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TRANSPORTATION RESEARCH BOARD

Options for Reducing Lead Emissions from Piston-Engine Aircraft

February 2, 2021

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Transportation Research Board Webinar

Consensus Study Report:

Options for Reducing Lead Emissions from Piston-Engine Aircraft

February 2, 2021

Webinar Agenda

Overview of National Academies Committee Report:

Amy Pritchett, The Pennsylvania State University

Respondents to Questions:

Amy Pritchett, moderator

Kim Kenville, University of North Dakota

Bernard Robertson, Daimler Chrysler Corporation (retired)

Jay Turner, Washington University

Tom Menzies, Transportation Research Board

Committee's Statement of Task

In Section 177 of the FAA Reauthorization Act of 2018, Congress called for an Academies study of aviation gasoline that includes assessment of:

- Existing non-leaded fuel alternatives to the aviation gasoline used by piston-powered general aviation aircraft;
- Ambient lead concentrations at and around airports where piston-powered general aviation aircraft are used; and
- Mitigation measures to reduce ambient lead concentrations, including:
    - Increasing the size of run-up areas,
    - Relocating run-up areas,
    - Imposing restrictions on aircraft using aviation gasoline, and
    - Increasing the use of motor gasoline in piston-powered general aviation aircraft.

Study Committee

- **Amy Pritchett**, The Pennsylvania State University, *Chair*
- **Brian German**, Georgia Institute of Technology
- **Jack Griffith**, NAS, University of North Carolina
- **Kimberly Kenville**, University of North Dakota
- **Marie Lynn Miranda**, University of Notre Dame
- **Robert Mitchell**, NAE, Northrop Grumman Aerospace Systems (*retired*)
- **Glenn Passavant**, Ingevity Corporation (*retired*)
- **Bernard Robertson**, NAE, Daimler Chrysler Corporation (*retired*)
- **Jay Turner**, Washington University
- **Asciatu Whiteside**, Dallas/Fort Worth International Airport

Committee Activities

- Held multiple meetings of the full committee and subgroups for information gathering and deliberation.
- Heard presentations from representatives of FAA, EPA, state agencies, aircraft and engine manufacturers, airports, fixed base operators who dispense aviation fuel, small airplane operators, suppliers and developers of aviation fuel, and environmental research community.
- Obtained a substantial amount of written information from FAA, EPA, and other relevant organizations.

Report Reviewers

Review was overseen by **David Allen**, NAE, University of Texas, and **Chris Hendrickson**, NAE, Carnegie Mellon University

- **Fred Cornforth**, ConocoPhillips (retired)
- **Shanetta Griffin**, Columbus Regional Airport Authority
- **Bruce Lanphear**, Simon Fraser University
- **Lourdes Maurice**, DLM Global Solutions
- **Neil Paton**, NAE, Howmet Corporation (*retired*)
- **Robert Olislagers**, Centennial Airport
- **Ann Richart**, Nebraska Department of Transportation
- **Noelle Eckley Selin**, Massachusetts Institute of Technology
- **Alan Washburn**, NAE, U.S. Naval Postgraduate School (*retired*)
- **Ron Wilkinson**, AvSouth LLC

Findings and Recommendations

General Aviation Functions

Recreation and personal transport

Transport and medevac in remote areas

Flight training

Law enforcement

Firefighting

Search and rescue

Piston Engine Aircraft

Serve many different purposes

- Personal and recreational flying
  - ~ 75% of the fleet and ~ 50% of hours flown.
- Business, government, and commercial purposes
  - ~25% of the fleet, ~ 50% of hours flown, and consumes more than half of all the avgas.

Annual fleet turnover is very low, ~ 900 new aircraft added per year.

- Average aircraft age ~ 50 years.
- Retrofitting can require extensive and expensive testing and FAA certification.

