

CAAFI Fuel Readiness Level Pass/Fail Criteria List
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FRL Level	FRL Description	Preliminary Toll Gate	Detailed Pass/Fail Criteria	Fuel Quantity	SPK reqts (blend component)	50/50 SPK/jet req't	notes
1	Basic Principles Observed and Reported	Feedstock and process basic principles identified	Feedstock identified	none	volume/mass req't ?		
			Conversion process identified		known chemistry?		
2	Technology Concept Formulated	Feedstock and complete process identified	Full pathway including all required steps identified.	none	where? how?		
			Cultivation.				
			Harvest.				
			Densification/logistics.				
			Feedstock refinement/cleaning				
			Conversion process steps				
		Final fuel product(s) and any coproducts identified					
3	Proof of Concept/Entrance Criteria	Small fuel sample available from lab basic fuel properties validated	Laboratory-scale production established	500 ml	report report < -40 C T90-T10>22 C <15% cycloparaffins >42.8 MJ/kg 0.73-0.77 >38 C <0.5 vol%	n/a n/a n/a n/a n/a n/a n/a n/a	a fully synthetic fuel would probably have to meet the SPK trace materials requirements and the 50/50 blend properties performed by AFRL -47 C for JP-8/Jet A-1
			First fuel produced via complete process identified in FRL 2				
			Independent confirmation of basic characteristics				
			MSDS provided by supplier				
			Thermal Stability (Quartz Crystal Microbalance)				
			Freeze Point (ASTM D5972)				
			Distillation (ASTM D86/D2887)				
			Hydrocarbon Type (ASTM D6379 & D2425)				
			Heat of Combustion (ASTM D4809)				
			Density (ASTM D4052)				
			Flash Point (ASTM D93)				
			Aromatics (ASTM D2425)				
4	Preliminary Technical Evaluation	4.1 - System performance and integration studies	Eval of integration into existing aircraft				
			Fuel gauge compatibility evaluated				
			Performance effects (for performance maps) evaluated				
			Aircraft range effects evaluated				
			Aircraft payload effects evaluated				
4	Preliminary Technical Evaluation	4.2 - Entry Criteria/Specification Properties Evaluated	Fuel produced at laboratory scale for further testing	10 gal (re-verification tests on synthetic then tests on blend)	<0.015 <0.5 vol% <0.0015 mass% n/a T90-T10>22 C T10<205 C FBP<300 C >38C 0.73-0.77 <-40 C n/a >42.8 MJ/kg n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a >325 C breakpoint n/a	<0.015 8-25 vol% <0.3 mass % <0.003 mass % T90-T10>40 T10<205 FBP<300 >38 C 0.775-0.84 <-40 C <8 cSt (-20) >42.8 MJ/kg n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a Pass at 260 C <0.85 mm	ASTM D7566 Table A1.1 and A1.2 for SPK; Table 1 for blend or >18 if naphthalenes <3 vol% if smoke point <25 in JP-8 in JP-8 JP-8 requires lubricity additive
			Total Acid Number (ASTM D3242)				
			Aromatics (ASTM D2425 & D6379)				
			Sulfur (ASTM D2622/5453)				
			Sulfur Mercaptan (ASTM D3227)				
			Distillation Temperature (ASTM D86)				
			Flash Point (ASTM D56, D93, or D3828)				
			Density (ASTM D1298 or D4052)				
			Freezing Point (ASTM D2386, D5972, D7153, or D7154)				
			Viscosity at -20°C & -40°C (ASTM D445)				
			Net Heat of Combustion (ASTM D4809)				
			Hydrogen Content (ASTM D3343 or D3701)				
			Smoke Point (ASTM D1322)				
			Naphthalenes (ASTM D1840)				
			Copper Strip Corrosion (ASTM D130)				
			Existent Gum (ASTM D381)				
			Particulate Matter (ASTM D2276 or D5452)				
			Filtration Time (MIL-DTL-83133F Appendix B)				
			Water Reaction Interface Rating (ASTM D1094)				
			Electrical Conductivity (ASTM D2624)				
Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels (JFTOT) Procedure (ASTM D3241)							
Lubricity Evaluation-BOCLE Test (ASTM D5001)							

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			Fuel System Icing Inhibitor (FSII) (ASTM D5006)		n/a report	in JP-8
			Gas Chromatography (Chemical Description)			
			Detect, Quantify, and/or Identify Polar Species - analyze as necessary		report	AFRL and SwRI testing
			Detect, Quantify, and/or Identify Dissolved Metals - ASTM D7511/UOP 389		<0.1 mg/kg (100 ppb) per "metal"	n/a
			Halogens ASTM D7359		<1 mg/kg	D7566-09 Table A1.2
			Water ASTM 6304		<75	D7566-09 Table A1.2
			Hydrocarbon composition (D2425)		<15%	D7566-09 Table A1.2
			Nitrogen D4629		cycloparaffins	D7566-09 Table A1.2
			Low Temperature Properties - Scanning Brookfield Viscosity		<2 mg/kg	D7566-09 Table A1.2
			Renewable Carbon Test (ASTM D 6866)		report	
			Literature Search on the fuel candidate and components		report	
5	Process Validation	5.1 Laboratory Production Development	Increased laboratory scale production			
		5.2 - Subscale Production demonstrated	Confirmation of fuel properties at larger scale production			
		5.3 - Scalability of production demonstrated	Confirmation of fuel properties at larger scale production?			
		5.4 - Pilot plant capability enabled	Opening of facility outside of lab Confirmation of fuel properties at larger scale production			
6	Full Scale Technical Evaluation	6.1 - Fit for Purpose Properties Evaluated	Fit for purpose properties to be evaluated at lab production scale	80 gal		
			Initial Material Compatibility Evaluation - typical o-ring/elastomer swell on limited set of materials		equivalent to JP-8/Jet A or better compatible	AFRL and SwRI testing
			Additive Compatibility (ASTM D4054-09)			
			Autoignition Temperature (ASTM E659)			see ASTM D4054-09 Figure A1.6; test method still being validated
			Bulk Modulus (ASTM D6793)		equivalent to JP-8/Jet A	see ASTM D4054-09 Figure A1.8
			Dielectric Constant vs T, density (ASTM D924)		report	see ASTM D4054-09 Figure A1.9
			Electrical conductivity vs concentration of SDA			
			Flammability Limits (ASTM E681)			
			Hot Surface Ignition (Federal Test Standard 791C Method 6053 or ISO 20823 Hot Surface Temperature)			
			Lubricity (ASTM D5001) as a function of concentration of CI/LI additive		equivalent to JP-8/Jet A or better	see ASTM D4054-09 Figure A1.2
			Specific Heat (as a Function of Temperature)		equivalent to JP-8/Jet A or better	see ASTM D4054 Fig A1.3; test method still being validated
			Storage Stability (MIL-STD-3004)		equivalent to JP-8/Jet A or better	
			Surface Tension vs. Temperature (ASTM D971 or D1331)		equivalent to JP-8/Jet A	see ASTM D4054-09 Fig A1.5
			Thermal Conductivity vs. Temperature (ASTM D2717)		equivalent to JP-8/Jet A	see ASTM D4054-09 Fig A1.7
			Vapor Pressure , True vs. Temperature (ASTM D5191 or D323)		equivalent to JP-8/Jet A	
			Viscosity vs. Temperature		equivalent to JP-8/Jet A or better (less at low T)	see ASTM D4054-09 Fig A1.1
			Density vs. Temperature		equivalent to JP-8/Jet A	see ASTM D4054-09 Fig A1.4
			ESOH review			

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			Ames Mutagenicity Test		report equivalent to JP-8/Jet A	report equivalent to JP-8/Jet A	limits being developed - typical jet fuel 38-48. Cetane index inaccurate for synthetic fuels		
			Dermal Irritation Test						
			Acute Oral or Inhalation Test						
			Cetane Number (ASTM D613, D6890)						
			Ostwald Coefficient/Gas Solubility (ASTM D2779)						
			Hot Surface Ignition						
			Electrical Conductivity vs. Temperature					equivalent to JP-8/Jet A	
