Figure 1- 8 Gen 2 Dock Systems under construction at CONEX West for the Phase 2 SOAR project.

Implementation Plan for Caltrans Stage 1 SMART Grant

Project Title: Deploying UAS Innovations for Remote, Autonomous Infrastructure Construction Inspection

Recipient Name: California Department of Transportation (Caltrans)

Fiscal Year of Award: FY22

Period of Performance: August 15, 2023 – August 15, 2025 (including extension)

Organization(s) Preparing the Implementation Report: California Department of Transportation, Division of Construction

Revised Implementation plan Submission Date: December 5, 2025

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Introduction and Project Overview

1.A Project Overview

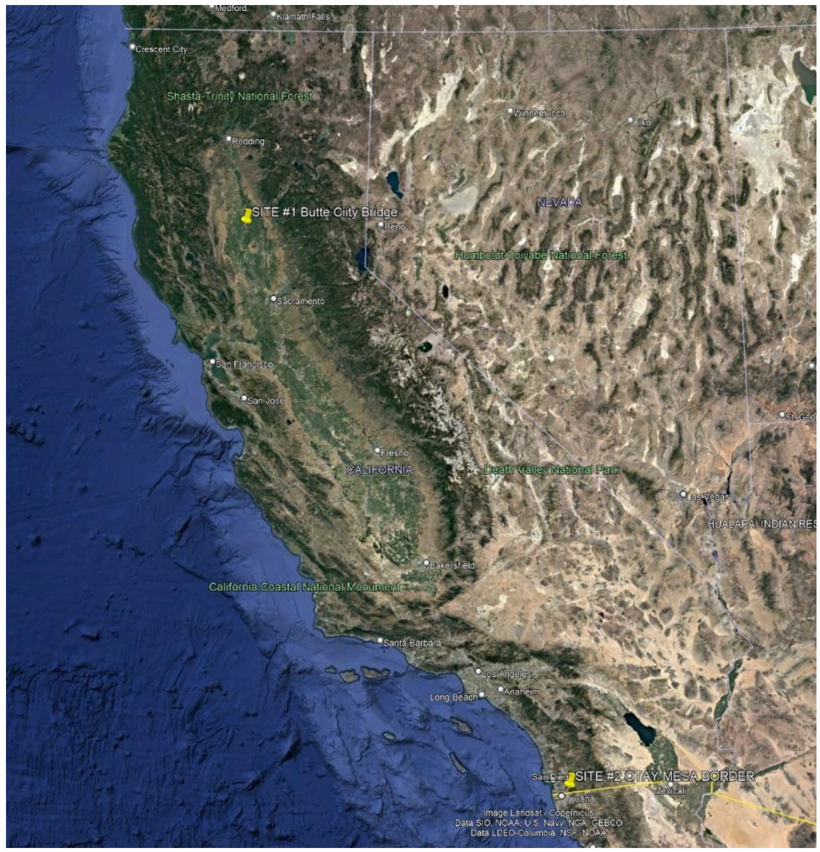
The California Department of Transportation (Caltrans) seeks to more efficiently and cost-effectively conduct assessments and inspections associated with its expanded portfolio of infrastructure projects arising from Infrastructure Investment and Jobs Act (IIJA) investments and inspections associated with its expanded portfolio of infrastructure projects arising from Infrastructure Investment and Jobs Act (IIJA) investments. Believing advancing Uncrewed Aircraft Systems (UAS) technology is key to addressing this workload and workforce issue in a repeatable and scalable manner, Caltrans proposes a Stage 1 Strengthening Mobility and Revolutionizing Transportation (SMART) demonstration to validate the innovative use of dock-based UAS fully designed, assembled and supported in the US for remote autonomous operations. While Caltrans currently utilizes manually piloted UAS across all divisions and has completed more than 10,000 UAS flights, evolution to remote autonomous operations will be an operational force multiplier for the Caltrans workforce, the project delivery performance and the citizens and communities of California.

1.B Current Conditions

Caltrans is currently engaged in 931 active infrastructure construction contracts valued at $15.2B and has a pipeline of approximately 2100 additional projects to be completed over the next 4 years. Approximately 900 of these active and pending projects are located in High-priority infrastructure corridors. Caltrans currently uses manually piloted UAS to assess infrastructure conditions and to collect data for design, construction and maintenance of transportation infrastructure. The use of UAS technology has proven to save time and money and provide better data to assist in administering infrastructure construction contracts compared to traditional inspection methods, and UAS-enhanced projects have fewer worker injury claims.

