Eliminate Aviation Gasoline Lead Emissions Initiative (EAGLE) Public Forum

Monday, July 22, 2024

10:00 a.m. – 11:15 a.m. Central Time

AirVenture Stage 7

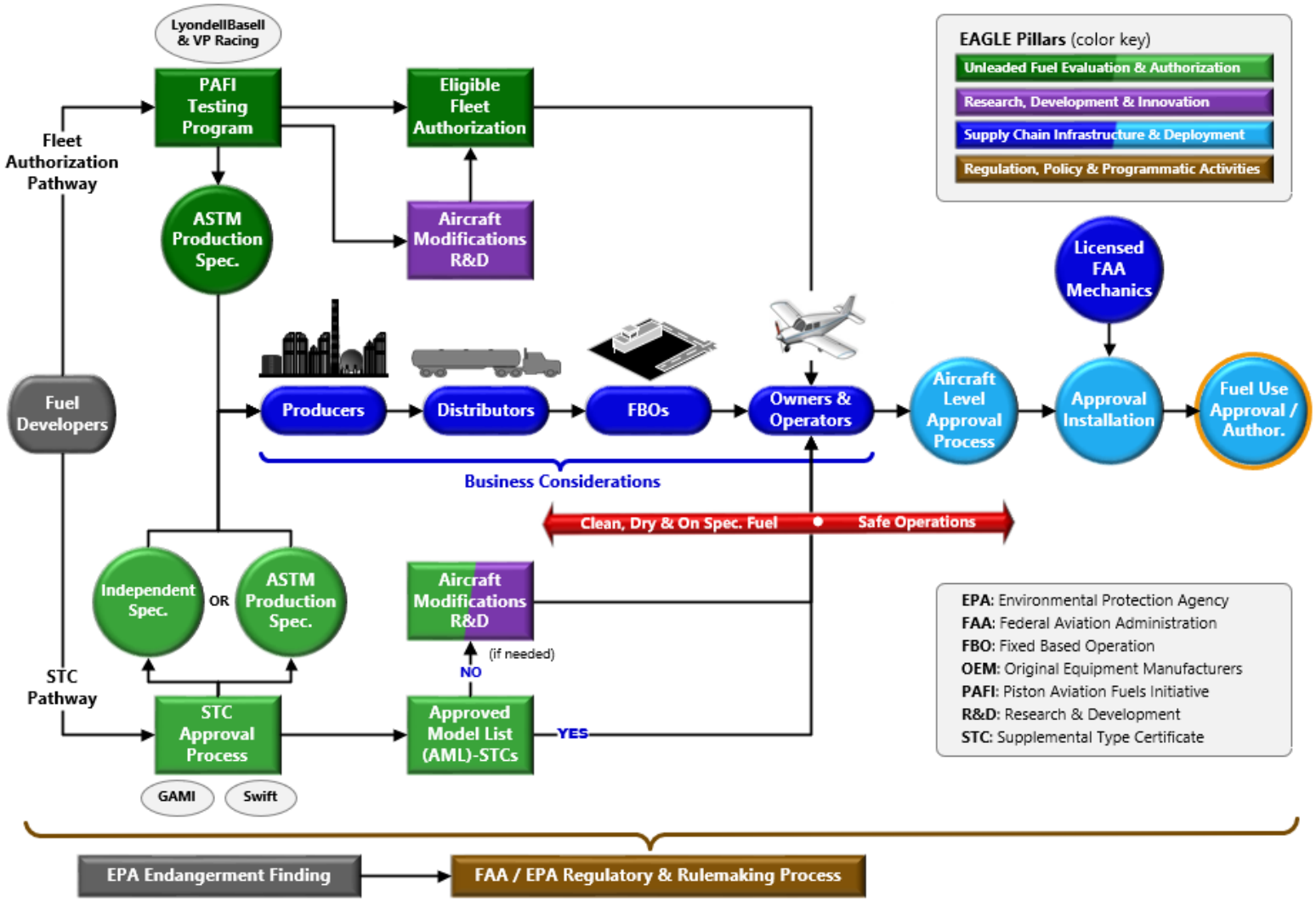
Welcome to the EAGLE Unleaded Fuels Forum at AirVenture 2024

- Introduction/Welcoming Remarks by the EAGLE Co-Chairs
- Transition to Unleaded (UL) Aviation Gasoline “Big Picture”
- UL Fuel Status Updates
- UL Fuel Evaluation and Authorization
- Supply Chain Infrastructure and Deployment
- Perspectives and Needs:
  - Fixed Base Operators (FBOs) and Distributors
  - Manufacturers
  - Communities
  - Pilots
- Q&A
- Summary and Next Steps

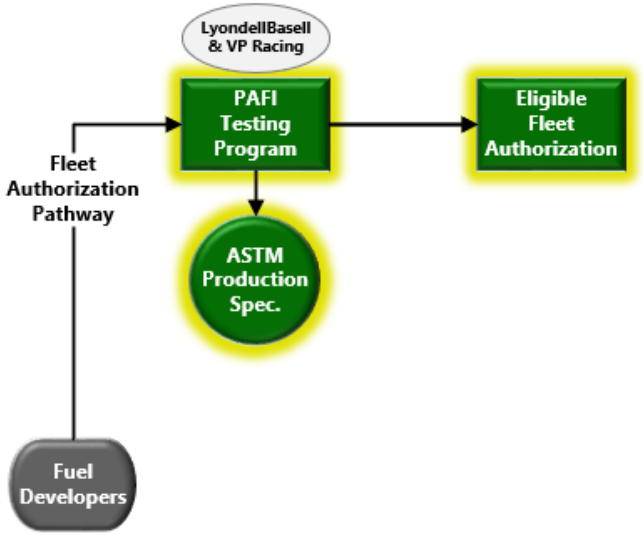
EAGLE's Goal and Partners

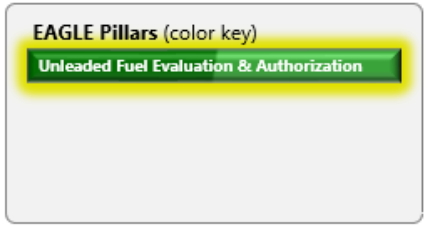
"Eliminate the use of leaded aviation fuels for piston-engine aircraft in the United States by the end of 2030 without adversely impacting the safe and efficient operation of the existing fleet."

Transition to Unleaded Aviation Gasoline "Big Picture"



Transition to Unleaded Aviation Gasoline "Big Picture"





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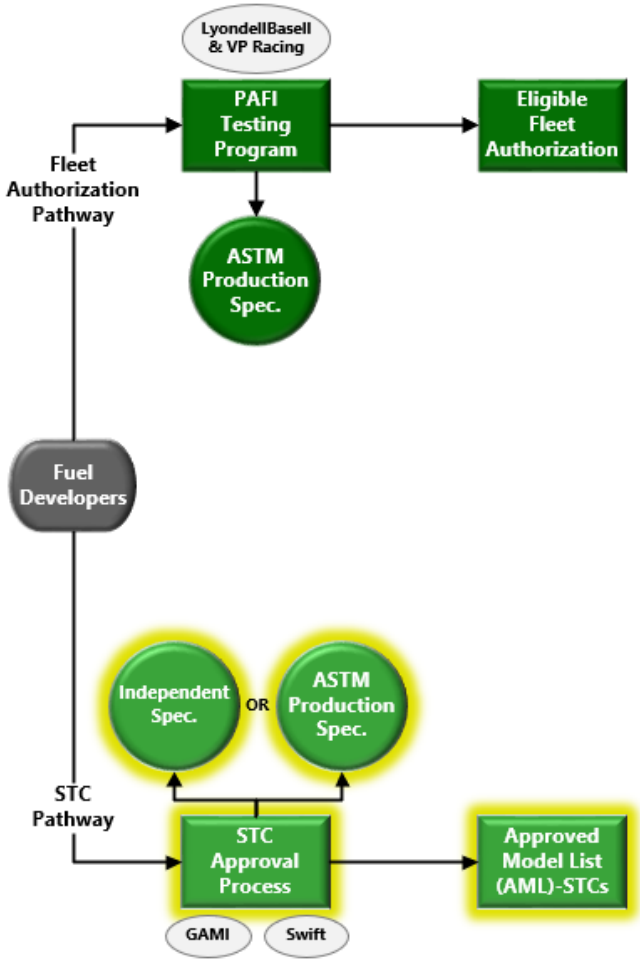

