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Unmanned Aircraft Systems (UAS) are increasingly a part of Caltrans operations for inspections, documentation, surveys, vegetation analysis, media promotion, and many other use cases. The Caltrans UAS Safety Management System has provided a measure of institutional support for the rapid expansion of use cases; however, it was designed for the most common modality at the time – a one-pilot/one-drone operation within visual line of sight with a small multi-rotor aircraft with a now standard control scheme. As UAS technology has evolved, new modalities have created opportunities for Caltrans to benefit from safety, efficiency, and accuracy improvements. This project proposes to enhance the existing UAS program by evaluating new UAS technology from a Safety Management System perspective to accommodate new modalities in 1) Expanded operations, including beyond visual line of sight, UAS docking systems, and tethered UAS, 2) Advanced Autonomy, Vertical Takeoff and Landing (VTOL) UAS and Fixed-wing UAS, and 3) Advanced Connectivity Oversight and Management. The key deliverables include a gap analysis report, recommendations for revised policies and procedures, and an updated training curriculum.

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FINAL REPORT

Incorporating New UAS Technology into the Caltrans UAS Safety Management System

Report Date: August 2026

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Center of Excellence on Unmanned Aircraft System Safety

University of California

Submitted to

California Department of Transportation under Contract No. 65A1193

Project Abstract:

Unmanned Aircraft Systems (UAS) are increasingly a part of Caltrans operations for inspections, documentation, surveys, vegetation analysis, media promotion, and many other use cases. The Caltrans UAS Safety Management System has provided a measure of institutional support for the rapid expansion of use cases; however, it was designed for the most common modality at the time – a one-pilot/one-drone operation within visual line of sight with a small multi-rotor aircraft with a now standard control scheme. As UAS technology has evolved, new modalities have created opportunities for Caltrans to benefit from safety, efficiency, and accuracy improvements. This project proposes to enhance the existing UAS program by evaluating new UAS technology from a Safety Management System perspective to accommodate new modalities in 1) Expanded operations, including beyond visual line of sight, UAS docking systems, and tethered UAS, 2) Advanced Autonomy, Vertical Takeoff and Landing (VTOL) UAS and Fixed-wing UAS, and 3) Advanced Connectivity Oversight and Management. The key deliverables include a gap analysis report, recommendations for revised policies and procedures, and an updated training curriculum.

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Table of Contents

Table of Tables iii
Background and Purpose 1
FAA Safety Management System Requirements 1
Caltrans UAS Program Overview 1
Gap Analysis 1
Improving the Existing UAS Program 2
Policy Management 2
SMS Management 3
Structural Limitations of the Current System 5
Adding additional layers 6
Relational Database Model 7
Safety Assurance 7
Structured Analytics Policy 9
Proactive Safety Assurance Processes 9
Formalizing Program Improvements 9
Safety Culture and Promotion 10
Reporting Environment 12
UAS Program Community 12
Communication and Recognition 13
Flight Planning 14
Flight Operations 15
Moving Beyond Part 107 17
Waiver Management 17
Training Programs 18
14 CFR 108 – Operations Beyond Visual Line of Sight 20
New UAS Platforms 21
Autonomy and Pre-Flight Planning 23
Pilot Qualification and Progression 23
Platform-Specific Gaps 24
Training Curriculum Development 25
Automation Literacy: Risk Management for Automation 25
Model-tracing 25

Boundary Awareness 26
Intervention Timing 26
Updates to Existing Curriculum 26
New Platform Training: Hands-On Over eLearning 27
References 29
Appendix 31
UAS Pilot Training Logging System 31
Explanation 31
Adding Pilot Specific Forms 32
Display Training Information 32
Potential Training Approaches 35
Task 1 – Gap Analysis Report 36
Task 2 – Updates to Existing Training 115
Task 3 – Policy and Procedure Recommendations 117

Table of Tables

Table 1: Policy Management Recommendations 2
Table 2: SMS Management Recommendations 4
Table 3: Data Categories 5
Table 4: Database Reorganization Recommendations 7
Table 5: Safety Assurance Recommendations 8
Table 6: Safety Culture and Promotion Recommendations 11
Table 7: Flight Planning Recommendations 14
Table 8: Flight Operation Recommendations 15
Table 9: Waiver Management Recommendations 17
Table 10: Training Recommendations 19
Table 11: Part 108 Recommendations 20
Table 12: Recommendations Related to New UAS Platforms 21
Table 13: Core Supervisory Skills 25
Table 14: Training Medium Effectiveness 27

Background and Purpose

This report documents the recommendations and updates to the Caltrans UAS Program's policies, procedures, and training framework to support a broader operational scope. The program's Safety Management System, developed with the UC Center of Excellence on Unmanned Aircraft System Safety [1] in 2019, was built around the small multirotor platforms that dominated commercial UAS at the time. That foundation still works, but the program must shift to accommodate new aircraft types, expanded operating authorities, and greater regulatory complexity.

FAA Safety Management System Requirements

The FAA SMS framework in 14 CFR Part 5 [2] treats safety as an organizational function comprised of four components: Safety Policy, which defines accountability and objectives; Safety Risk Management, which identifies hazards and applies controls before incidents occur; Safety Assurance, which evaluates whether those controls are working through monitoring and analysis; and Safety Promotion, which distributes safety knowledge and normalizes reporting.

Caltrans UAS Program Overview

The Caltrans UAS Program [3] operates across the twelve districts within California, supporting infrastructure inspection, construction monitoring, emergency response, and environmental surveys. Since the SMS was established, the program has expanded in both scale and platform diversity. Current operations now include advanced autonomous systems, VTOL and fixed-wing aircraft, and early use of tethered and dock-based systems. The regulatory environment has evolved as well, with Part 107 waivers becoming more attainable and the proposed Part 108 framework introducing organizational certification requirements that did not exist when the current SMS was designed.

Gap Analysis

The gap addressed in this report has two dimensions. First, it is structural: policies, data systems, and qualification frameworks built for a smaller, more uniform fleet are under strain as the program scales. Second, it is forward-looking: advanced platforms already in use or under consideration bring operational demands, training needs, and policy questions the current framework does not address. This report addresses both the strengthening of the existing program foundation and the expanded operational envelope, including waivers, Part 108 readiness, and platform-specific qualification and policy gaps. The full list of recommendations is provided in Appendix – Task 3 Policy and Procedure Recommendations.

Improving the Existing UAS Program

The Caltrans UAS program has expanded steadily in scale and operational scope, but the policies, data systems, and processes supporting it were designed for the common operations of its time under Part 107 regulations [4]. What worked when the program was smaller, informal coordination, ad-hoc working groups, manual tracking, judgment calls on reporting, now creates fragility as activity increases and the operational envelope widens. The recommendations in this section address that gap by formalizing the structure that already exists informally, improving the quality and utility of data already being collected, and building the habits of analysis and communication that a program of this size and complexity needs to sustain itself.

Policy Management

While these items may seem simplistic, it's easy to lose sight of structure and processes during times of change. Without defined structure, a program's stability becomes dependent on the individuals managing it rather than the systems supporting it.

TABLE 1: POLICY MANAGEMENT RECOMMENDATIONS

ISSUE	RECOMMENDATION	JUSTIFICATION
Missing Policy Definitions for UAS Program Management	Define roles & responsibilities for UAS program manager, working groups or other management entities	Clear role definitions establish accountability, reduce ambiguity in decision-making, and ensure consistent application of safety processes across districts. Formalizing responsibilities also supports compliance with SMS principles by identifying who oversees governance, training, risk management, and continuous improvement.
Use of ad-hoc groups without defined structure	Establish procedures for creating, organizing, and disbanding ad-hoc UAS working groups	Ensures consistency, transparency, and accountability when temporary teams are created to address operational or safety issues.
Lack of clarity on how the UAS program is managed	Provide clear documentation for upper administration and end-users describing how the UAS program is structured and managed	Improves understanding of governance processes, strengthens administrative support, and enhances operator confidence in program decisions.
Advanced UAS platforms frequently introduce new autonomy behaviors and software updates. Caltrans currently has no policy stating who verifies that these features are understood and appropriate for operational use.	Include a simple policy statement that new automation features or major software behaviors should be reviewed by the UAS Program Administrator or designee prior to operational use.	A lightweight review ensures that new features are not used unexpectedly in the field, and prevents inconsistent district-level adoption

Defining roles and responsibilities for the UAS program manager is a key requirement as it helps define why the role exists, what it is accountable for, and how its scope may need to evolve as operations scale. Clear role definitions enable meaningful performance metrics for effective staffing assessments. The current program staff is already heavily involved in data entry, analysis and compliance tracking, but no formal connection to the workload relative to the operational demand.

A program that relies on informal processes managed by a small number of individuals is fragile, regardless of how well those individuals perform. Informal structures tend to work well on a small scale, but they break down as activity increases, personnel changes, or leadership transitions occur. Focusing on improving the UAS Program management policies will ensure the program's institutional memory stays intact. What is obvious to the person who built a program is often invisible to whoever inherits it. This is particularly important for a UAS program, which is subject to regular changes in regulation, technology and personnel.

A well-structured policy framework defines goals, outcomes, and performance boundaries, and it's recommended that processes can be moved to a living operational manual that can be updated at a faster cadence to accommodate those changes [5]. Policy should answer why things are done a certain way, whereas procedures answer how things are done. Keeping those layers separate also supports stakeholder trust. Operators and administrators are more likely to engage confidently with a program they understand. When governance is opaque, people fill the gaps with assumptions, and those assumptions are not always correct.

The same logic applies to the management of ad-hoc working groups and planned formal working groups. Working groups are a response to emerging operational or safety challenges, but when they are formed, managed and dissolved without documentation, the decisions they produce become difficult to trace and impossible to attribute. Establishing clear procedures for how these groups are created, structured and concluded ensures that their work contributes to the program's institutional knowledge.

This is particularly important when these working groups are involved in matters that impact regulatory compliance or safety enhancements. When something goes wrong, documented governance demonstrates due diligence. Informal practices, even effective ones, are difficult to defend after the fact because there is no evidence they were intentional.

SMS Management

The existing SMS program has a functional entry point for data collection, but limited vision on how the data should be utilized. The data collected works well for identifying trends by division, location, and purpose, which provide useful surface-level metrics but are not likely to reliably drive program improvement. When evaluating data collection, it is important to make sure that it aligns well. Primarily, having a clear understanding of what you are looking for, and what can that data influence.

At a Program Administration level, there are only a few adjustments that can be made. Direct operation management, though would have the most effect on operational safety, is the most difficult to move as it requires dictating specific low-level procedures (standardized checklists, etc) to the wide range of operations conducted by Caltrans. Some flight personnel will buy-in, but the number of exceptions and variations will easily outstrip the 'standard.' This is not uncommon for large diverse fleets and operations. Other than developing unique procedures for every possible

situation, there is no 'right' answer, only a balance between prescriptive requirements vs performance requirements. This makes the 'operations' level a little less effective to focus on in some cases. A couple of exceptions are highlighted in the subsection Flight Operations regarding emergency procedures and post-flight steps, though those will have limited influence on overall program growth.

The more tractable area that a Program Administration can make meaningful improvements is towards growing safety culture and training. Data-driven curriculum development, adjusting onboarding and recurrent training based on what operators are doing, how frequently they encounter specific situations, and where gaps appear, is a natural and defensible progression for maturing an SMS [5]. But that progression depends entirely on data quality. If the underlying data is inconsistent, incomplete, or poorly structured, the analysis it supports will be shallow regardless of how sophisticated the tooling becomes.

This is where data entry and safety assurance becomes two sides of the same coin. Safety assurance, the systematic evaluation of whether controls are working, is only as reliable as the data feeding it. The following recommendations focuses on recommendations for improving data collection.

TABLE 2: SMS MANAGEMENT RECOMMENDATIONS

ISSUE	RECOMMENDATION	JUSTIFICATION
Smartsheet is functional but limited for long-term program needs	Adopt a purpose-built database (e.g., relational or aviation-oriented system) to manage UAS operations, training, aircraft, and safety data	A more refined system supports data integrity, enables multi-year analytics, and improves program oversight as activity scales.
The system relies heavily on manual data upkeep and lacks automated connections to analytical tools.	Explore adopting automation tools (Smartsheet Bridge, Zapier, Power Automate) to better manage data for improvements to UI or to develop better analytic tools	Automating synchronization improves efficiency, decreases administrative burden, and enables more robust analytics without disrupting existing user workflows.
Current Smartsheet workflows permit inconsistent data entry and incomplete linkage between hazards and operations.	Invest in the implementation of validation rules, controlled dropdowns, and integrated hazard-to-operations workflows within Smartsheet. Data automation tools can be used to improve UI and dashboards.	These controls reduce entry errors, improve form completion rates, and increase near-term reliability of UAS operational and safety data.
Current Caltrans UAS documentation uses inconsistent naming conventions (for example, "UAS Operations Plan Pre-Flight" vs. "Caltrans UAS Program Pre-Flight	Adopt standardized, FAA-aligned naming conventions for all UAS planning and pre-flight forms. Specifically: 1) Mission Planning and Risk Assessment (for office-based planning completed hours to days before flight).	Consistent terminology improves clarity, reduces operator confusion, and aligns Caltrans practices with FAA language in §107.49 and common industry usage. Distinguishing between planning activities and pre-flight inspections also reinforces proper sequencing

Data"), creating ambiguity for operators and reducing alignment with FAA terminology.

2) Preflight Inspection Checklist (for at-aircraft checks performed immediately before launch).

and supports training and compliance efforts.

Structural Limitations of the Current System

Smartsheet has been effective as an entry-level solution: straightforward form creation, centralized storage and accessible dashboards that allow pilots to initiate missions and documentation with minimal friction. At a program scale, however, its structural limitations are becoming a constraint.

The platform's flat data model forces every new requirement to be handled by adding columns. The pilot roster contained over 80 fields, mixing essential identifiers like FAA certificate number and expiration date with administrative items like whether a welcome email has been sent. Core datasets are approaching Smartsheet's structural limits (500,000 cells, 20,000 rows [6]), and continued growth risks exceeding platform capacity entirely. More importantly, flat sheets are poorly suited for historical tracking: training completions, aircraft renewals, and certification updates are stored in single cells that overwrite prior values, erasing historical context and preventing longitudinal analysis.

As noted in the Gap Analysis (Appendix – Task 1 Gap Analysis Report), operations and hazard are stored in separate sheets linked only by a manually entered operations ID number, and only 62% of those were entered correctly, and accounted for less than 10% of all reportable missions. Without reliable relationships between operations and hazards, it's difficult to identify recurring risks, correlate incidents with specific mission types or demonstrate consistent hazard assessments. While this is an operations issue, it's something that improvements to the SMS infrastructure can play an outsized role in improving.

Addressing these limitations does not have to be all or nothing. In the near term, the most immediate improvements are within Smartsheet itself: implementing validation rules, controlled dropdowns, and improving the form workflow as identified in the prior Gap Analysis report. Additionally, Smartsheet does have the capability to implement advanced functionality in the form of cell equations and functions that can help make data input and management a little easier. Table 3 lists some minor adjustments that can be made.

TABLE 3: DATA CATEGORIES

Category	Current Approach	Proposed Adjustment
Identifiers	OPS-ID, Index IDs, Districts, Pilot info (duplicated)	Keep OPS-ID + District. Link pilots/aircraft via dropdowns synced from master sheets.
Crew tracking	Separate columns for Secondary Pilot, VO, etc.	True crew log (OPS-ID, Role, Person) is not feasible in Smartsheet; workaround is limited slots or automation.
Mission purpose	Dropdowns with "If Other" free-text	Consolidate to validated dropdown list; reduce narrative entries.
Special conditions	Night Ops, Emergency, FAA Night Compliance, etc.	Use condition checkboxes; metrics limited in Smartsheet, but improves usability.

Incidents	Free-text "Incident Type/Details"	Dropdown categories with optional narrative; enables trend tracking.
Hazards	Separate sheet, OPS-ID typed manually (62% accuracy)	Hazard log with OPS-ID dropdown + reminders for missing hazards.

Examples of extending Smart Sheet functionality

Combining LMS training with Smartsheet tracking

Within Rise Articulate, and other LMS training, it's possible to embed a SmartSheet form directly into one of the pages using iframes.

The setup requires the creation of a dedicated sheet for tracking trainings – set up for collecting names and emails from the participants. Then using email as a primary key, it's possible to use cross-sheet formulas to tie the last active training (and date) to a user's profile in the main pilot sheet.

Improving UAS Pilot Training management

Manually tracking every pilot's training can be overwhelming as the number of pilots and required training increases. It is possible to create a log system to track pilot training, then utilize cross-reference formulas to automatically check for training status and determine their state. Further information can be found in the Appendix.

Tracking Flight Record Completions

Similar to the UAS Pilot Training Management, it's possible to improve the workflow and connections between pre-flight hazard assessment, flight missions and pilot completion status.

For example, if the Hazard Analysis questions are included in the Mission Initiation Form, the Pre Flight Checklist can still be a separate form connected by OPS-ID, and the Post-Flight questions are included as an Update to the Mission Form. This is the most similar to the existing system, but with the added feature of URL formation to pre-populate the OPS-ID.

The form URL generation is straight-forward, but an additional logic IF can be used to prevent extra submissions.

```
= IF([Preflight Completed]@row, //if the checkmark for completion exists
           "Completed", //show completed, else show the url
      "https://app.smartsheet.com/b/form/01980fd14b6f70f8aa87d7f0cb0f60
2e?OPS-ID=" + [Primary Column]@row
      )
```

The formula for the Preflight Completed checkmark is a simple COUNTIF() for the existence of the OPS-ID in the log of the preflight checklist submissions.

Adding additional layers

In the medium term, a hybrid approach such as keeping Smartsheet as the front-end for data collection and utilizing automation tools (Smartsheet Bridge, Zapier, Power Automation) to synchronize data to a more capable analytical platform is worth exploring. This will have a steep

learning curve for the UAS Program administrators but would extended analytical capacity without changing the user experience too drastically.

Relational Database Model

However, long term, a relational database model [7] will resolve the structural issues that Smartsheet cannot. As identified in the Gap Analysis Report, implementing the data as linked tables, enabling one-to-many relationships and utilizing historical logs rather than overwrites, would better support advanced analytics across the full program cycle. A recommended structure can be seen in Table 4. As data maturity increases, the system could evolve towards a unified pilot profile consolidating certifications, training history, flight hours, and currency by aircraft type (required for Waivers) into a single view.

TABLE 4: DATABASE REORGANIZATION RECOMMENDATIONS

CATEGORIES	EXAMPLES OF CURRENT COLUMNS	STREAMLINES APPROACH
Core Identifiers	UAS ID Number Make Model FAA Serial Number FAA Registration Number Districts	Keep in a Fleet table with unique UASID and minimal required fields.
Registration/compliance	FAA Registration Dates Renewals Expiration Warnings	Move to a Registration Log: (UASID, RegistrationNumber, StartDate, EndDate, EnteredBy).
Status/assignment	UAS Status Status Date Inactive Reason Out of Service Date Supervisor Contact	Split into Status Log (UASID, Status, Date, Reason) and Assignment Log (UASID, AssignedTo, Dates).
Approvals/admin	Supervisor Approval Coordinator Approval OPS Data Dropdown List	Log as Administrative Actions: (UASID, Action, Date, ByWhom).
Critical but missing	*(none captured)*	Add a Fleet Utilization Log: (UASID, Date, MissionID, FlightHours, Cycles). Supports usage trends and maintenance planning.

Safety Assurance

Safety assurance in a maturing SMS is not a single process, it's a set of related analytical habits, each with different questions to answer. For a UAS program at this stage, trend monitoring, near-miss and precursor analysis, and use-case risk evaluation are the most actionable.

Trend monitoring asks whether the rate or pattern of activity is changing. This does not require high data volume but should be reflective of total activity. Even modest flight-hour and counts of incidents, tracked consistently over time, can reveal whether a particular use case, platform, or operating environment is generating disproportionate issues.

Near-miss and precursor analysis asks whether the system is accumulating latent risk before an incident occurs [5]. Near-misses are chronically underreported in UAS programs as pilots often don't flag events that are resolved without consequence. Formalizing a low-barrier reporting path for events will give the program early-warning visibility.

Use-case and equipment risk evaluation asks whether the risk profile of what the program is asked to do is outpacing the controls designed to manage it. An SMS built around routine inspections or surveys may not adequately account for the risk profile of advanced autonomy, or different platform archetypes.

TABLE 5: SAFETY ASSURANCE RECOMMENDATIONS

ISSUE	RECOMMENDATION	JUSTIFICATION
UAS SMS Program lacks structured analytics to inform safety and growth	Define policy for routine analysis of hazards, risks, trends, flight hours, and time-in-type	Consistent analytics enable early detection of emerging risks, support evidence-based decision-making, and align with SMS continuous-improvement expectations.
Safety assurance is currently limited to post-flight incident review	Develop proactive safety-assurance processes including trend monitoring, equipment-related issue tracking, near-miss analysis, and use-case risk evaluation	Proactive surveillance strengthens the SMS, reduces reliance on incident-only triggers, and creates opportunities to adjust policies, checklists, and training before incidents occur.
The SMS does not currently convert operational trends into program improvements	Formalize a process requiring that hazard and performance trends be reviewed and used to update training curricula, procedures, and operational guidance	Ensures that lessons learned translate into program-wide improvements, maintaining compliance with SMS principles and supporting safe program growth.
SOPs and guidance can lag behind field experience; pilots want "living" documents and case studies that evolve with operations.	Designate responsibility (person or role) to maintain living SOPs, collect trainer and pilot feedback, and regularly publish curated best practices and case-study summaries.	Keeping procedures aligned with field reality improves relevance of forms and guidance, and strengthens safety culture by learning from unique missions.
The current post-flight section lacks structured prompts and does not consistently capture anomalies, deviations, wildlife encounters, or near-miss events.	Expand and formalize the post-flight reporting section with required prompts for deviations, anomalies, wildlife interactions, equipment issues, and corrective actions.	Robust post-flight data is necessary for incident trend analysis, hazard identification, and continuous improvement of procedures.

Structured Analytics Policy

The absence of a defined analytics cadence doesn't mean the program is operating without data, it means the data is not being interrogated on any schedule. Flight hours accumulate, hazard reports get filed, and time-in-type increases, but without a policy that says when that data gets reviewed and what questions it should answer, the review either doesn't happen or happens inconsistently depending on who happens to be paying attention.

This poses two concerns. First, emerging risks in UAS operations tend to be gradual such as a particular airframe logging a disproportionate share of equipment anomalies, a specific use case generating more near-misses than others. Second, regulatory and standards frameworks for SMS applied to UAS contexts treat continuous monitoring as a baseline expectation and will be an expectation for Part 108 operations [8]. Policies don’t need to be elaborate to be effective. Defining review frequency, the data fields that feed it, and who is accountable for producing and acting on findings is sufficient to create the discipline.

Proactive Safety Assurance Processes

Limiting safety assurance to post-flight incident review is a reactive posture by definition. It means the program only learns from events that were significant enough to be reported, which systematically underweights the precursor signals that precede most incidents. In aviation safety, the incident is rarely the first sign something was wrong but rather the point at which accumulated latent risk became visible. The result is that a program that only responds to incidents is perpetually one step behind.

Proactive surveillance changes the question from "what went wrong?" to "what conditions are developing that could go wrong?" Trend monitoring across flight hours and use cases identifies whether risk is concentrating in operational areas. For a UAS program, equipment monitoring is a good use-case, but human-error remains one of the leading causes of serious incidents. Providing opportunities for flight crews to share their near misses can provide valuable insight into future improvements. Near-miss analysis, which requires a low-barrier, genuinely non-punitive reporting path to function, surfaces the recoverable events that carry the same informational value as incidents without the consequence.

Proactive safety assurance is straightforward to justify in that proactive surveillance is cheaper than incident response. Adjusting a training module or issuing a procedural notice costs far less, in time and organizational credibility, than managing an incident that a trend review might have flagged three months earlier.

Formalizing Program Improvements

Generating analytical findings has no program value if there's no defined path from finding to action. This is a common failure mode in SMS programs in that the data gets reviewed, patterns get identified, someone notes it in a meeting, and the next training cohort goes through the same material as the last one because no one had clear authority or responsibility to change it [5].

Formalizing the process means specifying the feedback loop explicitly in policy. Document a process in which hazard and performance trends feed a defined review, that review produces recommendations, and recommendations have a documented path to training updates, procedural

revisions, or operational guidance changes. This doesn't have to be too detailed or prescriptive; the level of depth should match the program's capabilities. Some groups assign this as a formal working group within their organization, whereas in others the responsibility may lie with the program manager.

This is also where SMS compliance becomes most visible to external viewers. Continuous improvement is a structural requirement that demonstrates the chain from operational data to curriculum change to updated guidance.

Living Documents and Designated Responsibility

SOPs written at program launch reflect the operational assumptions of program launch. As mission types diversify, platforms change, and operators accumulate field experience, those documents become progressively less relevant and when procedures don't reflect reality, operators either ignore them or work around them, neither of which strengthens safety culture.

One of the findings from the gap analysis survey was the pilot feedback on wanting "living" documents. When experienced operators feel that guidance doesn't reflect what they encounter, they disengage from the formal system and rely on informal knowledge transfer instead. However, that leads to institutional knowledge that's now person-dependent leading to new operators don't benefit from accumulated experience, and the program's safety culture narrows to whoever happens to be in the room.

Designating explicit responsibility for SOP maintenance and best-practice publication closes that gap. Regardless of who, it requires that someone owns it, has a defined process for collecting field feedback, and publishes updates on a predictable schedule. Case study summaries from unusual or instructive missions are particularly high value: they're concrete, they're credible to operators because they reflect real situations, and they build the kind of shared operational knowledge that forms alone can't capture.

For leadership, this is also a retention and culture argument. Programs that visibly learn from their operators' experience, and publish that learning back to the field, build engagement. Programs that don't signal to their people that their experience doesn't feed the system.

Safety Culture and Promotion

Data collection and safety assurance processes create the infrastructure for a safe program, but infrastructure alone doesn't produce safety culture. Culture is built through repeated interactions, how reporting is received, whether participation is recognized, whether operators feel like contributors to the program or subjects of it. For a distributed UAS program where pilots aren't co-located and drone operations aren't most operators' primary job responsibility, that culture must be deliberately constructed rather than assumed to emerge organically. The hard part about managing safety is that everyone wants to be safe, but everyone has a different definition of safety. Part of the training should always focus on building a community definition of safety – peer support leads to effective safety culture.

TABLE 6: SAFETY CULTURE AND PROMOTION RECOMMENDATIONS

ISSUE	RECOMMENDATION	JUSTIFICATION
Operators strongly support more opportunities for peer exchange and clearer communication channels across districts.	Establish a central communication hub (for example, Teams channel, Slack workspace, or similar) and schedule regular cross-district calls or virtual forums for sharing lessons learned and updates.	Nearly 90 percent of respondents indicated that more peer-to-peer opportunities would be helpful; structured networks leverage existing expertise without major new training costs.
Operators may avoid reporting minor issues due to fear of blame or misunderstanding of consequences.	Adopt and publish a Just Culture framework that distinguishes honest mistakes, at-risk behavior, and reckless behavior, and explicitly states that near-misses and good-faith errors will not trigger punitive action.	
Voluntary near-miss reporting can be low because forms are long, narrative-heavy, or require too much detail.	Develop a short, mobile-friendly near-miss reporting form with checkboxes, dropdown hazards, and only two required prompts ("What happened?" and "What should we know?").	
Safety conversations are inconsistent and often occur only after incidents.	Integrate regular low-stakes safety dialog practices such as Safety Moments at meetings, brief pre-mission huddles, and short debrief discussions into UAS workflows.	Frequent, informal safety touchpoints normalize discussion, encourage early reporting, and strengthen organizational awareness.
Operators lose motivation to report when they do not see how information is used.	Create a recurring communication process (for example, quarterly bulletins or safety updates) summarizing de-identified reports, improvements made, and lessons learned.	Visible action based on reports reinforces trust and shows operators that their contributions materially improve safety.
Reporting may feel risky or socially uncomfortable; there is no positive reinforcement.	Create mechanisms for non-individualized recognition (such as district acknowledgment or program-level appreciation) when teams show strong participation in safety reporting or near-miss documentation.	Team-based reinforcement encourages participation without creating competition or fear of judgment.

The survey data reflected this gap (Appendix – Task 1 Gap Analysis Report). Program effectiveness was rated well overall, but perceived effectiveness declined with operational frequency, meaning the operators with the most experience and the most exposure to real conditions were the least

satisfied. The bifurcation suggests the program works reasonably well for operators who engage with it occasionally, but doesn't adequately serve, or fully retain the confidence of, those doing the most flying. Experienced operators are also the program's most valuable source of practical knowledge, so their disengagement from formal systems is a concern.

Reporting Environment

Near-miss and precursor reporting is the leading indicator most safety programs underutilize, and underreporting is rarely a function of operator indifference. It's a function of environment. If reporting feels risky, even implicitly, even without explicit punishment, operators will self-censor. If reporting is administratively burdensome, operators will skip it for minor events. Both conditions are correctable.

Adopting and publishing a Just Culture framework addresses the first problem directly. Just Culture is not a blanket no-consequences policy instead it's a principled distinction between honest mistakes, at-risk behavior, and reckless behavior, with clearly different responses to each. Publishing that framework explicitly, rather than asserting informally that "we don't punish reporting," gives operators something concrete to trust. The difference between "leadership says it's safe to report" and "the program has a written policy distinguishing errors from recklessness" is the difference between a social assurance and a structural one. Additional layers of organization, such as program mentors, can be useful in ensuring trust in reportable incidents.

Addressing reporting friction is equally important and more tractable. Long, narrative-heavy forms are a known barrier to near-miss reporting in aviation contexts. A short, mobile-friendly form using checkboxes for hazard categories, dropdowns for situation type, two required open fields can help remove the administrative cost of reporting and learning from a minor event. The goal is to make the act of reporting feel proportionate to the event being reported. A recoverable airspace conflict shouldn't require the same documentation burden as a serious incident.

Closing the feedback loop is what sustains reporting behavior over time. Operators who file reports and never see any visible result stop filing reports. A recurring communication process, such as quarterly bulletins, safety updates, or similar, can be useful to disseminate de-identified reports, identifies patterns, and describes what changed as a result makes the value of reporting concrete. When operators can see that a curriculum update or procedural change traces back to field reports, reporting becomes something the program visibly does something with rather than something that disappears into a database.

Recognition reinforces the same message. Non-individualized, team-based acknowledgment of strong reporting participation, something at the district-level, not person-level, normalizes safety engagement without creating the social discomfort of singling out individuals. The goal is to make participation visible enough that it becomes a standard expectation rather than an exceptional behavior.

UAS Program Community

Nearly ninety percent of survey respondents indicated that more peer-to-peer opportunities would be helpful. That's strong signal of unmet need, and it's worth exploring. In the context of the Caltrans UAS Program, where there are many distributed flight crews with no central location and no shared daily environment, it’s difficult to develop informal safety culture. The watercooler conversations,

the "let me show you what happened last week" moments, the accumulated shared context that experienced teams build naturally won't happen without deliberate structure to create it.

Familiarity and opportunities for greater communication and community is a common approach; but in practical matters, it's difficult to align schedules and job responsibilities. As with many groups, drone use is not a primary job responsibility of most of the UAS pilots.

This requires further support from administration to make these connection opportunities a stronger requirement. Support for annual gatherings, regional training, and mentorship opportunities are all actions that administration can do to assist. Despite the willingness of the operators to engage in peer-to-peer opportunities, relying on them to initiate or coordinate will be ineffective.

Though policy requirements could help, incentives are still a more powerful draw. What makes attending and participating in peer-to-peer opportunities attractive? The typical draws of financial or professional advancement are valid options if they could be arranged – another value of strong UAS program administration – but many groups have found success with other forms of motivation.

Some recommendations:

- Make them feel like contributors, not attendees.
    - Ask specific people to lead a session – an opportunity to lead a discussion, teach safety, or present their work
    - Rotate a subject matter expert spotlight
    - Create small working groups that shape the agenda – vary it throughout the year
- Normalize participation with documentation
    - Make attendance and participation visible to peers – not to shame, but to show who and how many are attending
    - Pair newer crew members with experienced operators as informal mentors during activities or sessions. Help encourage the building of professional networks
- Other ideas
    - Connect with hands-on activities – test out new equipment, teach new techniques or software
    - Occasionally bring in high-profile guests – higher-ups, division heads, CEOs
    - Make the trip comfortable with food, quality Wi-Fi, good hotels – nothing tanks a meeting like poor hospitality

Communication and Recognition

A moderated communication channel complements in-person or virtual gatherings by maintaining program visibility between events. The goal is straightforward: every operator should know there is a place to ask a question, share an observation, or flag a concern, and that the channel is actively maintained rather than nominally available. Platform choice matters less than moderation quality, an actively managed Teams channel or Slack workspace is substantially more useful than a theoretically available but inactive one. The moderation function ensures questions get answered, relevant updates get surfaced, and the channel doesn't drift into irrelevance through disuse.

Participation in safety reporting responds to reinforcement, and the absence of it sends its own message. When reporting generates no visible acknowledgment, the rational inference for an

operator is that it doesn't matter and that inference compounds over time. On the other hand, individual recognition carries real risks as well as spotlighting specific reporters, even positively, can create the impression that reporting is being monitored at the individual level, which undermines the psychological safety voluntary reporting depends on. Team-based and district-level recognition sidesteps these problems without abandoning reinforcement entirely. Acknowledging a district or operating group for strong reporting participation, in a quarterly bulletin, at a program-wide call, in internal communications, signals that the program values engagement without creating individual exposure or competitive dynamics that distort reporting behavior.

Recognition doesn't have to be formal to be effective. A safety manager or program lead who responds to a submitted near-miss report with a brief confirming receipt and noting what will be done with it would close a feedback loop that most reporting systems leave open. The operator learns their report landed and has a destination, which is a fundamentally different experience than submitting into a void. Reporting culture is a behavior the program actively shapes, not a baseline it can assume. Programs that treat reporting as something operators either naturally do or don't will consistently underperform programs that make it easy, acknowledge it visibly, and act on it, sustaining the near-miss and precursor data that proactive safety assurance depends on.

Flight Planning

The quality of a flight operation is largely determined before the aircraft leaves the ground. The current hazard form attempts to serve two roles simultaneously: 1) advance planning and 2) on-site verification. This unfortunately makes it less effective at both. An analysis of existing form responses found that 17 of 22 questions are answered the same way more than 95% of the time, with some reaching 100% uniformity. A form that rarely produces variation is not meaningfully discriminating between different operational risk conditions. Instead, it is generating administrative burden without generating safety information.

TABLE 7: FLIGHT PLANNING RECOMMENDATIONS

ISSUE	RECOMMENDATION	JUSTIFICATION
The current Hazard Analysis form mixes in-office risk assessment with on-site checks, producing redundancy and reducing the usefulness of data for hazard tracking.	Shift all risk assessments that can be done pre-departure into the Mission Planning form, where hazards, mitigations, airspace, weather, and operational constraints can be evaluated prior to arriving at the work site.	Completing hazard assessment during planning enables more thoughtful analysis, supports data standardization, and allows for better trend tracking and safety assurance.
Pilots currently complete lengthy hazard-identification questions on-site, slowing operations and creating inconsistent application of safety checks.	Develop a streamlined Pre-Flight Checklist dedicated to readiness verification, equipment condition, environmental confirmation, crew setup, and go/no-go items that can be completed quickly at the field location.	A short checklist will be easier for the pilots to utilize. Data loss is less significant
Current questions are repetitive, inconsistently structured, and do not support	Reorganize questions into structured categories with standardized options, including expanded hazard	Structured data and more meaningful questions will

ISSUE	RECOMMENDATION	JUSTIFICATION
meaningful analytics (for example, weather hazards, airspace classifications, or common operational risks).	selections, airspace authorization types, detailed weather categories, and improved post-flight anomaly reporting.	enable analysis for safety and trends.

Separating the Mission Planning form from the Pre-Flight Checklist addresses the core structural problem. Questions that can be answered before arriving at the site such as airspace classification and authorization, weather forecasts, right-of-way permissions, identification of nearby hazards and obstructions, belong in planning, where pilots can think deliberatively and flag issues before they become field problems. Questions that require physical presence such as equipment condition, crew setup, environmental confirmation, and go/no-go verification, belong in a short, task-focused checklist at the aircraft. Keeping the checklist short helps make it reliable.

Restructuring the questions themselves matters as much as separating the forms. Several current questions overlap in scope, airspace type and TFR checks, for example, address the same restriction landscape and can be consolidated without losing safety intent. Others use yes/no formats where structured options would produce data that can be analyzed. Converting weather entries from free text to categorized selections, adding airspace authorization sub-fields (LAANC, COA, not required), and expanding post-flight anomaly prompts all move the form from a compliance checkbox toward a data collection instrument. That structured data is what feeds the safety assurance processes described earlier in this report - without it, trend analysis across districts, mission types, and hazard categories is not reliably possible.

