Small Community Air Transportation

Oklahoma -- CASI
Dr. Bruce J. Holmes, NASA
November 14, 2003

Outline

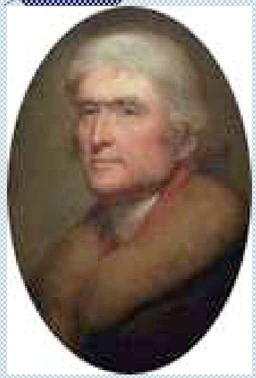
- **Context for Transportation System Transformation**
- **The Vision:**
  - **Longer-term:**
    On-demand, Distributed, Dis-aggregated
    vs.
    Scheduled, Centralized, Aggregated
- **The Technologies**
  - **Nearer-term:**
    Operational Capabilities
    For Airport & Airspace Access
- **Modern Network Theory Implications to Air Transportation Systems**
- **Transformational Roadmapping**

It is extremely unlikely that the world will ever take such a step forward in every means of locomotion as has been taken ... between the year 1830 and the present date."

-- The Rudder magazine, October 1899

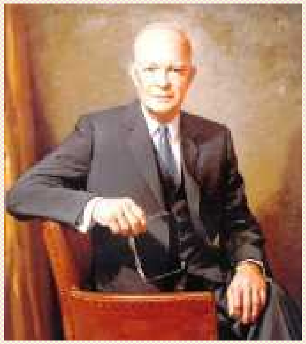
Context for Transportation Innovation

(Bi) Centennial Context for Disruptive Innovation in Transportation Systems



Jefferson sends Lewis and Clark to discover a path for commerce

The Transcontinental Railroad connects east and west



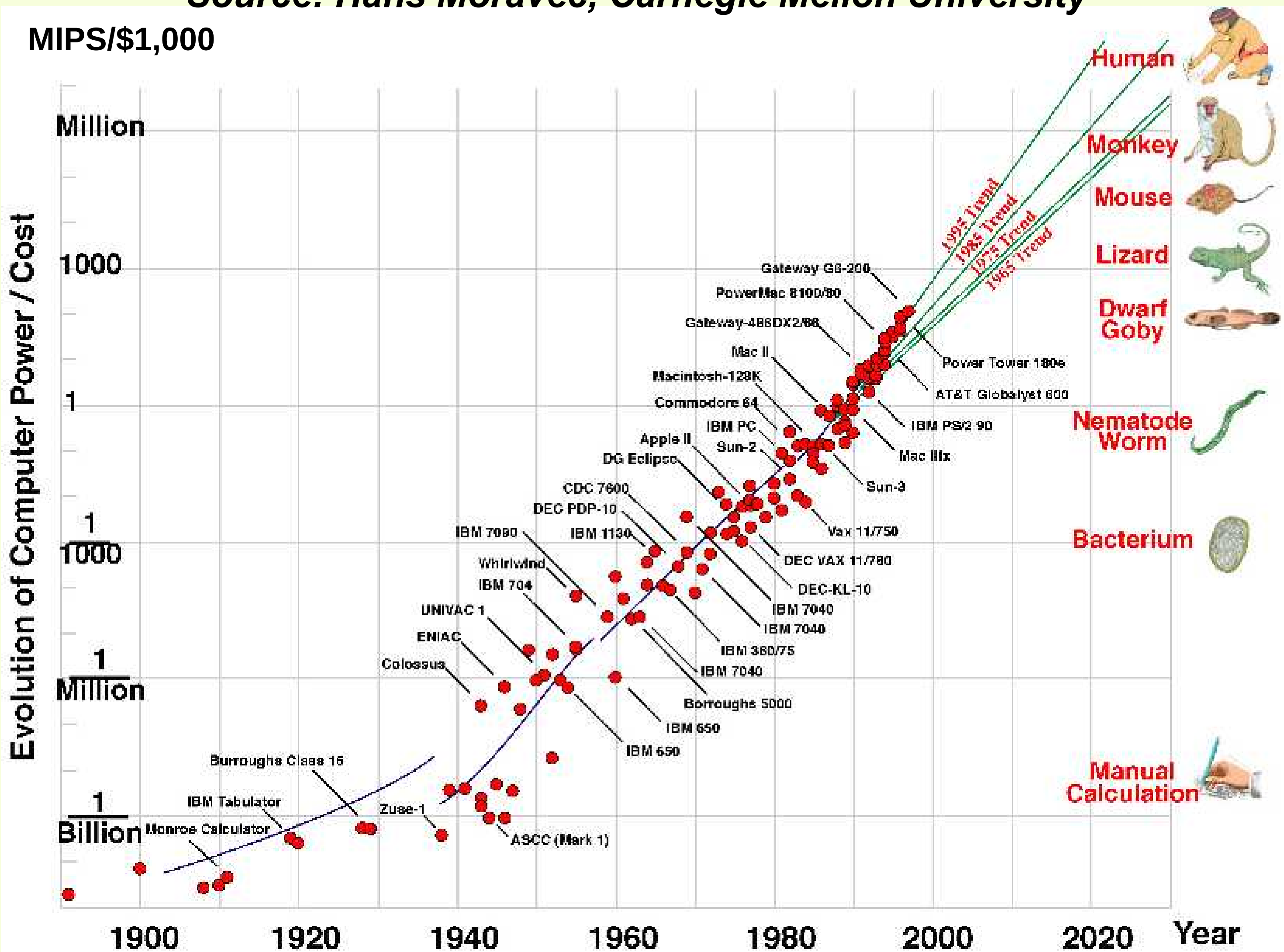
The Interstate Highway system connects the nation's cities

Technological Underpinnings for Mobility Alternatives

1. **Moore's Law**
   on microprocessor cost/performance
2. **Gilder's Law**
   on bandwidth performance
3. **Metcalf's Law**
   on network performance
4. **The unwritten law**
   of abundance
5. **The unwritten rule**
   of gridlock
6. **Kurzweil's Law**
   of Accelerating Returns
7. **The Golden Rule**
   of the information age

Evolution of Computer Power/Cost (Moore's Law)

Source: Hans Moravec, Carnegie Mellon University



Impact: Processing power that can mimic the human brain

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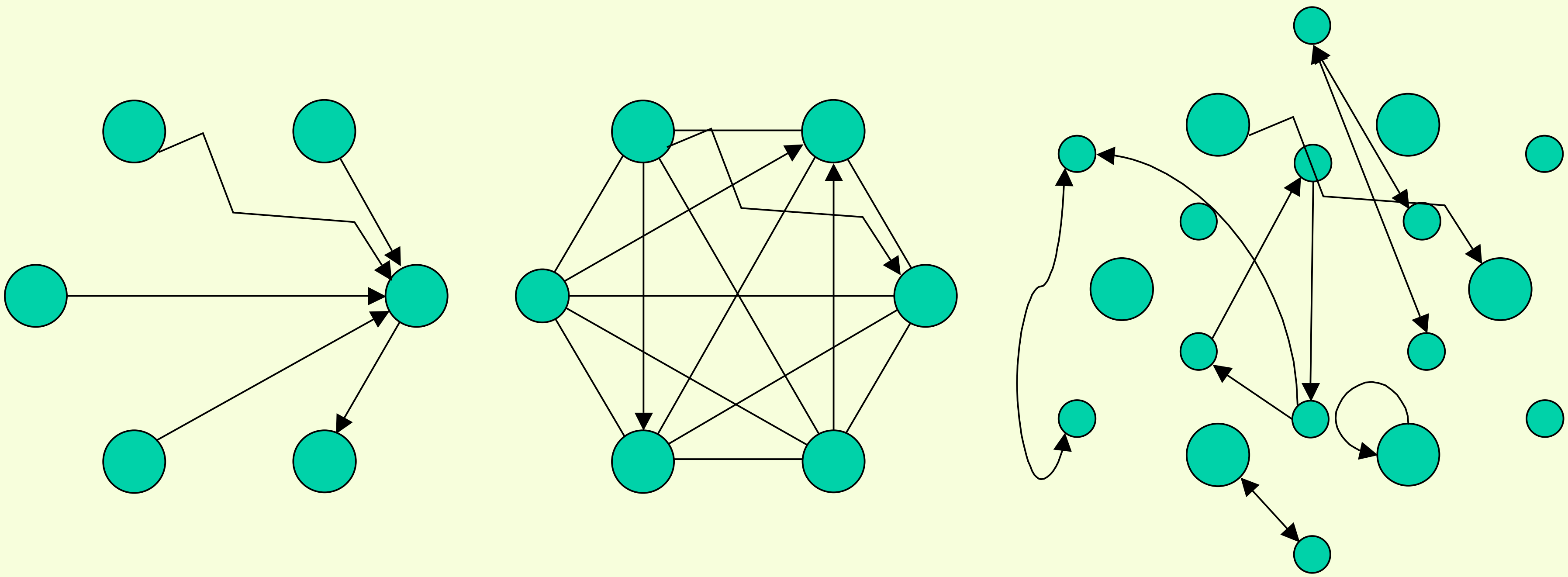
Value of Networks $\propto$ (# of Nodes)^2
(Metcalf's Law)

A. Hub-and-Spoke
Directed, Scheduled, Aggregated

B. Point-to-Point
Directed, Scheduled, Aggregated

C. Distributed
Undirected, On-Demand
Dis-Aggregated



Nodes (n) = 6
Links (k) = n-1 = 5
Tier 1,2 Carriers

Nodes (n) = 6
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Nodes (n) = 18
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(Three times the nodes = 10X links)
Tier 4 Carriers, UAVs, RIAs, PAVs

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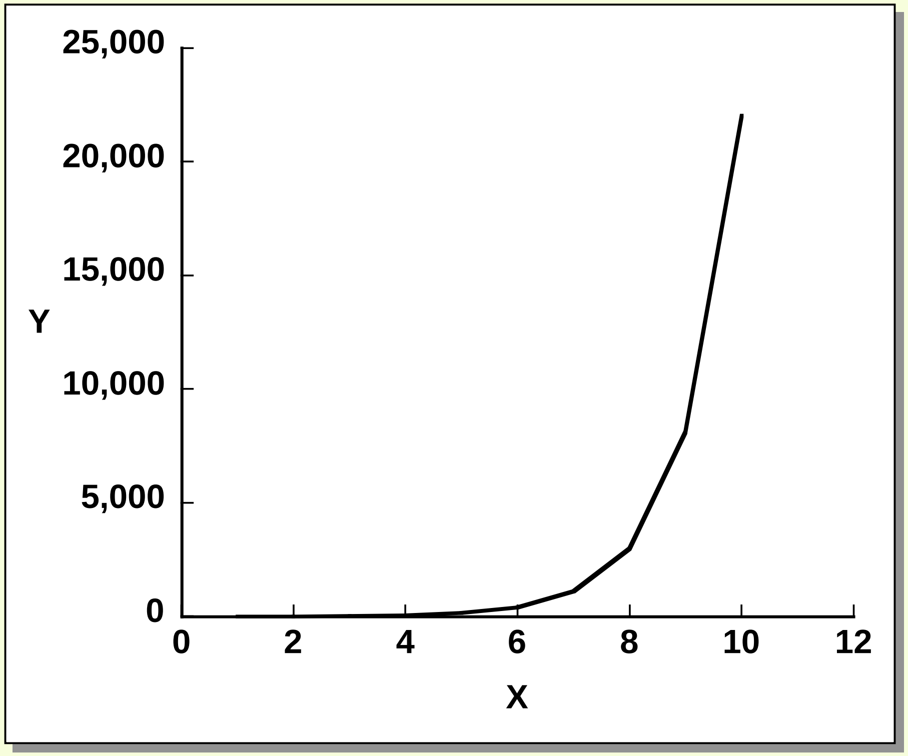
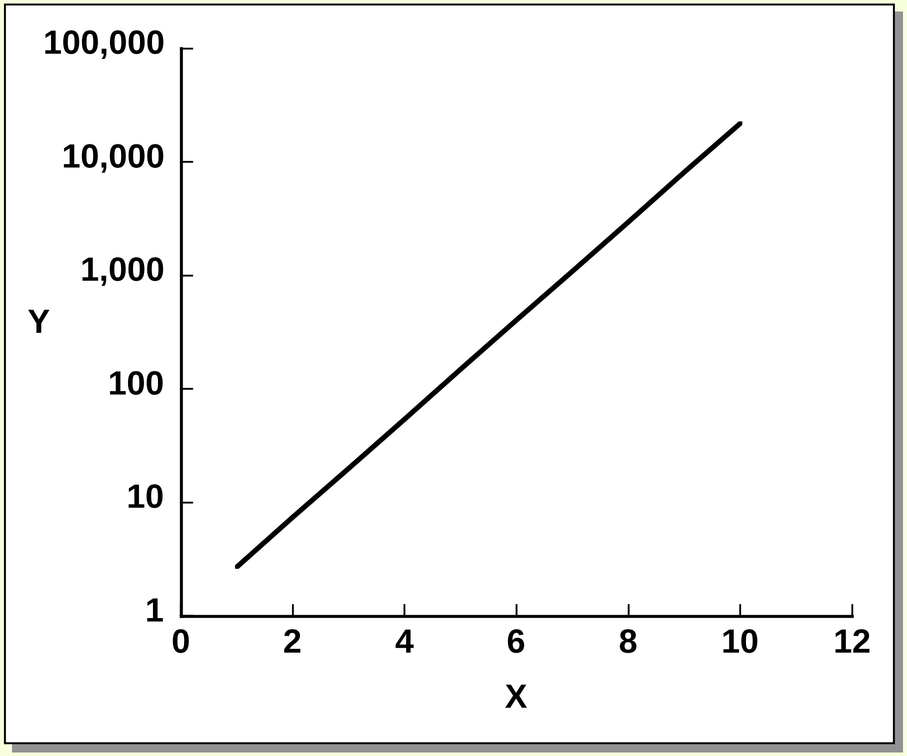
Accelerating Trends in Supporting Technologies (Kurzweil's Law)

