UAV-SIRMS: Seismic Infrastructure Risk Management System with Unmanned Aerial Vehicles

NewSpace @Berkeley

USRA

April 26, 2024

MEET THE TEAM

Ally Schiffmaier
Computer Science

Alysa Boada
Aerospace Engineering

Isaac Tsang
EECS

Priscilla Jou
Project Manager

Hannah Wehbeh
Aerospace Engineering

Akshath Mirukula
Business

Youyang Qin
Architecture

AGENDA

01 OVERVIEW

THE PROBLEM

1989 - *The Bay Bridge collapses during the Loma Prieta earthquake*

Current Inspection Methods are Limited:

Human Inspection

Manual inspections involving personnel scaling structures are dangerous, incur significant costs, and require considerable time.

Manual Drone Inspection

Piloted drones still bear substantial costs and demand extensive pilot training to navigate safely.

OUR SOLUTION

Last Semester, we developed a CONOPs document for a ***UAV Seismic Infrastructure Risk Management System***.

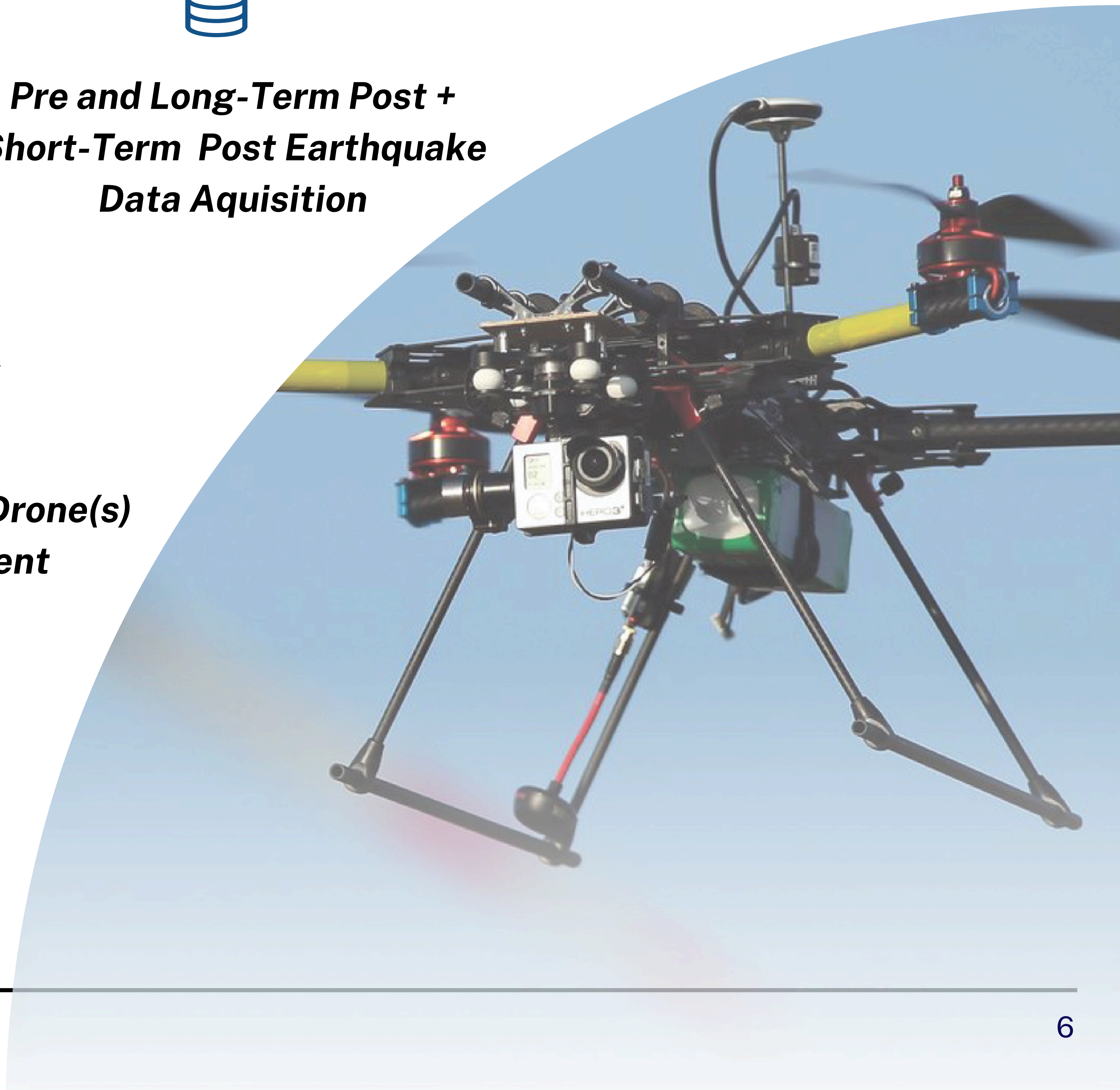
UAV-SIRMs provides detailed assessments of infrastructure using autonomous drones and algorithms for both pre-earthquake maintenance and post-earthquake response.

Pre-flight Planning + Analysis

Autonomous Drone(s) Deployment

Pre and Long-Term Post + Short-Term Post Earthquake Data Aquisition

Real-Time Data Transmission and Risk Analysis



MOVING FORWARD...

This Semester, we dove into the Business + Development End.

SOFTWARE SPECIFICATION

Prototype Data/Reasoning Services

BUSINESS + MARKETING

Market Research
Total Addressable Market
Value Proposition
Marketing Plan

HARDWARE

CAD Prototype
Material Components + Cost
Physics

02 BUSINESS + MARKETING

NewSpace @Berkeley USRA

OUR VALUE PROPOSITION

With ***increasing government focus*** and r**ising infrastructure age**, we offer an innovative solution.

Faster and Instant Detection of Faults

Higher Detailed Analysis

Less Labor Intensive

Advanced Detection Technologies + Software

Cheaper Maintenance Cost

MARKET RESEARCH

HIGHWAY INSPECTION

Serviced by CA Dept. of Transportation

ROAD CHARGE PROGRAM

On track to be implemented in 2027 - Citizens pay for maintenance + inspection based on drive activity