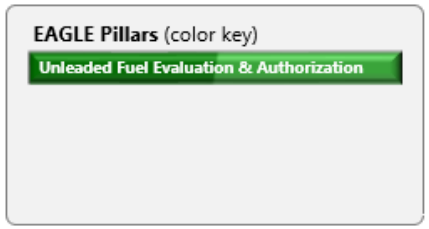

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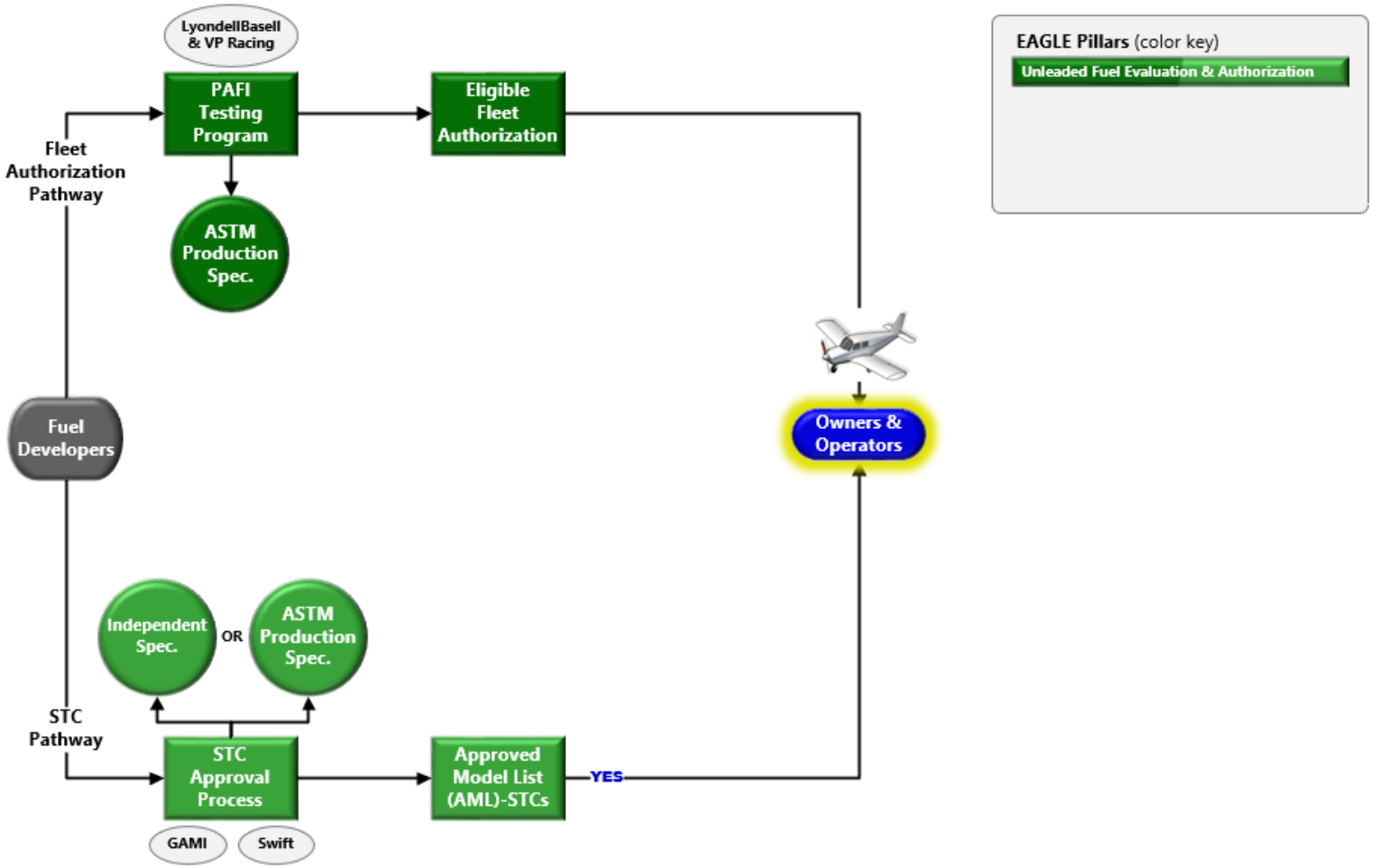

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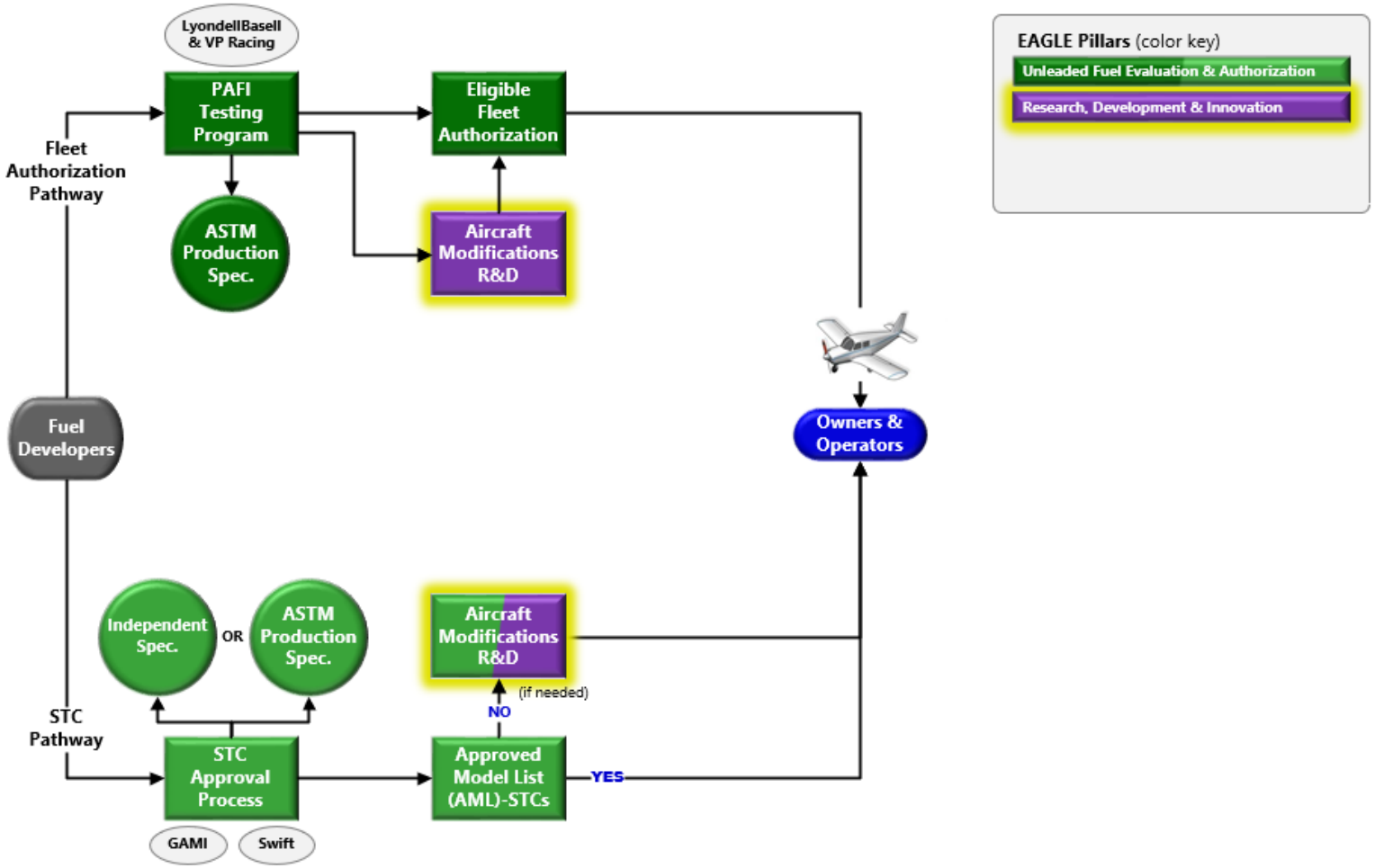

