NASA'S AERONAUTICS VISION

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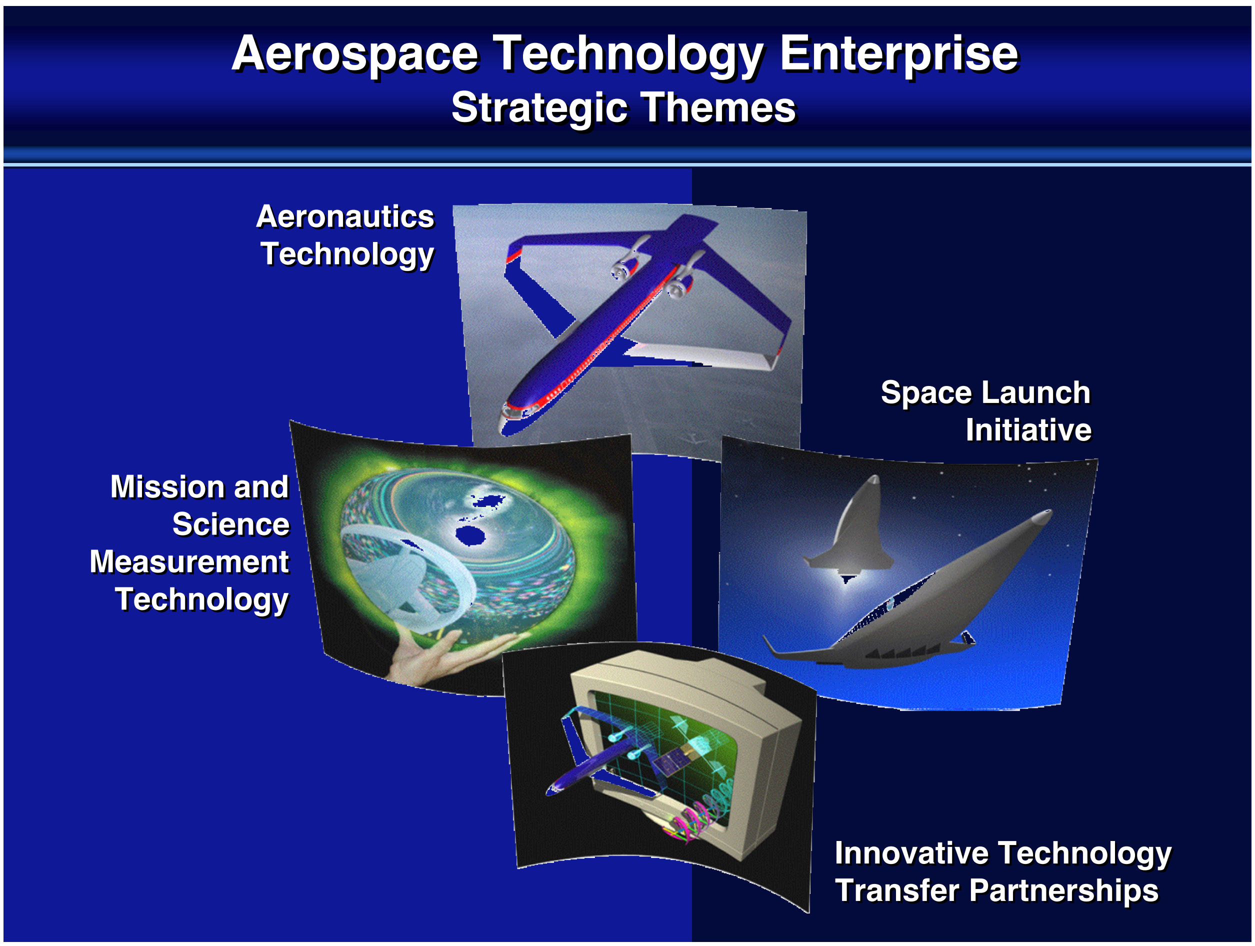
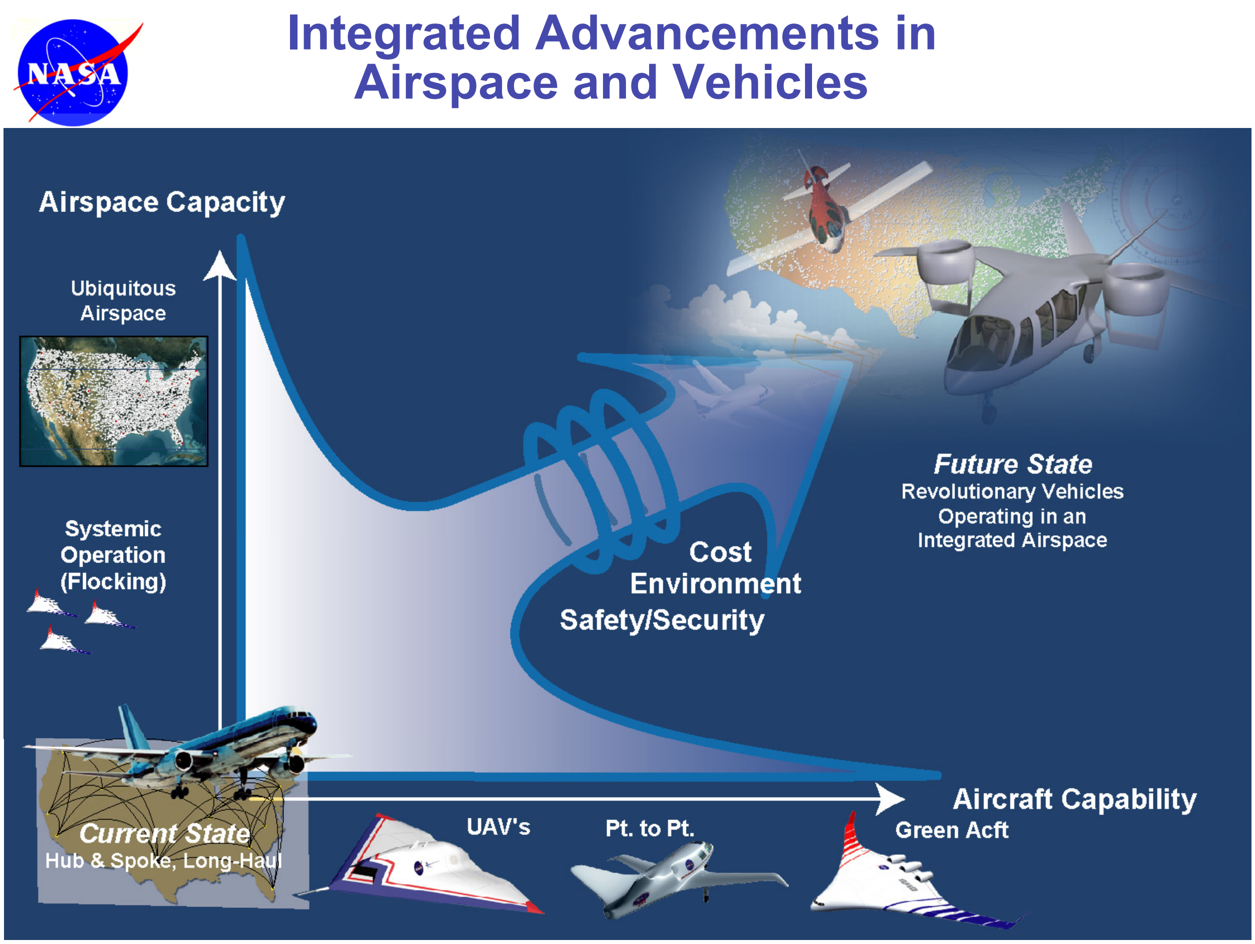
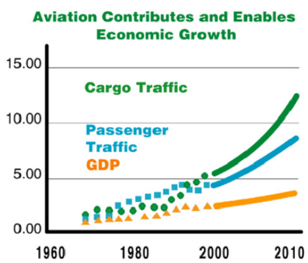
NASA
Space Science
Earth Science
Biological & Physical Research
Space Flight
Aerospace Technology
Education
6 Strategic Enterprises - One NASA
NASA's Vision
• To improve life here
• To extend life to there
• To find life beyond
NASA's Mission
• To understand and protect our home planet
• To explore the universe and search for life
• To inspire the next generation of explorers
...as only NASA can

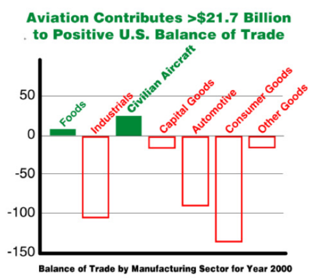

Aerospace Technology Enterprise
Strategic Themes
Aeronautics Technology
Space Launch Initiative
Mission and Science Measurement Technology
Innovative Technology Transfer Partnerships