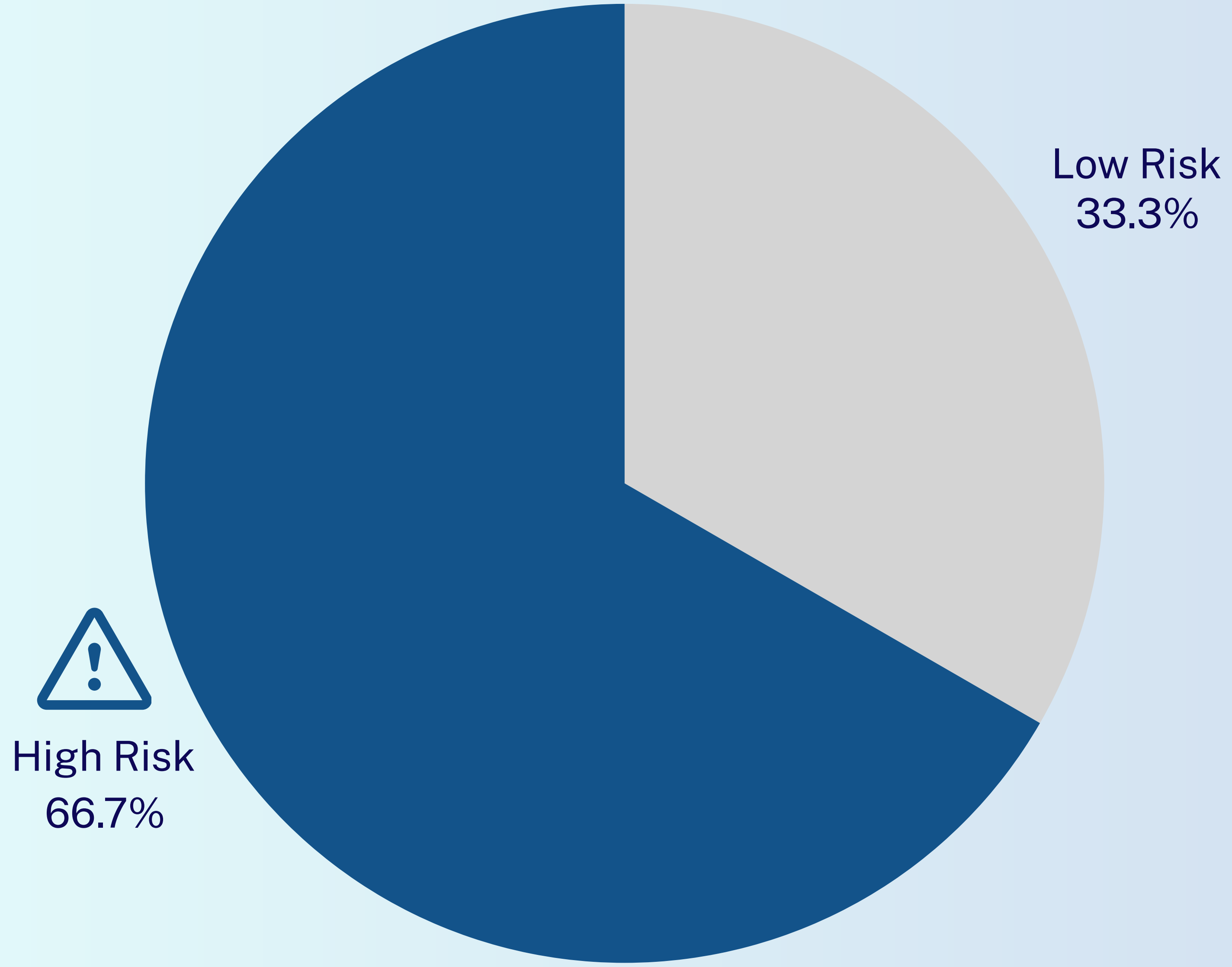
Could Fund UAV-SIRMS

ZERO THREATS

Zero Private Sector Competition

TOTAL ADDRESSABLE MARKET

2/3 of California lives in High Risk Earthquake Areas



MARKET APPROACH

Direct and personalized sales intensive strategy - 1 on 1 engagements to tailor solutions effectively

PRIMARY MARKET

LOCAL + REGIONAL GOVERNMENTS

Routine + Emergency Monitoring of Earthquake Prone Infrastructure

Continual Assessment

Emergency Response + Monitoring Capabilities in Disaster Scenarios

SECONDARY MARKET

CONSTRUCTION + UNIVERSITIES

Maintain facility compliance with safety standards

Routine Maintenance

Upgrade Evolving Facilities

CASE: REGULAR MONITORING

LA Greater Area

MAP ASSESSMENT	STRUCTURE SPECFIC CHARGES	INSPECTION COSTS	ESTIMATE DRONE FLIGHT TIME + COST	SUM UP TOTAL COST
Access total area and identify specific structures to inspect	Roads, Buildings, Bridges, etc.	Multiply total metric by Respective Unit Price	Based on Speed + Coverage Capabilities Variable Hourly Operation Rate of Drone	Sum all costs to find Total Service Charge

03 SOFTWARE SPECIFICATIONS

OBJECTIVES

PRIMARY OBJECTIVE
To Efficiently Take and Transmit Data from Drone Inspection

SECONDARY OBJECTIVE
To use Artificial Intelligence to Analyze Data from Drones

Pre-flight Planning
Determine the best path for drone

Test Case Considerations
Ground communication will likely not stay intact after earthquake

Other Considerations
Size of upload, cloud service provider, privacy of data

Data Analysis
Requires high accuracy + precision

High Automation
Elimination of manual labor

Data Presentation
User-friendly format

PRIMARY OBJECTIVES

ROUTE PLANNING

Determining optimal data collection route with flight and distance limitations

OUR SOLUTION

Utilizing Clarke-Wright Savings Algorithm
Graphing intersections of roads into “nodes”; drone depot as start & end

Optimize based on time

Utilizing Google Maps API

Can iteratively improve and add conditions

DATA TRANSFER

Transferring data from drones to secured storage with emergency bandwidth limitations

OUR SOLUTION

Prioritize Important Data
Need to identify what data is most important for decision making

Usage of Satellite Communication
Much more reliable in areas where it is remote or disaster-affected

SECONDARY OBJECTIVES

NEED

To accurately analyze the road condition, and present it in a user-friendly format

CURRENT SOLUTION

Department staff needs to drive each road and carefully identify cracks or distresses of roads, if any

Uses **Pavement Condition Index (PCI)** to assess road quality
Scaled from 0 to 100
Categorized roads into "Poor" to "Excellent" condition
Determine strategy of treatment

Some agencies use Pavement management system to systematically quantify PCI

OUR PROPOSED SOLUTION

Using **AI** to speed-up and optimize process in inspection

Need to **pre-process road images** to reduce noise

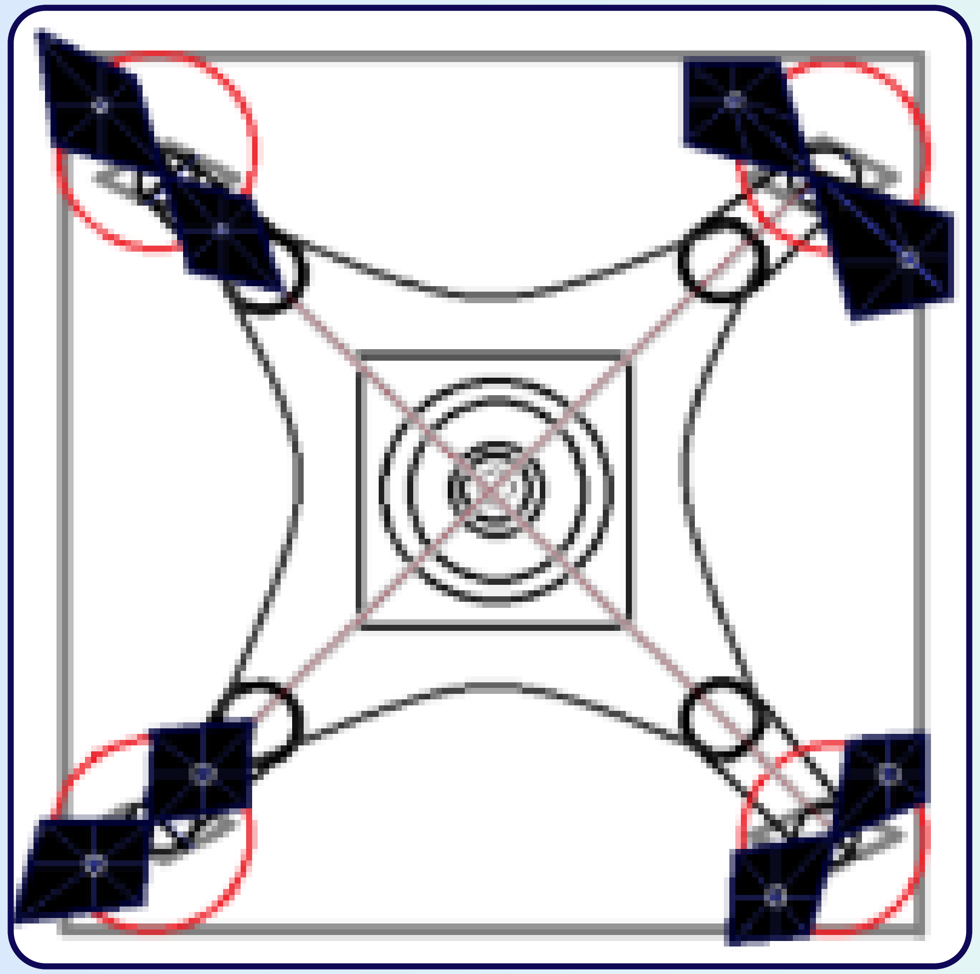
Using computer vision to detect crack, potholes, etc.
Continue usage of PCI (Proven method)
After AI detects the amount of suspected damages, Calculate that road section's PCI, Categorize the road's condition, and provide strategy of treatment
Prioritize highly important/heavy traffic roads

