Skydio

SKYDIO AUTONOMY ENGINE: ENABLING THE NEXT GENERATION OF AUTONOMOUS FLIGHT

HOT CHIPS, 2021

Abraham Bachrach
Co-Founder & CTO

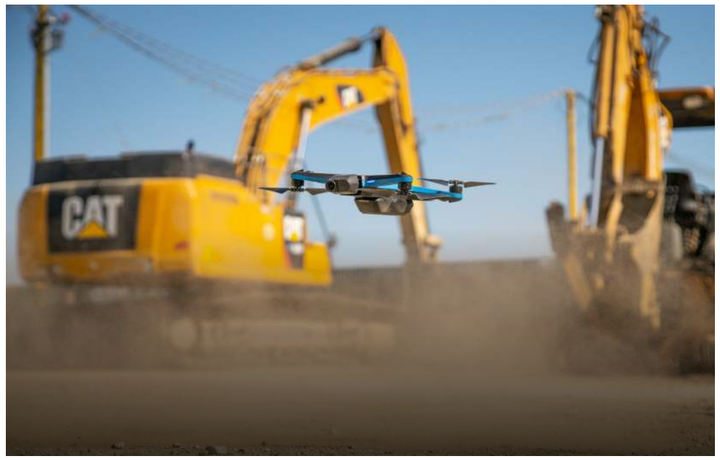
BRIEF HISTORY OF CONVENTIONAL DRONES

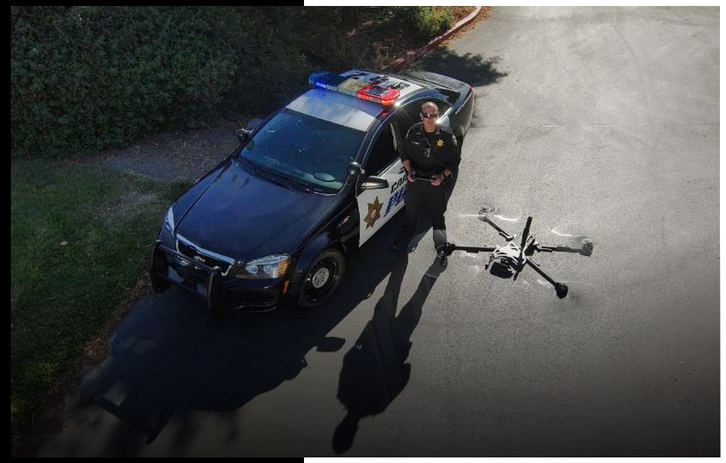
Lithium Polymer Batteries

MEMS IMUs and GPS

Add a Camera

Drones hold the promise of massive positive impact





Drones are 10x More Effective and 100x Cheaper and Safer than Legacy Methods and Heavy Machinery

CINEMATOGRAPHY

Drones are more versatile and cheaper than camera cranes

PUBLIC SAFETY

Drones are much simpler to deploy and scale than helicopters

TOWER INSPECTION

Drones are much safer for inspectors than tower climbs

BRIDGE INSPECTION

Drones are far less disruptive to society than snooper trucks

ECONOMICS OF MANUAL DRONES DON'T SCALE

Up to 80% of an average drone program's budget can be consumed by pilot training and salary

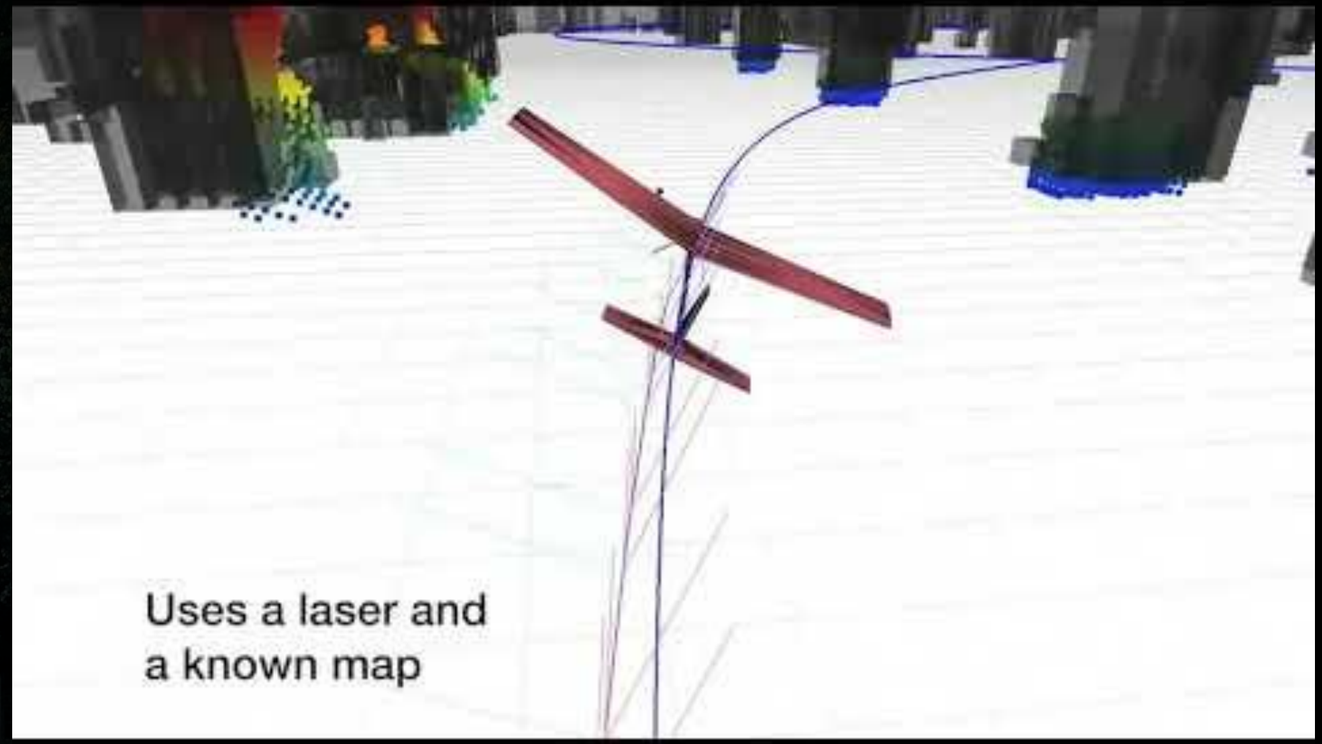
Hard to fly

Easy to crash

More man hours IN than flight hours OUT

Skydio

Our roots go back 12+ years with cutting-edge research at MIT's AI lab



Skydio

OUR MISSION

Make the world more productive, creative, and safe with autonomous flight.

INSPECTION + MAPPING

Digitize the physical world with millimeter precision.

SITUATIONAL AWARENESS

Risk a drone instead of the lives of public safety or service members.

CINEMATOGRAPHY

Capture amazing moments with a Hollywood film crew that fits in your backpack.