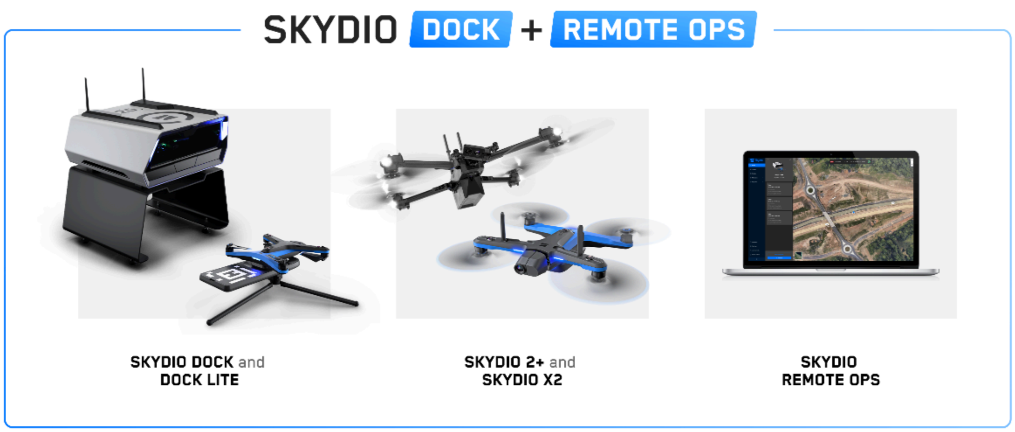
1.C Project Locations

Caltrans' Stage 1 project has installed dock-mounted UAS at two active and fully permitted infrastructure construction sites to validate the enhanced capabilities of dock-based UAS to augment traditional inspection tasks. Manually piloted, visually observed UAS have demonstrated efficiencies over physical inspections, and docked systems represent another opportunity to expand usage and enhance capabilities. The two sites identified for the demonstration are the Butte City Bridge Replacement project in Glenn County, CA and the East Otay Port of Entry project in San Diego County, CA. The Butte City project is replacing a 4200' long structurally deficient bridge that spans the Sacramento River with a modern cast in place concrete structure. This bridge serves as a major economic engine for the local community, as it is the only river crossing for 20 miles in either direction. The East Otay Port of Entry project will construct a new freight port of entry from Mexico into the United States. These two projects will provide data on the operation of the dock -based UAS, the amount of reductions in travel realized by operators not driving to and from the sites to conduct flights and the statistical reduction of worker injury. A second component of the Stage 1 demonstration will integrate assessment data into the secure, cyber-aware Digital Construction Management System Caltrans is currently developing. The core integration will be to automate the UAS data capture and processing functions into this Common Data project delivery performance to provide data useful for the inspection, measurement, and payment of contract bid items. Legacy processes currently in use are heavily reliant on manual processes. This integration will provide detailed, actionable data to improve the overall inspection and management of a variety of critical infrastructure projects administered by Caltrans. Data generated through the Stage 1 demonstration will inform an understanding of how to best repeat and scale docked UAS utilization in Stage 2 and as a nationwide model.



1.D Technologies Utilized

- **Skydio X2 UAS**: Autonomous drones with advanced obstacle avoidance and remote operation capabilities.
- **Skydio X2 Docking Stations**: Semi-permanent, site-deployed Skydio X2 drone docks for long-term management of data, response, and live monitoring of deployment areas. The X2 platform supports continuous operations with automated charging and secure data transmission, enabling persistent surveillance and data collection over extended periods.
- **Digital Construction Management System**: A secure platform for integrating UAS-generated data into Caltrans' existing project management workflows.



- Solar Power/Battery Backup - Conventional Solar power and battery backup systems were designed and installed to meet power requirements at Site #2 at Otay Mesa Port of Entry.
- Starlink Satellite Internet- satellite internet has been the backbone of making this program successful. Starlink mobile Backpacks and Vehicle mounted panels have been deployed in rural locations where traditional means of communication are unavailable. The setup involves a Starlink mobile pack with battery backup allowing for 6-8 hours of connectivity.
- Performance metrics indicated an average latency of 20-40 milliseconds and download speeds Starlink ranging from 50-150 Mbps. These speeds were sufficient to support UAS operations, real-time data transmission at both sites.
- The reliability of Starlink was tested under various weather conditions, and it maintained stable connections with minimal downtime, ensuring continuous operational capabilities.

