Unleaded AVGAS Transition Aviation Rulemaking Committee

FAA UAT ARC Final Report Part I Body

Unleaded AVGAS Findings & Recommendations

17 February 2012

Table of Contents

<u>APPENDICES (Separate Document - Part II)</u>

LIST OF FIGURES

Executive Summary

Aviation gasoline (AVGAS) is a vital element of the piston engine aircraft safety system. Approximately 167,000 aircraft in the United States and 230,000 worldwide rely on 100 low lead (100LL) AVGAS for safe operation. 100LL is also the only remaining transportation fuel in the United States that contains the additive tetraethyl lead (TEL). The AVGAS used today has its origins in the development of the high power aircraft engines necessary to enable reliable and economical military and commercial flight. TEL has been used as an AVGAS additive for decades to create the very high octane levels required to prevent detonation (engine knock) in high power aircraft engines. Operation with inadequate fuel octane can result in engine failure and aircraft accidents.

Petitions and potential litigation from environmental organizations regarding lead-containing AVGAS have called for the US Environmental Protection Agency (EPA) to consider regulatory actions to eliminate or reduce lead emissions from aircraft. Similar regulatory actions are under consideration globally. These activities raise concerns about the continued availability and use of leaded AVGAS. Worldwide uncertainty and concern exists amongst piston aircraft equipment manufacturers, AVGAS producers, AVGAS distributors, fixed base operators, aircraft owners and aircraft operators regarding:

(a) Future utility and value of existing aircraft

(b) Availability and cost of aviation gasoline to maintain viable business operations

(c) Justification of new aviation product development

(d) Justification of new aircraft purchases.

With the current number of piston aircraft in the US alone more than 200 times larger than annual new aircraft production, the turnover rate of the existing fleet is very low. This low turnover rate leaves existing piston engine aircraft owners particularly vulnerable to devaluation of their aircraft should an unleaded replacement AVGAS be incompatible with the existing fleet. This vulnerability, combined with the stagnation of new aircraft sales and an overall deteriorating economic condition within the aviation industry, has created a sense of urgency regarding the development and deployment of an unleaded AVGAS that meets the performance demands of the current fleet.

In response to the rapidly increasing concerns expressed by the General Aviation community, the Unleaded AVGAS Transition Aviation Rulemaking Committee (UAT ARC) was chartered on January 31, 2011, by the Federal Aviation Administration (FAA) Administrator to investigate, prioritize, and summarize the current issues relating to the transition to an unleaded AVGAS; and to recommend the tasks necessary to investigate and resolve these issues. The committee was also tasked to provide recommendations for collaborative industry-government initiatives to facilitate the development and deployment of an unleaded AVGAS with the least impact on the existing piston-engine aircraft fleet. The committee was comprised of key stakeholders from the General Aviation community including aviation trade/membership associations, aircraft and engine manufacturers, petroleum and other fuel producers, the EPA and the FAA.

The UAT ARC has identified the following issues that must be considered in any effort to transition the aviation industry to an unleaded AVGAS:

- An unleaded replacement fuel that meets the needs of the entire fleet does not currently exist.
- No program exists that can coordinate and facilitate the fleet-wide evaluation, certification, deployment, and impact of a fleet-wide replacement AVGAS.
- No market driven reason exists to move to a replacement fuel due to the limited size of the AVGAS market, diminishing demand, specialty nature of AVGAS, safety, liability, and the investment expense involved in a comprehensive approval and deployment process.
- No FAA policy or test procedures exist to enable fleet-wide assessment and certification of a replacement unleaded fuel.
- There is no standardized method for communicating to the industry and end-users the impacts posed by a newly proposed fuel.

In response to these issues the UAT ARC has developed five Key Recommendations and fourteen additional recommendations to facilitate the transition to a fleet-wide replacement AVGAS. The UAT ARC respectfully submits these recommendations accompanied by the supporting material contained in this report and eagerly awaits FAA feedback and questions.

Key Recommendations:

1) *The UAT ARC recommends* implementation of the "Fuel Development Roadmap – AVGAS Readiness Levels (ARL)" developed by the UAT ARC that identifies the key milestones in the aviation gasoline development process and the information needed to support assessment of the viability of candidate fuels in terms of impact upon the existing fleet, production and distribution infrastructure, environment and toxicology, and economic considerations. (See Section 4.2.1)

2) *The UAT ARC recommends* centralized testing of candidate unleaded fuels at the FAA William J. Hughes Technical Center (Tech Center) funded by government and industry in-kind contributions. Centralized assessment and testing would generate standardized qualification and certification data that can be used by the fuel developer/sponsor to support both ASTM specification development and FAA fleet-wide certification eliminating the need for redundant testing. (See Section 4.3)

3) *The UAT ARC recommends* the establishment of a solicitation and selection process for candidate unleaded aviation gasolines for the centralized fuel testing program. This process should include a FAA review board with the technical expertise necessary to evaluate the feasibility of candidate fuels. (See Section 4.3.2)

4) *The UAT ARC recommends* the FAA establish a centralized certification office with sufficient resources to support unleaded aviation gasoline projects. (See Section 4.4)

5) *The UAT ARC recommends* the establishment of a collaborative industry-government initiative referred to as the Piston Aviation Fuels Initiative (PAFI) to implement the UAT ARC recommendations in this report to facilitate the development and deployment of an unleaded AVGAS with the least impact on the existing piston-engine aircraft fleet. The overall objective of this initiative is to identify candidate unleaded aviation gasolines, to provide for the generation of qualification and certification data on those fuels, and to support fleet-wide certification of the most promising fuels. (See Section 4.5)

The 14 additional UAT ARC recommendations are detailed in Section 4 and support various components of the 5 key recommendations to transition to a fleet wide replacement AVGAS.

Implementation of Recommendations – Piston Aviation Fuels Initiative

The UAT ARC believes that an integrated strategy for implementation of its recommendations provides for the greatest opportunity for a successful transition. This implementation will require an estimated $57.5M of public funds and $13.5M of industry in-kind support over 11 years. PAFI is the vehicle for implementation of this strategy. The components of PAFI will include an FAA Fuel Testing Program, FAA Centralized Certification Office and a PAFI Steering Group (PSG). The PSG will be composed of industry stakeholders and serves to marshal industry expertise and to facilitate FAA's testing and certification processes. It is important to note that the costs associated with the PAFI initiative do not include aircraft and engine recertification and incorporation of potential aircraft modifications to the existing fleet that might be necessary to accommodate any new fuel (see Section 5.5.2). It is impossible to quantify these costs without a clearer picture of the properties of the fuels that emerge from the PAFI program, but it is clear that it will represent a significant investment by industry.

The overall objective of PAFI is to utilize industry experts to support an FAA process that identifies candidate unleaded aviation gasolines, provides for the generation of qualification and certification data on those fuels, supports fleet-wide certification of the most promising fuels and facilitates deployment of those fuels throughout the industry. The UAT ARC has provided significant details on the creation, operation, costs and tasks to be performed under PAFI in section 5.0.

The projected activities, milestones, estimated resources, and estimated funding required for PAFI and the FAA to accomplish the above activities are presented in this report. The UAT ARC considers the adoption of these recommendations to be critically important to the health and welfare of the national economy due to the significant role that General Aviation and piston engine-powered aircraft play in our aviation transportation system and this nation's production of goods and services.

In the construction of these recommendations, alternate scenarios were examined that did not address the key issues identified in this executive summary and hence reduced the direct expense of the effort. These scenarios, however, carried significant risk of fleet impact, the risk of environmental regulatory action, prolonged economic uncertainty and substantive devaluation of consumer property.

1. *Background*

1.1. *Value of General Aviation*

Over the past century, General Aviation, which includes all flying except for military and scheduled airline operations, has become a significant and integral part of the U.S. economy creating millions of jobs and making a positive impact on the U.S. balance of trade. The United States continues to be one of the world leaders in the design, manufacture, and use of General Aviation airframes, engines, avionics, and supporting technologies.

General Aviation is a key catalyst for economic growth and has a profound influence on the quality of life in the United States. General Aviation today touches nearly every aspect of our daily lives, and its continued success will shape American society and the American economy over the next century.

The Societal and Economic Impacts of General Aviation and piston-engine aircraft are a key component of our nation's transportation infrastructure and economy. There are 5,261 public-use airports that can be directly accessed by General Aviation aircraft—more than ten times the number of airports served by scheduled airlines. These public use airports are the only available option for fast, reliable, flexible air transportation to small and rural communities in every corner of the country. General Aviation directly supports jobs in these communities, provides a lifeline for small to mid-sized businesses, and provides critical services to remote cities and towns, particularly in time of natural disaster or crisis. In addition, there are an estimated 11,500 additional private landing facilities in the nation giving additional rural access when necessary. As a result, General Aviation is uniquely situated to serve some of the public's most crucial transportation needs.

The economic impact of General Aviation is also significant representing more than one percent of the U.S. GDP. General Aviation contributes to the U.S. economy by creating manufacturing output, employment, and earnings that would not otherwise occur. Direct impacts, such as the purchase of a new aircraft, multiply as they trigger transactions and create jobs elsewhere in the economy (e.g., sales of materials, electronics, and a wide range of other components required to make and operate an airplane). Indirect effects accrue as General Aviation supports other facets of the economy, such as small business, rural economies, and tourism. Directly or indirectly, General Aviation accounted for over 1.25 million high-skill, high-wage jobs in professional services and manufacturing in 2005 (with collective earnings exceeding $53 billion) and contributed over $150 billion to the U.S. economy. General Aviation is one of the few remaining manufacturing industries that still provide a significant trade surplus for the United States generating nearly $5 billion in exports of domestically manufactured airplanes.
Often, General Aviation is thought of as recreational aviation, but there are many commercial and governmental operations that fall within this category of flying.

General Aviation is a particularly critical resource in rural and remote parts of the nation where surface transportation is limited or non-existent. In the State of Alaska for example, General Aviation is often the only means of transporting food, clothing, fuel, and all other forms of life sustaining supplies throughout the state. The Alaska Department of Transportation Aviation Division estimated that in 2007 aviation contributed $3.5 billion directly and indirectly to the state economy and supported 47,000 jobs. This accounts for 8 percent of state GDP and 10 percent of average employment, making aviation the 5th largest employer in the state. General Aviation makes up by far the vast majority of aviation activity in the State of Alaska. While Alaska is the most extreme example of dependence on General Aviation, other rural and remote areas of the country in the other 49 states also depend heavily on General Aviation for their transportation and supply needs.

General Aviation also plays an important role in supporting air carrier and military flying. General Aviation piston powered aircraft are utilized in most, if not all training programs for commercial pilot training. Both single and multiengine piston aircraft serve as the primary and advanced training aircraft at the flight schools and University aviation programs that train today's and tomorrow's airline pilots. The military uses piston engine General Aviation aircraft in training programs such as the United States Air Force's Initial Flight Screening Program (IFS).

General Aviation Facts

- ✓ Piston engine aircraft, those aircraft that use AVGAS and are directly impacted by this issue, account for 73% (167,000 aircraft) of the U.S. General Aviation fleet.
- ✓ Over two-thirds of all the hours flown by General Aviation aircraft are for business purposes.
- ✓ General Aviation is the primary training ground for most commercial airline pilots.
- ✓ In the U.S., General Aviation aircraft fly almost 24 million hours and carry 166 million passengers annually.
- ✓ 225 million gallons of aviation gasoline were produced within the U.S. in 2010 reflecting $1.3 billion in revenue.
- ✓ Production of aviation gasoline has declined on average approximately 6.5 million gallons per year since 1981.

Figure 1.0 – General Aviation Facts

Refer to the following link at the General Aviation Manufacturers Association for statistics on the general aviation fleet and operation.

http://www.gama.aero/files/GAMA_DATABOOK_2011_web.pdf

Refer to the following link to the U.S. Energy Information Administration for historical data on domestic production of aviation gasoline.

http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MGAUPUS1&f=A

1.2. *History of Leaded Aviation Gasoline*

Aviation Gasoline evolved to its present state out of the need for maximized engine performance by producing the greatest possible power output per unit weight under all environmental conditions. The development of piston engine technology in the first decades of human powered flight was directly responsible for the evolution of ever larger, faster and more capable aircraft. This advance in engine power to weight ratio was directly attributable to advances in fuel technology.

After years of laboratory and practical testing of some 30,000 chemicals and compounds, in 1921 General Motors Corporation discovered that a lead compound called TEL could significantly improve the anti-detonation characteristics of gasoline. The anti-knock qualities of TEL was many orders of magnitude greater than any other chemical or metal researched and adding only small amounts of the lead compound to gasoline could have dramatic results. It was quickly learned that by increasing the anti-knock characteristics of the fuel or what became known as the octane rating, engines could be developed to produce significantly greater power output. By 1944 the war effort dramatically accelerated the advancement of piston powered aircraft technology to its zenith that coincided with the development of the highest octane, widely available fuel ever produced with a lean motor octane rating of 115. The fuel was referred to as 115/145 and contained a maximum of 4.6 grams per gallon of TEL.

In the 1950’s, commercial aviation reached its pinnacle of aviation gasoline use and General Aviation was rapidly growing in the United States. During this decade there were six grades of aviation gasoline commonly produced ranging from a low of 73 octane up to the 115 octane fuel required for many military and commercial piston powered aircraft. However, the change in propulsion technology from piston to turbine engines was well underway in the military and finding its way into the commercial fleet. This marked the beginning of the long-standing decline in aviation gasoline production to this day.

In 1970, the original Clean Air Act was passed by Congress and this legislation targeted lead as one of the primary emissions to be controlled. Accordingly, regulations were introduced by the newly formed Environmental Protection Agency to reduce and eventually eliminate lead from motor vehicle fuels. However, while lead emissions from aviation were to be studied no specific action to remove lead from aviation gasoline was undertaken.

The public awareness and legislative/regulatory pressure to remove lead from fuels and the rapid decline in aviation gasoline consumption brought about by the transition of the commercial and military aircraft fleet to turbine engines made it economically infeasible to continue to produce multiple grades of aviation gasoline. A period of consolidation occurred in the 1970’s and 1980’s leading to the one grade of aviation gasoline available today; 100 octane low lead (100LL) which contains a maximum of 2.0 grams per gallon of TEL. This represented a roughly 50% reduction in lead emissions per gallon from the time when 115/145 fuel was commonly used by the airlines and the military. Lead emissions were further reduced as consumption of high octane aviation gasoline was replaced by jet fuel.

Like any good compromise, 100LL was not the best fuel for all aircraft. Those aircraft requiring the highest possible octane characteristics designed for 115/145 AVGAS were required to operate at lower power settings causing adverse impacts in payload capacity, takeoff distances, altitude and other performance characteristics. Conversely, low compression engines found in the light end of the General Aviation fleet found 100LL to contain too much lead for their best operation resulting in lead fouling of spark plugs and sticking valves among other difficulties. For the bulk of the General Aviation fleet though, 100LL proved to be an acceptable fuel and most of the aircraft and engines produced since the 1970's were designed around the octane characteristics of 100LL.

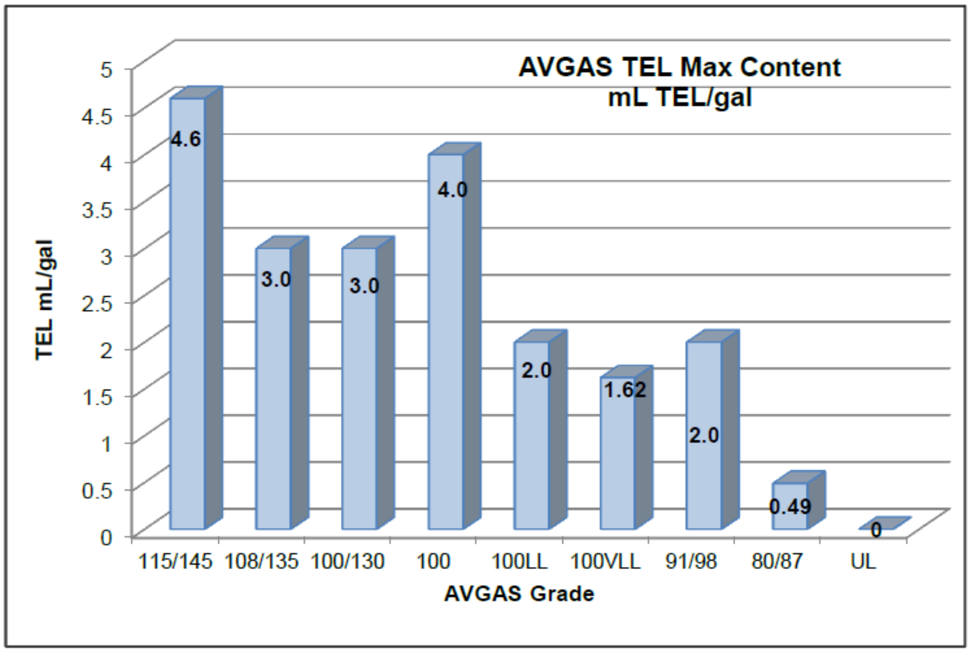


Figure 2.0 - Historical AVGAS TEL Content, Ref ASTM D910

1.3. *Drivers for Development of Unleaded Aviation Gasoline*

With passage of the Clean Air Act Amendments in 1990 new regulations were promulgated by the EPA to eliminate lead from the gasoline powering non-road engines and vehicles. It was feared at that time that aviation gasoline might be considered a non-road fuel and thus be subject to the lead elimination deadline in 1995. This sparked the beginning of serious exploration to remove lead from AVGAS while attempting to preserve the performance characteristics of the fuel and thus aviation safety. Over the ensuing 15 years, considerable research was undertaken by the aviation and petroleum industries to develop a direct replacement for 100LL without the use of lead. The FAA's William J. Hughes Technical Center played a key role in this effort. Test procedures were developed and numerous compounds and additives were tested including a matrix of 245 fuels examined in a blind round robin test overseen by the Coordinating Research Council. Forty-five of the most promising blends were examined more closely in full-scale engine testing. However, none of the fuels could satisfy all the performance requirements of 100LL.

With the threat of law suits by environmental groups, a potential EPA endangerment finding for lead emissions from aircraft, and mounting concern for the long-term availability of TEL, a group of organizations representing aviation consumers, manufacturers, and petroleum producers and distributors gathered together under the banner of the Aviation Gasoline Coalition to examine the state of the fuel marketplace. They examined research into unleaded fuels, the legal and regulatory landscape and fuel producibility and availability. The conclusion was that there were no technically feasible and safe options for high octane unleaded gasoline that would satisfy the existing fleet, though several research efforts were underway. Further, there was considerable uncertainty about the cost and availability of candidate fuels that came closest to approximating the performance of 100LL and recognition that these candidate fuels could not safely meet the high horsepower needs of the fleet. It was also recognized that while the high performance portion of the fleet represented a minority of aircraft (approximately 30 percent), these aircraft used a majority of the AVGAS (estimated to be 70 to 80 percent) by virtue of their higher fuel consumption per hour and concentration of these aircraft in commercial/business operations that fly far more hours relative to the broader General Aviation community. This meant that any unleaded fuel solution needed to be of the highest practicable octane level to satisfy that portion of the fleet that consumes the majority of the fuel

Economic considerations play a role including the ability to produce any new fuel in large quantities and in a cost-effective manner. Dual fuel solutions such as a high octane unleaded or partially leaded fuel for the high performance aircraft and a low octane unleaded fuel for the remainder of the fleet were considered. Upon careful examination, it was concluded that the volumes of consumption and cost for dual infrastructure would prohibit any widespread availability of two grades of aviation gasoline. In other industries where leaded fuel has been phased out, attrition of the fleet has been the primary means of implementing the change. However, the General Aviation fleet has an average age of 39 years, and growing, indicating that conversion to unleaded fuel by attrition is not viable in the near term and that recertification of the existing fleet to any new fuel would be required.

The formidable combination of technical and economic barriers to developing a satisfactory and safe replacement unleaded fuel, combined with the never before attempted challenge of recertifying the entire General Aviation piston fleet, will require the expertise and support of entities involved in aviation aircraft, engine and gasoline production, testing, distribution, sale, and use along with regulatory bodies such as the Environmental Protection Agency and the Federal Aviation Administration. Accordingly, the General Aviation AVGAS Coalition made a formal request to the FAA for the creation of a Federal/Private partnership to examine the full range of issues associated with replacing leaded aviation gasoline with an unleaded alternative that would satisfy the needs of the existing fleet. In January of 2011, the FAA responded by chartering the UAT ARC whose membership includes representatives of aviation gasoline producers and distributors, aircraft and engine manufacturers, aircraft owners and pilots, fixed base operators and environmental and aviation regulatory agencies. Friends of the Earth, an environmental organization pursuing legal action regarding lead emissions from aviation gasoline, was invited to participate but declined.

2. UAT ARC Committee

2.1. FAA Charter

The UAT ARC was established in response to a July 2010 petition from the General Aviation Coalition with the official Charter signed by the FAA Administrator on January 31, 2011. The period of performance was initially designated as being six months. The term of the Charter was subsequently extended in June 2011 by an additional six months to January 31, 2012. A copy of the Charter is included in Appendix A. The UAT ARC functioned under the provisions of FAA ARM Committee Manual ARM-001-015 latest Rev 38 which may be accessed at the following link.

http://www.faa.gov/regulations_policies/rulemaking/committees/arac

The FAA establishes an ARC to solicit the public's input on issues with potential regulatory implications and to exchange ideas with representatives of industry. The ARC serves in an advisory capacity with the work product being a final report presenting findings and recommendations. The UAT ARC goals and tasks as specified by the Charter are summarized as follows.

Goals

- Recommend a framework and implementation plan to guide the General Aviation community towards the deployment of an unleaded AVGAS as an alternative to 100LL
- The committee is NOT tasked with identifying a specific fuel

Tasks

- Investigate, prioritize, and summarize issues relating to the transition to an unleaded AVGAS
- Identify key issues
- Recommend tasks necessary to investigate and resolve key issues
- Provide recommendations for a joint industry-government framework to facilitate the development and deployment of an unleaded AVGAS
- Provide a report with recommendations by January 31, 2012

2.2. Membership

The UAT ARC membership represented many of the key constituencies of the General Aviation community. The FAA charter invited General Aviation stakeholders representing user groups, engine and aircraft manufacturers, industry associations, fuel producers, distributors, FBOs, environmental groups, FAA, and EPA (see Figure 3.0).

Discipline/Specialty		Member Organization
Leadership		**FAA Certification, Industry Consultant**
Certification		**FAA Certification**
Manufacturing		**GAMA, Cessna, Cirrus, Continental, Lycoming**
Environment		**EPA, FAA Office Environment & Energy**
Distribution		**NATA**
Research & Development		**FAA Tech Center**
Petroleum Industry		**API**
Owners/Operators		**AOPA, EAA, Clean 100**
Fuels		**ExxonMobil, Shell Aviation, Swift, GAMI**

Figure 3.0 – UAT ARC Membership

2.3. Meetings, Telecons, & Deliberations

The UAT ARC performed most of its work from March 2011 to January 2012. During this time there were 7 full committee meetings of 3 days duration each held in Washington DC. This represented in excess of 3300 hours of commitment on the part of the combined membership. These meetings were complemented by 11 full committee telecons with an additional 35 focus area telecons which encompassed an estimated additional 800 man hours of participation. All meetings and deliberations were conducted in accordance with FAA ARM Committee Manual ARM-001-015 antitrust guidelines, which are included in Appendix B.

3. UAT ARC Assessment of Key Issues

3.1. Summary of Key Issues Affecting Development and Transition to an Unleaded AVGAS

The following is a list of key issues identified by the UAT ARC as affecting the development and transition to an unleaded AVGAS. Further discussion follows in Section 3 providing additional insight into the group's discussion of the issues.

3.1.1. General Issues

- Replacement fuel will not be a drop-in or transparent fuel for the entire fleet.
- The existing fleet of approximately 167,000 aircraft and engines were designed and certified to operate on a known leaded AVGAS fuel meeting the ASTM D910 Specification. This fleet will require re-certification to operate with a different fuel.
- No program exists that can coordinate and facilitate the fleet-wide evaluation, certification and deployment of a non-drop in replacement AVGAS.

3.1.2. Market & Economic Issues

- With neither a drop-in replacement fuel nor a regulatory mandate to use an unleaded fuel, no market driven reason exists to move to a replacement fuel.
- Market forces have not supported the development and transition to a replacement unleaded AVGAS. The size of the AVGAS market, diminishing demand, specialty nature of AVGAS, safety ramifications and liability concerns limit the business case for the development of replacement fuels and aircraft modifications.
- Aircraft owners, present and prospective, are uncertain about the future of AVGAS, the cost of transition to an unleaded AVGAS, and the potential impact on the utility and value of their aircraft. They have no horizon or understanding of information needed to make decisions, stifling the purchase of new aircraft and modification/sale of existing aircraft.
- It will be very challenging to provide an unleaded replacement fuel that meets the demands of the two major sub-groups of the piston powered aircraft fleet; the low-utilization recreational aircraft, and the high-utilization business aircraft.
- The participation of aircraft and engine Design Approval Holders (DAHs) in the effort to develop and deploy a replacement unleaded aviation gasoline may be constrained by liability concerns.

3.1.3. Certification & Qualification Issues

- FAA regulations and policy are structured to approve specific engine and aircraft type designs for operation on a known AVGAS fuel specification. There are no FAA policy or test procedures for fleet-wide assessment and certification of a non-drop-in replacement fuel.

- Fuel testing and data requirements necessary to develop an ASTM specification and to obtain FAA certification for engine and aircraft are redundant, extremely costly, and time consuming.
- Applicants seeking both a design and fuel approval must deal with multiple FAA offices, such as ACOs and Directorates that may have limited experience with AVGAS related certification projects. This may lead to standardization issues and make efficient and timely certification difficult.
- Diversity of the fleet provides for daunting certification programs.
    - Small numbers and uniqueness of some models provides technical and economic challenges.
    - It is expected that engineering and recertification efforts for approval of a new unleaded AVGAS for many aircraft will not be supported by type certificate holders.
    - The existing fleet is comprised of different classes of aircraft, such as type certificated, light sport aircraft, and experimental, that will require different approval procedures.

3.1.4. *Aircraft & Engine Technical Issues*

- Research and testing to date has not identified an AVGAS formulation that meets all of the performance requirements of the current AVGAS specification on which the general aviation fleet was certified.
- The anti-knock capability or octane number of unleaded aviation gasolines is difficult to correlate to full-scale engine performance.
- Achieving the necessary octane number with unleaded AVGAS formulations results in undesirable trade-offs with other important fuel properties.

3.1.5. *Production & Distribution Issues*

- There is no existing method of determining the production and distribution impact posed by a new fuel.
- There is no standardized method for communicating to the industry the impacts posed by a newly proposed fuel.
- There are multiple third party regulations, standards and codes that may impact the deployment of any newly proposed fuel.

3.1.6. *Environmental & Toxicology Issues*

- There is no process to assess potential environmental and toxicology issues related to a candidate unleaded AVGAS formulations.