Visualize **condition** of roads on map; provide **ease of use** in system

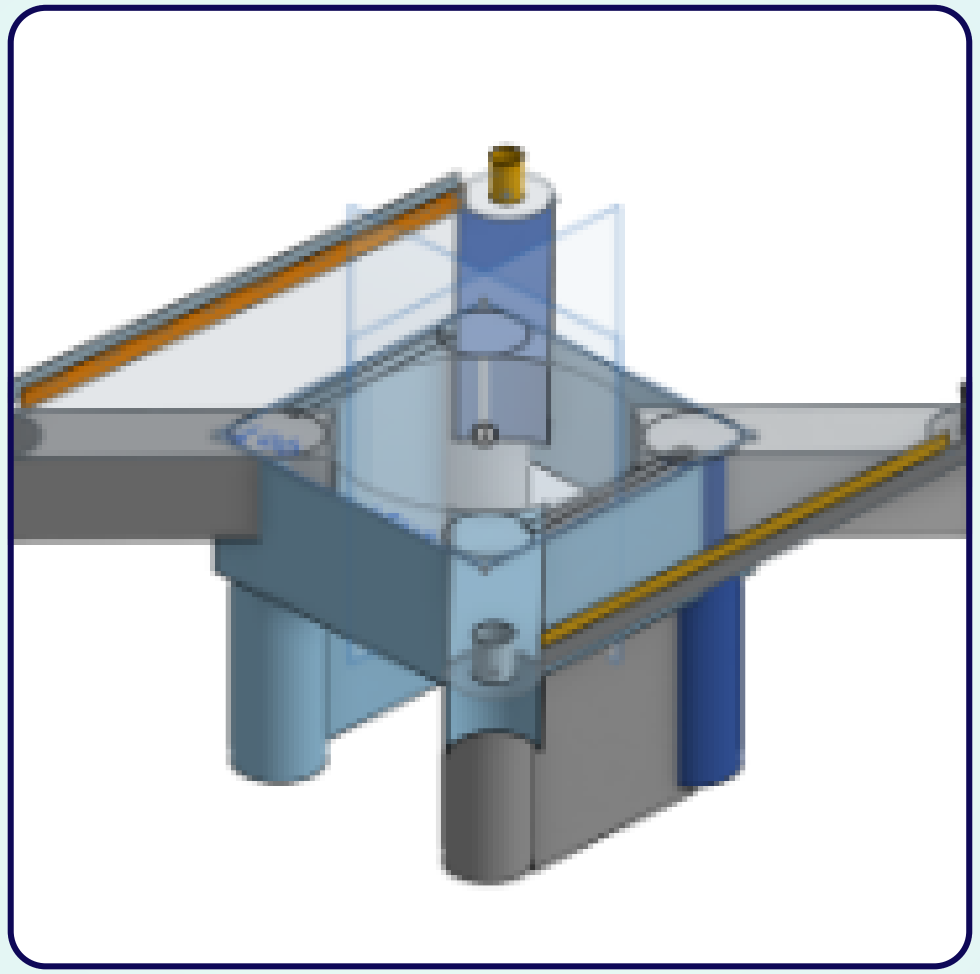
04 UAV DRONE PROTOTYPE

NewSpace @Berkeley USRA

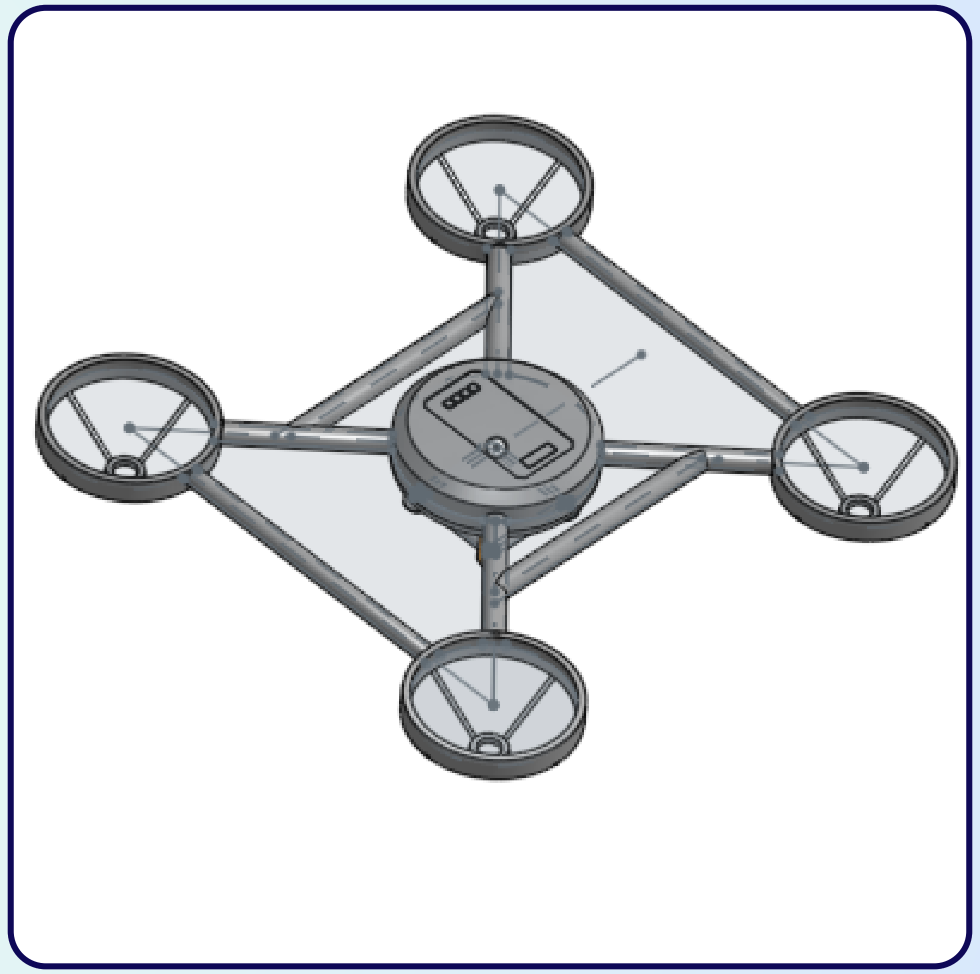
2D TO 3D: DRONE MODEL



Sketch



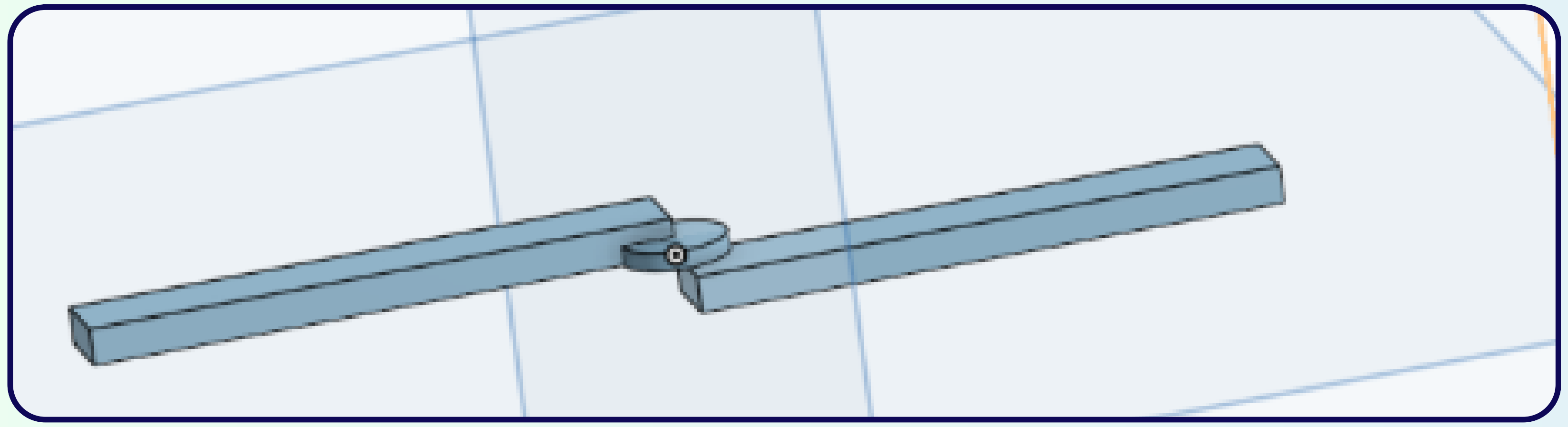
CAD



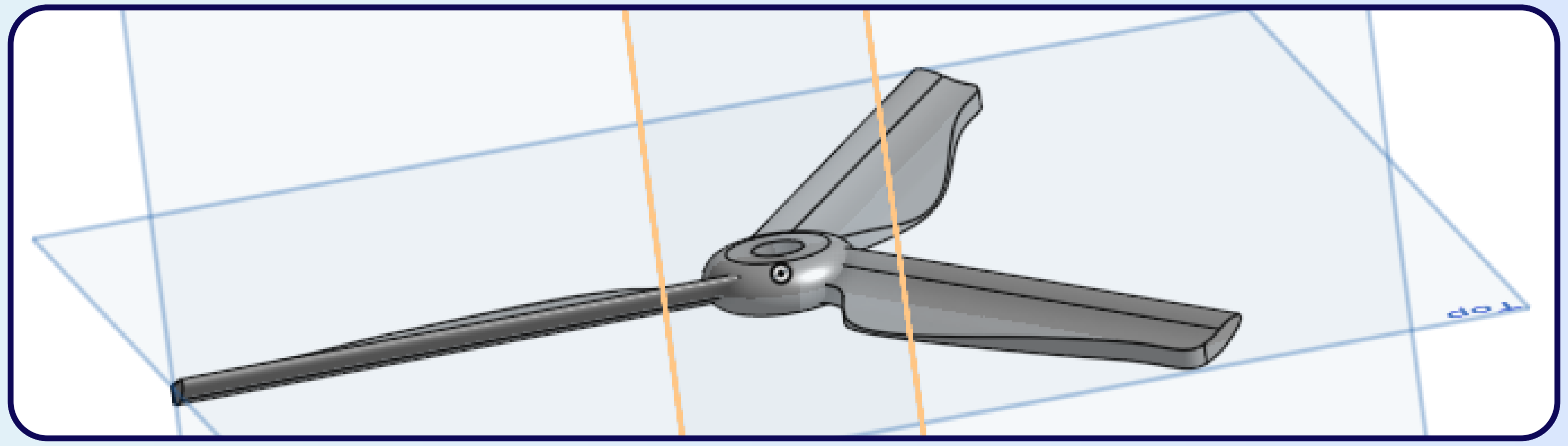
Prototype

Inspired by DJI’s Phantom 3 and Matrice 300 RTK Drone
Adapted for Increased Aerodynamics, Added Component Drag, and Maneuver in Flight

PROPELLERS

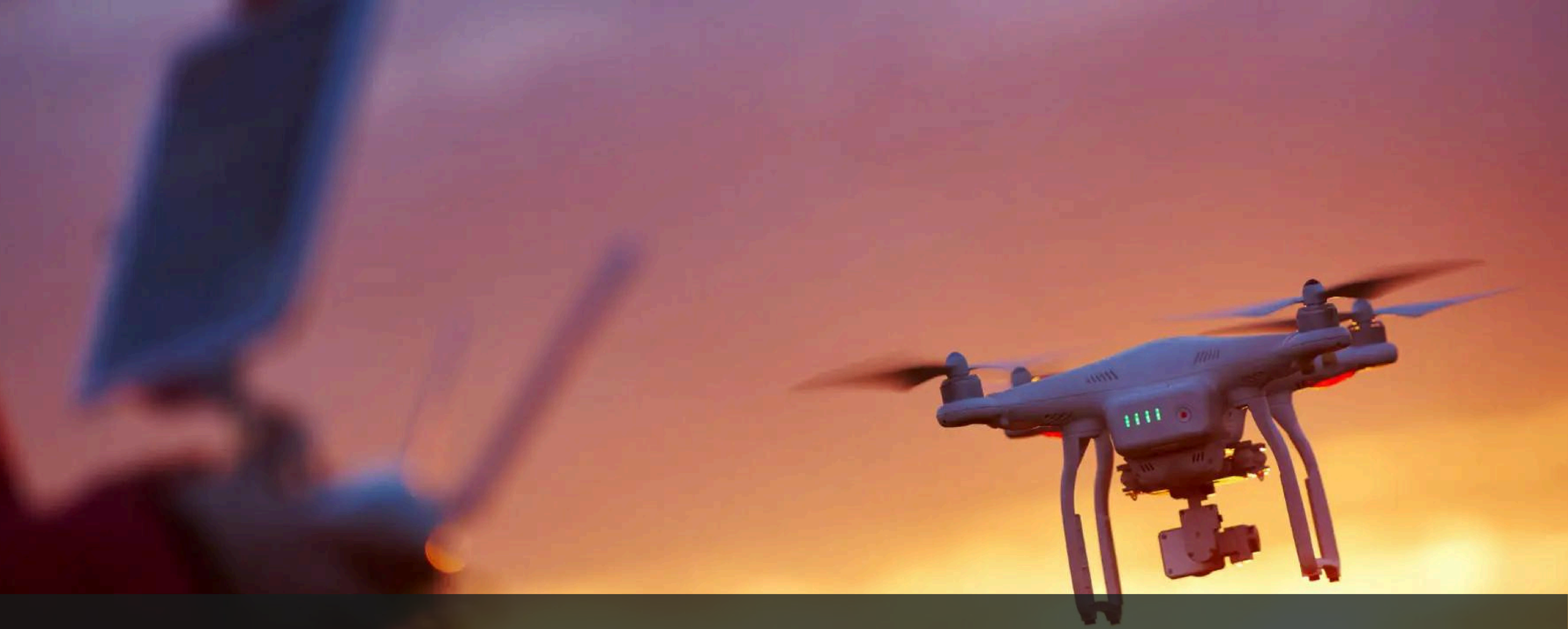


Two-Blade CAD



Three-Blade Prototype

Adapted from the Lightweight CAD
Two-Bladed Wing transformed to Three-Bladed Wing for Added Stability, Clearance, and Horsepower for Added Durability



05 DRONE COMPONENTS + COST

NewSpace @Berkeley USRA

COST

Component	Price
Accelerometer	$129
Battery	$865
Frame	$304
Infrared Sensor	$370
Motherboard	$73
Parachute	$151
ShortRange LiDAR Sensor	$8,544
Wiring	$40
Total Cost Per Unit	**$10,476**

06 PHYSICS ANALYSIS

DRONE MASS ANALYSIS

Component:

Mass

Battery - 4.2 kg
LiDAR Sensor - 0.94 kg
Infrared Sensor - 0.26 kg
Parachute - 0.05 kg
Industrial Drone (accounts for mass of other components) - ~3.6 kg
Total - ~9 kg

Example Industrial Drone:

Matrice 300 RTK by DJI

This drone provides the specs of an industrial drone. As its specifications show that it can take off with 9 kg, we can be assured that a drone with all of our sensors and components is viable.