Flight Operations

Informal knowledge of how to handle emergencies has accumulated among experienced operators and program staff, but it has not been formalized into documented procedures. Unfortunately, that matters as informal knowledge is person-dependent, and it breaks down during personnel transitions, high-pressure situations, or operations in unfamiliar districts.

TABLE 8: FLIGHT OPERATION RECOMMENDATIONS

ISSUE	RECOMMENDATION	JUSTIFICATION
The policy does not include detailed emergency procedures for common failure modes (flyaway, lost link, mid-air collision, payload failure, fire, etc.).	Create scenario-based emergency response procedures for common major UAS failure modes and include them in the UAS Handbook and training materials.	Clear procedures ensure consistent, safe responses under pressure and support compliance with SMS expectations for emergency readiness.
Communication requirements during emergencies (ATC notification, emergency services, internal escalation) are not defined.	Define mandatory communication protocols for emergency events, specifying when and how to contact ATC, emergency responders, district management, and program leadership.	Standardized communication reduces response delays and aligns Caltrans procedures with aviation best practices.

ISSUE	RECOMMENDATION	JUSTIFICATION
The policy does not specify required steps after an incident, including aircraft recovery, site securing, and evidence preservation.	Add procedures for post-incident aircraft recovery, site control, preservation of evidence, and documentation of environmental conditions.	Supports effective investigation, protects Caltrans liability interests, and satisfies SMS requirements for structured incident follow-up.
Incidents are reported, but near-misses are not consistently captured; anonymous reporting does not exist; follow-up improvements are inconsistent.	Establish a unified reporting system that requires near-miss reporting, includes an optional anonymous submission pathway, and ensures follow-up actions and trend tracking.	Near-miss data is essential for identifying precursors and closing the SMS continuous-improvement loop.

UAS failure modes are not all equivalent and do not call for the same response. Scenario-based emergency procedures give pilots a rehearsed framework for common failure modes, reducing decision latency under pressure and ensuring consistent, defensible responses. The same logic applies to communication protocols: pilots need to know in advance, not in the field, when ATC notification is required, who within Caltrans is notified and in what sequence, and when emergency services should be contacted. Without that, individual operators are making those calls under pressure with incomplete information.

Post-incident response is equally time sensitive. What happens in the first hour after an incident largely determines what can be learned from it. Without defined procedures, the instinct is to recover the aircraft, clear the area, and move on, which destroys the evidentiary record an investigation depends on. Formalizing post-incident steps protects Caltrans' ability to investigate what happened and demonstrates structured response to any external reviewer.

Finally, the reporting gap identified here connects directly to the safety culture section: the program currently captures incidents operators felt obligated to report and misses the near misses that would be most useful for prevention. A unified system with a low-friction submission path and an anonymous option closes that gap and feeds the operational data pipeline that safety assurance depends on.

Moving Beyond Part 107

The Caltrans UAS SMS was developed with Part 107 operations in mind. Though it still is functional, it still has gaps that will need to be rectified for future advanced operations beyond regular Part 107. Some of that expansion is already underway with active waivers, new platform types entering the fleet, pilots operating in environments that exceed the assumptions built into standard qualification frameworks. Some of it is near-term: Part 108's framework for beyond visual line-of-sight operations, autonomous and dock-based systems, and the training demands that come with higher-complexity platforms. In both cases, the policy and procedures need refinement. The recommendations in this section address the authorities, qualifications, and operational structures needed to support that expanded envelope safely and accountably.

Waiver Management

FAA waivers and Certificates of Authorization extend Caltrans' operational envelope beyond the default limits of Part 107 such as enabling BVLOS operations, flight above 400 feet AGL, or operations over people, but they do so by substituting FAA-approved institutional controls for the regulatory defaults [9]. That substitution is the core of what makes waiver management distinct from standard Part 107 compliance. A waiver is an agreement that Caltrans will maintain specific pilots, aircraft, procedures, and records that the FAA reviewed and accepted as equivalent to the protections Part 107 provides by default. When those elements drift out of compliance, the waiver authority is undermined regardless of whether the FAA has been notified.

As documented in the gap analysis, the current Caltrans UAS policy does not define who is authorized to prepare or submit waiver applications, how waiver scope should be applied across divisions, districts, or statewide, or how compliance with waiver provisions should be monitored once an authority is active. The Division of Construction waiver (107W-2024-01814) illustrates the common institutional requirements embedded in the waiver conditions: pilot lists, aircraft records, approved procedures. As of today, those are not assigned to any role or supported by any program-level process. At present, compliance with those requirements depends on whoever happens to be managing them informally. That is a workable arrangement until there is a personnel change, an audit, or an incident that puts the waiver under scrutiny.

TABLE 9: WAIVER MANAGEMENT RECOMMENDATIONS

ISSUE	RECOMMENDATION	JUSTIFICATION
No policy defining who is authorized to prepare or submit FAA waivers and COAs.	Establish formal authority for waiver/COA preparation, review, and submission, including a standardized internal review process.	Clear submission authority ensures consistency, accountability, and compliance with FAA requirements, reducing the risk of incomplete or non-compliant applications.
Waivers and COAs lack defined organizational scope and assigned program-level compliance responsibilities.	Define how waivers may be applied at the division, district, or statewide level and define how to assign program-level responsibility for ongoing	Clarifying scope and oversight prevents misapplication of authorities and ensures continuous monitoring of pilot qualifications, aircraft lists, and

ISSUE	RECOMMENDATION	JUSTIFICATION
	compliance with waiver provisions.	waiver-required documentation.
Policy does not address how personnel should be trained on waiver requirements or how waiver updates are communicated.	Create requirements for the development of mandatory waiver-specific training and establish communication channels for distributing waiver conditions and updates.	Training and structured communication ensure pilots, supervisors, and managers understand the operational limitations and requirements of each waiver, reducing the likelihood of non-compliant operations.

The forward-looking concern is equally significant. As Caltrans expands into BVLOS operations, autonomous platforms, and higher-risk mission types, waivers and COAs will become more common and more operationally consequential. The complexity of waiver conditions scales with operational complexity. For example, a BVLOS waiver over a populated corridor carries substantially more institutional overhead than a high altitude operations waiver [10]. Building waiver management infrastructure now, while the program has a few active examples to learn from, is considerably easier than building it retroactively across multiple active authorities with different conditions, scopes, and compliance timelines.

Structured waiver management should include clear submission authority, defined scope at the appropriate organizational level, assigned compliance responsibility, and a communication process that ensures pilots and supervisors operating under a waiver understand its conditions. The gap analysis recommendations address each of these. Waivers represent Caltrans' most operationally capable and most scrutinized to flight authorities. Managing them informally is inconsistent with the level of accountability those authorities require.

Training Programs

The current Caltrans pilot training and qualification system was designed for a program operating primarily small multirotor platforms under standard Part 107 conditions. Two things have changed. First, the operational risk profile has increased with more districts flying, more complex mission environments, and platforms with higher inertia, greater autonomy, and less room for in-flight correction. Second, the fleet has diversified. VTOL aircraft, fixed-wing platforms, tethered systems, and dock-based autonomous systems each have distinct control characteristics, automation behaviors, and failure modes that a single qualification track does not adequately address. Training that was sufficient for a small multirotor inspection program is not sufficient for the program Caltrans is becoming.

Platform-specific qualification tracks and tiered proficiency level can be used to establish the structural framework to define what pilots need to demonstrate before advancing to higher-complexity aircraft or higher-risk operations. Formalizing the UAS Trainer role within policy establishes accountability for how that training is delivered and assessed. These are the prerequisite conditions for everything else in this section to function consistently.

TABLE 10: TRAINING RECOMMENDATIONS

ISSUE	RECOMMENDATION	JUSTIFICATION
No structured process for progressing from small multirotors to larger, fixed-wing, VTOL, or specialized platforms as the program expands.	Create a tiered pilot qualification framework that defines advancement requirements and competencies for each aircraft class.	A structured progression path ensures consistent skill development, and supports safe assignment of pilots to aircraft with higher complexity and risk.
Caltrans Designated UAS Trainer not defined in policy	Formalize UAS Trainer program within policy	Ensures consistency, transparency, and accountability for UAS Trainers.
Current pilot sign-off and training system does not provide sufficient experience for medium- and high-risk UAS operations.	Initiate a structured review and redesign of Caltrans pilot training and qualification standards to ensure pilots gain the experience, decision-making skills, and mission-level proficiency necessary for higher-risk operations.	Caltrans' higher risk profile necessitate training that better develops mission preparedness.
The current Caltrans UAS qualification system was designed for small multirotors and does not account for the higher operational complexity, unique control schemes, and elevated risk profiles of VTOL, fixed-wing, tethered, or dock-based autonomous platforms.	Adopt platform-specific qualification tracks that include tailored initial qualification, currency, and recency requirements for each major UAS category (small multirotor, heavy multirotor, VTOL, fixed-wing, tethered, dock-based autonomous systems).	Operational demands, training needs, and risk factors vary significantly between platforms. A single qualification path does not ensure pilots have the system-specific competencies required for safe operation, particularly on aircraft with higher inertia, limited manual control, or complex automation.

The approach recommended for building depth within that structure combines three elements. Multi-level pilot proficiency creates a defined progression path tied to mission readiness rather than time-in-program, which has two practical benefits: newer pilots can begin contributing in lower-risk operations sooner, and higher-risk operations have a defensible qualification standard rather than an informal one. Scenario-based mission training builds the decision-making skills that flight hours alone do not reliably develop, particularly important for automation-dependent platforms, where the relevant skill is not stick-and-rudder proficiency but understanding what the system will do, when it will do it, and how to intervene. Structured mentorship connects newer pilots to accumulate field knowledge that formal curriculum cannot fully capture, and is especially valuable for complex missions where tacit judgment matters.

Each of these approaches carries real costs in trainer time, curriculum development, and scheduling coordination, as detailed in the Appendix. None of them is low effort. The tradeoff is that the alternative, a qualification system that does not keep pace with operational complexity, concentrates risk at the point where pilot capability and mission demand diverge. For a program

operating under public agency authority and increasing regulatory scrutiny, that is not a sustainable position.

14 CFR 108 – Operations Beyond Visual Line of Sight

Part 108 represents a fundamental shift in how the FAA expects complex UAS operations to be governed [8]. Where Part 107 places accountability on the individual remote pilot, Part 108 moves it to the organization, requiring defined roles, controlled documentation, formal management systems, and FAA operating certificates. For Caltrans, that shift is significant: it means the program itself, not individual pilots, bears primary responsibility for training standards, safety oversight, maintenance records, and regulatory compliance. Although the rule remains in proposed form (maybe June 2026 now), the organizational infrastructure it requires takes time to build, and Caltrans already has one active waiver and an expanding fleet that will increasingly depend on the framework Part 108 establishes.

TABLE 11: PART 108 RECOMMENDATIONS

ISSUE	RECOMMENDATION	JUSTIFICATION
Current roles and responsibilities do not include Part 108 roles	Define an Operations Supervisor (primary accountable person) for Part 108 operations.	This will be an involved position and will likely exceed the responsibilities of any UAS pilot responsibilities.
Current roles and responsibilities do not include Part 108 roles	Incorporate the responsibilities of the Part 108 Flight Coordinator under the existing UAS Operator role, with an additional training requirement	While Flight Coordinators may not require a Part 107 in the current proposal, the existing UAS Program is more than satisfactory for Flight Coordinators after necessary manufacturer-specific training.
Physical site security for tethered and dock-based systems is expected under Part 108, but current Caltrans UAS policy does not explicitly require secured locations for long-duration or pilot-less deployments.	Add a policy stating that all tethered and dock-based UAS deployments must ensure physical site security, including restricted access to equipment, clear signage, and controls to prevent unauthorized interference with aircraft, docks, tethers, and support infrastructure.	

The recommendations in this section address the most immediate structural gaps. The Operations Supervisor role, the anticipated position for a designated individual accountable to the FAA for safe and compliant execution of all UAS operations, could be a separate position or overlap with the UAS Program administrator. While it will still require a significant level of technical expertise, it also carries a level of formal authority and institutional accountability that exceeds typical UAS pilot responsibilities. The Flight Coordinator role is more tractable as its responsibilities align closely with existing UAS Operator functions, and the additional requirements such as manufacturer-specific

training, currency through recent flight coordination, defined handoff procedures, can be incorporated as an extension of the current qualification framework rather than a new track.

A readiness assessment against the full Part 108 checklist, detailed in the prior gap analysis report, identified strengths in safety policy, hazard identification, and standard operating procedures, areas where Caltrans has built functional practice. The material gaps fall in four areas: training and competency management, which lacks the structured pathways and recurrent assessment cycles Part 108 requires; maintenance and airworthiness, currently tracked through spreadsheets rather than controlled logs with defined intervals and parts traceability; records management and document control, which lack versioning and retrieval standards; and safety assurance, where Safety Performance Indicators and corrective action tracking are not yet formalized. These are not trivial gaps, but they are also not novel problems, they are the same data quality and accountability themes that appear throughout this report, surfacing again at the higher compliance threshold Part 108 sets.

Similarly connected is the siting for Part 108 operations and tethered or docked-based systems. A minor adjustment, but one that should be developed and documented before it becomes an issue.

Making progress towards Part 108 readiness is not a separate workstream from the improvements described in the preceding sections. Formalizing the SMS, improving data systems, structuring training, and designating clear organizational roles all advance both goals simultaneously. Programs that treat Part 108 preparation as a future compliance project rather than a present organizational maturity effort will find themselves building the same infrastructure twice.

New UAS Platforms

The Caltrans UAS fleet is diversifying beyond the small multirotors that defined the program's early operational profile. Larger fixed-wing aircraft, VTOL platforms, tethered systems, and dock-based autonomous systems are either already in use or near-term acquisitions, each with distinct control characteristics, automation behaviors, training demands, and policy requirements that the current framework does not fully address. The recommendations in this section are organized around three problem areas: how pilots prepare for and interact with automated systems, how qualification and progression standards need to evolve for a more complex fleet, and where platform-specific policy gaps require explicit coverage.

TABLE 12: RECOMMENDATIONS RELATED TO NEW UAS PLATFORMS

ISSUE	RECOMMENDATION	JUSTIFICATION
Platforms with limited or no manual override require substantially more pre-flight planning and rehearsal, but current policy treats pre-flight requirements uniformly across platforms.	Require expanded pre-flight planning for autonomy-dependent systems, including documented route validation, obstacle and terrain review, contingency planning, link-quality checks, and verification of automation behavior using simulation or route-preview tools where available.	When manual intervention is constrained or unavailable, the effectiveness of the mission depends heavily on pre-flight validation and operator understanding of automation logic.

ISSUE	RECOMMENDATION	JUSTIFICATION
Outside of the familiar small multi-rotor platforms, the Ground Control Station (GCS) interfaces for advanced platforms are dense and unfamiliar, leading to reluctance to use automation features and slower adoption of system capabilities.	Ensure that flight training for new platforms include training on GCS software, including navigation of menus, interpretation of system messages, automation settings, and safe use of autonomy modes.	Competent GCS operation is essential for effective use of advanced platforms.
Pilots hesitate to engage with automation due to uncertainty, concern about unintended behaviors, and difficulty interpreting system responses.	Include automation literacy as a required component of training, covering autonomy modes, failsafe behaviors, obstacle avoidance logic, mode transitions, and system limitations.	Automation literacy ensures pilots understand what the system will do, when it will do it, and how to intervene safely.
Emerging platforms require skills (automation management, mission planning, system integration) that extend beyond current training, but no platform-specific qualification standards exist.	Develop explicit training modules and qualification criteria tied to aircraft type and operational complexity.	Platform-specific standards allow Caltrans to match pilot capability to mission risk, reduce uneven skill development, and maintain operational readiness as the fleet diversifies.
Operators require significantly more flights (10–15 vs. 1–8) to achieve control comfort and confidence on larger UAS (>10 lbs).	Establish additional flight training for larger platforms, exceeding those required for small UAS, before pilots may operate independently.	Larger aircraft have greater inertia, slower response times, and higher risk of damage, all of which slow skill acquisition and increase consequence of error.
Pilots reported needing a structured progression through increasingly complex environments to build confidence near structures and obstacles.	Develop a staged progression model (open-area -> controlled obstacles -> mission-representative environments) for initial qualification on larger aircraft.	Builds confidence gradually
Missing tethered drone operations in policy	Establish policy defining tethered flights operate under Part 107	Unless Public Agency Exception under 49 USC 44806(c) is supported, flight operations with tethered drones do not encumber additional risk that would necessitate a special or unique restriction
No existing policy defines when and how autonomous docking systems may be used.	Establish conditions for deployment, authorization, pilot qualifications, and oversight	Dock-based operations assume BVLOS-like workflows and require clear definition of responsibility and authority.

ISSUE	RECOMMENDATION	JUSTIFICATION
	structure for docking-system operations.	
Extended-duration operations introduce fatigue and ergonomic risk factors not addressed in policy.	Incorporate ergonomic requirements including equipment supports, break schedules, crew rotations, and fixed-station ergonomic guidance for when in-flight time exceed one hour	Reduces fatigue-related errors and maintains situational awareness during multi-hour operations.

Autonomy and Pre-Flight Planning

The automation features built into advanced UAS platforms are only useful if operators understand them well enough to use them correctly and intervene when necessary. The Gap Analysis identified a number of issues as new pilots gained access to advanced autonomy that wasn't well described or known. That reluctance is a rational response to inadequate documentation and training. When operators do not understand what an automation mode will do or how the system will respond to a contingency, avoiding those features is the safer choice, but it also means the program is not getting the operational value the platform was acquired to provide, and pilots are not building the competencies they will need as the fleet diversifies further.

Addressing this requires treating automation literacy as a distinct training requirement, not an assumed byproduct of flight hours. Understanding autonomy modes, failsafe logic, obstacle avoidance behavior, mode transitions, and system limitations is a learnable skill set that belongs in initial qualification for any platform with meaningful automation. GCS proficiency including navigation of menus, interpretation of system messages, safe use of autonomy settings, is similarly trainable and similarly underweighted in current qualification frameworks.

Pre-flight requirements for autonomy-dependent platforms warrant separate treatment from standard preflight checks. When manual intervention is constrained or unavailable, the effectiveness and safety of the mission depend on what was validated before the aircraft left the ground. Route validation, terrain and obstacle review, contingency planning, link quality checks, and simulation or route-preview where available are effective primary risk controls. Current policy treats pre-flight requirements uniformly across platforms, which undersupplies the preparation that high-autonomy operations require.

Pilot Qualification and Progression

The existing Caltrans qualification framework was built around small multirotors, where the primary pilot skill is manual aircraft control and the consequences of errors are relatively contained. Larger platforms including heavier multirotors, fixed-wing aircraft, VTOL systems, have materially different characteristics: greater inertia, slower response times, higher consequence of error, and in many cases, control schemes with no direct analog to small multirotor experience. Gap analysis evaluations indicated that pilots require significantly more flights to achieve control confidence on larger platforms than on small ones and reported needing structured progression through

increasingly complex environments before feeling prepared for operational use near structures and obstacles.

The qualification framework needs to account for this. Platform-specific tracks with defined initial qualification, currency, and recency requirements for each major aircraft category establish a consistent standard and make it explicit that a Part 107 certificate and small multirotor sign-off do not constitute readiness for every aircraft in the fleet. A tiered proficiency model within those tracks, such as a structured progression from open-area flight through controlled obstacle environments to mission-representative conditions, can help build confidence gradually and produces pilots who have encountered complexity in a controlled setting before encountering it operationally.

Formalizing the UAS Trainer role within policy is a prerequisite for this to function consistently. Qualification standards that are not tied to accountable, trained instructors applying them uniformly will produce uneven outcomes regardless of how well the standards are written. Trainer formalization is what converts a qualification framework from a document into a program.

Platform-Specific Gaps

Several platform types now in use or near-term acquisition operate in policy gaps, areas where the current Caltrans UAS policy applies Part 107 assumptions that do not fit cleanly.

Tethered systems are the most straightforward to address. Unless operating under the Public Agency Exception, tethered drone operations fall under Part 107 and do not require special restrictions beyond what that framework already provides. Establishing this explicitly in policy removes ambiguity without adding burden. Extended-duration operations, whether tethered or otherwise, introduce fatigue and ergonomic risk factors that current policy does not address. A minor recommendation for operations exceeding one hour of in-flight time is worth incorporating ergonomic assessments to develop platform or situational guidance.

Dock-based autonomous systems represent the most significant policy gap in this category. These platforms assume BVLOS workflows, extended or automated deployment without continuous pilot presence at the site, and the questions they raise about authorization, oversight responsibility, physical site security, and pilot qualification do not have answers in the current policy framework. Program administrators are a natural fit for oversight, but authority could be delegated with defined structure. Minimum experience, documented flight operation expectations, and other requirements relevant for a major stakeholder would be appropriate. Establishing deployment conditions, authorization requirements, and oversight structure for docking systems before they are operationally active is considerably more tractable than developing that framework after incidents or compliance questions arise. The site security requirement in particular, restricted access to equipment, clear signage, controls against unauthorized interference, is straightforward to define and directly relevant to public-agency operations in accessible locations.

Training Curriculum Development

The training recommendations in the preceding sections address what the qualification framework needs to become. This section describes what has been built in parallel with this report: curriculum updates to the existing eLearning program and one new module developed to address the automation literacy gap identified through pilot survey data and operational review.

Automation Literacy: Risk Management for Automation

The most significant curriculum addition is a new eLearning module, *Risk Management for Automation*, developed in response to a consistent pattern identified across pilot survey data and training observations: pilots with standard Part 107 qualifications and small multirotor experience were poorly prepared to supervise platforms where automation plays a significant role in flight execution. The issue was not unfamiliarity with controls, instead it was a more fundamental gap in how pilots understood what automated systems were doing and why. Pilots who treat autonomy as set-and-forget often fail to notice early signs of degradation. When a Skydio X10 pauses unexpectedly beneath a bridge girder, a pilot trained only in manual flight may interpret it as a malfunction. A pilot with automation literacy recognizes it as a reasoning change as a low-confidence signal from vision-based perception and responds accordingly.

The module addresses this by shifting the framing from flight control to supervision. Modern UAS missions increasingly rely on aircraft that manage their own flight paths, detect and avoid obstacles, and decide how to capture data. What was once a task of continuous joystick input is now a process of monitoring how well automated decisions match the mission and the environment. The pilot's role is changing. While responsibility remains with the operator, the operator role and how they perceive, process, and act on have changed [11]. This shift also changes what constitutes a hazard. In autonomous operations, hazards include not only environmental conditions but automation states, degraded sensing, mode transitions, and unexpected reasoning outputs, none of which are visible to a pilot whose training focused entirely on stick-and-rudder response.

The module is organized around three core supervisory skills, each grounded in the FAA's aeronautical decision-making framework and illustrated through scenario-based examples drawn from platforms relevant to Caltrans operations.

TABLE 13: CORE SUPERVISORY SKILLS

SKILL	CORE QUESTION	KEY INSIGHT
MODEL-TRACING	What is the system reasoning?	Observable behavior reflects internal logic
BOUNDARY AWARENESS	When does that reasoning break down?	Degradation is detectable before failure
INTERVENTION TIMING	When should the pilot act?	Act during deviation, not after failure

Model-tracing

Model tracing is the ability to infer what the system is reasoning based on observable behavior, hesitations, re-pathing, micro-adjustments, mode transitions, and determine whether that

reasoning remains valid for the conditions [12]. The skill is not about knowing the algorithm; it is about reading behavior as evidence. When a Skydio X10 pauses near a structure, ascends slightly, shifts laterally, and resumes its route, a model-tracing pilot recognizes this as the system attempting to restore visual context after encountering a change in visibility which is not a malfunction, not a weather event, but an uncertainty management response. That interpretation determines whether the pilot logs the conditions and continues or intervenes unnecessarily.

Boundary Awareness

Boundary awareness builds on model-tracing by teaching pilots to recognize when conditions are approaching the limits of the system's sensing or reasoning envelope, before those limits are reached rather than after [13]. During a coastal mapping mission, a Freefly Astro maintaining its survey line through a wind corridor begins showing sharper lateral corrections, widening oscillations, and intermittent position-hold degradation warnings. A pilot with boundary awareness reads this as a control limit approaching actuator saturation where the motors are near maximum output countering the wind, and distinguishes it from a software issue or sensor failure. That attribution determines the appropriate response. Degradation detection and limit attribution are skills that develop through exposure to varied conditions and structured training.

Intervention Timing

Intervention timing addresses the temporal judgment of when to assume manual control [14]. Autonomy rarely fails instantly, instead it follows a pattern of compensation, then deviation, then loss of validity. The goal is to act during the deviation phase, while the aircraft is still stable enough for a smooth transition, not after failure has developed. In practice this is harder than it sounds. One common error is waiting too long: a pilot delaying intervention until the Astro visibly departs its intended mapping path finds that control authority is nearly exhausted and several images have lost usable overlap. The opposite error, intervening at the first gust before any sustained deviation appears, overrides automation that would have recovered, increases workload, and wastes battery on unnecessary repositioning. Effective timing requires calibrated trust: neither passive reliance on automation nor reflexive override of it.

At approximately 20–30 minutes, the module is deliberately scoped to establish the conceptual framework that structured field experience then develops. Platform-specific GCS training is intentionally excluded as that content is too manufacturer-dependent to generalize and is better addressed through hands-on practice and manufacturer training. The module was developed through the UC Center of Excellence on UAS Safety and adapted to meet Caltrans requirements and standards. It is designed for initial qualifications on any platform with meaningful automation features and can serve as a recurrent refresher as the fleet diversifies.

Updates to Existing Curriculum

Recommendations for updates to the supervisor training module were provided to reflect the program's current scale and the governance recommendations in this report. Recommendations address program oversight responsibilities, the procedures for applying for and obtaining advanced UAS authorizations including waivers and COAs, and the administrative role supervisors play in supporting SMS compliance. These updates are designed to run in parallel with the SMS improvements recommended elsewhere in this report, as the program formalizes data review

processes, reporting structures, and safety assurance practices, the supervisor curriculum provides the institutional context supervisors need to support those changes rather than work around them.

New Platform Training: Hands-On Over eLearning

The decision to push new platform training toward structured hands-on practice rather than additional eLearning modules reflects a deliberate finding from the gap analysis. Training scenarios across platform types produced consistent observations about how pilots develop proficiency on advanced systems and where eLearning reaches its limits. Table 14 summarizes which competencies are well-suited to eLearning, which require hands-on practice, and which benefit from eLearning as an introduction only. The subsections below explain why.

TABLE 14: TRAINING MEDIUM EFFECTIVENESS

Competency	*eLearning*	*Hands-On*	*Notes*
Regulatory Knowledge	✓		Part 107, airspace rules, waiver requirements
Automation Literacy	✓		Model-tracing, boundary awareness, intervention timing
Emergency Response Concepts	✓		Procedures and decision frameworks
GCS Software Proficiency	Intro only	✓	Interface density and workflow require direct practice
Advanced Autonomy Management	Intro only	✓	Trust calibration develops through operational exposure
Non-Stabilized Control		✓	No conceptual substitute for flight experience
Runway / TLOF Management		✓	Site-specific, environment-dependent
Long-Range Awareness		✓	Develops through varied field exposure
Telemetry Interpretation	Intro only	✓	Pattern recognition requires repeated real-world exposure
Planning and Simulations	Intro only	✓	Platform-specific tools require direct use
Crew Resource Management		✓	Role discipline emerges through team practice

Small vs. Large Multirotors

Small multirotors are forgiving in a way that masks their own limitations as training tools. GPS hold makes hovering easy, stability systems smooth out inputs, and the low cost and consequence of error encourages experimentation. New pilots often build confidence quickly, sometimes faster than their actual skill warrants. While useful, these platforms do not teach the discipline that larger aircraft will demand.

The same pilots flying the same inspection scenarios on a Freefly Astro encountered a different operation entirely. The gravel road, tree, and barbed wire fence that posed a minimal issue on a small quad became a different problem without collision avoidance. Very rarely did pilots test the aircraft limits until they had significantly more experience. They stayed further back, relied on the 61MP zoom camera instead of closing distance, and depended on observer support for depth perception near the tree. The crew discussed abort criteria before launch. Roles were assigned formally. Post-flight inspection covered motor temperatures, prop integrity, and vibration mounts.

This gap shows up in the data too. Pilots transitioning from small UAS reached basic control comfort within one to two flights and confidence near structures within five to eight. On platforms above ten pounds, the same milestones required ten to fifteen flights, with many continuing to express hesitancy near obstacles beyond that point. Increased inertia, slower response times, higher consequences of error, and the psychological weight of operating more expensive equipment all contribute. That shift from orientation and comfort to systems management and risk trade-offs, is itself a training outcome that only the larger platform produces. [15]

Fixed-Wing and VTOL Operations

Fixed-wing operations moved the training challenge upstream entirely. The AgEagle eBee has no manual flight controls. Every input must be pre-programmed before launch, which means the crew spent more time at the planning table than at the controls. Simulating flight paths, accounting for wind direction, identifying launch and landing corridors that avoided tree lines and roads, managing hairpin survey turns that consumed more airspace than the software predicted had to be resolved before the aircraft left the ground. Once airborne, the crew monitored telemetry and stayed ready to abort as there was nothing else to do.

Landing was the highest-stress phase. The eBee's requirement to land into the wind made site layout a hard constraint. The long shallow glide slope had to be kept clear throughout the approach, with no option to adjust if something changed. The crews debrief during the Gap Analysis was clear that fixed-wing operations front-load the workload. The planning phase carries the risk, and mistakes made there were harder to correct in flight.

The WingtraOne VTOL removed the wind-alignment landing constraint but introduced its own. Similar to the eBee, the interface with no live camera feed meant pilots had to trust system telemetry entirely rather than verify through direct imagery. But with the Wingtra, the controller was a handheld tablet in contrast to the eBee’s laptop. Long endurance flights were now a bit more taxing holding up a tablet for the entire time. The experience reinforced similar issues from the eBee in which platforms where manual intervention is limited or unavailable, crew discipline and pre-flight preparation are the primary risk controls.

Implications for Curriculum Design

The field observations point that the skills that need to develop for advanced platform readiness are almost entirely in the hands-on column. Non-stabilized control, GCS software proficiency, runway

and TLOF management, telemetry interpretation, long-range awareness, planning and simulation workflows, and crew resource management. None of these develop reliably through online instruction alone. Instead, they require practice, repetition, and feedback in conditions that produce real consequences for error.

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Appendix

UAS Pilot Training Logging System

Explanation

As more users and crew are onboarded, keeping up to date with everyone's training assignments and completion can get overwhelming to handle manually. The goal with this Example is to showcase the use of a separate training log system that enables a better record keeping system and reduces manual management of pilot's training status.

The key addition to this system is the addition of a sheet used for logging all training, called 'log_pilot_training' and two forms: Assign Training form to assign training to a user, and an Update Training form for users to mark that they have completed a training.

This sheet is simple in its setup - it consists of

- TRAINING_LOG - Primary Column - displays the ROW ID with function "=ROW@row"
- ROW - hidden - Autonumbering column to generate a unique row id
- EMAIL - Email address of the person to whom which training is assigned, or training was completed.
- TRAINING TYPE - Dropdown selection of all selectable training.
- DATE - User submitted date - can be used to document date of completion, or date that training is due.
- CREATED DATE - Date the row was added for auditing purposes
- ASSIGNED - Checkbox indicating that the training was assigned. Is set to TRUE and hidden when using the Assign Training form, and not included in the Update Training Form.
- COMPLETED - Checkbox indicated that the training was completed. Is set to TRUE and hidden when using the Update Training form, and not included in the Assignment Form.
- CERT # - optional field for users to document the number for their certification
- Notes - optional field for additional notes
- VALIDATED - optional field for Program Administrator to vet/validate any submissions

From the data on this sheet, the Program Administrator can filter by EMAIL to see all assigned and completed training by each individual. Each Assignment and Completion are separate rows, enabling better auditing of when items are assigned, and when used with Attachments, makes it easier to search for specific attachments associated with different training types. Adding additional Training Types can be accomplished by adding it to the Dropdown Selection, rather than creating new columns to track Assignment/Completion.

Forms for data collection

To add data to this sheet, two forms are created: Assign Training and Update Training. In the Assign Training form, only the following fields are used:

- EMAIL
- ASSIGNED - this field is set as HIDDEN and with a Default Value of Checked
- TRAINING TYPE
- DATE
- NOTES

In the Update Training form, only the following fields are used:

- EMAIL
- TRAINING TYPE
- COMPLETED - this field is set as HIDDEN and with a Default Value of Checked
- DATE
- CERT # (if applicable)
- NOTES
- ATTACHMENT - enabled as 'File Upload' and relabeled to provide users an opportunity to upload a copy of their Certificate

The use of the HIDDEN and Default Values enable a simplified form input experience.

Adding Pilot Specific Forms

The forms by themselves require the user to input the target's email address. This may not be a major issue for the users using the the Update Training form, it may be an unnecessary burden for the UAS Program Administrator. This can be remedied using prepopulated forms and url generation. In the example database, two columns were added labeled "Update Training Link" and "Assign Training Link." Each column contains an active link to the Update Training and Assign Training forms, prepopulated with each user's email address using the formula:

```
=
"Active link to the Update Training and Assign Training forns ail=" +
[Email typed]@row
```

Where the URL to the form (in yellow) is appended with ?Email= (in green), enclosed within quotations (in purple), followed by + [Email typed]@row (in blue), where [Email typed] is the column name of the pilot's email address. Set as a column formula, all pilots will have a link to both forms with their email address prepopulated. This link can be accessible to the UAS Program Administrator in the grid/table view of Smartsheet, in a Report (viewable on a Dashboard), or emailed to the email address via automation.

Display Training Information

Once a pilot is in the UAS Pilot Database, it may be useful to display additional information related to their training. Code explanations are provided in comments (delete before utilizing in Smartsheet). Items in curly brackets {*} denote a cross-sheet reference, in this case to the sheet containing the log of all training.

Display the Certificate Number associated with the latest Certificate

```
=IFERROR( // If the following expression produces an error (e.g., no
match found), return "Missing"

    INDEX(
        {log_pilot_training (Simple) cert num}, // Get the certificate
number from the matching row
        MATCH(
            MAX(
                COLLECT(
                    {log_pilot_training (Simple) Date}, // Return a list
of training dates that match all the criteria below
                    {log_pilot_training    (Simple)    Email},    [Email
Typed]@row, // Where the email matches the current row's email
                    {log_pilot_training (Simple) Training Type}, "Part
107", // And the training type is "Part 107"
                    {log_pilot_training (Simple) Validated}, 1 // And
the training has been validated (checkbox = checked)
                )
            ),
            {log_pilot_training (Simple) Date}, // Find the row number
in the full date column that matches the latest (MAX) date
            0 // Exact match
        )
    ),
    "Missing" // If the above fails (e.g., no valid training found),
return "Missing"
)
```

Return the last date of a Part 107 Certificate or Part 107 Renewal

```
=MAX(
    COLLECT(
        {log_pilot_training (Simple) Date}, // Return a list of training
dates that match all criteria below:
        {log_pilot_training (Simple) Email}, [Email Typed]@row, // Where
the email matches the current row's "Email Typed" value
        {log_pilot_training (Simple) Training Type},
           OR(@cell = "Part 107", @cell = "Part 107 Renewal")
                // And where the training type is either "Part 107" or
"Part 107 Renewal"
    )
)
```

Display a color-coded icon for Part 107 Status

```
=IF(
    ISBLANK([Part 107]@row),
    "No", // If the Part 107 date is blank, return "No"
    IF(
```

```
        TODAY() - [Part 107]@row <= {Part 107 Timeline Warning Date},
        "Yes", // If today's date minus the Part 107 date is less than
or equal to the "Warning" threshold, return "Yes"
        IF(
            TODAY() - [Part 107]@row <= {Part 107 Timeline Expiration
Date},
            "Hold", // Else, if the age is less than or equal to the
"Expiration" threshold, return "Hold"
            "No"     // Else, the training is too old and considered
expired — return "No"
        )
    )
)
```

In the above code, [Part 107]@row is a in-sheet reference to the Part 107 Certificate Date. The cross-sheet references point to a single cell within a helper sheet called "timeline - Part 107" that stores the number of days until expiration and warning. These are stored in a helper sheet rather than within the formula for ease of future modification. The strings "No", "Hold" and "Yes" are the required values to utilize the symbols for Red X, Yellow Caution, and Green Checkmark respectively.