1.E Goals and Desired Outcomes

Safety and Reliability

- **Goal**: Enhance the safety and reliability of infrastructure inspections by reducing the need for on-site personnel. Complete 100 flights at each site during performance period demonstrating reliability of systems.
- **Outcome**: Reduce worker injury rates and improve the frequency and quality of inspections.

Resiliency

- **Goal**: Increase the resiliency of infrastructure management by enabling continuous, remote monitoring capabilities.
- **Outcome**: Improve response times to infrastructure issues and reduce project delays.

1.F Operational Efficiency Details

Overview of Operational Efficiency Objectives

The Caltrans Stage 1 SMART project was designed to demonstrate measurable efficiencies in infrastructure inspection and data collection workflows. By transitioning from traditional, manually piloted UAS operations to remote, autonomous systems, the project substantially reduced the amount of staff travel time and field resources required for site inspections. These improvements directly translated into time savings, cost reductions, and better utilization of Caltrans' technical workforce.

Key operational objectives included:

- **Reduced Staff Travel:** Decrease the number of vehicle trips required for field inspection and documentation.
- **Improved Workforce Productivity:** Enable inspectors and engineers to perform more evaluations in less time by remotely accessing project data.
- **Optimized Resource Use:** Lower agency operating costs through reduced mileage, fuel use, and equipment wear.
- **Reliable Remote Operations:** Utilize autonomous, solar-powered docking systems to maintain continuous uptime without dedicated on-site support.

Analysis of Efficiency Gains

A primary achievement of the Stage 1 demonstration was the measurable reduction in on-site inspection trips—approximately **30 percent fewer** visits were needed across both project locations (Butte City Bridge and East Otay Mesa Port of Entry). This reduction directly corresponds to significant **savings in staff hours and travel costs**.

Details of the Analysis

1. **Reduction in Site Visits**
    - Autonomous UAS operations reduced the need for manual site inspections by roughly 30 percent across both pilot sites.
    - Each avoided trip typically represented a 50-mile round-trip drive and 1.5 to 2 hours of staff time.
2. **Time and Cost Efficiency**
    - **Average Distance Avoided:** 50 miles per trip (≈ 60 for Butte City; ≈ 40 for Otay Mesa).
    - **Trips Reduced:** ≈ 60 annual site visits eliminated (based on 100 inspections per site per year).
    - **Staff Time Saved:** ≈ 90 to 120 hours annually per site—time redirected to higher-value inspection and analysis activities.
    - **Operational Cost Savings:** Reduced mileage reimbursements, fuel expenditures, and vehicle maintenance associated with frequent field travel.
3. **Power and Connectivity Efficiencies**
    - Off-grid solar power and battery-backed systems enabled full operational uptime without reliance on utility connections.
    - Remote connectivity through satellite (Starlink) ensured continuous access to data, minimizing the need for in-person oversight or troubleshooting.

Summary

The Stage 1 demonstration clearly validated that autonomous, dock-based UAS provide a **force-multiplying effect** for the Caltrans workforce—reducing travel requirements, recovering staff hours, and enabling continuous site visibility. These operational efficiencies strengthen safety, improve project delivery timelines, and support scalable statewide implementation under the upcoming Stage 2 SOAR initiative.

1.G Community Impact

Impact on Local Communities

Successful demonstration and use of UAS dock systems on the Glenn County Butte City Bridge Replacement Project and the East Otay Port of Entry Construction Project is expected to yield quantifiable, repeatable impacts to infrastructure construction and maintenance standards, and in turn to the High-priority infrastructure corridors in which these projects are undertaken. Assuming successful Stage 1 demonstration outcomes, the UAS dock systems will remain in place and be used for maintenance and asset management. The Stage 2 vision includes additional deployments statewide, allowing Caltrans to efficiently execute impactful transportation infrastructure projects throughout California and to sustainably inspect and manage that infrastructure. Negative externalities are not expected. Anticipated positive impacts specifically related to the Stage 1 demonstration communities include:

