White Paper

AI for Inspection: Precise and cost-effective aerial capture using autonomous drones

By Guillaume Delepine, Senior Product Marketing Manager

Prologue

The purpose of this white paper is to explain how Skydio autonomous drone solutions are best-suited for commercial inspection of diverse assets. We propose that the Skydio 2 and Skydio X2 sUAS can help supplement existing inspection techniques to improve precision and documentation, reduce cost and social disruption, and ensure operator safety. This white paper was crafted through over one hundred interviews with industry leading organizations.

AUTHOR

Guillaume Delepine

Senior Product Marketing Manager at Skydio, the leading American drone manufacturer and world leader in autonomous flight. In his tenure at the company, he previously led Skydio's efforts to serve first responders as Public Safety lead. Then, as Enterprise Strategy Manager, Guillaume contributed to the fundraising, planning, and hiring process that led to Skydio's recent announcements of a Series D fundraise at a valuation of over $1 billion USD, expanded roadmap, and growing executive team. Guillaume holds a BA from Princeton University, and took leave of the joint MPP/MBA program at Harvard University to join Skydio.

KEY CONTRIBUTORS

Alden Jones

Vice President of Customer Success at Skydio. Previously founded and led American Tower Corporation's UAS program, which conducted 20,000 automated inspections per year. Alden's team trained 175 existing employees to become UAS pilots and built a custom back-end automated post-processing system for analysis.

Kabe Termes

Director of Solutions Engineering at Skydio. Prior to this role, Kabe was the Business Development Lead at Motorola Solutions Aerial Suite, where he led the nation's first BVLOS, urban based emergency response drone program (4,000+ flights to date). Before this, he was Director of Operations and Regulatory Compliance at Cape, which was later acquired by Motorola Solutions.

Cory Knittel

Director of Enterprise Sales at Skydio. Cory has built the enterprise sales team at Skydio, previously running business operations and business development. Prior to Skydio he completed a leadership rotational program at Boeing across six different functions, landing in product development building business cases for all new commercial airplanes. Cory holds a BS from Georgetown University and MBA from Harvard Business School.

We would also like to acknowledge the expansive committee of current and future Skydio customers that have helped us develop this material, from single-person inspection shops, to state entities, to global engineering firms. Through hundreds of hours of site visits, interviews, and product feedback workshops, you have helped craft our vision to serve inspectors around the world, and for that, we thank you from the bottom of our hearts.

Table of Contents

The Rise of Drones in Inspection

As drone technology has improved since the 2010's, its use has become a hallmark of the world's most effective inspection programs. UAS allow teams to quickly collect, process, and disseminate inspection data throughout their organizations with minimal overhead and operating costs. Drone-captured inspection data helps asset owners and managers more rapidly assess status, and make informed decisions about upgrades and repairs.

Traditional techniques for inspection come with drawbacks that have made inspection team managers eager to search for an alternative. Whether it be high cost, low inspection quality, or the extreme danger to operators, inspection managers face the urgent need to adopt new technology as soon as possible. A few of the most common pre-drone inspection methods are summarized below - for each it is clear that uncrewed aerial systems, if implemented effectively, carry significant and immediate advantages.

Method		Why Drones for Inspection
Helicopters		• Up to 90% lower cost[1] - low maintenance, no fuel, and lower cost of pilots • Reduced ground risk - smaller airframes, with no airborne workers
Climbers / Rappelers		• 33% faster inspections[2] - fewer staff completing jobs faster • Limited labor risk - workers safely on ground
Bucket Trucks (incl. Snooper Trucks)		• 75%+ cheaper[3] - lower capital and maintenance expense • Less downtime - lower-cost machinery enables redundancy within a program • Faster and less disruptive - no lane or sidewalk closures

[1]International Aviation HQ. "15 Cheapest Helicopters in the World."
Published: 9.2.2020. Accessed: 4.13.2021. https://internationalaviationhq.com/2020/09/02/15-cheapest-helicopters/
[2]Based on Skydio operator experience
[3]Transportation Officials (AASHTO). "2019 AASHTO UAS/Drone Survey of All 50 State DOTs."
Published: 2019. Accessed: 4.13.2021. https://www.transportation.org/wp-content/uploads/2019/05/MissionControl_Drones3.pdf
Figure 1. Image Source: Lou Dzierzak, Gear Patrol
Figure 2. Image Source: Jessie Stenzland, Whidbey News-Times
Figure 3. Image Source: TLC Auto Truck Repair Center

