# NASA's Global Green Challenge

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Vice President
Technology & Environment

**NASA Green Engineering Masters Forum**

**San Francisco, September 2009**

# NASA's Green Challenge: Outline of Talk

## Green Aerospace – Opportunity for Innovation

- Green Engineering: processes, products
- Green Aviation
- Green Space
- A New Global Endeavor

# Context of Discussion

## Aerospace is the largest manufacturing export of US

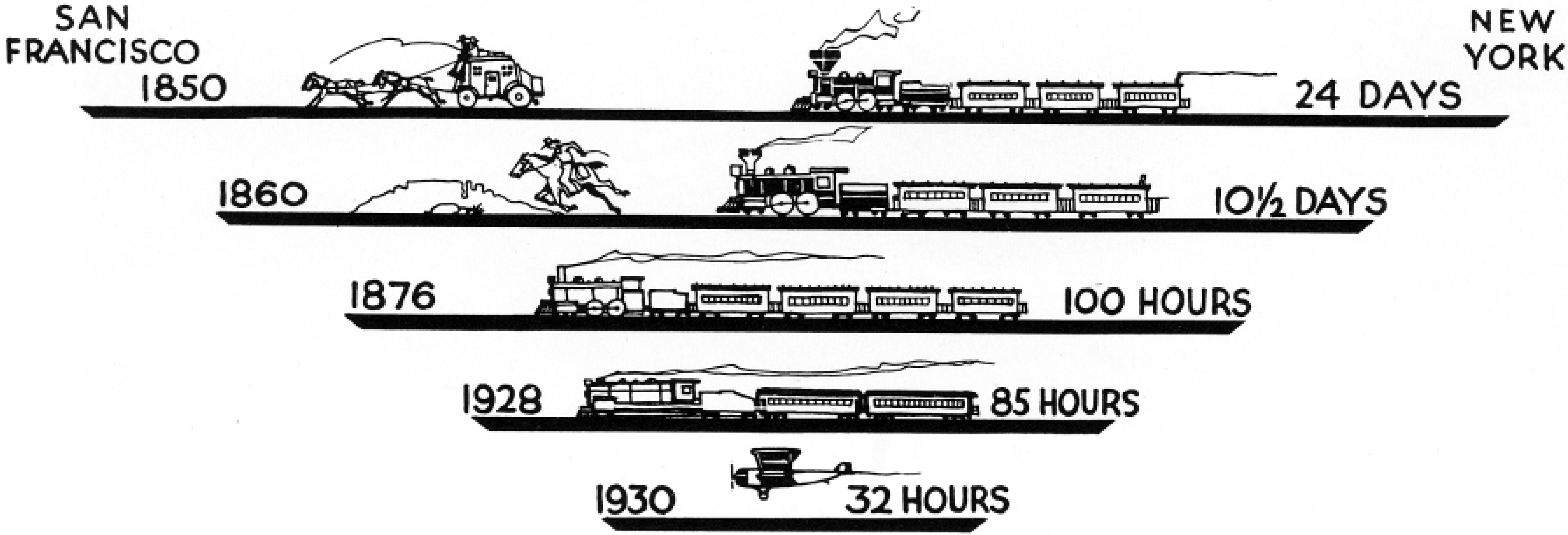




- Emphasis on what’s important to the nation
- Answering society’s need for transportation, defense & science

# What Are We Trying to Accomplish?

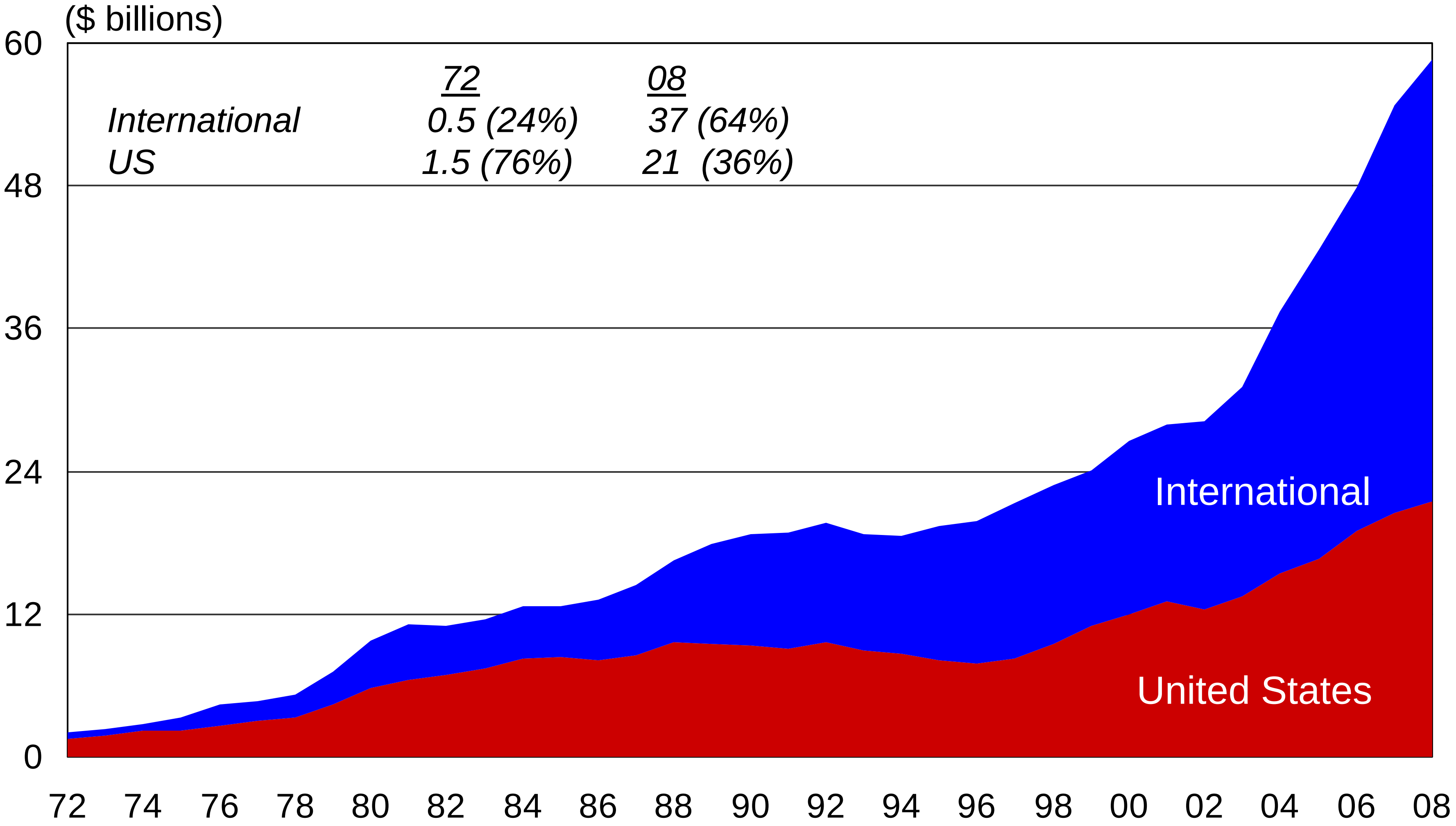
## Measuring progress – United Aircraft Co., 1930



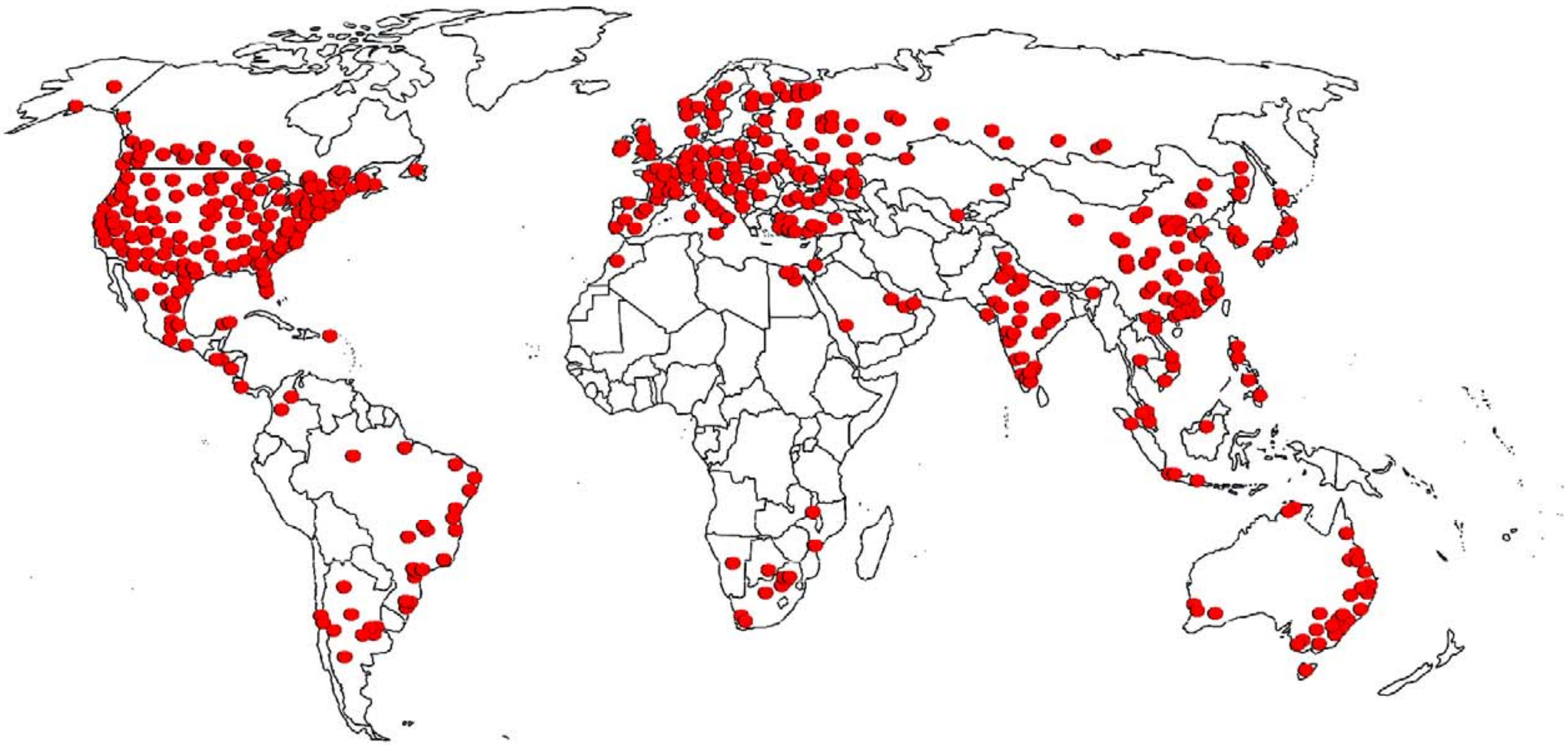

*Diminishing Distance Across the Continent*

- What we do now but at lower environmental cost?
- Enable new capabilities, new economics?