SERVICE RANGE ANALYSIS

Specs for Matrice 300 RTK
(Our Example Drone)

Maximum Flight Time - ~1 hour
Maximum Flight Speed - 23 m/s (~50 mph)

Maximum Covered Distance in One Flight - 50 miles

Range of Service - 25 mi

By looking at the abilities of our example drome, we can conclude that our drones will be able to survey locations within 25 miles of their starting location, or slightly less if more time is needed to survey.

Thank you | Questions?

NewSpace @Berkeley USRA

ACKNOWLEDGEMENTS

PROJECT MANAGER
Priscilla Jou

USRA Company Mentors
Sebastian Gutierrez-Nolasco
David Bell

NewSpace@Berkeley Fellowship
Pearl Bhatnager
Anya Pendyala
Victoria Elfend

CAD Advisor
Joseph Mattson

APPENDIX

IDENTIFIED STAKEHOLDERS

ACADEMIC

Conducts relevant research, hosts testbed implementations, and contributes to research funding through grants and as a potential customer.

COMMERCIAL

Requires consistent monitoring and regular inspections to uphold safety standards in commercial buildings and other real estate.

GOVERNMENT

Demands widespread deployment for routine infrastructure assessments and action in emergency situations.

WHY NOW?

Increasing Focus From the Government to Focus on Infrastructure

The Infrastructure Investment & Jobs Act (2021) allocated $110B specifically towards roads and bridge maintenance

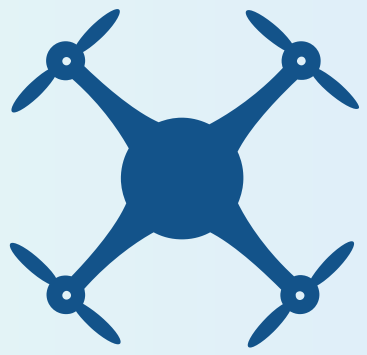
Infrastructure is Showing Age and Requires Proper Maintenance or Replacement

36% of U.S's bridges need major work
68% of California roads are in "poor" or "mediocre" condition

OUR ADVANTAGE

AUTONOMY

Drones operate autonomously, reducing the risk to human operators during aftershocks.



MANEUVERABILITY

Drones can traverse and inspect over larger cracks and more severely damaged road sections, areas where traditional vehicles may fail to reach.

PRICING

VARIABLE METRICS

Roads: Miles
Buildings: Surface Area
Bridges: Length

ADDITIONAL INPUTS

Drone Flight Time
Geographic Area Covered

DATA DELIVERABLES

Detailed Imagery
Comprehensive Report
Risk Categorization

EMERGENCY SERVICES

Additional Charges
On-Demand Deployment +
Monitoring

CASE 02: EMERGENCY

STRUCTURE SPECFIC CHARGES

Apply Higher Emergency Rate

ROAD INSPECTION COSTS

Variable Emergency Rate for Mileage

ESTIMATE DRONE FLIGHT TIME + COST

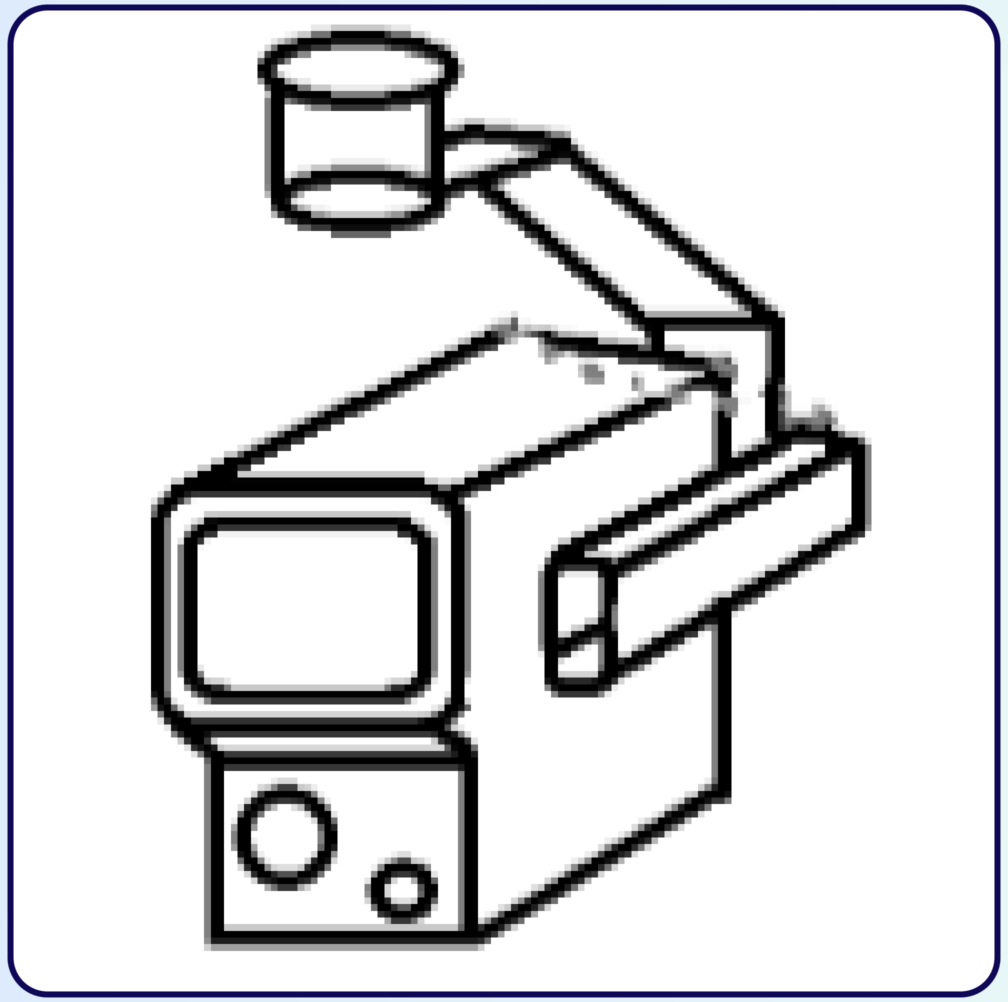
Calculate Expected Drone Time, Considering Aftershocks + Hazards

