Green(er) Aviation

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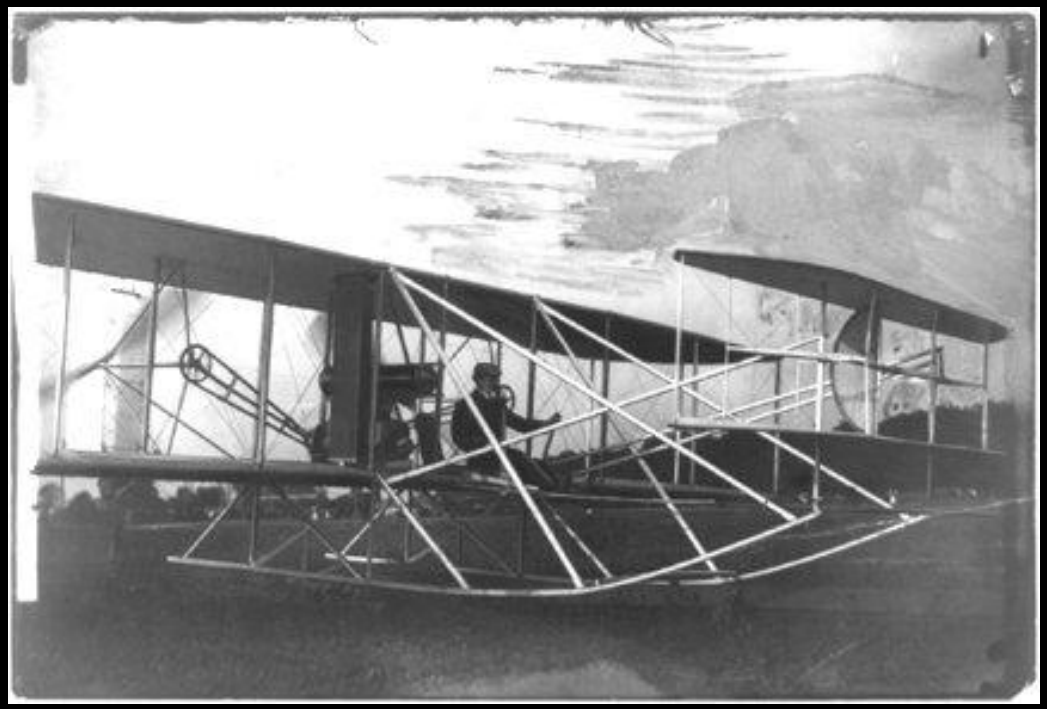
Aircraft Driven by Performance



June 29, 2009

Orville Wright at
Ft Myer, VA

Reached top speed
42.583 mph on
July 30, 400 ft alt.

From the beginning of flight, the U.S. Army's interests were **Performance** – and that's still the primary concern…

But Performance and Efficiency Are Tied Together

- Increasing range, payload generally means increasing fuel efficiency
- Improving fuel handling can mean environmentally friendlier
- New performance technologies compatible with greener aviation (e.g. electric planes)

2009 AIAA "Emerging Technologies"

1. Greener Aviation
2. Alternative Fuels
3. High Speed Flight Technologies
4. Efficient Propulsion Technologies
5. Active Flow Technologies
6. Advanced Materials
7. Active Structures
8. Health Management
9. Remote Sensing Technologies
10. Advanced Space Propulsion Technologies