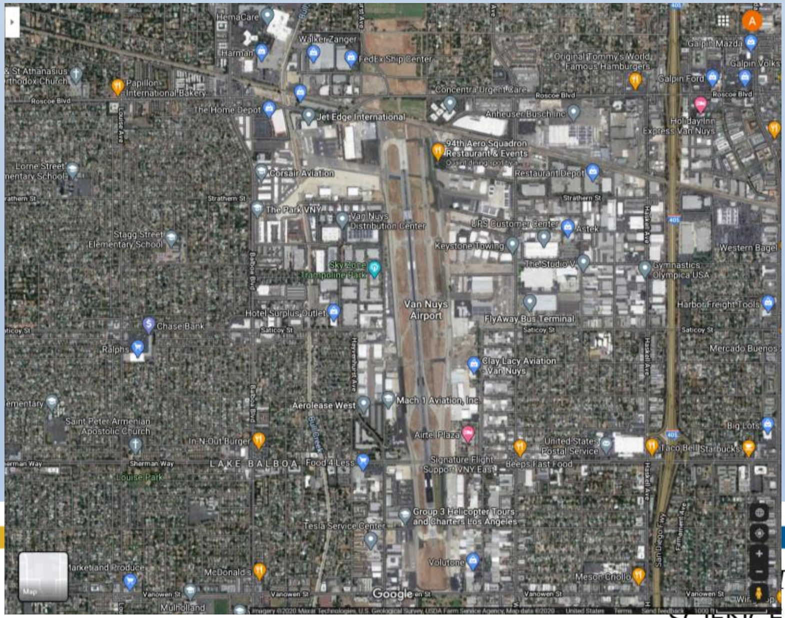
Built 1935 – Still In Use

Built 1955 – Still In Use, Still In Production

Built 2020

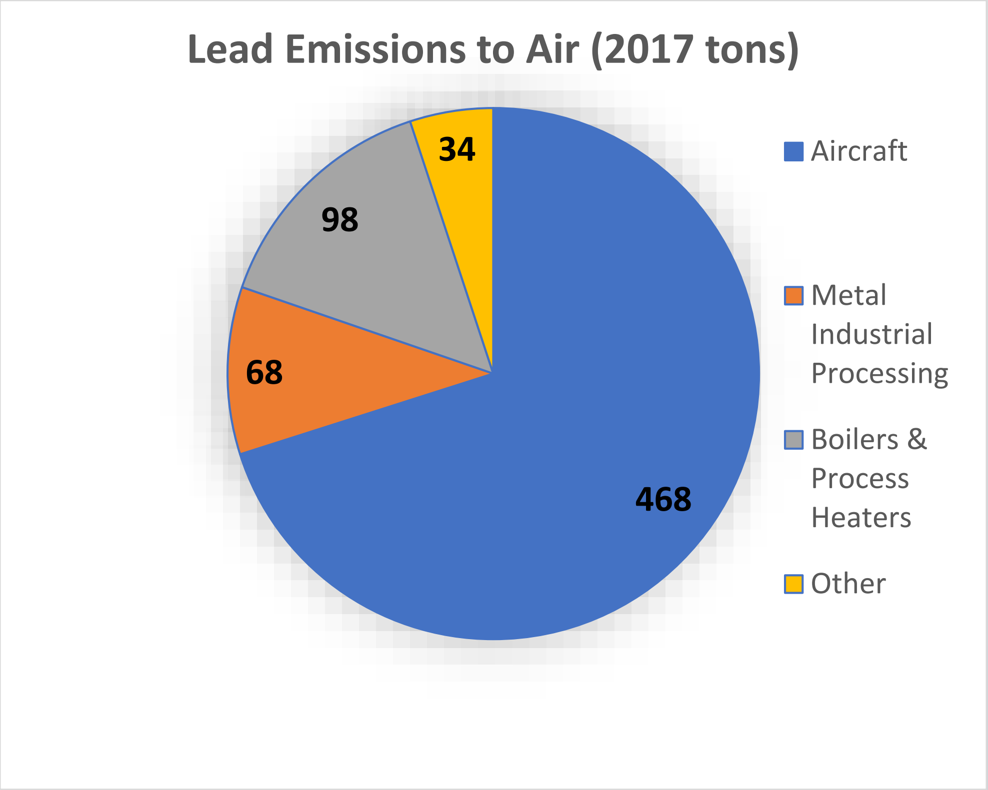
13,100 Different Airports

- ~ 75% of fleet is based at 3,300 airports
  - Mostly publicly owned
  - Are in the National Plan of Integrated Airport Systems (NPIAS) and receive federal assistance.
- ~ 25 % of fleet is based at 9,800 airports.
  - Many are very small, with limited capability to add fueling infrastructure or assess lead impact of airport layout.
- Wide variations in proximity to people, number of operations, fueling infrastructure, etc.



