State of Washington
Joint Transportation Committee

Evaluation of Washington State Patrol's Cessna Aircraft Fleet

Project Report

DYE MANAGEMENT GROUP, INC.

in conjunction with

Kimley»Horn

Washington State Joint Transportation Committee

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Project Report

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Executive Summary

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A. Background

The Washington State Legislature's Joint Transportation Committee (JTC) commissioned a comprehensive evaluation of the Washington State Patrol's (WSP) fleet of Cessna aircraft. WSP asked the 2022 Legislature to fund replacement of all five Cessna aircraft over a five-year period. This prompted the legislative request for an evaluation of the duties of the WSP Aviation Section as well as the current state of the Cessna aircraft to determine if there are any other options for modernizing the fleet.

JTC contracted with Dye Management Group, Inc. (DMG), in partnership with Kimley-Horn (K-H), to assess the current use and performance of the aircraft; evaluate the timing of needed replacement of the aircraft; evaluate the feasibility and costs of using aircraft powered by alternative fuel; and review other potential technologies, including unmanned aerial vehicles, to achieve some or all of the WSP Aviation Section's mission.

B. Summary of Current WSP Fleet

The WSP Aviation Section's fleet consists of the following:

- Three Cessna 182s (C182)
- Two Cessna 206s (C206)
- Two forward-looking infrared (FLIR) camera units
- One Beechcraft Super King Air B200 used for transport of the governor and other state officials (This was not included in the original scope of analysis for this project)

C. Original WSP Funding Request

WSP's original funding request submitted to the Legislature included a complement of five C206 aircraft and five new FLIR cameras. The total cost, including interest payments on the requested Certificates of Participation, is over $12.4 million. Exhibit 1 shows the payment amounts by year and total for WSP's original funding request.

Exhibit 1: Original WSP Funding Request

Year	Total
FY 2023	$69,158
FY 2024	$554,658
FY 2025	$1,010,079
FY 2026	$1,226,250
FY 2027	$1,234,500

Year	Total
FY 2028	$1,240,250
FY 2029	$1,233,750
FY 2030	$1,215,500
FY 2031	$1,210,375
FY 2032	$1,222,500
FY 2033	$1,231,375
FY 2034	$739,750
FY 2035	$246,000
TOTAL	**$12,434,145**

To make a comparison between WSP's original request and DMG's recommendation (see Exhibit 3), we eliminated the financing mechanism and adjusted the fleet purchasing outlook to five years to match the cost scenarios. Exhibit 2 shows the cost impact of five C206 aircraft and five new FLIR cameras, per the original WSP request, over a five-year period.

Exhibit 2: Original WSP Request Over Five-Year Period

Item	FY2024	FY2025	FY2026	FY2027	FY2028	Resale Value	Total
Cessna 206	$2,210,000	$0	$2,344,589	$0	$1,243,687	**($512,915.65)**	$5,285,361
FLIR Camera and Equipment	$5,585,050	$0	$0	$0	$0	$0	$5,585,050
Total	**$7,795,050**	**$0**	**$2,344,589**	**$0**	**$1,243,687**	**($512,915.65)**	**$10,870,411**

D. Fleet Recommendations and Cost Impacts

DMG provides the following recommendations:

- WSP operates a fleet of five aircraft: four Cessna 206s and one Cessna 182.
- WSP utilizes three FLIR camera units.

This recommended complement of aircraft and FLIR cameras results in a decreased cost of approximately $3.78 million relative to WSP's original funding request while still providing the ability to successfully deliver the Aviation Section's mission. These recommendations also increase WSP's capacity to conduct FLIR-enabled aerial missions with the resulting positive impacts on public safety. Additional detail on the analysis and justification of these recommendations is included in subsequent sections of this report.

DMG also accompanied its recommendations with four additional scenarios for WSP's review, along with a five-year outlook of the agency's original fleet replacement request. Additional detail on the scenarios and results are included in Section J of this report.

Exhibits 3 and 4 provide cost comparisons between the original funding request and DMG's recommendations.

Exhibit 3: Comparison of Original Request and Recommendation

	Original WSP Request		Recommendation	
	Aircraft	FLIR	Aircraft	FLIR
Purchase FY 24	(2) C206	2	(2) C206	2
Purchase FY 26	(2) C206	2	(1) C206	
Purchase FY 28	(1) C206	1	(1) C206 (1) C182	
Total New Equipment	(5) C206	5	(4) C206 (1) C182	2
Total Equipment	(5) C206	5	(4) C206 (1) C182	3
5-Year Cost	**$10,870,411***		**$7,086,432**	

Exhibit 4: Total Cost of WSP Original Request vs. Recommendation (Scenario 1)

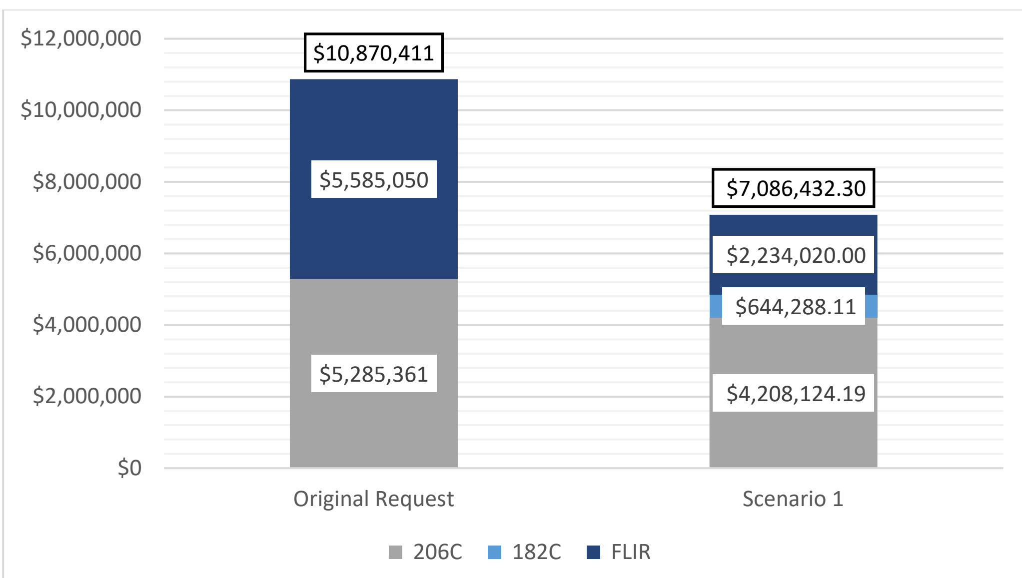

Exhibit 5 provides a summary of the current and future (recommended) fleet complement. The key impact of increasing the number of C206 aircraft is that it provides WSP the ability to increase the number of hours available to conduct FLIR-enabled missions, with the resulting positive impact on public safety, (See Section I for additional detail on the benefits of these missions.)

Exhibit 5: Current and Future State Comparison

Current State				Future State			
Aircraft	**Mission**	**Days of Operation**	**Benefit to the Public**	**Aircraft**	**Mission**	**Days of Operation**	**Benefit to the Public**
(3) Cessna 182s	Transport[1]/training / traffic enforcement	7 days a week, Monday–Sunday	Monitor speed and traffic from the air	(1) Cessna 182	Transport/training/ traffic enforcement	7 days a week, Monday-Sunday	Monitor speed and traffic from the air
(2) Cessna 206s	Traffic enforcement pursuits/night missions/search and rescue	4 days a week, Wednesday–Saturday No Sunday–Tuesday operation	FLIR-enabled aerial missions (speed and DUI enforcement, pursuits, search and rescue)	(4) Cessna 206s	Traffic enforcement pursuits/night missions/search and rescue	7 days a week, Monday–Sunday	FLIR-enabled aerial missions (speed and DUI enforcement, pursuits, search and rescue) **Capacity for 7 days/week coverage**
(2) FLIR Camera Units	Traffic enforcement pursuits/night missions/search and rescue	4 days a week, Wednesday–Saturday No Sunday–Tuesday Operation	FLIR-enabled aerial missions (speed and DUI enforcement, pursuits, search and rescue)	(3) FLIR Camera Units	Traffic enforcement pursuits/night missions/search and rescue	7 days a week, Monday–Sunday	FLIR-enabled aerial missions (speed and DUI enforcement, pursuits, search and rescue) **Capacity for 7 days/week coverage**

E. Alternative Fuels and Electric Aircraft

1. Background

The DMG team was asked to assess whether alternative technologies such as alternative fuels and electric aircraft could be viable options for the WSP. The request for this evaluation comes in light of growing concern for environmental sustainability, as the aviation sector in Washington accounted for approximately 9.4 million metric tons of greenhouse gas emissions (GHG) in 2018—nearly 10 percent of the state's total emissions.[2] While general aviation aircraft like those operated by WSP account for only a small portion of these emissions, there has been growing interest in reducing general aviation aircraft emissions.

Several avenues are currently being explored to achieve environmental sustainability goals, including the implementation of alternative and sustainable aviation fuels and

[1] Approximately 40 percent of Cessna 182 missions are transport-related
[2] Washington State Department of Ecology, *Washington State Greenhouse Gas Emissions Inventory: 1990-2018,* January 2021, https://apps.ecology.wa.gov/publications/documents/2002020.pdf (accessed September 2022)

development of alternative electric aircraft and propulsion systems such as battery-electric powertrains and hydrogen fuel cells.

2. Recommendations

The following is a summary of the recommendations stemming from this analysis.

- **Alternative fuels:** WSP should not plan to use unleaded aviation fuels or sustainable aviation fuels as their primary fuels in the near term due to lack of availability, operational constraints to source the fuel, and significantly increased costs when it is available for use. These fuels are very limited in availability nationally and are limited to only a few facilities in Washington State. However, WSP should monitor cost and availability and use these alternative fuels as they become more readily available.
- **Electric and other alternative aircraft:** Electric aircraft currently in service or expected to be approved for service in the near future do not meet the needs of WSP's missions and therefore should not be pursued at this time. However, the technology is rapidly evolving, and several suitable replacement aircraft currently in development are expected to be released for service by 2028. WSP and the JTC should reevaluate what aircraft options are available at the time of each individual aircraft replacement, particularly if fleet replacement takes place over the next ten years.
- **Alternative aircraft engines and powertrains:** The Soloy compression-ignition engine conversion kit[3] provides several benefits compared to the standard C182 engine, but given the separate recommendation to reduce the size of WSP's C182 fleet, implementation of such a kit will likely not provide enough benefit to overcome the increased costs. Electric and hydrogen fuel-cell powertrains are in development, but are not a suitable replacement for the C182 or C206 engines at this time. WSP should evaluate the market at the time of individual aircraft replacement to determine if an alternative powertrain is available that meets WSP mission requirements and can provide a more environmentally sustainable solution.

F. Unmanned Aerial Systems

1. Background

The DMG team was asked to evaluate the potential for WSP to utilize other technologies, including unmanned aerial systems (UAS or drones), to achieve some or all of the Aviation Section's mission.

UAS are the operation of an unmanned aerial vehicle (UAV) by an autonomous or human-operated ground-based control and command system.t. For additional detail about UAS and types of utilization (e.g., recreational, commercial and civil, etc.), including current use by WSP, see Section E of this report.

[3] https://www.soloy.com/cessna-182.html

2. Conclusions of Analysis

The following is a summary of the recommendations identified from this analysis:

- Most of the current UAS technology available for commercial/civil use under FAA Part 107 rules is not a suitable alternative to traditional aircraft for conducting WSP missions due to the limitations in speed and battery life of most UAVs under 55 pounds. There are some UAVs under 55 pounds that can be used for longer periods of time and at speeds necessary to support WSP missions, however the high cost for this technology is a limiting factor in its applicability to WSP missions.
- FAA Part 107 rules have strict guidelines related to the types of operations that are permitted, including operations needing to occur within the line of sight and within certain airspace. If operations are required outside of the boundaries of Part 107 rules, additional waivers must be submitted to and approved by the FAA. The administrative burden of WSP pilots earning their FAA Part 107 certification and filing for waivers to conduct routine missions creates unnecessary obstacles which do not exist when missions are conducted using traditional aircraft.
- Concerns related to unlawful surveillance and the violation of Fourth Amendment rights add to the challenges associated with integrating UAS technology into WSP missions.
- Until technology advances to the point that UAVs with long battery life and fast speeds become more affordable, and policy adapts to better align with using UAS for WSP missions, it is not feasible to consider the integration of UAS technology into the WSP operations currently being conducted by the Cessna fleet.

I. Evaluation of Current Use of the Aircraft and Strategic Management of Fleet Including Timing of Replacements

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A. Background

The Washington State Legislature's Joint Transportation Committee (JTC) commissioned a comprehensive evaluation of the Washington State Patrol's (WSP) fleet of Cessna aircraft. WSP asked the 2022 Legislature to fund replacement of all five Cessna aircraft over a five-year period. This prompted the legislative request for an evaluation of the duties of the WSP Aviation Section as well as the current state of the Cessna aircraft to determine if there are any other options for modernizing the fleet.

JTC contracted with Dye Management Group, Inc. (DMG), in partnership with Kimley-Horn (K-H), to assess the current use and performance of the aircraft; evaluate the timing of needed replacement of the aircraft; evaluate the feasibility and costs of using aircraft powered by alternative fuel; and review other potential technologies, including unmanned aerial vehicles, to achieve some or all of the WSP Aviation Section's mission.

B. Introduction

For Task 1 of this evaluation, the DMG team evaluated the current use of the WSP Cessna aircraft and the strategic management of the fleet, including the timing of replacements. As part of this task, the DMG team met with WSP personnel at the WSP hangar in Olympia, Washington. The DMG team reviewed and analyzed historical maintenance and operating data for the Cessna aircraft; reviewed and evaluated the assumptions in WSP's funding request to the Legislature; and developed a proposed future state of WSP operations, aircraft complement, etc. This report summarizes the results of the analysis.

C. Summary of Current WSP Fleet

The WSP Aviation Section's fleet consists of the following:

- Three Cessna 182s (C182)
- Two Cessna 206s (C206)
- Two FLIR camera units
- One Beechcraft Super King Air B200 (not included of the original scope of analysis for this project)

D. Original WSP Funding Request

WSP's original funding request submitted to the Legislature included a complement of five C206 aircraft and five new FLIR cameras. The total cost, including interest payments on the requested Certificates of Participation, is over $12.4 million. Exhibit 6 shows the payment amounts by year and total for WSP's original funding request.

Exhibit 6: Original WSP Funding Request

Year	Total
FY 2023	$69,158
FY 2024	$554,658
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FY 2026	$1,226,250
FY 2027	$1,234,500
FY 2028	$1,240,250
FY 2029	$1,233,750
FY 2030	$1,215,500
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FY 2032	$1,222,500
FY 2033	$1,231,375
FY 2034	$739,750
FY 2035	$246,000
TOTAL	**$12,434,145**

To make a comparison between WSP's original request and DMG's recommendation (see Exhibit 10), we eliminated the financing mechanism and adjusted the fleet purchasing outlook to five years to match the cost scenarios. Exhibit 7 shows the cost impact of five C206 aircraft and five new FLIR cameras, per the original WSP request, over a five-year period.