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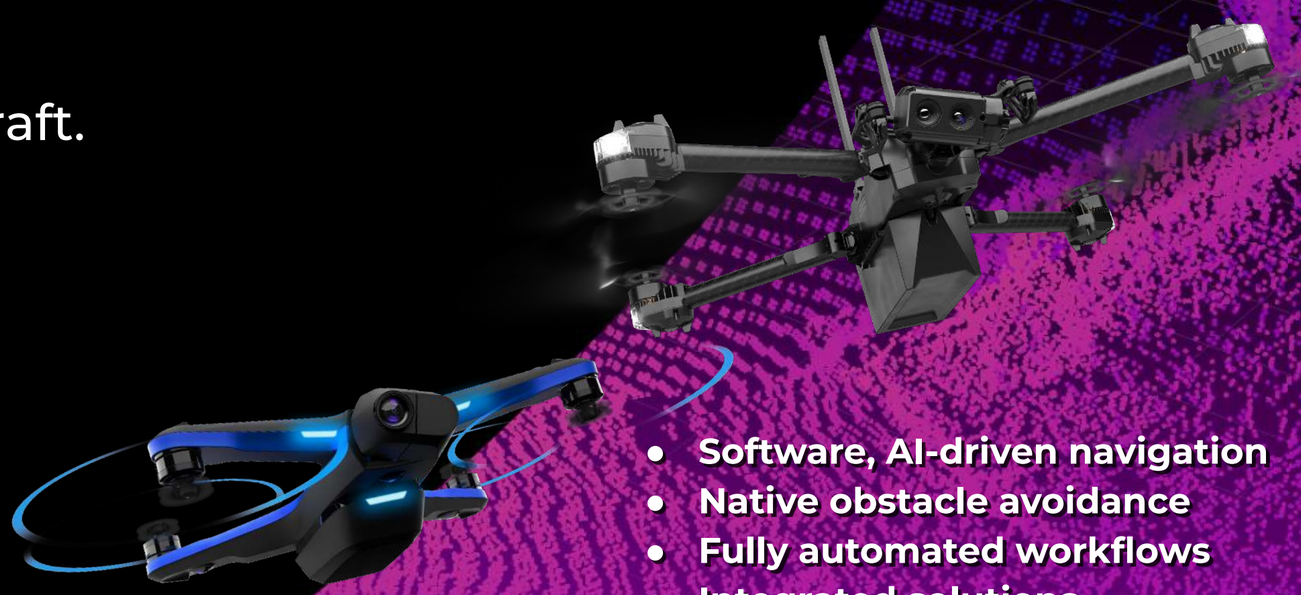
The Evolution of Drones

Manual drones have peaked.
The future belongs to software-driven aircraft.

AGE OF AI-DRIVEN AUTONOMY



- Software, AI-driven navigation
- Native obstacle avoidance
- Fully automated workflows
- Integrated solutions

AGE OF MANUAL HARDWARE

- Pilot operated
- GPS-based
- Sensor payloads

AGE OF TOYS

- Pilot operated
- RC-based

AUTONOMY: BOTTOM LINE

- Existing use cases are easier and more reliable
- New use cases that were previously impossible are enabled

Manual Drones

Autonomous Drones

HARDWARE-CENTRIC

SOFTWARE-DRIVEN

Flip phone

Smartphone

Skydio


SKYDIO
CUSTOMER HIGHLIGHTS

Skydio

World-leader in autonomous flight technology

First US drone company unicorn. Over $340M raised

300+ world class team in AI, robotics, hardware and GTM

Trusted by US DoD, enterprises and everyday consumers

Company Heritage:

Tesla, GoPro, Google, Apple, MIT, Stanford

Investors:

Andreessen Horowitz, Levitate Capital, Next47, IVP, playground, Accel, Lockheed Martin, UP.Partners, NVIDIA

WHY CUSTOMERS LOVE SKYDIO

A flight experience unlike any other

Up in the air faster

Easier to fly

Safer from crashes

Flies where others can’t

Flies closer for better data

Automates entire workflows

Skydio is the leading U.S. drone manufacturer and world leader in autonomous flight.

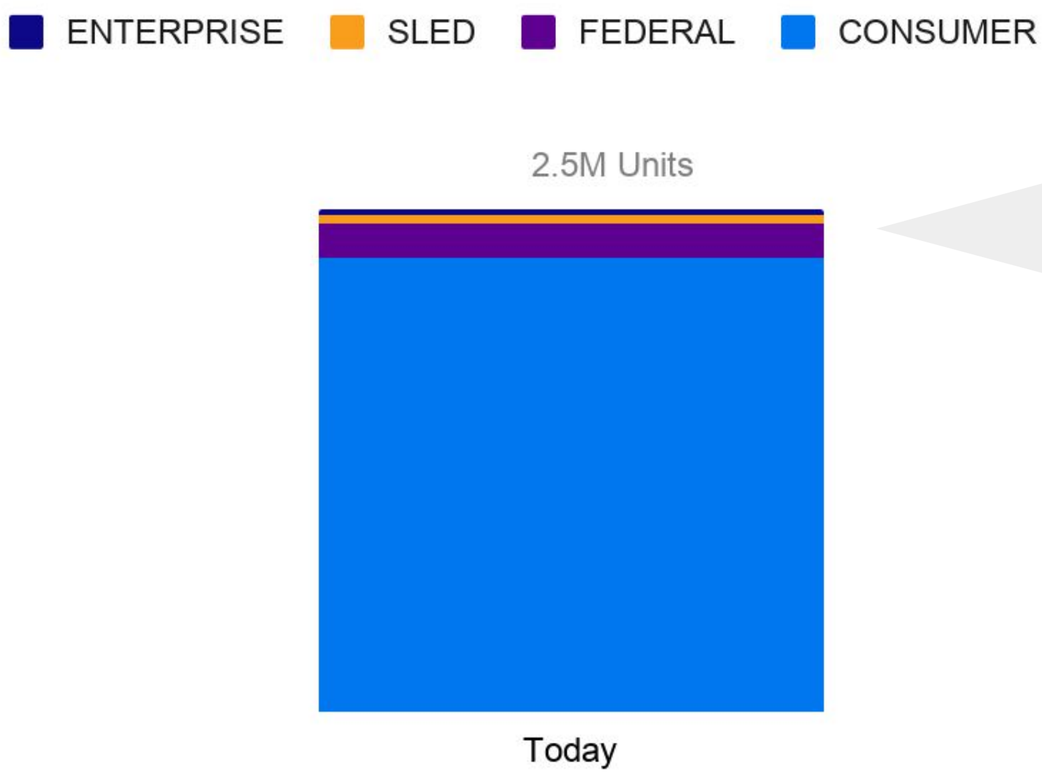
FROST & SULLIVAN

"Skydio is the fastest growing small UAS manufacturer in the world, and is **almost single-handedly re-establishing an industrial base for commercial drones in the United States**...Frost & Sullivan has identified autonomy and AI as the two main technologies that will drive commercial drone adoption in the future and **Skydio is at the forefront** of both."

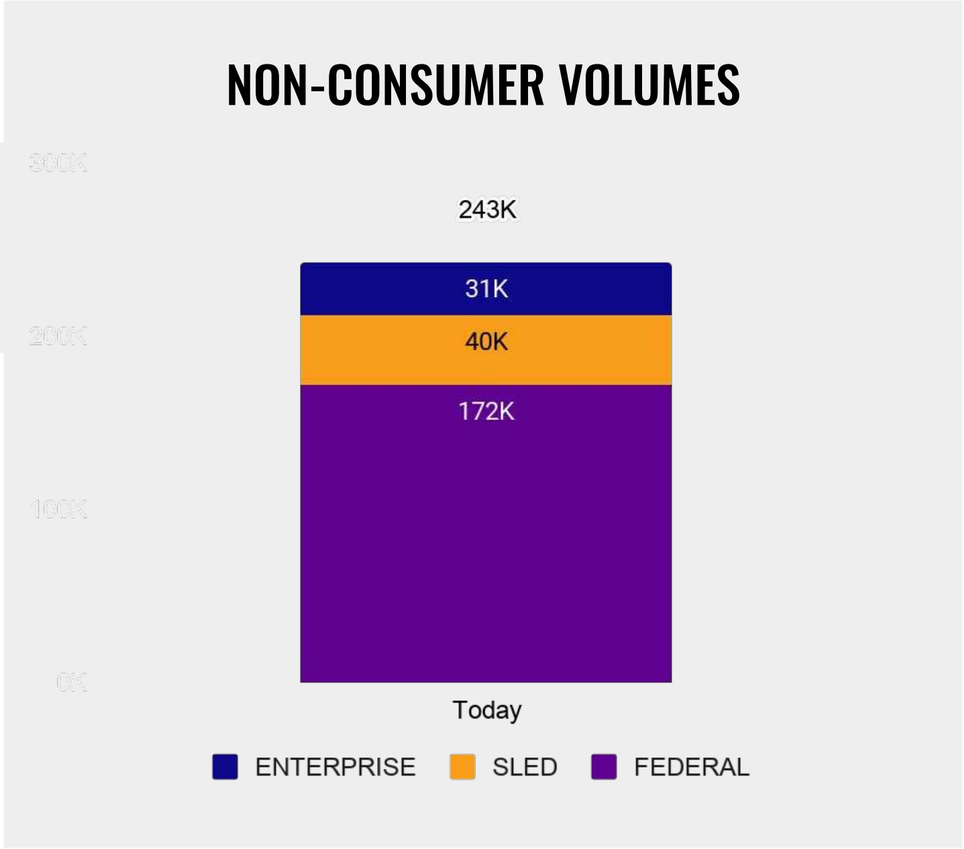
Michael Blades
VP Aerospace, Defense, and Security