Potential Training Approaches

Approach	Description	Pros	Cons	Costs
Multi-Level Pilot Proficiency	Create levels (beginner, intermediate, advance) for pilots to advance, tied to mission readyness.	Clear progression path, can enable low-risk flight operations for newly certified pilots to get them in the field faster, better standardization of mission preparedness for higher-risk operations.	Requires new curriculum and standards, increases administrative workload, requires trainers to be more involved, may create bottlenecks	more trainer hours, development of tracking tools, travel and scheduling
Pre-Flight Authorization Review	UAS Program manager reviews flight activity to ensure flight missions match pilot proficiency/experience.	Ensures appropriate pilot-to-mission alignment, works for high-consequence missions, provides standard oversight	Administrative delays, requires expert reviewers, may frustrate experienced pilots	Staff time for reviews, requires a more comprehensive tracking system
Longer / More Involved Training Program	Expand the training program to include more hands-on experience with flight time and mission preparedness	Produces More capable pilots, Builds decision-making skills, Reduces reliance on mentorship	More trainer time needed, Slower pilot throughput, Scheduling challenges	Increased instructor workload, Time away from field, Facility usage
Structured Mentorship Program	Formalize a program to newly certified pilots to shadow a more experienced pilot to gain experience	Builds tacit knowledge, good for complex missions	Variable mentor quality, Risk of unproductive shadowing, lack of regular operations available to shadow	High cost of mentor time and coordinating
Scenario-Based Mission Training	Include scenario-based mission training within existing program	Strengthens mission-planning skills, Good for automation platforms	Requires scenario design, extends basic training significantly, requires more expert trainers	Scenario development effort, more effort and time commitment to trainers
Self-Study and Certified Practice Hours	Require a certain number of certified practice time before advancing to higher risk operations	Low cost, Reduces trainer burden	Hard to verify quality, May build bad habits, limited exposure to higher risk operations	Requires a more suitable tracking system, need to develop task list

Caltrans UAS Safety Management System
Task 1 - Gap Analysis

Dr. Brandon Stark

Oct 16, 2025

Contents

1 Introduction **40**
1.1 Background and Context 40
1.2 Focus Areas and Analytical Approach 40

2 Safety Management System **41**
2.1 Review of the Safety Management System Documentation 41
2.2 Flight Record Review 43
2.3 Safety Risk Management Workflow 45
2.3.1 Form Naming Convention 45
2.3.2 Connecting Pre-Flight with Hazard Analysis 47
2.4 Hazard Analysis Form 47
2.4.1 Analysis of Existing Form 47
2.4.2 Improving the Flow 48
2.5 Caltrans UAS Program Participant Feedback 49
2.5.1 Survey of Caltrans UAS Program 49
2.5.2 Feedback from UAS Program Pilots 56
2.5.3 Final Remarks 57
2.6 Management of the Safety Management System 58
2.6.1 Assessment of Smartsheet 58
2.6.2 Management of Waivers 62
2.6.3 Pilot Advancement 63
2.7 Part 108 NPRM 63
2.7.1 Part 108 Requirements 64
2.7.2 Part 108 Transition Checklist 65
2.7.3 Priority Steps Toward Part 108 Readiness 67

3 UAS Platform Review **68**
3.1 Introduction 68
3.2 Expanded Operations 69
3.2.1 Tethered Drones 69
3.2.2 Docking Systems 72
3.3 New Aircraft Types and Autonomy 74
3.3.1 Large Multi-Rotor 74
3.3.2 Fixed-Wing 75
3.3.3 VTOL 75
3.3.4 Visual Line of Sight 75
3.4 Scenario-Based Testing 79
3.4.1 Introductory Drone Training 79
3.4.2 Drone Infrastructure Inspection (Manual Flying) 79
3.4.3 Survey Mission 80
3.5 Platform Functionality 80
3.5.1 Increased Platform Size Prolongs Skill Acquisition 80

3.5.2 Increased System Complexity Requires Extended Familiarization 80
3.5.3 Reduced Manual Control Increases Planning Requirements 81
3.5.4 Expanded Awareness of System-Level Requirements 81
3.5.5 Summary 81
3.6 Automation and Integration 82
3.6.1 Automation and Connectivity in Field Operations 82
3.6.2 Human-Automation Interaction and Cognitive Load 82
3.6.3 Operational Implications and Evolving Roles under Autonomy 85
3.6.4 Integration with the Caltrans UAS Safety Management System 86
3.6.5 Policy and Programmatic Considerations 86

4 Summary **88**
4.1 Summary 88

5 Appendix **91**
5.1 Review of the Safety Management System Documentation 91
5.2 Hazard Analysis Form 95
5.2.1 Pre-Flight 95
5.2.2 Onsite Checklist 95
5.2.3 Post-Flight Addendum 96
5.3 Survey Questions 97
5.4 Survey Results - Text Entry 100
5.4.1 Recommendations for Improvement to Process 100
5.4.2 Final Comments 101
5.5 §108.40 Operator recordkeeping requirements 103
5.6 §108.135 Company operations manual 104
5.7 Rapid Entire Body Assessment (REBA) 106
5.8 Scenario Evaluations 107
5.8.1 Introductory Training 107
5.8.2 Inspection 109
5.8.3 Survey Mission 111

Executive Summary

Purpose of Analysis

Chapters 2 and 3 assess how the Caltrans Unmanned Aircraft Systems (UAS) Program is progressing from foundational safety documentation toward a fully developed Safety Management System (SMS) capable of supporting advanced and autonomous operations.

Chapter 2 evaluates the structure and performance of the current SMS, while Chapter 3 examines platform functionality, automation, and data integration. The goal of this analysis is to identify systemic gaps, organizational, technical, and human, that limit the program's ability to scale safely under future FAA Part 108 frameworks.

Summary of Key Findings

Caltrans has a strong policy and safety foundation, but several areas constrain SMS maturity and integration across the organization.

Organizational and Data Gaps

- Flight and hazard records are inconsistently completed, reducing visibility into operational risk trends.
- Risk assessments and corrective actions are not consistently linked, weakening continuous improvement.
- Data are stored in flat spreadsheets, preventing traceability and long-term performance analysis.

Operational and Human Factors Gaps

- Field operators report redundant paperwork, unclear form sequencing, and limited tool integration.
- Training and advancement opportunities are uneven, especially for newer or less frequent pilots.
- Emerging UAS platforms (tethered, fixed-wing, VTOL) shift workload from manual control to cognitive supervision, increasing monitoring demands.

Systemic Alignment Needs

- SMS data and automation telemetry must be integrated to enable predictive safety insight.
- Feedback mechanisms should connect field operations to policy and training development.

Overall, Caltrans' UAS Program demonstrates strong intent and structure but remains limited by fragmented data systems, inconsistent documentation practices, and incomplete feedback loops. Addressing these gaps is critical for achieving organizational-level safety assurance and readiness for future Part 108 operations.

Chapter 1

Introduction

1.1 Background and Context

The Caltrans UAS Management System (USMS) Gap Analysis provides a foundation for understanding how new and emerging drone technologies can be safely and effectively integrated into Caltrans operations. The Caltrans UAS Program has grown rapidly since the implementation of their Safety Management System (SMS)[1] with support from the University of California Center of Excellence on Unmanned Aircraft System Safety at UC Merced [2]. While the current USMS effectively supports routine operations of small multirotor aircraft under Part 107 [3], the accelerating pace of innovation in Unmanned Aircraft Systems (UAS) now demands an updated framework to ensure continued safety, efficiency, and regulatory alignment.

Recent advances, such as beyond visual line of sight (BVLOS) operations, tethered and docked systems, and vertical takeoff and landing (VTOL) aircraft, have introduced new operational modes that differ substantially from the original one-pilot/one-drone paradigm. These capabilities extend mission duration, expand coverage, and improve data continuity but also shift the human-automation relationship, increase network dependencies, and complicate the definition of pilot responsibilities [4]–[6]. As such, Caltrans requires an updated evaluation of policies, training, and oversight practices to incorporate these technologies into a unified, safety-driven operational ecosystem [7], [8]. This report builds on a systematic review of field practices, documentation, and user experiences to highlight both strengths and areas where additional support or standardization are needed.

1.2 Focus Areas and Analytical Approach

The analysis centers on three primary focus areas:

1. Operational practices
2. Training requirements
3. Management oversight

Each focus area addresses unique challenges presented by expanded operations, advanced autonomy, and advanced connectivity systems. The approach includes structured interviews with Caltrans UAS operators, site audits at active flight locations, and mission task analyses. Additional reviews of anonymized safety data, incident reports, and manufacturer-provided training curricula inform the evaluation of organizational readiness.

By comparing Caltrans' existing practices against regulatory frameworks and manufacturer standards, the report identifies discrepancies and opportunities for harmonization. This process not only clarifies the technical and procedural gaps but also informs policy and curriculum recommendations that align with FAA guidance on Safety Management Systems (SMS) [7], [9], [10]. The ultimate objective is to support the development of a more resilient and scalable USMS, one capable of managing future Caltrans operations that leverage BVLOS capabilities, tethered and docked systems, and autonomous flight management technologies under the emerging Part 108 framework [4].

Chapter 2

Safety Management System

Section 2 examines the structure and implementation of the Caltrans Unmanned Aircraft Systems (UAS) Safety Management System (SMS). It evaluates how existing documentation, data practices, and operational procedures align with recognized SMS principles of safety policy, risk management, assurance, and promotion. The goal of this section is to identify strengths, gaps, and opportunities for improving the Caltrans SMS so it can better support statewide UAS operations and prepare for future regulatory frameworks such as FAA Part 108.

2.1 Review of the Safety Management System Documentation

The Caltrans UAS Safety Management System (SMS) program provides a structured framework for ensuring that unmanned aircraft operations are conducted safely, effectively, and in compliance with both regulatory and organizational requirements.

To evaluate its current state of implementation, a structured checklist was developed based on recognized SMS elements: policy structure and clarity, leadership commitment, scope and applicability, regulatory compliance, risk management, roles and responsibilities, training, emergency preparedness, reporting, continuous improvement, and integration of new technologies. This checklist was developed from the following sources: [1], [9], [11] and ongoing work with the Drone Safety Team (DST) [12] specifically on SMS development in preparation for Part 108 operations [4]. The DST, formerly the Unmanned Aircraft Safety Team (UAST), is an FAA-sponsored, industry-government partnership focused on advancing safety performance within the national UAS community. Modeled after the Commercial Aviation Safety Team (CAST), the DST collaborates across industry, academia, and government to identify hazards, analyze operational data, and promote the voluntary adoption of safety management principles.

The complete checklist can be found in Appendix 5.1. Each element was reviewed against the documentation and practices described in the program.

This checklist serves as both a gap analysis and a tool for prioritizing improvements. Categories marked as fully compliant ('Y') reflect areas where the SMS is consistent with industry expectations. Items requiring refinement or development ('N') highlight opportunities to strengthen clarity, consistency, and safety promotion. Together, these results provide a roadmap for enhancing Caltrans' UAS SMS so it can support both current operations and future expansion into advanced UAS applications, including Part 108.

Figure 2.1 shows the percentage of completion in each of the eleven specific areas:

1. **Policy Structure and Clarity:** Assesses the overall organization, readability, and accessibility of the policy documentation. Questions address whether sections are clearly structured, definitions are current, and technical terminology is used consistently to ensure that personnel at all levels can interpret and apply the policy accurately.

2. **Leadership Commitment and Safety Culture:** Evaluates leadership's visible commitment to safety and the presence of a positive safety culture. This includes endorsement of safety goals, establishment of a "just culture," and mechanisms for open communication, employee participation, and continuous improvement.

3. **Policy Scope and Applicability:** Reviews whether the policy clearly defines its operational boundaries, including which UAS activities, personnel, and contractors are covered. It also examines how well the document integrates with other Caltrans safety and operational policies.

4. **Compliance with Regulatory and Industry Standards:** Determines alignment with FAA regulations, state requirements, and recognized industry standards. This section also examines whether procedures exist for maintaining compliance through periodic reviews and regulatory reporting.

5. **Risk Management Framework:** Evaluates the mechanisms for hazard identification, risk assessment, and mitigation planning. The questions focus on whether risk management is systematic, documented, and used proactively to inform operational decision-making.

6. **Roles and Responsibilities:** Examines whether all key roles-such as UAS operators, safety officers, supervisors, and managers, are clearly defined, with corresponding responsibilities and lines of accountability. It also checks for redundancy and delegation in safety-critical roles.

7. **Safety Promotion and Training:** Reviews communication and training programs that support safety awareness and competency. Questions address whether safety briefings, lessons learned, and recurrent training are maintained and updated to reflect evolving technology and regulation.

8. **Emergency Preparedness and Response:** Focuses on the adequacy of emergency planning, including defined procedures for different incident scenarios, notification protocols, and recovery and debriefing processes. It emphasizes readiness, clarity of responsibilities, and communication under pressure.

9. **Incident Reporting and Investigation:** Evaluates the effectiveness of processes for reporting, investigating, and learning from incidents and near-misses. Questions cover root-cause analysis, documentation, follow-up actions, and the presence of anonymous reporting options.

10. **Continuous Improvement and Performance Monitoring:** Reviews the existence of metrics, audits, and feedback loops to track performance and drive improvements. This section assesses how effectively safety data and audit results are used to refine policies and reduce recurring risks.

11. **Integration of New Technologies and Innovations:** Analyzes how well the policy anticipates and accommodates emerging technologies such as BVLOS, AI-enabled systems, and automated docking or tethered platforms. It also includes cybersecurity safeguards and procedures for safely phasing out obsolete systems.

Some key items from the review:

- **Documentation of leadership:** The program's foundational structure is under-specified. The program hierarchy and delegation of authority are not documented at the level that would make decision paths obvious, and the intended steering committee and working groups are referenced but not established or scoped. Standards that would express "what safety looks like here," the workflows that convert those standards into daily practice, and the criteria for evaluating novel technology are not yet articulated.

- **Risk-management gaps:** The pathway from identifying hazards to closing the loop on outcomes is fragmented. Off-nominal or unusual missions do not have a consistent assessment process. Hazards and controls and their review criteria are not collected in one place. The connection between risk assessments and continuous improvement is weak, so lessons do not reliably feed back into planning or controls except at an individual pilot level.

- **Continuous-improvement gaps:** Safety indicators have not been defined, data that would support reviewable metrics is not aggregated in a structured form, and feedback mechanisms for operators and stakeholders are inconsistent. Narrative information exists, but there is no standard method to turn those narratives into trackable signals, and dissemination of findings back to the field is not clearly described. As a result, leadership lacks a dashboard for safety oversight, and operators lack clear visibility into how information is used to improve the system.

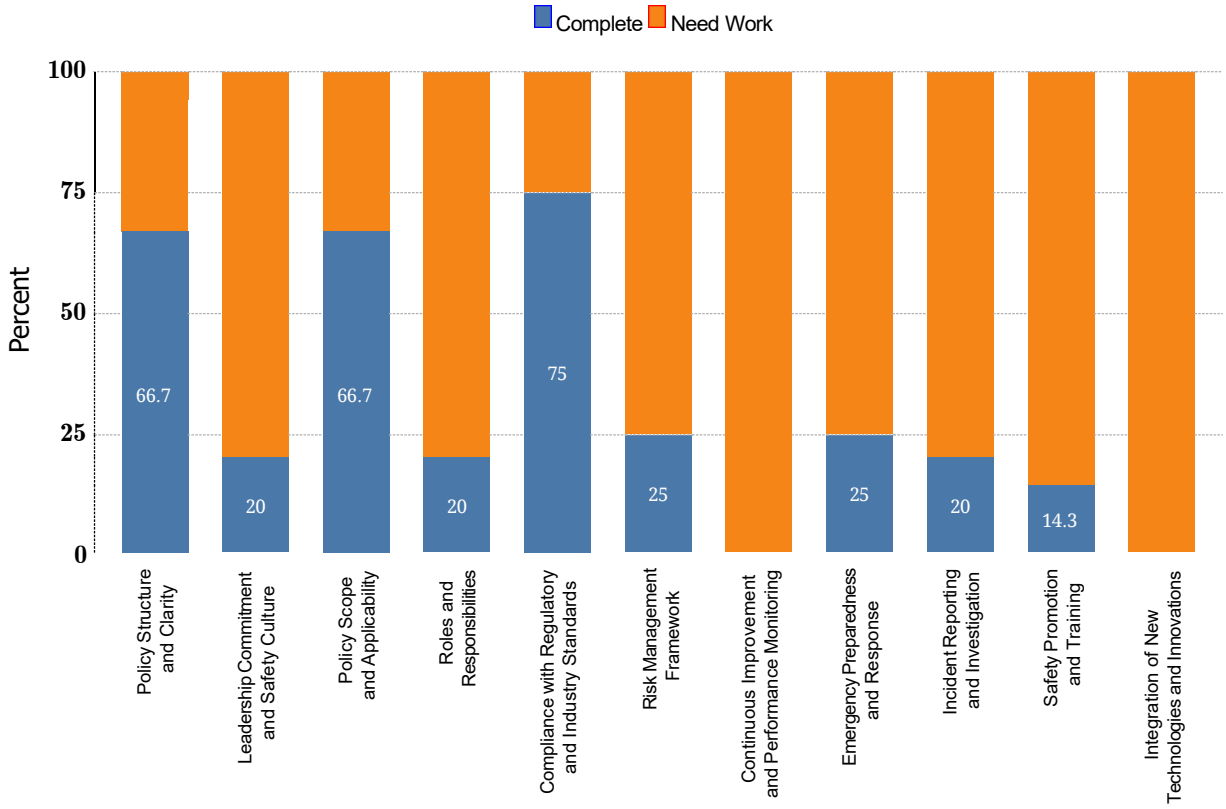


Figure 2.1: SMS Policy Review - completeness of documentation

2.2 Flight Record Review

Flight records are the foundation of a reviewable and adaptable Safety Management System (SMS). They should consistently capture three categories of information: accountability, safety, and trend analysis (Figure 2.2). Accountability establishes traceability of who, what, when, and where. Safety captures events requiring review, including near-misses, incidents, and accidents. Trend analysis identifies operational patterns such as hazards, mission types, and usage rates. Collectively, these categories sustain an "evergreen" SMS that remains current as operations evolve.

The earlier checklist identified fragmentation in how hazards and outcomes are connected. Flight records can close this gap if accountability and safety data are structured so that each outcome links directly to the associated hazard and corrective action. Structured entry fields such as validated IDs, pull-down select lists, and checkboxes, would reduce ambiguity and enable aggregation for analysis. Program-level indicators remain undefined, and existing data are scattered across forms. Aligning record fields with performance indicators would transform these entries into measurable signals for leadership oversight and operator feedback. In this way, the flight-record framework becomes both the foundation for compliance and the mechanism for continuous improvement.

Table 2.1 summarizes how current data fields map to the three information categories (accountability, safety, and trends) and where usability or flow adjustments are needed. Improved question order and clearer stage separation between planning, on-site verification, and post-flight reporting would increase accuracy and reduce cognitive load. Strengthened post-flight sections, capturing deviations, near-misses, wildlife encounters, and corrective actions, would close the feedback loop and sustain an evidence-driven SMS.

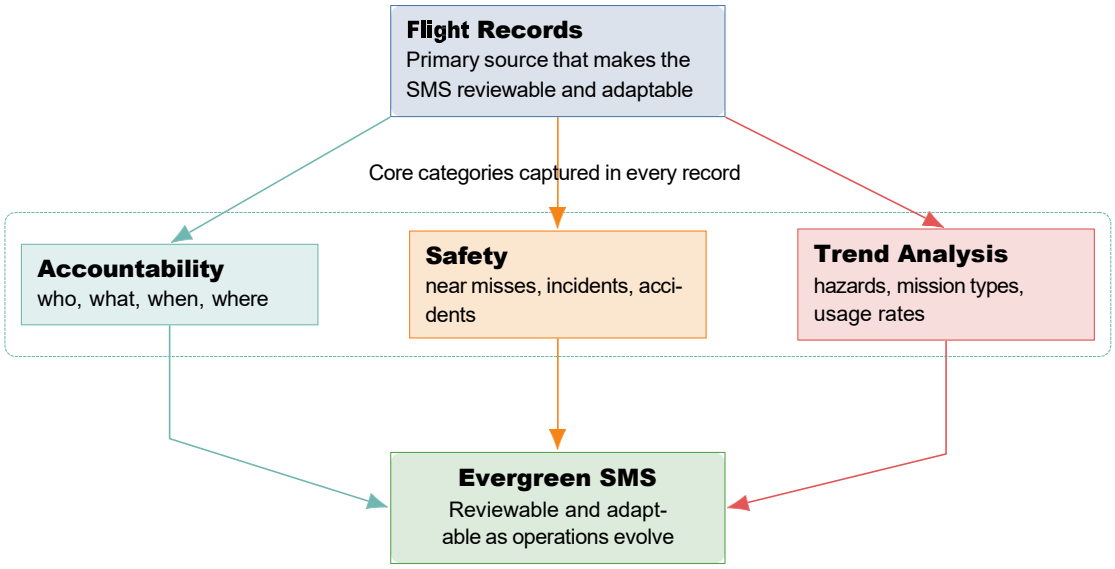


Figure 2.2: Flight records feed three categories of information that together sustain an evergreen Safety Management System: accountability, safety, and trend analysis.

Table 2.1: Flight Record Review by SMS Information Bucket

Data Collection	Form	Role	Needs	Recommendation / Justification
Mission Name / OPS-ID#	Pre-Flight	Accountability	UI Improvement	Inconsistent data entry
Pilot	Pre-Flight	Accountability	-	-
Flight Crew	Pre-Flight	Accountability	UX Improvement	Missing support for non-standard flight crews
Drone / UAS ID#	Pre-Flight	Accountability	UI Improvement	Consider smart selection options
Date	Pre-Flight	Accountability	-	
Route (Post Mile or GPS)	Pre-Flight	Accountability	UX Improvement	Allow GPS/address option for usability
Purpose	Pre-Flight	Trends	-	
Time of Day	Pre-Flight	Trends	UI Improvement	Inconsistent data entry
Flight Duration	Pre-Flight	Trends	UX Flow Adjustment	Move to post-flight for accuracy
Interval / Frequency	Pre-Flight	Trends	-	Works as-is
Emergency Request	Pre-Flight	Trends	-	Works as-is
Airspace / LAANC	Hazard	Trends	Flow Adjustment	See Hazard Form
Hazards	Hazard	Trends	UX + Flow Adjustment	See Hazard Form
Mission Profile (plan)	Hazard	Safety	UX + Flow Adjustment	Missing insight into mission planning
Accident / Incidents	Incident	Safety	Flow Adjustment	Needs a lower barrier
Post-Flight Notes / Near-Misses	Post-Flight	Safety	Flow Adjustment	Clarify form, reduce barriers

Many fields are currently collected but in formats that makes analytic value difficult. Free-text narratives, raw ID strings, and open entries introduce inconsistency and prevent reliable metatagging or coding. Converting these

items to structured inputs-controlled pull-down options, checkboxes for multi-select, validated ID lookups, and brief rationale fields with fixed options-would enable consistent entry, reduce ambiguity, and support downstream analysis. These are primarily UI improvements that unlock measurement and quality control without altering policy intent.

One of the challenges in improving the use of flight records is the manner at which flight records are collected. Flight records are collected during three phases:

1. **UAS Operations Plan Pre-Flight Form:** Initial entry upon pilot deciding to initiate a flight mission
2. **Hazard Analysis Form:** Conducted prior to flight operations; manually connected via OPS-ID string.
3. **UAS Flight Log Post-Flight:** A follow-up to the Flight Record with some notes. Accidents and incidents are collected on a separate form.

As a result, question flow is also misaligned with operational timing (See Section 2.3). Several prompts are asked at the wrong stage or in an order that increases cognitive load and produces stale responses. Planning items are better located in a planning form completed in the office, with a separate document functioning as a day-of verification checklist at the site. For example, airspace checks fit the planning phase, with the hazard checklist reconfirming late changes such as TFRs or site alterations. Clearer form names, light conditional logic, and an order that moves from high-level context to tactical checks would improve accuracy and auditability.

Post-flight data capture is limited, which obscures events that should inform training and mitigation. A Post-Flight section should record outcomes, deviations, near-misses, wildlife interference, equipment anomalies, and corrective actions, using a simple taxonomy with category and severity. Without these data, trends and training priorities cannot be reliably established. Strengthening post-flight reporting would close the feedback loop and support an evidence-driven, continually improving SMS.

2.3 Safety Risk Management Workflow

The published flight operations workflow provides a structured sequence from pre-flight certification data through hazard analysis and operational logging. The review of the operations data indicated that the flow of data collection could be refined to improve data collection, necessitating a closer review of the process. While the individual steps are documented, the process becomes hindered at points of ambiguity that create inconsistent expectations across teams (Figure 2.3).

The first two steps of the flow includes an expectation of documentation submission, not necessarily a time-constraint and could reasonably be expected to be done at the office. However, the submission of the UAS Operation Plan Pre-Flight is expected only 'prior to the start of the UAS Operation' and introduces two key ambiguities: (i) Does 'prior' mean 5 minutes or 5 days before a UAS operation?; and (ii) What constitutes the 'start'? The departure from the office, or the launch of the UAS.

At the "Deployment" step, it is unclear whether the requirement refers to traveling to the site or to the act of launching the aircraft. This uncertainty can delay the analysis of the site and generate inconsistent practices in the field, especially for airspace information that can be difficult to analyze on a mobile device. Items that are 'difficult' to analyze are usually the first to be discarded in practice.

A second ambiguity arises in the hazard analysis step. The workflow shows this requirement, but the expectation for when and where it is completed is unclear. Operators may interpret this as an on-site activity performed immediately prior to flight, while others may fold it into pre-planning. As seen in Subsection 2.3.2, this form has a low submission rate and a low rate of correct entry.

The lack of clarity creates the risk of either overlooking the step or duplicating effort. Addressing these ambiguities would strengthen alignment between planning, field execution, and safety assurance.

2.3.1 Form Naming Convention

The naming convention utilized is additionally a source of ambiguity. The handbook calls it 'UAS Operations Plan Pre-Flight,' whereas their web portal calls it 'Caltrans UAS Program Pre-Flight Data.' Though the FAA has

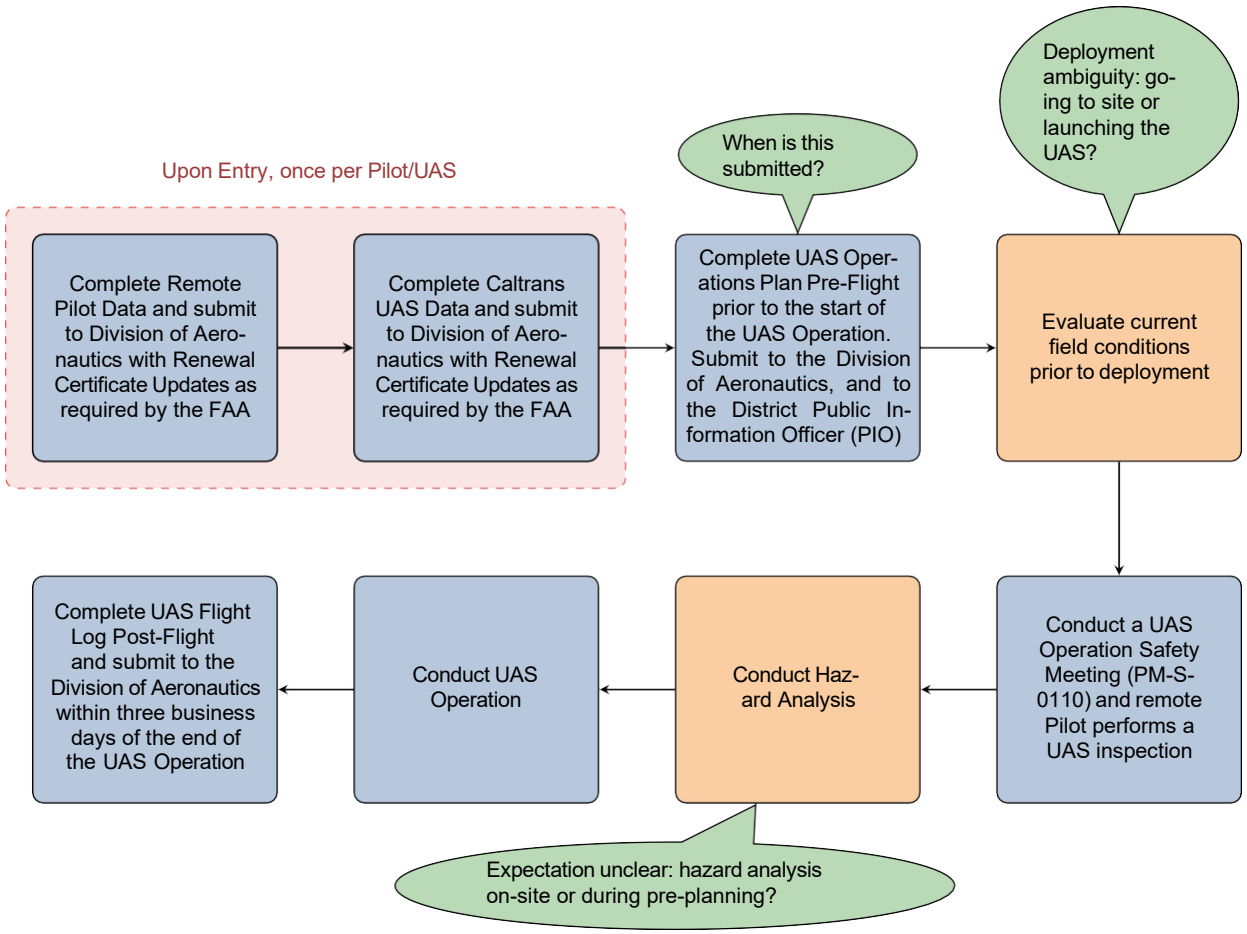


Figure 2.3: Caltrans UAS Flight Operations Flow Chart

no strict nomenclature for the process for initiating a flight, in industry, other groups refer to the first step as mission planning and the second step as a Pre-Flight Checklist.

Table 2.2: Recommended terminology mapping for FAA-aligned UAS documentation

Purpose	Term that aligns with FAA language and common practice	Why
Office or desk-based planning done hours to days before flying. Covers airspace, weather, site hazards, people, permissions, mitigations, briefings.	**Mission Planning & Risk Assessment** *(or Preflight Assessment of the Operating Environment per §107.49(a))*	Matches the "assessment of the operating environment" language in §107.49 and the planning focus in AC 107-2A [7], mirrors WSDOT [13], and TxDOT [14] usage.
At-aircraft checks immediately before launch. Covers control links, power, attachments, aircraft condition, calibrations, go/no-go.	**Preflight Inspection Checklist**	Matches the inspection and actions items in §107.49(c)-(e) and FAA plain-language guidance that a preflight inspection is required [3].

2.3.2 Connecting Pre-Flight with Hazard Analysis

Compliance rates for the submission of the hazard analysis form (UAS-0054) are very low. As of Feb 18, 2025, there were only 678 entries for 7458 reportable entries for a 9.1% compliance rate. Part of this can be attributed to the barrier of submission. The first entry in the Hazard Analysis form requires the user to manually enter the right OPS code. The entry is currently a string, but is intended to match a string in the format of "OPS-#####". Even of the 678 entries, not all of them are immediately useful for metrics as less that 63% were completed correctly (Table 2.3).

Table 2.3: Sample Table with Items and Grand Total

ID Format	Count
OPS-####	426
#### only	225
Incorrect Format or Typo	27
Grand Total	**678**

2.4 Hazard Analysis Form

2.4.1 Analysis of Existing Form

The hazard form currently contains 22 questions (Table 2.5). An analysis of responses shows that 17 of these questions are answered the same way more than 95% of the time (Table 2.4). In some cases, the similarity reaches 100%. This indicates that the process has a low information return on the time invested by operators. When the overwhelming majority of responses are uniform, the form does not meaningfully discriminate between different operational risk conditions, yet still requires pilots to spend time on repetitive entries. As a result, in its present form, this does not provide meaningful information for safety assurance processes. While there is value in this as a checklist for operators, it doesn't necessitate submission on a per-question basis.

Table 2.4: Percentage of uniform responses for each hazard analysis question in the UAS SMS survey. Shaded boxs indicates less than 95% agreement.

Q#	%	Q#	%	Q#	%	Q#	%	Q#	%	Q#	%
Q1	99.0%	Q2	92.3%	Q3	98.8%	Q4	87.9%	Q5	68.4%	Q6	98.8%
Q7	98.2%	Q8	95.7%	Q9	98.4%	Q10	100.0%	Q11	99.6%	Q12	97.3%
Q13	99.6%	Q14	100.0%	Q15	97.6%	Q16	94.7%	Q17	58.4%	Q18	97.5%
Q19	96.8%	Q20	99.7%	Q21	97.8%	Q22	41.6%				

Several questions show significant overlap, which slows completion without adding additional safety insight. For example, Q1 (Airspace type identified, Airmap Application checked) and Q12 (Temporary Flight Restrictions checked) both address airspace restrictions. Merging these into a single, comprehensive question such as: *"Have airspace restrictions, including Temporary Flight Restrictions (TFR), been identified and checked using available tools?"* would preserve safety intent while improving efficiency. Similarly, Q15 (Nearby roadways, bridges, and properties identified) and Q7 (Obstructions identified) address the same operational hazard space. A merged version such as: *"Have all potential obstructions, including roadways, bridges, and surrounding properties, been identified?"* reduces redundancy while clarifying scope.

The form suffers from attempting to serve two different roles simultaneously: advance planning and on-site checks. Some questions (e.g., airspace review, weather forecasts, crew permissions) can and should be answered prior to deployment, while others (e.g., emergency abort site, presence of pedestrians, inspection of equipment condition) are inherently on-site verifications. Mixing these two categories within a single sequence makes the form

less intuitive, creates uneven workload distribution, and increases the chance of partial or incomplete responses. Greater clarity in phasing would help align each question to the most logical point in the workflow.

Addressing redundancy and clarifying phases would improve both the efficiency and the usefulness of the hazard form. By reducing repetitive questions, aligning each prompt with its proper stage, and ensuring that the remaining questions capture meaningful variation in responses, the form could provide better data to support safety assurance. This in turn strengthens the ability to identify real hazards, aggregate actionable metrics, and integrate lessons learned into continuous improvement processes.

Table 2.5: UAS Operations Hazard Analysis Checklist annotated with Phase of evaluation

Question	Phase	Question	Phase
Have the following been completed: Airspace type identified? Airmap Application checked?	**MP**	Has the presence of civil aviation activities nearby, including small landing strips, heliports, or potential crop dusting activities in agricultural areas been evaluated?	**MP**
Is there three statute miles visibility?	**OS**	Have State right-of-way boundaries been identified?	**MP**
Has right-of-way permission been secured?	**MP**	Is the UAS Flight Crew adequately protected from roadway traffic or other hazards?	**OS**
Have obstructions been identified?	**MP**	Is cell phone service available? If no, will radio communication be in use?	**MP**
Is a first-aid kit and fire extinguisher on-site and within immediate access?	**OS**	Is the operation adequately staffed to maintain a safe working environment?	**OS**
Has the UAS Flight Crew been briefed on the operation and are they aware of their duties?	**OS**	Have Temporary Flight Restrictions (TFR) been checked?	**OS**
Have forecasted weather conditions and wind speed been verified?	**OS**	Is there a suitable takeoff and landing zone?	**MP**
Have nearby roadways, bridges, and properties been identified?	**MP**	Is the flight area free from pedestrians, bicyclists, or moving vehicles?	**OS**
Will there be a roadway closure in effect?	**MP**	Is there a site for emergency abort?	**MP**
Is Personal Protective Equipment in use?	**OS**	Has the UAS and associated equipment been checked and are they in safe operating condition?	**OS**
Is the UAS Flight Crew situated away from the projected flight path of the UAS?	**MP**	Do you have a map of the UAS Operations Area showing the flight path?	**MP**

Phase: **MP**= Better Suited for Analysis in Mission Planning (MP) **OS**= Better Suited for Analysis On-Site (OS)

2.4.2 Improving the Flow

The revised approach separates Hazard Analysis into two coordinated components: a **Hazard Analysis Form** that supports comprehensive hazard identification and trend tracking within the Safety Management System, and a

streamlined **Pre-Flight Checklist** optimized for operational readiness and compliance verification. The complete flow can be seen in Figure 2.4. This restructuring improves clarity and reduces redundant inputs. Though there will be additional challenges for streamlining the form submission, once the data is available, it'll enable more consistent integration with Smartsheet for digital recordkeeping and safety performance monitoring. The summary of revisions can be found in Table 2.6 and recommendations can be found in the Appendix 5.2.

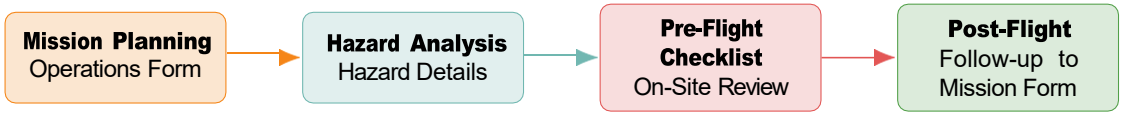


Figure 2.4: Sequential flow of forms and procedures from mission planning through hazard review, pre-flight verification, and flight execution.

