Part 1: Executive Summary and Detailed Project Overview

Executive Summary:

Maintaining safe and reliable transportation infrastructure has traditionally relied on periodic, in-person visual inspections of critical assets. While effective, these methods are costly, labor-intensive, and expose both workers and the traveling public to risk. They also limit the ability to capture the rich data needed for advanced analytics and predictive maintenance, particularly for aging structures.

The Stage 1 SMART Grant project was designed to address these challenges by piloting prototype innovative inspection approaches. The New York State Thruway Authority (NYSTA) explored the use of unmanned aerial systems (UAS) combined with newly developed advanced digital workflows to improve safety, efficiency, and data quality. The intent of this effort is not to replace state and federally mandated inspection processes, but to augment them with technological means and methods that enables more frequent, accurate, and cost-effective assessments.

Project Objectives:

- Validate UAS-based inspection methods for bridges and other critical assets.
- Demonstrate integration of digital data collection with existing reporting systems.
- Enable predictive maintenance through advanced analytics and digital modeling.

Why This Matters:

Traditional inspections often require lane closures, specialized equipment, and significant labor hours. UAS technology can reduce these impacts, improve worker safety, and provide richer data for decision-making. Frequent, automated data collection also supports proactive maintenance planning and extends asset life.

Approach:

NYSTA deployed UAS equipped with cameras and other sensors to capture high-resolution imagery and structural data. These datasets were processed into supplemental data for traditional inspection practices and digital models to detect changes over time and forecast deterioration trends. The project also developed policies, training programs, and workflows to ensure safe and repeatable operations.

Obtained Benefits:

- Reduced lane closures and hazardous work hours.
- Lowered operational costs and environmental impact.
- Improved accuracy and reliability of inspection data.
- Developed foundation for future AI-driven predictive maintenance.

The availability of this technology encourages supplemental inspections between regulatory cycles, enabling more frequent monitoring of persistent issues. By creating digital models of structures and quantifying deterioration trends, NYSTA can generate predictive maintenance schedules tailored to each asset. While many aspects of infrastructure inspection remain Federally regulated, automated vision systems are increasingly recognized as viable tools. FHWA has indicated interest in remote inspection

processes and is considering their inclusion in future regulations. Recent NYSDOT technical advisories already permit UAS-assisted inspections for high-mast structures, signaling a shift toward broader adoption.

The Stage 1 program demonstrated that UAS technology can reliably augment traditional inspections and provide the data necessary for predictive modeling. Scaling these processes statewide is projected to deliver significant financial, safety, and environmental benefits—estimated at over $219 million in annual savings, and a 60% decrease in hazardous work hours for highway employees.

Detailed Project Overview

By using unmanned aerial systems (UAS) to perform automated and repeatable data collection with on-board sensors such as digital cameras and other sensor types on NYSTA infrastructure, digital models of each structure can be created—enabling automated condition or change detection. Additionally, by quantifying trends and rates of decline for a given structure, a detailed projection of future deterioration may be generated providing an accurate predictive maintenance schedule specific to the structure. Although many aspects of infrastructure inspection are federally regulated on certain structures, including bridges, the use of automated vision systems are not precluded from use in many types of required infrastructure inspection. In fact, the FWHA has stated that they are evaluating the use of remote inspection processes and considering allowing their use under future inspection regulations.[1] Further, regulations regarding high mast structures are already beginning to include opportunities for the application of UAS technology. In a Technical Advisory issued by NYSDOT on 10-18-2024 (TA24-002), an updated FHWA policy includes the following language.

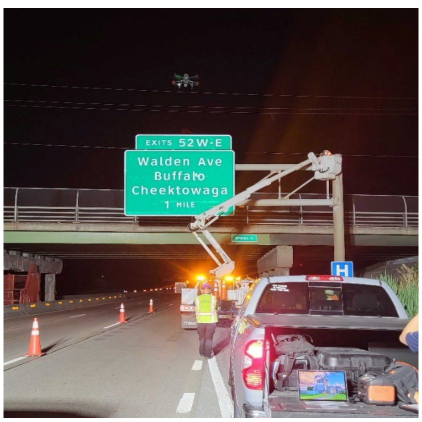

Figure 1 - Prototyping sUAS Sign Inspection simultaneous to NYSTA engineer conventional inspection in Buffalo region.

"Inspection – Type 4: This inspection type applies to High Mast Structures (HMS) only. Portions of the HMS and its attachments accessible by walking must receive a 100% hands-on inspection; otherwise, conduct a full-circumferential, visual inspection of the HMS and its attachments. A tripod-mounted camera, a tripod-mounted spotting scope with a camera adaptor, ***or an Unoccupied Aerial System (UAS) (a.k.a. drone)-mounted camera*** must be used to assist the visual inspection and record field condition photos; the ensuing results must be sufficient to detect all defects, and of particular importance, those which could affect public safety (attachment falling hazard, etc.) or the HMS's structural integrity (e.g., cracks, bulges, loss of steel, etc.)."

The NYSTA team has successfully demonstrated the feasibility of using UAS for reliable and repeatable data collection as both a useful augmentation to regulatory inspection and as providing the information necessary to develop predictive models supporting maintenance planning priorities. The benefits of collecting this additional data and streamlining the processing of the data is significant in all categories identified in the grant requirements. The scaling of these processes state-wide is forecast to have financial, safety, ecological, and sociological benefits that far exceed the cost of implementation, and which will continue to accrue long after the project has been fully implemented. Annual savings of over $219 million, and a 60% reduction in hazardous work hours for highway employees is anticipated to be realizable following full scale implementation across New York State.

[1] https://www.fhwa.dot.gov/uas/resources/hif23065.pdf.

NYSTA has found that the accuracy and safety of gathering and using structural condition data for the Thruway's highly trafficked infrastructure systems can be greatly improved using emerging technologies such as UAS, advanced processing algorithms, and integrated workflows. The Stage 1 program has demonstrated the validity of this hypothesis and quantified the potential benefits through implementation throughout the state. The program accomplishments are summarized below:

Stage 1 Accomplishments

- Demonstrated the effectiveness of commercially available technology to collect the necessary data for effective condition state assessment which meets SMART Grant performance metrics, including reduced lane closures, improved worker safety, and enhanced data accuracy.
- Developed a comprehensive UAS program including safety management, training, policies, and workforce development in preparation for at-scale implementation.
- Developed and validated the generation of inspection reports compatible with the current reporting and archiving systems using enhanced field digital data collection and purpose-built digital forms to organize the collected data.
- Completed integration of the various data collection and data processing systems through full end-to-end testing of the process and comparative analysis of the resulting data products.
- Tested and validated advanced UAS capabilities to enable repeatable data collection on key structural elements sufficient for infrastructure inspection accuracy and enable predictive maintenance, initially demonstrated on early-stage platforms and later validated and finalized using Skydio's X10 Dock system.
- Proven advanced data collection during infrastructure inspection activities in the Buffalo region—one of the most restrictive and trafficked zones of the Thruway—on a 6-lane section with Short Duration Left Lane closure, including UAS night operations with FAA approval for flight within a 0' (zero) altitude LAANC grid in Class C Airspace.
- Demonstrated capabilities in the Albany and Buffalo sections as having the variety of infrastructure types required to validate the flexibility of the process, assess the ability to achieve maintenance improvements and life-extension benefits, as well as measure the potential impact on communities.