3.2. General Issues – Will not be a drop-in

After 20 years of research, no unleaded formulation has been found that can meet the octane needs of the existing fleet while also maintaining the other necessary safety qualities of an aviation gasoline such as vapor pressure, hot and cold starting capabilities, material compatibility, water separation, corrosiveness, storage stability, freeze point, toxicity and a host of other necessary traits necessary to be a true drop-in.

Consumers consistently demanded that a replacement fuel be drop-in and envision a seamless transition with little or no negative impacts. Because of this demand from the consumer, research into fuels that were near or only partially drop-in and did not meet all of the safety and performance parameters of the existing fuel were quickly discarded. Fuels that were advanced (i.e. UL82) and that fell short in some areas were not manufactured and distributed due to lack of consumer demand. It is now apparent that a replacement unleaded AVGAS will not be a drop-in fuel.

3.2.1. Drop-In vs. Transparent

The terms "drop-in" and "transparent" are often used in the discussions surrounding AVGAS. It is apparent that these terms have different meanings to many in the aviation world and have still different meanings when considering the broader scope of the production, distribution and consumption of AVGAS. For the purposes of the UAT ARC discussion and to have all players working from common understanding, it was discussed and ultimately agreed that it is unlikely that any replacement fuel will be completely drop-in for the entire fleet. Depending on the fuel composition, it is possible however that a new fuel could be transparent to large portions of the fleet thus reducing the challenges of transitioning to an unleaded fuel. To avoid any possible ambiguity or confusion over the use of these terms in this report, definitions and examples are provided in the following three paragraphs.

Drop-In Fuel: A "Drop-In" fuel does not affect the airworthiness and performance of the existing fleet of aircraft and engines and typically does not require new aviation fuel operating limitations. An extensive qualification test program that encompasses both fuel property evaluation and engine and aircraft testing would be required to determine if a new fuel is a drop-in. However, FAA certification approval is typically not required for existing aircraft and engines to operate with the new fuel. An example of a lead-containing Drop-In fuel is the 100 Very Low Lead (100VLL) fuel, which has been added to the current AVGAS fuel specification, ASTM D910. This fuel was introduced to the existing fleet without the need for FAA approval because it met all the compositional and performance criteria of existing 100LL AVGAS. If a fuel is not a drop-in fuel for the entire fleet, then the following definitions apply:

Transparent Fleet: The segment of the existing fleet of engines and aircraft for which a new fuel is a drop-in is called the "transparent fleet". Changes such as new or modified hardware, adjustments, or new operating procedures/limitations are not required for the aircraft and engines in the "transparent fleet", but FAA approval may be required to enable operation under the existing operating limitations.

Non-Transparent Fleet: The segment of the existing fleet of engines and aircraft for which a new fuel is not a drop-in is called the "non-transparent fleet". FAA approval of new operating limitations and changes such as new or modified hardware, adjustments, or new operating procedures/limitations will be required for aircraft and engines in the non-transparent fleet.

It is likely that replacement fuels will not match or mirror all of the performance characteristics of current AVGAS, thus the transition will have some impact on segments of the fleet. Assuming the new fuel meets many, but not all of the characteristics of current AVGAS, its impact would be felt differently by various segments of the industry. For the transparent segment of the fleet, the only likely impact would from FAA approval requirements, but this could be mitigated through FAA fleet-wide actions that address a large number of aircraft/engines. For the non-transparent segment of the fleet, new materials, operating procedures/limitations or hardware will be required in addition to FAA approval. These costs could be mitigated by FAA support of testing and approval of the required modifications.

3.2.2. *Historic Efforts Focused on Drop-In*

There has been extensive testing to find a fuel that meets all of the current ASTM D910 leaded aviation gasoline specification properties for 100LL, satisfies the safety and performance requirements of engines and aircraft, is compatible with the existing infrastructure, and poses no additional compositional issues. Thus, the fuel would have been considered a drop-in fuel, and if such a fuel had been available, it is likely the industry would have transitioned to this fuel once it became available to the General Aviation market.

Unleaded fuels typically require the addition of significant amounts of specialty chemicals to meet the same anti-knock performance that can be attained from the addition of a relatively small amount of TEL. These proposed high octane chemical additions often include heavier molecules with higher boiling points that when added in the quantity necessary to meet the same anti-knock performance of leaded fuels, often produces fuel blends that exceed many other current aviation gasoline specification limits. The legacy fleet was designed to operate safely on fuels that met the ASTM D910 specification property limits, with each fuel property addressing a different safety, performance or operability characteristic. The impact changes to these specification properties will have on the safety, operability and performance of engines and aircraft is understood in general terms but has never been studied or quantified.

In addition to the properties listed above, there are additional critical fuel properties that determine whether the fuel is fit for the purpose it was intended, such as the need for fuel to be compatible with the fleet infrastructure and co-mingle with the existing fuel to ease the transition.

3.2.3. *No Program to Support Development of AVGAS*

With a drop-in replacement for leaded aviation gasoline unavailable, it is clear that a replacement fuel will need to be developed. As detailed in Section 1.2, the development of the current leaded aviation gasoline was an evolutionary process that occurred over decades in response to the performance needs of piston aircraft engines and aircraft safety. Each successive evolution of AVGAS further improved the performance, capability and safety of the aircraft engines in which it was used. This effort intended to transition the General Aviation industry to a fleet wide replacement AVGAS proposes, for the first time, to develop an entirely new fuel and apply it to a large existing fleet while attempting to minimize the impacts or possible changes to the existing fleet. Such a new fuel would need to be developed in a manner that ensured that the existing performance and safety characteristics of AVGAS were replicated or differences clearly identified and understood in areas where they could not be matched.

While some have already begun independent processes of developing replacement fuels, there currently exists no widely accepted development process. Without such a process, the industry and regulators have no standard or criteria by which to review the sufficiency of the varied development processes undertaken by prospective fuel developers.

In addition, there exists no organizational entity around which the aviation gasoline stakeholders can organize and work the development process for candidate fuels. Such a process is necessary to coordinate the many faceted dimensions of this type of program.

3.3. *Market & Economic Issues*

3.3.1. *Market Forces*

Market forces have not supported the development of and transition to a replacement unleaded AVGAS. The size of the AVGAS market, diminishing demand, specialty nature of AVGAS, safety considerations and liability concerns limit the business case for the development of replacement fuels and aircraft modifications. Since the 1970's, 100LL has been the primary fuel used in General Aviation piston aircraft. The industry and market have developed in a way that not only relies on this fuel, but has evolved in a way that has maximized the value and efficiencies of the production, distribution, and performance of aviation fuel and engines that operate on this fuel. This is because market forces strongly support 100LL as the best aviation gasoline in terms of performance and cost. This is not surprising since the industry has relied on and maximized aircraft engines based on the capabilities of the fuel.

It is also important to understand that the pressures to replace 100LL are not market driven but are extraneous to the markets. Current pressures include the threats of legal action at the state level, and EPA consideration of potential regulatory actions at the federal level driven by the Clean Air Act. Prior to these actions, the market continued to maximize itself to the existing fuel.

Market forces alone to date have not and are not likely to support, by themselves, the development and deployment of an unleaded AVGAS in the future. This is not unexpected considering that no unleaded fuel to date has been able to match the characteristics of 100LL in and thus compete naturally in the market. Couple this with the many challenges and business risks, including the relatively small size of the market, diminishing demand, certification challenges, specialized nature of AVGAS and liability issues and it becomes apparent that the market alone cannot drive this change. There is also concern about the return on investment and potential demand for an unleaded AVGAS once it is developed and certified. Recognizing that an unleaded AVGAS will not be a drop-in replacement for 100LL, there is going to be some adverse impact upon the existing fleet.

Within the constraints of any regulatory drivers, the market must decide which of the fuels will emerge and be manufactured, supplied, distributed and sold at airports. The market consists of those companies that will use private funding to manufacture and deploy the new product in response to consumer demand. It is the candidate fuel developers' responsibility to solicit and acquire business agreements from these different companies that shows the government review panel that their product is viable in the open market and is capable of replacing 100LL.

3.3.2. *Aircraft Owner Market Perspective*

The current situation surrounding AVGAS has generated uncertainty and concern among piston aircraft owners and operators regarding (a) the future utility and value of their current assets, (b) the availability and price of aviation gasoline to maintain viable operations and (c) the uncertainty of justifying new aircraft purchases. Worldwide shipments of General Aviation airplanes fell for the third year in row. In 2010, 2,015 units were delivered around the globe, as compared to 2,274 units in 2009, an 11.4 percent decline. The piston airplane segment shipped a total of 889 units in 2010, compared to 963 units in 2009, a 7.7 percent decline. With the current fleet more than 200 times larger than annual new production, sales of new aircraft stagnating and the resulting overall economic condition of the industry deteriorating, a sense of urgency has evolved regarding the development and deployment of an unleaded AVGAS.

Consumers have multiple concerns ranging from the grounding of their aircraft due to lack of a suitable fuel if action to ban the sale of the current fuel is taken too quickly to the premature devaluation of their existing aircraft if a process is not established to qualify and implement a suitable alternative. The concerns and the impact on consumers include but are not limited to the fuel price and availability, cost and impacts of modifications, lifespan and cycle of aircraft including typical overhaul cycles and the various uses of aircraft and how users would be impacted differently. These and other consumer concerns will need to be considered in the ongoing effort to establish an implementation plan, milestones and timeline after an alternative to existing fuel has been established. Each of these concerns and issues varies greatly depending on the attributes, performance characteristics and composition of actual fuel alternatives and any associated modifications to the fleet. Of paramount consideration in the UAT ARC discussions was the need to develop mitigation strategies for these issues prior to and during the implementation process.

An additional significant point of discussion during the UAT ARC deliberations was the need to consider the value of the existing fleet and the affects transitioning to a new fuel could have on the current and future value of aircraft. PAFI and fuel developers will need to be cognizant of the impact of potential alternatives on the market value of aircraft. If, for instance, a solution comes to market that has an adverse impact on aircraft capabilities because they are either grounded (zero value) or have a reduction in their operating envelopes, there will be substantive impact on their value. The number of aircraft impacted by this devaluation is

largely dependent on the proposed fuel so it is nearly impossible to define in detail at this stage, but it remains a key consideration when evaluating each potential alternative fuel.
Another important consideration is the timeline by which alternatives are implemented and ultimately brought to market. An alternative that has a substantial impact, including the devaluation of a portion of the fleet, would require a significantly longer implementation timeline, perhaps decades, to allow for the use of the remaining life of the airframes and engines and allow natural retirement and attrition of the this portion of the fleet. The challenge with this approach is that the industry keeps heavy utilization aircraft active for decades. These aircraft are flying critical missions and are difficult, expensive, or in many cases, impossible to replace due to a lack of new aircraft produced that can fit the mission profile. The average age of the General Aviation piston fleet is 39 plus years highlighting the need for an extended transition for any alternative fuel that could significantly devalue the existing fleet.

3.3.3. *Fleet Utilization*

The current fleet of aircraft ranges from low octane light utilization with small volumes of fuel consumption to high octane high utilization with large volumes of fuel consumption and combinations in between. Each type of General Aviation aircraft owner/operator is important to the future health of General Aviation for a host of varying reasons. The impact of alternatives on each segment must be considered and mitigated in the evaluation and implementation phases.

The light utilization group of owners and operators represents one extreme in the composition of the fleet. These aircraft likely fly less than 100 hours per year, do not require high octane fuel, and purchase a relatively small volume of the total fuel consumed. However, they represent the largest number of actual aircraft in the fleet. The typical profile of this group would be an aircraft in private ownership utilized for primarily recreational flying. Because of their recreational/personal use and private ownership, these aircraft represent the group most sensitive to price fluctuations. Their reaction to a significant increase in the price of fuel would be to reduce their amount of flying or to stop flying altogether. The negative effect of either of these outcomes would be felt throughout the industry in the form of reduced operations at airports, fewer aircraft transactions, and a general degradation of the General Aviation industry through reduced participation.

The other extreme in fleet composition is represented by owners and operators of heavy utilization aircraft. These aircraft likely fly more than 300 hours per year in commercial service or in support of business activities and typically demands the highest performing fuel. This group represents perhaps the smallest number of aircraft, but because it has such a high utilization rate and includes large and multiengine aircraft it represents the majority of actual fuel consumed by the industry. A primary consideration for this group is that of aircraft performance and utility. Two examples are aircraft payload and takeoff performance. A reduction in either of these imposed by a limitation of the fuel significantly reduces the viability of these aircraft. In many cases, the reduction would exceed the point at which the aircraft is no longer viable for this type of operation. This is compounded by the fact that suitable replacements for these aircraft are not available in a commercially and economically viable manner. The inability of these aircraft to continue to perform their missions would have a significant impact on the industry through not only the loss of utility and size of the General Aviation fleet but also a major reduction in the amount of fuel burned. This loss of fuel consumption could reach the point at which fuel volume is reduced sufficiently to no longer warrant production at an economically suitable price to sustain the industry. The loss would also have an extreme effect on other industries and the communities supported by these aircraft.

While these two scenarios attempt to represent the extremes of the current market, they are not provided to attempt to illustrate a greater importance or significance of one over the other. The purpose of these discussions by the UAT ARC was to understand how alternatives and their impacts could impact various segments of the industry.

3.3.4. Design Approval Holder (DAH) Perspective

The current state of the General aviation industry has DAHs bearing disproportionately large costs for products liability insurance and litigation. As a result, the DAHs will likely not want to increase their liability by participating directly in the determination of an unleaded fuel, unleaded fuel approval and distribution process.

The passage of the General Aviation Revitalization Act (GARA) in 1997 established an 18-year time limitation (statute of repose) on civil actions that could be brought against aircraft manufacturers, with certain exceptions. If the transition to a non-drop-in unleaded aviation gasoline opens the door to additional OEM liability a "chilling effect" on DAH participation in recertification activities would result. Also considering the large number of aircraft in the General Aviation fleet no longer in production, it is highly unlikely that DAHs will be willing to recertify equipment, develop new performance data, and re-issue manuals to accommodate the anticipated fuel because of the expense and lack of accessibility to assets for confirming flight tests.

Of further concern is the potential for class action suits based on a potential devaluation of consumer asset value. In the event that the unleaded AVGAS solution results in performance degradation or aircraft grounding, the parties involved in the determination process would likely be targeted for litigation.

Based on the aforementioned considerations, it is anticipated that DAHs will not actively participate in the determination and recertification process without mechanisms for liability protection. Without such protections, DAHs would support the overall PAFI effort, however, determination, approval and transition will require the FAA to lead and mandate the action. While this would not redress the situation for DAH products and aircraft no longer in new unit production, it would likely provide an acceptable basis for support of active production. The alternative to DAH participation on either inactive or active production would be for third parties to create, test, and approve data to support the issuance of a Supplemental Type Certificate (STC) or STCs to certify the new fuel. Examples are the STCs currently in place for automotive gasoline. This scenario also presents challenges in that third parties typically do not have access to the entire scope of data in the same manner as a DAH, thus the expense of a comprehensive validation program via STC or other means may be larger than that which could be conducted with DAH participation.

3.4. *Certification & Qualification Issues*

3.4.1. *FAA Regulatory Structure*

Historically, the commercial Aviation industry has relied on a very limited number of well proven, conventional fuels for certification and operation of aircraft and engines. The vast majority of today's engines and aircraft were designed and certified to operate on one of two basic fuels; kerosene-based fuel for turbine powered aircraft and leaded AVGAS for spark ignition reciprocating engine powered aircraft. These fuels are produced and handled as bulk commodities with multiple producers sending fuel through the distribution system to airports and aircraft. These fuels are defined and controlled by industry consensus-based fuel specifications; ASTM International D1655 for jet fuel and ASTM D910 for aviation gasoline. These specifications, along with the oversight of the ASTM International aviation fuel industry committee, accommodate the need to move the fuel as a commodity.

The ASTM consensus standard process is well suited to support the development of a new fuel specification for use in future aviation products designed to operate on an unleaded fuel. However, the evaluation and qualification process is far more complex if the new fuel specification is intended for existing aircraft and engines that are designed to operate on 100LL. The procedure to evaluate new aviation gasoline is progressive and iterative in nature, with the extent of continued testing determined by the fuel properties, characteristics and test results revealed at each successive stage. The extent of testing that may be necessary grows with increasing degree of divergence from the composition, properties, performance, and experience with existing 100LL. ASTM committee members evaluate this degree of divergence and its consequences during the analysis of research report data provided by the fuel developer during the creation and maturation of new specifications.

The FAA regulations pertaining to aircraft, engines, and aviation fuel were structured to compliment this industry development and oversight concept. They require that type certificate applicants identify the fuel specifications that are used in their products during certification. Once compliance with the airworthiness certification regulations has been demonstrated, the grade designation or specification becomes part of the airplane, rotorcraft, and engine operating limitations. These operating limitations are specified in the type certificate data sheet (TCDS) and in the airplane flight manual (AFM) or rotorcraft flight manual (RFM). Aircraft operators are required by 14 CFR § 91.9 to only use fuels and oils listed in the AFM or RFM (see Figure 4.0). These fuels must, therefore, be identified with sufficient specificity to ensure that the engine and aircraft continue to meet their airworthiness certification basis during service.

The fuel must be shown to have no adverse effects on durability or safety and must perform satisfactorily on the products for which it is specified. This is demonstrated during the type certification program, amended type certification program, or supplemental type certification program. Specifically, applicants must demonstrate that the type-certificated product meets certification standards when operated with the new fuel over the complete range of operating conditions that the product originally satisfied. FAA Advisory Circular (AC) 20-24C describes the applicable regulations for fuel related certification projects.

FAA regulations are structured to approve specific engine and aircraft type designs for operation with a fuel specified by the type design holder. Therefore, it is difficult to "certify" a fuel for the entire fleet of certificated aircraft, or for a large portion of that fleet. The FAA needs to develop policy to accommodate this.

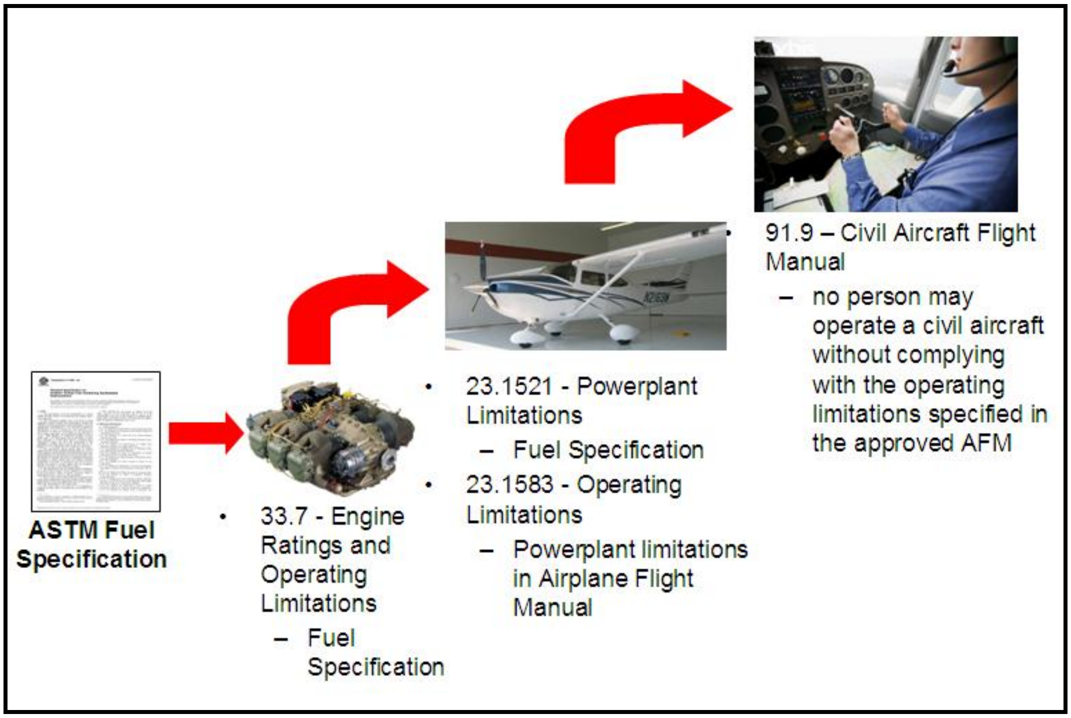


Figure 4.0 - FAA Regulatory Structure for Aviation Fuels

3.4.2. <u>ASTM and FAA Data Requirements</u>

As described above, the current ASTM and FAA processes are based on the historical practice and experience of being conducted in series and completely independent of each other. This is because engine/aircraft are designed and certified to an existing fuel specification and certification is conducted completely independently from the development of new fuels. ASTM report data on fuel specification and fit-for-purpose properties are recognized and accepted by FAA in certification programs as acceptable definition of the fuel, but are not acceptable as certification data to support the issuance of design approvals for engine or aircraft Type Certificates (TC)/STC.

Certification data must be developed in accordance with 14 CFR Part 21 certification procedures that require FAA approval of applicable requirements and test plans, as well as conformity inspection of test materials and equipment. This traditional process of defining an aviation fuel through the development of an ASTM specification independently and prior to the certification of engines/aircraft specifying that fuel as an operating limitation is not conducive to developing a non-drop-in unleaded AVGAS. Since fuel development and qualification is an iterative process, a prospective new fuel proponent must determine during the specification development that the new fuel also meets FAA safety requirements for operational approval. This is because the overall potential market for the new fuel depends on the ability to certify engines and airplanes to operate on that fuel. It is extremely redundant, costly and time consuming for ASTM and FAA fuel qualification processes and test data to be conducted independently resulting in significant uncertainty and risk. Background information on ASTM is included in Appendix K.

3.4.3. FAA Certification Offices

Applicants typically interface with multiple FAA offices, such as ACOs and Directorates based on the nature of the project and the geographic location of the applicant. This situation poses significant risk to the success of the unleaded fuel initiative due to varying degrees of experience and knowledge of fuel related certification policy from office to office and the need for national coordination for what has to be a national solution. Other risks include the potential for non-standardized application of FAA regulations and policy, difficulty in sharing and comparing data between fuel programs and certification programs, prioritization of aviation fuel related certification projects, and FAA management support of these projects.

3.4.4. Existing Fleet

Of paramount importance and complexity is the impact of transitioning to a new fuel including upfront costs to develop and qualify an unleaded fuel as well as the long-term cost impact of deploying a new fuel. Converting in-use aircraft/engines to operate on a non-drop-in unleaded aviation gasoline is a significant logistical challenge, and in some cases, a technical challenge as well. A change of approved fuels with different performance characteristics and modifications to engines and aircraft require FAA certification to ensure compliance with applicable airworthiness standards necessary for safety. The FAA certification process is comprehensive and requires significant investment of resources, expertise and time to complete. The cost and resource impact upon both industry and government could be extremely significant depending upon the level of effort and number of modifications that may be necessary to support a transition of the in-use fleet to an unleaded AVGAS. However, the closer the physical and performance properties of an unleaded AVGAS to 100LL, the less upfront economic impact there would be to the existing fleet, not including the cost of the new fuel. In particular, octane rating is a critical fuel property for aircraft engines to maintain rated horsepower which in turn is necessary for aircraft to continue to meet performance limitations.

Fleet Makeup & Typical Mission Scenarios

As the future Unleaded AVGAS is not expected to be 100% drop-in with full comparability to the current 100LL fuel, some percentage of the certificated piston powered fleet may not be able to operate safely (properly) without procedural and/or hardware modifications. In all cases, some form of approval process will be necessary for every aircraft in the existing fleet to be able to legally use the future unleaded AVGAS. In addition, there are other portions of the diverse piston powered fleet that are non-FAA certified aircraft. The following describes the piston powered General Aviation fleet with an emphasis on impact and special considerations for implementation of approval of use for a new unleaded fuel. Figure 5.0 indicates the piston fleet basic categories of certificated and non-certificated aircraft.

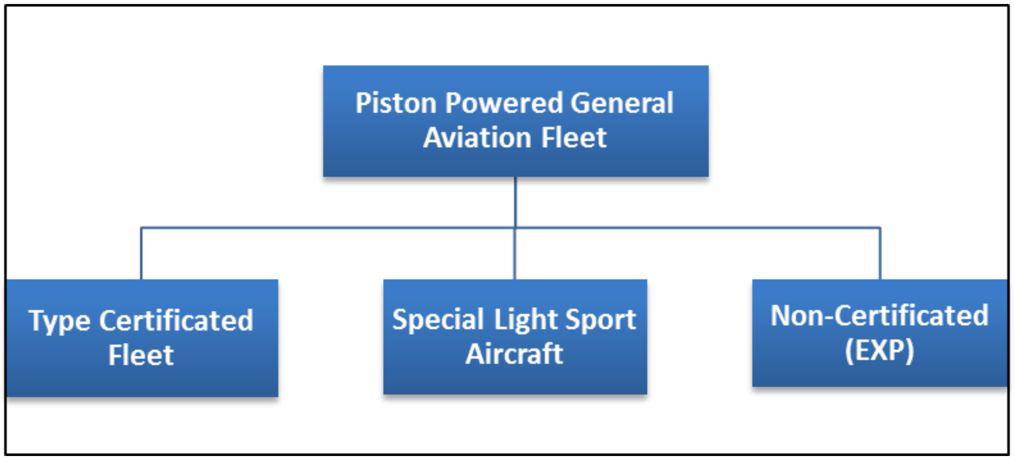


Figure 5.0 –Piston Powered General Aviation Fleet Categories

Type Certificated Fleet

Certification issues relative to the type-certificated fleet are described above in the certification discussion (Section 3.4). Approval mechanisms for use of a new unleaded AVGAS may involve one or more of the following.

- Change to type certificate for in-production aircraft/engines
- Manufacturer approval via Information Service Bulletins for legacy fleet
- Other FAA approval method providing blanket approval of engines and airframes
- FAA STC approval by industry sponsors if equivalency to 100LL cannot be demonstrated or manufacturer approval via TC change is not available

Orphaned Type-Certificated Fleet

The General Aviation piston fleet includes a significant group of FAA certified engine and aircraft where, although the TC holder may remain active, the product is no longer supported by the TC holder. The orphaned category may also include engine and aircraft products where the TC has been abandoned or the DAH TC/Production Certificate (PC) holder is no longer active. Orphaned type-certificated aircraft are limited to using the fuel specified on their type certificate or a fuel deemed by the FAA to be acceptable. A broad based FAA approval process, individual STCs, or some combination of the two would likely be required to transition these legacy orphaned type-certificated aircraft to a new unleaded fuel.