# UTC Revenues



# 2008 UTC World Presence



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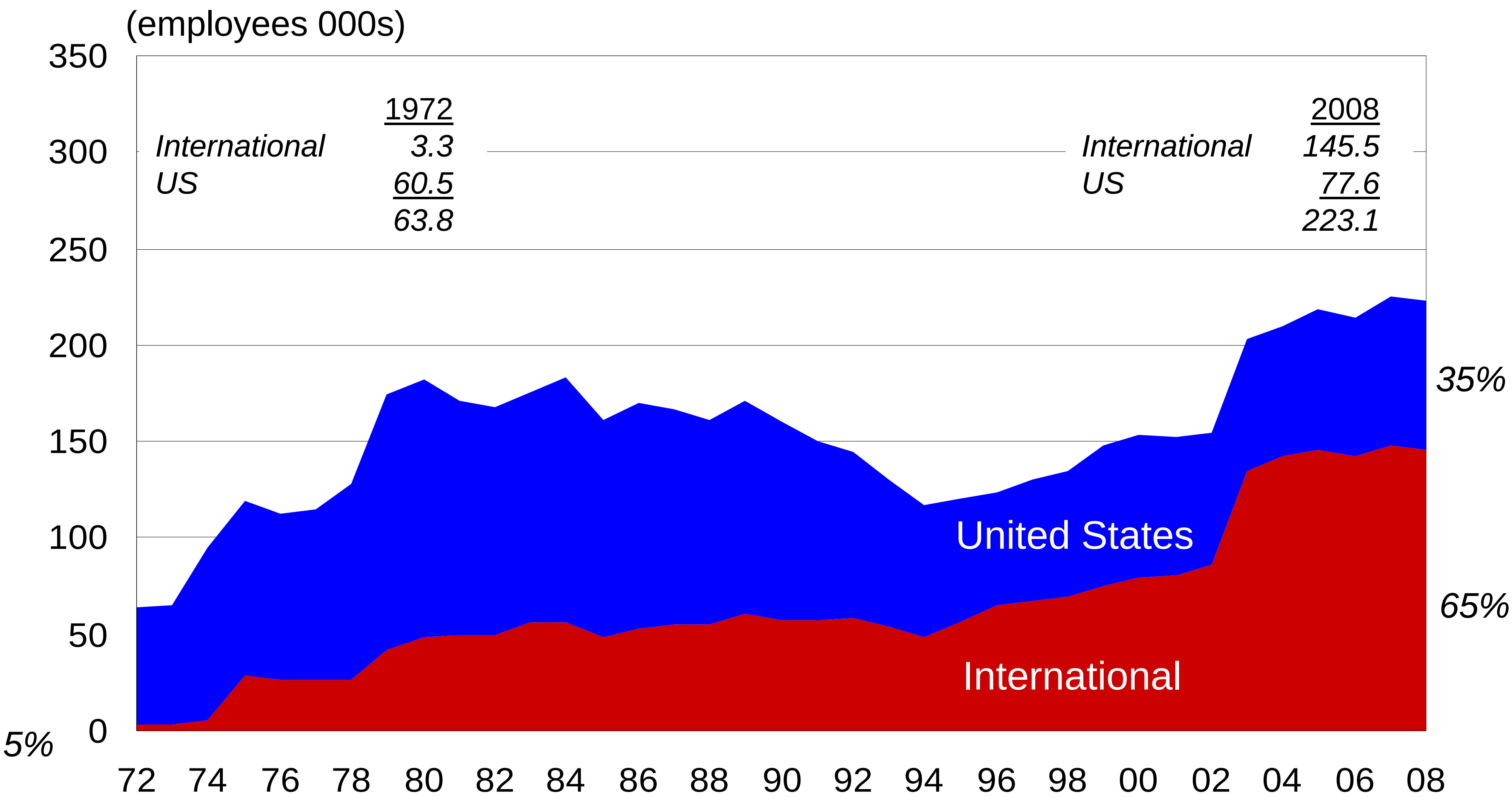
# UTC Employment

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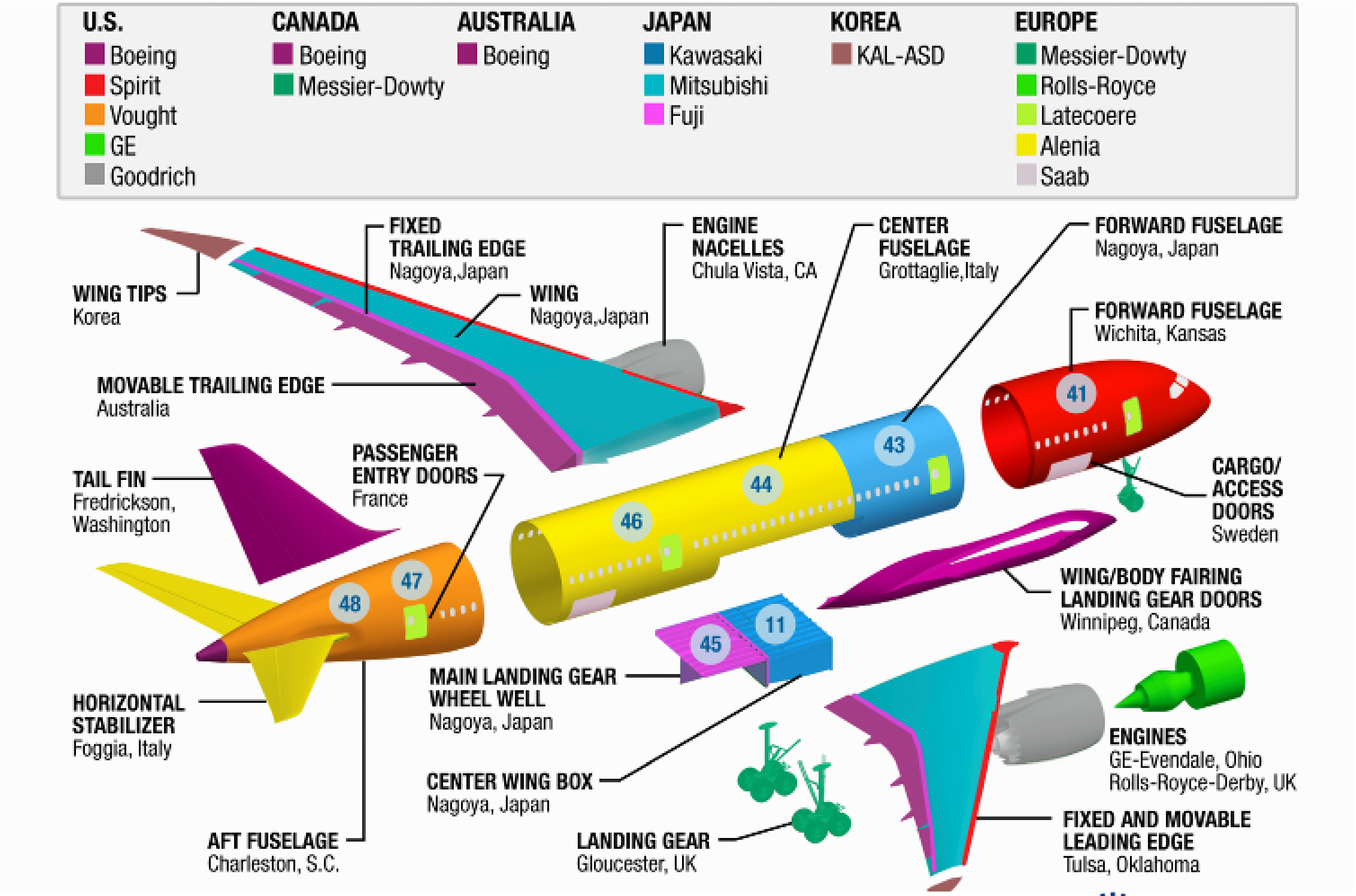
# SOA of Engineering & Manufacturing in 1969

## B-747 Designed and Built in the USA

# SOA of Engineering & Manufacturing in 2009

## Boeing 787 Designed & Built Around the World



# P&W And The Environment

## Why Do We Care?

- Responsibility
  - To our customers
  - To our people
  - To society

- Opportunity
  - Changes to markets can create new opportunities
  - Innovation in products & processes can fuel growth

