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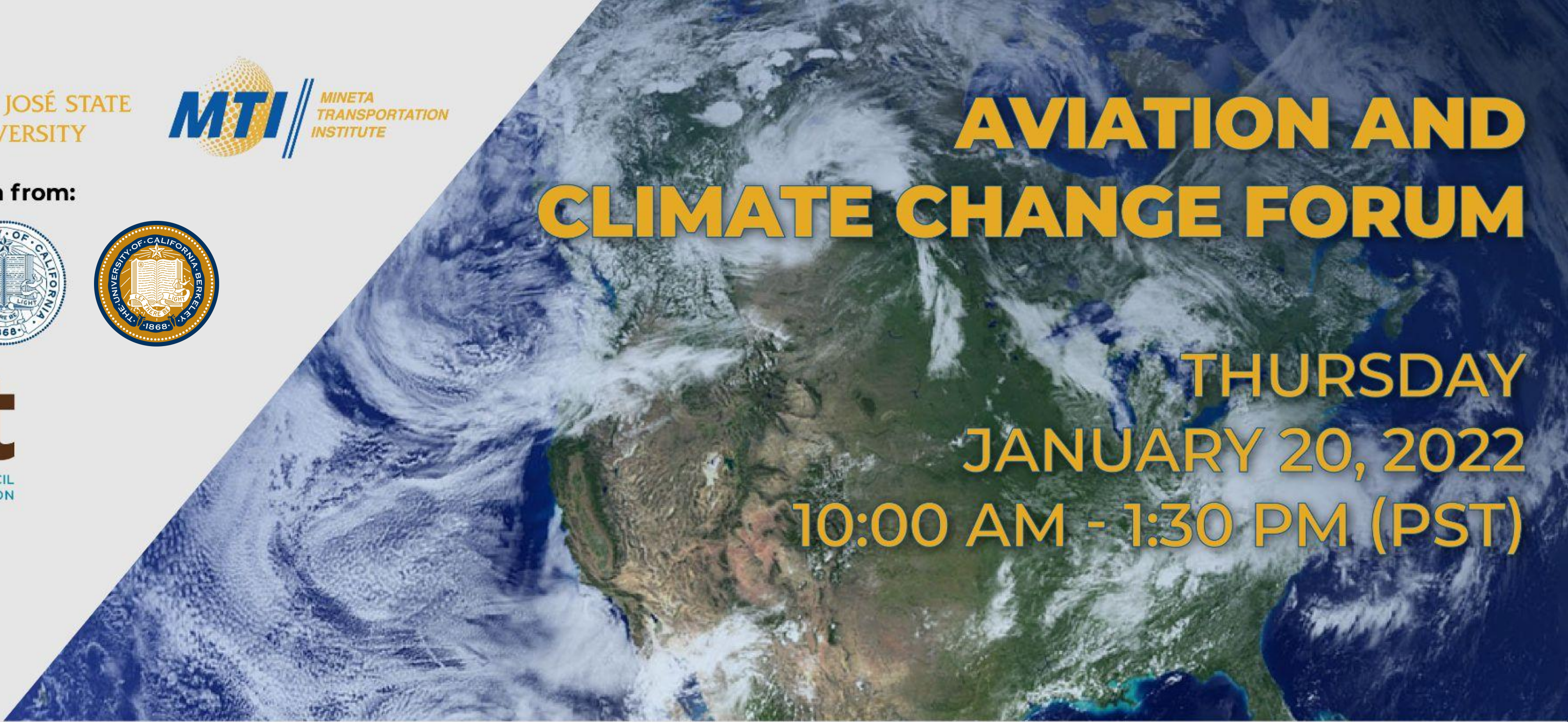
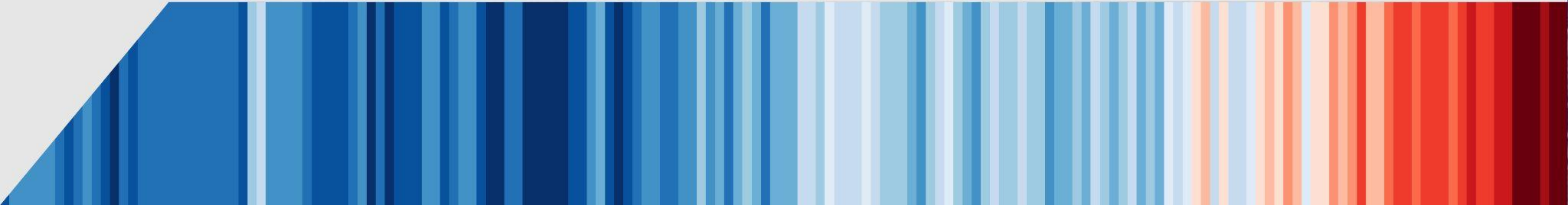


AVIATION AND CLIMATE CHANGE FORUM

THURSDAY JANUARY 20, 2022 10:00 AM - 1:30 PM (PST)

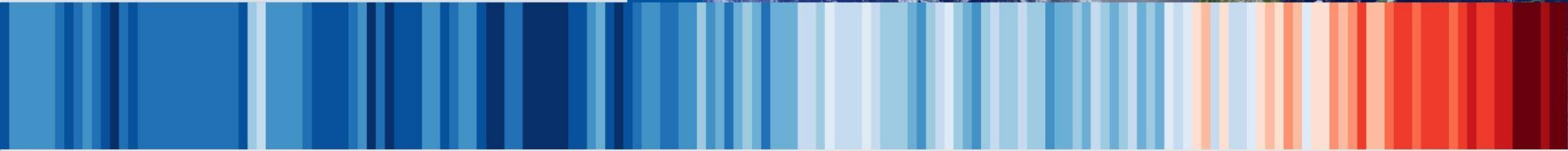
Globe warming stripe graphic is produced by Professor Ed Hawkins (University of Reading)



Welcome & Forum Overview

Dr. Karen Philbrick,
Executive Director, SJSU,
Mineta Transportation Institute

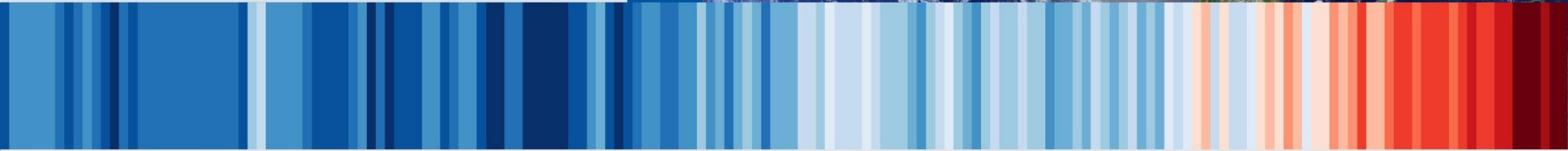
Dr. Tina L. Panontin, Director of Program Content, Professor of Practice, SJSU COE



Globe warming stripe graphic is produced by Professor Ed Hawkins (University of Reading)

Welcome & SJSU Perspective

Dr. Vincent Del Casino,
Provost and Senior Vice President, SJSU

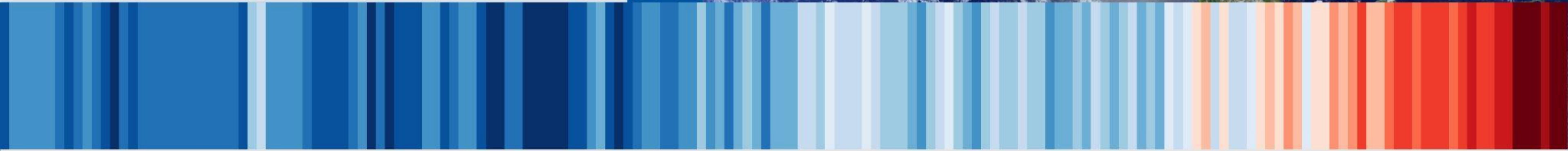


Globe warming stripe graphic is produced by Professor Ed Hawkins (University of Reading)

Silicon Valley Policy-Maker Perspectives

Congresswoman Zoe Lofgren, 19th District of California

Senator Dave Cortese, State Senate District 15



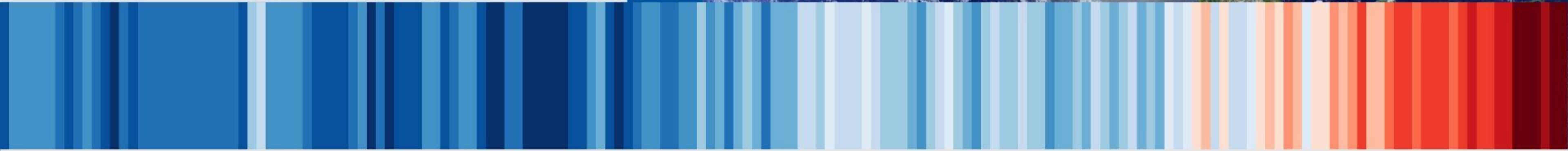
Globe warming stripe graphic is produced by Professor Ed Hawkins (University of Reading)


TATES CONGRESSWOMAN
LOFGREN
California's 19th District


DAVE CORTESE
REPRESENTING SENATE DISTRICT 15

Phenomenology

- *Effects of Aviation on Climate Change*, **Dr. Minghui Diao**, SJSU COS
- *Climate Change Effects on Aviation*, **Raj Pai**, NASA ARC



Globe warming stripe graphic is produced by Professor Ed Hawkins (University of Reading)

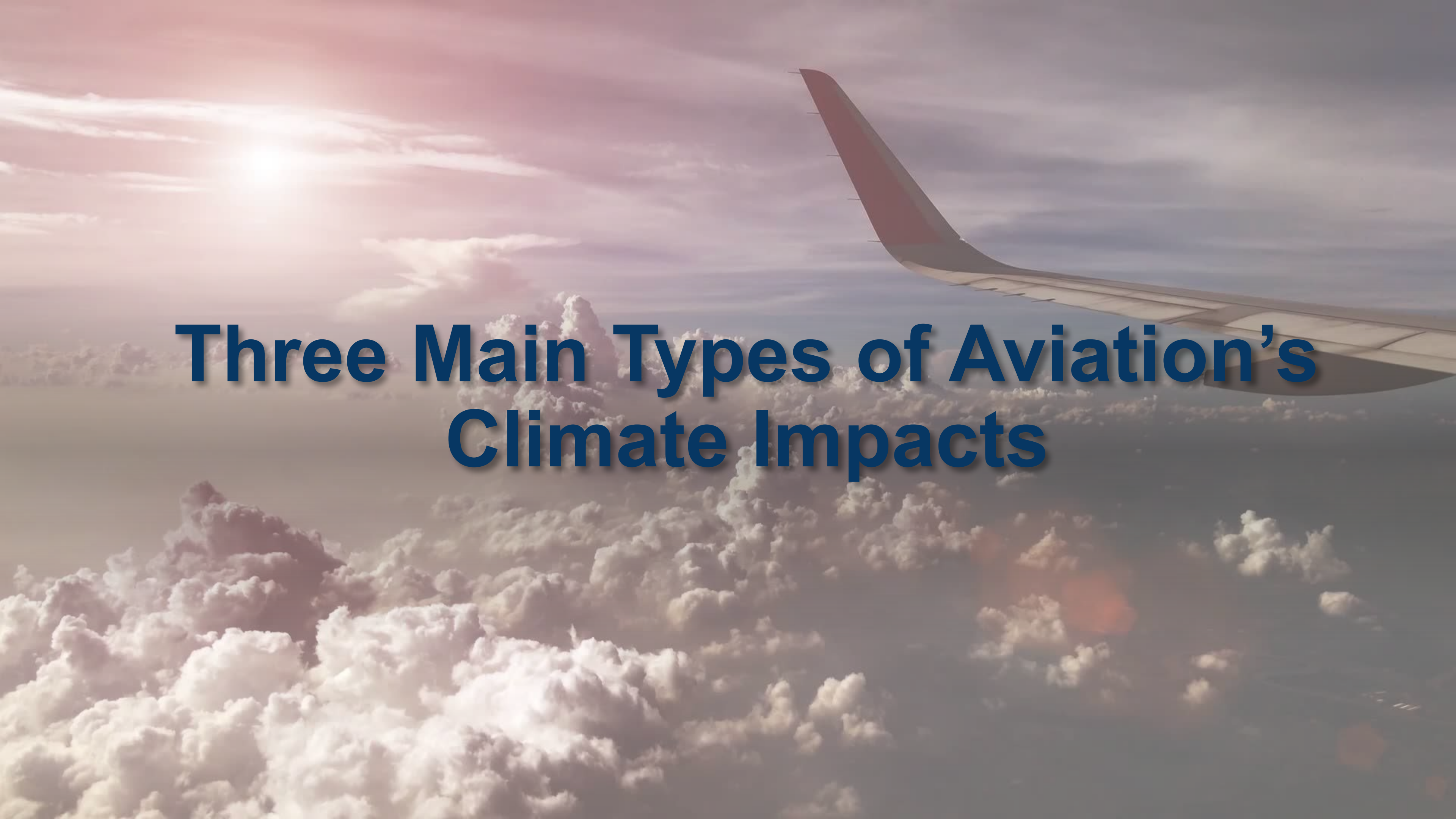
Effects of Aviation on Climate Change

Minghui Diao

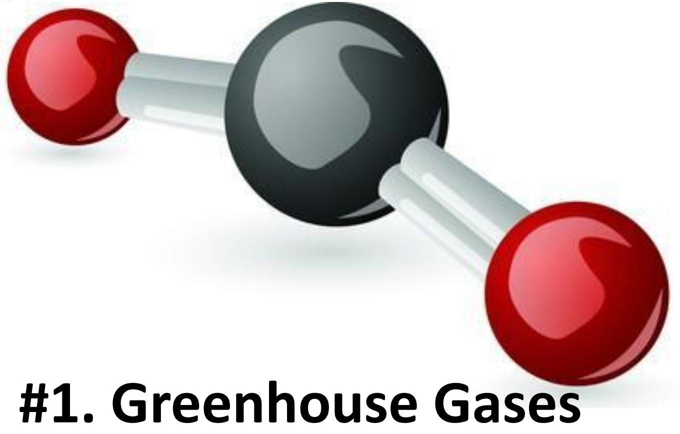
Department of Meteorology and Climate Science

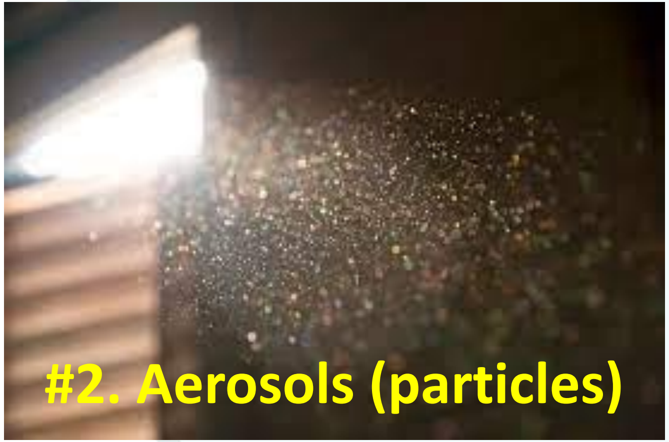
San Jose State University

AVIATION AND CLIMATE CHANGE FORUM, Jan 20, 2022



Three Main Types of Aviation’s Climate Impacts


#1. Greenhouse Gases


#2. Aerosols (particles)


#3. Modifications of Clouds

Effect #1. Greenhouse Gases

Air

(oxygen, nitrogen)

Fuel: CmHn + Sx

CO_2, NOx, SOx, HC, CO, H_2O, Black carbon

- Main greenhouse gases added to the air due to engine combustion
  - CO_2, H_2O, etc. (directly emitted)
  - CH_4, O_3 (enhanced by other products from combustion)
- Let's talk about a few examples –
  - CO_2, lifetime of 100-300 years
  - CH_4, lifetime of 12 years

Carbon Footprint of Aviation

*This slide only accounts for CO_2 emission.

What is the weight of a Boeing 737 aircraft?

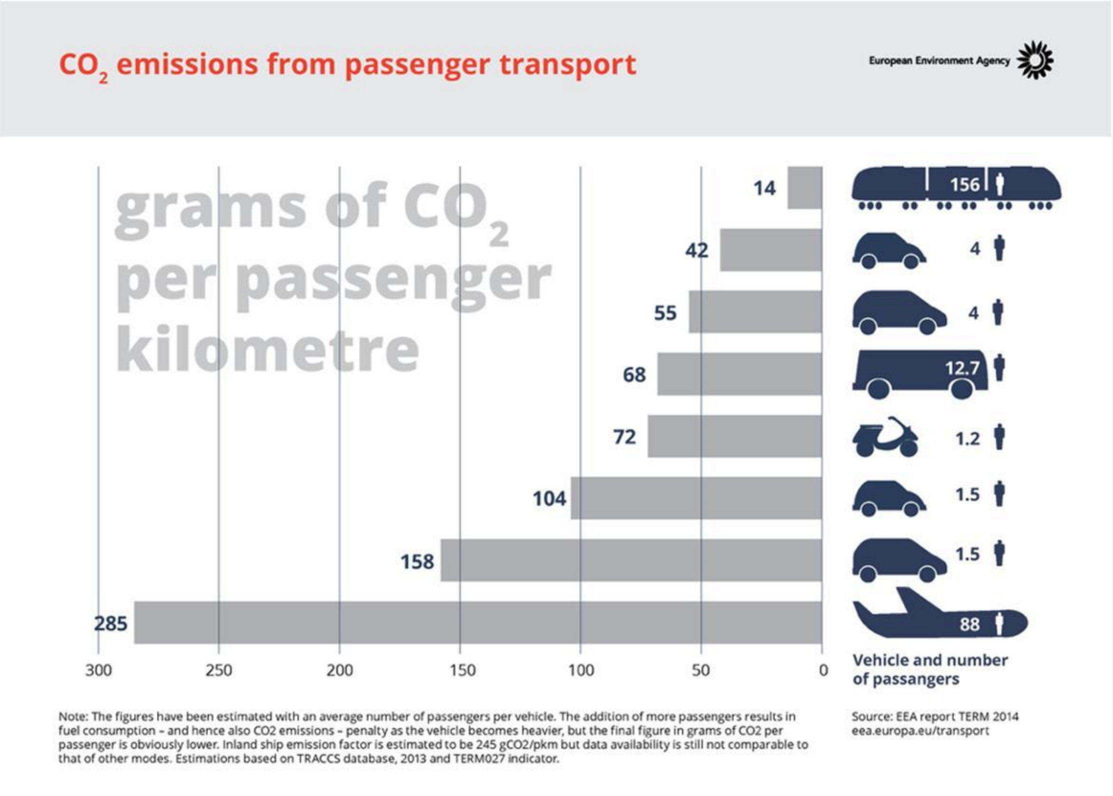
91,300 lbs

How much CO_2 is emitted for 737-400 flying from SFO to JFK?

1100 lbs

How many round trip SFO-JFK would emit the same weight of CO_2 as a Boeing 737?

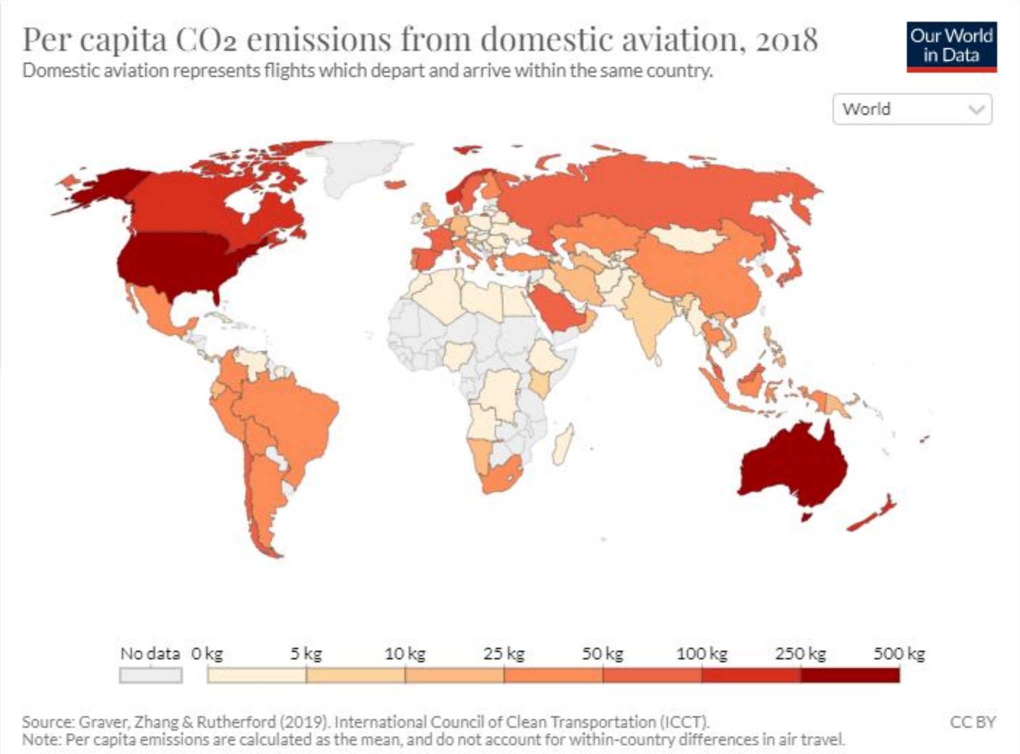
40



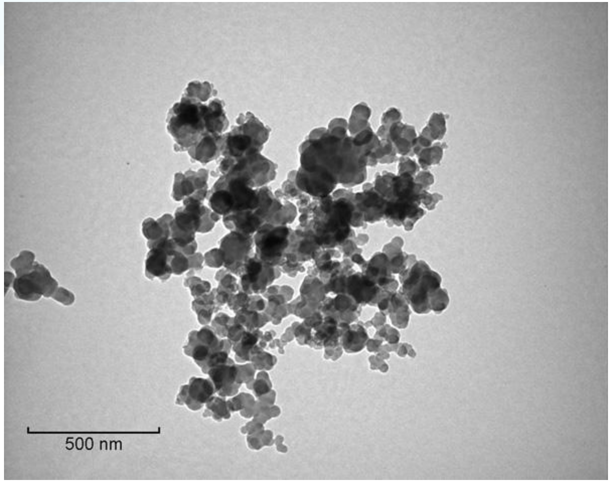
Which Country Has the Highest Aviation CO_2 Emission Per Person for Domestic Flight?