Aeronautics Technology
Aerospace Technology Themes:
Aeronautics Technology
Space Launch Initiative
Innovative Technology Transfer Partnerships
Mission and Science Measurement Technology
Aeronautics Theme Objectives
Protect Air Travelers and the Public
Protect the Environment
Increase Mobility
Protect the Nation
Explore New Aeronautical Missions


Integrated Advancements in
Airspace and Vehicles
Airspace Capacity
Ubiquitous
Airspace
Systemic
Operation
(Flocking)
Cost
Environment
Safety/Security
Future State
Revolutionary Vehicles
Operating in an
Integrated Airspace
Current State
Hub & Spoke, Long-Haul
UAV's
Pt. to Pt.
Aircraft Capability
Green Acft

Aviation is Critical to Society

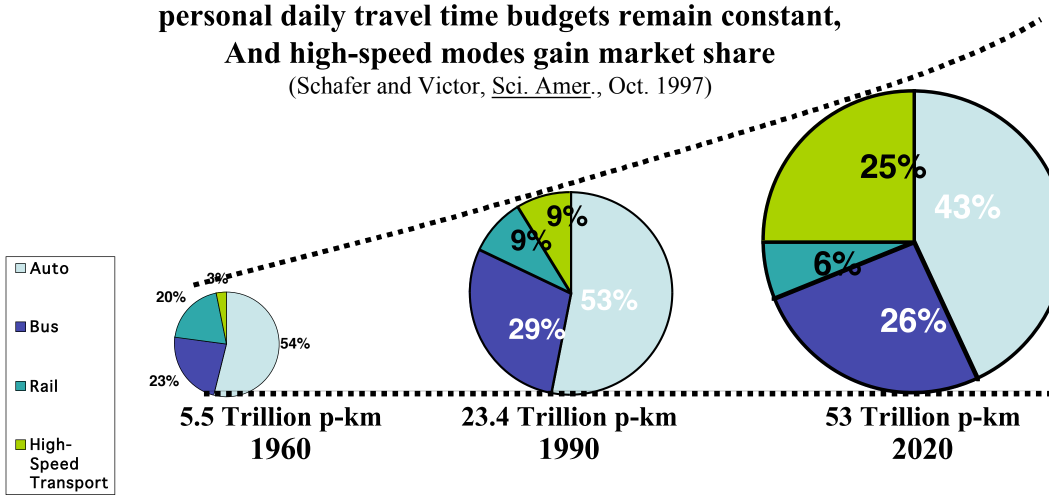




Aviation Extends and Accelerates the E-Commerce Revolution

Global Trends in Transportation Mode Market Shares

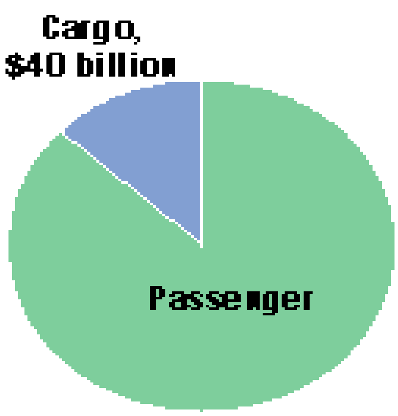
As *per capita* income rises, *per capita* annual travel rises,
personal daily travel time budgets remain constant,
And high-speed modes gain market share
(Schafer and Victor, Sci. Amer., Oct. 1997)



Demand for transportation, especially high-speed air travel, will soar beyond supply early in the 21st century.
The demand for air travel in 2020 could exceed the volume of ALL auto travel in 1990.

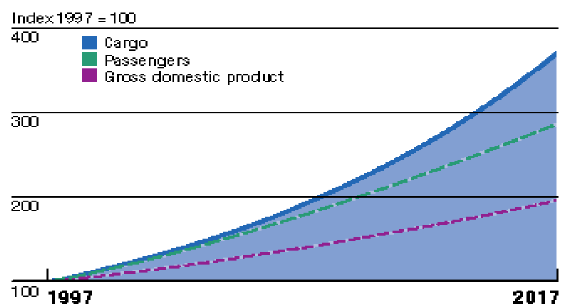
Indicators of Demand
Air Cargo Growth

Air cargo revenues are $40 billion per year



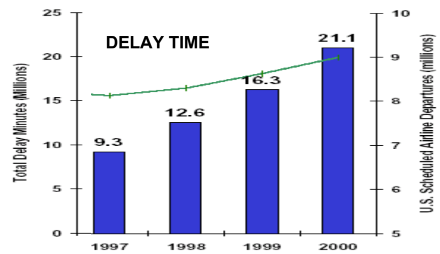
(Source: Boeing, 2000)

Air cargo traffic is expected to triple and outpace passenger growth in next 20 years

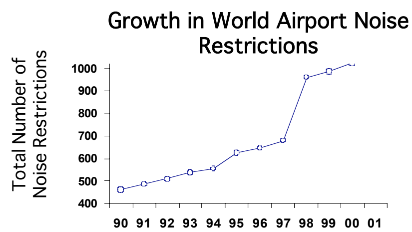


There are Major Issues in Aviation

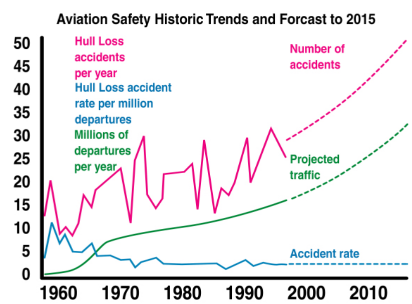
Capacity Limits



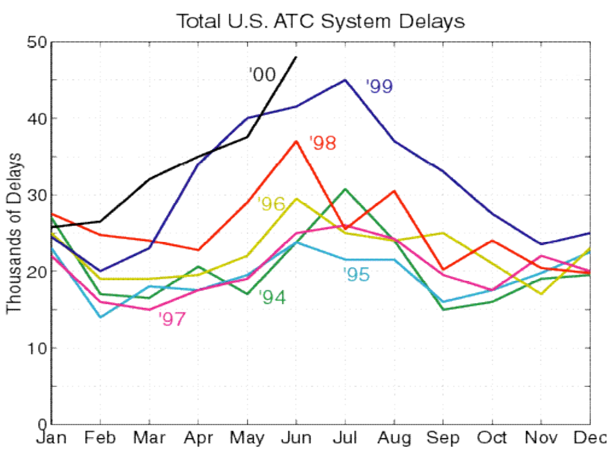
Noise & Emissions



Safety & Security

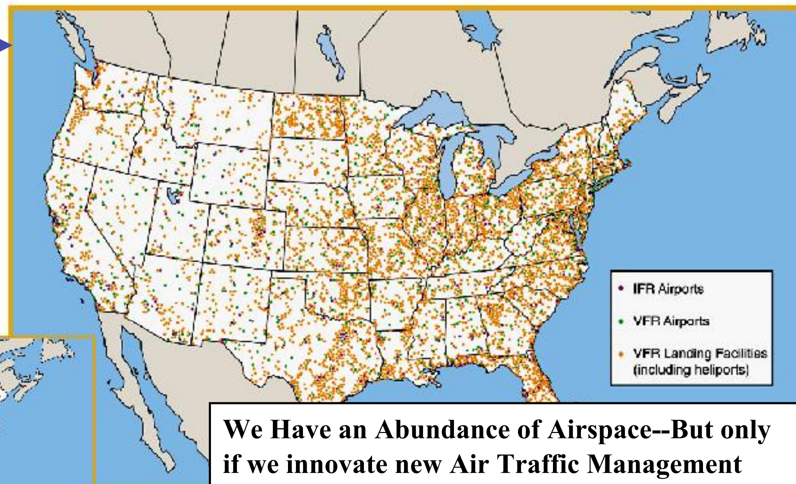


Congestion is an Issue

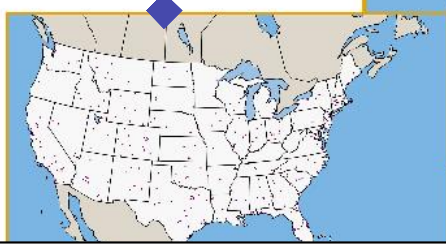


Highways are not the solution

On Demand
(Airspace and Airports are Abundant, not Scarce)



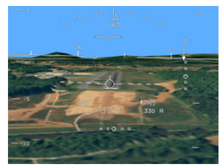
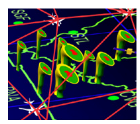
***Expanded Accessibility* to thousands more destinations creates economic opportunity independent of location**