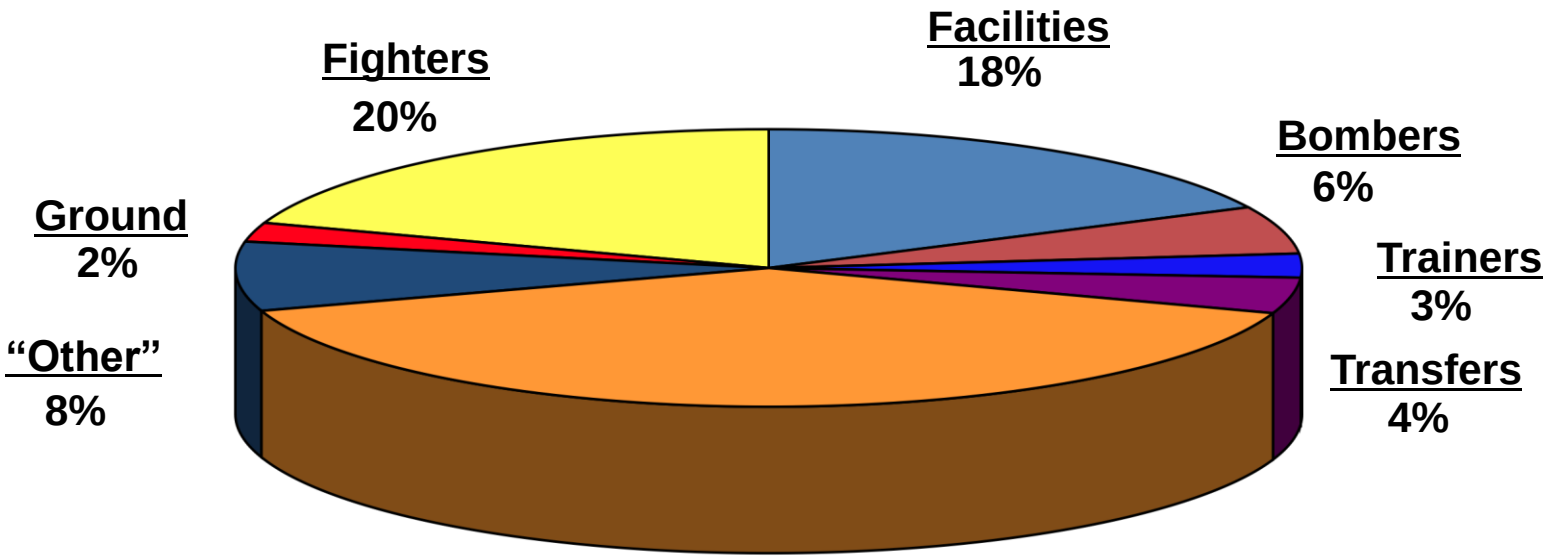
Relevance to Green

1. Greener Aviation
2. Alternative Fuels – synthetics including bio-derived.

4. Efficient Propulsion Technologies – open rotors & geared fans.
5. Active Flow Technologies – such as plasma actuators.
6. Advanced Materials – such as nanotechnology and composites.
7. Active Structures – shape memory alloys, morphing, and flapping.

9. Remote Sensing Technologies – UAV's and satellites.

DoD Energy Use (by cost)



Total $7B FY 2009

The Air Mobility Fleet is the Biggest Consumer, followed by Fighters

Fuels Enterprise System & Defense Utility Reporting System

Aviation's Economic Impact

- USAF flew 1 Mth sortie in May 2008, 350 per day.
- Convoy fuel costs $13/gal.
- Fully-burdened cost is $40/gal - $250/gal
- USAF uses ~10% of private sector consumption
- USAF fuel budget is 3x S&T expenditures

Environmental Impact

- Worldwide aviation fuel use is 8% of 1.3 T gals. of refined fossil fuel products
- 18,000 commercial airplanes, fuel is 20% of operating cost
- Aviation releases 600 M tons of CO_2 per year
- 3% of greenhouse gases, but 13% of overall climate impact
- Water vapor? Nox? Etc.

What Can We Do to Address Energy?

- Propulsion solutions - it's hard to build a better gas turbine, but we are trying…
- Alternate fuels - WWII German, South African, Brazilian experience; it's hard to beat hydrocarbons…
- Configurations - better L/D from winglets (?), blended configurations, engine installation, etc.
- Conservation – but pilots really like to fly…