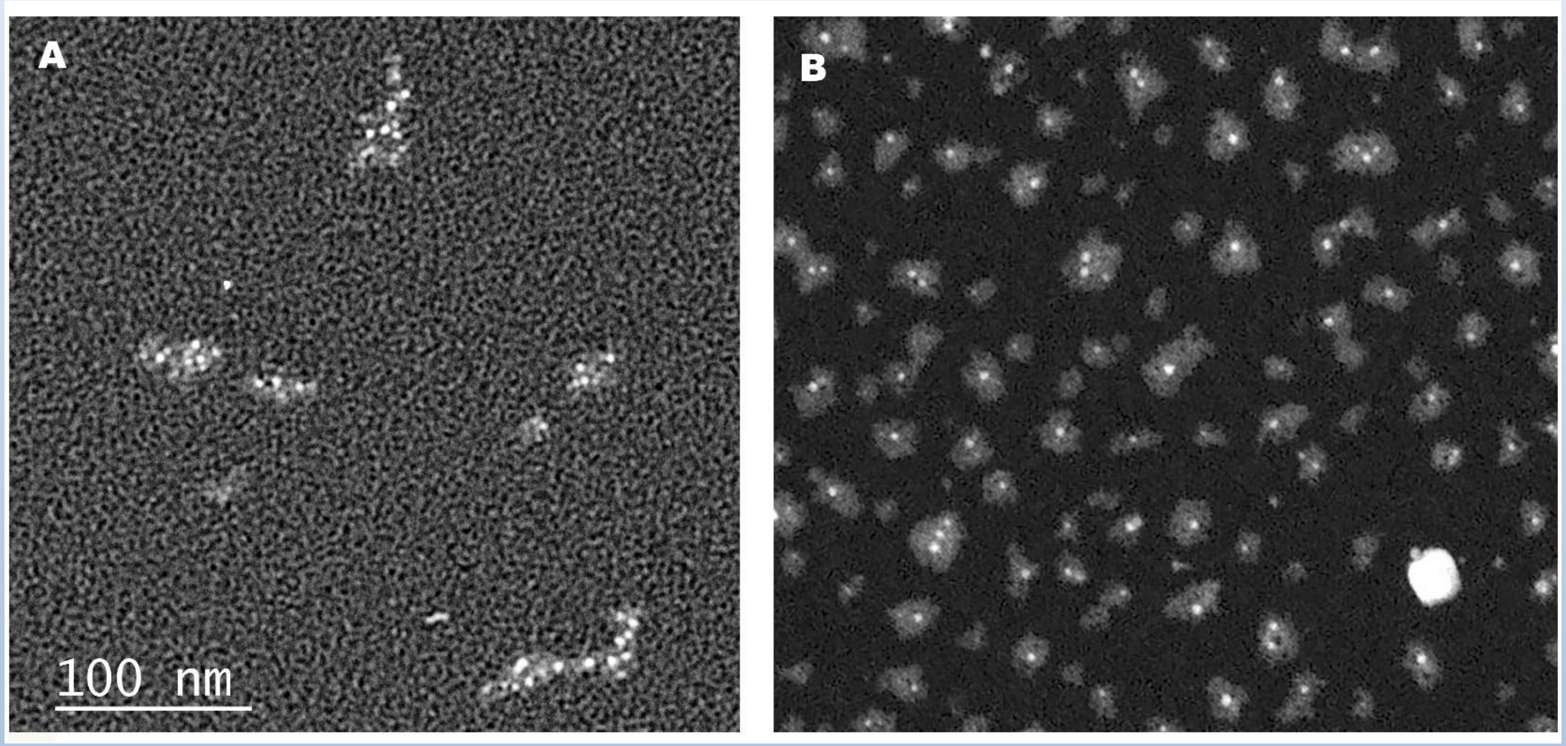
Lead Emissions from Piston Engine Aircraft

- Lead persists.
- Emitted lead accumulates.
- In the past, (civil) piston engine aircraft weren't the largest source…
- … but they are now



Unique Aspects of Aviation Emissions

Aviation emissions may have unique attributes, e.g., smaller particle size than automotive emissions



(A) Automotive (B) Aircraft

Image courtesy of Jack Griffith, committee member

Ambient Lead Concentrations at and Around Airports

- There are no known safe levels of human lead exposure.
- Importance of reducing lead exposures motivates the development and implementation of measures to reduce or eliminate lead emissions and/or zones of high airborne lead concentration.
- Lead exposure can occur through multiple routes:
    - Airborne lead emissions impacting neighboring communities
    - Past emissions deposited to soil and other surfaces
    - Occupational lead exposures for airport workers, including inhalation, ingestion, and dermal absorption of combusted and uncombusted fuel additives: tetraethyl lead (TEL) and ethylene dibromide (EDB).