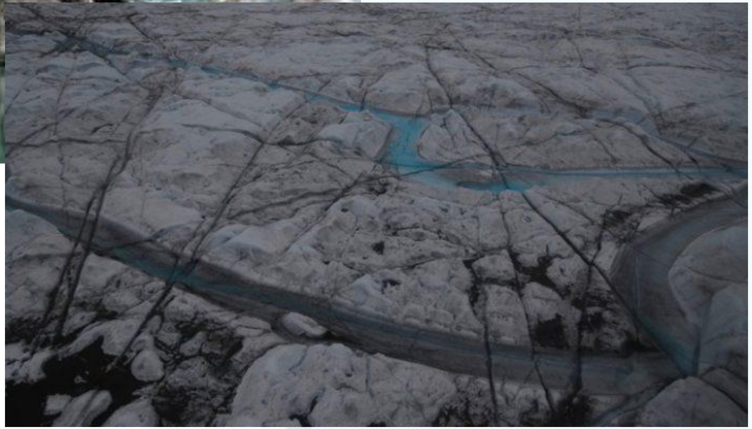
United States
Australia
Russia
United Kingdom

Globally, aviation accounts for around 2.5% of CO_2 emissions. But for many, it accounts for a much larger share.



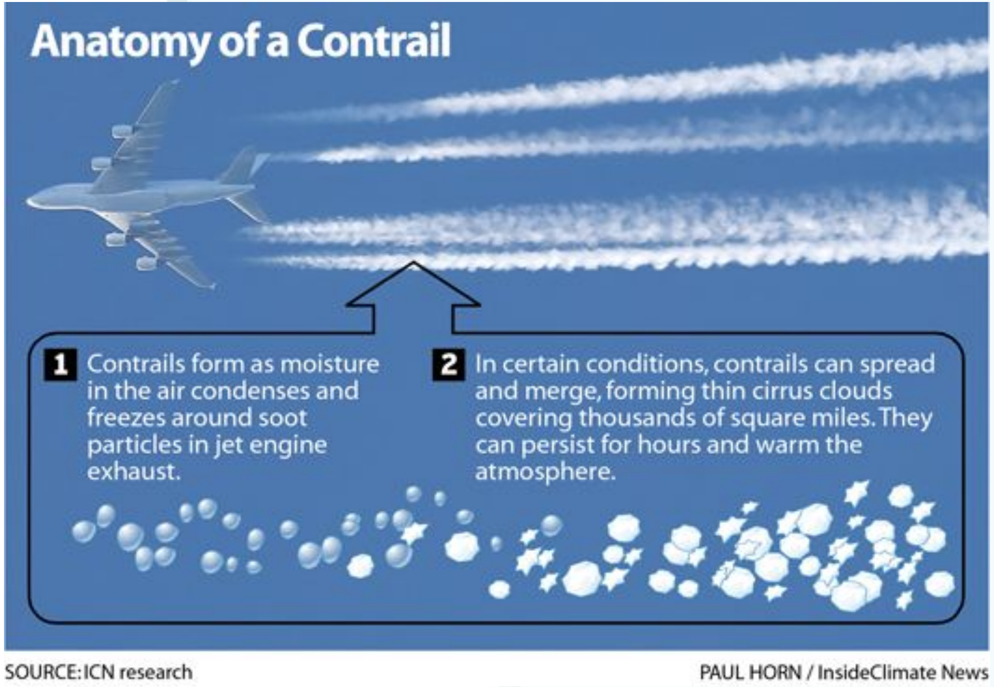
Effect #2. Black Carbon on Glaciers and Sea Ice





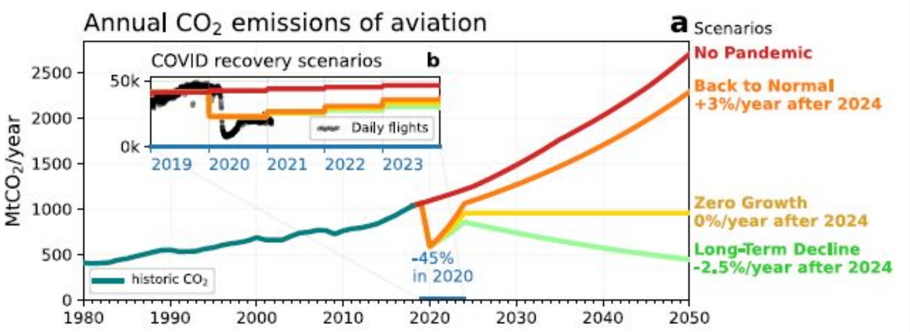
Effect #3. Modification of Cloud Cover

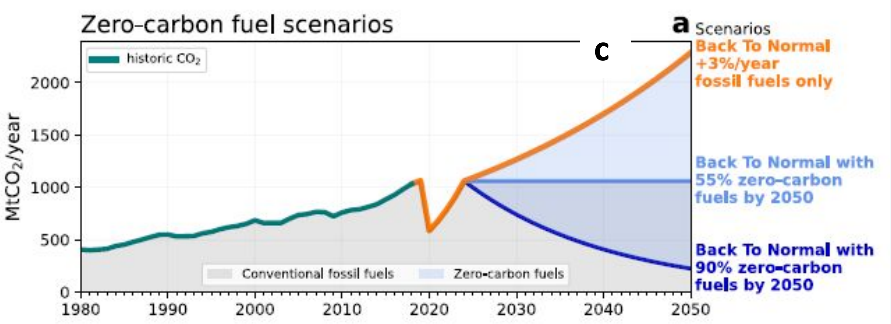
- Two types of clouds added to the atmosphere
  - Contrails (linear shape)
  - Contrail Cirrus (look like natural cirrus)
- Impacts on radiative forcing (how Earth is being warmed up)
  - Combined effect: 50 (20-150) mW m^{-2}
  - About **twice** as much as the warming effect from CO_2 emitted by aviation *(IPCC 2013; Burkhardt and Karcher 2011; Shumann and Graf, 2013; Minnis et al. 2013; Karcher, 2018)*



Summary of Aviation Effects on Climate Change

- Three main effects of aviation on climate
  - Greenhouse gases
  - Aerosols (mainly black carbon)
  - Contrails and contrail cirrus
- Greenhouse emission of aviation is the highest for travelling the same distance compared with other transportation methods (cars, trains, ships, bikes, etc.)
- Overall, aviation contributes to **~4%** of the human-induced global warming, even though only 2.4% of the global CO_2 emission is from aviation. *(Fahey et al., 2016; Klower et al., 2021)*
- ***The future depends on air traffic scenarios and conversion to carbon-neutral fuels.***

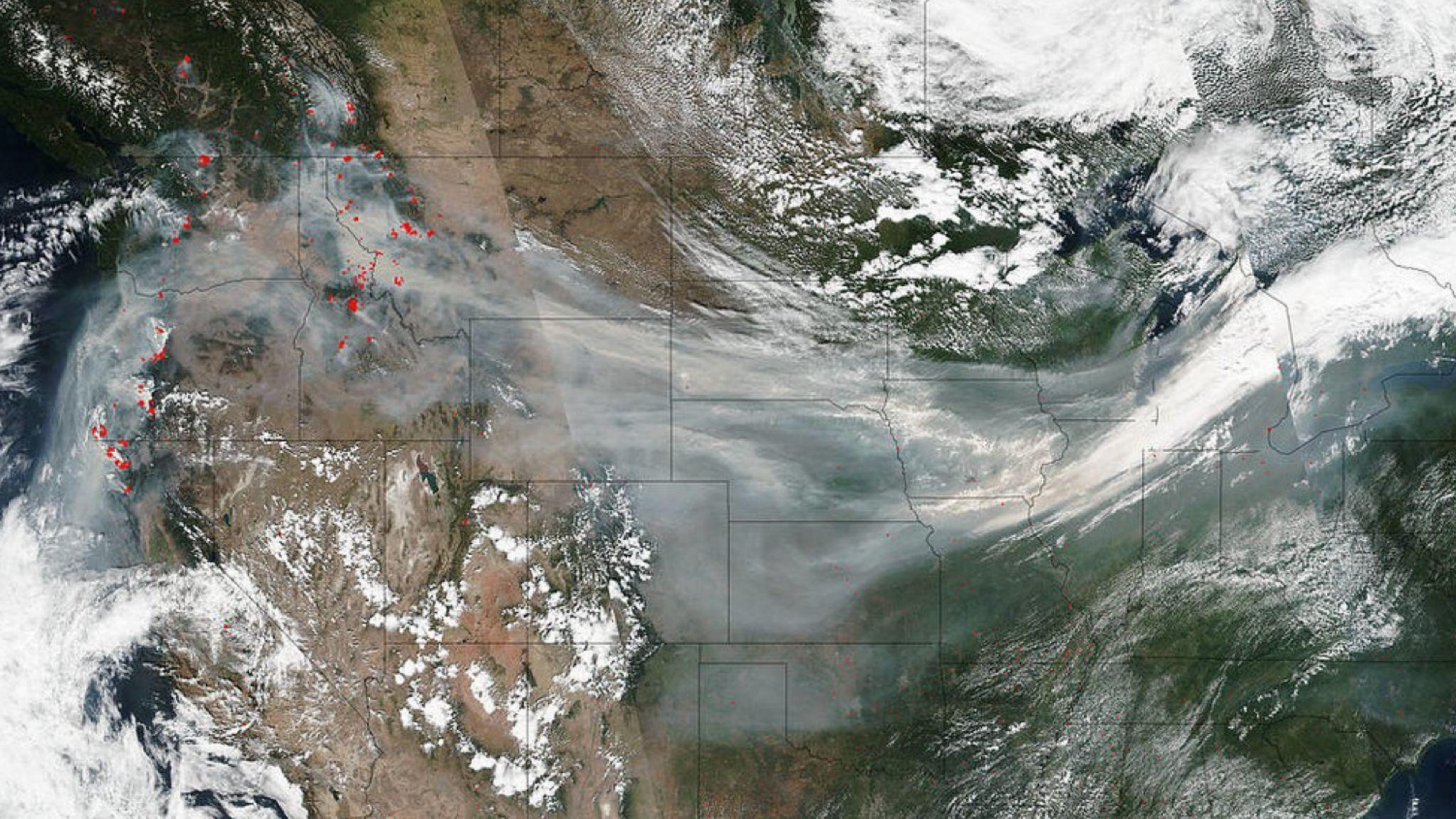




Klower et al., 2021, Envr. Res. Lett

Climate Change Impact on Aviation

Raj Pai, Senior Technologist, NASA Aeronautics, raj.pai@nasa.gov



Consumers, Business Operations Impacted

- Flight Delays & Airport Disruptions
- Scheduling, Flight Planning
- Contractual and/or Compliance Risk

Impact on Aviation Industrial Complex

- Rising Sea Levels
- Service Provider Facilities
- Workforce Planning

NASA Aeronautics "With You When You Fly"

Growth
New Users, New Vehicles

Sustainable
Electric, Biofuels

Safe, Efficient Global
Operations

Future is Bright, Welcome Aboard.

Raj Pai, raj.pai@nasa.gov

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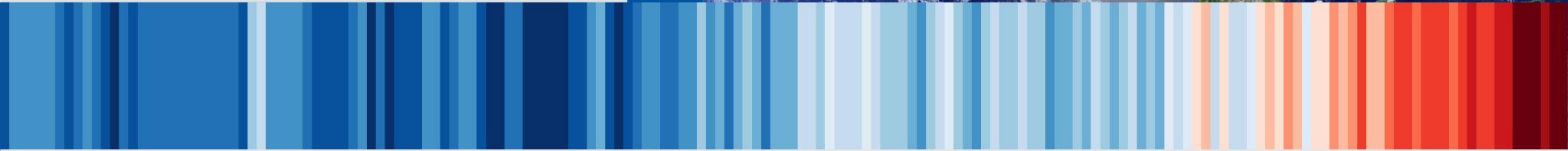
Strategic Frameworks

- *NASA Sustainable Aviation Program*, **Robert A. Pearce**, Associate Administrator, Aeronautics Research Missions Directorate
- *Basket of Measures: Policies to Reduce Aviation Impacts*, **Dr. Brandon Graver**, International Council on Clean Transportation



Globe warming stripe graphic is produced by Professor Ed Hawkins (University of Reading)

NASA Aeronautics Research – Presentation to the Aviation Climate Change Forum

Robert Pearce
Associate Administrator, Aeronautics Research Mission Directorate, NASA

January 20, 2022

Four Transformations for Sustainability, Greater Mobility, and Economic Growth

Next Generation - Sustainable Flight National Partnership

Small Core Gas Turbine for 5%-10% fuel burn benefit
(HyTEC Project)

High-Rate Composites for 6x manufacturing rate increase
(HiCAM Project)

Sustainable Aviation Fuels for reduced lifecycle carbon emissions
(AATT Project)

Electrified Aircraft Propulsion for ~5% fuel burn and maintenance benefit
(EPFD Project)

Integrated Trajectory Optimization for 1%-2% reduction in fuel required and minimization of contrail formation
(ATM-X Project)

Transonic Truss-Braced Wing for 5%-10% fuel burn benefit
(AATT Project)

Beyond Next Generation - Net Zero Aviation Emissions Innovation

NASA Distributed Propulsion Concept
- Turbo-Electric with superconducting electric drivetrain
- Over 70% reduction in energy use

Examples of current Research at Low TRL

University of Illinois, Urbana-Champaign (NASA ULI) fully electric concept
- Hydrogen fuel cell, superconducting electric drivetrain
- Zero carbon emissions

Foster radical aviation technology advancement – new energy sources, aircraft architectures – necessary for large aircraft with extremely low or zero emissions

Low TRL concepts can be further conceptualized, researched, developed, ground and flight tested and advanced for late 2030s / early 2040s

Recent University Leadership Initiative awards included net-zero emissions topics

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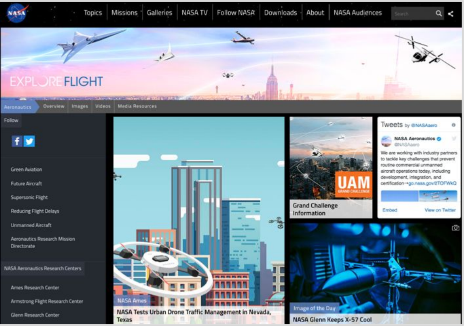

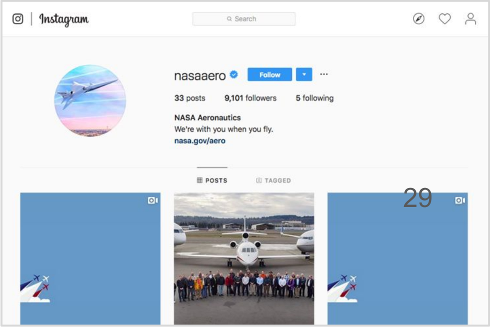

www.nasa.gov/aeroresearch/strategy | www.nasa.gov/aeroresearch/solicitations

Basket of Measures: Policies to Reduce Aviation Impacts

Brandon Graver PhD

20 January 2022

SJSU Aviation and Climate Change Forum

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International Council on Clean Transportation

- **Goal:** to dramatically reduce conventional pollutant and greenhouse gas emissions from all transportation sources in order to improve air quality and human health, and to mitigate climate change
- Promote best practices and comprehensive solutions to:
  - Improve vehicle emissions and efficiency
  - Increase fuel quality and sustainability of alternative fuels
  - Reduce pollution from the in-use fleet
  - Curtail emissions from international goods movement

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www.theicct.org

“Basket of Measures”

- Aircraft technology improvements
- Sustainable aviation fuels (SAFs)
- Operational improvements
- Market-based measures

Aircraft Technology Improvements

ICAO Aircraft CO_2 Standard (2017)

- New type aircraft must meet standard now

***** Currently, no new type aircraft *****

- In-production aircraft must meet standard by 2028

Boeing 737 MAX 8
below standard **7%**

Airbus A320neo
below standard **9%**

Boeing 787-10
below standard **11%**

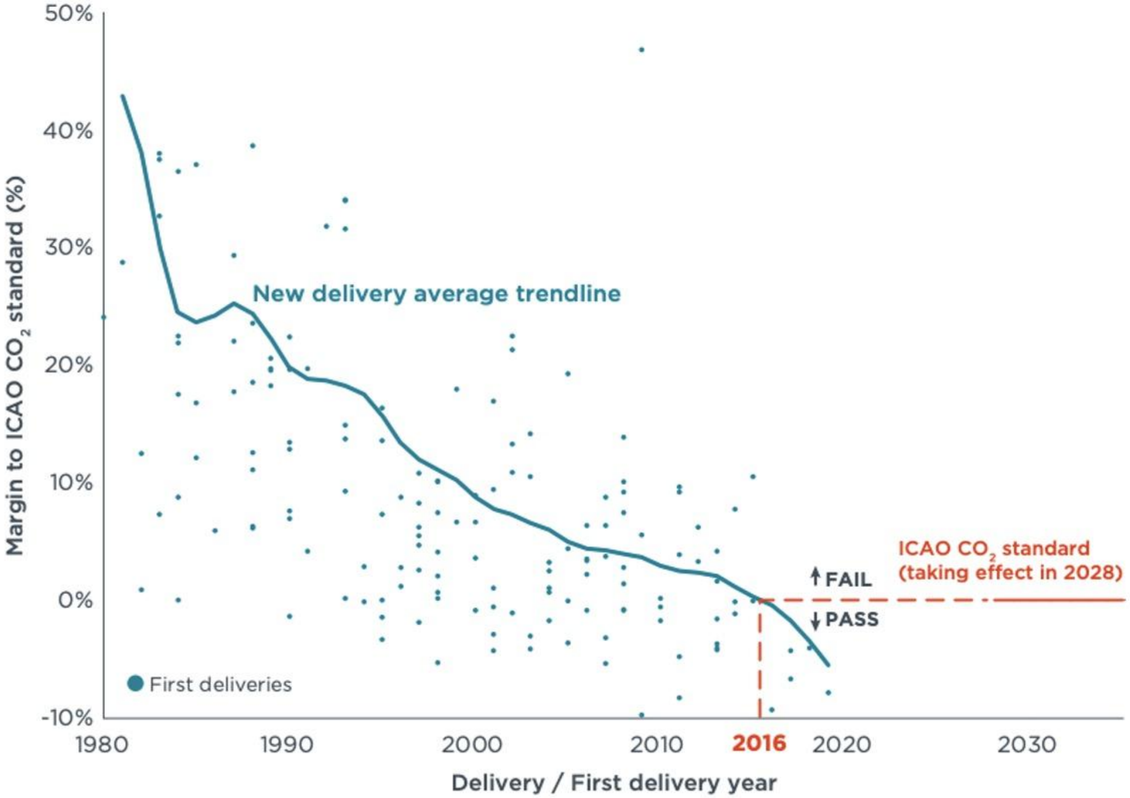
Airbus A330-900
below standard **13%**
EASA Certified

A decade ahead of schedule…

From ICCT white paper

Fuel burn of new commercial jet aircraft: 1960 to 2019

- The average new aircraft delivered in 2016 already complied with 2028 standard
- In 2019, the average new aircraft delivered passed the standard by 6%



EPA sued for stronger CO_2 standard

- Jan 2021: Trump's EPA promulgates US aircraft CO_2 standard that mimics ICAO standard
- Jan 2021: 11 states (including CA) and DC ask US Court of Appeals for a review (USCA Case #21-1018)
- Feb 2021: Lawsuit in abeyance while Biden reviews regs
- Nov 2021: EPA decides to stick with aircraft standard citing that US will push for more stringent ICAO standard, lawsuit resumes

Sustainable Aviation Fuels (SAFs)

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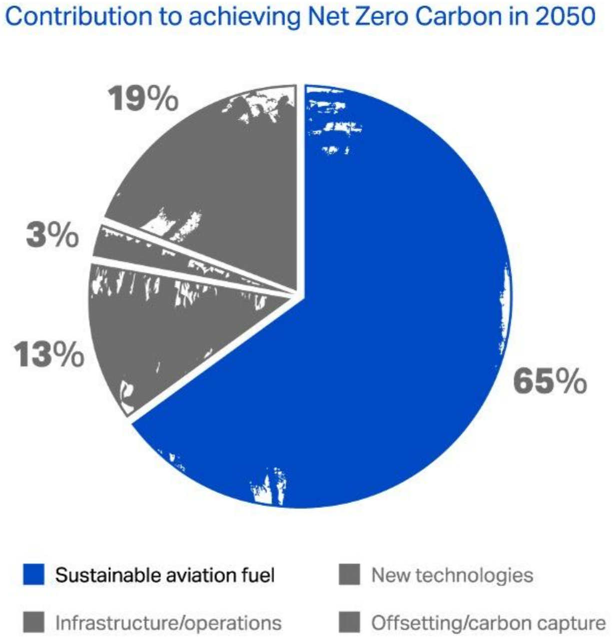
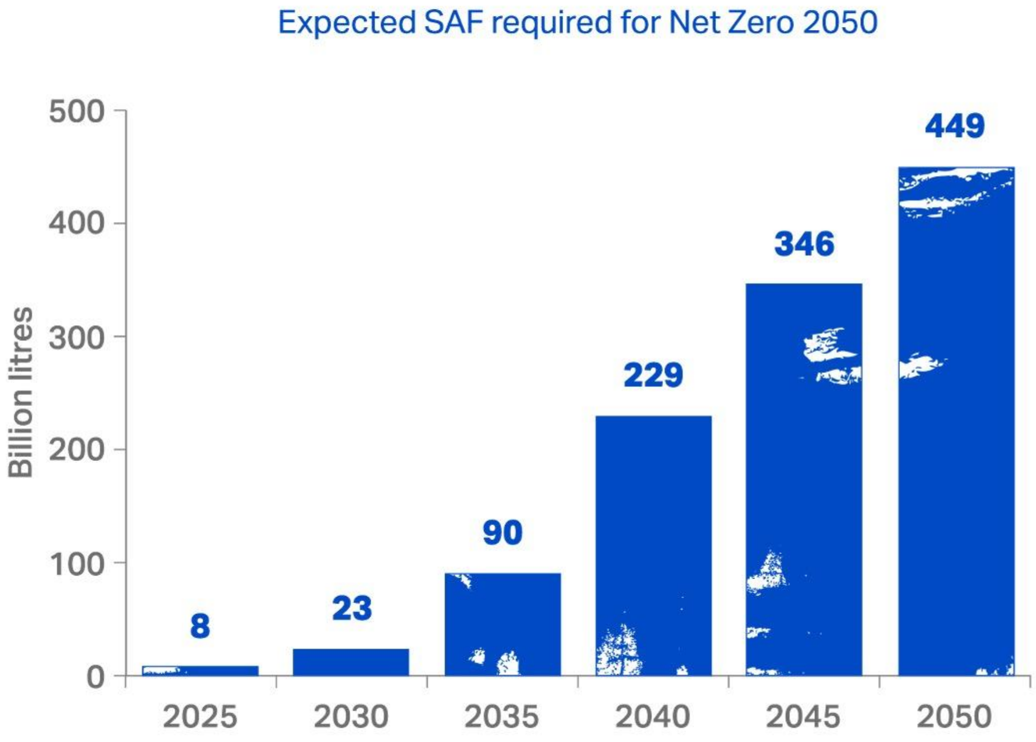
A lot of eggs in the SAFs basket…