Building on earlier demonstrations, the NYSTA team completed validation of automated waypoint missions through live flight using Skydio's X10 Dock and Remote Flight Deck. This milestone closed the final technology gap in achieving true repeatable precision. Missions created during a live flight were replayed multiple times with identical telemetry, imagery, and positional data, confirming consistent capture across iterations. This capability establishes the foundation for long-term structural monitoring, enabling AI-driven change detection and predictive analysis.

Anticipated Scale

- Utilizing a "crawl, walk, run approach" aligned with USDOT deployment readiness guidance, starting with HQ-staff, then regionally based, then system-wide within NYSTA. This approach is scalable to other agencies.
- Enabled through capability-first approach; a platform-agnostic program offers more flexibility and adaptability to new and emerging requirements while mitigating potential technical debt(s).
- Anticipated infrastructure operations and maintenance improvements over current methods will lead to mitigated closure-times, positive safety impacts, and reduce the overall life-cycle cost of a new bridge, including being able to integrate smart, innovative technologies during the pre-construction phase through completion.
- Artificial Intelligence (AI) & Machine Learning (ML) digital models, digital twin benefits, potential new construction methods and materials. Applying engineering judgement over AI data analysis to spot indicative factors so Capital funding for maintenance and repairs achieves the highest return on investment to prolong the life of the structure.

Key Milestones Accomplished

- Field inspection activities:
    - Conducted field inspections on several types of infrastructure (bridges, overhead signs, light poles, radio towers) with field engineering teams validating the capabilities of the UAS-based data collection methods, as well as digital field data collection processes as comparable in performance as conventional methods. Metric-driving data was also collected on key parameters of both methods for input to the benefit model.
    - ID, development, and testing of supplemental inspection methods (rivet) process and digital/web-based form
- End-to-end data workflow:
    - Successful and proven field testing of automated workflows starting with data collection through to final report generation was conducted with the analyzed and verified results demonstrating a significant efficiency gain over conventional methods and reporting requirements while significantly reducing the labor hours and report generation duration.
    - Developed digital web-form MVP including adaptive GUI design, field-level configurability, and data library/structure/etc.
- Repeatable Data Collection
    - Demonstrated the ability to conduct multiple, repeated data collection on the same infrastructure delivering the same visual data sufficient to perform time-sequenced data analysis of condition state. This was verified through multiple collections reviewed by licensed engineers experienced in infrastructure inspection.
    - The live-flight waypoint mission proof-of-concept demonstrated how pilots can record telemetry and positional data during a manual flight to define precise inspection perspectives before automating repeat missions. Using Skydio's X10 Dock architecture, each subsequent flight launched autonomously and reproduced the recorded waypoints with high accuracy, ensuring consistent image framing and environmental context. These findings confirm that automated repetition is achievable without sacrificing human oversight, greatly improving safety, efficiency, and long-term data reliability.

Partners Engaged:

The continued response from identified partners and community organizations throughout Stage 1 of the project has been overwhelmingly positive. Additionally, to optimize the UAS technology in the prototyping stage and create partnerships to allow for scale and full realization of benefits across multiple agencies and applications, a strong focus has been placed on working with NYSDOT, NYPA and other NYS Agency drone programs. Educational Institutions and workforce development organizations have supported input on gaps in workforce skillsets to refine curriculum and offerings while creating employment pipelines directly to NYSTA and NYSDOT including the Syracuse City School District RPIC program, BOCES vocational, continuing education programs and University and Community College programs.

Figure 2 - NYSTA and NYSDOT joint sUAS infrastructure inspection.

Outside Attention:
The work on the SMART grant project with NYSTA has been featured by NUAIR in outreach, conferences and work with other NYS agencies with additional external facing events, activities, and media opportunities occurring throughout 2024 and into 2025. An article was published in eSpatially New York, quote: While the program began by exploring applications for UAS in bridge inspections, opportunities to apply the technology have grown agency wide. Efforts by the UAS team in 2023 lead to a $1.5 million SMART Grant…to update workflows and inspection procedures and develop exciting capabilities like structural monitoring and digital 3D modeling.'[2] And, Local CBS-affiliate, WRGB/CBS6 in Albany, featured the Thruway's Stage 2 award shortly after the December announcement by USDOT.[3]

Project Deviations:
There were no significant deviations from the original concept proposal required during the execution of Stage 1, however, several meaningful lessons were learned. The key lessons learned are listed below:

- Many aspects of bridge inspection are presently regulated by the FHWA, specifically the methods and processes for ensuring every aspect of the inspected asset is seen and examined. While direct utilization of UAS technology to accomplish these critical inspection items is currently limited, the team has been able to demonstrate various efficiency and process improvements, including:
    - Certain critical aspects of the inspection, such as the regulatory-required elevation photo, are easily achievable by using UAS over current methods.
    - Increased situational awareness of potential areas which may have gone unnoticed without an initial, UAS scan which may otherwise pose a threat or danger to persons or property near the infrastructure asset.
    - Recognizing the significant operational and maintenance value of data collected by UAS outside of regulatory purposes including the ability for digital twin development across the various types of assets under Thruway management, leading to more timely maintenance prioritization, planning, and scheduling through analysis such as bridge deck deterioration data—to name one example.
    - The FHWA has acknowledged that future regulations will allow for automated data collection once the agency has deemed sufficient to provide adequate safety assurance.[4]
- Authorization to operate within controlled airspace around airports is simplified by utilizing an FAA-approved Low Altitude Authorization and Notification Capability (LAANC) service provider and can be obtained rapidly, often within minutes or seconds if all other Part 107 requirements are met, with options and pathways available for operations falling outside of Part 107 available.
- Flight operations over moving traffic are permitted under Part 107 without waivers under 14 CFR §107.145, although more regulatory, safety, and operational research is required.
- In the rare case where regulatory relief is required, NYSTA has identified several FAA pathways that maintain operational flexibility while ensuring regulatory compliance through waivers, Certificates of Authorization (COA), and the Special Governmental Interest (SGI) program, to name a few.
- During Stage 1, the NYSTA team initially demonstrated repeatable waypoint mission capabilities using the Sony Airpeak platform. However, the manufacturer announced the discontinuation of the Airpeak, creating a temporary gap in our operational workflow. This prompted a reassessment of available UAS platforms and led to a successful collaboration with Skydio to implement live-flight waypoint mission recording using the X10 Dock and Remote Flight Deck. This transition not only

[2] https://espatiallynewyork.com/2024/03/26/new-york-state-thruway-authority-drone-program-continues-to-soar/.
[3] https://cbs6albany.com/news/local/thruway-authority-gets-15-million-federal-grant-for-drones
[4] "Use of Unmanned Aircraft Systems (UAS) to Enhance the Design, Construction, Inspection, and Maintenance of Transportation Infrastructure" August 2023, FHWA Global Benchmarking Program Study Report RPT NO FHWA-PL-23-007.

restored the lost capability but enhanced it by enabling real-time mission creation with improved precision and safety features. The experience underscores the importance of platform-agnostic planning and adaptability in technology selection to mitigate risks associated with vendor changes.