Exponential Processes





The Difficulty About Predictions…

1. **"The telephone has too many shortcomings to be seriously considered as a means of communication."**
   – Western Union executive, 1876
2. **"The problem with television is that the people must sit and keep their eyes glued on a screen; the average American family hasn't time for it."**
   – NY Times, 1939 (World's Fair)
3. **"I think there is a world market for maybe five computers."**
   – IBM Chairman Thomas Watson, 1943
4. **"Computers in the future may weigh no more than 1.5 tons."**
   – Popular Mechanics, 1949
5. **"There is no reason for individuals to have a computer in their home."**
   - DEC Chairman Ken Olson (DEC), 1977
6. **"640,000 bytes of memory ought to be enough for anybody."**
   – Microsoft Chief Software Architect Bill Gates, 1981

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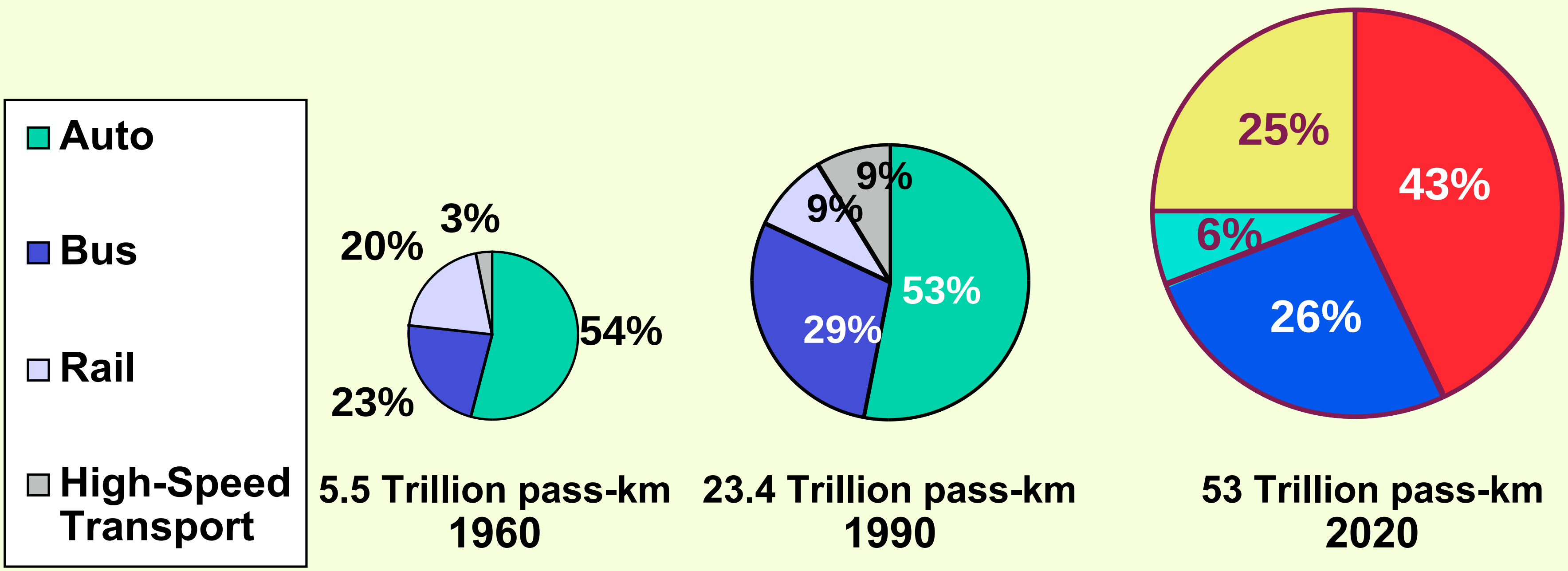
Demand Growth for Higher Speed Travel Modes

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)

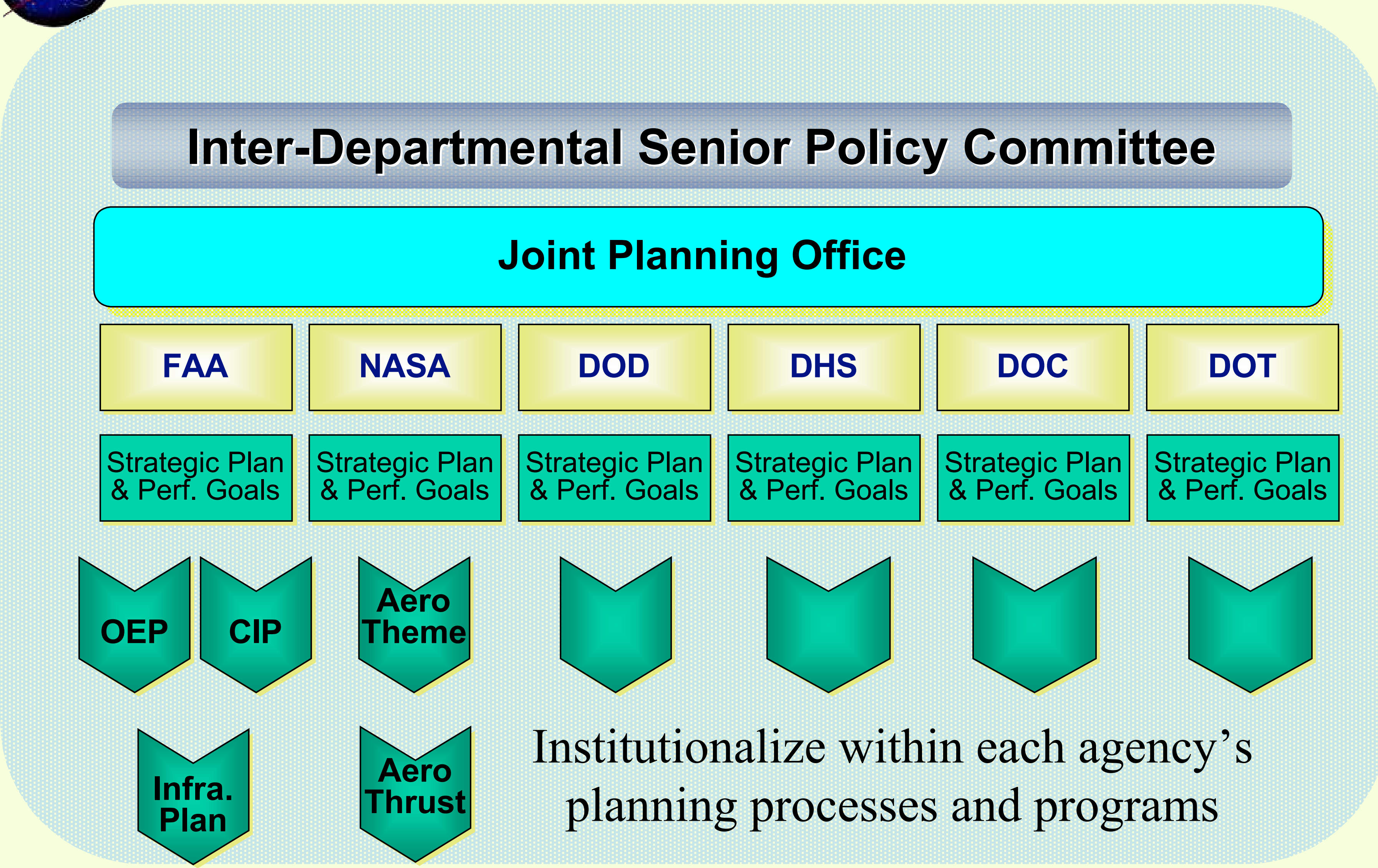


5.5 Trillion pass-km
1960

23.4 Trillion pass-km
1990

53 Trillion pass-km
2020

Presidential Commission Recommendation: Transform the Aviation System



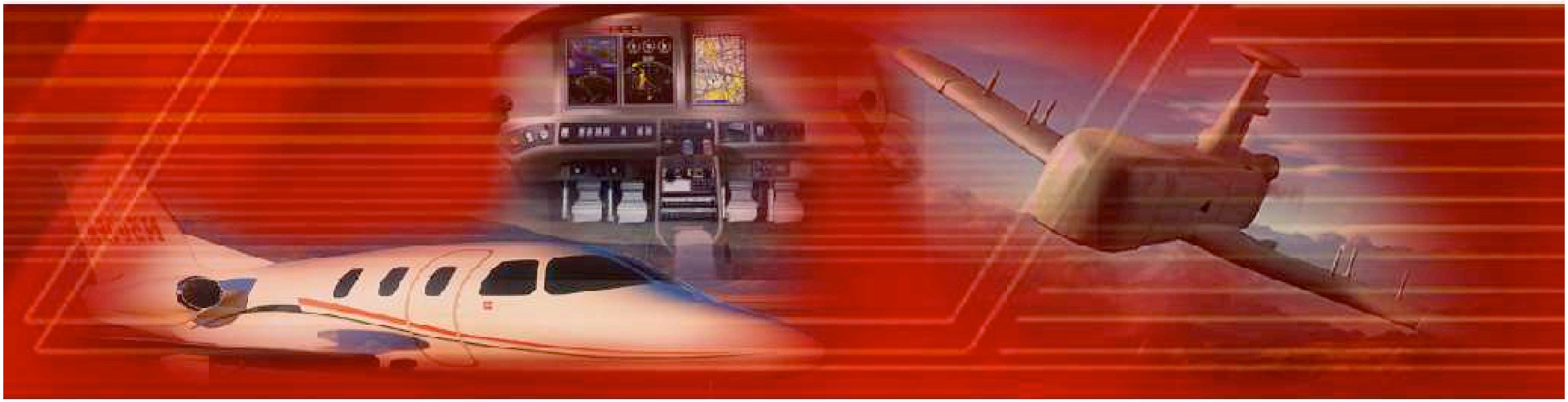
JPO is also transforming the way Government works!

John Kern

Chairman, JPO

NASA, FAA, DOT, DOC (NOAA), DHS (TSA), DOD

JPO



Next Generation
Air Transportation System
Joint Planning and Development Office

"Charting the Next Century of Flight"

What Next? Why Now?

Vision For Advanced Personal Air Mobility:
"Enable a safe, secure, affordable, easy-to-use, advanced mode of personal air transportation that expands access to more communities and decreases travel time for a broad segment of the American public.

The FASTER Alliance
2003

[An] "area of focus is improving the capability of local airports. …
get more traffic in and out of small airports more safely. We've learned a lot about the needs of these airports through Capstone in Alaska … and from NASA's work on the Small Aircraft Transportation System, or SATS, program."

FAA Administrator Marion C. Blakey
AIA Conference May 22, 2003

"The cost of inaction [in aviation advancements] is gridlock, constrained mobility, unrealized economic growth, and loss of U.S. aviation leadership."