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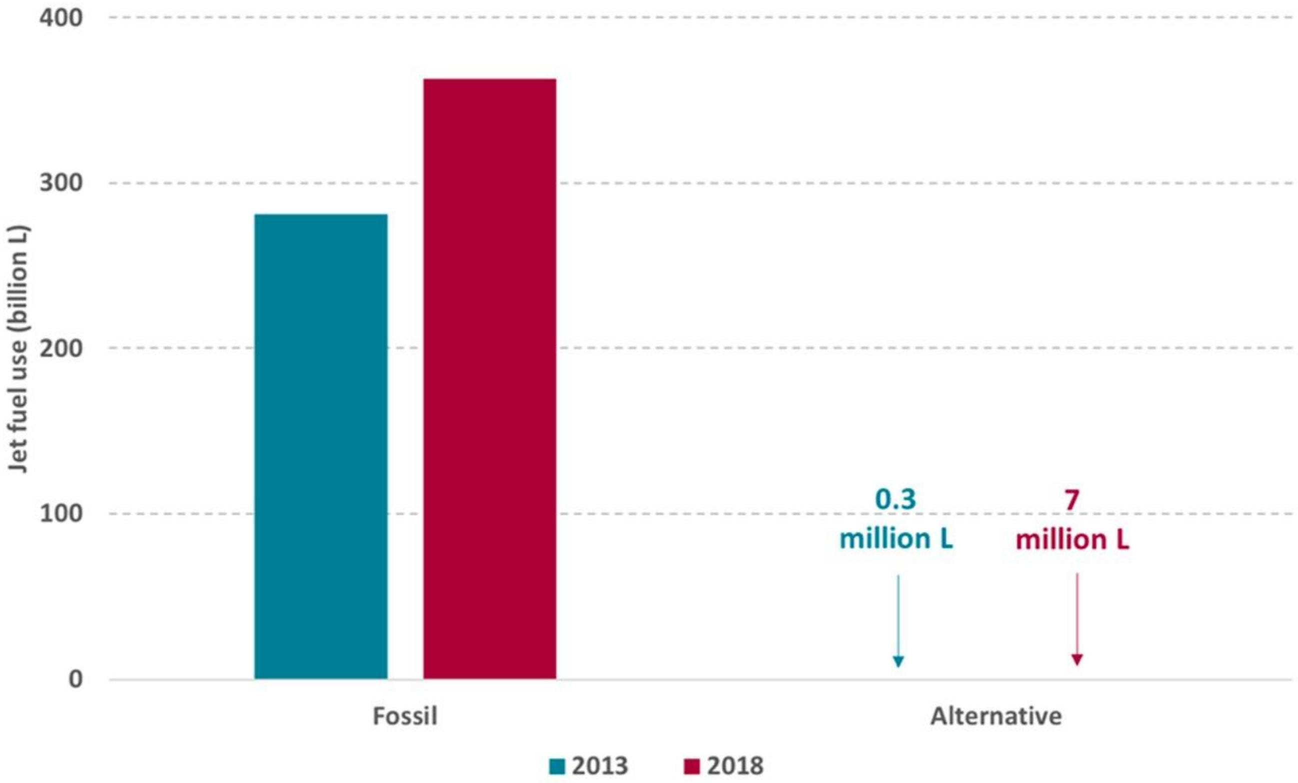
Graphics source: IATA

Production needs to scale up quickly…

BIG PROBLEM:
SAFs cost 2-5 times more than Jet-A



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H.R. 5736 - Build Back Better Act

SEC. 136203. SUSTAINABLE AVIATION FUEL CREDIT.

(a) In General.—Subpart D of part IV of subchapter A of chapter 1 is amended by inserting after section 40A the following new section:

"SEC. 40B. SUSTAINABLE AVIATION FUEL CREDIT.

"(a) In General.—For purposes of section 38, the sustainable aviation fuel credit for the taxable year is, with respect to any sale or use of a qualified mixture which occurs during such taxable year, an amount equal to the product of—

"(1) the number of gallons of sustainable aviation fuel in such mixture, multiplied by

"(2) the sum of—

"(A) $1.25, plus

"(B) the applicable supplementary amount with respect to such sustainable aviation fuel.

"(b) Applicable Supplementary Amount.—For purposes of this section, the term 'applicable supplementary amount' means, with respect to any sustainable aviation fuel, an amount equal to $0.01 for each percentage point by which the lifecycle greehouse gas emissions reduction percentage with respect to such fuel exceeds 50 percent. In no event shall the applicable supplementary amount determined under this subsection exceed $0.50.

$1.25 - $1.75
tax credit for the user of SAFs

Airlines' thoughts on this?

Source: @IATA Twitter

Operational Improvements

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ON CLEAN TRANSPORTATION

Operational Improvements

- Improvements to air traffic management
  - United States: NextGen
  - Europe: Single European Sky 2+
- Estimated total emissions reduction by 2050: 6-10%
- Other measures
  - Single engine taxi
  - Formation flying

Market-Based Measures (MBMs)

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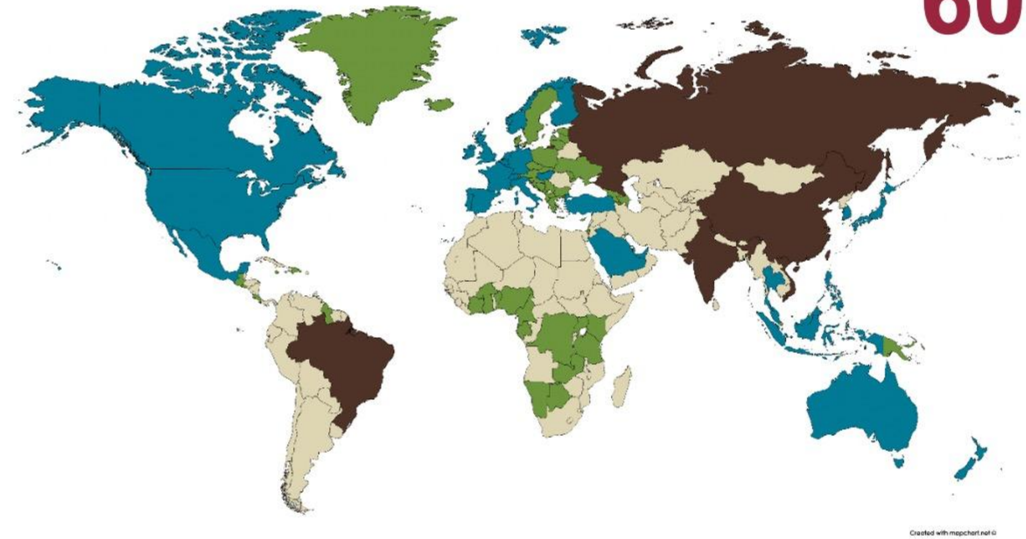
Examples of MBMs

- Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)
- European Union Emissions Trading Scheme (EU ETS)
- Carbon taxes

ICAO's CORSIA



State classification	Participation description
Mandatory I	Mandatory in 2027, but opting-in starting in 2021
Mandatory II	Mandatory in 2027 and not opting-in earlier
Opt-In	Exempt, but opting-in starting in 2021
Exempt	Exempt and not opting-in at any phase

Figure 1. CORSIA participation status as of April 3, 2020

606,479,990 tonnes

total international CO_2 emissions in 2019

2021 offsetting threshold:
339 million tonnes

2022 offsetting threshold:
344 million tonnes

EU ETS – Cap and trade scheme

- 2008: legislation applies to emissions from flights from, to, and within EEA (EU, Iceland, Liechtenstein, Norway)
- EU agrees to keep scope to flights within EEA until 2016 as ICAO works on CORSIA
- 2016: CORSIA adopted, scope remains intra-EEA
- 2021: ETU revisions proposed
    - Include Switzerland and United Kingdom
    - Reduce number of free allowances/credits

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Carbon taxes

- Canada: direct tax on fuel based on carbon content
- Switzerland: variable environmental levy on airline tickets based on distance and travel class
- Sweden: proposed changes to landing fees based on aircraft emissions
- UK: proposed changes to Air Passenger Duty on each long-haul ticket to help achieve carbon reduction goals

Airlines’ thoughts on this?

Source: @IATA Twitter

Other Measures: Domestic Flight Bans

- Domestic operations: 40% of aviation emissions
- France bans domestic flights that can be replaced with high-speed rail travel less than 2.5 hours
- Others made similar proposals: Germany, Italy, Spain
- Issue: flights with passengers connecting at international hub airports are exempt

France: 5 routes

Spain: 3 routes

Germany: 1 routes

Italy: 4 routes

What needs to be done?

- ICAO subsonic aircraft CO_2 standard needs review (2022-2024) and revision (2025 adoption)

- All stakeholders need to come together to develop an aviation decarbonization strategy with agreements on <u>who is going to pay for what</u>

> *"Engaging with travelers, environmental NGOs and governments based on transparent reporting will ensure that our flightpath to net zero is fully understood."*
>
> -- IATA Director General Willie Walsh

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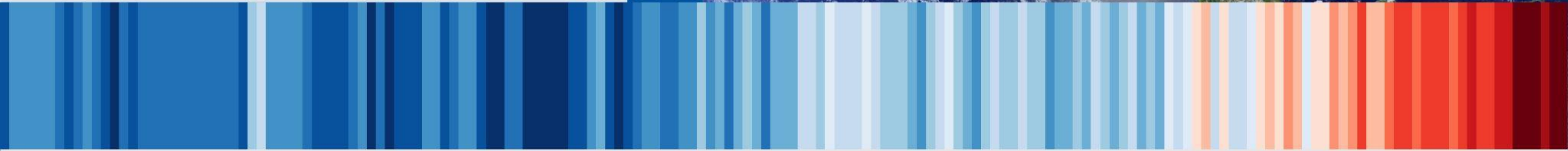
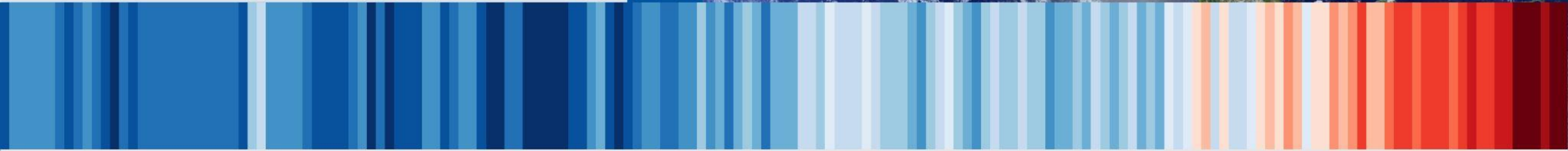
Break/Q&A



Globe warming stripe graphic is produced by Professor Ed Hawkins (University of Reading)

Strategic Frameworks, Cont.

- *SJSU Mission and Capabilities*, **Dr. Sheryl Ehrman**, SJSU COE and **Dr. Michael Kaufman**, SJSU COS
- *NASA ARC Mission and Capabilities*, **Dr. Eugene Tu**, Center Director



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Charles W. Davidson College of Engineering

Right engineers, right place, right time

75+ years strong for Engineering!

Aviation flying as a club since 1936, participated in Civilian Pilot Training Program (CPT) in WWII, established as a department in 1946

#4 - Best College of Engineering among BS/MS public institutions, US News and World Report, 2021

Growing source of ideas: 3 of the 12 Inno under 25 for 2021 in the Silicon Valley Business Journal are SJSU grads + increasing research activity

Facts and Figures - Fall 2021

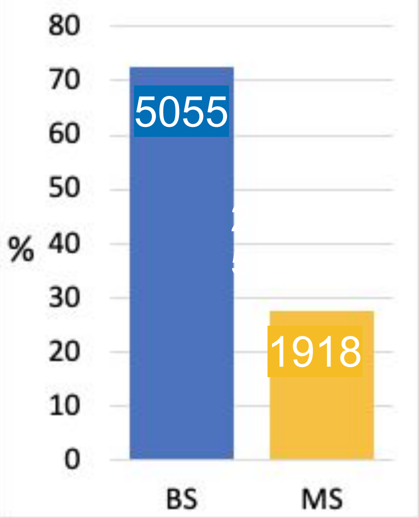
PROGRAMS HIRING

- Aerospace
- Aviation
- Biomedical
- Chemical
- Civil
- Computer and Software
- Electrical
- Interdisciplinary
- Industrial and Systems
- Engineering Technology
- Materials
- Mechanical

6,973
undergraduate + graduate students

LARGEST MASTERS PROGRAM
among CSU + comparable university peers

Fall 2021 enrollment



College of Science Overview

Michael Kaufman, Dean

- ~3000 students (BS/BA/MS) studying for degrees in Biology, Chemistry, CS, Geology, Math & Statistics (incl. Appl. Math), Marine Science (@MLML), Meteorology & Climate Science, Physics & Astronomy, Science Education
- Special degrees in Bioinformatics, Data Science, Medical Product Development, Biotechnology
- 25% are from groups traditionally underrepresented in the sciences, 45% women
- Strong focus on research, especially student-centered research, as a transformational educational experience
- $20M/year in external funding (NASA, NIH, NSF, DOE, State of CA, NOAA, USDA, etc.)

Unique Programs

Meteorology & Climate Science (only program in the CSU)

Expertise in stratospheric ices and aerosols, climate modeling, climate impacts (physical and economic), fire-weather interactions, Mars global circulation, education as a mitigation to climate change, airborne campaigns, home of Wildfire Interdisciplinary Research Center (WIRC)

Moss Landing Marine Labs

Expertise in ocean acidification, agricultural runoff, genetic tracers of ocean health, long-term climate change, sustainable aquaculture, healthy fisheries, etc.


SJSU
COLLEGE OF SCIENCE

SJSU | COLLEGE OF SCIENCE


NASA
SILICON
VALLEY
AMES RESEARCH CENTER

NASA Ames Research Center

Missions and Capabilities

Dr. Eugene Tu

Center Director

SILICON VALLEY
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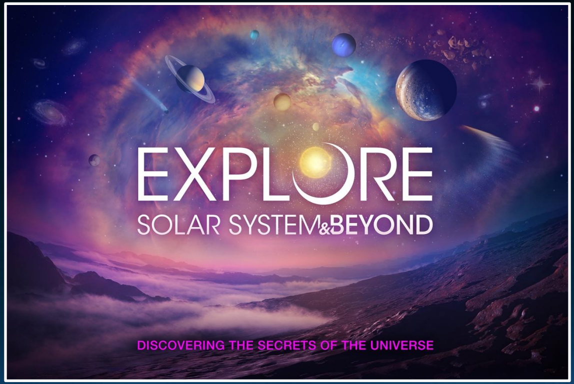

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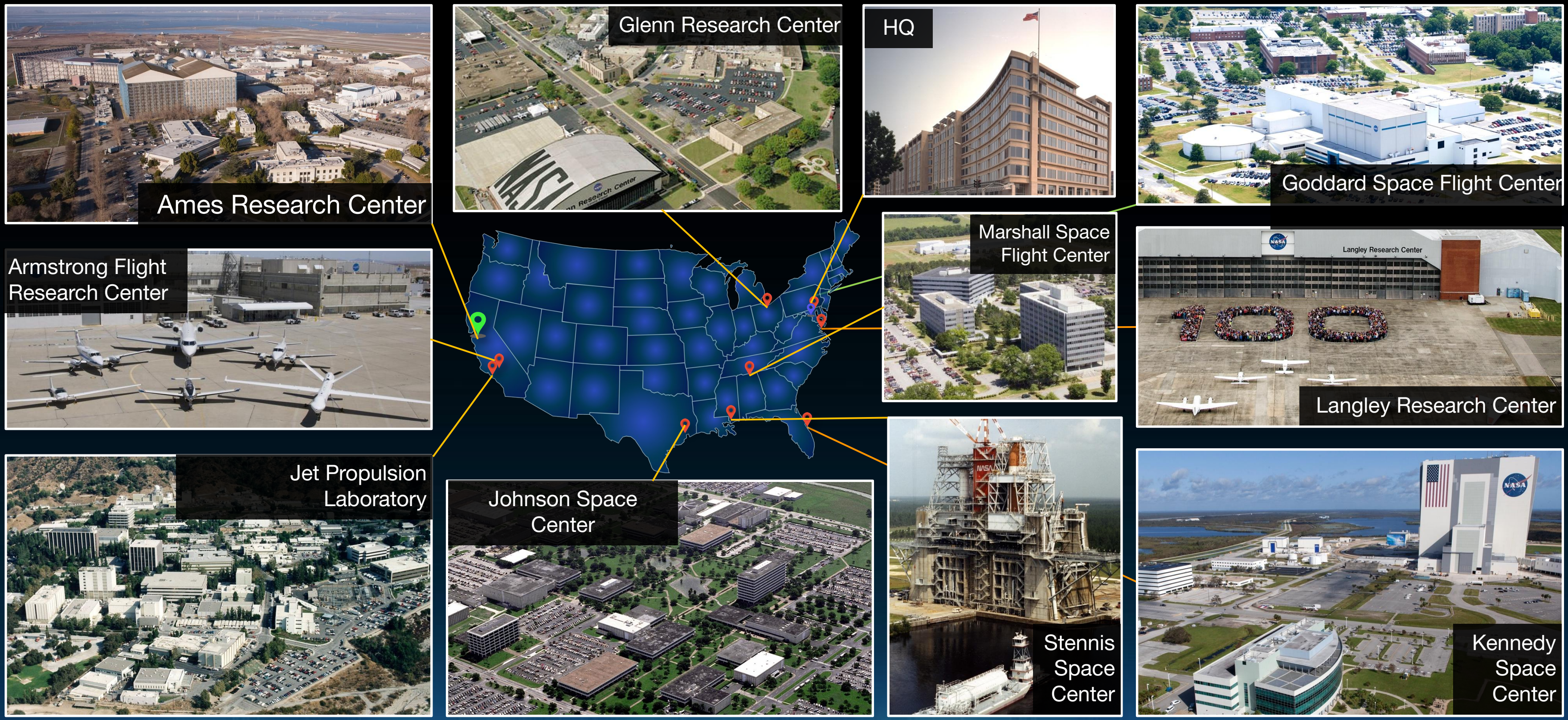
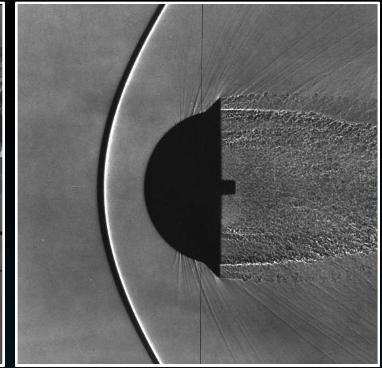
AMES RESEARCH CENTER

NASA Centers



Ames Aeronautical Laboratory

The NACA's Second Laboratory



NACA Est. 1915

- *Langley – 1917*
- *Ames – 1939*
  - *Research Hangar*
  - *7x10-foot Tunnels*
  - *40x80-foot Full Scale*
  - *16-foot High Speed*
  - *12-foot Pressure Tunnel*

1940s: Quick & Practical

- *De-icing*
- *Duct Rumble*
- *Aileron Flutter*
- *Buffeting*
- *Dive Control*

The Supersonic Age

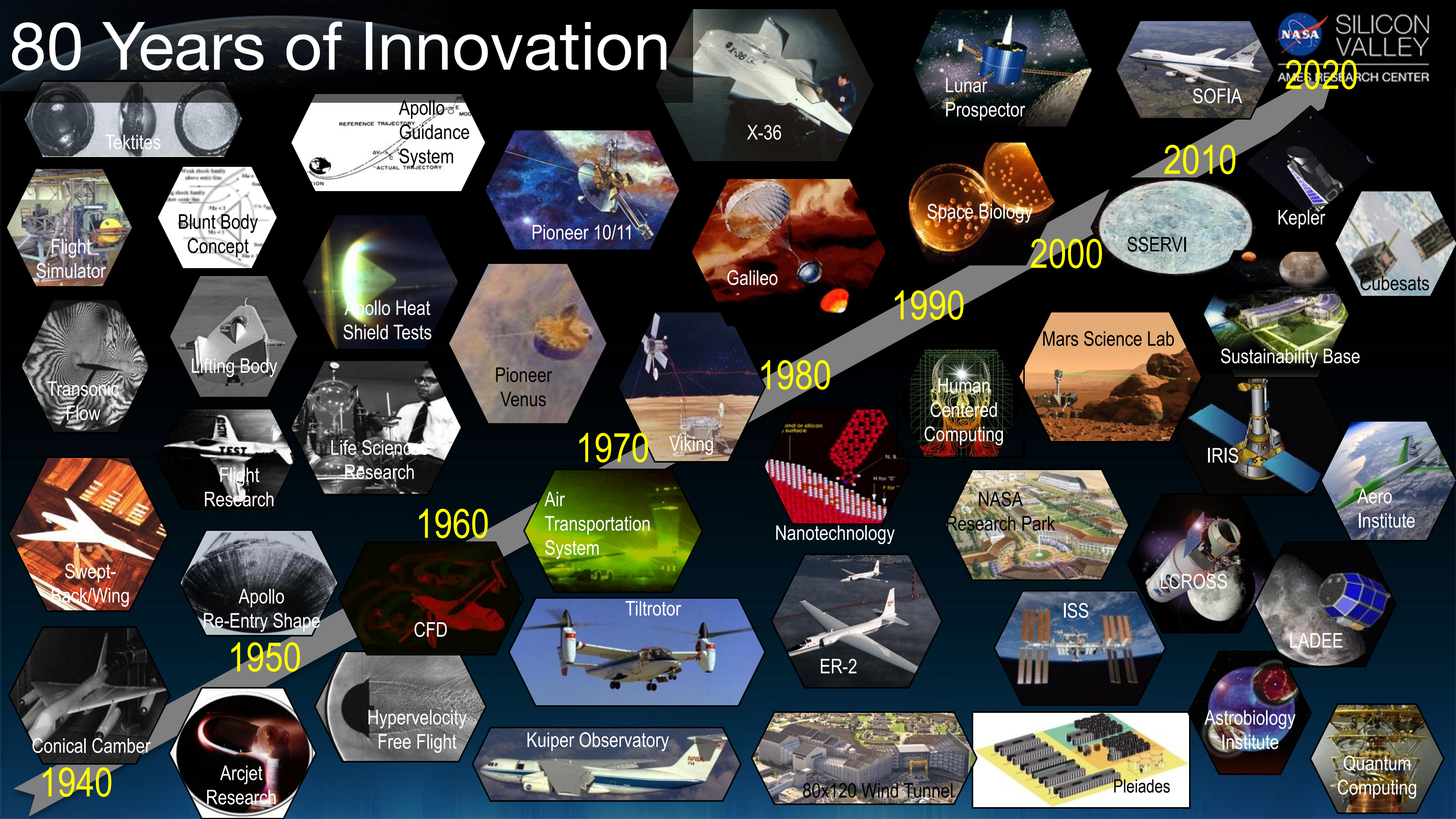
- *Swept Wings*
- *Supersonic Tunnels*
- *Supersonic Area Rule*
- *Conical Camber*
- *Hypervelocity Research*