Case Study: Jacobs Engineering - Bob Hall Pier, Corpus Christi, TX

In Summer 2020, Jacob's Engineering was asked to inspect the Bob Hall Pier in Corpus Christi, TX. Pier inspections are a frequent task for the 52,000-employee company, which generates $13B in annual revenue. The traditional method of inspection involves dive teams capturing underwater imagery, then spending multiple days treading water under the pier with handheld cameras pointing up to capture the above-surface elements. This method can take up to a week, and involves crews of 5+ divers who accumulate salary, insurance, equipment, and travel expenses.

Fig 4. Image Source: Jacobs Engineering Group

Manual Drones Failed to Uproot Traditional Methods

The inspection sector is not a monolith. Depending on the asset being inspected, and the inspector's relationship to that asset, requirements can vary significantly. However, all inspection programs looking to document assets efficiently need their equipment to enable operations that are precise, cost-effective, and safe. In this section, we will examine these requirements as they pertain to a few industries that have been early adopters of drone inspections.

Bridge Inspection

Fig 5. West Virginia's New River Gorge Bridge. Image Source: Burgess & Niple.

Inspection frequency: 2-year cycle (Federal Highway Administration), 1 year in certain states (e.g., Ohio)

Precision requirements: Identify cracks in concrete, rust or loose bolts

Traditional techniques: Ground-based inspection (low-precision), rappels (high danger), snooper trucks (high operating and social cost)

A recent study by the American Association of State Highway and Transportation Officials (AASHTO) found that the average cost to inspect a typical freeway bridge comes out to $4,600 using traditional deck inspection methods. The social costs to the users of the bridge are calculated to be $14,600 due to the disruption caused by extended lane closures. With such drastic cost disadvantages, it is no surprise that Departments of Transportation across America have been looking to drones as a replacement.

However, bridge inspectors have encountered difficulties building programs around manual drones, because these aircraft need reliable GPS and magnetometer data to ensure stable flight, which makes them inoperable while inspecting the underside of a bridge. Bridge inspection teams will need devices capable of capturing high resolution imagery from up close, even inside truss structures, with pilot assistance tools that help get the job done faster without compromising safety.

Cell Tower Inspection

Fig 6. Image Source: NYSenate.gov

Inspection frequency: Varies, but requires rapid turnaround for cell providers to provide up-to-date colocation information to their carrier customers

Precision requirements: Identify rust or loose bolts, be able to read the labels on antennas and other components

Pre-drone techniques: Tower climbs (slow, dangerous to inspectors)

Drones are an attractive alternative to tower climbs to inspect cell towers. The airspace around the tower can often be a better vantage point for assessing the frame and attached antennas than a ladder attached to the structure itself. Further, avoiding the need for a tower climb directly reduces the risk taken on by the company. Drone data can also be superior - instead of a human inspector working down a checklist and taking written notes, drones can generate a full 3D model of an inspected asset, ensuring full coverage of the structure and providing a superior inspection report.

However, manual drones are inefficient tools for inspecting large and distributed tower networks. Cell tower quality management programs are often composed of teams of hundreds of inspectors, responsible for the assessment of tens of thousands of assets that are intentionally far apart from each other. As a result, these programs need to train large numbers of pilots to capture inspection data consistently across inspectors, assets, and geographies. To build these programs in scalable ways will require engaging with an enterprise-focused drone provider to apply technologies with enough pilot assistance technologies to reduce the need for pilot training while promoting high-quality inspections.

Utility Inspection

Fig 7. Image Source: T&D World

Inspection frequency: 5-year cycle (many utilities are up to 20 years behind schedule, carrying high liability and safety risks)

Accuracy requirements: Identify anomalies (e.g., corrosion, excessive wear, lightning strikes) and read labels on components

Pre-drone techniques: Tower climbs, ground-based inspection, helicopter inspection

Power utilities must inspect a wide variety of assets, ranging from power plants, electric substations, transmission lines, and distribution poles for electric utilities, to wells, offshore rigs, refineries, and pipelines for petroleum and natural gas providers. These assets can also be located in hard-to-inspect areas. Remote locations provide challenges because of the difficulty of transporting inspectors to the scene, while urban and suburban areas present obstacles such as vegetation to navigate, and the increased ground risk that comes with conducting operations in close proximity to civilians' private property.