- Climate change concerns will shape aerospace

# Engine Company Impact On The Environment

## What is new?

**Suppliers** + **Processes** + **Products**

**Suppliers**

**Materials of concern**
**Solid & liquid waste**
**Gaseous emissions**
**Direct & Indirect $CO_2$**

**Processes**

**Materials of concern**
**Solid & liquid waste,**
**Gaseous emissions**
**Direct & Indirect $CO_2$**

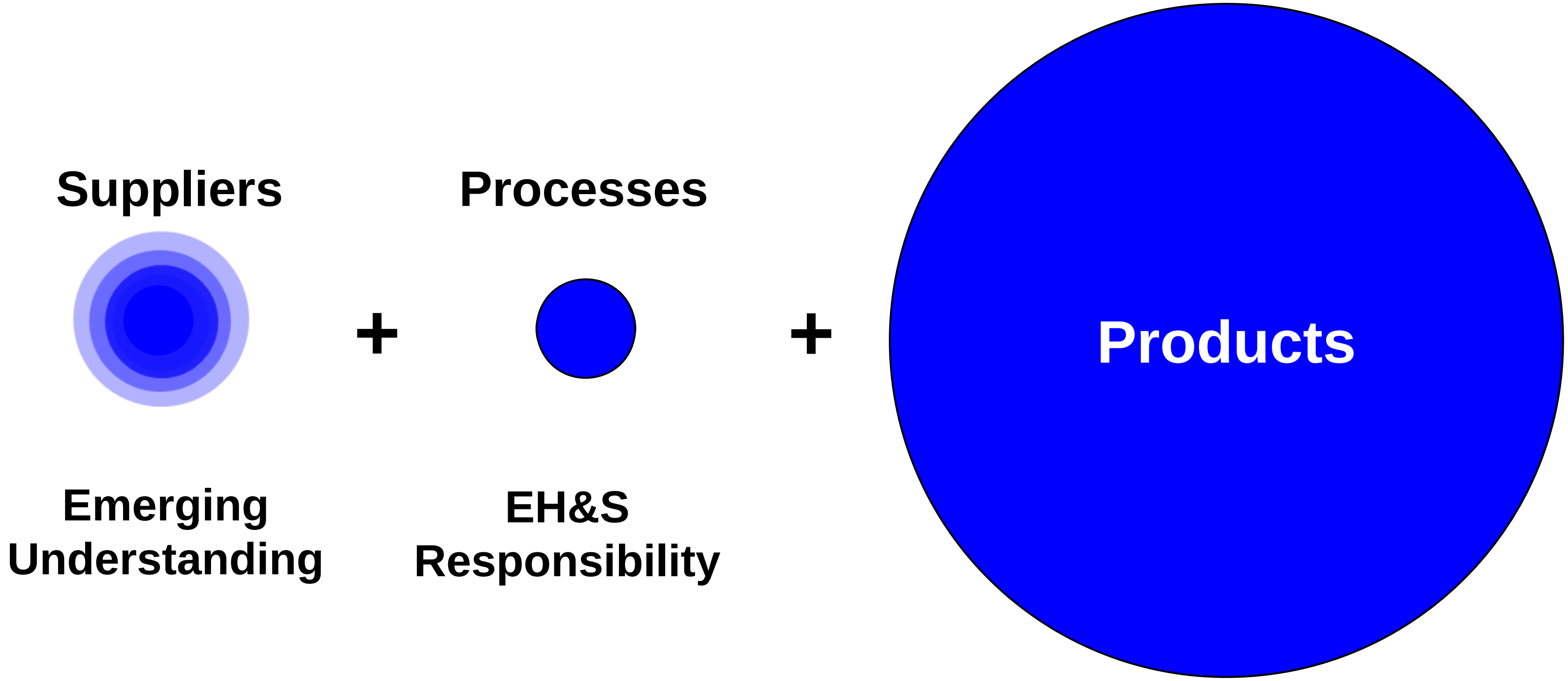
**Products**

**Scrap, Noise,**
**$NO_X$, Particulates,**
**Direct & Indirect $CO_2$**

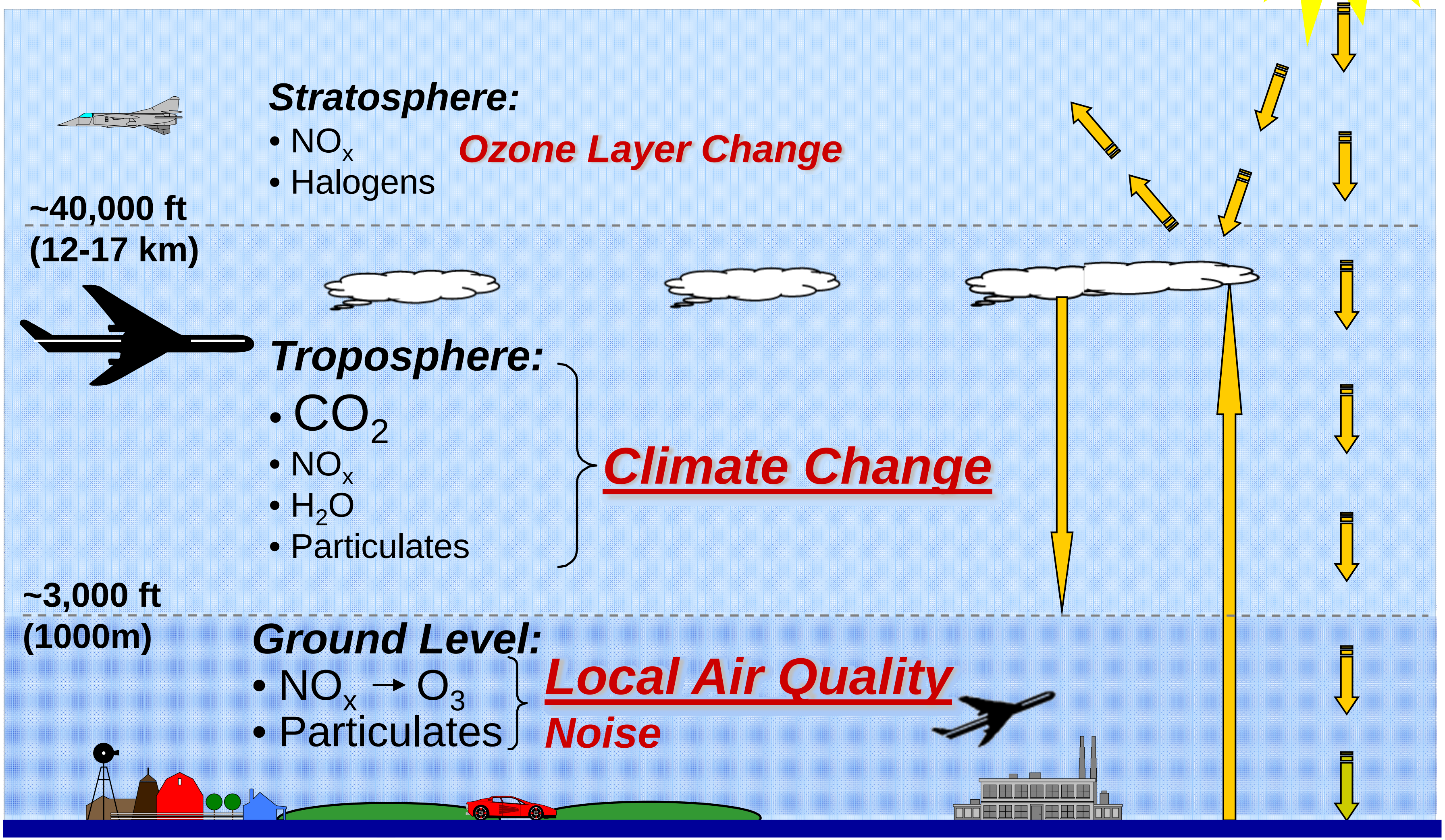
Red denotes a concern for climate change

# Engine Company Impact On Climate Change

## Relative $CO_2$ Annual Production



# Impact of Aviation on The Environment

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# Aeronautical Challenges in 1911

## The AERO

THE CONTENTS OF THIS NUMBER.

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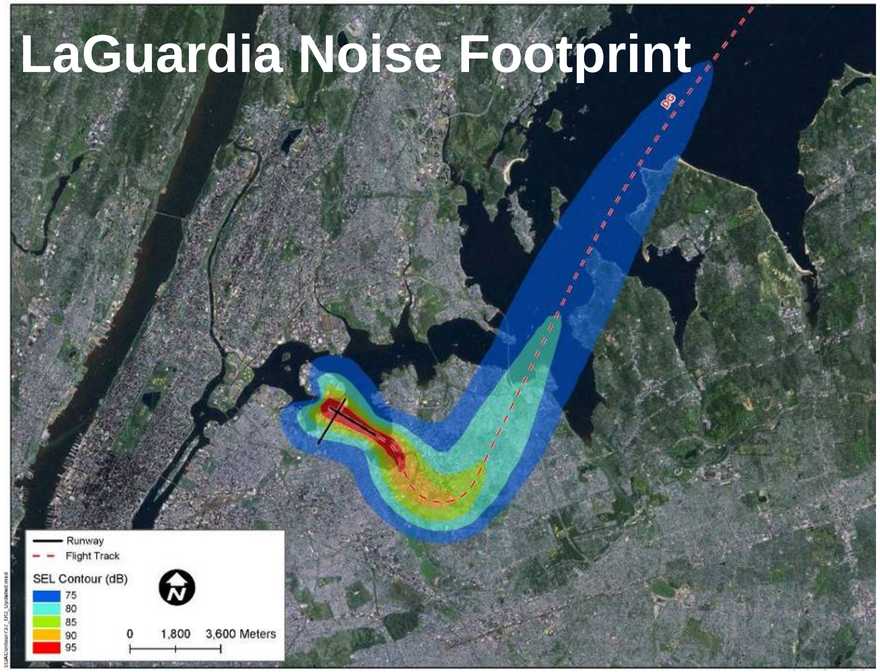
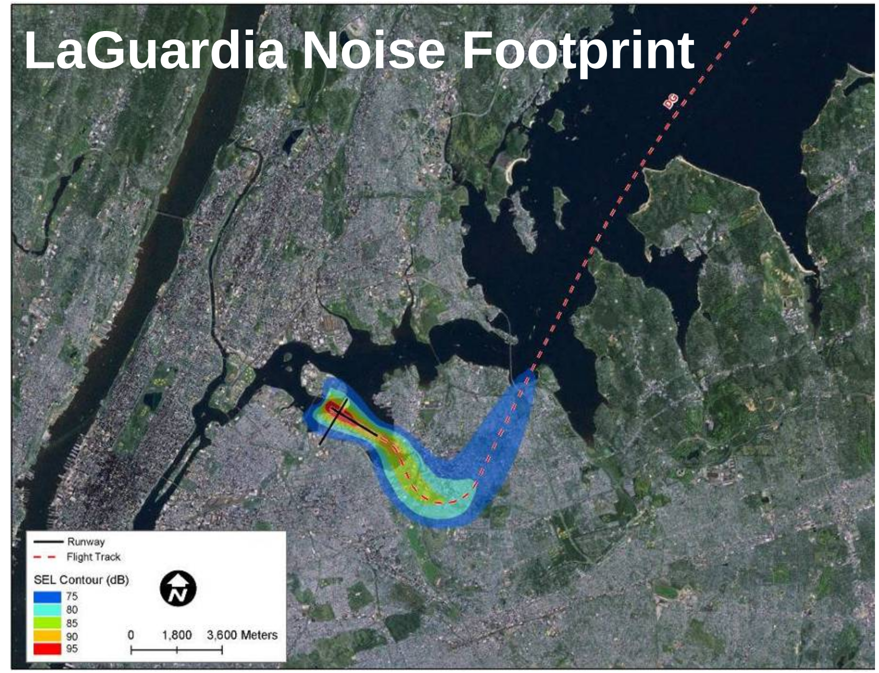
# PurePower® Engine Significantly Reduces Noise




Current B-737/A-320




PurePower® Engine
Engine (77% reduction)

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# The Climate Change Challenge