			Velocity of Sound					equivalent to JP-8/Jet A	limits being developed - needed for some fuel gauging systems
			Minimum Ignition Energy					equivalent to JP-8/Jet A	
			Low Temperature Fuel Nozzle Spray Test					spray equivalent to Jet A/JP-8 or better	
			Two week rangefinder with genotoxicity					equivalent to Jet A/JP-8 or better	
			Human Lymphocyte Genotoxicity					equivalent to Jet A/JP-8 or better	
			Conduct a 90-day toxicity test with doses based on 2 week rangefinder study					equivalent to Jet A/JP-8 or better	
		6.2 Materials Compatibility Evaluation							
			D4054 Short List (37 materials) (Tables A3.2 and A3.3) or as defined by OEMs	50-300 gals		equivalent to Jet A/JP-8 or better	Scope of evaluation will depend upon fuel chemistry		
		6.3 Turbine Hot Section Testing	Hot Section Oxidation/Erosion	2000-5000 gal		equivalent to Jet A/JP-8 or better (less material loss/reaction)	all industry OEMs have testing capability		
		6.4 - Component/Rig/Emissions Testing	Fuel pump test	100 - 2000 gal		Durability similar to Jet A/JP-8 or better	e.g. SwRI Industry team developing common methodology - figures of merit - lean blow out, starting, altitude restart, pattern factor, comb efficiency, emissions		
			Fuel nozzle durability (coking) test	TBD		Durability similar to Jet A/JP-8 or better			
			Combustor rig testing	50-5000 gal		Operability similar to Jet A/JP-8			
			Fuel system/controls rig testing	TBD		Durability similar to Jet A/JP-8			
			Advanced Reduced Scale Fuel Simulator System- evaluation of fuel's coking tendency in large-scale test rig with actual airframe components	1000 gal		equivalent to Jet A/JP-8 or better			
		6.5 - Engine/APU testing	Engine/APU/Demo Flights				Proposed		
			Short duration small engine/APU testing	50-500 gal		equivalent to Jet A/JP-8 or better	Includes emissions measurements		
			Small engine/APU durability demonstration	4000 gal for 150 hr T63		equivalent to Jet A/JP-8 or better			

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			Short duration large engine testing	1000-5000 gal	equivalent to Jet A/JP-8 or better	Includes emissions measurements
			Large engine durability demonstration	~500,000 gal	equivalent to Jet A/JP-8 or better	single/multiple engines - not flight testing
			Short duration flight demonstration	1000-5000 gal	equivalent to Jet A/JP-8 or better	
7	Certification/Fuel Approval	Fuel Class/Type Listed in International Fuel Standards				
			Fuel Handling and Storage Systems Analysis			
			Aircraft Flight Evaluations as "Pathfinders", by aircraft class (e.g. for military - fighter, transport, high altitude surveillance)			
			All Others by Analysis/Similarity (Using pathfinder and validation/certification analysis/test/demonstration data.)			
			Toxicity Testing: Conduct additional studies that were recommended based on the results of the 90-day study and health hazard assessment.			
			Exposure Assessment: The Health Hazard Assessment should be reviewed or revised using additional exposure assessment and toxicity data. This would result in verification or an update of exposure limits (standards) for safe use of the alternative fuel.			
			Environmental: Conduct additional studies that were recommended based on the results of Subset 1.			
8	Commercialization Validated	Business Model Validated for Production Go-Ahead	Business Model Validated for Production Go-Ahead			
		Airline/Military Purchase agreements	Airline/Military Purchase agreements			
9	Production Capability Established	Full Scale Plant Operational				