Variable Operation Rate + Risk Premium Charge

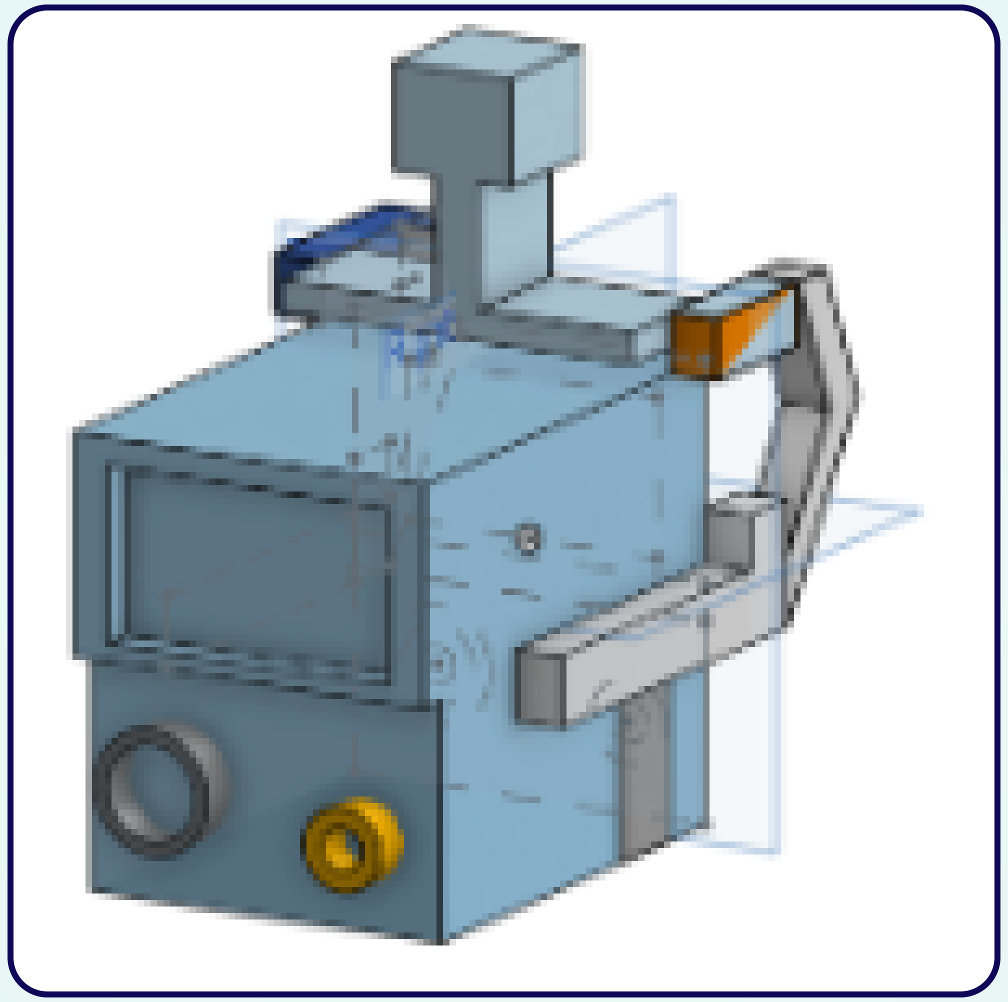
SUM UP TOTAL COST

Inspection + Operation Costs

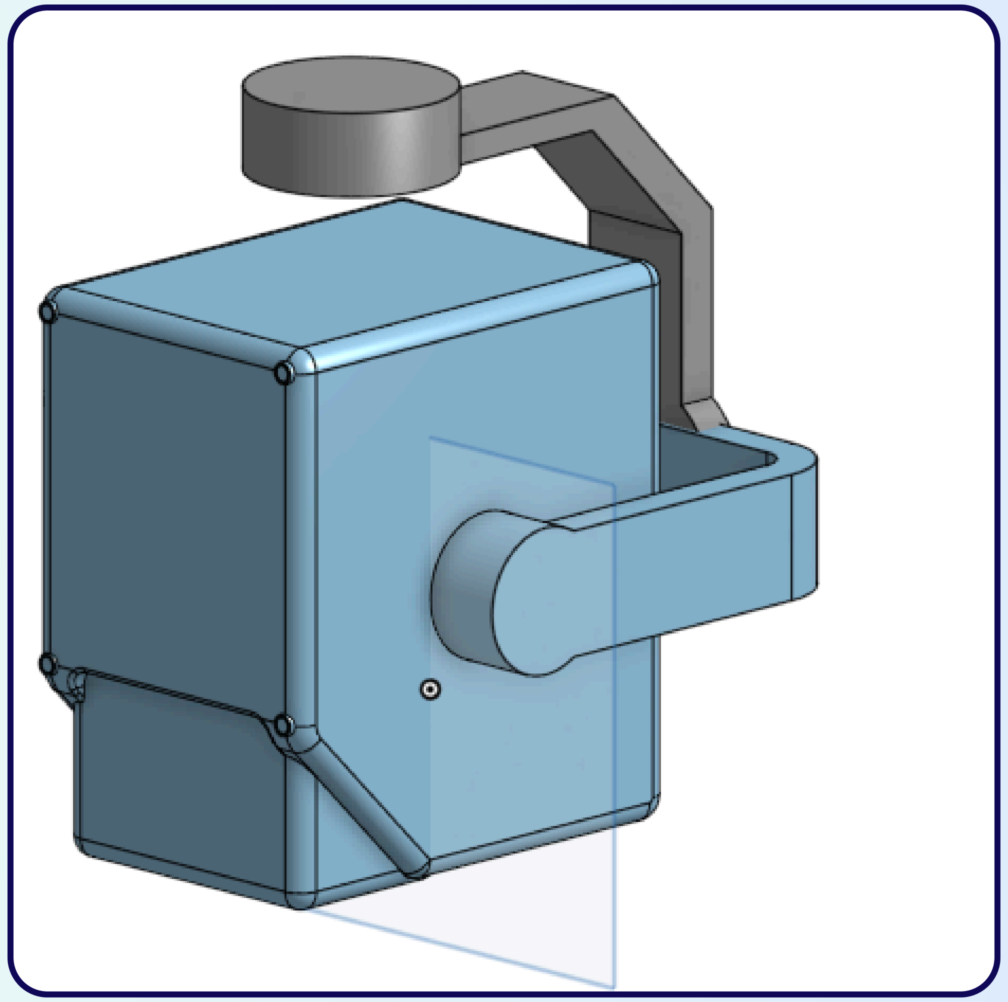
Short Range LiDAR Camera Gimbal



Sketch



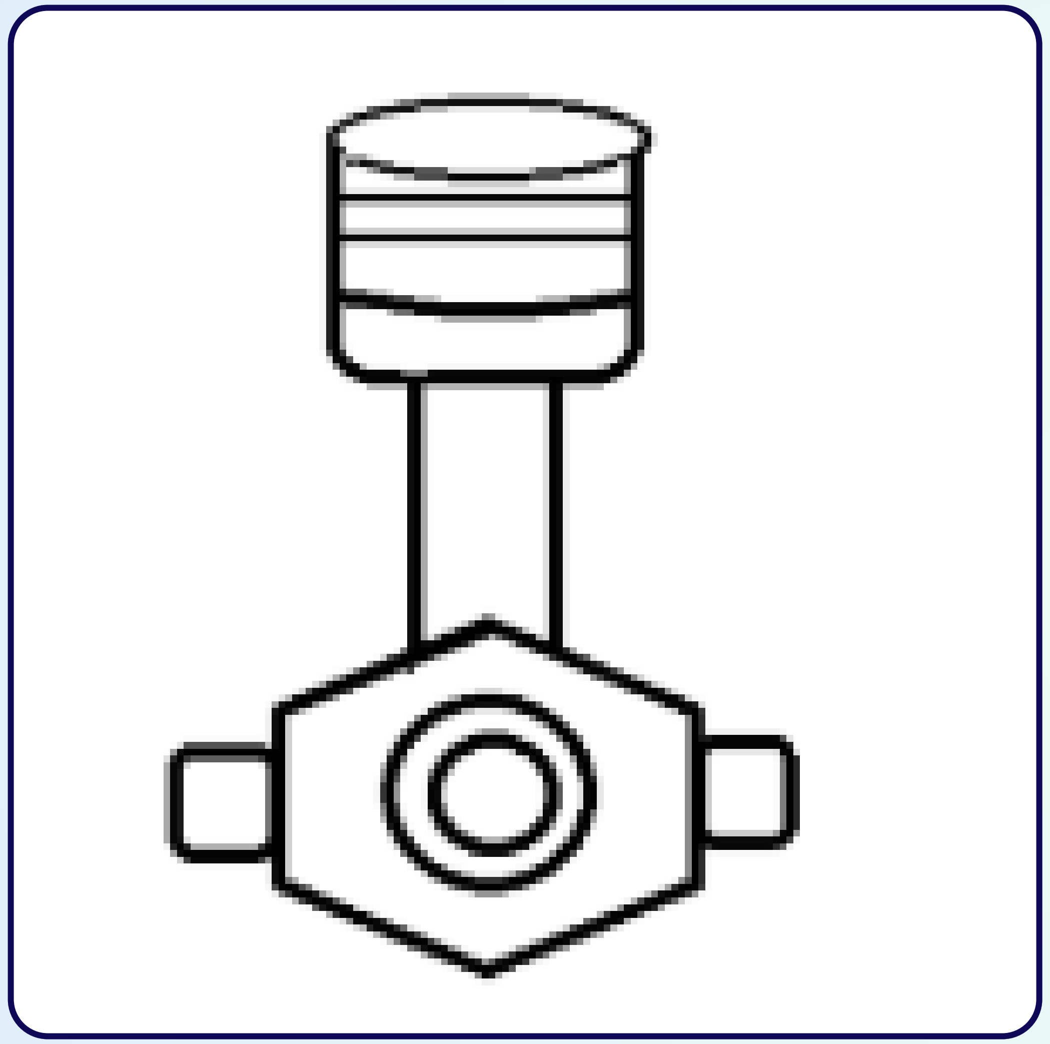
CAD



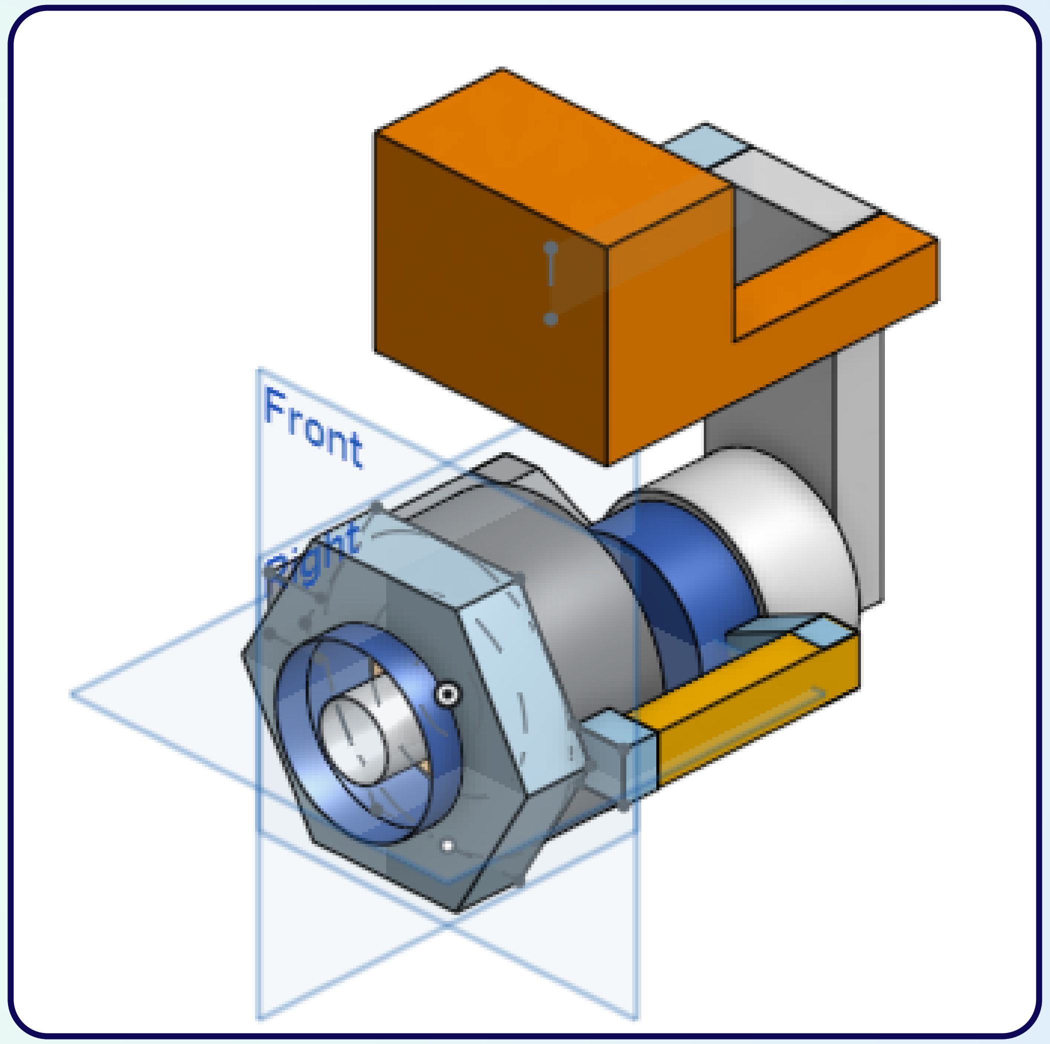
Model