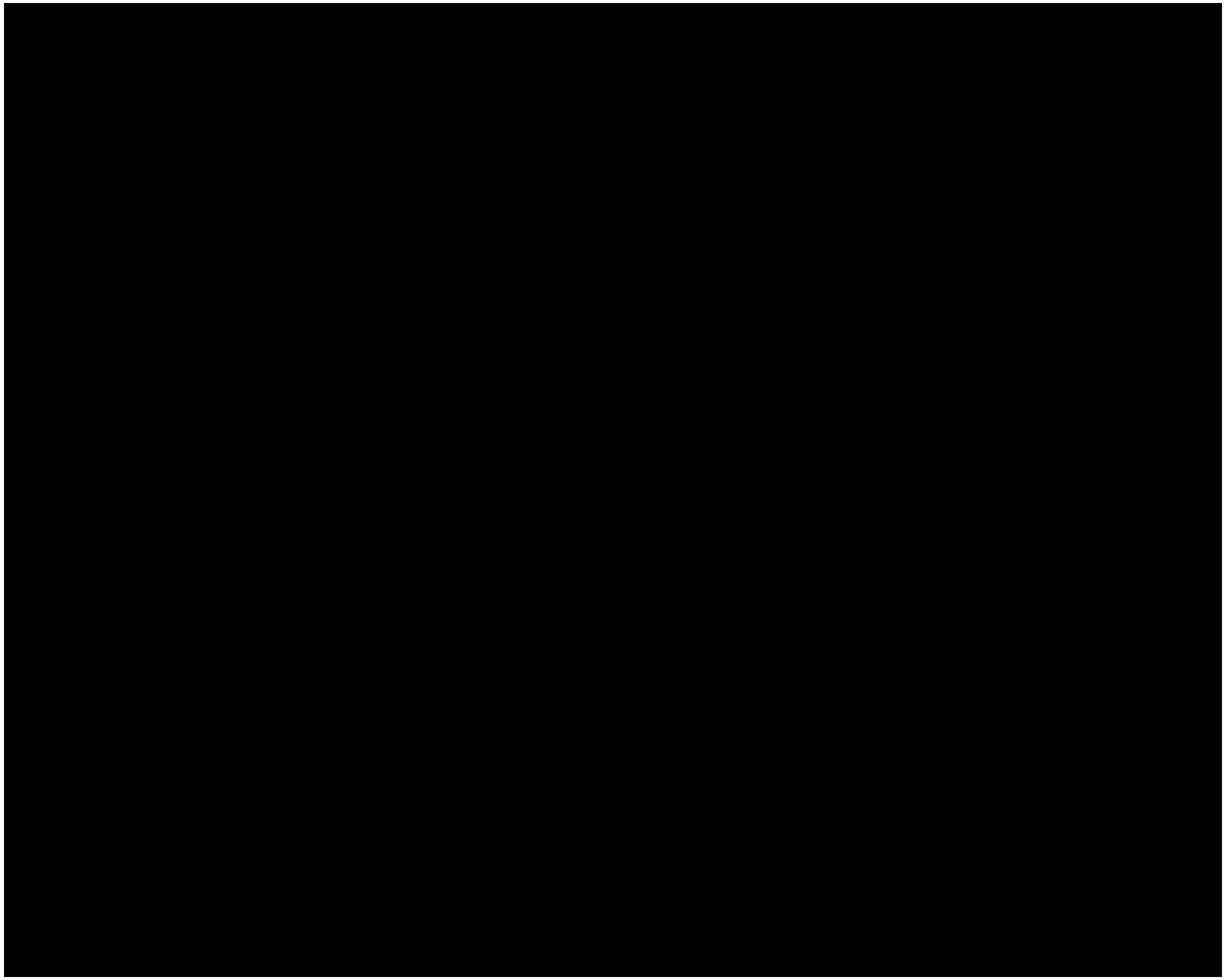
"The world can not regulate its way out of global warming, it must innovate"

Tom Friedman,

New York Time Columnist

Author, *The World Is Flat*

# The Innovation Challenge



# The Aviation Climate Debate Is Intensifying

**"Flying — the worst thing to do … The dirtiest industry in the world"**
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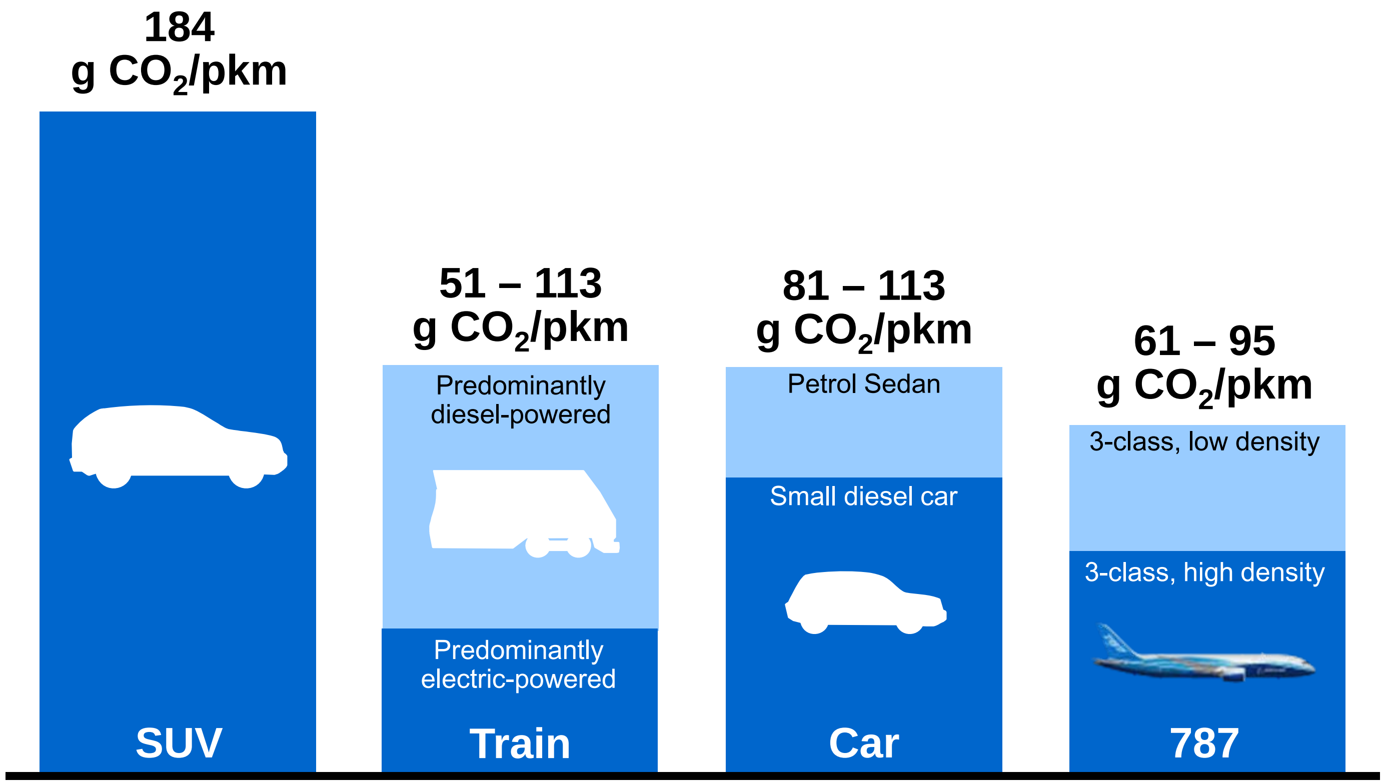
"Passengers face new tax to halt rise in air travel"
Times Online Sept 9, 2009

# Are Airplanes Green?

## Aircraft As Low Carbon Transportation

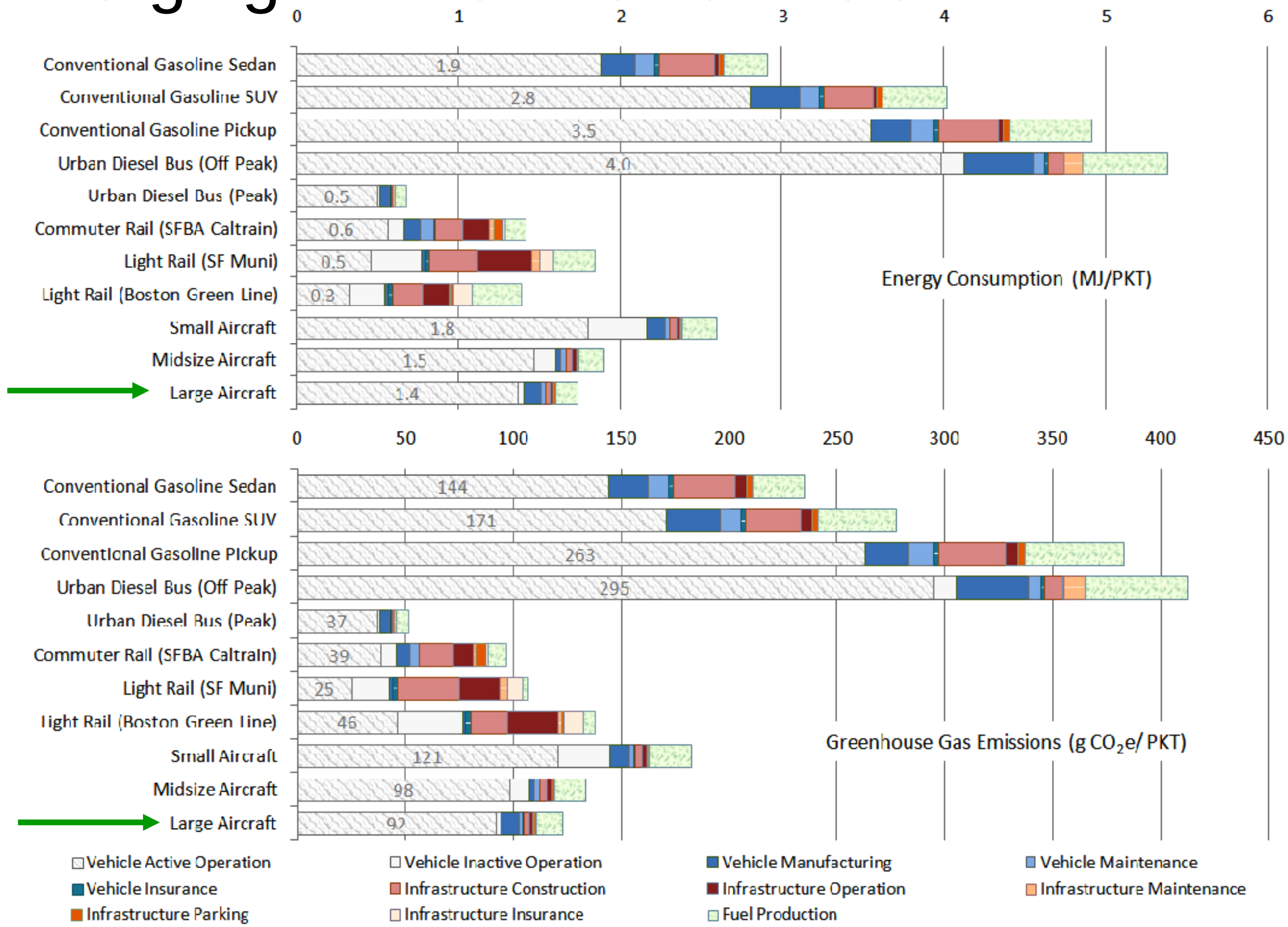



- Equivalent grams $CO_2$ / passenger kilometers, assuming average modal load factors (1.6 passengers for SUV and cars, 38.7% for diesel train, 47.6% for electric trains, 70% for low density 787 and 90% for high density 787).
- Electric trains are assumed to have typical $CO_2$/kWh electrical generation factors, reflecting a mix of fossil fuels, nuclear and hydroelectric sources.