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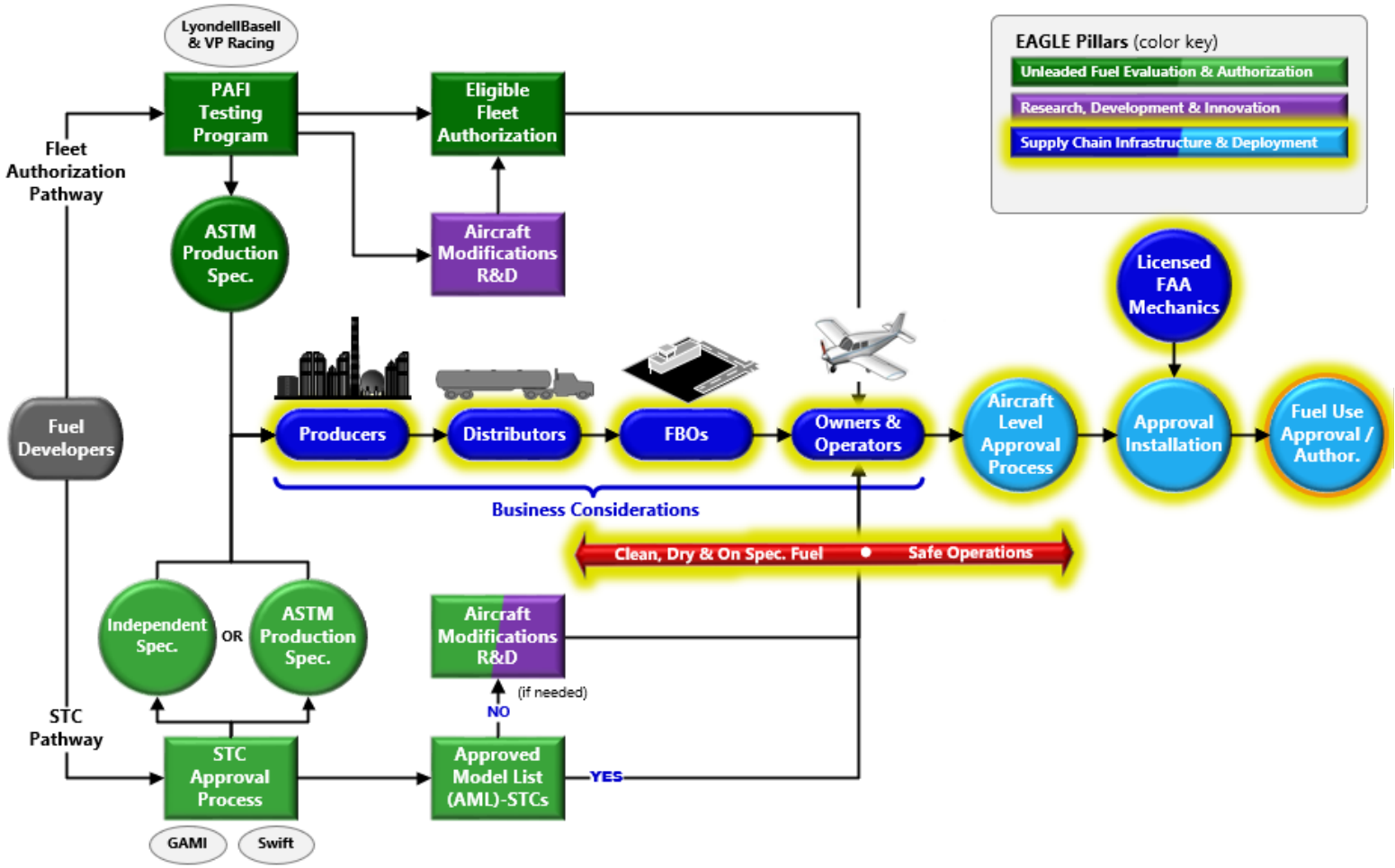

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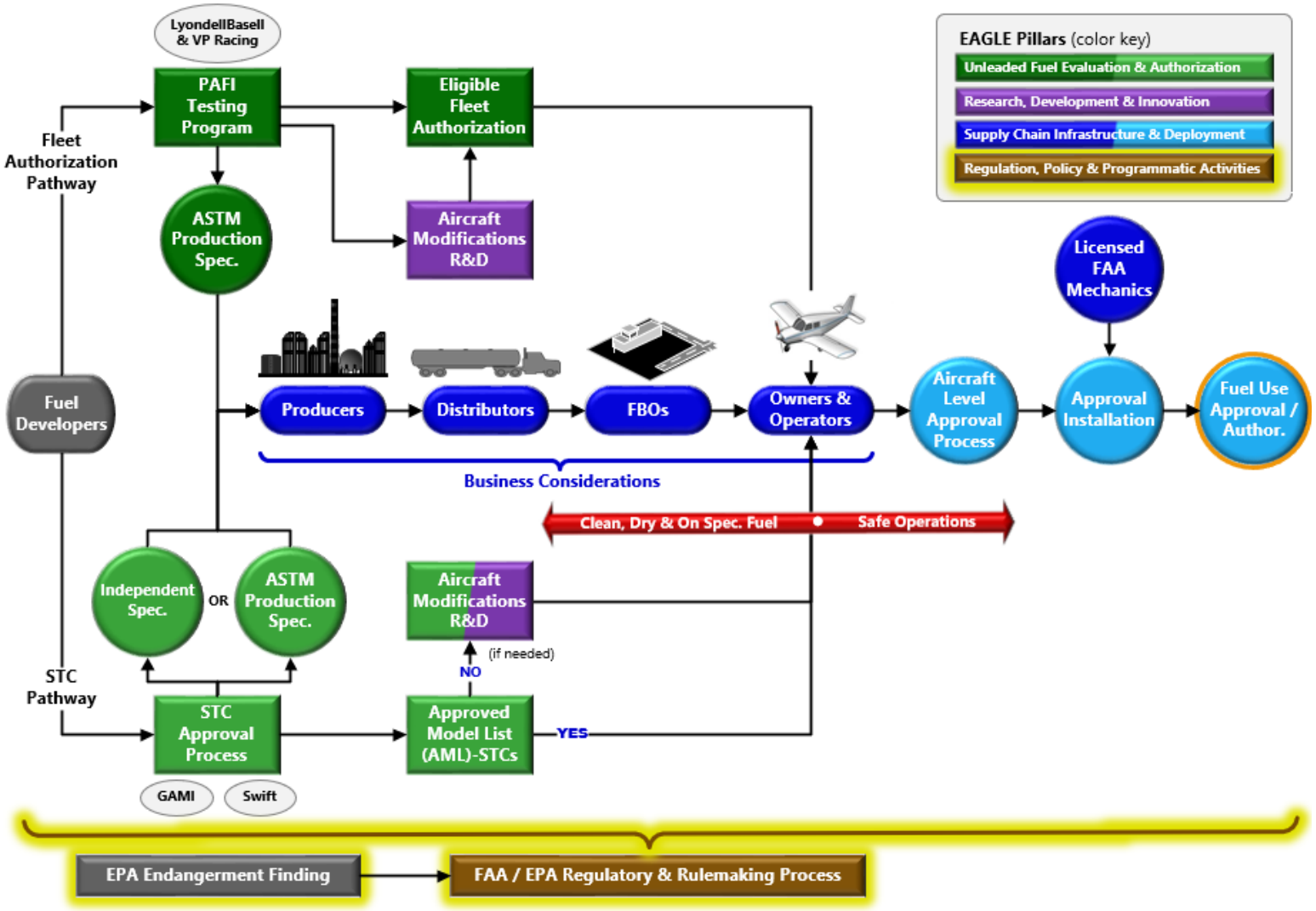

