Federal Aviation Administration
AVS Research, Engineering and Development

AVS RE&D Portfolio:

Alternative Fuels for General Aviation (A11M)

Research Plan: 2022- 2027

January 26, 2022

Part 1: BLI Definition and Scope

Program Area: Alternative Fuels for General Aviation (A11M)

FAA Domain: Environment and Weather Mitigation

BLI Scope: Alternative Fuels for General Aviation (A11M)

The Alternative Fuels for General Aviation Program coordinates and conducts the research and testing of different unleaded fuel blends and formulations under development by different fuel producers. In addition the Program will research advanced propulsion technologies which can be incorporated through modifications to existing piston engines. This Program will also conduct research into sustainable piston engine fuels, new fuel additives as well as new alternative energy driven systems such as hybrid-electric and fuel cell propulsion systems with the aim of reducing the impact of General Aviation on the environment, including local air quality, and climate and health impacts.

Currently 100LL (100 octane Low Lead) leaded aviation gasoline (avgas) is the most commonly used and reliable fuel for general aviation that meets the necessary octane and energy needs for the continued safe operation of the approximately 190,000 piston engine aircraft in the general aviation fleet, including fixed wing, helicopters and experimental aircraft. These aircraft are used for a variety of purposes such as pilot training, business and recreational travel, firefighting, agricultural spraying, medical transport and many other important services.

Lead is added to avgas to prevent damage to the engine at higher power settings. Unfortunately lead in the engine exhaust emissions can have a negative health impact on the human population within a wide area around aircraft operating on leaded avgas. The Environmental Protection Agency is conducting studies to determine if lead emissions from these aircraft cause endangerment and should be regulated. Various studies have linked emissions to higher blood lead levels in children. There is only one remaining producer of aviation grade lead additive, tetraethyl lead, based in the UK, whose world market is shrinking due to various environmental pressures.

The vital replacement of leaded avgas with unleaded avgas is crucial to eliminating lead emissions. Engine and aircraft ground and flight testing is coordinated and conducted at the FAA's William J Hughes Technical Center through a collaboration between the FAA and Industry under PAFI or the Piston Alternative Fuel Initiative. Research and testing is necessary to ensure that the chemicals in a new unleaded fuel do not have any negative unintended consequences on aircraft operation while having the same performance as 100LL and support environmental studies as required. To ensure the continued safe operation the unleaded fuel must meet certain criteria such as:

1) Having an octane rating sufficient to allow engines to produce their rated power without damage;
2) Providing the similar engine performance as when using ASTM D910 100LL avgas;
3) Operation resulting in low internal engine deposits which may reduce engine durability;
4) Being compatible with existing engine and aircraft materials across the fleet;
5) Being able to be mixed with existing approved fuels with no negative or unintended consequences;

6) Not requiring significant changes in aircraft and engine operation or maintenance to achieve the same level of performance as when operated using 100LL;
7) An ASTM Specification that provides the necessary compositional and performance control of the fuel to meet aviation needs will have to be issued for the new fuel.
8) The unleaded fuel producer will have to work with the FAA and Industry Team to ensure the fuel will be available and effectively deployed within the existing infrastructure.

Part 2: Service/Office Research Requirements and Research Gap Analysis

1.0 Operational Capability: ***Alternative Unleaded Fuels for Piston Engined General Aviation Aircraft***
Definition: Authorization for fleet wide use of one or more unleaded aviation fuels for piston engine aircraft in accordance with Section 565 of the 2018 FAA Reauthorization Act. Research Elements: Determination that the unleaded aviation gasoline qualifies as a replacement for an approved leaded gasoline. This is accomplished by coordinating and conducting the following testing and research on candidate unleaded fuels using different engines and aircraft representing a wide range of general aviation operational characteristics: 1.1 Conduct engine detonation testing to understand the fuel detonation characteristics at higher power settings and at simulated altitude conditions. 1.2 Conduct engine durability testing to determine the impact of the fuel use on internal deposit formation and engine wear. 1.3 Conduct engine performance testing to characterize unleaded fuel performance compared to the performance of ASTM D910 100LL leaded fuel. 1.4 Conduct aircraft flight testing to determine the inflight engine cooling, handling and hot weather characteristics of the candidate unleaded fuels. 1.5 Conduct materials compatibility testing to characterize the effect of the alternative fuels on engine and aircraft materials. 1.6 Perform analysis and/or emissions testing as necessary. 1.7 Evaluation of the post-test engine teardown inspection findings. 1.8 Coordinate and conduct other fuel and related testing and analysis as necessary.
Primary S/O: Maria DiPasquantonio, AIR-670 **Secondary S/O**: n/a
S/O Priority: One (1)