Type-Certificated Fleet Modified by Supplemental Type Certificate

Many aircraft in the General Aviation piston fleet have been modified by STC over the years. Of particular concern relating to the transition to an unleaded AVGAS are aircraft that have received STC modifications to the engine installation. These modifications can range from "bolt-on" changes to the induction, ignition, or exhaust systems, to complete firewall forward replacements of the original engine installation. Cessna estimates that in the past 20 years, as many as 3,000 to 4,000 Cessna piston engine aircraft in the U.S. registered fleet (approximately 5% of the U.S Cessna fleet) have received STCs that have either completely replaced the originally certified engine installation, or modified the original engine to a significantly different build standard. It is unknown how many additional Cessna piston engine aircraft have received STCs that modify the factory engine installation without changing the build standard of the factory-installed engine. A similar situation is present across the entire General Aviation fleet from the major manufactures past and present.

This creates the following challenges for an unleaded AVGAS transition:

- The variety of aircraft and engine combinations is much greater than an examination of the FAA registration and type certificate databases would indicate.
- Many engine STCs are done to increase performance of the aircraft, and in many cases replace engines that are more tolerant of a variety of fuels, including lower octane fuels, with engines that are more dependent on high octane fuels.
- The technical data to support a transition of aircraft equipped with engine STCs resides with a diverse base of General Aviation aftermarket modification companies with varying levels of technical expertise and financial resources to support their STCs through a transition. Many STC holders are no longer in existence.
- Owners who install engine STCs generally use their aircraft more and invest in them at a higher level than owners of unmodified aircraft. A transition to a non-drop-in unleaded fuel could potentially have a higher economic impact on this group of owners.

Special Light Sport Aircraft (S-LSA)

In recent years a new category of manufactured recreational aircraft, Special Light Sport Aircraft (S-LSA), have evolved that do not hold type certificates in the traditional sense but rather are shown by the manufacturer to conform to industry consensus standards. These aircraft are unique in the sense that they cannot be legally modified without the express approval of the manufacturer and therefore it falls solely on the manufacturer to approve the use of a new fuel in their aircraft. Changes cannot be legally accommodated by STC or other means. In instances where there is no longer a manufacturer supporting in-service S-LSA aircraft, the aircraft loses its S-LSA airworthiness certification status and is issued an experimental airworthiness certificate in the E-LSA category with all of the attendant operational limitations that accompany E-LSA experimental certification. At this point the aircraft is treated like any other aircraft certificated in the experimental category (such as amateur-built) and modifications including fuel use is at the discretion of the owner/operator.

Most S-LSA aircraft are certificated to operate on low octane unleaded fuels as well as 100LL so are not critical applications for a high octane future fuel. The primary considerations for this fleet will likely not be performance but rather materials compatibility assurance and actual final approval for use.

Non-Type-Certificated Experimental Fleet

There are a large number of non-type certificated aircraft in the fleet that are not supported by a DAH manufacturer. These aircraft are certificated in the Experimental category. This fleet is wide ranging in terms of performance, octane requirement, size, age and materials. This fleet includes amateur built aircraft, former military aircraft that were not certificated under civilian standards, imported aircraft, and aircraft used for other experimental purposes. Amateur built aircraft alone comprise more than 33,000 registered aircraft making them a significant portion of the General Aviation fleet. Experimental aircraft have no regulatory requirement to operate on a particular fuel provided the owner determines the fuel to be suitable.

The following are principle assessments that should be performed relative to evaluation of use of a new fuel in the Experimental fleet.

1) Composition and size of the fleet
2) Technical challenges in operating these airplanes using a new unleaded fuel
3) FAA fleet data (group of engines) should be made available to the end consumer (experimental category) and type clubs to enable the owner/operator to determine the impact of any new fuel
4) Economic impact of any new fuel on the Experimental fleet should be included in any total aviation industry economic impact assessment

3.5. Aircraft & Engine Technical Issues

3.5.1. Aviation Gasoline Performance Requirements

There has been extensive testing to find a fuel that meets all of the current ASTM D910 leaded aviation gasoline specification properties for 100LL, satisfies the safety and performance requirements of engines and aircraft, is compatible with the existing infrastructure, and poses no additional compositional issues. The fuel specification, which is listed in the Type Certificate Operating Limitations, is a key component of engine and aircraft certification.

Typically, aviation fuel specifications set forth performance criteria in the following seven categories.

1. Combustion
2. Fluidity
3. Volatility
4. Corrosion
5. Contaminants
6. Additives
7. Stability

For example, anti-knock performance is a combustion category performance requirement. Unleaded fuels typically require the addition of significant amounts of specialty chemicals to meet the same anti-knock performance that can be attained from addition of a relatively small amount of TEL. These proposed high octane chemical additions often include heavier molecules with higher boiling points. They often produce fuel blends that exceed many other current aviation gasoline specification limits when they are added in the quantity necessary to meet the same anti-knock performance of leaded fuels. The legacy fleet was designed to operate safely on fuels that met these specification property limits, with each fuel property addressing a different safety, performance or operability characteristic. It is unknown what impact changes to these specification properties will have on the safety, operability and performance of engines and aircraft.

In addition to the properties listed above, there are additional critical fuel properties that determine whether the fuel is fit for the purpose it was intended, such as:

- Co-mingling/compatibility of the fuel with the fleet infrastructure and existing fuel
- Other combustion issues, such as flame speed
- Other fluidity issues, such as latent heat of vaporization

The safety, performance, and operability impacts of the above discussed specification and fit for purpose properties on engine and aircraft performance are shown with more detail in Appendix H.

The areas of greater concern for any new proposed unleaded fuel requiring additional extensive testing are directly related to the composition of the proposed new fuel. Complex or novel fuels may produce additional areas of concern due simply to their significantly different nature.

3.5.2. Unleaded Aviation Gasoline Anti-Knock Performance

Octane is one of the most important parameters for a replacement unleaded aviation fuel. Extensive historical testing has indicated a difference in full-scale engine detonation performance between unleaded and leaded aviation fuel of equivalent motor octane number. Fuel motor octane number is determined from an ASTM single cylinder test that was originally designed for leaded fuels and it provided a high degree of predictability of fuel anti-knock performance in a full-scale engine. Further, the addition of a relatively small amount of the lead additive TEL to aviation alkylate provides significant octane increase to the base fuel, which can only be equaled in the absence of TEL by the addition of significant amounts of specialty unleaded chemicals to the base fuel.

Appendix H contains a presentation that illustrates these complex detonation chemical reactions. The presentation provides detailed explanation of why the TEL based additive provides superior anti-knock effectiveness.

3.5.3. Aviation Gasoline Property Trade-offs with Octane Number

Some of the aircraft safety, performance, and operability issues that may be impacted by replacing the current 100LL with an unleaded fuel are as follows.

- Detonation
- Cooling Airflow
- Fuel Consumption
- Performance
- Restarts
- Cold/Hot Fuel
- Icing
- Min Climb Gradient
- Engine Out Performance (Twins)
- Ceiling
- Go Around
- Payload
- Noise
- Takeoff

Removal or reduction of the TEL additive in current aviation gasoline results in significant reduction in fuel octane values. Attempts to increase the unleaded fuel octane or pursue novel unleaded fuel compositions have typically included the use of significant amounts of novelty or specialty chemicals. The higher the unleaded fuel octane requirement for any future fuel, the greater the complexity of the unleaded fuel blend. A trade-off ensues between engine and aircraft performance and the compatibility of the fuel with the current distribution infrastructure, existing fuel, and current fleet infrastructure. Attempts to reduce the fuel octane and move the fuel closer to the octane of the existing base alkylate increases the issues related to the engine and aircraft safety and performance. In short, the greater the compositional deviation of the proposed unleaded fuel from the current aviation gasoline composition, in attempting to meet the performance, operability and safety of the existing engines and airframes, the greater the impact on distribution infrastructure, comingling with the existing fuel, and current fleet infrastructure compatibility issues. The closer the unleaded fuel composition is to the existing aviation gasoline composition, in attempting to meet the distribution infrastructure, existing fuel, and current fleet infrastructure compatibility requirements of a new unleaded fuel, the lower the motor octane number of the fuel and the greater the impact on engine and aircraft safety and performance issues.

Appendix H contains a presentation that illustrates the trade-off of fuel complexity with fuel octane requirement.

3.5.4. Aviation Gasoline Conclusions

As previously stated, the motor octane of a fuel is significantly impacted by removal of the TEL additive. Fuel motor octane is determined by a single cylinder ASTM standard test and for leaded fuels the value obtained provides a high degree of correlation with the full-scale engine anti-knock performance. However, for unleaded fuels using chemical components such as aromatics or aromatic amines to boost anti-knock capability, the motor octane number (MON) of the fuel may not translate to a predictable engine anti-knock performance. There are a number of detonation issues that will need testing and evaluation to address. These issues are listed below. A more detailed breakdown of the following issues can be found in Appendix H.

- Unleaded fuels possessing the same MON as leaded fuels (that defines a given engine minimum octane requirement) may not provide a full-scale engine the octane performance it requires.

- Use of mixtures of high octane chemical components may result in significant antagonistic and synergistic effects of octane response.

- An unleaded fuel possessing a supercharged rich (SR) octane value that is equivalent to or greater than a leaded fuel that is known to satisfy a given full-scale engine, may not provide the same engine the octane performance that the engine requires.

- FAA AC 33.47-1, providing guidance for detonation testing, includes outdated test equipment and analyses methods.

- Detonation instrumentation and combustion instability measurement methods have not been standardized or correlated among the FAA Tech Center, engine DAHs, and others.

- There is no agreement on what constitutes limiting detonation among FAA Tech Center researchers, engine DAHs, and others.

- Detonation onset response for unleaded fuels is different from leaded fuels and can affect detonation margin.

- A significant percentage of engines and airframes may require modifications to compensate for the reduced octane performance of unleaded fuels.

3.6. Production & Distribution Issues

Any effort to transition the aviation industry toward an unleaded fuel raises concerns relating to the production and distribution of a new fuel. In recognition of this fact, the charter establishing the UAT ARC specifically required the committee to address factors relating to production and distribution infrastructure when performing its analysis of issues involved in transitioning to an unleaded AVGAS.

AVGAS is a blended petroleum product that is produced using typical and traditional refining processes. Currently, nine refiners across the U.S. produce AVGAS, although often only in limited runs at specific times of the year. As an aviation fuel, AVGAS is subject to certain quality control procedures, such as dedicated tankage and piping, which require refineries to ensure that aviation fuels are completely segregated from other products.

After production, AVGAS enters the distribution system, which, as opposed to being a fixed system that moves a product to market by well-defined routes and transportation systems, is a flexible system utilizing barges, rail cars, and over the road transport trucks. Typically, AVGAS will leave the refinery via rail car for eventual delivery to a terminal. At the terminal, the AVGAS is stored until loaded onto an over-the-road truck for final delivery. However, the AVGAS may be transported from the refinery via barge to a terminal or to railcars. Also, the terminal storage and delivery may be completely skipped and over-the-road trucks loaded directly from railcars by a process known as trans-loading. The final step in the distribution chain is on-airport storage from which the fuel is either directly delivered to aircraft or loaded into mobile refuelers that then refuel aircraft. In Alaska and other remote regions, AVGAS may be flown in barrels to outlying airports and landing facilities.

The signature quality of the AVGAS distribution system is its flexibility, allowing AVGAS to be transported from the limited number of production facilities to the over 5000 airports across the country that sell aviation gasoline.

Early discussions focused on identifying any systematic obstacles inherent in the existing production and distribution system that would prevent the adoption of a lead free AVGAS. The UAT ARC found that there were not any generalized systematic issues that prevent the production and distribution of a lead free AVGAS. Existing refinery technology and infrastructure combined with the existing distribution system is currently capable of providing a lead-free AVGAS; however, that fuel would only satisfy a limited percentage of the fleet. The UAT ARC recognized that production and distribution issues would occur as fuel developers attempted to craft a new fuel that would address a greater percentage of the existing fleet. These impacts would be specific to any newly proposed fuel and have the potential to be highly variable between fuels. New fuels that closely followed existing production methods and composition of AVGAS would pose little to no production and distribution impact while novel fuels that utilized new production methods and a significantly different composition could pose a very large impact. Since the impacts would be based on the specifics of any newly proposed fuel, the UAT ARC steered away from attempting to develop mitigation strategies for hypothetical impacts and focused on developing a structure for ensuring that the impact arising from newly proposed fuels could be identified in a manner that allowed the industry to assess adequately the impact arising from changes to the existing production and distribution systems required to utilize those fuels.

Three basic issues related to production and distribution impact were defined as follows.

1. There is no existing method of determining the production and distribution impact posed by a new fuel.
2. There is no standardized method for communicating to the industry the impacts posed by a newly proposed fuel.
3. There are multiple third party regulations, standards and codes that may impact the deployment of any newly proposed fuel.

3.6.1. *Impact Assessment*

Since production and distribution issues are not tied to the existing system but rather to the particularities of any new proposed fuel, the UAT ARC did not attempt to quantify any impact but rather develop a system that would ensure that those impacts were properly identified.

From a production standpoint, four areas were identified that should be addressed to ensure the impact is accurately addressed.

1. Feedstock Issues
2. Production Pathway Issues
3. Production Facility Issues
4. Quality control during production scale-up

Impacts that need to be determined from a distribution standpoint include the following.

1. *Materials compatibility* - If an unleaded replacement fuel to be found incompatible with some portion of the existing distribution system, including base metals, seals or transfer components, alternative components would need to be developed and installed prior to distribution of the new fuel.
2. *Geographic Impact* - If a new fuel could only be produced in one geographic location, there would be an impact upon the distribution system that would need to be determined.
3. *Fuel Compatibility* - If a new fuel is not compatible with existing AVGAS, individual aircraft, tanks, and distribution systems would need to be segregated to ensure the two fuels did not come into contact, this would create an impact that would need to be addressed.
4. *Storage Stability* – Due to the low volume of AVGAS consumption relative to other petroleum products, AVGAS is produced in short runs and stored for long periods. AVAS is a very stable product. The ability of an unleaded replacement fuel to be stored for prolonged periods while retaining all of its specification requirements will need to be assessed.

3.6.2. *Communication of Distribution System Changes*

Currently, no standardized method to communicate potential impacts of a new fuel(s) on the distribution network to the industry exists. The UAT ARC believes that it will be necessary to develop standardized methods for communicating any change to the industry. This would facilitate decision making by industry stakeholders on methods to eliminate miscommunication and potential adverse flight safety conditions related to miss-fueling, improper handling and storage or materials compatibility.

3.6.3. *Third-Party Regulations, Standards and Codes*

The distribution, sale and use of aviation gasoline are currently controlled by a number of third-party regulations, standards and codes. These standards are created and maintained by organizations and local, state and federal agencies covering everything from fire safety, occupational health, and the markings that are applied to storage tanks and piping. Any new fuel will present the possibility that these regulations, standards or codes will need to be modified or adapted based upon the specific properties and composition of the proposed fuel.

3.7 *Environment & Toxicology Issues*

General Aviation has come under scrutiny due to the use of the TEL additive in the current 100LL aviation gasoline. New fuels should be assessed for their environmental, toxicological and emissions properties relative to current fuels. Testing will need to address additional areas of concern, that are not covered by the current specification, important to ensuring that any new proposed fuel does not worsen environmental impact. For this reason bulk gas, air toxic gas engine emissions testing, and fuel toxicity testing may be needed. The extent of the testing is directly related to the complexity of the proposed unleaded fuel.

For instance, fuel developers and the General Aviation community should be made fully aware early in the process if a new fuel is proposed that may contain metallic additives to boost octane or substances like methyl-tertiary butyl ether (MTBE) which has been banned as an automotive fuel additive in numerous states. This ensures a more informed decision regarding possible adoption, handling and use, and consideration of approaches to mitigate the potential impact upon environment and/or health. Likewise, if a new fuel is proposed that is very similar to current, petroleum based fuels, it may be considered to present less risk in terms of its long-term future availability with respect to environmental and handling considerations. Preference might also be considered for renewable and sustainable alternative fuels that do not come from traditional fossil sources, in order that they may help meet national goals for the purposes of energy security, price stability, and environmental benefit.

Several environmental actions have recently led to increased pressure to remove lead from AVGAS. In 2006, Friends of the Earth (FOE) petitioned the EPA to: 1) make a finding under the Clean Air Act (CAA) that lead emissions from General Aviation aircraft engines cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare and issue proposed emission standards for such lead emissions or, alternatively, 2) if the Administrator of EPA believes that insufficient information exists to make such a finding, commence a study and investigation under the CAA of the health and environmental impacts of lead emissions from General Aviation aircraft engines, including impacts to humans, animals and ecosystems, and issue a public report on the findings of the study and investigation. In response to the FOE petition, the EPA has undertaken studies to inform issues of lead emissions and exposure resulting from the use of leaded AVGAS in General Aviation, and has published two notices in the Federal Register describing the agency's progress to date. The EPA continues to evaluate the data and issues, and has not yet issued a final response to FOE's petition.

In a separate action, in 2008, the EPA revised its National Ambient Air Quality Standards (NAAQS) for lead, tightening the NAAQS by a factor of ten. Related to the NAAQS revision, the EPA also promulgated regulations that require lead monitoring by local air monitoring agencies at airports with lead emissions greater than one ton and at 15 additional airports where there is a high volume of piston engine aircraft operations and annual lead emissions of 0.5 to 1.0 tons per year. The data from these monitors will be used to evaluate compliance with the NAAQS for lead and will also be used by EPA to assess the need for additional lead monitoring at airports. If ambient air near an airport was found to be exceeding the NAAQS, there would be limits under federal law as to the measures a state could propose to adopt to limit lead emissions from General Aviation aircraft operations. See Appendix I for additional background information on the CAA, the NAAQS, and EPA and FAA authorities related to the regulation of aircraft fuel and emissions standards. Appendix J contains the General Aviation Coalition's response to the EPA Advance Notice of Proposed Rulemaking (ANPR).

Separate from activities focused on the possible public health and environmental effects of lead emissions from General Aviation aircraft engines, it is also noted that General Aviation is the only remaining user of lead additives in the U.S. transportation sector.

Although lead emissions from piston engine aircraft are not currently subject to CAA standards, a description of the statutory responsibilities between the EPA and FAA that are pertinent to AVGAS and lead emissions under the CAA and U.S. Code has been provided in Appendix I. In summary, the EPA is authorized under section 231(a)(2)(A) of the CAA (42 U.S.C. § 7571(a)(2)(A)) to determine if aircraft engine lead emissions cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare (referred to here as the "endangerment finding"). If EPA makes a positive endangerment finding, then EPA would be required under CAA section 231(a)(2)-(3) to prescribe standards applicable to the emissions of lead from General Aviation engines, and the Secretary of Transportation would be required under CAA section 232 to prescribe regulations to ensure compliance with such standards (42 U.S.C. § 7572). In addition, the FAA would be required under section 44714 of the U.S. Transportation Code to prescribe standards for the composition or chemical or physical properties of AVGAS to control or eliminate aircraft lead emissions (49 U.S.C. § 44714). In the evaluation and setting of any new standards, the EPA and FAA must work in consultation so that necessary and appropriate considerations are given to safety, noise, and the ability and time needed to implement new technology.

The level and types of screening or testing required for candidate fuels will depend upon the exact nature of the fuel being proposed. Fuels that have novel additives or components and that are less like current, petroleum-based fuels should be given close attention. Compositional data and Material Safety Data Sheets about the candidate fuels should be made available early in the fuel development and approval process so that they may be assessed from an environmental and toxicological perspective with respect to current fuels. In addition, changes in emissions should be assessed and characterized through engine testing as early as possible in the research and development phase. Fundamental emissions test data can be obtained through the FAA Tech Center in conjunction with other engine testing during the research and development phases. If the capability for more advanced testing is needed, this may be performed through coordination with the EPA or a contractor.

4. UAT ARC Recommendations

4.1. Summary of UAT ARC Recommendations

The following is a summary of the recommendations made by the UAT ARC to support the development and transition to an unleaded aviation gasoline. The recommendations were developed with the strategic recognition that the fuels industry, engine/aircraft DAHs, regulatory authorities, and owner/operators must work together in a coordinated way if we are to develop a new unleaded aviation gasoline that will have the least impact to the existing fleet and the production and distribution infrastructure. The broad-based approval of a novel composition fuel is unprecedented in the fleet; this led the UAT ARC to develop an integrated and structured process for bringing a fuel from concept to full transition. As outlined in Section 3, there are many barriers to market entry for a new fuel. This structured process is designed to lower the barriers to the fuel entering the marketplace. Further discussion follows in Section 4 providing additional insight into the structured process and the recommendations.

4.1.1. Key UAT ARC Recommendations

1) *The UAT ARC recommends* implementation of the "Fuel Development Roadmap – AVGAS Readiness Levels (ARL)" developed by the UAT ARC that identifies the key milestones in the aviation gasoline development process and the information needed to support assessment of the viability of candidate fuels in terms of impact upon the existing fleet, production and distribution infrastructure, environment and toxicology, and economic considerations. (See Section 4.2.1)

2) *The UAT ARC recommends* centralized testing of candidate unleaded fuels at the FAA William J. Hughes Technical Center (Tech Center) funded by government and industry in-kind contributions. Centralized assessment and testing would generate standardized qualification and certification data that can be used by the fuel developer/sponsor to support both ASTM specification development and FAA fleet-wide certification eliminating the need for redundant testing. (See Section 4.3)

3) *The UAT ARC recommends* the establishment of a solicitation and selection process for candidate unleaded aviation gasolines for the centralized fuel testing program. This process should include a FAA review board with the technical expertise necessary to evaluate the feasibility of the candidate fuel. (See Section 4.3.2)

4) *The UAT ARC recommends* the FAA establish a centralized certification office with sufficient resources to support unleaded aviation gasoline projects. (See Section 4.4)

5) *The UAT ARC recommends* the establishment of a collaborative industry-government initiative referred to as the Piston Aviation Fuels Initiative (PAFI) to implement the UAT ARC recommendations in this report designed to facilitate the development and deployment of an unleaded AVGAS with the least impact on the existing piston-engine aircraft fleet. The overall objective of this initiative is to identify candidate unleaded

aviation gasolines, to provide for the generation of qualification and certification data on those fuels, and to support fleet-wide certification of the most promising fuels. (See Section 4.5)

4.1.2. *Additional UAT ARC Recommendations*

6) *The UAT ARC recommends* the use of a consensus standard peer review process as an integral and required element of the UAT ARC's recommendations. ASTM is the historically accepted consensus body for aviation fuels and is the practicable and accepted means to universally produce and distribute aviation gasoline as a commodity. (See Section 4.6.1)

   NOTE: Appendix L, "UAT ARC Member Dissenting Opinion & ARC Response", includes a dissenting opinion submitted by a UAT ARC member that is directed at the above recommendation. A response to that submittal prepared by the UAT ARC is also provided in this appendix.

7) *The UAT ARC recommends* the completion of the new ASTM "Standard Practice for the Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives". This standard will significantly reduce the uncertainty, risk, timeline and cost to developers or sponsors of new unleaded aviation gasolines by describing the test and analysis requirements necessary to generate data to support the development of a new ASTM specification. (See Section 4.6.1.1)

   NOTE: Appendix L, "UAT ARC Member Dissenting Opinion & ARC Response", includes a dissenting opinion submitted by a UAT ARC member that is directed at the above recommendation. A response to that submittal prepared by the UAT ARC is also provided in this appendix.

8) *The UAT ARC recommends* development of specialized test procedures to support centralized testing of candidate unleaded aviation gasolines. The specialized test procedures will be used by the FAA Tech Center to generate fuel property data and engine/aircraft performance data necessary to support ASTM specification development and certification approval of existing engines and aircraft that can operate transparently using a new unleaded aviation gasoline. (See Section 4.6.2)

9) *The UAT ARC recommends* the development of specialized certification guidance to support the centralized certification of unleaded aviation gasoline. The certification guidance should define the applicable certification basis and compliance requirements for Part 33 reciprocating aircraft engines, Part 23 airplanes, and Part 27/29 rotorcraft and should provide acceptable methods of compliance to assess and qualify expected differences in fuel properties, performance and composition from 100LL. (See Section 4.6.2)

10) *The UAT ARC recommends* that the FAA Centralized Certification Office coordinate with the FAA Tech Center to develop certification test plans, conformity requirements, and test witnessing protocols that are acceptable for certification of unleaded aviation gasoline/s participating in the centralized testing. (See Section 4.6.2)

11) *The UAT ARC recommends* that methods and/or guidelines be developed to assess the impact of a candidate unleaded aviation gasoline on the existing fleet, including the need for proposed aircraft/engine modifications that could mitigate those impacts. (See Section 4.7.1)

12) *The UAT ARC recommends* that methods and/or guidelines be developed to assess the impact of a candidate unleaded aviation gasoline on the existing production and distribution infrastructure. (See Section 4.7.2)

13) *The UAT ARC recommends* the identification of appropriate environment and toxicological issues that a candidate unleaded aviation gasoline should be assessed against. (See Section 4.7.3)

14) *The UAT ARC recommends* the FAA develop specialized policy and procedures to facilitate the most efficient approach possible for fleet-wide approval of aircraft and engines to use a new aviation gasoline. Fuel qualification and certification data from the centralized FAA fuel test program would support fleet-wide approval of the “in-scope” fleet of aircraft that can operate transparently on an unleaded aviation gasoline. (See Section 4.8)

15) *The UAT ARC recommends* that a mechanism be developed to mitigate the liability exposure of design approval holders (DAH) due to modification of the type design of their products in approving a new aviation gasoline. (See Section 4.8.1)

16) *The UAT ARC recommends* that the centralized FAA test program and the centralized FAA Certification Office support the approval of key aircraft and/or engine modifications that will allow the largest portions of “out-of-scope” aircraft and engines to operate with a new unleaded aviation gasoline. The FAA would have to develop procedures/guidance to facilitate certification of the out-of-scope aircraft/engines requiring modifications. (See Section 4.8.4)

17) *The UAT ARC recommends* that the FAA, working with industry, develop a deployment and transition plan and timeline only after unleaded aviation gasoline(s) with least impact upon the piston-engine aircraft fleet has been identified and a process for fleet-wide approval to use the new fuel in aircraft has been clearly established. Any FAA action should support the efforts of the industry to transition to unleaded aviation gasoline(s) in a safe and orderly manner. (See Section 4.9.1)

18) *The UAT ARC recommends* that the FAA and EPA continue to coordinate closely with stakeholders and take into consideration implementation of the UAT ARC's recommendations in any potential rulemaking efforts. Consideration must be given to safety, costs, and the ability and time needed to implement new technology. (See Section 4.9.2)

19) *The UAT ARC recommends* the FAA establish a line item in its annual 2013-2020 budget requests to fully support the UAT ARC recommendations for PAFI which includes centralized FAA fuel testing to support the development of an ASTM unleaded aviation gasoline specification and fleet-wide certification approval. (See Section 4.9.3)

4.2. Fuel Development Roadmap

The UAT ARC was tasked with identifying the key issues and obstacles to the development, certification and deployment of an unleaded aviation gasoline with the least impact upon the existing piston engine fleet of aircraft, and to develop recommendations to overcome those obstacles. Several recommendations discussed in this report address some of the technical and process issues designed to reduce the overall uncertainty, risk and cost of developing an unleaded AVGAS. But, in order to facilitate a successful initiative, the UAT ARC recommendations must also address the overarching economic and market issues affecting the business case for fuel producers and aviation equipment manufacturers to invest in the development and deployment of an unleaded replacement for high octane aviation gasoline.