Courtesy the Boeing Company

# Life Cycle Analysis of Transportation

## An Emerging Environmental Field




M V Chester and A Horvath, 2009: stacks.iop.org/ERL/4/024008

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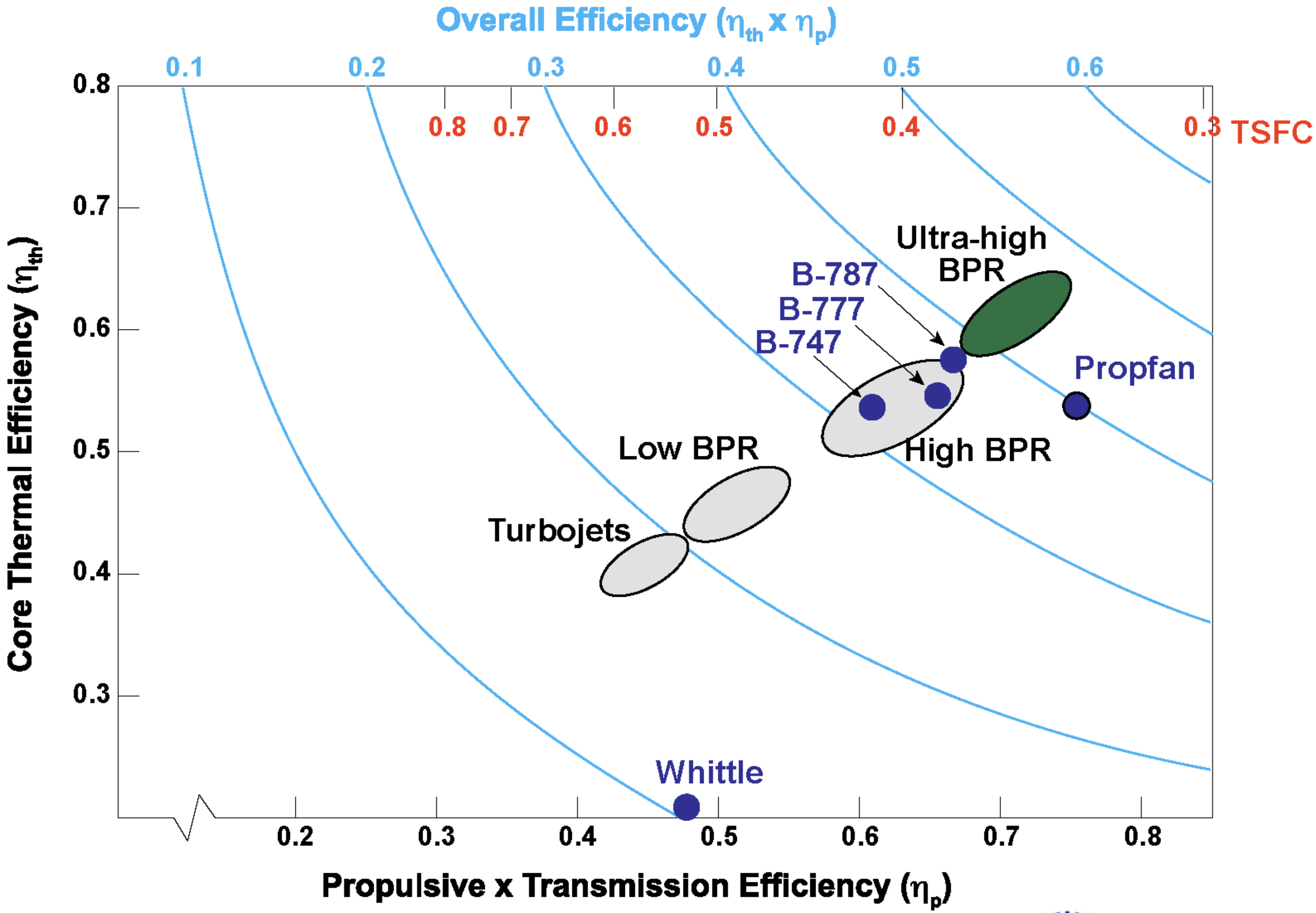
# Evolution of Gas Turbine Efficiency



# A $2B Investment in Technology Innovation

## 25 Years to PurePower® Engines

40K Demo engine

11K Demo engine

30K Flight demos


Entry Into Service

1990 2000 2008 2013

Flight weight design

Gear Test Rigs

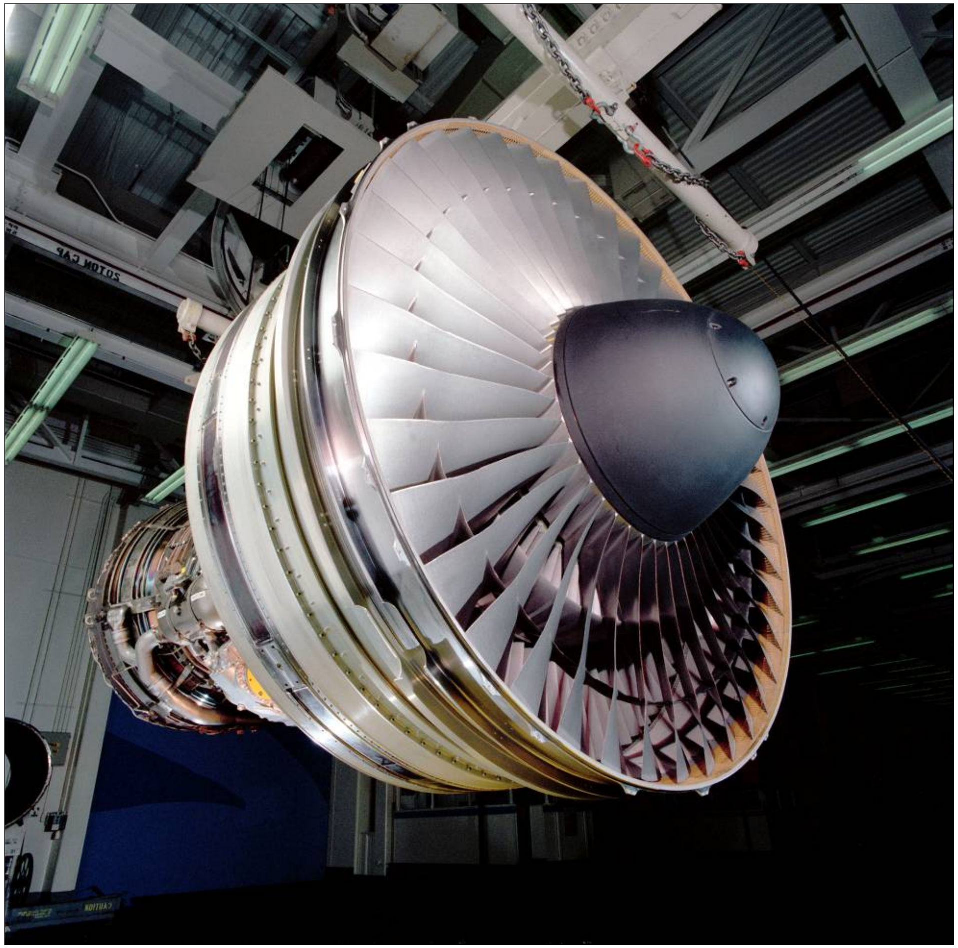
30K Ground demo

Entry Into Service

Thrust in thousands of pounds (K)