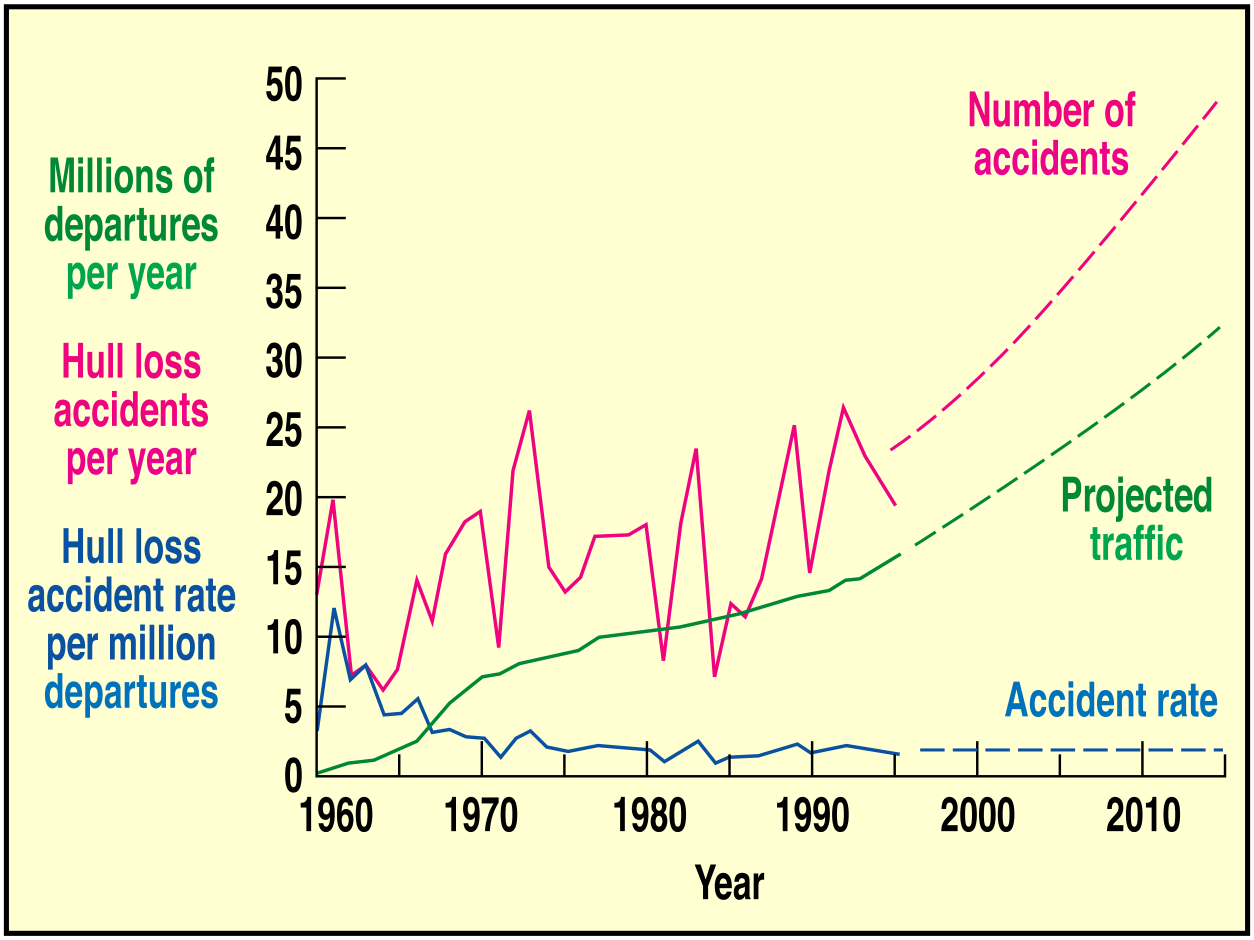


We Have an Abundance of Airspace--But only if we innovate new Air Traffic Management and transportation services concepts!
- **Aggregate customers by e-commerce and wireless networks**
- **Serve low-density, price sensitive markets**
- **Provide mass customization of air service**
- **Open up America like the interstate highway system, but with five times the speed**

Affordable Air Service is Constrained to only a Limited Number of Hub-and-Spoke Airports
- **Need expanded and more distributed service**
- **Need safe accessibility to any airport**
- **Need hub-like affordability at any community**

Safety

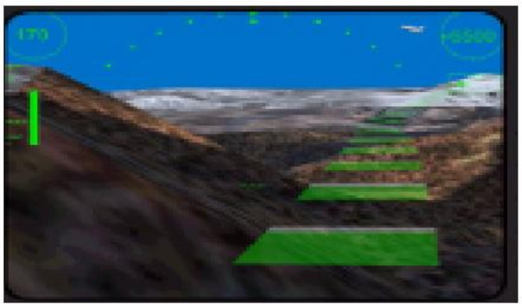
Today's Challenges:	Future Opportunities:
• Limited Visibility	 • Synthetic Vision Provides Visibility in all Conditions
• Human Error	 • Human-Centered Designs
• Component Failures	• Self-healing, Fault Detection and Reconfigurable systems
• Weather Hazards	 • Weather Precisely Known
• Hidden/Emerging Risks	 • Aviation Risks Monitored and Managed
• Asymmetrical Threats	 • "Refuse to Crash" Digital Terrain Technology

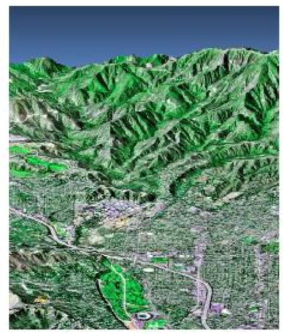


Millions of departures per year
Hull loss accidents per year
Hull loss accident rate per million departures
50
45
40
35
30
25
20
15
10
5
0
Number of accidents
Projected traffic
Accident rate
1960
1970
1980
1990
2000
2010
Year

Synthetic Vision

Example of How Technology Will Transform Aviation





Safety

Controlled Flight into Terrain

Approach & Landing

Loss of Control

Runway Incursion

Efficiency

All Weather

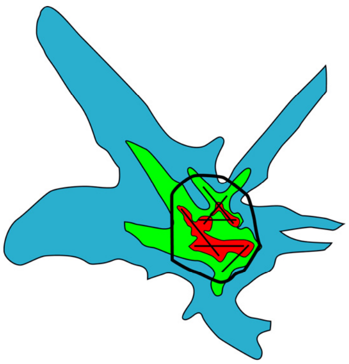
Visual Departures & Visual Approaches

Visual Spacing

Accessibility

Virtually any runway end or heli-pad in the nation becomes accessible in near-all-weather, without traditional ground infrastructure expense

Environmentally Friendly Aircraft

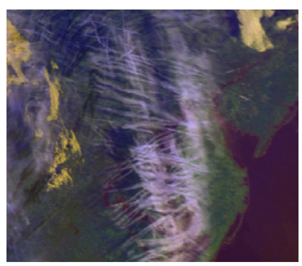


Noise within airport boundaries

Constrain objectionable noise to within airport boundaries

Smog-free

Minimize the contribution of air vehicles to the production of smog



No impact on global climate

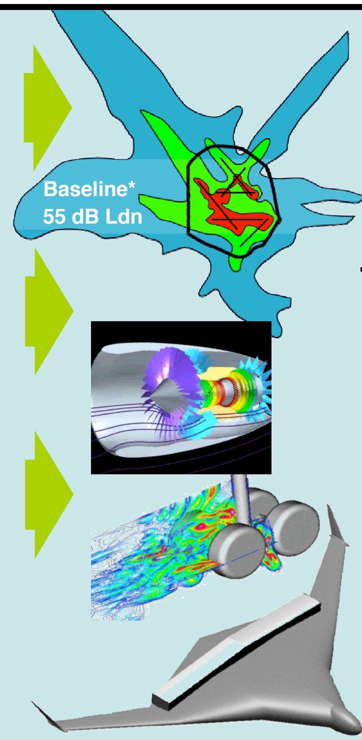
Minimize the impact of air vehicles on global climate

Noise Reduction

Today's Challenges:

- 825 (and growing) airports with noise restrictions
- $4B (and growing) to condition homes
- To keep noise inside airport boundaries
- Understanding the sources of noise
- Integrate emerging materials, structures, flow control technologies