The UAT ARC believes it is essential to establish a "Fuel Development Roadmap" which identifies the key milestones in the aviation fuel development process and information necessary to address the technical issues related to ensuring aviation safety as well as market and economic issues related to deployment. Development of this "roadmap" serves several roles, all with the fundamental purpose of ensuring that a new unleaded fuel is developed in a manner that replicates the existing performance and safety characteristics of leaded AVGAS or clearly identifies the areas where those characteristics are not matched and how they are to be addressed.

1. *Facilitation of Development* – The recommended roadmap will serve to inform prospective replacement fuel producers of the numerous factors that need to be considered and accounted for in an aviation fuel development endeavor.
2. *Communication Standard* – By creating a standardized process for development of a fleet-wide replacement AVGAS, a "roadmap" would allow for standardized communication about development progress within the industry and General Aviation community. Specifically such a roadmap would provide guidance to fuel developers on the criteria that would need to be evaluated in order to perform various assessments on the impact to the industry of the new fuel. This data could then be utilized by others to determine the "viability" of the fuel under development.
3. *Process Standard* – A "roadmap" would also serve as a standard by which parties could evaluate multiple unleaded aviation gasolines on a level playing field. The nature of the

"roadmap" would work to standardize data and information presentation so that fair and accurate comparisons could occur.

4.2.1. *AVGAS Readiness Levels (ARL)*

The UAT ARC has begun the process of defining a framework for a fuel development roadmap. The Commercial Aviation Alternative Fuels Initiative (CAAFI) concept of jet "fuel readiness levels (FRLs)" has been evaluated and applied by the UAT ARC to the unique needs of aviation gasoline development and definitive AVGAS Readiness Levels (ARLs). The resulting AVGAS ARLs are specifically designed to facilitate the development of a **non-drop-in fleet-wide replacement unleaded aviation gasoline**, and as such do not represent every possible approach for developing and bringing to market an aviation gasoline. All of the recommendations in this report to facilitate the development and deployment of unleaded AVGAS support the following roadmap ARLs.

Unleaded AVGAS Transition Fuel Development Roadmap
AVGAS Readiness Levels (ARL)

ARL	Title	Description	Deliverable
1	**Fuel Definition**	Utilize data developed during experimentation phase to establish process elements and parameters (such as reactor hardware and catalyst materials) and fuel compositional definition by GC analysis.	Fuel sample and report including process flow diagram and fuel compositional analysis
2	**Material Safety Review**	Initial review of candidate fuel composition relative to published guidance on material safety with respect to environmental and safe handling considerations. Develop Material Safety Data Sheet (MSDS).	MSDS and other data as needed
3	**Basic Fuel Properties and Composition**	Intended to support initial engagement with ASTM to form Task Force. Lab analysis of fuel sample to identify composition and measure key Fit-For-Purpose properties per test methods defined in ASTM International Standard Practice, "Standard Practice for the Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives" : ▪ Motor Octane Number (detonation) ▪ Vapor Pressure (starting, vapor lock) ▪ Freezing Point (high-altitude operation) ▪ Corrosion, copper strip (metal fuel system components) ▪ Oxidation stability (gumming) ▪ Water reaction (hygroscopic effect) ▪ Electrical conductivity (fuel handling) ▪ Distillation curve ▪ Initial material compatibility testing	Independent lab analysis report(s), report how the fuel was produced (blending purchased components, lab scale production, etc.)

Unleaded AVGAS Transition Fuel Development Roadmap AVGAS Readiness Levels (ARL)			
ARL	**Title**	**Description**	**Deliverable**
4	**Preliminary ASTM Research Report**	Compile data derived from laboratory analysis of candidate fuel in accordance with Section 6.2 of ASTM International Standard Practice, "Standard Practice for the Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives". This data will include: ▪ Basic Specification properties ▪ Compositional analysis ▪ Preliminary Fit-For-Purpose (FFP) Properties ▪ Preliminary Materials Compatibility Assessment ▪ Information from preceding ARLs	Preliminary ASTM Research Report
5	**ASTM Test Specification**	ASTM Test Specification defines the properties of the fuel for subsequent testing and analysis.	Issued ASTM Test Specification
6	**Preliminary Feasibility Assessment**		
6.1	**Preliminary Production and Distribution Assessment**	Analyze current AVGAS production and distribution infrastructure to identify gaps in current system and develop preliminary plan to address gaps and to scale-up production and distribution to commercially viable volumes.	Report
6.2	**Environmental & Toxicology Assessment**	Review candidate fuel composition with consideration to use and handling from an environmental perspective, including OSHA, EPA and other regulatory entities.	Report with compositional data, MSDS, environment and toxicology assessment, and other relevant environmental data.

Unleaded AVGAS Transition Fuel Development Roadmap AVGAS Readiness Levels (ARL)			
ARL	**Title**	**Description**	**Deliverable**
6.3	**Preliminary Business Plan**	Provide a business plan that addresses the following: a) Scope of Solution: Describe the fuel, engine/aircraft hardware and operational concept proposed. If hardware or operational changes are proposed summarize and characterize in accordance to CFRs as minor, major or model changes. b) Production Concept: Describe how the candidate fuel composition can be scaled up and commercialized. Include summary of fuel production process flow and related hardware c) Applicability: Define fleet satisfaction concept relative to either actual aircraft cross section as defined in the FAA Aviation Fuels Reciprocating Engine Aircraft Fleet Fuel Distribution Report or BMEP/detonation propensity as defined by TBD document. d) Cost: Describe market cost of proposed solution inclusive of recurring cost/volume and non-recurring associated with hardware or operational limitation changes. e) Implementation: Describe defined or to-be-defined strategic partnerships, financing strategies, infrastructure leveraging opportunities, distribution strategies and other relevant details facilitating path to market. f) Deployment Concept: Describe whether the proposed fuel is miscible and fungible with 100LL. Does the solution require a separate distribution and control system? g) Intellectual Property: Declare IP associated with the Scope of Solution and how stated IP is protected or public domain considerations.	Report
7	**Initial Pilot Production Capability**	Scale-up lab production capability, and define production process flow and hardware for novel production capability requirements.	Fuel sample produced by the defined process
8	**Final ASTM Research Report**		
8.1	**Final ASTM Research Report – Part 1**	Compile data derived from laboratory analysis and of candidate fuel in accordance with Section 6.3 of ASTM International Standard Practice, "Standard Practice for the Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives". This data will include: ▪ Final Fit-For-Purpose (FFP) Properties ▪ Final Materials Compatibility Assessment	Report

Unleaded AVGAS Transition Fuel Development Roadmap AVGAS Readiness Levels (ARL)			
ARL	**Title**	**Description**	**Deliverable**
8.2	**Final ASTM Research Report – Part 2**	Compile data derived from equipment testing of candidate fuel in accordance with Section 6.3 of ASTM International Standard Practice, "Standard Practice for the Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives". This data will include: ▪ Engine Testing ▪ Aircraft Testing	Final ASTM Research Report
9	**ASTM Production Specification**	ASTM Production Specification defines the properties of the fuel and other criteria necessary for high-volume production and distribution.	Issued ASTM Production Specification
10	**Pilot Production Capability**	Scale-up initial pilot production capability, using the production process flow from the initial pilot production capability requirements (ref: ARL 7). Demonstrate the ability to produce at least 10,000 gals/yr (40,000 liters/yr).	Production Process Demonstration
11	**Airworthiness Certification**		
11.1	**Engine Certification Testing**	Completion of all rig, component and engine certification tests in accordance with compliance program established by the cognizant airworthiness regulatory authority.	Certification Test Reports
11.2	**Engine Certification**	Obtain certification approval from cognizant airworthiness regulatory authority.	Issued Amended or Supplemental Type Certificate(s)
11.3	**Aircraft Certification Testing**	Completion of all ground and flight testing in accordance with compliance program established by the cognizant airworthiness regulatory authority.	Certification Test Reports
11.4	**Aircraft Certification**	Obtain certification approval from cognizant airworthiness regulatory authority.	Issued Amended or Supplemental Type Certificate(s)
12	**Final Feasibility Assessment**		
12.1	**Final Production and Distribution Assessment**	Update preliminary report based on data and information developed during the fuel development.	Report
12.2	**Final Environmental & Toxicology Assessment**	Update preliminary report based on data and information developed during the fuel development. This may include testing for baseline emission data.	Report and MSDS
12.3	**Final Business Plan**	Update preliminary report based on data and information developed during the fuel development.	Report
13	**Initial Production Capability**	Scale-up pilot production capability, using the production process flow from the pilot production capability requirements for the large-scale (ref: ARL 10). . Establish production capability to produce at least 100,000 gals/yr (400,000 liters/yr).	Fuel inventory

Unleaded AVGAS Transition Fuel Development Roadmap AVGAS Readiness Levels (ARL)			
ARL	**Title**	**Description**	**Deliverable**
14	**Initial Limited-Scale Fleet Operations**	Introduce fuel on a regional basis to gain experience with commercial operations.	Coordinated plan with fuel distributors and fleet operators to demonstrate operational use of fuel
15	**Production Scale-up**	Construct facilities to produce at least 10,000,000 gals/yr (40,000,000 liters/yr).	Fuel inventory
16	**Wide-Scale Fleet Operations**	Fuel availability and usage over several geographic regions.	Coordinated plan to transition production, distribution, and use on a regional basis

These ARLs are specifically designed to identify the steps and information necessary to address all of the issues and challenges discussed in Section 3 of this report including market and economic issues as well as the assessment of the viability of candidate fuels in terms of impact upon the existing fleet, production and distribution infrastructure, and environment and toxicology. The ARL's are laid out in chronological order for a typical development project, however, it is in envisioned that fuel developers may approach various elements in a slightly different order to align with their own business needs.

1) *The UAT ARC recommends* implementation of the "Fuel Development Roadmap – AVGAS Readiness Levels (ARL)" developed by the UAT ARC that identifies the key milestones in the aviation gasoline development process and the information needed to support assessment of the viability of candidate fuels in terms of impact upon the existing fleet, production and distribution infrastructure, environment and toxicology, and economic considerations.

4.3. Centralized Testing at FAA William J. Hughes Technical Center

Aviation fuels are defined and controlled by industry consensus-based ASTM fuel specifications that specify the properties, performance, and composition necessary to provide a level of control to support large-scale production, distribution, and the conduct of commerce for use in aircraft. In addition, FAA regulations pertaining to aircraft, engines, and fuel recognizes and accepts the well-proven ASTM specifications to define and control the properties, performance and composition of aviation fuels. The FAA has not established specific airworthiness requirements for fuel or required design or production approval for fuel due to the dependability of ASTM specifications. FAA regulations require that a fuel grade or specification be identified as an operating limitation for each make/model type certificated aircraft and engine in order for them to be able to operate using the fuel.

The UAT ARC recommendations to facilitate the development and deployment of an unleaded AVGAS address both the development of a new ASTM specification and the use of that specification to accomplish FAA fleet-wide certification approval of the fuel. As discussed in Section 3 of this report, both the ASTM specification development and FAA certification processes are progressive and iterative in nature. The scope of applicable data requirements for these processes and extent of testing that may be necessary grows with increasing degree of divergence from the properties, performance, and experience with existing 100LL. However, there are a significant number of identical or similar requirements and data needed to support the evaluation and qualification of candidate unleaded fuels through both the ASTM and FAA processes.

Ideally, fuel tests and generation of assessment data would be performed in such a way that it would be acceptable to support both ASTM specification development and FAA certification approval processes to the greatest extent possible. However, the UAT ARC recognizes that this poses significant challenges as the two processes and associated requirements are completely independent from one another. The FAA presently is not directly involved with fuel development programs and the data to support development of a fuel specification is not generated in accordance with 14 CFR Part 21 requirements for certification.

In addition, the UAT ARC discussed various concepts that would not only reduce the uncertainty and cost of fuel qualification and approval through the ASTM and FAA processes, but also address economic and market issues in order to incentivize businesses to pursue the development of an unleaded AVGAS. Considering the small size of the AVGAS market, significant diversity in the types of aviation products and operations, and importance of ensuring safety is not compromised; the UAT ARC concluded that centralized fuel testing through a collaborative industry-government process is the best approach to address the overarching issues.

2) *The UAT ARC recommends* centralized testing of candidate unleaded fuels at the FAA William J. Hughes Tech Center funded by government and industry in-kind contributions. Centralized assessment and testing would generate standardized qualification and certification data that can be used by the fuel developer/sponsor to support both ASTM specification development and FAA fleet-wide certification eliminating the need for redundant testing.

4.3.1. Benefits of Centralized AVGAS Test Program

The FAA Tech Center has established itself as the leading expert resource and world class capability for testing of aviation gasolines. A centralized FAA fuel testing program would utilize the FAA Tech Center to perform fuel property testing during fuel development stages and engine and aircraft equipment testing during fit-for-purpose fuel assessment and certification stages. A centralized AVGAS test program managed by the FAA would be able to generate standardized data in such a way that it can be used to support both the ASTM specification development process and FAA certification approval process. This will provide for a more efficient and expeditious approach to the overall process for fuel development and support the qualification and certification of the most promising fuels.

In addition, a centralized AVGAS test program will offer the significant incentive to fuel developers/sponsors of government funded and industry in-kind contribution to test candidate unleaded AVGAS fuels. This approach also offers a significant benefit of testing candidate fuels in the same manner using the same equipment, instrumentation and test facilities. This will allow for more accurate comparisons of the results and fleet impact assessment.

4.3.2. *FAA Solicitation & Selection Process*

A centralized fuel testing program will require the establishment of an FAA solicitation process for prospective unleaded AVGAS producers to submit candidate fuels for testing. In the event that there are more candidates than program funding can accommodate, a selection process will need to be established in order for FAA to select a limited number of the most promising fuels for testing.

> 3) *The UAT ARC recommends* the establishment of a solicitation and selection process for candidate unleaded aviation gasolines for the centralized fuel testing program. This process should include a FAA review board with the technical expertise necessary to evaluate the feasibility of the candidate fuel.

4.4. *FAA Centralized Certification Office for AVGAS Approvals*

Applicants for a design and fuel approval have historically dealt with multiple FAA offices, such as ACOs and Directorates that may have had limited experience with AVGAS related certification projects. Continuing this pattern may lead to standardization issues affecting efficient and timely certification. In addition, the qualification and certification data generated during the FAA fuel testing program by the FAA Tech Center is intended to support certification approval for engines/aircraft to operate on the new fuel. This data will be generated using specialized test procedures and processes and the applicability or scope of certification for unleaded AVGAS approvals will be based on the resulting test data. Local geographic FAA offices will not be familiar with the specialized procedures used to generate data in the FAA test program and fleet-wide approaches to issuing approvals which may also lead to standardization issues affecting efficient and timely certification related to unleaded AVGAS projects.

> 4) *The UAT ARC recommends* the FAA establish a centralized certification office with sufficient resources to support unleaded aviation gasoline projects.

4.5. *Establish Piston Aviation Fuels Initiative (PAFI) to Implement UAT ARC Recommendations*

The UAT ARC has strived to identify the key issues and obstacles to the development, certification and deployment of an unleaded AVGAS with least impact upon the existing piston-engine aircraft fleet and develop recommendations to overcome those obstacles. While each of these recommendations has independent value in addressing the barriers to transitioning the industry to an unleaded-aviation gasoline, the UAT ARC recognizes that the best chance for success lies in a coordinated approach to implementation.

> 5) *The UAT ARC recommends* the establishment of a collaborative industry-government initiative referred to as the Piston Aviation Fuels Initiative (PAFI) to implement the UAT ARC recommendations in this report designed to facilitate the development and deployment of an unleaded AVGAS with the least impact on the existing piston-engine aircraft fleet. The overall objective of this initiative is to identify candidate unleaded aviation gasolines, to provide for the generation of qualification and certification data on those fuels, and to support fleet-wide certification of the most promising fuels.

4.6. *Develop AVGAS Assessment & Qualification Guidance and Procedures*

As discussed previously, the civil aviation industry has evolved to rely on a very limited number of well-proven, conventional fuels for the design, operation and certification of aircraft and engines. The AVGAS production and distribution system, controlled by industry consensus-based ASTM standards, and FAA safety regulations also evolved to rely on these available aviation fuels. All existing standards and corresponding assessment and qualification methodologies and guidance are structured to ensure that new aviation products can be safely operated using an existing aviation fuel. However, additional procedures and guidance for the assessment and qualification of the existing fleet of aircraft/engines to operate on a non-drop-in alternative to 100LL is needed to facilitate the development and deployment of an unleaded AVGAS. In addition, guidelines are needed to assess the viability of a candidate unleaded AVGAS from both a fleet impact perspective and fuel production and distribution perspective.

4.6.1. *ASTM Fuel Properties and Performance*

Aviation fuels are produced and handled as bulk commodities with multiple producers sending fuel through the distribution system to airports and aircraft. These fuels are defined and controlled by industry consensus-based fuel specifications; ASTM International D1655 for jet fuel and ASTM D910 for leaded aviation gasoline. These ASTM aviation fuel production specifications define the properties, performance, and composition necessary to provide a level of control to support large-scale production, distribution, and the conduct of commerce for use in aircraft.

> *6) The UAT ARC recommends* the use of a consensus standard peer review process as an integral and required element of the UAT ARC's recommendations. ASTM is the historically accepted consensus body for aviation fuels and is the practicable and accepted means to universally produce and distribute aviation gasoline as a commodity.

4.6.1.1. ASTM Standard Practice for the Evaluation of New Aviation Gasolines

At present there are no ASTM guidelines or procedures for the development and qualification of a new aviation gasoline intended to be used by the existing fleet of aircraft as an alternative to ASTM D910 and/or 100LL. This situation results in significant uncertainty, business risk, and cost impact for potential unleaded AVGAS fuel developers.

In response to recommendations by industry, ASTM is currently developing a "*Standard Practice for the Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives*" which provides procedures to develop data for use in research reports to support the development and issuance of new or revised AVGAS specifications. The procedures, tests, selection of materials, engines and aircraft detailed in the standard practice document have been collaboratively developed by industry and the FAA reflecting their respective expertise in these specialized areas. This standard is intended to be used by developers or sponsors of new aviation gasolines or additives as an aid to determining and standardizing the data requirements necessary to support the review and qualification of these new products by ASTM members.

The draft standard describes laboratory and aircraft equipment test requirements to evaluate a new aviation gasoline intended to be used by an existing fleet of aircraft that was designed and certified to operate using another aviation gasoline (i.e. 100LL). It includes requirements that address the following subjects:

- Basic specification properties
- Fit-for-purpose properties (see below)
- Materials Compatibility
- Compatibility with other aviation gasolines and aviation piston-engine lubricants
- Aircraft component bench or rig testing
- Engine test cell evaluation
- Aircraft flight test evaluation

Of particular importance for the evaluation of a non-drop-in alternative to 100LL are the requirements for fit-for-purpose properties relating to engine and aircraft operability and performance as well as properties relating to fuel handling and distribution. These properties are characteristics of an aviation fuel that are not controlled by the fuel specification or specification properties, but that are necessary for evaluation in addition to the specification properties to provide a comprehensive assessment of the suitability of an aviation fuel for use on aircraft and aircraft engines. The data generated during this testing should be compared to corresponding data for ASTM D910 100LL fuel properties and differences reconciled in the Research Report. See Appendix K for background on ASTM.

7) *The UAT ARC recommends* the completion of the new ASTM "Standard Practice for the Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives". This standard will significantly reduce the uncertainty, risk, timeline and cost to developers or sponsors of new unleaded aviation gasolines by describing the test and analysis requirements necessary to generate data to support the development of a new ASTM specification.

4.6.2. FAA Specialized Test Procedures & Certification Guidance

FAA certification relative to aviation fuels is designed to evaluate the airworthiness of specific engine and aircraft models when operating on the candidate fuel, whereas the ASTM process described above is designed to evaluate the properties of the candidate fuel under prescribed conditions. The UAT ARC recognized the synergy between the two processes when a common set of technical data is generated to support both evaluations.

For example, the airworthiness standards for aircraft engines in 14 CFR Part 33 require that performance, operability, durability, and safety be evaluated throughout the full envelope of extreme conditions the engine is expected to encounter in service, including extreme cold/hot temperatures and altitudes. Fuel properties such as vapor pressure, freeze point and distillation curve directly affect these engine performance envelopes. The most important performance indicator for an engine is horsepower and the safety critical limiting factor is detonation. The octane level of AVGAS is a measure of protection against the onset of detonation so the higher the octane the higher the horsepower that is possible from a particular engine and vice-versa. While octane is evaluated during the ASTM qualification process, a specific regulation (14 CFR 33.47) requires a test program to ensure that an aircraft engine can operate without destructive detonation throughout its full range of operation.

Similar to engines, the airworthiness standards for aircraft in 14 CFR Part 23 and rotorcraft in 14 CFR Part 27/29 require demonstration of minimum aircraft performance requirements such as takeoff runway length, climb, speeds and distance over a range of conditions such as maximum weight/payload, maximum outdoor temperatures and airport altitudes up to 10,000 feet. The critical performance envelopes and operational safety limitations for an aircraft established by these tests are directly dependent upon the engine and its associated performance, which in turn is dependent upon the fuel properties.

In addition, 14 CFR parts 33, 23 and 27/29 require materials compatibility testing to substantiate that the fuel is compatible with all engine and aircraft materials to ensure that there are no safety and airworthiness impacts upon components and parts such as pistons, valves, turbochargers, carburetors, pumps, hoses, gaskets, seals, fuel tanks, structure, sealants etc. Materials compatibility will be dependent upon the fuel composition, which is evaluated by ASTM.

Just like the ASTM evaluation process, the certification procedure and testing requirements to approve an engine/aircraft to operate on a new fuel is progressive and iterative in nature, determined by the fuel properties, characteristics and test results revealed at each successive stage. The scope of applicable certification basis requirements and extent of testing that may be necessary grows with increasing degree of divergence from the properties, performance, and experience with existing 100LL. As discussed previously, a high octane unleaded AVGAS that is intended to meet the needs of the existing fleet is not expected to be a drop-in and, therefore, will likely have some differences in properties, performance and/or composition from 100LL. Aviation fuel has a direct and significant impact upon both the engine and aircraft performance and, therefore, compliance with the applicable FAA safety standards.

Consequently, great efficiencies could be realized by developing one portfolio of tests that could provide data to support both the ASTM process and FAA certification process. This requires that the new ASTM Standard Practice and the FAA regulations and guidance be reviewed to identify where common tests and/or analyses can satisfy both sets of requirements. Test procedures will then be developed for both the common tests and unique tests for use by the FAA Tech Center under the centralized testing concept.

Of particular importance are detonation issues related to octane and the differences in behavior of anti-knock performance between leaded and unleaded fuels. The existing guidance in AC 33.47-1 for detonation testing is based on outdated test equipment and analyses methods. The FAA Tech Center detonation measurement methods and associated instrumentation should be correlated with industry test facilities, and there is industry interest in further investigation of the thresholds used to define limiting detonation levels (i.e. acceptable versus unacceptable).

8) *The UAT ARC recommends* development of specialized test procedures to support centralized testing of candidate unleaded aviation gasolines. The specialized test procedures will be used by the FAA Technical Center to generate fuel property data and engine/aircraft performance data necessary to support ASTM specification development and certification approval of existing engines and aircraft that can operate transparently using a new unleaded aviation gasoline.

In addition, template versions of FAA certification compliance plans will need to be developed that reflect the new test procedures and analyses. These template compliance plans can then be used for all candidate fuel projects.

> *9) The UAT ARC recommends* the development of specialized certification guidance to support the centralized certification of unleaded aviation gasoline. The certification guidance should define the applicable certification basis and compliance requirements for Part 33 reciprocating aircraft engines, Part 23 airplanes, and Part 27/29 rotorcraft and should provide acceptable methods of compliance to assess and qualify expected differences in fuel properties, performance and composition from 100LL.

> *10) The UAT ARC recommends* that the FAA Centralized Certification Office coordinate with the FAA Technical Center to develop certification test plans, conformity requirements, and test witnessing protocols that are acceptable for certification of unleaded aviation gasoline/s participating in the centralized

4.7. *Impact Assessment of Candidate Unleaded Aviation Gasoline*

The viability of a candidate unleaded AVGAS to be deployed as an alternative to 100LL depends upon the total impact upon the existing fleet of aircraft, fuel production and distribution infrastructure, and environment.

4.7.1. *Aircraft Fleet*

An unleaded AVGAS is expected to be transparent for large portions of the current aircraft fleet. It should have no physical impact or change in the design, operation or performance of engines and aircraft other than to list the new fuel specification in the operating limitations. These engines and aircraft are referred to as the transparent fleet. However, it is not expected to be a drop-in which means there will be some differences in certain fuel properties, performance or composition compared with 100LL that will impact certain portions of the fleet and require modification in order to operate safely using the new fuel. These engines and aircraft are referred to as the non-transparent fleet. However, there is no defined methodology to assess the impact of a candidate unleaded AVGAS upon the existing fleet of aircraft.

> *11) The UAT ARC recommends* that methods and/or guidelines be developed to assess the impact of a candidate unleaded aviation gasoline on the existing fleet, including the need for proposed aircraft/engine modifications that could mitigate those impacts.

4.7.2. AVGAS Production & Distribution Infrastructure

As discussed previously, an unleaded AVGAS is expected to have a different composition than 100LL due to the need for specialty chemicals to compensate for the absence of lead. This raises potential materials compatibility issues and possible impact upon the production and distribution infrastructure. However, there is no defined methodology to assess the impact of a candidate unleaded AVGAS upon the existing AVGAS production and distribution infrastructure.

> 12) *The UAT ARC recommends* that methods and/or guidelines be developed to assess the impact of a candidate unleaded aviation gasoline on the existing production and distribution infrastructure.

4.7.3. Environment & Toxicology

The potential use of specialty chemicals raises potential environmental and toxicological issues. There are no existing FAA or EPA regulatory requirements for piston aircraft emissions. It is important that a candidate unleaded fuel does not introduce any new or more harmful emissions or environmental impact than the current leaded 100LL.

> 13) *The UAT ARC recommends* the identification of appropriate environment and toxicological issues that a candidate unleaded aviation gasoline should be assessed against.

4.8. FAA Support for Fleet-Wide Certification Approval

Each new make and model of engine and aircraft introduced into the fleet was specifically designed, tested and FAA certificated using 100LL (or equivalent ASTM D910 leaded AVGAS). It is not practical or even possible to re-certify each and every individual make and model engine and aircraft in the entire fleet to operate on a new unleaded fuel. Although there are a large number of different engine and aircraft make/models with broad ranges of configurations and performance, there are many key characteristics from a design and safety perspective that would allow for large groups of "like" engines and aircraft to be assessed, qualified and approved for operation on an unleaded fuel.