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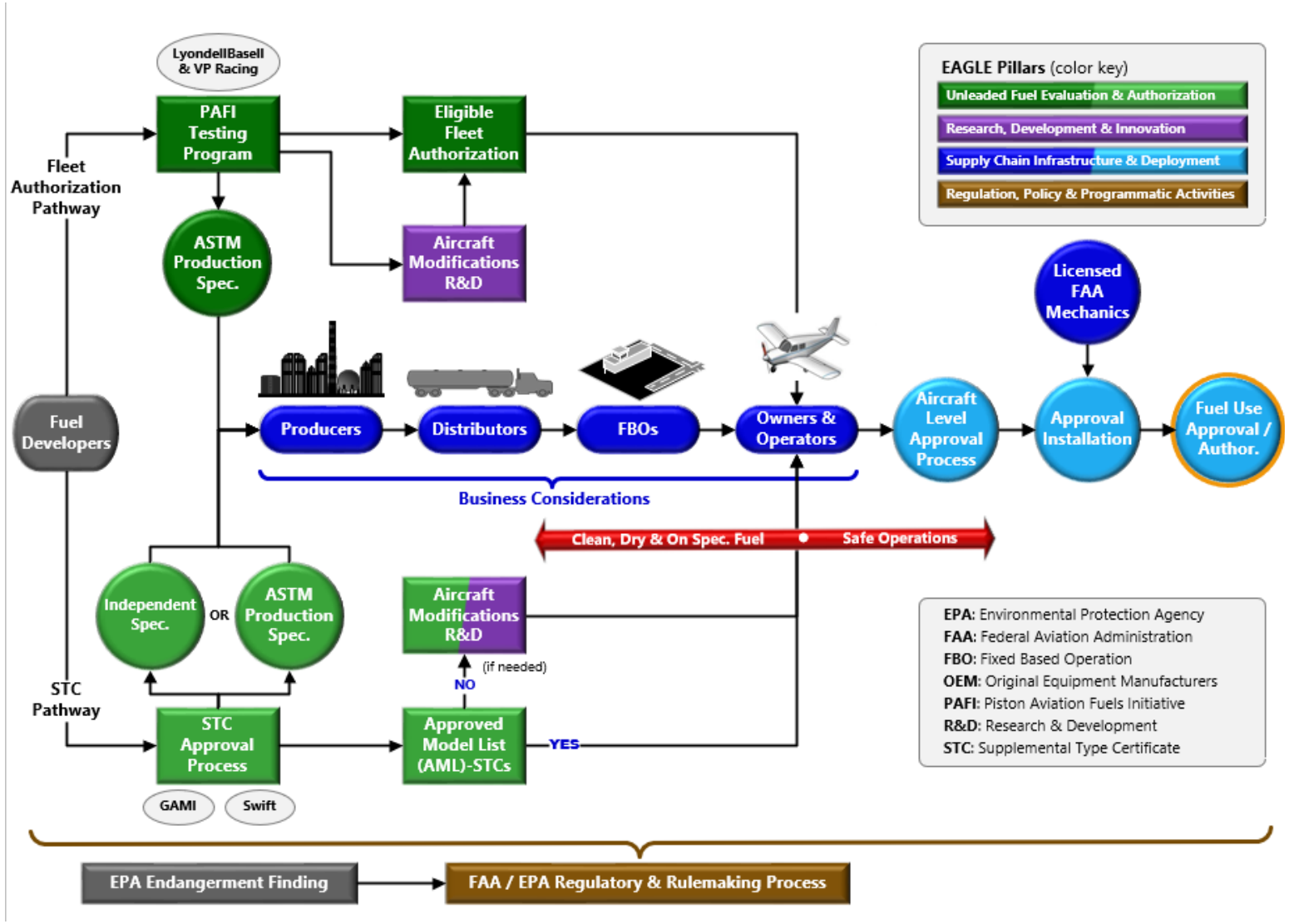
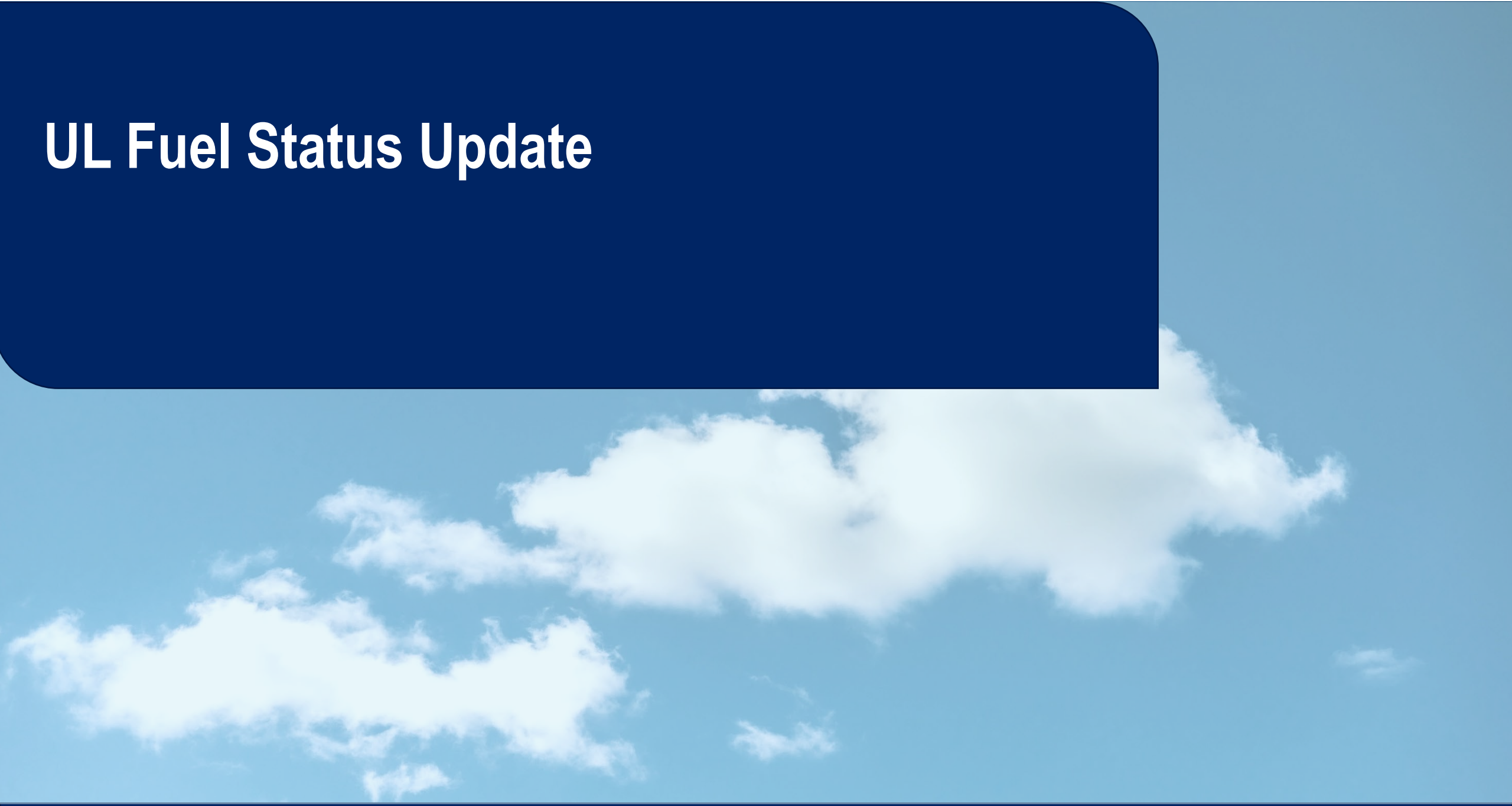


UL Fuel Status Update



Unleaded Fuel Evaluation and Authorization

UL100E Testing Status

20-Nov-2023 thru 15-Jul-2024

Unleaded Fuel Evaluation and Authorization Pillar Objectives

- **Complete test and evaluation** of candidate replacement fuels for 100 Low Lead (100LL) aviation fuel
- **Identify at least one unleaded fuel** acceptable for widespread use
- **Institutionalize fleet authorization process** for unleaded fuels
- **Include education, training, awareness, and outreach** responsibilities

Cornerstones
- Transparency / Accountability
- Stakeholder Participation / Collaboration
- Technical Excellence / Objectivity