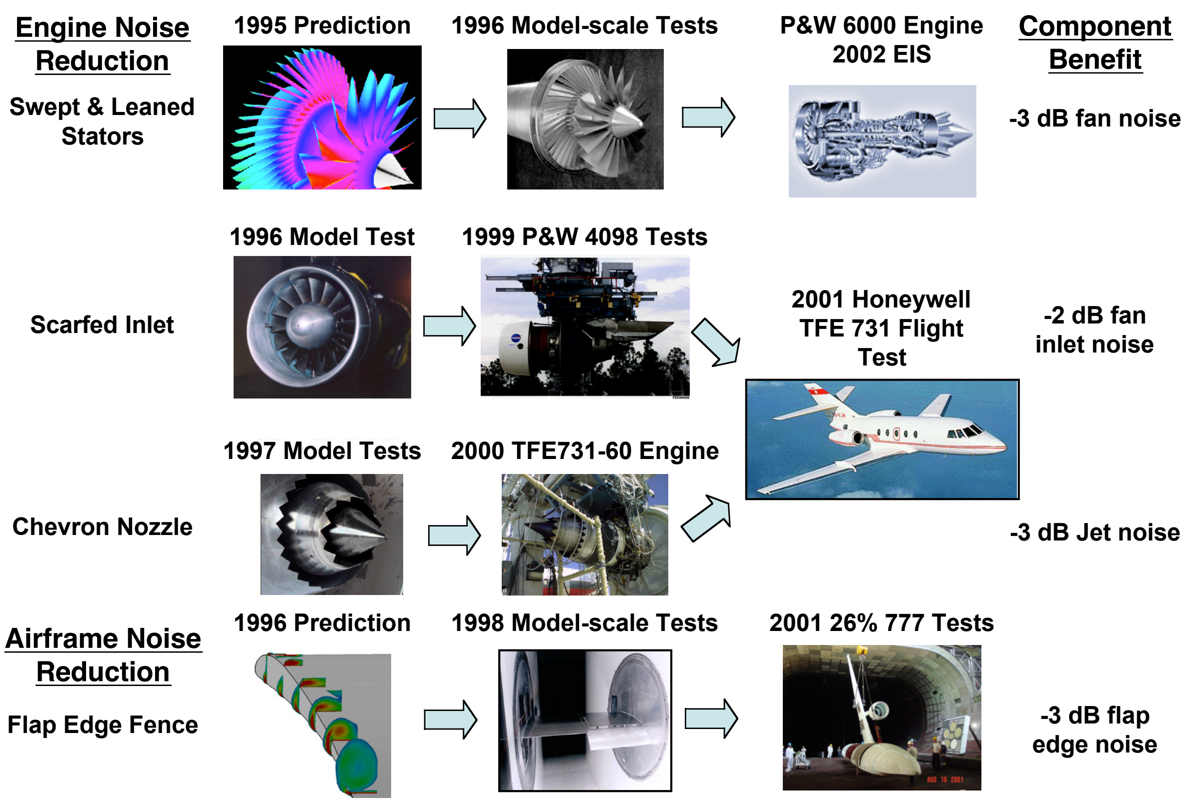
Future Opportunities:



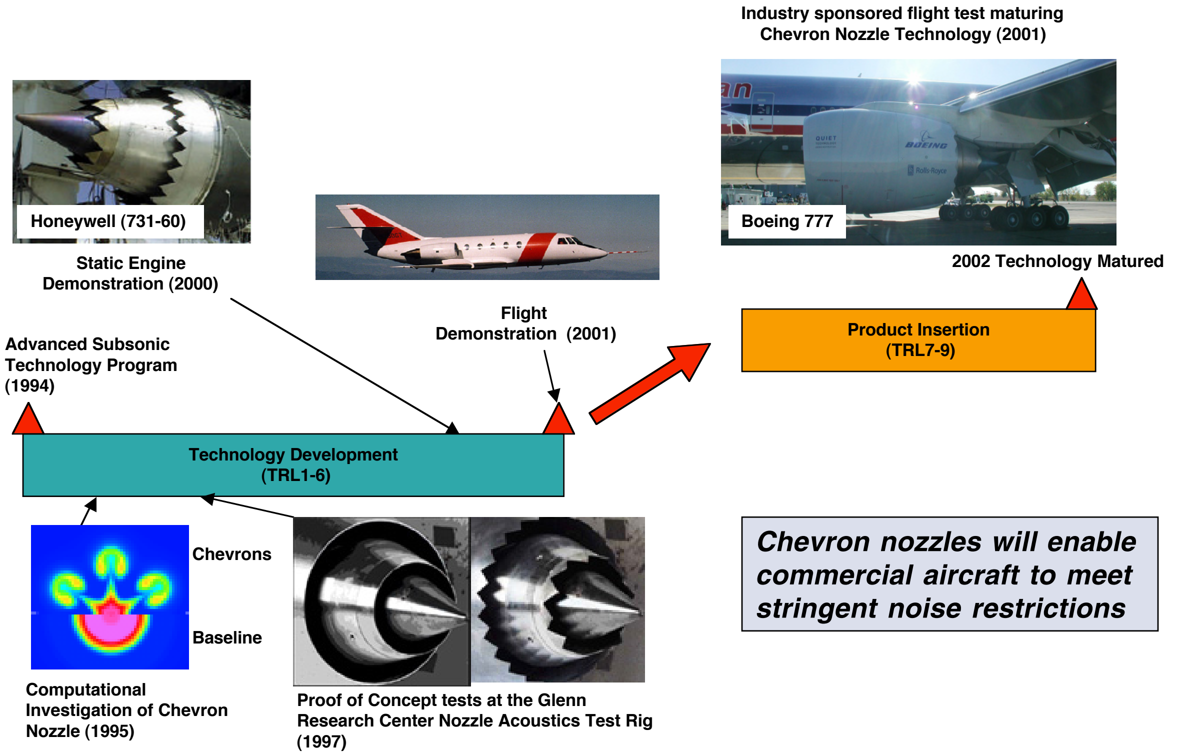
- Revolutionize How Citizens View Airports
- Eliminate Noise by Design
- Quiet Design Engines, Landing Gear, and Airframes
- Revolutionary Vehicles (BWB)

* DNL 55 is the EPA outdoor noise exposure level "requisite to protect the public health and welfare with an adequate margin of safety".

Technology Discovery, Maturation, and Implementation

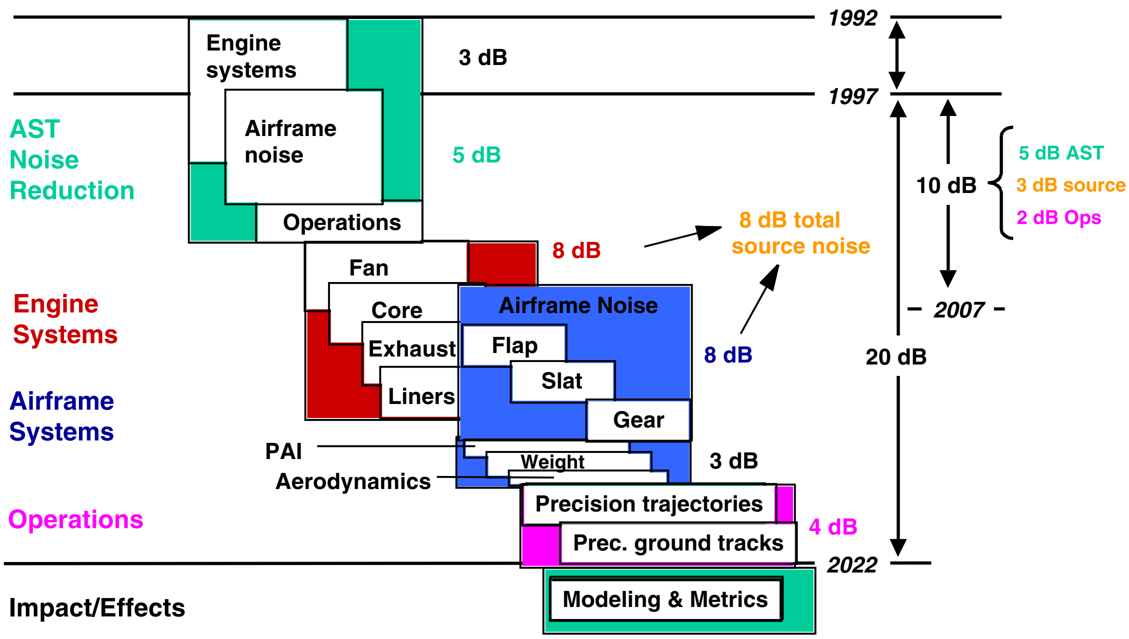


Chevron Nozzle Technology for Engine Noise Reduction



Noise Reduction

Gap Analysis: Technical Challenges, Objectives, and Investment Areas



Environment

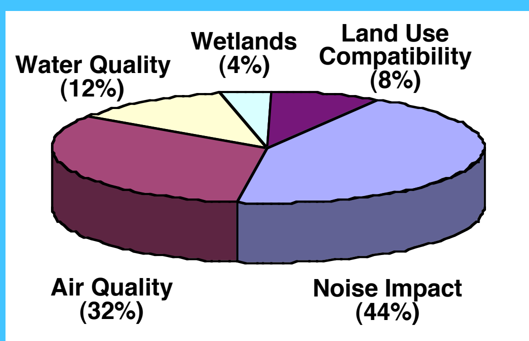
- **Reducing CO_2 emissions by 50% and NOX emissions by 80% in 25 years will require radically new propulsion and airframe concepts**
  - **CO_2 reduction directly related to fuel burn**
    - **Smart vehicles, structures and active flow control technology to reduce drag, improve propulsion/airframe integration and optimize performance**
    - **Advanced propulsion systems (e.g. fuel cells)**
- **NOX reduction related to combustion properties/design and <u>fuel burn</u>**
  - **Advanced materials and designs for turbines, fans, and compressors**
  - **New combustion cycles**
- **Operational environmental issues with painting, de-icing, etc.**
  - **Application of riblets/coatings & smart wing de-icing systems**

