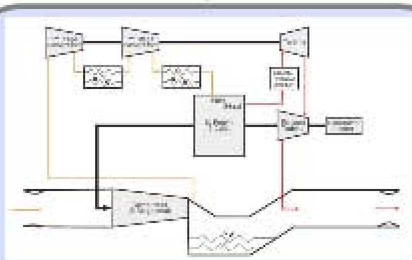
High Altitude Low Cost Configurable Jet Engine Trade Study

STATUS QUO

Current UAV High Altitude Record for Air-Breathing Power Plants is 65,381 feet, Combined with High SFC's and Lower On-Station Persistance

NEW INSIGHTS



Recent Research on Turbocharged Compound 2-Stroke IC Engines at High Altitude Combined with Low Pressure Ratio Jet Propulsion, has Demonstrated High Power Density & Substantial Reductions in SFC's up to 100 kft

TRADE STUDY ACHIEVEMENT

MAIN ACHIEVEMENT:

- Qualitative & Quantitative Assessment of Propulsion Concept and Air Vehicle Configuration Compromises and Performance Benefits
- Major Trades to be Assessed: Adiabatic Expansion Chamber and Port Area Time, 3-Wheel High Pressure Ratio Turbocharger, Primary Shaft-Driven Compressor, Compound Power Recovery Turbine, ICE Compression Ratio, 2-Stream Droplet Heat Exchanger, Thermal Management, Mass Properties, Scaling, & Performance
- Configuration & Performance in Subsonic Airframes & Flow Regimes to be Assessed

HOW IT WORKS:

- Adiabatic Expansion Chamber Operates Choked at High Power Density Level
- Leverages Choked Characteristic to Reduce SFC via Compound Power Recovery Turbine
- Leverages Remaining ICE Exhaust Stream Energy to Increase Jet Pipe Stream Enthalpy
- Low Pressure Ratio Jet Propulsion Provides Lower SFC's at Higher Altitudes with Low Plume Temps

ASSUMPTIONS AND LIMITATIONS:

- ICE Derived From Rotax FR125 Max COTS Engine
- Breadth & Depth of Study Analyses will be Dependent on DARPA Program Schedule & Funding