Key Considerations
- Fuel Quality
- Safety
- Fleet Impact
- Mitigations
- Research and Development

Deliverables
- Fleet Authorization Process
- Authorizations for Fuels / Eligible Models
- Test & Evaluation Process / Test Plans
- Lessons Learned / FAQs
- Data and Reports → R&D Efforts (Pillar B)

Pillar Interdependencies
- Business (Fuel) Infrastructure and Implementation (Pillar A)
- Research, Development, and Innovation (Pillar B)
- Regulation, Policy, and Programmatic Activities (Pillar D)

PAFI Unleaded Fuel Testing Protocols – UL100E

PAFI Initial Testing

COMPLETE (GATES 1, 2, and 3)

☑ Mini-Materials Compatibility
Subset of full materials compatibility testing involving articles representative of sealants, fuel bladders, and elastomers, performed by fuel developer

☑ Engine Performance/Fuel Properties
Rated power check of TIO-540-J2BD to compare engine operational parameters and CoA to 100LL

☑ Performance & Detonation
Comparative testing between minimum specification 100LL and test fuel performed in altitude test cell on TSIO-520-VB engine

☑ Mini-Durability
Engine test to evaluate the deposit forming characteristics and effects of the fuel during a § 33.49 150-hour endurance test, TSIO-550-K engine

Full Scale PAFI Testing

IN PROGRESS (GATE 4)

➡ Materials Compatibility *(23% Complete)*
Full materials compatibility lab and bench tests
- **Rig Testing**: Storage stability, cold soak storage, hot surface ignition temperature, low temperature flow ability

➡ Performance & Detonation *(6% Complete)*
Testing of multiple engine models at simulated altitude, hot day conditions

➡ Durability *(25% Complete)*
1) § 33.49 150-hour endurance engine test followed by
2) 200-hour flight duty cycle durability test per AC 33.19-1 to characterize effects on engine durability and TBO on multiple engine models

➡ Additional Testing *(3% Complete)*
Evaluate propeller stress levels compared to 100LL for multiple engine / propeller combinations and cold starting and fuel tank quantity sensing

➡ Aircraft *(4% Complete)*
Ground and flight testing on multiple aircraft to evaluate engine and aircraft operability, handling, cooling, and fuel system hot weather

PAFI GATE 4 – UL100E Full Scale Testing Status as of 12-Jul-2024

Detonation & Performance

6.2%

37%	Continental TSIO-520-VB
0%	*Lycoming TIO-540-J2B*
5%	Lycoming IO-540-K1A5
0%	*Continental IO-550-D*
0%	*Continental O-470-U*
0%	*P&W R-1830 S1C3-G*

Durability & Performance

(150 Hr. § 33.49 + 200 Hr. flight duty cycles)

25.0%

350 hr	Continental TSIO-550-K
0 hr	*Lycoming IO-360-C1F*
0 hr	*Air Repair W670-6N*
0 hr	*Lycoming O-360-A1A*

Aircraft Testing

(Engine Handling, Cooling Climb, Hot Fuel)

4.0%

75%	Lancair Super Legacy
0%	*Robinson R44 II*
0%	*Cirrus SR22T*
0%	*Beechcraft G36*
0%	*Cessna T206H*
0%	*Cessna 402C*
0%	*Piper PA-46-350*
0%	*Cessna 182Q*
0%	*T-6G (Harvard 4)*

Additional Testing

3.3%

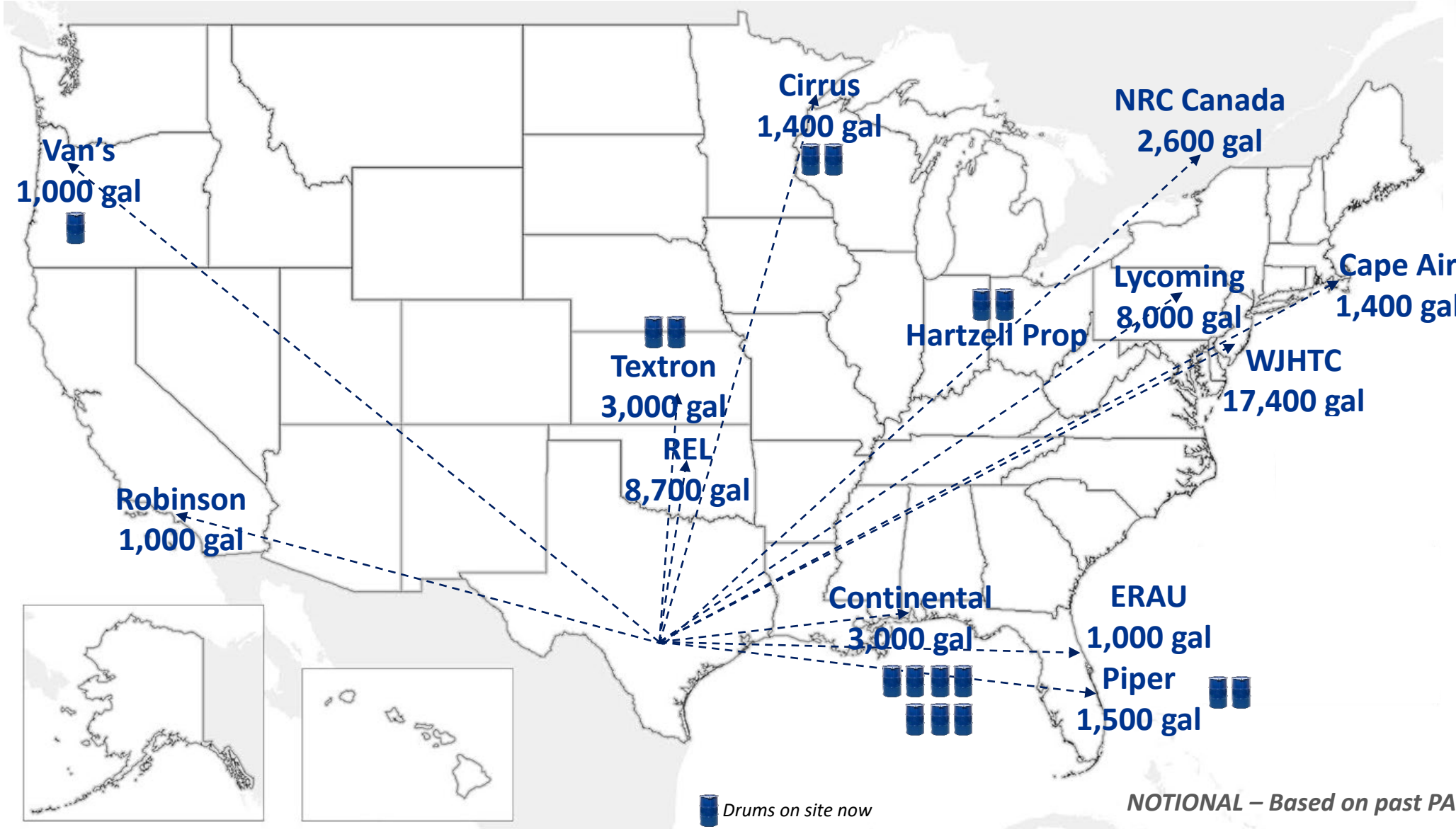
10%	Propeller Vibe
0%	*Cold Starting*
0%	*Fuel Qty Sensing*