Table 2.6: Reorganization of Questions for Flight Mission

Section	Type	Summary of Revision or Change	Notes
Pre-Flight 1	Reworded	Adjusted Question for tracking (e.g., 'Have the following been completed: Airspace type identified? Airmap Application checked?" → "Airspace Class").	Monitors the common airspace class used
Pre-Flight 1	Expanded Options	Added Airspace Authorization sub-selection (LAANC, COA, Not Needed).	Tracks the frequency of LAANC or COA operations
Pre-Flight 1	Combined	Replaced "Other Aviation Activities Nearby" Yes/No with detailed multi-select options.	Better tracking of common airspace hazards
Pre-Flight 1	Expanded Weather Detail	Added "Moderate Winds," "Reduced Visibility," and "Other" fields; renamed to "Weather Forecast."	Only certain weather hazards are impactful and should be tracked.
Pre-Flight 1	Added Guidance	Inserted text prompting operator to consider what they would tell a new pilot at the site.	Recommend adding a personal touch as guidance.
Pre-Flight 1	Consolidated	Combined several operational items (distance, autonomy, people nearby) into one question.	These are more impactful hazards to track frequency.
Pre-Flight 1	Moved Question	Relocated "Map of Operations Area" to end of pre-flight section.	
Checklist	Reworded	Simplified yes/no phrasing for clarity (e.g., "Is visibility ≥ 3 SM?").	Adjust to improve 'checklist' functionality.
Checklist	Added Items	Added checks for permits, PPE, staffing adequacy, communications, and emergency site.	
Post-Flight	Expanded Section	Replaced "Any changes to post-flight?" with specific prompts for anomalies and feedback.	Help with near-miss documentation.

2.5 Caltrans UAS Program Participant Feedback

This section summarizes findings from the survey of Caltrans UAS operators and in-person discussions conducted as part of the gap analysis. The purpose of this activity was to identify strengths, challenges, and opportunities within current UAS practices, with a particular focus on documentation, workflows, safety management, and support systems.

2.5.1 Survey of Caltrans UAS Program

A survey was shared across the current UAS program within Caltrans (Questions can be found in Appendix 5.3). Respondents provided both structured and open-ended feedback, offering insight into the effectiveness of planning forms, the practical realities of paperwork submission, perceived barriers to safe and efficient operations, and the availability of support and communication networks. While many operators balance UAS duties with other

responsibilities, the survey results capture a diverse range of experiences that highlight both the resilience of the program and areas where refinements could enhance safety, efficiency, and user satisfaction.

Caltrans UAS Program Respondents

The survey was distributed to Caltrans employees engaged in UAS operations across districts and divisions. A total of 65 respondents participated, representing a diverse mix of experience levels, operational frequency, and job responsibilities. Because UAS duties are not the primary role for most staff, the respondent pool reflects a cross-section of engineers, surveyors, construction staff, and other specialists who incorporate UAS operations into their broader work. This diversity provides valuable insight into how the program's tools and processes function across different operational contexts.

Table 2.7: Respondents: Experience × PIC frequency

Experience	< 1/mo	1/mo	2–3/mo	1/wk	2–3/wk
Less than 1 year	5	1	2	1	1
1–2 years	9	6	3	3	0
2–3 years	5	8	4	0	0
3–5 years	7	2	3	1	0
More than 6 years	1	3	2	0	0

The respondent profile highlights both the breadth and depth of UAS experience within Caltrans as seen in Table 2.7. While a portion of pilots reported fewer than one or two years of experience, others indicated sustained involvement spanning three to six years, demonstrating that the program has matured into a stable capability across the state. Flight frequency also varied widely, from operators flying less than once a month to a small group conducting missions multiple times per week.

Drone use within Caltrans is generally infrequent, often occurring only once per month, which limits opportunities to develop or maintain deep proficiency . Because no member's primary role is that of a drone pilot, operations are carried out as needed rather than as a regular practice. Consequently, forms and processes must be designed to support safe and competent performance without assuming expert-level familiarity or reliance on memory.

The diversity of experience and flight frequency among respondents provides important context for evaluating the usefulness of current tools. Operators who fly less often may view forms as a helpful guide, while those with more frequent or advanced missions may perceive them differently. With this variation in mind, the survey next examined how respondents rated the effectiveness of the existing Caltrans UAS documentation and processes.

Perceived Effectiveness of Existing System

The survey next asked operators to evaluate the effectiveness of the existing Caltrans UAS forms and processes. This set of questions was designed to capture how well current tools support safe and efficient operations, whether they provide meaningful value during planning and execution, and how perceptions differ by pilot experience or frequency of flight. Understanding these views is critical for identifying which aspects of the system reinforce safe practices and which may hinder performance or add unnecessary burden.

The Pre-Flight Data and Hazard Analysis workflow was rated positively overall, with 28 respondents (43%) describing it as very effective and another 7 (11%) as extremely effective. A smaller group found it only moderately effective (19 respondents, 29%), while 8 (12%) rated it slightly effective and 3 (5%) said it was not effective at all. These results suggest that while a majority of end-users view the form as a helpful tool, there remains room to improve clarity and usability for those who found limited value.

Overall, 54% of respondents (35 of 65) rated the hazard analysis form as very or extremely effective, with a mean score of 3.43 out of 5. Table 2.8 shows the breakdown by pilot experience and frequency of use. By experience, newer pilots were the most positive: 90% of those with less than one year of flying rated the form highly, compared to only 31% among those with 3-5 years of experience. However, sample sizes at the extremes are small (Table 2.8a). By PIC frequency, less frequent operators expressed greater confidence in the form, with

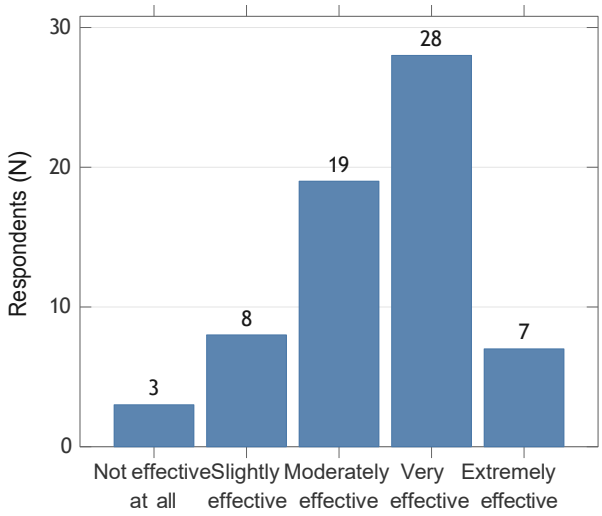


Figure 2.5: Respondents' overall rating of UAS planning forms ($N = 65$).

(a) Effectiveness by Experience

Experience	N	% Very/Ext
Less than 1 year	10	90
1–2 years	20	55
2–3 years	17	47
3–5 years	13	31
More than 6 years	5	60

(b) Effectiveness by PIC frequency

PIC frequency	N	% Very/Ext
Less than once a month	26	65
Once a month	19	47
2–3 a month	14	43
Once a week	5	40
2–3 times a week	1	100

Table 2.8: Respondents' ratings of effectiveness by experience and by PIC frequency.

65% of those flying less than once a month rating it highly, compared to 47% of those flying once a month and 43% of those flying 2-3 times a month (Table 2.8b).

These findings suggest that the hazard analysis form provides greater perceived value to newer and less frequent pilots, likely because it offers structure and reassurance during planning. In contrast, more experienced or frequent operators appear to find the form less effective, perhaps reflecting limitations in its ability to address the complexities they encounter. This divergence highlights the need to adapt the form so it remains useful across levels of experience and operational rate.

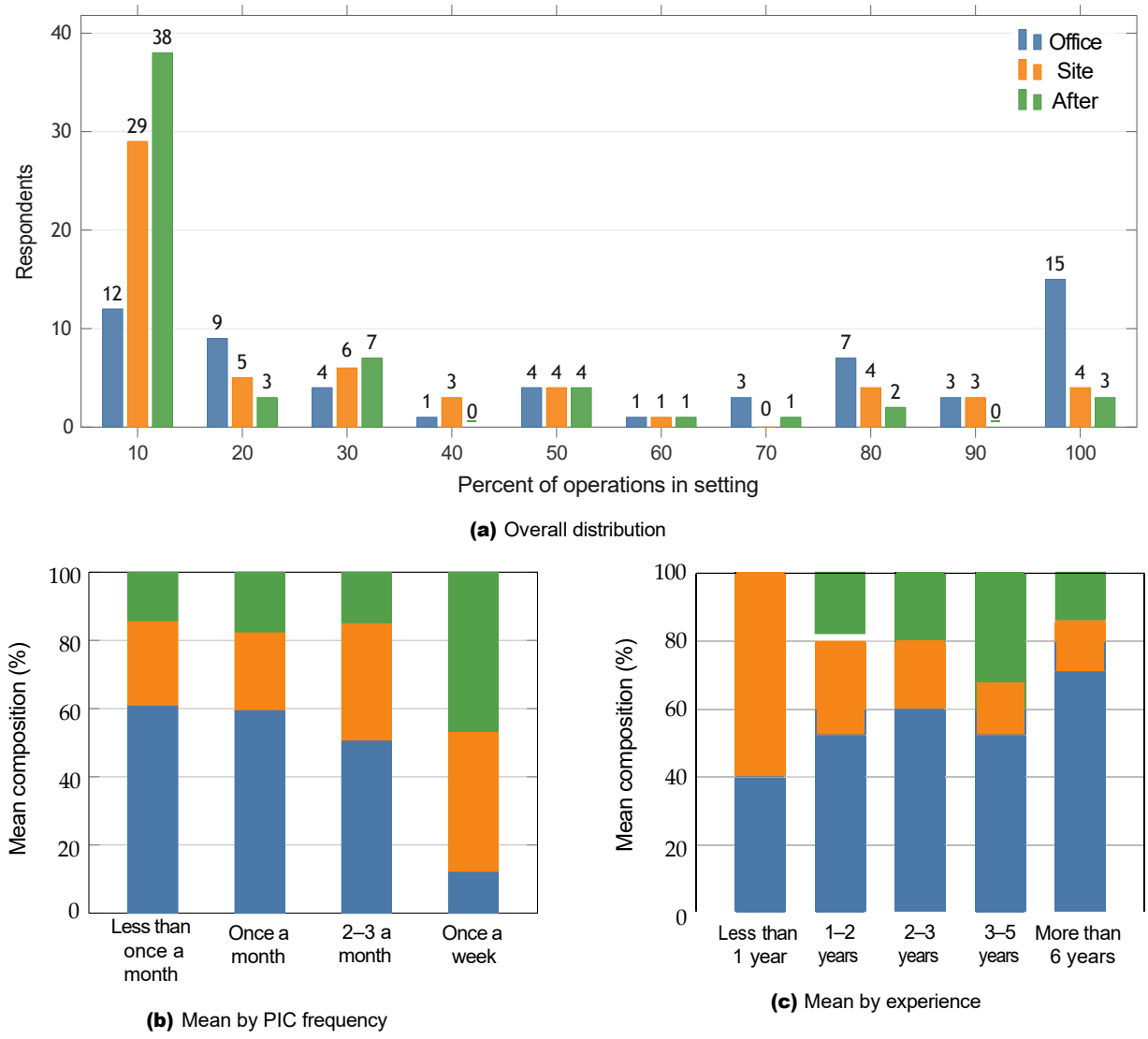
Location of Paperwork Submission

Where pilots fill out the flight request and hazard analysis form is generally consistent across the board. On average, users fill out the form at the office 53.8% of the time, on-site 27.8% of the time, and after the flight 18.4% of the time. This indicates a strong preference for completing paperwork at the office and for preplanning flight operations.

These numbers hold across frequency of use and with experience, with two notable exceptions. Operators that conduct flight operations frequently (more than once per week) are more likely to complete paperwork on-site or after the flight, and pilots with less than one year of experience complete paperwork in the office less frequently than those with more experience.

The overall distribution in Figure 2.6a shows that the majority of pilots complete at least 90% of their paperwork in a single setting, most often in the office. This concentration suggests established routines and organizational norms that favor office-based preparation. However, a smaller subset of respondents reported splitting paperwork across multiple settings, pointing to flexibility or situational constraints that influence their workflow.

Breaking down the results by frequency of use (Figure 2.6b), a clear shift appears among more active pilots. Those flying once a week reported significantly less reliance on office-based submission, with a greater share of their paperwork occurring on-site or after operations. This trend implies that increased operational tempo reduces



(a) Overall distribution

(b) Mean by PIC frequency

(c) Mean by experience

Figure 2.6: Location of paperwork submission across settings. (a) Overall distribution of percent of operations where paperwork was completed in each setting. (b) Breakdown of mean composition by PIC frequency. (c) Breakdown of mean composition by pilot experience.

the practicality of completing all paperwork in advance and instead pushes some recordkeeping into the field or post-flight stages.

Experience level also plays a role in shaping submission practices (Figure 2.6c). While pilots with one to two years of experience align closely with the overall averages, the least experienced group shows lower reliance on the office. This may reflect a steeper learning curve or less familiarity with established administrative practices, while the most experienced pilots return to heavier office use, possibly due to stronger adherence to organizational procedures. Together, these patterns highlight that while preplanning in the office is the norm, both operational frequency and pilot experience can alter where and when paperwork is completed.

Form Inconsistencies

To better understand how often paperwork procedures align with operational realities, respondents were asked: "How often do you encounter inconsistencies or gaps between standard operating procedures and real-world mission conditions?" However, the results were fairly inconclusive.

The survey results show that most respondents reported encountering inconsistencies only occasionally, with 42 out of 63 indicating "sometimes" and another 15 selecting "never." Very few reported that inconsistencies occurred "about half the time" (4), "most of the time" (1), or "always" (1). This aligns with earlier feedback in which many pilots described the paperwork process as repetitive but not fundamentally flawed, suggesting that while inefficiencies exist, major breakdowns are relatively rare. Combined with the finding that most paperwork is completed in the office before operations, these results imply that users generally maintain a structured workflow, though some inconsistencies may stem from the burden of switching contexts between office-based preplanning and field adjustments.

The subsequent question asking for specific examples as open-feedback provided no meaningful responses.

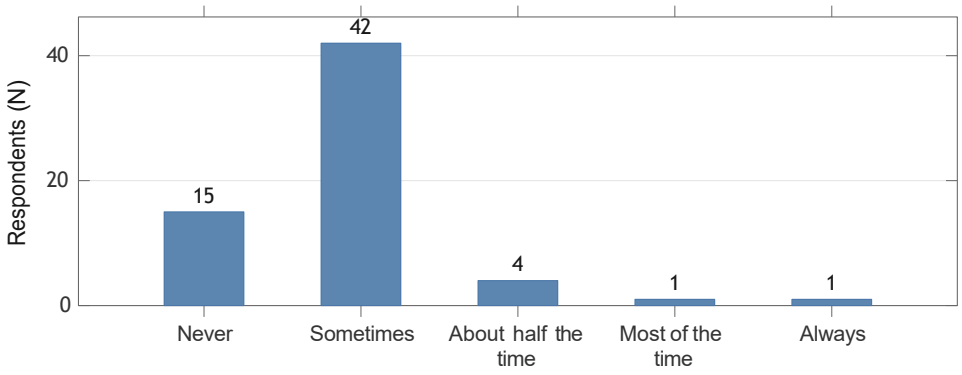


Figure 2.7: How often respondents reported encountering inconsistencies in the forms ($N = 63$).

Freeform Response - Recommendations for improving forms

However, open-ended feedback on the flight request and hazard analysis forms overall revealed a wide range of perspectives. Complete survey results can be found in Appendix 5.4.1. Some comments suggested that the current system is not perceived as a major barrier, with one pilot noting, "I don't believe changing the process will make a significant difference in improving the process." Others expressed skepticism about the value of the paperwork itself, with a more critical response stating, "Get rid of it? A 13-year-old can literally do this. The paperwork just... isn't necessary if there's no incident." These remarks highlight that while dissatisfaction is present, not all participants see structural changes as either necessary or impactful. However, three major themes were apparent.

A recurring theme was the desire to simplify and streamline the process. Several respondents argued for merging or consolidating forms to reduce redundancy: "combined pre flight forms into one," "There should be one pre-flight form and one post-flight form to fill out for a mission," and "Consolidate the UAS Operation Plan form and the Hazard Analysis form." Others called for different presentation formats to speed up completion, such as "maybe a check list options instead of text boxes required typing" and "more simple forms. more icons photos instead of text." Collectively, these comments reflect frustration with repetitive or text-heavy inputs and a preference for a more efficient workflow.

A second major theme involved integration with tools and platforms that pilots already find useful. Respondents referenced Aloft as a model, observing, "The aloft platform was more beneficial as a pilot. Having airspace classification and LAANC all in one place was convenient." Another pilot noted, "Prefer to do preflight data, mission planning, and LAANC check/clearance all in one spot/software." Similarly, others suggested that Caltrans could support specific platforms or provide links to authoritative resources: "If the UAS program could endorse specific flight planning apps and set up a very short checklist of pre-flight tasks, it would be even more helpful," and "It would be helpful to be able to have links to see the airspace or just a little usable platform." These comments show interest in reducing the need for multiple disconnected systems.

Finally, several respondents highlighted the value of training and tailored support. One noted that "Each district has some unique challenges. I believe some district by district customization of the forms could be helpful." Others emphasized the importance of reminders and instructional aids, suggesting, "Quarterly reminder of pre-flight procedures and FAA safety compliance" and "It would be helpful to new pilots and pilots who do not fly often to have a training bite/slideshow provided that outlines the helpful websites to determine airspace and

weather conditions." A related theme was the call for more hands-on practice, with one pilot remarking, "I wish the process was faster and there was more training stick time." Together, these responses suggest that improving the forms alone may not be sufficient; additional training and contextual support could enhance both compliance and pilot confidence.

Barriers

In addition to evaluating the usefulness of forms and support structures, the survey asked respondents to reflect on the challenges they face when conducting UAS operations for Caltrans. This portion of the survey was designed to capture both systemic and practical obstacles that may hinder safe or effective operations, ranging from resource limitations to organizational issues. Because respondents could select more than one option, the results highlight the relative prevalence of different barriers across the operator community.

Understanding barriers is critical for identifying where improvements can have the greatest impact. While some operators reported no significant obstacles, others pointed to gaps in resources, training, or organizational clarity. The following results break down responses by both years of experience and frequency of flight, illustrating how challenges shift depending on the pilot's background and operational tempo. This context provides valuable insight into which areas may require quick adjustments and which may call for broader, systemic changes.

Table 2.9: Barriers to operating safely/effectively - by experience and PIC frequency (% of subgroup, counts in parentheses)

	Experience		PIC frequency	
Barrier	0–2 yrs (n=31)	2–6 yrs (n=35)	≤1/mo (n=46)	2–3+/mo (n=20)
I feel well supported, no major barriers	35% (11)	**54% (19)**	**50% (23)**	35% (7)
Limited access to tools, equipment, resources	29% (9)	37% (13)	26% (12)	**50% (10)**
Lack of time or competing priorities	29% (9)	31% (11)	33% (15)	25% (5)
Not enough training / development	23% (7)	26% (9)	26% (12)	20% (4)
Unclear / conflicting expectations	6% (2)	11% (4)	7% (3)	15% (3)
Too much administrative burden	10% (3)	9% (3)	11% (5)	5% (1)
Difficulty getting support outside team	10% (3)	9% (3)	7% (3)	15% (3)
Other (please specify)	**13% (4)**	3% (1)	7% (3)	10% (2)

Note: Respondents could select multiple barriers; percentages are within each subgroup.

The data indicate that perceptions of barriers vary meaningfully by both experience and PIC frequency (Table 2.9). Among pilots with 2-6 years of experience, more than half (54%) reported feeling well supported with no major barriers, compared to only 35% of those with 0-2 years. A similar pattern emerged by frequency, where half of the less frequent operators (≤1/month) felt well supported versus just 35% of more frequent pilots. This suggests that time in the program and lower operational tempo may both buffer perceptions of difficulty, while newer or more active pilots are more likely to encounter obstacles.

Limited access to tools, equipment, and resources was one of the most commonly cited barriers overall, but it was particularly pronounced for frequent operators. Fully 50% of those flying two to three times per month or more identified resource limitations, compared to 26% of less frequent pilots. This gap implies that as operational demand increases, pilots become more acutely aware of the limits of available infrastructure and support. The fact that both early-career and mid-career respondents cited this barrier at comparable levels (29% vs. 37%) indicates that resource concerns cut across experience levels.

Training and competing priorities were cited at moderate levels across all groups, with around a quarter to a third of respondents identifying these issues regardless of experience or frequency. This consistency suggests that the need for continued development opportunities and the challenge of balancing UAS responsibilities with other duties are persistent features of the program. While not as dominant as resource limitations, these factors remain important contributors to perceived barriers.

Some responses point to less common but still notable concerns. Unclear or conflicting expectations were mentioned more often by mid-career pilots (11%) and more frequent operators (15%), suggesting that greater exposure to different missions may increase the likelihood of encountering inconsistent guidance. Interestingly, newer pilots were more likely to select "Other" barriers (13% compared to 3%), hinting at unique early-stage challenges that may not have been fully captured in the predefined categories. Taken together, the results

highlight a dual pattern: while many pilots feel adequately supported, those with higher activity levels or limited experience are more likely to report structural and logistical barriers.

Support

To assess perceptions of safety promotion and communication, respondents were asked: "Do you feel that you have a good support team for questions or support about UAS operations or technology?" The options ranged from having access to knowledgeable people or resources, to relying on external guidance, to uncertainty about where to go, or not yet needing support.

Most respondents indicated that they feel well supported, with 47 out of 64 reporting that they have access to knowledgeable people or resources (Figure 2.8). Smaller groups noted that they rely more on external resources (10) or that help did not meet their needs (4), while only three said they had not yet needed support. These results suggest that, despite frustrations with paperwork and administrative burdens expressed elsewhere, pilots generally perceive that the necessary expertise and guidance are available when needed.

This suggests that the program's strengths lie in its people and knowledge base rather than in its paperwork tools. Efforts to streamline forms, integrate planning platforms, and provide tailored training, issues raised repeatedly in the feedback, would complement this existing support system, ensuring that both new and experienced pilots can operate effectively while feeling confident in the resources available to them.

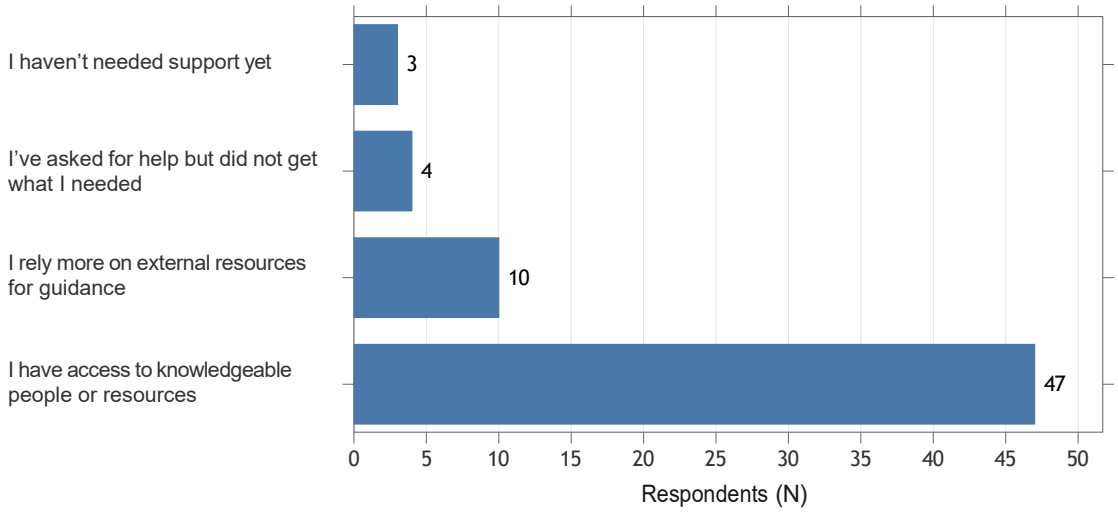


Figure 2.8: Perceptions of support availability and effectiveness.

Peer to Peer Opportunities

To assess interest in peer-to-peer learning, respondents were asked whether it would be valuable for the Caltrans UAS Program to create more opportunities for operators to share lessons learned, updates, or best practices with each other.

A majority expressed strong support: 42 out of 64 respondents indicated "Yes, this would be very helpful" and another 16 selected "Maybe, it depends on how it's set up." (Figure 2.9). Taken together, nearly 90% of participants signaled that improved communication opportunities would be useful, with only a small minority reporting satisfaction with the current network (4) or uncertainty (2).

The results suggest that pilots see clear value in additional communication channels, but that success will depend on thoughtful implementation. Feedback elsewhere in the survey emphasized the importance of user-friendly tools, streamlined processes, and practical training aids, all of which point to the need for a system that is easy to access and adds value to ongoing operations. Expanding peer-to-peer communication could therefore be a high-impact initiative that builds consistency in safety practices while reinforcing the program's culture of support.

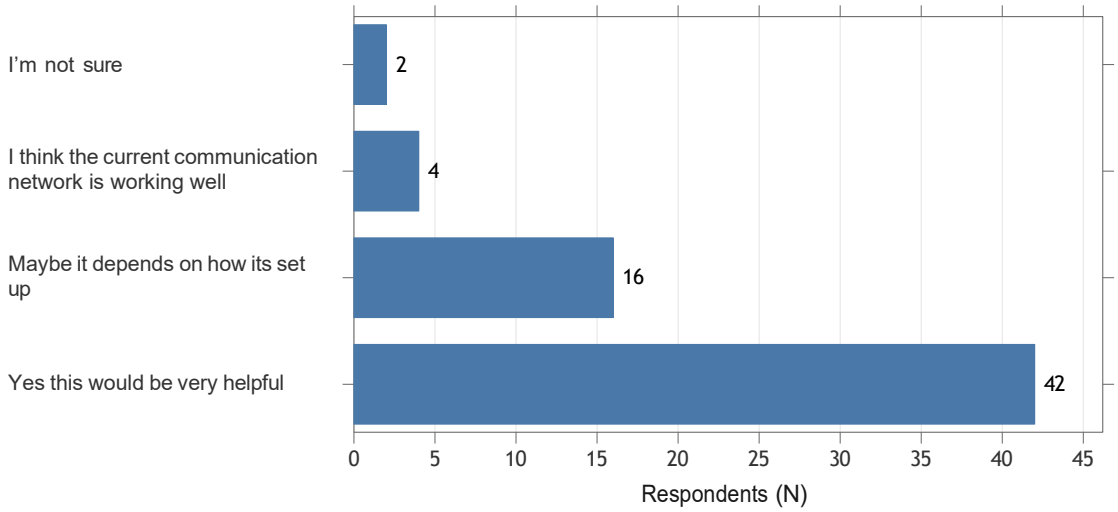


Figure 2.9: Interest in peer to peer learning opportunities.

Open Remarks

Respondents were provided one last opportunity to provide feedback on the Caltrans UAS SMS program. The complete remarks can be found in Appendix 5.4.2. Their closing comments reinforced themes already visible in the structured survey data. While some respondents are broadly content with the program (e.g., *"I am content with the UAS program as of now"*), many still reported friction with tools, training, and resources. Several highlighted frustration with changing or non-intuitive mission planning platforms, login barriers (e.g., *"Can't login to Aloft Air Control with my state email"*), or inconsistent guidance on which software to use (e.g., DroneDeploy vs. Trimble Business Center). Others emphasized the need for more hands-on training, collaboration, and clarity in processes.

2.5.2 Feedback from UAS Program Pilots

Outside of the Caltrans UAS Program Survey, additional conversations were had with program pilots. During these discussions, several themes emerged regarding desired improvements and ongoing challenges within the program. The feedback reflects field experiences and operational needs, highlighting opportunities to refine training, knowledge management, policy support, and communication practices. These notes capture what crews would like to see addressed in order to make the program more effective and sustainable.

Training & Mentorship

Participants expressed a desire for continued development of training materials, with flexibility to address different platforms and operating contexts. Mentorship opportunities and periodic gatherings for instructors were seen as valuable ways to strengthen skills and share lessons learned. Practical refreshers were also requested to ensure continued confidence over time.

- Continue refining a standardized training curriculum with optional modules for platform-specific skills.
- Explore a mentorship program pairing experienced pilots with newer ones to supplement basic training.
- Host an annual in-person summit or retreat for instructors and trainers.
- Develop recertification modules with practical scenario-based refreshers.

Knowledge & Process Management

Participants emphasized the need for living documents and clear processes that evolve with operational experience. Regular updates and curated best practices would help crews stay aligned. Practical examples, such as case studies, were identified as a useful way to capture lessons from unique operations.

- Support living SOP documents that evolve based on trainer feedback.
- Assign responsibility for curating best practices and distributing regular updates.
- Record and share debriefs or case studies (e.g., thermal detection near culvert).

Policy & Operational Support

Operational support was another common area of feedback. Participants asked for clearer guidance on recommended equipment to help justify procurement and supplemental gear. They also noted differences in workflow preferences, such as filing documentation in the office versus the field. Common data processing tools were suggested to bring consistency across projects.

- Provide guidance on recommended equipment for teams (e.g., canopies, StarBatt).
- Acknowledge variation in documentation practices (field vs. office), with Smartsheet generally serving well.
- Support adoption of a standard data processing system (e.g., DroneDeploy, ESRI, Pix4D).

Communication & Collaboration

Finally, participants pointed to the importance of consistent communication channels across districts. Regular calls, forums, and a central communication hub were viewed as essential for sharing updates, troubleshooting, and coordinating operations statewide.

- Encourage cross-district collaboration through regular calls or a digital forum.
- Establish a central communication hub (e.g., Teams, Slack, or an enhanced Smartsheet setup).

2.5.3 Final Remarks

Taken together, the survey results and the discussions with flight crew reveal a mixed picture. Pilots value the structure provided by current forms and most feel they have access to knowledgeable support, but there is widespread frustration with paperwork duplication, inconsistent software tools, and limited resources. Barriers vary by experience and frequency of operations: newer pilots tend to find forms more useful, while more experienced or frequent operators identify resource constraints and inefficiencies more clearly. Across the board, respondents expressed interest in more opportunities for peer-to-peer exchange, streamlined and consistent mission planning tools, and expanded training tailored to both new and advanced users.

The individual pilot discussions provided additional insight into these themes. Participants called for refinements in training, including mentorship opportunities, recertification modules, and periodic instructor gatherings. Knowledge management was highlighted as another priority, with strong interest in living SOPs, curated best practices, and case studies to capture lessons from unique operations. On the operational side, pilots requested clearer guidance on recommended equipment, acknowledgment of differing documentation practices between office and field, and support for standardized data processing platforms. Finally, they emphasized the importance of communication and collaboration, pointing to the need for cross-district calls and a central hub for coordination. Together, these findings underscore three key themes: (1) the need to simplify and standardize forms and platforms to reduce administrative burden, (2) the value of reinforcing communication and training systems that support both new and experienced pilots, and (3) the importance of addressing resource and organizational gaps to ensure consistency across districts. Quick and relatively easy wins include facilitating peer connection through periodic gatherings or simple communication channels, standardizing and simplifying software guidance, and increasing visibility of training opportunities. Systematic areas for improvement include expanding training and skill development, addressing resource allocation and equipment needs, strengthening organizational support (e.g., coordinators or district-level crews), and ensuring consistency and integration across forms, software, and access to flight data. These changes would directly address recurring frustrations while reinforcing the program's existing strength in peer and organizational support.

Table 2.10: Quick wins and systematic focus areas identified from survey results and crew discussions

Quick / Easy Wins	Systematic Focus for Improvement
• Facilitate peer connection (e.g., mentorship, quarterly gatherings) • Provide clear list of approved software/tools • Highlight and circulate training opportunities • Share case studies and debriefs	• Refine and standardize operational workflows • Expand hands-on training and advanced skill development • Address equipment gaps and budget planning • Add organizational capacity (e.g., coordinators, district crews) • Standardize processes and integrate data/software use • Build central communication and collaboration platforms

2.6 Management of the Safety Management System

2.6.1 Assessment of Smartsheet

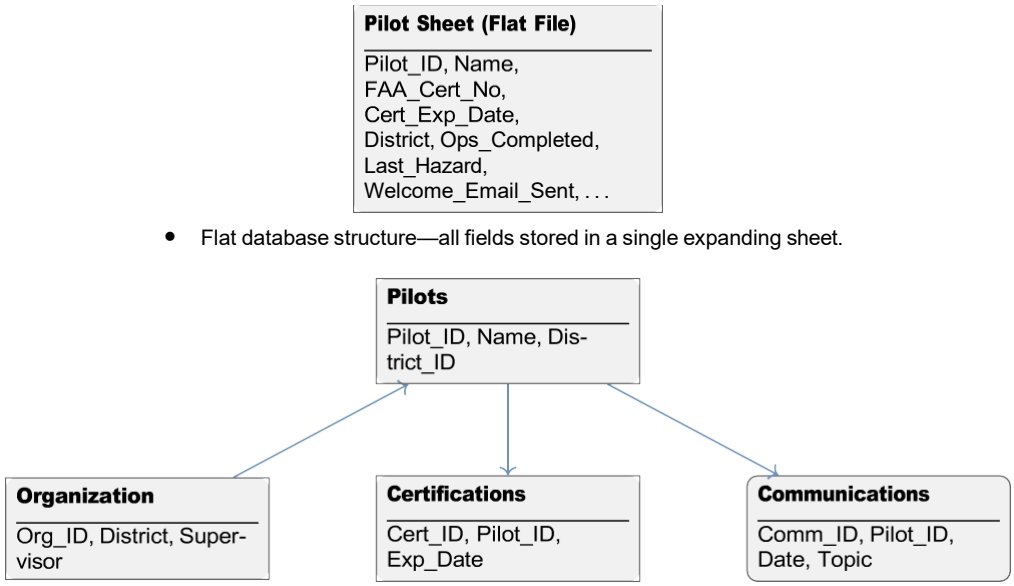
The Caltrans UAS SMS program currently relies on Smartsheet as its primary platform for data tracking and form submission. The system has been effective as an entry-level solution, offering straightforward form creation, centralized storage, and a consistent statewide process for collecting pilot, fleet, and operations information. Dashboards, one of the platform's strongest features, embed forms directly within their interface, allowing pilots to initiate mission or hazard entries easily. Managers benefit from consolidated metrics and quick access to reference materials, improving accessibility and reducing friction in day-to-day operations. However, the dashboards are not customizable by role, limiting their ability to deliver targeted views for specific user groups such as district coordinators, supervisors, or program managers.

Scaling Challenges:

As the program has expanded, Smartsheet's structural limitations have become increasingly apparent. Each sheet is capped at 500,000 cells, 400 columns, and 20,000 rows. Core datasets such as the pilot roster and operations log are now approaching these thresholds, with hundreds of columns and thousands of entries. At this scale, sheets are cumbersome to navigate and slow to update, and continued growth risks exceeding platform capacity. More importantly, Smartsheet's flat data model forces every new requirement to be handled by adding additional columns. This approach has produced extensive "column creep," as seen in the pilot roster, which now contains over 80 fields, from essential identifiers such as FAA certificate number and expiration date to administrative items like whether a welcome email has been sent. The result is a system that captures more information each year but becomes increasingly difficult to interpret, maintain, and validate (Figure 2.10a).

Data Integrity and Traceability:

Flat sheets are poorly suited for historical tracking. Training completions, aircraft renewals, and other time-sensitive updates are stored in single cells that overwrite prior values, leaving only the most recent record visible. This erases historical context, prevents longitudinal analysis, and weakens auditability. Fleet and operations data follow a similar pattern: registration renewals, maintenance events, and mission records are overwritten or spread across duplicate columns, obscuring lifecycle trends. Without the ability to link pilots, aircraft, and operations dynamically, redundant data entry becomes unavoidable, and inconsistencies accumulate over time. Manual maintenance adds further strain. For several years, statewide data management was handled by a single program manager, and even with additional staff, frequent updates to dropdown lists, training records, and aircraft rosters consume substantial time while introducing opportunities for human error.



- Flat database structure—all fields stored in a single expanding sheet.
- Relational database structure—linked tables for pilots, certifications, communications, and organizational hierarchy.

Figure 2.10: Comparison of the current flat data structure (a) and a proposed relational database model (b).

Operational Consequences:

These structural weaknesses have direct effects on safety oversight and reporting. Operations and hazard analyses are stored in separate sheets that rely on manual entry of an operations ID number to establish a link. Only 62% of these identifiers match correctly, and hazard forms are completed for fewer than 10% of reportable missions (see Section 2.3.2). Without reliable relationships between operations and hazards, it is difficult to identify recurring risks, correlate incidents with specific mission types, or demonstrate consistent hazard assessment across districts. Dropdown lists compound the issue: because Smartsheet does not support dynamic or relational lookups, pilot and aircraft names must be manually updated in every form. As a result, records for the same individual or aircraft may differ slightly across sheets, reducing overall data quality and undermining confidence in analytics derived from the system.

Relational Transition:

A relational database model (Figure 2.10b) offers a long-term solution to these structural limitations. By separating essential operational data from auxiliary administrative details, a relational approach improves both clarity and performance. Core entities, pilots, aircraft, operations, hazards, and incidents, would exist as distinct but linked tables, enabling accurate one-to-many and many-to-many relationships. Logs would replace overwriting, preserving historical records and improving auditability. Non-critical information such as communications or approvals could be maintained in linked sub-tables without burdening the core dataset. This structure would enhance traceability, reduce redundancy, and ensure that every pilot, operation, and asset remains individually tracked as the program scales.