Increases the Short Range Gimbal Visibility Range, Terrain Input, and Calculation of Flight Accuracy

INFRARED CAMERA



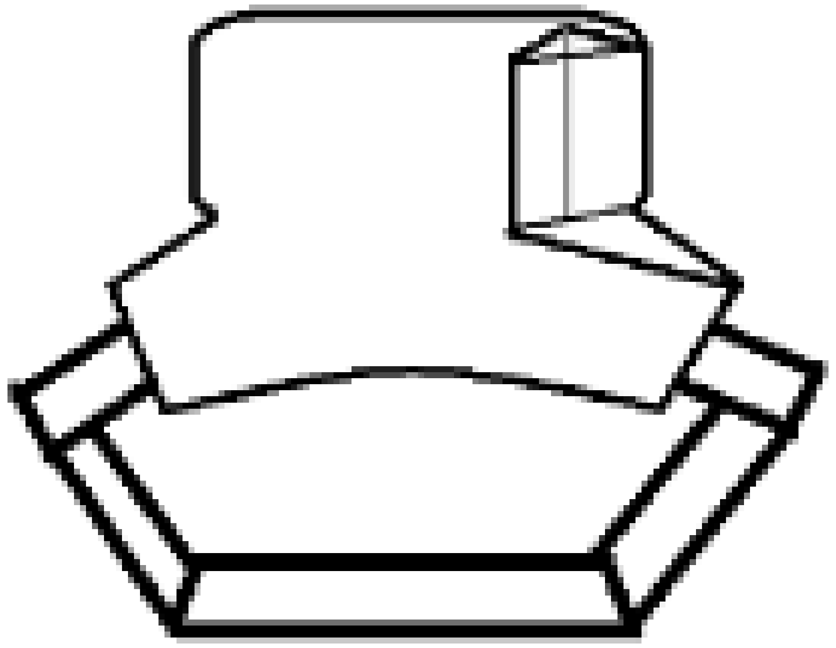
Sketch



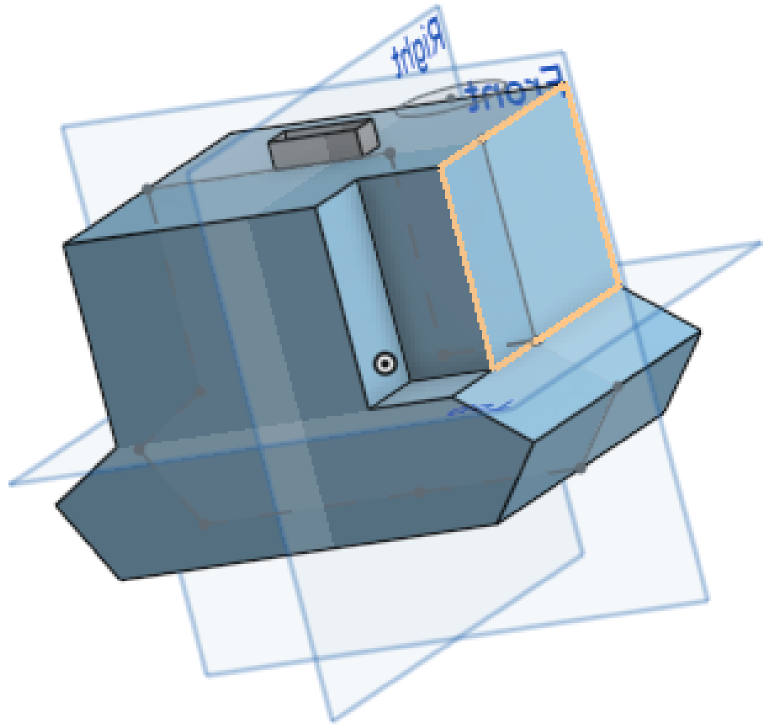
CAD

Scans Surrounding Shapes and Temperature Gauge for Greater Input and Calculation of Dangers, Increasing Safety for Drone Operation and Report Strategies.

