Aerospace and Aircraft Thermoelectric Applications

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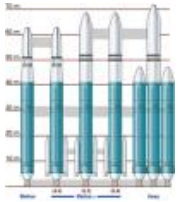
Agenda

- What is “Aerospace”?
- How can thermoelectric contribute?
- Limitations & Suggested Improvement
- Aircraft Application
- Comparison of aircraft power generation means
- Potential benefit assessment

What is “Aerospace” ?

- Anything that flies

Boeing 787



Delta-IV

Space Shuttle

Space Station

702 Satellite

Lunar Lander

- Defense

F-18A Hornet

V-22 Osprey

C-17 Globemaster

B-1B Lancer

FCS Vehicle

Network Centric Operation

- Associated infrastructures

Radar Station

Air Traffic Management

Communication Center

Flight Training

Logistics

Maintenance

Characterizing Aerospace Applications

- Application Environment – Severe, e.g., vibration and thermal swing
- Life Cycle – Long, e.g., 30 years for airplane
- Complexity – High, e.g., chip-board-box-subsystem-system integrated systems
- Volumetric – Limited, e.g., cockpit & launch vehicle payload profile
- Cost – High, e.g., FAA certified
- Safety – High to extremely high, e.g., human life

How can Thermoelectric Contribute?

- Reduce Weight, e.g., high-efficiency cooling eliminating liquid cooling and associated thermal management weight
- Improve Performance, e.g., communication RF front end cooling reduces noise
- Improve System Efficiency, e.g., paired with solar cell to produce more power
- Reduce Cost, e.g., reduce fuel consumption through aircraft engine waste heat harvesting
- New Capabilities

Limitations & Suggested Improvement

Thermoelectric Device

- Efficiency Limitation: Available thermoelectric devices on the market have relatively low efficiencies and generally can't compete with alternative approaches
- Costs Limitation: For large scale and broad applications, the cost must be reduced.
- Suggested improvement: Develop high-efficiency devices that can be manufactured in volume with cost-effective techniques.

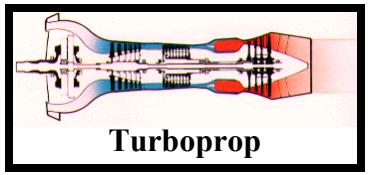
Aerospace Platform

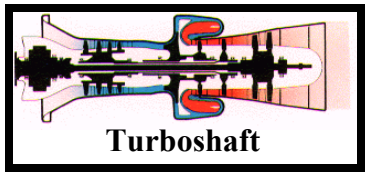
- Space and Weight Limitations: Highly weight sensitive with limited space
- ΔT Environment Limitation: Sustainable operating environment must be provided to match candidate device performance profile, e.g., operating temperature range vs. achievable energy conversion efficiency
- Suggested improvements: Choose high payoff applications capable of circumventing above limitations to a maximum degree