> 14) *The UAT ARC recommends* the FAA develop specialized policy and procedures to facilitate the most efficient approach possible for fleet-wide approval of aircraft and engines to use a new aviation gasoline. Fuel qualification and certification data from the centralized FAA fuel test program would support fleet-wide approval of the "in-scope" fleet of aircraft that can operate transparently on an unleaded aviation gasoline.

The following summarizes UAT ARC discussion on some of the fleet impact considerations and provisions necessary to address both the certificated and non-certificated aircraft categories. It also includes possible approval mechanisms and actions that could be considered.

4.8.1. Type-Certificated Aircraft

An unleaded AVGAS that is not drop-in will require some form of FAA approval to operate in each airplane and engine. These approvals could range from some type of FAA issued fleet-wide approval for the transparent portion of the fleet, to a change in type design for entire make/model series by a TC or STC DAH, to aircraft specific design changes or alterations. The most effective and efficient approaches would include support from the original equipment manufacturer of the aircraft and engine that hold certification and test data across the broadest range of make/models. However, as discussed previously, there are significant business risk factors that affect the potential level of DAH involvement in making application for and/or directly supporting approvals or design changes. Beyond economic interests and whether there is a potential return on investment, there is an ongoing regulatory responsibility for the continued airworthiness of any design approval along with product liability for 18 years. Since fuel is such an integral component to engine and aircraft performance and operation, the product liability risk exposure and associated insurance and litigation costs would likely be significant.

Therefore, it is anticipated that original equipment manufacturer DAHs will not likely be able to make application for and/or directly participate in unleaded AVGAS determination and recertification without some mechanism for liability protection. This could include approaches whereby the DAH can fully support FAA issuance of fleet-wide approvals, third-party STCs, field approvals, etc.

> 15) *The UAT ARC recommends* that a mechanism be developed to mitigate the liability exposure of design approval holders (DAH) due to modification of the type design of their products in approving a new aviation gasoline.

In addition, there are many make/model engines and aircraft that are not supported by an original equipment manufacturer DAH because the type certificates and supplemental type certificates are orphaned, abandoned or otherwise unsupported. Various approval mechanisms as well as industry and FAA support activities will need to be considered in order to support the broadest possible range of type-certificated products.

Approval Mechanisms - Type-certificated fleet transition approval mechanisms for use of a new unleaded AVGAS may involve one or more of the following.

- Manufacturer DAH change to type certificate for in-production aircraft/engines
- Manufacturer DAH approval via Service Bulletins for legacy fleet
- FAA methods to provide some form of fleet-wide/blanket approval of engines and airplanes

- FAA Supplemental Type Certificate approval by industry sponsors
- FAA field approval of an aircraft/engine alteration

Industry Support - may include but is not limited to the following.

- Lobbying by industry members at Federal and state government levels for tax incentives and financial support to aid in technical and legal transition
- Providing available technical data to potential third-party solution providers (STC/field approval) to reduce work required and accelerate time to market

FAA Support - may include but is not limited to the following.

- Provide information and assist in fleet certification and approvals
- Make FAA Tech Center available to help conduct standardized tests needed to derive solutions and obtain group STC approval.

Fuel Developer Support - may include but is not limited to the following.

- Provide test fuel for development and testing
- Provide baseline fuel test and certification data to potential solution provider

4.8.2. Special Light Sport Aircraft (S-LSA)

In recent years a new category of manufactured recreational aircraft, Special Light Sport Aircraft (S-LSA), have evolved that do not hold type certificates in the traditional sense but rather are shown by the manufacturer to conform to industry consensus standards. The FAA uses manufacturer's certification as the basis for FAA issuance of an airworthiness certificate. These aircraft are unique in the sense that they cannot be legally modified by the owner/operator or third parties and therefore it falls solely on the manufacturer to approve the use of a new fuel in these aircraft. Changes cannot be legally accommodated by STC or other means of FAA approval. In instances where there is no longer a manufacturer supporting in-service S-LSA aircraft, the aircraft lose their S-LSA airworthiness certification status and are placed in the experimental category (E-LSA) with all of the attendant operational limitations that accompany experimental certification. At this point the aircraft is treated like any other aircraft certificated in the experimental category (such as amateur-built) and modifications, including fuel use, are at the discretion of the owner/operator.

Most S-LSA aircraft are certificated to operate on low octane unleaded fuels as well as 100LL so these aircraft are not expected to be significantly impacted by a transition to a future unleaded fuel. The primary considerations for this fleet will likely not be performance but rather materials compatibility assurance and an appropriate method for final approval for use.

Approval Mechanisms - S-LSA fleet transition approval mechanisms for use of a new unleaded AVGAS may involve one or more of the following.

- Engine manufacturers provide approval for use of the new unleaded fuel for their respective engine models

- Aircraft manufacturers address specific aircraft design and field aircraft solutions and approvals leveraging available test data derived for the type certificated fleet

S-LSA Industry Support - may include but are not limited to the following

- Coordinate fleet transition effort on Light Sport Aircraft and similar models certificated in other categories with support from stakeholder groups
- Coordinate with user groups and type clubs to provide info and better develop group solutions for similar types of aircraft
- Coordinate fleet transition with ASTM Committee F37

FAA Fuel Developer Support - may include but are not limited to the following.

- Provide information and test results generated to support approval of the TC products that can be communicated by the FAA to the S-LSA fleet.

4.8.3. Non-Certificated Fleet

There are a large number of non-type certificated aircraft in the fleet that are not supported by an original equipment manufacturer (OEM). These aircraft are certificated in the Experimental category and can include former military aircraft that were not designed and type certificated under civilian standards as well as amateur-built aircraft, some foreign aircraft, and those placed within this category for research, testing, and other purposes. This fleet is wide ranging in terms of performance, octane requirement, size, age and materials. Experimental aircraft have no regulatory requirement to operate on a particular fuel provided the owner determines the fuel to be suitable.

Experimental Fleet Assessment - the following are principle assessments that should be performed relative to evaluation of use of a new fuel in the experimental fleet.

- Composition and size of the experimental fleet
- Technical challenges in operating these airplanes with a new unleaded fuel
- FAA fleet data (group of engines) should be made available to the end user (amateur-built category) and type clubs to enable determination of impact by the user
- Economic impact on the experimental fleet should be included in the total aviation industry economic impact assessment

Experimental Fleet Approval Mechanisms - Experimental fleet approval mechanisms for use of a new unleaded AVGAS may involve one or more of the following.

- FAA provides specific guidance in the form of an AC or SAIB based upon type certificated products for owners of experimental aircraft to evaluate the impact (performance, materials compatibility, etc.) of the unleaded fuel on their individual aircraft and make informed decisions about its use

- SAIBs issued by FAA in support of the type-certificated fleet may be supportive of the amateur-built and other experimental aircraft impact determinations

Industry Support – may include but are not limited to the following.

- Engine manufacturers provide approval for use of the new unleaded fuel for their respective engine models (TC and non-TC)
- Provide applicable technical data to enable assessment of impact by users and type clubs
- Type Club coordination with FAA, manufacturers and fuel developer to provide data and information to the experimental community enabling assessment of any new fuel and approval means for the experimental fleet

FAA Fuel Developer Support **-** Provide information and test results generated to support approval of the TC products that can be communicated by the FAA to the experimental fleet.

4.8.4. *Aircraft/Engine Modification Testing Approval*

The UAT ARC recognizes that an unleaded AVGAS that completes the qualification and certification process will most likely not meet the full range of performance demands or be fully compatible with the entire fleet of existing piston-powered aircraft. Therefore, some portion of the fleet will not be able to operate safely using a new unleaded AVGAS without some form of aircraft and/or engine modifications. These are referred to as "out-of-scope" aircraft and engines.

> 16) *The UAT ARC recommends* that the centralized FAA test program and the centralized FAA Certification Office support the approval of key aircraft and/or engine modifications that will allow the largest portions of "out-of-scope" aircraft and engines to operate with a new unleaded aviation gasoline. The FAA would have to develop procedures/guidance to facilitate certification of the out-of-scope aircraft/engines requiring modifications.

4.9. *Development of Unleaded AVGAS Deployment Strategy*

A clearly defined transition plan from 100LL to a replacement unleaded AVGAS is necessary to provide a common timeline to all stakeholders including manufacturers, operators, FAA, EPA, industry associations, etc. The UAT ARC Recommendations are designed to facilitate the development and deployment of an unleaded AVGAS and provide this transition plan. Implementation of the UAT ARC recommendations and the associated transition plan will ensure the continued safety and viability of general aviation. The Recommendations lay out three stages of the transition; Preparatory, Project and Deployment with significant detail provided for the first two stages. The Preparatory and Project stages address the development of an ASTM fuel specification, FAA approval and certification policy as well as the economic viability of a candidate unleaded AVGAS. These stages represent a significant portion of the UAT ARC Recommendations.

The *Deployment stage* is, however, as critical as the first two Stages in managing the impact of a transition to an unleaded AVGAS. The Deployment Stage addresses the introduction of the unleaded AVGAS into the field and the eventual phase out of 100LL. The UAT ARC understands the need to provide the FAA with a recommendation for the framework and milestones to address the transition of the fleet to an unleaded fuel. At this time, the UAT ARC cannot recommend a specific timeline beyond the Preparatory and Project Stages of the recommendations due to the unknown impact of an unleaded fuel on the existing fleet.

Another important consideration in this discussion is the timeline by which alternatives are implemented and ultimately brought to market. An alternative that has a substantial impact, including the devaluation of a portion of the fleet, would require a significantly longer implementation timeline, perhaps decades, to allow for the consumption of the remaining life of the airframes and engines. This will enable the natural retirement and attrition of this portion of the fleet. The challenge with this approach is that the industry presently keeps heavy utilization aircraft active for decades. These aircraft are flying missions in support of critical roles and are difficult, expensive or in many cases, impossible to replace due to a lack of new aircraft produced that can fit the mission profile. The average age of the General Aviation piston fleet exceeds 39 years. This highlights the need for an extended transition for any alternative fuel that would otherwise significantly devalue or limit the capability of the existing fleet.

Another key consideration for a viable unleaded AVGAS replacement for 100LL is the economic impact. This includes both the upfront costs to transition to an unleaded AVGAS as well as the long term cost impact of operating on a new fuel. The EPA's Advance Notice of Proposed Rulemaking on Lead Emissions from Piston-Engine Aircraft recognized that converting in-use aircraft/engines to operate on unleaded aviation gasoline would be a significant logistical challenge, and in some cases, a technical challenge as well. As discussed previously, a change to the approved AVGAS or modifications to engines and aircraft require FAA certification to ensure compliance with applicable airworthiness standards necessary for safety. The FAA certification process is comprehensive and requires significant investment of resources, expertise and time to complete. The cost and resource impact upon both industry and government can be significant depending upon the level of effort and number of modifications that may be necessary to support a transition of the in-use fleet to an unleaded AVGAS. However, the closer the physical and performance properties of an unleaded AVGAS to 100LL, the less upfront economic impact there would be, particularly with respect to octane rating. This is a critical fuel property for aircraft engines to maintain rated horsepower that in turn is crucial for high performance aircraft to meet their performance limitations. Another potentially significant upfront cost for an unleaded AVGAS is the impact upon the fuel production and distribution infrastructure and level of modifications/investment that may be necessary. Long-term economic impacts that should be considered are the cost of unleaded AVGAS per gallon and any potential impact on aircraft/engine operating and maintenance costs. These are ongoing costs incurred by entire in-use fleet for the foreseeable future.

4.9.1. *Milestones and Timeline*

It is imperative to understand that at this time the UAT ARC is only able to discuss major milestones that are expected to be necessary for the Deployment Stage. Timelines for these milestones can only be established once a potentially viable unleaded AVGAS has been identified and the industry has an understanding of the impact upon the existing fleet and production and distribution infrastructure. The UAT ARC also highlights the importance of understanding that the milestones may also represent decision points. Once a milestone is reached, all information available to that point must be evaluated. Future milestones may need to be altered, adjusted or completely reevaluated as information about new fuels becomes known.

The following summarizes some of the key milestones necessary for deployment of an unleaded AVGAS once a potentially viable unleaded AVGAS with least impact upon the piston-engine aircraft fleet has been identified:

- **Identification of an Unleaded AVGAS with Least Impact Upon Existing Fleet**
  - ASTM production specification to support commercial acceptance
  - FAA qualification and certification test data to support maximum fleet approval
  - Aircraft fleet impact assessment and potential modification data
- **New Aircraft Certified for Unleaded AVGAS Capability**
  - New production engines/aircraft certified to operate on unleaded AVGAS
    - Only affects engine/airplane certification and not current operations
    - Would require dual certification for unleaded AVGAS and 100LL
  - Consideration of some type of regulatory mandate may be necessary
- **Transition to Unleaded AVGAS**
  - Applies to fuel availability and operations of all General Aviation aircraft
  - Transition timeline dependent upon impact of unleaded AVGAS
    - Level of FAA certification required for fleet-wide approvals
    - Development and implementation of modifications (i.e. overhaul cycle)
    - Level of change to AVGAS production and distribution infrastructure
  - Consideration of special case
    - Portions of fleet that cannot transition (i.e., cargo operations in remote areas, public safety operations, historic aircraft, etc.)
  - Consideration of some type of regulatory mandate may be necessary

> *17) The UAT ARC recommends* that the FAA, working with industry, develop a deployment and transition plan and timeline only after unleaded aviation gasoline(s) with least impact upon the piston-engine aircraft fleet has been identified and a process for fleet-wide approval to use the new fuel in aircraft has been clearly established. Any FAA action should support the efforts of the industry to transition to unleaded aviation gasoline(s) in a safe and orderly manner.

4.9.2. Consideration of Regulatory Action

The UAT ARC recognizes that an ultimate transition to unleaded aviation gasoline for general aviation is not likely to occur due to market forces alone and accordingly some form of regulatory action may be required to effect a permanent and complete change from leaded to unleaded AVGAS. However, given the uncertainties surrounding what a future fuel might look like relative to its performance, safety and economic impact it is premature for the UAT ARC to recommend any form or regulation or timeline. We only acknowledge that such an action may need to occur once a satisfactory replacement has been identified and approved

> *18) The UAT ARC recommends* that the FAA and EPA continue to coordinate closely with stakeholders and take into consideration implementation of the UAT ARC's recommendations in any potential rulemaking efforts. Consideration must be given to safety, costs, and the ability and time needed to implement new technology.

4.9.3. Funding for Piston Aviation Fuels Initiative (PAFI)

This implementation of the proposed PAFI will require an estimated $57.5M of public funds and $13.5M of industry in-kind support over 11 years. Specifics for the estimated funding are addressed in Section 5.5.

> *19) The UAT ARC recommends* the FAA establish a line item in its annual 2013-2020 budget requests to fully support the UAT ARC recommendations for a Piston Aviation Fuels Initiative (PAFI) which includes centralized FAA fuel testing to support the development of an ASTM unleaded aviation gasoline specification and fleet-wide certification approval.

5. *Implementation of UAT ARC Recommendations*

The implementation concept recommended by the UAT ARC relies upon both a process and an organization called the Piston Aviation Fuel Initiative (PAFI) formed by the FAA and an industry-government coalition. The overall objectives of this initiative are to identify candidate unleaded aviation gasolines, to provide for the generation of qualification and certification data for those fuels, and to support the qualification and certification of the most promising fuels. The elements of PAFI will be an FAA Test Program, centralized certification office, a FAA review board, and a PAFI Steering Group (PSG) (refer to Figure 6.0). The FAA test program will test candidate fuels at the FAA William J. Hughes Technical Center (FAA Tech Center) to generate data that can then be used by the fuel developer to support ASTM specification development and FAA certification. The PSG will facilitate, coordinate, expedite, promote, and oversee the PAFI process that is identified throughout this report. The PSG will consist of an Executive Director and a coalition of industry associations and government representatives who will engage subject matter experts (SMEs) as necessary (refer to Figure 7.0). The PSG will provide input to candidate fuel developers to facilitate the process to result in an unleaded fuel that would have the least impact to the existing fleet and distribution system.

A secondary objective of PAFI will be to support the testing and approval of key aircraft/engine modifications that would have a significant impact on compatibility of the existing fleet with new unleaded AVGAS.

The following roles, responsibilities, resources, funding, and scheduling requirements are designed to support these objectives. In addition, a description of the integration of PAFI with the FAA fuel testing program and with the prospective AVGAS developers who participate in that program is also provided.

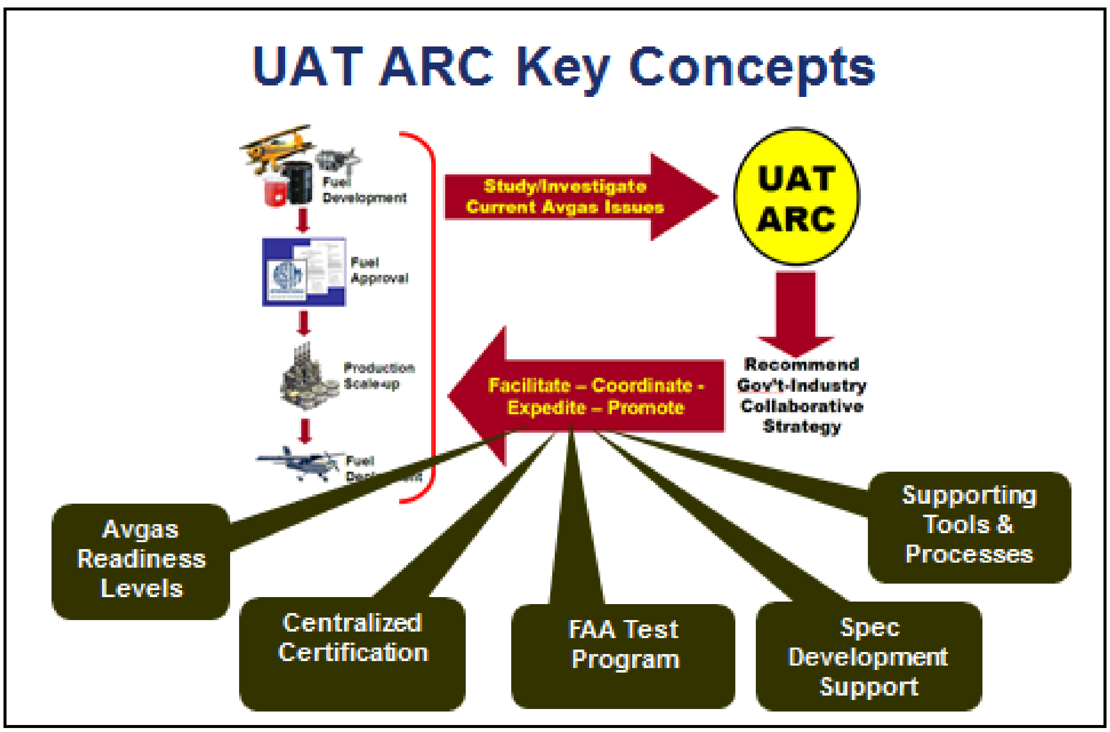


Figure 6.0 – UAT ARC Key Concepts

5.1. PAFI Organization

It is recommended that PAFI be organized as an industry-FAA coalition; similar to the structure of the existing FAA sponsored Commercial Aviation Alternative Fuels Initiative (CAAFI); see Appendix D for a description of CAAFI. It is also recommended that the FAA fund and provide administrative support for a PAFI Director, and fund other consultants as required. This administrative support would include the establishment and maintenance of a web site for the PAFI organization. The membership of PAFI would be comprised of stakeholders from the General Aviation community including aviation trade and other directly involved industry trade and membership associations, and the FAA as illustrated in the following Figure 7.0. The members would be expected to provide in-kind support to perform the tasks necessary for PAFI to perform its role as described in this report. Members would allocate resources to support unique PAFI tasks, such as the generation of job aids and to support industry tasks related to development and approval of unleaded AVGAS, such as ASTM Task Forces.

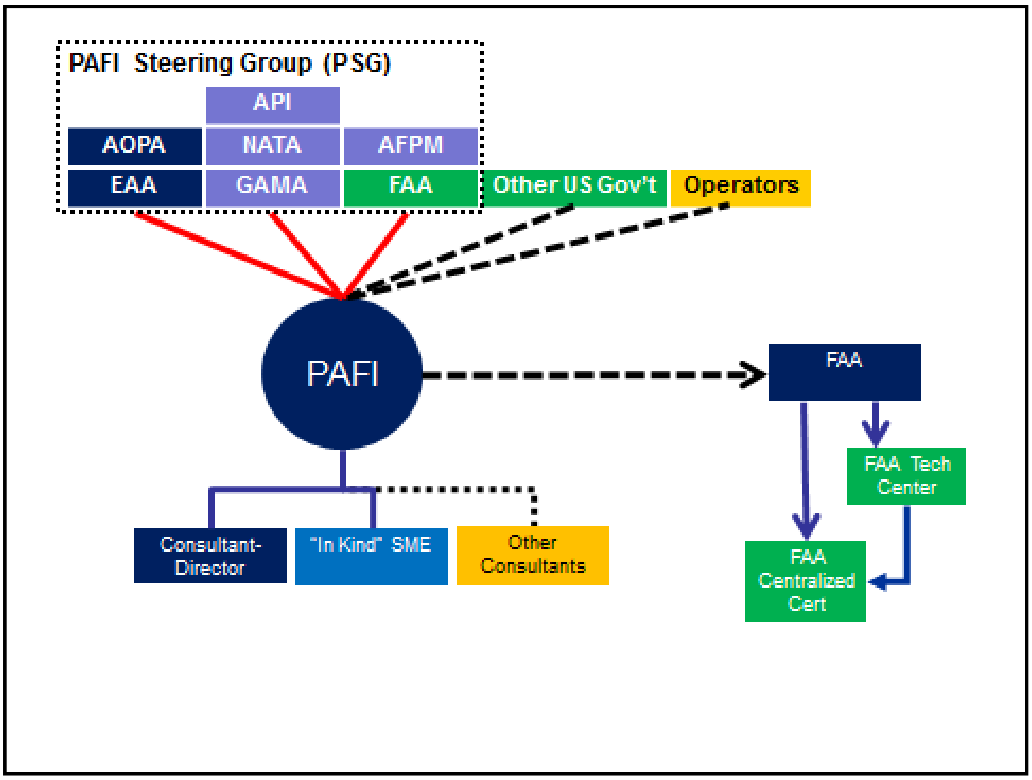


Figure 7.0 – PAFI Organization

5.2. The PAFI Process

5.2.1. PAFI Fuel Development Stages

The PAFI roles, responsibilities, resources, funding and schedule requirements are presented for three distinct stages which are structured to facilitate the integration with FAA fuel testing program and the AVGAS development process (see Figure 8.0).

Preparatory Stage

This stage precedes the start of the FAA fuel testing program and associated testing of candidate fuels. Job Aids will be developed during this stage by PAFI to support the subsequent stages. These job aids will include technical, logistical, economic and other AVGAS-related industry information that are necessary for the FAA Tech Center to conduct testing in support of the FAA fuel testing program. These job aids will also provide reference information for prospective fuel producers, potential investors, and government agencies that may play a future role in the commercialization of unleaded AVGAS. It is recommended that the FAA establish an aviation fuel centralized certification office during this stage.

Project Stage

The FAA will issue a solicitation for prospective unleaded AVGAS producers to submit fuel for testing for the FAA fuel testing program during this stage. The FAA will select a limited number of the most promising fuels for testing at the FAA Technical Center. The data generated from this testing will support the concurrent ASTM specification development and FAA certification activity during this stage. As appropriate, PAFI members may also advocate for and promote both private and government financing opportunities to support this initiative.

Deployment Stage

This stage commences upon the completion of fuel testing, specification development, and FAA certification activities. PAFI provides expert support to facilitate the production, distribution, and initiation of fleet-wide operations of the new unleaded aviation gasolines.

A more detailed overview of the PAFI activities in each of these stages is provided in Section 5.7 PAFI & FAA Work Scope.

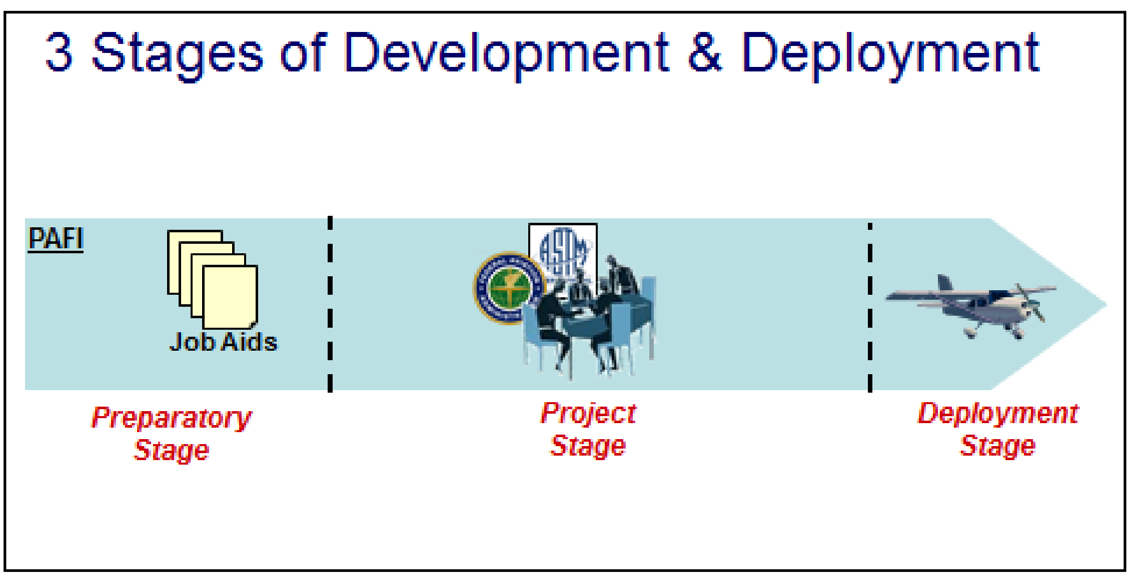


Figure 8.0 - PAFI Fuel Development & Deployment Stages

5.2.2. FAA Integration

During the Preparatory Stage, the PSG will facilitate the development of job aids that the FAA will use to support screening and testing of candidate fuels. The FAA will use the job aids to develop "Request for Proposals" (RFPs) to solicit new fuels to undergo testing at the FAA Tech Center. This FAA Test Program will generate data that can be used by the applicant to support fuel approval. The FAA will establish an FAA Review Board that will use the job aids to screen candidate fuels for admittance to the FAA Test Program (see Section 5.2.5). The FAA Review Board will require the technical expertise necessary to evaluate fuel property and composition data to determine the feasibility of the candidate fuel. In addition, the FAA will establish a centralized certification office (see Section 5.2.4). During the Project Stage, the fuel testing program will be conducted at the FAA Tech Center. See Figure 9.0.

