Engineering for One Planet Inclusion: Leveraging Emergent Technologies and Project-Based Learning

Patrick Sun, Ph.D., Arthur Huang, Ph.D., Vicente Sosa Landivar

College of Engineering and Computer Science
Rosen College of Hospitality Management
University of Central Florida

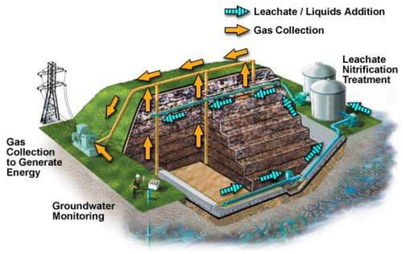
Contact: arthur.huang@ucf.edu; Patrick.sun@ucf.edu

Municipal Solid Waste Landfills:

Sustainability has become an increasingly urgent global priority. In the United States alone, each person generates between 4.5 and 5 pounds of trash daily, contributing to a staggering 300 million tons of waste annually. This waste management crisis directly impacts multiple United Nations Sustainable Development Goals.

Municipal Solid Waste (MSW) landfill operations face complex environmental challenges, including the management of dust emissions, waste containment, storm water runoff, cover material stability, leachate control, odor mitigation, and greenhouse gas emissions.

This ASEE project aims to leverage this context and a hands-on project to teach undergraduate civil engineering students and graduate students in travel technology programs in learning about key principles in the Engineering for One Planet Framework.



Nations Sustainable Development Goals

This waste management challenge intersects with several United Nations Sustainable Development Goals (SDGs), particularly:

- SDG 11: Sustainable Cities and Communities
- SDG 12: Responsible Consumption and Production
- SDG 13: Climate Action
- SDG 10: Reduced Inequalities

Experimental Setup

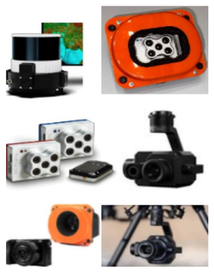
Matrice 300 Drone

M300 drone

The Matrice 300 is a 6 directional sensing and positioning drone that counts with a battery life of 55 minutes of flight time that is compatible with a vast number of payloads.

Sensing Payloads

H20T, P1, L1
Micasense RedEdge Mx-Dual, Altum PT



Sensing Payloads

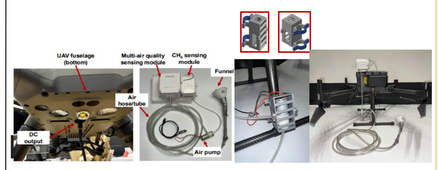
RTK Units & Weather Station

DJI M300 RTK is a drone RTK base station that gives centimeter leve RTK.
Emlid Reach RS2+ is a GNSS base with centimeter-level RTK and PPK flexible to various platforms.

Method and Materials

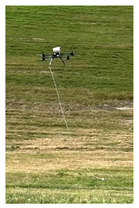
In order to get the 3D models that will serve us to calculate the volumes and settlement of Landfills there is multiple steps that are to be taken to followed. Setting up the drone based on the payload being used, planning the route, setting the RTK unit, flying the drone, retrieving the data, processing the data starting on DJI terra, LP360, and ending on ArcGIS Pro. The steps listed tend to vary depending on the payload used, and in this case is worth mentioning we are using the DJI Lidar(L1) as base. Extra peripherals may be implemented like could be methane detectors for air quality checks.

1.The methane sensor is integrated into DJI M300 by connecting a Multi-Air Quality sensing module with a CH4 module into an air hose that connects to an air-pump with a funnel at the end. This is done with the help of a 3d printed support.

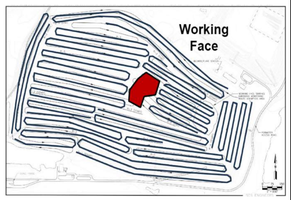


Air Quality Module Integration

2. To plan the route for odor sensing it is required to subdivide the route into smaller sections for the drone safety.

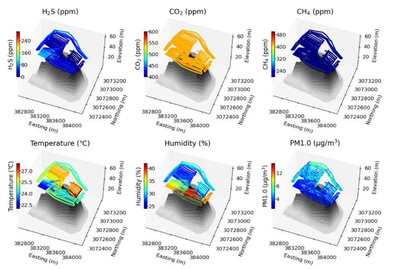


Mission Pictures



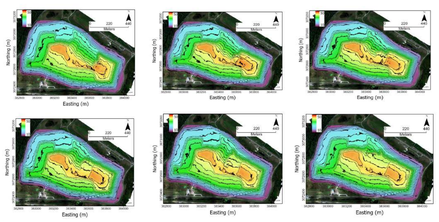
SEM Routes

3. The study gave the following results for the mission done on Nov. 2023



Air Quality Study(Nov. 2023)