- Lessening the need for engineers to physically travel to infrastructure construction locations to conduct assessments and inspections will reduce fuel expenditures.
- The use of UAS dock systems will reduce project delivery time and costs, hastening the access for local commerce attributable to the Butte City Bridge Replacement Project and the reduced vehicle wait times, reduced inspection-related project delays, regional mobility and economic growth attributable to the East Otay Port of Entry.
- Due to unforeseen project delays of the Otay Mesa Project related to funding, the community impacts of that sire were not measurable. The Butte City Bridge project is nearing completion, and the Gen 2 dock system is in use were able to use the portion of the old bridge and the majority of the old project photos were published UAS system that were the status of the work. The

Caltrans project delivery performanceal staff radiometric/thermal remotely to monitor a structure for bats. This proved successful, structure has been removed. IN addition, to the community that were taken from the beneficial in informing the community as to joint SMART Award project SOAR will continue to develop these workflows. Work is already underway on the Joint SOAR phase 2 project that will demonstrate the scalability of Dock based drones.

1.H Stage 1 Project Sites

SITE #1 Butte City Bridge Replacement

- **UAS Installation**: Deploy Skydio X2 drone and docking station at the Butte City Bridge. System is co-located with
- **Pilot Training**: Train Caltrans personnel on the operation and maintenance of the UAS and docking stations.
- **Data Integration**: Integrate UAS-collected data into the Digital Construction Management System.

Deployment Metrics:

- 341 Completed missions as of 8/15/2025
- 39 hours 21 minutes total flight time
- Zero flight failures

SITE #2 Otay Mesa

- **UAS Installation**: Deploy Skydio X2 drones and docking station at the East Otay Port of Entry.
- **Pilot Training**: Train Caltrans personnel on the operation and maintenance of the UAS and docking stations.
- **Data Integration**: Integrate UAS-collected data into the Digital Construction Management System.

Deployment Metrics:

- 216 Completed missions as of 8/15/2025
- 26 hours 20 minutes total flight time
- Zero flight failures
- 100% off-grid power in use