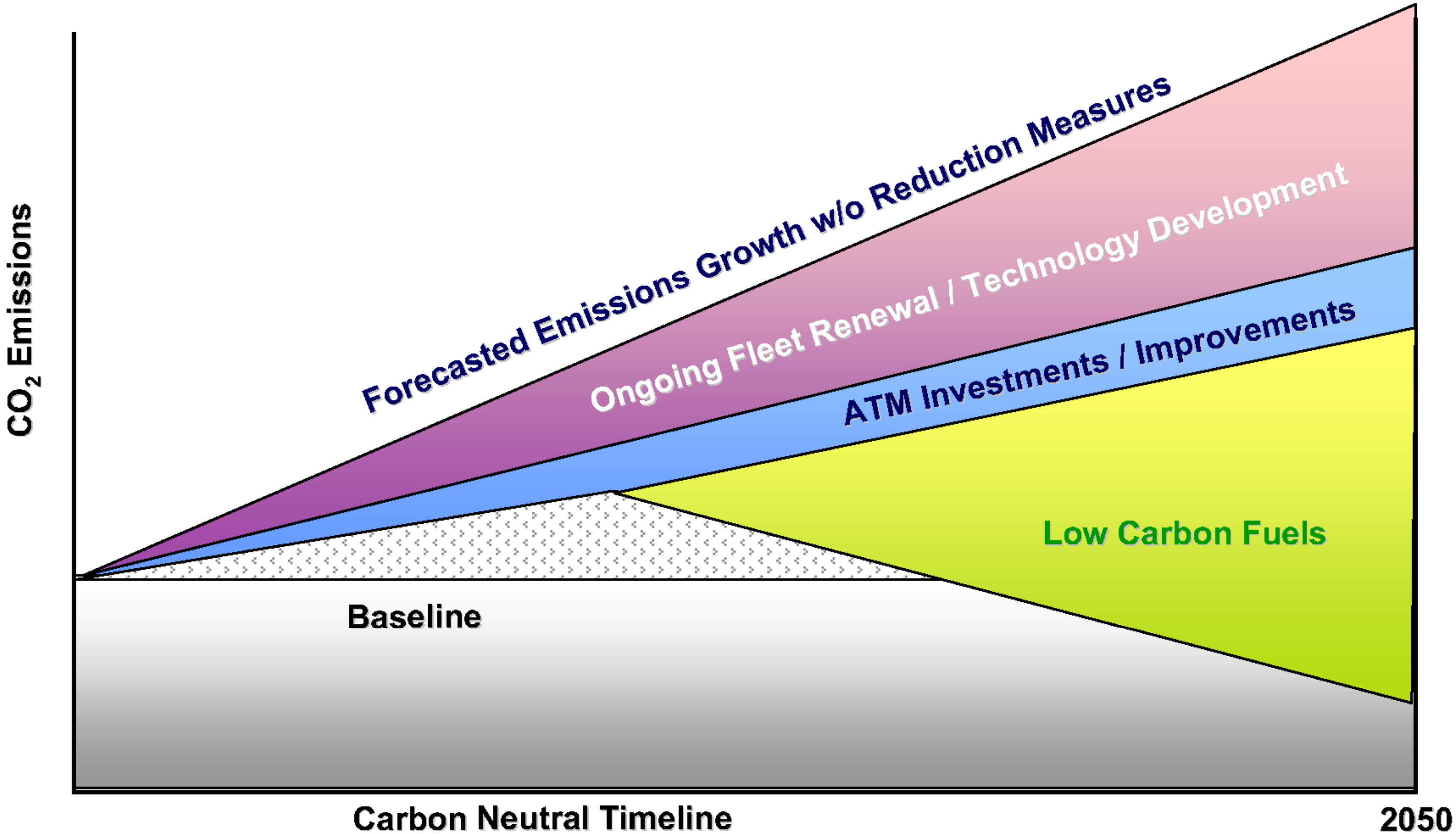
# Biojet Fuel

## What is it & Why Should I Care?



# Carbon Neutral Growth – Carbon Free Flight?

## Only Possible with a Fuel Based Solution

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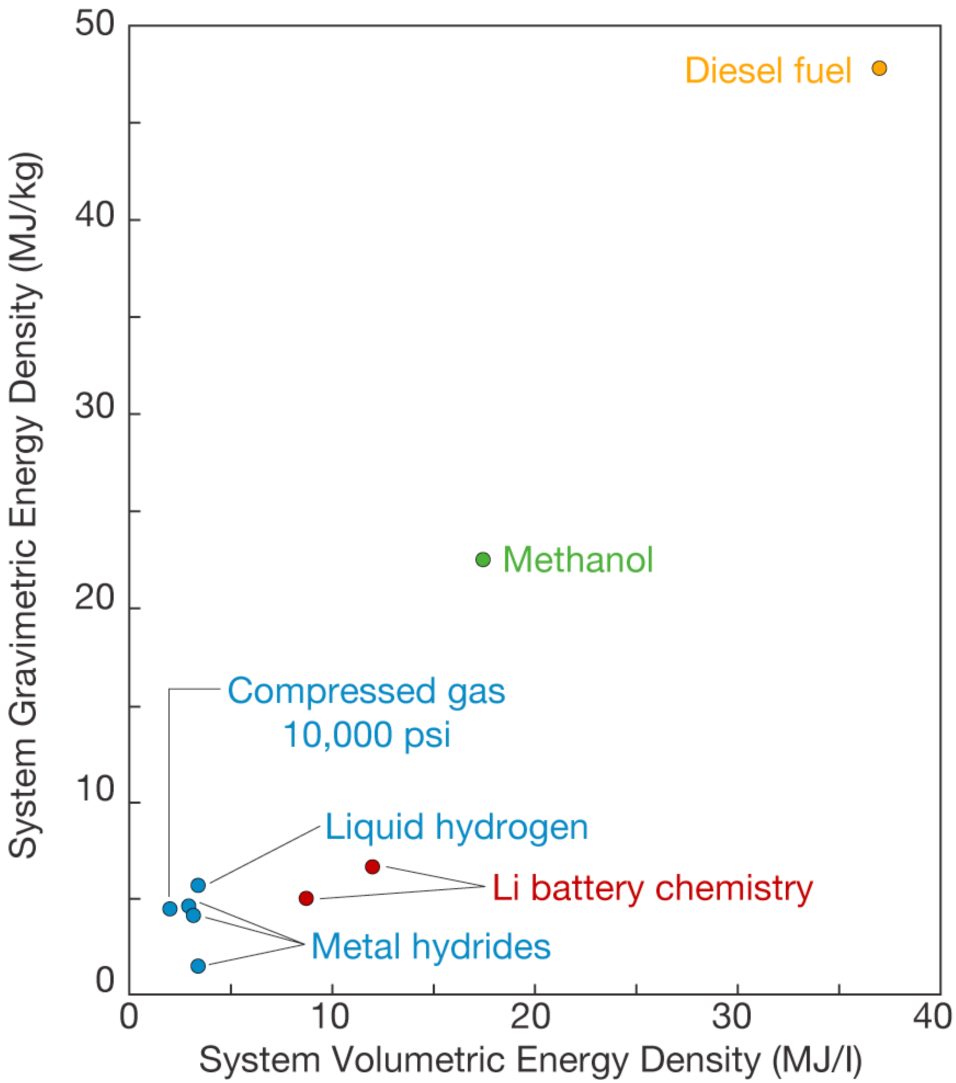
Courtesy the Boeing Company

# Fuel Energy Per Unit Mass

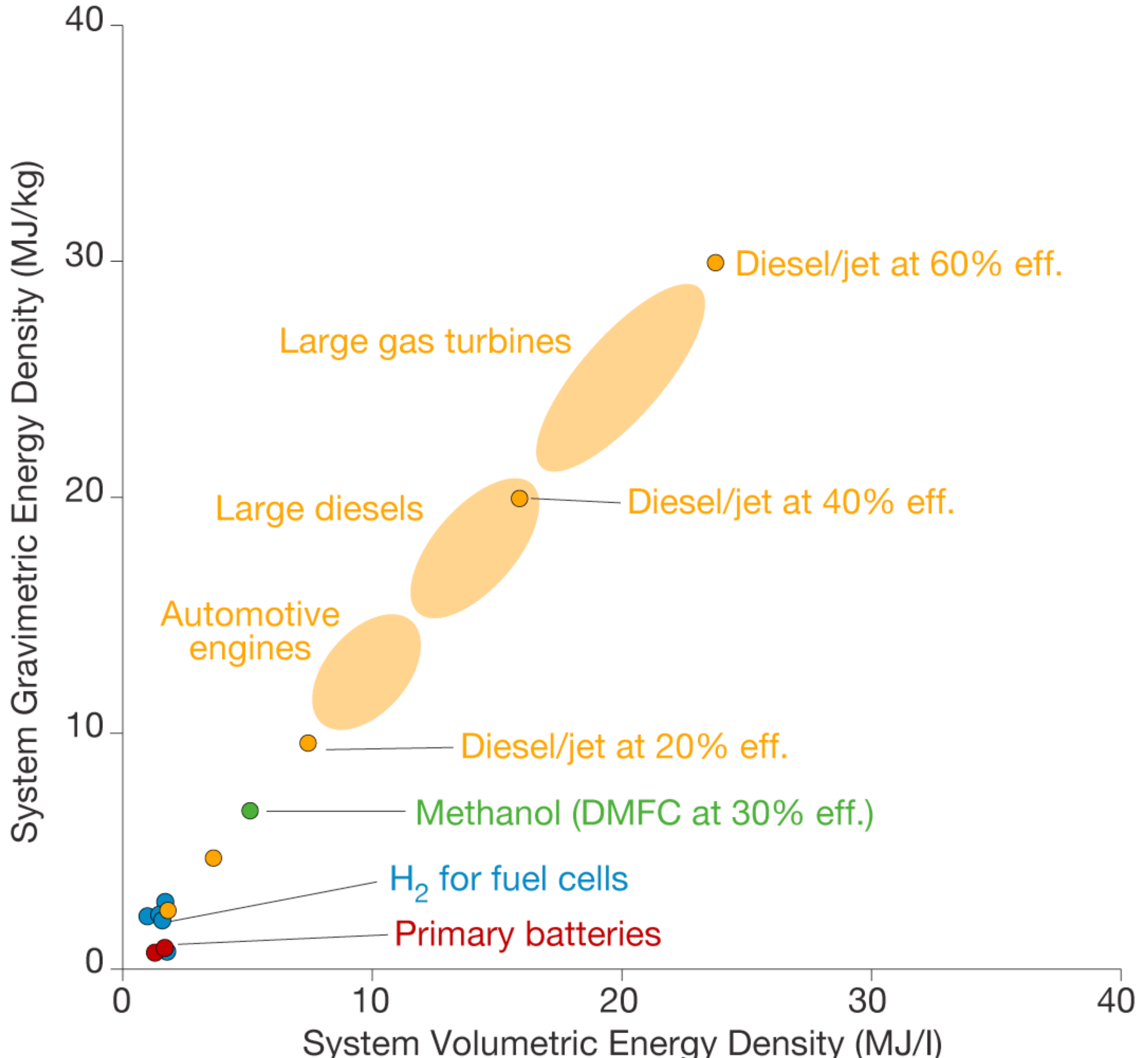
| | MJ / kg | $ / MJ |
|---|---|---|
| Beef | 4.0 | 2.0 |
| Whole Milk | 2.8 | 0.32 |
| Honey | 14 | 0.29 |
| Sugar | 15 | 0.07 |
| Peanut Butter | 27 | 0.15 |
| Bacon | 29 | 0.14 |
| Vegetable Oil | 36 | 0.06 |
| Kerosene | 42 | 0.010 |
| Natural Gas | 45 | 0.005 |
| Hydrogen | 117 | 0.05 |

(from *The Simple Science of Flight*, by H. Tennekes)