DRONE MARKET INSIGHTS

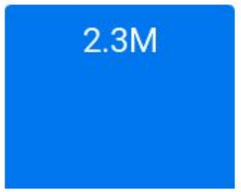
ANNUAL DRONE VOLUMES TODAY



$5.1B Global



CONSUMER MARKET TODAY VS. POTENTIAL



Today

120M

Point and shoot cameras/yr in 2010

11M

Action cameras sold in 2016

2030+

ENTERPRISE MARKET TODAY VS. POTENTIAL

11.3M
Construction Workers in US

✖

1 drone per 100 workers

=

113k
Construction drones

60k
Electrical Substations in US

✖

1 dock per substation

=

60k
Docked drones

✚ **614k** Bridges in the US

✚ **200k** Mi of Transmission Line

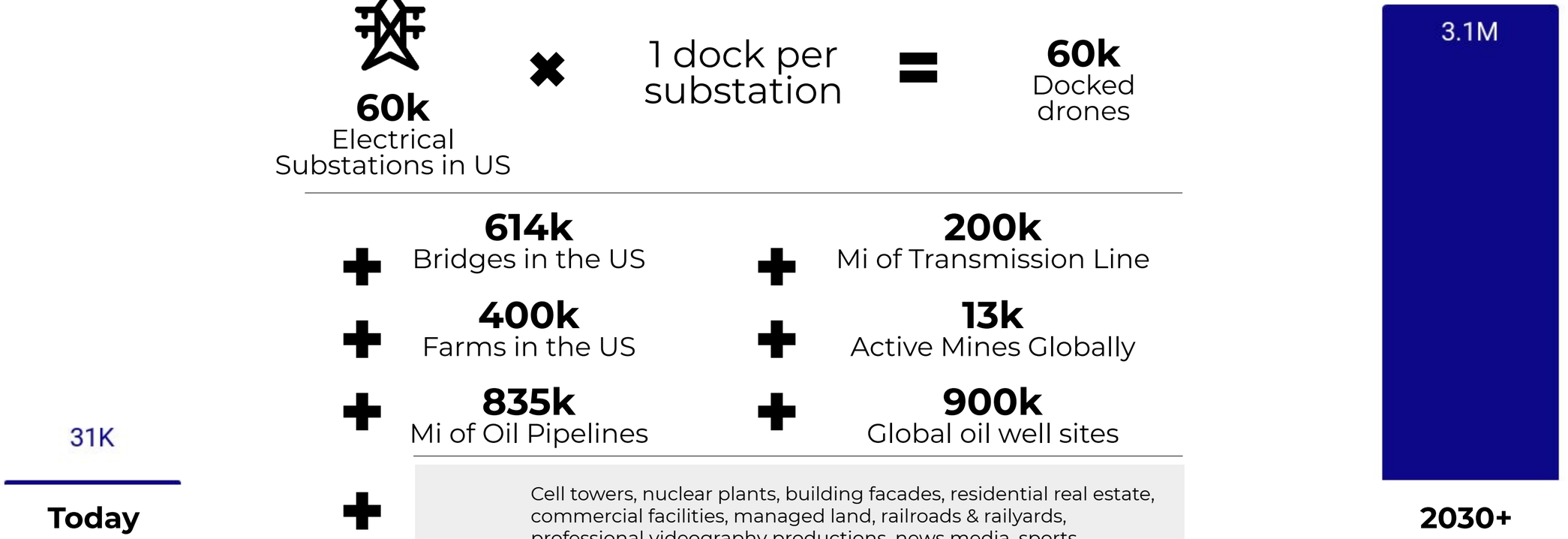
✚ **400k** Farms in the US

✚ **13k** Active Mines Globally

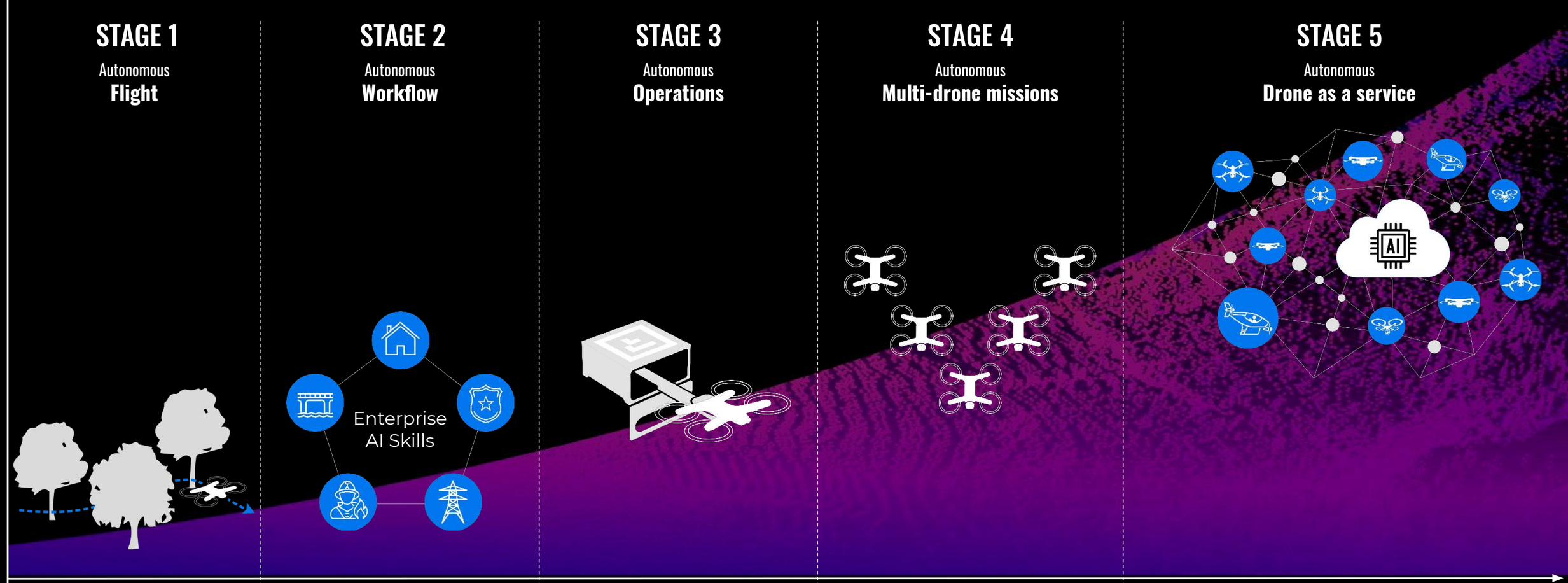
✚ **835k** Mi of Oil Pipelines

✚ **900k** Global oil well sites

✚ Cell towers, nuclear plants, building facades, residential real estate, commercial facilities, managed land, railroads & railyards, professional videography productions, news media, sports, ...