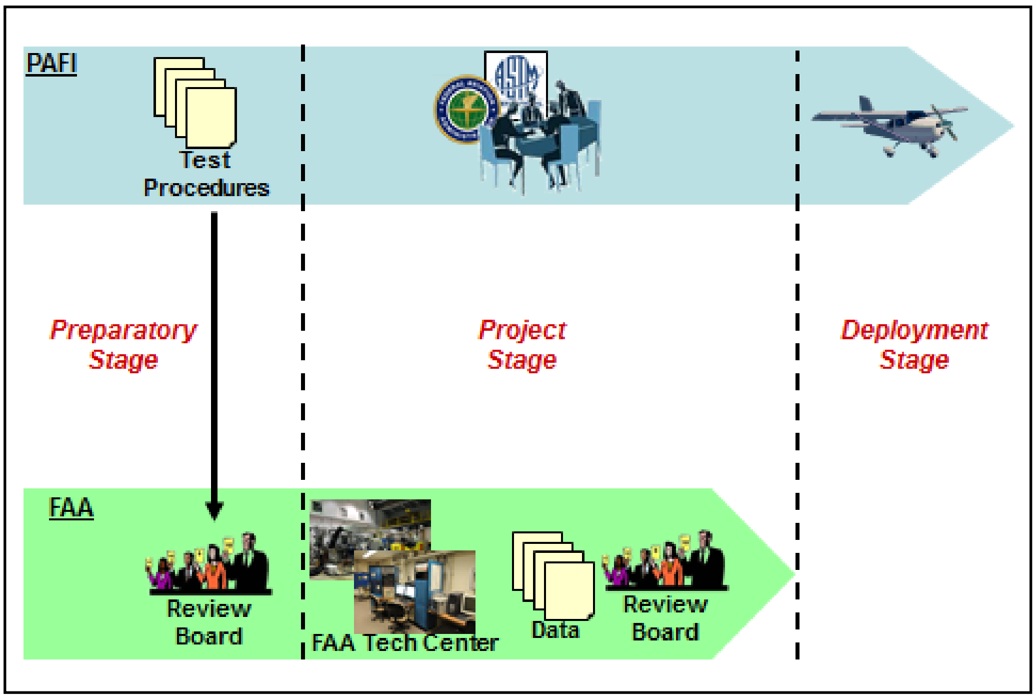


Figure 9.0 - FAA Integration

5.2.3. Fuel Developer Integration

Both the PSG and the FAA will be working closely with the prospective fuel developers during the Project and Deployment Stages. The fuel developers will need to provide test fuel to the FAA Test Center for conduct of the testing. The data generated during the testing at the FAA Tech Center will be used by the fuel developer to support specification development and FAA certification. The fuel developer will progress through the AVGAS Readiness Levels (ARLs) during the development and deployment of the fuel. The PSG will support the fuel developer during the project and deployment stages to facilitate the specification issuance, certification approvals, and distribution and deployment of the approved fuel. See Figure 10.0.

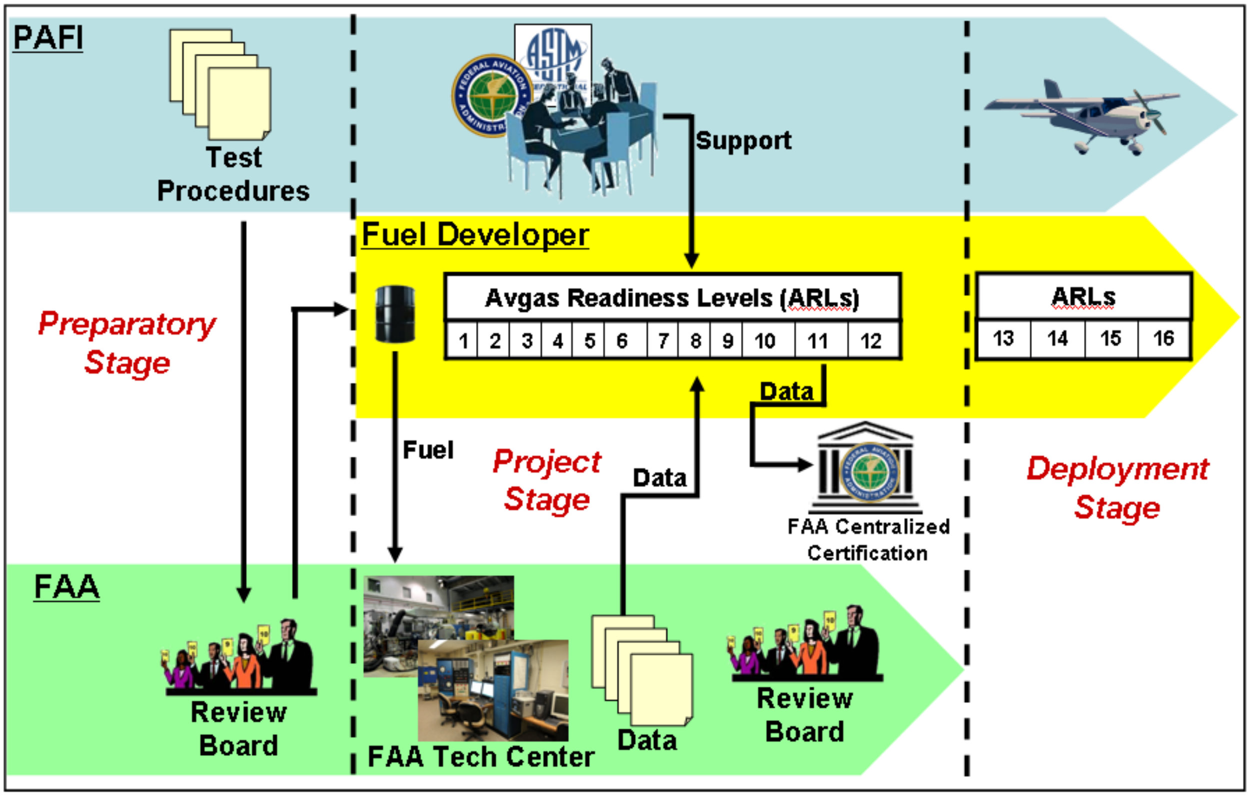


Figure 10.0 - PAFI & FAA fuel testing program Integration with Fuel Developer

5.2.4. FAA Centralized Certification

In accordance with the UAT ARC recommendations, the FAA will establish a centralized certification office for aviation fuel projects. The PSG will coordinate with the centralized certification office and with the FAA Tech Center to develop test procedures and conformity and test witnessing protocols that are acceptable for certification. The data generated during the FAA fuel testing program by the FAA Tech Center is provided to the candidate fuel developer. The fuel developer can then submit this data to the FAA Centralized Certification office as certification data. The applicability or scope of certification will be based on the test results and will be reflected in the application to the centralized FAA certification office. See Figure 10.0.

5.2.5. FAA Testing Program Overview

The FAA fuel testing program will occur during the Project Stage of the PAFI fuel development process (see Figure 10.0). The program will be managed by the FAA and will offer the incentive of government funding and industry in-kind contribution to test the fuel at the FAA Tech Center. The program consists of a screening phase that the fuel candidate conducts to measure key fuel properties. The fuel developer will then provide the fuel property data when responding to the FAA RFP. If selected by the FAA Review Board, the fuel developer will then be required to provide specified quantities of fuel that will be subjected to Phase 1 testing under the FAA test program. The FAA Review Board will then select a limited number of candidate fuels to continue on to Phase 2 testing upon receipt of an additional specified quantity of fuel from the fuel developer (see Figure 11.0).

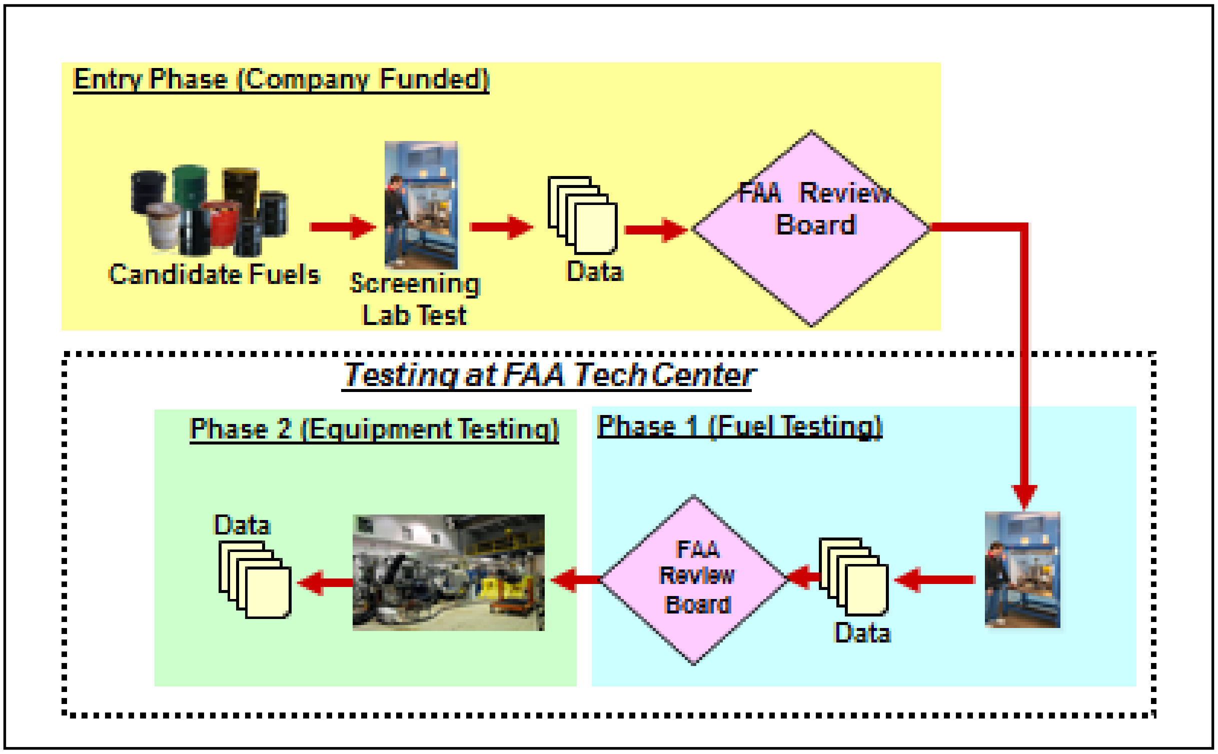


Figure 11.0 - FAA Fuel Testing Program

The FAA Testing Program is described separately; the following is a short overview of the anticipated structure of the program.

Entry Phase

The fuel developer will send on the order of 10 gallons (final quantity TBD) of the candidate fuel to a laboratory designated by the FAA during the evaluation period defined in the RFP. The lab will perform initial testing to measure fuel properties. The fuel developer will submit the data to the FAA Review Board for review. The best performing fuels will be admitted to Phase 1 of the program.

Phase 1

If the fuel passes the screening phase, the fuel developer will send on the order of 100 gallons (final quantity TBD) of the candidate fuel to the FAA Tech Center for expanded fuel properties testing. The test data will be submitted to the FAA Review Board for review. The best performing fuels will be admitted to Phase 2 of the program.

Phase 2

The fuel developers of the candidate fuels selected after Phase 1 testing will send on the order of 10,000 gallons of the candidate fuel (final quantity TBD) to the FAA Tech Center for engine and aircraft testing. The final test data will be provided to the fuel producer to support ASTM specification development and FAA certification. A final report or appropriate information will be provided to the PSG with an assessment of the scope of the transparent fleet to aid the fuel developer and FAA centralized certification office to facilitate subsequent ASTM and certification approval.

This recommended program includes both the conduct of testing and the provision of data that can be used to support development of ASTM International fuel specifications and for FAA certification (see Figure 12.0). Availability of test data to persons other than the fuel developer when using public funds needs to be further evaluated and addressed by the PSG. The PSG will coordinate with the FAA Fuel Testing Program, the FAA Tech Center, and PSG member companies to facilitate the ASTM specification development process. PSG will also coordinate with the FAA Tech Center and the FAA centralized certification office to facilitate the FAA certification process.

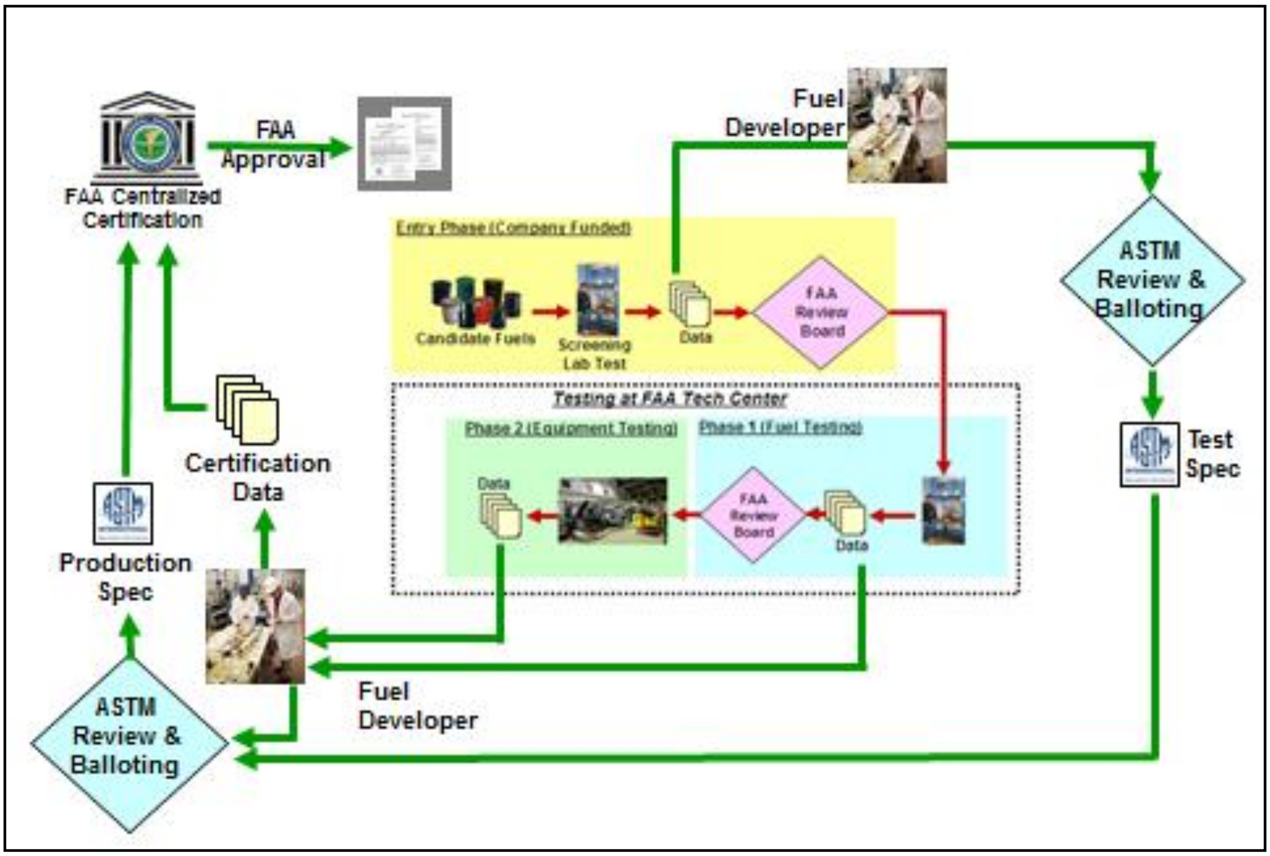


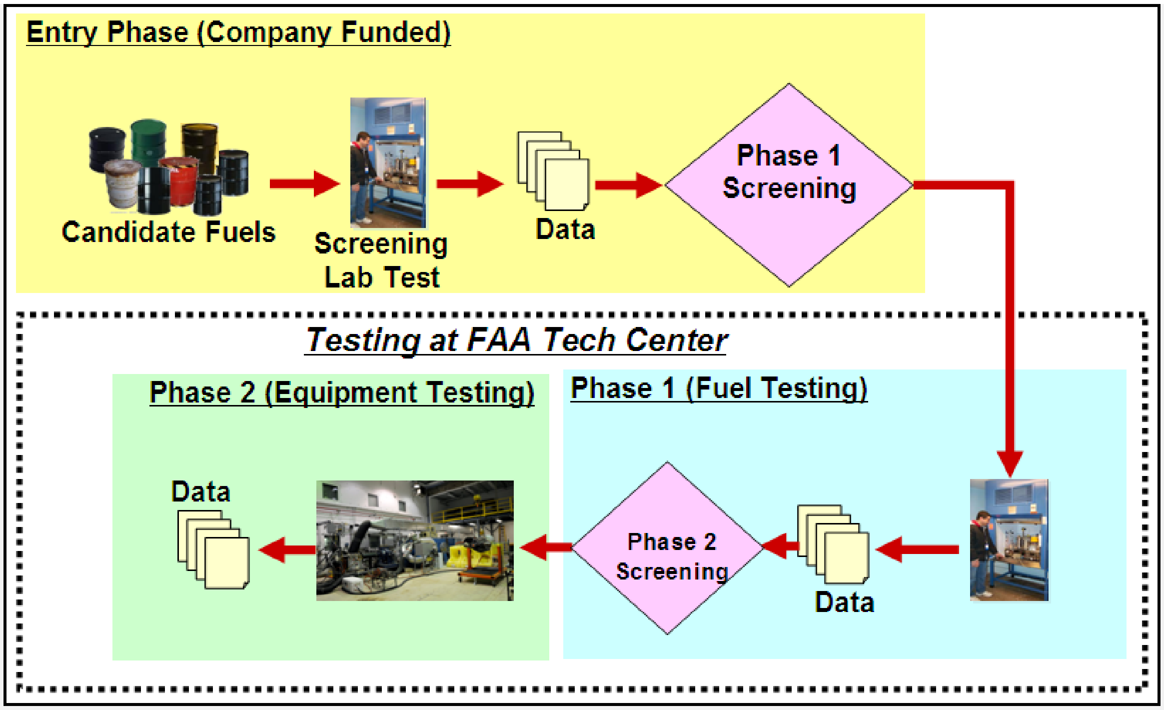
Figure 12.0 - Integration of FAA Fuel Testing Program with ASTM and FAA

5.2.6. FAA Technical Center Support

The FAA Tech Center has established itself as the leading expert for testing of candidate aviation gasolines. The FAA fuel testing program will utilize the FAA Tech Center to perform fuel property testing in Phase 1 and equipment (engine and aircraft) testing in Phase 2 of the program. All the candidate fuels will be tested in the same manner using the same equipment, instrumentation and test facilities. This will allow for accurate comparisons of the results, and also for standardized data to be used in the ASTM specification development process and in the FAA certification process. This will provide for a more efficient and expeditious overall approval process.

5.2.7. AVGAS Readiness Levels (ARLs)

The UAT ARC applied the CAAFI concept of jet “FRLs” to the unique needs of AVGAS development. The ARLs are designed to reflect the fuel developer’s progression through the FAA fuel testing program, ASTM specification development, FAA certification, and deployment as shown in Figure 10.0. The ARLs will be used to develop the screening criteria to be used by the FAA Review Board to select fuels for each of the respective phases of the FAA Test Program. The ARLs are color coded in Figure 13.0 to identify where they apply during the project stage and deployment stage (ARLs are not applicable to the preparatory stage). Within the project section, they are further divided into screening phase, Phase 1 and Phase 2, to correlate with the FAA fuel testing program concept shown in Figure 11.0. Figure 14.0 provides a detailed description of the ARLs developed by the UAT ARC.



ARL Color Legend :

- Project Stage: Screening Phase
- Project Stage: Phase 2 Equipment Testing
- Project Stage: Phase 1 Fuel Property Testing
- Deployment Stage

Figure 13.0 – ARL Color Coding

Figure 14.0
AVGAS Readiness Levels

ARL	Title	Description	Deliverable (Informational / Data / Regulatory)	Fuel Qty Guidance
1	Fuel Definition	Utilize data developed during experimentation phase to establish process elements and parameters (such as reactor hardware and catalyst materials) and fuel compositional definition by GC analysis.	Fuel sample and report including process flow diagram and fuel compositional analysis	4 Liters
2	Material Safety Review	Initial review of candidate fuel composition relative to published guidance on material safety with respect to environmental and safe handling considerations. Develop material safety data sheet (MSDS).	MSDS and other data as needed	
3	Basic Fuel Properties and Composition Iterative process	Intended to support initial engagement with ASTM to form Task Force. Lab analysis of fuel sample to identify composition and measure key Fit-For-Purpose properties per test methods defined in ASTM International Standard Practice , "Standard Practice for the Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives": ▪ Motor Octane Number (detonation) ▪ Vapor Pressure (starting, vapor lock) ▪ Freezing Point (high-altitude operation) ▪ Corrosion, copper strip (metal fuel system components) ▪ Oxidation stability (gumming) ▪ Water reaction (hygroscopic effect) ▪ Electrical conductivity (fuel handling) ▪ Distillation curve ▪ Initial material compatibility testing	Independent lab analysis report(s), report how the fuel was produced (blending purchased components, lab scale production, etc.)	20 to 50 Liters Minimum
4	Preliminary ASTM Research Report	Compile data derived from laboratory analysis of candidate fuel in accordance with Section 6.2 of ASTM International Standard Practice, "Standard Practice for the Evaluation of New	Preliminary ASTM Research Report	200 – 400 liters minimum

		Aviation Gasolines and New Aviation Gasoline Additives". This data will include: ▪ Basic Specification properties ▪ Compositional analysis ▪ Preliminary Fit-For-Purpose (FFP) Properties ▪ Preliminary Materials Compatibility Assessment ▪ Information from preceding ARLs		
5	ASTM Test Specification	ASTM Test Specification defines the properties of the fuel for subsequent testing and analysis.	Issued ASTM Test Specification	
6	Preliminary Feasibility Assessment	Prepare the following reports to assess the potential viability of the candidate fuel concurrent with the previous ARLs 1-5.		
6.1	Preliminary Production and Distribution Assessment	Analyze current AVGAS production and distribution infrastructure to identify gaps in current system and develop preliminary plan to address gaps and to scale-up production and distribution to commercially viable volumes.	Report	
6.2	Environmental & Toxicology Assessment	Review candidate fuel composition with consideration to use and handling from an environmental perspective, including OSHA, EPA and other regulatory entities.	Report with compositional data, MSDS, environment and toxicology assessment, and other relevant environmental data.	
6.3	Preliminary Business Plan	Provide a business plan that addresses the following: a) Scope of Solution: Describe the fuel, engine/aircraft hardware and operational concept proposed. If hardware or operational changes are proposed summarize and characterize in accordance to CFRs as minor, major or model changes. b) Production Concept: Describe how the candidate fuel composition can be scaled up and commercialized. Include summary of fuel production process flow and related hardware c) Applicability: Define fleet	Report	

		satisfaction concept relative to either actual aircraft cross section as defined in the FAA Aviation Fuels Reciprocating Engine Aircraft Fleet Fuel Distribution Report or BMEP/detonation propensity as defined by TBD document. d) Cost: Describe market cost of proposed solution inclusive of recurring cost/volume and non-recurring associated with hardware or operational limitation changes. e) Implementation: Describe defined or to-be-defined strategic partnerships, financing strategies, infrastructure leveraging opportunities, distribution strategies and other relevant details facilitating path to market. f) Deployment Concept: Describe whether the proposed fuel is miscible and fungible with 100LL. Does the solution require a separate distribution and control system? g) Intellectual Property: Declare IP associated with the Scope of Solution and how stated IP is protected or public domain considerations.		
7	Initial Pilot Production Capability	Scale-up lab production capability, and define production process flow and hardware for novel production capability requirements.	Fuel sample produced by the defined process	400 liters minimum, or as needed to support ARL 8
8	Final ASTM Research Report			
8.1	Final ASTM Research Report – Part 1	Compile data derived from laboratory analysis and of candidate fuel in accordance with Section 6.3 of ASTM International Standard Practice, “Standard Practice for the Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives”. This data will include: ▪ Final Fit-For-Purpose (FFP) Properties	Report	

		▪ Final Materials Compatibility Assessment		
8.2	Final ASTM Research Report – Part 2	Compile data derived from equipment testing of candidate fuel in accordance with Section 6.3 of ASTM International Standard Practice, "Standard Practice for the Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives". This data will include: ▪ Engine Testing ▪ Aircraft Testing	Final ASTM Research Report	
9	ASTM Production Specification	ASTM Production Specification defines the properties of the fuel and other criteria necessary for high-volume production and distribution.	Issued ASTM Production Specification	
10	Pilot Production Capability	Scale-up initial pilot production capability, using the production process flow from the initial pilot production capability requirements (ref: ARL 7). Demonstrate the ability to produce at least 10,000 gals/yr (40,000 liters/yr).	Production Process Demonstration	10,000 gals (40,000 liters) minimum, or as needed to support ARL 11
11	Airworthiness Certification			
11.1	Engine Certification Testing	Completion of all rig, component and engine certification tests in accordance with compliance program established by the cognizant airworthiness regulatory authority.	Certification Test Reports	
11.2	Engine Certification	Obtain certification approval from cognizant airworthiness regulatory authority.	Issued Amended or Supplemental Type Certificate(s)	
11.3	Aircraft Certification Testing	Completion of all ground and flight testing in accordance with compliance program established by the cognizant airworthiness regulatory authority.	Certification Test Reports	
11.4	Aircraft Certification	Obtain certification approval from cognizant airworthiness regulatory authority.	Issued Amended or Supplemental Type Certificate(s)	
12	Final Feasibility Assessment	Prepare the following reports to assess the potential viability of the candidate fuel concurrent with the previous ARLs 7-11.		
12.1	Final Production and Distribution Assessment	Update preliminary report based on data and information developed during the fuel development.	Report	

12.2	Final Environmental & Toxicology Assessment	Update preliminary report based on data and information developed during the fuel development. This may include testing for baseline emission data.	Report and MSDS	
12.3	Final Business Plan	Update preliminary report based on data and information developed during the fuel development.	Report	
13	Initial Production Capability	Scale-up pilot production capability, using the production process flow from the pilot production capability requirements for the large-scale (ref: ARL 10). . Establish production capability to produce at least 100,000 gals/yr (400,000 liters/yr).	Fuel inventory	
14	Initial Limited-Scale Fleet Operations	Introduce fuel on a regional basis to gain experience with commercial operations.	Coordinated plan with fuel distributors and fleet operators to demonstrate operational use of fuel	
15	Production Scale-up	Construct facilities to produce at least 10,000,000 gals/yr (40,000,000 liters/yr).	Fuel inventory	
16	Wide-Scale Fleet Operations	Fuel availability and usage over several geographic regions.	Coordinated plan to transition production, distribution, and use on a regional basis	

5.3. Aircraft/Engine Modification Testing and Approval

The UAT ARC recognizes that unleaded aviation gasolines that complete the above described PAFI process will most likely not meet the performance demands of, or not be compatible with the entire fleet of existing piston-powered aircraft. Therefore, this implementation plan includes tasks to support the testing at the FAA Tech Center and approval of aircraft and/or engine modifications that will allow a portion of the non-transparent fleet to operate with a new unleaded AVGAS. This recommendation will include the following key elements (see Figure 15.0).