NASA Blueprint for 21st Century Aeronautics
2002

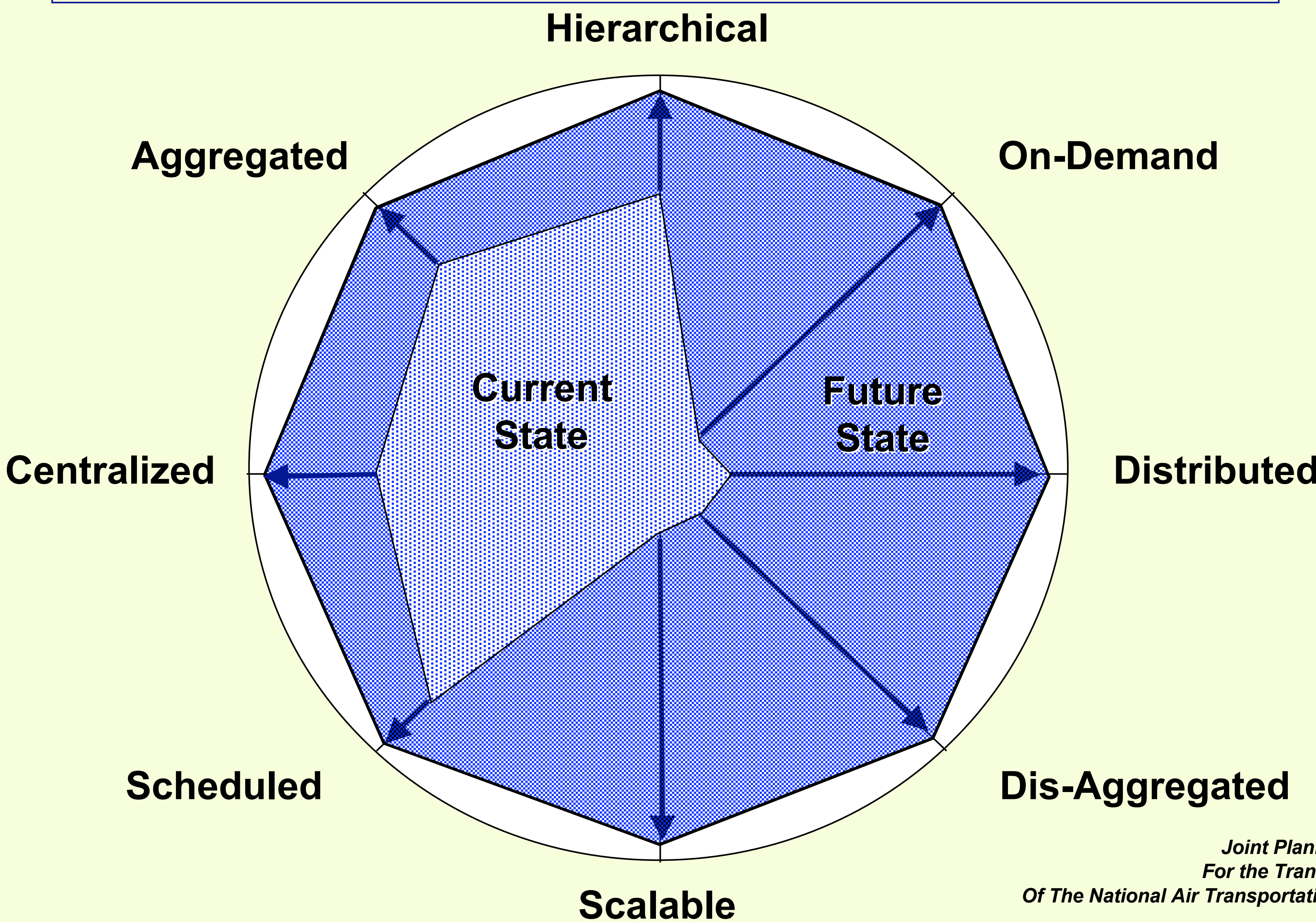
"Fast, safe, and secure point-to-point transportation should be available not just between major hub airports, but also between convenient local airports via low-cost, jet air-taxis."

President's Commission on the Future of the U.S. Aerospace Industry
2002

Transformation Concept Space

(Notional)

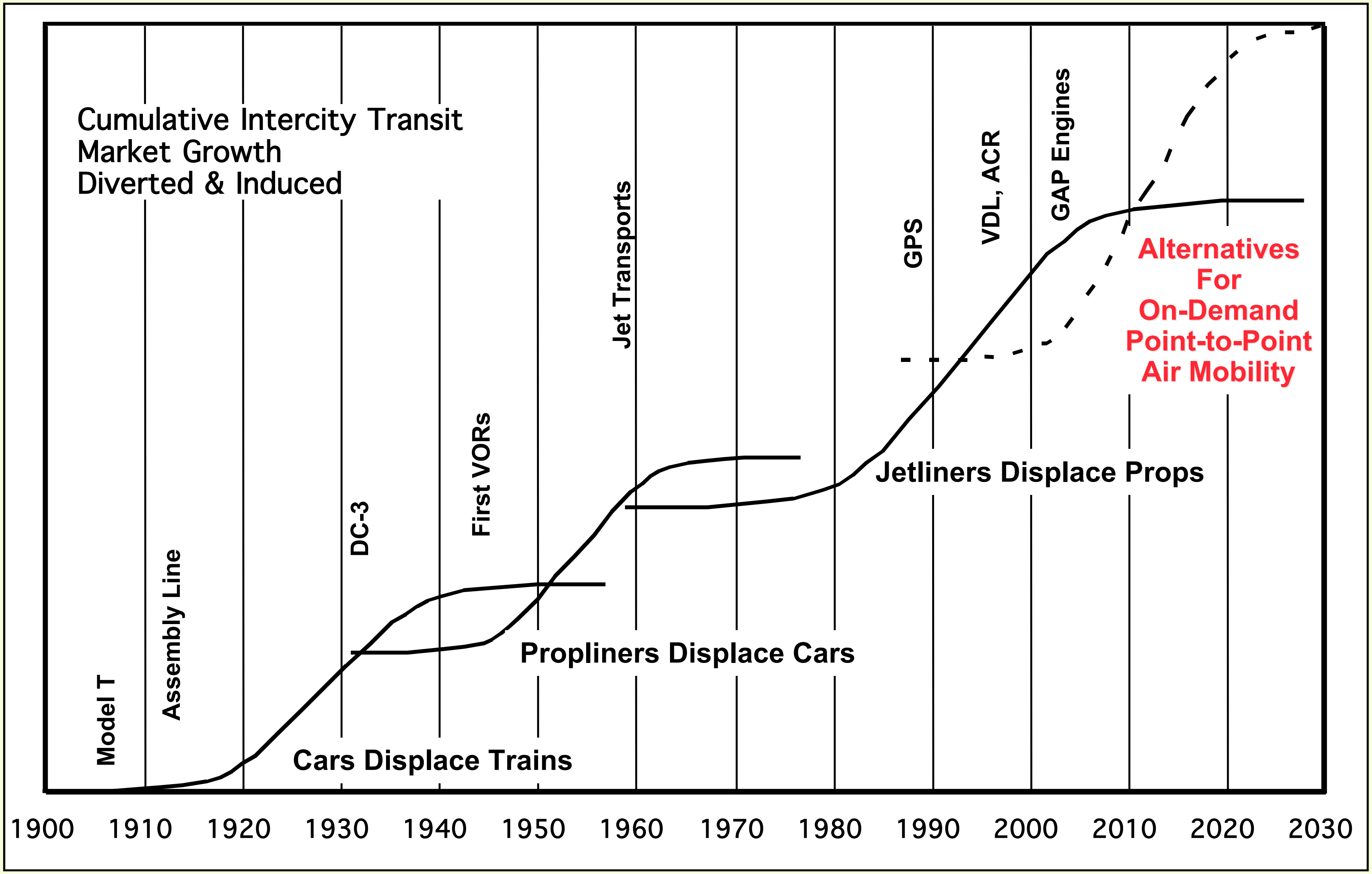
The vision is to expand the concept space along *all* dimensions.



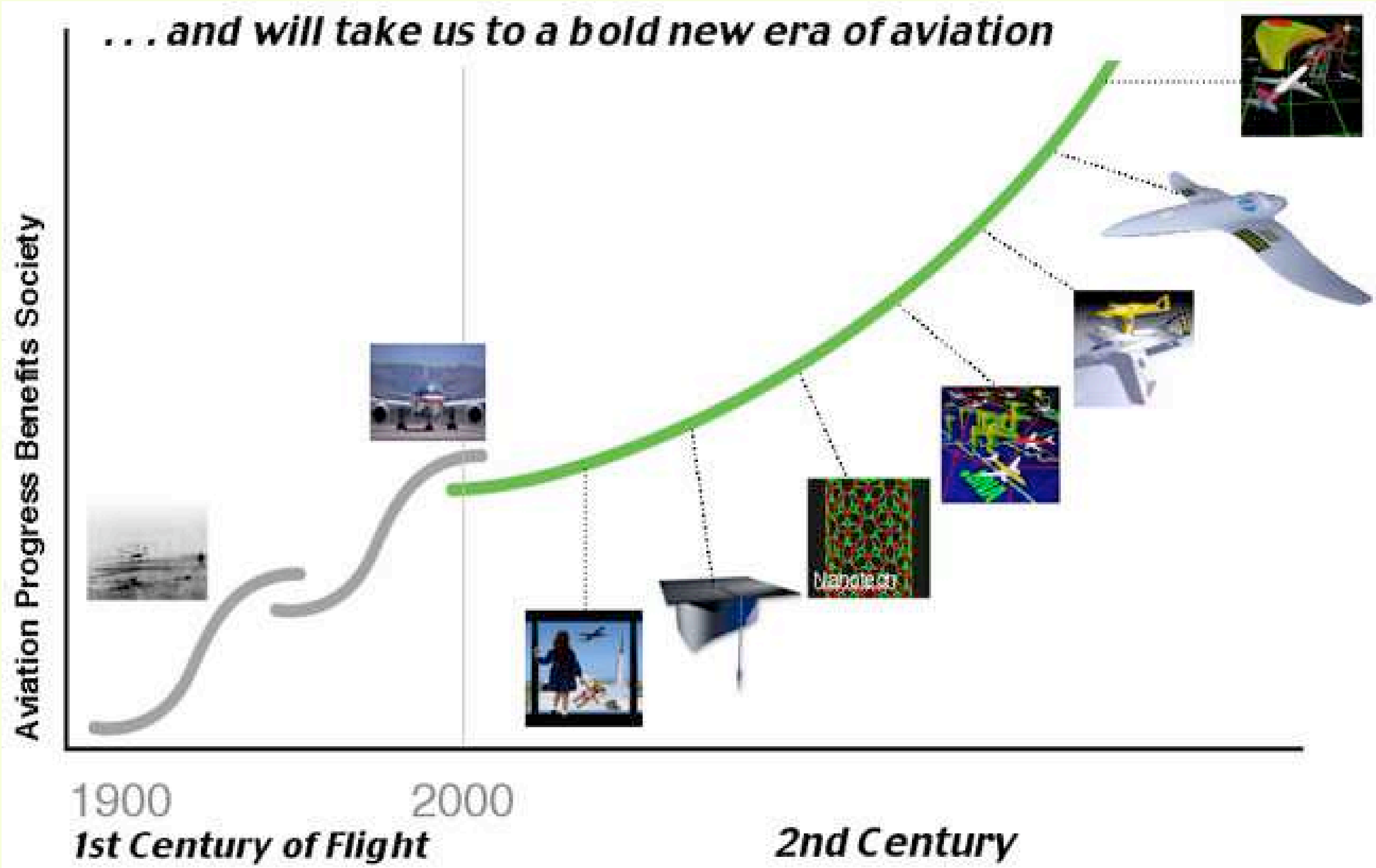
Joint Planning Office
For the Transformation
Of The National Air Transportation System