Exhibit 7: Original WSP Request Over Five-Year Period

Item	FY2024	FY2025	FY2026	FY2027	FY2028	Resale Value	Total
Cessna 206	$2,210,000	$0	$2,344,589	$0	$1,243,687	**($512,915.65)**	$5,285,361
FLIR Camera and Equipment	$5,585,050	$0	$0	$0	$0	$0	$5,585,050
Total	**$7,795,050**	**$0**	**$2,344,589**	**$0**	**$1,243,687**	**($512,915.65)**	**$10,870,411**

E. Recommendations and Cost Impacts

DMG provides the following recommendations:

- WSP operates a fleet of five aircraft: four Cessna 206s and one Cessna 182.
- WSP utilizes three FLIR camera units.

This recommended complement of aircraft and FLIR cameras results in a decreased cost of approximately $3.78 million relative to WSP's original funding request while still providing the ability to successfully deliver the Aviation Section's mission.

These recommendations also increase WSP's capacity to conduct FLIR-enabled aerial missions with the resulting positive impacts on public safety. Additional detail on the analysis and justification of these recommendations is included in subsequent sections of this report.

DMG also accompanied its recommendations with four additional scenarios for WSP's review, along with a five-year outlook of the agency's original fleet replacement request. A summary of the request and each scenario is shown in Exhibit 8. Scenario 1 is described in Section J. Scenarios 2 – 5 are described in Appendix A.

Exhibit 8: Summary of Fleet Scenarios

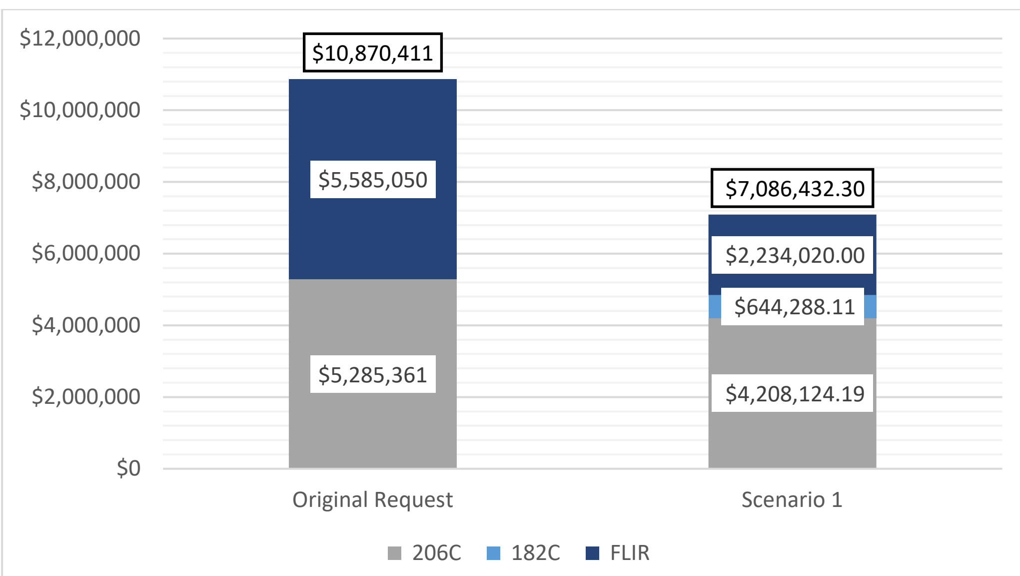
	Original WSP Request		Scenario 1 (Recommended)		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
	Aircraft	FLIR	Aircraft	FLIR	Aircraft	FLIR	Aircraft	FLIR	Aircraft	FLIR	Aircraft	FLIR
Replace FY 24	206(2)	2	206(2)	2	206(2)	1	206(2)	2	206(2)	1	206(2)	2
Replace FY 26	206(2)	2	206(1)		206(1)		206(1)		206(1)		182(2)	
Replace FY 28	206(1)	1	206(1) 182(1)		206(1) 182(1)		182(1)		182(1)		182(1)	
Total New Fleet and Equipment	206(5)	5 FLIR	206(4) 182(1)	2 FLIR	206(4) 182(1)	1 FLIR	206(3) 182(1)	2 FLIR	206(3) 182(1)	1 FLIR	206(2) 182(3)	2 FLIR
5-Year Cost	**$10,870,411**		**$7,086,432**		**$5,969,422**		**$5,833,483**		**$4,716,473**		**$6,119,623**	

Exhibit 9 provides a summary of the current and future (recommended) fleet complement. The key impact of increasing the number of C206 aircraft is that it provides WSP the ability to increase the number of hours available to conduct FLIR-enabled missions with the resulting positive impact on public safety.

Exhibit 9: Current and Future State Comparison

Current State				Future State			
Aircraft	**Mission**	**Days of Operation**	**Benefit to the Public**	**Aircraft**	**Mission**	**Days of Operation**	**Benefit to the Public**
(3) Cessna 182	Transport/training/ traffic enforcement	7 days a week, Monday–Sunday	Monitor speed and traffic from the air	(1) Cessna 182	Transport/training/ traffic enforcement	7 days a week, Monday-Sunday	Monitor speed and traffic from the air
(2) Cessna 206	Traffic enforcement pursuits/night missions/search and rescue	4 days a week, Wednesday–Saturday No Sunday–Tuesday operation	FLIR-enabled aerial missions (speed and DUI enforcement, pursuits, search and rescue)	(4) Cessna 206	Traffic enforcement pursuits/night missions/search and rescue	7 days a week, Monday–Sunday	FLIR-enabled aerial missions (speed and DUI enforcement, pursuits, search and rescue) **Capacity for 7 days/week coverage**
(2) FLIR Camera Units	Traffic enforcement pursuits/night missions/search and rescue	4 days a week, Wednesday–Saturday No Sunday–Tuesday Operation	FLIR-enabled aerial missions (speed and DUI enforcement, pursuits, search and rescue)	(3) FLIR Camera Units	Traffic enforcement pursuits/night missions/search and rescue	7 days a week, Monday–Sunday	FLIR-enabled aerial missions (speed and DUI enforcement, pursuits, search and rescue) **Capacity for 7 days/week coverage**

Exhibit 10: Total Cost of WSP's Original Request vs Recommendation



F. Current State Assessment of WSP Aviation Section

WSP's Aviation Section relies on six aircraft to support its many law enforcement and transport responsibilities. This fleet includes five Cessna aircraft and one Beechcraft King Air. The Cessna aircraft engage in most of the activities and are the focus of this analysis.

G. WSP Aviation Section Background and WSP Mission

The Washington State Patrol Aviation Division manages a fleet of six aircraft and conducts a variety of public safety missions related to law enforcement, surveillance, traffic monitoring, transport, enforcement, and support other law enforcement agencies. The six aircraft fleet includes:

- Three Cessna 182s (182s)
- Two Cessna 206s (206s)
- One Beechcraft Super King Air B200 (not included of the original scope of analysis for this project).

Exhibit 11: WSP Cessna 206 equipped with FLIR Camera

Source: WSP Recruiting Twitter

The Cessna 182s were purchased between 1999 and 2002 and over their 20+ years in operation have flown between 7,800 and 10,500 hours. The 182s in WSPs' fleet are equipped with specialized law enforcement radios and LoJack technology to communicate with ground units and track stolen vehicles. When fully-fueled the aircraft can operate for approximately six hours. A "good mission" for the 182s is to contribute to thirty traffic stops in one hour when working in conjunction with WSP vehicles monitoring the highway system from the ground. The 182s are also frequently used for transport missions, with about 40 percent of the 182 missions being for transportation. 182s are also relied upon heavily for training missions, both for pilots who are new to the WSP Aviation Division and to keep existing pilots current on their certifications

The Cessna 206s have also been operational within WSPs fleet for over twenty years and are piston-powered single-engine aircraft. A key aspect of the 206 aircraft's capabilities is supporting nighttime traffic enforcement and pursuits and support other law enforcement jurisdictions across the state and primarily along the Interstate 5 (I-5) corridor. This became especially important in 2021 when the Washington State Legislature enacted a "no pursuit" law in which a police officer may not engage in a vehicular pursuit unless there are extreme circumstances.[4] The 206s use Forward-Looking Infrared Cameras (FLIR) to conduct their missions, which are thermal imaging cameras used in traffic surveillance. A Tactical Flight Officer (TFO) is required on board the 206 to operate the camera and associated systems. The FLIR cameras are also used when WSP contracts with the U.S. Navy to escort ships and submarines traveling to and from various bases in the Puget Sound region.[5] The FLIR cameras and associated monitors and controls take up a considerable amount of space in the aircraft, reducing the seating capacity to one pilot and three passengers. The FLIR camera attachments creates noticeable drag on the airframe, slightly lowering the cruising speed and range of the aircraft while putting additional aerodynamic strain on the control surfaces on the wing behind the camera. The FLIR camera equipment also enables WSP to support search and rescue missions. The Cessna 206 and FLIR-enabled aerial law enforcement and search and rescue operations have been implemented and proven effective at numerous other agencies, including the North Dakota Highway Patrol[6] and South Dakota Highway Patrol.[7]

Due to the nature of the 206's missions, it is required that these aircraft are able to travel at high speeds over long durations of time (typically operating for six to eight hours at a time).

Exhibit 12: FLIR Camera Mounted on WSP owned 206 Wing

Source: Kimley-Horn

All WSP aircraft are currently based at Olympia Regional Airport and are fueled between missions by the local fixed-base operator (FBO) at the airport. However, WSP aircraft will land at any public-use airport in the state to fuel or pick up passengers as the airport will allow based on aircraft operating requirements. WSP aircraft typically use airports in Olympia, Tacoma, Seattle, Spokane, Yakima, Bellingham, and Pasco as they are near large population centers where the majority of traffic monitoring and surveillance missions are carried out. Most of the missions WSP conducts with the FLIR cameras equipped take place in Western Washington, while missions in the eastern part of the state are primarily for traffic monitoring/speed enforcement and transport purposes.

[4] https://app.leg.wa.gov/RCW/default.aspx?cite=10.116.060

[6] https://www.kfyrtv.com/2021/10/12/birds-eye-view-nd-highway-patrol-soars-new-heights-pursue-vehicles-find-missing-persons/

[7] https://www.newscenter1.tv/high-flying-help-south-dakotas-only-law-enforcement-plane-gives-officers-an-edge/

H. Summary of Current Mission Types

- WSP currently conducts the following types of aerial missions:
- Traffic enforcement
- DUI Aerial Response Team (DART)
  - First program in the nation to use FLIR-equipped airplanes to locate, track, and coordinate the apprehension of impaired, reckless, and aggressive drivers.
- Target Zero Aerial Patrols (TZAP) highway safety program
  - Utilize Cessna 206 and FLIR equipment to conduct statewide day and night aerial traffic enforcement targeting collision causing violations speed, aggressive and reckless driving, and DUI. Supports Washing State DOT's Target Zero Safety Plan[8]
- Transportation (governor, other state officials, Department of Natural Resources, and Washington State Department of Transportation)
- Other (demonstration/protest, drug, emergency, LoJack, maintenance, marijuana, medical, media and public relations, U.S. Navy operations/missions, photographs, pursuit, search and rescue, security, surveillance, training)

The Cessna 182 aircraft are used for traffic enforcement, transportation, photographs, and training. The 182 aircraft are only used in daytime missions. The Cessna 206 aircraft, which can carry forward-looking infrared (FLIR) cameras and surveillance equipment, are used for traffic enforcement and hazard response.

I. Operations Data

WSP provided the DMG team with documentation related to the operation and maintenance of the fleet, including historical flight and maintenance cost data. Exhibit 13 shows the flight hours by aircraft since 2012. Exhibit 14 shows the total flight hours by aircraft. WSP has increased its usage of the 206 aircraft in recent years compared to the 182 aircraft as WSP have placed a heavier emphasis on supporting the FLIR-enabled aerial missions.

Exhibit 13: Flight Hours by Aircraft, 2012–2021

Tail Number/ Model	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
N3532K (182)	392.9	335.9	486.4	554.6	408.4	348.6	497.2	198.5	184.6	183.8
N305RC (182)	409.9	263.2	385.8	401.0	370.6	205.2	371.7	290.6	291.7	302.9
N102LP (182)	537.0	330.1	474.7	478.2	416.5	322.6	353.1	436.4	353.9	317.0
N2446X (206)	405.9	328.9	168.1	626.8	310.4	358.6	245.6	101.2	308.8	594.1
N305DK (206)	121.2	383.5	358.7	18.9	111.5	188.7	187.7	257.3	822.9	568.7
TOTAL	**1,866.9**	**1,641.6**	**1,873.7**	**2,079.5**	**1,617.4**	**1,423.7**	**1,655.3**	**1,284.0**	**1,961.9**	**1,966.5**

[8] https://wsdot.wa.gov/construction-planning/statewide-plans/strategic-highway-safety-plan-target-zero

Exhibit 14: Lifetime Aircraft Hours (through 12/31/21)

Tail Number/ Model	Year in Service	Age	Airframe Hours
N3532K (182)	2001	20	10,505
N305RC (182)	2001	20	9,563
N102LP (182)	2002	19	8,626
N2446X (206)	2000	21	8,581
N305DK (206)	1999	22	8,060
TOTAL			**45,335**

J. Analysis of Future State Options

1. Composition of Fleet

Based on the findings from the current state assessment, the DMG team developed multiple aircraft usage scenarios and evaluated their ability to most effectively meet WSP's mission. The DMG team also developed multiple fleet purchasing scenarios over a five-year period, including different compositions of fleet and aircraft type and multiple combinations of FLIR cameras.

2. Cost and Other Assumptions

For this analysis, the DMG team made the following assumptions:

- Capacity (aircraft availability) to conduct daily (seven days per week) FLIR-enabled aerial missions with the 206 aircraft enable WSP to maximize the positive impact on public safety.
- WSP will continue to have training and transport mission requirements.
- For every fifty hours of flight time, there are approximately twenty-eight hours of required maintenance (scheduled and unscheduled).
- Cessna estimates an 18-month lead time to procure new aircraft.
- WSP's FLIR cameras were purchased in 2015 and have 3,066 and 3,866 hours, respectively.
- FLIR camera maintenance costs were not included in the analysis due to their minimal impact on total cost of ownership. According to WSP, the total cost the agency incurred for repairs of both FLIR cameras over a 7-year duration was $151,346.43 combined.
- 3 percent annual inflation rate.9,10

[9] https://ofm.wa.gov/washington-data-research/economy-and-labor-force/inflation
[10] https://www.bls.gov/regions/west/news-release/consumerpriceindex_seattle.htm

- Does not assume a specific financing mechanism (cash versus Certificates of Participation, etc.).
- Does not assume staffing/pilot capacity to operate the aircraft. However, our team estimates that the recommended fleet complement can be staffed with the current number of positions and enable WSP to conduct more frequent (daily) FLIR-enabled missions.