Existing Sheets

The structural challenges appear across all major data sheets in the current Smartsheet system. Although each sheet serves a distinct purpose, tracking pilots, aircraft, or operations—they share common design patterns that limit scalability, traceability, and analytical value. Each uses a wide, flat format that mixes permanent identifiers with temporary updates, overwriting historical information and creating redundancy across records. The following tables illustrate these issues and outline how a relational model would streamline data management by separating core entities from their associated logs.

The Pilot sheet (Table 2.11) demonstrates the effects of column creep most clearly. More than eighty columns capture a mix of essential identifiers, training completions, approvals, and administrative notes. In a relational design, stable information such as pilot identifiers would remain in a central *Personnel* table, while dynamic elements like training completions or communications would shift to dedicated logs that preserve history and reduce clutter. This approach improves both data clarity and the ability to track recurrent training, certifications, and pilot experience by aircraft type.

A similar pattern occurs in the Fleet sheet (Table 2.12). Registration dates, renewals, and status changes are stored in single cells that overwrite prior entries, obscuring lifecycle history. Supervisor names and district information are duplicated across records, creating inconsistencies with personnel data. A relational structure would separate durable identifiers, such as aircraft type, serial number, and registration number, from transient data like renewals, assignments, and status logs, allowing the system to track maintenance and utilization over time without losing prior entries.

The Operations sheet (Table 2.13) compounds these limitations because it combines identifiers, crew details, mission parameters, and incident reporting in a single table. Different crew roles are stored in separate columns, and incident data appear as free-text fields that cannot be analyzed systematically. Most critically, hazards are logged in a separate sheet and linked to operations only through manually entered identifiers, resulting in a 62% match rate. Under a relational model, operations would be linked to crew, aircraft, and hazard records through unique IDs, ensuring accurate relationships and improving the program's ability to monitor risk trends and evaluate mission outcomes consistently.

Together, these examples highlight how Smartsheet's flat structure constrains the Caltrans UAS program's ability to manage complex, interdependent data. By transitioning to a relational database, each dataset can retain historical fidelity, eliminate redundancy, and support advanced analysis across pilots, aircraft, and operations.

Table 2.11: Current pilot sheet columns grouped by category, with streamlined relational alternative

Category	Examples of Current Columns	Streamlined Approach
Core identifiers	First Name Last Name Email Phone Districts Classification FAA Certificate Number FAA Expiration Date	Keep in a *Personnel* table with unique PilotID and minimal required fields.
Training/compliance	Temporary Certificate Date Renewal Dates Basic Flight Field Training Supplemental Training Online Courses Completed	Move to a *Training Log* table: (PilotID, TrainingType, Date, Status, EnteredBy). Preserves history.
Approvals/notifications	Supervisor Approval Coordinator Approval Add to Email List Portal Access Training Complete Email Sent	Move to an *Access/Approvals Log*: (PilotID, Action, Date, ByWhom).
Administrative/temporary	Notes Expiration Warning Pending Receipt Admin Updates Completed	Eliminate or move to an *Admin Notes Log*.
Critical but missing	*(none captured)*	Add a *Flight Experience Log*: (PilotID, Date, AircraftType, FlightHours, Role). Supports tracking recency and experience by type.

Table 2.12: Current fleet sheet columns grouped by category, with streamlined relational alternative

Category	Examples of Current Columns	Streamlined Approach
Core identifiers	UAS ID Number Make Model FAA Serial Number FAA Registration Number Districts	Keep in a *Fleet* table with unique UASID and minimal required fields.
Registration/compliance	FAA Registration Dates Renewals Expiration Warnings	Move to a *Registration Log*: (UASID, RegistrationNumber, StartDate, EndDate, EnteredBy).
Status/assignment	UAS Status Status Date Inactive Reason Out of Service Date Supervisor Contact	Split into *Status Log* (UASID, Status, Date, Reason) and *Assignment Log* (UASID, AssignedTo, Dates).
Approvals/admin	Supervisor Approval Coordinator Approval OPS Data Dropdown List	Log as *Administrative Actions*: (UASID, Action, Date, ByWhom).
Critical but missing	*(none captured)*	Add a *Fleet Utilization Log*: (UASID, Date, MissionID, FlightHours, Cycles). Supports usage trends and maintenance planning.

Table 2.13: Current operations data structure vs. proposed streamlined design

Category	Current Approach	Proposed Adjustment
Identifiers	OPS-ID, Index IDs, Districts, Pilot info (duplicated)	Keep OPS-ID + District. Link pilots/aircraft via dropdowns synced from master sheets.
Crew tracking	Separate columns for Secondary Pilot, VO, etc.	True crew log (OPS-ID, Role, Person) is not feasible in Smartsheet; workaround is limited slots or automation.
Mission purpose	Dropdowns with “If Other” free-text	Consolidate to validated dropdown list; reduce narrative entries.
Special conditions	Night Ops, Emergency, FAA Night Compliance, etc.	Use condition checkboxes; metrics limited in Smartsheet, but improves usability.
Incidents	Free-text “Incident Type/Details”	Dropdown categories with optional narrative; enables trend tracking.
Hazards	Separate sheet, OPS-ID typed manually (62% accuracy)	Hazard log with OPS-ID dropdown + reminders for missing hazards.

Implementation Path.

In the short term, several improvements can extend Smartsheet’s usefulness. Validation rules and controlled dropdowns could reduce entry errors, while better integration between hazard and operations workflows could improve completion rates. Dashboards can be refined to highlight key compliance metrics and upcoming deadlines. Medium-term strategies include hybrid systems where Smartsheet remains the front-end for form submission but synchronizes data to more capable analytical platforms such as Power BI, Access, or SQL. Automation tools including Smartsheet Bridge, Zapier, or Power Automate, could reduce manual upkeep by syncing dropdown lists and records automatically. Ultimately, however, full transition to a relational system (Figure 2.10b) would be a better long-term solution, especially for considerations of Part 108. Such a model will enable advanced analytics, including tracking pilot experience by aircraft type, assessing fleet utilization, and identifying hazard trends over time. As data maturity increases, the system could evolve toward a CRM-style interface, giving each pilot a

unified profile that consolidates certifications, training history, flight hours, and support needs into a single view.

2.6.2 Management of Waivers

FAA waivers and Certificates of Authorization (COAs) provide Caltrans with the ability to expand operations beyond the default limits of Part 107, such as flying beyond visual line of sight (BVLOS), above 400 ft AGL, or over people. These authorities, however, come with additional operational and institutional requirements that must be met in order to remain compliant. Currently, the Caltrans UAS Policy does not specify how waivers or COAs should be managed. Several key gaps exist:

- **Authorization to Submit:** The policy does not establish who is permitted to prepare or submit waiver and COA applications to the FAA. This raises questions about consistency, accountability, and whether submissions meet FAA requirements.
- Scope of Applicability: Waivers and COAs often apply to specific locations, operations, or organizational units. The policy does not define whether these authorities should apply at the division, district, or statewide level, leaving ambiguity around use and enforcement.
- **Compliance Oversight:** At present, oversight is limited to "Supervisors," but waiver requirements are highly technical. Supervisors may lack the specific UAS knowledge needed to ensure pilots, aircraft, and procedures remain compliant under waiver provisions.
- **Institutional Requirements**: Waivers and COAs typically require maintaining up-to-date records of pilots, aircraft, and FAA-approved procedures. These responsibilities are not assigned or acknowledged in the current policy, and risk being informally managed by individuals rather than supported by the UAS Program.
- **Training and Communication:** The current policy does not address how pilots and supervisors should be trained on waiver-specific requirements, nor does it define communication channels for distributing waiver conditions or updates.

These gaps create uncertainty in how Caltrans would prepare, implement, and sustain operations under an FAA waiver or COA, leaving compliance dependent on individual interpretation rather than a consistent, program-level approach.

Example Waiver

The FAA waiver (107W-2024-01814) issued to the Caltrans Division of Construction highlights several institutional requirements that are not addressed in the current Caltrans UAS Policy. These requirements represent critical gaps in Caltrans' ability to manage and sustain waiver operations consistently across the organization.

1. **Pilot and Aircraft Recordkeeping:** The waiver requires maintaining current lists of pilots (including certificate numbers) and aircraft (by registration number) used in operations, with documentation available for FAA inspection. While Caltrans has a centralized process for tracking flight activity, there is not a clean mechanism to split off flight activities for this waiver. Additionally, responsibility for such records is not assigned in policy, leaving the risk that records are incomplete, outdated, or dispersed across districts.
2. **Training and Safety Briefings:** The waiver mandates documented training for Remote PICs and Visual Observers covering operational procedures, abnormal procedures, air traffic avoidance, crew resource management, and demonstration of flight skills. It also requires pre-flight safety briefings addressing roles, operational areas, emergency procedures, and waiver-specific conditions. Current Caltrans policy does not define how waiver-specific training or briefings are delivered, documented, or standardized across divisions. Supervisors may not have the subject matter expertise to ensure compliance, creating inconsistency and risk of noncompliance.
3. **Operations Manual and Recordkeeping:** The waiver requires maintaining an operations manual as submitted with the application, ensuring revisions are tracked, available during operations, and aligned with FAA requirements. Additionally, detailed maintenance logs and functional test flight records must be kept

for each aircraft. The current Caltrans UAS Policy does not acknowledge or assign responsibility for maintaining an FAA-approved operations manual, nor does it establish standards for maintenance or test flight logging. Without a structured process, compliance with these provisions depends on individual initiative rather than institutional support.

Alignment with Part 108 Transition:

Many of the institutional gaps described above parallel the challenges to advanced towards Part 108 operations. The proposed Part 108 certificates require a more complete Safety Management System (SMS), with mandated reporting requirements of organizational authorization, requiring documented oversight of pilot competency, aircraft maintenance, operational risk assessment, and safety assurance. Transitioning toward Part 108 certificates would therefore address many of the same needs identified under current waiver operations by formalizing record-keeping, training, and audit responsibilities within the program itself. However, Part 108 will not, by itself, define who within Caltrans holds authority to apply for, manage, or enforce waiver provisions. Clear internal governance, establishing who submits, maintains, and audits FAA authorizations, remain essential for better management of FAA waivers and COAs.

2.6.3 Pilot Advancement

The Caltrans UAS Program was originally developed around small, entry-level multi-rotor aircraft typical of the 2018–2020 period. Training and qualification standards remain centered on these systems, even as operations expand to include larger, fixed-wing, VTOL, and specialized platforms. This evolution introduces several challenges unique to pilot advancement and program growth.

1. **Advancement Across Aircraft Classes:** There is no defined process for progressing from small multi-rotor platforms to complex aircraft with different control schemes, automation levels, and risk profiles. Pilots who complete initial training may not have structured opportunities to develop the competencies required for new categories, creating uneven capability across the workforce.
2. **Platform-Specific Competency Requirements:** Emerging platforms demand proficiency in mission planning, automation management, and system integration that extend beyond current curriculum content. Without explicit qualification standards tied to platform type or operational complexity, Caltrans cannot reliably match pilot capability to mission risk.
3. **Future Integration and Oversight:** As autonomy and advanced systems become more common, pilot progression must link to organizational oversight within the Safety Management System, in line with expectations under Part 108. Doing so would establish measurable benchmarks for competency, ensure standardization across districts, and align personnel development with evolving operational requirements.

Developing tiered qualifications that reflect aircraft complexity and automation levels would close this remaining gap and prepare the program for next-generation UAS operations. Section 3.6 addresses this in additional detail.

2.7 Part 108 NPRM

Part 108 is a proposed FAA regulation intended to enable safe and scalable beyond visual line of sight (BVLOS) operations for unmanned aircraft systems (UAS)[4]. In contrast to Part 107, which governs small UAS operations within visual line of sight, Part 108 introduces a broader regulatory framework that encompasses higher-risk and more complex missions, including operations over people and with larger aircraft. Although the rule remains in draft form, Caltrans can begin preparing for its adoption by aligning existing practices with its organizational requirements. A key feature of the proposal is the transition from an *airman-centric* model to one based on *organizational oversight*, where responsibility for compliance, training, maintenance, and safety rests with the operating organization rather than individual remote pilots.

2.7.1 Part 108 Requirements

Part 108 requires clear organizational roles, documentation standards, and management systems comparable to those required of traditional aviation entities. Instead of a single "remote pilot in command," the rule introduces positions such as the *operations supervisor* and *flight coordinator*, supported by required systems such as the company operations manual, safety management system (SMS), and cybersecurity program. Together, these form an integrated compliance structure designed to ensure operators function with defined authority, traceable records, and continuous safety oversight.

Categories of Change.

The proposed rule introduces three principal areas of change relevant to Caltrans:

1. New **organizational roles** are responsible for operational authority and control;
2. Required **management systems and documentation** that formalize existing processes; and
3. FAA-issued **operating certificates** for defined categories of UAS activity.

The following summarizes the major provisions most applicable to the Caltrans UAS Program.

Organizational Roles

Together, these roles shift accountability from the individual pilot toward structured organizational control, reflecting the central oversight principle of Part 108.

- **Operations Supervisor (§108.305):** A designated individual qualified through training, experience, or expertise who oversees the safe and compliant execution of all UAS operations. This position carries primary accountability for adherence to company policy, aviation safety standards, facility security, and regulatory compliance. Any personnel change must be reported to the FAA within ten days.
- **Flight Coordinator (§108.310):** A qualified individual assigned by the operator to direct and oversee unmanned aircraft during flight. The flight coordinator maintains situational awareness, ensures regulatory compliance, and prevents operations from posing hazards to people or property. They must complete at least five hours of supervised experience in the make and model of aircraft operated, maintain currency through recent flight coordination, and follow handoff procedures defined in the company operations manual.

Core Management Systems

Together, these management systems institutionalize the oversight, safety, and data-protection practices necessary for scaling to advanced and autonomous operations.

- **Company Operations Manual (§108.135):** Each organization must maintain a current manual that defines policies and procedures acceptable to the FAA Administrator. The manual, which may consist of multiple documents, must clearly identify its revision status and be available to the FAA upon request. It provides the foundation for operational standardization, covering personnel duties, preflight procedures, maintenance and inspection criteria, recordkeeping and reporting, accident and emergency response, aircraft retrieval, and hazardous-materials handling.
- **Safety Management System (§108.560):** Each certificated operator must establish and maintain a Safety Management System that satisfies the requirements of 14 CFR Part 5. This system integrates safety policy, risk management, assurance, and promotion processes into organizational decision-making.
- **Cybersecurity Program (§108.535):** Operators must implement policies and processes to protect operational networks, software, and data from unauthorized access. These include controls on employee access privileges, procedures for responding to cyber incidents, removal of access for former personnel, and annual policy reviews to ensure the integrity and reliability of UAS operations.

Operational Certification Framework

Part 108 establishes two primary authorization pathways for UAS organizations: *operational permits* and *operating certificates*. Permits are intended for smaller-scale operators with limited fleets and defined operational constraints, while certificates support larger, more complex organizations capable of meeting expanded safety and management requirements. For Caltrans, the operating certificate model would provide greater flexibility and long-term scalability, enabling broader operational scope under a structured compliance framework. Together, these certification mechanisms define how organizations demonstrate operational readiness and sustained compliance within the Part 108 regulatory structure.

- **Operating Certificate (§108.500-108.515):** An FAA-issued authorization that enables specific categories of UAS activity such as package delivery, agriculture, aerial surveying, or civic interest operations. To obtain certification, an operator must demonstrate compliance readiness through documentation covering personnel qualifications, aircraft systems, company manuals, training, safety management, and risk assessments. Certificates remain valid until surrendered, suspended, or revoked, and may be amended by the FAA as safety or public interest requires.
- **Aerial Surveying Certificate (§108.580):** Covers mapping, inspection, and monitoring operations performed under a dedicated aerial surveying certificate. Operations must adhere to population-density and weight restrictions (generally Category 4 or lower) unless otherwise authorized. This classification enables routine infrastructure and environmental survey work under standardized operational and safety conditions, with no fleet size limitations.

2.7.2 Part 108 Transition Checklist

For Caltrans, transitioning to Part 108 builds on existing Safety Management System practices but requires additional structure, documentation, and standardization. The program already demonstrates strengths in safety policy, hazard reporting, and operational tracking, but will need to formalize training frameworks, competency standards, and maintenance procedures to fully align with Part 108. Documentation management will also require improvement to meet FAA expectations for controlled manuals, traceable updates, and comprehensive recordkeeping.

The following checklist maps key NPRM elements to Caltrans organizational responsibilities, providing both a readiness assessment and a roadmap for progressive compliance.

Table 2.14: Caltrans UAS Part 108 Program Checklist

Category	Subcategory	Checklist Item	Y/N	Notes
General Information	Company Info	Company information is included and current	Y	
	Manual Purpose & Scope	Purpose and scope clearly describe the manual's intent and applicability	Y	
	Definitions	Definitions list covers key terms used throughout the manual	N	Needs updating
Organizational Structure and Responsibilities	Org Chart	Organizational chart shows reporting lines and is current	N	Needs updating
	Key Personnel Roles	Roles and responsibilities for key personnel are defined	N	Needs updating with new Part 108 roles
	SMS Committee Structure	SMS committee membership, duties, and meeting cadence are documented	N	Needs to be defined, but the foundation is there
Safety Policy (14 CFR §5.21–5.29)	Safety Policy Statement	Safety policy statement is published and endorsed by leadership	Y	
	Safety Accountability	Lines of safety accountability are assigned and traceable	N	Needs work on Safety Assurance

Continued on next page

Table 2.14: Caltrans UAS Part 108 Program Checklist (Continued)

Category	Subcategory	Checklist Item	Y/N	Notes
Safety Risk Management (14 CFR §5.51–5.57)	System Description	System description covers people, equipment, procedures, and environment	N	Will need to be defined before BVLOS
	Hazard Identification	Methods for identifying hazards are defined and accessible to staff	Y	
	Risk Assessment	Risk matrix and assessment process are defined and in use	N	Will need to be reassessed for BVLOS
	Risk Control Implementation	Risk controls are assigned, tracked, and verified after implementation	N	Missing Safety Assurance
Safety Assurance (14 CFR §5.71–5.77)	Safety Performance Monitoring	SPIs/targets are defined, monitored, and reported	N	
	Internal Investigations	Investigation procedures and triggers are documented	Y	
	Continuous Improvement	Corrective actions and effectiveness checks are documented	N	
Safety Promotion (14 CFR §5.91–5.97)	Training and Competency	Training requirements and competency standards are defined	N	Will need to be developed for BVLOS
	Safety Communication	Safety communication channels and frequency are defined	N	Will need to be strengthened for BVLOS
Part 108 Operations Specifications	Authorized Operations	Authorized operations are listed and match current capabilities	N	
	Requirements	Required aircraft configuration and equipment lists are documented	N	
	Aircraft Registration (108.115)	Part 108 requires Part 47 Aircraft Registration	N	New process required for aircraft registration, and aircraft titling.
	Operator Identification (108.35)	Aircraft are clearly marked with identification information	Y	Should develop a larger/more conspicuous branding.
	Personnel Requirements	Personnel qualifications, medicals, and currency requirements are defined	N	Will require additional logging
Standard Operating Procedures	Pre-Flight Procedures	Preflight planning, briefing, and checklists are included	Y	Will need to incorporate BVLOS
	Flight Operations	Normal and abnormal flight procedures are documented	Y	
	Maintenance Procedures	Routine and non-routine maintenance procedures are included	Y	
Emergency and Contingency Procedures	Lost Link	Lost link procedures and notifications are documented	N	Missing link procedures
	DAA System Failure	Detect-and-Avoid failure procedures are defined	N	
	Aircraft System Failures	Common system failure responses are included	N	Should track with flight records
	Weather Emergencies	Adverse weather and emergency diversion procedures are included	N	
Training and Competency Management	Training Program Structure (108.40)	Training paths, syllabi, and recurrent schedules are defined	N	Needs to be finished

Continued on next page

Table 2.14: Caltrans UAS Part 108 Program Checklist (Continued)

Category	Subcategory	Checklist Item	Y/N	Notes
	Competency Assessment	Initial and recurrent competency assessments are defined	N	
Maintenance and Continuing Airworthiness	Maintenance Program	Maintenance program and intervals are documented	N	
	Parts and Component Control	Parts control, traceability, and MEL/deferral rules are defined	N	
Document Control and Records Management	Document Control System	Version control, approvals, and distribution are defined	N	
	Records Management	Records retention, storage, and retrieval are defined (108.40)	N	Needs additional record keeping details

2.7.3 Priority Steps Toward Part 108 Readiness

Initial review indicates strengths in safety policy, hazard identification, and standard operating procedures. However, several gaps remain in areas critical to Part 108 approval. Training and competency management are not yet formalized into structured, recurrent programs. Maintenance and airworthiness processes are maintained through spreadsheets rather than controlled logs. Records management and document control lack versioning and retrieval standards, important for compliance even if not immediately safety-critical. Addressing these items is essential to progress from Part 107 compliance toward the organizational oversight expected under Part 108.

1. **Training and Competency Management:** Establish structured training pathways, platform-specific instruction, recurrent cycles, and standardized competency assessments.
2. **Maintenance and Continuing Airworthiness:** Adopt log-based systems for renewals, inspections, and repairs. Define scheduled maintenance intervals and parts traceability processes.
3. **Records Management and Document Control:** Implement version-controlled systems for manuals and procedures with defined retention, storage, and retrieval standards.
4. **Safety Assurance and Performance Monitoring:** Define measurable Safety Performance Indicators (SPIs) with targets, reporting intervals, and corrective-action tracking.
5. **Organizational Roles and Oversight:** Formally designate operations supervisors, flight coordinators, and SMS committee members with documented responsibilities and training.

These actions establish a clear roadmap for phased readiness. While incremental improvements can be implemented within current tools such as Smartsheet, long-term compliance will require more robust data and document systems. Addressing these areas early positions the Caltrans UAS Program for safe expansion into BVLOS operations and alignment with the anticipated Part 108 framework.

Chapter 3

UAS Platform Review

The advancement of Unmanned Aircraft Systems (UAS) presents both opportunity and complexity for Caltrans. As the program transitions from traditional, manually piloted multirotors toward advanced autonomous, tethered, and VTOL systems, its Safety Management System (SMS) must evolve to ensure safe, consistent, and scalable operations. Emerging technologies such as automated docking, real-time connectivity, and beyond visual line of sight (BVLOS) capabilities challenge the existing one-pilot-one-drone model, demanding clearer definitions of crew roles, oversight responsibilities, and data governance.

This chapter examines representative UAS platforms and operational archetypes to identify how increasing automation and system integration affect training, risk management, and program policy. Through comparative analysis, scenario-based testing, and evaluation of human-automation interaction, it outlines the gaps and adjustments necessary for Caltrans to maintain safety assurance as it integrates new aircraft types, expanded operations, and supervisory frameworks envisioned under the forthcoming Part 108 rule.

3.1 Introduction

Unmanned Aircraft Systems (UAS) have evolved from manually piloted multi-rotors to advanced fixed-wing, VTOL, and tethered platforms with autonomous and networked capabilities. These developments increase operational range, efficiency, and data fidelity but exceed the assumptions of the current Caltrans UAS Safety Management System (USMS), which was designed for single-pilot, line-of-sight operations.

Regulatory frameworks are advancing in parallel. FAA waivers for beyond visual line of sight (BVLOS) and operations over people are increasingly common, introducing expanded requirements for training, documentation, and oversight. Public exceptions for tethered systems add further complexity, creating dual compliance pathways under Part 107 and statute-based exemptions. Consistent policy and role alignment are required to ensure safety assurance across these categories.

Automation is redefining operator functions. Control inputs are replaced by mission planning, supervision, and risk monitoring. Docking and tethered systems remove the pilot from direct flight control, while hybrid VTOL and fixed-wing platforms require new procedures, maintenance practices, and infrastructure. These changes necessitate revisions to training curricula, onboarding standards, and role definitions across Caltrans divisions.

Modern UAS architectures are increasingly network-dependent. Cloud-based telemetry, fleet dashboards, and automated analytics integrate flight operations with IT infrastructure. This integration introduces dependencies on data integrity, cybersecurity, and interoperability across heterogeneous platforms. Standardized data governance and consistent performance metrics are essential to maintain traceability and safety accountability.

The following sections analyze these emerging conditions, expanded operational envelopes, platform diversity, and digital integration, and their implications for USMS structure, oversight, and training requirements.

Platform Comparisons: Autonomy and Integration Archetypes

Representative platforms illustrate the progression of automation and system connectivity. The **eBee X**, **WingtraOne Gen II**, and **Sentaero 5** demonstrate evolution from mission-planned fixed-wing systems to hybrid VTOL architectures with limited pilot intervention. The **Freefly Astro**, **Skydio Dock**, and **Aloft Air Control** extend

this trajectory toward networked, cloud-supervised operations. Together, they define the range of operational contexts Caltrans must support, from field-deployed survey missions to persistent, enterprise-level fleets.

Table 3.1: Comparison of Autonomy and Integration Characteristics Across Representative UAS Platforms

Platform	Type / Configuration	Autonomy Level	Control Interface	Connectivity Features	Operational Notes
AgEagle eBee X	Fixed-wing, hand-launch	Planned autonomy; minimal in-flight control	Laptop (eMotion) mission planner	Local RF link; no live view	Survey platform; dependent on pre-flight mission validation.
WingtraOne Gen II	VTOL hybrid fixed-wing	Fully autonomous transitions; no manual flight mode	Tablet (WingtraPilot) interface	Wi-Fi / telemetry link	Simplified launch/recovery; Prone to wind issues when landing.
Censys Sentaero 5	VTOL hybrid fixed-wing	Fully autonomous transitions; no manual flight mode	Laptop (CensWise); Mobile Command Center	LTE network options	Supports BVLOS operations; dual payload capability; long-range infrastructure mapping.
Freefly Astro	Large multirotor	Semi-autonomous with manual fallback	Integrated Tablet (Auterion Suite)	Local RF link; live view	Enterprise mapping system; real-time telemetry; limited automation.
Skydio Dock + X2	Dock-based multirotor	Reactive autonomy with AI navigation	Remote dashboard (Skydio Cloud)	Dock Wi-Fi / 5G LTE	Unattended preprogrammed missions; dependent on stable network link.
Aloft Air Control	Software-as-a-Service (SaaS) fleet platform	Integration layer; not an aircraft	Web dashboard	Multi-platform cloud API	Centralized compliance management.

3.2 Expanded Operations

Emerging UAS configurations now enable longer-duration and semi-autonomous missions that extend beyond traditional visual line of sight operations. This section examines two representative capabilities, tethered systems and autonomous docking platforms, and their implications for Caltrans oversight, training, and safety assurance.

3.2.1 Tethered Drones

The Caltrans Interim Policy on Tethered UAS Operations established requirements for integrating tethered drones such as the Fotokite (Figure 3.1) into the agency's UAS Program. At the time of publication (March 4, 2024), federal law defined an actively tethered UAS as one weighing 4.4 pounds or less[1], attached to a ground station with a taut, load-rated tether that provides continuous power and control. While such systems may be exempt from Part 107 under Title 49 U.S.C. §44806(c), Caltrans requires all tethered operations to follow Part 107 rules and the Caltrans UAS Handbook. Oversight is provided by the Caltrans UAS Steering Committee to ensure compliance with federal and state regulations.

Program requirements for tethered operations largely mirror those for standard flights, including the mandatory use of a Visual Observer, but introduce additional restrictions. Tethered flights are limited to 150 ft AGL and must maintain a 24 ft setback from active traffic lanes. Because these systems enable extended-duration operations, crews must continuously monitor field conditions such as traffic, driver behavior, and weather. For specialized uses like lighting or surveillance, prior approval from the Caltrans UAS Program is required.

[1]Amended May 16, 2024, to remove the 4.4-pound limitation

Figure 3.1: Fotokite at UC Davis

The May 2024 amendment to Title 49 U.S.C. §44806(c) allows public agencies to operate "public actively tethered UAS" without FAA certificates or pilot licenses if specific restrictions are met, including a 150 ft altitude limit, visual line of sight, and avoidance of non-participants and other aircraft. Public agencies may choose to operate tethered UAS under either Part 107 or §44806(c) on a per-flight basis, provided all statutory conditions are met. While §44806(c) provides flexibility, Caltrans maintains that all operators should have at least basic airspace and safety knowledge. Two training approaches could support this:

- **Recreational UAS Safety Test (TRUST):** Provides a basic introduction to airspace and safety concepts.
- **Caltrans-Specific Module:** A tailored course focusing on safety and airspace requirements relevant to tethered operations.

Table 3.2 compares the training and regulatory coverage provided under TRUST and Part 107 with the requirements of the Public Agency Exception and Caltrans policies.

Table 3.2: Comparison of Training/Knowledge Provided (TRUST, Part 107) and Requirements (PA Exception, Caltrans Policies)

Subject	TRUST (Provides)	Part 107 (Provides)	PA Exception (Requires)	Caltrans Policy (Requires)	Caltrans Tethered Policy (Requires)
Drone Weight Restriction	None	55 lbs or less	55 lbs or less	55 lbs or less	55 lbs or less
Scope	All users	FAA-registered pilots	Public safety orgs.	Employees	Employees
Pilot Certification	TRUST	Remote Pilot Certificate	None	Remote Pilot Certificate	Remote Pilot Certificate
Altitude Limit (Std.)	400 ft	400 ft	150 ft	400 ft	150 ft
Airspace Authorizations	LAANC/DZ only	LAANC/DZ auto ≤ map; manual > map	≤ FM only; >150 ft w/ authorization	Same as TRUST	Same as TRUST
Risk Management	Basic preflight	Full risk analysis	Minimal	Full risk analysis	Tether-specific risk
VLOS	VO optional	VO optional	VO optional	VO mandatory	VO mandatory

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Table 3.2: Comparison of Training/Knowledge Provided (TRUST, Part 107) and Requirements (PA Exception, Caltrans Policies) (Continued)

Subject	TRUST (Provides)	Part 107 (Provides)	PA Exception (Requires)	Caltrans Policy (Requires)	Caltrans Tethered Policy (Requires)
Proximity to People	No overflight; Avoid risk	No overflight; Avoid risk	No overflight; Avoid risk	No overflight; Avoid risk	No overflight; 24 ft offset
Emergency/ Contingency	None	Lost-link procedures	Minimal	Hazard analysis	Tether failure, extended ops

Safety Impacts to Consider

Beyond statutory requirements, tethered operations introduce distinct safety concerns:

- **Tether safety and reliability:** The tether must be rated for tensile and electrical safety, inspected before use, and deployed within a defined footprint using secure anchor points. Testing and inspection can be done in a controlled setting prior to deployment in the field. Guards or barriers may be required when operating near the public.
- **Contingency procedures:** Crews must have protocols for loss of power or tether detachment, including rapid retrieval and designated safe landing zones. Though tethered drones can be safe, a safety buffer zone should still remain as part of loss of power contingency procedures.
- **Crew workload and staffing:** Extended operations increase fatigue; policies should establish limits on monitoring duration and require crew rotations. At minimum, a Remote Pilot and Visual Observer must be present.
- **Public and driver distraction:** Operations near active roadways must include criteria for suspension due to unsafe conditions (e.g., congestion or driver distraction) and may require signage or cones.
- **Special-use applications:** Missions involving lighting, surveillance, or communications relays require additional risk assessment and safety oversight, particularly for night operations.

However, none of these are majorly different than expectations under Part 107. All fall cleanly within Part 107 expectations of hazard risk analysis and mitigation actions. Flight operations in other contexts, such as traffic monitoring, promotional filming and carriage of alternative payloads all face similar risk profiles. The one potential novel issue is ergonomic comfort due to the potential of significantly longer flight time.

As an added requirement to Part 107, Caltrans currently assigns both a Remote Pilot in Command (RPIC) and a Visual Observer (VO) for all flight missions. When risk is demonstrably low, single-pilot operations could improve efficiency if mitigations are applied; conversely, maintaining a two-person crew provides redundancy but reduces flexibility. Given the potential of significantly longer flight times with tethered platforms, requiring VO could ease workload.

By consolidating training, operational limits, and safety management under the existing framework and only adding minor platform specific training, Caltrans can expand tethered UAS operations without compromising federal and departmental safety expectations. Only if Caltrans wishes to explore non-Part 107 operations should novel risks need to be analyzed and controlled.

Ergonomics

Extended-duration UAS operations, particularly those involving tethered, VTOL, and fixed-wing platforms, introduce human-factors risks distinct from short missions. Prolonged controller use can cause fatigue, discomfort, and reduced situational awareness, while monotony may lead to complacency. These effects should be more readily anticipated in Caltrans planning to maintain performance and safety during multi-hour operations.

Ergonomic analyses such as the Rapid Entire Body Assessment (REBA) [15] rate prolonged handheld control as a "Medium Risk" task (see Appendix 5.7). Repetitive gaze shifts between the aircraft and the display replicate the "tech-neck" phenomenon [16], producing sustained neck flexion and muscle strain. Over long periods, these non-neutral postures elevate the likelihood of fatigue and reduced attentional capacity, underscoring the need for equipment positioning, scheduled breaks, and crew rotation.

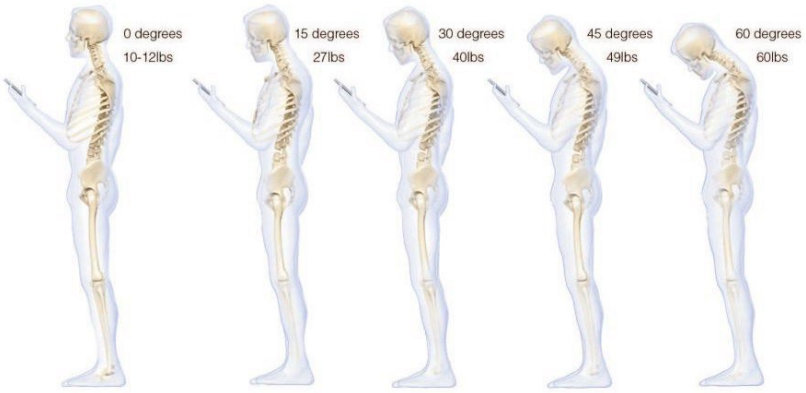


Figure 3.2: Example of neck flexion during handheld device use [16].

Mitigation strategies include portable tablet stands [17], controller trays or lanyards [18], and sunshades to reduce visual fatigue. Training should encourage pilots to self-assess comfort and take periodic breaks. Preliminary pilot evaluations over extended sessions showed minor performance degradation, though not to a degree warranting further investigation.

Fixed-station operations, where pilots remain at a table, workstation, or beside a tethered drone, present additional safety concerns. Restricted mobility can increase glare, narrow visual perspective, and limit the pilot's ability to adjust to dynamic conditions. These setups require ergonomic supports, clear monitoring protocols, and scheduled movement breaks to prevent attentional drift and ensure that environmental awareness is maintained. Incorporating these measures into Caltrans policy and training will strengthen both regulatory compliance and practical safety in long-duration and fixed-station UAS operations.

3.2.2 Docking Systems

A **drone docking system** (sometimes called a drone-in-a-box system, remote drone station, or autonomous docking platform) is an integrated ground station designed to let drones land, recharge, and relaunch without direct human handling. They are typically enclosed or semi-enclosed units that provide:

- Automated landing guidance (vision, RTK-GPS, beacons, or fiducial markers)
- Power management (battery swapping, automated charging pads, or wired/tethered power)
- Environmental protection (weatherproof enclosures, temperature/humidity control)
- Data handling (wired or wireless upload of flight data and imagery)
- Communications hub (persistent LTE/5G, Wi-Fi, or SATCOM connection for remote control)

Types of Docking Systems

1. **Charging Pad Systems**
   Drone lands on conductive contacts or a wireless induction pad.
   Examples: Skysense charging pad, Heisha DNEST.

2. **Enclosed Docking Stations ("Drone-in-a-Box")**
   Weatherproof boxes that house the drone, recharge batteries, and protect equipment between missions.
   Examples: DJI Dock, Percepto Air, Azur Drones Skeyetech.

3. **Battery Swap Systems**
   Robotic mechanisms replace depleted drone batteries with fresh ones. Designed for fleets with high operational tempo.
   Example: Airobotics Optimus docking system.

4. **Tethered Docking Systems**
   Provide continuous power through a tether, turning a drone into a semi-stationary aerial platform. Often paired with a ground dock for takeoff/landing.
   Uses: Traffic monitoring, construction, and security.

Challenges of Drone Docking Systems

Integrating docking systems into Caltrans operations requires a clear policy framework. Current FAA Part 107 rules limit routine beyond visual line of sight (BVLOS) operations, which are often assumed in autonomous docking workflows. Similar to the discussion of waiver management (Subsection 2.6.2), policies must explicitly state under what conditions docking systems can be used, what qualifications are required of Remote Pilots in Command (RPCs), and how accountability is maintained if a system malfunctions. Lack of policy clarity could create inconsistent practices across districts or crews.

However, with Part 108 regulations just around the corner, docking systems potentially are more feasible. Moving towards a Part 108-compliant organization will address many of the management needs for docking systems, even without fully obtaining a Part 108 permit or certificate[2]. Part 108 creates a clearer structure for BVLOS operations, including defined roles, responsibilities, and recordkeeping, which aligns with how docking systems are expected to operate. Under this framework, docking can be treated as part of a managed aviation ecosystem where operations supervisors, flight coordinators, and system maintainers all have documented responsibilities.