# Chemical Energy Sources For Flight



# Practical Energy Density Of Fuels

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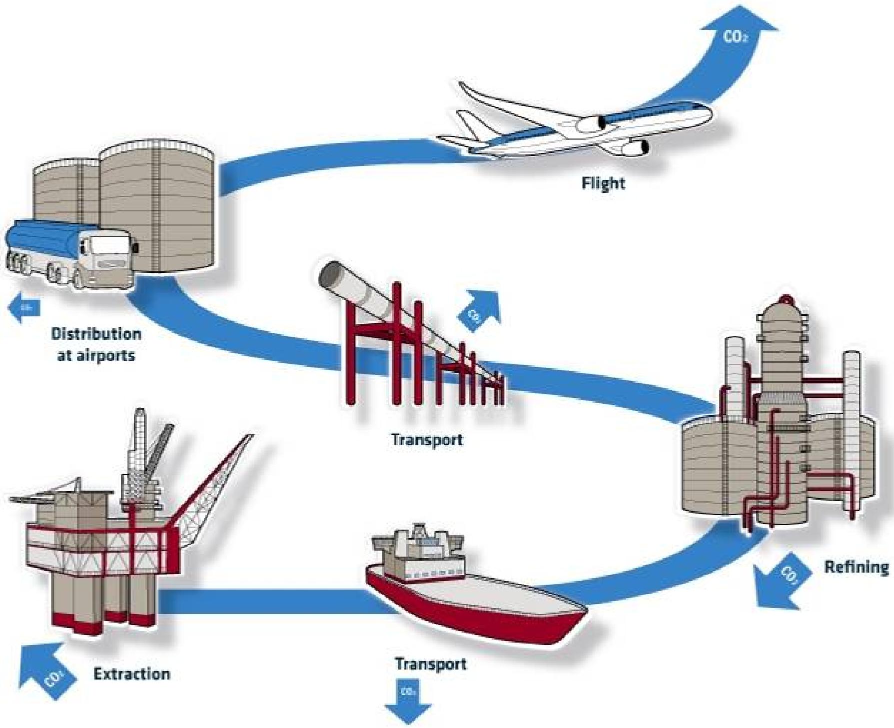
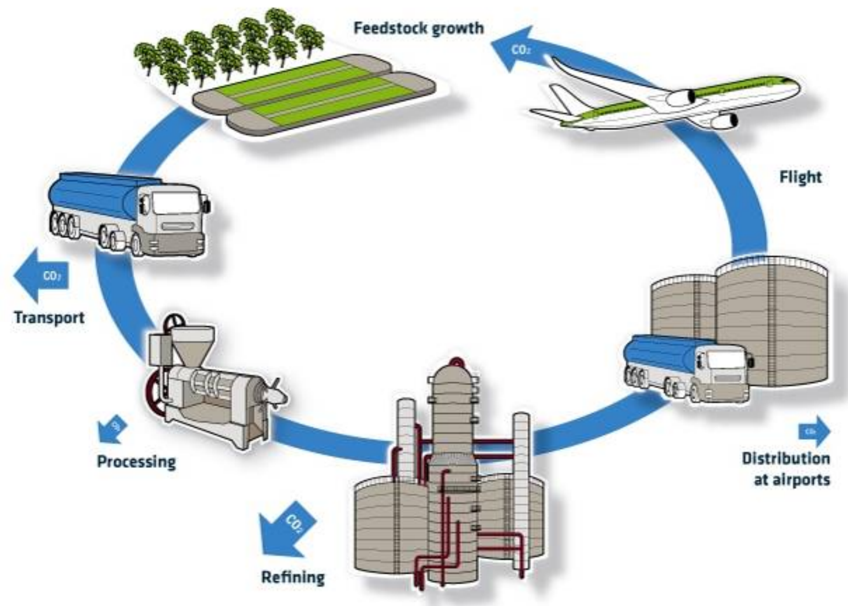
Fuel & Container Only

# How Does a Biofuel Help?

## Reduces Net $CO_2$ Into Atmosphere



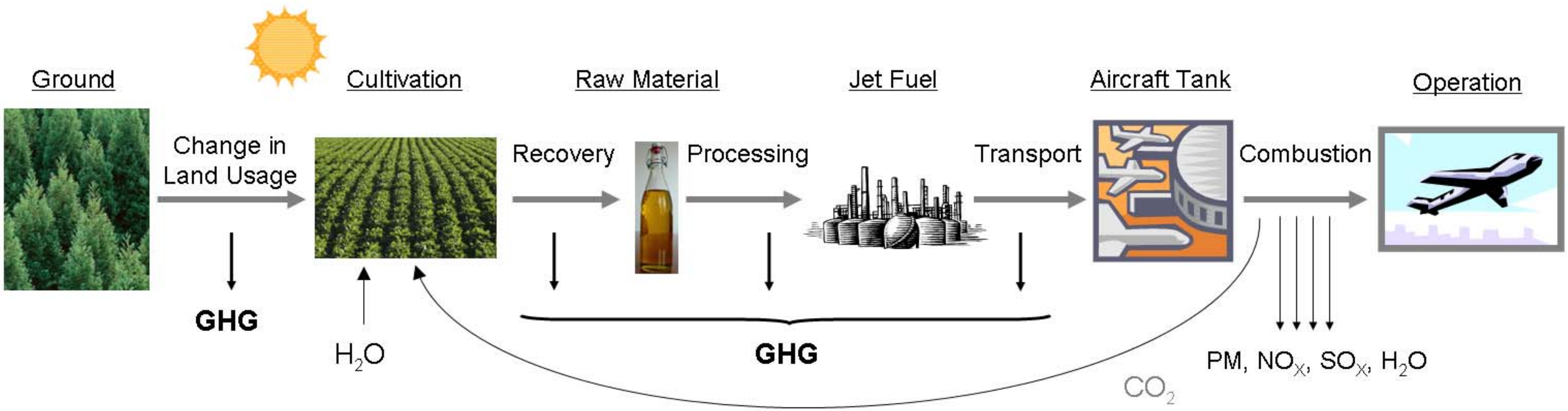

Conventional Fuel



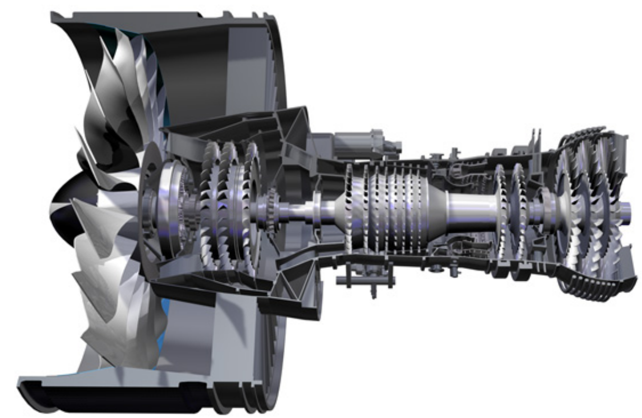

Bio Fuel

# Environmental Life Cycle Analysis

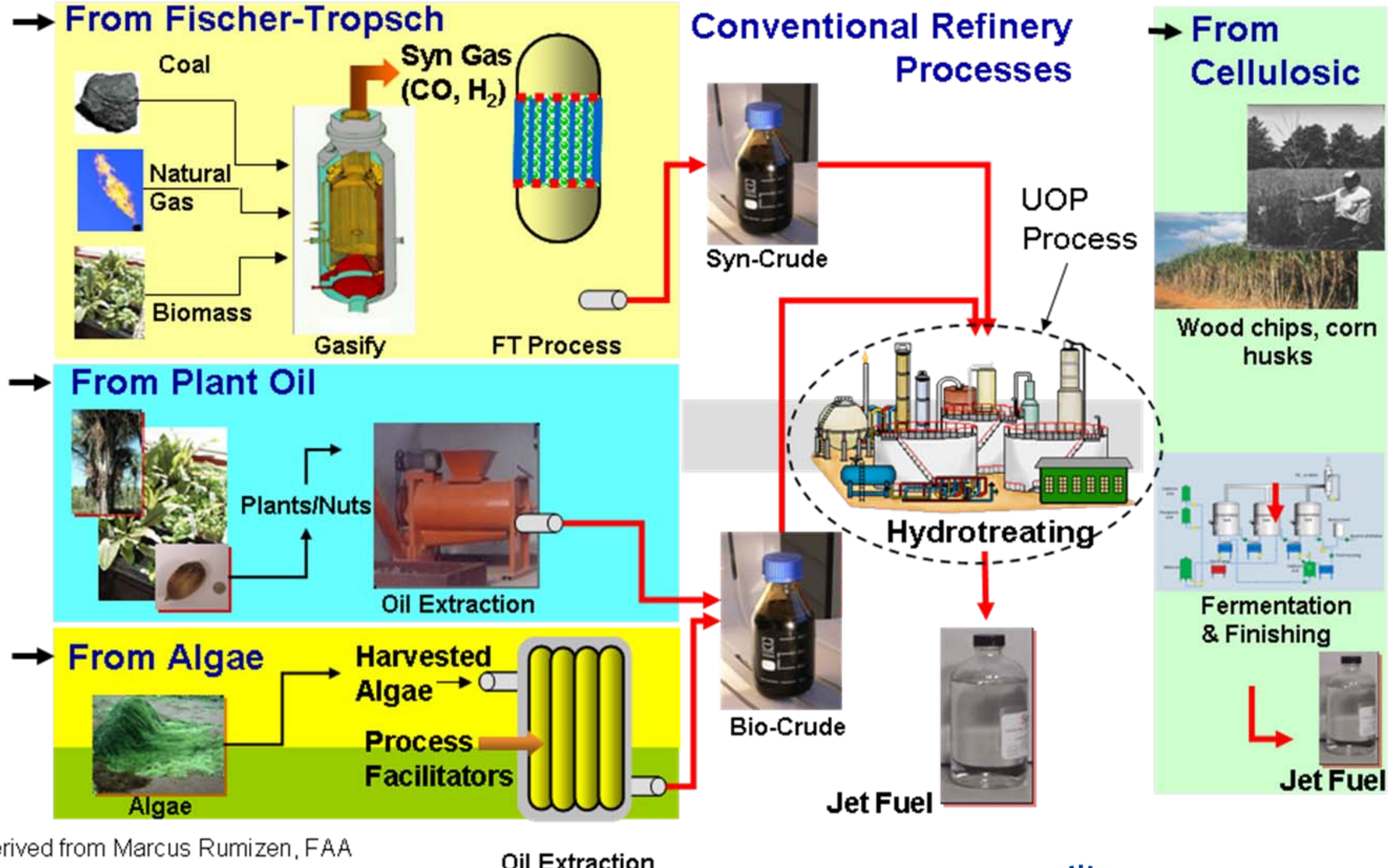
## “Well-to-Wake” Life-cycle Emissions & Energy