While manual drone inspections are safer than tower climbs, more complete than ground-based inspection, and can be less expensive than helicopter inspections, they still present inspection programs with substantial barriers to adoption. Manual drones' elevated crash risk around this kind of metallic structures exposes drone programs to liability risk and can discourage investment in the drone team. Further, the long standoff distance required to keep manual drones from crashing prevents pilots from flying close enough to structures to achieve the required angles to read labels, or generate complete 3D models of towers that can be used to effectively communicate inspection results across an organization. These challenges put excess burdens on pilots, who must be trained and then compensated accordingly - consuming up to 82% of a typical drone program's budget and raising the price for drone inspections back into the same range as helicopter inspections when large numbers of assets and pilots are involved. Utilities looking to apply drone technology to the inspection of their distributed assets will need to work with technologies that, unlike manual drones, can enable their pilots to capture data faster, and more efficiently, in a host of different settings and conditions.

Construction Site Mapping

Fig 8. Hinkley Point C Nuclear Power Plant. Image Source: Bloomberg

Inspection frequency: Up to daily for as-built reports for general contractors

Accuracy requirements: .25mm to ensure accuracy to blueprints to prevent rework

Pre-drone techniques: Ground-based total-stations and other surveying equipment

With the rapid adoption of Building Information Management (BIM), construction companies have felt first-hand the importance of data quality to align the myriad contributors to a job site toward completion of a shared project. Drone data has helped supplement ground-based site surveys to generate status reports including 3D models aligned to Computer-Aided Design (CAD) models. These models are critical to ensuring that the built environment mirrors the plan as the job comes together, and to avoiding costly rework should, for example, plumbing not match up with the foundations of a building and require concrete to be dug up and redone.

Today's 3D models are generated by flying manual drones in scripted patterns that they blindly follow at a user-determined altitude. On a job site, however, this process is dangerous and time-consuming, because manual drones cannot avoid common obstacles such as cranes and heavy machinery, which intersperse the constructed environment that is being modeled. As a result, operators are forced to perform multiple flight patterns at high altitudes that compromise quality and speed, as well as safety for both drone and construction teams below. Eliminating this tradeoff will require drones with sufficient intelligence to navigate autonomously around job sites, helping their pilots to both capture sufficient inspection data and avoid obstacles while in flight.

Case Study: Jacobs Engineering - Bob Hall Pier, Corpus Christi, TX

Manual drones also failed to efficiently inspect the Bob Hall Pier, even with highly trained pilots, because they were incapable of capturing imagery of the underside. Below the deck, lost GPS signal and magnetometer interference hampered the drones' navigational capabilities and made it impossible to safely capture inspection-quality data.

Fig 9. Image Source: Jacobs Engineering Group

"I took my DJI aircraft out there and wasn't able to do it. Then the research team followed that up with another DJI drone a few months later and they weren't able to do it either. It's a testament to Skydio and the great work they're doing moving the industry forward."

- Jarvis Worton, Global Platform Technology Specialist and sUAS SME

Jacobs

Because they are built around the fundamental assumption that a pilot needs to be focused 100% on keeping their aircraft from crashing, manual drones are incapable of meeting the demands of enterprise inspection programs looking for precision, cost-effectiveness, and safety.

Requirement	Capability	Manual Drone
Data Quality	✅ 12+ megapixel camera	Available
	✅ 20+ minute flight time	Available
	✅ GPS + magnetometer hover control	Available
	❌ Inspect structures up close	Increases crash risk
	❌ Fly in GPS-denied environments	Drones cannot hover in place without GPS
	❌ Line up precise imagery	No pilot assistance to provide stability in complex environments
	❌ Look straight up	Traditional drones are limited in the vertical gimbal range
	❌ Data capture automation in 3D	Relies on manual flight or 2D grid patterns for 3D scenes
Cost-effectiveness	✅ Affordable hardware	Available - multiple options below $25k
	❌ Scale a program	Requires highly-trained pilots
	❌ Cost of ownership	High from crash liability and pilot training cost
	❌ Inspection efficiency	Requires hours of painstaking flight, exhausting pilots
Safety and Security	✅ Return to home (RTH) capability	Available
	❌ Return to home with obstacle avoidance and intelligent path planning	RTH provides no obstacle avoidance on manual drones
	❌ Reduce crash risk	Obstacle avoidance is unreliable
	❌ Ensure data privacy and security	Often sourced from foreign manufacturers with country of origin concerns

Regulatory Hurdles

When the FAA finalized Part 107 regulations to allow for commercial use of sUAS in 2016, it specified that sUAS aircraft must be flown within Visual Line of Sight (VLOS). Although waivers are allowed, they have been few and far between; as of 2018, the approval rate for BVLOS waivers was 1%.