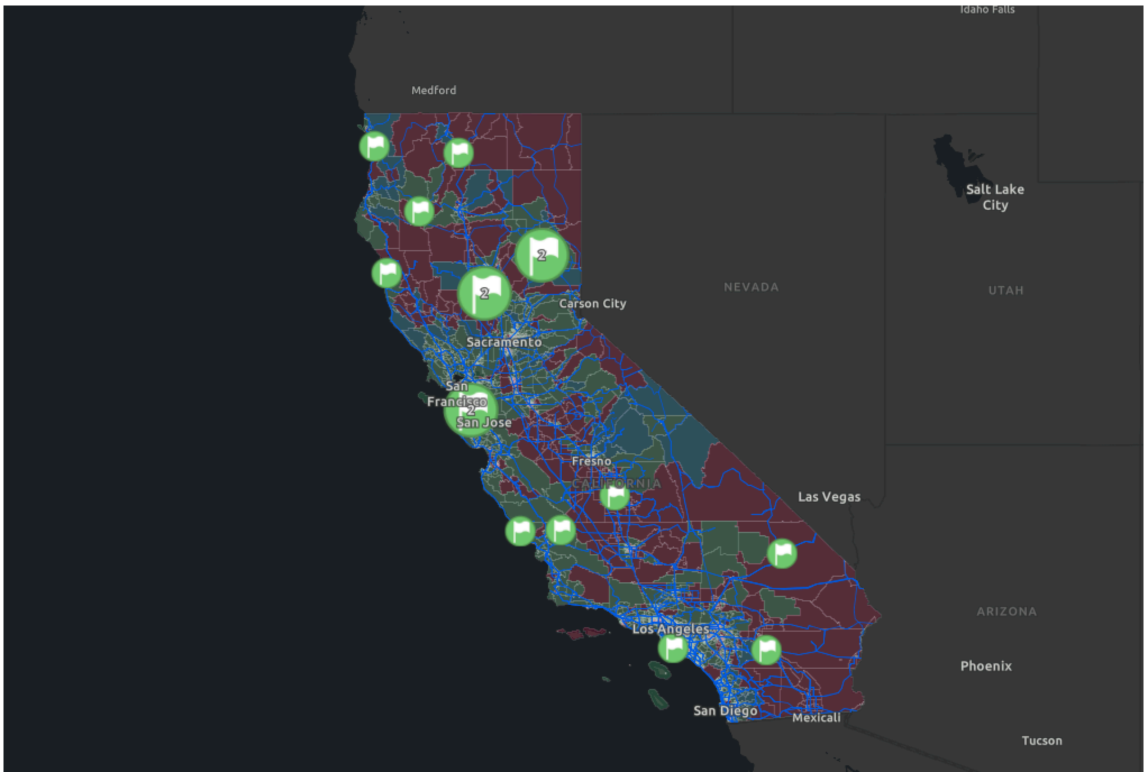
Expansion and At-Scale Implementation

2.A Phase 1 Collaboration with Alaska DOT and Phase 2 Planning

During early deployment activities, Alaska DOT and Caltrans DOT began collaborating and sharing data related to each corresponding Phase 1 Grant. During this process, it became apparent that the projects were utilizing similar technologies and applying them towards complimentary case uses. While Alaska and California are significantly different with respect to Climate zones and Geography, the projects benefit from increased collaboration and data sharing. Informally, Caltrans and Alaska began sharing project plans, data, and lessons learned with the respective technologies which accelerated progress on both projects.

2.B Phase 2 Locations and Case Uses

Following the successful demonstration at the pilot sites, Caltrans plans to scale up the deployment across other infrastructure projects statewide, with expanded case uses including inspections on ultra large facilities such as the Gerald Desmond Bridge in Long Beach, CA to project delivery performance monitoring both during and after construction of newly constructed wildlife crossings. 16 sites have been selected in California to scale the deployment of these



remote UAS systems to. Stage 2 Location Map in California

Additional information can be found on the Phase 2 combined application at the link below:

[SOAR - SMART Grant Phase 2 (arcgis.com)]

Challenges and Lessons Learned

3.A Anticipated Challenges

- **FAA Regulations**: Obtaining Beyond Visual Line of Sight (BVLOS) waivers may present regulatory challenges.

- **Technology Integration**: Ensuring seamless integration of UAS data with existing digital platforms will be critical.

3.B Successes from Phase 1 Project

The Caltrans Stage 1 SMART project, which focuses on the deployment of dock-based Uncrewed Aircraft Systems (UAS) for remote, autonomous infrastructure inspections, has already provided several valuable lessons, particularly in the areas of regulatory compliance and operational reliability. These lessons are crucial for guiding future expansions and ensuring the continued success of the project.

Successful Receipt of FAA BVLOS Waivers

- Successful Receipt of FAA BVLOS Waivers
  One of the most significant milestones of the Caltrans Stage 1 SMART project was the successful acquisition of Beyond Visual Line of Sight (BVLOS) waivers from the Federal Aviation Administration (FAA). This achievement has provided key insights critical for the success of BVLOS operations in infrastructure inspection.
- Early Engagement with Regulators
  Lesson Learned: Engaging with the FAA at the earliest stages of the project proved vital. By involving regulatory bodies from the beginning, Caltrans could clearly define the project's scope, understand the regulatory framework, and receive essential guidance on structuring waiver applications. Early and consistent engagement allowed Caltrans to align its operations with FAA expectations, particularly in adhering to the FAA's stringent safety and operational guidelines.

Best Practice: Maintaining continuous communication with the FAA and providing comprehensive operational plans, including site-specific criteria and robust safety measures, was instrumental in building trust and expediting the waiver approval process. This proactive strategy ensured that Caltrans could promptly address any regulatory concerns, resulting in a smoother approval pathway.

Comprehensive Safety Documentation
Lesson Learned: The preparation of detailed safety documentation, including an exhaustive Safety Risk Assessment (SRA), Waiver Safety Explanation Guidelines, and a comprehensive Concept of Operations (ConOps), was crucial in obtaining the BVLOS waivers. The SRA involved a meticulous analysis of potential hazards, system reliability, and emergency procedures, ensuring that all operational risks were thoroughly mitigated.

Best Practice: Developing a comprehensive SRA and a detailed ConOps in compliance with FAA Order 8040.4 was essential for addressing FAA concerns and expediting the approval process. The ConOps outlined specific criteria for shielded operations, ensuring that BVLOS flights were conducted within 50 feet of natural or man-made structures, thereby minimizing airspace risks.