The Vision

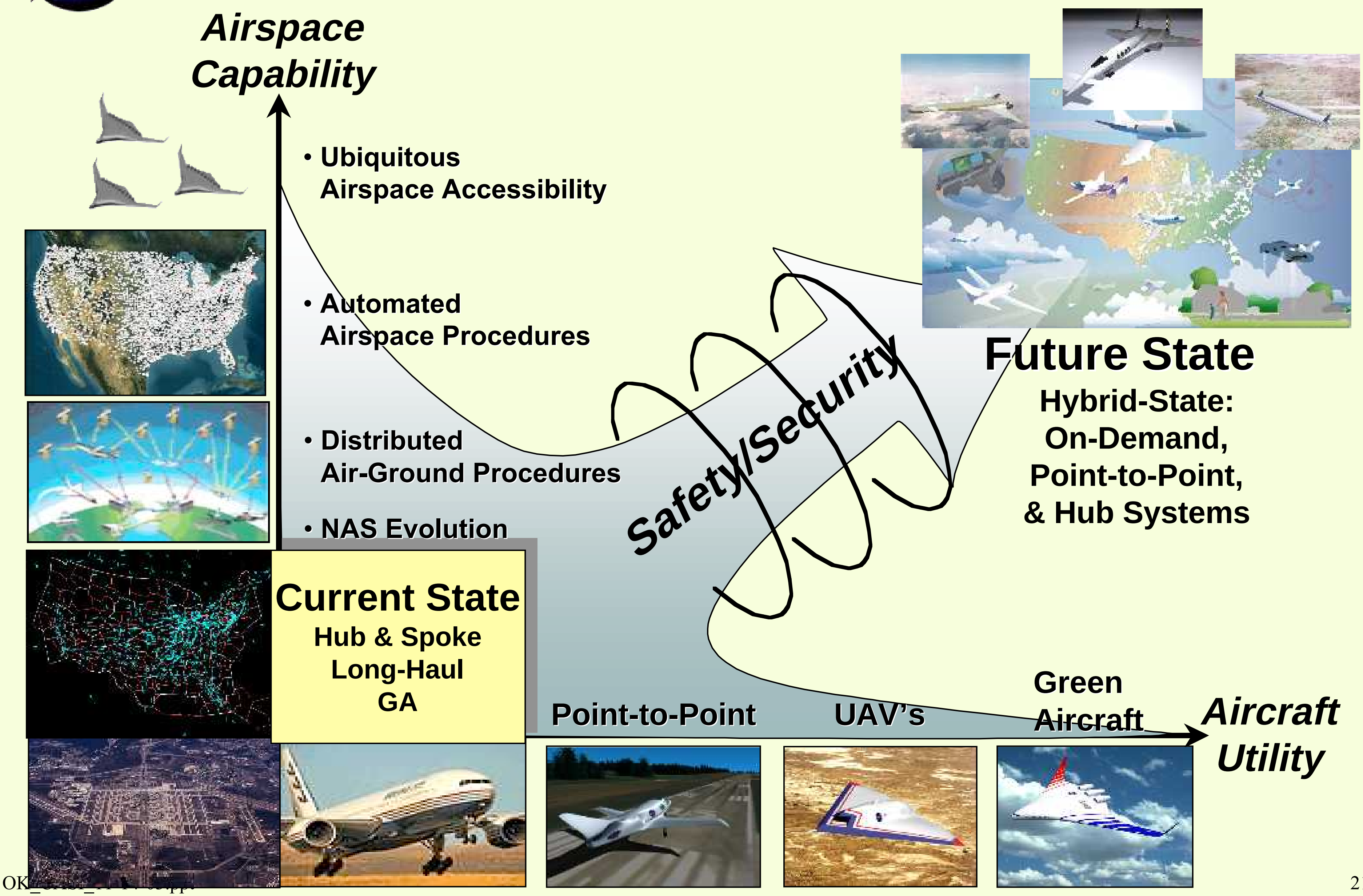
Notional Life Cycles in Transportation



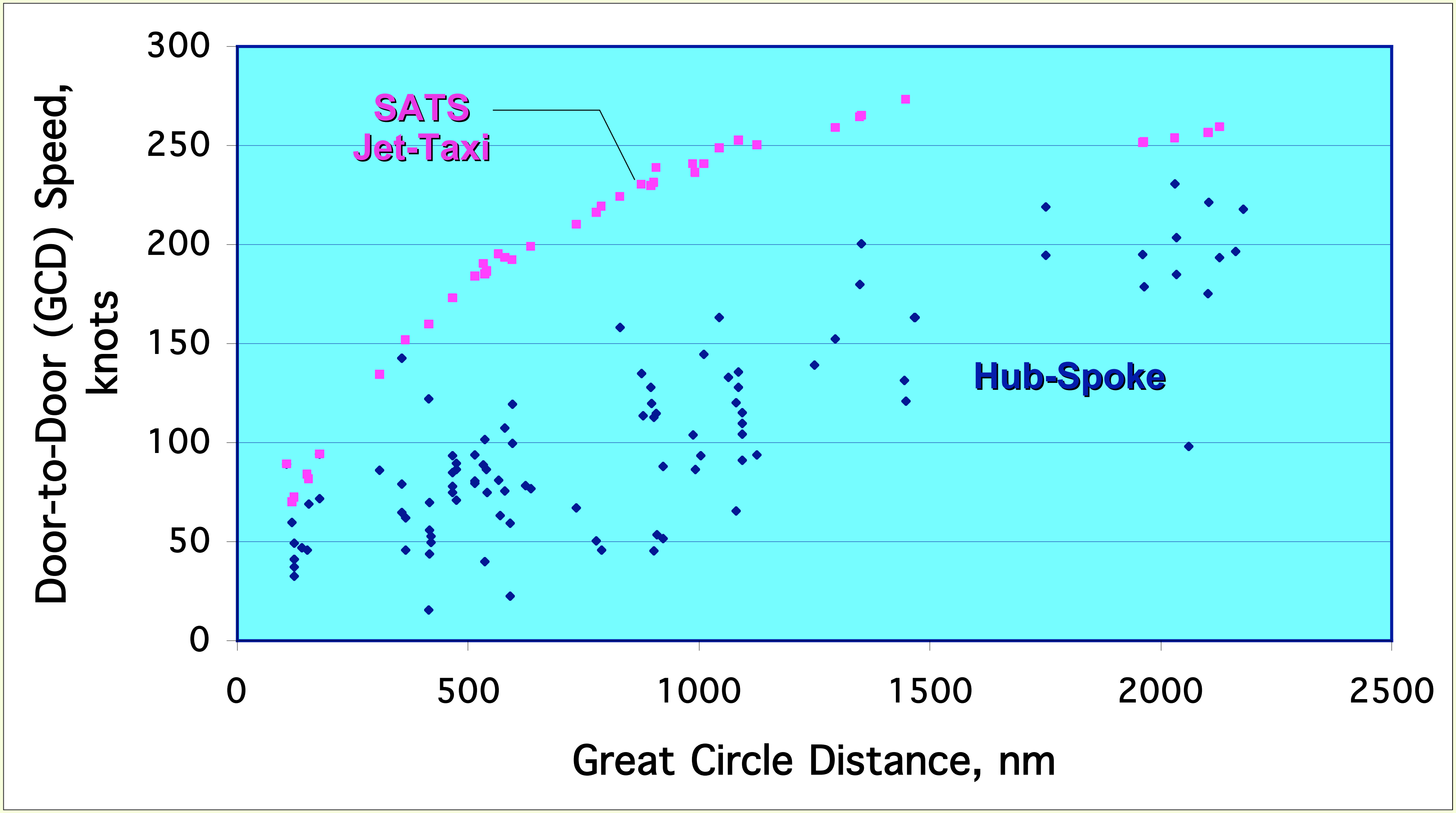
Aviation's Future is Driven By Technology (NASA Blueprint for 21st Century Aeronautics)



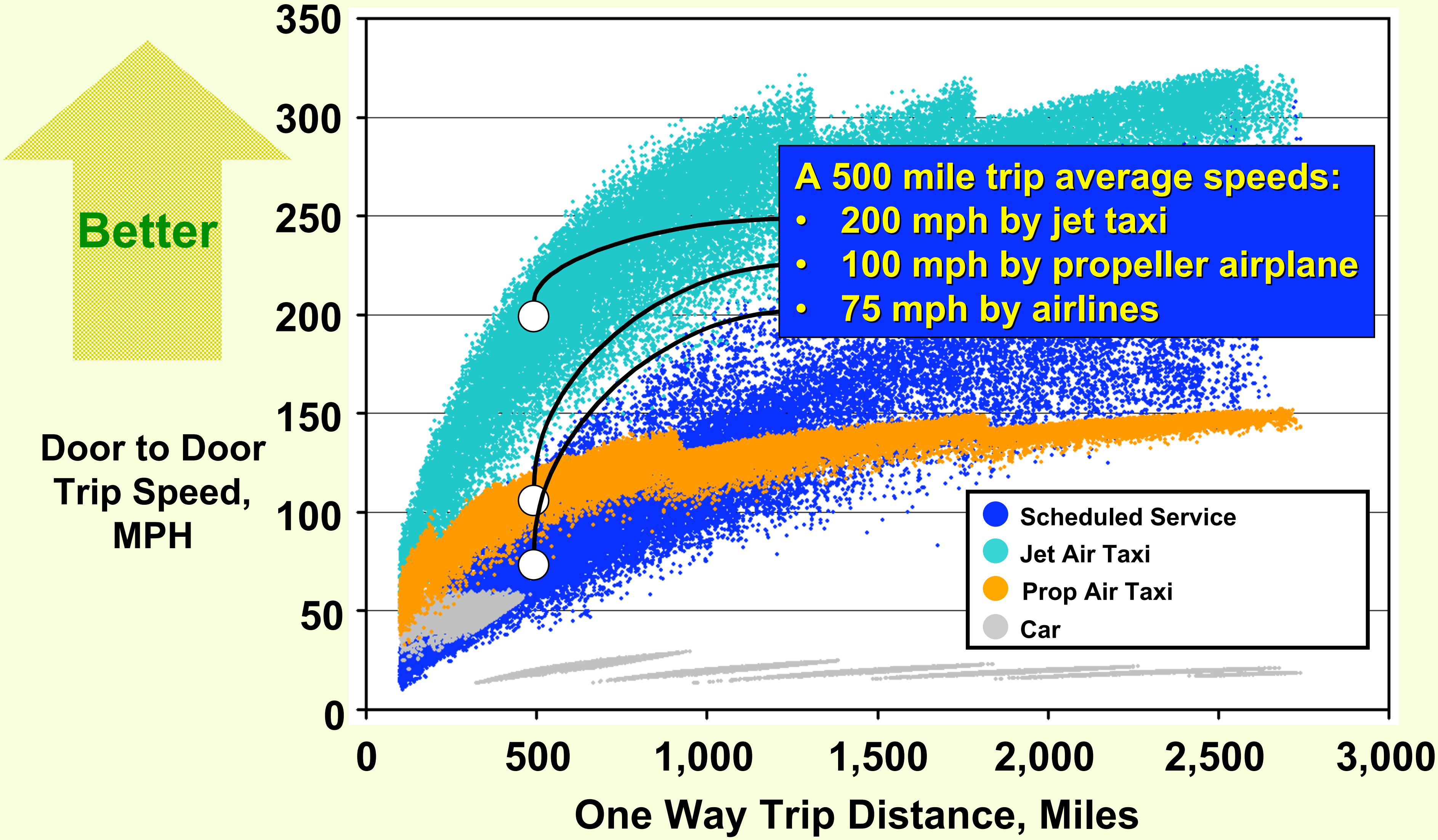
Integrated Advancements In Aircraft, Airspace, and Safety Systems



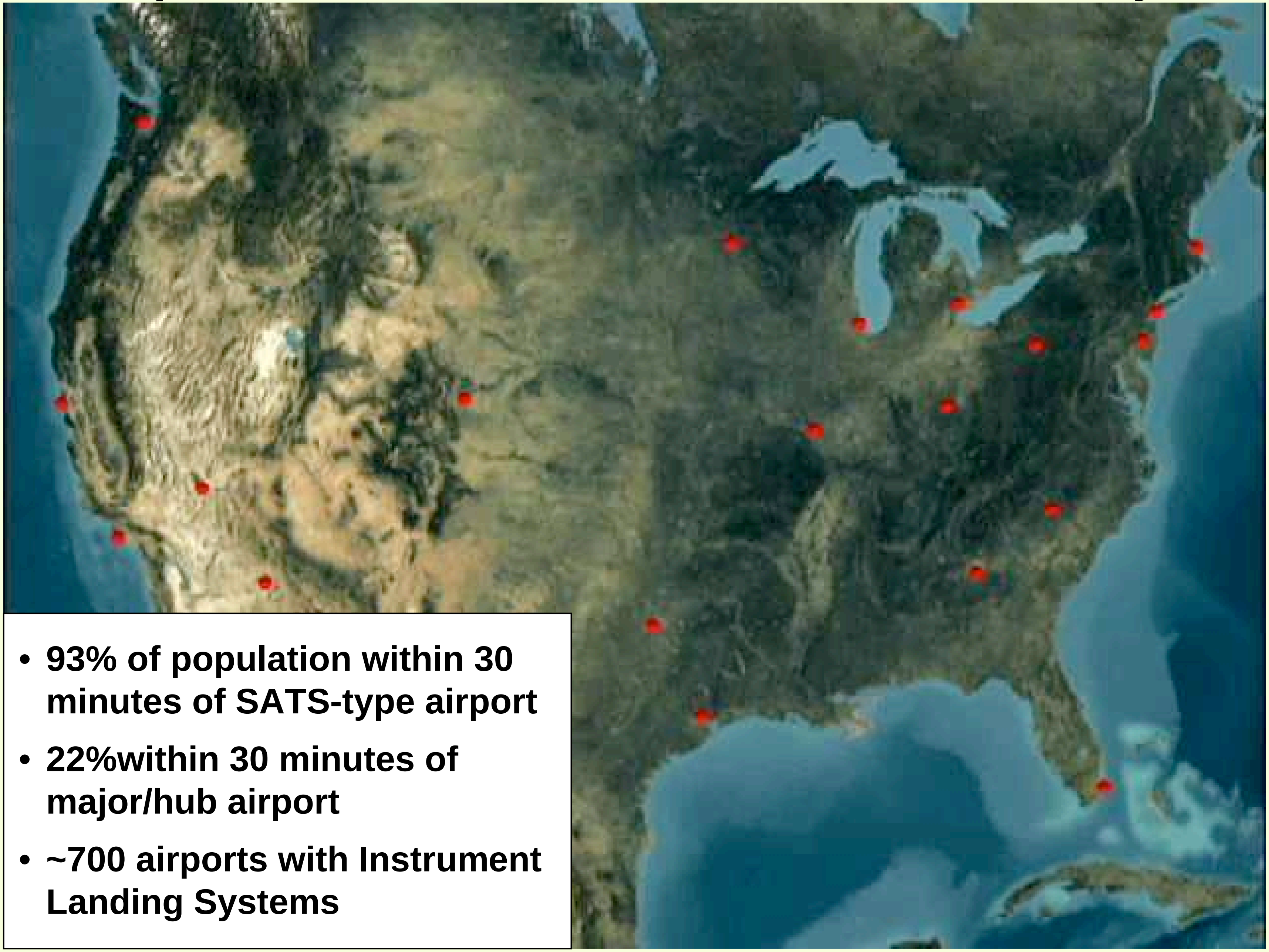
Comparison of Actual and Theoretical Speed of Doorstep-to-Destination Travel



If Time is Gold
Then Door-to-Door Speed is the Coin of the Realm



Equitable, On-Demand, Distributed Air Mobility



- 93% of population within 30 minutes of SATS-type airport
- 22%within 30 minutes of major/hub airport
- ~700 airports with Instrument Landing Systems