Even in the rare event that inspection teams receive a waiver, they soon discover that flying manual drones beyond line of sight can be a heart-stopping experience, requiring pilots to exercise supreme skill using only the screen of the ground control station. BVLOS operations have also been inordinately expensive. The FAA traditionally requires the use of expensive solutions – such as radar – designed to detect crewed aircraft, even in areas crewed aircraft are unlikely to fly. These restrictions on BVLOS effectively make it very difficult to allow manual sUAS operations to be scalable and broadly applicable.

True Autonomy is a Game-Changer for Inspection

With the well-documented shortcomings of manual drones, the industry has grown crowded with solutions purporting to provide autonomy. However, *true* autonomy requires a drone to be able to see, understand, predict, and act upon its environment, and each of these factors is an absolute requirement for a drone to be considered autonomous. The defining factors are listed below and have been discussed at length on the Skydio Blog.

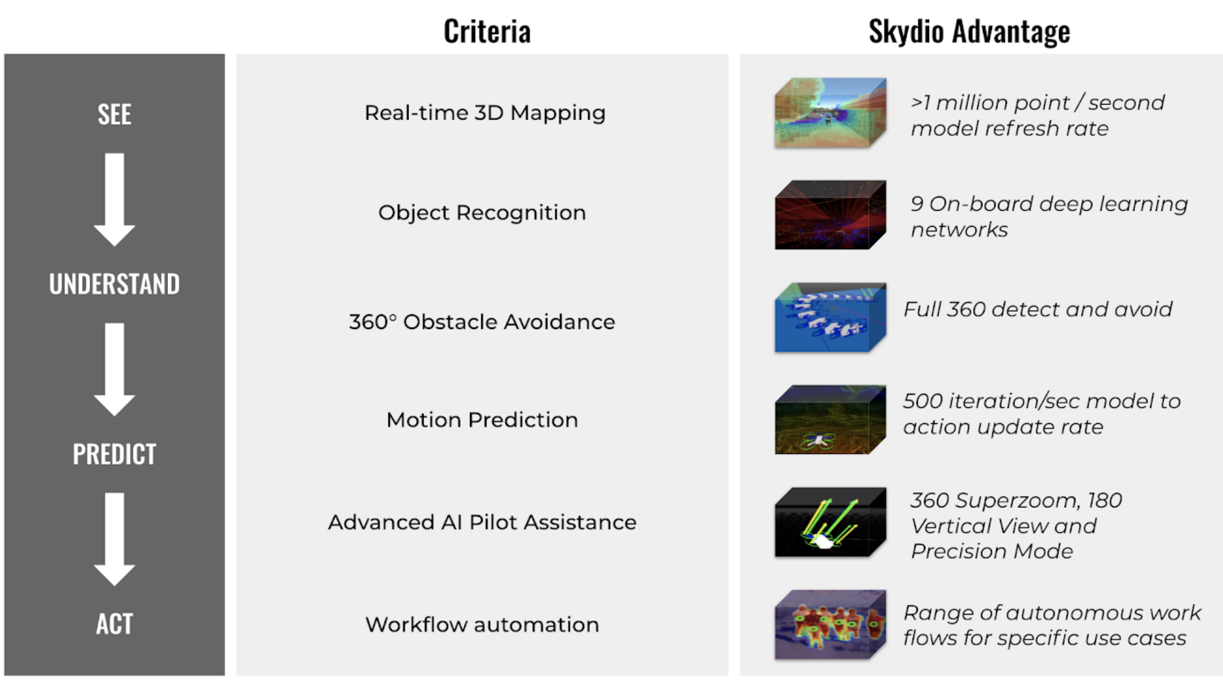

Fig 10.

Autonomy is often defined as the ability to satisfy one of the criteria above, but the combination of all these capabilities is critical. For example, pairing manual drones with workflow automation tools such as DroneDeploy and Pix4D leaves pilots exposed to collisions or having to fly at high obstacle-clearance altitudes for safety, where they are forced to sacrifice speed and quality for safety.