Some Actions That Cannot Widely Help

- Imposing restrictions on aircraft using avgas would not be a viable sole mitigation. Restricting their use, especially high-performance aircraft, would have far-reaching ramifications for many critical functions, including:
  - Transportation particularly in remote regions,
  - Medical transport, and
  - Pilot training.

- Increasing the use of motor gasoline is not a viable unleaded alternative to avgas.
  - Ethanol, which is added to motor gasoline, may cause vapor lock and is corrosive to aircraft components.
  - Without ethanol, automobile gasoline does not meet minimum octane requirements.

A Multi-Pathway Approach

- There is currently no single known technical solution that is certain to be available in the near-term.

- A multi-pathway approach is needed:
  - Ultimate development of a drop-in fuel (recognizing uncertainty in if/how/when it will succeed).
  - Ultimate development of new propulsion technologies.
  - Interim mitigation pathways focused on modifying airport operations and practices and on using existing fuels and aircraft.

- Implementation will require the participation of many across a diverse industry, involving private, corporate and public entities, including: pilots; airport managers and personnel; fuel suppliers; and aircraft propulsion and airframe manufacturers.

Broad Coordination

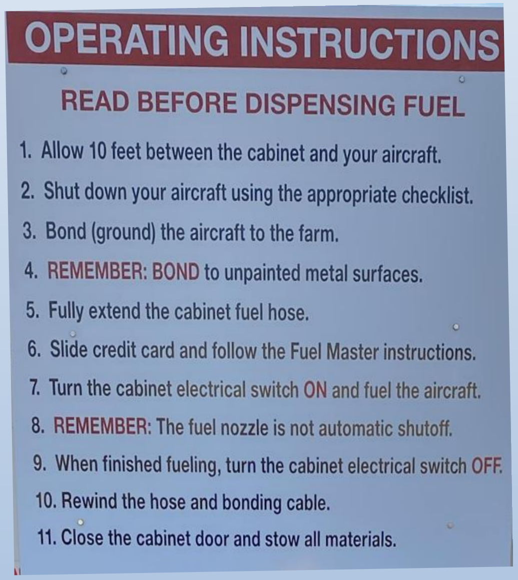
Recommendation: FAA should:

- Coordinate its efforts to reduce lead pollution and exposures at airports with those of other federal agencies that have key responsibilities for protecting public health, safety, and the environment at airports, including OSHA, as well as EPA.

- Collaborate with those agencies to explore the regulatory and programmatic means within their respective jurisdictions that can be brought to bear and combined in a complementary manner to reduce lead emissions and exposures at airports.

Pilot and Airport Personnel Practices

There is scarce mention of lead health hazards in FAA-related materials for flight training, aircraft maintenance, and airport management and guidelines for refueling to avoid spills and emissions.