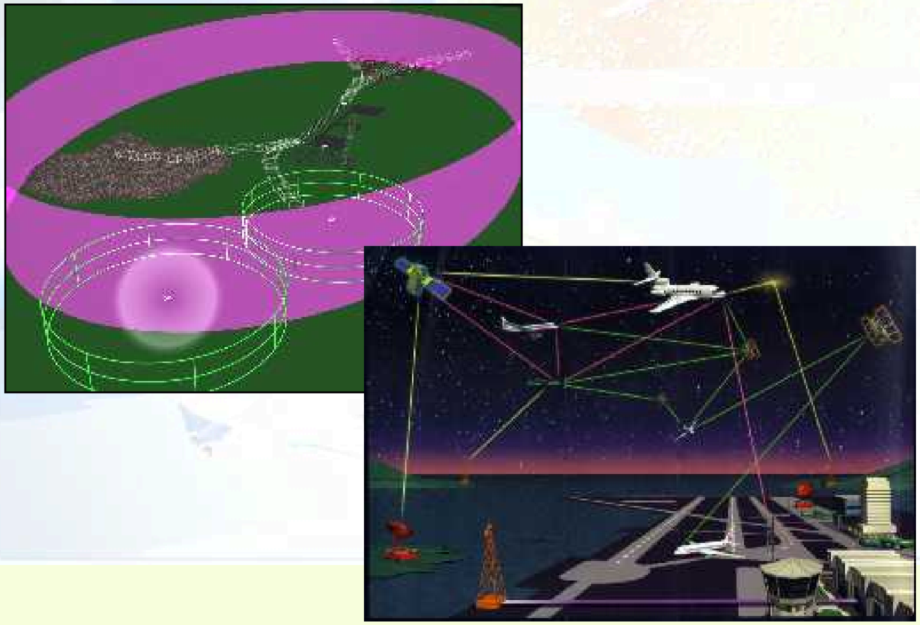
The Technologies

The New Industry
(as of September 2003)

Honda,
Toyota,
And others…

Innovations Affecting 21st Century General Aviation Airspace Operations

- A New Generation of Digital Aircraft
- All-Digital Cockpit Systems (PFD+MFD)
- Digital Flight Controls
- Digital Engine Controls
- Airborne-collaborative Sequencing Software
- Lower Landing Minima Without ILS



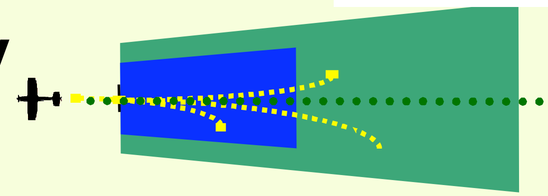
- Airborne Internet
- Digital Airport Information Systems
- Digital Airspace Management Systems
- ADS-B-based Separation
- Non-towered Airports Procedures
- Non-radar Operations in IMC

Small Aircraft Transportation System Project

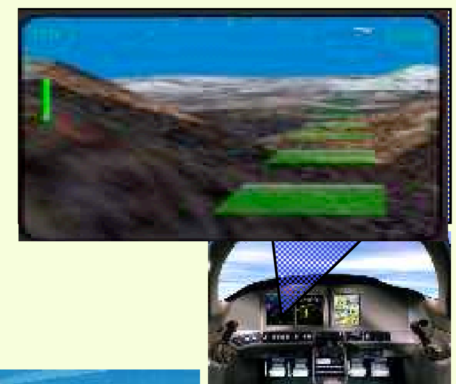
Operating Capabilities for Access to All Communities/

Higher Volume Operations in Non-Radar Airspace and at Non-Towered Airports

Lower Landing Minimums at Minimally Equipped Landing Facilities

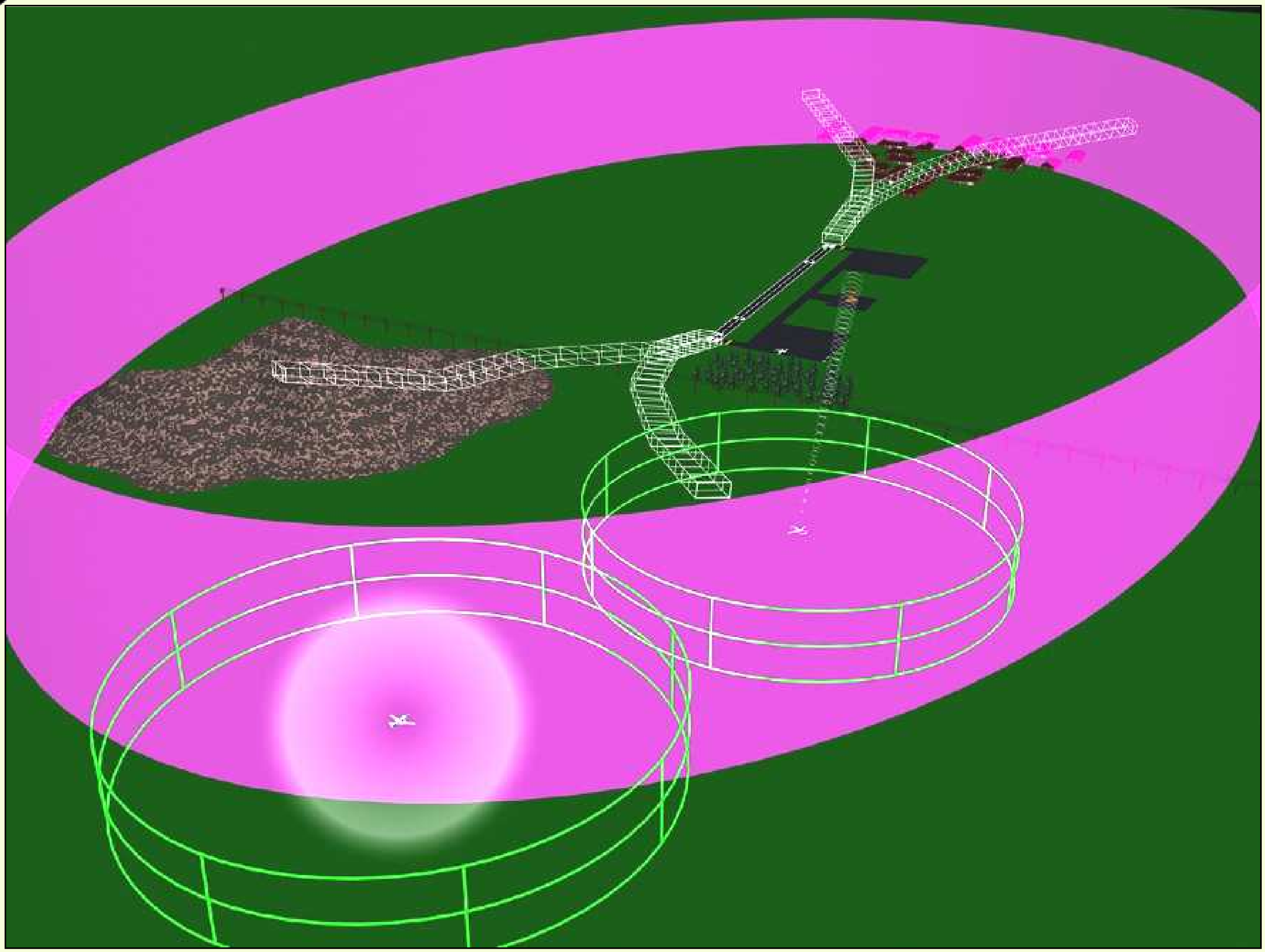


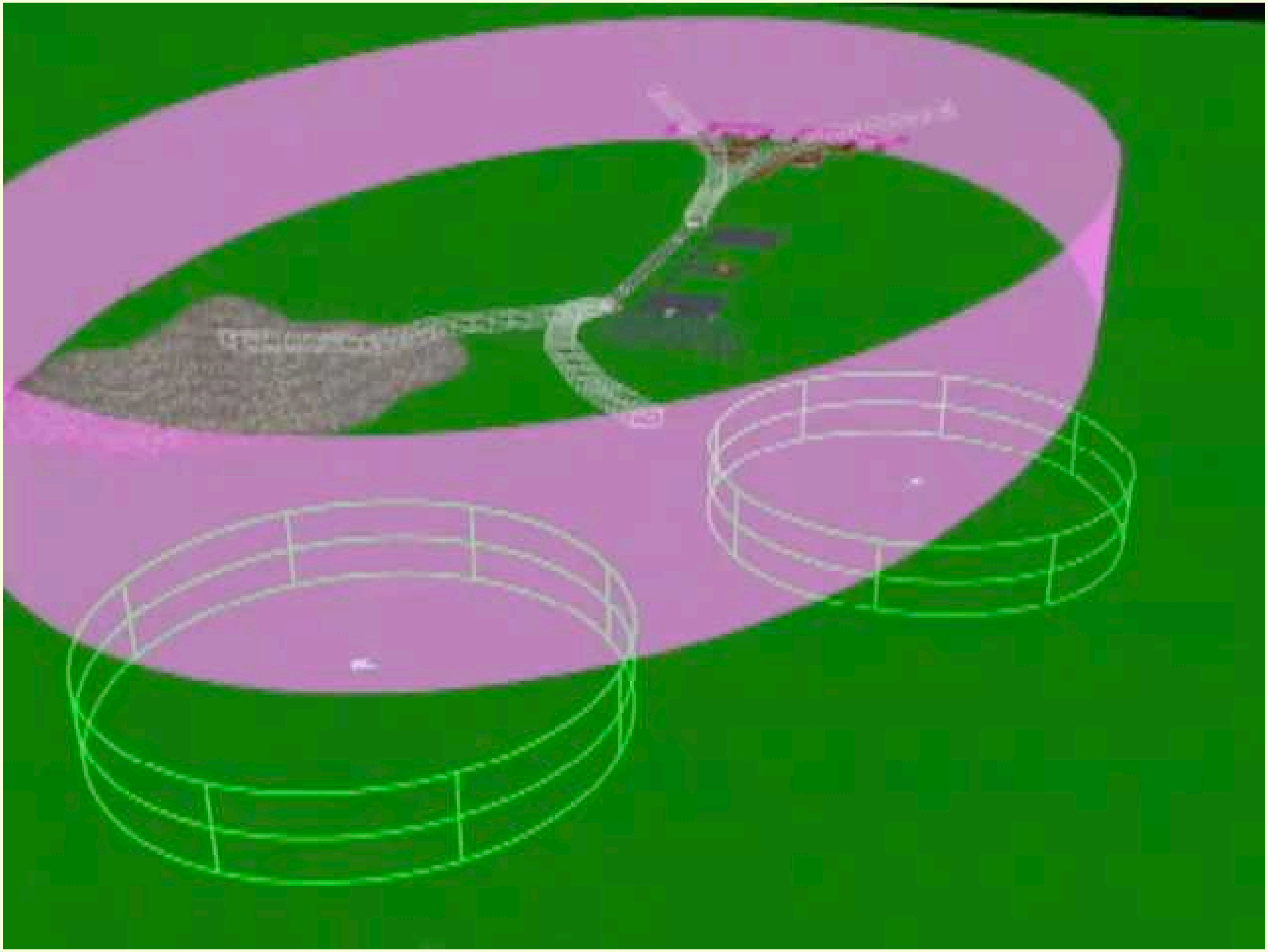
Increase Single-Pilot Crew Safety & Mission Reliability



En Route Procedures & Systems for Integrated Fleet Operations

SATS Operating Capabilities





FAA Roles

Small Community Airports Initiative

- CNS Infrastructure

Safe Flight 21

- Capstone

AVR-SATS Team

- Certification Issues

Flight Standards Services

- Flight Training Technologies
- RNP-based Operations

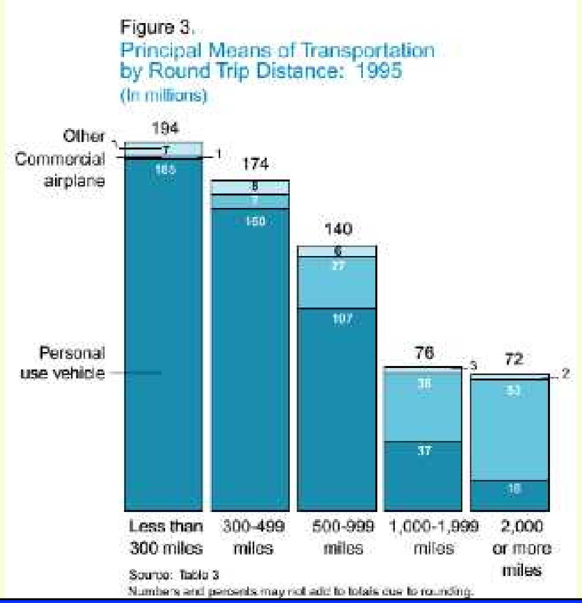
FAA Technical Center:

- Airborne Internet
- Advanced procedures simulations

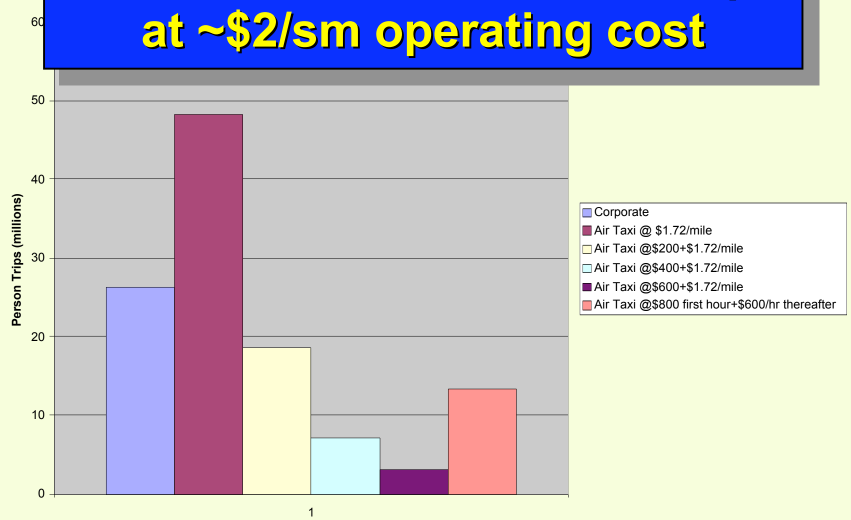
THE COMMON DENOMINATOR IN THESE DEVELOPMENTS IS THE IMPORTANCE OF EFFECTIVE TRAINING IN GENERAL AVIATION