Part 2: Proof-of-Concept or Prototype Evaluation Findings

The performance metrics defined in the Stage 1 Evaluation Plan were designed to assess the impact of any change, alteration, or advancement to the traditional infrastructure inspection process ensuring the desired benefits aligned with the goals of the NYSTA, NYSDOT, USDOT and the SMART Grant program, and the travelers and residents of NY State. The project targets reduced lane closure durations and other key actions to enable meaningful improvements including overall highway and worker safety, improved accessibility, and air quality, among others.

The measure for improved safety of highway personnel and the traveling public was examined through the reduction of lane closure hours, number of deployed vehicles, and required personnel. The reliability of the transportation infrastructure was examined through improved and more responsive maintenance, reducing overall cost and delays. The use of UAS technology to supplement infrastructure inspection during prototype inspections resulted in the reduction of lane closure time and the reduction in number of highway personnel and vehicles involved in lane closures directly impacting the desired outcome of improved safety. The collection of data with UAS into digital forms has provided the opportunity for more frequent, standardized, and repeatable infrastructure inspection including digital models to allow for more responsive, cost-saving maintenance of infrastructure with a clear path to improved long-term reliability of the Thruway's network.

Collected data aimed to compare conventional and drone-based approaches across a single infrastructure inspection prototype, the annual performance of the NYSTA system, and the annual performance of the NY State DOT. Additionally, key performance indicators (KPIs) are used to measure the effectiveness, efficiency, and impact of these inspection methods. The focus is on understanding the underlying metrics without relying on specific quantified data, offering a holistic view of the operational, environmental, and economic factors at play.

			Single Bridge		NYSTA (Annual)		NYS (Annual)	
			Stage 1 Prototyped		Thruway System		NYS including NYSDOT	
Grant Program Priorites	Metric	Units	Conventional	Drone	Conventional	Drone	Conventional	Drone
Safety and Reliability	No. of Accidents	No.	N/A	N/A	38	TBD	215	TBD
	Hazardous Work Hrs	Hrs	72	27	35,338	13,252	760,666	285,250
	Public Congestion Hrs	Hrs	148	56	60,720	22,770	1,570,277	588,854
Climate	Carbon Emissions	Metric tons	234	88	95,826	35,935	2,732,399	1,024,650
	Cost of CO2	$ (K)	$5.9K	$2.2K	$4,887K	$1,832K	$139,352K	$52,257K

Operational costs are a significant factor in determining the efficiency of bridge inspections. The technology developed and assembled for this concept generally offers lower fuel, labor, and maintenance costs; significantly reduces the time required for lane closures, both in setup and breakdown; offers a substantial reduction in vehicular costs by minimizing idle time and congestion for both commuter and commercial vehicles; significantly improves safety by reducing the number of accidents in work zones; and helps minimize productivity loss by reducing delays for commuters and businesses making this prototype concept a more cost-effective option compared to conventional methods.

NYSTA identified applications of technology that offer significant improvements in the collection, workflow, and back-office processing of infrastructure inspection information by both streamlining the process of incorporating collected data into existing inspection reporting systems and utilizing UAS as a data collection platform. The Stage 1 SMART Grant team successfully demonstrated and validated the ability to collect, process, and integrate required data from onboard a UAS platform into the existing reports database without any modifications to the front-end of the reporting system. Additionally, the creation of a transformational digital database as an asset management tool, or digital twin, to power cutting-edge developments in Artificial Intelligence and Machine Learning (AI/ML), current and historical data collected on various infrastructure structures and elements can be analyzed including identification of condition states and detailed change analysis, providing valuable engineering data to support individualized structure degradation models and improved maintenance planning and scheduling while maintaining the required level of safety.

The NYSTA Team developed and validated improved processes for the data collection and processing through end-to-end testing and equivalence comparison with present methods during Stage 1. Results showed meaningful decreases in lane closures, field time for highway engineers, and report generation time with outcomes that improve worker safety, motorist safety, accessibility, and which reduce traffic delays and reduce stress on engineering and maintenance personnel. The results of the Stage 1 benefit assessment demonstrate a **potential annual savings state-wide of over $219 million** accounting for improvements in safety, vehicular delay, traffic congestion, and operational efficiencies once the implementation is scaled across the Thruway and all DOT infrastructure.

			Single Bridge		**NYSTA (Annual)**		**NYS (Annual)**	
			Stage 1 Prototyped		**Thruway System**		**NYS including NYSDOT**	
Grant Program Priorites	Metric	Units	Conventional	Drone	Conventional	Drone	Conventional	Drone
Measurement and Validation	Operational Cost	$	$11.2K	$4.2K	$12.07M	$1.8M	$66.4M	$34.32M
	Direct Savings	$	N/A	$7K	N/A	$10.27M	N/A	$32.1M
	Total Savings	**$**	**N/A**	**$38K**	**N/A**	**$19.56M**	**N/A**	**$219.36M**

NYSTA performed on-site field testing of these technologies during the spring and summer of 2024, in a section of Thruway highway near downtown Buffalo deploying both a UAS drone team and the Division's traditional inspection team during one shift of asset inspection covering several overhead signs and a bridge structure. Results of the comparison to a traditional inspection shift demonstrated a 40% improvement in efficiency and improvements in worker safety due to the shorter duration of the operations, shorter lane closures, fewer stopped vehicles present for work zone traffic control, and the ability to conduct much of the inspection further from the side of the roadway.

Testing and development of the concept continued throughout the fall and winter of 2024 across several truss-bridges near Albany, NY focusing on identifying, classifying, and capturing individual rivet condition states across and entire bridge structure. Utilizing bridge plans, spreadsheets, and standard nomenclature, the project team was able to mature data collection and reporting from handwritten notes on paper to a web-based digital form, as depicted in Figure 4.