Autonomous drones, such as Skydio 2 and Skydio X2, carry significant advantages for inspection teams, whether they are flying their drones using controllers or using photogrammetry tools like DroneDeploy and Pix4D to capture data for 3D model generation. Embedded into every single Skydio drone, Skydio Autonomy™ **delivers the simplest and safest flight experience**, which lets the pilot focus on the task at hand, instead of the complexity of piloting the drone. Skydio Autonomy has ushered in a new generation of drone intelligence, using breakthroughs in artificial intelligence, computer vision, and robotics to fly autonomously through the most demanding environments. The following are some of the key benefits experienced with the use of autonomous drones.

Dramatically Reduce the Risk of Crashes. Pairing an autonomous drone with these same workflow automation tools provides the power and confidence for 360° obstacle avoidance, so pilots can perform automated photogrammetry capture flights at low altitudes where they can actually generate high-quality data, even among obstacles.

Speed Up the Inspection Process. Flying confidently at low altitude with the assistance of autonomous obstacle avoidance allowed Part 107 operator Sam De Long of Accurate Drone Solutions to save 37% of his pilot expense simply by upgrading from the manual DJI Phantom 4 Pro V2.0 to the less expensive Skydio 2.

Generate Higher Precision Data. Manual drones compensate for their inability to navigate complex environments by loading on increasingly large and expensive cameras and sensors, which only serve to increase the consequences of a crash and force even more conservative flight paths and longer standoff distances from inspection subjects. With Skydio's ability to fly up-close, Aeronyde was able to generate higher-quality 3D models for its clients by replacing the DJI Mavic 2 Enterprise with the Skydio 2.

Reduce Training Requirements. With built-in safety, extensive pilot training is no longer a requirement for safe operation of uncrewed aerial systems. Skydio enterprise customers report up to 90% reductions in required pilot training hours from time of hire to performing jobs independently in the field.

Autonomous Flight Helps Inspection Programs Scale

Skydio solutions are capable of supporting the diverse array of requirements across the inspection industry. When inspection programs are equipped with Skydio drones, they are able to provide higher levels of precision, cost-effectiveness, and safety than they can when using either pre-drone or manual drone techniques. Here is a glimpse of how Skydio's inspection solutions can play a role in delivering the results an inspection program needs.

Requirement	Capability	Autonomous Drone Solution
Data Quality	✓ 12+ megapixel camera	Available
	✓ 20+ minute flight time	Available
	✓ GPS + magnetometer hover control	Available
	✓ Inspect structures up close	Close Proximity Obstacle Avoidance allows detailed in-close flights
	✓ Fly in GPS-denied environments	Skydio Visual Navigator uses cameras and AI to fly safely even without GPS or magnetometers
	✓ Line up precise imagery	Precision Mode, paired with obstacle avoidance, helps pilots line up perfect inspection shots
	✓ Look straight up	Vertical View enables 90° upward vertical gimbal range, to inspect what is exactly above the drone
	✓ Data capture automation in 3D	3D Scan fully automates the image capture process required to generate 3D models
Cost-effectiveness	✓ Affordable hardware	Available - multiple options below $25k
	✓ Scale a program	Autonomy reduces training requirements and increases potential for in-sourcing
	✓ Cost of ownership	Dramatically lower thanks to reduced crash & replacement costs, and training burden
	✓ Inspection efficiency	Compact training programs to shorten the learning curve. Shortened times for inspection by not having to plan to circumvent obstacles
Safety and Security	✓ Return to home (RTH) capability	Available. Visual Return-to-Home (RTH) allows the drone to get back to base through GPS-denied environments using the computer vision system.
	✓ Return to home with obstacle avoidance and intelligent path planning	Available. Motion Prediction algorithms help drone navigate efficiently through any environment.
	✓ Reduce crash risk	Computer vision navigation with reliable 360° obstacle avoidance
	✓ Ensure data privacy and security	Skydio X2 offers an NDAA-compliant solution

Skydio's technology solutions are accompanied by world-class Solutions Engineering and Customer Success teams that can help program managers determine whether autonomous drones are a fit for their organization, train and manage certifications, and maximize the value of their investments. Inspection organizations ready to enter the Age of Autonomy will have full enterprise-grade support as they adopt these new capabilities and grow their programs.