4.From the Lidar camera the following results were given by surveying starting May 2023(Top Left), Sep. 2023, Oct. 2023, Nov. 2023, Dec. 2023, and Jan. 2024(bottom right)

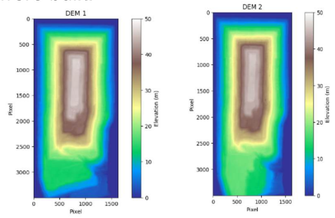


DSMs from Lidar(2023-2024)

5.At a different location at Orange County Utilites Class 1 Landfill a mission was conducted back on 04/09/2024 and other on 10/08/2024

Orthomap(10/08/2024)

6. Processing the images in DJI Terra, Lp360, and ArcGIS Pro the DEMs were built.



DEMs (04/09/2024 vs. 10/08/2024)

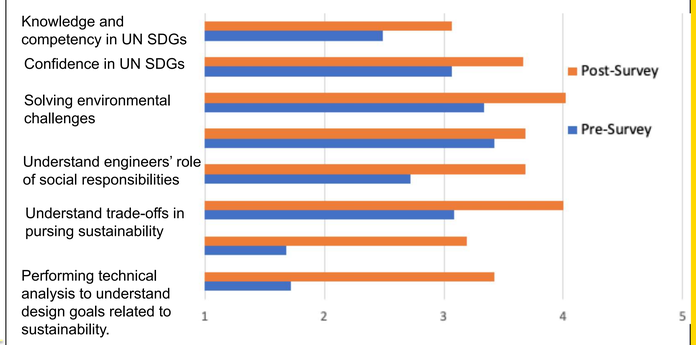
Assignment and Intervention Example

We created a course module introducing sustainability and EOP framework in HMG 6738 and EGN 3331 classes at UCF. We created a class presentation showcasing the case study and created 3D objects in video formats to students. Further, to reinforce learning outcomes, we designed a hands-on assignment that challenged students to address the following questions:

- If the landfill is a Class-III landfill, which only stores concrete debris (doesn't degrade). In addition, there is no additional waste has been dumped on top of the landfill between the first survey and second survey. What is the average strain in z direction, at the location (x=2861 px and y=6264 px) due to self-weight? Please list formula and computation process.
- If the landfill is a Class-I (municipal solid waste) landfill instead, with a lot of food waste and household waste, which can cause biodegradation during time. The bio-degradation will cause the green-house gases, such as methane (CH4) and carbon dioxide (CO2). Another reason for the decrease in elevation (or settlement) during the 4 months for a Class-I landfill is biodegradation of the municipal solid waste. Landfill operation will collect and treat the landfill gases, such as methane (CH4) and carbon dioxide (CO2). Do you know what is negative effect if excessive methane (CH4) and carbon dioxide (CO2) are emitted to our environment?

Evaluation

We conducted pre- and post-intervention surveys with 47 second-year engineering students enrolled in the Mechanics of Materials course. The intervention consisted of a classroom presentation and a hands-on laboratory assignment. The study was approved by UCF's IRB. The results demonstrated statistically significant improvements across all major assessment areas, such as students' knowledge of UN Sustainable Development Goals (UNSDGs), their competency in identifying environmental challenges and solutions, their confidence in understanding engineers' social responsibilities, and heir ability to perform technical analyses that incorporate environmental and social impact considerations. Statistical analysis using t-tests confirmed significant improvements in all measured domains.



Key takeaway Lessons

- Student feedback and evaluation demonstrated that undergraduate engineering students found significant value in real-world project assignments, which provided opportunities to develop systems thinking and complex problem-solving skills.
- Project-based learning proved to be an effective method for incorporating the Engineering Opportunities Program (EOP) framework into existing STEM curricula without requiring additional courses.
- Complementary activities such as mentorships and internships would further enhance students' practical skill development and professional readiness.

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