Other Environmental Issues

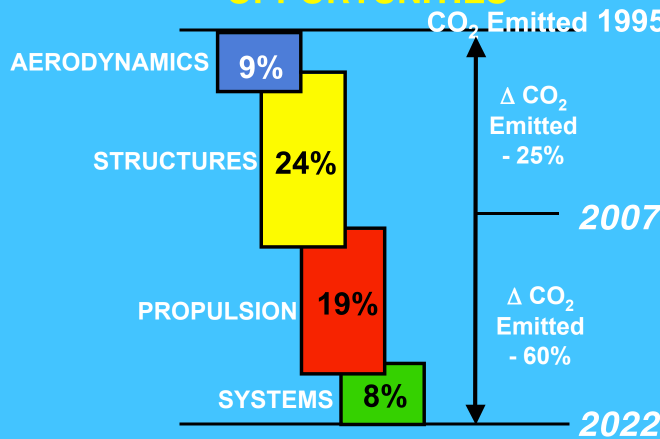
- **Deicing**
  - New systems required to stop runoff of harmful chemicals
  - Some European cities using Infrared heating
- **Painting**
  - Some manufacturers are flying unpainted aircraft off the assembly line to remote locations for painting

Issues and Technologies: Emissions

GAO SURVEY OF FUTURE ENVIRONMENTAL IMPACTS ON AIRPORTS



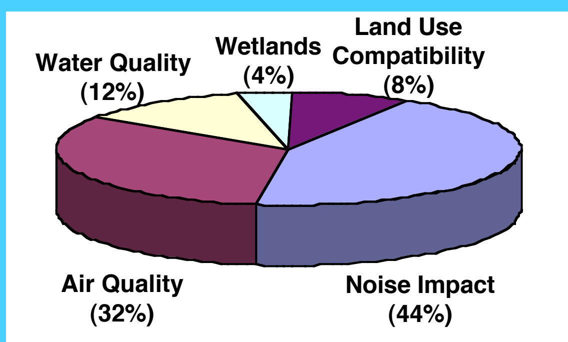
BREAKDOWN OF TARGET OPPORTUNITIES

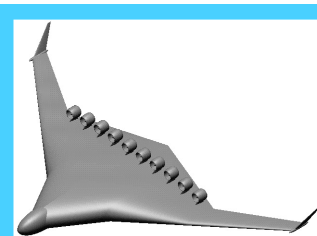


Issues and Technologies: Emissions Impact on 21st Century Mobility

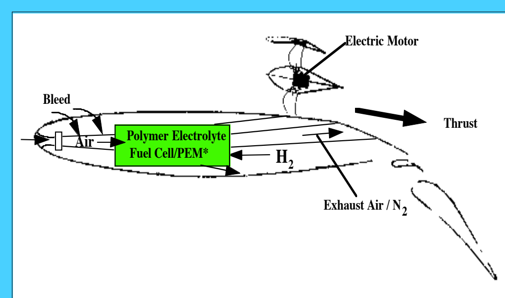
Possible Future Technologies

GAO Survey of Future Environmental Impacts on Airports

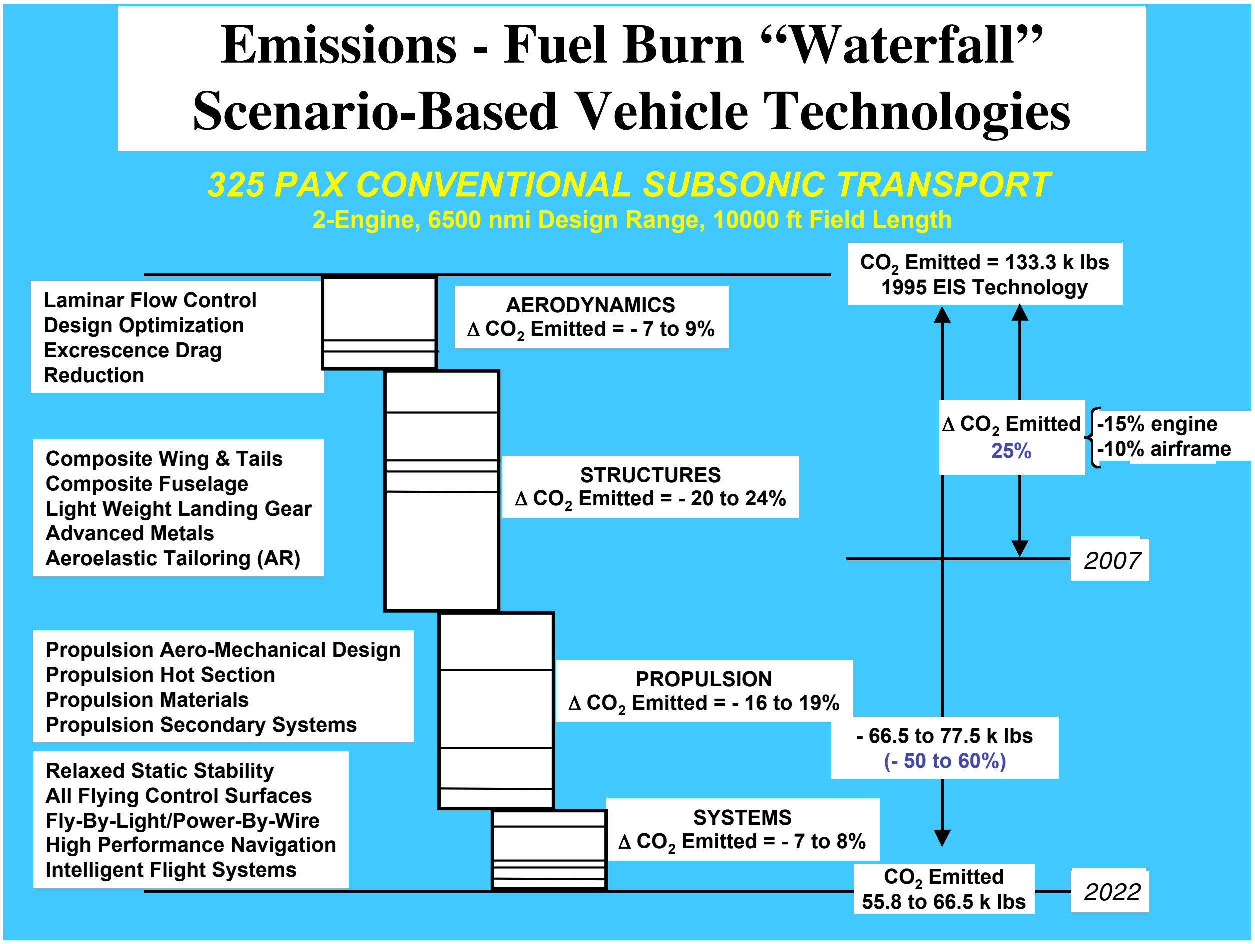




Quiet-Green Blended Wing Body Concept



Electric Aircraft Concepts



Emissions - Fuel Burn "Waterfall"
Scenario-Based Vehicle Technologies
325 PAX CONVENTIONAL SUBSONIC TRANSPORT
2-Engine, 6500 nmi Design Range, 10000 ft Field Length
CO_2 Emitted = 133.3 k lbs
1995 EIS Technology
Laminar Flow Control
Design Optimization
Excrescence Drag
Reduction
AERODYNAMICS
Δ CO_2 Emitted = - 7 to 9%
Δ CO_2 Emitted
25%
-15% engine
-10% airframe
Composite Wing & Tails
Composite Fuselage
Light Weight Landing Gear
Advanced Metals
Aeroelastic Tailoring (AR)
STRUCTURES
Δ CO_2 Emitted = - 20 to 24%
2007
Propulsion Aero-Mechanical Design
Propulsion Hot Section
Propulsion Materials
Propulsion Secondary Systems
PROPULSION
Δ CO_2 Emitted = - 16 to 19%
- 66.5 to 77.5 k lbs
(- 50 to 60%)
Relaxed Static Stability
All Flying Control Surfaces
Fly-By-Light/Power-By-Wire
High Performance Navigation
Intelligent Flight Systems
SYSTEMS
Δ CO_2 Emitted = - 7 to 8%
CO_2 Emitted
55.8 to 66.5 k lbs
2022

Aircraft for Public Mobility

More Convenient
Expand access to aviation to more locations and make it available on-demand

More Affordable
Make air travel available to the entire population

…without compromising safety

Faster
Increase the speed of air travel

Indicators of Demand
Regional Jet Growth

- New regional jets fly faster and farther and are adding new direct connections
  - 550 RJs in use by end of 2000
- Older 19-seat turboprops used by regional airlines declining
  - down 40% in last decade to 405 in 1999
- However, fewer cities are being served as airlines consolidate markets for profitability

Canada and Brazil are the leading makers of regional jets.