QUANTITATIVE IMPACT

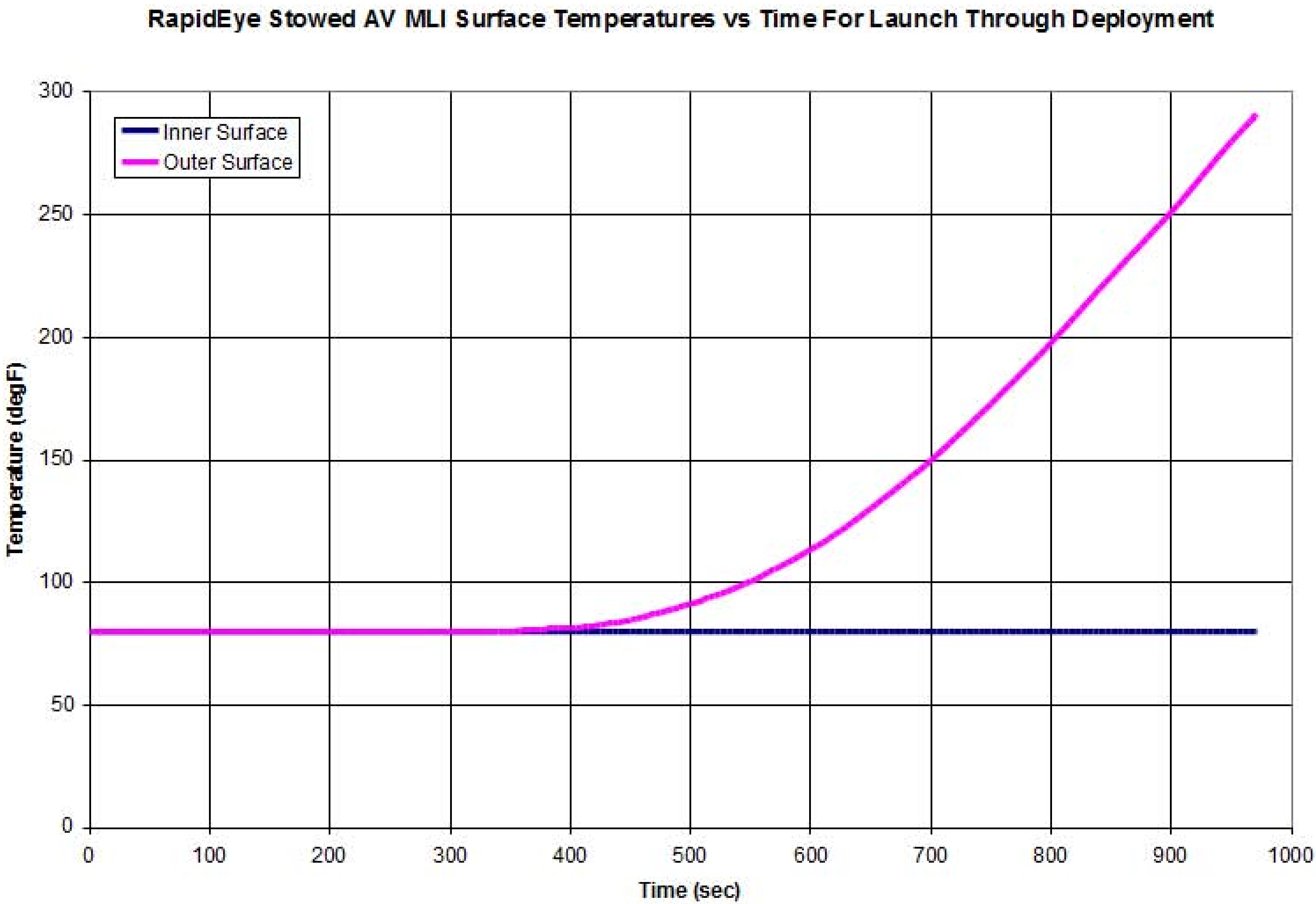
Trade Study Reduces Technical Risks Associated with Airframe Integration of Propulsion Concept while Narrowing the Design & Development Space Toward Optimal Configurations & Technology

END-OF-PHASE GOAL

- *Qualitative & Quantitative Description of Relationships Between Major Trade Parameters and Air Vehicle Performance*
- *Parameter Ranges for Optimal Performance & Endurance*
- *Identification of Component Sizing to Maximize Performance and Flight Envelope*

Specific Fuel Consumption of Less Than 0.6 pph/lbf is Attainable at 100 kft and Mach 0.4