The Arc of Autonomy

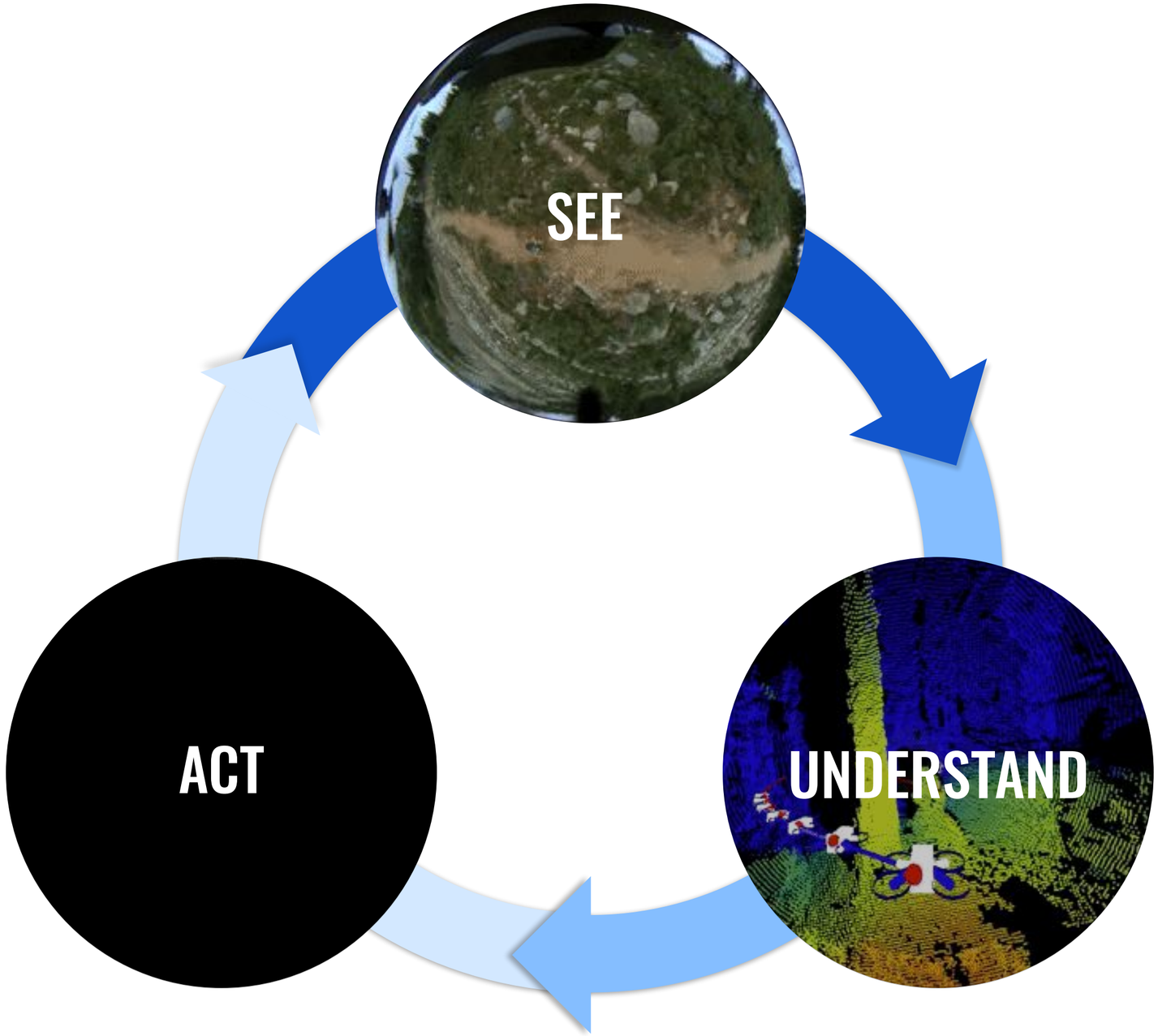


Skydio

SKYDIO AUTONOMY ENGINE

SKYDIO AUTONOMY™

A new generation of drone intelligence



SEEING THE WORLD

6x 4K fisheye cameras provide 360 degree coverage

Skydio

SKYDIO'S CORE AUTONOMY STACK

Goal: Robust visual navigation in complex, unknown environments across all use cases.

State Estimation - Estimate the robot's motion + sensor calibrations

Obstacle Avoidance - Don't crash into anything

Motion Planning + Control - Dynamic maneuvering with API to support higher level objectives

System Infrastructure - Underlying software platforms to support reliable real-time operation

CHALLENGES

- Computer vision encounters many difficult conditions
- High speed brings complex aerodynamics and little time to respond
- Little room for failure in an autonomous flying system
- Human trust in autonomy is a balance between doing too little and too much
- Constrained compute environment onboard the drone


Skydio

Vision-based 360 perception at high speed

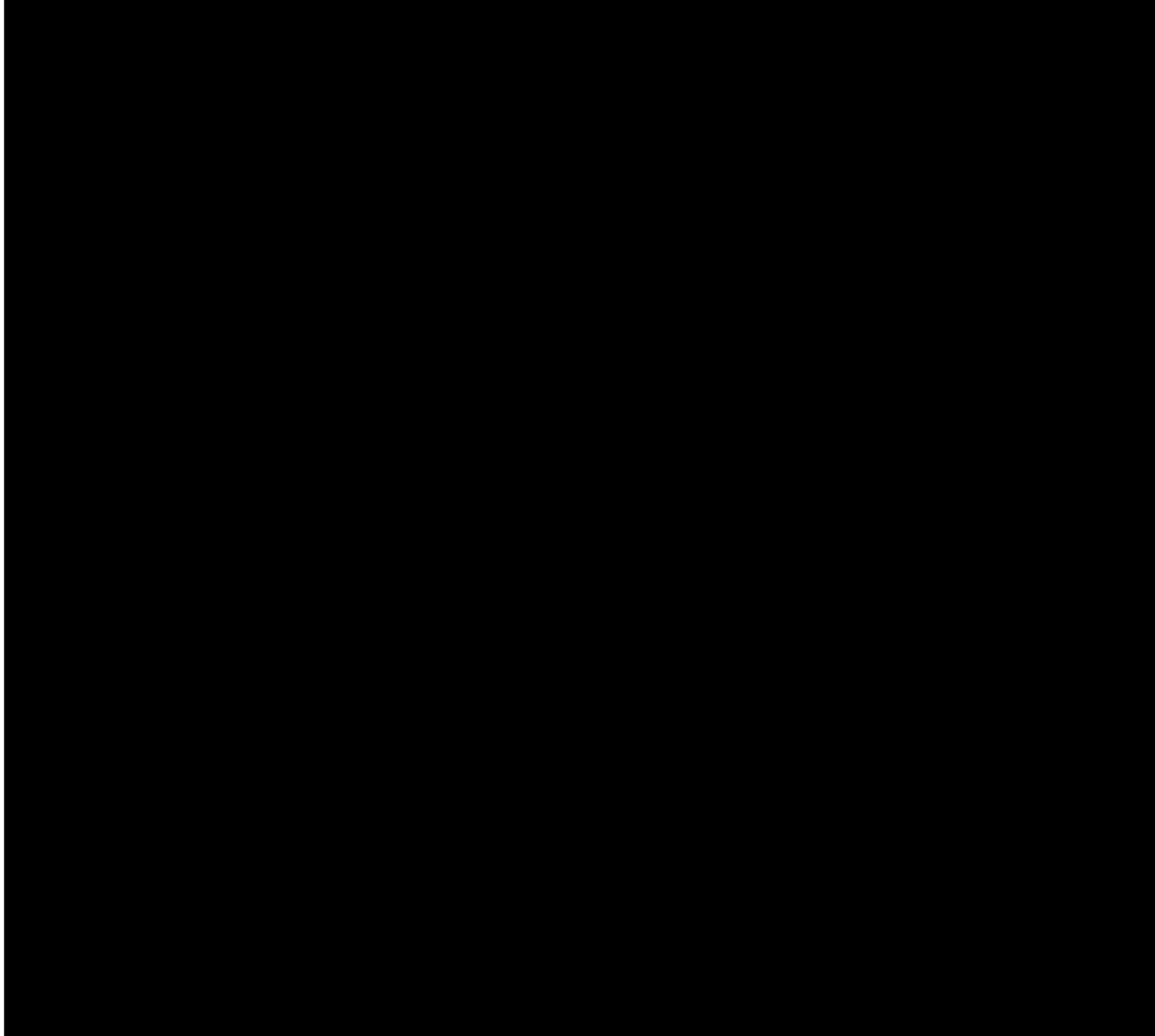
SKYDIO 3D SCAN™

Skydio

3D SCAN™

Adaptive scanning solution for autonomous inspection data capture.