A New Generation of Revolutionary Light Jet Products

- Strong Growth between 1994-1999
  - Billings up 235%
  - Deliveries up 172%
  - 636 Business & Corporate jets ($7.9 B) delivered in 1999
    - In comparison, 287 fighter planes ($9.7 B) delivered in 1999
    - Strong export market (>30%)
- Several new model jets
  - From low (<$1M) to high (>$40M) products
  - New engines stimulate new aircraft development
- New Aircraft Revolutionize the Cost of Speed
  - $1.00/aircraft mile (total for 5 passenger jet travel)
  - Ultimately propeller travel becomes obsolete
  - On-Demand jet trips become affordable for most travelers

New Quiet, Affordable Small Jet Engines

Highway in the Sky (HITS)

Graphically intuitive pilot interface system that provides a general aviation aircraft operator with the attitude and guidance inputs required to safely fly an aircraft in close conformance to air traffic procedures.

A multi function display showing a moving map and the path to any destination is available to the operator.

HITS
c. 2002

Demonstration of the AGATE Highway In The Sky (HITS) in a General Aviation Aircraft

Emerging New Applications for Composite Structures

UAV Systems

Operational

RQ-1 Predator

RQ-2 Pioneer

RQ-5 Hunter

RQ-5 Hunter/TRW/IAI/Army

Weight	Length	Wingspan	Ceiling	Radius	Endurance
1,600 lbs	23 ft	29.2 ft	15,000 ft	144 nm	11.6 hrs

Payload Weight: 200 lbs

Developmental

RQ-4 Global Hawk

Fire Scout

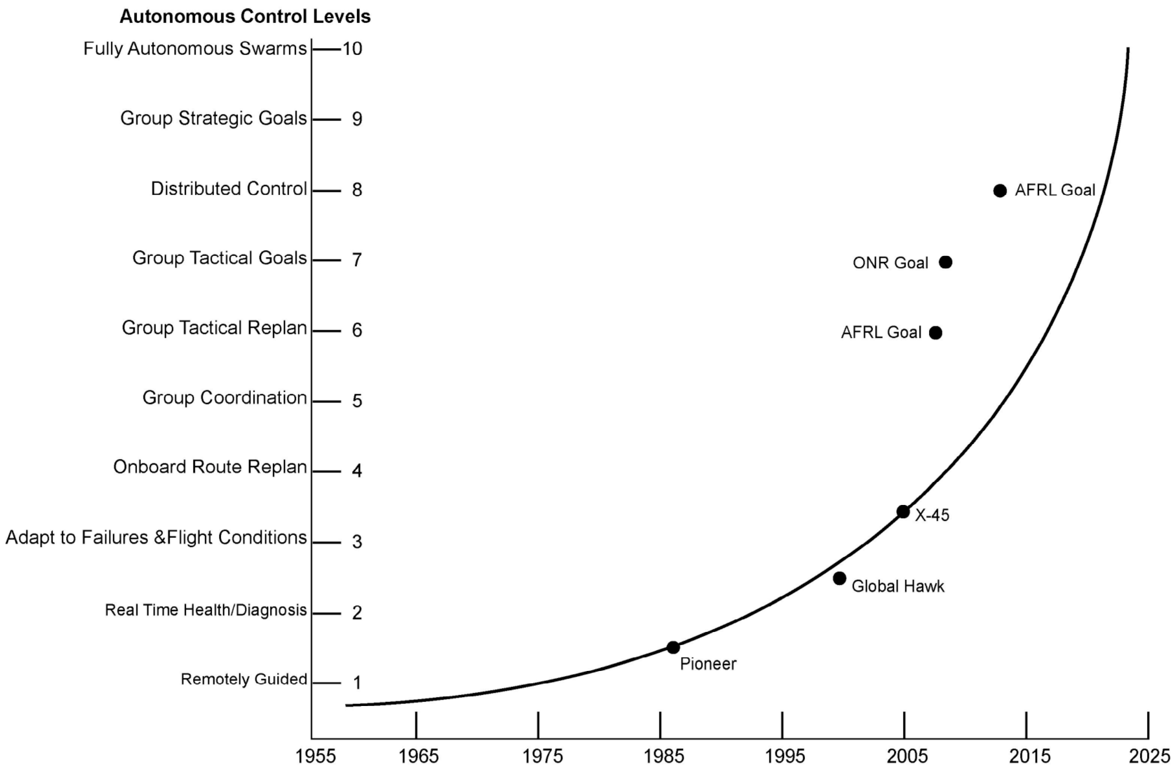
RQ-7 Shadow 200

RQ-7 Shadow/AAI/Army

Weight	Length	Wingspan	Ceiling	Radius	Endurance
327 lbs	11.2 ft	12.8 ft	15,000 ft	68 nm	4 hrs

Payload Weight: 50 lbs

Autonomous control Level Trends

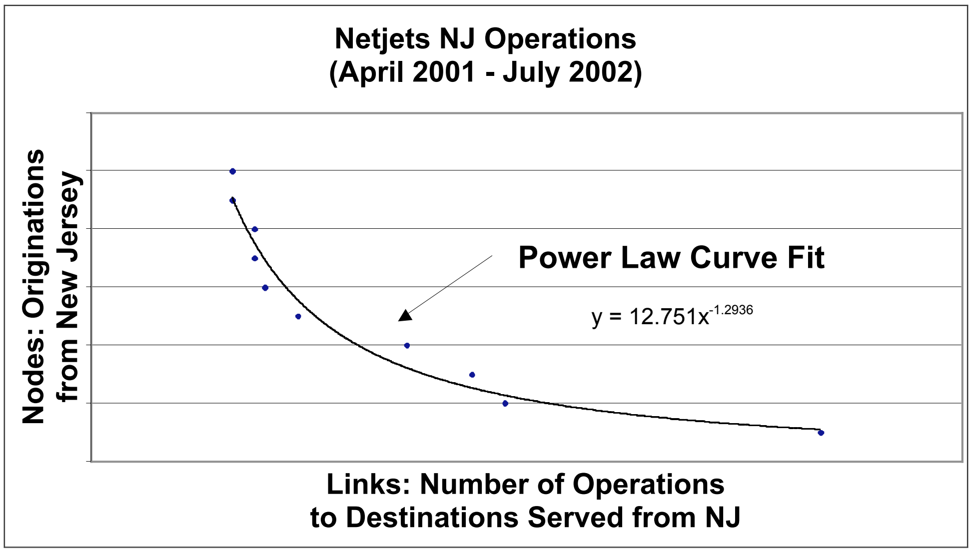


Source:Unmanned Aerial Roadmap 2000-2025

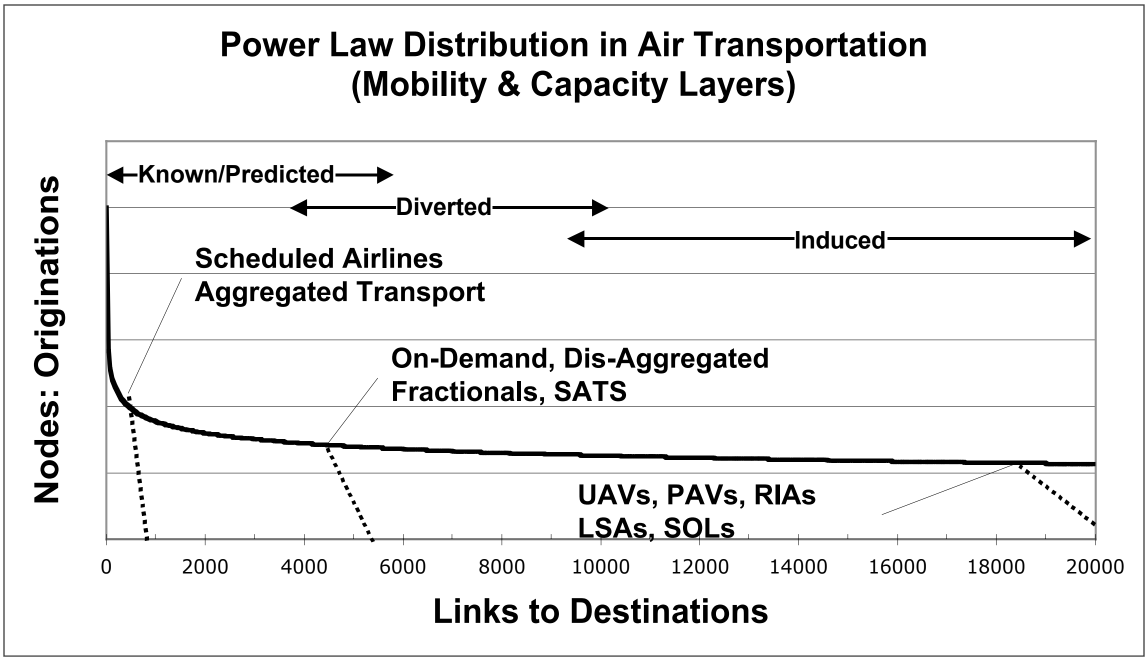

EagleVision


Personal Air Vehicle (PAV) Sector (Goal Based)
Ease of Use Equivalent to Automobile
• Blunder resistant controls, co-pilot on a chip, obstacle avoidance, etc…
• Seamless integration of airspace communication, navigation and surveillance
Improved Propulsion
• Engine-out robustness
• Efficient, simplified propulsors
• Alternative cycle engines
• Propulsion-airframe integration
Affordable Ownership
• Certification of automotive processes
• Lean design and manufacturing
• Advanced software certification
• Health monitoring systems
• Design to certification toolsets
Lower Weight Systems
• Durable, damage-tolerant structures
• Minimum gage materials and design
• Active control simplified high-lift
Low Community Noise
• Engine noise management systems
• Quiet propulsors