Exhibits 15 and 16 show the estimated costs to procure new aircraft and the estimated resale values of existing aircraft, respectively. Cessna 206 costs include upfitting the aircraft with avionics associated with FLIR cameras.

Exhibit 15: Cost of New Cessna 206 and 182 and FLIR Camera Equipment

Item	Cost
Cessna 206	$1,105,000
Cessna 182	$650,000
FLIR Camera and Equipment	$1,117,010
TOTAL	**$2,872.010**

Exhibit 16: Resale Value of Current Cessna Fleet

Tail Number/ Model	Year in Service	Hours as of 2021	Estimated Value (Used Market)
N305DK (206)	1999	7,930	$222,175
N2446X (206)	2000	8,380	$212,399
N102LP (182)	2002	8,620	$75,752
N305RC (182)	2001	9,520	$63,273
N3532K (182)	2001	10,470	$52,324

3. Benefits of FLIR-enabled Aerial Missions

The 206 aircraft with the FLIR camera is a highly beneficial airframe because it enables the Target Zero Aerial Patrol (TZAP) missions that WSP can undertake both day and night. These missions target unsafe drivers on the road and notify ground officers who pursue and stop the suspect. These incidents included stolen vehicles, DUI arrests, reckless driving, and accidents. In all the successful pursuits, the suspects were apprehended and taken into custody without incident. The FLIR-enabled 206 aircraft were the first response to all situations. Exhibits 17 shows an annual summary of missions.

Exhibit 17: 2021 Target Zero Aerial Patrol and Traffic Missions[11]

TZAP and Traffic Hours Flown	1,362
Hours of Traffic Back-up Saved	15
Miles of Traffic Back-up Saved	149
Total Estimated Traffic Management Cost Savings	$286,302
DUI Arrests	37
Aggressive Driver Apprehension Traffic Stops	1,276
Other Violations Stopped (e.g., Speed, Reckless, Drugs)	1,791
Suspect Searches/Containment	102
Pursuit Involvement	70
Calls for Service	820

DMG analyzed flight logs from recent TZAP missions and noted the amount of dangerous traffic situations that the FLIR-enabled 206 was able to mitigate in a short amount of time. For example, during the week of September 14th, 2022, the TZAP missions responded to forty-one incidents, identified fifteen aggressive vehicles, and initiated five pursuits which resulted in four arrests. Exhibit 18 is a weekly summary of TZAP FLIR-enabled missions, contacts, arrests, etc.

Exhibit 18: Incident Count Observed by TZAP FLIR-Enabled Missions with 206 Aircraft – Weekly Snapshot

Contact Type	Actual Count
Total Incidents	41
Aggressive Vehicles	15
Vehicle Pursuits	5
Arrests	4

It is difficult to specifically quantify the impact of increasing the capacity to conduct FLIR-enabled aerial missions. However, based on this historical data, we reasonably assume by providing additional capacity for these missions, we anticipate WSP can continue to increase the positive impact on public safety.

The FLIR-enabled Cessna 206 also:

- Supports the governor's Results Washington goal of healthy and safe communities[12]
- Provides aerial support to WSP troopers and other law enforcement agencies on the ground, including pursuit management

[11] https://www.wsp.wa.gov/2021-sod-ar/
[12] https://results.wa.gov/

  - Enhances public safety as the vehicle being pursued may not continue at high speeds if a ground unit is not following the vehicle closely
  - Enhances safety for ground units
- Supports the reduction in speeding and dangerous/drunk drivers
- Supports search and rescue functions
- Supports U.S. Navy operations/missions

4. Risks of Not Replacing the Aircraft and Cameras

- Increased downtime for aircraft maintenance leads to an inability to conduct aerial missions, resulting in a negative impact on public safety
- Increased maintenance costs as the airframe and engines continue to age
- 18-month lead time to procure new aircraft; delaying procurement may exacerbate that risk
- Decreased resale value for existing aircraft as hours increase
- Risk of obsolescence in keeping older cameras (purchased in 2015)

5. Scenarios for Analysis

The DMG team considered numerous scenarios and formally analyzed ten. We ruled out several scenarios that either did not provide WSP sufficient capacity to conduct daily (seven days per week) FLIR-enabled aerial missions or were overly costly. As a result of this analysis, Scenario 1 (outlined below) is our recommendation. Scenarios 2–5 are not recommended and are included in Appendix A of this report.

Note: To accommodate for the 18-month lead time for procuring new aircraft, we initiated each cost scenario in FY2024. To calculate resale values, we used the current estimated market value as a baseline and then calculated the reduction of the value for the year the aircraft will be sold.

a. Scenario 1 (Recommended)

In Scenario 1, WSP would retain one 182 aircraft, add four new 206 aircraft and purchase one additional FLIR camera. WSP would immediately retire the two 182 aircraft with the highest lifetime hours (N3532K and N305RC) and procure two new 206 aircraft. WSP would plan to procure additional 206 aircraft in FY2026 and FY2028 and retire the two 206 aircraft currently in the fleet (N2446X and N305DK) in each year. WSP would retire the remaining 182 aircraft currently in the fleet (N102LP) in FY2028 and procure a new 182 aircraft. Scenario 1 also provides for the replacement of an existing FLIR camera.

Exhibit 19: Scenario 1 (Recommended) – Five Aircraft (Four 206 and One 182) and Three Cameras (Replacing One Existing Camera)

Item	FY2024	FY2025	FY2026	FY2027	FY2028	Resale Value	GRAND TOTAL
Cessna 206	$2,210,000	$0	$1,172,295	$0	$1,243,687	(377,716.49)	$4,248,265
Cessna 182	$0	$0	$0	$0	$734,957	(130,810.19)	$604,147
FLIR Camera and Equipment	$2,234,020	$0	$0	$0	$0	$0	$2,234,020
GRAND TOTAL	**$4,444,020**	**$0**	**$1,172,295**	**$0**	**$1,978,644**	**(508,526.68)**	**$7,086,432**

Scenario 1 enables the following:

- Daily FLIR-enabled aerial missions with 206 aircraft, with resulting positive impacts on public safety
  - Assumes one 206 aircraft will be down for maintenance at any given time
- Sufficient capacity of FLIR cameras to support daily FLIR-enabled aerial missions
- Continued ability to deliver the transport and training missions
- Mitigated risk of obsolescence of existing cameras

K. Next Steps

To maximize the positive impact on public safety, the DMG team recommends providing sufficient aircraft to support daily (seven days per week) FLIR-enabled aerial missions. To achieve this, the DMG team recommends WSP implement Scenario 1 and purchase four 206 Cessna aircraft over a five-year period, and retain the current 182 aircraft with the lowest airframe hours (N102LP) until replacing it with a new 182 in FY2028. We also recommend purchasing two FLIR cameras. This option presents higher cost of ownership than several other scenarios but most effectively enables daily FLIR-enabled aerial missions. It also minimizes the risk of aircraft and/or FLIR camera downtime. This scenario also supports WSP's training and transport missions. This scenario represents a reduction of approximately $3.78 million from WSP's original funding request.

1. Supplemental Information on Beechcraft King Air

While not in the scope of this project, JTC is also interested in the feasibility of replacing WSP's current Beechcraft King Air aircraft. The DMG team researched the cost to procure a Pilatus PC-12NGX turboprop aircraft as a potential replacement, but we have not conducted a formal analysis for this aircraft or other possible replacement aircraft. The cost of the PC-12 base model at the top of the price range is approximately $6.3 million, with an 18–24-month lead time upon order of the aircraft. WSP may consider replacing the current Beechcraft King Air prior to 2030 which is the expected timeline for major engine overhaul, estimated at over $1 million. This information is for reference only. However, the DMG team may further investigate this option later in the project (as budget and schedule permit).

II. Alternative Fuels and Electric Aircraft

■

A. Introduction

This chapter assesses whether alternative technologies such as alternative fuels and electric aircraft could be viable options for the Washington State Patrol (WSP). The request for this evaluation comes in light of growing concern for environmental sustainability, as the aviation sector in Washington accounted for approximately 9.4 million metric tons of greenhouse gas emissions (GHG) in 2018—nearly 10 percent of the state's total emissions.[13] While general aviation aircraft like those operated by WSP account for only a small portion of these emissions, there has been growing interest in reducing general aviation aircraft emissions.

Several avenues are currently being explored to achieve environmental sustainability goals, including the implementation of alternative and sustainable aviation fuels and development of alternative electric aircraft and propulsion systems such as battery-electric powertrains and hydrogen fuel cells. This chapter examines the opportunities, limitations, and overall feasibility of each of these technologies, and makes a recommendation to the JTC on whether WSP should pursue each technology during this round of fleet replacement.

B. The WSP Fleet

The WSP Aviation Division manages a fleet of six aircraft and conducts a variety of public safety missions related to law enforcement, surveillance, traffic monitoring, transport, enforcement, and support for other law enforcement agencies. The six-aircraft fleet includes:

- Three Cessna 182s (C182s)
- Two Cessna 206s (C206s)
- One Beechcraft Super King Air B200

C. Recommendations Overview

The following is a summary of the recommendations stemming from this analysis.

- **Alternative fuels:** WSP should not plan to use unleaded aviation fuels or sustainable aviation fuels as their primary fuels in the near term due to lack of availability, operational constraints to source the fuel, and significantly increased costs when it is available for use. These fuels are very limited in availability nationally and are limited to only a few facilities in Washington State. However, WSP should monitor cost and availability and use these alternative fuels as they become more readily available.

[13] Washington State Department of Ecology, *Washington State Greenhouse Gas Emissions Inventory: 1990-2018,* January 2021, https://apps.ecology.wa.gov/publications/documents/2002020.pdf (accessed September 2022)

- **Electric and other alternative aircraft:** Electric aircraft currently in service or expected to be approved for service in the near future do not meet the needs of WSP's missions and therefore should not be pursued at this time. However, the technology is rapidly evolving, and several suitable replacement aircraft currently in development are expected to be released for service by 2028. WSP and the JTC should reevaluate what aircraft options are available at the time of each individual aircraft replacement, particularly if fleet replacement takes place over the next ten years.
- **Alternative aircraft engines and powertrains:** The Soloy compression-ignition engine conversion kit[14] provides several benefits compared to the standard C182 engine, but given the separate recommendation to reduce the size of WSP's C182 fleet, implementation of such a kit will likely not provide enough benefit to overcome the increased costs. Electric and hydrogen fuel-cell powertrains are in development, but are not a suitable replacement for the C182 or C206 engines at this time. WSP should evaluate the market at the time of individual aircraft replacement to determine if an alternative powertrain is available that meets WSP mission requirements and can provide a more environmentally sustainable solution.

D. Feasibility of Alternative Fuels in Existing WSP Fleet

In light of growing concerns about the environmental impacts of aviation fuel, a number of alternative and sustainable fuels are being developed and tested. These include unleaded fuels, which present an opportunity to reduce emissions, and sustainable aviation fuels (SAF), which are derived from non-fossil sources. Research into these alternative fuels revealed a selection of options for consideration as possible fuel sources for the WSP fleet.

1. Alternatives to 100LL Avgas

Currently, the majority of the national piston aircraft fleet, including the C182 and C206 aircraft owned and operated by WSP, use 100-octane, low lead (100LL) aviation gas (Avgas). 100LL contains tetraethyl lead (TEL), an additive that increases fuel octane and has anti-knock properties, helping to prevent engine damage from fuel detonation. TEL has been identified as a harmful toxin if ingested. General aviation aircraft have been identified as one of the primary emitters of airborne lead in the U.S. While TEL has largely been retired in other applications since the 1990s—most notably the ban of leaded gasoline in passenger cars—it is still used in Avgas because a suitable alternative has not been approved for use.

In recent years, however, technological and legislative developments have prompted efforts to study unleaded Avgas. Specifically, the Federal Aviation Administration (FAA) announced an initiative in February 2022 to move away from leaded Avgas and completely eliminate its use by 2030. The FAA has since initiated multiple programs to promote the development and testing of unleaded Avgas, including Piston Aviation Fuels Initiative (PAFI) and Eliminate Aviation Gasoline Lead Emissions (EAGLE). Several aviation fuel producers have developed alternative unleaded Avgas to replace 100LL under these programs and independently.

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[14] https://www.soloy.com/cessna-182.html

Exhibit 20 presents a selection of unleaded fuels being used or developed to replace 100LL.

Exhibit 20: Alternative Avgas Options Available

Fuel Name	Provider	Service Status/Estimated Service Entry Date	Approved for use	
			C182	C206
UL91	AirBP	In service in Europe/no plans to introduce in U.S. market	Yes	No
UL94	Swift Fuels	In service/available at select U.S. airports	Yes	No
G100UL	General Aviation Modifications, Inc. (GAMI)	FAA approved/industry rollout expected to start in late 2022	Yes	Yes
Swift 100R	Swift Fuels	Advanced testing/expected service entry mid-2023	N/A	N/A
100M	Phillips 66/Afton Chemical	Initial testing/expected service entry 2025-2026	N/A	N/A
UL100E	Lyondell/VP Racing	Initial testing/expected service entry 2026-2027	N/A	N/A

Note: N/A: not applicable. Sources: AirBP, *Unleaded Avgas grade UL91,* https://www.bp.com/en/global/air-bp/aviation-fuel/ul91.html; GAMI, *Press Release, September 1, 2022,* https://gami.com/g100ul/PressReleaseG100UL9_1_22.pdf; Namowitz, D, *Several Cessna Models Can Now Burn Reduced-Lead Avgas,* https://www.aopa.org/news-and-media/all-news/2021/october/27/several-cessna-models-can-now-burn-reduced-lead-avgas; Phillips 66, *Focused on the Future of Avgas: UL100 Q&A*, https://www.phillips66aviation.com/about-us/news/industry-news/focused-on-the-future-of-avgas-ul100-qa; Swift Fuels, *Frequently Asked Questions*, https://www. swiftfuelsavgas.com/faq; Swift Fuels, *Swift 100R,* https://www.swiftfuels.com/swift-100r

All of the fuels in Exhibit 20 are designed to be drop-in replacements for 100LL, allowing aircraft to run on unleaded Avgas, leaded Avgas, or a mix of both simultaneously, so long as the fuel is approved for use. Of these, UL91 and UL94 are furthest along in their deployment and are sold at dozens of airports abroad and in the U.S., respectively. UL91 and UL94 have removed TEL without replacing it with an alternative anti-knock additive, thereby lowering the octane of the fuel. While these fuels are suitable for more than half of the national piston aircraft fleet, they do not provide adequate fuel detonation protection to be used in high-compression engines.