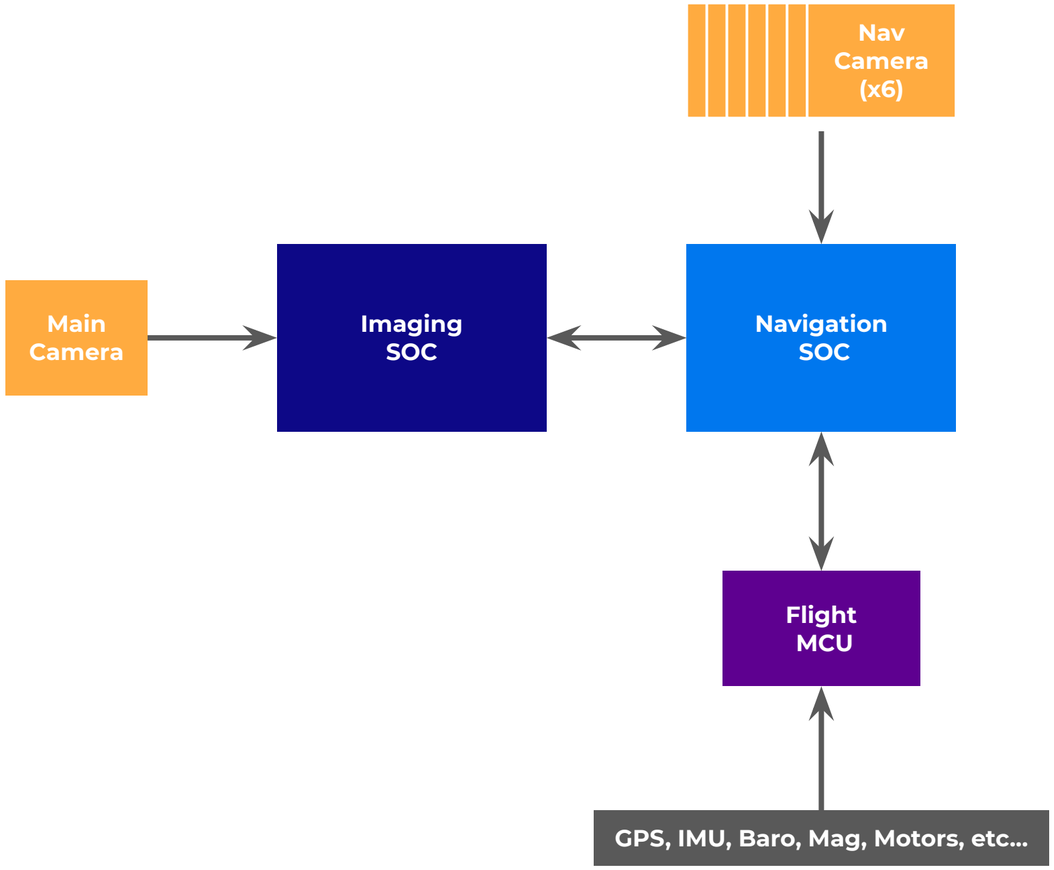
- AI-driven workflow
- Adaptive mapping
- Reduced dependence on specialist pilots

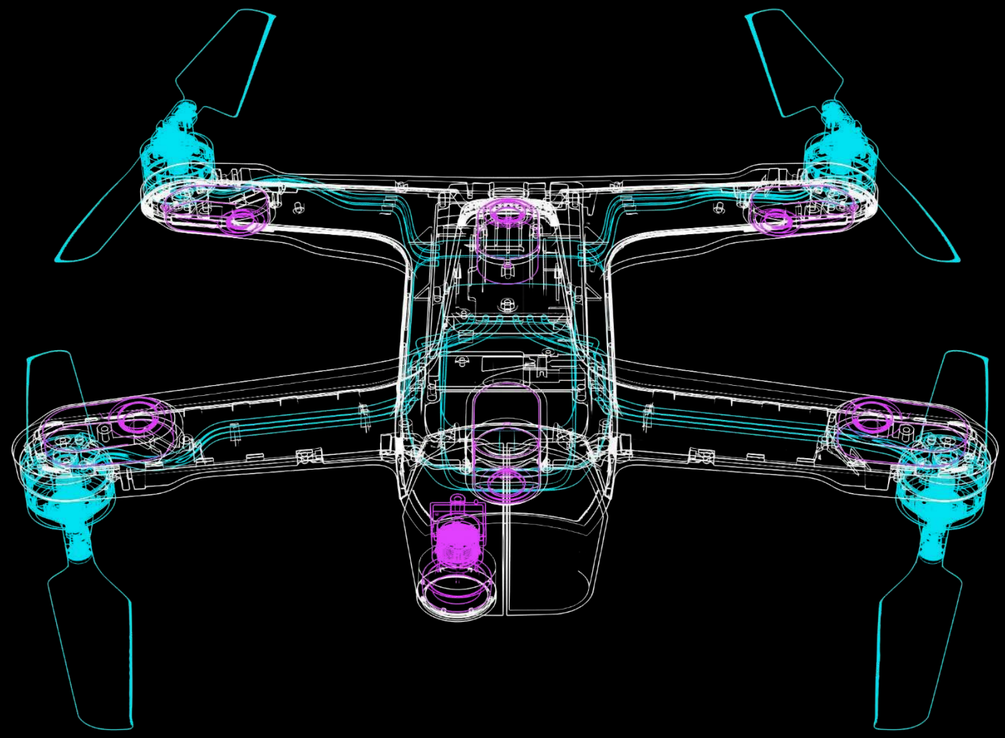


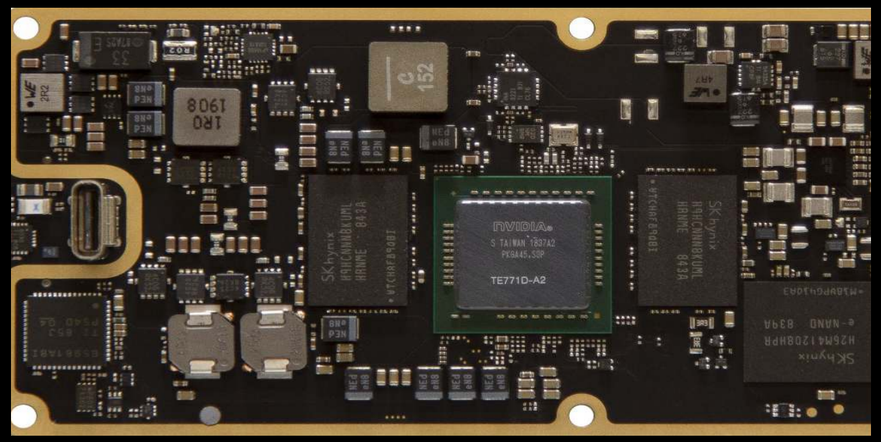
Skydio 3D Scan™
Complex structures. Effortless inspections.

WHAT GOES INTO MAKING AN AUTONOMOUS DRONE?