Scale-Free Distribution of NetJets Operations



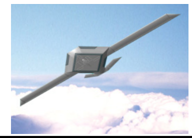
- The links (operations) from a few of NetJet's nodes in NJ to their top ten destinations from NJ nodes (originations) follow a power law distribution.
- For NetJets, this distribution of nodes with links extends out to about 1250 airports annually.



Small World Behaviors in Air Transportation Topologies

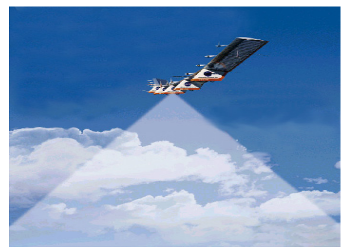
- **Hub-and-spoke exhibits single-scale (truncated)**
- **Regional jet operations exhibit single-scale (truncated)**
- **SATS Jet-taxi operations (5,000 airports) exhibits broad scale**
- **Self-operated rural/regional PAVs exhibits broader scale**
- **Intra-urban PAVs approach scale-free**

Air Vehicles for New Missions



Science platforms

Develop innovative air vehicles for science missions in the earth's atmosphere and beyond

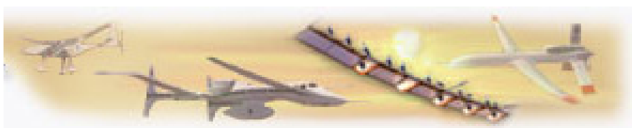


Hazardous environments

Enable uninhabited air vehicles to fly in hazardous environments

HALE UAV for Earth Science Measurements

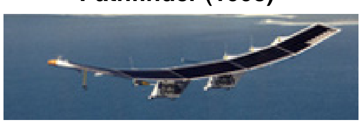
Goal: Long-endurance, high altitude, unmanned flight



ERAST program begins (1994)

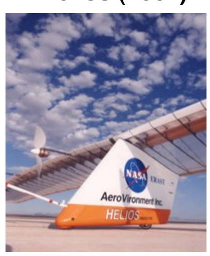
Technology Development
(TRL1-6)

Pathfinder (1995)



Reached 50,000 ft during a 12-hr flight

Helios (2001)



Reached 96,000+ ft

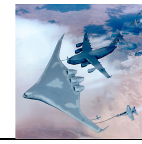
Pathfinder Plus

Mobile Imaging Demonstration (2002)

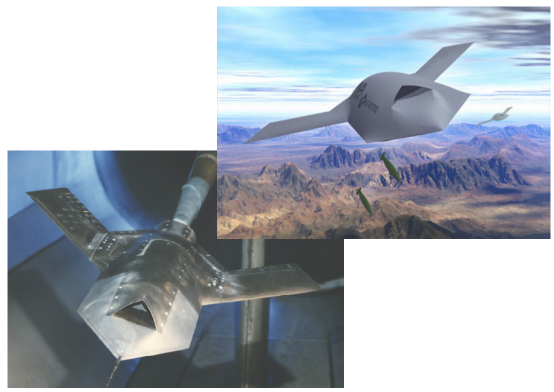
Technology Demonstration
(TRL7-9)

Cloud-free images of coffee plantation obtained after 4-hr loiter showed areas ready for harvest.

Superior Air Power

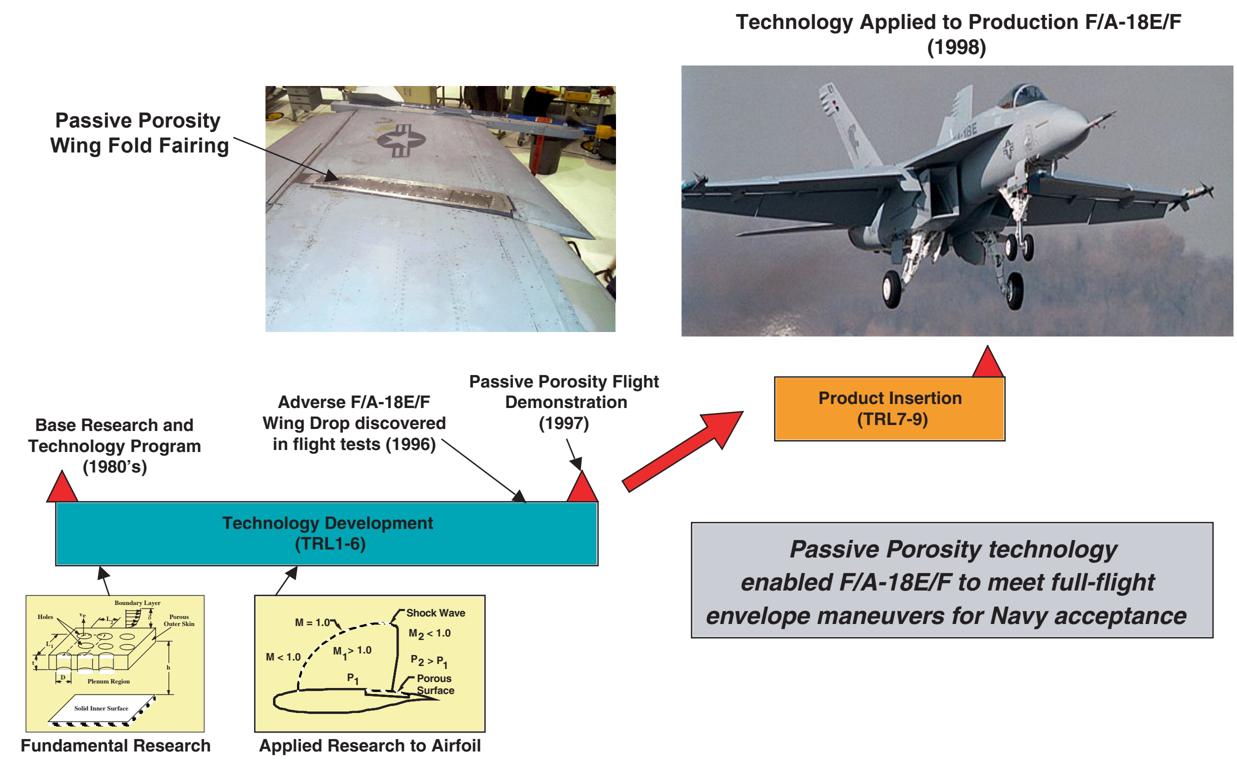


Technological superiority
Cooperatively develop technologies that enable air superiority



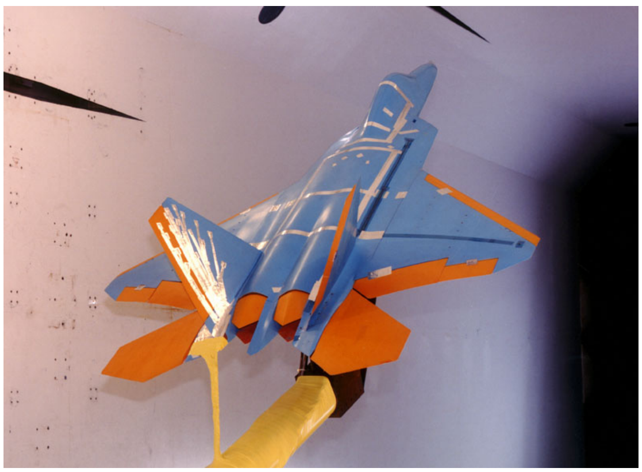
Partners in freedom
Support the development of advanced military aircraft

