

CAAFI Fuel Readiness Level Pass/Fail Criteria List  
-DRAFT-

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 process 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					
			Materials compatibility evaluated					
			Aircraft range effects evaluated					
			Aircraft payload effects evaluated					
		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)				
			Total Acid Number (ASTM D3242)			<0.015	<0.015	
			Aromatics (ASTM D2425 & D6379)			<0.5 vol%	8-25 vol%	
			Sulfur (ASTM D2622/5453)			<0.0015 mass%	<0.3 mass %	
			Sulfur Mercaptan (ASTM D3227)			n/a	<0.003 mass %	
			Distillation Temperature (ASTM D86)			T90-T10>22 C	T90-T10>40	
						T10<205 C	T10<205	
						FBP<300 C	FBP<300	
			Flash Point (ASTM D56, D93, or D3828)			>38C	>38 C	
			Density (ASTM D1298 or D4052)			0.73-0.77	0.775-0.84	
			Freezing Point (ASTM D2386, D5972, D7153, or D7154)			<-40 C	<-40 C	
			Viscosity at -20°C & -40°C (ASTM D445)			n/a	<8 cSt (-20)	
Net Heat of Combustion (ASTM D4809)			>42.8 MJ/kg	>42.8 MJ/kg				
Hydrogen Content (ASTM D3343 or D3701)			n/a	n/a				
Smoke Point (ASTM D1322)			n/a	>25 mm	or >18 if naphthalenes <3 vol% if smoke point <25			
Naphthalenes (ASTM D1840)			n/a	<3 vol%				
Copper Strip Corrosion (ASTM D130)			n/a	No. 1				
Existent Gum (ASTM D381)			n/a	<7 mg/100 mL				
Particulate Matter (ASTM D2276 or D5452)			n/a	n/a	in JP-8			
Filtration Time (MIL-DTL-8313F Appendix B)			n/a	n/a	in JP-8			
Water Reaction Interface Rating (ASTM D1094)			n/a	n/a				
Electrical Conductivity (ASTM D2624)			n/a	n/a				
Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels (JFTOT) Procedure (ASTM D3241)				>325 C breakpoint	Pass at 260 C			

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			Lubricity Evaluation-BOCLE Test (ASTM D5001)		n/a	<0.85 mm	JP-8 requires lubricity additive in JP-8	
			Fuel System Icing Inhibitor (FSII) (ASTM D5006)		n/a			
			Gas Chromatography (Chemical Description)		report			
			Initial Material Compatibility Evaluation - typical o-ring/elastomer swell on limited set of materials		report	report		AFRL and SwRI testing
			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		D7566-09 Table A1.2
			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			
					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				
			Material Compatibility Evaluation - short list					
			Additive Compatibility (ASTM D4054-09)				performed by AFRL/RX (in D4054)	
			Autoignition Temperature (ASTM E659)				see ASTM D4054-09 Figure A1.6; test method still being validated	
			Bulk Modulus (ASTM D6793)					
			Dielectric Constant vs T, density (ASTM D924)				equivalent to JP-8/Jet A	
			Electrical conductivity vs concentration of SDA				see ASTM D4054-09 Figure A1.8	
			Flammability Limits (ASTM E681)				see ASTM D4054-09 Figure A1.9	
			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	
			Specific Heat (as a Function of Temperature)				equivalent to JP-8/Jet A or better	
			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	
			Thermal Conductivity vs. Temperature (ASTM D2717)				equivalent to JP-8/Jet A	
			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)	

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			Density vs. Temperature			equivalent to JP-8/Jet A	see ASTM D4054-09 Fig A1.4  limits being developed - typical jet fuel 38-48. Cetane index inaccurate for synthetic fuels
			ESOH review				
			Ames Mutagenicity Test				
			Dermal Irritation Test				
			Acute Oral or Inhalation Test				
			Cetane Number (ASTM D613, D6890)		report equivalent to JP-8/Jet A	report equivalent to JP-8/Jet A	
			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	
			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 Conduct a 90-day toxicity test with doses based on 2 week rangefinder study			equivalent to Jet A/JP-8 or better	
		6.2 Turbine Hot Section Testing	Hot Section Oxidation/Erosion	2000-5000 gal		equivalent to Jet A/JP-8 or better (less material loss/reaction)	
		6.3 - 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  Proposed
			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	
		6.4 - Engine/APU testing	Engine/APU/Demo Flights				Includes emissions measurements
			Short duration small engine/APU testing	50-500 gal		equivalent to Jet A/JP-8 or better	
			Small engine/APU durability demonstration	4000 gal for 150 hr T63		equivalent to Jet A/JP-8 or better	
			Short duration large engine testing	1000-5000 gal		equivalent to Jet A/JP-8 or better	

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			Large engine durability demonstration	~500,0000 gal		equivalent to Jet A/JP-8 or better	
			Short duration flight demonstration	1000-5000 gal		equivalent to Jet A/JP-8 or better	single/multiple engines - not flight testing
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					