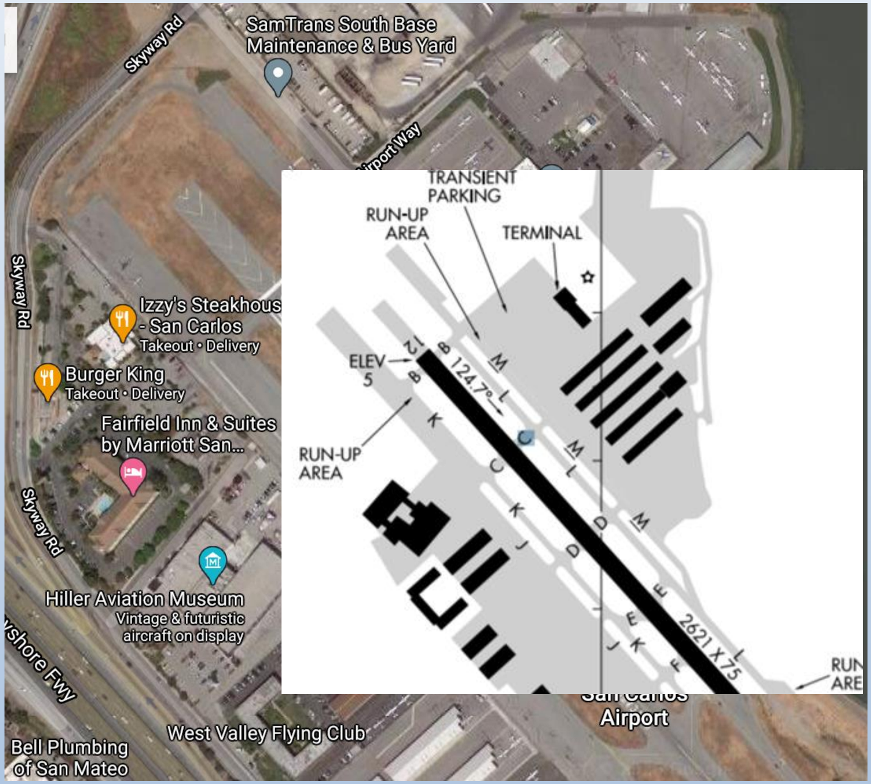
Pilot and Airport Personnel Practices

<u>Recommendation</u>: FAA should initiate an ongoing campaign for education, training, and awareness of avgas lead exposure that is targeted to GA pilots, aircraft technicians, and others who work at airports.

- Partner with prominent organizations within the GA community.
- The campaign should be multi-pronged by ensuring that information on lead risks and mitigation practices is prominent in relevant materials for pilots, airport management, and aircraft technicians.
- Where appropriate, the information should also be covered in relevant certification and licensure examinations.
- The information should be featured on FAA and GA organization websites and included in written materials distributed at GA industry conferences, tradeshows, and fly-ins.

Aircraft Operations at Airports

FAA has not updated its run-up area planning guidance to reflect the results of air quality studies suggesting the desirability of moving airport run-up locations away from where human activities occur (both on-airport and in neighboring communities) and away from high-traffic locations, such as runway ends where lead is emitted from aircraft taking off.



Aircraft Operations at Airports

Recommendation:

FAA should update its guidance on the location of run-up areas to reflect the results of research since the latest interim guidance was issued in 2013

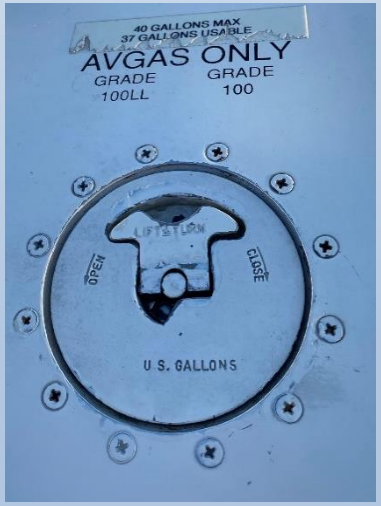
- Include the need to account for both the emissions of engine run-ups and takeoffs when analyzing the geographic distribution of lead emissions at the airport.
- Analysis should support decisions of whether to move run-up areas to reduce people's exposure to lead emissions, while accounting for other concerns including safety and aircraft noise.

Existing Specified Fuels and Fleet

- 100VLL has the same octane rating as 100LL, nearly 20% less lead content, and could be used by all piston-engine aircraft. Although it is not currently being produced, the fleetwide use of 100VLL could reduce total lead emissions from avgas by up to 20%.

- At least 57% of the current fleet could use UL94, which is the only existing grade of unleaded avgas. It would require a second supply chain and fuel distribution system across the nation. Consequently, widespread availability of UL94 is likely to be restricted to a portion of airports that have or can afford to add the required fueling facilities.

- Interim reductions in lead emissions:
  - If all suitable aircraft use UL94, lead emissions would be reduced by up to 30%.
  - If higher-performance aircraft were also to use 100VLL, reductions in lead emissions could exceed 40%.



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Existing Specified Fuels and Fleet

Recommendation: FAA should research public policy options for motivating refiners to produce and airports to supply 100VLL.

- Strive for rapid implementation at the federal and state levels and by Congress.
- The objective is to reduce lead emissions from the entire fleet while fleetwide unleaded alternatives are being pursued.

Existing Specified Fuels and Fleet

Recommendation: FAA should research public policy options to enable and encourage greater use of available unleaded avgas (UL94). Possible options include:

- Issuing a Special Airworthiness Information Bulletin, and
- Providing airports with incentives and means to supply unleaded fuel, particularly airports eligible for FAA-administered federal aid.

Existing Specified Fuels and Fleet

Recommendation: A mechanism should be established for facilitating the increased availability of existing grades of unleaded avgas across the fleet. Congressional involvement would likely be needed, such as by providing incentives:

- For pilots to use existing unleaded avgas, and
- For more small airports to add requisite fuel storage and dispensing capacity.