Now that we have detailed how Skydio autonomous drones fill the capability gaps experienced with manually operated drones, let's explore how these enhancements have a positive impact on the use cases discussed in Chapter 2 to perform inspections more effectively.

Fig 11. Image Source: Japan Infrastructure Waymark

Bridge Inspection. Skydio Visual Navigator allows the drone to fly in GPS and Magnetometer-denied environments. Vertical View allows inspectors to look up and inspect the underside of the bridge, while 360° Obstacle Avoidance helps the operator navigate among trusses and other obstacles. With 3D Scan, inspectors can autonomously capture comprehensive imagery and generate 3D datasets for viewing in the field or exporting to photogrammetry engines.

Furthermore, Skydio's partnership with the North Carolina Department of Transportation (NCDOT) led to a first-of-a-kind waiver under Part 107 to inspect bridges beyond visual line of sight. One of the first Part 107 waivers that does not require visual observers, the new waiver allows NC bridge inspectors to send a Skydio drone to inspect elements of the bridge that would otherwise require the use of dangerous rappels or snooper trucks. The waiver is based on the use of Skydio drones due to their ability to avoid stationary obstacles.

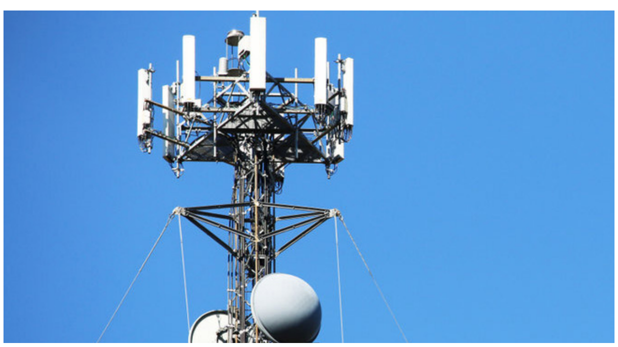

Fig 12. Image Source: GovTech

Cell Tower Inspection. Skydio Visual Navigator and 360° Obstacle Avoidance combine to help pilots safely navigate up close to cell tower structures, where the 12MP sensor on Skydio 2 or Skydio X2 can generate imagery capable of reading labels on equipment. With 3D Scan, inspectors can autonomously capture comprehensive imagery and generate 3D datasets for viewing in the field or exporting to photogrammetry engines.

Fig 13. Image Source: Skydio

Utility Inspection. Thanks to Skydio's computer vision navigation system that doesn't rely on magnetometer calibration, pilots can fly confidently near transmission and distribution towers that emit high levels of electromagnetic interference (EMI). With the added safety, fewer visual observers need to be sent to remote areas to provide redundancy on complex inspections.

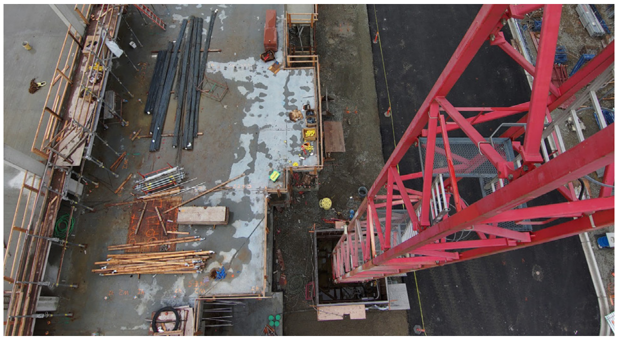

Fig 14. Image Source: Accurate Drone Solutions

Construction Site Mapping. Using 3D Scan's ability to capture complex structures up close from every angle, Skydio drones can autonomously capture the data required to build digital twins and 3D models of construction sites, even at low altitude among obstacles. This allows for more frequent and accurate progress tracking to keep the various teams on a job site working together effectively.

Skydio Products for Inspection

Now that we have explored how Skydio technology can address pain points and challenges of the UAS status quo while meeting key operating requirements, here's a concise summary of the components that make up the Skydio solution for industrial asset inspection.

Skydio 2. An entry-level drone to introduce autonomy to inspection workflows. Features a 12MP camera, and six 4K color sensors used to support Skydio Autonomy. Backpack portable and easy-to-use, Skydio 2 can be provided to any inspector to start taking advantage of aerial data.