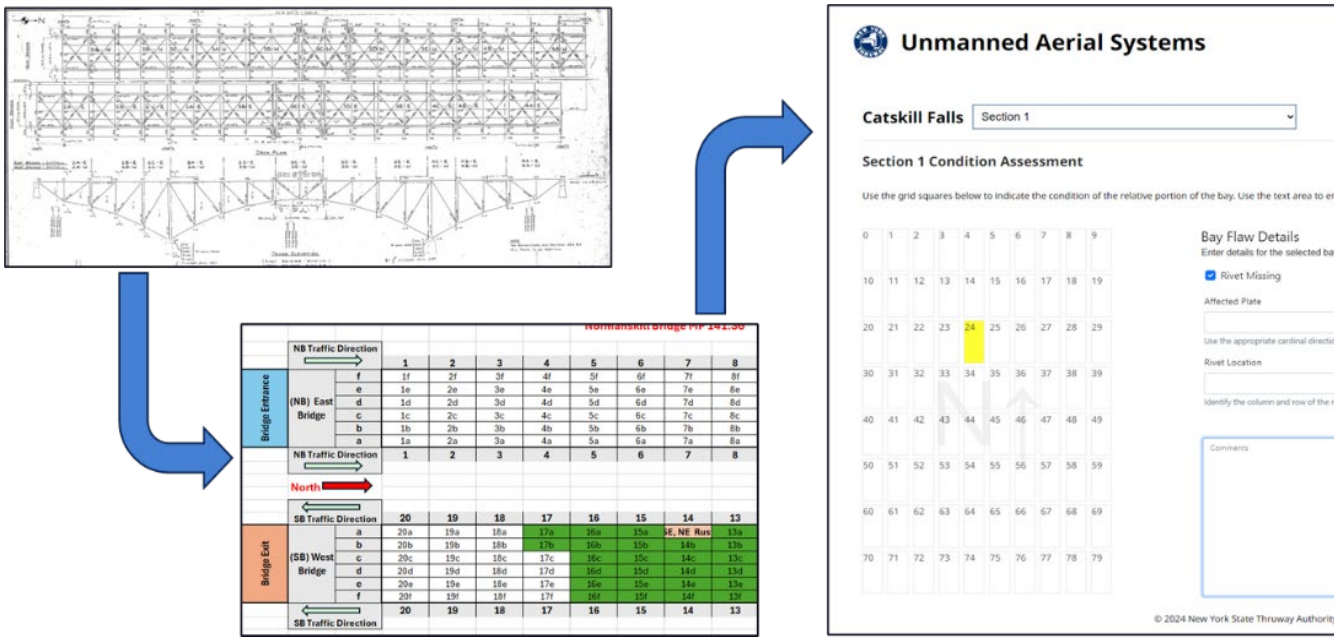

Figure 3 - Digital Form Development Progression

How Your Stage 1 Project Demonstrated Improvement Across the Program Goal Areas?

Resiliency:
NYSTA has performed data collection and processing across a subset of infrastructure, demonstrated benefits, and reduced development risk. The use of UAS and digital assets of infrastructure provides processed data for a robust proactive maintenance program taking reliability of individual assets to scale for greater resiliency of the transportation network, including the security of the data through existing and enhanced cybersecurity requirements. The data analysis tools utilize condition state rate of change assessment to provide specific decision-making information to aid in the prioritization and scheduling of preventative maintenance to extend the life of infrastructure and defer major maintenance and replacement, when possible and without compromising safety. Additionally, extending the useful life of key infrastructure elements will have significant maintenance cost impacts, potentially saving tens of millions of dollars annually. Applying artificial intelligence (AI) and machine learning (ML) to aid in data classification and identification of trends in component degradation, engineering judgement can be employed to select proactive maintenance measures and repairs to prolong the life of structures.

This data-driven approach will better assess the actual impacts of the variability and severity of severe weather events and its impact on maintenance requirements for each individual infrastructure element increasing overall resiliency. Through the data collected and the long-term analysis of the data, infrastructure mangers will have the ability to make more informed decisions as to the needs and benefits of each individual infrastructure element resulting in a more proactive approach to maintenance prioritization increasing the resilience of the transportation network.

Access:

The Thruway system provides the most efficient and direct access to and from cities and commercial centers where critical services, educational centers, and employment opportunities are concentrated for hundreds of urban and rural communities across the state, including many disadvantaged communities. Reducing lane closures and delays, increasing system reliability, and improving processes to ensure this infrastructure is optimally maintained supports connectivity for underserved and disadvantaged populations to access jobs, education, and essential services including critical medical care and timely response from first responders.

Figure 4 - Example of Region 4 disadvantaged communities serviced by the NYSTA system.

The Niagara Section of the Thruway (I-190) is a prime access example as it provides the most direct route between the cities of Niagara Falls and Buffalo, New York. This segment of I-190 includes 4 truss arch bridges to cross the Niagara River providing a crucial regional transportation artery for 74 disadvantaged communities in the Buffalo-Niagara region. Similar benefits accrue to communities in other regions of the state where the Thruway provides the primary transportation option for underserved communities.

I-190 helps public transit remain a viable option for lower-income and historically underserved populations that rely on public transportation to access work, school, and essential services. This segment is part of three bus routes utilized by the Niagara Frontier Transportation Authority (NFTA) with a combined annual ridership of over 250,000 passengers, with one route serving an area where 41% of the population lives in poverty. I-190 links the 47,993 residents of Niagara Falls, 23.8% of whom live below the poverty line, to employment opportunities in and around the City of Buffalo. I-190 also connects residents to jobs in the medical, education, and public sectors including the Buffalo Niagara Medical Campus—employing approximately 17,000 people—and the State University of New York at Buffalo which employs approximately 24,000 people.

I-190 links high risk cardiac patients to specialized care available at the Gates Vascular Institute (GVI), an extensive regional medical center in the City of Buffalo. Roswell Park is another critical care provider serving the city of Niagara Falls which has an age adjusted incident rate above both the US and New York State average. Reliable access to specialized medical care in the greater Buffalo region and in many other communities close to the Thruway rely on this critical transportation link for life saving services.

Environmental Sustainability, Air Quality, and Quality of Life:

The environmental benefits of the new inspection processes are primarily realized through reduced lane closure durations, which lead to less congestion, fewer idling vehicles, improved fuel efficiency, and air quality. These changes are expected to contribute positively to overall air quality and quality of life.

The project benefits communities affected by poor air quality. Reducing traffic congestion and delays through shorter lane closures has several positive effects on communities located along the highway, including:

- **Improved Air Quality:** Cleaner air reduces health risks such as respiratory and cardiovascular diseases, improving overall public health.
- **Enhanced Quality of Life:** Cleaner air and reduced noise levels from less traffic congestion contribute to a better living environment.

As the new inspection processes and data collection methods, including UAS, are deployed and implemented at scale across the State of New York, these operational improvements are anticipated to support substantive fuel savings and air quality enhancements statewide.

Partnerships & Workforce Development:
NYSTA, in collaboration with key partners, developed a scalable model that supports USDOT workforce development priorities, including pathways to good paying jobs and training programs for UAS pilots and data analysts. This model includes eight essential elements to support scaling to other agencies, private sector technology development, community benefits, and workforce development in UAS and Data Management, with a focus on skills in piloting, data analysis, and cybersecurity.

Figure 5 - NIST UAS Pilot course hands-on build event with High School P-Tech program.

The development of a network of partners during the prototyping stage has provided a robust model for harnessing existing infrastructure and leadership at institutions, organizations and industry to provide the necessary support to achieve the aggressive goals of the project at scale. As a prime example during Stage 1 prototyping, NYSTA and NYSDOT combined in scheduling and attending demonstrations of leading vendor UAS platforms, post-processing and geospatial software, and UAS continuing education events. Additionally, educational institutions have provided an overwhelmingly positive response to match industry needs with refinements to curriculum, course offerings and certifications to continue to build out the workforce development pipeline. This same enthusiasm has been expressed by partnerships with private sector OEM’s and technology providers to inform development and deliver field-ready solutions.

The NYSTA has harnessed relationships with the NYSDOT and other New York State agencies, UAS operations and regulatory expertise in NUAIR, the private sector, and educational and community organizations. Educational institutions are open to feedback on gaps in workforce skillsets to refine curriculum and offerings while creating direct pipelines from these institutions directly to NYSTA and NYSDOT, including the Syracuse City School District RPIC program, Mohawk Valley Community College RPAS program, and BOCES vocational and continuing education programs.