Materials Compatibility

23.1%

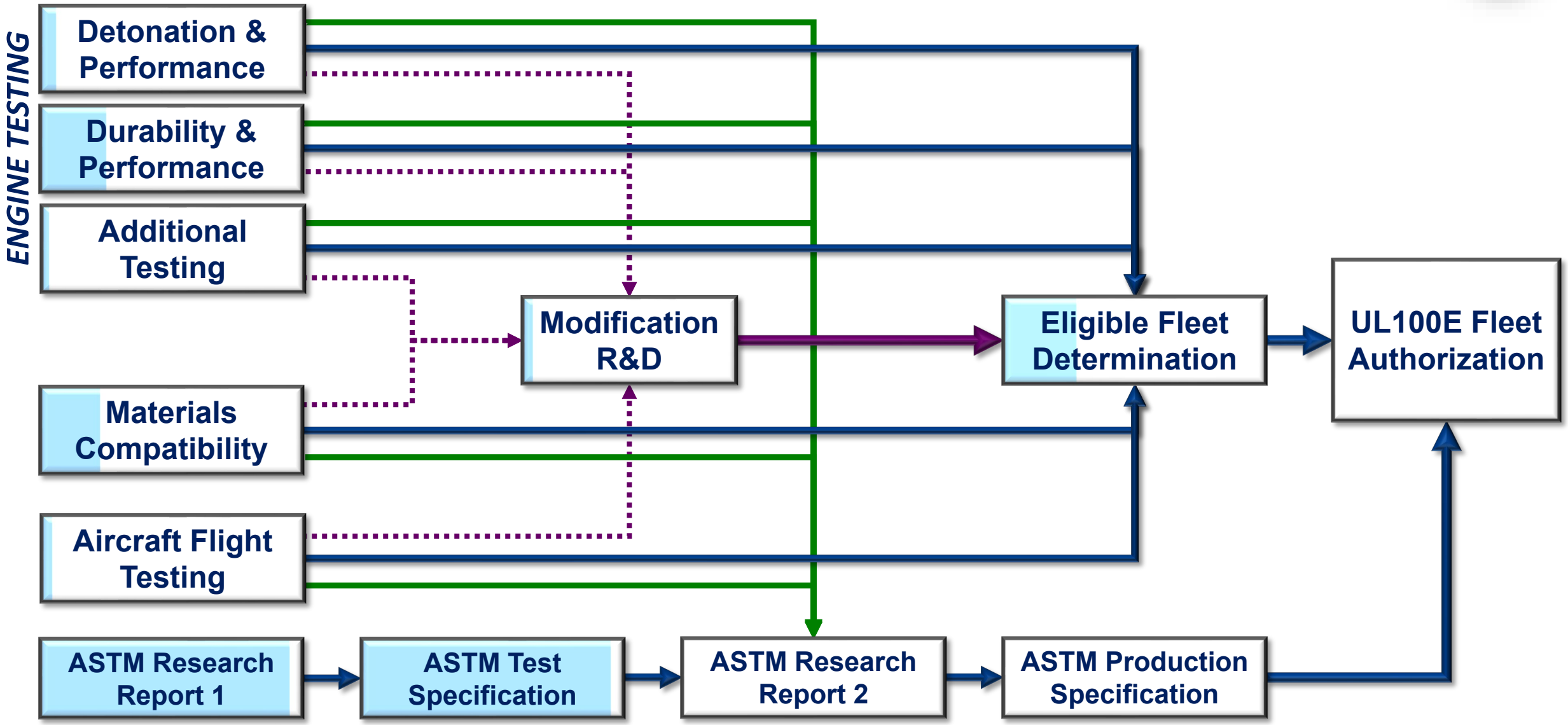
9%	Metallics (32)
19%	Non-Metallics (26)
0%	*Finished Parts (5)*
90%	Paint Systems (10)
0%	*Fabric Systems (5)*
35%	Polysulfides (17)
100%	O-Rings (5)
20%	Aircraft Hoses (5)
0%	*Distrib. Sys. (13)*
0%	*Fuel Bladders (2)*
0%	*Comp. Resins (16)*
0%	*Composites (6 - 18)*
0%	*OEM Materials (5)*
50%	OEM Wing Test (4)

PAFI GATE 4 – Full Scale Testing – ~ 50,000 gallons of UL100E



NOTIONAL – Based on past PAFI activities

PAFI Fleet Authorization Process / Status - UL100E as of 12-Jul-2024



Materials Compatibility Testing Matrix

Paint Systems

- ✓ **Primer: Axalta Corlar 13580s Epoxy, Base Coat: Imron AF400, 0.040" 2024-T3 aluminum per AMS-QQ-A-250/5B**
- ✓ **Primer: AN 10P8-11 VOC compliant Epoxy Primer, Base Coat: Imron AF400, 0.040" 2024-T3 aluminum per AMS-QQ-A-250/5B**
- ✓ **Primer: Axalta Corlar 13580s Epoxy, Base Coat: Imron AF700, Clear Coat: AF740, 0.040" 2024-T3 aluminum per AMS-QQ-A-250/5B**
- ✓ **Primer: AN 10P8-11 VOC compliant Epoxy Primer, Base Coat: Imron AF700, Clear Coat: AF 740, 0.040" 2024-T3 aluminum per AMS-QQ-A-250/5B**
- ✓ **Primer: Axalta Corlar 13580s Epoxy, Base Coat: Imron AF3500, 0.040" 2024-T3 aluminum per AMS-QQ-A-250/5B**
- ✓ **Primer: AN 10P8-11 VOC compliant Epoxy Primer, Base Coat: Imron AF3500, 0.040" 2024-T3 aluminum per AMS-QQ-A-250/5B**
- ✓ **Primer: Axalta Corlar 13580s Epoxy , Base Coat: Centari 5.10, 0.040" 2024-T3 aluminum per AMS-QQ-A-250/5B**
- ✓ **Primer: High Solids Epoxy Primer (CM0483787), Base Coat: Jet Glo Express 840, 0.040" 2024-T3 aluminum per AMS-QQ-A-250/5B**
- ✓ **Primer: 10P30-5Y [Fuel tank coating], Base Coat: NA, 0.040" 2024-T3 aluminum per AMS-QQ-A-250/5B**
- ✓ **Primer: 454-4-1 [Fuel tank coating], Base Coat: NA, 0.040" 2024-T3 aluminum per AMS-QQ-A-250/5B**

Fabric Systems

- ❑ Poly-Fiber, Fabric- Polyester, Cement, Coating- Vinyl
- ❑ Ceconite/Randolph, Fabric-Polyester, Cement, Coating- Butyrate Dope
- ❑ Ceconite/Randolph, Fabric-Polyester, Cement, Coating- Nitrate Dope
- ❑ Aircraft Spruce, Fabric- Superflite Fa315bric VI, Superflite U500 Cement, Coating 2 part Urethane Fabric Primer Catalyst
- ❑ Stewart Systems, Ecobond Glue, Ekofill, Superflight Fabric VI (Aircraft Spruce), Cleaner

O-Rings

- ✓ **BunaN (Nitrile) SAE-AMS-P-5315**
- ✓ **Fluorocarbon SAE-AMS-7276**
- ✓ **Fluorosilicone SAE-AMS-R- 25988, Type I**
- ✓ **Fluorocarbon SAE-AMS-7379**
- ✓ **Fluorocarbon SAE-AMS-7826**

Aircraft Hoses

- ❑ Low Pressure Rubber hose (MIL-H-6000)
- ❑ Med. Pressure Metal Braided hose (MIL-H-8794)
- ❑ Med. Pressure PTFE hose (MIL-DTL-27267)
- ✓ **MIL-DTL-6000 Nitrile Hose**
- ❑ MIL-DTL-5593 Hose

Fuel Bladders

- ❑ Meggitt Bladder
- ❑ EAGLE Fuel Cell

OEM Wing Test

- ❑ Cirrus Materials Tests
- ❑ Van's Aircraft Materials Tests
- ❑ Textron Aviation Materials Tests
- ❑ Piper Materials Tests

** Refer to PAFI-MTP-002*

Materials Compatibility Testing Matrix

Metallics

- ❑ 1100 Aluminum
- ❑ 2017 Aluminum
- ❑ 2024-T3 Aluminum
- ❑ 2024-T351 Aluminum, hard anodize
- ❑ 2024-T4 Aluminum, hard anodize and dry film lubricant coated
- ✓ **5052-0 Aluminum**
- ❑ 6061-T6 Aluminum anodized
- ❑ 7075 Aluminum
- ✓ **AMS 4505 Brass (~C260)**
- ❑ AMS 4610 Brass (~C360)
- ❑ CA122 (ASTM B187) Brass
- ❑ C46400 Brass
- ❑ Phosphor Bronze 510
- ❑ Copper
- ❑ Lead
- ❑ Monel
- ❑ Nickel plating, electro, QQ-N-290A over cold rolled Steel
- ❑ Chrome plate, over Steel
- ❑ Tin plate, ASTM B545, Class B (Bright) over cold rolled Steel
- ❑ Zinc plate ASTM B633 SC2, Type 2 over cold rolled Steel
- ❑ 1010 Steel, Cadmium plate
- ❑ 17-4 PH Steel, passivate
- ❑ 303 Steel
- ❑ 316 Steel, passivate
- ❑ 321 Steel, passivate (stainless)
- ✓ **416 Stainless Steel**
- ❑ 440C Steel
- ❑ Chrome Steel (4140 Alloy)
- ❑ 52100 bearing Steel
- ❑ AMS 4750, QQ-S-571-SN63 lead tin solder
- ❑ Silver braze
- ❑ Plated music wire (springs) RSA Carburetor P/N CF24-A10