Unlike existing UAS operations, a drone docking system introduces unique hazards that must additionally be assessed as part of the organization's hazard risk process. These items would necessitate inclusion into analysis. Hazards include:

- Automated launch/recovery failures (misalignment, unstable landing, or drone not properly secured).
- Power system hazards (battery charging faults, thermal runaway, electrical fires, or inadequate surge protection).
- Communications failures (loss of C2 link between drone and dock, dock-network disconnection, or cyber intrusion).
- Physical security vulnerabilities (unauthorized access, tampering, or theft of aircraft, batteries, or data).
- Environmental degradation (rain, heat, ice, or dust impairing sensors, doors, or charging contacts).
- Obstruction hazards (improper siting near roadways, vegetation growth, or objects that interfere with drone ingress/egress).
- Maintenance and inspection gaps (failure to detect wear in moving parts, stuck hatches, or degraded charging leads).
- Emergency response limitations (inability to access or safely disable the dock after malfunction or fire).

Each of these hazards should be evaluated using a formal risk assessment framework that assigns likelihood and severity scores, with results documented in the organization's hazard analysis records. Residual risks must be clearly tracked, along with the mitigation strategies applied. Long-term safety assurance under Part 108 requires not only initial scoring but also continuous monitoring of dock performance, incorporation of incident and near-miss reports, and periodic re-evaluation to ensure that mitigations remain effective as systems, environments, and operations evolve.

[2]To be clear, it is recommended that Caltrans obtain Part 108 certification. It will be a necessary programmatic development for UAS integration

Dock-based operations often rely on remote flight coordinators who may be geographically separated from the local environment, creating potential latent safety risks. This distance can foster a cultural hazard in which automation is perceived as self-sufficient, reducing active human oversight. Such assumptions conflict with the principles of safety promotion, which require continuous human engagement in monitoring and intervention. Under the emerging Part 108 framework, safety promotion must explicitly reinforce that automation does not remove human accountability. In addition to operational oversight, Part 108 expands the scope of safety assurance to include site security and cybersecurity, requiring that docking systems be protected against unauthorized access, data compromise, and physical tampering. Flight coordinators and system administrators must therefore remain engaged in both operational risk management and the protection of system integrity throughout all phases of autonomous operation.

3.3 New Aircraft Types and Autonomy

While many drones have been capable of autonomous flight operations for some time, new technology has dramatically increased autonomy to the point where traditional "stick" skills are less central. Systems now range from large multi-rotors to fixed-wing and VTOL platforms, each with distinct operational profiles, user interfaces, and hazards. These differences have significant implications for Caltrans training, risk assessment, and policy development.

Table 3.3: Comparison of Hazards and Training Implications by Aircraft Type

Aircraft Type	Unique Hazards	Training Implications
Large Multi-Rotor	- Higher kinetic energy, greater damage potential - Longer stopping distances near structures - Greater operational stress due to cost and size	- Precision maneuvering in tight spaces - Emergency procedures for heavier aircraft - Awareness of safe operating envelopes
Fixed-Wing	- Continuous forward motion, stall speed limits - Extended take-off/landing zone requirements - Reliant on autonomy	- Automation literacy - Flight path risk and emergency route planning - Landing site evaluation and contingency planning
VTOL	- Hazards during hover/forward flight transitions - Susceptible to wind or software errors in transition - Often lacks manual override controls	- Transition mode awareness training - Understanding flight envelope and limits - Automation literacy

3.3.1 Large Multi-Rotor

Large multi-rotors (e.g., Freefly Astro, DJI Matrice 200) extend the familiar quadcopter design to heavier platforms capable of carrying advanced sensors, LiDAR units, or multispectral payloads. These aircraft generally retain manual controls, but their size, inertia, and cost amplify risks in confined or populated environments. Hazards include greater kinetic energy on impact, longer stopping distances near structures, and increased stress on pilots who must manage more complex systems under pressure. From a training perspective, transitioning to large multi-rotors requires emphasis on precision maneuvering, emergency procedures, and awareness of safe operating envelopes near roadways and infrastructure.

3.3.2 Fixed-Wing

Fixed-wing UAS such as the eBee X provide efficiency and coverage far beyond multirotors, enabling missions that span tens of miles or hundreds of acres. However, they introduce unique risks tied to their flight characteristics: continuous forward motion, stall speed limits, and the need for extended take-off and landing zones. Most fixed-wing systems operate with little or no manual flight control, relying instead on mission plans executed through specialized ground control software (e.g., eMotion). This creates operational hazards if autonomous recovery fails or if pilots are unprepared for emergency handover. Training must therefore include flight path risk assessments, landing site evaluations, and proficiency automation literacy.

3.3.3 VTOL

Vertical Take-Off and Landing (VTOL) platforms, such as the WingtraOne, combine multirotor launch and recovery with fixed-wing cruise efficiency. This hybrid design offers flexibility but also introduces transition hazards: the shift between hover and forward flight can be sensitive to wind, software errors, or operator missteps. Additionally, VTOL systems often eschew traditional manual controls, requiring the pilot or flight coordinator to trust autonomous transitions managed through ground station software. Risks include misconfigured mission plans, loss of situational awareness during transitions, and the challenge of operating from improvised or constrained landing sites. Training requirements must therefore emphasize transition mode awareness, flight envelope limits, and automation literacy.

3.3.4 Visual Line of Sight

Maintaining visual line of sight (VLOS) remains a foundational requirement under 14 CFR Part 107. Regulations (§107.31) specifies that the remote pilot in command or visual observer must be able to determine the aircraft's location, attitude, altitude, and direction of flight without visual aids other than corrective lenses. Despite this clear standard, there has been little systematic work to quantify the distance limits of VLOS across different UAS platforms. Most industry practice relies on conservative rules of thumb and subjective judgment, which creates variability and potential risk.

Modeling Approach

To address this gap, VLOS was evaluated using two complementary approaches: (1) geometric modeling of the angle subtended by a drone's visible profile relative to human visual acuity, and (2) comparative formulas provided in recent EASA guidance (2024) for Attitude Line of Sight (ALOS) and Detection Line of Sight (DLOS). The analysis incorporated both multirotor and fixed-wing platforms, using representative dimensions from common operational aircraft (e.g., Autel Evo II, AgEagle eBee).

The visual angle (θ) subtended by the drone's profile can be calculated using the arc cosine function, as visualized in Figure 3.3. The two relevant drone corners are defined as:

$$A = \left(dis - \frac{w}{2},\ alt + \frac{h}{2}\right), \quad B = \left(dis + \frac{w}{2},\ alt - \frac{h}{2}\right),$$

where dis is the horizontal distance to the drone, alt is the altitude, w is the drone width, and h is the drone height.

Using the arccosine formula to solve for the angle between two vectors gives:

$$\theta = \arccos\left(\frac{\mathbf{A} \cdot \mathbf{B}}{\|\mathbf{A}\|\,\|\mathbf{B}\|}\right). \tag{3.1}$$

Given a drone's dimensions (w, h) and a target angular resolution θ, varying the altitude from 0 to 400 ft allows estimation of the maximum distance at which the drone remains within visual line of sight.

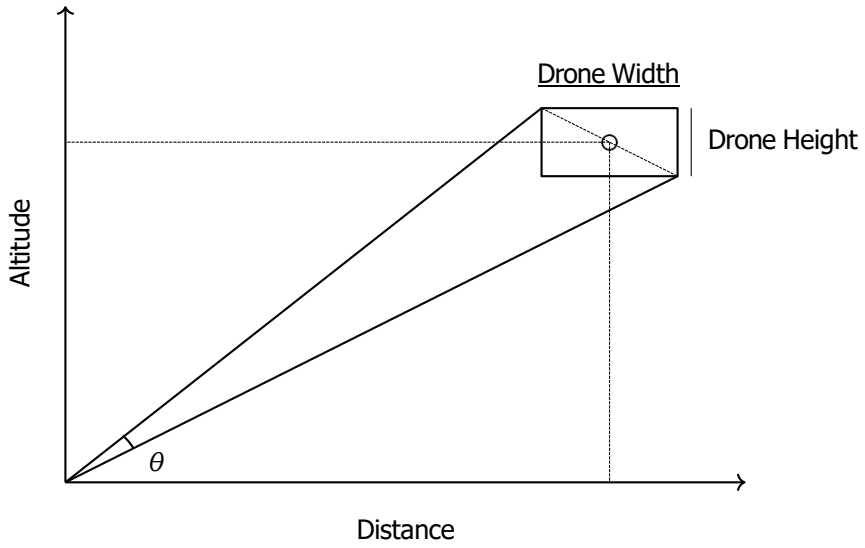


Figure 3.3: Estimating the angle θ subtended by the drone's profile as a function of altitude and distance.

Using this model, the visual line of sight (VLOS) thresholds for any drone can be predicted by relating the aircraft's physical dimensions to angular acuity requirements. For the eBee fixed-wing platform, three curves are plotted in Figure 3.4, corresponding to different visual acuity thresholds:

- **Limit of Human Vision (1'):** the smallest angular resolution achievable under ideal conditions, representing the absolute limit of unaided human sight.
- **Estimated Max VLOS Range (3'):** a practical operational threshold where observers can typically discern aircraft orientation and detect major changes in flight.
- **Estimated Safe Range (6'):** a conservative margin providing increased confidence under real-world conditions such as glare, haze, or background clutter.

Together, these curves illustrate how altitude and distance jointly constrain effective VLOS. The red 1' line represents the theoretical boundary of detection, while the green and blue lines reflect progressively more practical operating thresholds. Comparison of these modeled ranges with field observations highlights potential discrepancies between regulatory definitions of VLOS and actual observer capability in fixed-wing operations.

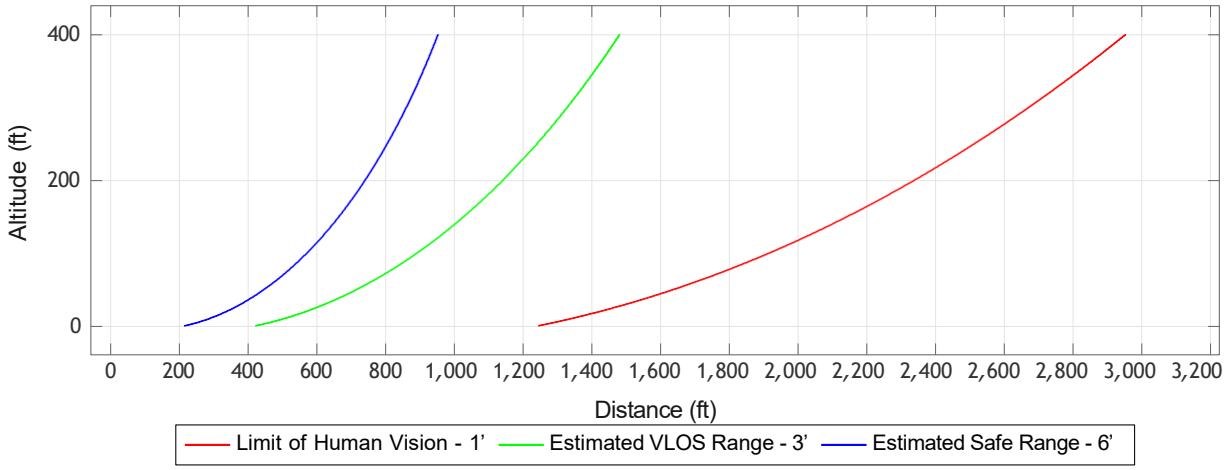


Figure 3.4: Modeled Thresholds for eBee - distance vs. altitude.

Results

A total of 30 evaluation flights were conducted across four different UAS platforms, involving 10 users categorized into three levels of experience (Beginner, Competent, Experienced). This distribution allowed us to compare visual line of sight thresholds both across aircraft types and between pilot skill groups, ensuring that the findings reflect not only platform-specific performance but also variation in human observer capability.

The analysis of the results indicates a generalizable relationship between aircraft size and the maximum reliable VLOS distance. Larger characteristic dimensions (e.g., wingspan for fixed-wing aircraft) extend visibility, while smaller multirotors are constrained to shorter distances. Across observers, a practical operational threshold was identified in the range of 3-6 arc minutes of visual angle, with 3' representing a realistic maximum distance under favorable conditions, and 6' serving as a conservative 'safe' margin. Comparison to EASA's formulas showed that while their ALOS/DLOS estimates were broadly consistent, they tend to overstate visibility compared to empirical observer data, especially for fixed-wing platforms.

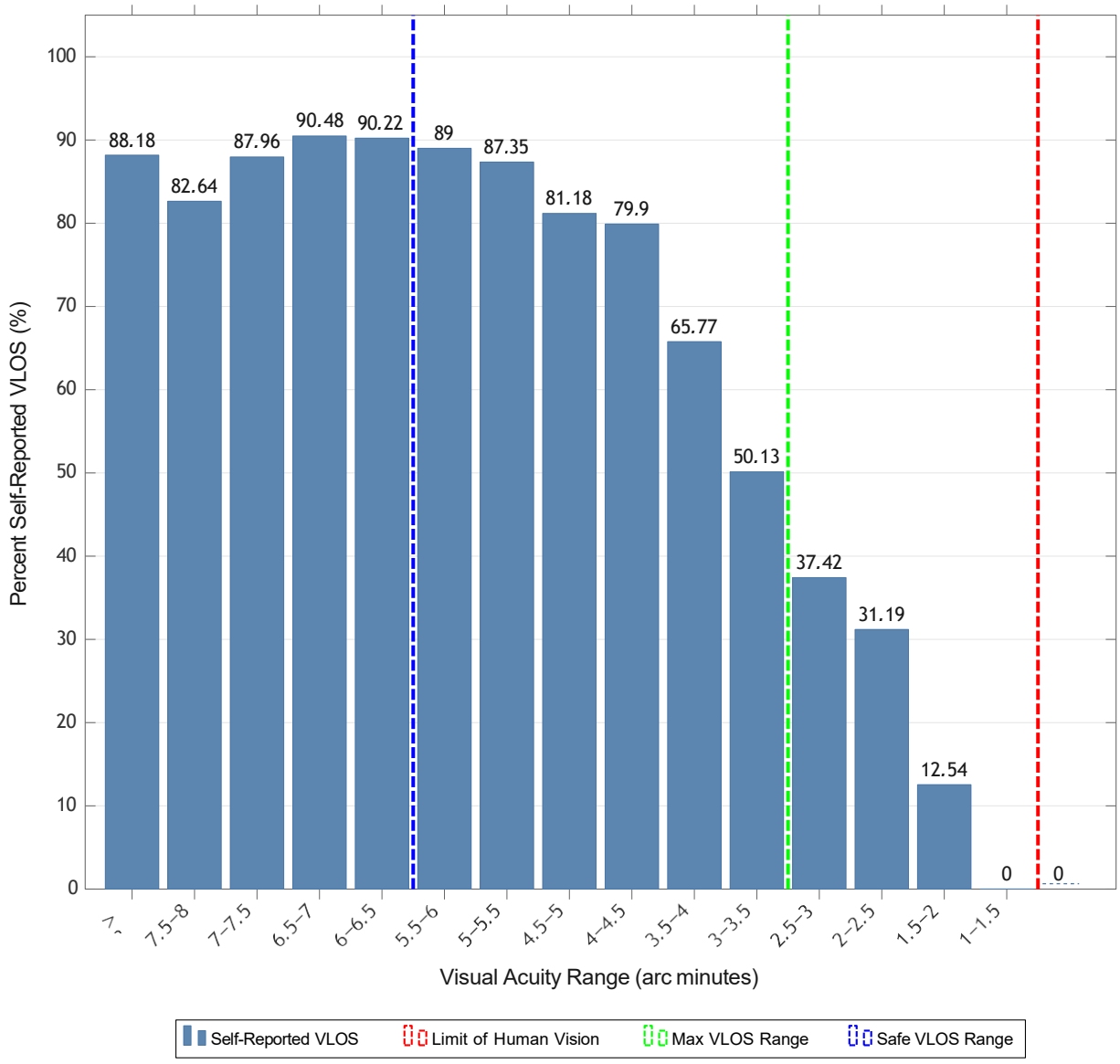


Figure 3.5: Self-reported VLOS by visual acuity range with threshold line.

Breakdown of Users

Receiver Operator Characteristic (ROC) curves and Youden's Index were used to estimate the optimal thresholds for self-reported VLOS detection. The optimal threshold (in arc minutes) represents the acuity point at which the true positive and false positive rates are best balanced. The area under the curve (AUC) serves as a measure of predictive performance, where a value above 0.5 indicates performance better than random guessing.

Background on ROC and Youden's Index

A Receiver Operator Characteristic (ROC) curve is a plot of the true positive rate (sensitivity) against the false positive rate (1-specificity) across a range of possible thresholds. It is widely used in signal detection, medical diagnostics, and classification problems to evaluate the discriminative ability of a binary classifier. The area under the ROC curve (AUC) provides a single scalar value summarizing this performance: an AUC of 1.0 indicates perfect separation, whereas an AUC of 0.5 indicates no better than random chance.

Youden's Index (J) provides a simple way to identify the "optimal" cutoff on an ROC curve. It is defined as:

$$J = \text{Sensitivity} + \text{Specificity} - 1,$$

with values ranging from 0 (no discriminative ability) to 1 (perfect classification). The threshold that maximizes J represents the best balance between correctly identifying true positives and minimizing false positives. In this analysis, the optimal angular threshold for VLOS was determined using the maximum Youden's Index for each observer-drone combination.

Table 3.4 summarizes the optimal thresholds by drone type and observer skill level. Results demonstrate a clear trend: more experienced observers consistently required lower angular thresholds to maintain VLOS, while beginners tended to rely on higher thresholds. Variability was most evident in intermediate users. Drone platform also played a significant role, with fixed-wing aircraft (e.g., eBee) generally producing lower thresholds than multirotors.

Skill Level	Ebee	Autel	Inspire	Mini	Avg
Experienced	3.15	4.34	3.33	2.80	3.41
Competent	2.74	X	4.07	3.04	3.28
Beginner	X	5.42	3.86	3.41	4.23
Mean	2.95	4.88	3.76	3.08	3.64

Table 3.4: Optimal thresholds (arc minutes) by drone type and observer skill level. Missing values are denoted with "X."

Threshold Trends and Model Performance

Across platforms, thresholds generally decreased with user experience, indicating that more skilled observers were comfortable at longer distances. Beginners consistently reported the highest thresholds, while advanced users required less angular size to maintain VLOS. Intermediate users were the most variable, sometimes performing closer to beginners, suggesting inconsistency in judgment.

Performance also differed by platform. Multirotors such as the Inspire 2, Mini 2, and Autel Evo 2 Pro V3 followed the expected trend of decreasing thresholds with experience, though the Autel required higher thresholds overall. The fixed-wing eBee showed an unexpected reversal, with advanced users reporting slightly higher thresholds than intermediates, likely related to its changing profile depending on viewing angle.

Model performance, as measured by AUC, further supports these findings. Advanced users maintained consistently high AUC values (above 0.96) across platforms, indicating reliable self-assessment. Beginners showed strong consistency on some platforms (Autel, Inspire), while intermediates exhibited the lowest AUCs, particularly with the eBee, suggesting difficulty in consistent decision-making.

Overall, the results demonstrate that both skill level and aircraft type influence VLOS thresholds, with platform shape and viewing geometry emerging as critical factors.

Implications for Fixed-Wing Operations

These findings are particularly relevant for Part 107 fixed-wing operations. Unlike multirotors, fixed-wing aircraft do not hover and present narrow profiles when viewed head-on or tail-on, making orientation harder to judge. At operational speeds, even minor misperceptions of orientation can quickly erode situational awareness. Results from the eBee evaluation reflected this challenge: thresholds for maintaining VLOS did not consistently decrease with observer experience, and AUC values were markedly lower than for multirotor platforms. This inconsistency highlights how fixed-wing geometry and changing visual profiles complicate visual detection and orientation cues. Taken together, these data suggest that effective VLOS for fixed-wing aircraft may be substantially shorter than current operational practice assumes. Without explicit, empirically informed thresholds, operators face heightened risk of unintentional noncompliance with §107.31 and increased hazard exposure in the National Airspace System. A simple calculator with these thresholds in mind can be implemented to assist with flight planning to ensure VLOS.

3.4 Scenario-Based Testing

A structured series of training and mission scenarios was conducted to evaluate the suitability of various UAS platforms for Caltrans operations. The scenarios represented both entry-level and advanced operational contexts, beginning with introductory training on small and large multirotor systems. This structure enabled measurement of learning curves, pilot proficiency, and operational performance as participants transitioned from lightweight, low-risk drones to heavier and more complex aircraft.

Subsequent scenarios focused on mission-specific tasks, including infrastructure inspection and survey operations. Platforms assessed included small and large multirotors, tethered drones, fixed-wing aircraft, VTOL systems, and controller-less platforms, providing a representative cross-section of technologies applicable to Caltrans field missions.

All scenarios were documented to explore mission planning, execution, and post-flight activities, forming the basis for identifying training needs, operational planning requirements, and system support functions. The process provided insight into both individual platform performance and the organizational capabilities required to integrate these systems into statewide operations.

Each scenario emphasized aircraft performance, operator adaptability, and alignment with operational objectives and constraints. The following subsections describe the testing environments and evaluation results for each platform.

3.4.1 Introductory Drone Training

This scenario introduced pilots to both small and large multirotor systems in a controlled training environment.

- **Objective:** Establish baseline pilot comfort with basic flight controls and maneuvering.
- **Platforms:** Small multirotors (< 1.2 lbs) and large multirotors (e.g., Freefly Astro, DJI Matrice 200).
- **Focus:** Differences in skill acquisition, confidence near structures, and time required to achieve safe proficiency.

3.4.2 Drone Infrastructure Inspection (Manual Flying)

This scenario replicated common inspection activities where pilots must manually navigate close to structures such as bridges or roadways.

- **Objective:** Assess pilot ability to maintain control and situational awareness in constrained environments.
- **Platforms:** Small multirotors (< 1.2 lbs) and large multirotors (e.g., Freefly Astro, DJI Matrice 200).
- **Focus:** Precision flight near obstacles, operational stress due to aircraft size or cost, and the role of tethered systems in extended-duration inspections.

3.4.3 Survey Mission

This scenario emphasized systematic area coverage for data collection, such as mapping or terrain surveys.

- **Objective:** Evaluate platform performance in extended flight patterns and autonomy use.
- **Platforms:** Small multirotors (< 1.2 lbs) and large multirotors (e.g., Freefly Astro, DJI Matrice 200), and eBee fixed-wing aircraft. Wingtra VTOL was observed only.
- **Focus:** Efficiency of flight planning, effectiveness of autonomy tools, adequacy of landing zone requirements, and challenges unique to fixed-wing and controller-less platforms.

3.5 Platform Functionality

The transition from small, entry-level UAS platforms to larger and more advanced systems introduces challenges that extend beyond basic flight control. While initial training in the Caltrans UAS Program emphasizes lightweight, multi-rotor aircraft, student feedback demonstrates that platform size, system complexity, and autonomy features significantly influence the rate of skill acquisition and confidence development. In practice, the transition from small drones to larger or more specialized platforms creates new demands on pilot training, risk management, and operational oversight.

The following subsections summarize observations from training scenarios. Each highlights a factor where platform functionality directly affects the learning curve and readiness of pilots.

3.5.1 Increased Platform Size Prolongs Skill Acquisition

Students reported that moving from small drones (e.g., < 1.2 lbs) to larger aircraft such as the Freefly Astro or Matrice 200 fundamentally altered the pace at which proficiency was achieved. With small UAS, pilots typically reached basic control comfort within one or two flights, and most developed confidence operating near structures after five to eight flights.

In contrast, larger UAS (> 10 lbs) generally required ten to fifteen flights before operators expressed similar levels of control comfort, and many continued to indicate hesitancy when flying in proximity to obstacles. The increased inertia of larger systems, slower response times, and higher potential for damage contributed to slower skill acquisition.

Students also noted the effect of cost and consequence: operating more expensive aircraft introduced additional stress, which in turn influenced their willingness to attempt precision maneuvers. This was especially evident during takeoff and landing phases, where the perceived risk of error was highest.

Overall, these findings indicate that larger platforms require not only greater flight time but also structured progression through increasingly complex environments, supported by supervision and deliberate practice.

3.5.2 Increased System Complexity Requires Extended Familiarization

The complexity of advanced systems was also identified as a major factor affecting learning. Platforms such as the Freefly Astro or Skydio X10 demanded mastery of autonomy features, advanced camera configurations, and failsafe settings in addition to basic flight operation.

The Ground Control Station (GCS) software associated with these platforms was frequently described as challenging, with dense interfaces and unfamiliar workflows. Students expressed reluctance to engage with advanced functions, citing concerns about triggering unintended behaviors or struggling to interpret the system's responses. This led to slower adoption of automation and extended reliance on manual modes even when autonomous features were available.

Additional observations pointed to the operational burden of supporting tasks, including mission planning, sensor calibration, and data management. Students observed that these activities often consumed as much or more time than flight operations themselves, underscoring the importance of treating operational readiness as encompassing the full workflow, not solely in-flight control.

These findings suggest that training for advanced platforms must devote equal emphasis to system software, mission planning, and automation literacy, ensuring that pilots are prepared to manage both flight and supporting operational processes.

3.5.3 Reduced Manual Control Increases Planning Requirements

Several advanced platforms provided limited manual override capability, or in some cases none at all. This absence of direct intervention options significantly altered how operators prepared for missions.

Students reported devoting considerably more effort to pre-flight planning, including route validation, obstacle review, and contingency development. Even in relatively simple operational environments, many described a heightened sense of risk because they were unable to intervene directly once the system was airborne.

Access to high-quality simulation and route preview tools was identified as an essential element for building trust in the platform's logic. Where such tools were absent or insufficient, students expressed significantly lower confidence in proceeding with planned missions.

In this context, preparation and rehearsal became as important as flight practice itself. Effective training for such platforms must therefore emphasize pre-flight validation and system understanding, ensuring operators can anticipate and mitigate risks in the absence of manual intervention.

3.5.4 Expanded Awareness of System-Level Requirements

Progression into fixed-wing and autonomous platforms broadened the scope of factors that students considered during operations.

Radio control link quality, rarely emphasized in small drone training, became a primary concern, with students monitoring signal strength and line-of-sight conditions more closely. Landing area requirements also shifted; a five-foot landing pad was regarded as insufficient for larger or more autonomous platforms, with students planning expanded and clearly marked zones that accounted for potential GPS drift and reduced manual correction options. Fixed-wing aircraft introduced additional demands, including approach and departure path planning, wind alignment, overshoot areas, and the management of linear runway environments. These considerations were markedly different from vertical takeoff and landing operations, requiring new habits and procedures.

Finally, as operational complexity increased, the role of the crew became more significant. Students emphasized the importance of clear role definition-such as pilot, visual observer, and safety officer-and reported improved performance when these roles were formally assigned rather than assumed.

These observations suggest that advanced training must extend beyond individual flight proficiency to include site management, communications discipline, and structured crew resource management.

3.5.5 Summary

Taken together, these findings demonstrate that advanced pilot development cannot be treated as platform-agnostic. Larger and more complex systems slow the acquisition of flight proficiency, require substantial familiarization with autonomy tools, and demand greater attention to system-level planning and crew coordination.

Without structured pathways for exposure, practice, and evaluation, operators experience uneven progress and elevated uncertainty when transitioning to advanced platforms. These findings reinforce the need for a formalized pilot advancement framework that accounts for differences in size, complexity, and autonomy, ensuring readiness is defined not simply by hours of flight time, but by demonstrated competence across a range of UAS categories.

Operation Requirements	Small MR	Large MR	Fixed-Wing	VTOL	Controller-less	Tethered
Regulatory Knowledge						
Part 107 License	x	x	x	x	x	
Airspace Management	x	x	x	x	x	x
Control Interface						
Hovering Motion Control	x	x		x		x
Forward Flight Motion	x	x	x	x		
Non-Stabilized Control			x			
Camera Controls	x	x				x
Advanced Autonomy		x		x	x	
Emergency Response	x	x	x	x	x	x
Ground Station Software		x	x	x	x	
Operational Management						
Close-range Awareness	x	x			x	x
Long-range Awareness			x	x	x	
TLOF Management	x	x		x		
Runway Management			x			
Contingency LZ (CLZ)	x	x	x	x	x	
Telemetry Management			x	x	x	
Planning & Simulations			x	x	x	

Table 3.5: Operational requirements by platform. Green = currently in use but not needed for advancement. Orange = not currently in use but necessary for advancement.

3.6 Automation and Integration

The shift toward advanced automation and network integration is transforming how Caltrans conducts UAS operations. Platforms now feature adaptive flight control, real-time connectivity, and AI-assisted analytics, all of which redefine the human-system interface. These changes promise efficiency and standardization but also introduce new challenges for reliability, safety management, and operator training.

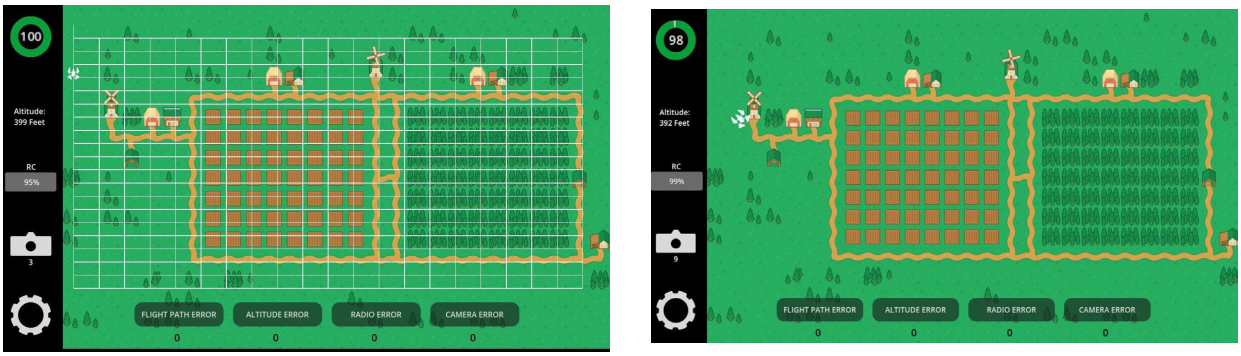
3.6.1 Automation and Connectivity in Field Operations

Some new platforms are now marketed with advanced networked functionality, such as the Freefly Astro, Skydio Dock system, and LTE-enabled mission software suites. These systems promise near-real-time telemetry, automated data uploads, and live video streaming for mission coordination.

However, in testing the Skydio X10's 5G connectivity performance, actual use did not meet expectations. On the UC Merced campus, with generally strong 5G signal strength (4+ bars), pilots reported noticeable latency and buffering that made precise operations challenging when operating through first-person view. In weaker coverage regions, repeated command dropouts forced early mission termination. Operators consistently cited reduced trust when live video and telemetry lagged, even with half-second drop-outs. Further testing was not conducted.

3.6.2 Human-Automation Interaction and Cognitive Load

A controlled experiment was conducted to examine how operators detected and responded to system anomalies under two autonomy paradigms: (i) **planned autonomy**, in which the flight path was visible and pre-validated by the operator prior to launch (Figure 3.6a), and (ii) **reactive autonomy**, in which the aircraft adapted its path dynamically without displaying a planned trajectory (Figure 3.6b). Eight participants ($N = 8$) completed a series of simulated missions, each containing 21 potential anomaly events drawn from three categories: *camera*, *flight-path*, and *hardware* errors. Participants were instructed to identify anomalies in real time; both their reaction lag (time between cue onset and acknowledgment) and detection accuracy (proportion of correctly identified events) were recorded. Blank responses represented missed detections. Variability is reported at two levels: the mean within-participant standard deviation ($\mathbf{SD}_{within}$), representing trial-to-trial consistency, and the between-participant standard deviation ($SD_{between}$), representing variability in participant means.



(a) Planned-autonomy condition.

(b) Reactive-autonomy condition.

Figure 3.6: Reactive Autonomy Simulation under two conditions.

Performance under Planned Autonomy.

When the motion path was known, participants demonstrated moderate overall performance with notable variation across categories (Table 3.6). For Camera Errors, mean lag was relatively long ($M = 3.20$ s), and within-participant variability was high ($SD_{within} = 0.83$), indicating inconsistent reaction times across trials. Accuracy averaged 75%, suggesting that most stimuli were successfully detected. Flight Path errors produced shorter mean lags ($M = 2.61$ s) and slightly reduced within-participant variability ($SD_{within} = 0.75$), but accuracy declined to approximately 54%. Hardware errors (altitude and radio) displayed a similar mean lag ($M = 2.75$ s) and the highest between-participant variability ($SD_{between} = 0.49$), with accuracy near 50%. Taken together, results from planned autonomy indicate that while predictability of motion supported consistent detection of camera errors, flight path and hardware errors elicited faster yet less accurate responses, suggesting trade-offs between speed and precision.

Error Type	Mean Lag (s)	SD_{within} (s)	$SD_{between}$ (s)	Accuracy (%)
Camera	3.20	0.83	0.17	75.0
Flight Path	2.63	0.75	0.33	53.6
Hardware	2.75	0.64	0.48	50.0

Table 3.6: Reaction lag and detection accuracy under planned autonomy.

Performance under Reactive Autonomy.

Under reactive autonomy, participants exhibited more variable patterns of response and overall declines in detection performance (Table 3.7). Camera errors showed a reduction in mean lag ($M = 2.33$ s) and lower within-participant variability ($SD_{within} = 0.52$), yet between-participant variability increased markedly ($SD_{between} = 0.36$). Accuracy decreased to 63%, reflecting reduced reliability of detection. For flight path errors, mean lag increased slightly to $M = 2.86$ s while accuracy dropped sharply to 32%, the lowest across all conditions. Hardware errors maintained a comparable mean lag ($M = 2.81$ s) but exhibited higher within-participant variability ($SD_{within} = 0.77$) and moderate accuracy (64%). Overall, unpredictable trajectories appeared to increase cognitive load, producing less uniform response profiles across participants.

Error Type	Mean Lag (s)	SD_{within} (s)	$SD_{between}$ (s)	Accuracy (%)
Camera	2.33	0.52	0.36	62.5
Flight Path	2.85	0.41	0.43	32.1
Hardware	2.80	0.77	0.29	64.3

Table 3.7: Reaction lag and detection accuracy under reactive autonomy.

Analysis

Paired differences highlight how the removal of flight-path preview affected operator behavior. When comparing the planned- and reactive-autonomy missions (Table 3.8, Figure 3.7, and Figure 3.8), distinct patterns emerge across categories. For Camera errors, reaction times decreased (from 3.20 s to 2.33 s), but accuracy also declined ($75\% \rightarrow 63\%$) and between-participant variability doubled, indicating faster but less consistent responses. For Flight Path errors, mean lag slightly increased ($2.61 \rightarrow 2.86$ s) while accuracy decreased substantially ($54\% \rightarrow 32\%$), showing that the unpredictable path strongly impaired both timing and detection. Hardware errors exhibited relatively stable mean lags ($2.75 \rightarrow 2.81$ s), yet within-participant variability rose and accuracy improved modestly ($50\% \rightarrow 64\%$), suggesting partial adaptation to reactive conditions. Across all categories, the loss of path predictability reduced accuracy and increased inter-participant divergence, consistent with degraded perceptual certainty and greater attentional demand under uncertainty. Together, these results reinforce that reactive autonomy did not lessen operator workload but redistributed it, shifting cognitive effort from manual control to continuous monitoring and verification of system behavior, an effect explored further in the following section.

Error Type	Δ Lag (s)	Δ Accuracy (%)
Camera	−0.87	−12.5
Flight Path	+0.22	−21.5
Hardware	−0.05	+14.3

Table 3.8: Change in lag and accuracy from planned to reactive autonomy (reactive - planned).

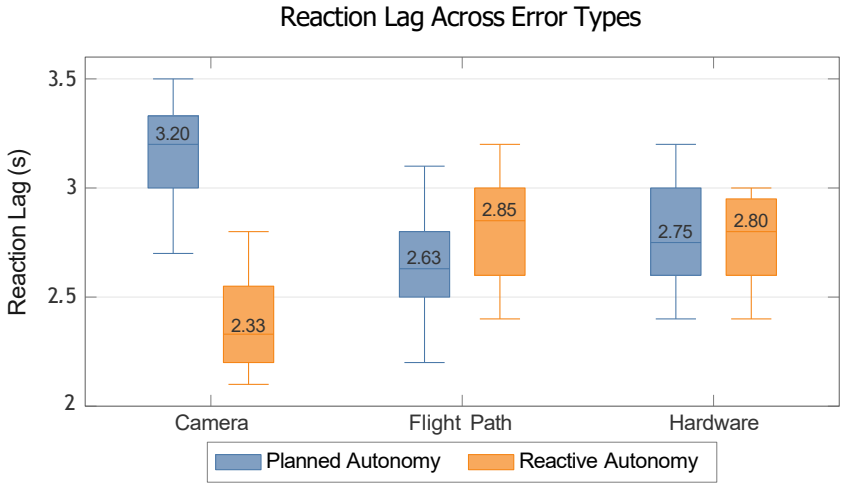


Figure 3.7: Distribution of mean reaction lag across error types under planned and reactive autonomy.