Outcome: Test data and test reports will contribute to the development of an ASTM specification, an AIR-600 Approval Policy Memo, and a Safety Alert Information Bulletin (SAIB) which are the required elements for the implementation of the Fleet wide Authorization Process for use of an unleaded aviation gasoline in piston engine aircraft.

Research Gap Analysis

Research Questions	Contribution	Research Output
1.1 Are the ground and in-flight fuel system, engine and aircraft operability characteristics, with alternative fuels under cold day, standard day, and hot day atmospheric conditions, within allowable safety tolerances compared to lab made min spec 100LL aviation fuel? This addresses research elements 1.1, 1.2, 1.3, 1.4 and 1.5, 1.6, 1.7 and 1.8.	35%	Test data and reports on the ground handling and in-flight test performance of alternative fuels. The data from testing including operability, propeller vibration, and aircraft testing will validate that engine and aircraft performance with the alternative fuels is within an acceptable tolerance and repeatability compared to min spec 100LL aviation gasoline.
1.2 Are the performance, detonation, and durability characteristics of aircraft engines, operating on alternative unleaded fuels, within allowable safety tolerances compared to lab made minimum specification (min spec) 100LL aviation fuels? Addresses research elements 1.1, 1.2, 1.3, 1.6 and 1.8 identified in the section above.	35%	Ground, simulated altitude and flight test data and reports validating the performance, detonation and engine durability characteristics, ground handling and in-flight test performance of alternative fuels that validate their safety of flight operations compared to min spec 100LL aviation gasoline. Detonation testing will show that the engine can function without detonation (inefficient and damaging explosive fuel combustion) throughout its intended range of operation. Engine performance and durability testing will show that there is no significant engine wear and performance degradation using the alternative unleaded fuel compared to when the same engine is operated on min spec 100LL. Engine operability will show engine idle stability, transient performance and other characteristics.
1.3. Do alternative fuel chemistries interact with engine and aircraft fuel wetted materials and components in a way that negatively affects safety? This	10%	Materials compatibility test data and reports on the comparative performance of alternative vs. baseline 100LL avgas on engine and fuel system components and materials, and any variances outside of

question addresses research elements 1.5, 1.7 and 1.8.		acceptable tolerances. Testing will be conducted on aircraft and engine fuel wetted components, and other components as necessary, to verify no adverse impact.
1.4 What engine fluid properties and chemistries are compatible with new unleaded avgas formulations? This addresses research elements 1.5. and 1.8	10%	Fluid compatibility evaluation and reports on the comparative effect of engine fluids mixed with both alternative vs. baseline 100LL fuel on engine components and any variances outside of acceptable conditions.
1.5 What fuel properties are required to ensure a safe and reliable fuel supply for evaluating candidate unleaded/lower lead fuels? Addresses research elements 1.8.	10%	Laboratory and chemical analysis data on the properties of candidate fuels that ensures sufficient compositional and performance properties control to support alternative fuel co-mingling and safe flight operations relative to 100LL aviation gasoline.

2.0 Operational Capability: *Propulsion Technologies to Reduce the Impact of General Aviation on the Environment.*

Definition:
Increased availability of propulsion technologies to the general aviation fleet that can reduce the overall impacts to the environment from general aviation. The overall impact on the environment can be reduced by:

- Piston engine technologies able to efficiently use fuel derived from renewable resources
- Lowering harmful exhaust emissions by developing fuel with less harmful constituents
- Technologies to improve fuel efficiencies
- Understanding detonation and the resulting impact on engine condition and operation to allow for the targeted use of more environmentally friendly anti-detonation fuel additives.