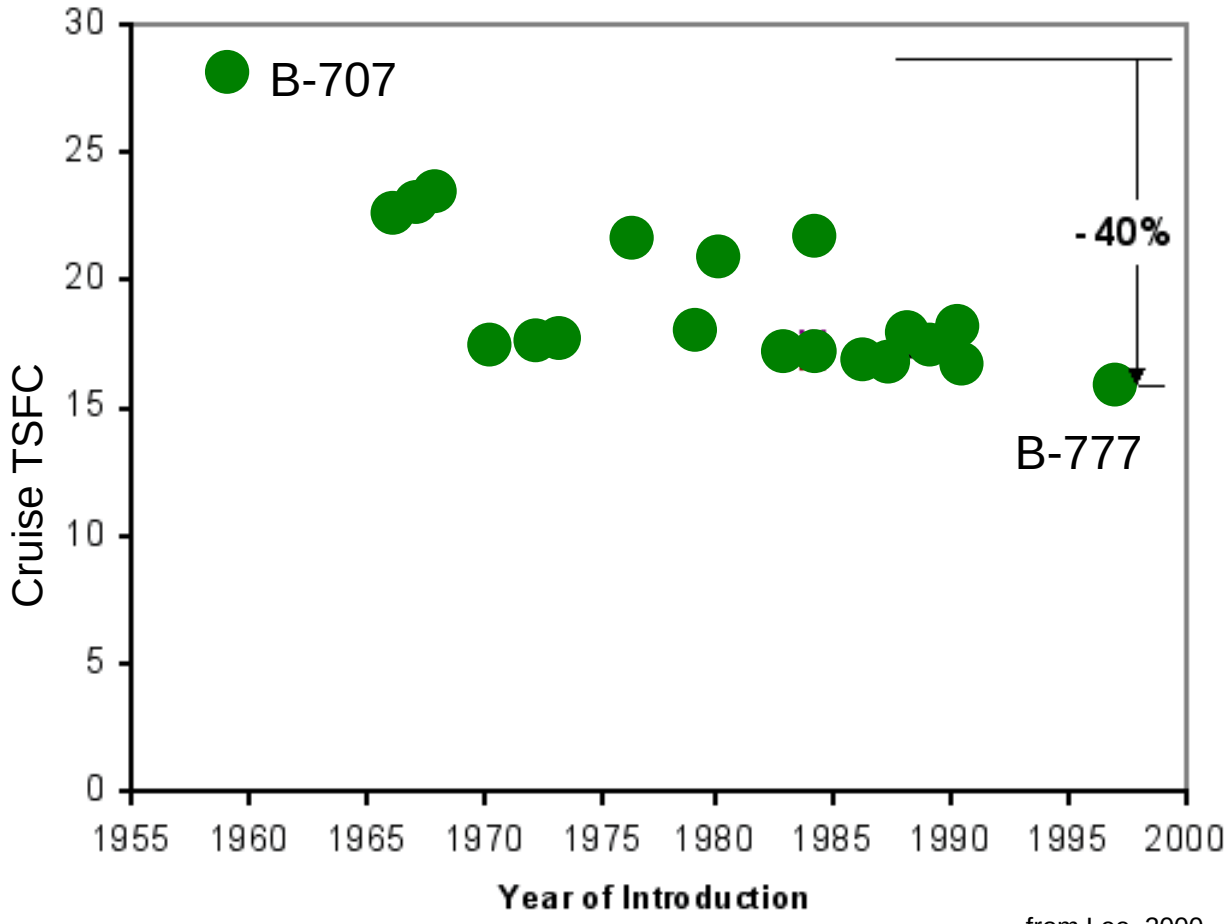
Simple Aircraft Range

- Simple range equation:

$$R = u_o Isp \left[\frac{L}{D}\right] \ln\left\{\frac{W_{total}}{W_{total} - W_{fuel}}\right\}$$

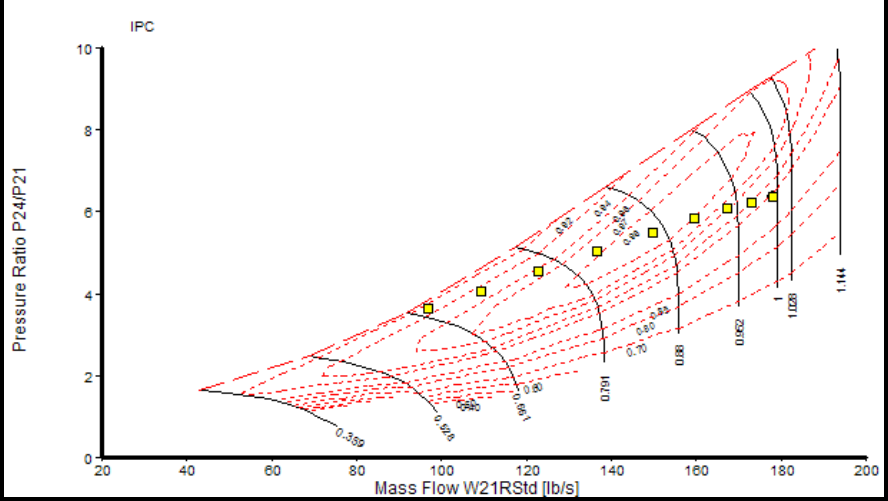
- To improve distance traveled on a tank of gas (or reduce gas used to travel a given distance):
  - Improve Engine Efficiency - fuels or engine.
  - Reduce structural weight.
  - Improve aerodynamics.

