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
Our roots go back 12+ years with cutting-edge research at MIT's AI lab.
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.
The Evolution of Drones

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

AGE OF TOYS
- Pilot operated
- RC-based

AGE OF MANUAL HARDWARE
- Pilot operated
- GPS-based
- Sensor payloads

AGE OF AI-DRIVEN AUTONOMY
- Software, AI-driven navigation
- Native obstacle avoidance
- Fully automated workflows
- Integrated solutions

Manual drones have peaked. The future belongs to software-driven aircraft.
AUTONOMY: BOTTOM LINE

- Existing use cases are easier and more reliable
- New use cases that were previously impossible are enabled
SKYDIO
CUSTOMER HIGHLIGHTS
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
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.

“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

2.5M Units

ENTERPRISE  SLED  FEDERAL  CONSUMER

NON-CONSUMER VOLUMES

Today

243K

31K

40K

172K

ENTERPRISE  SLED  FEDERAL
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**

- **Construction Workers in US**: 11.3M
- **Electrical Substations in US**: 60k
- **Bridges in the US**: 614k
- **Farms in the US**: 400k
- **Mi of Oil Pipelines**: 835k
- **Mi of Transmission Line**: 200k
- **Active Mines Globally**: 13k
- **Global oil well sites**: 900k

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

STAGE 1
Autonomous Flight

STAGE 2
Autonomous Workflow

STAGE 3
Autonomous Operations

STAGE 4
Autonomous Multi-drone missions

STAGE 5
Autonomous Drone as a service

SCALE & VALUE

STAGE 1
On site, IN the loop

STAGE 2
On site, ON the loop

STAGE 3
Remote 1:1

STAGE 4
Remote 1:Many

STAGE 5
Remote Many:Many

AUTONOMY: FROM TOOLS TO TEAMMATES TO SERVICE
SKYDIO AUTONOMY ENGINE
SKYDIO AUTONOMY™

A new generation of drone intelligence

SEE

UNDERSTAND

ACT
SEEING THE WORLD

6x 4K fisheye cameras provide 360 degree coverage
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

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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
Vision-based 360 perception at high speed
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?
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

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<th>GPU</th>
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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: $\pi$

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?