1950s

- *Simulation*
- *Unitary Tunnel*
- *Blunt Body Concept*

NACA Becomes NASA

- *Reentry Studies*
- *Arc Jet Development*
- *Spaceflight Projects*


80 Years of Innovation
NASA
SILICON VALLEY
AMES RESEARCH CENTER
1940
1950
1960
1970
1980
1990
2000
2010
2020
Tektites
Flight Simulator
Blunt Body Concept
Transonic Flow
Lifting Body
Swept-Back/Wing
Flight Research
Conical Camber
Apollo Re-Entry Shape
Arcjet Research
Apollo Guidance System
Apollo Heat Shield Tests
Life Sciences Research
CFD
Hypervelocity Free Flight
Pioneer 10/11
Pioneer Venus
Air Transportation System
Tiltrotor
Kuiper Observatory
X-36
Viking
Galileo
Nanotechnology
ER-2
80x120 Wind Tunnel
Lunar Prospector
Space Biology
Human Centered Computing
NASA Research Park
ISS
Pleiades
Mars Science Lab
SOFIA
SSERVI
Kepler
Cubesats
Sustainability Base
IRIS
LCROSS
Aero Institute
LADEE
Astrobiology Institute
Quantum Computing

Ames Today

Occupants

- ~1,200 civil servants
- ~1,900 on-site contractors
- ~2,500 NRP workforce
- ~700 summer students in 2019

FY20 Budget

- ~$1,011M (est.) & includes reimbursable/EUL

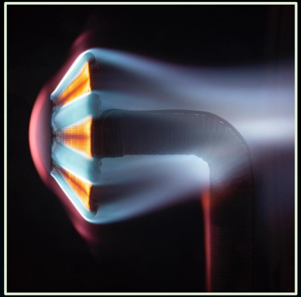
Real Property

- ~1,900 acres
- 400 acres security perimeter
- 5M building ft^2
- Airfield with ~9,000 and 8,000 ft. runways

Core Competencies

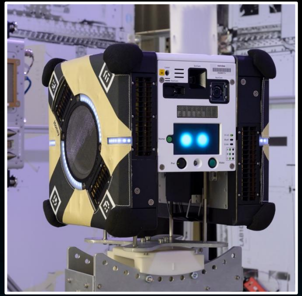
Air Traffic Management

Entry Systems



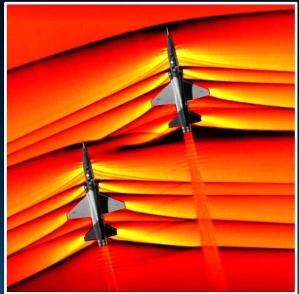
Advanced Computing & IT Systems

Intelligent & Adaptive Systems



Cost-Effective Space Missions

Aerosciences



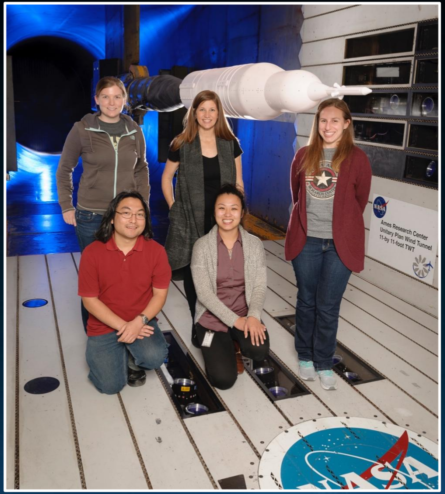
Astrobiology & Life Science

Space & Earth Sciences

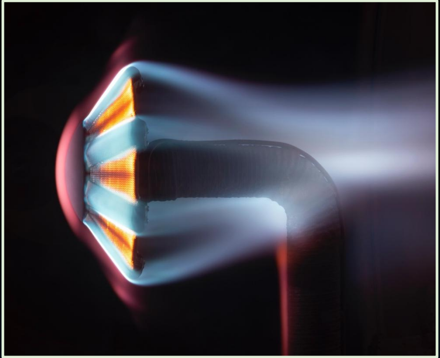
NASA SILICON VALLEY
AMES RESEARCH CENTER

Major Research Facilities

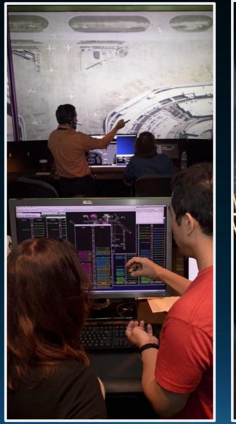
Wind Tunnels

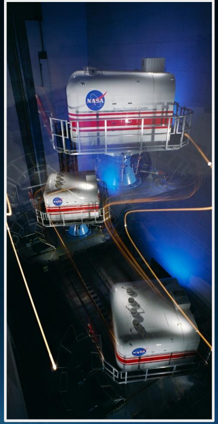


Arc Jet Complex

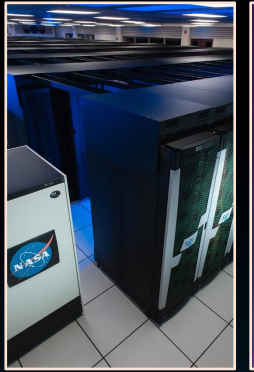


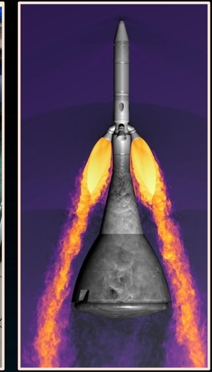
Simulators





Supercomputing



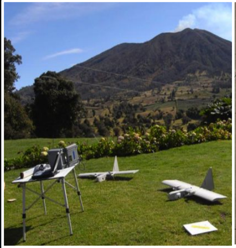


Evaluating Sustainable Aviation Aircraft Configurations (Unitary Plan Wind Tunnel Facility)

NASA SILICON VALLEY
AMES RESEARCH CENTER

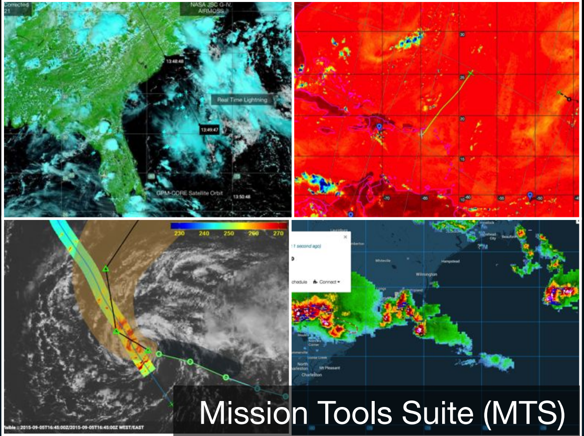
Large Scale Simulations of Sustainable Aviation Operations (Future Flight Central)

Airborne Earth Science Helps Us Understand and Mitigate Climate Change Effects/Impacts



New unmanned aircraft available to science from SUAS to HALE

MODIS/ASTER Airborne Simulator (MASTER) sensor supports "Surface Biology and Geology (SBG)" and wildfires



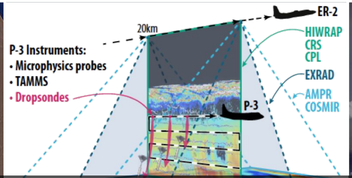
Mission Tools Suite (MTS)

Next-Gen onboard hardware: computing, instruments, and SATCOM

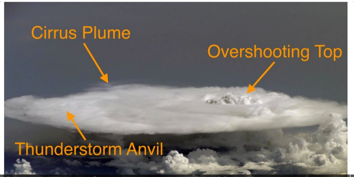
ESPO

Earth Science Project Office

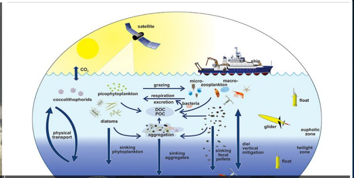
Asian Summer Monsoon Chemical & CLimate Impact Project



Investigation of Microphysics and Precipitation for Atlantic Coast



Dynamics and Chemistry of the Summer Stratosphere



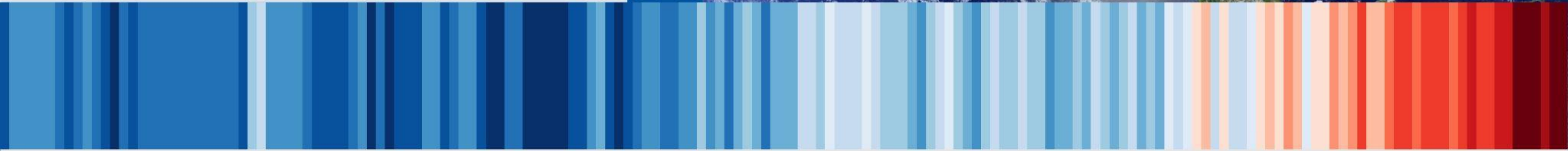
Export Processes in the Ocean from RemoTe Sensing

Research For Wildfire And Disaster Support (Capabilities In The Field)


NASA
EXPLORE FLIGHT
WE'RE WITH YOU WHEN YOU FLY

Technology Advances

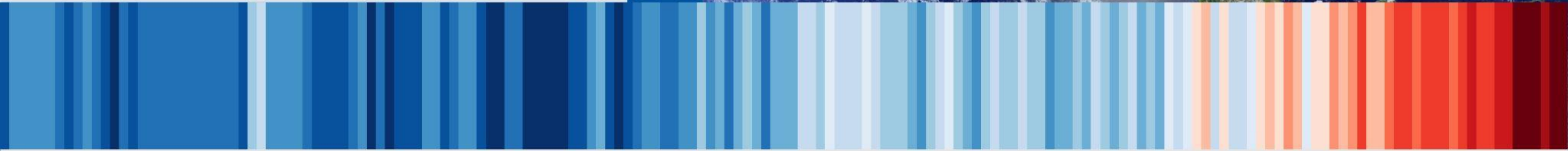
- *Biofuels*, **Dr. David Wagner**, SJSU COE
- *Meteorology/Weather Prediction*, **Dr. Alison Bridger**, SJSU COS
- *Airport Surface Operations*, **Shawn Engelland**, NASA ARC
- *Air Traffic Management*, **Dr. Mark Hansen**, UC Berkeley
- *Commercial Aircraft Configurations Design and Testing*, **Kevin James**, NASA ARC
- *Infrastructure*, **Dr. Serena Alexander**, SJSU/MTI



Globe warming stripe graphic is produced by Professor Ed Hawkins (University of Reading)

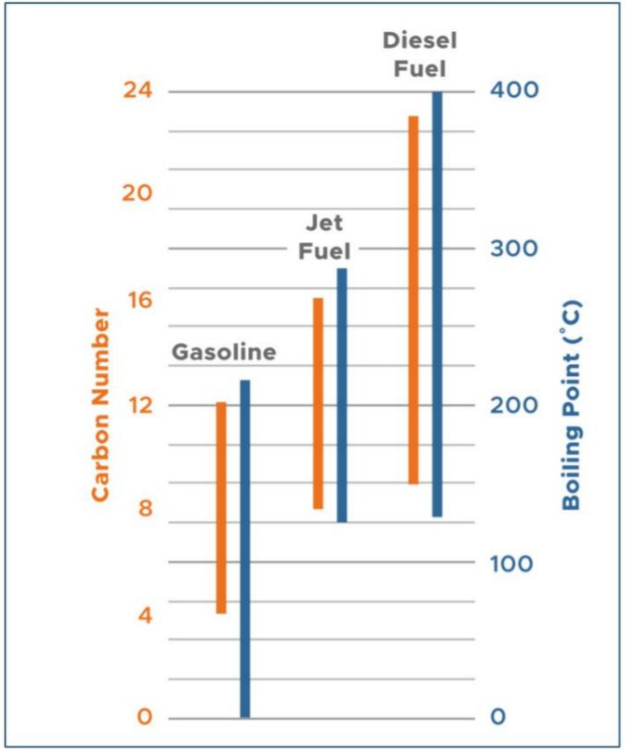
Technology Advances in Biofuels

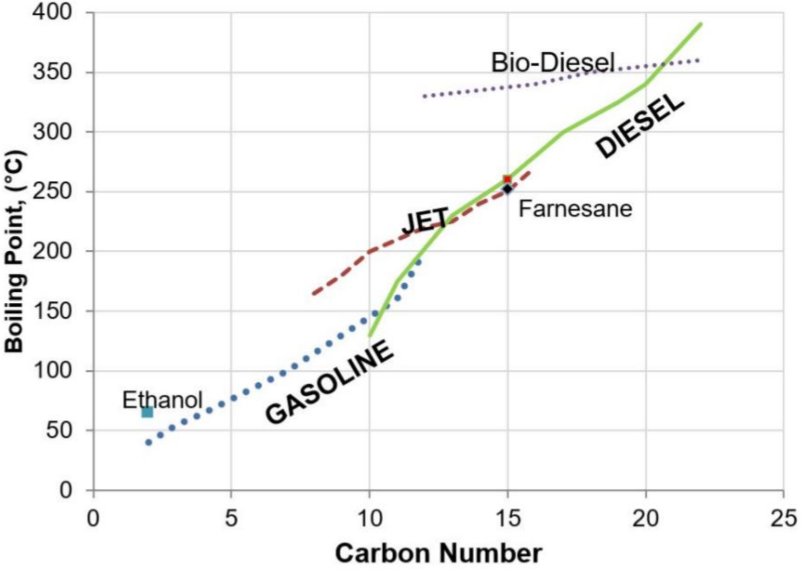
David Wagner, PhD
Department of Chemical and Materials Engineering
San Jose State University



Globe warming stripe graphic is produced by Professor Ed Hawkins (University of Reading)

Overview of Transportation Fuels





There is less disruption to the refinery sector producing alternative jet fuel than gasoline or diesel

DOE EERE: Sustainable Aviation Fuel - Review of Technical Pathways

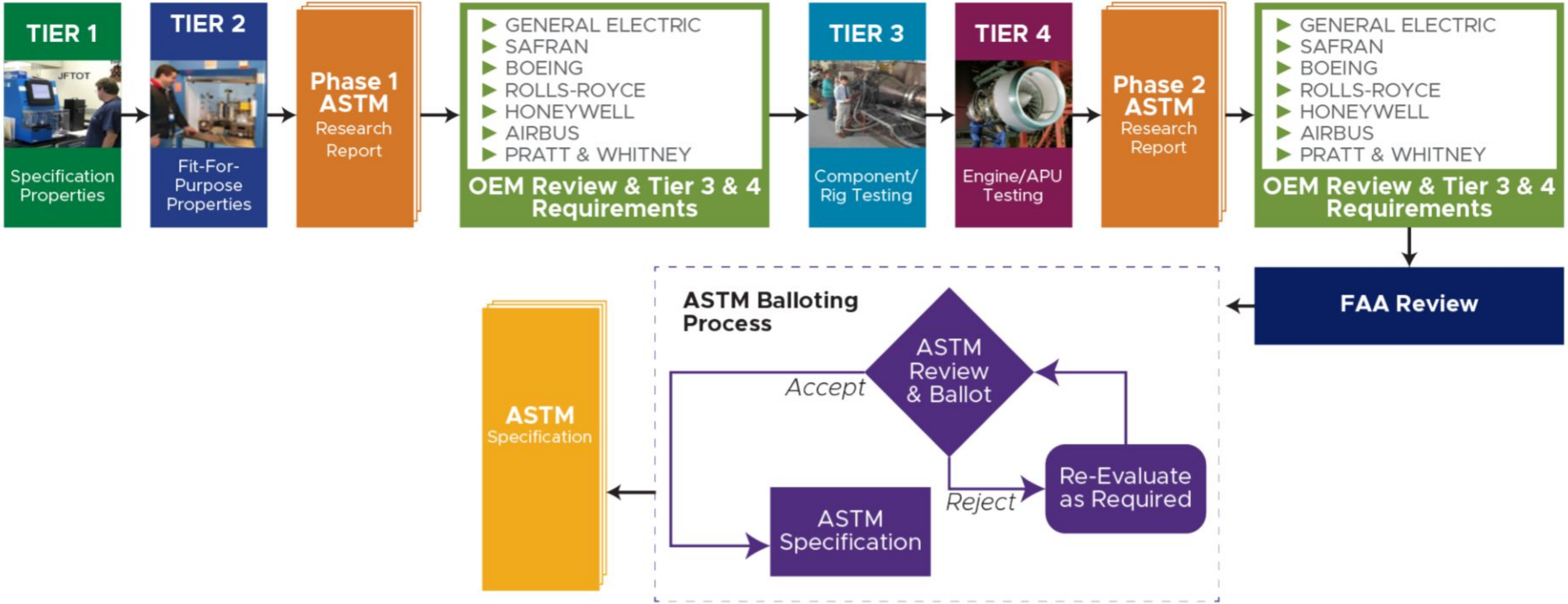
Production Platforms and Feedstocks

SPK	Production platform	Brief process description
HEFA-SPK	Oil-to-jet	Deoxygenation of oils and fats → hydroprocessing
FT-SPK	Gas-to-jet	Gasification of biomass → Fischer-Tropsch → hydroprocessing
FT-SPK/A	Gas-to-jet	Gasification of biomass → Fischer-Tropsch → hydroprocessing → increase aromatics content
ATJ-SPK	Alcohol-to-jet	Hydrolysis of biomass → sugar fermentation to alcohol → dehydration → oligomerization → hydrogenation → fractionation
SIP-SPK	Sugar-to-jet	Hydrolysis of biomass → sugar fermentation to farnesene → hydroprocessing → fractionation

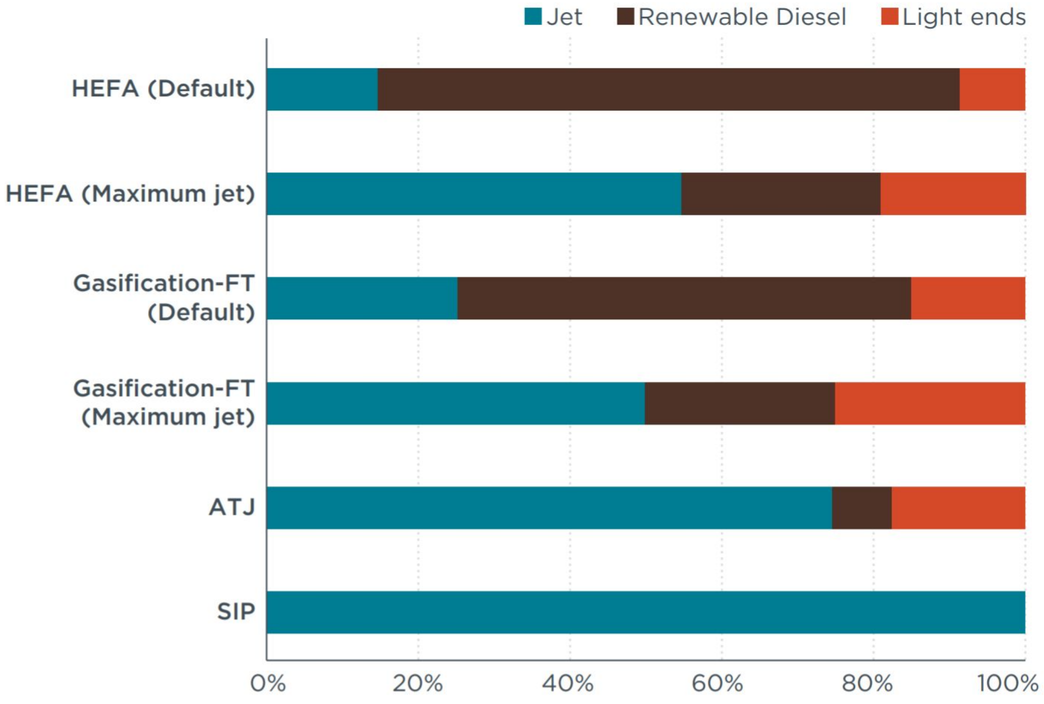
First-generation (1-G)	Second-generation (2-G)	Third-generation (3-G)	Fourth-generation (4-G)
• Oil-seed crops: camelina, oil palm, rapeseed, soybean, sunflower, salicornia • Sugar and starchy crops: corn, wheat, sugarcane, sugar beets	• Oil-seed energy crops: jatropha, castor bean • Grass energy crops: switch grass, miscanthus, Napier grass • Wood energy crops: poplar, willow, eucalyptus • Agricultural and forestry residues: corn stover, sugarcane bagasse, wood harvesting/processing residues • Food and municipal waste: used cooking oil, animal fats, biogenic fraction of municipal solid waste	• Algae: microalgae	• Genetically modified organisms • Non-biological feedstocks: CO_2, renewable electricity, water

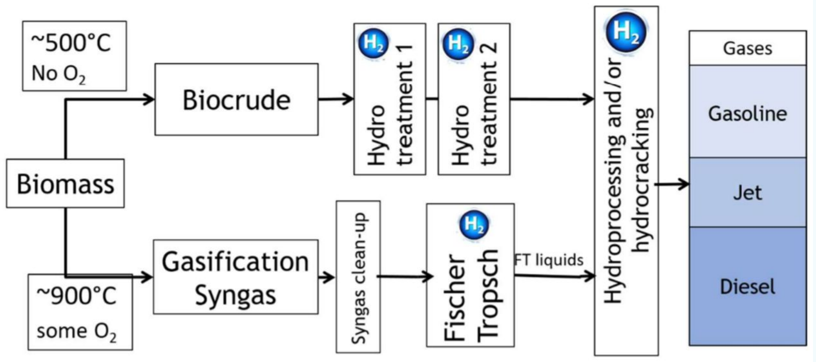
"Bio-aviation Fuel: A Comprehensive Review and Analysis of the Supply Chain Components" (2020)