Fig 15. Skydio 2

Skydio X2E. Pairs the breakthrough Skydio Autonomy™ engine with a ruggedized airframe that features a dual color/thermal sensor, long-range operations, and extended battery life for up to 35 minute flight time. Core autonomy capabilities of the drone previously described in this paper include **360° Obstacle Avoidance, Object and Scene Recognition, and Skydio Visual Navigator.**

Fig 16. Skydio X2E

Skydio Enterprise Controller. Ground control for X2E is enabled via the Skydio Enterprise Controller, which was designed from the ground up for pilots with demanding operating requirements. Ground control software is natively delivered via the Skydio Enterprise App.

Fig 17. Skydio Enterprise Controller

Skydio Autonomy Enterprise Foundation. An add-on software package that augments the core autonomy engine. It provides AI-pilot assistance capabilities that enhance situational awareness and facilitate flight in obstacle-dense environments. Key features of this package previously presented in this paper include Superzoom, Close Proximity Obstacle Avoidance, POI Orbit and Visual Return-to-Home.

Fig 18. Skydio Autonomy Enterprise Foundation

Skydio 3D Scan™. The first-of-its-kind adaptive scanning software built on top of Skydio Autonomy. 3D Scan allows the drone to automate the data capture process needed to generate 3D models with comprehensive coverage and ultra-high resolution, so that crews can perform higher quality scans in less time and with minimal pilot training.

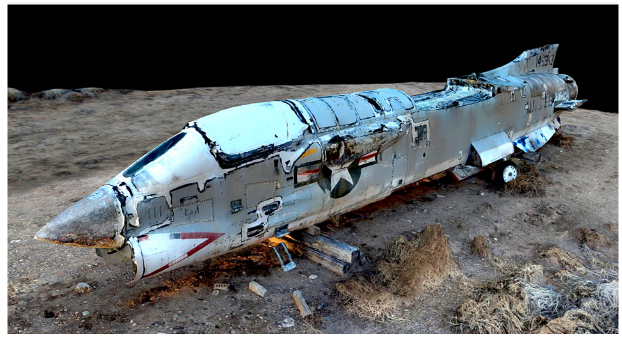

Fig 19. Skydio 3D Scan

Skydio Academy. Delivered online, or in-person, in both self-paced and instructor-led configurations, Skydio Academy provides flexible options for your pilots to achieve the **Skydio Professional Operator (SPO)** and **Skydio Expert Operator (SEO)** certifications that can help a program manager manage and track core competencies across a distributed pilot fleet.

Skydio Professional Operator (SPO)

Certifies **foundational knowledge** about Skydio aircraft, preflight, launch, flight skills, landing, postflight, maintenance, and troubleshooting.

Skydio Expert Operator (SEO)

(requires Skydio Professional Pilot certification)

Certified **real-life flight skills** to safely and efficiently operate Skydio aircraft and software. As an SEO, you will be ready to take flight with complete confidence.

Autonomous Drones: The Next Wave of Inspection Innovation

Infrastructure inspectors are some of the hardest working, least visible professionals in the world, often putting their bodies in harm's way to make sure that our bridges, power plants, and cellular networks perform in safe ways for the general population. Inspectors hang from bridges, expose themselves to nuclear radiation, and climb towers, often crossing long and harsh distances, to keep society's infrastructure investments functional. The coming Age of Autonomy for drones will usher in a new wave of inspection innovation that can help keep workers out of harm's way, while making them more effective and efficient than ever before.

With powerful, modern hardware and Skydio AutonomyTM, Skydio drones are state-of-the-art inspection data collection assets, completely changing how assessments can be performed. Skydio drones will help inspection teams grow faster than ever before, complete more jobs, and provide internal and external clients with better data to make decisions on tighter timelines, and with smaller inspection budgets.

BVLOS operations are critically important for inspection teams, enabling them to cover greater distances and larger structures, collect more data with fewer deployments, and can keep inspectors out of dangerous situations. In the age of manual drones, with limited ability to sense and avoid stationary obstacles, it was difficult to obtain BVLOS authorizations. In the age of autonomy, Skydio solutions are helping to unlock safe and routine advanced BVLOS operations.

From a societal standpoint, the opportunities are exciting - today's inspection teams will be able to multiply their output, scanning more assets at greater frequency than ever before, and enabling rapid-response, preventive maintenance that promotes greater uptime of the assets that we all depend on. All of this is accomplished by using autonomy to ***augment*** human skills rather than replace them.