Use of Proven Technology

Lesson Learned: The use of reliable and well-established UAS technology, such as the Skydio X2E platform, significantly contributed to the credibility and success of the waiver request. The Skydio X2E's advanced safety features, including obstacle avoidance, real-time telemetry, and a robust communication system, were critical in ensuring safe BVLOS operations. The integration of an ADS-B receiver provided real-time data on nearby air traffic, further enhancing operational safety.

Best Practice: Selecting UAS technology with a proven track record, like the Skydio X2E, which has been vetted under similar conditions, greatly facilitated the regulatory approval process. Caltrans' choice of a system that integrates ADS-B In technology for detecting cooperative air traffic and ensuring compliance with FAA operational standards was a pivotal factor in securing the BVLOS waivers.

Completion of 100+ Flights at Each Site with No Major Failures

Another major milestone for the project has been the successful completion of over 100 flights at each pilot site without any major failures. This achievement highlights several important lessons:

1. **Robust Training Programs:**
    - **Lesson Learned**: The success of these flights can be attributed to the robust training programs implemented for the Caltrans UAS pilots. These programs ensured that all operators were thoroughly trained in both manual and autonomous UAS operations, including emergency procedures. On-Site trainings were held with remote pilots on the operations of the dock systems at each site respectively. This helped greatly with overall implementation.
    - **Best Practice**: Implementing a comprehensive and ongoing training program is essential for ensuring that all operators are capable of handling both routine and emergency scenarios effectively.
2. **Reliable Technology Deployment:**
    - **Lesson Learned**: The use of dock-based UAS with autonomous capabilities, such as the Skydio X2, proved highly reliable. The technology's advanced obstacle avoidance and autonomous navigation systems contributed to the high success rate of the flights. Only one minor issue was observed related to automated landing sequences which was related to QR code reading of the landing arm in partial shade/sunlight conditions. After being reported, a software fix was implemented to mitigate this issue.
    - **Best Practice**: Investing in reliable, state-of-the-art UAS technology reduces the likelihood of operational failures and increases the overall success rate of missions.
3. **Preventive Maintenance and Regular System Checks:**
    - **Lesson Learned**: Regular maintenance and system checks before each flight played a crucial role in preventing failures. By adhering to a strict maintenance schedule, potential issues were identified and addressed before they could affect operations.

- **Best Practice**: Establishing a rigorous maintenance routine and conducting pre-flight checks are critical to ensuring the long-term reliability of UAS operations.

4. **Incremental Scaling and Testing:**
   - **Lesson Learned**: The gradual scaling of operations, starting with a smaller number of flights and progressively increasing to over 100, allowed the team to identify and resolve issues in a controlled manner. This approach helped build confidence in the system's reliability before full-scale deployment.
   - **Best Practice**: Adopting an incremental approach to scaling operations ensures that systems are thoroughly tested under various conditions, reducing the risk of failures during more extensive deployments

Power Supply Challenges and Solutions

At the East Otay Mesa Port of Entry site, one of the key lessons learned centered around the implementation of an off grid supply. The initial goal was 120/240V power from a local utility company, which proved to be not possible to acquire in the project timelines. The project pivoted and designed an alternative power system that utilized solar power combined with lithium-ion battery backup systems to ensure continuous, reliable energy for the UAS docking stations and communication equipment. This approach provided several valuable insights:

Solar Power Integration:

Lesson Learned: Integrating solar power as the primary energy source proved to be an effective strategy for ensuring a sustainable and reliable power supply. The solar panels were able to generate sufficient energy to meet the operational demands of the UAS docking stations and other onsite equipment.

Best Practice: Careful planning and sizing of the solar array were critical to meet the site's energy needs, even during periods of low sunlight. It is essential to consider seasonal variations in sunlight and design the solar power system accordingly.

Battery Backup System:

Lesson Learned: The lithium-ion battery backup system was crucial for maintaining operations during nighttime and cloudy periods. The system provided a stable power source, preventing interruptions in UAS operations and ensuring that all equipment remained functional.

Best Practice: Utilizing high-capacity lithium-ion batteries with advanced battery management systems ensures long-term reliability and efficiency. Regular monitoring of battery health and performance is necessary to maximize their lifespan and maintain consistent power supply.