On September 1, 2022, General Aviation Modifications, Inc. (GAMI) received fleetwide authorization for use of its G100UL fuel. Unlike UL91 or UL94, G100UL has the same octane and anti-knock properties as 100LL, allowing it to be used in any aircraft currently using 100LL. GAMI has partnered with AvFuel to begin production and distribution of G100UL, which is expected to be deployed to select airports in the coming months.

Other 100-octane unleaded Avgas in development include Swift Fuels' 100R, Phillips 66/Afton Chemical's 100M, and Lyondell/VP Racing's UL100E products. Swift 100R is undergoing FAA and ASTM International Standards certification, And the company plans to deploy the fuel by mid-2023. The 100M and UL100E fuels are currently in early stages of testing and are expected to be approved for fleet-wide use in the next three to five years.

ASTM International Standard D910-11, Standard Specification for Aviation Gasolines, established a standard for 100-octane very low lead (100VLL) Avas, capping the maximum amount of TEL in fuel at 0.45 milliliters (mL) per liter (L) of fuel, 0.12 mL less than the standard for standard 100LL fuel.[15] At this time, there are no major producers of 100VLL fuel, although certain blends of 100LL have been found to meet the 0.45 mL/L TEL limit.

2. Alternatives to Jet-A Fuel

The Jet-A fuel used by the Beechcraft Super King Air B200 does not contain lead, but there have been efforts to reduce emissions from aircraft using Jet-A fuel. These efforts culminated in the development of sustainable aviation fuel (SAF), which is derived from non-fossil sources. Various methods have been developed to produce SAF, including extracting alcohol from feedstocks like corn or sugarcane and recycling used cooking oils. SAF is a drop-in alternative and is approved for use in any aircraft currently using Jet-A.

A number of fuel producers currently offer both blended and 100% SAF products. At this time, the only commercially available general aviation facility in Washington State that offers SAF is Boeing Field-King County International Airport. Individual commercial airlines source and purchase their own fuel for delivery to commercial service airports, including limited quantities of SAF, but these are not available for purchase by other users. SAF currently represents a very small fraction of the jet fuel provided at airports in the state, though the Port of Seattle has established a goal to provide it to all aircraft at Seattle-Tacoma International Airport by 2028.[16]

Exhibit 21 presents a selection of current SAF producers and new start-ups entering the SAF market.

Exhibit 21: SAF Producers and Start-up Companies

Producer	Notes
Neste	Plans to increase annual SAF production from 34 million gallons to 515 million gallons by end of 2023. Provides SAF to 6 major airlines including Alaska Airlines.
World Energy	Leading SAF producer for United Airlines at Los Angeles International Airport. Currently expanding its Paramount, California facility to produce 340 million gallons of SAF annually.

[15] ASTM International, Standard D910-11 *Standard Specification for Aviation Gasolines,* May 2011, https://www.aviation-fuel.com/pdfs/avgas100llspecsastmd910_2011.pdf (accessed September 2022)
[16] Port of Seattle, n.d., Sustainable Aviation Fuels, https://www.portseattle.org/page/sustainable-aviation-fuels (accessed September 2022)

Producer	Notes
Alder Fuels	In partnership with United Airlines to provide up to 1.5 billion gallons of SAF annually. Partnered with AvFuel to provide SAF to business aviation users in coming years.
SkyNRG	Provides sourced and blended SAF for 40 airlines worldwide and has a partnership with Boeing to provide SAF for testing and delivery flights from the west coast.
Start-up	**Notes**
Red Rock Biofuels	Completed testing of Fischer-Tropsch and hydroprocessing production methods to create SAF from wood-based feedstock. Lakeview, Oregon plant expected to produce 20 million gallons of SAF annually.
Prometheus Fuels	Developed proprietary membrane technology to extract carbon dioxide from air and use alcohol-to-jet (AtJ) method to convert to SAF. Expected to begin SAF production in 2022.
WasteFuel	Developed proprietary technology to extract hydrocarbons from municipal and agricultural waste. Biorefinery in Philippines expected to begin SAF production in 2025.

Sources: Ahlgren, L., "Which Producers Are Leading the Sustainable Aviation Fuel Race?", https://simpleflying.com/producers-leading-sustainable-aviation-fuel/; Businesswire, "Red Rock Biofuels, Frontline BioEnergy Successfully Gasify Residual Woody Biomass Into Syngas for Production of Sustainable Aviation Fuel", https://www.businesswire.com/news/home/20220818005417/en/Red-Rock-Biofuels-Frontline-BioEnergy-Successfully-Gasify-Residual-Woody-Biomass-Into-Syngas-for-Production-of-Sustainable-Aviation-Fuel; Prometheus Fuels, "Technology", https://prometheusfuels.com/technology; WasteFuel, "About", https://www.wastefuel.com/about

3. Limitations

Although the aforementioned fuels provide an attractive alternative to 100LL, there are significant limitations to their use at this time. Namely, none of these fuels are currently commercially available in Washington State and most have yet to be certified or deployed. UL91 and UL94 are the only products currently in service, but have only been approved in lower-power, naturally-aspirated aircraft engines, including the Cessna 182, but are prohibited from use in aircraft such as the Cessna 206.

While G100UL is approved for all piston aircraft, it is unknown when the fuel will be made widely available. G100UL is expected to be 60 to 85 cents more expensive per gallon than 100LL when first introduced, which may deter fuel providers and airports from offering it. G100UL may become more comparable in price as production rates increase and economies of scale are realized, but the timeline for this is unknown. At this time, it is also unclear if supplemental type certificates (STC) will need to be issued for aircraft using G100UL fuel, as had been done prior to the fleetwide authorization. If so, WSP will need to include the cost of an STC (approximately $200 per aircraft) into the cost of switching to G100UL.

100VLL seems to be an option to immediately reduce aircraft lead emissions, as it is approved for fleetwide use. However, its deployment has been very limited as most fuel producers have opted to continue producing 100LL until unleaded Avgas is fully approved. As such, it is unlikely that a sufficiently adequate supply of 100VLL could be established at airports around the state for WSP to consistently use the fuel.

SAF faces similar challenges due to its limited commercial availability, but is more constrained by cost rather than technical limitations. The cost of producing, delivering, and dispensing SAF is between two and eight times more expensive than traditional Jet-A fuel, making it very unattractive for widespread use. Improvements to production processes are projected to reduce SAF costs, but it is still expected to cost one-and-a-half to three times more than conventional jet fuel.[17] Washington State offers fuel rebates and other incentives to reduce the cost of SAF for end users, but it is still over a dollar more per gallon than traditional Jet-A fuel.

4. Opportunities

Use of unleaded Avgas in WSP Cessna 182 and 206 aircraft would generally align with statewide initiatives to reduce emissions from government vehicles. The absence of lead in G100UL and similar fuels allows the fuel to burner cleaner than 100LL, reducing hydrocarbon emissions and eliminating airborne emissions.

Unleaded fuels such as G100UL have also been found to have better engine cleaning properties than 100LL, eliminating metal buildup in the engine and on spark plugs. In turn, engine maintenance is expected to be less frequent with unleaded fuel. It is still too early to determine exactly how much an engine's lifespan will increase between overhauls, but early indications from high-performance racing engines (another user of leaded fuel that recently transitioned to unleaded fuel) show a substantial improvement. The elimination of lead also opens the door for the development of synthetic oil for aircraft engines, providing another potential increase in engine reliability and longevity.

SAF presents no change in aircraft performance as it is chemically identical to traditional Jet-A fuels. However, use of SAF will dramatically lower the carbon emissions of the WSP fleet, which aligns with Washington State's Climate Commitment Act of 2021, which set the goal of achieving net zero carbon emissions by 2050.

5. Recommendations

Given the current operational limitations of UL91 and UL94 and the limited availability of G100UL fuels, it is not recommended that WSP pursue use of unleaded fuels at this time. While SAF is a viable alternative being sold at select airports, its increased cost and limited availability compared to Jet-A also make it unsuitable for full-time use by WSP aircraft. However, it is recommended WSP and JTC monitor both markets, as the technologies and economics of each fuel type are rapidly changing and may become an attractive substitute in the near future to help WSP achieve environmental sustainability goals.

E. Feasibility of Alternative Aircraft for WSP Missions

In recent years, growing concerns about climate change have prompted the development of alternate aircraft and propulsion systems to reduce the environmental impact of aircraft. Although unleaded fuels present an opportunity to reduce emissions, current iterations have

[17] ICAO, *Sustainable Aviation Fuel Guide, Version 2*, December 2018, https://www.icao.int/environmental-protection/Documents/Sustainable%20Aviation%20Fuels%20Guide_100519.pdf (accessed September 2022)

little impact on the carbon footprint of piston aircraft. As such, aircraft designers have begun to explore alternative propulsion technologies for aircraft.

Significant improvements in electric vehicle technologies in the past decade have spurred the development of battery-electric aircraft, particularly in the general aviation sector. Other alternative technologies being developed for new aircraft include compression ignition (diesel) engines and hydrogen fuel cells. Some technologies are being applied to clean-sheet aircraft designs, while others are converted from existing airframes.

Exhibit 22 presents a list of alternative electric aircraft and their performance specifications compared to the Cessna 182T and 206H of the current WSP fleet. These aircraft are clean-sheet designs (meaning they've been completely originally designed rather than a redesign or modification of an existing type of aircraft) that have already entered service, or have near-finalized designs with projected performance specifications.

Exhibit 22: Cessna 182 and 206 Specifications and Alternative Electric Aircraft Options

Aircraft Model	Existing WSP Fleet		Alternative Electric Aircraft						
	C182	C206	Alpha Electro	Velis Electro	eFlyer2	Cora	ALIA-250c	Lilium Jet	Alice
Manufacturer	Cessna	Cessna	Pipistrel	Pipistrel	Bye Aerospace	Wisk Aero	Beta Technologies	Lilium	Eviation
Propulsion Type	Piston	Piston	Electric	Electric	Electric	Electric	Electric	Electric	Electric
Maximum Range (NM)	930	703	32	75	220	25	250	162	440
Cruise Speed (Kts.)	145	142	90	85	135	95	145	162	250
Service Ceiling (Feet)	18,100	15,700	12,000	12,800	14,000	10,000	NA	NA	32,000
Useful Payload (Lbs.)	1,186	1,404	378	401	450	400	1,400	NA	2,500
Takeoff Distance (Feet)	795	735	791	870	NA	VTOL	VTOL	VTOL	2,600
Seats (includes pilot)	4	6	2	2	2	2	6	7	9
Crew Required	1	1	1	1	1	0*	1	0*	1
Operation Status	In Service	In Service	In Service-Not Certified	In Service-Not Certified	In Certification	Flight Testing	Flight Testing	Flight Testing	Flight Testing
Expected Service Entry Date	In Service	In Service	In Service	In Service	2022	After 2023**	2024	2025	2025

Notes: *Remotely/autonomously piloted. **Demonstrator planned in 2023. NM – Nautical Miles, NA = Information not available. VTOL = vertical takeoff and landing. Sources: Beta Aircraft, *ALIA-250c*, https://www.beta.team/aircraft/; Bye Aerospace, *Electric Training Aircraft,* https://byeaerospace.com/electric-airplane/; Cessna, *Information Manual Model 206H.* http://www.sydneyaviators.com.au/Uploads/C206H%20POH.pdf; Cessna, *Pilots Operating Handbook and FAA-Approved Flight Manual – Skylane*, https://www.rainierflightservice.com/aircraftdocs/182-poh.pdf; Eviation, *Alice,* https://www.eviation.co/aircraft/; Pipistrel, *Alpha Electro*, https://www.pipistrel-aircraft.com/products/light-sport-microlight/alpha-electro/#tab-id-2; Pipstrel, *Velis Electro*, https://www.pipistrel-aircraft.com/products/general-aviation/velis-electro/#tab-id-2; Soloy Aviation Solutions, *Cessna 182 Skylane Power Conversion to the SMA SR305-230E Compression Ignition (CI) Engine,* https://www.soloy.com/cessna-182.html; Wisk Aero, *Aircraft*, https://wisk.aero/aircraft/

Pipistrel has made the furthest progress in deploying electric aircraft. The Pipistrel Velis Electro was the first fully electric aircraft to be certified for regular use, earning certification from the European Union Aviation Safety Agency (EASA) in June 2020. The two-seat Velis Electro and Alpha Electro have been certified as experimental aircraft in the U.S. and are in use for flight training and general aviation activities around the world.

Bye Aerospace is in the later stages of testing for its eFlyer 2, a two-seat flight training aircraft expected to be certified by the end of 2022. A four-seat version, the eFlyer 4, is expected to enter service soon after.

Another area experiencing significant growth is the advanced air mobility (AAM) sector, which is expected to consist of air taxi aircraft with fewer than 20 seats operating point-to-point trips under 60 minutes. Most AAM aircraft are expected to have electric vertical takeoff and landing (eVTOL) capabilities and be autonomously piloted. While more than a dozen companies are currently developing AAM aircraft, Wisk Aero has made the greatest progress with the Cora aircraft, having built a full-scale prototype that has conducted more than 1,000 test flights. The two-seat Cora is expected to introduce a demonstrator for certification by 2023. Other AAM aircraft include Beta Technologies' ALIA-250 and the Lilium Jet, both eVTOL aircraft expected to enter service in 2024 and 2025, respectively.

Lastly, Eviation is developing the Alice, a nine-seat electric aircraft designed for executive transport, commuter service, or light air cargo missions. The Alice is planned as an alternative to the Beechcraft King Air B200, as both aircraft can carry eight passengers or a payload of 2,500 pounds and can cruise at approximately 250-270 knots. The Alice is currently in flight testing with an expected service entry date of 2025.

Several other aerospace companies are developing other aircraft that are in earlier stages of development or have made their performance specifications publicly available. A selection of these aircraft is presented in Exhibit 23.