PARACHUTE



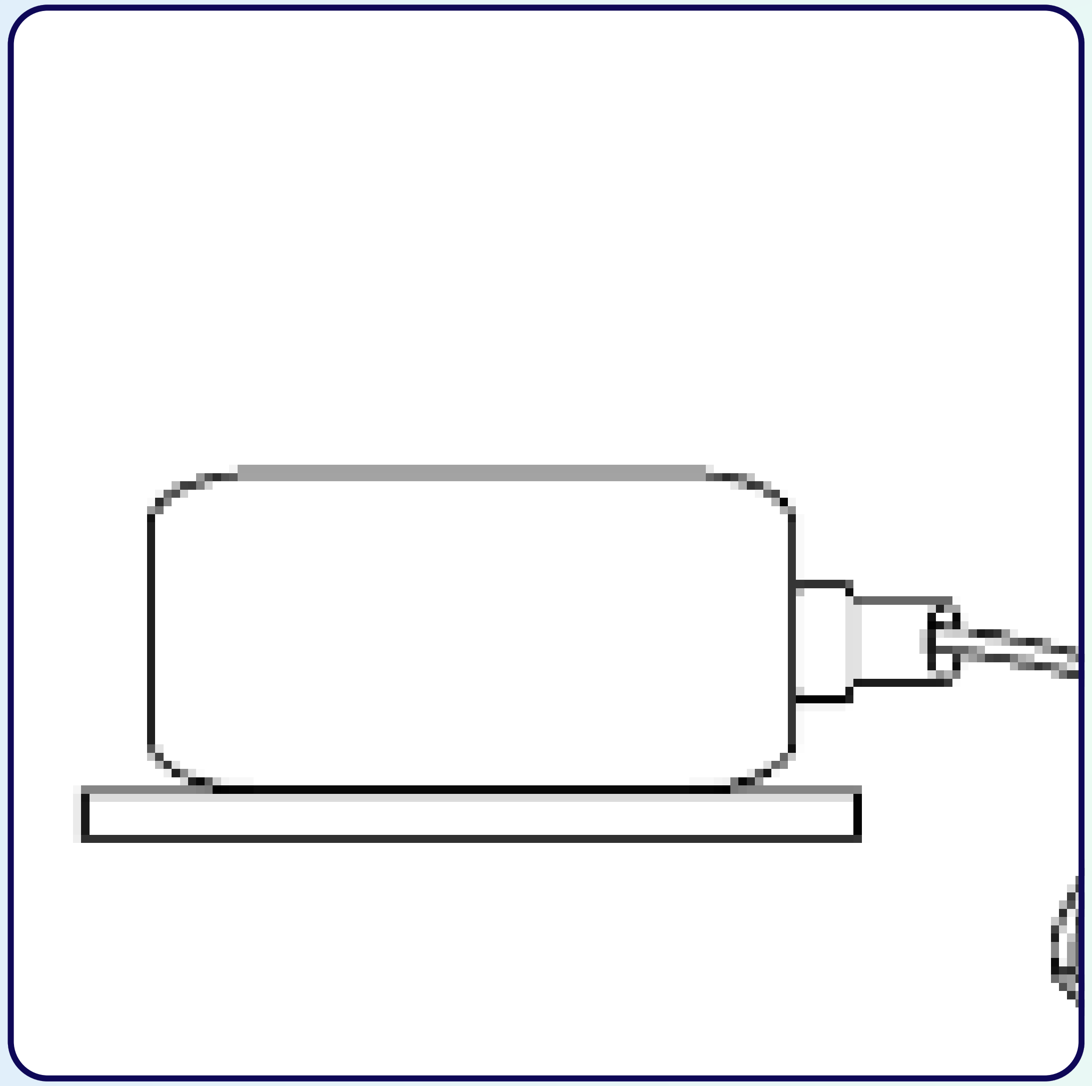
Sketch



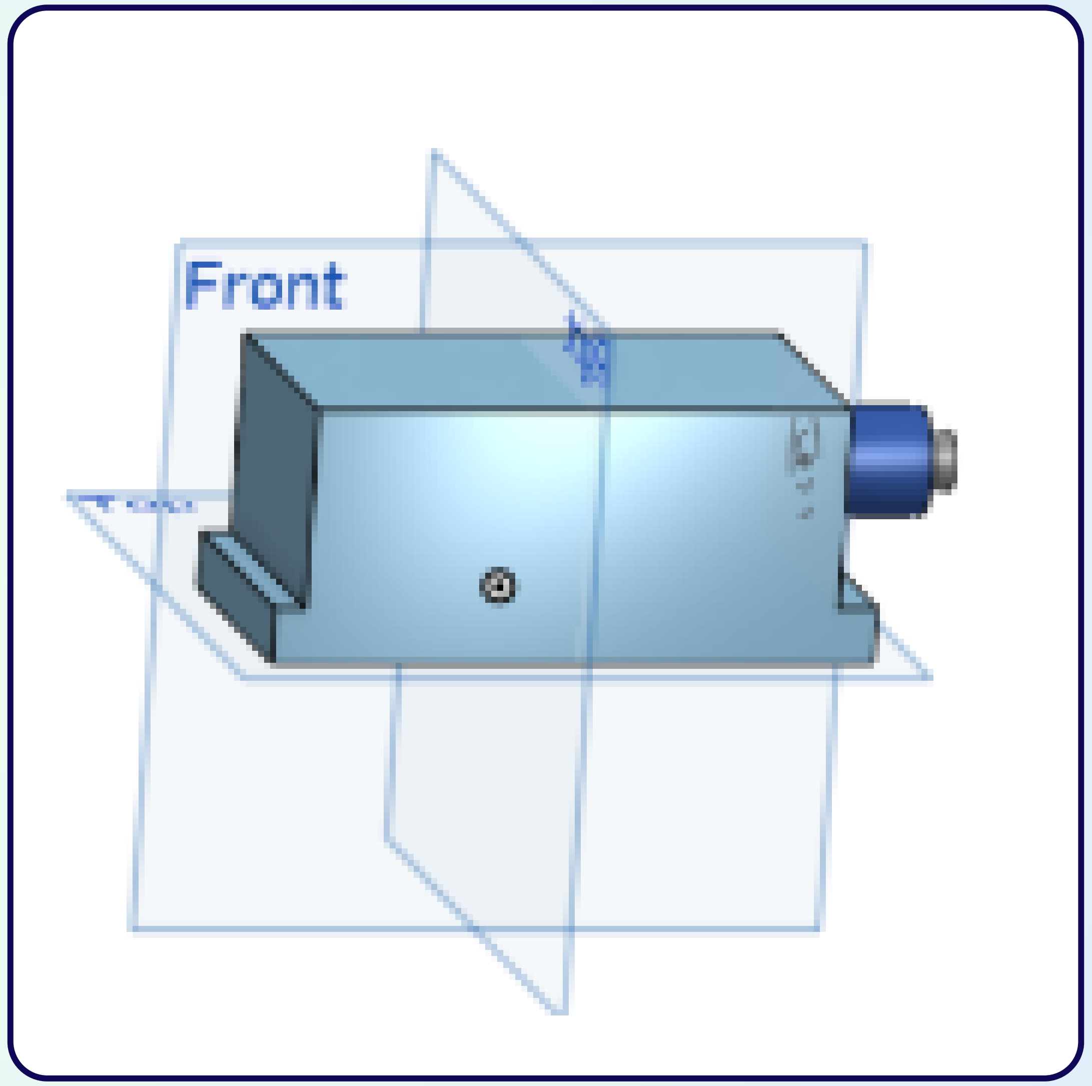
CAD

Aids Drone in Entry, Descent, Landing Protocols (EDL) to Increase Safety for Failure of Main Landing Components and Control

ACCELEROMETER



Sketch



CAD Prototype

Aids in Measurement of Real-Time Speed to Time for Greater Understanding of Remote Control and AI Assist