Cruise Fuel Consumption Has Leveled Off



from Lee, 2000

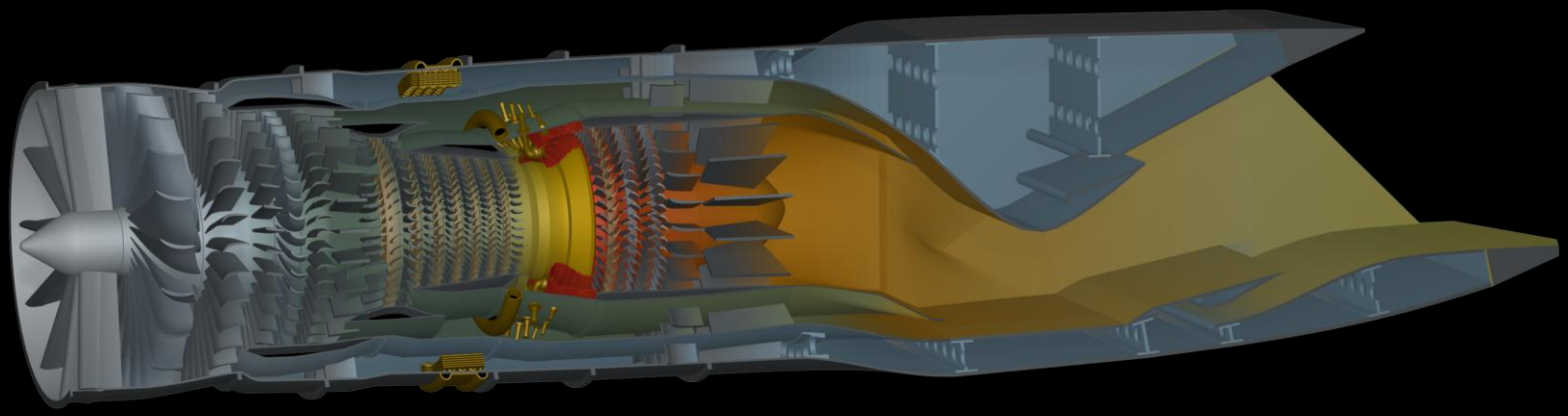
Typical Compressor Map



- Designed for a single Operating point
- Can be efficient cruiser or thruster but not both
- Inlet-compressor mismatch
- Bypass ratio and propulsive efficiency: most efficient engine has low thrust.

$$\eta_{prop} = \frac{\dot{m}(u_{exit} - u_o)u_o}{\frac{1}{2}\dot{m}u_{exit}^2 - \frac{1}{2}\dot{m}u_o^2} = \frac{2u_o}{u_{exit} + u_o}$$

ADVENT – A Variable Cycle Engine



Advanced Variable Engine Technology uses a third bypass stream to vary pressure ratio while keeping mass flow constant