Research Elements:
2.1 Conduct investigations to understand how aircraft piston engines modified with advanced propulsion technologies will allow the use of unleaded fuels and can reduce the impact of aviation on the environment by reducing emissions.

2.2 Evaluate the characteristics of detonation to determine the levels at which it causes engine performance loss and damage.

2.3 Conduct investigations to establish key considerations for development of environmentally friendly fuels for piston engines.

2.4 Investigate the development and use of environmentally friendly fuel additives which may potentially be used to improve octane rating, improve scavenging and reduce emissions.

2.5 Establish key technical criteria for alternative liquid and gaseous fuels which will be used as direct or indirect energy sources for propulsion in advanced propulsion technologies such as hybrid-electric, hydrogen fuel cell and compression ignition engines.

Primary S/O: Maria DiPasquantonio, AIR-670
Secondary S/O: n/a

S/O Priority: Two (2)

Outcome:
Issuance of technical data to support certification compliance guidance for one or more propulsion technologies and alternative, unleaded fuels that will replace 100LL and reduce environmental impact by 2035.

Research Gap Analysis		
Research Questions	**Contribution**	**Research Output**
2.1 What environmental impact reducing alternative propulsion technologies can be incorporated on existing engines through modifications such as: - Staggered ignition timing - Electronic engine/ignition controls - Anti-detonation injection Which of these technologies can safely be incorporated into a percentage of the legacy fleet of engines in general aviation aircraft and what would be the environmental impact of this change? This question addresses research element 2.1.	40%	Test data and reports that will support: - Policy, and guidance development for the incorporation of piston engine technologies which can reduce general aviation's impact on the environment, and which will support the implementation of the alternative fuels transition roadmap. - The development of performance-based standards for modified propulsion systems incorporating new technologies - A detailed assessment of what it would take such as for each of the alternative propulsion technologies to safely replace a percentage of the legacy fleet of engines and aircraft in the general aviation fleet.
2.2 What are the actual performance effects and physical damage impacts of engine detonation? At what levels of detonation does engine performance loss and engine damage start to occur. Are the existing detonation margins sufficient? This question addresses research element 2.2.	20%	Research, analysis and testing to evaluate the detonation levels that actually cause engine damage and assess the existing detonation margin. Analysis and testing to determine the impacts that combustion chamber geometry, physics, chemistry, and pressures and other variables have on detonation occurrence and intensity. This is in order to understand exactly what causes the engine damage and when it occurs.
2.3 What are practical environmentally friendly drop-in fuels for piston engines that produce fewer harmful emissions and/or are produced from sustainable materials? These may include: - New sustainable fuels for piston engines, - Fuels with some sustainably derived constituents.	20%	Data and assessments that clearly show the relationship between potential new environmentally friendly piston engine fuels and how piston engines and aircraft fuel systems can successfully operate utilizing these fuels, without negative impacts or unintended consequences.

This question addresses research element 2.3.		
2.4 What fuel additives can be developed to facilitate the use of environmentally friendly fuels? This question addresses research element 2.4.	10%	Analysis, test data and reports that will help to determine the effectiveness and environmental impact of the use of fuel additives which allow the use of more environmentally friendly fuels, such as scavengers and octane boosting chemicals.
2.5 What are the key characteristics of liquid and gaseous fuels used in reducing environmental impacts, alternative propulsion technologies? Technologies incorporated into new aircraft designs such as: - Hybrid-electric propulsion systems - Fuel-cell propulsion systems - Compression ignition engines running on Jet-A or other fuels. This question addresses research element 2.5.	10%	Test data and reports that will support the development of guidance, requirements and/or specifications for liquid and gaseous fuels. These fuels can be used in alternative propulsion technologies which can reduce general aviation's impact on the environment.