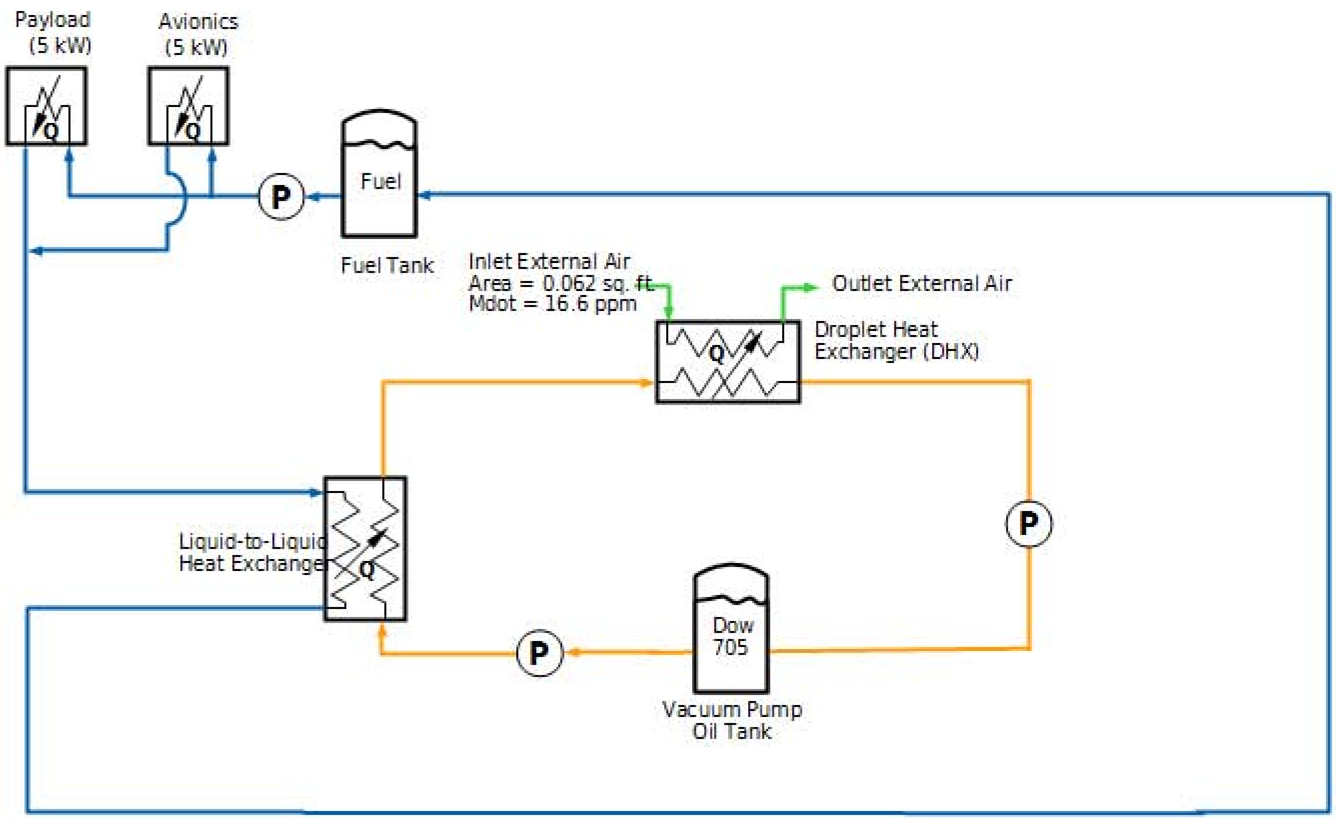
Launch-to-Deployment Stowed AV Backface Temperature vs. Time:



Use Fuel as Coolant for Avionics & Payload:

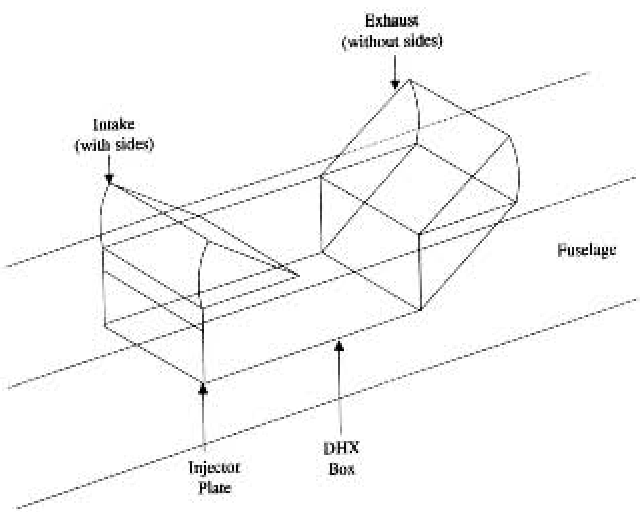
- Used as intermediate coolant loop fluid
- Safety-of-flight issues associated with flammability of coolant leaks
- Marginal value as energy sink to engine consumed fuel
- Assumptions:
  - Maximum Avionics Power Dissipation Load = 5 kW
  - Maximum Payload Power Dissipation Load = 5 kW
  - Avionics & Payload are Liquid-Cooled Using JP4
  - Jet Engine Fuel Pump Provides Flow Pressure differential
  - No Engine Air Bleed is Required
  - Ram-Air to Liquid Fuel Heat Exchanger Air deltaP is 50 percent Dynamic Pressure
  - Maximum Liquid Fuel Inlet Temperature = 100 degF
- Conclusion:
  - Combined Frontal Area of Ram-Air Heat Exchanger = 1.6 sq. ft.
  - Combined Weight of Ram-Air Heat Exchanger = 4.6 lbm