Future Aircraft Market
Diverted Demand and Sensitivity Assessments

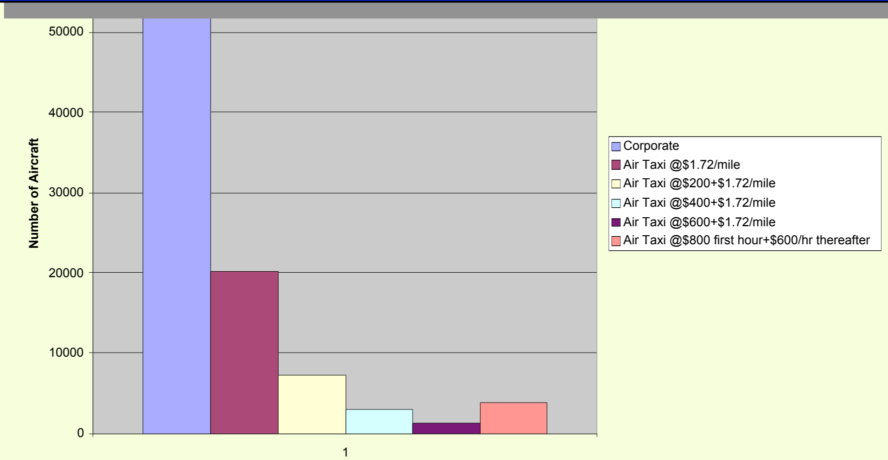
- **Approach - Predict diverted mode choice at National level between automobile, scheduled air, and on-demand air travel based on the value of a traveler's time and the cost of the trip (NASA CR 2002-211927).**
  - **Data Source - 1995 American Travel Survey + 2000 US Census**
  - **Tools - Integrated Air Transportation System Evaluation Tool (IATSET), macro economic model**



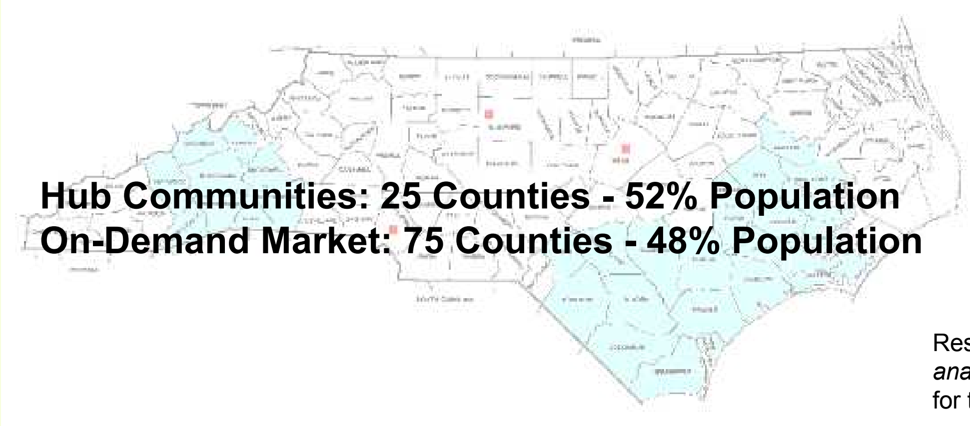
Between 13 and 47 million trips at ~$2/sm operating cost



Between 7,000 and 52,000 aircraft required to serve new markets



North Carolina Market Assessment For Diverted (On-Demand) Business Travel



Assumptions

- Business Travel (no personal tvl)
- 98% Accommodation @ ≤ 3 hours
- 20% ROI held constant
- No weather impacts assessed

Research Triangle Institute (2002). *North Carolina fourth-tier air transportation market analysis*. NCDoA Contract No. A304132: NC DOT Division of Aviation market Analysis for the Small Aircraft Transportation System (SATS) in North Carolina.

Findings:

175 fleet of next generation jets required to serve 425 passengers/day demand at $1.85 per passenger-seat mile

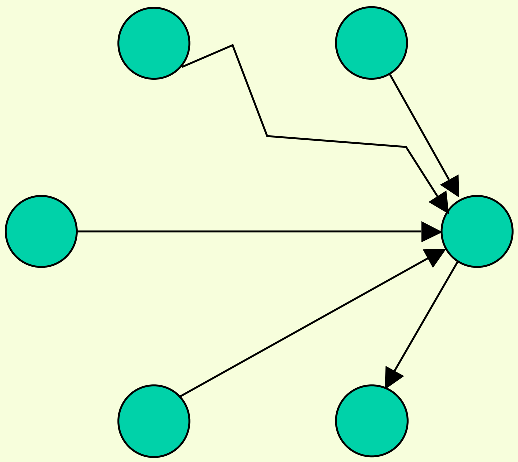
- Demand highest in communities most remote from commercial air service
- Air-taxi service best meets needs of surveyed likely business travelers
- Increased passenger volume allows higher profit margins and/or lower ticket prices and shorter accommodation intervals
- Advanced technology significantly reduces required ticket price

* Ignores potential passenger demand from “hub communities”, ignores passenger travel originating external to NC, ignores leisure and vacation travel demand, uses simplified dispatch strategy with no “optimization”

Network Theory Implications/Applications

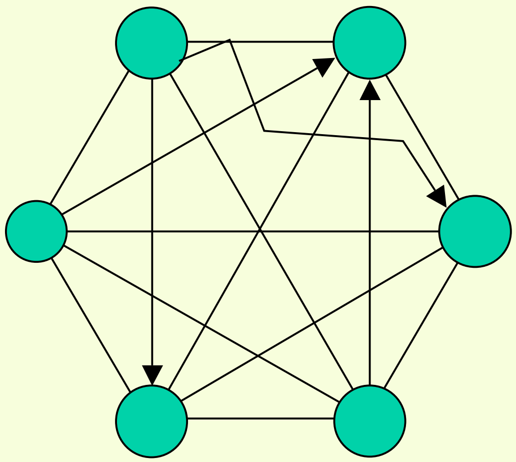
Air Transportation Network Topologies

A. Hub-and-Spoke Directed, Scheduled, Aggregated



Nodes (n) = 6
Links (k) = n-1 = 5
Tier 1,2 Carriers

B. Point-to-Point Directed, Scheduled, Aggregated



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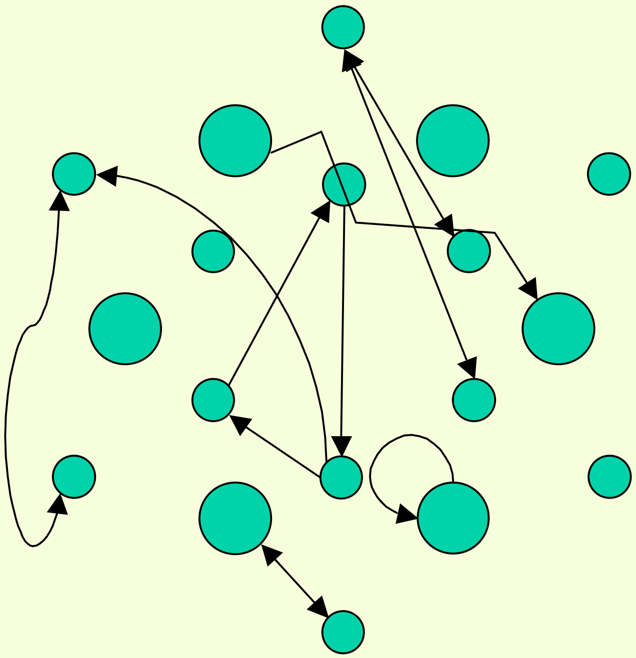
Tier 2,3 Carriers

C. Distributed Undirected, On-Demand Dis-Aggregated

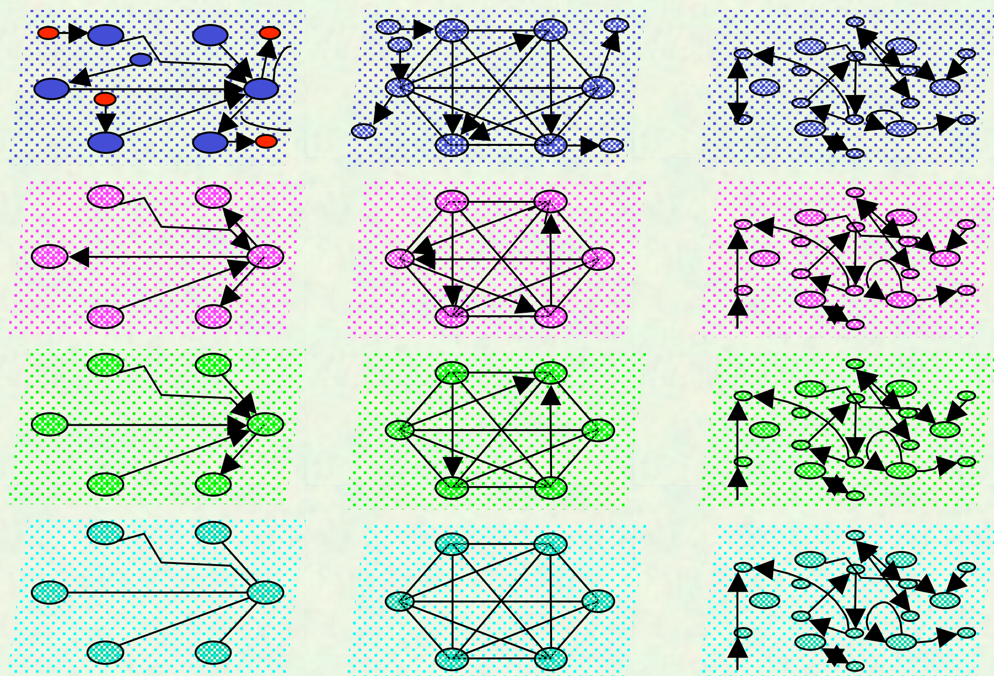


Nodes (n) = 18
Links (k) = n(n-1)/2 = 153
(Three times the nodes = 10X links)
Tier 4 Carriers, UAVs, RIAs, PAVs

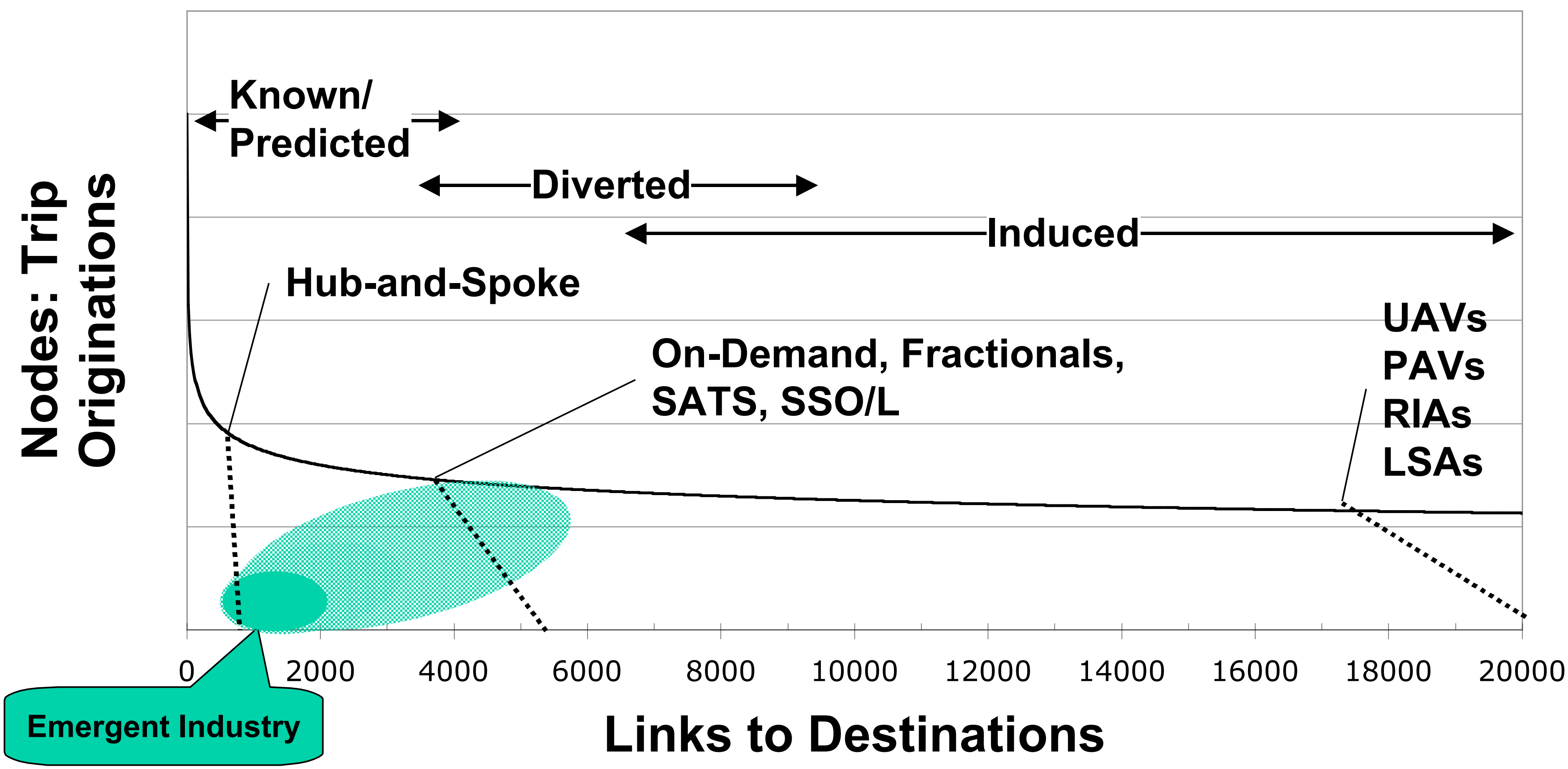
Topologies for Air Transportation Networks

Q: What network characteristics, topologies, and technology strategies would lead to scalable air transportation system behavior?