DRONE HIGH LEVEL BLOCK DIAGRAM







NVIDIA. Qualcomm

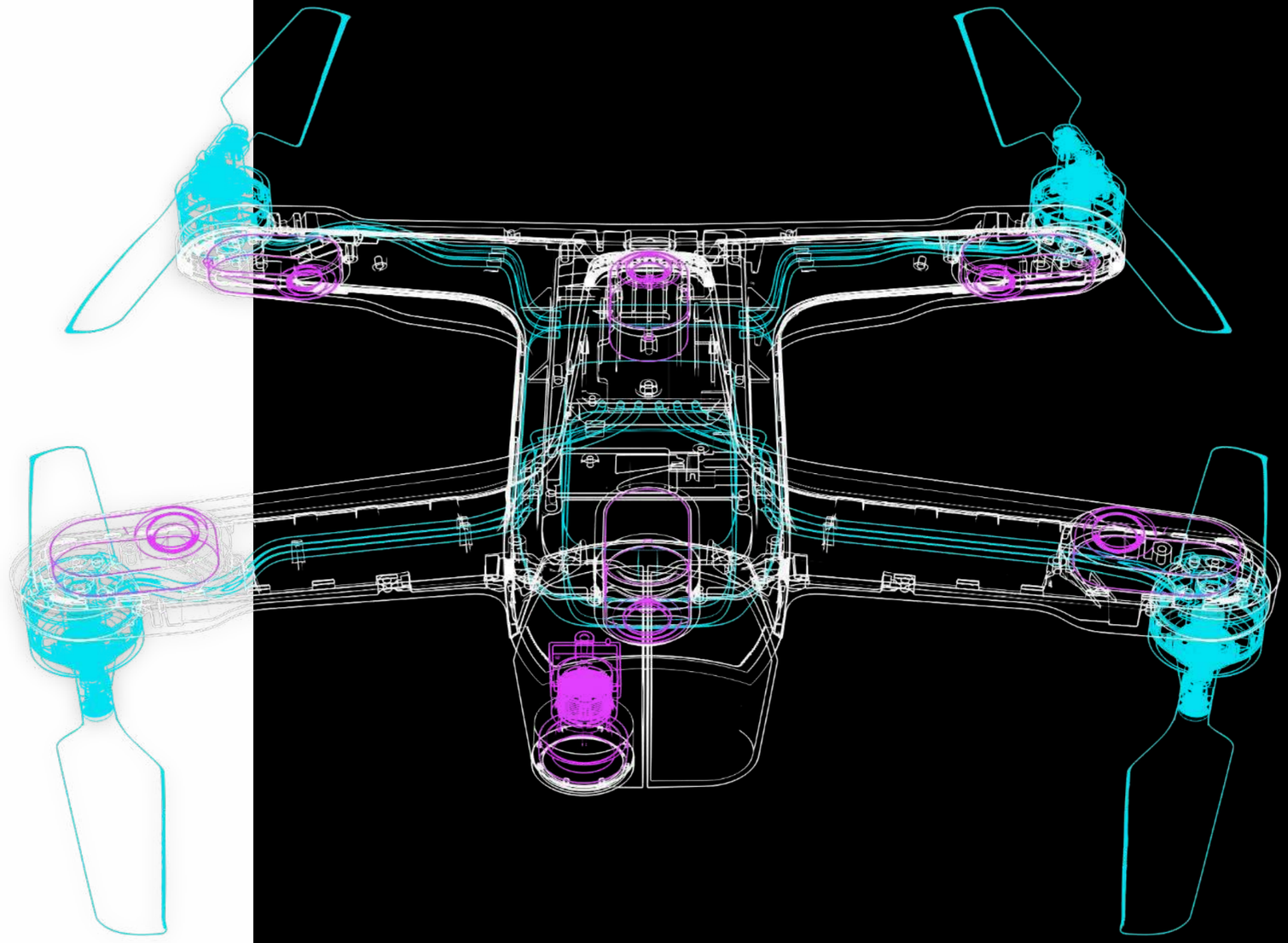
DRONES VS MOBILE PHONE ELECTRONICS

Similarities:

- Size
- Weight
- Cost
- High quality imaging
- Software flexibility is key

Differences:

- More cameras
- Much larger power budget



POWER BUDGET

A medium size drone

- Consumes 100-200W
- 20 to 40 minute flight time

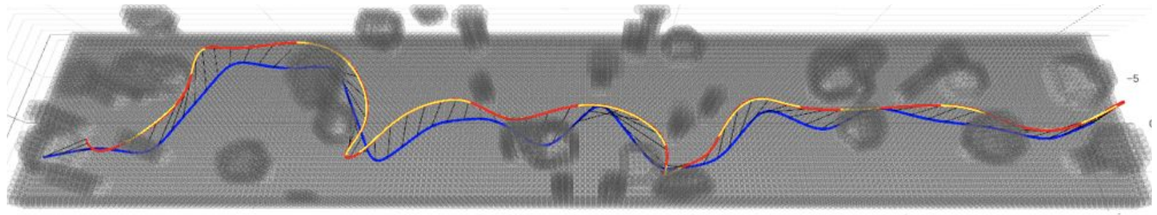
1 Watt of compute reduces flight time by ~10s

4g of payload reduces flight time by ~10s

Final compute constraint is mostly driven by size/weight of the board

TYPES OF COMPUTE

- High Level Logic/Health Monitoring
- Low-level image processing
- Geometric Computations
- Deep Learning
- Nonlinear Optimization

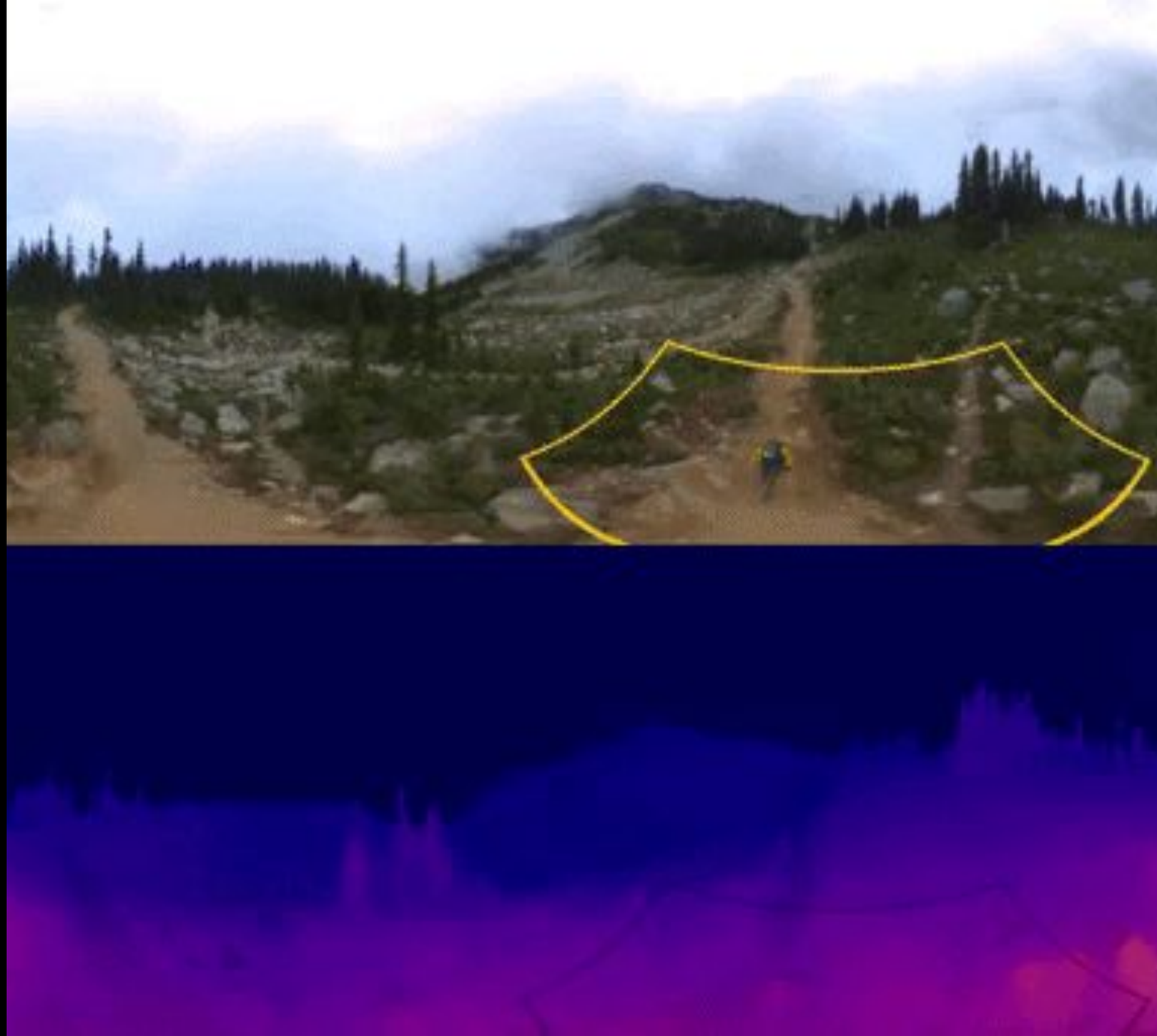


COMPUTE RESOURCE MAPPING

	CPU	ISP	GPU	DSP	NPU
HIGH LEVEL LOGIC	✓				
LOW LEVEL IMAGE PROCESSING		✓	✓	✓	
GEOMETRIC COMPUTATIONS			✓	✓	
DEEP LEARNING			✓	✓	✓
NONLINEAR OPTIMIZATION	✓				