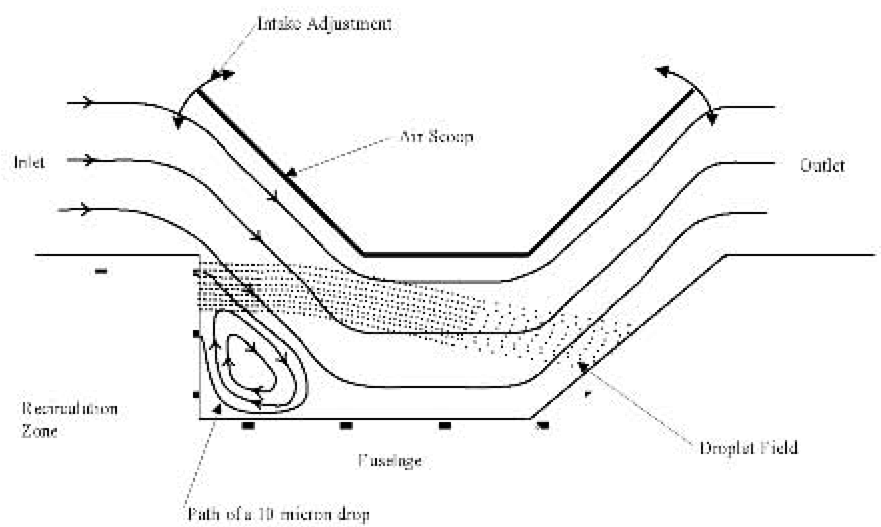
Direct-Contact/"Droplet" Heat Exchanger (DHX) System Schematic Overview:



Direct-Contact/"Droplet" Heat Exchanger (DHX) for Avionics & Payload Heat Loads:

- Injects Dow 705 Vacuum Pump Oil Directly into Ducted Air Stream
- Higher Heat Transfer Effectiveness Due to Higher Thermal Contact Area
- Negative Drag Coefficient Due to Heated Air Acceleration
- Low Vapor Pressure Mitigates Vaporization @ High Altitude
- Air Duct Designed To Recapture Liquid & Mitigate Fluid Loss





Reference: S.C. Bates, "UAV Droplet Heat Exchanger," SBIR Phase I Final Report, NASA Contract # NAS4-97018, Sept. (1997).

Estimated AV Fuel Temperature Increase Due to Pre-Deployment Avionics Power Dissipation:

- Assumptions:
  - Maximum Pre-Deployment Power Dissipation Avionics Load = 1 kW
  - Pre-Deployment Power Dissipation Avionics are Liquid Convective Coupled to a Minimum of 500 lbm JP4 AV fuel
  - Maximum Duration of Pre-Deployment Power Dissipation Avionics = 3 hours
  - Specific Heat of JP4 = 0.485 btu/lbm-degF
  - Maximum Initial JP4 Fuel Temperature = 80 degF
- Calculation:
  - DeltaT = (time [hr]) x (power[kW]) x (3412 btu/hr-kW) / ((mass fuel[lbm]) x (specific heat[btu/lbm-degF])
  - Max deltaT Fuel = 42.2 degF = (3 hr)(1 kW)(3412 btu/hr-kW)/((500 lbm fuel)(0.485 btu/lbm-degF))
  - Maximum Final Fuel Temperature = 80 degF + 42.2 degF = 122.2 degF
- Conclusion:
  - Maximum Final Fuel Temperature of 122 degF is Less Than 130 degF (typical upper limit of fuel cooled jet engine control electronics), and is Acceptable Given Conservative Nature of Assumptions.

Summary

- Storage Environment: Stored in enclosure with conditioned air not exceeding 80 degF
- Pre-Launch Environment: Conditioned air supplied to stowed AV not exceeding 80 degF
- Launch to AV Deployment:
  - AV Fuel used as thermal sink for power dissipating avionics (< 1 kW)
  - MLI blanket insulation reduces stowed AV to a maximum backface temperature of 100 degF
- Powered Flight:
  - "Droplet" Heat Exchanger (DHX) using Dow 705 Vacuum Pump Oil and engine fuel as the inner cooling loop fluid for liquid-cooled avionics and payload
  - No engine air bleed is required