It can be an efficient cruiser OR an effective thruster

Work in Alternate Fuels

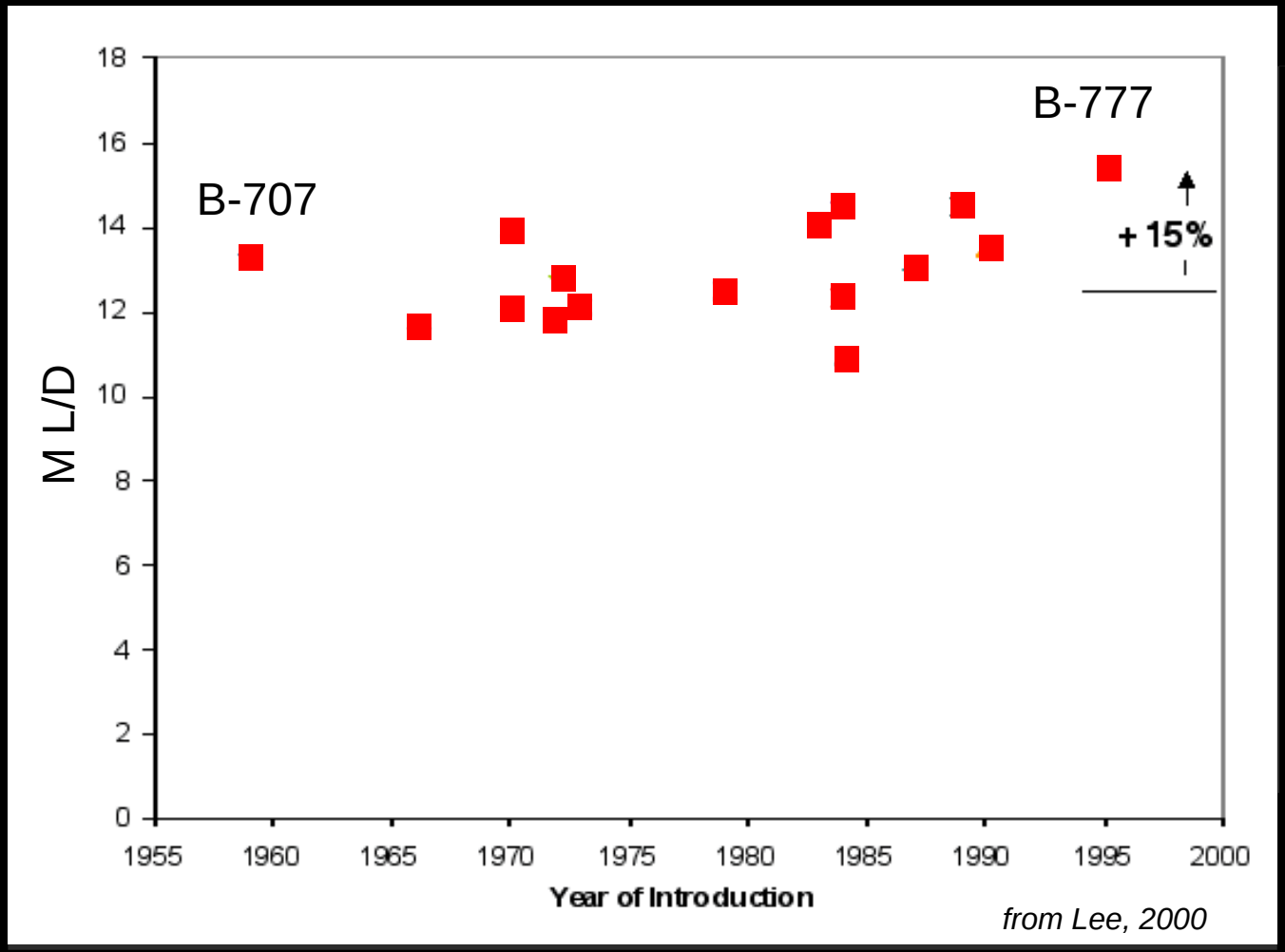
- Fischer-Tropsch fuels certification effort – many lessons learned
- Air Force moving to bio-fuels
- Key issue – must be drop-in replacement for JP-8
  - Similar physical properties
  - Equal or greater energy release
  - Emissions
  - Engine lifetime (seals)

Fuel: Energy/Mass vs. Energy/Volume

Fuel	Energy / Mass (MJ/kg)	Energy / Volume (MJ/l)	Density (kg/m^3)
Liq. H_2	119.7	8.5	71
Slush H_2	119.6	9.8	82
Methane	50.0	21.2	424
Heptane	42.4	30.5	717
JP-4	41.9	33.2	792
JP-5	41.2	35.2	854
JP-7	41.9	34.4	823
JP-8	40.9	34.7	849
Jet A	41.1	35.1	855
MCH	41.4	33.4	807

Hydrogen is likely not the answer for aerospace

Lift Over Drag Hasn't Changed Much in 50 Years



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Advanced Airframe Concepts

X-48b at Dryden/Edwards AFB

Range is proportional to L/D, so best way to affect Fuel consumption is better Aerodynamics.

Blended Wing Body Aircraft Concept