# BioJet – What Is It? How To Make It?

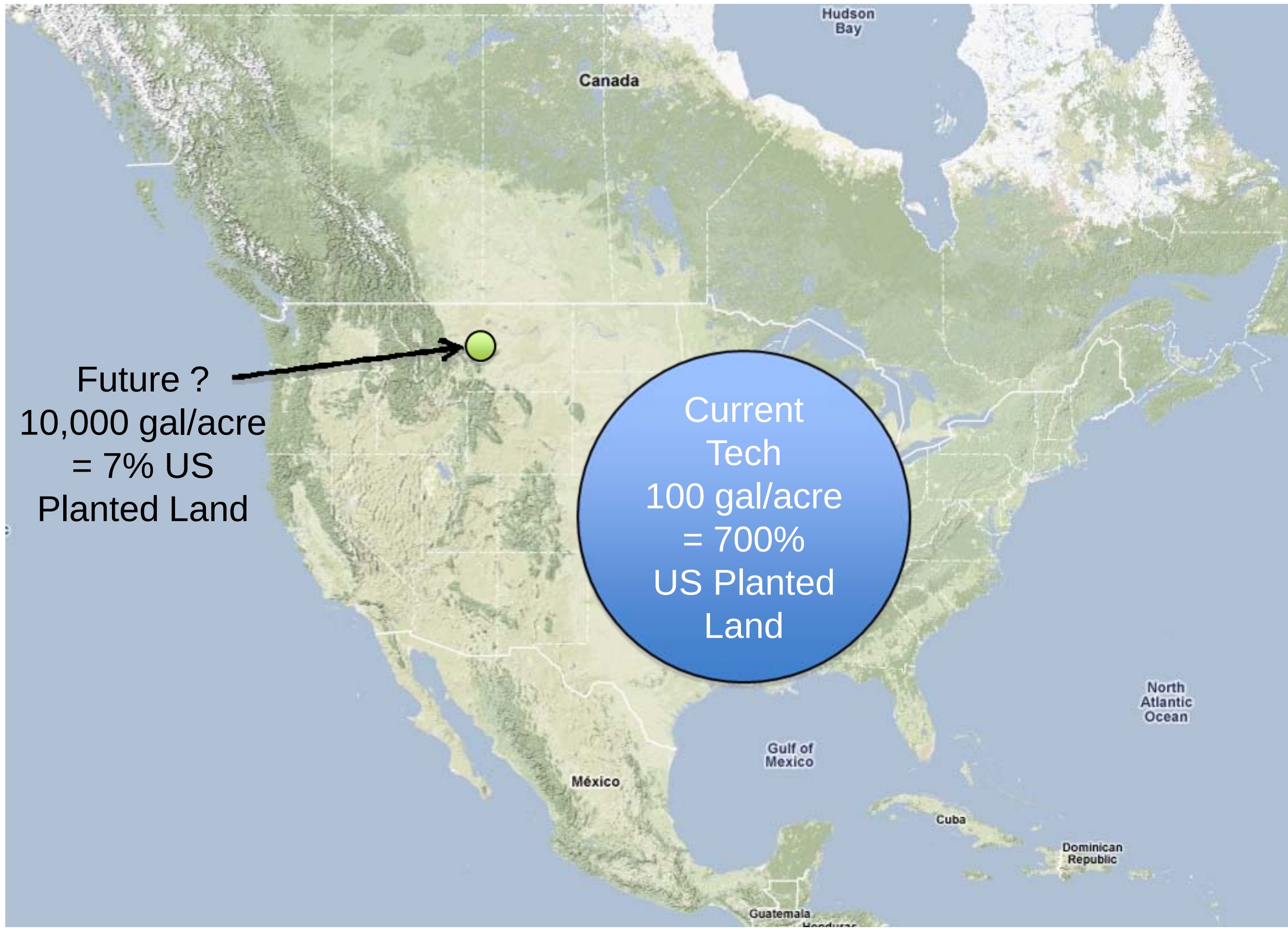



Derived from Marcus Rumizen, FAA

# Crop Yields Set Land Requirements

## Significant Use Requires Greatly Improved Yields

| Oil Yield gal/acre/yr | |
|---|---|
| Soybeans | ~70 |
| Camelina | 100 |
| Jatropha | 200 |
| Palm Oil | 400 |
| Algae | 1000? |



# Is NASA's Access to Orbit Green?

## Which Launch Vehicles Are Climate Friendly?


Not Green

1100 tons of Chlorinated Exhaust

Green

Just adds water

# Innovation vs. Novelty

- Innovation
  - “the alteration of what is established by the introduction of new elements or forms”*

- Novelty:
  - “An…amusing object…relying for its appeal on the newness of its design”*

(*Source: *OED*)

# Impressive Novelties

## Technical tour de forces

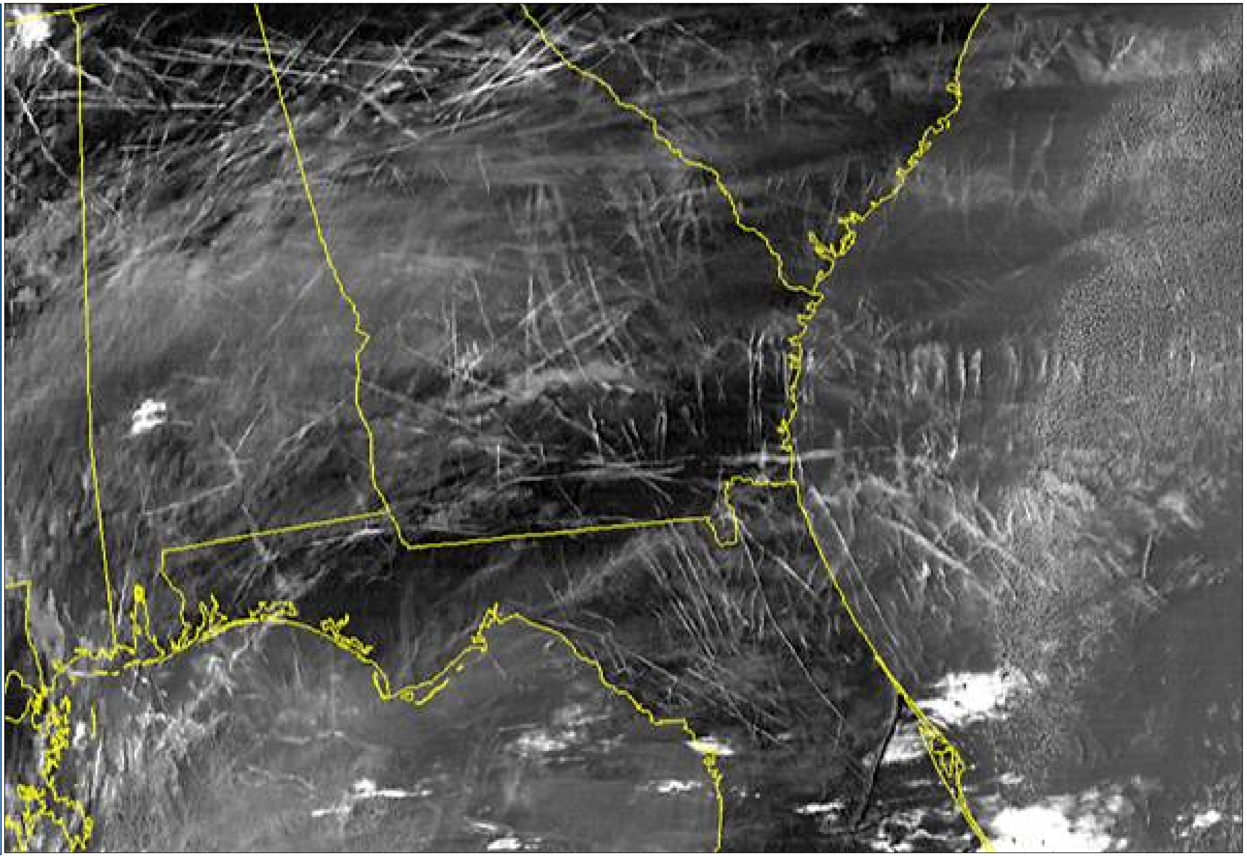
Human Power

Solar Power

Boutique aircraft can be fun & fascinating
but where's the (economic) beef?

# Contrail-Induced Cirrus Clouds

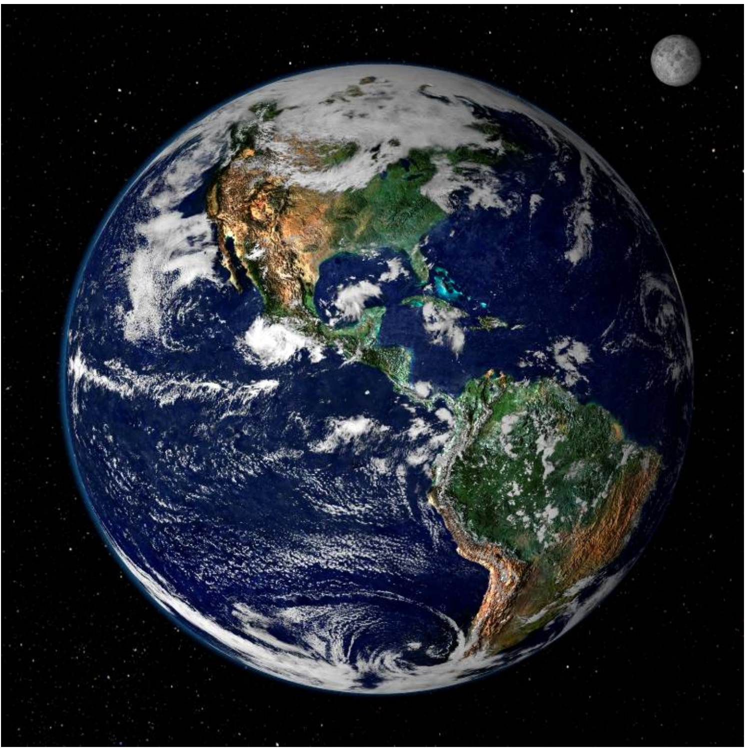
## Largest Known Aviation Scientific Uncertainty

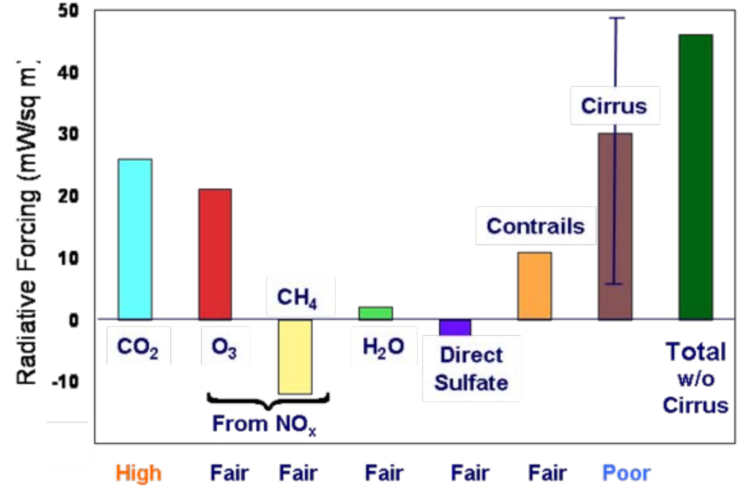


Scientific uncertainty can lead to poor decisions

# A Global Challenge For NASA

## Climate Change and Aviation






Only NASA has all the deep, world class expertise need:
Expert in climate change, earth observation, and aeronautics

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# Some Technology Challenges For NASA

## Helping the Environment, Realistic but *hard*

- Eliminate aircraft noise as community concern
- Reduce aircraft climate change impact by 50-80%
- Reduce the cost of access to space
  - On a mass basis ($/kg)
  - On a mission basis ($/mission)