Exhibit 23: Alternative Aircraft in Early Development

Aircraft Model	Manufacturer	Propulsion Type	Description	Expected Service Entry Date
Hexa	Lift Aircraft	Electric	Single-seat, 18-rotor eVTOL aircraft intended for short distance air taxi and first response.	In production – not certified in US
S4	Joby Aviation	Electric	Autonomously-piloted eVTOL aircraft with four-passenger capacity, 200 Kt cruise speed, and projected range of 130 nautical miles.	2024
Maker	Archer	Electric	Autonomously-piloted eVTOL aircraft with two-passenger capacity, 130 Kt cruise speed, and projected range of 52 nautical miles. Currently in early flight testing.	2024
Eco Otter	Ampaire	Electric	Converted de Havilland Canada DHC-6 Twin Otter aircraft with 19-passenger capacity or 4,000 lbs. payload and projected range of 610 nautical miles.	2024
Tailwind	Ampaire	Electric	Early concept nine-passenger ducted-fan executive aircraft.	Unknown
HyFlyer	ZeroAvia	Hydrogen Fuel Cell	Converted 19-seat Dornier 228 with projected range of 435 nautical miles.	2024
Project Fresson	Cranfield Aerospace	Hydrogen Fuel Cell	Multi-phase project to introduce zero-emission aircraft. First phase plans to convert a 10-passenger Britten-Norman Islander to hydrogen-fuel cell for commercial use.	2025

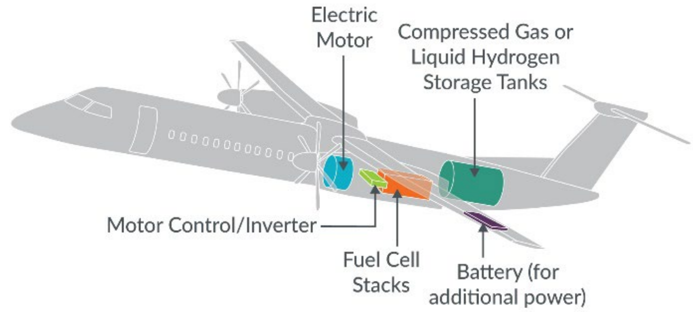
Archer Aviation, *Introducing Maker,* https://www.archer.com/maker; Ampaire, *Meet the Eco Otter,* https://www.ampaire.com/vehicles/Eco-Otter-Aircraft; Ampaire, Meet the Tailwind, https://www.ampaire.com/vehicles/Tailwind%E2%84%A2-Aircraft; Joby Aviation, *Home,* https://www.jobyaviation.com/; Lift Aircraft, *Story*, https://www.liftaircraft.com/story; Project Fresson, *Our Mission,* https://projectfresson.co.uk/our-mission; ZeroAvia, *About Us*, https://www.zeroavia.com/about-us

Of these, the Archer Maker, Joby Aviation S4, and Lift Hexa are planned to compete in the AAM market. The Maker and S4 are expected to carry two and four passengers over distances up to 52 and 130 nautical miles, respectively. The Lift Hexa is a single seat eVTOL aircraft intended to be used for very short distance air taxi and emergency response, competing with unmanned aerial systems (UAS). The feasibility of UAS is discussed further in Chapter 3.

Ampaire is currently working to develop two aircraft. The first, the Eco Otter, is a de Haviland Canada DHC-6 Twin Otter modified to use electric propulsion that is capable of carrying 19 passengers with a range of approximately 610 nautical miles. The second is the Tailwind, a clean-sheet design for a nine-passenger electric ducted-fan aircraft, similar in size to the King Air or Eviation Alice. The Tailwind is still a concept, and it is unknown when it will enter service.

While all of the aircraft previously mentioned use batteries and electric motors, other projects are utilizing innovative technologies to power aircraft. Hydrogen fuel cells appear to be an attractive option, as they provide many of the noise and emission benefits of electric aircraft without needing heavy batteries. Exhibit 24 presents an example of an aircraft with hydrogen fuel cells and necessary components.

Exhibit 24: Example of Hydrogen Fuel Cell Propulsion



Source: Kimley-Horn

Project Fresson is a consortium of multiple aerospace companies working to convert a 10-passenger Britten Norman Islander to be powered by hydrogen-fuel cell powertrains. The hydrogen-powered Islander is expected to be made commercially available, but will also serve as a technological demonstrator for the application of hydrogen technologies in larger aircraft. ZeroAvia is also pursuing hydrogen technology for aircraft as it works to develop the HyFlyer, a Dornier 228 regional commuter aircraft converted to use ZeroAvia's ZA600 hydrogen fuel cell powertrain. ZeroAvia has already flown a technological demonstrator and is expected to introduce the HyFlyer by 2024.

F. Limitations

1. Electric Aircraft

As shown in Exhibit 22, the electric aircraft that are currently available are unable to match the performance of the existing WSP aircraft fleet. This is a result of many factors, but can mainly be attributed to the lower energy density of batteries compared to liquid Avgas or Jet-A. As a result, an aircraft must be considerably heavier to accommodate enough batteries to achieve comparable performance, or must sacrifice performance to remain in the same weight class.

Most aircraft manufacturers have opted to use small, lightweight batteries at the cost of speed and range. The maximum endurance of the electric aircraft presented here is three hours, with many unable to stay aloft for more than one hour. This is less than one-quarter the time of the typical WSP aircraft mission. As such, use of an electric aircraft at this time would require the WSP to land and charge more frequently, significantly limiting WSP's ability to loiter in an area for traffic monitoring or surveillance missions. If electric aircraft were only used on demand to get around this issue, the increased response time would have a substantial impact on the effectiveness of the WSP.

The other consequence of batteries' low energy-density is that speed and payload capacity is compromised for weight savings. The maximum payload of electric aircraft currently in service is 450 pounds, nearly 1,000 pounds less than the C206. Given this, most electric aircraft would not be able to conduct transport missions and would be entirely unable to carry the Forward Looking Infrared (FLIR) camera equipment that WSP uses to conduct their surveillance and monitoring missions. Furthermore, most current electric aircraft cruise at 85 to 95 knots, with only the eFlyer 2 exceeding 100 knots. The low cruise speed would the ability of affect WSP aircraft to follow vehicles, as many ground pursuits can exceed speeds of 100 miles per hour or more.

Much like the alternative fuels discussed in Section II, electric charging infrastructure for aircraft is sparsely available in the state. Although companies including Beta Technologies offer standard aircraft charging stations that could be installed at WSP's home base, it is unlikely these charging stations would be in widespread use to provide a comparable charging network as what is available with 100LL. This would limit where WSP could fly in the state, diminishing its ability to meet its public safety and transport missions.

Additionally, the aircraft batteries currently in operation have an average life expectancy of 370 cycles (discharging and recharging the battery), which may provide less than 1,000 flight hours before needing to be replaced.[18] Conversely, the engines in the Cessna 182 and 206 have a time between overhaul (TBO) period of 2,000 flight hours but can be run up to 30,000 hours. Some electric motors have similar TBO periods as piston engines but have a lifespan limited to 6,000 hours.[19] The limitations to battery and motor life would require WSP to shut down aircraft for major maintenance more often, reducing their operational effectiveness. Future electric aircraft are likely to have swappable battery packs, allowing for quick replacement without the need for significant downtime.

As demonstrated by the projected performance specifications of the ALIA-250, Alice, and Tailwind, more suitable electric aircraft options are coming to the aviation industry. However, the proposed timeline for their introduction is not expected to be early enough for these products to be a useful substitute for WSP fleet replacement at this time. Many of these first-generation electric aircraft may have technological limitations due to the novelty of the technology, so it may not be practical for them to be used in a highly intensive role for the WSP.

2. Hydrogen Fuel Cell Aircraft

Hydrogen fuel cell technology will overcome some of the shortcomings of electric aircraft due to the ability to store more energy at a lower weight than electric aircraft, but has challenges of its own. Hydrogen requires complex storage systems to maintain its liquid state and has a lower energy density by volume than petroleum-based liquid fuels. Therefore, most hydrogen aircraft will need to store fuel in the fuselage rather than the wings, substantially limiting the space available to carry passengers or cargo. There are also difficulties associated with the production, transportation, and storage of liquid hydrogen. Most of the hydrogen produced today is extracted from fossil sources, emitting high levels of greenhouse

[18] Garrett-Glasser, B., "The Batteries Behind the Electric Aircraft Revolution", September 2020, https://www.aviationtoday.com/2020/09/08/batteries-behind-electric-aircraft-revolution/ (accessed September 2022)
[19] Pipistrel, *Pipistrel ALPHA ELECTRO Information Pack,* October 2017, https://www.pipistrel-usa.com/wp-content/uploads/2018/03/Pipistrel-Alpha-ELECTRO-Information-Pack.pdf (accessed September 2022)

gases. Similar to alternative fuels, there is very limited infrastructure currently in use to transport or distribute hydrogen fuels, which would restrict which airports these aircraft could operate in and out of.

1. Opportunities

Electric aircraft offer several environmental benefits compared to traditional piston and jet aircraft. Electric aircraft have zero tailpipe GHG emissions – meaning the only carbon emissions produced when operating an electric aircraft are generated from electricity production. If WSP is able to source electricity from a sustainable source (i.e wind or solar), it could achieve carbon neutrality while operating an all-electric aircraft fleet. Electric aircraft have also been found to have reduced noise emissions, as initial studies indicate that electric propulsions systems are as much as 85 percent quieter than their piston engine counterparts.[20] A quieter aircraft would not only reduce WSP's impacts on the communities they overfly but may also allow WSP to fly at a lower altitude without detection—particularly at night—providing a closer, more detailed view of on-ground activities through the FLIR cameras.

Small flight training aircraft like those made by Pipistrel and Bye Aerospace have been found to cut operating costs by as much as half compared to piston aircraft. Larger aircraft such as the Eviation Alice and Ampaire Tailwind are projected to have fuel (electricity) costs and maintenance expenses that are 90 and 50 percent lower than their piston and turbofan counterparts, respectively.[21] While the cost of most electric aircraft in development have yet to be published, these lower operating costs would offset the expense of new aircraft over their operating lifespan.

Hydrogen fuel cell aircraft share many of the same environmental benefits as electric aircraft. Hydrogen fuel cells produce only water and do not produce GHG emissions. While there has been limited study into the noise emissions and maintenance costs of hydrogen fuel cells compared to traditional engines, it is expected that fuel cells will perform favorably as there are no moving parts in the fuel cell.

2. Recommendations

The electric aircraft currently in service, such as the Pipistrel Velis and eFlyer II, do not have the range, speed, or capacity to meet the needs of WSP's missions and therefore should not be pursued for WSP fleet replacement at this time. However, the technology is rapidly evolving, and several larger, faster, and longer-range aircraft are in development to be operational in the next five years that could help achieve environmental sustainability goals. As such, it is recommended that WSP and the JTC evaluate what aircraft are in service at the time of each individual aircraft replacement during this period and beyond, particularly if fleet replacement takes place over the next ten years.

[20] Schwab, A., et al.
[21] Schwab, A., et al., "Electrification of Aircraft: Challenges, Barriers, and Potential Impacts" October 2021, https://www.nrel.gov/docs/fy22osti/80220.pdf

G. Feasibility of Alternative Powertrains in Existing WSP Aircraft

During the data gathering process of this study, WSP identified a compression-ignition engine conversion kit currently being developed that would provide an alternative powertrain for the Cessna 182. Additionally, research into alternative aircraft identified several stand-alone electric or hydrogen powertrains currently being developed that could be installed on WSP aircraft. A selection of these powertrains is presented in Exhibit 25.

Exhibit 25: Alternative Engines/Powertrains

Model Name	Manufacturer	Propulsion Type	Maximum Power (HP/KW)	Maximum Operating Altitude (Feet)	Dry Weight (Lbs.)	Operational Status
IO-540-AB1A5	Lycoming	Piston	230/170	18,100	372	In use – C182
IO-540-AC1A	Lycoming	Piston	300/220	15,700	444	In use – C206
PT6A-52	Pratt & Whitney	Turboprop	850/640	35,000	403	In use – Super King Air B200
SMA SR305-230E	Soloy Aviation	Compression-ignition piston	230/170	20,000	456	Available for C182 conversion
magniDrive 100	MagniX	Electric	230/170	35,000	26	In testing and certification – unknown service entry date
magni350 EPU	MagniX	Electric	450/350	35,000	245	In testing and certification – unknown service entry date
magni500 EPU	MagniX	Electric	750/560	35,000	NA	Used in testbed application – unknown production status
magni650 EPU	MagniX	Electric	850/640	35,000	441	In testing and certification – unknown service entry date
ZA600	ZeroAvia	Hydrogen fuel cell	805/600	NA	NA	In testing – expected service entry 2024

Sources: European Union Aviation Safety Agency (EASA), *TCDS No.:E.076*, https://www.easa.europa.eu/en/downloads/7673/en; FAA, *Type Certificate Data Sheet No. 1E4*, https://drs.faa.gov/browse/excelExternalWindow/C0D4C6893F4D7871862586F6005B8B8B.0001; FAA, *Type Certificate Data Sheet No. E4EA,* https://drs.faa.gov/browse/excelExternalWindow/C0D4C6893F4D7871862586F6005B8B8B.0001; Garrett-Glaser, B. *First Flight of MagniX eCaravan Showcases Maturity of Electric Aviation*, https://www.aviationtoday.com/2020/05/29/historic-flight-of-magnixs-ecaravan-showcases-maturity-of-electric-aviation/; MagniX, *Industry-leading Products*, https://magnix.aero/services; ZeroAvia, *Hindustan Aeronautics Ltd (HAL) Collaborating with ZeroAvia to Develop Hydrogen Powertrain for Dornier 228 Zero-Emission Aircraft*, https://www.zeroavia.com/hal

Soloy Aviation Solutions offers the compression-ignition conversion kit, consisting of the SMA SR305 compression ignition engine and components to mount the engine to the existing airframe hardpoints in the Cessna 182. The SMA SR305 is currently offered in two variants: the -230E variant with 230 horsepower (HP)—the same power as the Lycoming IO-540-AB1A5 fitted to the C182—and the -260E variant with 260 HP. Prices for the kit and installation range from $200,000 (-230E) to $240,00 (-260E), not including the cost of a standard C182 needed to complete the conversion. Compression-ignition engines are capable of running on both diesel or Jet-A fuel, though the SMA SR305 is only approved to run Jet-A or equivalent jet fuels.

magniX is developing a range of electric powertrains to be used in both clean-sheet aircraft designs and conversions of other airframes. Their current product line includes three stand-alone powertrains—the magni350, magni500, and magni650—and one inverter-motor controller unit, the magniDrive100, that can be paired with another electric motor. The magniDrive 100 is capable of handling up to 170 kilowatts of power (230 HP), the same as the current engine in the C182. The magni350, magni500, and magni650 are in various stages of testing and use and are expected to be fully certified within the next three years. The magni650 has been selected to power the Eviation Alice, and the magni500 has been applied as an engine conversion for a De Havilland Canada DHC-2 Beaver and Cessna 208 Grand Caravan. These conversions are testbeds for regional airlines establishing a proof of concept for electric commuter aircraft. At this time, it is unknown if the magni500 will only be used in these aircraft or if it will be made commercially available.

Finally, ZeroAvia is developing a hydrogen fuel cell powertrain to initially be used in its HyFlyer II aircraft before being made available for other commercial applications. The ZA600 fuel cell is expected to enter service with the HyFlyer II in 2022 and will be applied in other aircraft at some point afterwards. The ZA600 is projected to have approximately 805 HP, 45 HP less than the Pratt & Whitney PT6A-42 used in the King Air B200.

1. Limitations

The SMA SR305-230E engine has many similar performance characteristics as the Lycoming IO-540-AB1A5 currently in the C182, but it also has a few key limitations that may be unattractive for WSP use. Namely, the SR305-230E and associated components is 84 pounds heavier than the Lycoming engine, which reduces the aircraft’s payload capacity by 168 pounds. The lower payload capacity would limit the amount of people and equipment the aircraft is able to carry on transport missions, or would require less fuel to be carried, thereby limiting range. WSP staff indicated that the C182 cannot be fitted with a FLIR camera without substantially impacting the amount of fuel that can be carried. The reduced payload of the SR305-230E conversion may entirely preclude the use of FLIR cameras on the C182 if WSP wishes to use it.