- The FAA will maintain the FAA Review Board to review proposed aircraft/engine modifications.
- Prospective aircraft/engine modifiers will submit proposed modifications to the FAA Review Board.

- The FAA Review Board will select those modifications that will enable the greatest number of aircraft in the non-transparent fleet to operate safely with a new unleaded AVGAS.
- Once selected, the modifier will provide the modification hardware to the FAA Tech Center.
- The FAA Tech Center will test the hardware to test plans developed with the FAA Centralized Certification Office
- The test data will be provided to the modifier who will then work with the FAA Centralized Certification Office to approve the modification.
- A final report or appropriate information will be provided to PSG with an assessment of the applicability of the proposed modification to aid the fuel developer and FAA centralized certification office to facilitate subsequent certification approval.

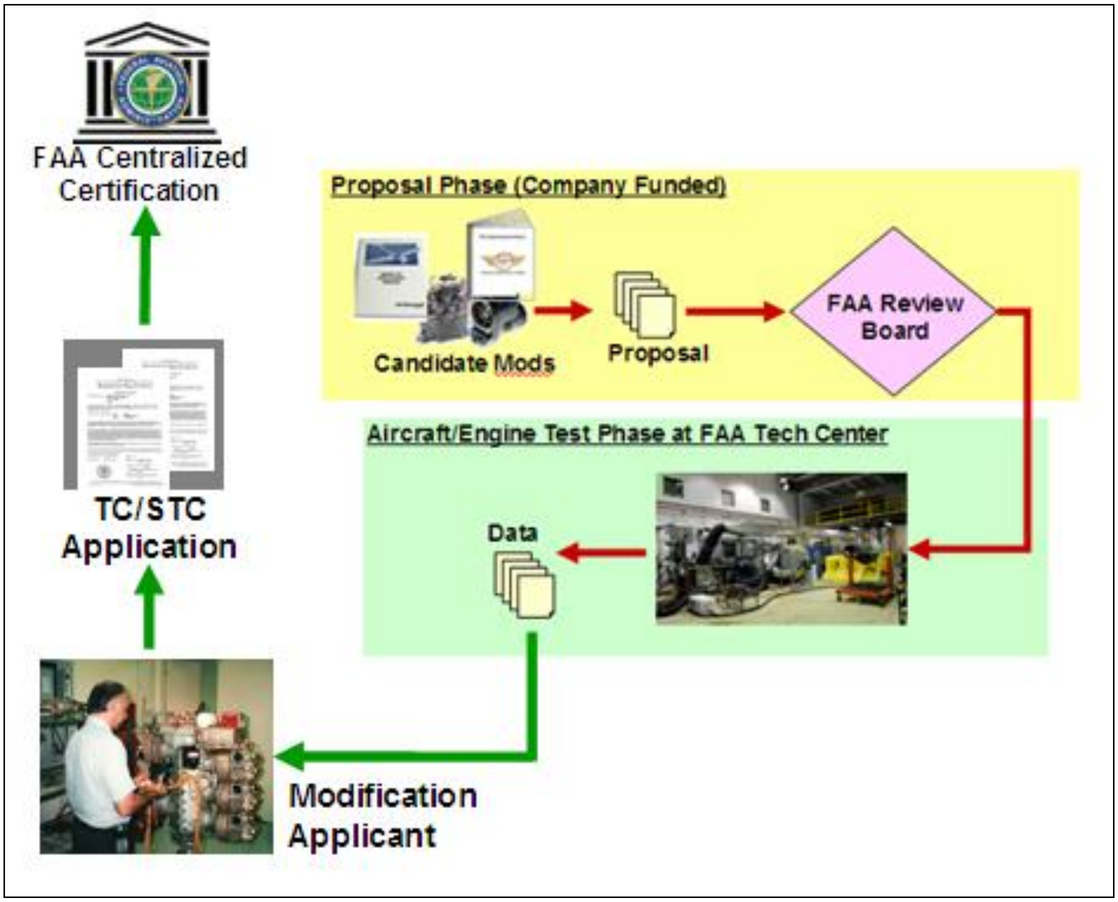


Figure 15.0 - PAFI Aircraft/Engine Modification Concept

5.4. PAFI Management

The PSG is envisioned to be a coalition, rather than a formalized legal entity. The FAA fuel testing program will perform the selection and testing of the candidate fuels separately from the PSG. The role of the PSG will be limited to providing supporting data, and coordinating the activities of member organizations to provide the necessary project and deployment support.

The recommended organization for PAFI is modeled after CAAFI. Like CAAFI, it is proposed that the FAA fund a full-time consultant to act as the PAFI Director, other consultants as required, and that the FAA provide administrative support for the Director. In addition, like CAAFI, it is recommended that the FAA fund the construction, maintenance, and updating of a web site for the PAFI organization. It is expected that both the PAFI Director and PAFI members will need to participate in dedicated PAFI meetings and perform other tasks unique to the PAFI organization.

PAFI management is projected as being an on-going program management function throughout the Preparatory, Project, and Deployment stages. The PAFI Executive Director, reporting to the FAA and the PSG, will act as the program manager monitoring, directing, and coordinating overall PAFI activities and interfaces with industry, government, and candidate fuel developers. The PAFI Executive Director will represent PAFI at industry meetings and will interface with government agencies, PAFI members, and other external organizations as directed by the PSG. The PAFI Executive Director will act as a champion and advocate for the PAFI program. PAFI management tasks and associated work scope are illustrated in Figure 16.0.

A cost estimate for the PAFI management-function and associated overhead is provided in Figure 17.0. Included in the cost estimate are subcontract costs for the director, administrative support, travel, PAFI website maintenance, and other direct costs (ODC). Other direct costs provides for miscellaneous costs such as expenses and small service subcontracts. This cost estimate is presented as an annual cost that covers PAFI management and overhead tasks such as Program Management, Advocacy, PAFI Meetings, and Communications. It is envisioned that the PAFI Executive Director will report to the FAA and the PSG of which the FAA is a member.

Note that Figure 17.0 does not included cost of specific subcontracts to SME and other specialists as required to support the specific FAA-PAFI tasking and work scope of Section 5.7; these subcontract costs are included in the total program cost estimates of Figure 18.0. It is anticipated that Industry will provide SME as in-kind-resources similar to commitments currently made to ASTM, Coordinating Research Council (CRC) and other standardization bodies.

Figure 16.0
PAFI Leadership & Management
Tasks & Work Scope

Task No.	Task	Work Scope	Cost Estimate	Schedule
PREPARATORY, PROJECT, & DEPLOYMENT STAGES				
O&C-1	Program Management	Active on-going program management: Monitoring, directing, and coordination of PAFI activities and interfaces with industry, government, and fuel developers. Reports directly to the PSG.	See Figure 17.0	On-going
O&C-2	Advocacy	Represent PAFI at industry meetings, interface with government agencies and offices.	See Figure 17.0	On-going
O&C-3	PAFI Meetings	Plan, organize, coordinate, and convene PAFI meetings. Issue meeting reports.	See Figure 17.0	On-going
O&C-4	Communications	Provide communications regarding status and progress to users and General Aviation industry. Provide reports at industry meetings. Provide and coordinate input to PAFI website.	See Figure 17.0	On-going

Figure 17.0
PAFI Management & Overhead
Estimated Cost

Year	Director Labor	Admin Support	Travel	Web Site	ODC	FAA Cost	Industry Cost	Total FAA + Industry
1	$150K	$26K	$21K	$10K	$2K	$209K	$360K	$569K
2	$150K	$26K	$21K	$2K	$2K	$201K	$360K	$561K
3	$150K	$26K	$21K	$2K	$2K	$201K	$360K	$561K
4	$150K	$26K	$21K	$2K	$2K	$201K	$360K	$561K
5	$150K	$26K	$21K	$2K	$2K	$201K	$360K	$561K
6	$150K	$26K	$21K	$2K	$2K	$201K	$360K	$561K
7	$150K	$26K	$21K	$2K	$2K	$201K	$360K	$561K
8	$75K	$13K	$10K	$2K	$1K	$101K	$180K	$281K
9	$75K	$13K	$10K	$2K	$1K	$101K	$180K	$281K
10	$75K	$13K	$10K	$2K	$1K	$101K	$180K	$281K
11	$75K	$13K	$10K	$2K	$1K	$101K	$180K	$281K
					Totals	$1.82M	$3.24M	$5.06M

Notes:
1) The above represents management and overhead cost only and does not include subcontracts to SME and other external specialists.
2) Industry in-kind estimate based upon assumption of 8 PSG members + 4 SME

5.5. PAFI Program Estimated Cost

The following Figure 18.0 identifies estimated program cost for the total FAA-PAFI program as proposed within the context of the recommendations presented within this report. For planning purposes, the cost estimate is based upon the assumption of 11 years of funding (subject to change). It is not possible at this point to project funding beyond 11 years. The estimated cost is segregated into categories of FAA, PAFI, and industry in-kind participation.

Figure 18.0
Estimated Total Cost
Cumulative FAA-PAFI Work Scope

		Estimated Cost				
		FAA Direct Funding	**FAA Funding of PAFI**	**FAA Total**	**Industry In-Kind Support**	**Total Funding**
PAFI PREPARATORY – PROJECT – DEPLOYMENT STAGES						
1	Certification & Qualification (C&Q)	$3.85M	$0	$3.85M	$236K	$4.09M
2	Test & Evaluation (T&E)	$51.22M	$0	$51.22M	$9.65M	$60.9M
3	Production & Distribution (P&D)	$0	$8K	$8K	$182K	$0.19M
4	Impact & Economics (I&E)	$0	$300K	$300K	$210K	$0.51M
5	Environment & Toxicology (E&T)	$300K	$0	$300K	$0	$0.30M
6	PAFI Management & Overhead (O&C)	$0	$1.82M	$1.82M	$3.24M	$5.06M
	Total Funding	$55.37M	$2.13M	$57.5M	$13.52M	**$71M**

Notes:
1. See Figure 17.0 for PAFI Management & Overhead Annual Cost Estimate
2. See Figures 19.0 & 19.1 for FAA Direct Funding of PAFI Annual Cost Estimate

> ***Caution*** *– the industry in-kind participation represents support furnished to the FAA Test & Evaluation Program and does not include industry non-recurring engineering costs. An estimate of industry DAH non-recurring engineering costs is included in Appendix M.*

5.5.1. Industry In-Kind Participation

Industry in-kind participation does not reflect the total cost to transition to new fuel(s). The total PAFI Estimated Cost of $71 million dollars as shown in Figure 18.0 reflects only the direct industry in-kind support of $13.5 million that will be provided to PAFI during the Preparatory and Project stages. It does not reflect, nor does this report attempt to estimate, the actual cost and in-kind support that industry will bear during basic research conducted by fuel sponsors prior to entering the PAFI process or transition of the fleet to a new fuel during the Deployment Stage. The Deployment Stage represents the potential for the largest impact to all segments of the industry and is the most difficult to estimate without knowing the properties and composition of the fuel. The impact and cost to the industry of the Deployment Stage can only be determined and estimated as the impact of the potential candidate fuels becomes apparent. Fuels necessitating significant changes to production, distribution, aircraft operations, or that require aircraft modifications will result in additional costs to segments of the industry. These impacts cannot be quantified or shown at this time and are not reflected in the industry in-kind support. However, consideration must be given to these significant economic impacts, when contemplating contributions of the stakeholders in this effort. The collaborative effort presented in this report relies on the FAA funding of a significant portion of the upfront cost of the PAFI program as reflected in this report, but also on the potentially much larger costs that industry will incur to transition the existing fleet and future production aircraft and engines to a new fuel or fuels.

5.5.2. Industry Deployment Stage Costs Not Reflected in In-Kind Support

Examples of potential industry costs which may be encountered during the Deployment Stage but are not reflected in the industry in-kind support cost estimate include the following.

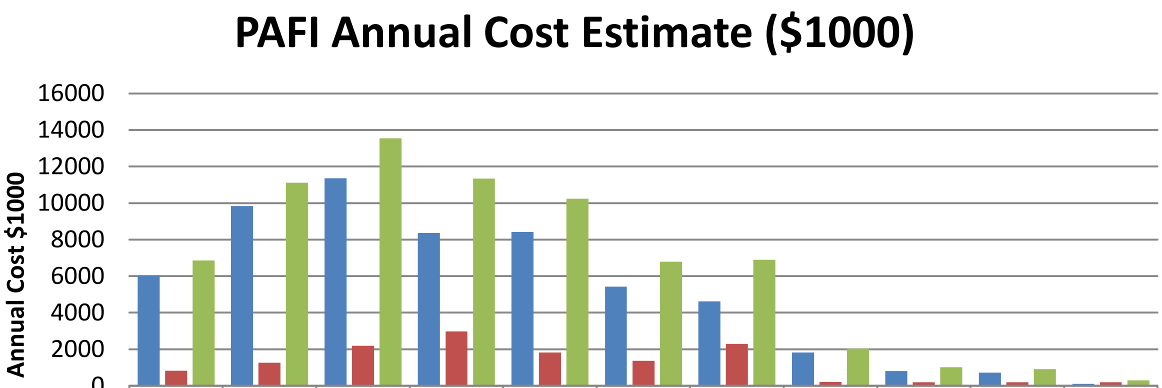
Production and Distribution – It is anticipated that new unleaded fuels will require some change to the production and distribution systems currently used for avgas. These changes are likely to include physical infrastructure changes to accommodate new fuels, including the need for new production facilities and changes to distribution infrastructure materials to accommodate new chemicals. Facilities that produce, transport, store and dispense these fuels will, at a minimum, likely need to change product labeling, educate staff on handling characteristics, and potentially make changes to dispensing equipment and practices.

Aircraft Operations - New fuels may require changes to aircraft operations. While it is the intent of the UAT ARC recommendations and subsequently PAFI to minimize these impacts, any change will have a subsequent effect on some portion of the fleet. That portion of the fleet that may see operational changes will experience an economic impact that will affect the entire industry.

Aircraft Modifications – This report recommends FAA support of some key aircraft modifications to lessen the impact of a new fuel on the non-transparent fleet. However, the incorporation of these aircraft modifications after approval will still have a significant economic impact on industry. These modifications may vary from minor changes to the aircraft operating limitations, Pilot Operating Handbook (POH), and placards to hardware modifications necessary to accommodate a new fuel. Even what may appear to be a simple modification such as placarding or a POH update will result in costs to owners and operators. Depending on the size of the non-transparent fleet, these costs may be significant when compared to the overall PAFI costs presented in this report.

5.5.3. PAFI Annual Cost Estimate

The following figures 19.0 through 19.3 identify the estimated PAFI annual funding requirements. Figure 19.1 provides a breakdown for the annual FAA funding requirements for the PAFI tasks. Similarly, Figure 19.2 provides an indication of the annual Industry In-Kind funding requirements. Figure 19.3 identifies PAFI annual subcontract cost estimates.



	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11
FAA $	6040.1	9837.8	11350	8363.5	8418	5421	4611	1820	811	711	108
Industry $	817.9	1267.3	2192.3	2974.1	1819.2	1361	2290	209	200	200	187
Total $	6858	11105	13542	11338	10237	6782	6901	2029	1011	911	295

Figure 19.0 – PAFI Annual Cost Estimate FAA & Industry In-Kind

Figure 19.1
FAA Funding Annual Cost Estimate
PAFI Tasks

Year	C&Q	T&E	P&D	I&E	E&T	PAFI Mgt & OH	PAFI Subcon	Total
1	$74.1K	$5277K	$0	$0	$300K	$209K	$180K	$6040.1K
2	$34.8K	$9572K	$0	$0	$0	$201K	$30K	$9837.8K
3	$139.5K	$11009K	$0	$0	$0	$201K	$0	$11349.5K
4	$139.5K	$7963K	$0	$0	$0	$201K	$60K	$8363.5K
5	$36K	$8178K	$0	$0	$0	$201K	$3K	$8418K
6	$12K	$5208K	$0	$0	$0	$201K	$0	$5421K
7	$395K	$4008K	$0	$0	$0	$201K	$7K	$4611K
8	$1712K	$0	$0	$0	$0	$101K	$7K	$1820K
9	$703K	$0	$0	$0	$0	$101K	$7K	$811K
10	$603K	$0	$0	$0	$0	$101K	$7K	$711K
11	$0	$0	$0	$0	$0	$101K	$7K	$108K
Totals	$3848.9K	$51215K	$0	$0	$300K	$1819K	$308K	$57490.9K

Notes:

1) The above identifies FAA annual funding requirements for each PAFI task including PAFI management and overhead. See Figures 29.9 – 39.0 for PAFI Task Descriptions and Appendices E – G for PAFI Task Cost Estimates. See Figure 19.3 for PAFI Annual Subcontract Cost Estimate.

Figure 19.2
Industry In-Kind Annual Cost Estimate
PAFI Tasks

Year	C&Q	T&E	P&D	I&E	E&T	PAFI Mgt & OH	Total
1	$57.4K	$175K	$75.5K	$150K	$0	$360K	$822.9K
2	$1.8K	$853K	$52.5K	$0	$0	$360K	$1267.3K
3	$45.3K	$1787K	$0	$0	$0	$360K	$2192.3K
4	$44.1K	$2510K	$0	$60K	$0	$360K	$2974.1K
5	$19.2K	$1425K	$15K	$0	$0	$360K	$1819.2K
6	$12K	$989K	$0	$0	$0	$360K	$1361K
7	$12K	$1910K	$8K	$0	$0	$360K	$2290K
8	$21K	$0	$8K	$0	$0	$180K	$209K
9	$12K	$0	$8K	$0	$0	$180K	$200K
10	$12K	$0	$8K	$0	$0	$180K	$200K
11	$0	$0	$7K	$0	$0	$180K	$187K
Totals	$236.8K	$9649K	$182K	$210K	$0	$3240K	$13517.8K

Notes:
1) The above identifies industry annual in-kind cost estimates for each PAFI task. See Figures 29.9 – 39.0 0 for PAFI Task Descriptions and Appendices E – G for PAFI Task Cost Estimates.
2) PAFI industry in-kind support estimate based upon 8 PSG member + 4 SME

Figure 19.3
PAFI Annual Subcontract Cost Estimate
PAFI Tasks

Year	C&Q	T&E	P&D	I&E	E&T	Total
1	$0	$0	$0	$180K	$0	$180K
2	$0	$0	$0	$30K	$0	$30K
3	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$60K	$0	$60K
5	$0	$0	$3K	$0	$0	$3K
6	$0	$0	$0	$0	$0	$0
7	$0	$0	$1K	$6K	$0	$7K
8	$0	$0	$1K	$6K	$0	$7K
9	$0	$0	$1K	$6K	$0	$7K
10	$0	$0	$1K	$6K	$0	$7K
11	$0	$0	$1K	$6K	$0	$7K
Totals	$0	$0	$8K	$300K	$0	$308K

Notes:
1) The above identifies annual cost estimates for PAFI subcontracts required to support PAFI tasks. See Figures 29.9 – 39.0 for PAFI Task Descriptions and Appendices E – G for PAFI Task Cost Estimates.

5.6. *PAFI Program Estimated Schedule*

It is recommended that PAFI begin operating by June 2012. Operations are estimated to continue for at least 11 years from the initial authorization of funding to support development and approval of candidate fuels. In addition, it is anticipated that PAFI activities will continue through the deployment phase. Master schedules for the PAFI preparatory, project, and deployment phases are shown in the following Figures 20.0 through 22.0

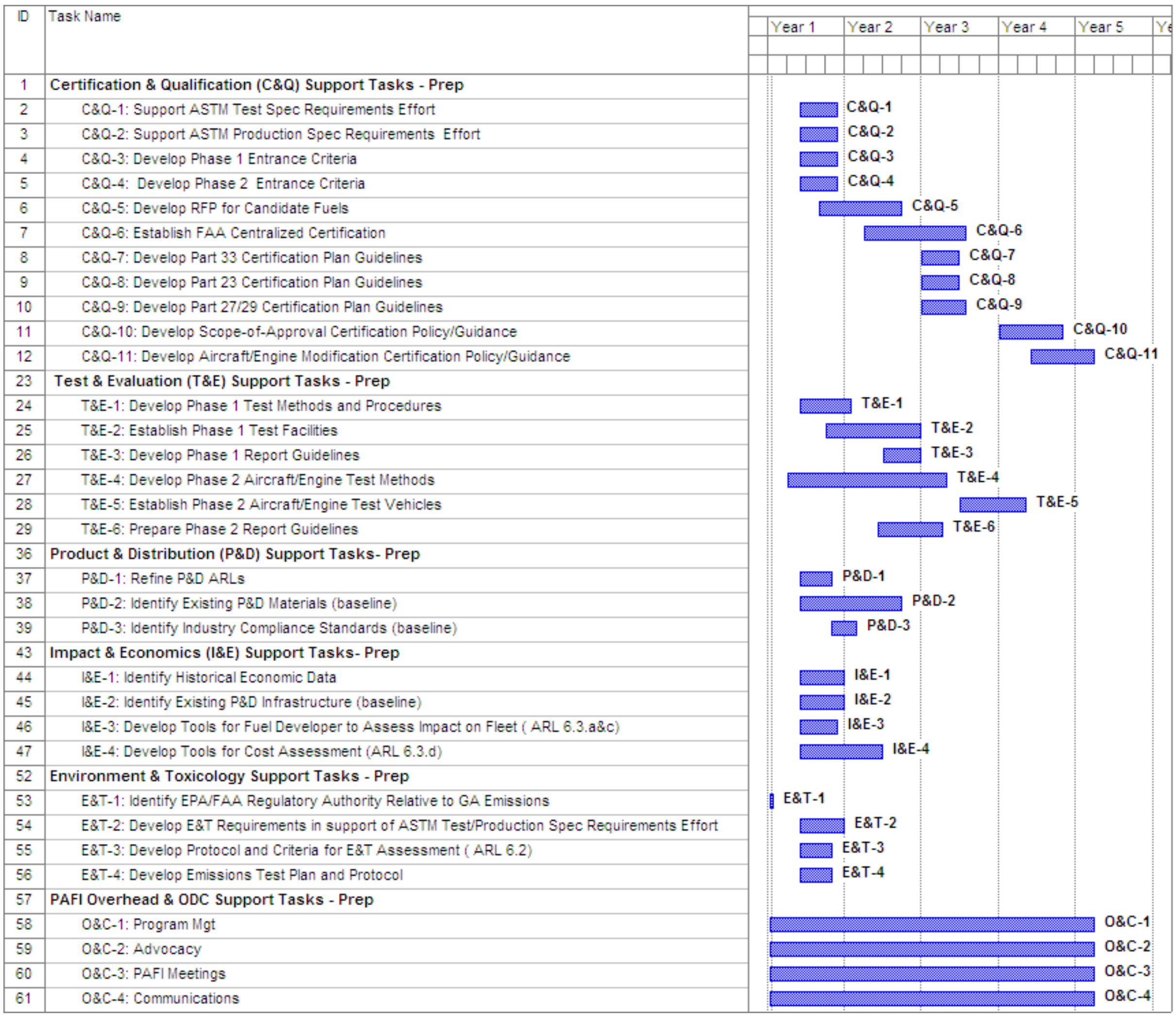


Figure 20.0 – Master Schedule PAFI Preparatory Phase

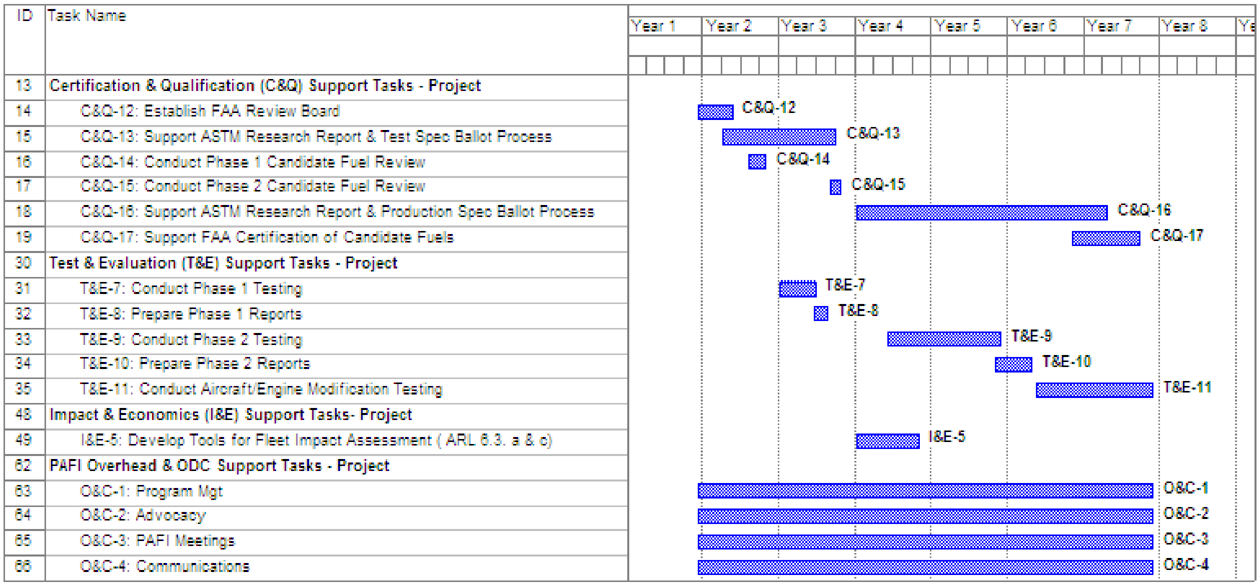


Figure 21.0 – Master Schedule PAFI Project Phase

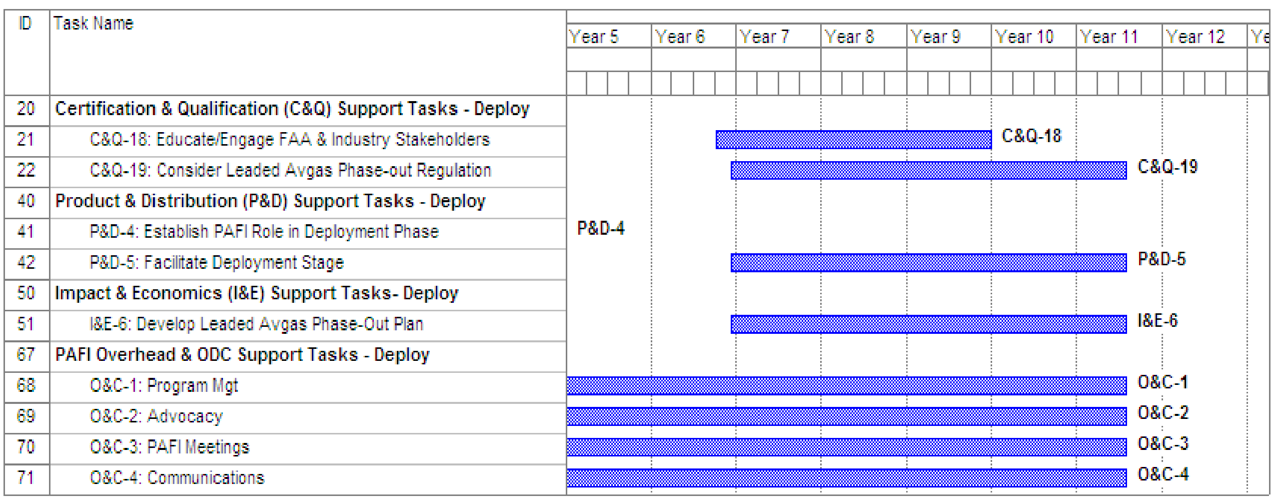


Figure 22.0 – Master Schedule PAFI Deployment Phase

5.7. PAFI and FAA Work Scope

The following describes the PAFI and FAA work scope for each of the three stages - Preparatory, Project, and Deployment. Within each stage, PAFI and the FAA will perform tasks designed to facilitate, incentivize, subsidize, and promote the approval and deployment of candidate unleaded aviation gasolines. For each stage, the UAT ARC developed work scope tasks and associated resource and schedule requirements are identified. Specific tasking is segregated into five major support functions that are illustrated in Figure 23.0.