New Lead-Free Fuels

Although it has not yet yielded a viable replacement, the Piston Aviation Fuels Initiative (PAFI) has led to the development of a fuel testing and evaluation process, prompted supplier interest in developing replacement fuels, and sought solutions to many challenges associated with supplying an unleaded replacement fuel.

New Lead-Free Fuels

Recommendation: FAA should continue to collaborate with the GA industry, aircraft users, airports, and fuel suppliers in the search for and deployment of an acceptable and universally usable unleaded replacement fuel. The collaboration should be carried out:

- Through PAFI or an alternate holistic process for evaluating all the properties and conditions necessary for production, distribution, and safe use of the fuel, including the use of common test protocols and procedures, and
- By making available the needed testing facilities for the development of the data required to support FAA approvals for the fuel to be used by existing piston-engine aircraft.

Transition to Lead-Free Propulsion Systems

- Incentives are needed to develop new technologies to expand use of currently available unleaded fuels.

- The slow turnover rate of GA fleet would limit the transition to new technologies without new incentives.

Recommendation: A clear goal should be established that all newly certified gasoline-powered aircraft after a certain point in time (e.g., within 10 years) are approved to operate with at least one ASTM-approved unleaded fuel

- An additional amount of time should be identified by which all newly produced gasoline-powered aircraft, including those currently produced with older type certificates, would attain that same goal.
- Congressional action may be required to establish the goal and timeframes.

Lead-Free Propulsion Systems

Small aircraft pose unique engineering challenges: propulsion systems have to be small, light-weight and reliable.

- Miniaturize systems used by larger aircraft (diesel, turboprop, turbogenerator)
- Look to new electric and alternate fuel engines

Currently, these technologies are typically not certified for broad use.

Certification and retrofit costs can be prohibitive.

Examples:

https://www.pbsaerospace.com/our-products/tp-100-turboprop-engine

http://www.boeing.com/aboutus/environment/environmental_report/_inc/flash-2-1-2.html