Perhaps the biggest drawback to the SMA SR305-230E kit is cost, which requires the purchase of a standard C182 at the standard price (~$650,000) plus the $200,000+ price tag of the kit. While the Lycoming engine could be sold to recoup some of the costs, the kit would increase the cost of replacing each Cessna by as much as 30 percent.

Additionally, the separate recommendation presented in Chapter 1 is to transition to a smaller fleet of C182s in exchange for more C206s. However, the SMA SR305-230E kit is not available for the C206, requiring WSP to continue to run an Avgas fleet. Finally, many of the smaller airports in Washington State do not sell the Jet-A fuel that the SMA SR305-230E is approved to run on, even where 100LL is available. This would limit where WSP aircraft can land and refuel, reducing their ability to quickly transport personnel and equipment to all areas of the state.

The electric and hydrogen powertrains presented in Exhibit 23 have many of the same limitations as the alternative aircraft discussed in Section II. The main drawback is the uncertainty surrounding their availability to be used on the C182, C206, and King Air B200 aircraft. If they are offered commercially in the future, substantial modifications may be necessary to accommodate the batteries or hydrogen storage tanks. The cost and complexity of this innovative technology and additional modifications may result in more negative impacts than the benefits they would provide.

2. Opportunities

Soloy Aviation has identified several benefits associated with the SMA SR305-230E conversion kit compared to the standard C182 engine: an approximately 35 percent fuel burn reduction, increasing the maximum range from 930 to 1,480 nautical miles; an increase in maximum flight time with reserves from 7.6 hours to 12.3 hours; an automated engine control unit and variable-pitch propellor that reduce pilot workload and control complexity; and the propellor and streamlined engine cowl that increase the maximum speed by 11 knots to 156 knots. Jet-A fuel is also traditionally less expensive than Avgas—as much as $1/gallon cheaper at the airports WSP commonly uses—which may offset some of the expense associated with the installation of the kit.

The electric and hydrogen powertrains share many of the operational and environmental advantages of the electric aircraft presented in Section II. In addition, the use of a stand-alone powertrain would allow WSP to continue to use the same type of aircraft, thereby limiting the amount of training needed for WSP pilots to transition to new aircraft. Furthermore, the FLIR cameras and associated equipment could be transferred to the new aircraft without needing to purchase new accessories to fit the equipment to a new model of aircraft.

3. Recommendations

The Soloy compression-ignition engine conversion kit offers improvements to range and speed compared to the standard Lycoming engine in the C182, but it also significantly increases the costs of replacing WSP's fleet. Given the separate recommendation for WSP to reduce the size of WSP's C182 fleet in favor of the C206, the provided benefits are unlikely to outweigh the increased costs. While the electric and hydrogen fuel-cell powertrains present a promising alternative for piston engines, they are not currently available to be fitted to any aircraft in the WSP fleet and should not be pursued. Similar to electric aircraft, WSP should monitor the alternative powertrain market to determine if a suitable option is available at the time of individual aircraft replacement that meets WSP mission requirements and can provide a more environmentally sustainable solution.

H. Conclusion

The various technologies presented in this chapter illustrate just how quickly aviation is innovating and moving toward more environmentally sustainable alternatives. A number of alternative fuels, aircraft, and powertrains offer many benefits over the current WSP aircraft fleet. However, most of these technologies have their own drawbacks, including their limited availability for commercial applications.

Alternative fuels: As 100-octane unleaded Avgas has yet to be commercially deployed, it does not seem advantageous to pursue use of any unleaded fuel in WSP aircraft at this time. Given the potential environmental and operational benefits of unleaded Avgas, it would be pragmatic for WSP to investigate the economic and logistic factors and consider using unleaded fuel in its Cessna 182 and 206 aircraft when these products become widely available. Additionally, the current cost of SAF makes its use infeasible for the King Air B200, but may be more attractive in the future as production costs reach parity with traditional Jet-A fuel.

Electric and other alternative aircraft: The electric aircraft currently in service are not comparable to the C182 or C206 and cannot meet WSP's mission needs. It is recommended that WSP continue to monitor the electric aircraft and AAM market to determine if an electric aircraft, either those discussed in this chapter or those yet to be unveiled, is suitable to replace WSP aircraft at the time of the next fleet replacement cycle or if fleet replacement takes place over several years.

Alternative aircraft engines and powertrains: The compression-ignition engine conversion kit offers an attractive replacement for the standard C182 powertrain. The kit increases the C182's speed and range but reduces the useful payload. While the kit increases the cost of replacing the C182, this expense would be somewhat offset over the life of the aircraft by the lower operating cost of Jet-A compared to 100UL. However, the recommendation to move away from a C182 fleet reduces the attractiveness of the kit. There are also many electric and hydrogen powertrains in development that may be able to serve WSP in the future, but they are unavailable to replace WSP's current fleet at this time.

III. Unmanned Aircraft Systems (UAS)

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A. Introduction

Unmanned Aircraft Systems (UAS) are the operation of an unmanned aerial vehicle (UAV) by an autonomous or human-operated ground-based control and command system. Recently, industry terminology for UAS and UAV has shifted from “unmanned” to “uncrewed,” and as a result, “uncrewed” is the definition for the “U” in UAS and UAV throughout this document. However, not everyone utilizes this terminology yet, and both “unmanned” and “uncrewed” can be used interchangeably for the purposes of this document.

This chapter examines the current applications of UAS technology by Washington State Patrol’s (WSP) UAS Program, and documents the applicability of existing and emerging UAS technology for WSP Aviation Division missions.

B. What is UAS?

In a UAS, the control and command system is used by a person, or computer, to pilot the UAV. The four main components of a UAS are:

- An aircraft with no pilot on board,
- A remote pilot station,
- A command or control link, and
- Equipment or applications installed on the aircraft that allows it to execute its particular function (referred to as a payload)[22]

The aircraft used in UAS operations vary greatly from small, insect-size UAVs to large UAVs with wingspans of roughly 60 feet, like the MQ-9 Reaper. Large UAVs that would be comparable in size to a small passenger jet with an approximate wingspan of 60-feet and fits 19 passengers, are typically only used for military purposes. The U.S. Department of Defense (DoD) groups UAVs into categories by size, as shown in Exhibit 26.

[22] International Trade Administration, *Unmanned Aircraft Systems (UAS)*, https://www.trade.gov/unmanned-aircraft-systems (accessed 08/2022)

Exhibit 26: UAV Classifications

Category	Size	Maximum Gross Takeoff Weight (MTGW)	Normal Operating Altitude (ft)	Maximum Airspeed (knots)
Group 1	Small	0-20 lbs.	< 1,200 AGL	<100
Group 2	Medium	21-55 lbs.	< 3,500	<250
Group 3	Large	<1,320	<18,00 MSL	Any airspeed
Group 4	Larger	>1,320	<18,00 MSL	Any airspeed
Group 5	Largest	>1,320	>18,000 MSL	Any airspeed

Notes: AGL = above ground level, MSL = medium sea level. Source: US DoD, Classification of the Unmanned Aerial Systems.

The applications of UAS expand across multiple sectors and are commonly identified as serving one of three markets: recreational, commercial/civil, or military. The type and functionality of UAVs used within these markets varies, however UAVs under 55 pounds (those in Groups 1 and 2) are used almost exclusively for recreational and commercial/civil operations, in compliance with Federal Aviation Administration (FAA) Part 107 rules, which require that UAVs used for commercial or civil purposes weigh 55 pounds or less.

1. Recreational Use

Recreational UAS operations are conducted by hobbyists who fly small to medium UAVs. Recreational UAS pilots are not required to earn a license for these operations, however they must complete The Recreational UAS Safety Test (TRUST) as required by the FAA. While there is no requirement for recreational UAS pilots to register their UAV with the state of Washington, they must register their UAV with the FAA.[23]

Recreational UAS activities may include flying the UAV for entertainment or taking photos or videos for personal use. Recreational UAS operations must occur within Class G (uncontrolled) airspace. If recreational UAS operations need to occur in controlled airspace (Classes B–E), airspace pre-authorization is required through the Low Altitude Authorization and Notification Capability (LAANC) program.[24]

2. Commercial and Civil Use

Commercial and civil uses vary greatly and may include operations for public safety, law enforcement, agriculture, environmental conservation, education, video production and photography, entertainment, and more. The UAS operations conducted by the WSP UAS Program would be considered civil use.

[23] UAS pilots operating under Part 107 rules must register their UAV with the state of Washington. Only recreational pilots are exempt from registering their UAS with the state of Washington.
[24] Federal Aviation Administration, Recreational Flyers and Modeler Community-Based Organizations, https://www.faa.gov/uas/recreational_flyers (accessed August 2022)

Exhibit 27: Example of a UAS Operation for Construction Site Monitoring

Source: Adobe Stock Images, 2022

In some cases, utilizing UAS can save on costs and enhance safety conditions for tasks that would be otherwise performed by people on the ground. One example of how UAS are being used to save on costs can be seen in precision agricultural practices, which use UAVs to capture more precise measurements of their land and crops, conduct precise spraying or seeding operations (without trampling crops), more efficiently identify and manage crop diseases, and maximize overall crop yield more effectively.[25] As shown in Exhibit 27, tasks like construction inspection work are one example of how UAS can increase workplace safety. Inspectors use UAVs to collect aerial imagery across an inspection site from a distance, rather than having to canvas the site and expose themselves to potentially hazardous environments.

Commercial and civil UAS operators are required to hold a FAA Part 107 certification, which includes completing an online training course and earning a remote pilot certificate from the FAA. Part 107 certification covers the operation of small to medium UAVs (under 55 pounds) for commercial and civil operations. Additional Part 107 waivers may be required for certain UAS operations, so it is important that commercial and civil UAS operators have a clear understanding of Part 107 requirements and the activities that require additional waivers prior to conducting any missions.

Recent market analysis reports indicate that the U.S. commercial UAS market was valued at almost $900 million in 2020. Market forecasts indicate a compound annual growth rate (CAGR) of 15.8 percent, resulting in an estimate that the U.S. commercial UAS market could reach $3.75 billion by 2030.[26]

3. Military Use

Military operations conducted with UAS rely on UAVs of all sizes. Military UAV operations are used generally for combat and surveillance operations, often referred to as intelligence, surveillance, and reconnaissance (ISR) operations. ISR operations help military personnel anticipate change, mitigate risk, and shape outcomes, with the DoD defining ISR operations as "an integrated operations and intelligence activity that synchronizes and integrates the planning and operation of sensors, assets, and processing, exploitation, and dissemination systems in direct support of current and

[25] *Precision Agriculture with Drone Technology – How drones are raising precision agriculture to new heights*, DJI Enterprises, December 2021. https://enterprise-insights.dji.com/blog/precision-agriculture-drones (accessed September 2022)
[26] Mutreja, S and Singh, A., *U.S. Commercial Drones Market Statistics 2030*, Allied Market Research, December 2021, https://www.alliedmarketresearch.com/us-commercial-drones-market-A06731 (accessed August 2022)

future operations".[27] The types of UAV used in military UAS operations are not likely to be used in any commercial operations, because they are specifically designed to carry out military functions, have incredibly high price points, and are typically larger than 55 pounds.

It is difficult to estimate the domestic market for large defense UAS because it is completely dependent on the U.S. defense budget, which is subject to fluctuation. However, estimates based on global procurement of military UAS in fiscal year (FY) 2020 indicate that the U.S. market accounts for 32 percent of the almost $8 billion global market, which translates to roughly $2.56 billion.[28]

Exhibit 28 presents images of different types of UAS, and Exhibit 29 provides examples of common UAS used for different types of operations.

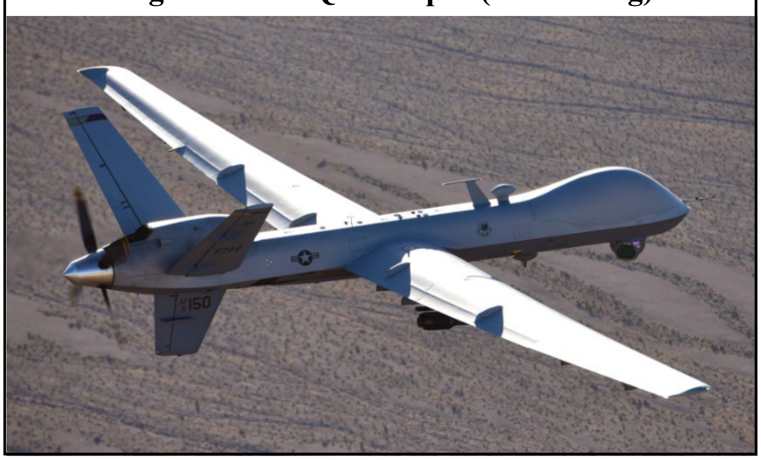
[27] Smagh, N., *Intelligence, Surveillance, and Reconnaissance Design for Great Power Competition*, Congressional Research Service, June 2020. https://sgp.fas.org/crs/intel/R46389.pdf (Accessed August 2022).
[28] International Trade Administration, *Unmanned Aircraft Systems (UAS), Defense Market Analysis,* https://www.trade.gov/unmanned-aircraft-systems (Accessed August 2022).