Part 3: RE&D Management Team Programming

BLI Planning 3 Year Funding Profile (FY22-24) as of 01/28/2022

YEAR	Appropriation or Formulation Contract Funding ($)	INITIAL BLI TEAM PLANNING CONTRACT FUNDING – AFN BLI Target minus the Hold Back ($)	AVS-1 APPROVED CONTRACT FUNDING ($)
FY22 formulation or appropriation (if known)	**$4,612,882**		
FY23 formulation	**$2,207,246**		
FY24 AFN funding allocation target		**$4,045,259**	**$4,376,681**

BLI Plan 5 Year Outlook (FY22-27)

Complete (C)	In Progress (IP)	Programmed (P)	Need (N)

Research Activities	FY22	FY23	FY24	FY25	FY26	FY27
Operational Capability 1.0: *Alternative Unleaded Fuels for Piston Engined General Aviation Aircraft A11M.PS.6*						
Research Question #1.1: Are the ground and in-flight fuel system, engine and aircraft operability characteristics, with alternative fuels under cold day, standard day, and hot day atmospheric conditions, within allowable safety tolerances compared to lab made min spec 100LL aviation fuel?	*N*	*N*	*P*	*N*	*C*	*C*
Research Question #1.2: Are the performance, detonation, and durability characteristics of aircraft engines, operating on alternative unleaded fuels, within allowable safety tolerances compared to lab made minimum specification (min spec) 100LL aviation fuels?	*IP*	*P*	*P*	*N*	*C*	*C*
Research Question #1.3: Do alternative fuel chemistries interact with engine and aircraft fuel wetted materials and components in a way that negatively affects safety?	*N*	*N*	*P*	*N*	*C*	*C*
Research Question #1.4: What engine fluid properties and chemistries are compatible with new unleaded avgas formulations? This addresses research elements 1.5. and 1.8	*The BLI Team has decided that this research question is better suited to be addressed by industry. Not for consideration for AVS RE&D funding.*					
Research Question #1.5: What fuel properties are required to ensure a safe and reliable fuel supply for evaluating candidate unleaded/lower lead fuels?	*IP*	*P*	*P*	*N*	*C*	*C*

Research Activities	FY22	FY23	FY24	FY25	FY26	FY27
Operational Capability 2.0: *Propulsion Technologies to Reduce the Impact of General Aviation on the Environment. A11M.PS.7*						
Research Question #2.1: What environmental impact reducing alternative propulsion technologies can be incorporated on existing engines through modifications such as: - Staggered ignition timing - Electronic engine/ignition controls - Anti-detonation injection Which of these technologies can safely be incorporated into a percentage of the legacy fleet of engines in general aviation aircraft and what would be the environmental impact of this change?	*N*	*N*	*P*	*C*	*C*	*C*
Research Question #2.2: What are the actual performance effects and physical damage impacts of engine detonation? At what levels of detonation does engine performance loss and engine damage start to occur. Are the existing detonation margins sufficient?			*P*	*N*	*N*	*C*
Research Question #2.3: What are practical environmentally friendly drop-in fuels for piston engines that produce fewer harmful emissions and/or are produced from sustainable materials? These may include: - New sustainable fuels for piston engines, - Fuels with some sustainably derived constituents.	*N*	*N*	*P*	*N*	*C*	*C*
Research Question #2.4: What fuel additives can be developed to facilitate the use of environmentally friendly fuels?	*N*	*N*	*P*	*N*	*C*	*C*
Research Question #2.5: What are the key characteristics of liquid and gaseous fuels used in reducing environmental impacts, alternative propulsion technologies? Technologies incorporated into new aircraft designs such as: - Hybrid-electric propulsion systems - Fuel-cell propulsion systems - Compression ignition engines running on Jet-A or other fuels.	*N*	*N*	*P*	*N*	*C*	*C*

Part 4: BLI Team Members

Participants Name	Role	Routing Symbol
Jorge Fernandez	BLI Chair	AIR - 670
Maria DiPasquantonio	REDMT Voting Member	AIR-670
Mark Rumizen	Senior Technical Specialist	AIR-600
Tim Owen	Sponsor SME	AIR - 670
Ansel James	Sponsor SME	AIR - 670
Jon Doyle	Performer SME	ANG - E283
Dave Atwood	Performer SME	ANG – E28