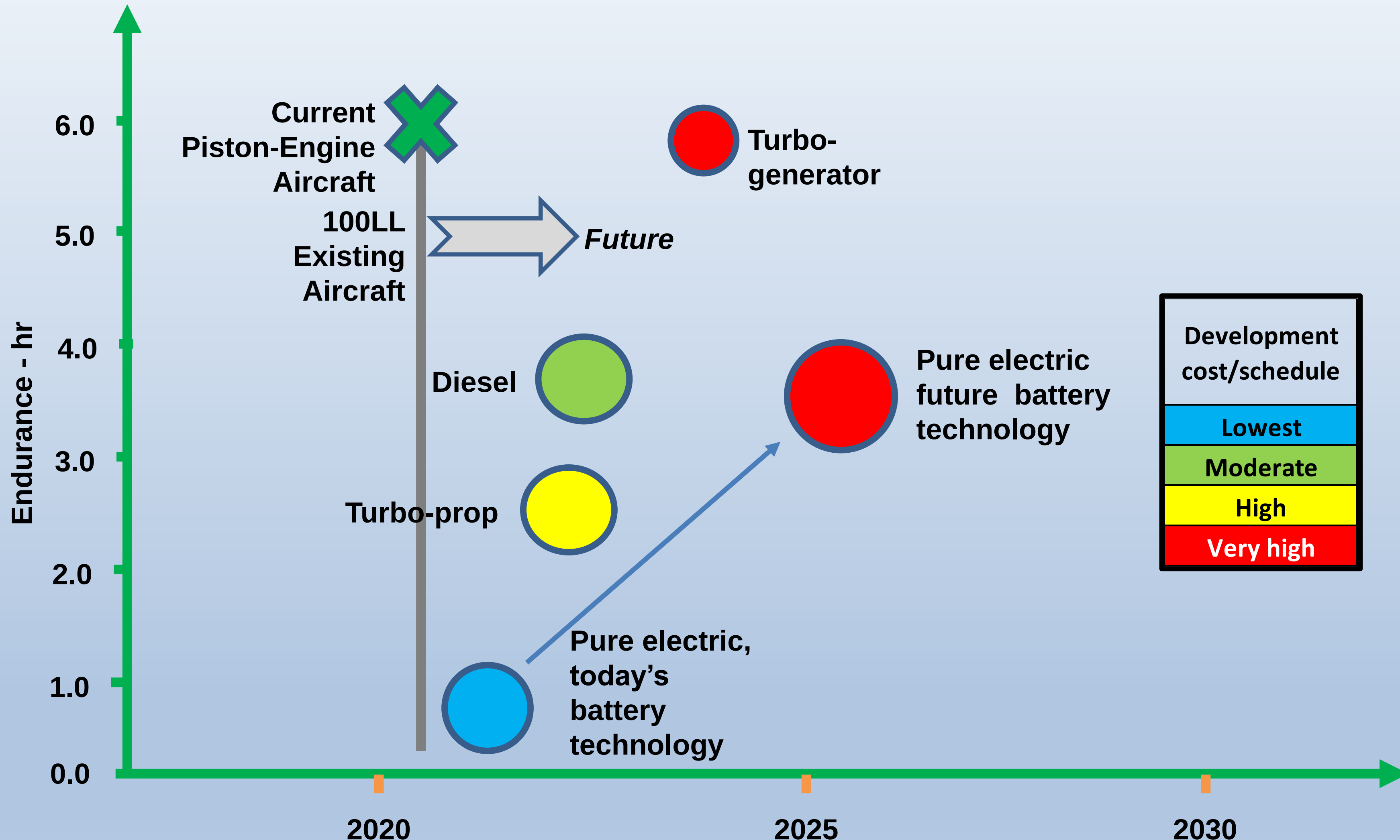
Lead-Free Propulsion Systems

- Incentives are needed to develop new technologies to expand use of lead-free means of propulsion.
- The slow turnover rate of GA fleet would limit the transition to new technologies without new incentives.
- Long timeline – need to start now

Recommendation: FAA initiatives should be used to promote the development, testing, and certification of safe and environmentally desirable lead-free emerging propulsion systems (e.g., diesel, electric, and jet fuel turbine engines) for use in GA aircraft, including the requisite airport refueling and recharging infrastructure.

- Include collaborations with industry and other government agencies, such as NASA.
- Congressional encouragement and provision of resources may be required.

Notional Timeline Starting Now to Develop a Typical 4-seat GA Aircraft with Different Propulsion Systems