Exhibit 28. Examples of UAS Types by Classification

Small UAS – DJI Mavic Air 2 (Quadcopter)

Medium UAS – Insitu Scan Eagle (Fixed-wing)

Large UAS – MQ-9 Reaper (Fixed-wing)



Sources: General Atomics Aeronautical, MQ-9 Reaper (Predator B) Data Sheet, https://www.ga-asi.com/remotely-piloted-aircraft/mq-9a; *U.S. Air Force, Scan Eagle Fact Sheet,* https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104532/scan-eagle/; *DJI, Mavic Air 2 Data Sheet*, https://www.dji.com/mavic-air-2/specs

Exhibit 29: Examples of UAS Aircraft for Recreational, Commercial, and Military Operations

Aircraft Type	UAS Group	UAS Style	Engine Type	Takeoff Type	Flight Time	Maximum Flight Distance	Maximum Flight Speed	Maximum Payload Capacity	Summary of Uses	Cost
Recreational										
DJI Mavic Air 2	Small	Quadcopter	Electric	VTOL	34 minutes	11.5 miles	42 mph	No payload capacity (fixed with camera)	Recreational flying and personal photography	$800 - $1,200
Commercial										
The Albatross	Small	Fixed-wing	Electric	50-100 meters	Up to 4 hours	115 miles	42 mph	10lbs.	Aerial mapping, construction monitoring, agricultural surveying. an be built to suit	$2,000 - $8,000
Fixar 007	Small	Quadcopter	Electric	VTOL	60 minutes	37 miles	30-35 mph	4-5 lbs.	Mapping, aerial inspections, surveillance, precision agriculture	$20,000
Matrice 300	Small	Quadcopter	Electric	VTOL	55 minutes	< 50 miles	51 mph	~5 lbs.	Mapping, aerial inspections, surveillance, precision agriculture	> $10,000
ScanEagle	Medium	Fixed-wing	Piston	Launch/recovery system	20+ hours	1,600 miles	80 mph	45 lbs.	Surveillance, monitoring; can be built to suit	$4.7 million
Plyrotech XV-H/L	Small	Fixed-wing	Hybrid (battery and combustion engine)	VTOL	4-7 hours	200-400 miles	70 - 105 mph	55 lbs.	Surveillance, monitoring, search and rescue; can be built to suit	Unknown
Military										
MQ-9 Reaper (Predator)	Largest	Fixed-wing	Turboprop	Unknown	27 hours	5,000+ miles	270+ mph	Internal: 850 lbs. External: 3,000 lbs.	ISR missions. Highly modular and can be built to suit needs. Capable of carrying multiple payloads.	$32 million

Note: VTOL = vertical takeoff and landing. Sources: General Atomics Aeronautical, MQ-9 Reaper (Predator B) Data Sheet, https://www.ga-asi.com/remotely-piloted-aircraft/mq-9a*; Fixar 007 Products Brochure,* https://fixar.pro/wp-content/uploads/2021/02/FIXAR-007-PRODUCTS-BROCHURE-2022_S.pdf*; Applied Aeronautics, The Albatross Data Sheet,* https://static1.squarespace.com/static/58b9cb34b3db2b86c9ce082d/t/61faee3d82a11c70bd59615c/1643834941740/ALBATROSS+DATASHEET+%282022%29.pdf*; DJI, Mavic Air 2 Data Sheet,* https://www.dji.com/mavic-air-2/specs*; DJI Matrice 300 Series Spec Sheet, https://www.dji.com/matrice-300/specs U.S. Air Force, ScanEagle Fact Sheet,* https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104532/scan-eagle/*; Plyrotech, XV Fixed-wing VTOL UAS – Specifications,* https://www.plyrotech.com/wp-content/uploads/specs/XV.pdf

C. Mission of the WSP Aviation Division

As mentioned in Chapter 2 – Alternative Fuels and Electric Aircraft, WSP is responsible for managing a fleet of six aircraft: five single-engine, piston-powered aircraft (three Cessna 182s [C182] and two Cessna 206s [C206]) and one twin-engine turboprop aircraft, the Beechcraft Super King Air 200 (B200).

WSP uses the C182s and C206s largely for law enforcement, surveillance, traffic monitoring, tracking stolen vehicles or impaired drivers, transporting state officials, and to provide support to other law enforcement agencies. The C206s also conduct nighttime operations and are equipped with Forward Looking Infrared (FLIR) cameras to conduct surveillance and monitoring missions. The C182s and C206s are typically used for missions that last approximately six to eight hours and they largely operate along the Interstate 5 corridor.

The B200 was acquired by WSP to conduct transportation missions. The aircraft can carry seven passengers and two pilots and was used frequently for prisoner transport across the state. However, in recent years there have been significantly fewer prisoner transport missions, so the aircraft is now primarily used to transport state officials.

D. Conclusions of Analysis

The following is a summary of the recommendations identified from this analysis:

- Most of the current UAS technology available for commercial/civil use under FAA Part 107 rules is not a suitable alternative to traditional aircraft for conducting WSP missions due to the limitations in speed and battery life of most UAVs under 55 pounds. There are some UAVs under 55 pounds that can be used for longer periods of time and at speeds necessary to support WSP missions, however the high cost for this technology is a limiting factor in its applicability to WSP missions.
- FAA Part 107 rules have strict guidelines related to the types of operations that are permitted, including operations needing to occur within the line of sight and within certain airspace. If operations are required outside of the boundaries of Part 107 rules, additional waivers must be submitted to and approved by the FAA. The administrative burden of WSP pilots earning their FAA Part 107 certification and filing for waivers to conduct routine missions creates unnecessary obstacles which do not exist when missions are conducted using traditional aircraft.
- Concerns related to unlawful surveillance and the violation of Fourth Amendment rights add to the challenges associated with integrating UAS technology into WSP missions.
- Until technology advances to the point that UAVs with long battery life and fast speeds become more affordable, and policy adapts to better align with using UAS for WSP missions, it is not feasible to consider the integration of UAS technology into the WSP operations currently being conducted by the Cessna fleet.

E. Current Use of UAS by Washington State Patrol

Currently, WSP's Aviation Division does not operate UAS for any of their missions. WSP staff are not trained in UAS operations, nor are they licensed to operate UAS for civil operations. Additionally, WSP does not have any maintenance or storage facilities for UAS equipment.

However, separate and distinct from WSP is the WSP UAS Program, part of the Criminal Investigation Division (CID), which utilizes UAS frequently to conduct their missions.

1. WSP UAS Program

The WSP UAS Program is primarily responsible for accident and crime scene reconstruction operations, which use photogrammetry at a static crime or accident scene to recreate the scene after the fact. A Part 107 certified pilot will fly a UAV over the scene and use software to stitch photos together, with the use of Trimble Forensics programs, to create a three-dimensional (3-D) environment for use by investigators and in subsequent trials.

The benefit of reconstructing crime or accident scenes with UAS technology is that it saves time and improves safety conditions for investigators and other personnel. Prior to UAS utilization, active roadways would need to be closed for long periods of time to allow for investigators to manually take scene measurements and on-the-ground photos. Using UAS technology to recreate accident scenes has reduced investigative time by approximately 80 percent, with most scenes mapped in 15 minutes or less. UAS also significantly minimizes the time that roadways need to be closed for scene investigation. In addition to the significant time savings in accident documentation and traffic flow, this UAS application also increases safety for investigators because they spend less time working in potentially heavy traffic conditions on the roadway.

UAS operations have also been used by the WSP UAS Program to identify the status of threats, determine if a suspect is armed during a stand-off incident, and to locate a body in a heavily forested and difficult-to-access terrain in the aftermath of a vehicle accident. The WSP UAS Program has also conducted missions to monitor protests, marches, and other public-space activities, however concerns over civil liberties and privacies can make these missions difficult or impossible to conduct. For example, due to concerns over privacy and security, UAS operations are prohibited on Washington State's Capitol Building and Campus.

Unrelated to the WSP UAS Program within CID, UAVs have also been deployed by the Investigative Assistance Division (IAD) and Special Weapons and Tactics (SWAT) teams during arson investigations, when intel is needed inside a building that is not safe for personnel to enter due to fire.

2. UAVs Currently in Use by WSP UAS Program

There are currently 150 medium-size UAVs within the WSP UAS Program, all manufactured by DJI: 50 Matrice Drones and 100 Mavic 2 Pros.

The smaller Mavic 2 Pro (shown in Exhibit 30) is stored in CID detectives' offices across the state so they are easily accessible when needed. The larger Matrice Drone is stored in one of eight district offices. The Collision Technical Specialist Troopers, who use the Matrice Drones and the other smaller UAVs, are also located across these eight district offices, which are indicated by green stars in Exhibit 31.

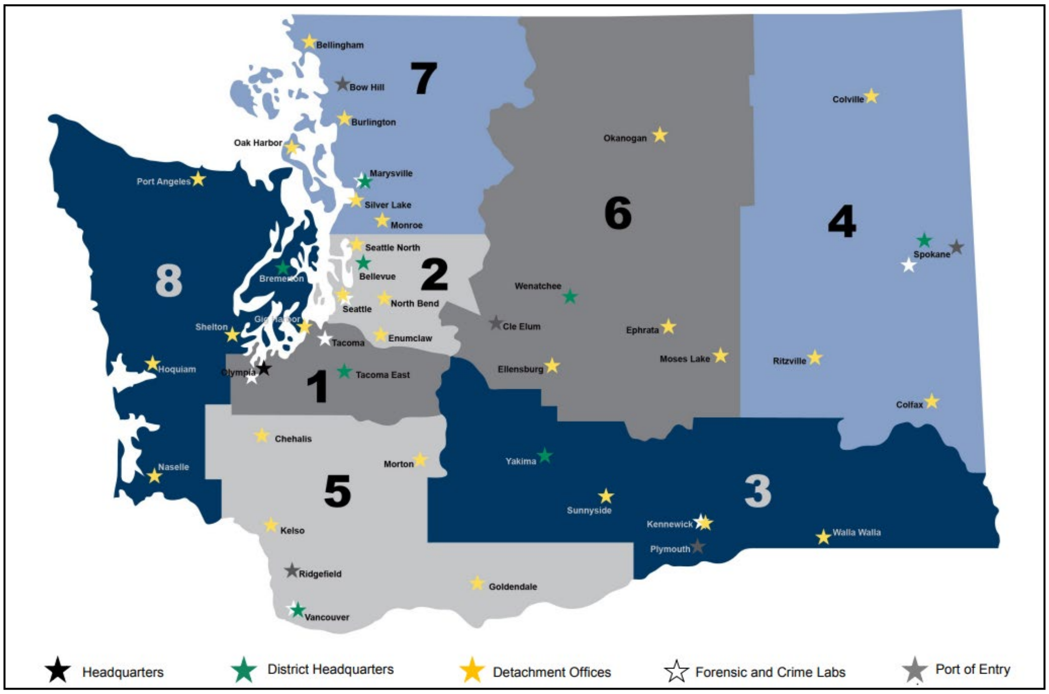
Exhibit 30: DJI's Mavic 2 Pro

Source: Adobe Stock Images, 2022

The eight district offices are:

- District 1: Tacoma (East)
- District 2: Bellevue
- District 3: Yakima
- District 4: Spokane
- District 5: Vancouver
- District 6: Wenatchee
- District 7: Marysville
- District 8: Bremerton

Exhibit 31: Location of WSP District Offices



Source: WSP Annual Report, 2017, https://www.wsp.wa.gov/wp-content/uploads/2018/10/2017-Annual-Report.pdf *(accessed September 2022)*

Exhibit 32: DJI's Matrice Drone

Source: DJI Matrice 200 Series, www.dji.com/matrice-200-series-v2/payloads

The Matrice Drone (shown in Exhibit 32) is more durable and stable during inclement weather, and is therefore used instead of the Mavic 2 Pro in certain weather conditions. However, some inclement weather scenarios prohibit use of either UAV, and they do not conduct missions at night.

Both the Matrice Drone and the Mavic 2 Pro have about a 30-minute battery life, and batteries in these aircraft are beginning to degrade due to routine use. While the UAV fleet has very little need for maintenance or scheduled down-time, a preflight checklist must be conducted before any operation that helps identify broken propellers, bad batteries, and other maintenance needs. The UAVs are on a three-to-four-year replacement cycle, and many are nearing their replacement time period. The WSP UAS Program averages about one flight mission a day, however on some days there are no missions and on other days there are multiple.

A current challenge facing the WSP UAS Program is the introduction of FAA requirements that state all UAVs must be fixed with remote identification (ID) technology. This requirement allows the FAA to identify UAVs that are operating within a particular airspace. Unfortunately, there are no retrofit devices that can be used to equip an existing UAV with remote ID technology. As such, the WSP UAS Program will need to acquire new UAVs to replace its existing UAVs by September 2023 to remain compliant with FAA requirements. The WSP UAS Program has submitted a request to acquire a new fleet of 51 UAVs that are equipped with remote ID technology.

UAS pilots within the WSP UAS Program are required to become Part 107 certified and complete an additional 40-hour in-house training course which teaches new pilots how to fly the UAV, use the associated technologies, and conduct the 3-D modeling process. Additionally, WSP UAS Program personnel are required to complete necessary waivers whenever their UAS missions require it. The WSP UAS Program currently has 95 pilots on staff who have Part 107 certification.

It is important to note that there is no crossover between the Aviation Division's missions and the WSP UAS Program's missions. The battery life, speed, and distance limitations of the UAVs owned and operated by the WSP UAS Program cannot accommodate the needs of the Aviation Division, which often require extended flight times at high speeds.

F. Feasibility of UAS for Aviation Division Missions

This section explores the feasibility of integrating UAS applications into existing WSP Aviation Division missions.

1. Physical Limitations

UAS applications within the WSP are conducted within the CID unit and are used to recreate accident and crime scenes using aerial imagery and 3-D modeling software. While helpful, this is a fairly narrow utilization that is not applicable to the operations conducted by WSP.

The primary missions of the Aviation Division include surveillance, traffic monitoring, passenger transport, enforcement, and support of other law enforcement agencies. The WSP UAS Program's current fleet of UAVs is made up of medium-sized electric rotorcraft that travel at speeds around 40 miles per hour (mph) and have an approximate battery life of 30 minutes. The Aviation Division would need UAVs that can easily fly at, or faster than, 70 mph and operate for much longer than 30 minutes. The fast travel speeds and longer flight duration are important for Aviation Division operations as they are often required to pursue speeding or reckless drivers traveling at high speeds, and have typical flight times of six to eight hours. There are also limitations with the FLIR equipment that would need to be mounted to the UAV, and this equipment would far exceed the payload capacity of these medium UAVs.

Based on these limitations, the existing fleet of UAVs currently owned and operated by the WSP UAS Program is not feasible for use by the Aviation Division. Other UAVs are available commercially that could meet the traffic monitoring and enforcement needs of the Aviation Division missions. However, they come at a much higher cost than that of the traditional fixed-wing aircraft currently in use by the Aviation Division.

With regard to passenger transport missions, UAS is not currently a feasible alternative for the operations conducted by the Aviation Division. There are no passenger-carrying UAVs that are approved by the FAA and available on the market. While it is difficult to predict when passenger-carrying UAS may be available, experts say it may be as early as 2040. The technology for passenger-carrying UAS exists, and experts say the demand is also there, however developing effective policy and gaining government approval and public acceptance still remain significant barriers to the actualization of this technology.29 With the anticipated timeframe for this technology still almost two decades away, UAVs are not a feasible option to accomplish the WSP's mission of passenger transport.

2. Regulatory Limitations

In addition to the physical limitations of the UAVs currently being used by the WSP UAS Program, there are also policy and operational limitations that would hinder the Aviation Division's ability to conduct its aerial law enforcement operations.

UAVs used in commercial operations under FAA Part 107 certification must weigh 55 pounds or less (including any applicable payload). Operations must occur within line of sight and cannot occur from a moving vehicle or aircraft or at night without anti-collision lighting, among other restrictions. Operations that do not comply with these requirements requires the filing of waivers. In the case of the Aviation Division, waivers would be required for a significant number, if not all, of operations, as most would need to occur beyond the visual line of sight, and some during low visibility or nighttime hours. While waivers can be requested, they are not always granted.