Integration:

NYSTA has been able to demonstrate successful integration of UAS data workflows with existing inspection systems, meeting SMART Grant requirements for interoperability and cybersecurity compliance. This integration included various systems and data streams across the end-to-end inspection workflow including data generated by several commercially available UAS platforms and sensors. Back-end developer tools available through Amazon Web Services (AWS), Google, and Microsoft provided the ability to connect and exchange preliminary inspection data across disparate systems—initially thought to be unlikely to occur for legacy systems and tools—prior to significant investments in both time and development dollars. Additionally, progress has been made on further integration with archived datasets potentially unleashing the ability to apply advanced computing tools like AI and Machine Learning (ML) in areas like predictive maintenance, materials science and construction methods, and asset management.

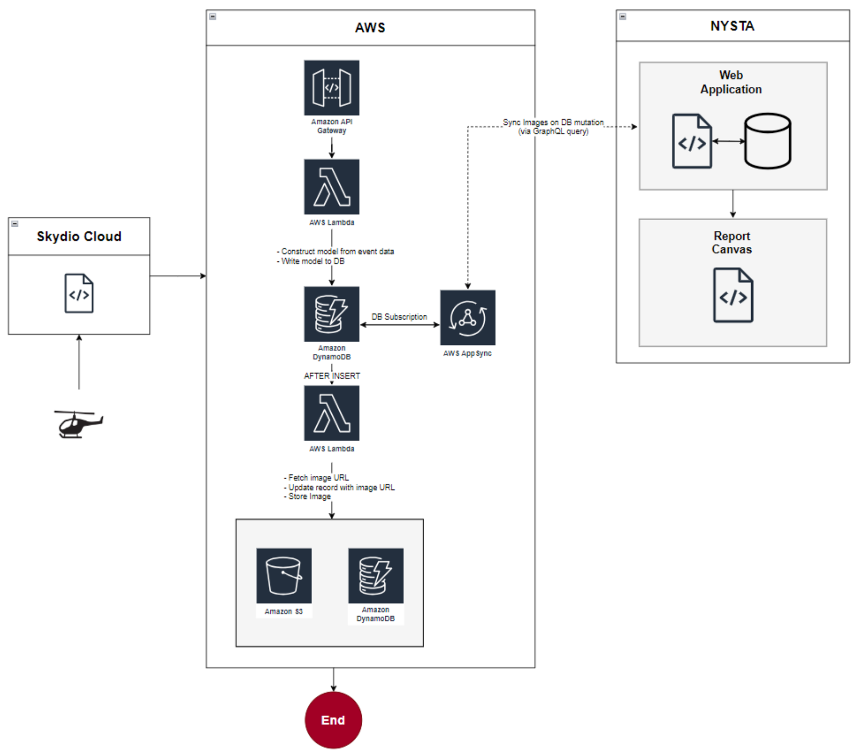

Figure 6 – Back-end MVP Notional Architecture

Leveraging simple Application Programming Interface (API) protocols with the features offered by Microsoft's Power Automate and AWS, NYSTA created a digital infrastructure inspection workflow comprised of web-based forms to capture digital inspection notes while in the field (Figure 8); UAS flight logs and collected images (Figure 9); and post-processing routing, analysis, and reporting as required by USDOT.

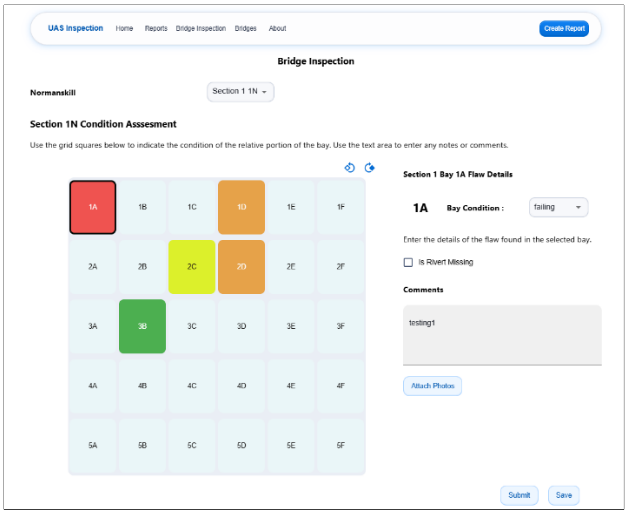

Figure 7 - Supplemental Inspection Form; Condition Assessment

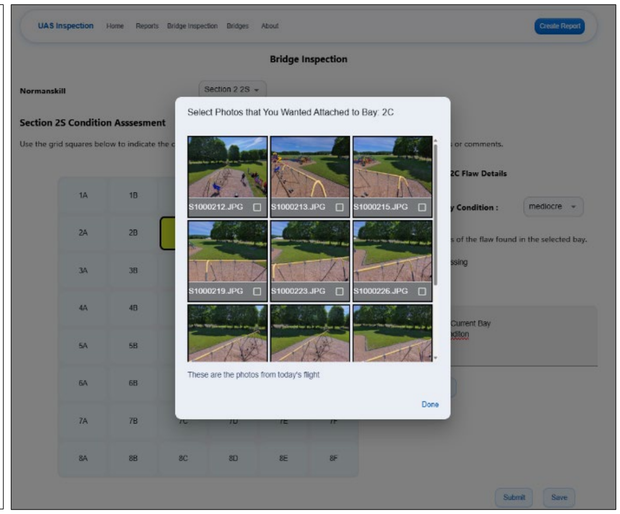

Figure 9 - Supplemental Inspection Form; UAS images

Designed and intended to be utilized in the field, this web-based form acts as a digital bridge across the various information and data collection or retention gaps that exist within conventional methods and procedures. During an inspection, assigned Thruway personnel would access the digital form through NYSTA's secure website and internal logins from a tablet or other internet-connected device with a browser.

Part 3: Anticipated Costs and Benefits of At-Scale Implementation

The initial cost of deploying drones for infrastructure inspection includes procurement of aircraft and payloads, training programs, and integration of the technology into pre-existing physical and IT workflows. While these upfront costs may be substantial, they are offset by long-term savings. Drones reduce the need for installation and removal of scaffolding, Under Bridge Inspection Units (UBIU) bucket trucks, and temporary traffic control that are otherwise required by traditional inspections. Personnel can access hard to reach areas quickly and without the need for costly logistical preparations. Additionally, inspection frequency can be increased at a much lower proportional expense, leading to a cost-effective outline for preventative maintenance and potentially avoiding expensive emergency repairs. Over time, these savings can more than compensate for the initial investment in drone technologies.

The use of UAS to supplement manual infrastructure inspections enhances safety for both employees and the traveling public by minimizing workers' exposure to high-risk environments, such as active roadways and elevated structures. UAS technology minimizes the risk of work zone-related accidents by enabling more frequent and efficient inspections without requiring additional lane closures or significantly shortening their duration. Keeping traffic moving not only reduces congestion and travel delays but also decreases the likelihood of secondary crashes caused by sudden slowdowns, ultimately improving overall roadway safety and efficiency. For highway workers, this means fewer hours spent in hazardous conditions, while the traveling public benefits from reduced disruptions, improved traffic flow, and a safer, more reliable transportation network.