Four-Tiered Process for Testing New Aviation Fuels (ASTM D4054)



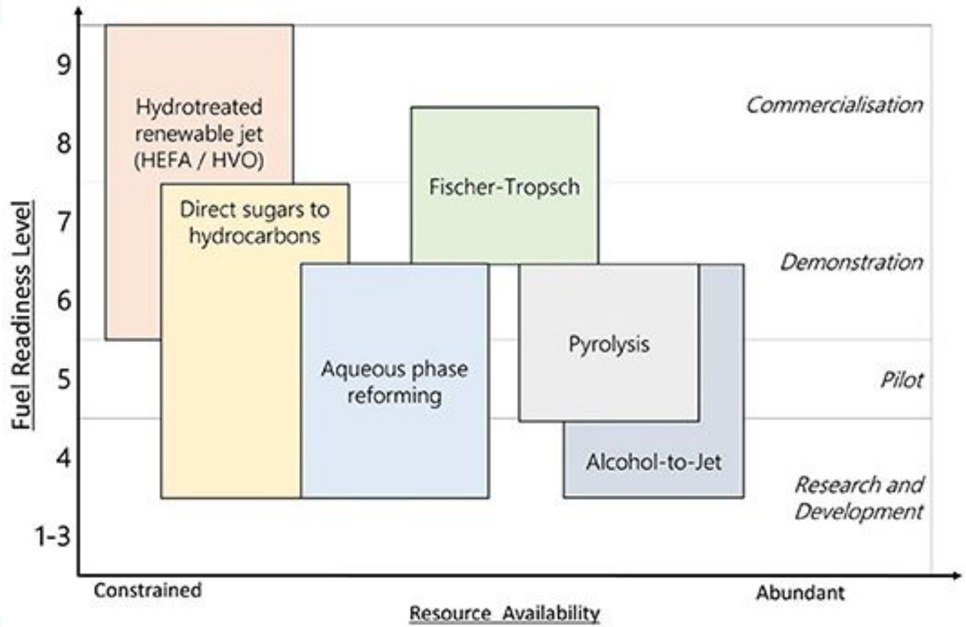
Comparison of Product Slates Across Fuel Conversion Pathways

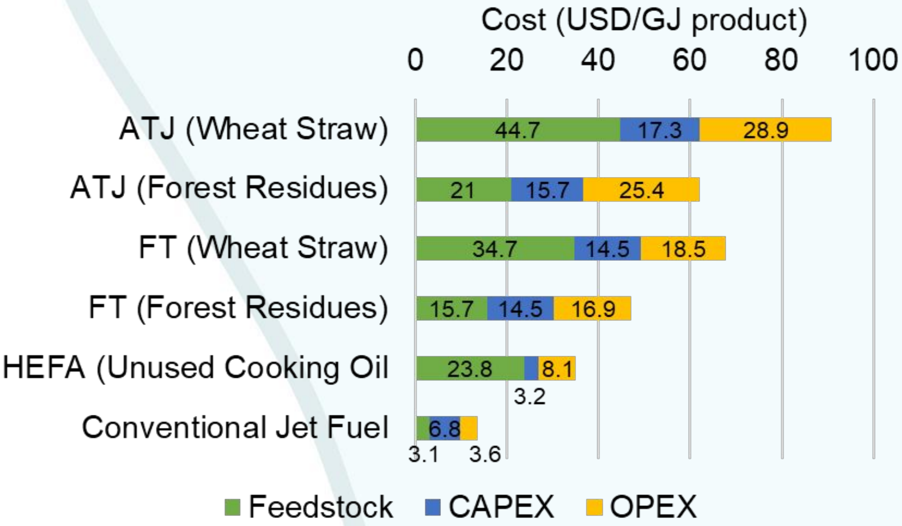




IEA BioEnergy: Progress in Commercialization of Biojet /Sustainable Aviation Fuels (SAF)

Technology Maturity and Cost Comparison



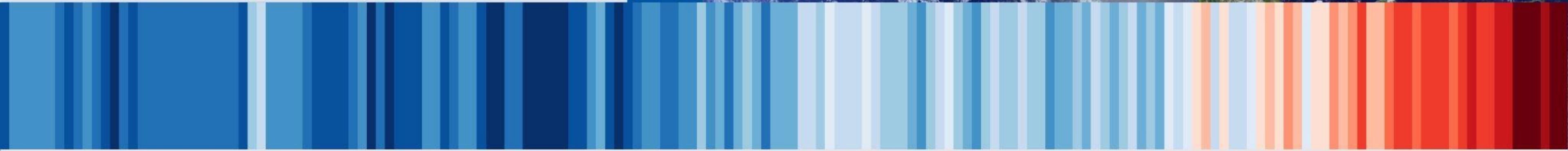


“Bio-aviation Fuel: A Comprehensive Review and Analysis of the Supply Chain Components” (2020)

Climate Change and Aviation

Prof. Alison F. C. Bridger
SJSU Meteorology and
Climate Science
San Jose State University

January 20, 2022

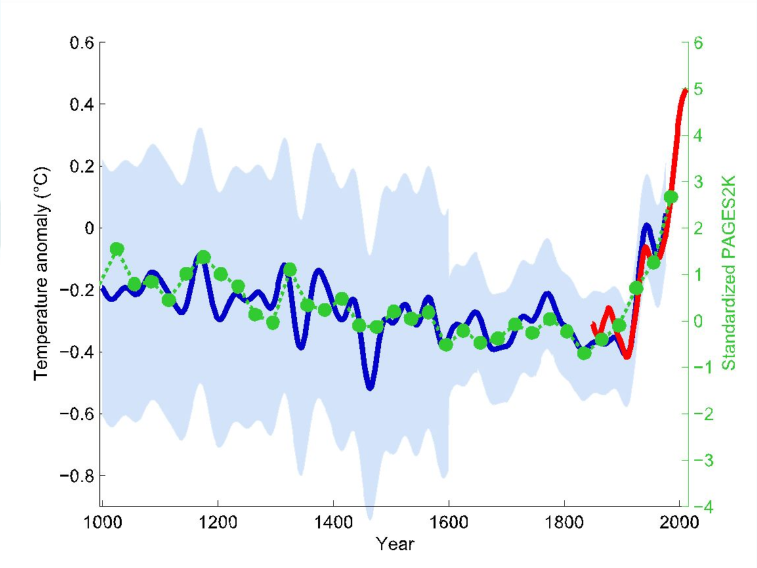


Globe warming stripe graphic is produced by Professor Ed Hawkins (University of Reading)

- EXTREME HEAT
- SEA LEVEL RISE
- JET STREAM

A: EXTREME HEAT

- Temperatures keep rising – “hockey stick” graph

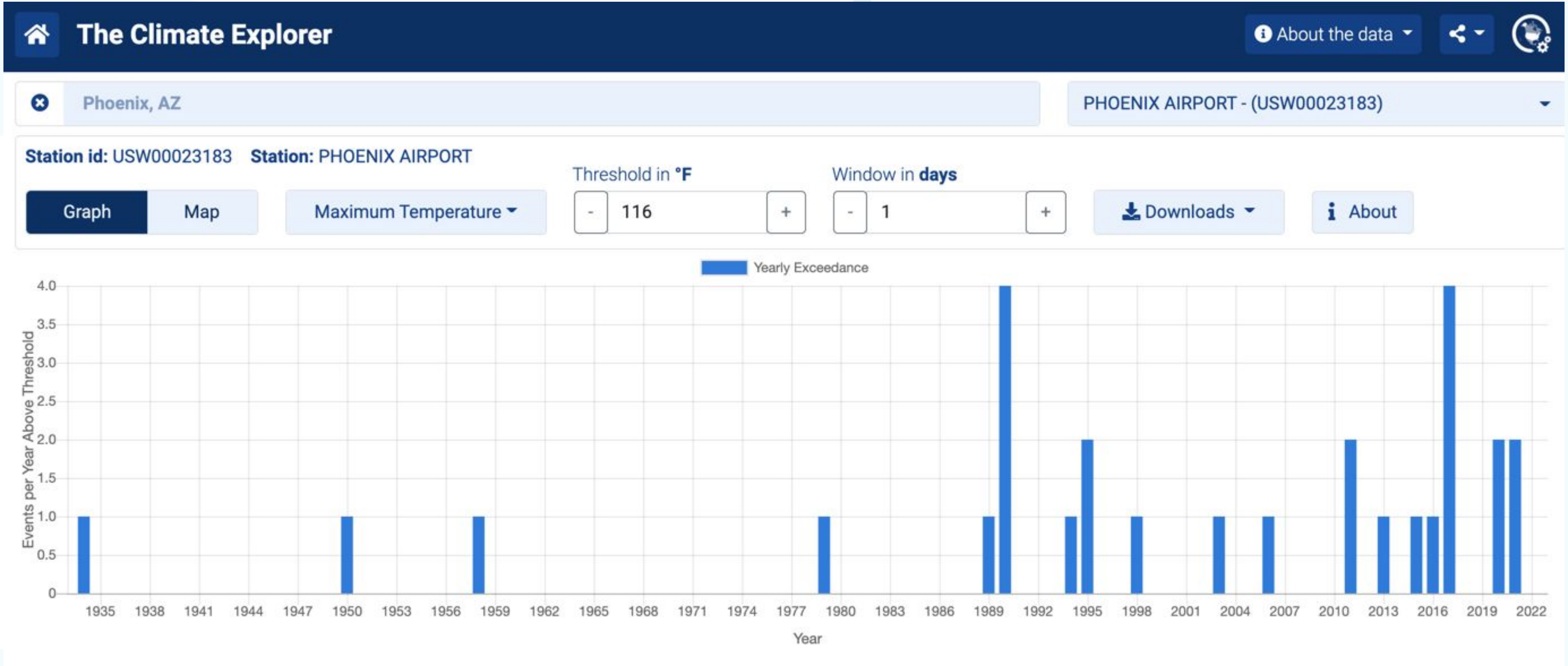


Latest examples:

- Australia (Jan 22) – 123°F
- Argentina (Jan 22) – 120°F
- Portland (June 21) – 116°F

Aviation impact: restricted take off due to reduced air density

- Example: PHX in June 2017

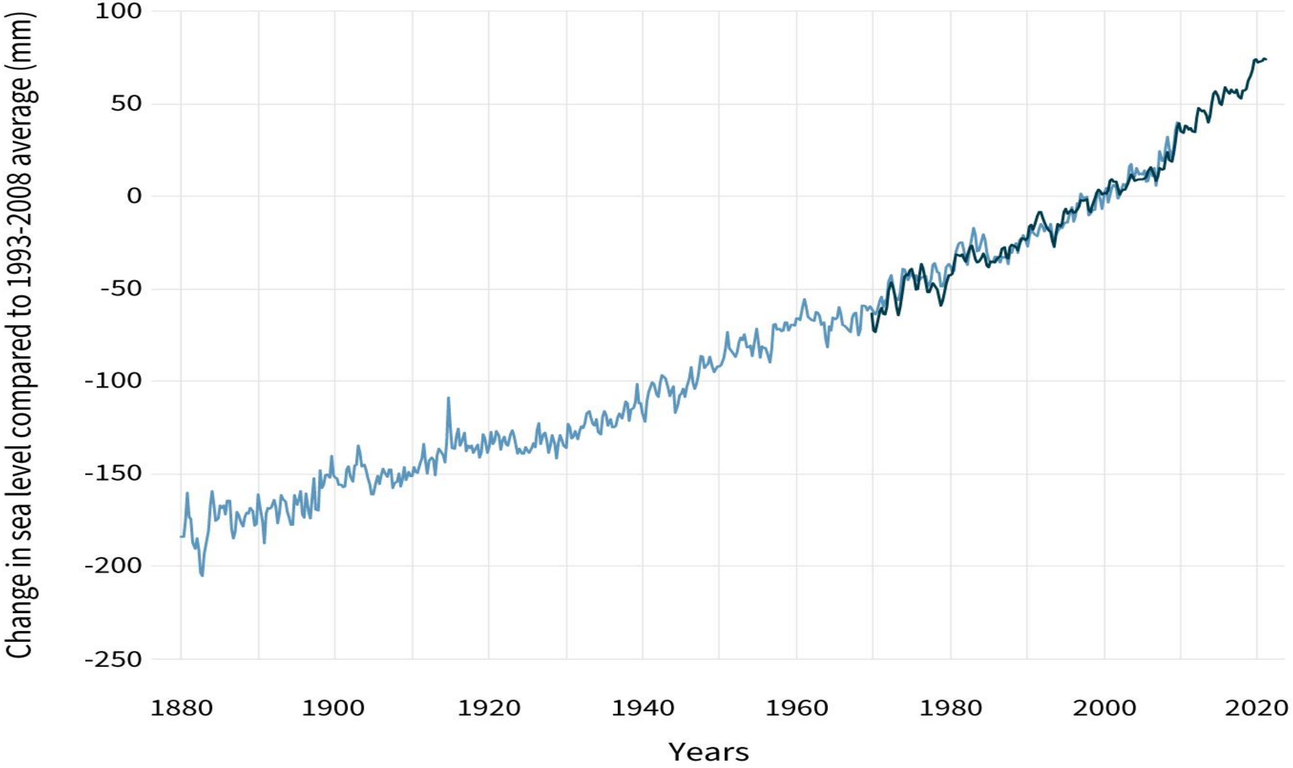

The Climate Explorer
About the data
Phoenix, AZ
PHOENIX AIRPORT - (USW00023183)
Station id: USW00023183 Station: PHOENIX AIRPORT
Threshold in °F
Window in days
Graph
Map
Maximum Temperature
116
1
Downloads
About
Yearly Exceedance
Events per Year Above Threshold
Year
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
1935 1938 1941 1944 1947 1950 1953 1956 1959 1962 1965 1968 1971 1974 1977 1980 1983 1986 1989 1992 1995 1998 2001 2004 2007 2010 2013 2016 2019 2022

B: SEA LEVEL RISE

ATMOSPHERIC WARMING IS ACCOMPANIED BY OCEANIC WARMING AND EXPANSION

LOCAL AIRPORT ELEVATIONS	NATIONALLY
SFO………13’	BOSTON……………..19’
OAK……...10’	MIAMI………………...10’
SJC………..62’	NEW ORLEANS………4’

GLOBAL SEA LEVEL



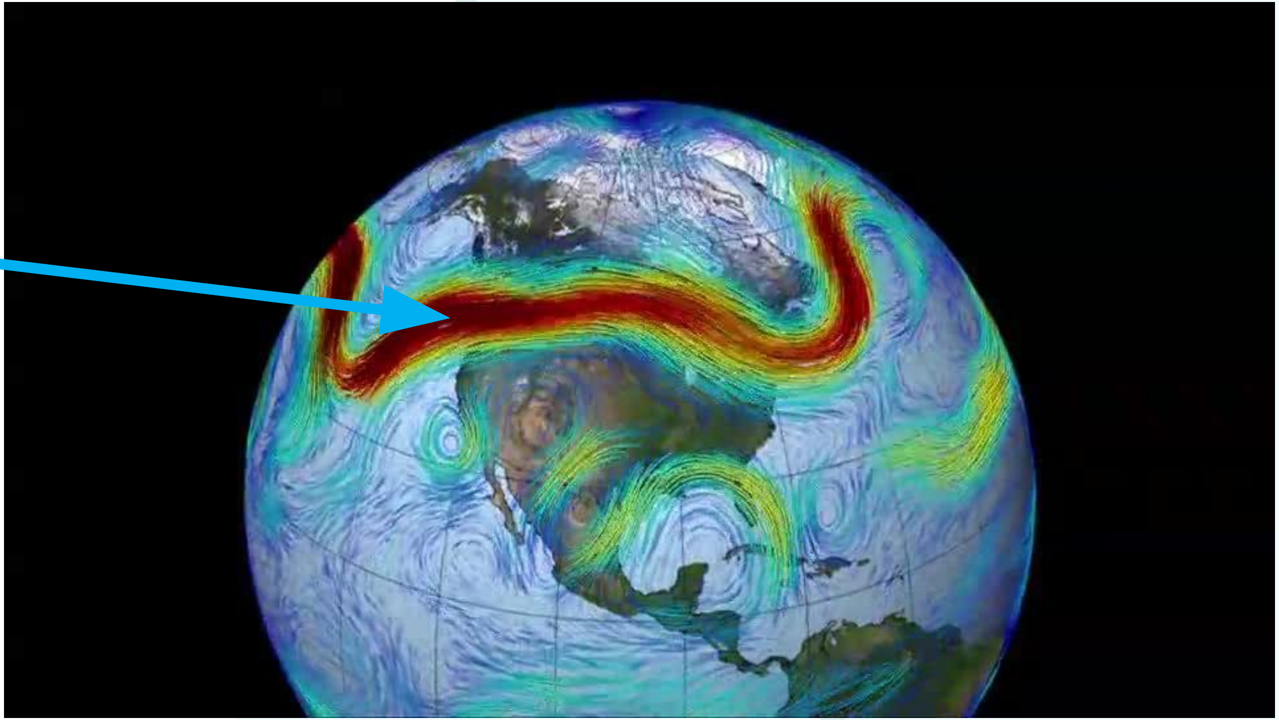
Roughly 250 mm
Roughly 10”

C: JET STREAMS

JET STREAM…

A “TUBE” OF

FAST-MOVING AIR (RED)



AROUND

10 km

6 miles

32K feet

JET STREAMS GUIDE STORM SYSTEMS …AND WEATHER

PROJECTED CHANGES

1. WEAKER WINDS?
2. MORE “WAVY” NORTH-SOUTH?
3. NORTHWARD DISPLACEMENT OF THE JET STREAM AND “WEATHER”?

ATD AIRSPACE TECHNOLOGY DEMONSTRATIONS

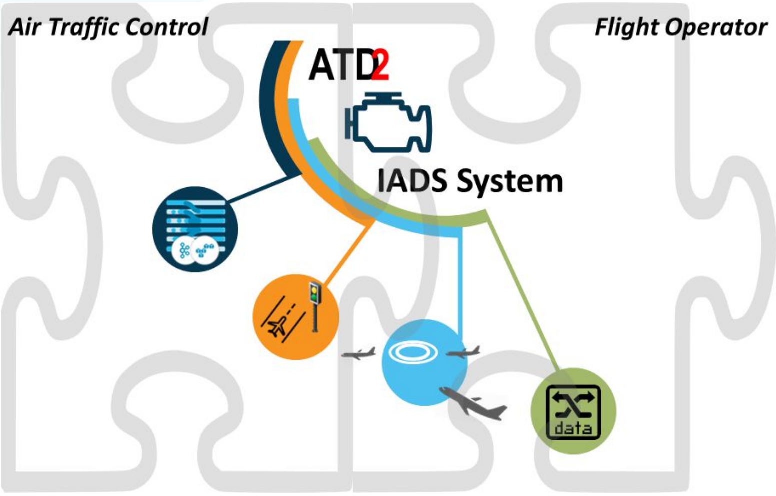
Shawn Engelland, NASA ATD Project Manager

Aviation and Climate Change Forum

Technology Advances – Surface Operations

January 20, 2022

ATD-2 IADS Field Demo at Charlotte, NC



Integrated Arrival/Departure/Surface (IADS)
NASA's ATD-2 Single-Airport IADS demo was a ***pathfinder*** for the FAA's Terminal Flight Data Manager (TFDM) Program

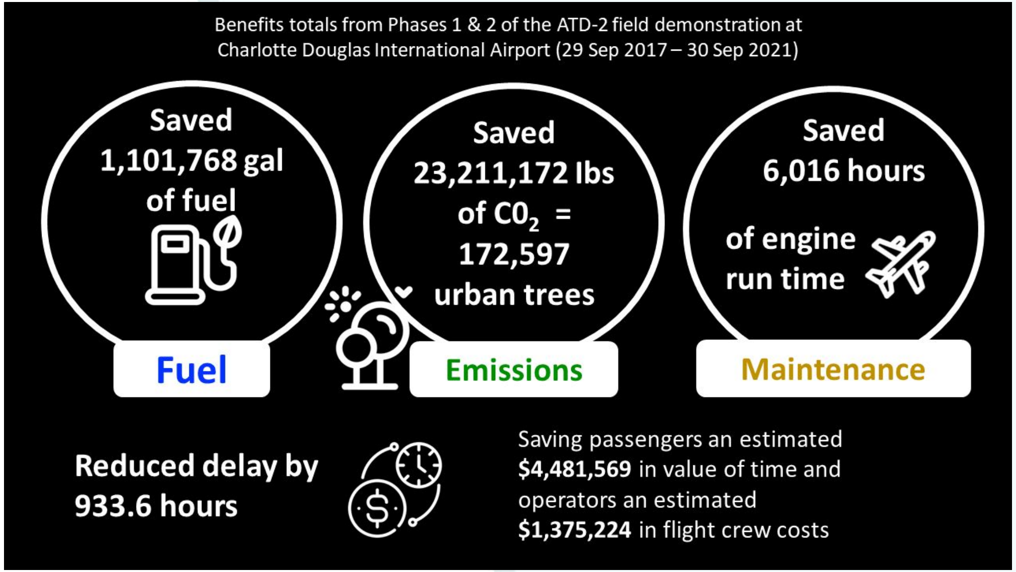
- The TFDM concept depends on unprecedented levels of collaboration between ATC and Operators
- TFDM will provide tools for ATC, but only data for Operators
- The ATD-2 IADS system implemented ***both*** ATC and Operator ***pieces of the puzzle***
- ATD-2 transferred Technology and Knowledge to ***both*** FAA and Industry (operators and vendors)

IADS Single-Airport Benefits and Mechanisms

Benefits (1) and (2a) achieved through tactical gate holds *prior to pushback*
49,777 flights