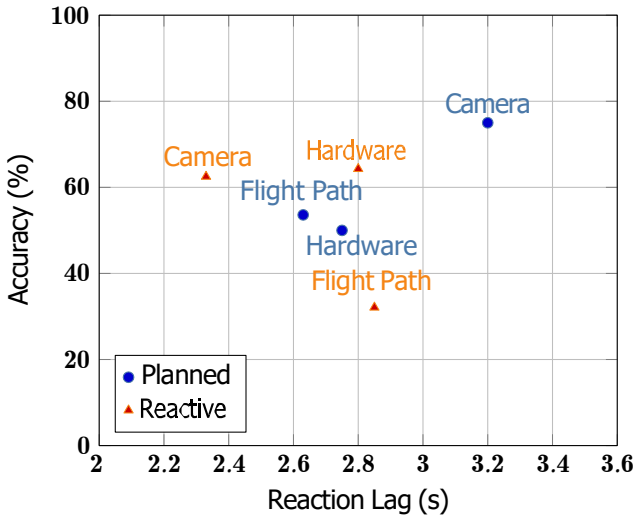


Figure 3.8: Relation of Mean Accuracy and Lag

3.6.3 Operational Implications and Evolving Roles under Autonomy

These findings highlight that automation introduces new forms of workload and decision-making. Under planned autonomy, pilots anticipated behavior and divided attention among navigation, telemetry, and visual feedback; under reactive autonomy, manual effort decreased but cognitive demand rose as operators monitored and verified system behavior. Operator performance increasingly depends on understanding and managing automation rather than direct control.

Training Gaps and Cognitive Demands

The Caltrans UAS Training Program has historically emphasized manual flight proficiency and airspace awareness under Part 107. While foundational, this focus does not yet address the supervisory and diagnostic reasoning skills required under autonomy. Two primary shortfalls define this gap:

- **Cognitive integration:** Training lacks structured exercises in automation transparency, mode awareness, and fault recognition.
- **Supervisory mindset:** Instruction remains centered on flight control rather than managing automated decision processes.

Addressing these will require developing *autonomy management competency*, the ability to interpret system logic, anticipate automated behavior, and identify deviations from mission intent.

Emerging Roles under Part 108

The proposed Part 108 framework formalizes this evolution, distinguishing between manual and supervisory functions. Where Part 107 defines the **Remote Pilot in Command (RPIC)** as the operator in direct control, Part 108 introduces the **Flight Coordinator (FC)**, emphasizing oversight, coordination, and management of autonomous or BVLOS missions. Under § 108.310, flight coordinators must remain qualified, current, and proficient, maintaining **time in type** for each platform. For Caltrans, this shifts recordkeeping from missions completed to cumulative hours and recency per make and model.

These developments point toward two complementary pathways:

- **Part 107 (Manual Operations):** Focused on flight control, situational awareness, and safety.
- **Part 108 (Supervisory Operations):** Focused on automation oversight, coordination, and multi-system management.

Caltrans currently lacks a structured transition between these roles, leaving a gap between pilot training and supervisory qualification.

Competency and Training Continuity

Preparing for higher autonomy requires new skill domains that complement traditional piloting:

- **Automation literacy**, understanding how sensors, algorithms, and environmental factors shape system behavior;
- **Supervisory control**, maintaining oversight, recognizing degraded modes, and intervening effectively;
- **Scenario-based learning**, practicing anomaly response and recovery procedures; and
- **SMS integration**, embedding automation metrics into safety reporting.

To maintain continuity, Caltrans training can evolve in two stages:

1. **Integrated Module (current):** Builds on Part 107 competencies while introducing automation oversight.
2. **Onboarding Module (future):** Dedicated Part 108 pathway for personnel entering directly into supervisory or coordination roles.

Summary

Reactive autonomy did not reduce workload but redefined it toward cognitive monitoring and decision verification. Current training develops capable pilots but not yet effective supervisors of autonomy. Bridging this gap, through autonomy management training, structured progression, and data-driven oversight, will be essential as Caltrans transitions toward organizational-level operations under future Part 108 frameworks.

3.6.4 Integration with the Caltrans UAS Safety Management System

The growing use of automation in Caltrans operations requires a Safety Management System (SMS) capable of integrating both human and machine-derived safety data. As UAS platforms transition from pilot-controlled to increasingly autonomous systems, traditional reporting frameworks, built around manual flight actions and event logs, must evolve to capture and evaluate the performance of automation itself. This subsection outlines how automation data can be incorporated into Caltrans' SMS to improve transparency, accountability, and predictive safety analysis.

Oversight and Data Integration

As autonomy increases, effective supervision depends on data traceability and the quality of system feedback. Automated operations generate extensive telemetry, diagnostics, and mission metadata, yet few commercial platforms translate these into actionable safety information. For the Caltrans Safety Management System, and as part of the transition to Part 108 requirements, the goal is to move from descriptive data capture toward predictive insight, linking human and automation performance to identify precursors to risk. This requires expanding data collection beyond flight duration or positional accuracy to encompass:

- **Automation performance**: including success or failure rates of autonomous behaviors such as obstacle avoidance, return-to-home, and mode transitions;
- **Human-automation interactions**: documenting interventions, overrides, or replanning events that indicate workload or trust thresholds;
- **System health and connectivity**: recording latency, link quality, and throughput affecting supervisory awareness; and
- **Contextual safety data**: such as near misses, airspace incursions, or environmental conditions that shape system behavior.

Consistent capture of these dimensions requires linking telemetry to post-mission evaluations, enabling staff to trace not only *what* occurred but *why*. Current autonomy platforms, such as Skydio Dock and Auterion Suite, record telemetry and maintenance data but lack mechanisms for reporting hazards, missed detections, or causal factors. Under the proposed Part 108 framework, organizations remain responsible for documenting automation anomalies and demonstrating corrective actions through their SMS.

3.6.5 Policy and Programmatic Considerations

Automation shifts operational accountability from individual pilots to organizational oversight. Under the proposed Part 108 framework, operators such as Caltrans will be evaluated on their ability to maintain a documented system

of qualification, currency, and safety assurance. This marks a transition from individual licensure under Part 107 to institutional responsibility for verifying competency, experience, and system reliability. Future operators may function primarily as system managers, accountable for data quality, signal integrity, and automation performance.

Organizational Accountability under Part 108

Sections 108.310 and 108.315 require operators to ensure that Flight Coordinators remain qualified and current, with validity maintained within a 24-month cycle. The new requirement for time in type obliges organizations to track cumulative operating hours and recency for each platform. For Caltrans, this entails:

- **Centralized qualification tracking** linking operators to verified experience and automation training records;
- **Automation-specific proficiency checks** addressing supervisory control and multi-system coordination;
- **Data governance protocols** defining ownership, retention, and validation of telemetry-derived safety data;
- **Alignment of training** to Caltrans' qualification standards.

Automation and connectivity can enhance efficiency and situational awareness but demand parallel evolution in training, and policy. For Caltrans, this means expanding qualification frameworks to include automation oversight and maintaining transparency in how autonomous systems are supervised. The goal is not to replace human judgment but to ensure that autonomy strengthens organizational accountability and safety assurance.

Chapter 4

Summary

4.1 Summary

Chapter 2 and 3 together describe how Caltrans' Unmanned Aircraft Systems (UAS) program is evolving from a collection of field practices into a structured, data-driven safety organization. Chapter 2 examined the current Safety Management System (SMS), identifying its strengths, gaps, and readiness for transition to emerging FAA Part 108 regulations. Chapter 3 extended that analysis to the aircraft platforms themselves, showing how advances in autonomy, connectivity, and new vehicle types reshape operator training, data integration, and organizational oversight.

The SMS review in Chapter 2 found a well-established foundation of policy and documentation but uneven implementation in risk management, data traceability, and continuous improvement. Flight-record analysis showed low submission and inconsistent data entry, limiting feedback loops between hazards, outcomes, and lessons learned. The hazard-analysis form captured little variation across missions, suggesting the need for shorter, better-targeted questions and clearer phasing between planning and on-site checks. Survey and participant feedback confirmed that while pilots value structure and peer support, they experience administrative redundancy and limited access to tools and training. Improvements in data systems, such as transitioning from flat Smartsheet tables to relational, log-based records, will be essential for future scalability and regulatory compliance.

Chapter 3 demonstrated how platform technology now challenges traditional pilot roles. Tethered, fixed-wing, and VTOL systems introduce longer flight durations, new ergonomic and human-factors demands, and reliance on automation. Experimental studies showed that autonomy redistributes rather than reduces workload: pilots shift from manual control to cognitive monitoring and verification of system behavior. These findings underline the importance of training for automation literacy, supervisory control, and situational awareness. As autonomy and connectivity increase, the SMS must expand to capture automation-specific metrics, linking telemetry, human interventions, and system reliability into predictive safety insight.

Together, these sections establish a clear progression from institutional readiness to operational validation. Caltrans has the foundational policies and culture to support safe UAS operations; the next step is integrating structured data, advanced training, and automation oversight within a unified SMS framework. Aligning policy, technology, and human performance under this model will position Caltrans to meet forthcoming Part 108 standards and ensure a resilient, adaptive UAS program capable of supporting statewide infrastructure missions.

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Chapter 5

Appendix

5.1 Review of the Safety Management System Documentation

Table 5.1: Caltrans UAS SMS Program Checklist

Category	Subcategory	Checklist Item	Y/N	Notes
Policy Structure and Clarity	Document Organization	Is the policy structured with clear sections (e.g., Purpose, Scope, Roles and Responsibilities, Procedures)?	Y	
		Are tables of contents, definitions, and abbreviations included for ease of reference?	Y	
	Language and Terminology	Is the language clear, concise, and accessible to all personnel?	Y	
		Are industry-specific terms defined to avoid ambiguity?	N	Need to include additional terminology
	Additional Clarity	Is the policy reviewed to ensure clarity for all team members?	Y	
	Definitions and Abbreviations	Are abbreviations and definitions updated regularly?	N	Needs updating
Leadership Commitment and Safety Culture	Leadership Endorsement	Is the safety policy endorsed by leadership to show commitment to safety?	Y	
		Is there evidence that safety objectives are prioritized at all organizational levels?	N	Documentation doesn't include details on delegation to districts and divisions
	Safety Culture	Does the policy emphasize a 'just culture' where employees can report incidents without fear of punishment?	N	Missing anonymous or low-barrier reporting
		Are there explicit statements promoting open communication, learning from incidents, and continuous improvement?	N	Missing feedback mechanisms
	Safety Goals Prioritization	Are there mechanisms to enable participation in SMS	N	Working Groups mentioned, but not defined
Policy Scope and Applicability	Operational Scope	Does the policy clearly define which UAS operations it applies to (e.g., training flights, BVLOS operations, inspection missions)?	N	Not explicit, but implied

Continued on next page

Table 5.1: Caltrans UAS SMS Program Checklist (Continued)

Category	Subcategory	Checklist Item	Y/N	Notes
		Are both internal and external stakeholders covered (e.g., contractors, consultants)?	Y	
	Integration with Existing Policies	Does the policy align with broader organizational safety goals and regulatory requirements?	Y	
		Does it reference related policies (e.g., emergency response, maintenance, cybersecurity)?	Y	Includes emergency response, purchasing, right-of-way, encroachment. Could use cybersecurity
	Special Use Cases	Does the policy have mechanisms to address unique scenarios?	N	
	Additional Stakeholder Clarity	Does the policy specify any special considerations for contractors?	Y	
Compliance with Regulatory and Industry Standards	FAA and Legal Requirements	Is the policy compliant with FAA regulations (e.g., Part 107, BVLOS, waivers)?	Y	Only covers P107
		Are there references to applicable federal/state/local regulations?	Y	
	Updates and Reviews	Is there a defined schedule for periodic review and updates to ensure ongoing compliance?	N	No explicit reference
	Regulatory Report Submission	Are there documented procedures for submitting regulatory reports (e.g., incident reports to the FAA)?	Y	
Risk Management Framework	Hazard Identification	Does the policy describe processes for identifying operational hazards (e.g., weather, airspace conflicts, equipment failures)?	Y	
	Risk Assessment	Is there guidance on conducting risk assessments using tools such as risk matrices?	N	Could benefit from a shared description of risk
	Mitigation Strategies	Does the policy outline risk mitigation measures (e.g., safety protocols, pre-flight checks, contingency plans)?	N	Some processes defined, but could benefit from additional guidance
	Documentation of Hazards	Is a formal log of hazards maintained for review?	N	
Roles and Responsibilities	Defined Roles	Are key roles and responsibilities (e.g., UAS operators, safety managers, crew members) clearly defined?	N	Needs additional personnel defined
		Is there a dedicated point of contact for safety concerns and incident reporting?	Y	
		Are there documented backup roles in case key safety personnel are unavailable?	N	Backup roles for the program
	Accountability	Is accountability established for ensuring safety procedures are followed?	N	No follow through described
		Are supervisors and team leaders responsible for implementing corrective actions after incidents?	N	Not explicitly mentioned
Safety Promotion and Training	Safety Communication	Are there procedures for communicating safety-related information (e.g., incident reports, lessons learned)?	N	
		Does the policy mandate regular safety meetings or briefings?	Y	

Continued on next page

Table 5.1: Caltrans UAS SMS Program Checklist (Continued)

Category	Subcategory	Checklist Item	Y/N	Notes
	Training Requirements	Are there provisions for initial and recurrent training of UAS operators and support staff?	N	Initial training, but recurrent training not described
		Is training content updated to reflect new regulations, technologies, and incidents?	N	
	Training Updates	Are training modules reviewed for updates on a regular basis?	N	
	New Technology Awareness	Is there awareness training for emerging technologies?	N	
	Emergency Drill Frequency	Is there a schedule for conducting emergency drills?	N	
Emergency Preparedness and Response	Emergency Scenarios	Does the policy include detailed emergency response plans for different failure modes (e.g., flyaway, mid-air collision, payload failure)?	N	
	Communication Protocols	Are procedures in place for notifying air traffic control (ATC), emergency services, and internal stakeholders during an emergency?	N	
	Recovery Procedures	Does the policy specify post-incident actions, such as recovery of the UAS and securing evidence?	N	
	Debrief After Emergency	Is there a post-emergency debrief process for lessons learned?	Y	
Incident Reporting and Investigation	Incident Reporting	Is there a clear process for reporting incidents, near-misses, and hazards?	N	Yes for Incidents, injury, illness and property damage, but not 'near-misses'
		Is there a system for anonymous reporting if necessary?	N	
	Incident Investigation	Are there procedures for conducting root-cause analyses of incidents?	Y	
	Near-Miss Follow-up	Are follow-ups done for near-misses to identify potential trends?	N	
	Improvement After Incidents	Are improvements implemented after incident investigations?	N	
Continuous Improvement and Performance Monitoring	Safety Metrics	Are there KPIs (Key Performance Indicators) to measure safety performance (e.g., number of incidents, corrective actions implemented)?	N	
	Audits and Reviews	Are regular internal audits of safety processes and policies conducted?	N	
		Is feedback from audits and reviews used to make policy improvements?	N	
		Are audit results shared with leadership?	N	
	Use of Historical Data	Is historical data used to improve risk assessments?	N	
	Feedback Loops	Are feedback loops in place to update processes based on lessons learned?	N	
Integration of New Technologies and Innovations	Adaptability	Does the policy address new operational modes (e.g., BVLOS, autonomous systems, tethered UAS)?	N	

Continued on next page

Table 5.1: Caltrans UAS SMS Program Checklist (Continued)

Category	Subcategory	Checklist Item	Y/N	Notes
	Technology-Specific Guidelines	Are there protocols for incorporating new technologies (e.g., detect-and-avoid systems, automated docking stations)?	N	
	Cybersecurity	Does the policy include measures to prevent unauthorized access to UAS communication and control systems?	N	
	Protocols for AI Systems	Are there guidelines for testing AI and automation before full deployment?	N	
	Decommissioning Outdated Systems	Is there a process for decommissioning outdated or retired systems?	N	

5.2 Hazard Analysis Form

5.2.1 Pre-Flight

Table 5.2: Final Pre-Flight Hazard Analysis Form

#	Question	Features / Options
1	Airspace Class	Drop-down list: Class A-G (default G). If not G, select authorization: LAANC, COA, Not Needed.
2	Aviation Activities Nearby	Multi-select: Small Private Airstrips, Agricultural Aviation, Special Use Airspace (Restricted, Alert, Warning, MOA), Heliports, Gliders/Parachutes, Other, None.
3	Weather Forecast	Multi-select: High Heat (>95°F), Freezing (<32°F), Moderate Winds (>10 mph), Reduced Visibility (Fog, Haze, Smoke), Rain/Snow, Other.
4	Common Hazards in Flight Zone	Multi-select: Tall Trees, Powerlines, Roads/Traffic, Pedestrian or Bicycle Paths, Cranes, Buildings, Wildlife, Other, None. Prompt: "Think about what you would tell someone flying at this site for the first time."
5	Familiarity with Location	Drop-down: Very Familiar - visited recently; Somewhat Familiar - been here before; Not Familiar - similar sites only; Unfamiliar - new site.
6	Operational Items	Multi-select: ROW Permissions, Long-Distance Ops (>500 ft), Radio Communication, Multiple/Coordinated Flights, Operations Near People, Autonomy Use.
7	Map of Operations Area	Yes/No. If Yes, attach map of flight path.

5.2.2 Onsite Checklist

Table 5.3: Final Onsite Hazard Analysis (HA 2) Form

#	Question	Checkbox
1	Was the pre-flight hazard analysis complete and accurate?	Yes/No. If No, describe what was missed.
2	Is the airspace suitable for flight operations?	Yes/No.
3	Is visibility at or above three statute miles?	Yes/No.
4	Have all required permits and authorizations been secured?	Yes/No.
5	Is the flight crew adequately protected from roadway or site hazards?	Yes/No.
6	Is reliable communication available (cell or radio)?	Yes/No.
7	Are first-aid kit and fire extinguisher on-site and accessible?	Yes/No.
8	Is the operation adequately staffed for safety?	Yes/No.
9	Has the flight crew been briefed and aware of duties?	Yes/No.

Continued on next page

Table 5.3: Final Onsite Hazard Analysis (HA 2) Form (Continued)

10	Have Temporary Flight Restrictions (TFRs) been checked?	Yes/No.
11	Have weather and wind conditions been verified?	Yes/No.
12	Is there a suitable takeoff and landing zone?	Yes/No.
13	Is there a designated emergency abort site?	Yes/No.
14	Is appropriate Personal Protective Equipment (PPE) in use?	Yes/No.
15	Has the UAS and equipment been checked and safe for operation?	Yes/No.

5.2.3 Post-Flight Addendum

Table 5.4: Added Questions for Post-Flight Review Form

#	Question	User Form
1	Were there any near-misses, anomalies, or unusual events during the operation?	Open text field for operator input.
2	Do you have any concerns or feedback the UAS Program should review (related to this mission or overall program)?	Open text field for feedback.

5.3 Survey Questions

Background

1. How long have you been involved with the Caltrans UAS Program?

- □ Less than 1 year
- □ 1–2 years
- □ 2–3 years
- □ 3–5 years
- □ More than 6 years

2. How often are you involved in leading or acting as a Pilot in Command for a UAS Operation?

- □ Less than once a month
- □ Once a month
- □ 2–3 a month
- □ Once a week
- □ 2–3 times a week

UAS Mission Planning

3. How effective do you feel the UAS Operation Plan form and the Hazard Analysis form are in helping you prepare for a UAS mission?

- □ Not effective at all
- □ Slightly effective
- □ Moderately effective
- □ Very effective
- □ Extremely effective

4. Over the past year, when you conducted a UAS flight operation, how often did you complete the UAS Operation Plan form in each of the following settings? *Please estimate the percentage of operations for each. The total should equal 100%.*

In the office (before going out): _____
In the field (on-site): _____
After the flight: _____
Total: _____

5. Do you have any recommendations for improving the mission planning process?

_____
_____
_____
_____
_____

UAS Program Management and Administration

6. How often do you encounter inconsistencies or gaps between standard operating procedures and real-world mission conditions?

- □ Never
- □ Sometimes
- □ About half the time
- □ Most of the time
- □ Always

7. (Optional) Are there any specific examples of inconsistencies or gaps you'd be willing to share at this time?

_____
_____
_____
_____
_____

8. What factors, if any, are currently making it harder for you to operate safely and effectively as a UAS pilot? *(Select all that apply)*

- □ I feel well supported, no major barriers
- □ Lack of time or competing priorities
- □ Unclear or conflicting expectations from higher up
- □ Limited access to tools, equipment, or resources
- □ Too much administrative burden
- □ Difficulty getting support outside my immediate team
- □ Not enough opportunities for training and development
- □ Other (please specify): _____

Safety Promotion and Communication

9. Do you feel that you have a good support team for questions or support about UAS operations or technology?

- □ I have access to knowledgeable people or resources
- □ I rely more on external resources for guidance
- □ I've asked for help but did not get what I needed
- □ I'm not sure who to go to
- □ I haven't needed support yet

10. Would you find it valuable if the Caltrans UAS Program created more opportunities for UAS operators to share lessons learned, updates, or best practices with each other?

- □ Yes, this would be very helpful
- □ Maybe, it depends on how it's set up
- □ I think the current communication network is working well
- □ I'm not sure

11. Is there anything you would like to see the Caltrans UAS Program work on to support your needs better?

_____
_____
_____
_____
_____

5.4 Survey Results - Text Entry

5.4.1 Recommendations for Improvement to Process

- I don't believe changing the process will make a significant difference in improving the process.
- "I'm not sure we are talking about the same thing. I initiate and complete the ""Pre-flight Data"" smartsheet before going into the field (approx. 75% of data), and then receive an email from CT UAS to finalize the flight data after the flight (25% of data). Email comes immediately after I complete the preflight data but I leave it unread until after the fiight(s).
- Prefer to do preflight data, mission planning, and LAANC check/clearance all in one spot/software."
- combined pre flight forms into one
- There should be one pre-flight form and one post-flight form to fill out for a mission.
- None
- Each district has some unique challenges. I believe some district by district customization of the forms could be helpful.
- Combine any and all forms
- Have not flown for CalTrans.
- none
- The aloft platform was more beneficial as a pilot. Having airspace classification and LAANC all in one place was convenient. The additional features on aloft were better for safe mission planning. Better features for tracking flights and managing missions as well.
- Not at this time.
- Consolidate the UAS Operation Plan form and the Hazard Analysis form. I only use the Hazard Analysis form with my own flight plan and map.
- no
- Combine all in one reporting
- I think the hazard page is time consuming and irrelevant as most hazards are found on site.
- maybe a check list options instead of text boxes required typing. Especially for locations we fly often
- No. We already follow more laws and restrictions than any other drone pilots I know of. Our department follows the rules and plans accordingly.
- I wish the process was faster and there was more training stick time.
- If the UAS program could endorse specific flight planning apps and set up a very short checklist of pre-flight tasks, it would be even more helpful.
- Quarterly reminder of pre-flight procedures and faa safety compliance.
- Include flight map within the UAS Operation Plan form
- more simple forms. more icons photos instead of text.
- I am not sure. I think the platform could be improved. It would be helpful to be able to have links to see the airspace or just a little useable platform.
- It would be helpful to new pilots and pilots who do not fly often to have a training bite/slideshow provided that outlines the helpful websites to determine airspace and weather conditions.
- Get rid of it? A 13-year-old can literally do this. The paperwork just... isn't necessary if there's no incident.

5.4.2 Final Comments

- I am content with the uas program as of now.
- I have found it challenging since I started with the UAS program to use the mission planning tools. There have been multiple changes to the tools/software we are supposed to use, and none of them have been especially user friendly. Having a tool that you can type in a bridge number, identify the area and air space, and get LAANC authorization (if needed) all in one spot would be very helpful. I currently use AirHub Portal and find it frustrating to use.
- It's not that we have a communication channel, but ******* is very good at communicating with the group, so I assume if anything were to be notable, **** would send it along to the group.
- Can't login to Aloft Air Control with my state email anymore for checking airspace prior to flights. I have to use my personal email to access Aloft. This should be fixed.
- Ability to cross or fly over traffic
- mainly more training and/or learning by participating with experienced pilots. Not necessarily safety - but training in efficient flying and different types of projects...also how to create finished products from the photo/video we captured.
- more CT training opportunities or highlight external trainings that remote pilots can request to attend from their respective districts
- Let me fly
- none
- We need more options in equipment. The price of equipment has been hard to justify to most units operating budgets.
- Perhaps hire a second coordinator to off-set the responsibilities and get one who will be more responsive to those like myself who only have a short amount of available time to allocate to taking on the UAS pre-construction flights to capture footage or images of our construction sites.
- Creating UAS crews per district, as work load becomes more
- More hand on training for the processing drone data for earth work quantity.
- It would be nice to have a centralized location discussing different ways to get approval when flying in an airspace. For example, whether to go through LAANC, FAA, etc.
- To have a standard processing software throughout the state. I've used and liked DroneDeploy, but am currently being told to use Trimble Business Center within Construction. I'm not getting the best results with TBC. It could be to the learning curve or the fact I'm using a Skydio x10 now, compared to the DJI Mavic 2 pro that I was previously using.
- more collaborations between construction, surveys, environmental, hydraulics, and others. If asked to fly a location the data may be already available from other units that have flown the area but I have no access or knowledge of their flights.
- No. We don't seem to ever have any issues besides Drone software updates in the middle of a mission, but if we have questions, we often just contact *****.
- Workshop on how to fly certain missions
- quarterly gatherings of UAS pilots. and real world training in person
- caltrans has made it very difficult for a part 107 holder to fly a uas for Caltrans. I currently work with 3 part 107 holders yet they wont fly for caltrans because they dont want to do an online training and travel 6 hours to fresno/merced for 4 hour training

- Not that I can think off hand.
- Obtain drones that are suited to our needs. In geotechnical we predominantly use the drones for mapping, reconnaissance, emergencies, and scans. A drone that can have the flight path pre-planned in the office is crucial to high quality scans.
- Less onerous paperwork.

5.5 §108.40 Operator recordkeeping requirements

Each operator shall keep records of the items listed in paragraphs (a) through (e) of this section per the timelines specified in paragraph (f) of this section and must provide access or copies to the Administrator upon request in a manner acceptable to the Administrator.

a) **Unmanned Aircraft.** Each operator must maintain records on each unmanned aircraft used in operations under this part, including:
   1) The total time in service of each unmanned aircraft.
   2) The status of any life-limited parts.
   3) Records of each flight performed under this part which includes-
      i) The time, date, and duration of the flight;
      ii) The unmanned aircraft registration number;
      iii) The type of operation;
      iv) The individual flight paths of each flight including origin, destination, and altitude(s);
      v) The name of the designated operations personnel assigned to each flight;
      vi) Landing locations (if different from takeoff origin or destination locations);
      vii) For package delivery operations, the pickup points and delivery locations for the flight; and
      viii) For agricultural operations, the name and address of each person for whom agricultural unmanned aircraft services were provided, the date of the service, and the name and quantity of the material dispensed.

b) **Personnel.** Each operator shall maintain records on each operations personnel required by the company operations manual and used in operations under this part, including-
   1) The full name of the individual;
   2) The individual's qualifications in sufficient detail to determine their ability to participate in operations under this part;
   3) The individual's current duties and the date of assignment to those duties;
   4) Any information concerning the individual's release from employment for cause; and
   5) For operators holding an operating certificate pursuant to subpart E of this part-
      i) The dates and times of operations personnel assigned work shifts,
      ii) The length of the rest period prior to each duty period for each of the required operations personnel, and
      iii) Total hours on duty per calendar day for each of the required operations personnel.

c) **Mechanical Irregularities.** Each operator shall provide a log for operations personnel to record mechanical irregularities for the unmanned aircraft and its associated elements.
   1) Each operations person shall enter, or cause to be entered, each mechanical irregularity in the log for the unmanned aircraft and its associated elements that comes to the person's attention.
   2) Each operations personnel who takes corrective action concerning a reported or observed failure or malfunction for the unmanned aircraft or its associated elements shall enter, or have entered, the action taken in the log.

d) **Maintenance.** Each operator shall ensure that it maintains records of the unmanned aircraft inspection status and for each maintenance or alteration activity to the unmanned aircraft or its associated elements.
   1) The records must include the current inspection status of the unmanned aircraft and, for each maintenance or alteration activity performed by operations personnel on the unmanned aircraft or its associated elements, a record that includes-
      i) A general description of the work performed;
      ii) The completion date of the work;
      iii) The identification of the person performing, or who performed, the work; and
      iv) The approval for return to service.

2) An operator need not comply with the requirements of paragraph (d)(1) of this section for the removal and replacement of unmanned aircraft batteries designed for frequent, toolless swapping if the operator has other means of tracking battery use, life, and performance.

3) An operator need not comply with the requirements of paragraph (d)(1) of this section for the removal and replacement of unmanned aircraft components that are designed for toolless removal and reinstallation if the operator has procedures for ensuring that any part that is removed is inspected for serviceability prior to being reinstalled and-

   i) The parts are reinstalled on the same unmanned aircraft; or

   ii) The parts are not subject to time limits; or

   iii) The operator has other means of tracking installation and use.

e) **Training.** Each operator must maintain a record of all initial and recurrent training taken by each person required to receive training under this part.

1) The record shall contain, at a minimum:

   i) The person's name and assigned job function,

   ii) The date of hire or start of a related job function,

   iii) The most recent training completion date,

   iv) A description, copy, or reference to training materials used to meet the training requirement,

   v) The name and address of the organization providing the training, and

   vi) A copy of the certification issued when the individual was trained, which shows that a test has been completed satisfactorily.

2) Training records required to be kept under this section include:

   i) Records of the initial and recurrent training required under §108.315.

   ii) Records of the initial and recurrent training for the recognition of hazardous materials required under §108.440.

   iii) Records of the initial and recurrent hazardous materials training taken by each person who performs or directly supervises a job function specified in §108.570(b).

   iv) Records of the training received for agricultural operations in accordance with the training required under §108.445(i) and 108.575(g).

f) **Timeframes.** Records required under this paragraph shall be kept per the following timeframes.

1) Unmanned Aircraft. Records required under paragraphs (a)(1) and (2) of this section must be maintained for the life of the unmanned aircraft. Data required under paragraph (a)(3) of this section must be maintained for a minimum of 24 months.

2) Personnel. Records required under paragraphs (b)(1) through (3) of this section must be maintained for the length of employment of that individual plus 12 months after separation. Data required under paragraph (b)(4) of this section must be maintained for 12 months after the separation from employment of that individual. Records required under paragraph (b)(5) of this section must be maintained for three (3) months.

3) Mechanical Irregularities. Records required under paragraph (c) of this section must be maintained for a minimum of 24 months.

4) Maintenance. Records required under paragraph (d) of this section must be maintained for a minimum of 24 months.

5) Training. Records required under paragraph (e) of this section must be maintained for the length of employment of that individual plus 12 months after separation.

5.6 §108.135 Company operations manual

a) Each operator shall prepare and keep current a company operations manual that sets forth the operator's procedures and policies acceptable to the Administrator.

b) The company operations manual may be in the form of one or more documents.

c) The manual must be made available to the Administrator upon request.

d) The manual must not be contrary to any applicable Federal regulations, the operator's operating certificate or permit, or any authorizations held.

e) The information and instructions contained in the manual must be displayed clearly and be retrievable in the English language.

f) The revision status must be controlled in such a way a person can immediately ascertain the information is the most current.

g) The manual must address the following-

1) The operations personnel required under §108.300 and their assigned area of responsibility, duties, responsibilities, and authority;
2) The number and positions of operations personnel required for safe operations under §108.300 and their responsibilities;
3) Preflight procedures;
4) Unmanned aircraft weight and balance procedures;
5) Accident notification procedures;
6) Procedures for determining and communicating unmanned aircraft condition to appropriate operations personnel;
7) Procedures for complying with the recordkeeping and reporting requirements as required under §108.40 and 108.45;
8) Access to and use of unmanned aircraft maintenance procedures and inspection criteria;
9) Procedures for developing and implementing emergency procedures;
10) Procedures for the retrieval of unmanned aircraft that fail to return to their intended landing location;
11) Unmanned aircraft loading procedures, as applicable; and
12) Procedures for the identification and disposition of hazardous materials.

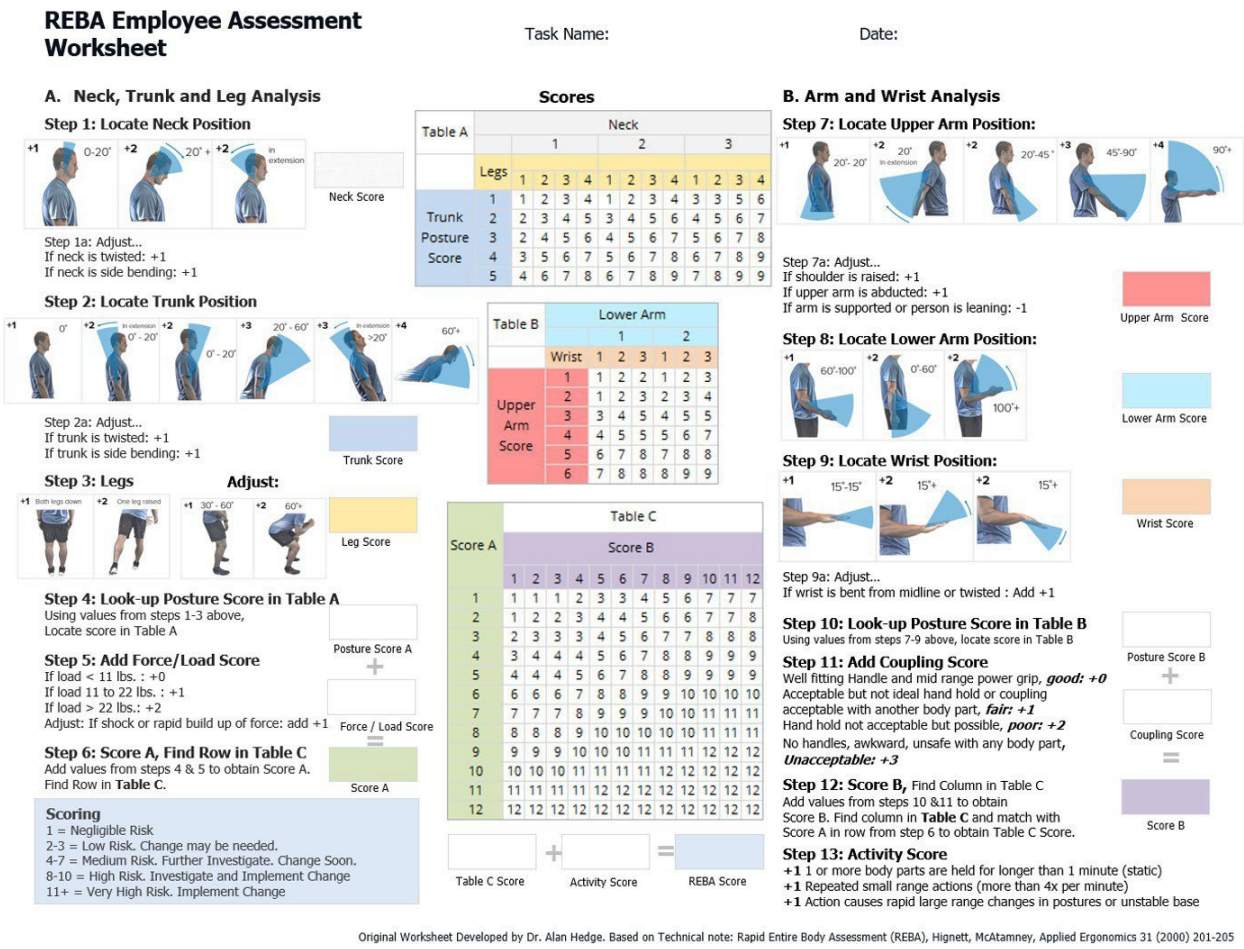

Figure 5.1: Rapid Entire Body Assessment [15]

5.7 Rapid Entire Body Assessment (REBA)

The evaluated task (drone controller operation, long duration) produced the following intermediate and final REBA scores:

- Neck = 3
- Trunk = 1
- Legs = 1
- **Table A score = 5**
- Upper Arm = 2
- Lower Arm = 2
- Wrist = 1
- **Table B score = 5**
- Coupling = +0
- Load/Force = +0
- **Table C score = 6**
- Activity = +1
- **Final REBA Score = 7 (Medium Risk)**

5.8 Scenario Evaluations

5.8.1 Introductory Training

Small Multirotor Introductory Training

Organization and Planning

- Decided to keep the exercise simple - short flights, close range, low altitude.
- Goal was to let participants feel the controls and get oriented, not push limits.
- Training space unmarked, plenty of buffer from obstacles.

Mission Preparation

- Preflight checks were quick; the small quad has minimal setup compared to larger rigs.
- Batteries charged, no special ground equipment needed. Laid out launch pad.
- Fiddled with inserting phone into controller, some annoyance with screen glare.
- Safety briefing emphasized fundamentals - stick orientation, "which way is forward," return-to-home basics.