In October 2024, our UAS team was engaged by NYSTA's Engineering Department to conduct preliminary inspections of rivet conditions on two steel truss bridges. Prompted by an understanding that conditions existed requiring repair of rivets on the structures, the UAS team was able to immediately deploy to locate target areas for repair. Rather than using an UBIU, including lane closures, with associated costs and efforts to identify areas of concern, the UAS team thoroughly inspected the underside of these bridges, located the areas requiring attention, and reported conditions to engineering staff. This process enabled the use of an under-bridge inspection unit to have a shorter duration as areas targeted for repair were identified before the unit arrived on site.

Drones equipped with a wide variety of payloads can capture detailed data that is often superior to what human inspectors can obtain. This technology enables the detection of micro-crack, corrosion, and other early signs of structural degradation such as rivet conditions that might be missed during traditional inspections. The ability to conduct regular and detailed inspections increases the reliability of the infrastructure, as issues can be identified and addressed before they become critical. Furthermore, drones can store and analyze data in large amounts over time, providing valuable insights into the long-term health of the structures and enabling predictive maintenance strategies that further enhance reliability.

From a technical standpoint, the merits of using drones for infrastructure inspections are centered around their ability to deliver high-quality, actionable data more efficiently and safely than traditional methods, while also enabling more proactive maintenance strategies through advanced sensing and real-time analytics.

Figure 10 - Benefiting Disadvantaged Communities (Systemwide)

UAS based inspection significantly reduces fuel consumption compared to traditional methods. Conventional inspections typically require large vehicles and machinery—such as attenuators, UBIU, and other support equipment—which involve multiple trips and substantial fuel use. By contrast, drones operate on battery power, consuming minimal energy and eliminating the need for fuel altogether.

Reducing reliance on vehicles for inspections translates into major fuel savings and lower operational costs. Drones, being electric and pre-charged, avoid the logistical and financial burden associated with fueling and transporting heavy equipment.

Inspectors typically require lane closures, detours, and support vehicles causing traffic congestion. Inspector teams utilizing UAS will be eliminating the need for these disruptions, reducing traffic delays and associated fuel and time costs.

Compared to traditional inspection methods which often require extensive use of additional equipment and idling vehicles, drones offer a more environmentallypol friendly alternative by reducing the need for these resource intensive processes. They can quickly and efficiently survey large areas without the vehicle costs associated with conventional inspections. Moreover, the data collected via UAS from interim inspections can identify potential structural issues earlier, allowing for timely maintenance and preventing the need for more extensive repairs that will more than likely require additional energy and resources. This proactive approach not only ensures the longevity of infrastructure but also minimizes the environmental footprints associated with maintenance, leading to a more sustainable process.

Anticipated Costs of At-Scale Implementation

The table below contains anticipated costs for at-scale implementation over 3 years, including:

- Budgeted reimbursable expenses related to direct salary and fringe labor costs by NYSTA staff.

- Procurement of geospatial positioning equipment, vehicles/aircraft, and computer hardware and software services.
- An outreach program to provide job & educational training for historically disadvantaged communities.
- Consulting services provided by the Northeast UAS Airspace Integration Research Alliance, Inc (NUAIR) covering:
    - Project management support,
    - Delivery of airspace situational awareness and management tools,
    - Process implementation support across the Thruway system,
    - Training development and delivery for new and existing employees,
    - Implementation for data collection including flight plans and baseline data acquisition for specific infrastructure elements,
    - Final process and training validation, and,
    - Deployment support for DOT implementation.

Future Project Costs $Thousands				
Project Development Activity	**Project Costs**	**Non-Federal Funds[1]**	**SMART Funds**	**Other Federal Funds**
Thruway Authority Personnel	$4,967.3	$0	$4,967.3	$0
Fringe Benefits	$3,228.8	$0	$3,228.8	$0
Subtotal: Labor Costs	**$8,196.1**	**$0**	**$8,196.1**	**$0**
Equipment	$1,303.9	$0	$1,303.9	$0
Supplies	$70.0	$0	$70.0	$0
Subtotal: Equipment & Supplies	**$1,373.9**	**$0**	**$1,373.9**	**$0**
Contractual (NUAIR)	$3,507.7	$0	$3,507.7	$0
Contractual (NYSDOT)	$1,480.1	$0	$1,480.1	$0
Subtotal: Contractual Expenses	**$4,987.8**	**$0**	**$4,987.8**	**$0**
Other	$310	$0	$310	$0
Subtotal: Other	**$310**	**$0**	**$310**	**$0**
Indirect Charges:	**$0**	**$0**	**$0**	**$0**
Total Future Project Cost:	**$14,868 (rounded)**	**$0 (0%)**	**$14,868 (100%)(rounded)**	**$0 (0%)**

The potential compounding benefits offered by integrating this concept into the infrastructure inspection process are analyzed through comparing prototype stage data extrapolated out across the Thruway for annual program benefits and cost savings, shown in the correlating table, with the notional costs shown in the table above. A 3-to-1 return on investment over a 3-year implementation period is anticipated based on savings known so far. Where excitement builds within our project team is the potential benefits at scale— especially safety improvements, vehicular delay reductions, cost savings, and process efficiencies—over a 10- or 20-year period through assumed down-stream asset management impacts. Advancements in AI/ML, graphics processing, and analysis tools offer benefits not previously applied.

The following table shows the impact of these improvements quantifying the significance of benefits realized across New York State for an at-scale implementation. These early metrics and the calculated savings will be updated regularly as the impact of the new methods are more accurately quantified.

			Single Bridge		NYSTA (Annual)		NYS (Annual)	
			Stage 1 Prototyped		Thruway System		NYS including NYSDOT	
Grant Program Priorites	Metric	Units	Conventional	Drone	Conventional	Drone	Conventional	Drone
Safety and Reliability	No. of Accidents	No.	N/A	N/A	38	TBD	215	TBD
	Hazardous Work Hrs	Hrs	72	27	35,338	13,252	760,666	285,250
	Public Congestion Hrs	Hrs	148	56	60,720	22,770	1,570,277	588,854
Resilency	Inspection Frequency	Yrs.	1	2	491	980	10,565	21,128
	Maintenance Vehicles	$ (K)	$24.07K	$3.2K	$11,816K	$1.5K	$60,713K	$28,788K
Equity and Access	Lane Closures	Closures	5	1	304	71	6,553	1,529
	Disadvantaged	# of ppl	N/A	N/A	N/A	930,000	TBD	TBD
Climate	Carbon Emissions	Metric tons	234	88	95,826	35,935	2,732,399	1,024,650
	Cost of CO2	$ (K)	$5.9K	$2.2K	$4,887K	$1,832K	$139,352K	$52,257K
Partnership and Integration	Infrastructure	No.	N/A	15	N/A	759	52425.6	16383
	Regions	No.	0	1	0	4	0	15
Fit, Scale, and Adoption	Overall Infrastructure	No.	N/A	15	N/A	1392	N/A	TBD
	Automated Flights	Inspections	0	5	0	1018	0	TBD
Data Sharing, Cybersecurity, and Privacy	Post Processing	No. of Hours	5	2	2,454	982	52,824	17,608
Workforce Development	Employees Trained	No.	1	3	3	32	8	300
	New Jobs Created	No.	0	1	1	15	N/A	135
Measurement and Validation	Operational Cost	$	$11.2K	$4.2K	$12.07M	$1.8M	$66.4M	$34.32M
	Direct Savings	$	N/A	$7K	N/A	$10.27M	N/A	$32.1M
	Total Savings	**$**	**N/A**	**$38K**	**N/A**	**$19.56M**	**N/A**	**$219.36M**