In addition, operations conducted within certain airspace classes require pre-authorization through the FAA's LAANC program. While this hasn't been much of a barrier to WSP UAS Program operations, as they are typically conducted at low altitudes (100-125 feet above ground level) in uncontrolled Class G airspace, this would not necessarily be the case for operations needed by the Aviation Division. The Aviation Division is currently and would likely continue to need to operate at higher elevations and in areas of restricted airspace. The administrative burden of filing for the necessary waivers, and the possibility that those waivers could be denied, would pose significant delays or cancellation of the WSP Aviation Division's law enforcement operations.

In the future, if UAS become a viable alternative for Aviation Division missions, there may be an option for WSP to obtain a certification of authorization (COA) for all airspaces, which would only need to be renewed every two years. The COA would allow for UAS use without filing individual waivers for each mission, however, an individual on staff would need to manage the COA process full-time.

[29] Sims, J., Are Flying Taxis the Future of Transport?, https://www.scmp.com/magazines/style/news-trends/article/3176015/are-flying-taxis-future-transport-experts-say-passenger (accessed September 2022)

It is important to note that the regulatory limitations explored in this section are based on FAA Part 107 requirements. The only commercial UAS operations that occur outside of Part 107 are those that fall under Part 135 requirements. As of June 2022, only four UAV operators in the U.S. operate under the Part 135 certificate, and they conduct only cargo and package delivery.30 Commercial UAS operations occurring under the purview of WSP would not meet Part 135 requirements and would remain under the Part 107 requirements. This is an important distinction because the Part 107 certification limits UAVs to 55 pounds or less, whereas Part 135 certification does not limit the weight of the UAVs, which means the heavier UAVs can travel faster, for longer periods of time, and can carry additional payload.

3. Opportunities

While there are considerable limitations associated with utilizing small or medium UAS for the law enforcement operations conducted by WSP, there are also a few opportunities to be considered. Note that these opportunities are dependent on WSP personnel becoming Part 107 certified pilots.

One opportunity is the use of small or medium UAS for crowd surveillance during protests or events. It is reasonable that the pilot could be within visual line of sight of the aircraft during this type of surveillance, and the short battery life may not pose as much of an issue for this type of surveillance compared to vehicle traffic surveillance. (There are also options to tether the UAV to constant power where battery life is not an issue.) However, while this type of operation may be suitable for the small UAVs that are readily available in today's market (including those already owned and operated by the WSP UAS Program), social limitations may prohibit the use of this level of surveillance. The public may see UAS surveillance—particularly during protests or large events—as a violation of their civil liberties, and in extreme cases as a violation of the Fourth Amendment, which prohibits unreasonable searches and seizures. Evaluations of case law related to unlawful search and seizures indicate that the Fourth Amendment may be reasonably protective with respect to government UAV observations.[31] The Aviation Division would need to receive the appropriate waivers and consent to consider these types of missions.

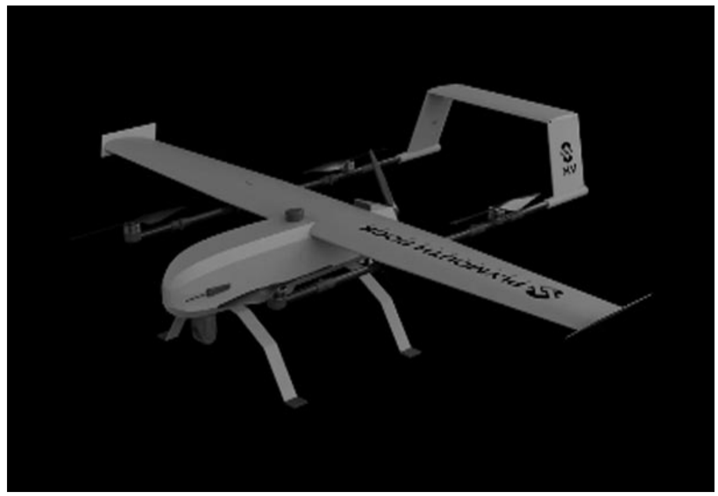
As previously noted, opportunities to integrate UAS operations into the Aviation Division's mission of providing traffic monitoring and enforcement would require different UAVs than what the WSP UAS Program uses for accident and crime scene reconstruction. There are small UAVs available on the market today that come built with FLIR technology, such as the R80D-SkyRaider by Teledyne FLIR, which would address the payload capacity issue. However, the battery power of this UAV maxes out at 60 minutes with the extra-large battery packs and has a maximum speed of approximately 31 mph. These battery and speed limitations make this FLIR-equipped

[30] Federal Aviation Administration. Package Delivery by Drone (Part 135), https://www.faa.gov/uas/advanced_operations/package_delivery_drone (accessed August 2022)
[31] Villasenor, *Will Drones Outflank the Fourth Amendment?,* Brookings, September 2012. https://www.brookings.edu/opinions/will-drones-outflank-the-fourth-amendment/ (accessed August 2022)

small UAV, and other similar models, unable to meet the needs of many WSP missions.[32]

Other small and medium-sized UAVs on the market have the capabilities needed to conduct traffic surveillance and monitoring, but they come at an extremely high cost. One example is the ScanEagle, a medium UAS developed by Insitu, A Boeing Company. The ScanEagle is a portable fixed-wing UAS that includes a ground control station and a remote video terminal. The ScanEagle does not require a runway for its launch or recovery due to the Skyhook catapult and retrieval hook system. The system currently includes a color electro-optical camera and an infrared camera for night operations, both of which can be easily interchanged. The ScanEagle is powered by a piston engine and is therefore not electric. The piston-powered engine provides incredible endurance with more than 20 hours of flight time. It can also operate at speeds up to 80 mph and can operate 16,000 feet above ground level. The ScanEagle could be a viable option for traffic monitoring due to its ability to travel at higher speeds and for its significant endurance, however, the cost may prove prohibitive at approximately $4.7 million.[33] Additionally, the nighttime capabilities can only be used if WSP has waivers to operate at night, and waivers to operate beyond line of sight would still be needed.

Exhibit 33: Image of a Plyrotech XV from Plymouth Rock Technologies



Source: Plymouth Rock Technologies, www.plyrotech.com/products/

Another UAS that allows for enhanced battery time and faster speeds is the Plyrotech XV (shown in Exhibit 33), a fixed-wing VTOL small UAS with a hybrid lithium polymer battery and internal combustion engine that offers four hours of battery life and a maximum speed of 70 mph.[34]

Both the ScanEagle and the Plyrotech XV demonstrate that UAS with faster travel speeds and longer battery life are available in the commercial market, however, these enhanced features come with incredibly high price points, require significant training to master the operations of this equipment, and require waivers to operate.

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[32] Teledyne Flir, R80D SkyRaider Datasheet https://www.flir.com/support/products/r80d-skyraider/?vertical=uas&segment=uis#Documents (accessed August 2022)

[33] U.S. Air Force, ScanEagle Fact Sheet, https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104532/scan-eagle/ (Accessed August 2022). Cost for the ScanEagle was adjusted for inflation from 2006 dollars.

[34] Plyrotech, XV Fixed-wing VTOL UAS – Specifications, https://www.plyrotech.com/wp-content/uploads/specs/XV.pdf

G. Conclusions

The current commercial UAVs available for a reasonable price, like those used by the WSP UAS Program, are limited in their battery life and travel speeds, and are therefore not feasible replacements for the Cessna C182s or C206s currently operated by WSP to carry out the majority of their missions (except for potentially localized surveillance operations). Some more expensive UAVs are available commercially that better meet the speed and duration requirements needed to conduct some of these missions, however they are cost prohibitive when compared to the traditional aircraft being utilized by WSP today.

In addition to the need to acquire additional equipment, WSP Aviation Division staff would need to be trained and earn their Part 107 certifications to conduct UAS operations. The parameters for Part 107 certification would also create challenges for WSP due to the limited scope of Part 107 operations, including the need to file for, and receive approval of, specific waivers related to operations that occur at night without anti-collision lighting, or beyond the visual line of sight, and other circumstances.

Finding opportunities to deploy UAS to conduct WSP Aviation Division missions would not only pose operational challenges due to the limitations of current commercial UAS technology, but it would also add to, not replace, WSP's operational costs. Considering the operational and administrative limitations of UAS technology, the use of traditional aircraft remains the most suitable option for carrying out WSP's missions.

Appendix A: Alternative Scenarios

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A. Scenario 2 (Alternative)

Scenario 2 follows the same procurement and replacement schedules for aircraft as Scenario 1, but retains an inventory of two FLIR cameras (replacing one existing camera with a new unit).

Exhibit 34: Scenario 2 – Five Aircraft (Four 206 and One 182) and Two Cameras (Replacing One Existing Camera)

Item	FY2024	FY2025	FY2026	FY2027	FY2028	Resale Value	GRAND TOTAL
Cessna 206	$2,210,000	$0	$1,172,295	$0	$1,243,687	(377,716.49)	$4,248,265
Cessna 182	$0	$0	$0	$0	$734,957	(130,810.19)	$604,147
FLIR Camera and Equipment	$1,117,010	$0	$0	$0	$0	$0	$1,117,010
GRAND TOTAL	**$3,327,010**	**$0**	**$1,172,295**	**$0**	**$1,978,644**	**(508,526.68)**	**$5,969,422**

Scenario 2 enables the following:

- Daily FLIR-enabled aerial missions with 206 aircraft, with resulting positive impacts on public safety
  - Assumes one 206 aircraft will be down for maintenance at any given time
- Continued ability to deliver the transport and training missions
- Mitigated risk of obsolescence of existing camera

There is a risk due to the limitation of two FLIR cameras, as we can assume there will be maintenance requirements throughout the years. Also, while transferring FLIR cameras from one aircraft to another is relatively easy, there is a risk of damage to cameras and components due to continued equipment transfers.

B. Scenario 3 (Alternative)

In Scenario 3, WSP would maintain a 182 in the fleet in addition to three new 206 aircraft, and would purchase one additional FLIR camera. WSP would immediately retire the two 182 aircraft with the highest lifetime hours (N3532K and N305RC) and the two 206 aircraft (N2446X), and procure two new 206 aircraft and a new FLIR camera. WSP would plan to procure an additional 206 aircraft in FY2026 and retire the 206 aircraft (N305DK). WSP would retire the remaining 182 aircraft currently in the fleet (N102LP) in FY2028 and procure a new 182 aircraft. Scenario 3 also provides for the replacement of an existing camera with a new unit.

Exhibit 35: Scenario 3 – Four Aircraft (Three 206 and One 182) and Three Cameras (Replacing One Existing Camera)

Item	FY2024	FY2025	FY2026	FY2027	FY2028	Resale Value	GRAND TOTAL
Cessna 206	$2,210,000	$0	$1,172,295	$0	$0	(377,716.49)	$3,004,578
Cessna 182	$0	$0	$0	$0	$734,957	(140,072.34)	$594,885
FLIR Camera and Equipment	$2,234,020	$0	$0	$0	$0	$0	$2,234,020
GRAND TOTAL	**$4,444,020**	**$0**	**$1,172,295**	**$0**	**$734,957**	**(517,788.83)**	**$5,833,483**

Scenario 3 enables the following:

- Potentially daily FLIR-enabled aerial missions with 206 aircraft (depending on aircraft downtime), with resulting positive impacts on public safety
  - Assumes one 206 aircraft will be down for maintenance at any given time
- Sufficient capacity of FLIR cameras to support daily FLIR-enabled aerial missions
- Continued ability to deliver the transport and training missions
- Mitigated risk of obsolescence of existing cameras

There is a risk due to the potential of one or more 206 aircraft being down at any given time, which may hinder WSP's ability to conduct daily FLIR-enabled aerial missions.

C. Scenario 4 (Alternative)

In Scenario 4, WSP would procure the same complement of aircraft in the same timeframe as Scenario 3 but maintain the existing inventory of two FLIR cameras (replacing one existing FLIR camera with a new unit). WSP would immediately retire the two 182 aircraft with the highest lifetime hours (N3532K and N305RC) and the two 206 aircraft (N2446X) and procure two new 206 aircraft. WSP would plan to procure an additional 206 aircraft in FY2026 and retire the 206 aircraft (N305DK). WSP would retire the remaining 182 aircraft currently in the fleet (N102LP) in FY2028 and procure a new 182 aircraft.

Exhibit 36: Scenario 4 – Four Aircraft (Three 206 and One 182) and Two Cameras (Replacing One Existing Camera)

Item	FY2024	FY2025	FY2026	FY2027	FY2028	Resale Value	GRAND TOTAL
Cessna 206	$2,210,000	$0	$1,172,295	$0	$0	(377,716.49)	$3,004,578
Cessna 182	$0	$0	$0	$0	$734,957	(140,072.34)	$594,885
FLIR Camera and Equipment	$1,117,010	$0	$0	$0	$0	$0	$1,117,010
GRAND TOTAL	**$3,327,010**	**$0**	**$2,357,331**	**$0**	**$734,957**	**(517,788.83)**	**$4,716,473**

Scenario 4 enables the following:

- Potentially daily FLIR-enabled aerial missions with 206 aircraft (depending on aircraft downtime), with resulting positive impacts on public safety
  – Assumes one 206 aircraft will be down for maintenance at any given time
- Continued ability to deliver the transport and training missions
- Mitigated risk of obsolescence of existing cameras

There is a risk due to the potential of one or more 206 aircraft being down at any given time, which may hinder the ability to conduct daily FLIR-enabled aerial missions. There is also a risk due to the limitation of two FLIR cameras, as we can assume there will be maintenance requirements throughout the years. Also, while transferring FLIR cameras from one aircraft to another is relatively easy, there is a risk of damage to cameras and components due to continued equipment transfers.

D. Scenario 5 - Maintain Current Fleet Complement

Another possible scenario is to maintain the current fleet and technology complement and continue operations with the existing fleet. While this scenario eliminates the costs of procuring new aircraft, it comes with significant risks to WSP's ability to perform aerial missions and is not recommended.

DMG also evaluated the cost impact of maintaining the status quo by replacing the existing fleet with the same type of and quantity aircraft and FLIR cameras in the current fleet. Under this scenario, WSP will replace the existing two 206 aircraft, three 182 aircraft, and two FLIR cameras and maintain the same fleet composition. While this scenario does present some cost savings, it will inhibit WSP's goal of increasing FLIR related missions and is not recommended. Exhibit 37 below outlines this scenario.

Exhibit 37: Current Fleet Complement – Five Aircraft (Two 206 and Three 182) and Two Cameras (Replace Two Existing Cameras)

Item	FY2024	FY2025	FY2026	FY2027	FY2028	Resale Value	GRAND TOTAL
Cessna 206	$2,210,000	$0	$0	$0	$0	**(377,716.49)**	$1,832,284
Cessna 182	$0	$0	$1,385,535	$0	$734,957	**(135,199.16)**	$1,985,293
FLIR Camera and Equipment	$1,117,010	$0	$1,185,036	$0	$0	$0	$2,302,046
GRAND TOTAL	**$3,327,010**	**$0**	**$2,570,571**	**$0**	**$734,957**	(512,915.65)	**$6,119,623**