Passive Porosity Technology for F/A-18E/F Wing Drop



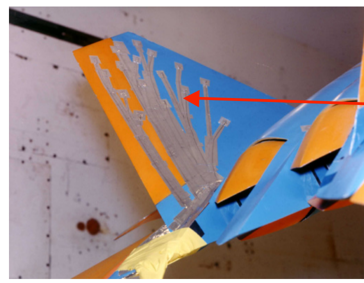
Support of DOD Programs - F-22

F-22 Tail Buffet Survey



13.5% Scale F-22 in
LaRC Transonic Dynamics Tunnel

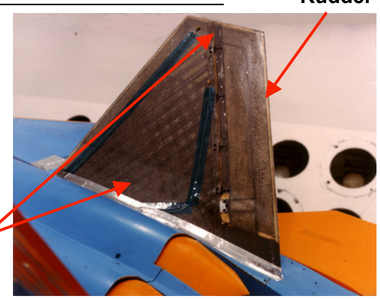
Port Fin - Rigid



Pressure
Transducers

Starboard Fin - Flexible

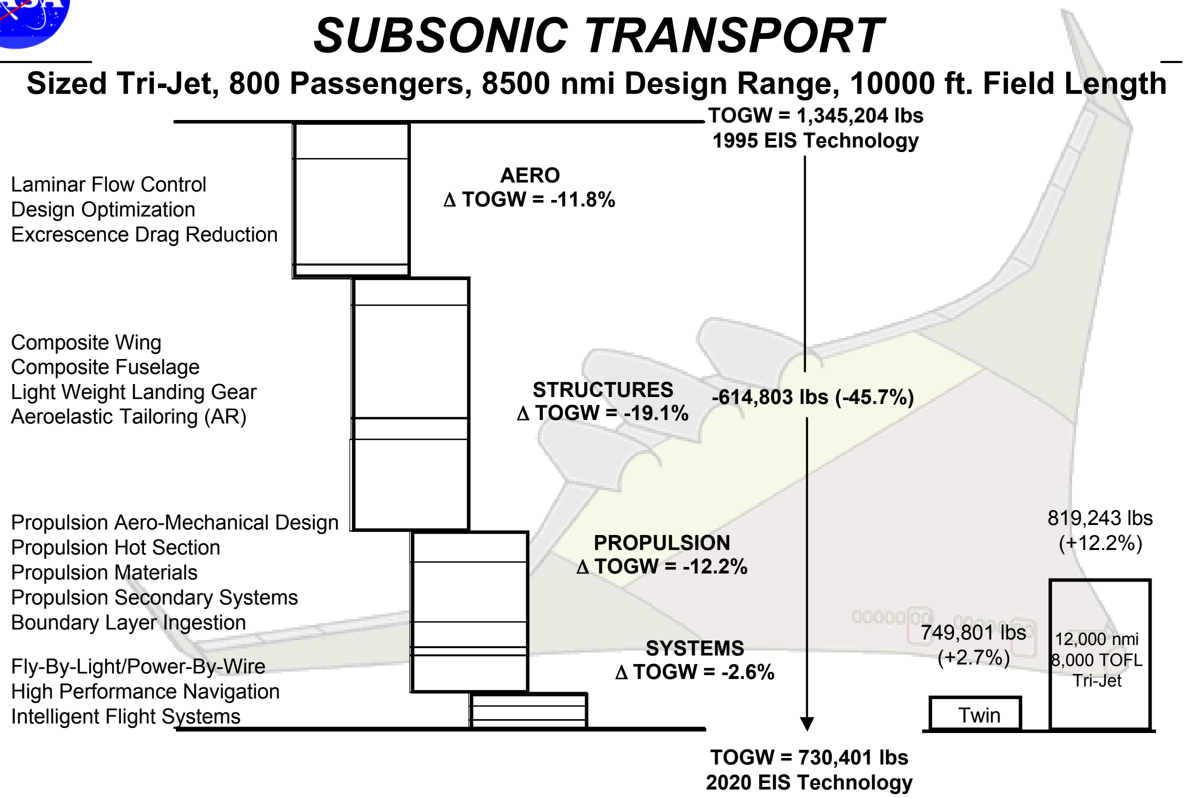
Active
Rudder



Accelerometers

LONG HAUL/HIGH CAPACITY BWB SUBSONIC TRANSPORT

Sized Tri-Jet, 800 Passengers, 8500 nmi Design Range, 10000 ft. Field Length



Vehicle Sectors

Subsonic

Vehicle capabilities defined within each sector

Supersonic

Personal Air Vehicle

Uninhabited Air Vehicle

Technology goals defined to support capabilities

Runway Independent Aircraft

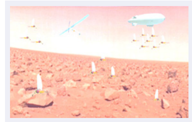
Innovative Vehicle Concepts to Identify Key Technology Requirements

Minimum environmental impact, maximum efficiency

Clean Transport

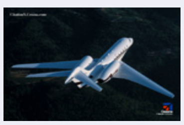
Strengthen national security through rapid deployment and global reach

Global Strike



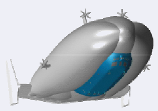
Conduct extended science and exploration missions

Planetary Flight Vehicles



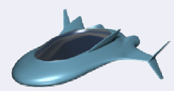
All hour access to any location without noise disturbance

Santa Monica at Midnight



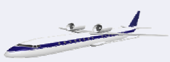
Global reach and on-demand delivery

Global Reach Transport



Rural, regional, and intra-urban transportation

Personal Air Vehicle

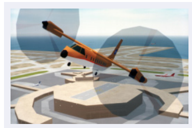


Rural and regional economic growth, time critical transport

Heartland Express

Automated refueling capability, ultra-long endurance, wide speed range

Tanker

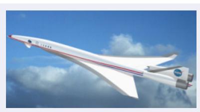


Enables city center access in all weather

V/STOL Commuter

Expands the use of existing airport infrastructure

Extreme STOL Transport



Reduce passenger flight time by at least a factor of 2

Supersonic Overland

High altitude observations for science and defense

High Altitude Long Endurance

Runway Independent Aircraft (RIA) Technology Goals

RIA is one of 5 vehicle sectors

Technology Areas	**Goal**	**SOA**
$C_L$max	10	7
L/D	16	12
Community Noise (Outside Fence)	55 EPNdB	Stage 3
Flight Controls	CAT IIIC	Special VFR
Hover Efficiency (EW/HOGE GW)	0.56	0.68
SFC	SOA -35%	SOA
Engine T/W	SOA +120%	SOA
Empty Weight Fraction	0.52	0.63
Cabin Noise	75dBA	88dBA
Cabin Vibration	0.03g's	0.10g's

Strategic Technology Focus Areas

Six long-term technology focus areas

- Key long-term investment areas
- Primary places where technology advances will occur
- Projects achieve finite steps within these areas

- *Environmentally Friendly, Clean Burning Engines*
  Focus: Develop innovative technologies to enable intelligent turbine engines that significantly reduce harmful emissions while maintaining high performance and increasing reliability

- *New Aircraft Energy Sources and Management*
  Focus: Discover new energy sources and intelligent management techniques directed towards zero emissions and enable new vehicle concepts for public mobility and new science missions

- *Quiet Aircraft for Community Friendly Service*
  Focus: Develop and integrate noise reduction technology to enable unrestricted air transportation service to all communities

Strategic Technology Focus Areas (contd)

- *Aerodynamic Performance for Fuel Efficiency*

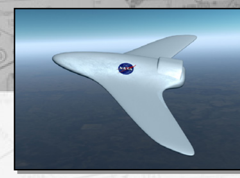
  Focus: Improve aerodynamic efficiency,structures and materials technologies, and design tools and methodologies to reduce fuel burn and minimize environmental impact and enable new vehicle concepts and capabilities for public mobility and new science missions

- *Aircraft Weight Reduction and Community Access*
  - *Focus: Develop ultralight smart materials and structures, aerodynamic concepts, and lightweight subsystems to increase vehicle efficiency, leading to high altitude long endurance vehicles, planetary aircraft, advanced vertical and short takeoff and landing vehicles and beyond*

- *Smart Aircraft and Autonomous Control*

  Focus: Enable aircraft to fly with reduced or no human intervention, to optimize flight over multiple regimes, and to provide maintenance on demand towards the goal of a feeling, seeing, sensing, sentient air vehicle

Future Vision



- **Inherently Multidisciplinary**
- **Exploit vehicle flexibility and adaptability (e.g. localized and large-scale vehicle shape change)**
- **Colonies of distributed sensors and actuators**
- **A paradigm shift from**
  - **Steady to the unsteady world (e.g. flow control, adaptive morphing)**
  - **Passive to active,**
  - **Rigid to design for flexibility,**
  - **Few discrete to many distributed (e.g. sensors, control surfaces)**
  - ***To obtain a vehicle that is always at optimum performance.***
- ***Therefore, the greatest technical challenges and opportunities occur at the intersection of disciplines***
  - ***but the real barrier may be cultural, not technical***

Summary

- Materials and structures technology advancements are required to achieve performance goals for next generation air vehicles
- Smart Materials and adaptive structures which enable flow control can significantly improve aerodynamic performance
- Advancements in process and manufacturing technologies critical to cost effective air vehicle structures
- Computational modeling essential to design of nano-materials and bio-inspired materials and structures