Non-Metallic Slab / Flat Stock

- ❑ BunaN (Nitrile) Abrasion resistant (orange)
- ✓ **BunaN (Nitrile) Med (black)**
- ❑ Nitrile (foam)
- ✓ **Fluorosilicone**
- ✓ **Viton A (FKM)**
- ✓ **BunaN/vinyl (white)**
- ❑ Phenolic
- ✓ **ABS Thermoplastic (Acrylonitrile Butadiene styrene)**
- ❑ Cork, plain back
- ❑ Cork, neoprene
- ❑ Nylon 6/6
- ❑ Glass-filled Nylon 6
- ❑ Leather
- ❑ Safety Foam
- ❑ Fairprene RSA carb seal P/N 626536 fuel manifold valve
- ❑ Polyester sheet
- ❑ Neoprene
- ❑ Polyester film (Mylar)
- ❑ Silicone
- ❑ Teflon (adhesive ready)
- ❑ Polypropylene (flame retardant)
- ❑ Fiberglass Fabric reinforced silicone
- ❑ Epichlorohydrin - foam
- ❑ ASTM D710 vulcanized fiber (red)
- ❑ Polyurethane
- ❑ Delrin

Other OEM Parts

- ❑ Piper 187-433 Synthetic Rubber Sheet (MIL-PRF-6855); 2’ x 2’
- ❑ Piper 462-049 Gaskets (ASTM D2000); 10 ea.
- ❑ Piper 462-056 Gaskets (ASTM D2000); 10 ea.
- ❑ Piper 106927-001 Duckbill Check Valve (ASTM D2000); 10 ea.
- ❑ Lycoming BN-0002.05 Fairprene Sheet; 2’ x 2’ sheet

Non-Metallic Finished Parts

- ❑ Epoxy carb floats
- ❑ 3M Scotch Weld Epoxy adhesive, EC2216
- ❑ Hysol EA9628 Epoxy with Solvay BR-127 Epoxy Primer
- ❑ Loctite 290
- ❑ Loctite 569 (dimethacrylate ester)

** Refer to PAFI-MTP-002 and ASTM D7826*

Materials Compatibility Testing Matrix – Polysulfide Sealants

Polysulfide Sealants

- ✓ **PR-1773 B-2 Polysulfide AMS 3284**
- ✓ **P/S 890 A-2 Polysulfide, AMS 8802**
- ❑ P/S 890 A-2 Polysulfide, AMS 8802, 2 aluminum panels (each), AMS4045, sulfuric acid anodized in accordance with AS5127 (6.3) and coated with AMS-C-27725 Type 2.
- ✓ **PR 1422 Polysulfide AMS-S-8802 Type 1, Class B-2**
- ❑ PR 1422 Polysulfide AMS-S-8802 Type 1, Class B-2, See AS5127 §8.1.1
- ✓ **PR-1440B Polysulfide AMS-S-8802 Type 2, Class B-2**
- ❑ PR-1440B Polysulfide AMS-S-8802 Type 2, Class B-2, 2 aluminum panels (each), AMS4045, sulfuric acid anodized in accordance with AS5127 (6.3) and coated with AMS-C-27725 Type 2.
- ❑ PR-2001B Polythioether AMS-3277 Type 2, Class B-2
- ❑ PR-2001B Polythioether AMS-3277 Type 2, Class B-2, 2 Aluminum alloy, AMS4045, panels, sulfuric acid anodized in accordance with AS5127 (6.3) and coated with AMS-C-27725.
- ✓ **Aerospace Sealant AC-350 Polysulfide, AMS 3276 Type 2, Class B-2**
- ❑ Aerospace Sealant AC-350 Polysulfide, AMS 3276 Type 2, Class B-2, 2 Aluminum panels, AMS4045, sulfuric acid anodized in accordance with AS5127 (6.3) and coated with AMS-C-27725 Type 2.
- ✓ **PR1776M or AC-370 B-1/2 Polysulfide, AMS-3281 Type 1, Class B-1/2**
- ❑ PR1776M or AC-370 B-1/2 Polysulfide, AMS-3281 Type 1, Class B-1/2, 2 aluminum test panels chemically treated according to AS5127 (6.2) shall be used. After conversion coating, the sealing compound shall be applied to the peel strength test panels as described in AS5127/1 (8.1.1).
- ❑ PR1776M or AC-370 B-1/2 Polysulfide, AMS-3281 Type 1, Class B-1/2, 2 FRC (Toray Advanced Composites BT250E-1/E-glass) test panels shall be grit blasted with aluminum oxide and/or abrasion with aluminum oxide sandpaper. After abrading the surfaces, the sealing compound shall be applied to the peel strength test panels as described in AS5127/1 (8.1.1).
- ❑ PR-1005-L Buna-N fuel tank topcoat; “Slosh Coat”, AMS-S-4383
- ❑ AMS-S-83318 Class B (3M AC-250 or PPG PS860)
- ❑ AMS-S-83318 Class B (3M AC-250 or PPG PS860), 2 AMS4045 aluminum test panels chemically treated according to AS5127 (6.2) shall be used. After conversion coating, the sealing compound shall be applied to the peel strength test panels as described in AS5127/1 (8.1.1).

** Refer to PAFI-MTP-002*

Materials Compatibility Testing Matrix – Distribution Components

Distribution System

- ❑ Distribution Hoses
  - ❑ MFC
  - ❑ Continental ContiTech Aeropal refueling hose, Inner liner is NBR, exterior cover is CR (chloroprene)
  - ❑ Hewitt Husky 4113 permanent aviation hose, Inner liner is NBR, exterior cover is neoprene
  - ❑ Goodyear Advantage Petroleum Aircraft Fueling hose, Inner liner NBR, exterior cover Wingprene™ synthetic rubber
  - ❑ Parker Gold Label Aircraft Fueling Hose Series 7776 CT (cold temperature), Inner liner is NBR, exterior cover is conductive nitrile
- ❑ Lining
  - ❑ Chemliner 4000, High Solid, Novolac Epoxy Lining Coated Sheet of 1018 Low Carbon Steel
  - ❑ Chemthane 4200PW, Solvent-Free Two Component Polyurethane Coated Sheet of 1018 Low Carbon Steel
- ❑ Filters/Coalescers
  - ❑ Paper Pleated Fuel Filter, Facet Fuel-Gard, VF-21SB, Filter Cartridge P/N: CF-609-2PLO, CF-609-5PLO
  - ❑ Paper Pleated Fuel Filter for Velcon VF-61 Housing, P/N; FO512PL-05
  - ❑ Coalescer/ Separator Cartridge, Facet Fuel Guard, VF-21SB, P/N: CC-21-7
  - ❑ Coalescer/ Separator Cartridge, Velcon, P/N: OS-51288
  - ❑ Housing, Velcon, P/N: VF-61
  - ❑ Housing, Facet Fuel Gard Series