	A. Hub-and-Spoke Directed, Scheduled, Aggregated	B. Point-to-Point Directed, Scheduled, Aggregated	C. Distributed Undirected, On-Demand, Dis-Aggregated	<u>NAS Layer</u>
Mobility Layer (Passengers/O-Ds)				Communication Navigation Surveillance
Operator Layer (Pilots-Crew/Missions)				A, B, C, D, E, SUA & TFR Architecture
Transport Layer (Aircraft/Routings)				
Capacity Layer (Airports/Routes)				Airspace Services & IFR/VFR Procedures



Power Law Distribution in Air Transportation (Physical & Transport Layers)

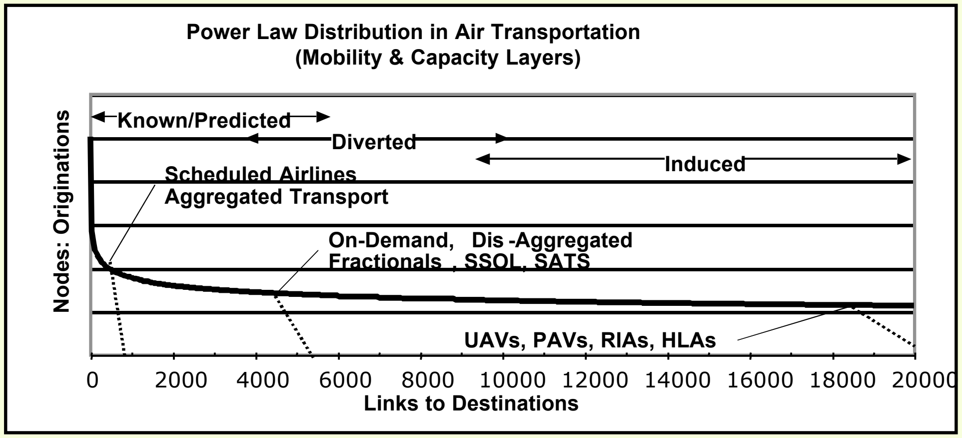


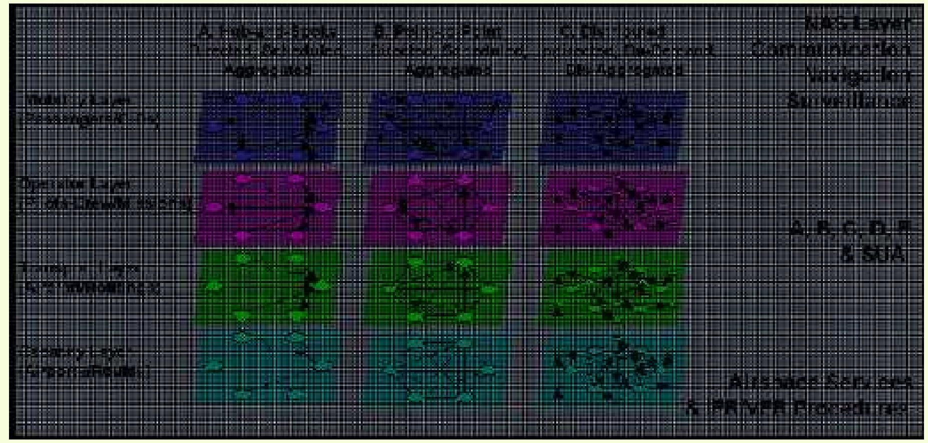
Examples of Scalable Behaviors in Air Transportation Topologies

- **Physical layer (Airports-infrastructure) supports growing access to more runways in more weather**
- **Transport layer (New aircraft) supports growing access to more markets/communities**

Topologies for Air Transportation Networks

As framework for primal questions





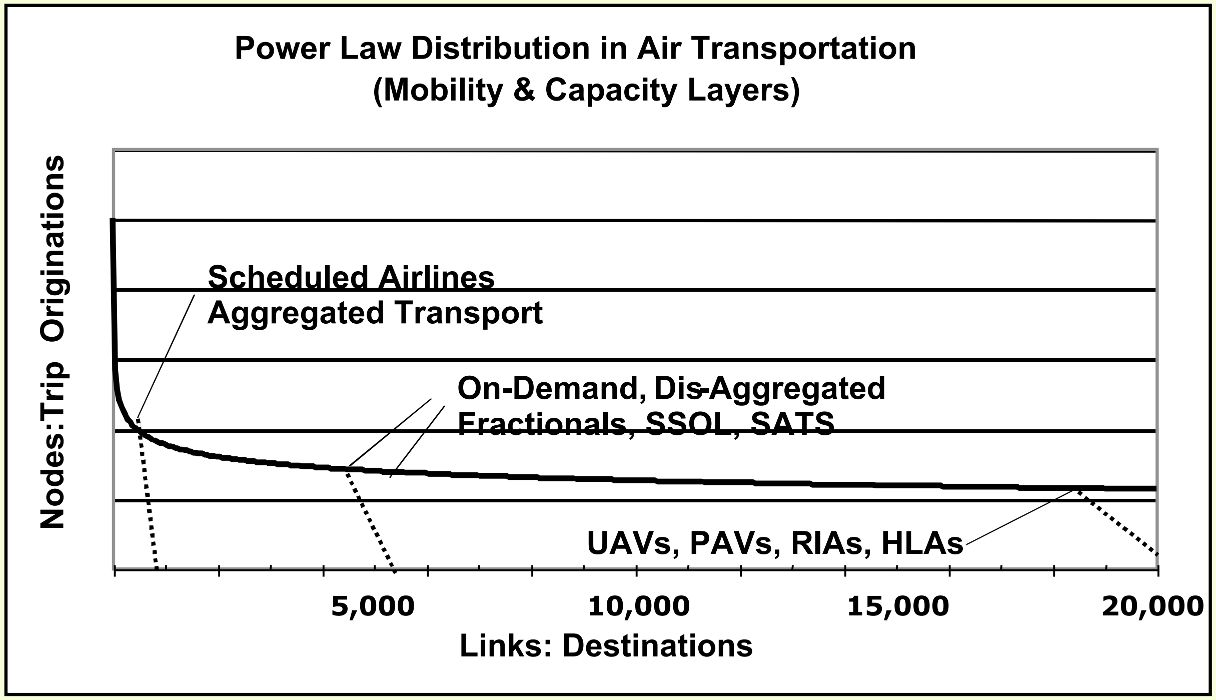
Primal Questions

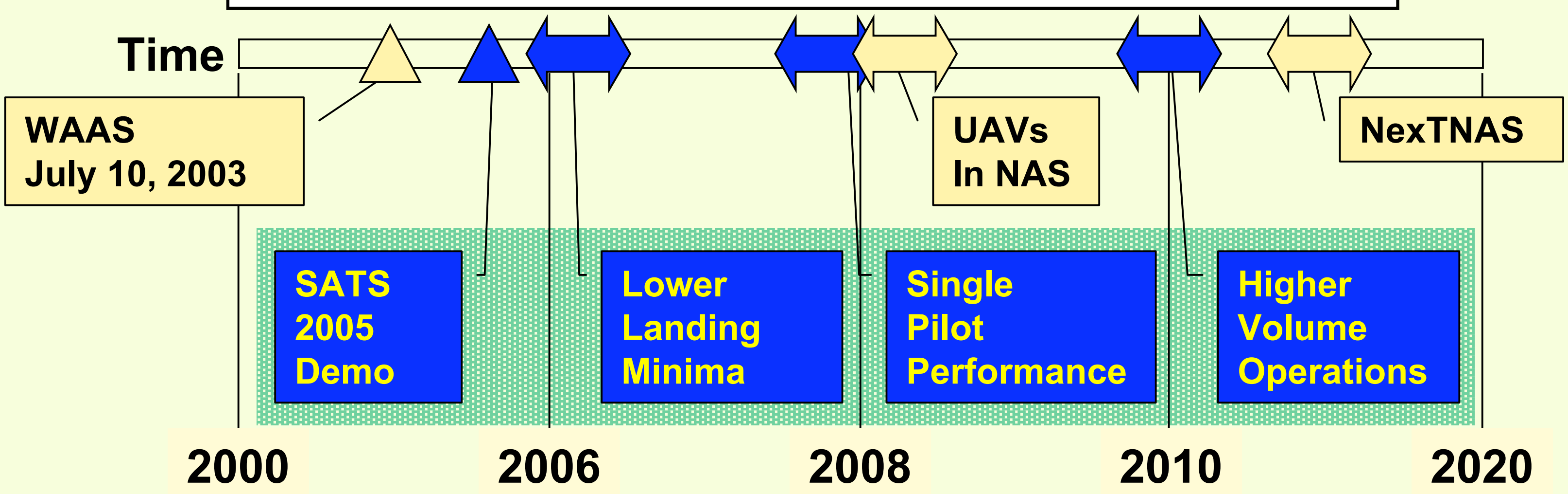
1. **What are the comparative mobility metrics (*e.g.,* door-to-door speeds) for networks A, B, and C?**
2. **What are the optimal sizes, costs, performance of aircraft for these networks?**
3. **What are the comparative energy consumptions for optimized operations of these networks?**
4. **What are the comparative noise constraint optimization issues for these networks?**
5. **What are the comparative infrastructure costs at each layer of these networks?**
6. **What are the comparative degrees of resistance to disruptions of these networks?**
7. **What are the comparative degrees of vulnerabilities of these networks?**
8. **What are the percolation behaviors for "events" in these networks?**
9. **What changes occur within the network when one of the layers is fundamentally altered?**
10. **<u>What topology of topologies (system of systems) expands the transformation concept space?</u>**

Transformation Roadmapping

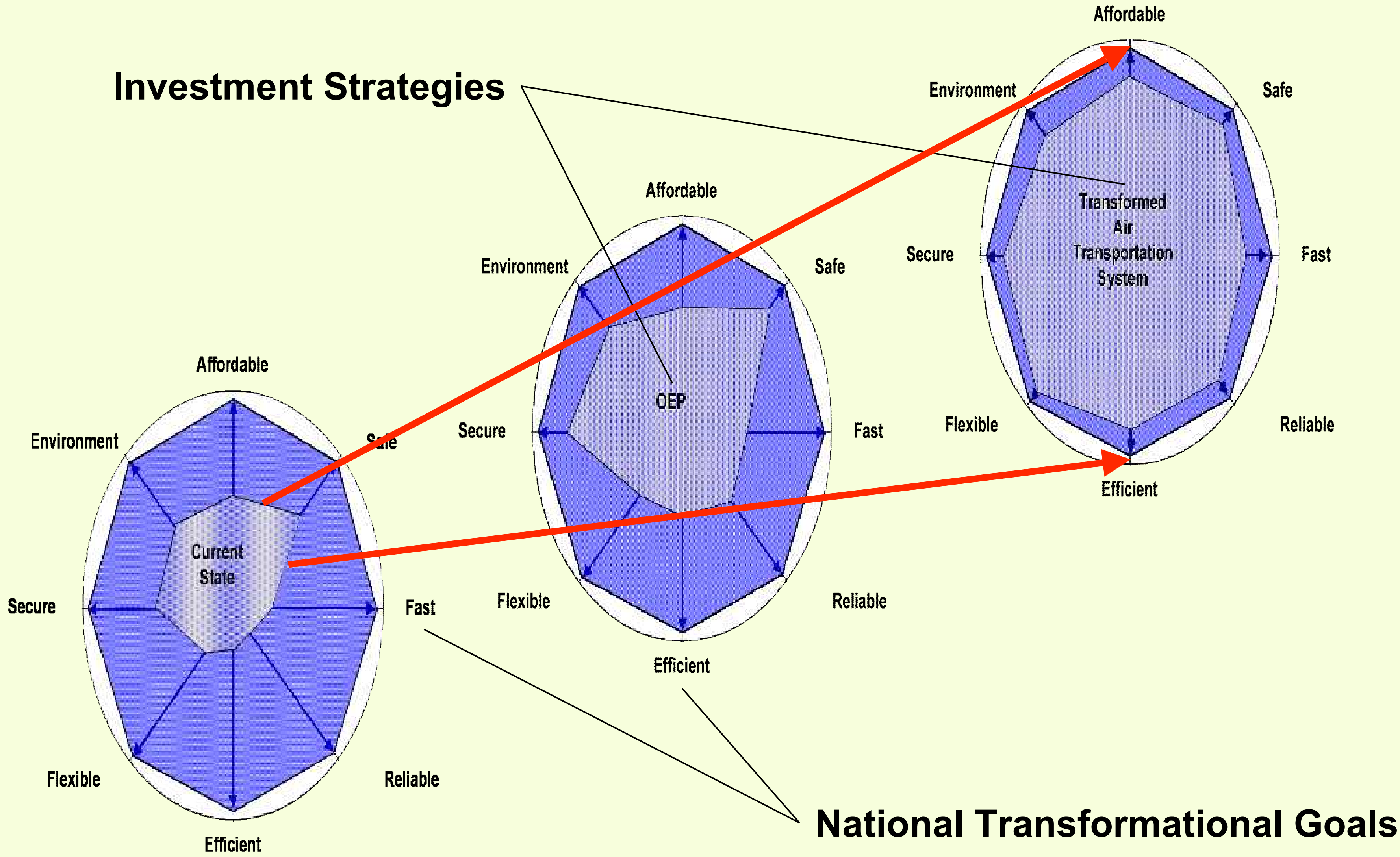
From a Smaller Community Air Transportation Perspective