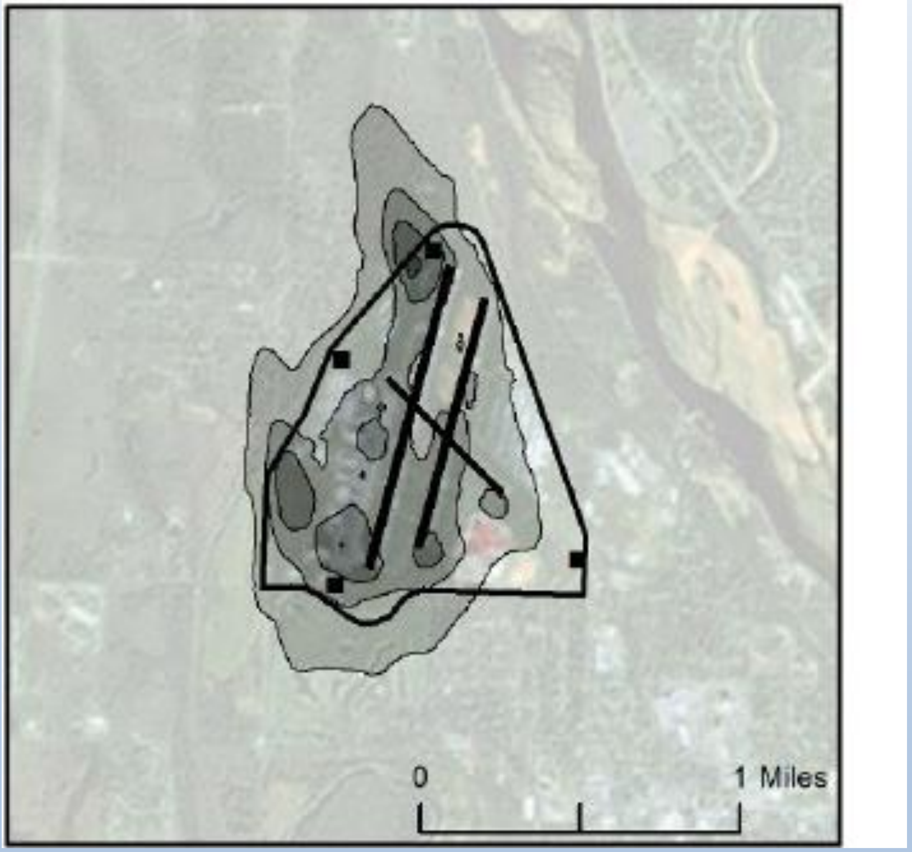


Summary of Mitigations

Considerations	Airport Operations and Practices		Existing Specified Fuels and Fleet		New Lead-Free Technologies (Fuels–Propulsion Systems)		
	Aircraft Operations at Airports	**Pilot and Airport Personnel Practices**	**100VLL**	**UL94 for low-performance aircraft**	**UL94 in all new aircraft**	**100+UL in all aircraft**	**New Propulsion Systems**
Potential Reduction in Lead Exposures	Small & variable, depends on individual airport	Small & variable, could be important for aircraft technicians	Up to 20% reduction (could be >40% if combined with UL94 use by low-perform aircraft)	Up to 30% reduction (could be >40% if combined with 100VLL use by other aircraft)	~0.5% reduction per year	100% reduction	~0.5% reduction per year
Time Frame for Lead Reduction Benefits if Started Soon	Near-term	Near-term	Near- to mid-term	Mid-term	Far-term for appreciable reductions	Unknown, may require technical breakthrough	Depends on cost, innovation rate, & applicability to GA fleet
Focus of Implementation	Airport Management	FAA Flight Stds, pilot instruction and training programs, GA community	Fuel supply chain, especially refiners	Fuel supply chain esp at airports	Engine and aircraft makers	Fuel supply chain, esp fuel developers; engine and aircraft makers	Technology developers, aircraft manufacturers, aircraft owners
Possible Policy Actions for Facilitating Implementation	Provide data and tools for analysis and identifying operations changes	Provide training and education materials, engage in awareness campaigns	Directives and/or incentives, perhaps focused on refiners	Incentives for airports to add fueling capacity, eased FAA certification	Directives and/or incentives applicable to GA industry	Public–private collaborative (PAFI-like) for R&D, testing, and certification	R&D support, FAA certification, incentives for aircraft owners to incur expense
Main Sources of Uncertainty in Effective Implementation	Variability in airport- specific factors	Potential to affect practices	Refiner capacity to meet tighter lead specifications	Feasibility of second fuel supply chain, certification	Ability to design suitable engines for all high-performance aircraft	Potential to meet fuel performance requirements	Rate of innovation, certification challenge, cost and owner interest
Ancillary Benefits and Concerns	Greater lead awareness & interest in lead-free fuels and propulsion	Greater lead awareness & interest in lead-free fuels and propulsion				Environmental and health impacts related to other fuel components	Changes in pollutants, including GHGs over life cycle

Mitigations at Specific Airports

Assessing the feasibility and effectiveness of airport-specific mitigations would benefit from an improved understanding of individual airport characteristics.



Modeled airborne lead concentrations at Richard Lloyd Jones Jr. Airport in Tulsa, Oklahoma

Mitigations at Specific Airports

Recommendation: EPA should conduct more targeted monitoring and enhanced computational modeling of airborne lead concentrations at airports of potential concern, as indicated by its recent screening study, to evaluate aircraft operations that are main contributors to lead hot spots and design airport-specific mitigation measures.

- Additional monitoring and modeling should include airports with airborne lead concentrations exceeding the concentration of the lead National Ambient Air Quality Standards, and airports with lead concentrations lower, but approaching, the NAAQS.

Airborne Particles Containing Lead

Lead in piston-engine aircraft exhaust can occur in particles smaller than the lead particles observed in automobile exhaust.

Recommendation: EPA and NIEHS should sponsor research to improve the understanding of the physical state of the lead-containing particles to inform future studies of atmospheric transport and deposition, human exposure, and health risks of lead emissions form GA aircraft.

- Include emissions from various types of GA-aircraft piston engines, e.g., turbocharged engines, using fuel formulations of different lead content, including an existing grade of avgas with a lower lead content (100VLL).

Routes of Lead Exposure

Past emissions from piston-engine aircraft that deposited to soil and other surfaces can contribute to present-day lead exposures at locations within and near airports.

Recommendation: EPA and NIEHS should sponsor research to enhance the understanding of lead exposure routes and their relative importance for people living near airports and working at them.

- Include studies, such as observations of blood lead levels among children, in communities representing a variety of geographic settings and socioeconomic conditions that are designed to examine the effectiveness of the lead mitigation strategies over time.

In Closing

- Key message: A lead mitigation strategy depending on an unleaded drop-in fuel has a high degree of uncertainty of success.
- Instead, a multi-pronged approach is required.
- Near and mid-term mitigations can reduce lead emissions and exposures.
- Other longer-term technical developments have the potential for much larger impacts.

Questions?