Aircraft Engine Waste Heat Harvesting has Large Potential Payoffs











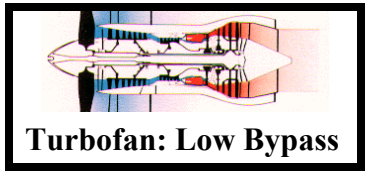




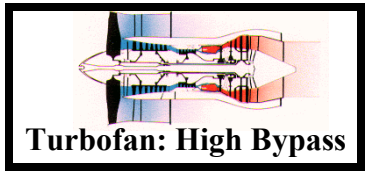






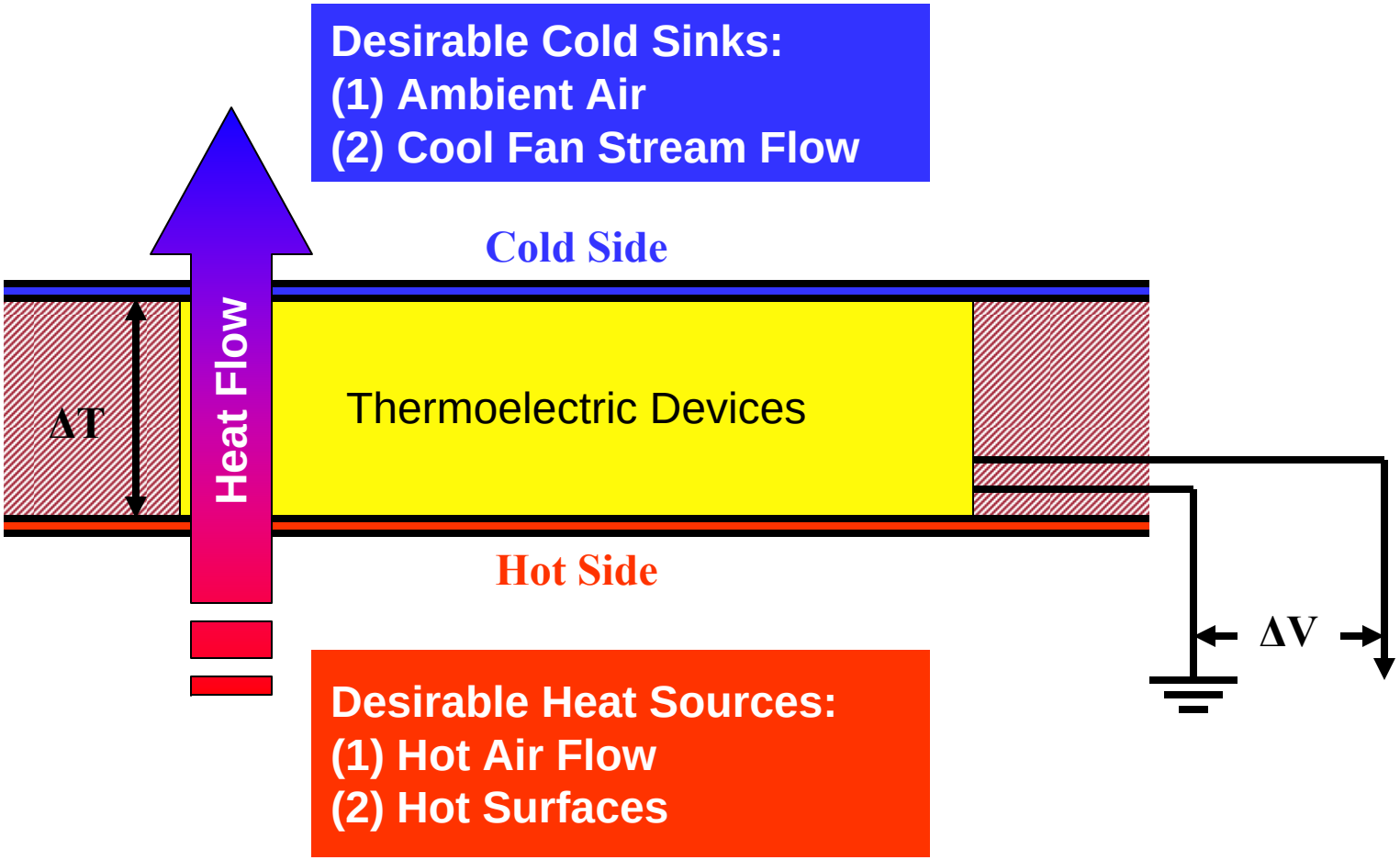







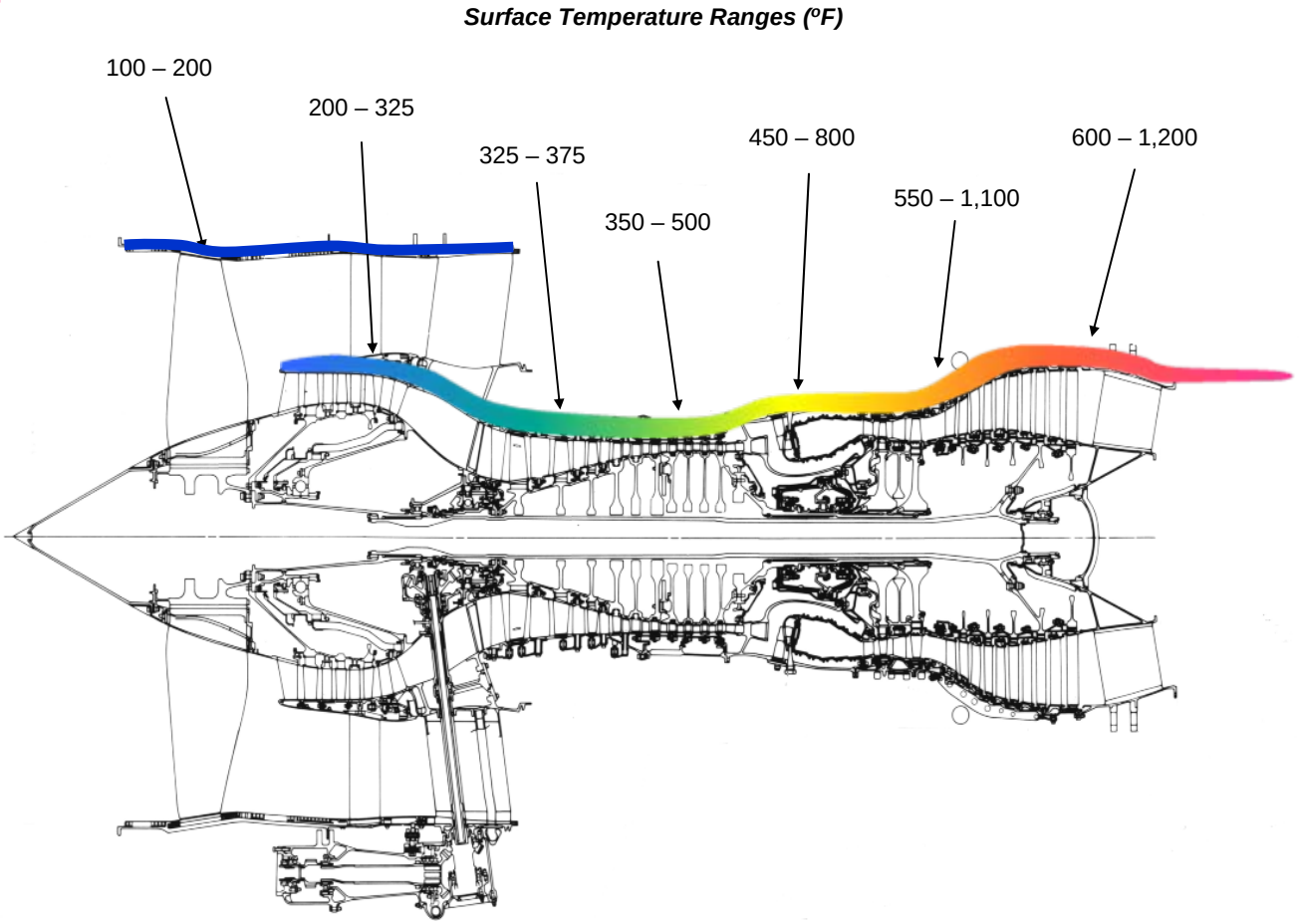


Solution is Desirable to be a Totally Passive Design With no Moving Parts



Knowledge in Engine Profile is Essential

Representative High By-Pass Engine Temperature Profile



Comparison of Aircraft Power Generation

	Advantages	Disadvantages
Engine Generator (IDG)	• Proven technology • Operates over the entire aircraft flight envelope	• Power output may be limited by flight conditions
Auxiliary Power Unit (APU) Generator	• Proven technology • Provides aircraft power on the ground when engines are not operating • Provides power to start main engine • Operates independent of engines and does not affect engine operations	• Some installation may not allow in-flight operation; non-operating APU is deadweight • Ownership costs are higher than those for aircraft engines
Fuel Cell APU/Generator	• Very efficient and no moving parts • Replaces both APU and IDG with a single system • Operates independent of engines and does not affect engine operations • Operates over the entire flight envelope	• New technology; currently heavy and reliability is uncertain • Requires a second fuel source, either a hydrogen fuel system or a jet fuel to hydrogen reformer system