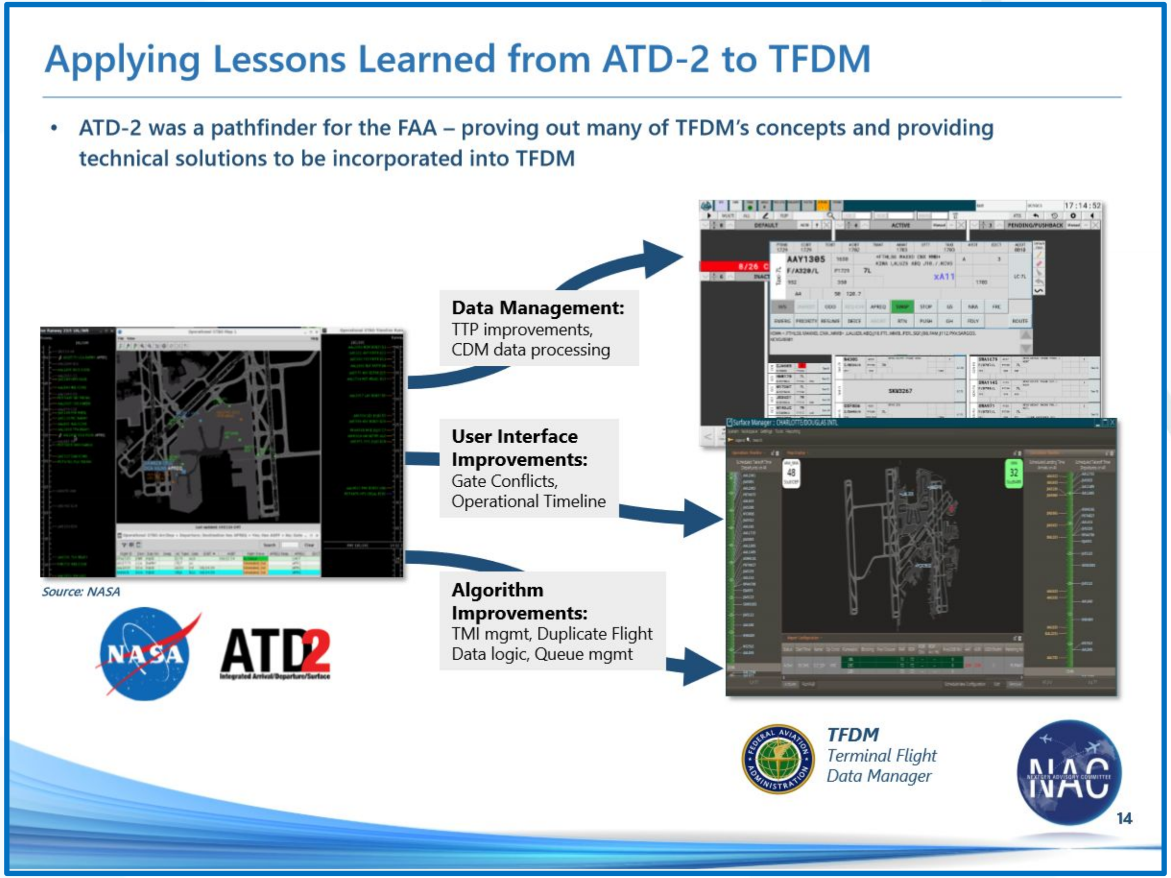
1. **Surface metering**
   - Reduced engine run time
   - Reduced fuel consumption and emissions
2. **Overhead stream insertion**
   a. Pre-scheduling controlled flights at the gate
      - Reduced engine run time
      - Reduced fuel consumption and emissions

   b. Electronic renegotiation for an earlier slot
      - Reduced total delay
      - Passenger value of time and crew costs
      - Reduced engine run time
      - Reduced fuel consumption and emissions



Benefit (2b) achieved through electronic renegotiation for an earlier slot for flights with controlled takeoff times *after pushback*
7,080 flights

ATD-2 to TFDM: Applying Lessons Learned

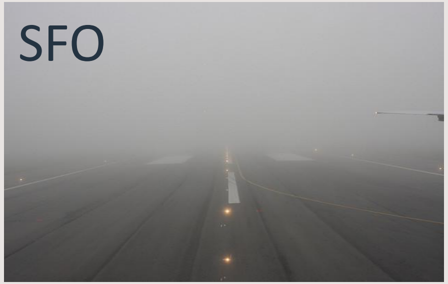


- This slide developed by FAA TFDM program office for communication to key stakeholders
- ATD-2 Field Demo validated TFDM concept and business case
- The slide highlights technology and knowledge transfers from ATD-2 to TFDM
- The FAA's TFDM program will deploy to 89 airports beginning in 2022
- 27 of those airports will have capabilities like those demonstrated by ATD-2

Air Traffic Management and Aviation Decarbonization

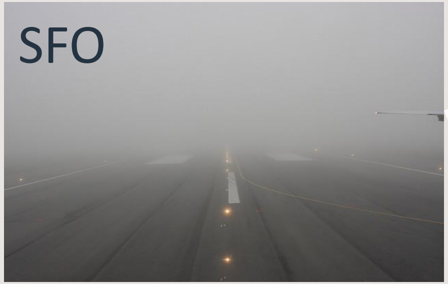
Mark Hansen
Institute of Transportation Studies
Department of Civil and Environmental Engineering
UC Berkeley

Ground Delay Program (GDP)



Without GDP

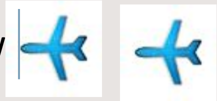
Expensive airborne delay



With GDP

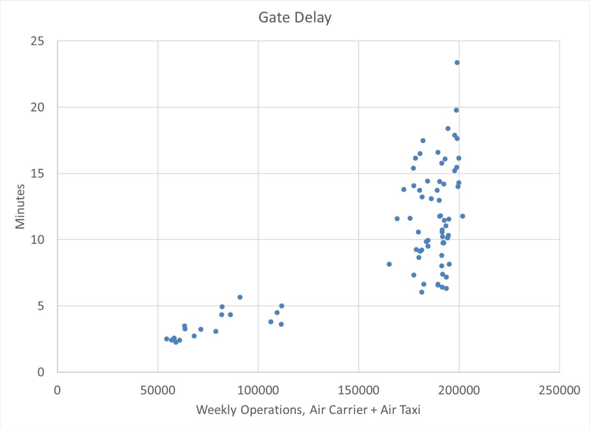

EWR

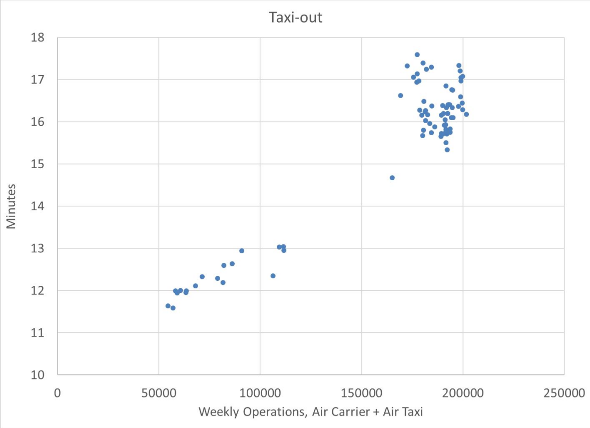

Cheaper and safer ground delay

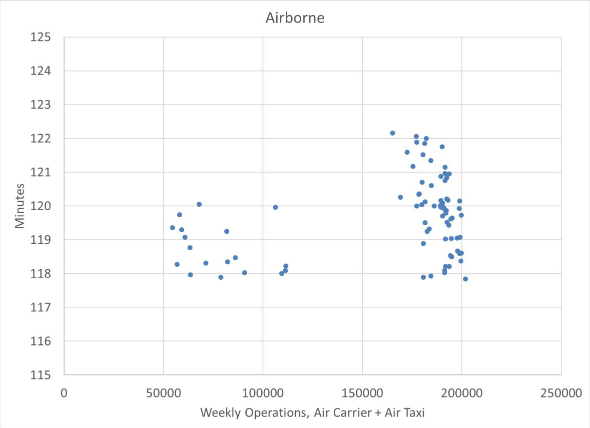

DFW


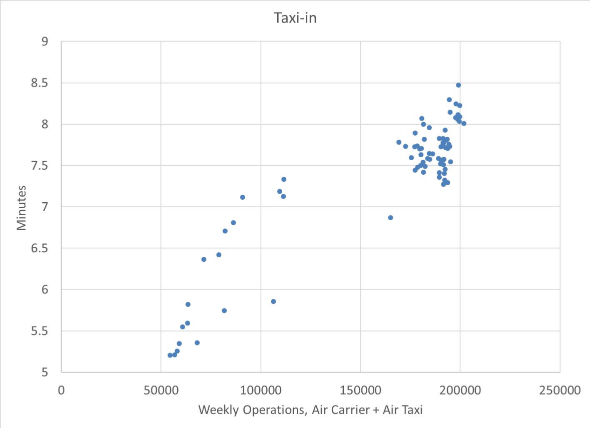
What the Pandemic Tells Us ...

- Ideally, ATM absorbs delay at the gate
- Reductions in congestion would affect only gate delay
- ATM is successful in preventing congestion from increasing airborne time
- However, ATM does not prevent congestion from increasing taxi times

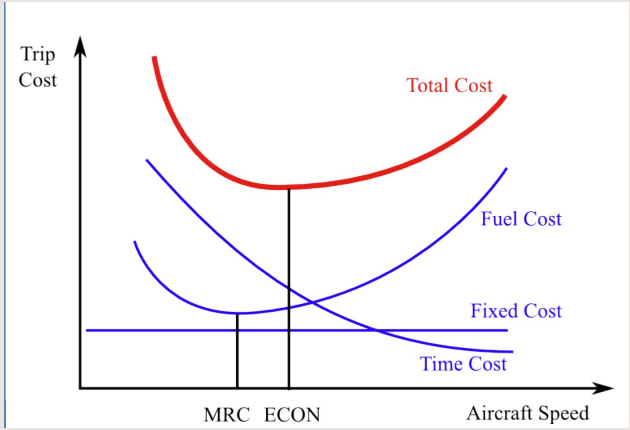


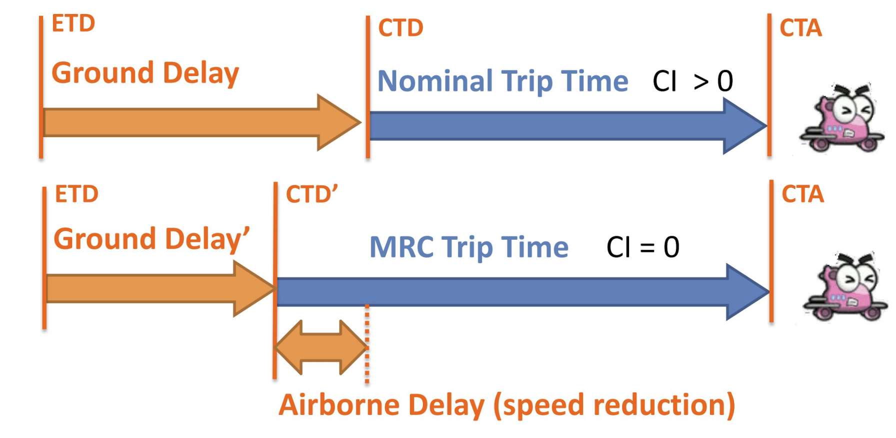


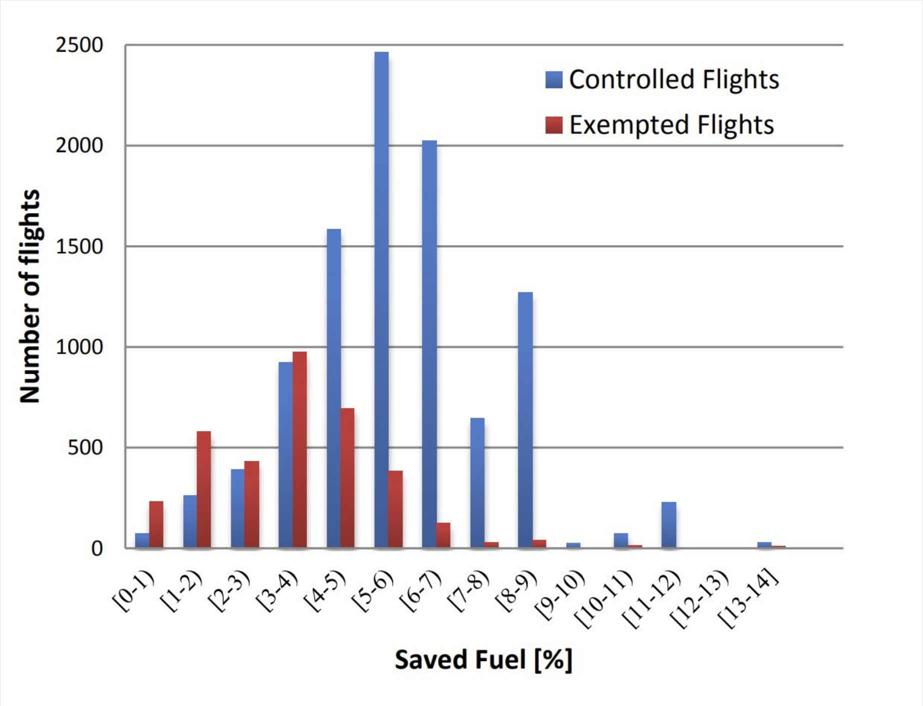




"Green" Delay Programs







Predictability and Fuel Loading

Table 2. Fuel on arrival and additional contingency fuel uplifted and the cost to carry this fuel.

		1st Qu.	Median	Mean	3rd Qu.
	Fuel on arrival (minutes)	84.4	105.3	111.9	132.3
FA	Fuel on arrival (lbs)	7500.0	9300.0	9970.0	11800.0
	Cost to Carry Fuel on arrival (lbs)	400.7	560.6	671.4	834.9
	Percent of total per-flight fuel consumed	3.65%	4.48%	4.86%	5.73%
[illegible]	[illegible]	[illegible]	51.6	59.7	79.5
	[illegible]	[illegible]	4400.0	5328.0	7171.0
	[illegible]	[illegible]	281.0	373.0	472.3
	[illegible]	[illegible]	2.21%	2.56%	3.39%
[illegible]	[illegible]	[illegible]	23.0	40.2	59.8
	[illegible]	[illegible]	2027.0	3578.0	5312.0
	[illegible]	[illegible]	131.50	225.20	316.00
	[illegible]	[illegible]	1.04%	1.74%	2.54%
[illegible]	[illegible]	[illegible]	16.0	17.5	23.0
	[illegible]	[illegible]	1431.0	1564.0	2025.0
	[illegible]	[illegible]	77.39	97.58	127.10
	Percent of total per-flight fuel consumed	[illegible]	0.70%	0.77%	1.02%

Landing on empty: estimating the benefits from reducing fuel uplift in US Civil Aviation

Megan S Ryerson[1,2], **Mark Hansen**[3], **Lu Hao**[3] **and Michael Seelhorst**[4]

1 Department of City and Regional Planning, University of Pennsylvania, 127 Meyerson Hall, 210S. 34th Street, Philadelphia, PA 19104, USA

2 Department of Electrical and Systems Engineering, University of Pennsylvania, 200 South 33rd Street, 203 Moore Building, Philadelphia, PA 19104, USA

3 Department of Civil and Environmental Engineering, National Center of Excellence for Aviation Operations Research, University of California, Berkeley, 109 McLaughlin Hall, Berkeley, CA 94720-1720, USA

4 Revenue Analytics, 3100 Cumberland Blvd., Suite 1000, Atlanta, GA 30339, USA

Other Ideas

- Slot Efficiency vs Carbon Efficiency
- ATM to Incentivize Decarbonization
  - Cleanest goes first
  - Special procedures to increase effective range of all-electric aircraft

Commercial Aircraft and Climate

Kevin James, Code AOX, NASA Ames

Lead, Independent Verification and Validation Team

20 January 2022

I like my job...

I like my job...

These are my personal opinions. They are founded on data; however, they do not represent the official stated policies of NASA or the US Federal Government.

None of the diagrams, drawings, figures, or charts were taken from any classified, restricted, or industry-partner company proprietary sources

The Problem – Mother Nature

Flight by machines heavier than air is unpractical and insignificant, if not utterly impossible. – Simon Newcomb (1835 – 1909)

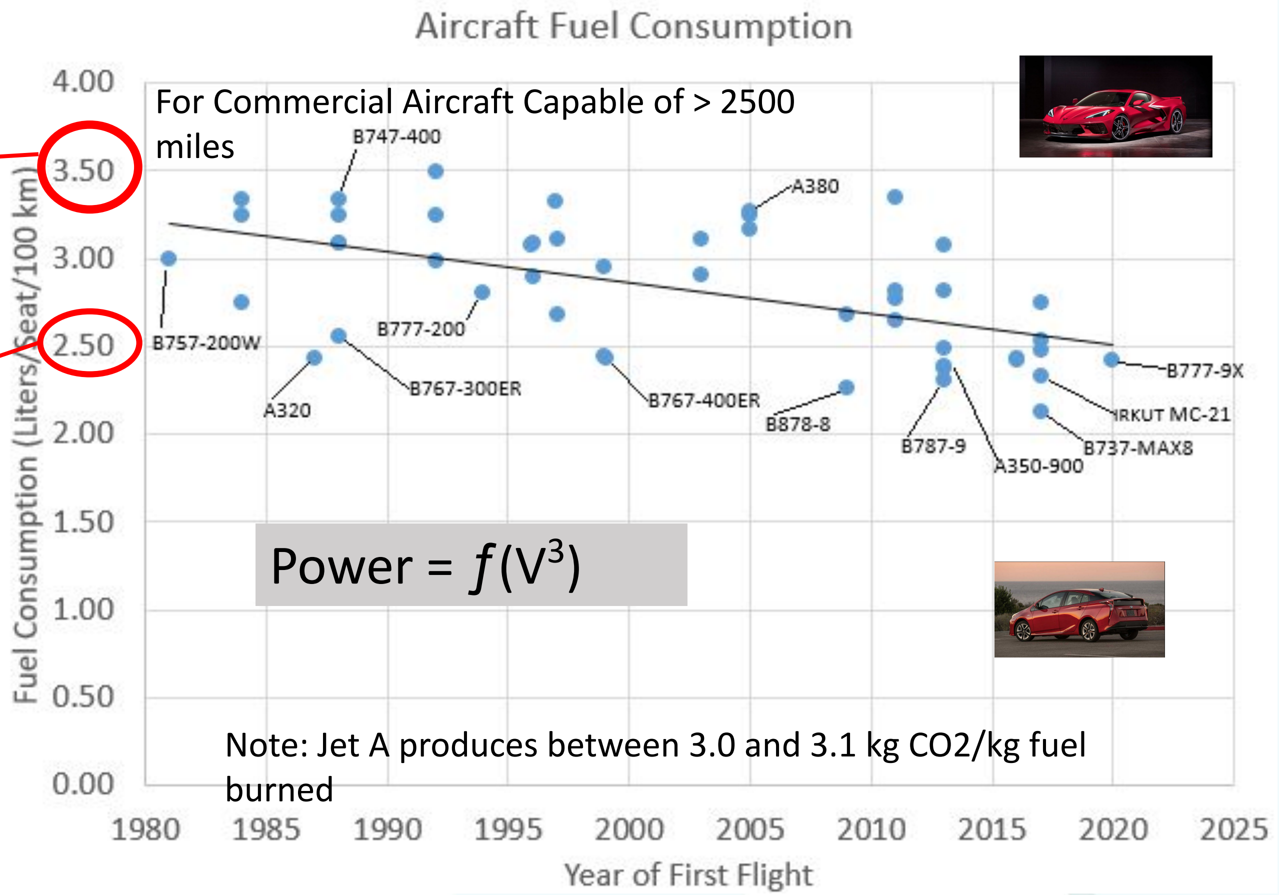
“Not within a thousand years will man ever fly...” – Wilbur Wright (1901)

“Brutal honesty isn’t always fun, but you can’t solve the problems without it...” - Kevin James

