspace.

LAANC is available at nearly 300 air traffic facilities covering approximately 500 airports. If you want to fly in controlled airspace near airports not offering LAANC, you can use the manual process to apply for an authorization.

The capability is in beta throughout 2018, and seeks to test the capability nationwide; the results will inform future expansions of the capability.

**Houston area airports covered by LAANC**
- IAH-George Bush Intcntl/Houston  HOUSTON   TX
- DWH-David Wayne Hooks Mem     HOUSTON   TX
Enchanted Rock State Natural Area
Fredericksburg, TX (~750 Acres)
NEW! DJI Phantom 4 RTK

- Announced October 15th
- Long Battery Life up to 30 Minutes.
- Fewer GCPs Required.
- RTK Horizontal Positioning Accuracy: **1cm**+1ppm*.
- RTK Vertical Positioning Accuracy: **1.5cm**+1ppm*.
- Absolute Horizontal Accuracy of Photogrammetric Models: **5cm** (When flying at 100m height, 2.7cm GSD, sunny.)
- Available Now. Total “Estimated” Cost with Base Station: **Under $10,000**

*When using D-RTK Base Station*
DJI Mavic 2 Enterprise (Dual)

- Announcements on October 29th and December 20, 2018
- 31 Minute Flight Time
- 12MP 1/2.3 CMOS sensor with 24-48mm optical zoom function and 3x digital zoom
- Accessories include a 2,400 lumens spotlight, speaker with a 100-decibel projection power and Beacon, a strobe light designed to be seen up to almost five kilometers away
- Dual: FLIR MSX®, Spot Meter, Area Measurement and Isotherm
- Available Now. Starting Cost: $2,000-$2,700
Texas State Parks & Wildlife
Enchanted Rock SNA
Fredericksburg, TX
Enchanted Rock State Natural Area
Fredericksburg, TX (~700 Acres)
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Enchanted Rock State Natural Area
Fredericksburg, TX (~750 Acres)
Results

Data has been provided to the Texas Parks & Wildlife and University of Houston Geophysics Department.

- The Park plans to use this Data for Biological Impact, Training and Planning.
- UH holds an Annual Geophysics Field Camp at Enchanted Rock. The Data will be used by Students during the Field Camp.