Thermoelectric	• Provides electrical power from waste heat – no fuel burn and no moving parts • Operates over the entire aircraft flight envelope • Operates independent of engines and does not affect engine operations	• New technology and unproven • Cost & efficiency; further development is needed • Power output limited by available waste heat, space, device efficiency, and sustainable ΔT

Integration and Application Challenges are Non-Trivial

- Thermal, e.g., temperature swing
- Vibration and shock
- Material compatibility, e.g., CTE mismatch creates thermal stress
- Noise
- Parasitic thermal paths
- ΔT maintenance, e.g., provide sustainable operating environment
- Maintenance and upgrade, e.g., incorporating the latest technology
- Reliability

Potential Benefit Assessment

Fuel Reduction

- Preliminary analysis showed that 0.5% or more fuel reduction is achievable

Operating Cost Reduction

- Average monthly fuel costs for U.S. commercial planes is $2.415B for the first 4 months of 2009 (Source: EIA)
- A 0.5% fuel reduction translates into **$12.075M** monthly operating cost reduction

Carbon Emission Reduction

- Aircraft contributes ~2% of global carbon emission (Source: EPA)
- Passenger airlines accounts for ~85% of fuel consumed by U.S. airlines, which account for an estimated 35% of global airline fuel consumption (Source: EIA)
- A 0.5% fuel reduction on U.S. passenger aircraft alone contributes to ~0.03 global carbon emission reduction