Fuel Consumption

67.2 miles/gallon/seat

94.1 miles/gallon/seat



For Commercial Aircraft Capable of > 2500 miles

Power = $f(V^3)$

Note: Jet A produces between 3.0 and 3.1 kg CO_2/kg fuel burned

The Big Picture

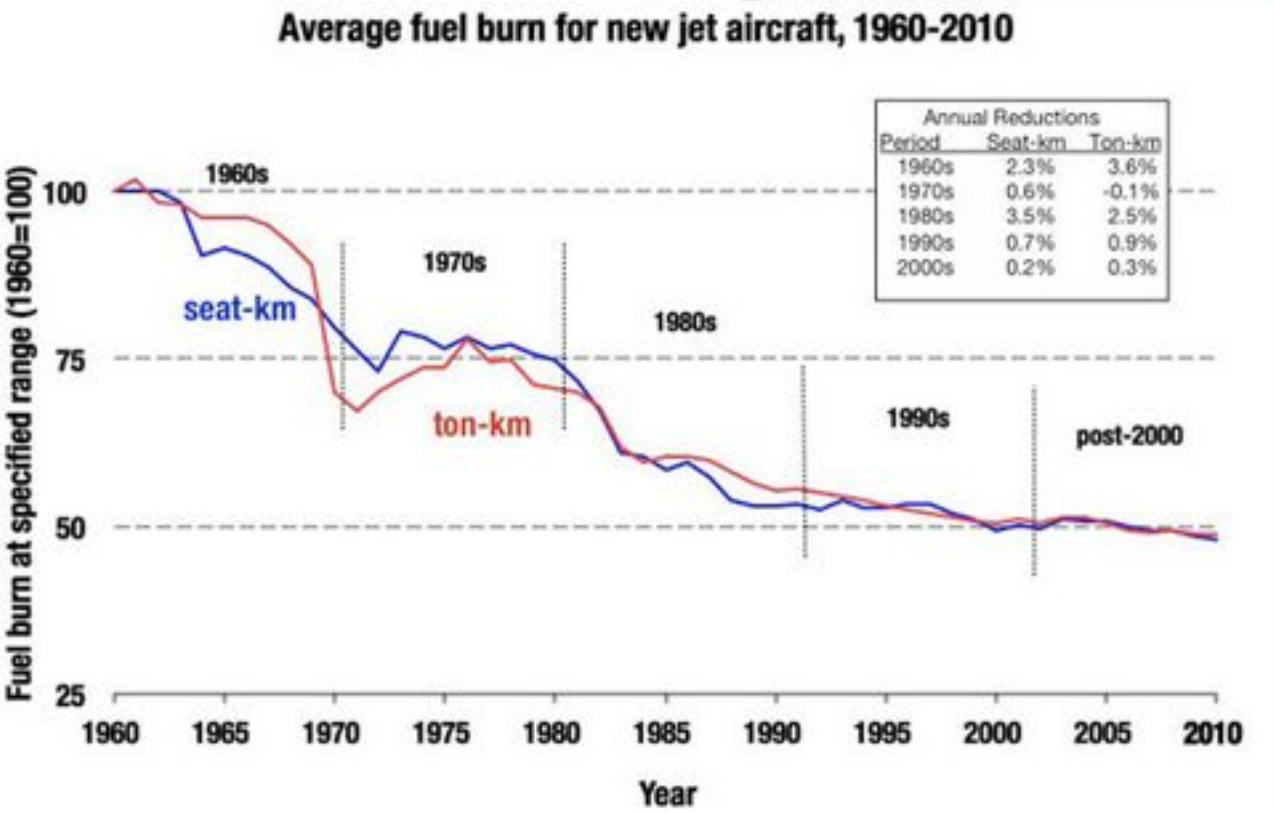


Chart from ref. 4

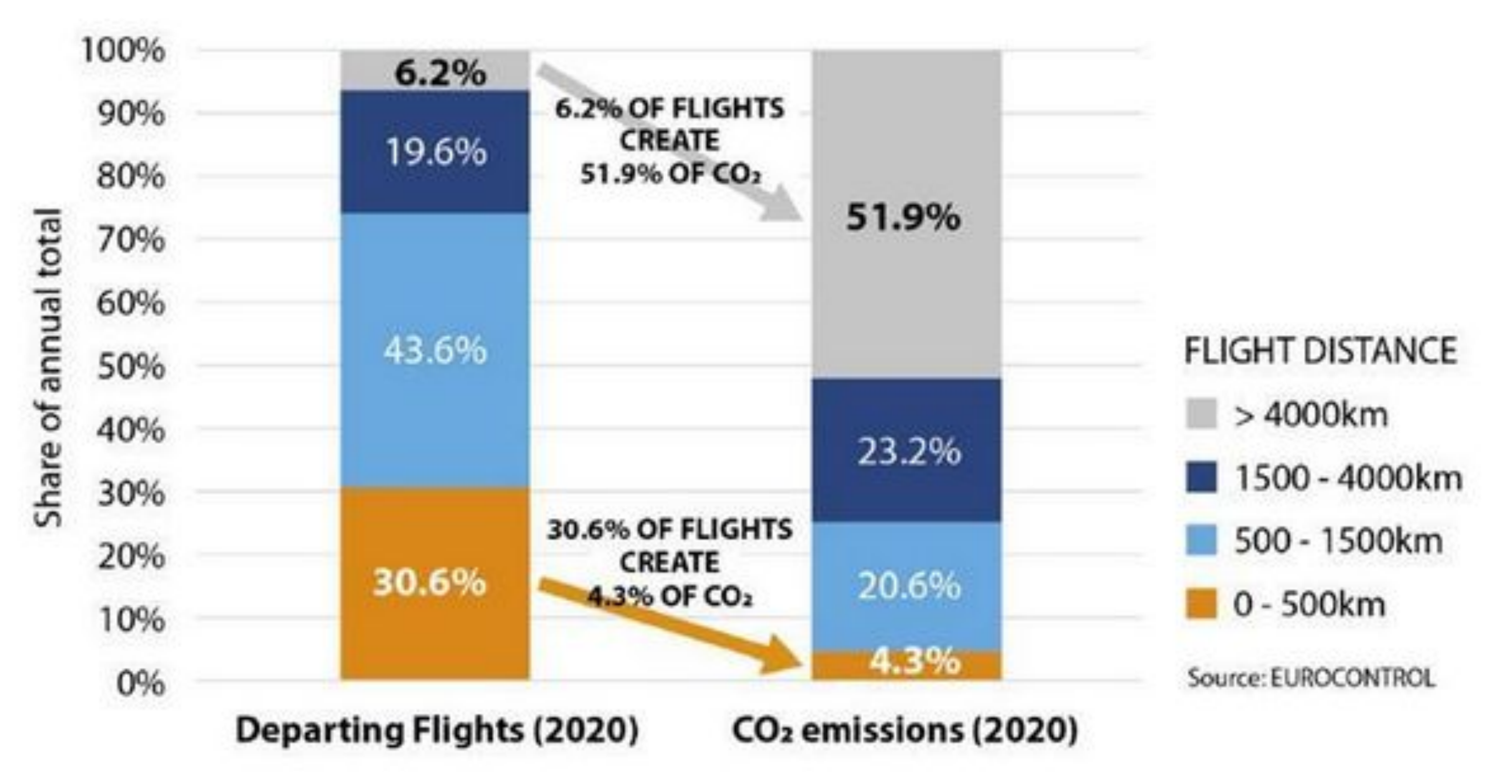
Efficiency gains of jet aircraft are stagnating Need breakthrough technology

Breakthrough Technologies?

- **Relative to 2015, International Air Transport Association (IATA) technology roadmap technologies considered:**
  - **6 to 12%** from airframe retrofits (winglets, riblets, lightweight cabin furnishing) currently available
  - **4 to 10%** from materials and Structure (composite structure, adjustable landing gear, fly-by-wire) also currently available
  - **1 to 4%** from electric taxiing from 2020+
  - **5 to 15%** from advanced aerodynamics (natural laminar flow, variable camber..etc) from 2020-25

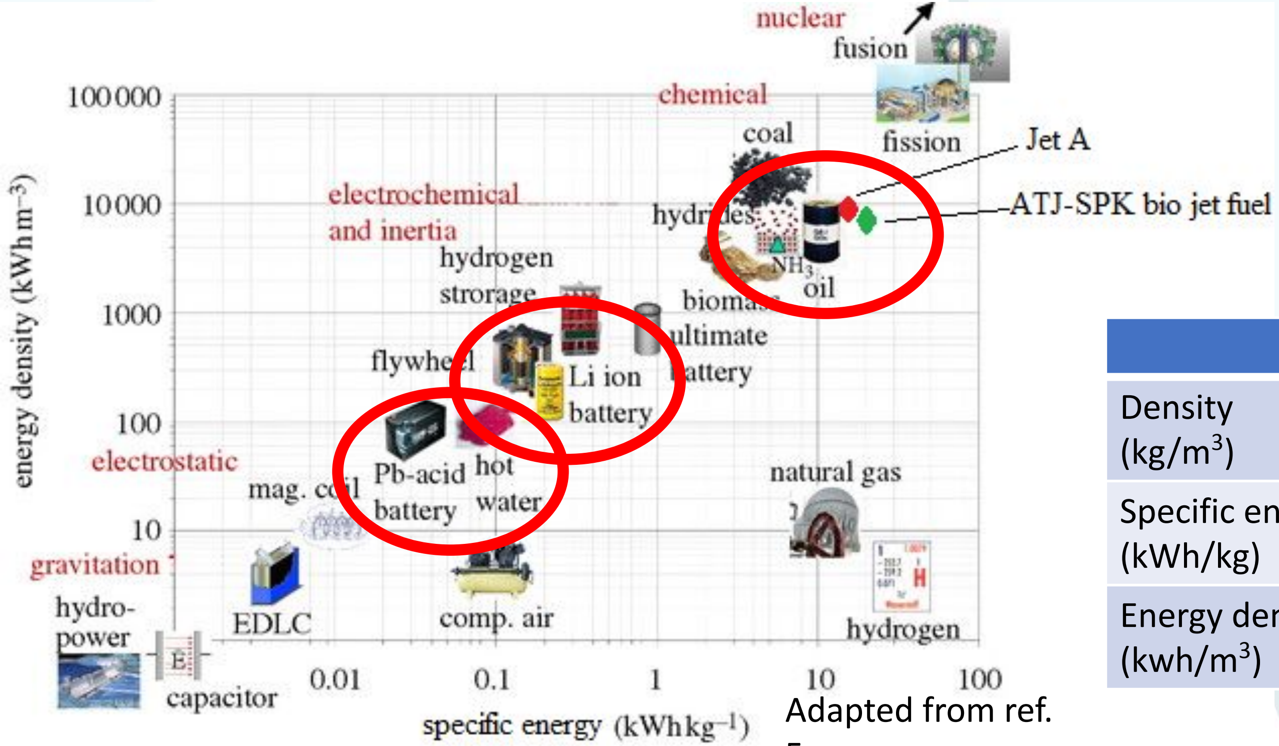
  - **30%** from strut-braced wings (with advanced turbofan engines, ~2030-35)
  - **30-35%** from a box/joined closed wing (with advanced turbofan engines, ~2035-40)
  - **27 to 60%** from a blended wing body design (with hybrid propulsion, ~2030-35)
  - Up to 100% with fully electric aircraft (short range, ~2035-45) **ONLY IF POWERED BY RENEWABLE SOURCES**

Long Haul Flights



Energy Storage

Specific energy and energy density of various energy storage systems



Adapted from ref. 5

	Jet A	ATJ-SPK
Density (kg/m^3)	820	760
Specific energy (kWh/kg)	11.95	12.2
Energy density (kwh/m^3)	9799	9272

Liquid fuels are particularly well suited to aviation

Conclusions

"There's no magic. Airplanes are energy agnostic and everything on an aircraft has to buy its way on." – Kevin James

Current and any foreseeable Fully-Electric Aircraft will require more energy than "conventional" hydrocarbon-fueled vehicles; however, that may just be a "Fully Burdened" and environmentally fair cost of flying.

If the problem is over-constrained – some of the requirements (expectations?) may have to be relaxed.

- Amount of Traveling
- Time required to travel (vehicle velocity)
- Mode of transportation

The World has gotten much smaller during the last few decades. Trend may not continue or may have to rely increasingly on virtual presence.

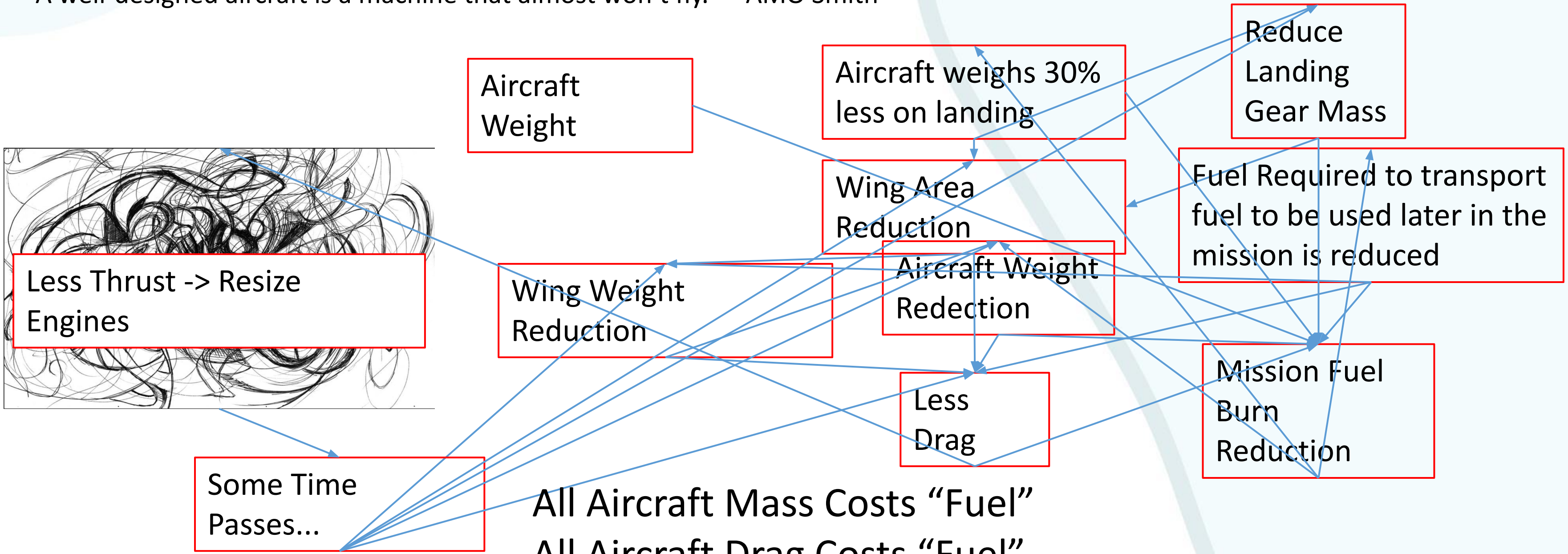
The Big Picture (You've probably already heard this)

- **Climate change caused by global greenhouse gas (GHG) emissions**
- It is generally agreed that current levels of GHG emissions must be slashed in half by 2030 and reach net-zero by mid-century to avoid irreversible and potentially catastrophic climate change.
- Aviation currently accounts for 2.8% CO2 emissions (3.5% effective GHG).
- Aviation CO2 emissions have doubled since 2000.
- Global aviation emissions are projected to triple by 2050[1] under the current regulations.
- NONE of the International Civil Aviation Organization (ICAO) regulations recently adopted by the EPA[2] are expected to reduce aviation GHG emissions enough to meet the mid-century net-zero goal.

Think Like an Aircraft Designer (or how did we get here?)

Current State-of-the-Art Aircraft are not “by accident”

“A well-designed aircraft is a machine that almost won’t fly.” – AMO Smith

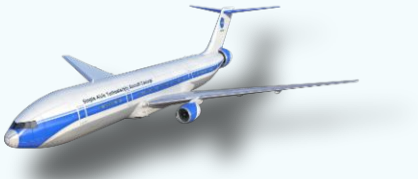


All Aircraft Mass Costs “Fuel”
All Aircraft Drag Costs “Fuel”

Virgin Atlantic – One pound reduction/aircraft leads to 53,000 liters reduction in fuel consumption (olives – fleet/year).
Quantas reduced trolley cart weight/aircraft by 7 kg and estimates they save 535,000 kg fuel (London – Perth fleet)

Potential Industry EAP Markets

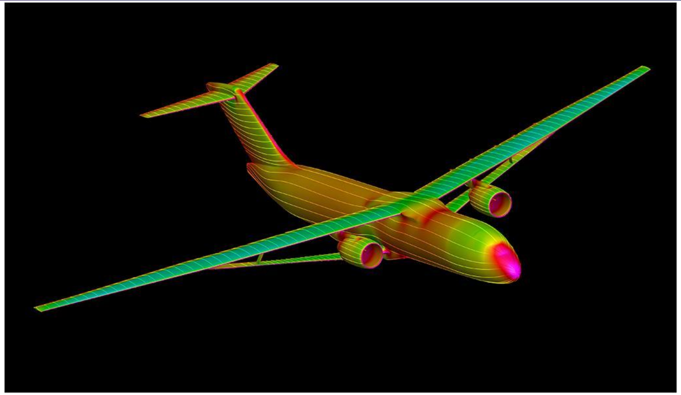
- NASA and its industry partners have identified turboprops, regional jets, and single aisle aircraft serving the thin-haul (very short flights), regional, and single-aisle markets as targets of opportunity for this technology.
- EAP systems included electric and hybrid systems in configurations that have the potential to give aircraft level benefits based on technology development that can be accomplished in the required timeframes

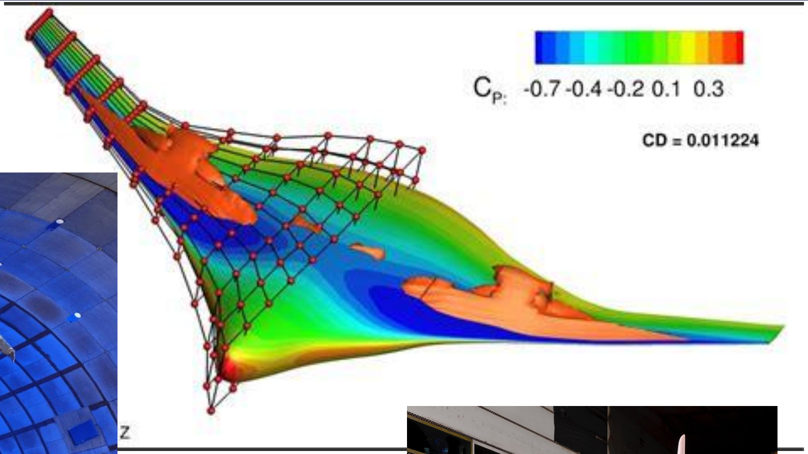


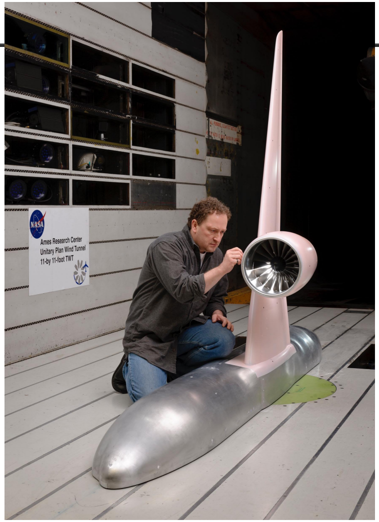
Market	Regional Air Mobility	Regional Turboprops & Turbofans	Single Aisle
Passengers	1-19	20-150	150-more
Speed	≈150-250 mph	≈300-400 mph	≈500-700 mph
Range	≈100-500 miles	500-1500 miles	1500-3500 miles
Power	≈1MW	1 to 5 MW	3 to 30MW
Heat	**≈200 kW heat**	**200kw to 1MW heat**	**600kW to 6MW heat**

Primary Testing Facilities at NASA-Ames

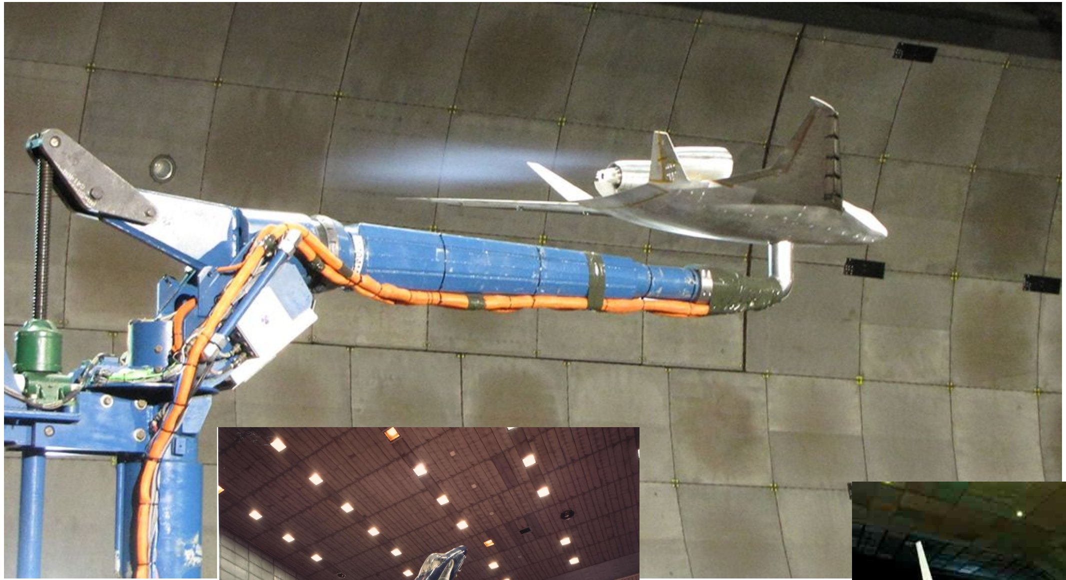
Models Being Tested

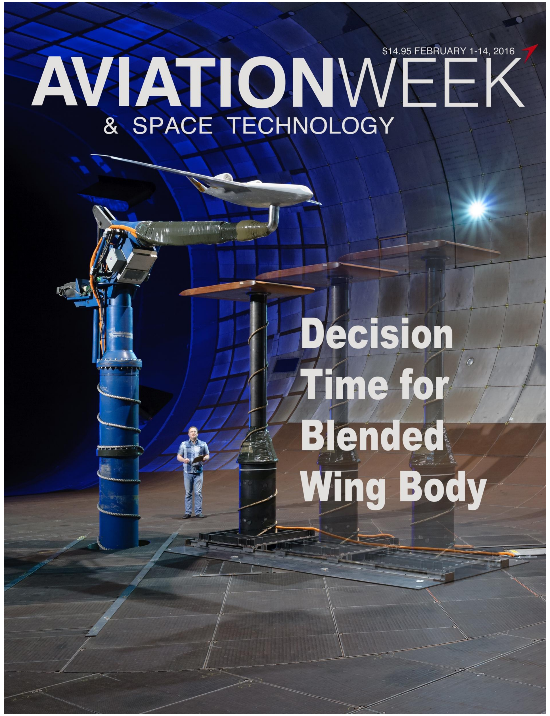






Models (cont)

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Aviation & Climate Change

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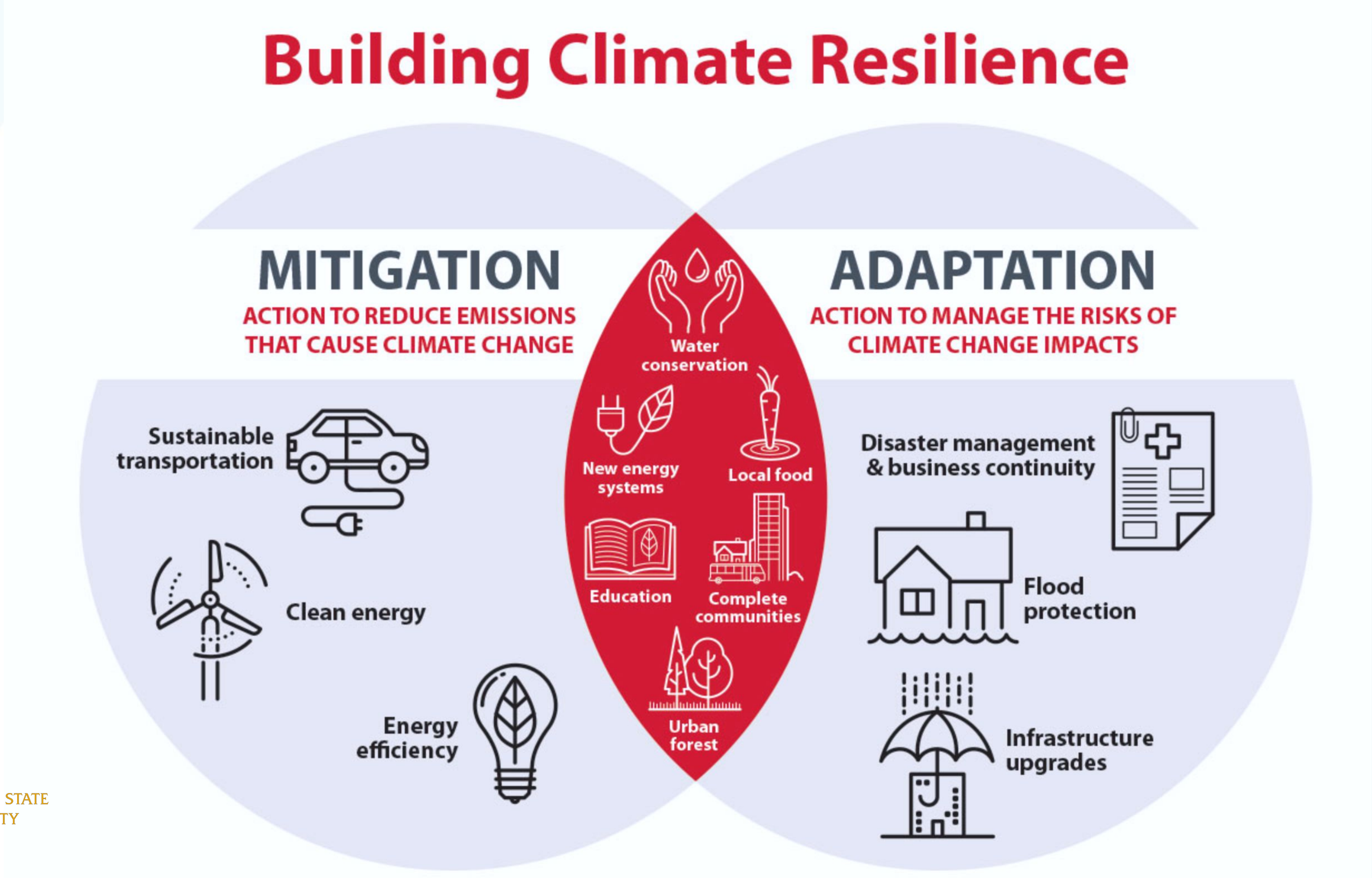

https://www.calgary.ca/content/dam/www/uep/esm/publishingimages/adaptation-mitigation-infographic-fullsize.jpg