Refer to PAFI-MTP-002 and ASTM D7826

Materials Compatibility Testing Matrix – Composite Materials

Composites

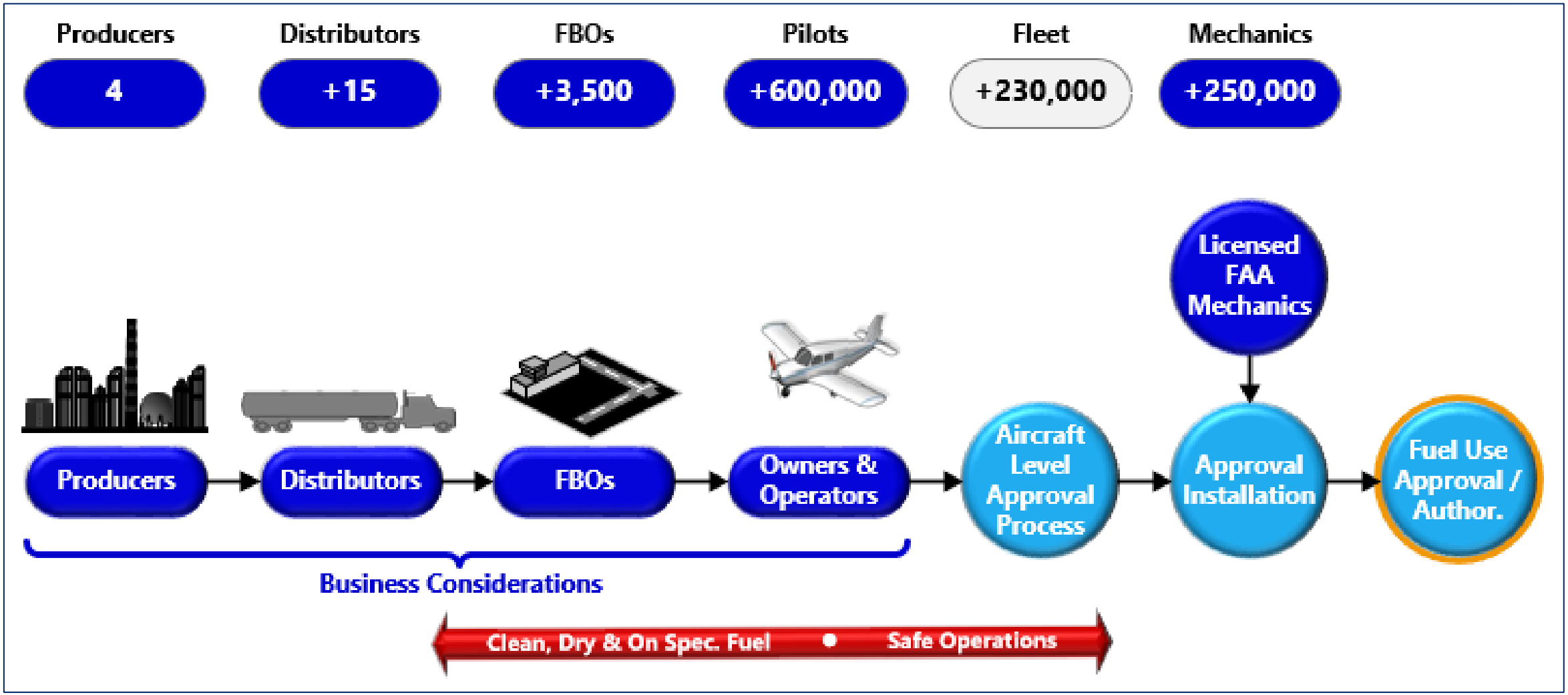
- ❑ **Resin Pre-Screening (16 materials)**
  - ❑ Bis A Epoxy with Slow Cure – EZ-Poxy EZ10A resin with EZ87B curative without fiber
  - ❑ Bis A Epoxy with Slow Cure – PTM&W Aeropoxy PR 2032 resin with PH3660 curative without fiber
  - ❑ *Bis A Epoxy with Fast Cure – Hexion MGS 285 with cycloaliphatic amine H287 curative without fiber
  - ❑ *Bis A Epoxy with Slow Cure – Hexion MGS 285 with cycloaliphatic amine H285 curative without fiber
  - ❑ Bis A Epoxy with Slow Cure – Hexion L 335 with cycloaliphatic amine H338 or H340 curative without fiber
  - ❑ Bis A Epoxy with Slow Cure – LAM-125 with LAM-229 curative without fiber
  - ❑ Bis F Vinyl – West System 105 with slow primary amine curative 209 without fiber
  - ❑ Bis F Vinyl – DPL 862 with TETA curative without fiber
  - ❑ Bis F Vinyl – RHINO 9700A with 9700B 30% TETA curative without fiber
  - ❑ *Bis F Vinyl with fast primary amine curative – Hexion 8014 with TETA curative without fiber
  - ❑ *Vinyl Ester – Derakane 470 with MEKP catalyst without fiber
  - ❑ Vinyl Ester – Derakane Signia 411-350 with MEKP catalyst without fiber
  - ❑ Epoxy – Toray Advanced 2510 Prepreg (unidirectional on T700G carbon fabric)
  - ❑ Non-toughened pre-preg – Toray Advanced Composites BT250 E1 on E-glass (fiberglass) fabric
    - ❑ PTM-W ES6292 low temperature cure epoxy paste adhesive samples using laminates constructed from Toray Advanced Composites BT250E-1 E-glass prepreg
  - ❑ Toughened Pre-preg – ACG MTM 45-1 on Carbon Fiber Fabric
  - ❑ Hysol EA 9360 low temperature cure epoxy adhesive samples using laminates constructed from ACG MTM 45-1 toughened pre-preg
- ❑ **Finished Composites - Property Testing. (6 to 18 materials)**
  - ❑ **Any of the above 12 resins not marked with * which have failed the pre-screening above: Built up on E-glass fiber**
  - ❑ *Bis A Epoxy with Fast Cure – Hexion MGS 285 with cycloaliphatic amine H287 curative on E-glass (fiberglass) fabric
  - ❑ *Bis A Epoxy with Slow Cure – Hexion MGS 285 with cycloaliphatic amine H285 curative on E-glass (fiberglass) fabric
  - ❑ *Bis F Epoxy with fast primary amine curative – Hexion 8014 with TETA curative on E-glass (fiberglass) fabric
  - ❑ *Vinyl Ester – Derakane 470 on E-glass (fiberglass) fabric
  - ❑ PVC Structural Foam (Diab Divinycell HT 61—Trademarked)
  - ❑ Rigid Polyurethane Foam (General Plastics FR-3700 Last-A-Foam—Trademarked)

** Refer to PAFI-MTP-002*

Supply Chain Infrastructure and Deployment

Presented by Karen Huggard, NATA

Scope


Producers
4
Distributors
+15
FBOs
+3,500
Pilots
+600,000
Fleet
+230,000
Mechanics
+250,000
Licensed FAA Mechanics
Producers
Distributors
FBOs
Owners & Operators
Aircraft Level Approval Process
Approval Installation
Fuel Use Approval / Author.
Business Considerations
Clean, Dry & On Spec. Fuel
Safe Operations

Inform – Support – Outreach

- **Inform**
  - Regulatory and policy proposals
  - EPA / FAA Rulemaking
  - Stakeholder decisions on transition
- **Support** EAGLE Pillars

  through
- **Outreach** to Stakeholders
- Content Development
  - Awareness, education, and guidance
  - Tools
  - Programs
  - Metrics

Key Challenges

- Maintaining 100LL avgas during transition
- Risk of mis-fueling
- Complexity of transition
- Independent state / local government action
- One TEL (lead) supplier

Perspectives and Needs

- Fixed Base Operators (FBOs) and Distributors – Curt Castagna, NATA
- Manufacturers – Pete Bunce, GAMA
- Rotorcraft – Jim Viola, VAI
- Communities – Jack Pelton, EAA
- Pilots – Mark Baker, AOPA

Stakeholder Questions and Answers

Please raise your hand so a representative can bring you a microphone.

Next meeting: Thursday, October 31, 2024; Virtual

Aviation Gasoline Forums at AirVenture 2024

Date, Time, Location	Presentation and Presenter
Wednesday, July 24 **8:30 AM – 9:45 AM at Forum Stage 11**	**UL100E PAFI Testing Update** **Presented by LyondellBasell**
Tuesday, July 23 **10:00 AM – 11:15 AM at Ultralight Forum Tent** **Thursday, July 25** **8:30 AM – 9:45 AM at Forum Stage 2**	**Swift Fuels Unleaded Avgas** **Presented by Swift Fuels**
Thursday, July 25 **11:30 AM – 12:45 PM at Forum Stage 8**	**Will Your Engine Survive Unleaded?** **Presented by GAMI**

Thank you!

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