Part 4: Challenges and Lessons Learned

The integration and adoption of emerging technologies such as UAS for otherwise manual or "hands-on" activities encountered various challenges throughout concept development. Each element of the broader concept has its own unique set of risks, issues, and opportunities; often requiring adjustments along the development path. While many of these challenges encountered throughout this Stage 1 effort could be seen as barriers, the project team's expertise and industry-wide reach offers the ability to quickly adapt to evolving requirements or technical realities.

Federal regulations, specifically FHWA inspection requirements, currently limit full automation. However, lessons learned highlight pathways for regulatory adaptation and operational flexibility through FAA waivers and other compliance mechanisms. These regulations currently limit inspection methods, including the ability to utilize automated data collection capabilities demonstrated in this concept. The FHWA has acknowledged that future regulations may need to be adjusted once sufficient data is collected from concepts, like this project, to ensure the safety and security of the traveling public. Despite these limitations, the project team identified significant asset management advantages and efficiency gains by utilizing collected data for advanced modeling and analytics, improving maintenance scheduling and planning.

Additionally, FAA regulations continue to evolve with emerging technology integration efforts related to uncrewed aircraft systems and commercial space operations. Capability enabling regulations will be issued over the coming years, however, the most advanced operations addressed by those expected rules largely fall outside of the operating environments of the NYSTA. Current regulations including 14 CFR 107 provide the operational enablers required for this concept and where limitations exist, coordination with the FAA will occur via the various pathways created for advanced operations/operators such as through granted waivers and authorizations or the Special Governmental Interest (SGI)[5] process. The SGI process enables certain public operations to occur, within planning and coordination requirements set forth by the FAA, where civil/recreational operations would otherwise be restricted and have been identified as an operational mitigation following multiple TFRs issued over Thruway assets in response to the UAS security concerns in New York and New Jersey.

Technology challenges should be expected in any concept development project, and this effort is certainly no different. Multiple *micro-solutions* focused on UAS platform and capabilities, cloud services and integration, and application development were established concurrently as part of the proof-of-concept stage. Selecting the UAS platform that most closely aligned with the concept's goals was slightly limited by NDAA requirements by removing platforms that may address all concept requirements but are prohibited based on their country of origin. The ability to meet concept requirements in the aggregate is possible across multiple platforms and peripherals, however, challenges often arise when working across multiple service providers and manufacturers including those as simple as system-to-system integration issues to long-term product viability as seen with the Sony Airpeak.

The transition from the discontinued Sony Airpeak to the Skydio X10 Dock proved the importance of platform-agnostic planning. Collaborating directly with Skydio, the team validated not only replacement capability but a superior approach: live-flight waypoint recording. This advancement highlighted the value of maintaining flexible architectures that can absorb rapid vendor or regulatory shifts without loss of functionality.

While modern cloud computing presents remarkable opportunities for serverless and microservice architectures, it is not an overstatement to say that it is also a complete paradigm shift for how the Thruway traditionally approaches application development. This organizational-level shift impacted items such as user roles, permissions, polices and budgets, and code development and validation, highlighting the need for an updated strategy and development approach for cloud services.

With an understanding of the factors that dictate the effectiveness of UAS for infrastructure inspection, there can be areas where data collection is required yet drone-based collection may not be the safest method. These situations may include the underside of bridge decks over highways or moving traffic, bridges or structures over or around rail lines, or other areas where regulations cause UAS technologies to be unavailable. For these areas, it is encouraged to supplement aerial data collection with terrestrial methods such as high-definition laser scanning using terrestrial LiDAR units or other precise survey instrumentation. Combining datasets from various collection methods is a proven process and can be helpful when data collected from alternate methods can validate the accuracies of other datasets.

Finally, as this concept focuses on the inspection process of existing structures within the NYSTA system and the data collected, there are no anticipated impacts nor additional requirements to be met for NEPA per the department's initial determination nor BABA as this project is not construction related.

Part 5: Deployment Readiness

Project Readiness for At-Scale Implementation

The NYSTA team is fully prepared to scale its UAS program statewide, supported by documented training plans, equipment lists, and compliance strategies that meet SMART Grant readiness criteria for at-scale implementation. The implementation strategy focuses on applying technologies and processes

[5] https://www.faa.gov/uas/advanced_operations/emergency_situations

developed during Stage 1 to realize the full benefit of this concept across New York State infrastructure systems covered by the NYSTA and NYSDOT.

The project's success, both demonstrated and anticipated, is based on the core requirement to ensure identified technologies, services, and/or capabilities are interoperable, adaptable, flexible, and individually scalable. This blended approach of using multiple, well-established, UAS manufacturers such as Skydio and Amazon Web Services for cloud support, not only meets the core requirements but may also mitigate what can be a volatile marketplace where vendors may exit rapidly, ensuring continuity and long-term viability.

The high-level scaling plan of the proposed processes, methods, and tools are shown below including these 3-key areas of planning required to take the validated processes system-wide:

- Finalizing the documentation and equipment list required by each division,
- Training the pilots and engineers in the new data collection and processing procedures,
- Identifying the set and inventory of infrastructure that will be the first to have inspections conducted under the new process.

The plan will sequence through the divisions, incorporating a new division approximately every 6 months. Initial actions will consist of training key operational roles (engineers and pilots) in the process of using UAS, including the regulatory rules and identifying and hiring any outstanding personnel. The first 2 divisions to be scaled up will be the Albany and Buffalo divisions as these regions provide significant benefit to a large, underserved community and they have actively participated in the Stage 1 process development and validation, increasing their readiness.