United States 2021 Aviation Climate Action Plan

- **Goal: Net-Zero GHG Emissions from the U.S. Aviation Sector by 2050**
- Development of new, more efficient aircraft and engine technologies
- Improvements in aircraft operations throughout the National Airspace System
- Production and use of Sustainable Aviation Fuels (SAF)
- Electrification and, potentially hydrogen, as solutions for short-haul aviation
- Advancements in airport operations across the United States
- International initiatives such as the airplane CO_2 standard and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)
- Support for research into climate science

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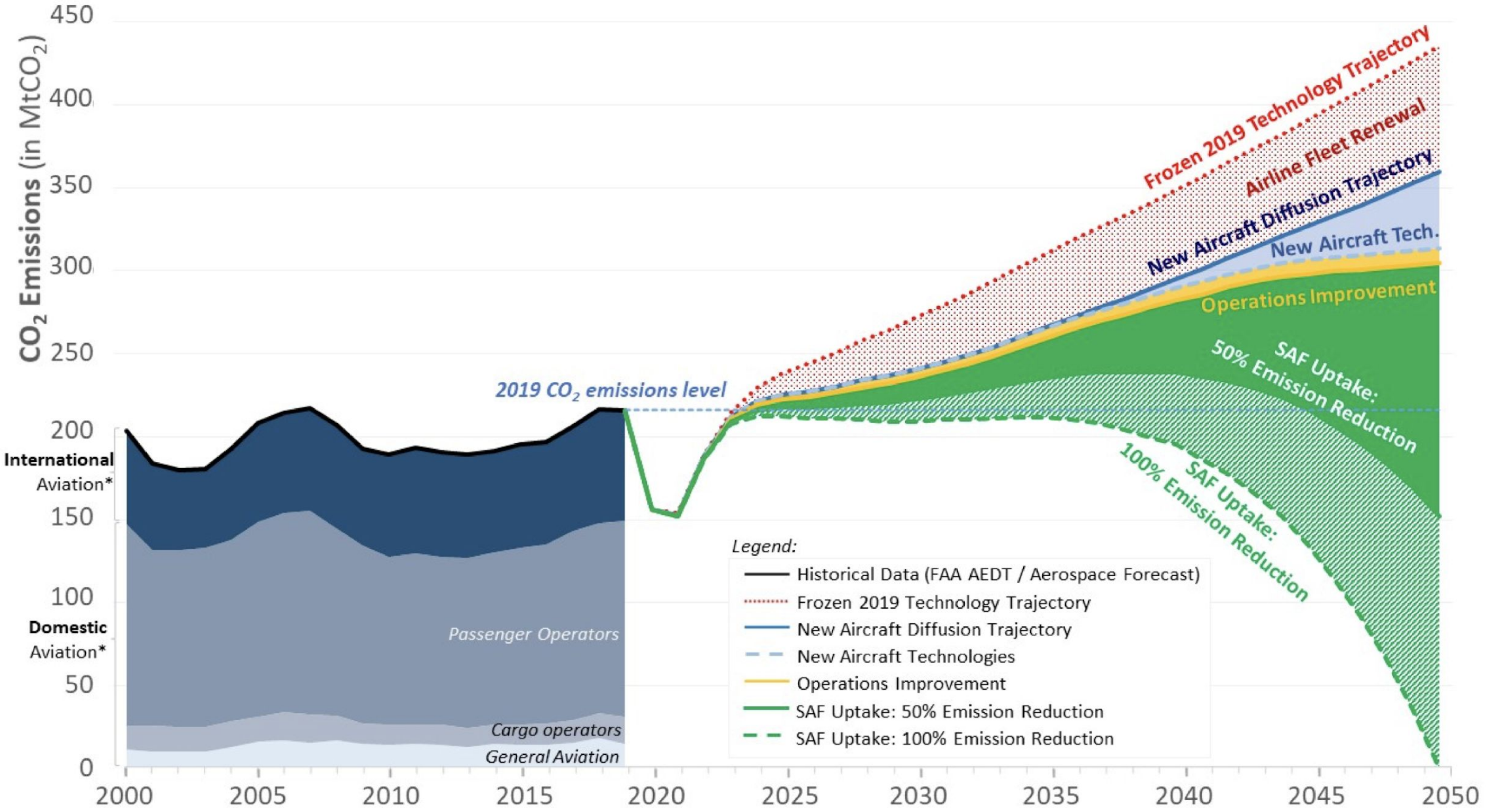
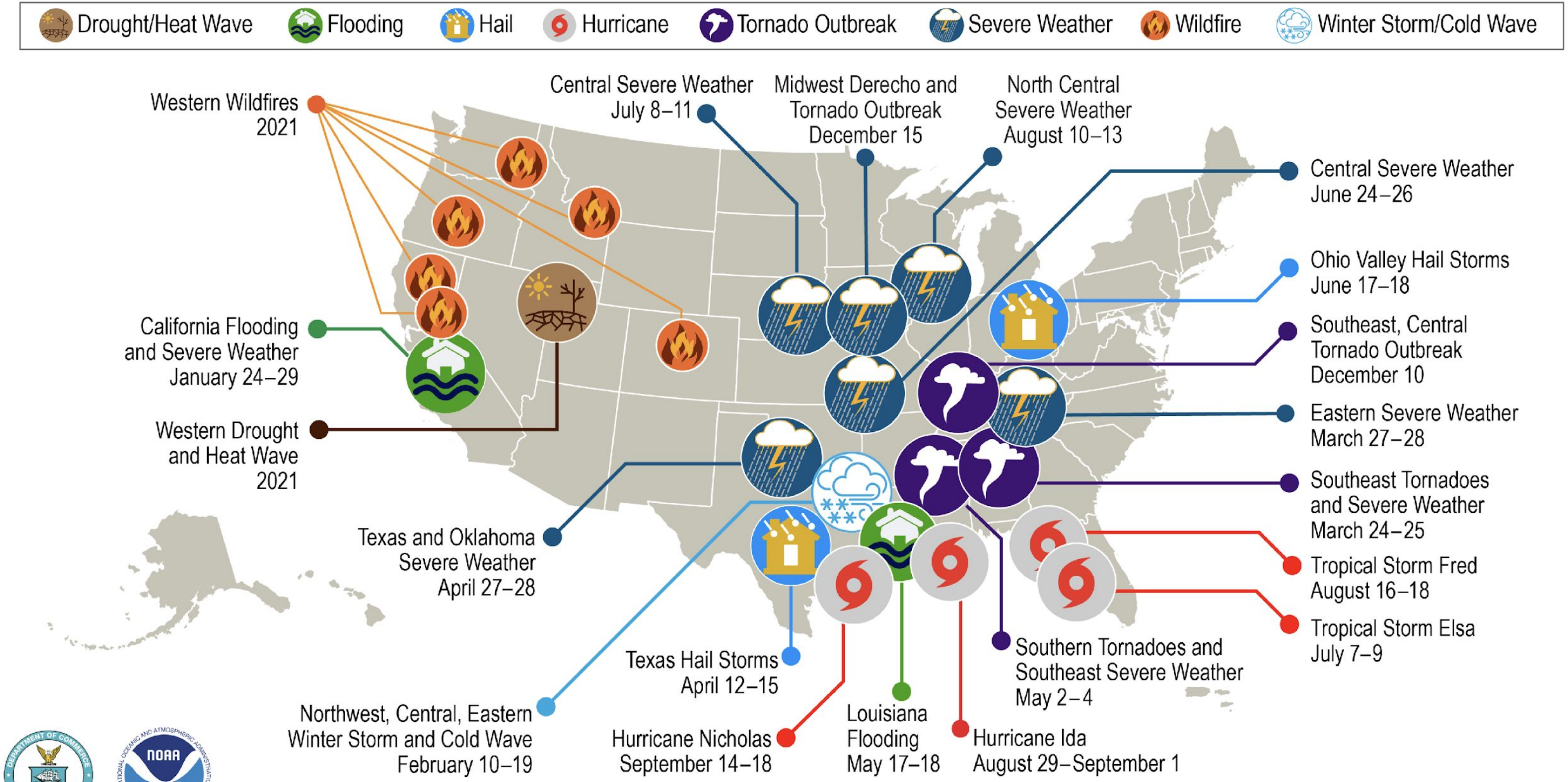


* Note: Domestic aviation from U.S. and Foreign Carriers. International aviation from U.S. Carriers.

Oslo Airport: The World's Greenest Terminal

- **Combines innovative design with energy-efficient strategies as well as on-site energy harvesting systems.**
- A reservoir of snow gathered during the winter to cool the building throughout the summer,
- Environmentally friendly materials (35% reduction in CO_2 emissions),
- 50% reduction in energy use compared to the existing terminal,
- An updated train station – at the heart of the airport –enabling 70% of all passengers to access the airport by public transport.

U.S. 2021 Billion-Dollar Weather and Climate Disasters



This map denotes the approximate location for each of the ***20 separate billion-dollar weather and climate disasters that impacted the United States in 2021***

Climate Change Adaptation Planning Process

1. Initiate the Adaptation Planning Process	2. Develop an Adaptation Plan	3. Implement, Monitor, & Refine
Establish a stakeholder advisory committee	Assess baseline climate and projected climate changes and risks	Gather climate and progress information
Set climate resilience goals	Identify critical assets and operations	Update as new data, models, technologies or tools become available
Develop tools for community engagement	Inventory asset and operational vulnerabilities	Update climate risks and vulnerabilities
	Develop and prioritize strategies	Monitor and revise on a 3-5 year time scale or as needed

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Thank you!

Serena E. Alexander, Ph.D.
Associate Professor &
Director of Urban Online
Department of Urban and Regional Planning
San José State University

Research Associate
Mineta Transportation Institute

serena.alexander@sjsu.edu

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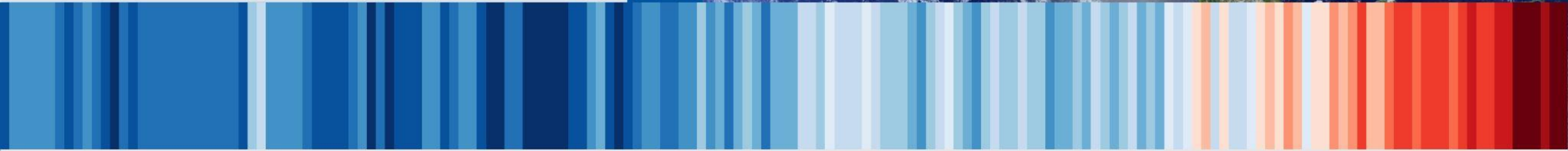
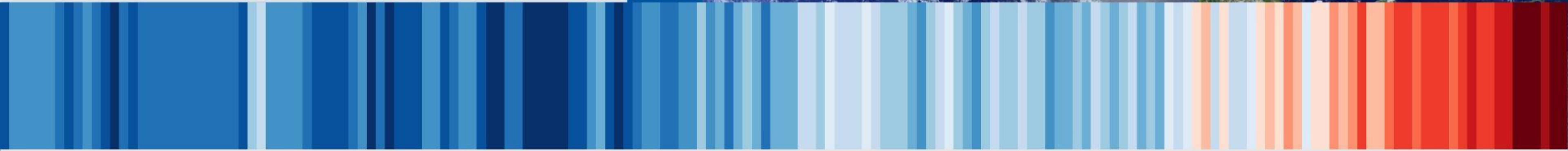
Break/Q&A



Globe warming stripe graphic is produced by Professor Ed Hawkins (University of Reading)

Public Private Partnerships

Shivanjli Sharma, National Campaign Deputy Lead, NASA ARC



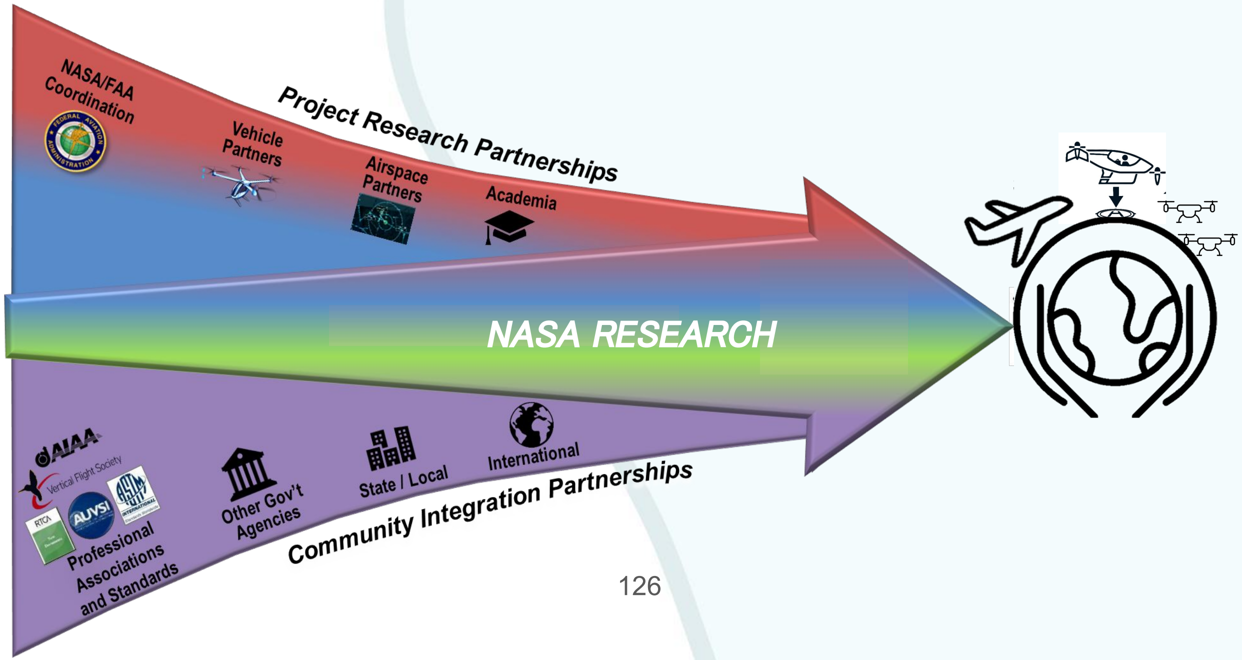
Globe warming stripe graphic is produced by Professor Ed Hawkins (University of Reading)

NASA AAM Partnership Strategy

- Foundational industry partners relationships with project research to formulate an ecosystem approach
- Collaboration with academia through programs like the University Leadership Initiative

- Leverage NASA Research as a centerpiece of the partnership strategy

- Community Integration partnerships are providing a valuable opportunity space for localities, international, and standards organizations



Partnerships across industry, academia, and the community are and continue to provide valuable collaboration in an ecosystem approach to address sustainability in aviation.

AAM Community Stakeholders

Government (Federal)
- NASA
- National Academies-Transportation Research Board
- National Institutes of Standards and Technologies (NIST)/Smart Cities
- National Transportation Safety Board (NTSB)

Incubators/Investors
- Alliance Texas
- Defense Innovation Experimental (DUIx)
- FAA/IPP: Choctaw, San Diego, IEIA (VA), KS DoT, Ft Myers (FL), Memphis Airport (TN), NC DoT, ND DoT, Reno (NV), UAF (Fairbanks, AK), LA DoT, WA DoT
- Starburst
- Strategic Alliances Resources Network (StarNet)
- Sustainable Aviation Limited
- Uber

Associations (Domestic)
- American Association of Airport Executives (AAAE)
- American Insurance Association
- Aircraft Owners and Pilots Assoc (AOPA)
- Community Air Mobility Initiative (CAMI)
- Chambers of Commerce
- Commercial Drone Alliance
- Coalition of UAS Professionals
- Environmental Groups (e.g. Sierra Club)
- Experimental Aircraft Association (EAA)

Community Integration

Local/National	National/International
Decision Makers (Local) • Mayors/City Councils/Boards of Supervisors • Tribal Councils • Departments of Transportation • Departments of Commerce • National League of Cities (2000+ cities, 49 states with additional cities) • Port Authority (of various big cities) • US Conference of Mayors • National Governors Association **Decision Makers (National)** • US Congress • DOT/FAA – AIR, AFS, ATO • DOC/NTIA (public/federal spectrum) • FCC (commercial spectrum) • DHS • DOJ/FBI	**Decision Makers (International)** • US Congress • DOT/FAA – AIR, AFS, ATO • DOC/NTIA (public/federal spectrum) • FCC (commercial spectrum) • European Aviation Safety Agency (EASA) • European Organization for Civil Aviation Equipment (EUROCAE) (Europe) **Standards** • American Society for Testing and Materials (ASTM) (I) • National Fire Protection Association • Radio Technical Commission for Aeronautics (RTCA) (I) • Society of Automotive Engineers (SAE) (I) • International Civil Aviation Organization (ICAO) (I)

Government (Intranational)
- Civilian Aviation Authority (CAA-UK)
- German Aerospace Center (DLR)
- Japan Aerospace Exploration Agency (JAXA)
- Korea Aerospace Research Institute (KARI)
- Netherlands Aerospace Center (NLR)
- ONERA (French Aerospace Center)
- Nordic Network for Electric Aviation (NEA)

Contributors (International)
- International Forum for Aviation Research (IFAR)

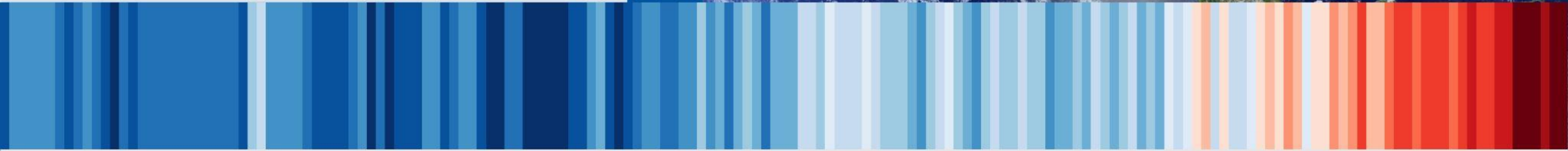
Associations (International)
- American Institute of Aeronautics and Astronautics (AIAA)
- Airports Council International (ACI)
- Association of Air Medical Services
- Association for Unmanned Vehicle Systems International (AUVSI)
- Civil Air Navigation Services Organization (CANSO) – ANSP providers
- Environmental (Greenpeace, WWF)
- Eurocontrol (Europe)
- General Aviation Manufacturers Association (GAMA)
- International Air Transport Association (IATA) - Airlines
- International Telecommunication Union (ITU)
- Joint Authorities for Rulemaking on Unmanned Systems (JARUS)
- Vertical Flight Society (AHS)

https://www.nasa.gov/partnerships/faqs.html

Roundtable

Moderator: **Andrea Pesce**, UC Santa Cruz

- **Amy Gross**, Joby Aviation
- **Chris Bley**, Monterey Bay DART
- **David Merrill**, Elroy Air
- **Michael Read**, Skybase



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THANK YOU!

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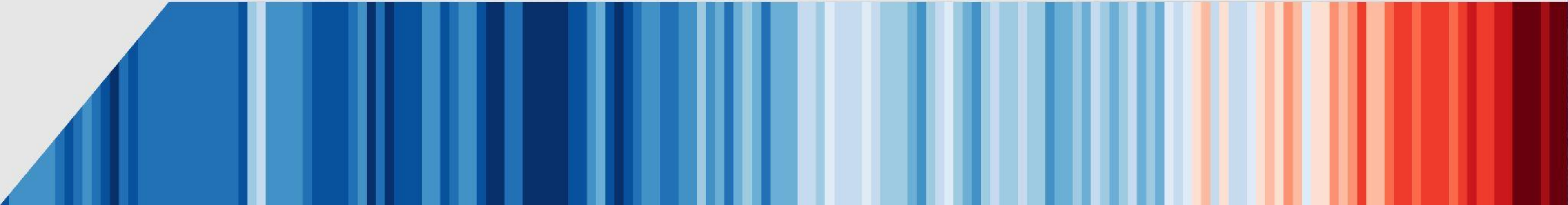

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Transportation to Combat Human Trafficking

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PART 1: The Inspiration

Join us for a three-part series about starting your own business!

Thinking about starting a consulting business? While the idea is exciting, the actual process can be quite daunting. Join us for this three-part series about starting your own business to help you get on your way.

This first session is an opportunity to talk with three business owners about how they started off, what they've learned on the way, and their successes and challenges. We've allotted plenty of time to get your questions answered. Panelists include **Eileen Goodwin** (Apex Strategies), **Ronny Kraft** (Ronny Kraft Consulting), and **Dominic Tafoya** (VST Engineering).

For questions, please contact programsWTSSanFrancisco@gmail.com

Costs: $5 for members, $15 for non-members, and free for students (funds are used to support the WTS scholarship fund).

Part 1 Date/Time:
February 10
6:00 - 7:15 PM (PST)

Registration Link:
https://tinyurl.com/BossTransit

Eileen Goodwin
President,
Apex Strategies

Ronny Kraft
Planner,
Ronny Kraft Consulting

Dominic Tafoya
Chief Sales &
Marketing Officer,
VST Engineering

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