Resiliant Operations:

Lesson Learned: The combination of solar power and battery backup successfully achieved the project's goal of maintaining an independent power supply.

Best Practice: To replicate this success in future deployments, it is recommended to continue leveraging off-grid power sources. Solar power systems should be designed to not only meet current energy needs but also accommodate potential future expansions.

Communications Infrastructure and Reliability

In addition to power supply, the East Otay Mesa site also provided important lessons related to communications infrastructure:

Primary and Redundant Communication Channels:

Lesson Learned: Ensuring reliable communications was a critical challenge at this site, especially given the remote nature of some operations. The project utilized a combination of high-speed satellite communications (Starlink) and LTE networks to maintain continuous connectivity.

Best Practice: Implementing both primary and redundant communication channels is essential to ensure uninterrupted operations. In this case, the dual-system approach allowed for seamless switching between communication methods in case of signal degradation or loss, ensuring that UAS operations could continue without interruption.

Weather-Related Challenges:

Lesson Learned: The site encountered some weather-related challenges, particularly with satellite communications during heavy cloud cover and rain. While the LTE network provided a reliable backup, this highlighted the need for robust, weather-resistant communication systems.

Best Practice: For future projects, it is advisable to conduct thorough testing of communication systems under various weather conditions to identify potential vulnerabilities. Additionally, investing in weatherproof communication equipment and infrastructure can further enhance reliability.

Data Transmission and Security:

Lesson Learned: The successful transmission of large volumes of data from UAS to the Caltrans Digital Construction Management System demonstrated the importance of secure, high-speed data links. Ensuring that data is transmitted securely and efficiently is crucial for maintaining the integrity of the project's operations.

Best Practice: Employing encryption and secure data transmission protocols is essential for protecting sensitive data. Regular audits of communication security and data handling processes should be conducted to prevent potential breaches and ensure compliance with regulatory standards.

Project Schedule and Status

4.A Project Schedule and Status

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Phase	Milestone Activity	Duration	Item Status
1	Acquire UAS via SB/DVBE solicitation	2 months	Completed
	Install UAS dock systems; finalize detailed plan and metrics		Completed
	Initiate Caltrans PIO community outreach		Completed
	Enhance training for current pilots		Completed
2	Operate UAS dock systems with **onsite pilot and onsite observer**	2 – 3 months	Completed
	Collect data re: travel time and trip reductions		Completed
	Submit quarterly report to USDOT		Compelted
3	Operate UAS dock systems with **remote pilot and onsite observer**		Completed
	Continue data collection and analysis		Completed
	Develop and submit BVLOS waiver request (Part 107 waiver request to 107.31 and 107.33)	6 months	Completed
	Continue Caltrans PIO community outreach		Completed
	Submit quarterly reports to USDOT		Completed
4	Operate UAS dock systems with **remote pilot and no observer** (upon receipt of waivers)	6 months	Completed
	Continue data collection and analysis		Completed
	Draft Stage 2 SMART grant workplan and application		Completed
	Submit quarterly reports to USDOT		Completed
5	Continue UAS dock system operation		Completed

Conclusions

5.A Future Recommendations

The Stage 1 SMART project has clearly demonstrated that dock-based UAS can deliver safer, more efficient, and more sustainable methods for infrastructure inspection and construction oversight. With more than 550 successful missions completed across pilot sites, zero major failures and enhanced data integration into Caltrans' Digital Construction Management System, the foundation has been set for scaling these operations. Building on these lessons learned, Caltrans and Alaska DOT were jointly awarded a $12.4 million Phase 2 SMART Grant for the SOAR project, which will expand deployment across 16 sites in California and additional locations in Alaska. This next phase will validate scalability,

refine workflows for nationwide replication. Together, these efforts position Caltrans as a national leader in applying autonomous UAS to modernize transportation infrastructure delivery and management. The project is currently in its early phases. Designs have been finalized with lessons learned from the Generation 1 Otay Mesa system, and those improvements have been incorporated into the next generation containerized system. The first of these second generation systems has been deployed at the Otay Mesa site, and is currently in operation. Enhanced capabilities of the gen 2 system such as RTK/PPK are being actively tested. These efforts ensure that the benefits of innovation—safer jobs, resilient infrastructure, and stronger communities—will be realized at scale for years to come.