DEEP LEARNING

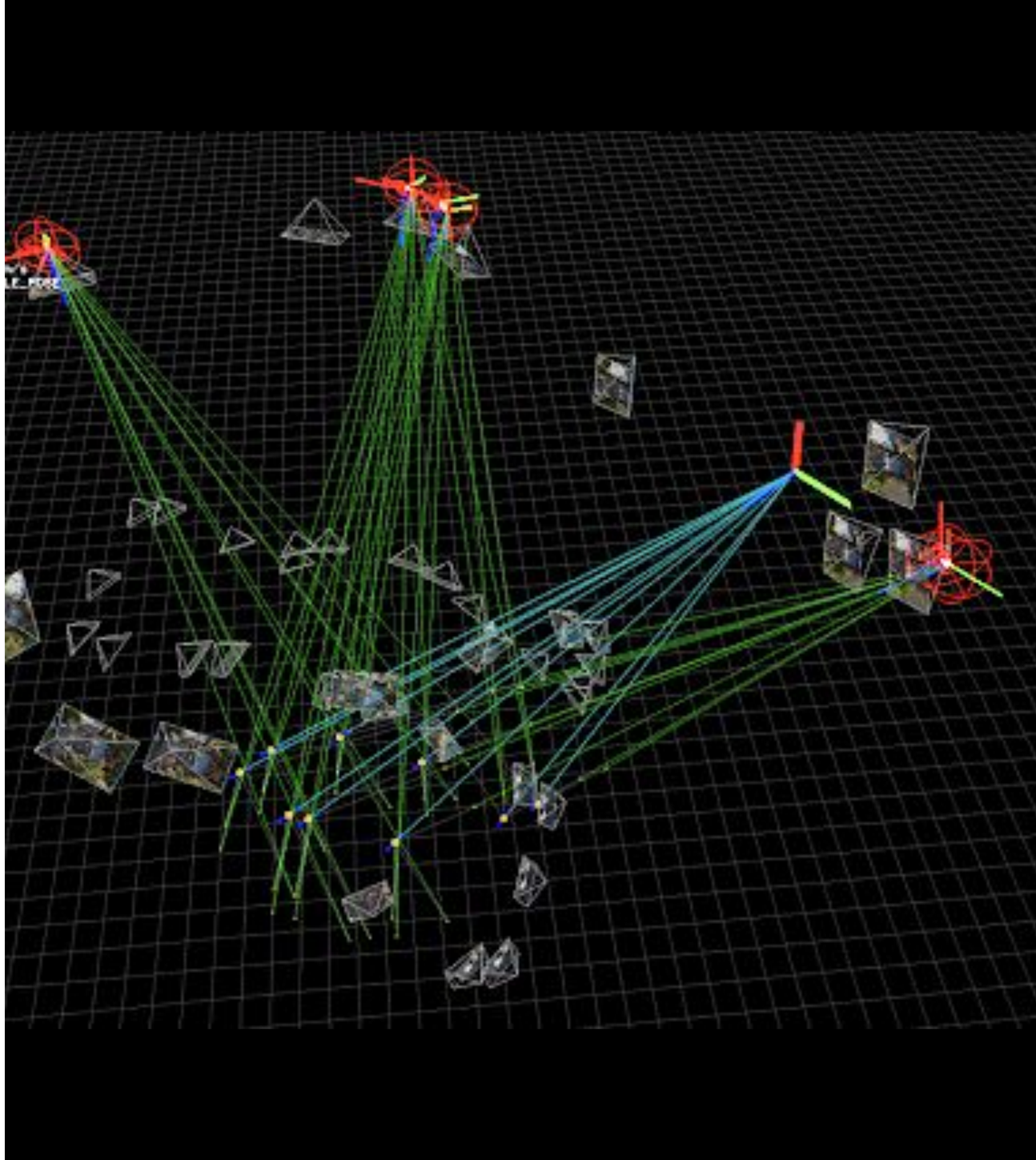
- 8 models used in flight
- Quantization works great for some
- Need some floating point layers



NONLINEAR LEAST-SQUARES OPTIMIZATION

The core of many robotics algorithms

- Visual Odometry
- Simultaneous Localization and Mapping
- System-Identification
- Model Predictive Control

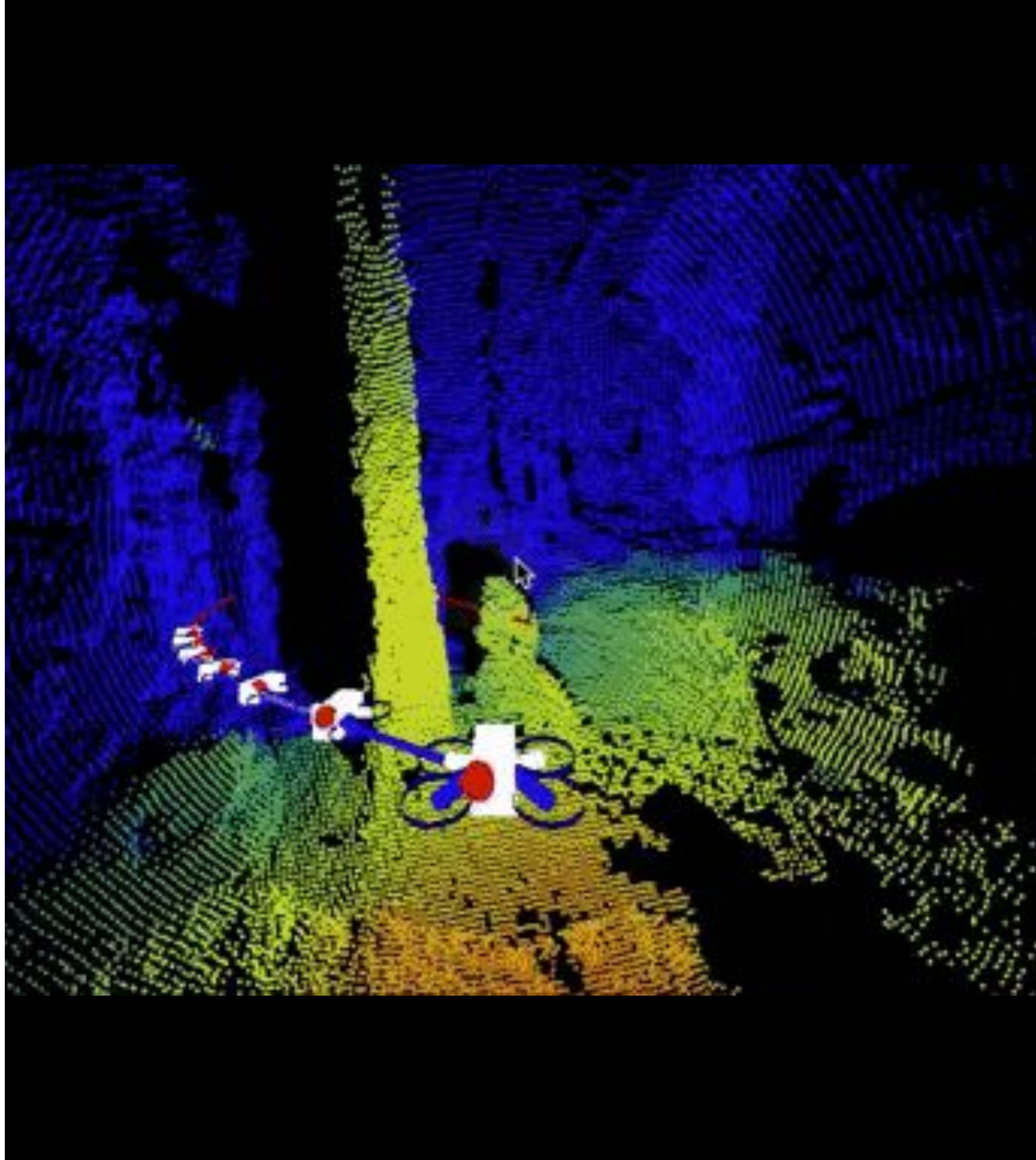


MOTION PLANNING

A large optimization problem that jointly solves over 50 objectives including:

- Rotor rates and 6dof vehicle state
- Robot dynamics and aerodynamics
- Obstacles in the world
- Cinematic flight

The optimization is run at 500 iterations a second to ensure fast dynamic response and smooth flight

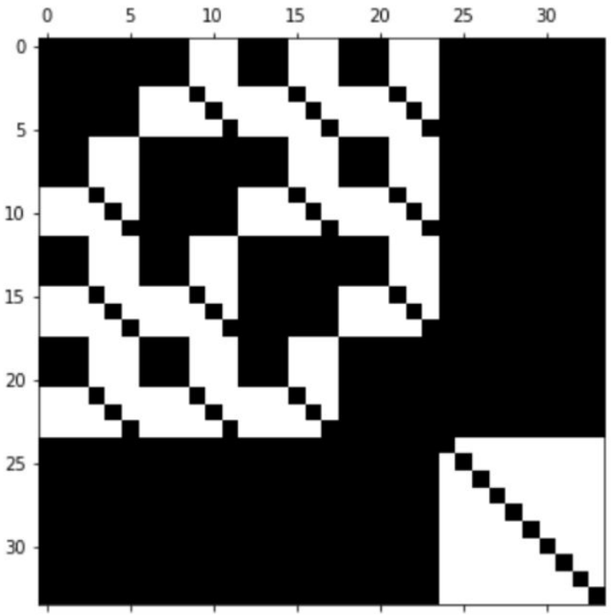


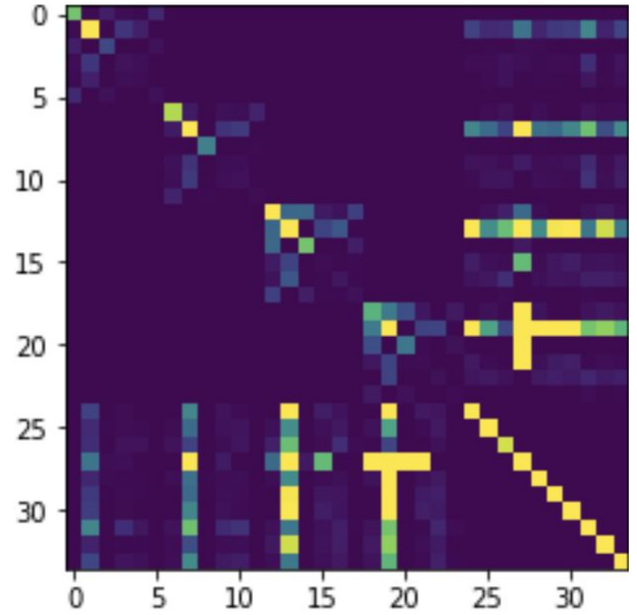
OPTIMIZATION FORMULATION

Iterate between:

- Linearize the Problem
- Factorize/solve the matrix
  - Medium size and dense
  - Large and sparse

Both steps are compute intensive





SYMBOLIC COMPUTATION

Skydio has developed a custom differential geometry library based on symbolic computation and code generation techniques.

Allows developers to formulate problems with high level symbolic python code

- Avoid handwritten derivatives
- Analytical simplification
- Common subexpression elimination
- Branchless generated code

Yields order of magnitude speed and debuggability gains.

Symbolic:

π

Numeric:

3.14159265359

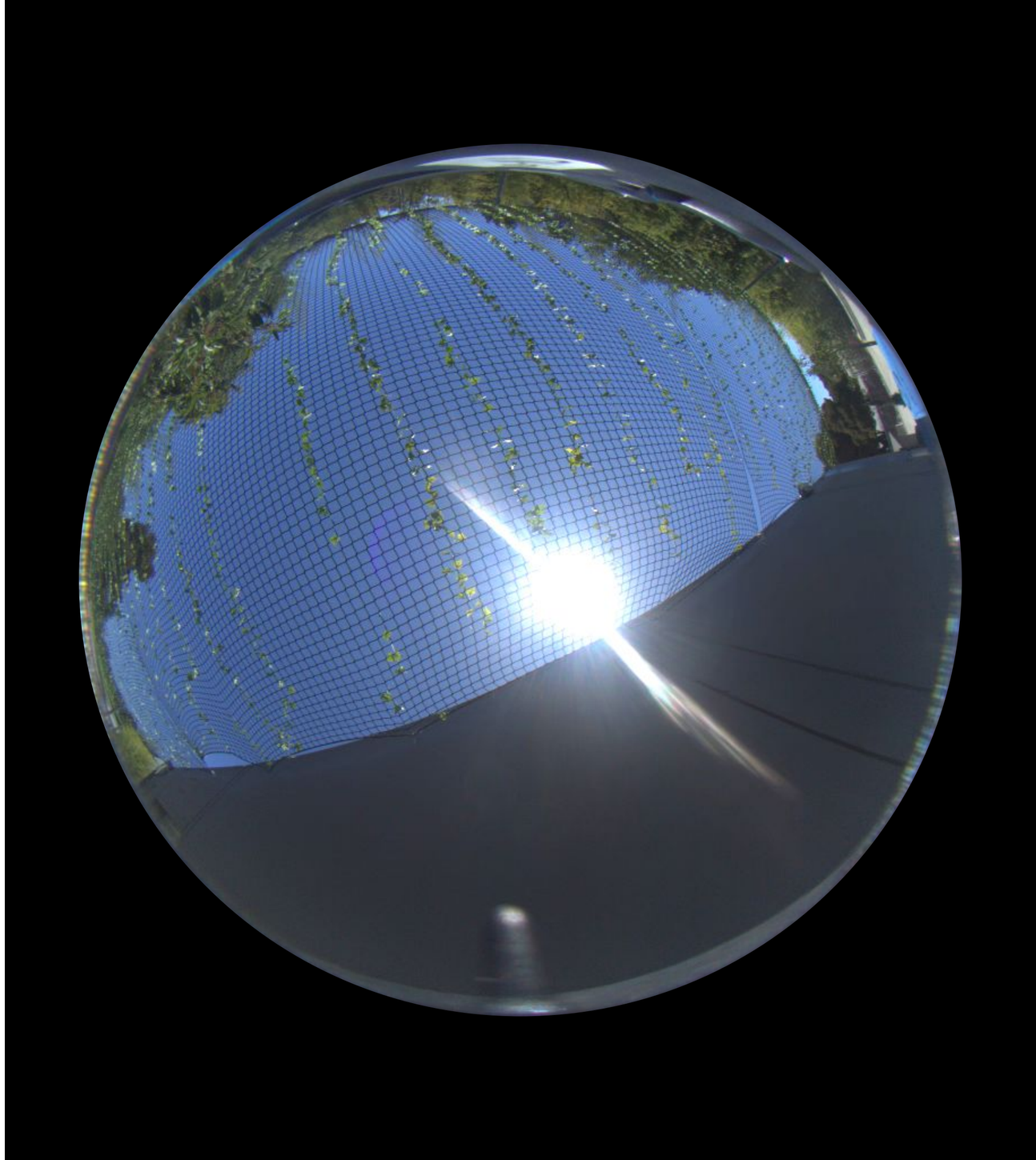
IMPORTANCE OF SOFTWARE FLEXIBILITY

Autonomous systems are VERY early

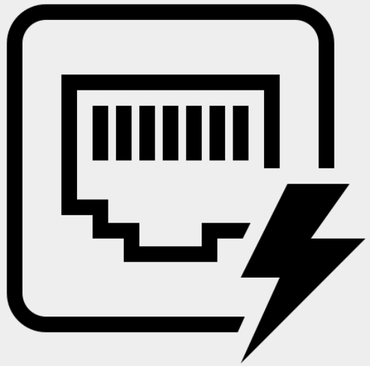
- Need flexibility to solve the next real world challenges

Good software abstractions are key

- Close the loop with real world feedback
- Focus on foundational building blocks



WISHLIST FOR FUTURE SOCS



More general
compute horsepower

Acceleration of the
key workloads

Clean high level
abstractions for HW

QUESTIONS?