Scalable Development of Air Transportation Starts with SATS Operating Capabilities

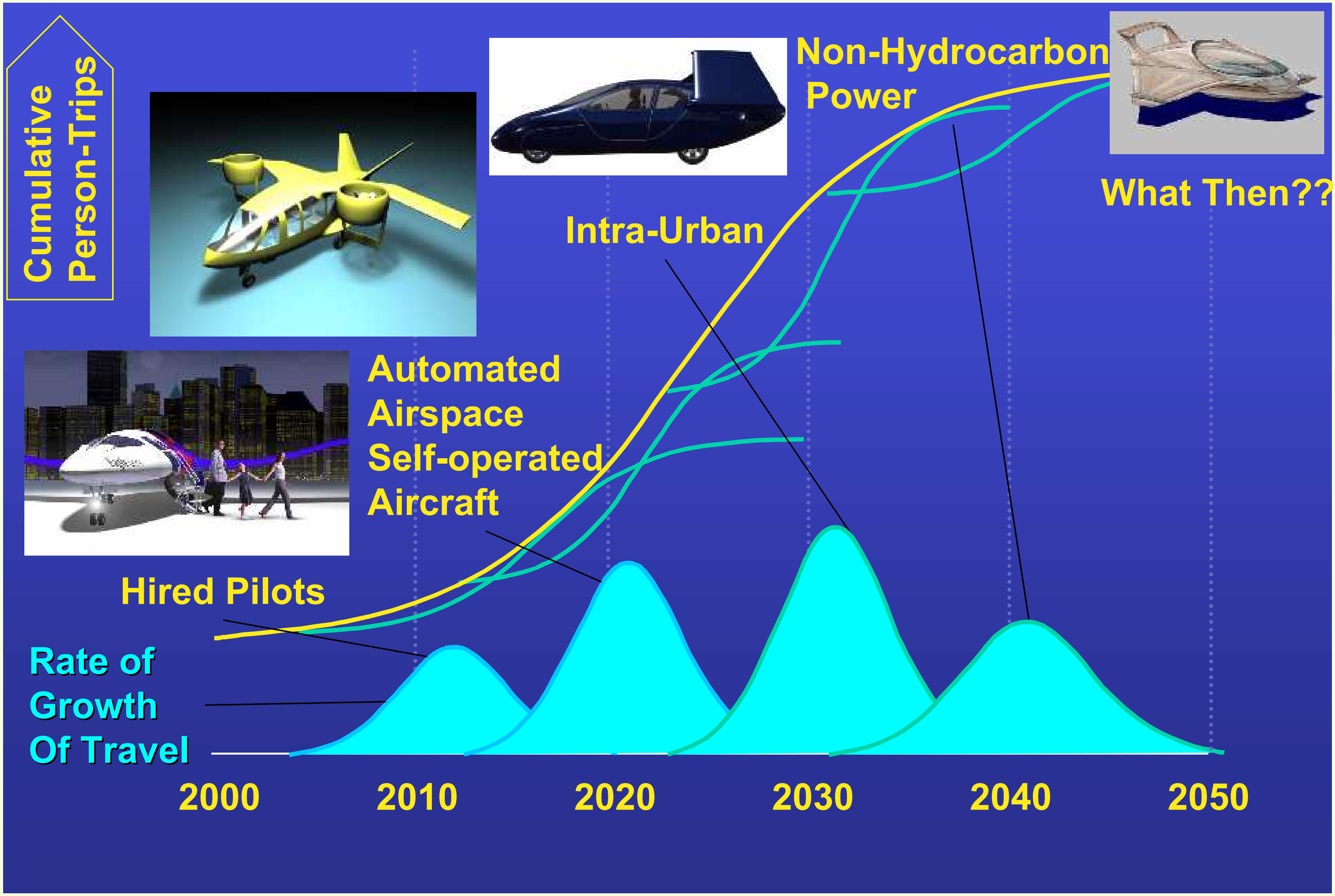




Defining a Transformational System



A Notional Life Cycle For Innovations in Air Mobility



Summary

- Market demand, emerging technologies, and national transformation goals provide context for transportation system innovation
- SATS, The Vision:
  - Scalable growth of
    On-demand, Distributed, Dis-aggregated, Air Mobility
    In
    Increasingly Autonomous Aircraft
    In
    Increasingly Demand-Adaptive Airspace

- SATS, The Project:
  - Proof of Concept for
    Airport & Airspace Access
    With Decreasing Traditional Terrestrial
    Infrastructure and Control
- Modern Network Theory Offers
  A System-Level Topology For Air Transportation Network Strategies
- Roadmapping for transformation requires all stakeholders' participation.

The vision for transformation is to allow all communities to participate in the global marketplace, to tailor transportation services to individual needs, and to accommodate seamless civil and military operations.

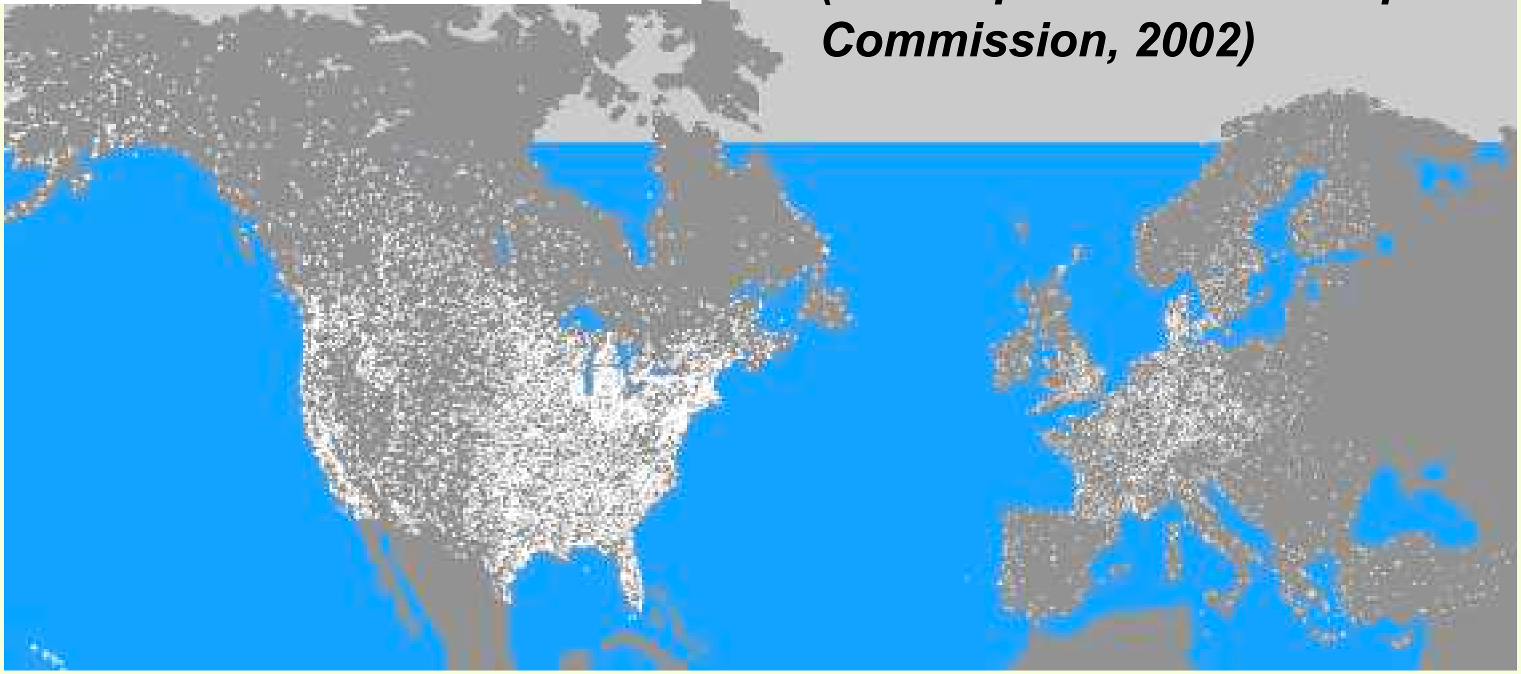
Epilogue … Or Prologue?

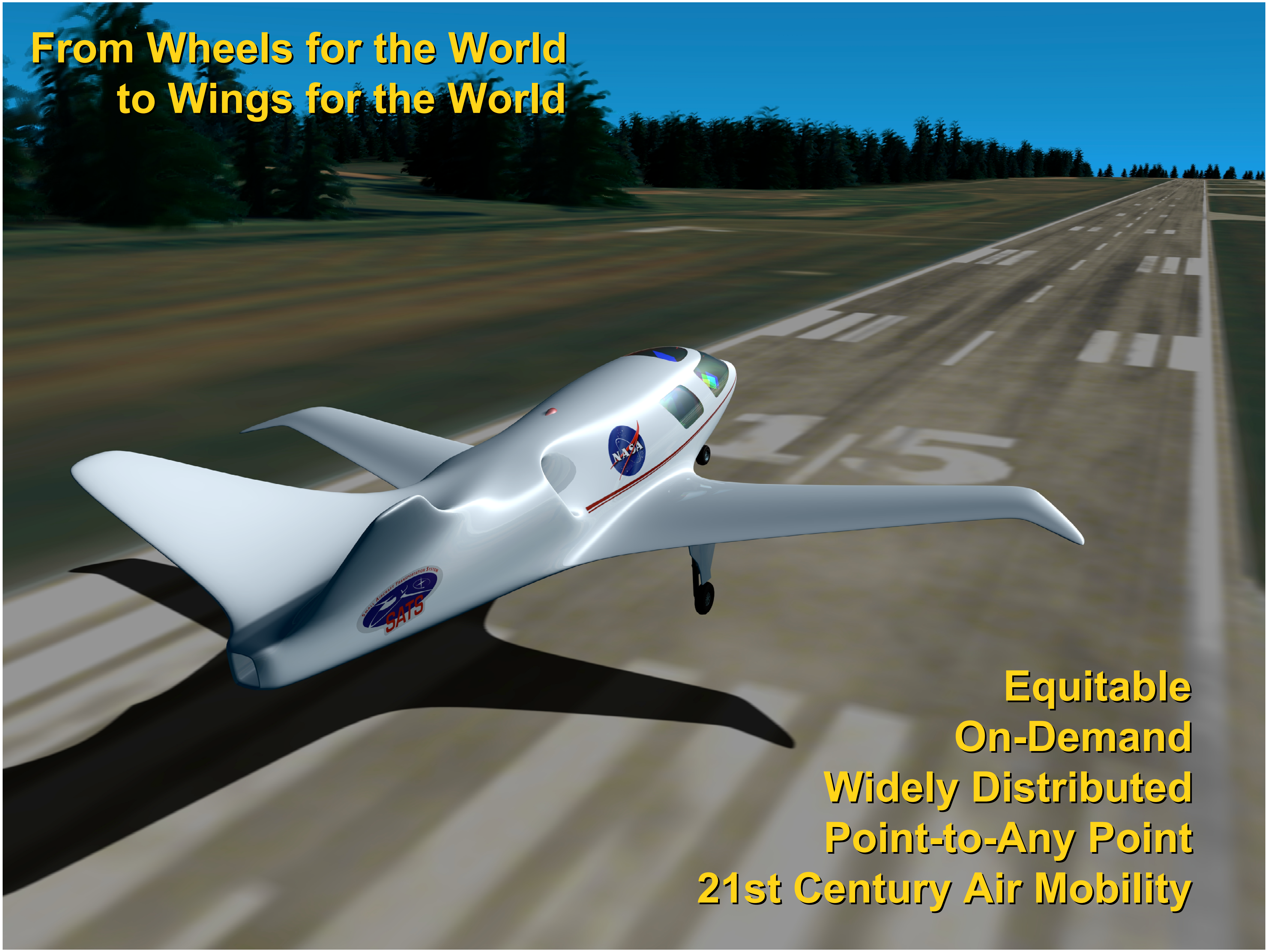
From the sands of Kill Devil Hill

To

"Anywhere, Anytime, Anyone, Anyplace"

(The Report of the Aerospace Commission, 2002)




From Wheels for the World
to Wings for the World
Equitable
On-Demand
Widely Distributed
Point-to-Any Point
21st Century Air Mobility