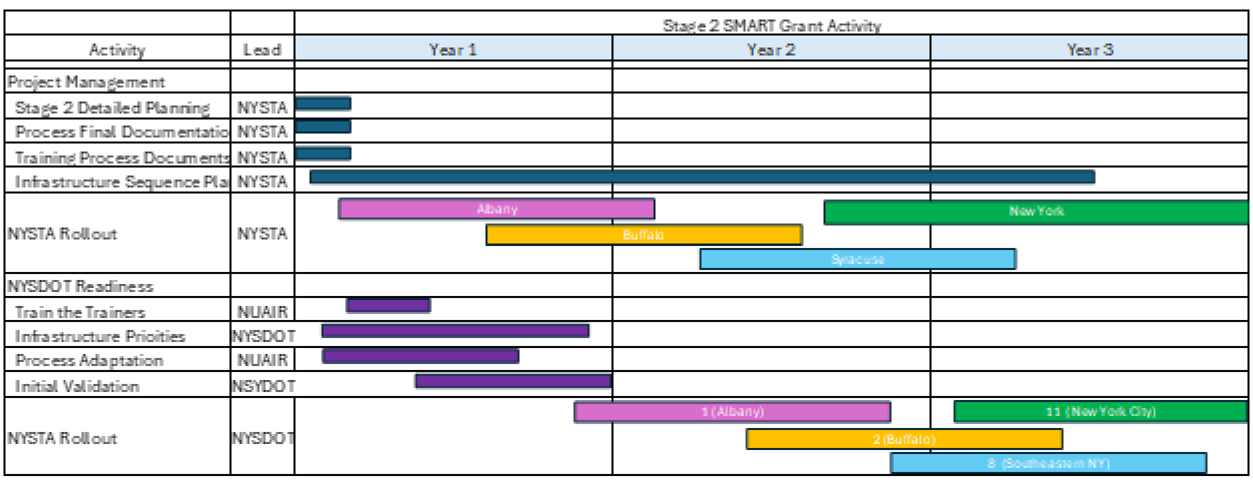

Figure 11 - Notional 36-Month Implementation Sequence.

The at-scale implementation of the Thruway system, particularly along the I-190 corridor, directly benefits disadvantaged and historically underserved communities (HDCs) by enhancing access to critical services, educational opportunities, and employment in urban and rural areas across the state. In the Buffalo-Niagara region, I-190 serves as a crucial link for 74 disadvantaged communities, improving connectivity to major employment centers, including private sector industries and public institutions such as the Buffalo Niagara Medical Campus and SUNY Buffalo. The improved infrastructure supports public transit systems, vital for lower-income populations, enabling reliable access to jobs, education, and essential services, including specialized medical care. These benefits in the Buffalo-Niagara region exemplify the broader statewide impact of maintaining and optimizing Thruway infrastructure, particularly for underserved populations.

Potential obstacles to at-scale implementation are largely logistical, having retired the majority of the development risks in Stage 1. These challenges include completing all the necessary training to ensure that all involved with the new process understand not only the execution but where it can be applied and where it is currently not applicable due primarily to regulatory requirements. Another part of the training will require operators to fully understand the FAA regulations and how to comply with them in different locations and scenarios. Leveraging enterprise-level tools such as fleet management, airspace awareness, and pilot tracking, all made available through UAS service suppliers (USS), will enable NYSTA UAS program managers and operators to comply with federal regulations and internal policies, smartly and efficiently. An important part of the deployment plan is providing objective evidence that the accuracy and completeness of the inspection reports are fully acceptable to the professional engineers responsible for ensuring they comply with regulatory requirements. Given the proportion of the processes that are being replaced, as opposed to augmented by new data collection techniques, this risk is relatively low for the initial deployment, and the process will include close communication with the engineering group to assure they agree with the compliance prior to any subsequent changes made to the process.

Gaps in Understanding the Operating & Maintenance Requirements

The project team has identified the lack of a cohesive, whole-concept O&M strategy as the primary gap. This gap will exist until final determinations are made on technical, hardware, and service elements of the concept. The current and working O&M strategy leverages policies and manuals for the individual elements of the concept, where they exist, and service-level agreements for software and cloud hosting services. The Thruway’s UAS Policy (Revised 2023) addresses key O&M elements such as aircraft maintenance and tracking and accident/incident reporting while individual manufacturer’s UAS manuals help define maintenance requirements and intervals.

To mitigate potential technical debts as the concept matures, the project team has prioritized adaptability and interoperability across the products, services, and partners tested during the prototype process. For UAS, the adoption of interoperable hardware components enabled by open-source mission or flight controller software languages allows an operator to create multi-purpose UAS platforms by selecting the specific sensors and peripherals required for their operational priorities and use-cases. As seen with the discontinuation of Sony Airpeak, focus can quickly shift to the next up and coming UAS platform versus what could have been otherwise detrimental impact to the overall concept. As data requirements and use-cases continue to mature, combining new technologies or capabilities with the flexibility, and scalability of cloud-based solutions along with ease-of-use tools offered by vendors like AWS, will allow the Thruway the ability to leverage future improvements, rapidly, without the need for entire technology solution or stack replacement.

Deployment readiness now includes standardizing waypoint mission workflows statewide. Initial dock placements will focus on high-priority assets to support repeatable inspections, with future phases expanding mobile waypoint mission capability to non-dock X10 aircraft. Continued collaboration with Skydio will ensure readiness for BVLOS operations under the forthcoming FAA Part 108 rule, enabling persistent and remote mission execution.

Assessment of How Implementation Would Harness Benefits and Mitigate the Negative Impacts of New Technologies on Good-Paying Jobs With the Choice to Join a Union.

Technology and tools as part of this concept are used for information gathering that would otherwise be dangerous and/or lengthy and as decision support tools creating new opportunities for preventative and predictive maintenance of NYSTA assets. Adoption of this concept will likely lead to additional opportunities for current employees as well as job creation ranging from UAS pilots to data science and asset management.

Part 6: Wrap-up

Did the Proposed Solution Meet Your Expectations?

The NYSTA team has successfully demonstrated the feasibility of its UAS program and alignment with SMART Grant objectives, using UAS for reliable and repeatable data collection as both a strategic and useful augmentation to regulatory inspection practices and to provide the information necessary to develop predictive models supporting maintenance planning priorities. The benefits of collecting these additional data points and streamlining the processing of this data is significant in all categories identified in the grant requirements. The scaling of these processes state-wide is forecast to have financial, safety, ecological, and sociological benefits that far exceed the cost of implementation, and which will continue to accrue long after the project has been fully implemented. Estimated annual savings of over $219 million, a substantive reduction of vehicular delay and congestion impacts, and, most notably, a 60% reduction in hazardous work hours for highway employees is realizable at full scale across New York State.

Notable Changes to the Proposed Solution for At-Scale Implementation?

At the time of this report's writing, it is unlikely any substantive changes or adjustments will be made, nor are they desired, for at-scale implementation. The intentional use of commercially available products and services to accomplish infrastructure inspections within the current regulatory enablers and limitations allows for this concept to mature and scale as originally intended.

What Advice Would You Give to Other Communities Embarking on the Same Path?

- Select a suitable technology partner;
- Select the appropriate technology;
- Select the right problem(s);
- Test the chosen technology;
- Make noted improvements to the process;
- Finalize the process;
- Solve the problem(s);
- Delivery the project on a larger scale.

For communities attempting to embark on a similar mission, one key that is paramount to success is to identify internal champions of this emerging technology and encourage them to drive the implementation and spread the concept agency-wide. Internal support from those who are not just willing to try the idea but those who pick up the ball and run is the catalyst by which programs like this advance. Securing enthusiasm in executive management also bolsters support to power through the stumbles associated with lessons learned along the way.

Additionally, employing a crawl, walk, fly approach to program development is key to long lasting success. While a fast build garners statewide interest and momentum, it's attention to detail and completion of each individual step that builds a proper foundation for continued long term growth. Identifying and then leveraging a targeted, supplemental inspection process as the first effort versus attempting to digitally re-create an entire regulated bridge inspection process translated into the project's overall, and continued, success.