The PAFI and FAA work scope for each of the three stages is described in the following sections 5.7.1, 5.7.2 and 5.7.3; there are a total of 45 tasks identified. The following Figures 24.0 – 28.0 identify the upper level PAFI work tasks grouped for each of the five major support functions shown in Figure 23.0. The PAFI management and leadership work scope was addressed in Section 5.4.

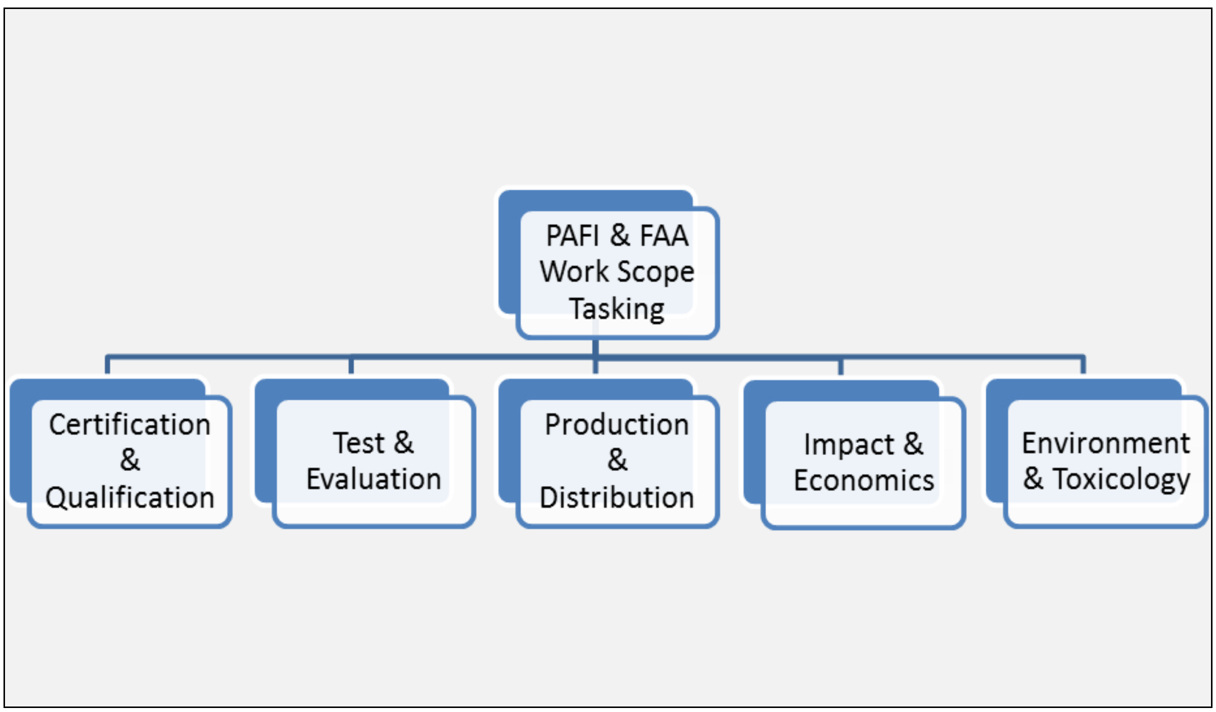


Figure 23.0 – PAFI & FAA Work Scope Tasking

PAFI Certification & Qualification Tasks

- PAFI Certification & Qualification Preparatory Stage Support
  - C&Q-1 – Support ASTM Test Spec Requirements Effort
  - C&Q-2 – Support ASTM Production Spec Requirements Effort
  - C&Q-3 – Develop Phase 1 Entrance Criteria
  - C&Q-4 – Develop Phase 2 Entrance Criteria
  - C&Q-5 – Develop RFP for Candidate Fuels
  - C&Q-6 – Establish FAA Centralized Certification
  - C&Q-7 – Develop Part 33 Certification Plan Guidelines
  - C&Q-8 – Develop Part 23 Certification Plan Guidelines
  - C&Q-9 – Develop Part 27/29 Certification Plan Guidelines
  - C&Q-10 – Develop Scope-of-Approval Certification Policy/Guidance
  - C&Q-11 – Develop Aircraft/Engine Modification Certification Policy/Guidance
- PAFI Certification & Qualification Project Stage Support
  - C&Q-12 – Establish FAA Review Board
  - C&Q-13 – Support ASTM Research Report and Test Spec Ballot Process
  - C&Q-14 – Conduct Phase 1 Candidate Fuel Review
  - C&Q-15 – Conduct Phase 2 Candidate Fuel Review
  - C&Q-16 – Support ASTM Research Report & Production Spec Ballot Process
  - C&Q-17 – Support FAA Certification of Candidate Fuels
- PAFI Certification & Qualification Deployment Stage Support
  - C&Q-18 – Educate/Engage FAA & Industry Stakeholders
  - C&Q-19 – Consider Leaded AVGAS Phase-Out Regulation

Figure 24.0 – PAFI Certification & Qualification Tasks

PAFI Test & Evaluation Tasks

- PAFI T&E Preparatory Stage Support
  - T&E-1 - Develop Phase 1 Test Methods & Procedures
  - T&E -2 - Establish Phase 1 Test Facilities
  - T&E -3 - Develop Phase 1 Report Guidelines
  - T&E -4 - Develop Phase 2 Engine/Aircraft Test Methods
  - T&E -5 - Establish Phase 2 Engine/Aircraft Test Articles
  - T&E -6 - Prepare Phase 2 Report Guidelines
- PAFI T&E Project Stage Support
  - T&E -7 - Conduct Phase 1 Testing
  - T&E -8 - Prepare Phase 1 Reports
  - T&E -9 - Conduct Phase 2 Testing
  - T&E -10 - Prepare Phase 2 Reports
  - T&E -11 – Conduct Aircraft/Engine Modification Testing

Figure 25.0 – PAFI Test & Evaluation Tasks

PAFI Production & Distribution Tasks

- PAFI P&D Preparatory Stage Support
  - P&D-1 – Refine Production & Distribution ARLs
  - P&D-2 – Identify Existing Production & Distribution Materials
  - P&D-3 – Identify Industry Compliance Standards (Baseline)
- PAFI P&D Deployment Stage Support
  - P&D-4 – Establish PAFI Role in Deployment Phase
  - P&D-5 – Facilitate Deployment Phase

Figure 26.0 – PAFI Production & Distribution Tasks

PAFI Impact & Economics Tasks

- PAFI I&E Preparatory Stage Support
  - I&E-1 – Identify Historical Economic Data (Baseline)
  - I&E-2 – Identify Existing Production & Distribution Infrastructure (Baseline)
  - I&E-3 – Develop Tools for Fuel Developer to Assess Impact on Fleet (ARL 6.3.a & c)
  - I&E-4 – Develop Tools for Cost Assessment (ARL 6.3.d)
- PAFI I&E Project Stage Support
  - I&E-5 – Develop Tools for Fleet Impact Assessment (ARL 6.3.a & c)
- PAFI I&E Deployment Stage Support
  - I&E-6 – Develop Leaded AVGAS Phase Out Plan

Figure 27.0 – PAFI Impact & Economics Tasks

PAFI Environment & Toxicology Tasks

- PAFI E&T Preparatory Stage Support
  - E&T-1 – Identify EPA/FAA Regulatory Authority Relative to GA Emissions (Completed; See Appendix I, Background on Environmental Regulations Related to AVGAS)
  - E&T-2 - Develop E&T Requirements in Support of ASTM Test/Production Spec Requirements Effort
  - E&T-3 – Develop Tools for E&T Assessment (ARL 6.2)
  - E&T-4 – Develop Emissions Test Plan and Protocol

Figure 28.0 – PAFI Environment & Toxicology Tasks

5.7.1. *Preparatory Stage Work Scope*

PAFI will develop job aids and screening criteria during this stage to support the activities in the subsequent Project and Deployment stages. The FAA will prepare for the testing and approval of candidate fuels by developing the FAA RFP and defining the concept for the FAA Centralized Certification Office. A summary of each task in the preparatory stage is provided in Figures 29.0 - 33.0. Refer to Figure 20.0 for the estimated schedule associated with each preparatory stage task. Implementation plans that include a detailed description and associated cost estimate for each preparatory stage task are provided in Appendix E.

5.7.1.1. *Certification & Qualification Prep Stage Work Scope*

Figure 29.0
PAFI Certification & Qualification
Preparatory Stage Tasks & Work Scope

Task No.	Issue/Task	Work Scope
PREPARATORY STAGE		
PREP-C&Q-1	Support ASTM Test Spec Requirements Effort	Support ASTM Task Force effort to develop Standard Practice.
PREP-C&Q-2	Support ASTM Production Spec Requirements Effort	Support ASTM Task Force effort to develop Standard Practice.
PREP-C&Q-3	Develop Phase 1 Entrance Criteria	Define criteria used to rate candidate fuel.
PREP-C&Q-4	Develop Phase 2 Entrance Criteria	Define criteria used to rate candidate fuel.
PREP-C&Q-5	Develop RFP for Candidate Fuels	FAA PAFI RFP Document specifying criteria for selection of candidate unleaded fuels for participation in the FAA Tech Center testing program.
PREP-C&Q-6	Establish FAA Centralized Certification	Define applicant & FAA responsibilities, FAA scope of support, deliverables, The UAT ARC respectfully submits the recommendations contained in this report and eagerly awaits your feedback and questions. FAA organizational support.
PREP-C&Q-7	Develop Part 33 Certification Plan Guidelines	Define applicable FARs and compliance requirements that are compatible with PAFI fuel development concept.
PREP-C&Q-8	Develop Part 23 Certification Plan Guidelines	Define applicable FARs and compliance requirements that are compatible with PAFI fuel development concept.
PREP-C&Q-9	Develop Part 27/29 Certification Plan Guidelines	Define applicable FARs and compliance requirements that are compatible with PAFI fuel development concept.
PREP-C&Q-10	Develop Scope-of-Approval Certification Policy/Guidance	Develop policy to facilitate the fleet wide approval of aircraft & engine sub-population based on non-model parameters.
PREP-C&Q-11	Develop Aircraft/Engine Modification Policy/Guidance	Develop procedures/guidance to facilitate certification of out-of-scope aircraft/engines requiring modifications.

5.7.1.2. *Test & Evaluation Program Prep Stage Work Scope*

Figure 30.0
PAFI Test & Evaluation
Preparatory Stage Tasks & Work Scope

Task No.	Issue/Task	Work Scope
PREPARATORY STAGE		
PREP-T&E-1	Develop Phase 1 Test Methods and Procedures	FAA Tech Center works with PAFI members to develop methods/procedures based on ASTM document guidance.
PREP-T&E-2	Establish Phase 1 Testing Faculties	FAA Tech Center procures necessary equipment and contracts to support Phase 1 testing.
PREP-T&E-3	Develop Phase 1 Report Guidelines	FAA Tech Center works with other PAFI members to standardize report content and format.
PREP-T&E-4	Develop Phase 2 Engine/Aircraft Test Methods	FAA Tech Center works with PAFI members to develop methods & procedures based on ASTM document guidance.
PREP-T&E-5	Establish Phase 2 Engine/Aircraft Test Articles	FAA Tech Center procures necessary equipment to support Phase 2 testing.
PREP-T&E-6	Prepare Phase 2 Report Guidelines	FAA Tech Center works with PAFI members to standardize report content and format.

5.7.1.3. *Production & Distribution Prep Stage Work Scope*

Figure 31.0
PAFI Production & Distribution
Preparatory Stage Tasks & Work Scope

Task No.	Issue/Task	Work Scope
PREPARATORY STAGE		
PREP-P&D-1	Refine Production & Distribution ARLs	Refine ARL's relating to production & distribution, including defining criteria for meeting an individual ARL step.
PREP-P&D-2	Identify Existing P&D Materials	Prepare report summarizing component materials used in existing P&D system for use by candidate fuel developer.
PREP-P&D-3	Identify Industry Compliance Standards (Baseline)	Prepare list of applicable industry compliance standards for use by candidate fuel developer (UL, AFPM, EI, etc.).

5.7.1.4. *Impact & Economics Prep Stage Work Scope*

Figure 32.0 PAFI Impact & Economics Preparatory Stage Tasks & Work Scope		
Task No.	**Issue/Task**	**Work Scope**
		PREPARATORY STAGE
PREP-I&E-1	Identify Historical Economic Data	Prepare market analysis & historical trends for AVGAS. Develop historical information regarding the industry reaction to price fluctuations. Analysis of historic price & consumption elasticity. Assess market size and future demand for unleaded AVGAS. Information will assist developers in making market assessments and in developing business plans. Data to also be used in the analysis-audit-validation tool in PREP-I&E-4.
PREP-I&E-2	Identify Existing Production & Distribution Infrastructure (Baseline)	Prepare summary of existing fuel production & distribution infrastructure. Provide fuel developer with useful data regarding existing fuel production infrastructure to help in understanding of existing capabilities when developing cost analysis. Data to also be used in the analysis-audit-validation tool in PREP-I&E- 4.
PREP-I&E-3	Develop Tools for Fuel Developer to Assess Impact on Fleet (ARL 6.3.a & c)	Develop tools and guidelines for assessment of impact of changes to fleet. Data to also be used in the analysis-audit-validation tool in PREP-I&E- 4.
PREP-I&E-4	Develop Tools for Cost Assessment (ARL 6.3.d)	Prepare an analysis-audit-validation tool to enable assessment of fuel developer's economic assumptions & factors for economic claims. Will use data generated in PREP-I&E-1 through -3.

5.7.1.5. *Environment & Toxicology Prep Stage Work Scope*

UAT ARC deliberations identified the roles of both the EPA in regulating lead emissions and the FAA in its authority to regulate fuel composition; the results of which are included in Appendix I. Consideration is being given to inclusion of environmental and toxicology requirements in ASTM International Standard Practice DXXXX, "Standard Practice for the Evaluation of New Aviation Gasolines and New Aviation Gasoline Additives".

During the preparatory stage, a consultant will review the composition of candidate fuels to assess any environmental or toxicological properties relative to current fuels in the widespread market in order to identify any potential regulatory (EPA, OSHA, etc.) concerns associated with their adoption, handling, and use. This information will then be used to develop an emissions test plan that can be implemented during engine testing at the FAA Tech Center in the Test and Evaluation Project Phase, Phase 2 (PROJ-T&E-9).

Figure 33.0 PAFI Environment & Toxicology Preparatory Stage Tasks & Work Scope		
Task No.	**Issue/Task**	**Work Scope**
	PREPARATORY STAGE	
PREP-E&T-1	Identify EPA/FAA Regulator Authority Relative to General Aviation Emissions	Document FAA & EPA authority, and obligations as related to General Aviation emissions. Completed & included in UAT ARC Final Report Part II , Appendix I.
PREP-E&T-2	Develop E&T Requirements in Support of ASTM Test/Production Spec Requirements Effort	Add environmental and toxicology requirements in ASTM TF responsible for dev of ASTM New Fuel Standard Practice.
PREP-E&T-3	Develop Protocol & Criteria for Environ-ment & Toxicology Assessment (ARL 6.2)	Develop protocol & Criteria for environmental & toxicological properties relative to current AVGAS.
PREP-E&T-4	Develop Emissions Test Plan and Protocol	Develop input & guidance to PAFI to develop a test plan and protocol for exhaust emissions testing.

5.7.1.6. *Fuel Developer Integration in Preparatory Stage*

There is minimal integration with the prospective fuel developers during this stage.

5.7.1.7. *FAA Integration in Preparatory Stage*

PAFI will coordinate with the FAA to establish the centralized certification office. PAFI will develop template compliance plans with the office to establish a common understanding of the certification compliance requirements for AVGAS approvals. PAFI will also facilitate the upfront acceptance of conformity and testing procedures to be conducted at the FAA Tech Center. The FAA will develop and issue the RFP to solicit candidate fuels for testing and the FAA Tech Center will be establishing facilities and test equipment to support the testing.

5.7.2. *Project Stage Work Scope*

Candidate fuels that are accepted into the FAA Test & Evaluation Program will be tested at the FAA Tech Center during this stage. PAFI will monitor and track the fuel developer's progress through the ARLs. The ARL deliverables will be integrated into the FAA review process and will need to be submitted to the FAA Review Board, but they can also be used to support other activities. The ARL deliverables can support ASTM specification development, FAA certification, and investor requests.

PAFI members will support the progression of the candidate fuels through the ASTM specification development and FAA certification processes. In addition, members will also support meetings with government agencies, private investors, financial institutions, and other stakeholders interested in commercialization of unleaded AVGAS.

A summary of each task in the project stage is provided in Figures 34.0-36.0. Refer to Figure 21.0 for the estimated schedule associated with each project stage task. Implementation plans that include a detailed description and associated cost estimate for each project stage task are provided in Appendix F.

5.7.2.1. Certification & Qualification Project Stage Work Scope

Figure 34.0
PAFI Certification & Qualification
Project Stage Tasks & Work Scope

Task No.	Issue/Task	Work Scope
PROJECT STAGE		
PROJ - C&Q-12	Establish FAA Review Board	Identify, recruit and contract technical specialists to serve on the FAA Review Board to review candidate unleaded fuels for acceptance into FAA Tech Center test.
PROJ - C&Q-13	Support ASTM Research Report and Test Spec Ballot Process	Support ASTM Task Force effort to ballot report and spec and to address ballot.
PROJ - C&Q-14	Conduct Phase 1 Candidate Fuel Review	FAA Review Board reviews and selects candidate unleaded fuels for Phase 1 testing.
PROJ - C&Q-15	Conduct Phase 2 Candidate Fuel Review	FAA Review Board reviews and selects candidate unleaded fuels for Phase 2 testing.
PROJ - C&Q-16	Support ASTM Research Report and Production Spec Ballot Process	Support ASTM Task Force effort to ballot report and spec and to address ballot comments.
PROJ- C&Q-17	Support Certification of Candidate Fuels	Review Tech Center reports and other data submitted by applicant and issue certification approval for in-scope fleet.

5.7.2.2. *Test & Evaluation Program Project Stage Work Scope*

Figure 35.0 PAFI Test & Evaluation Project Stage Tasks & Work Scope		
Task No.	**Issue/Task**	**Work Scope**
PROJECT STAGE		
PROJ-T&E-7	Conduct Phase 1 Testing	Test fuel samples using lab & rig equipment.
PROJ-T&E-8	Prepare Phase 1 Reports	Compile data and prepare report.
PROJ-T&E-9	Conduct Phase 2 Testing	Test fuel in engines & airframes.
PROJ-T&E-10	Prepare Phase 2 Reports	Compile data and prepare report.
PROJ-T&E-11	Conduct Aircraft & Engine Modification Testing	Selective testing of aircraft and engine modifications only for fuels that exceed specified threshold of fleet coverage.

5.7.2.3. *Production & Distribution Project Stage Work Scope*

There are no “Production and Distribution” related tasks defined at this time in support of the PAFI Project Stage.

5.7.2.4. *Impact & Economics Project Stage Work Scope*

Figure 36.0 PAFI Impact & Economics Project Stage Tasks & Work Scope		
Task No.	**Issue/Task**	**Work Scope**
PROJECT STAGE		
PROJ-I&E-5	Develop Tools for Fleet Impact Assessment (ARL 6.3.a & c)	PAFI oversight and advocacy role. In its advocacy role PAFI will develop tools and methods needed to enable the FAA Review Board to assess the potential adverse impact to the fleet which is not supported by a candidate proposed fuel solution. Impact assessment and mitigation is not within PAFI scope.

5.7.2.5. *Environment & Toxicology Project Stage Work Scope*

There are no "Environment & Toxicology" related tasks defined at this time in support of the PAFI Project Stage.

5.7.2.6. *Fuel Developer Integration in Project Stage*

The fuel developer progresses through the project ARLs during this stage and provides the necessary reports and data to demonstrate successful completion of each ARL step. PAFI members will assist the fuel producer in this progression through participation in ASTM Task Forces established for AVGAS specification development, support of proposed AVGAS specification balloting and deliberations at ASTM, and will coordinate with the FAA centralized certification office to facilitate the approval of the fuel. It is anticipated that these activities will be iterative in nature, and require frequent communications between the parties involved.

5.7.2.7. *FAA Integration in Project Stage*

The FAA plays three key roles during the Project Stage. First, the FAA Review Board will review data submitted by candidate fuel developers and select the best performing fuels for testing. Next, the FAA Tech Center performs the fuel property and aircraft equipment testing necessary to generate the data for the FAA test program, ASTM specification development, and FAA certification. Lastly, the FAA centralized certification office will coordinate with PAFI and the fuel producer to apply a standardized procedure to the review and approval of that data.

5.7.3. *Deployment Stage Work Scope*

The deployment stage will begin upon FAA certification approval of the first candidate unleaded AVGAS. PAFI members will support the fuel producer's efforts to establish the production and distribution infrastructure necessary for commercialization of the unleaded AVGAS. This will include providing expertise and counsel when dealing with investors, government agencies, local environmental organizations, equipment manufacturers, and other regulatory entities. Once an unleaded AVGAS with least impact on the fleet has been identified, the FAA may consider both short-term and long-term regulatory action to facilitate the transition to unleaded AVGAS in consultation with the EPA. The FAA & EPA will coordinate as appropriate under their respective authorities & obligations.

A summary of each task in this stage is provided in Figures 37.0 – 39.0. Refer to Figure 22.0 for the estimated schedule associated with each deployment stage task. Implementation plans that include a detailed description and associated cost estimate for each deployment stage task are provided in Appendix G.

5.7.3.1. Certification & Qualification Deployment Stage Work Scope

Figure 37.0 PAFI Certification & Qualification Deployment Stage Tasks & Work Scope		
Task No.	**Issue/Task**	**Work Scope**
DEPLOYMENT STAGE ARL 13-16		
DEPLOY-C&Q-18	Educate/Engage FAA & Industry Stakeholders	Communicate new fuel certifications and field approval requirements.
DEPLOY-C&Q-19	Consider Leaded AVGAS Phase-out Regulation	Once an unleaded AVGAS with least impact on the fleet has been identified, the FAA may consider both short term and long term regulatory action to facilitate the transition to unleaded AVGAS in consultation with the EPA.

5.7.3.2. Test & Evaluation Deployment Stage Work Scope

There are currently no “Test & Evaluation” tasks defined at this time in support of the PAFI Deployment Stage.

5.7.3.3. Production & Distribution Deployment Stage Work Scope

Figure 38.0 PAFI Production & Distribution Deployment Stage Tasks & Work Scope		
Task No.	**Issue/Task**	**Work Scope**
DEPLOYMENT STAGE		
DEPLOY-P&D-4	Establish PAFI Role in Deployment Phase	Identify the role PAFI may play in facilitating deployment of fuel.
DEPLOY-P&D-5	Facilitate Deployment Phase	Interface with applicable industry organizations to facilitate compliance with non-ASTM standards, codes, &requirements.

5.7.3.4. Impact & Economics Deployment Stage Work Scope

Figure 39.0 PAFI Impact & Economics Deployment Stage Tasks & Work Scope		
Task No.	**Issue/Task**	**Work Scope**
DEPLOYMENT STAGE ARL 13-16		
Deploy-I&E-6	Develop Leaded AVGAS Phase-Out Plan	PAFI advocacy role. Facilitate deployment by working with FAA to plan phase out of leaded AVGAS & transition to unleaded AVGAS. FAA & EPA coordinate as appropriate under their respective authorities & obligations.

5.7.3.5. Environment & Toxicology Deployment Stage Work Scope

There are no "Environmental & Toxicology" tasks defined at this time in support of the PAFI Deployment Stage.

5.7.3.6. Fuel Developer Integration in Deployment Stage

The fuel producer will be utilizing the PAFI and the FAA resources to accelerate the commercialization of the approved fuel.

5.7.3.7. FAA Integration in Deployment Stage

PAFI will need to coordinate with the FAA Flight Standards and Airports organizations to ensure a smooth transition to fielding of the new unleaded AVGAS.

6. References

(1) ASTM D910, “Standard Specification for Aviation Gasolines”, American Society for Testing and Materials.

(2) “Aviation Fuels Research Reciprocating Engine Aircraft Fleet Fuel Distribution Report”, DOT/FAA/AR-TN11/22, dated November 2011.

(3) CRC Report No. 657, “Investigation of Reduced TEL Content in Commercial 100LL AVGAS”, Rev A dated May 09, 2011.

(4) CRC Report AV-7-07, “Research Results Unleaded High Octane Aviation Gasoline”, June 17, 2010.

(5) FAA Advisory Circular 20-24C, “Approval of Propulsion Fuels and Lubricating Oils”, July 29, 2011.

(6) FAA ARM Committee Manual ARM 001-015, Revision 36, July 27, 2009.

(7) Orr, M., “The History, Specification, Production, Use and Evaluation of Unleaded Aviation Gasoline“, Report by the ASTM D910 Task Force of D02.J.02.

(8) “Review of Certificates of Analysis and Test Data of Aviation Gasoline for Current Ranges of Lead Additive”, DOT/FAA/AR-TN11/20, dated October 2011.

(9) ASTM Subcommittee J on Aviation Fuels Operating Procedures, Annex A6, “Guidelines for the Development and Acceptance of a New Aviation Fuel Specification for Spark-Ignition Reciprocating Engines”, approved June 2002

(10) General Aviation Statistical Databook & Industry Outlook 2010, General Aviation Manufacturers Association

(11) U.S. Energy Information Administration, http://www.eia.gov

– End of Report Part I Body –

Note: See UAT ARC Final Report Part II Appendices for Appendices A – M.