On-Site Actions

- Flights were uneventful - aircraft is very stable, GPS hold makes hovering easy.
- Most of our "thinking" was about letting people explore without overcorrecting.
- As experts, we noticed how forgiving the platform is. It smooths out inputs, masks pilot inexperience.
- Talked about how easy it is to underestimate risk because it feels so simple.

Post-Flight Actions

- Picked up drone - took a look at it before battery swap.
- Inconsistent with caring about controller.
- Quick discussion: everyone agreed confidence builds fast with this class of drone.
- No real maintenance needed beyond swapping packs.

What Made This Unique?

- For us, the striking thing is how little stress there is flying a small quad.
- You don't think about crash cost, airspace risk, or heavy payloads because the stakes are low.
- This makes it an excellent entry point, but also a trap: new pilots don't learn the same discipline they'll need on bigger aircraft.
- As experienced pilots, we noted how different the training mindset is: it's about comfort and orientation instead of systems management or risk trade-offs.

Large Multirotor Introductory Training

Organization and Planning

- Defined a clear training area with wider safety buffers - heavier aircraft carry more risk.
- Discussed abort criteria in advance (loss of GPS, unstable hover, unexpected traffic).
- Considered insurance, flight logs, and FAA compliance much more seriously compared to the small quad.

Mission Preparation

- Preflight checks were extensive: motor arms, gimbal locks, redundant battery health, firmware status.
- Needed a dedicated launch/landing pad to protect rotors and avoid debris ingestion.
- Crew roles divided more formally - one acted as visual observer, another handled logging.

On-Site Actions

- Takeoff required deliberate throttle and careful monitoring of attitude - no "hand launch" option.
- Aircraft response was precise but intimidating - the size and noise amplify stress.
- Pilot focus shifted from simple stick control to spatial awareness: keeping clear of people, structures, and rotor wash effects.
- We constantly tracked emergency landing options in case of battery or system fault.

Post-Flight Actions

- Logged flight in detail - airframe hours, battery cycles, environmental notes.
- Post-flight inspection included checking motor temperatures, prop integrity, and vibration mounts.
- Debrief centered on crew coordination and whether risk controls worked as intended.

What Made This Unique?

- Flying a 15 lb multirotor shifts the mindset - every maneuver feels consequential.
- Noise and rotor wash created a physical presence; bystanders instinctively stepped back.
- Unlike small drones, errors could damage infrastructure or cause injury, so we managed stress differently.
- Training value was high: pilots saw firsthand the difference in workload and seriousness when stepping up in class.

5.8.2 Inspection

Small Multirotor Inspection Exercise

Organization and Planning

- Selected a gravel road, tree, and nearby barbed wire fence as practice inspection features.
- Designed a conservative flight plan with progressive difficulty: start with road alignment at low altitude, then move to circling the tree canopy, using the fence only as a boundary marker.
- Assigned roles of pilot, visual observer, and note-taker to mirror operational discipline.

Mission Preparation

- Conducted preflight checklist with focus on GPS lock, obstacle sensing, and compass calibration.
- Checked wind conditions - light but gusty enough to highlight the aircraft's stability limits.
- Reviewed avoidance criteria: barbed wire was considered off-limits for safety, while gravel dust was identified as a possible nuisance factor.

On-Site Actions

- Practiced precision hovering and low, straight passes over the gravel road, paying attention to dust disturbance.
- Moved to tree inspection at varying altitudes - pilots noted challenges in depth perception due to shadow and background clutter.
- Used the fence as a visual "hard boundary" but avoided flying closer than 15-20 feet.
- Discussion during flight emphasized stick sensitivity: even small over-corrections were noticeable at close range.

Post-Flight Actions

- Logged observations on confidence levels: small drone felt forgiving and manageable even in tighter spaces.
- Inspected props and motors for dust and debris from gravel operations - none observed but noted as a maintenance check.
- Group debrief focused on transferability: lessons learned with small multirotor scale up in complexity with larger aircraft.

What Made This Unique?

- Demonstrated that even ordinary environmental features (gravel road, tree) provide meaningful precision-flight training.
- Highlighted how small drones allow new pilots to build confidence near obstacles without high cost or consequence of error.
- Showed clear differences in workload and stress compared to large aircraft - the small drone encouraged experimentation and repetition.

Large Multirotor Inspection Exercise (Freefly Astro)

Organization and Planning

- Identified the same features (gravel road, tree, barbed wire fence) to allow direct comparison with small multirotor performance.
- Adjusted flight plan to account for the Astro's larger size, inertia, and lack of collision avoidance.
- Planned conservative approach distances near the fence to avoid risk, with emphasis on using zoom optics instead of proximity.

Mission Preparation

- Conducted full preflight with special focus on propeller integrity and gimbal calibration, given the 61 MP camera payload.
- Checked wind conditions more carefully than with the small drone - larger airframe more affected by gusts.
- Discussed "abort criteria" before launch: any uncommanded drift near fence or tree would result in immediate climb-out.

On-Site Actions

- Practiced road passes at mid-altitude, with pilots noting the Astro's stability but heavier stick feel.
- Approached the tree cautiously; without collision avoidance, depth perception required strong observer support.
- Attempted limited fence inspection - zoom camera provided detail without needing to close distance. Team remained extra cautious, recognizing that the Astro lacks obstacle sensing.
- Zoom capability (61 MP sensor) was a major strength: fine detail of bark, gravel, and wire captured clearly without close approach.

Post-Flight Actions

- Collected high-resolution imagery and compared results with small multirotor. Image quality from the Astro was significantly better, especially at standoff distances.
- Inspected landing gear and props for dust from gravel takeoff/landing - minor residue observed, added to cleaning notes.
- Debrief highlighted increased pilot stress: larger size and higher cost made everyone more cautious around obstacles.

What Made This Unique?

- The Astro's lack of collision avoidance demanded more conservative flying - pilots did not "test limits" as with the small drone.
- Zoom and high-resolution camera compensated for standoff distance, demonstrating value of payload quality over proximity.
- Risk perception was much higher - mistakes could cause costly damage. This changed crew behavior, emphasizing caution and teamwork.
- Showed how larger aircraft shift inspection strategy: rely on optics and planning rather than close-in manual maneuvering.

5.8.3 Survey Mission

Fixed-Wing Survey Mission (AgEagle eBee)

Organization and Planning

- Unlike multirotors, the eBee cannot be manually flown with a controller. All inputs must be pre-programmed through the mission planning software.
- This shifted the majority of workload into the planning stage. The crew spent considerable time simulating flight paths to confirm that launch, orbit climb, survey pattern, and landing would fit within the available airspace and visual line of sight (VLOS).
- Identified several constraints early: tall trees on one side of the field, a gravel road on the other, and the need to land into the wind. These constraints narrowed the available "envelope" of operations.
- Extra emphasis was placed on contingency planning since no manual override was available to correct poor positioning near obstacles.

Mission Preparation

- Set up a small folding table as a mobile assembly area. This provided a stable surface to connect wings, install the battery, and perform preflight checks - an extra step not needed for multirotors.
- Verified GPS lock, airspeed sensor functionality, and wind direction before finalizing the launch and landing zones.
- Landing plan was particularly complex: the system required a defined approach path into the wind. This forced the crew to choose a zone that avoided low-altitude crossings over the road and tall tree canopy.
- Adjusted the survey block length to account for hairpin turns. These turns added extra distance and reduced the effective survey area that could be covered while staying within VLOS.

On-Site Actions

- The hand launch required a clear forward corridor and immediate altitude gain. Team members ensured that the climb-out path remained unobstructed.
- During survey flight, the aircraft executed its grid autonomously. The crew's main task was to maintain VLOS and monitor telemetry on the laptop ground control station. Unlike multirotors, there was no direct flight stick input; instead, focus shifted to monitoring performance and readiness to abort the landing sequence if needed.
- Hairpin turns proved more challenging than expected. Although planned in software, in practice the wide arcs consumed more space, which pressed against the VLOS boundary. This required the team to shorten the survey zone, highlighting the limits of fixed-wing platforms in smaller fields.
- Landing was the most stressful phase. The eBee's requirement to land into the wind meant the approach could not be flexibly adjusted without redesigning the mission. The chosen landing site avoided the tree line and road, but forced a tight glide slope that required constant monitoring.
- Unlike multirotors that "drop in" vertically, the eBee needed a long, shallow descent - forcing the crew to clear the area and stay alert for people or vehicles crossing into the landing corridor.

Post-Flight Actions

- Conducted an immediate inspection of the airframe, especially the underside, since the belly landing exposed the fuselage to gravel and dust. Minor scuffing was observed and logged.
- Removed the wings and packed the airframe back into its transport case, adding steps to teardown not present with multirotors.
- Logged mission data and compared the actual flight path to the preflight simulation. Differences in wind conditions and turning radii were noted, which slightly reduced coverage compared to the plan.
- Debrief emphasized the crew's sense that fixed-wing operations "front-load" the workload - once airborne, the mission was largely autonomous, but the risk of errors in planning or landing carried significant weight.

What Made This Unique?

- The lack of manual controls fundamentally changed how the mission was approached. Unlike multirotors, last-second adjustments were not possible. All corrections had to be pre-programmed.
- Landing direction tied to wind made the site layout a critical constraint - obstacles that would not matter to a multirotor (trees, roads, fence lines) became hard boundaries.
- The need for a long glide slope into the wind meant clearing more space and maintaining higher situational awareness of the environment.
- Belly landings introduced maintenance and inspection requirements absent from multirotors, where landing gear protects the aircraft.
- The eBee highlighted the trade-off between efficiency and flexibility: it covered more ground per flight than a multirotor could, but at the cost of higher planning burden, greater site requirements, and less room for human correction in-flight.

VTOL Survey Mission (WingtraOne)

Organization and Planning

- Observed Wingtra operations as a comparison to the eBee fixed-wing system.
- Mission planning resembled the eBee workflow, with survey grids pre-programmed on a tablet prior to flight.
- Unlike the eBee, takeoff and landing zones were less restrictive due to the VTOL design, but hairpin turns during survey grids still raised VLOS challenges.

Mission Preparation

- Setup required a stable table for assembly and preflight checks. The airframe was bulkier than the eBee and required extra hands to hold components in place during setup.
- Verified wind conditions and battery status, but there was less emphasis on aligning launch and landing with wind since the aircraft takes off and lands vertically.
- Crew noted that the system control was entirely tablet-based, with no live first-person camera feed. This created more uncertainty compared to multirotor or eBee operations, where imagery is visible in real time.

On-Site Actions

- Takeoff was conducted in VTOL mode: the aircraft lifted off vertically from its tail, transitioned into forward flight, and executed pre-programmed survey paths.
- The transition from vertical climb to forward flight appeared smooth, though it added a unique phase of flight not present in either multirotors or belly-launched fixed-wing systems.
- During survey execution, the lack of a live video feed meant the crew relied entirely on telemetry and visual observers to confirm performance. Pilots had to "trust the system" rather than verify through direct imagery.
- As with the eBee, long endurance flights required multiple visual observers. Breaks were necessary for observer handoff to sustain compliance with VLOS requirements.

Post-Flight Actions

- Landing in VTOL mode reduced site constraints compared to the eBee - the aircraft returned to its tail-down vertical position without requiring long approach corridors.
- Post-flight inspection was simpler than the eBee, since no belly landings were performed, though wear and tear on landing skids was noted.
- Crew discussed differences in operator workload: reliance on automation and tablet-based monitoring reduced direct pilot engagement but increased the importance of observer discipline.

What Made This Unique?

- Vertical takeoff and landing eliminated the need for long launch/landing zones, expanding site flexibility.
- Hairpin survey turns still constrained the operational area, requiring careful VLOS management.
- Tablet-only interface and lack of live camera feed placed unusual trust in autonomy and system reliability.
- Setup was more labor-intensive: assembly required a table and multiple people.
- Long endurance flights necessitated visual observer rotation - reinforcing that Wingtra operations are a team activity, not a single-pilot task.

Large Multirotor Survey Mission (Freefly Astro)

Organization and Planning

- Planned a standard grid survey mission, relying on the Astro's onboard autonomy and flight software.
- Unlike the eBee, there was no simulation environment to preview the mission. Flight plan review was limited to a visual inspection of waypoints and coverage patterns.
- Team accepted a smaller coverage area in exchange for the Astro's easier deployment and more flexible launch/landing requirements.

Mission Preparation

- Preflight focused on gimbal calibration, payload readiness, and battery checks, as the 61 MP camera was a central feature of the mission.
- Ground site setup was minimal compared to fixed-wing aircraft - no assembly table required. However, spare batteries were prepared given the expected endurance limits.
- Discussed the trade-off of resolution versus coverage: survey data would be high quality, but coverage efficiency would lag behind fixed-wing platforms.

On-Site Actions

- The Astro executed the programmed grid reliably, flying at a faster pace than anticipated. Pilots noted the contrast to manual flights, where speed was deliberately reduced for precision.
- Coverage was inherently limited by multirotor endurance and slower transit compared to fixed-wing aircraft. Despite speed in the pattern, the Astro could not match the area efficiency of the eBee or Wingtra.
- The 61 MP camera produced excellent imagery, capturing fine detail unnecessary for broad surveys but potentially useful for asset inspections or high-resolution mapping.
- Crew noted that while flight stability was excellent, the lack of a preflight simulation made it harder to anticipate edge cases or optimize coverage zones.

Post-Flight Actions

- Image review confirmed data quality exceeded needs for a standard survey - resolution was higher than required for general terrain mapping.
- Debrief emphasized that while multirotors are straightforward to deploy, they are less efficient for large-scale surveys and best suited when detail is more valuable than coverage.
- Maintenance check was straightforward compared to fixed-wing belly landers - minimal wear observed.

What Made This Unique?

- Lacked the simulation-driven planning of the eBee, requiring more trust in visual waypoint checks.
- Flew noticeably faster than in manual flights, underscoring the difference between operator caution and autonomous survey profiles.
- Delivered exceptional image resolution (61 MP), though this exceeded operational needs for general surveys.
- Reinforced the multirotor's trade-off: easy to field and control, but limited in area coverage compared to fixed-wing and VTOL platforms.

Type	Comment	Slide/Location
UI Improvement	Change the hyperlink into a button for Deputy Directive DD-118	Deputy Directive DD-118
Style Improvement	move the text "Important Tasks a UAS crew will perform include:" to a separate text block so that it lines up with the bullet points better	3.0 Roles and Responsibilities
UI Improvement	Change the hyperlinks to FAA DroneZone to a button	5.0 Regulatory Authority & Requirements
Content	Currently lists that "All Caltrans UAS Operations occur under FAR Part 107 Authority". Recommend update to include additional statutes: part 48 for registration, Part 89 Remote ID Compliance, Part 107 Small UAS Operations, and upcoming, Part 108 Operations	5.0 Regulatory Authority & Requirements
Content	Text says "Caltrans UAS must be registered with the FAA" - should update to clarify who's responsibility it is to register the drone.	5.0 Regulatory Authority & Requirements
UI Improvement	5.0 and 5.3 can be merged into one section.	5.0 Regulatory Authority & Requirements
Content	The section on UAS Restrictions is short and likely unproductive. This should be fleshed out. Some recommendations: Text Block : Purpose of Supervisor Oversight. Supervisors are not expected to perform detailed airspace analysis or replicate the technical responsibilities of a Remote Pilot. Their role is to ensure that the operation is aligned with Caltrans policy, FAA regulations, and safe operational practice. Effective oversight begins with confirming that the pilot has completed appropriate planning and that conditions on-site match what was anticipated.	6.0 UAS Restrictions
Content	Text Block: Airspace and Authorization Awareness Supervisors should confirm that the pilot has reviewed the airspace for the operation and identified any requirements for authorization. While supervisors do not determine airspace classifications, they should verify that: • The pilot has checked for Temporary Flight Restrictions (TFRs). • Any required ATC authorizations, COAs, or waivers are already in place. • Nearby airports, heliports, or other aviation activities have been considered. Supervisors should pause an operation if these elements are unclear or incomplete.	6.0 UAS Restrictions

Content	Text Block: Local Conditions and Environmental Factors Operational safety depends on real-time evaluation of conditions. Supervisors should ensure that pilots have assessed visibility, wind, smoke, dust, or other environmental hazards. If conditions have changed significantly from the original plan, supervisors should confirm that the pilot has updated the hazard assessment prior to flight.	6.0 UAS Restrictions
Content	Text Block: FAA Part 107 Restrictions Relevant to Supervisors Supervisors do not need to memorize Part 107, but they should recognize when a pilot may be entering waiver-only territory. Operations that require pause and verification include: • Beyond visual line of sight • Flight over people • Operations above 400 ft AGL • Night operations without proper lighting • Operations from moving vehicles • Any payload involving hazardous materials If any of these conditions are present, supervisors should confirm that a waiver or specific approval exists.	6.0 UAS Restrictions
Content	Text Block: Road Closures and Traffic Control Verification Supervisors must ensure that all required road closures, lane restrictions, or traffic control measures are in place before UAS operations begin. UAS missions conducted near or above active roadways introduce significant risk to both the crew and the traveling public. Supervisors should confirm that the pilot has coordinated with the appropriate traffic control personnel, verified the permit or closure schedule, and assessed whether traffic patterns have changed since the original plan. If any closure is incomplete, delayed, or inconsistent with the mission plan, the operation should be paused until proper controls are established.	6.0 UAS Restrictions
Content	Mission a section on the extra demands that leading UAS pilot training can take. This would also be a good area to include that there may also be designated UAS trainers who might need additional support time.	Resource Considerations

Task 3 - Policy Recommendations

General Policy

Category	Issue	Recommendation	Justification	Notes
Policy Management	Missing Policy Definitions for UAS Program Management	Define roles & responsibilities for UAS program manager, working groups or other management entities	Clear role definitions establish accountability, reduce ambiguity in decision-making, and ensure consistent application of safety processes across districts. Formalizing responsibilities also supports compliance with SMS principles by identifying who oversees governance, training, risk management, and continuous improvement	
Policy Management	Use of ad-hoc groups without defined structure	Establish procedures for creating, organizing, and disbanding ad-hoc UAS working groups	Ensures consistency, transparency, and accountability when temporary teams are created to address operational or safety issues.	
Policy Management	Lack of clarity on how the UAS program is managed	Provide clear documentation for upper administration and end-users describing how the UAS program is structured and managed	Improves understanding of governance processes, strengthens administrative support, and enhances operator confidence in program decisions.	
SMS Management	Smartsheet is functional but limited for long-term program needs	Adopt a purpose-built database (e.g., relational or aviation-oriented system) to manage UAS operations, training, aircraft, and safety data	A more refined system supports data integrity, enables multi-year analytics, and improves program oversight as activity scales.	
SMS Management	The system relies heavily on manual data upkeep and lacks automated connections to analytical tools.	Explore adopting automation tools (Smartsheet Bridge, Zapier, Power Automate) to better manage data for improvements to UI or to develop better analytic tools	Automating synchronization improves efficiency, decreases administrative burden, and enables more robust analytics without disrupting existing user workflows.	
SMS Management	Current Smartsheet workflows permit inconsistent data entry and incomplete linkage between hazards and operations.	Invest in the implementation of validation rules, controlled dropdowns, and integrated hazard-to-operations workflows within Smartsheet. Data automation tools can be used to improve UI and dashboards.	These controls reduce entry errors, improve form completion rates, and increase near-term reliability of UAS operational and safety data.	
Safety Assurance	UAS SMS Program lacks structured analytics to inform safety and growth	Define policy for routine analysis of hazards, risks, trends, flight hours, and time-in-type	Consistent analytics enable early detection of emerging risks, support evidence-based decision-making, and align with SMS continuous-improvement expectations.	
Safety Assurance	Safety assurance is currently limited to post-flight incident review	Develop proactive safety-assurance processes including trend monitoring, equipment-related issue tracking, near-miss analysis, and use-case risk evaluation	Proactive surveillance strengthens the SMS, reduces reliance on incident-only triggers, and creates opportunities to adjust policies, checklists, and training before incidents occur.	

Task 3 - Policy Recommendations

General Policy

Category	Issue	Recommendation	Justification	Notes
Safety Assurance	The SMS does not currently convert operational trends into program improvements	Formalize a process requiring that hazard and performance trends be reviewed and used to update training curricula, procedures, and operational guidance	Ensures that lessons learned translate into program-wide improvements, maintaining compliance with SMS principles and supporting safe program growth.	
Safety Assurance	SOPs and guidance can lag behind field experience; pilots want "living" documents and case studies that evolve with operations.	Designate responsibility (person or role) to maintain living SOPs, collect trainer and pilot feedback, and regularly publish curated best practices and case-study summaries.	Keeping procedures aligned with field reality improves relevance of forms and guidance, and strengthens safety culture by learning from unique missions.	Could use short "training bites," debrief writeups, and a simple update cycle (for example, quarterly).
Safety Culture	Operators strongly support more opportunities for peer exchange and clearer communication channels across districts.	Establish a central communication hub (for example, Teams channel, Slack workspace, or similar) and schedule regular cross-district calls or virtual forums for sharing lessons learned and updates.	Nearly 90 percent of respondents indicated that more peer-to-peer opportunities would be helpful; structured networks leverage existing expertise without major new training costs.	
SMS Management	Current Caltrans UAS documentation uses inconsistent naming conventions (for example, "UAS Operations Plan Pre-Flight" vs. "Caltrans UAS Program Pre-Flight Data"), creating ambiguity for operators and reducing alignment with FAA terminology.	Adopt standardized, FAA-aligned naming conventions for all UAS planning and pre-flight forms. Specifically: 1) Mission Planning and Risk Assessment (for office-based planning completed hours to days before flight). 2) Preflight Inspection Checklist (for at-aircraft checks performed immediately before launch).	Consistent terminology improves clarity, reduces operator confusion, and aligns Caltrans practices with FAA language in §107.49 and common industry usage. Distinguishing between planning activities and pre-flight inspections also reinforces proper sequencing and supports training and compliance efforts.	
Hazard and Risk Assessment	The current Hazard Analysis form mixes in-office risk assessment with on-site checks, producing redundancy and reducing the usefulness of data for hazard tracking.	Shift all risk assessments that can be done pre-departure into the Mission Planning form, where hazards, mitigations, airspace, weather, and operational constraints can be evaluated prior to arriving at the work site.	Completing hazard assessment during planning enables more thoughtful analysis, supports data standardization, and allows for better trend tracking and safety assurance.	

Task 3 - Policy Recommendations

General Policy

Category	Issue	Recommendation	Justification	Notes
Hazard and Risk Assessment	Pilots currently complete lengthy hazard-identification questions on-site, slowing operations and creating inconsistent application of safety checks	Develop a streamlined Pre-Flight Checklist dedicated to readiness verification, equipment condition, environmental confirmation, crew setup, and go/no-go items that can be completed quickly at the field location.	A short checklist will be easier for the pilots to utilize. Data loss is less significant	
Hazard and Risk Assessment	Current questions are repetitive, inconsistently structured, and do not support meaningful analytics (for example, weather hazards, airspace classifications, or common operational risks).	Reorganize questions into structured categories with standardized options, including expanded hazard selections, airspace authorization types, detailed weather categories, and improved post-flight anomaly reporting.	Structured data and more meaningful questions will enable analysis for safety and trends.	
Post-Flight Procedures and Assurance	The current post-flight section lacks structured prompts and does not consistently capture anomalies, deviations, wildlife encounters, or near-miss events.	Expand and formalize the post-flight reporting section with required prompts for deviations, anomalies, wildlife interactions, equipment issues, and corrective actions.	Robust post-flight data is necessary for incident trend analysis, hazard identification, and continuous improvement of procedures.	
Emergency Preparedness	The policy does not include detailed emergency procedures for common failure modes (flyaway, lost link, mid-air collision, payload failure, fire, etc.).	Create scenario-based emergency response procedures for common major UAS failure modes and include them in the UAS Handbook and training materials.	Clear procedures ensure consistent, safe responses under pressure and support compliance with SMS expectations for emergency readiness.	
Emergency Preparedness	Communication requirements during emergencies (ATC notification, emergency services, internal escalation) are not defined.	Define mandatory communication protocols for emergency events, specifying when and how to contact ATC, emergency responders, district management, and program leadership.	Standardized communication reduces response delays and aligns Caltrans procedures with aviation best practices.	

Task 3 - Policy Recommendations

General Policy

Category	Issue	Recommendation	Justification	Notes
Post-Incident	The policy does not specify required steps after an incident, including aircraft recovery, site securing, and evidence preservation.	Add procedures for post-incident aircraft recovery, site control, preservation of evidence, and documentation of environmental conditions.	Supports effective investigation, protects Caltrans liability interests, and satisfies SMS requirements for structured incident follow-up.	
Post-Incident	Incidents are reported, but near-misses are not consistently captured; anonymous reporting does not exist; follow-up improvements are inconsistent.	Establish a unified reporting system that requires near-miss reporting, includes an optional anonymous submission pathway, and ensures follow-up actions and trend tracking.	Near-miss data is essential for identifying precursors and closing the SMS continuous-improvement loop.	
Safety Promotio	Operators may avoid reporting minor issues due to fear of blame or misunderstanding of consequences.	Adopt and publish a Just Culture framework that distinguishes honest mistakes, at-risk behavior, and reckless behavior, and explicitly states that near-misses and good-faith errors will not trigger punitive action.		Should include simple examples of reportable events and non-punitive outcomes.
Safety Promotio	Voluntary near-miss reporting can be low because forms are long, narrative-heavy, or require too much detail.	Develop a short, mobile-friendly near-miss reporting form with checkboxes, dropdown hazards, and only two required prompts ("What happened?" and "What should we know?").		
Safety Promotio	Safety conversations are inconsistent and often occur only after incidents.	Integrate regular low-stakes safety dialog practices such as Safety Moments at meetings, brief pre-mission huddles, and short debrief discussions into UAS workflows.	Frequent, informal safety touchpoints normalize discussion, encourage early reporting, and strengthen organizational awareness.	
Safety Promotio	Operators lose motivation to report when they do not see how information is used.	Create a recurring communication process (for example, quarterly bulletins or safety updates) summarizing de-identified reports, improvements made, and lessons learned.	Visible action based on reports reinforces trust and shows operators that their contributions materially improve safety.	
Safety Promotio	Reporting may feel risky or socially uncomfortable; there is no positive reinforcement.	Create mechanisms for non-individualized recognition (such as district acknowledgment or program-level appreciation) when teams show strong participation in safety reporting or near-miss documentation.	Team-based reinforcement encourages participation without creating competition or fear of judgment.	

Task 3 - Policy Recommendations

General Policy

Category	Issue	Recommendation	Justification	Notes
SMS Management/ Technology Integration	Advanced UAS platforms frequently introduce new autonomy behaviors and software updates. Caltrans currently has no policy stating who verifies that these features are understood and appropriate for operational use.	Include a simple policy statement that new automation features or major software behaviors should be reviewed by the UAS Program Administrator or designee prior to operational use.	A lightweight review ensures that new features are not used unexpectedly in the field, and prevents inconsistent district-level adoption	

Task 3 - Policy Recommendations

Advanced Operations

Category	Issue	Recommendation	Justification	Notes
Waivers	No policy defining who is authorized to prepare or submit FAA waivers and COAs.	Establish formal authority for waiver/COA preparation, review, and submission, including a standardized internal review process.	Clear submission authority ensures consistency, accountability, and compliance with FAA requirements, reducing the risk of incomplete or non-compliant applications.	
Waivers	Waivers and COAs lack defined organizational scope and assigned program-level compliance responsibilities.	Define how waivers may be applied at the division, district, or statewide level and define how to assign program-level responsibility for ongoing compliance with waiver provisions.	Clarifying scope and oversight prevents misapplication of authorities and ensures continuous monitoring of pilot qualifications, aircraft lists, and waiver-required documentation.	Public Agencies COAs are issued to a point of contact on behalf of an agency. Part 108 will be issued to organizations. However, Part 107 waivers are issued to a person instead of an organization. Despite this, many organizations and entities still utilize these Part 107 waivers across their organization through delegated authority. As an example, within the UC system, I am authorized by University Policy to obtain and manage waivers on behalf of the University.
Waivers	Policy does not address how personnel should be trained on waiver requirements or how waiver updates are communicated.	Create requirements for the development of mandatory waiver-specific training and establish communication channels for distributing waiver conditions and updates.	Training and structured communication ensure pilots, supervisors, and managers understand the operational limitations and requirements of each waiver, reducing the likelihood of non-compliant operations.	
UAS Platforms	Emerging platforms require skills (automation management, mission planning, system integration) that extend beyond current training, but no platform-specific qualification standards exist.	Develop explicit training modules and qualification criteria tied to aircraft type and operational complexity.	Platform-specific standards allow Caltrans to match pilot capability to mission risk, reduce uneven skill development, and maintain operational readiness as the fleet diversifies.	
Tethered Platforms	Missing tethered drone operations in policy	Establish policy defining tethered flights operate under Part 107	Unless Public Agency Exception under 49 USC 44806(c) is supported, flight operations with tethered drones do not encumber additional risk that would necesitate a special or unique restriction	

Task 3 - Policy Recommendations

Advanced Operations

Category	Issue	Recommendation	Justification	Notes
Extended Duration Operations	Extended-duration operations introduce fatigue and ergonomic risk factors not addressed in policy.	Incorporate ergonomic requirements including equipment supports, break schedules, crew rotations, and fixed-station ergonomic guidance for when in-flight time exceed one hour	Reduces fatigue-related errors and maintains situational awareness during multi-hour operations.	
Docking Systems	No existing policy defines when and how autonomous docking systems may be used.	Establish conditions for deployment, authorization, pilot qualifications, and oversight structure for docking-system operations.	Dock-based operations assume BVLOS-like workflows and require clear definition of responsibility and authority.	
Part 108 Roles	Current roles and responsibilites do not include Part 108 roles	Define an Operations Supervisor (primary accountable person) for Part 108 operations.	This will be an involved position and will likely exceed the responsibilities of any UAS pilot responsibilities.	Upper management should be aware of the position expectations.
Part 108 Roles	Current roles and responsibilites do not include Part 108 roles	Incorporate the responsibilities of the Part 108 Flight Coordinator under the existing UAS Operator role, with an additional training requirement	While Flight Coordinators may not require a Part 107 in the current proposal, the existing UAS Program is more than satisfactory for Flight Coordinators after necessary manufacturer-specific training.	
Training Advancement	No structured process for progressing from small multirotors to larger, fixed-wing, VTOL, or specialized platforms as the program expands.	Create a tiered pilot qualification framework that defines advancement requirements and competencies for each aircraft class.	A structured progression path ensures consistent skill development, and supports safe assignment of pilots to aircraft with higher complexity and risk.	
Training and Pilot Qualification	Caltrans Designated UAS Trainer not defined in policy	Formalize UAS Trainer program within policy	Ensures consistency, transparency, and accountability for UAS Trainers.	Recognition that training takes a non-insignificant amount of time
Training and Pilot Qualification	Current pilot sign-off and training system does not provide sufficient experience for medium- and high-risk UAS operations.	Initiate a structured review and redesign of Caltrans pilot training and qualification standards to ensure pilots gain the experience, decision-making skills, and mission-level proficiency necessary for higher-risk operations.	Caltrans' higher risk profile necessitate training that better develops mission preparedness.	
Large Multi-Rotors	Operators require significantly more flights (10–15 vs. 1–8) to achieve control comfort and confidence on larger UAS (>10 lbs).	Establish additional flight training for larger platforms, exceeding those required for small UAS, before pilots may operate independently.	Larger aircraft have greater inertia, slower response times, and higher risk of damage, all of which slow skill acquisition and increase consequence of error.	

Task 3 - Policy Recommendations

Advanced Operations

Category	Issue	Recommendation	Justification	Notes
Large Multi-Rotors	Pilots reported needing a structured progression through increasingly complex environments to build confidence near structures and obstacles.	Develop a staged progression model (open-area -> controlled obstacles -> mission-representative environments) for initial qualification on larger aircraft.	Builds confidence gradually	
Advanced Autonomy	Outside of the familiar small multi-rotor platforms, the Ground Control Station (GCS) interfaces for advanced platforms are dense and unfamiliar, leading to reluctance to use automation features and slower adoption of system capabilities	Ensure that flight training for new platforms include training on GCS software, including navigation of menus, interpretation of system messages, automation settings, and safe use of autonomy modes.	Competent GCS operation is essential for effective use of advanced platforms.	
Advanced Autonomy	Pilots hesitate to engage with automation due to uncertainty, concern about unintended behaviors, and difficulty interpreting system responses.	Include automation literacy as a required component of training, covering autonomy modes, failsafe behaviors, obstacle avoidance logic, mode transitions, and system limitations.	Automation literacy ensures pilots understand what the system will do, when it will do it, and how to intervene safely.	
Training and Pilot Qualification	The current Caltrans UAS qualification system was designed for small multirotors and does not account for the higher operational complexity, unique control schemes, and elevated risk profiles of VTOL, fixed-wing, tethered, or dock-based autonomous platforms.	Adopt platform-specific qualification tracks that include tailored initial qualification, currency, and recency requirements for each major UAS category (small multirotor, heavy multirotor, VTOL, fixed-wing, tethered, dock-based autonomous systems).	Operational demands, training needs, and risk factors vary significantly between platforms. A single qualification path does not ensure pilots have the system-specific competencies required for safe operation, particularly on aircraft with higher inertia, limited manual control, or complex automation.	Define new qualification designations (e.g., "Fixed-Wing Qualified," "VTOL Qualified," "Tethered System Operator," "Dock Supervisor") with type specific currency requirements. Add qualification endorsements to the pilot profile within the UAS management database.
Mission Planning and Risk Management	Platforms with limited or no manual override require substantially more pre-flight planning and rehearsal, but current policy treats pre-flight requirements uniformly across platforms.	Require expanded pre-flight planning for autonomy-dependent systems, including documented route validation, obstacle and terrain review, contingency planning, link-quality checks, and verification of automation behavior using simulation or route-preview tools where available.	When manual intervention is constrained or unavailable, the effectiveness of the mission depends heavily on pre-flight validation and operator understanding of automation logic.	(Optional) Create a "Complex Mission Pre-Flight Worksheet" for high-automation platforms. Require simulation or route-preview confirmation for systems without manual override.

Task 3 - Policy Recommendations

Advanced Operations

Category	Issue	Recommendation	Justification	Notes
Operational Requirements and Site Safety	Advanced systems, especially VTOL and fixed-wing, require larger operational footprints, defined approach and departure corridors, overshoot areas, and better link management than small multirotors, but current requirements do not differentiate by platform.	Require a higher level of detail when planning for advanced platforms by requiring minimum landing zone sizes, wind-aligned approach paths, hazard cordons, overshoot/go-around areas, and link-quality/LOS-based siting criteria.	Larger and more automated platforms depend on predictable spatial environments for safe takeoff, landing, transition, and autonomous behavior.	
Operational Requirements and Site Safety	Physical site security for tethered and dock-based systems is expected under Part 108, but current Caltrans UAS policy does not explicitly require secured locations for long-duration or pilot-less deployments.	Add a policy stating that all tethered and dock-based UAS deployments must ensure physical site security, including restricted access to equipment, clear signage, and controls to prevent unauthorized interference with aircraft, docks, tethers, and support infrastructure.		

Task 3 - Policy Recommendations

Potential Training Approaches

Approach	Description	Pros	Cons	Costs
Multi-Level Pilot Proficiency	Create levels (beginner, intermediate, advance) for pilots to advance, tied to mission readyness.	Clear progression path, can enable low-risk flight operations for newly certified pilots to get them in the field faster, better standardization of mission preparedness for higher-risk operations.	Requires new curriculum and standards, increases administrative workload, requires trainers to be more involved, may create bottlenecks	more trainer hours, development of tracking tools, travel and scheduling
Pre-Flight Authorization Review	UAS Program manager reviews flight activity to ensure flight missions match pilot proficiency/experience.	Ensures appropriate pilot-to-mission alignment, works for high-consequence missions, provides standard oversight	Administrative delays, requires expert reviewers, may frustrate experienced pilots	Staff time for reviews, requires a more comprehensive tracking system
Longer / More Involved Training Program	Expand the training program to include more hands-on experience with flight time and mission preparedness	Produces More capable pilots, Builds decision-making skills, Reduces reliance on mentorship	More trainer time needed, Slower pilot throughput, Scheduling challenges	Increased instructor workload, Time away from field, Facility usage
Structured Mentorship Program	Formalize a program to newly certified pilots to shadow a more experienced pilot to gain experience	Builds tacit knowledge, good for complex missions	Variable mentor quality, Risk of unproductive shadowing, lack of regular operations available to shadow	High cost of mentor time and coordinating
Scenario-Based Mission Training	Include scenario-based mission training within existing program	Strengthens mission-planning skills, Good for automation platforms	Requires scenario design, extends basic training significantly, requires more expert trainers	Scenario development effort, more effort and time commitment to trainers
Self-Study and Certified Practice Hours	Require a certain number of certified practice time before advancing to higher risk operations	Low cost, Reduces trainer burden	Hard to verify quality, May build bad habits, limited exposure to higher risk operations	Requires a more suitable tracking system, need to develop task list